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Transmission and absorption analysis at different wavelengths: "ex vivo" study with a supercontinuum white light source

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Abstract

In this study was used a light, generated by a device called *supercontinuum*, that creates white light starting from a single wavelength source (a pulsed laser at 1064 nm, with duration pulse 2 nsec). The generated light encompasses all the wavelengths and it was applied on animal tissues for the purpose of this study. In the experiments, the light passes through the tested tissue and, by means a microscope lens, arrives to a spectrum analyzer which by means of a reticulum selects one wavelength at time and measures its corresponding received power level.

In our study, the passing light through the tissue, is measured with incremental step of 1.350 nm from 350.000 nm to 1700.000 nm and each value is stored by the instrument. For each tissue were made a total of 1000 measures.

We used fifteen sprague dawley rat tissues, immediately after the sample taking, and with the recorded values graphs were constructed. The spectrum analyzer recorded numbers and the graphics have allowed to evaluate the amount of light able to pass through each tissue and, vice versa, the amount of light not passing which it is reasonable to consider it was completely absorbed by the tissue under examination.

For the reasons stated reported in this study all values below -80 dBm were discarded. As part of our conclusion, it was found that tissue thickness is not all the time crucial and it is not always true that the thinner the tissue the more will be the light passing. It is not even true that the dark chromophore for a certain wavelength increases the light absorption in the tissue. Each tissue has a particular affinity for a specific wavelength and therefore the amount of light able to pass through a tissue, or the absorption into it, depends exclusively from the tissue and the wavelength used.

INTRODUCTION

This study analyzes the light that crosses fifteen sprague dawley rat tissues, generated by an apparatus, called *supercontinuum*, which emits white light starting from a single wavelength source. In particular, in this case it is used a pulsed laser at 1064 nm, with pulse duration of about 2 ns (the values of transmission power are not provided). This radiation is focused into an optical fiber with very small core, 1 µm. In this way nonlinear effects are generated that lead to the emission of a broadband radiation from 350 nm to 2400 nm.

The light passes through the tissue under examination and arrives to a spectrum analyzer, provided with a reticulum that allows the sensor to read only a certain wavelength of light that passes through the tissue. The read sequence is specified by the operator.

In this study, we speak mainly of light passing through the tissue, however, it must be understood that the light that does not pass through the tissue is light absorbed. The value of the absorption is equal to the difference between the generated light and the light that can pass through the tissue. It is not considered the amount of light reflected from the tissue and not even the amount of the light present in the laboratory room at the time of the surveys.

What has been executed in this study has never been done before. No bibliography exits in literature that gives information on how much light can pass through tissues and no publication reports per tissue absorption profile.

The light source was spanning from 350 nm up to 1700 nm with an incremental step of 1.35 nm. Per each step, the amount of passing light is recorded by the spectrum analyzer as single value. As final result, the spectrum analyzer reports the whole sequence of measurement as a unique curve.

The resulting curve of the received light for each tissue is stored. Each curve is then analyzed individually in the phases of this study. From this first analysis it is revealed the amount of radiation passing through each tissue and thus the quantity of the absorption, the wavelengths crossing the tissue and also those which are completely absorbed. Finally it is performed an overall analysis of the results and a comparison between all tissues examined.

In particular, it is verified whether or not the tissue thickness affects the amount of passing light. Moreover, it is also analyzed at specific wavelengths how much the thickness may impact the light passing through by comparing different types of tissue. It is checked as well if the measured values vary with wavelength variation or whether they vary with tissue thickness variation or with tissue histological nature.

These comparisons are performed using the values of the radiation passing through the tissue at the wavelengths of 620.000 nm, 755.000 nm, 890.000 nm, 1060.100 nm, 1160.000 nm, 1295.000 nm.

Materials and methods

The study aims to analyze the amount of laser light, emitted at different wavelengths, that is able to cross a tissue and the tissue radiation absorption. The laser light is generated by a dedicated source device. The light passes through the tissue and is picked up by a receiving device. The power that can pass through the tissue is read by the receiving device.

Initially, before starting any tissue analysis, the values read with no interposed tissue are considered as calibration of the instrument. Then, given a tissue known thickness, knowing the quantity of light emitted along with the amount of outgoing light from the tissue, we can also determine the light absorption of such tissue. To calculate this value it will be enough to make the difference between the power at the source and the power passing through the tissue for each wavelength emitted. In this study we will consider, for wavelengths from 350 nm to 1700 nm, only the power passing through the tissue, the absorption of light in the tissue and the thickness of the tissue. We do not consider the light that might be reflected by the tissue during the experiment being it negligible.

For this study, samples were taken from a sprague dawley rat. The tissues, after sampling, were placed in saline and immediately used for its intended purpose.

In **Table 1** are shown the tissue used and their thickness:

	Tissue	**Thickness**
1	Nerve	0.2 mm
2	Skin	0.3 mm
3	Small Intestine	0.1 mm
4	Lung	0.3 mm
5	Esophagus	0.4 mm
6	Stomach	0.8 mm
7	Kidney	2.4 mm
8	Heart	2.2 mm
9	Spleen	1.2 mm
10	Liver 1	5.7 mm
11	Liver 2	2.3 mm
12	Liver 3	0.6 mm
13	Muscle 1	2.5 mm
14	Muscle 2	0.3 mm
15	Bone	2.2 mm

Table 1 - List of used tissue.

The light source is the model SuperK Compact, produced by NKT Photonics. It can be defined a broadband laser, called s*upercontinuum*. It is an device which generates white light from a single wavelength source. It is a pulsed laser at 1064 nm, with duration pulse about 2 nsec (the values of transmission power are not provided), that for a series of nonlinear effects, generates wideband light (Fig. 1). This radiation is focused into an optical fiber with a core very small, 1 µm, in this way non-linear effects are generated that lead to the generation of broadband radiation with wavelengths comprised between 350 nm and 2400 nm.

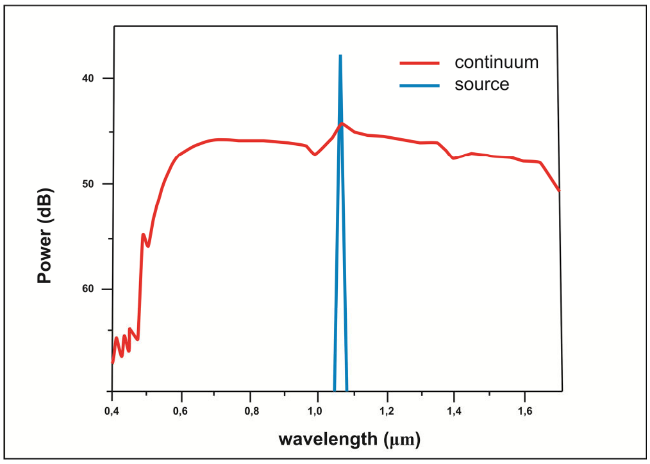

Fig. 1 - A typical supercontinuum spectrum. The blue line shows the spectrum of the pump source launched into a photonic crystal fiber, while the red line shows the resulting supercontinuum spectrum generated after propagating through the fiber.

At receiver side, the light beam is focused, by the means of a microscope objective, in the core of a multimode optical fiber with a diameter of about 50 μm. The radiation is sent via optical fiber to the optical spectrum analyzer. Such instruments is an AQ-6315A manufactured by Ando Electric Co. (now Yokogawa). The distance between the collimator and the lens, which collects the light, is 31 cm.

The source generates a light constituted by many wavelengths. The spectrum analyzer is capable to filter the light source, so that the read sequence is between a certain initial value up to a certain final value, according to the sequence desired by the operator. In this study, the analyzer is set so that the filter lets the light passing from 350 nm up to 1700 nm with increments of 1.350 nm. The measures executed per sequence are 1000 in total. The spectrum analyzer is equipped with a reticulum whose function is to separate light into its individual components (like a prism) before the photo detector. Between the photo detector and the reticle there is a tunable spatial filter that selects the single wavelengths.

The measurement chain can be described in this way: *supercontinuum* source (whose output is collimated, and the collimator is part of the source), tissue, lens by microscope , fiber, spectrum analyzer, which is part of the reticulum.

The light exits from the source, passes in the air and enters in the receiver lens. The receiver sensor is arranged so that the source outgoing light is coaxial with it. The spectrum analyzer records the light power, expressed in dBm, for each instantaneous value of the emitted wavelength. The diameter of the light source is variable by 1 mm to 3 mm. In particular the diameter of the radiation is 1 mm at 530 nm, 2 mm at 1100 nm and 3 mm at 2000 nm.

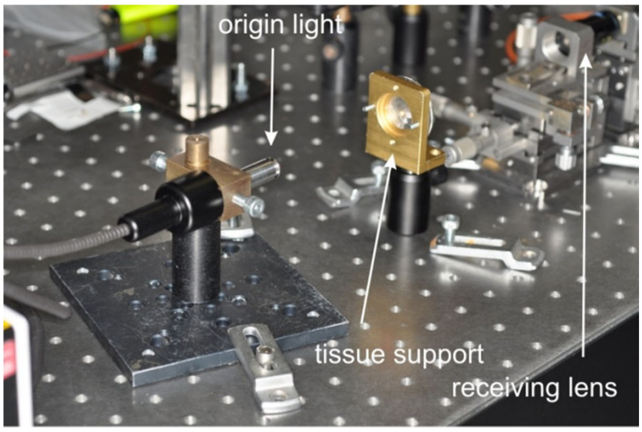

Fig. 2 - Registration device: origin light, tissue support, receiving lens (lateral view).

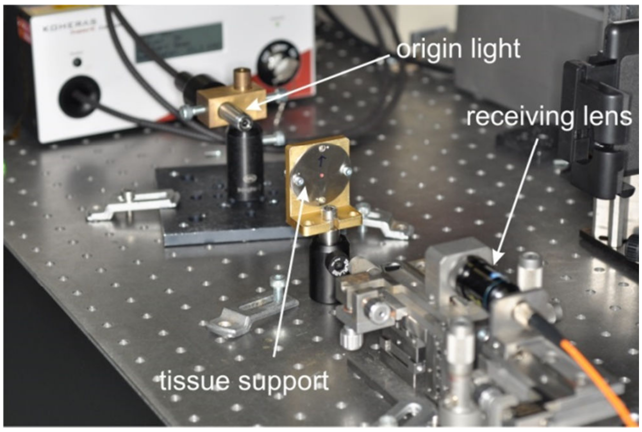

Fig. 3 - Registration device: origin light, tissue support, receiving lens (lateral view).

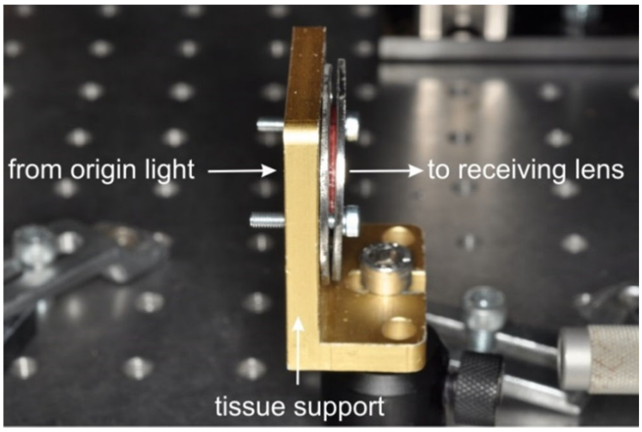

Fig. 4 - Tissue support detail view: fixing plates and the testing tissue (Lung).

Fig. 5 - The analyzer monitors showing the light passing through the sciatic nerve. At the top the REF graphic and at the bottom the nerve tissue graphic.

At the exit of the light source, at a distance of about 15 cm, it is placed the tissue under study held by a fixed support (Fig. 2, Fig. 3, Fig. 4). This structure is constituted by a support (Fig. 7, Fig. 8) to which are fixed two circular steel plates provided with a central concentric hole. There are three couples of plates (Fig. 9), two by two with the central hole of the same diameter and concentric to its homologous: the first couple has a central hole with a diameter of 1.5 mm, the second of 2.8 mm, the third of 3.8 mm. For measurement convenience, it is selected the most suitable plates couple for each analyzed tissue. The tissue under study is inserted, between these plates, in correspondence of the central hole through which the light in question passes. The plates are not pressed one another: the tissue is only held by them in a passive manner and thus the thickness of the tissue is not changed from the grip of the screws.

The hole of the support plates is coaxial with the ray and the outgoing beam passes perpendicularly to them. At a distance of about 15 cm from the support (Fig. 2, Fig. 3), is located the lens receiving the outgoing light from the tissue. The outgoing light from the source passes through the hole of the first support plate, it passes through the tissue, it comes out from the hole of the second plate (coaxial with the hole of the first) and finally it arrives to the lens of the receiver sensor, which is fixed from the outset in a coaxial manner with the light source.

The study is conducted in a univocal manner for each tissue, the procedures are applied in the same manner for all samples. The spectrum analyzer records the values (in dBm) of the light captured from 350 nm up to 1700 nm and draws on his monitor the resulting graph (Fig. 5, Fig. 6). On the abscissa are reported the wavelength of the light source and on the ordinate the power values of light able to cross the tissue under examination. For each measurement, the analyzer records the values of the light captured; they are then stored by the operator, by name, on a floppy disk, to be exported and processed in objective of the tests.

At the beginning of the study the light is emitted in a sequential manner, as already said, without crossing any obstacle, passing only through the air, through the space that separates the source from the receiver lens and enters into the optical fiber that leads to analyzer. The resulting graph is the reference path (REF) for following measures and represent setting of the instrument for the purposes of the experiment.

All recorded values were exported and loaded into an Excel spreadsheet, by which were constructed the graphs of measures (setting of the instrument, light values passing and absorption into the tissue). Excel was also used for the calculation of absorption values relating to each wavelength emitted from the source (Fig. 6).

The graphs are analyzed in detail, using the same criteria for each tissue.

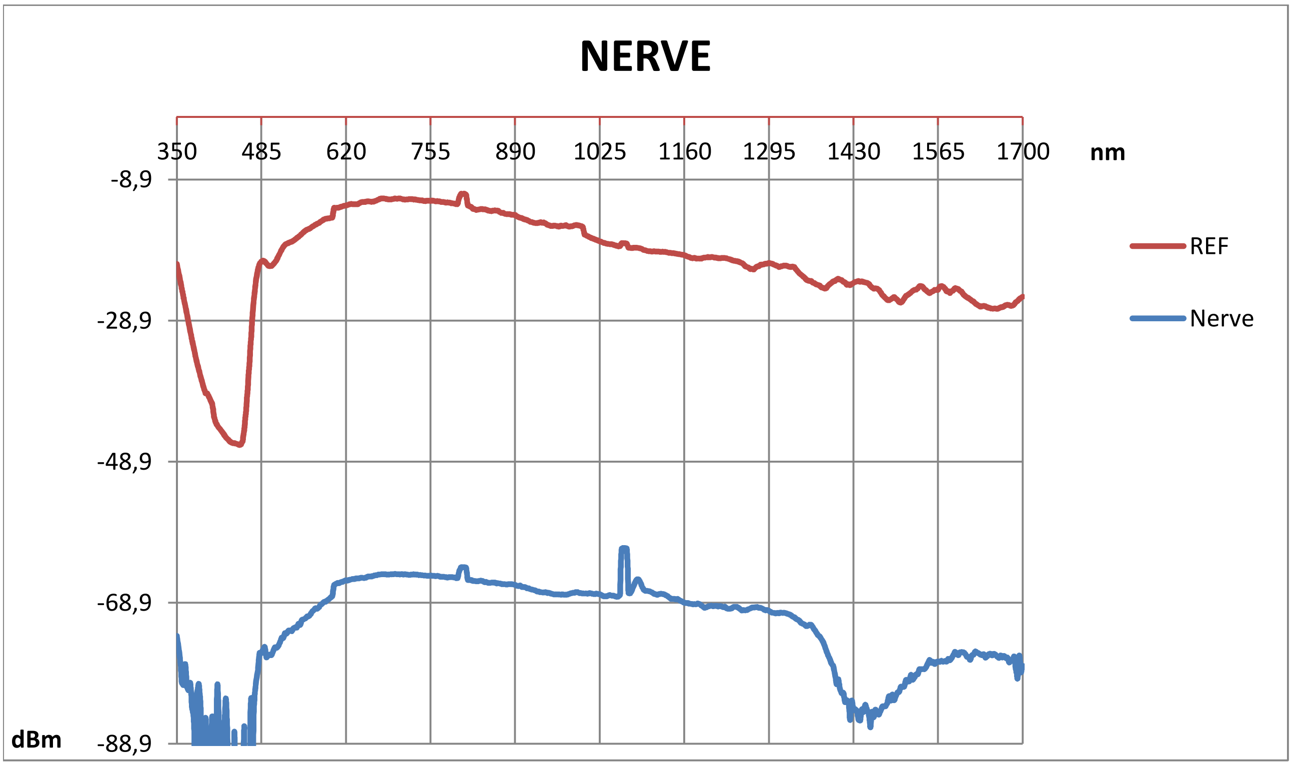

Fig. 6– Graphic created from the Excel spreadsheet of the values measured by the spectrum analyzer to the sciatic nerve of the sprague dawley rat. Compare this pattern with that shown in Fig. 5.

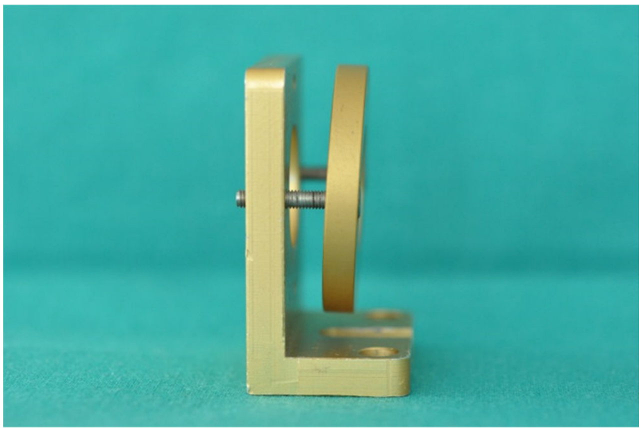

Fig. 7 - Support of steel plates, side view.

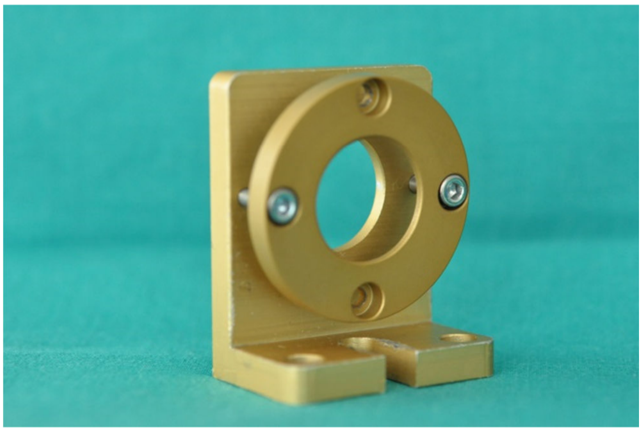

Fig. 8 - Support of steel plates, 3/4 view

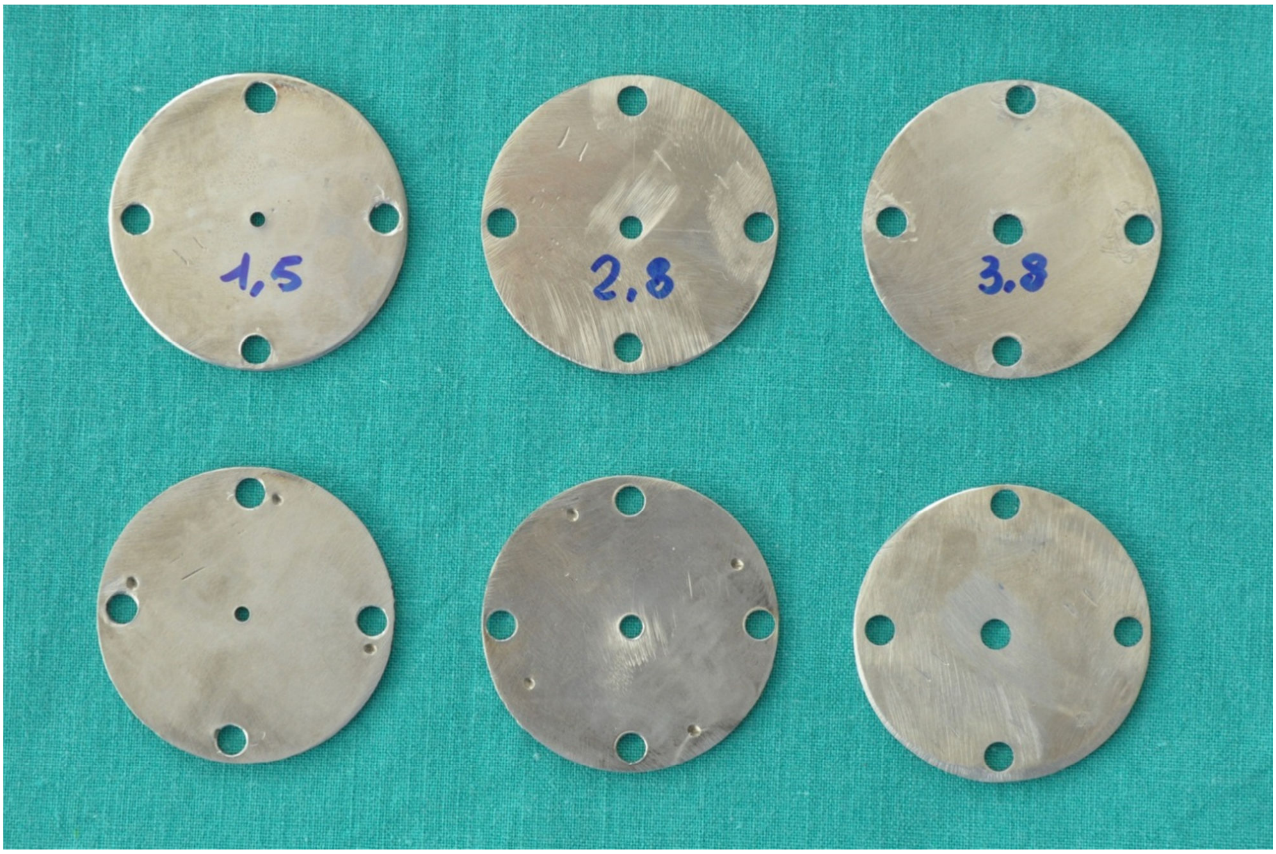

Fig. 9 - Steel plates with concentric center hole used by tissue support.

Method of calculation

The values recorded by the instrument are measured in dBm, which is an expression in decibels (dB) of ratio between the emitted power and 1 milliWatt (mW).

To understand the meaning of these values is necessary to introduce some concepts.

When a generator emits a light or a power and this, after having completed a certain path within a medium (air, glass, tissue, etc.), is picked up by a receiving system, it is said that the gain of the medium crossed is equal to the ratio between the output power P_{out} (measured by the receiving system) after traversing the medium and the input power P_{in} at the medium :

$$G = \frac{P_{out}}{P_{in}}$$

Similarly, in the same measurement system, it is said that the attenuation or the absorption, is equal to the ratio between the input power P_{in} (or power traversing the medium) and the power measured at the output of the medium, P_{out}:

$$A = \frac{P_{in}}{P_{out}} = \frac{1}{G}$$

Any relationship between mathematics quantity is better defined in decibels (*dB*), which is 10 times (10 db = 1 bel) the logarithm base 10 of both sides of that equation:

$$10 \log_{10} A = 10 \log_{10} \frac{P_{in}}{P_{out}}$$

so $\underline{10 \log_{10} A}$ is a measure expressed in decibels, which becomes:

$$10 \log_{10} A = 10 \log_{10} P_{in} - 10 \log_{10} P_{out}$$

If the power is expressed in milliWatt (1 mW is equal to 10^{-3} Watt) the value $\underline{10 \log_{10} P_{in}}$ in decibel becomes $10 \log_{10} \frac{P_{in}}{10^3}$ *dBm* (or *dBmW*, which means *decibel - milliWatt*).

So the attenuation or loss of power in the medium (or tissue), in milliWatts becomes:

$$\bar{A} = 10 \log_{10} \frac{P_{in}}{10^3} - 10 \log_{10} \frac{P_{out}}{10^3}$$

absorption (in decibel)* = *power in (in mW)* – *power out (in mW)

which becomes:

$$\bar{A} = \left(-30 + 10\log_{10} P_{in}\right) - \left(-30 + 10\log_{10} P_{out}\right)$$

which becomes:

$$\bar{A} = 10\log_{10} P_{in} - 10\log_{10} P_{out}$$

absorption (in decibel) ***= power in (in dBm) – power out (in dBm)***

In our study, both the light, source and the transmitted, are measured in *dBm*. They are both negative value because they are less than one milliWatt.

Therefore, from what has been shown so far, the calculation of light absorption within the tissue is equal to the difference between the power of the light emitted by the source and the light that can pass through the tissue, measured by the spectrum analyzer.

Absorption (dB) = light source (dBm) – light passing through the tissue (dBm)

Example:
In the sciatic nerve of the sprague dawley rat at wavelength of 620.000 nm light source has a value of -12.565 dBm, and the light that can pass through the tissue is equal to -65,709 dBm. With these numbers the absorption of light in the nerve, at that wavelength, is equal to 53.144 dB (decibels):

Nerve Absorption** $_{(at\ 620\ nm)}$ **= (-12.565 dBm) - (-65.709 dBm) = 53.144 dB

The power scale values are all negative values for the intrinsic value of the formula. All calculations for the tissues analyzed and tested in the present study will be performed in this manner. When a monochromatic light (laser) hits a tissue, a part of the light will be reflected, a part will pass through the tissue, and part will remain in the tissue, either diffused or absorbed.

In this study, the loss of the reflected light is neglected, and we do not consider the influence that could have the light illuminating the room of the experiment.

In this regard, see the chapter "Basic conditions for data analysis".

We will consider only the light that hits the tissue, the light passing through it and the light that is absorbed into the tissue.

Beer-Lambert law

When a light is emitted at a given intensity or power, and it passes through a medium, it follows the law of Lambert-Beer. It is an empirical relationship that correlates the amount of light absorbed by the medium, the chemical nature, the concentration and the thickness of the medium.

Suppose that a monochromatic light of intensity I_0 strikes a solution contained within a cuvette.

When a beam of light (monochromatic) of intensity I_0 passes through a layer of a thickness l of a medium, a part of it is absorbed by the medium itself, and a part of it is transmitted with residual intensity I_1. The relationship between the intensity of the light transmitted (outgoing) and the incident light (incoming) through the middle, is expressed by the relation

$$\frac{I}{I_o} = e^{-k_\lambda l}$$

where e is the base of natural numbers, $k\lambda$ is the absorption coefficient (which is a constant typical of the medium and depends on the wavelength λ) and l is the optical path (the thickness of the solution traversed). Transmittance is defined as the ratio between the intensity of the transmitted light and the light incident on the medium through. So the relationship becomes:

$$T = \frac{I}{I_0} = e^{-k_\lambda l}$$

If we do logarithm, base e, of both members of the equation and call absorbance (A) the $-\log_e T$ (the logarithm with negative sign of **T**) the relationship becomes:

$$A = k_\lambda l$$

If we consider that there is in the cuvette a solution with a certain molar extinction ε_λ (which depends on the wavelength of the incident light) and that the solution has a certain molarity M, we can affirm that

$$k_\lambda = \varepsilon_\lambda \cdot M$$

the constant k_λ depends on the molar extinction ε_λ and on molarity M. So the absorbance becomes

$$A = \varepsilon_\lambda \cdot l \cdot M$$

In conclusion the Lambert-Beer law assigns the value at the absorbance of a monochromatic light, having a certain intensity I_0, which passes through a medium of thickness l and affirm that it will depend on the absorption coefficient of the medium, having a defined chemical nature ***“c”*** and a defined concentration ***“α”***, and will depend on the wavelength of light.

So the absorbance, or absorption, is an exponential value, that expressed in dBm becomes linear.

Basic conditions for data analysis

In the measurement campaign, the analysis of data on the tissues showed spikes of light not transmitted, for some wavelengths, different tissue by tissue. The recorded values are very tiny.

So, to know and to establish the reliability of the results, we performed the measures without any light source input, except for the ambient light. The first test was performed removing the receiver lens using the free sensor, which sends the signal directly to the spectrum analyzer. The second was performed using the sensor with focusing, i.e. leaving in the test setup the microscope lens focusing the light in an optical fiber of diameter of 50 μ, as in the whole test campaign.

These measures were performed in the same laboratory environmental conditions, in other days with different outdoor weather conditions and with different recording sequence (wavelength step). Two tests were performed first using a step of 1.400 nm, one with free sensor and one with sensor and fiber starting from 350 nm up to 1750 nm at the same time a certain day. The measure recorded in these two tests are shown in the following graphs and are explained in this chapter.

Then other two tests were performed using a step of 1.350 nm, one with the free sensor and one with the sensor and fiber starting from 350 nm up to 1700 nm at the same time of another day at a distance of some weeks from the first two tests. The measure recorded in these two tests are shown in the following graphs and are explained in this chapter.

The measures executed on the tissues in our experiments were performed starting from 350 nm up to 1700 nm with incremental step of 1.350 nm and not 1.400 nm. Nevertheless, we reported both cases in this study.

The graph in Fig. 10, using 1.400 nm step and leaving the sensor directly connected to the spectrum analyzer, we notice that some wavelengths within the visible are much higher than -80 dBm. At other wavelengths the instrument detects peaks of very low value (-210.000 dBm) or lower than -80 dBm.

The graphs in Fig. 11, Fig. 12 and Fig. 13 show the details of the first test with the free sensor again with 1.400 nm step.

If we exclude the portion in the visible range, equal to -63.215 dBm at 546.000 nm, the highest significant value the analyzer succeeded to measure using the free sensor and only in the presence of ambient light, is of -76.238 dBm at 1013.660 nm (Fig. 12) and -78.697 dBm at 1531.600 nm (Table 2).

The values recorded at other wavelengths are all lower than those listed above or even lower than -80 dBm.

from	to	Wavelength (nm)	Light max value (dBm)
350.000	900.200	**546.000**	**-63.215**
901.600	1300.600	**1013.600**	**-76.238**
1302.000	1750.000	**1531.600**	**-78.697**

Table 2 – Wavelengths and maximum values of light recorded by the spectrum analyzer using the free sensor, 1.400 nm step.

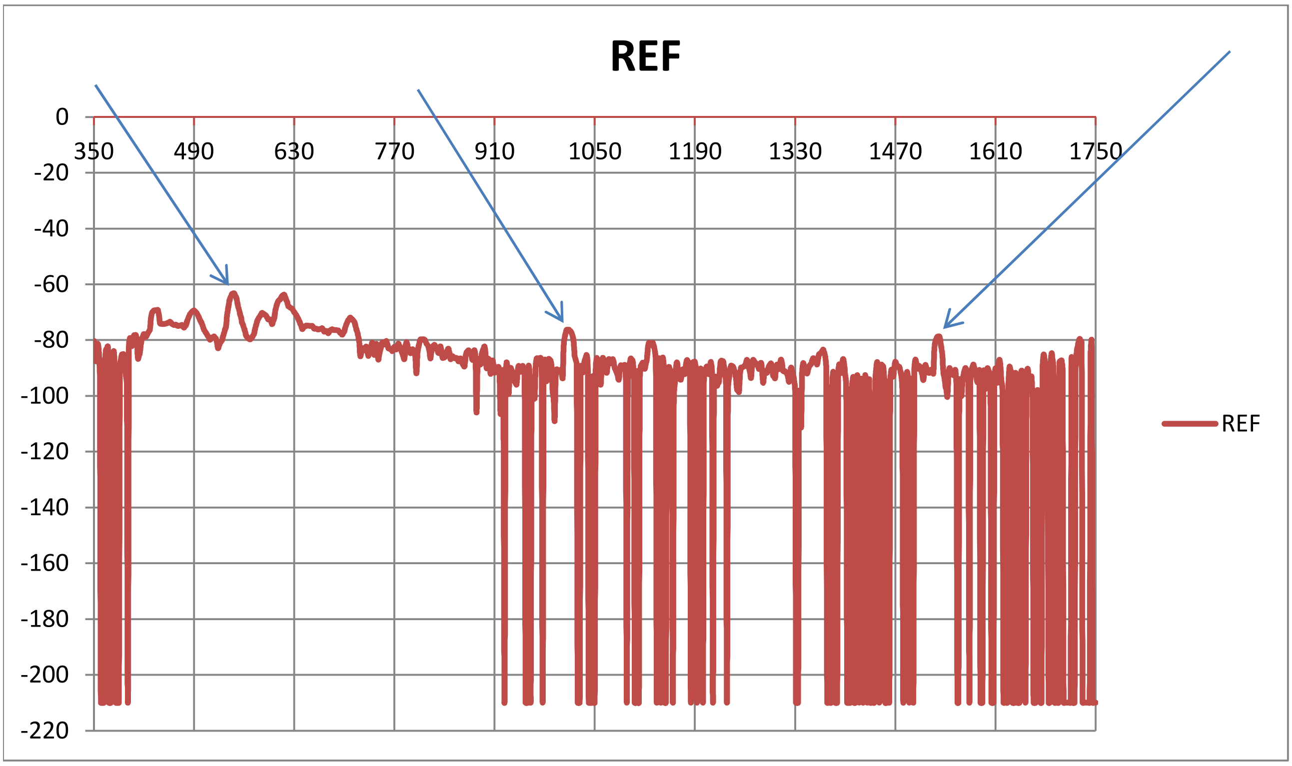

Fig. 10 – Graph recorded by the spectrum analyzer free sensor, 1.400 nm step, without no light input source with the exception of the ambient light. The arrows indicate the maximum values.

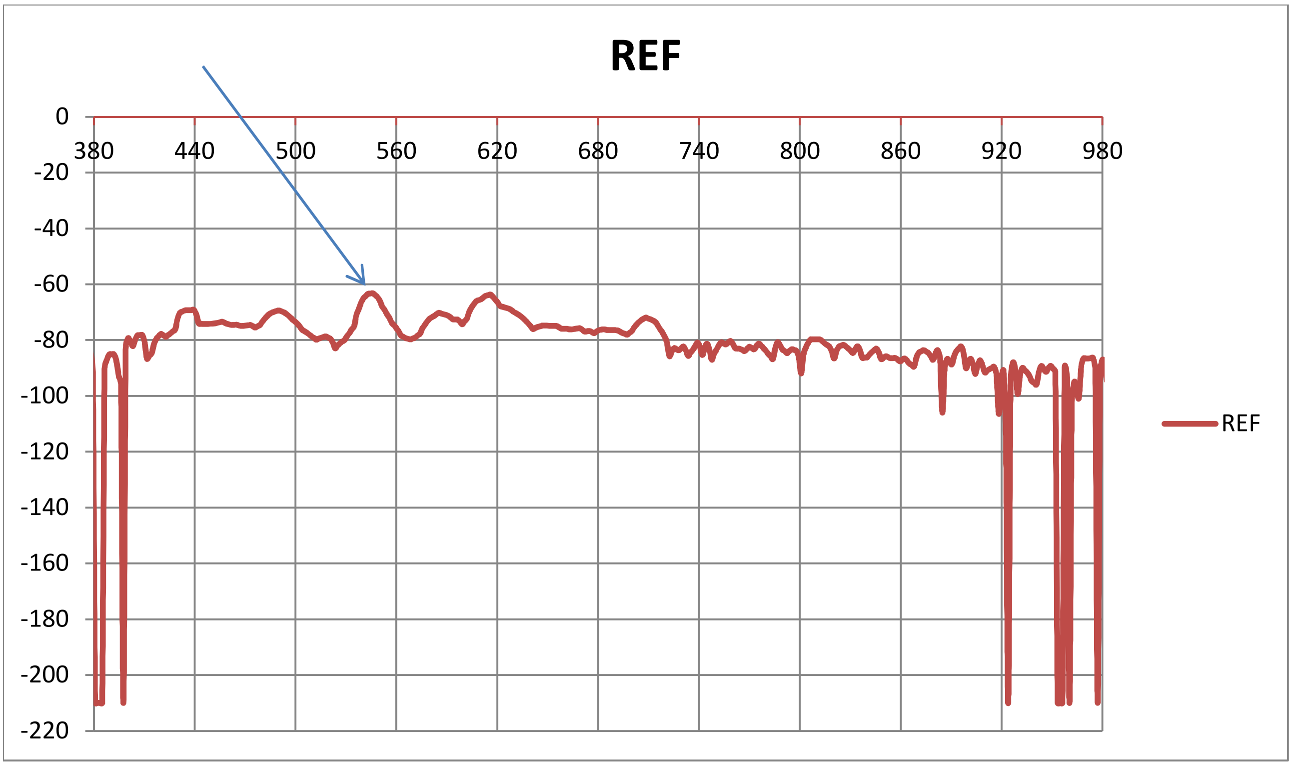

Fig. 11 - Graph recorded by the spectrum analyzer free sensor, 1.400 nm step, without no light input source with the exception of the ambient light. Graph from 380 nm to 980 nm with maximum value of -63.215 dBm at 546.000 nm (arrow).

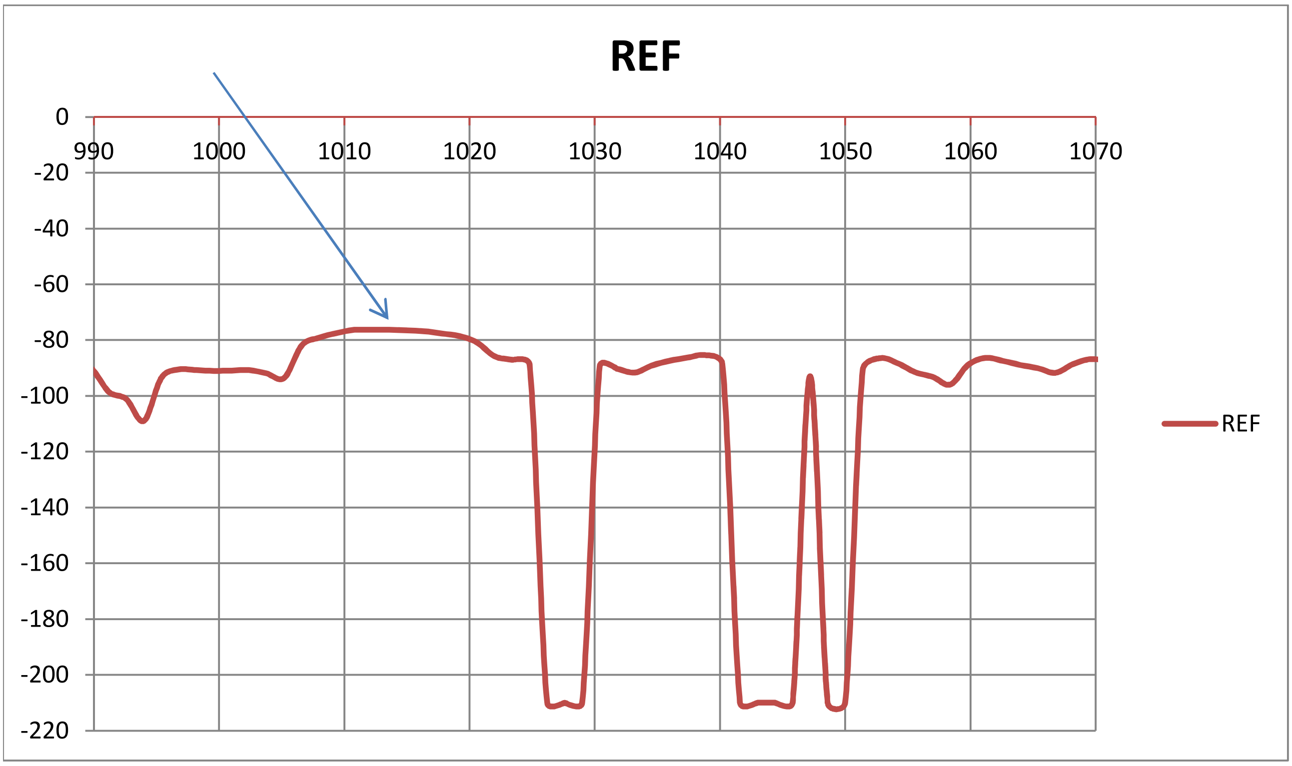

Fig. 12 - Graph recorded by the spectrum analyzer free sensor, 1.400 nm step, without no light input source with the exception of the ambient light. Graph from 990 nm a 1070 nm with maximum value of -76.238 at 1013.600 nm (arrow).

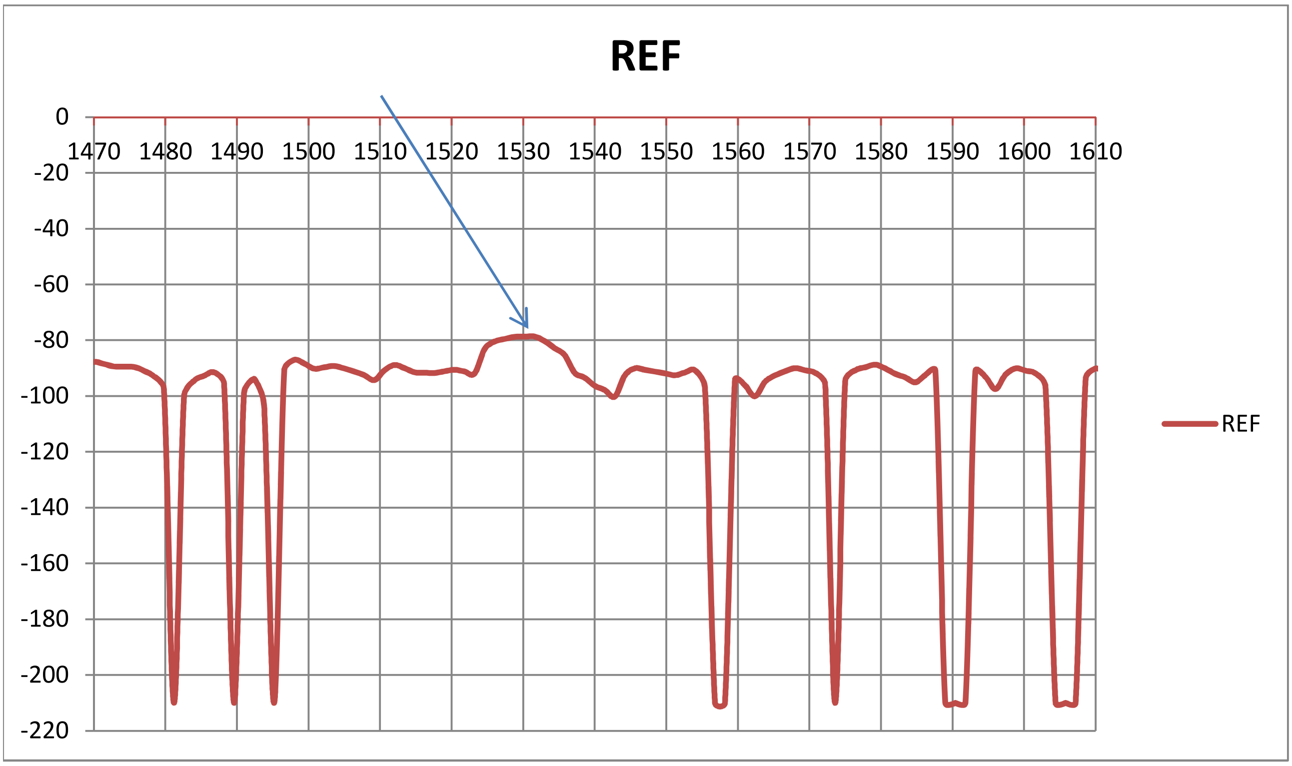

Fig. 13 - Graph recorded by the spectrum analyzer free sensor, 1.400 nm step, without no light input source with the exception of the ambient light. Graph from 1470 nm to 1610 nm with maximum value of -78.697 dBm at 1531.600 nm (arrow).

The graph in Fig. 14 shows the second test adopting instead 1.400 nm as step, using only ambient light and using sensor and fiber to send light to the instrument. It is noted that all the values, greater than -80 dBm, recorded in the previous test in the visible light range disappear because the fiber has a light receiving angle very small compared to the sensor connected directly. So only the light in axis with the fiber can reach the sensor. So, the portion of the light captured is much lower than the previous measure and of an intensity so low that the sensor is not able to detect it. The analysis of the graph of Fig. 14 shows immediately that all the values recorded are lower than -80 dBm except for the initial and final wavelengths. The graphs of Fig. 15 and Fig. 16 show the details of this second test with sensor and fiber.

The significant value that the analyzer succeeded to measure using the sensor and the fiber, without any light source, only in the presence of ambient light and in sequence of 1.400 nm is of -79.663 dBm at 383.600 nm (Fig. 15, Table 3) and -78.652 dBm at 1738.800 nm (Fig. 16, Table 3).

The values recorded at all other wavelengths are all lower than -80 dBm.

from	to	Wavelength (nm)	Light max value (dBm)
350.000	400.400	**383.600**	**-79.663**
401.800	900.200	**403.200**	**-82.192**
901.600	1300.600	**1033.100**	**-85.821**
1302.000	1750.000	**1738.800**	**-78.652**

Table 3 – Wavelengths and maximum values of light recorded by the spectrum analyzer using sensor and fiber with 1.400 nm step.

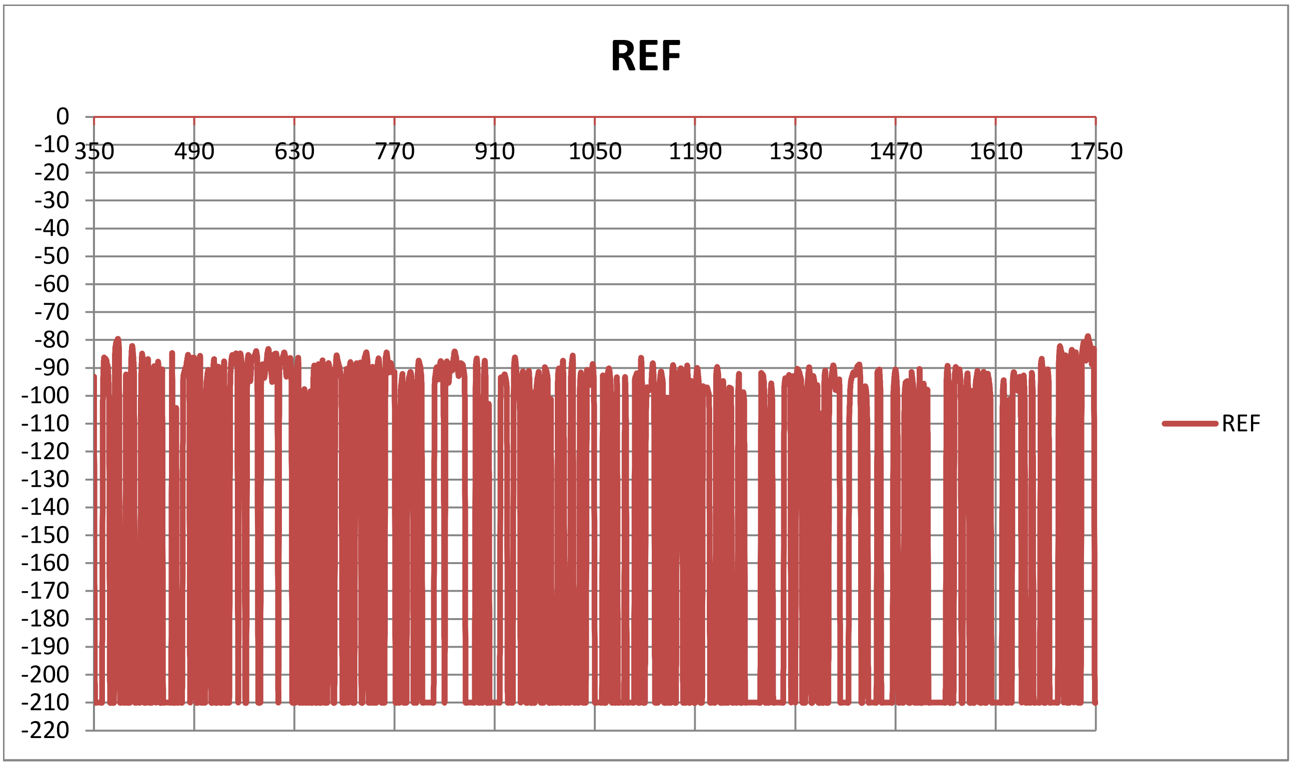

Fig. 14 - Graph recorded by the spectrum analyzer using sensor and fiber, 1.400 nm step, without light input source with the exception of the ambient light.

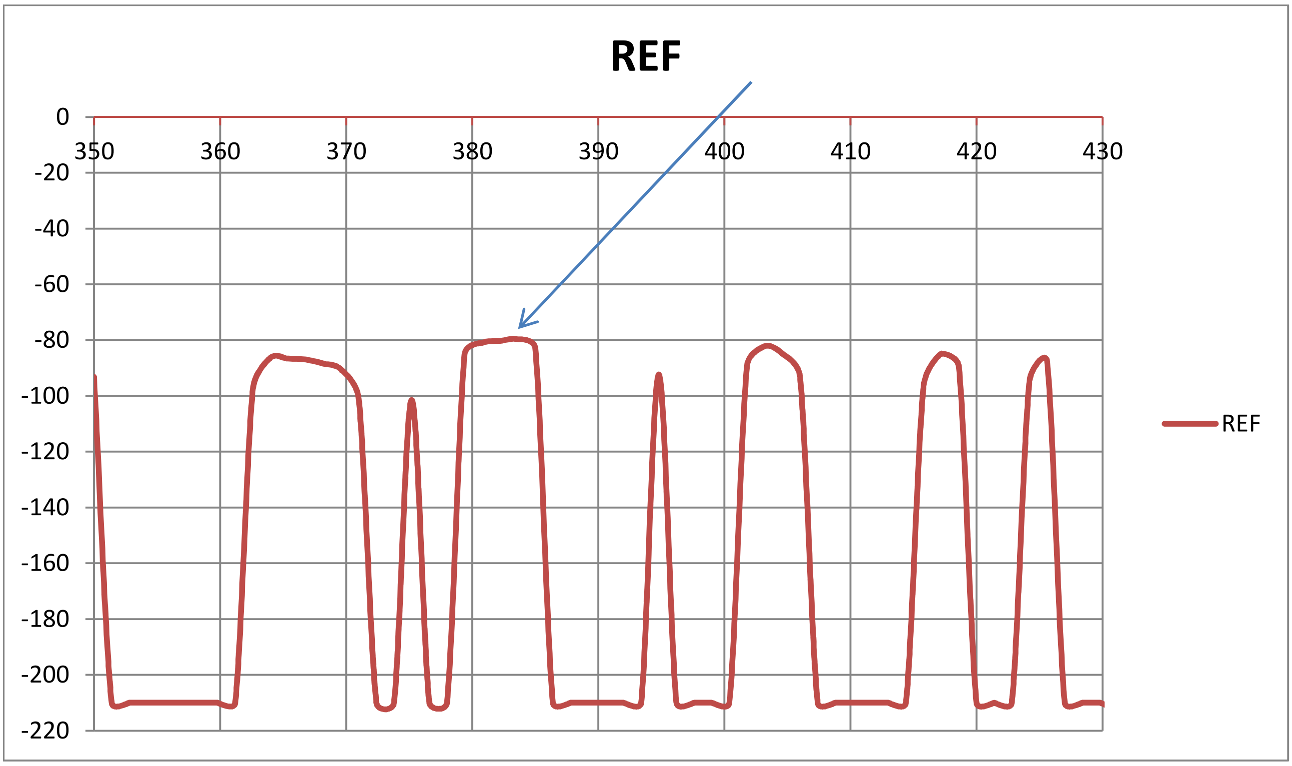

Fig. 15 - Graph recorded by the spectrum analyzer using sensor and fiber, 1.400 nm step, without light input source with the exception of the ambient light. Graph from 350 nm to 430 nm with maximum value of -79.663 dBm at 383.600 nm (arrow).

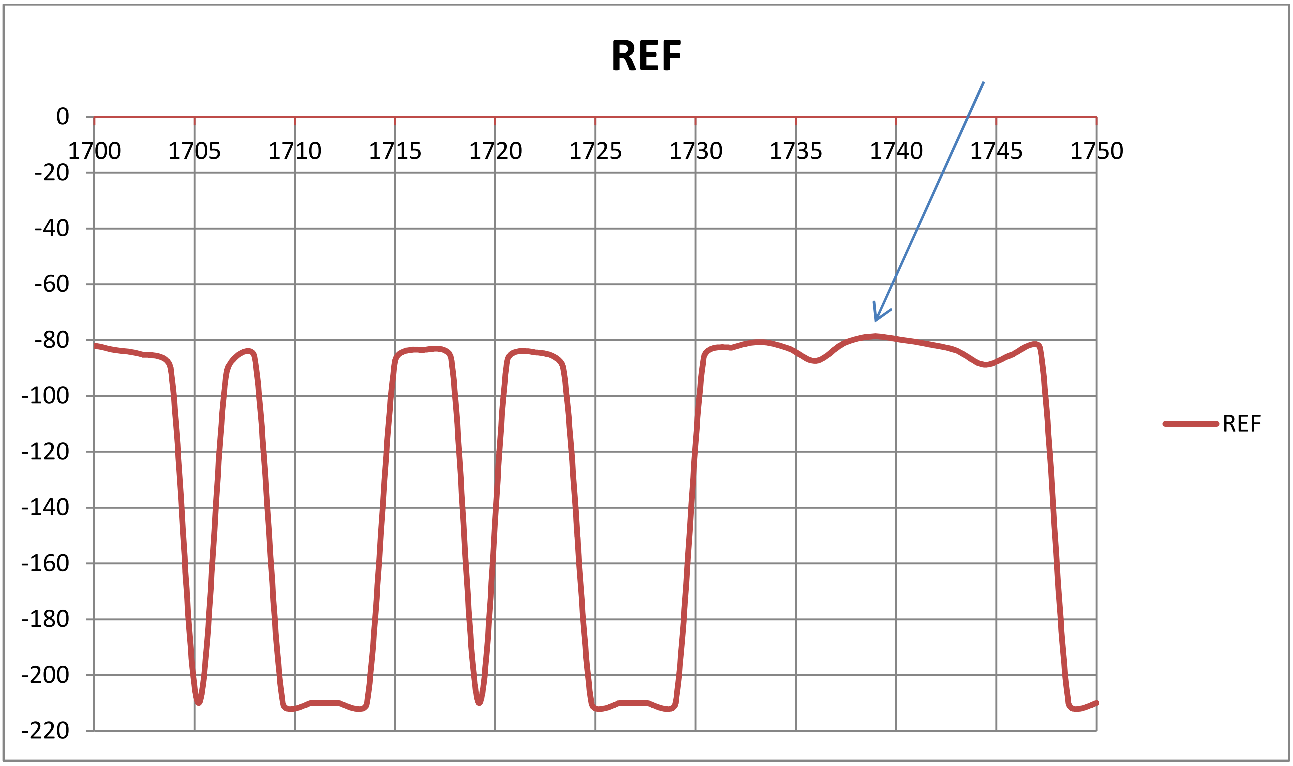

Fig. 16 - Graph recorded by the spectrum analyzer using sensor and fiber, 1.400 nm step, without light input source with the exception of the ambient light. Graph from 1700 nm to 1750 nm with maximum value of -78.652 dBm at 1738.800 nm (arrow).

Other two tests were performed using only ambient light, at the same time of another day after a few weeks from the first two tests, but using instead a step of 1.350 nm in agreement with all the measurements done on sprague dawley rat tissues. The first is performed using the free sensor and the second using the sensor and the fiber.

By analyzing the graph (Fig. 17) we note that almost all of the values are lower than -80 dBm, except for wavelengths from 350 nm up to 900 nm. In this range of wavelengths greater values are present of -80 dBm (Fig. 17, Fig. 18), but they are very few and the maximum value of -70.595 dBm is measured at 371.600 nm (Fig. 18). To understand and make sense of reading these values, the sequence of the wavelengths is divided into 4 parts: from 350.000 nm to 401.300 nm, from here up to 900.800 nm, then up to 1300.400 nm and then up to 1700 nm.

In the Fig. 18, Fig. 19 and Fig. 20 some details are shown. The maximum values recorded in these areas of wavelengths are listed in Table 4.

from	to	Wavelength (nm)	Light max value (dBm)
350.000	401.300	**371.600**	**-70.595**
402.650	900.800	**533.600**	**-72.513**
902.150	1300.400	**1033.100**	**-79.460**
1301.750	1700.000	**1700.000**	**-79.703**

Table 4 – Wavelengths and maximum values of light recorded by the spectrum analyzer using free sensor with 1.350 nm step.

The values recorded at other wavelengths are all lower than these listed above or even lower than -80 dBm.

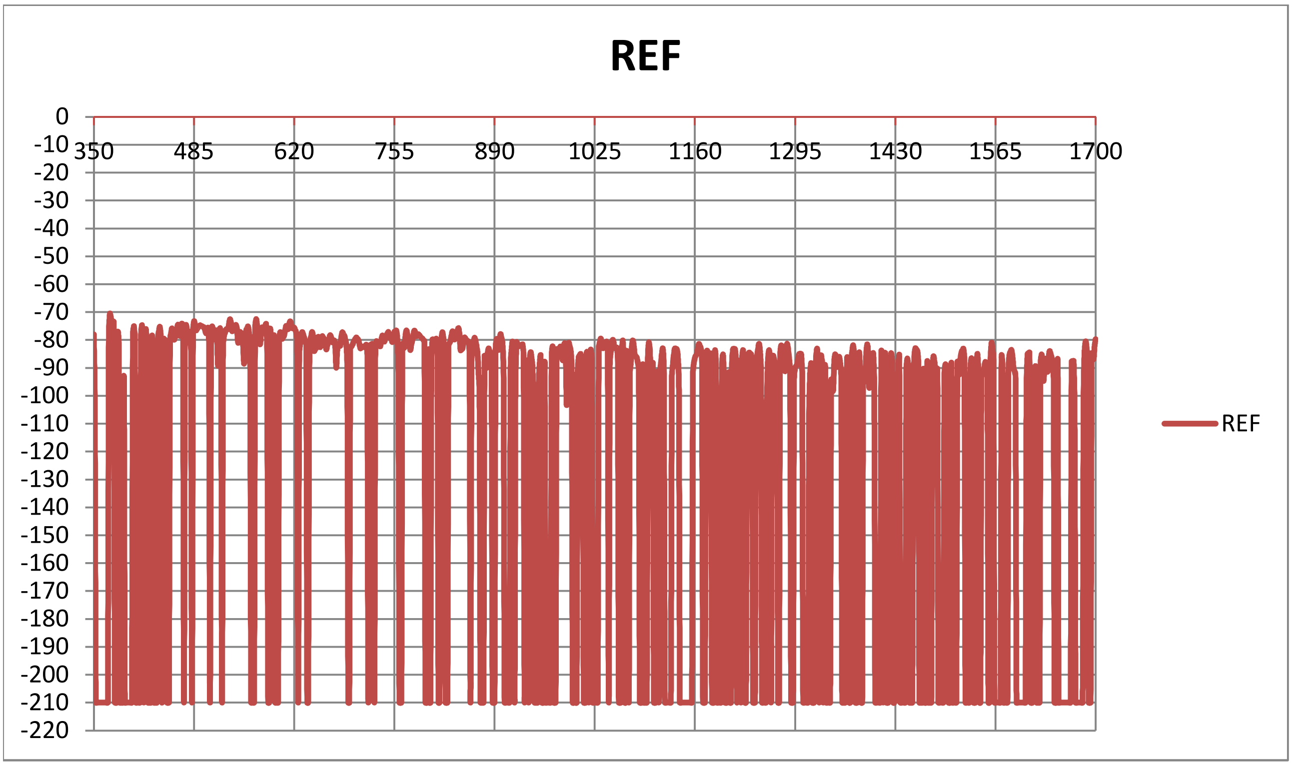

Fig. 17 – Graph recorded by the spectrum analyzer free sensor, 1.350 nm step, without light input source with the exception of the ambient light.

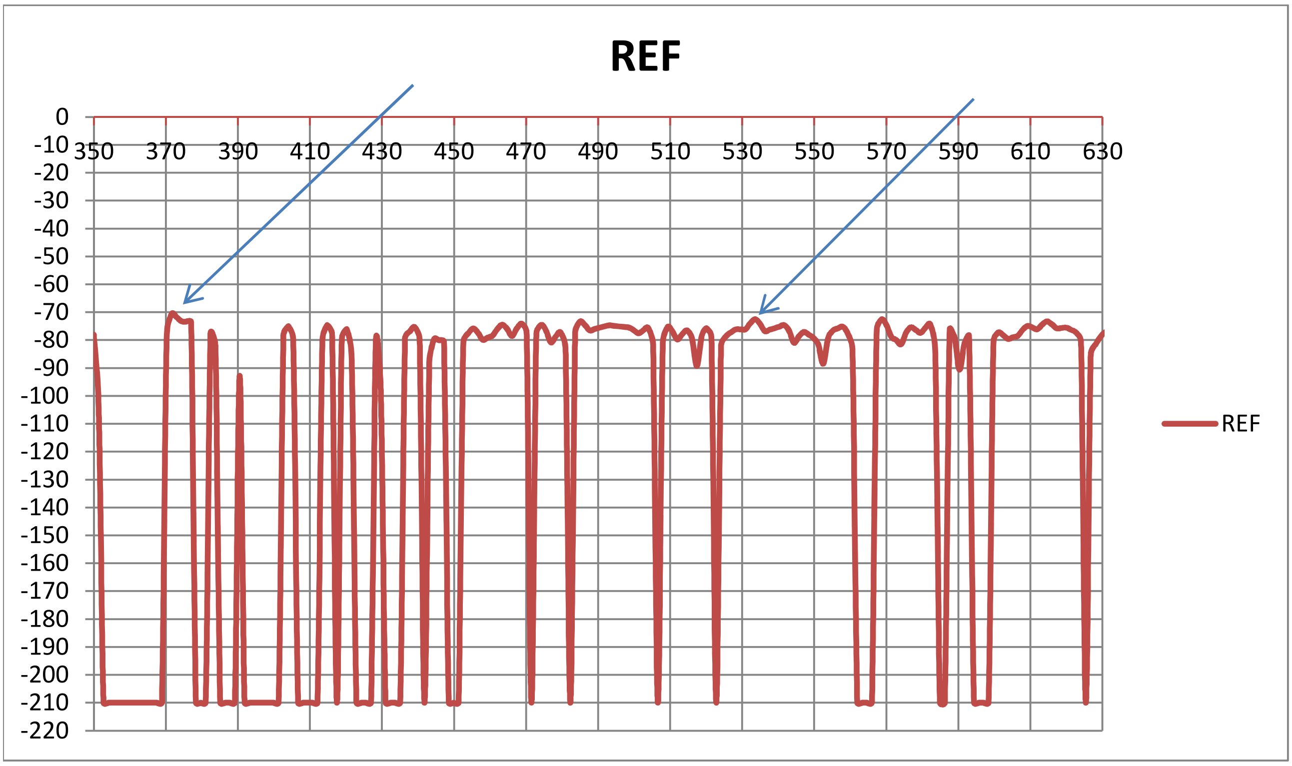

Fig. 18 – Graph recorded by the spectrum analyzer free sensor, 1.350 nm step, without light input source with the exception of the ambient light. Graph from 350 nm to 630 nm with maximum value of -70.595 dBm at 371.600 nm and of -72.513 dBm at 533.600 nm (arrow).

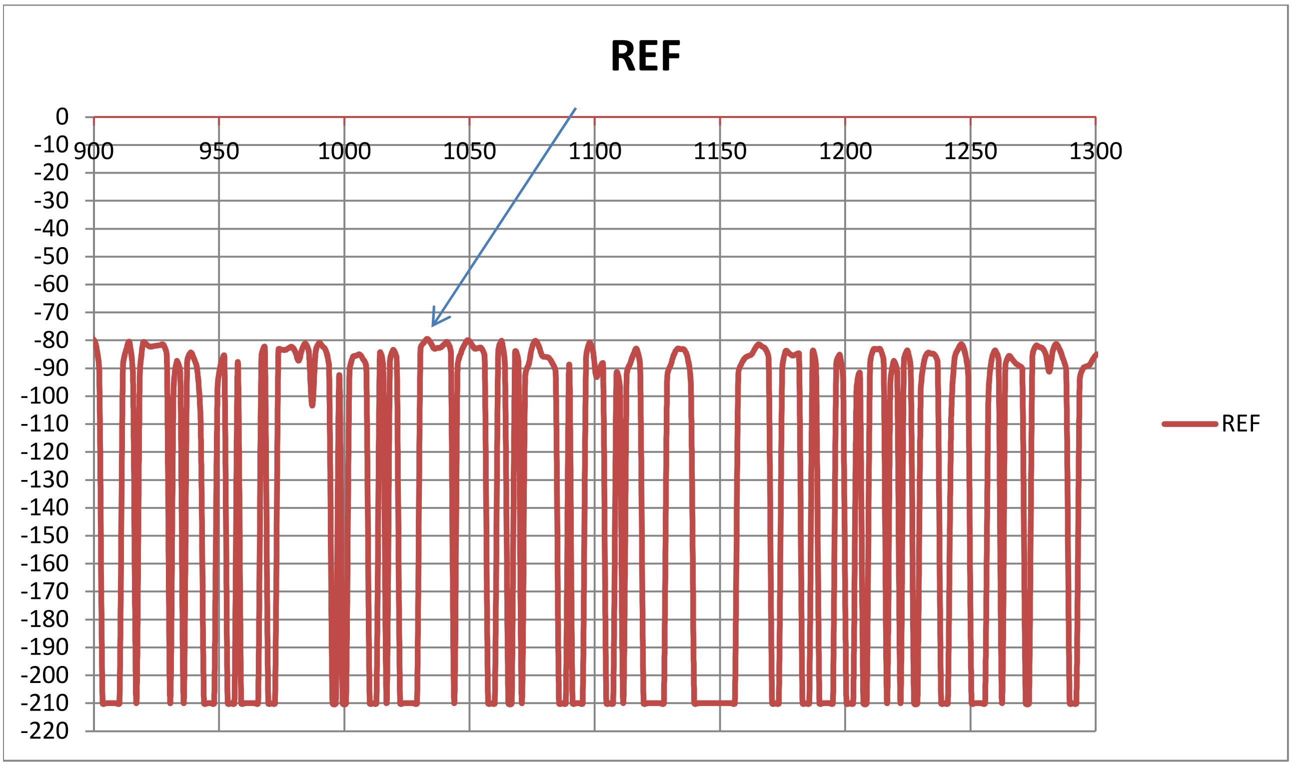

Fig. 19 – Graph recorded by the spectrum analyzer free sensor, 1.350 nm step, without light input source with the exception of the ambient light. Graph from 900 nm to 1300 nm with maximum value of -79.460 dBm at 1033.100 nm (arrow).

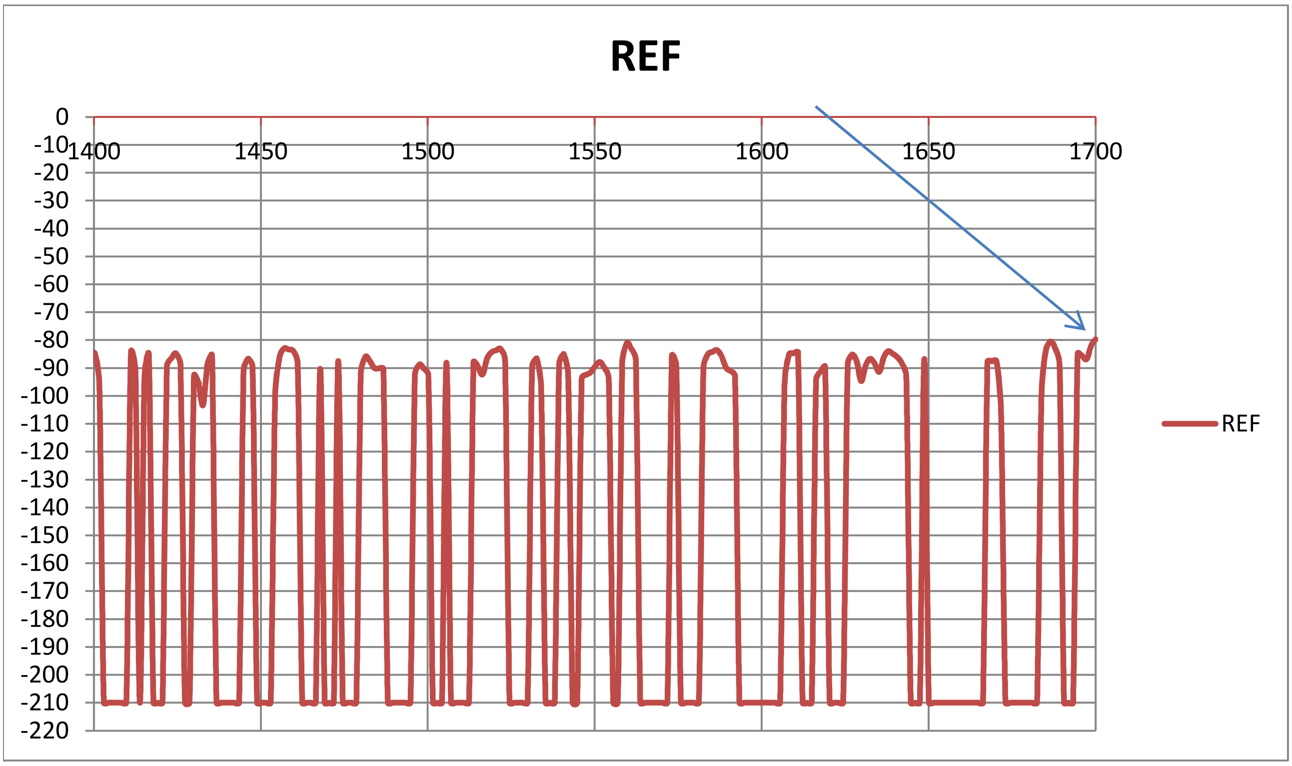

Fig. 20 – Graph recorded by the spectrum analyzer free sensor, 1.350 nm step, without light input source with the exception of the ambient light. Graph from 1400 nm to 1700 nm with maximum value of -79.703 dBm at 1700 nm (arrow).

Also the graph performed with sensor and fiber, with steps of 1.350 nm, shows that almost all of the values are lower than -80 dBm (Fig. 21). In this graph it is noted that there are values greater than -80 dBm, but these are very few and the maximum value of -72.250 dBm is measured at 371.600 nm (Fig. 22).

The highest values are recorded in the visible range from 425 nm to 890 nm.

To understand and give read meaning to these values, also now the sequence of the wavelengths is divided into 4 parts: from 350.000 nm to 401.300 nm, from here up to 900.800 nm, then up to 1300.400 nm and then up to 1700 nm. The maximum values recorded in these areas of wavelengths are listed in Table 5.

from	to	Wavelength (nm)	Light max value (dBm)
350.000	401.300	**371.600**	**-72.250**
402.650	900.800	**487.700**	**-74.010**
902.150	1300.400	**1022.300**	**-81.878**
1301.750	1700.000	**1694.600**	**-77.319**

Table 5 – Wavelengths and maximum values of light recorded by the spectrum analyzer, using sensor and fiber, with 1.350 nm step.

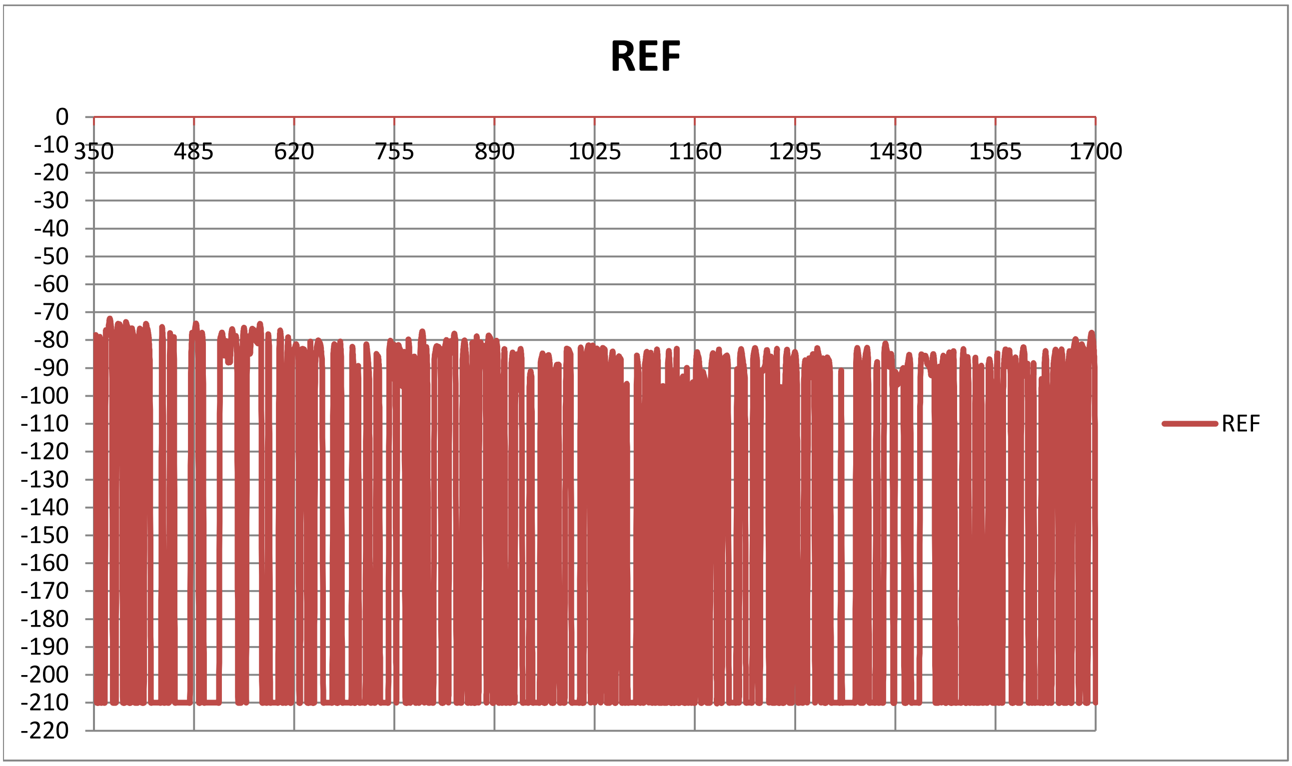

Fig. 21 – Graph recorded by the spectrum analyzer using sensor and fiber, sequence 1.350 nm, without light input source with the exception of the ambient light.

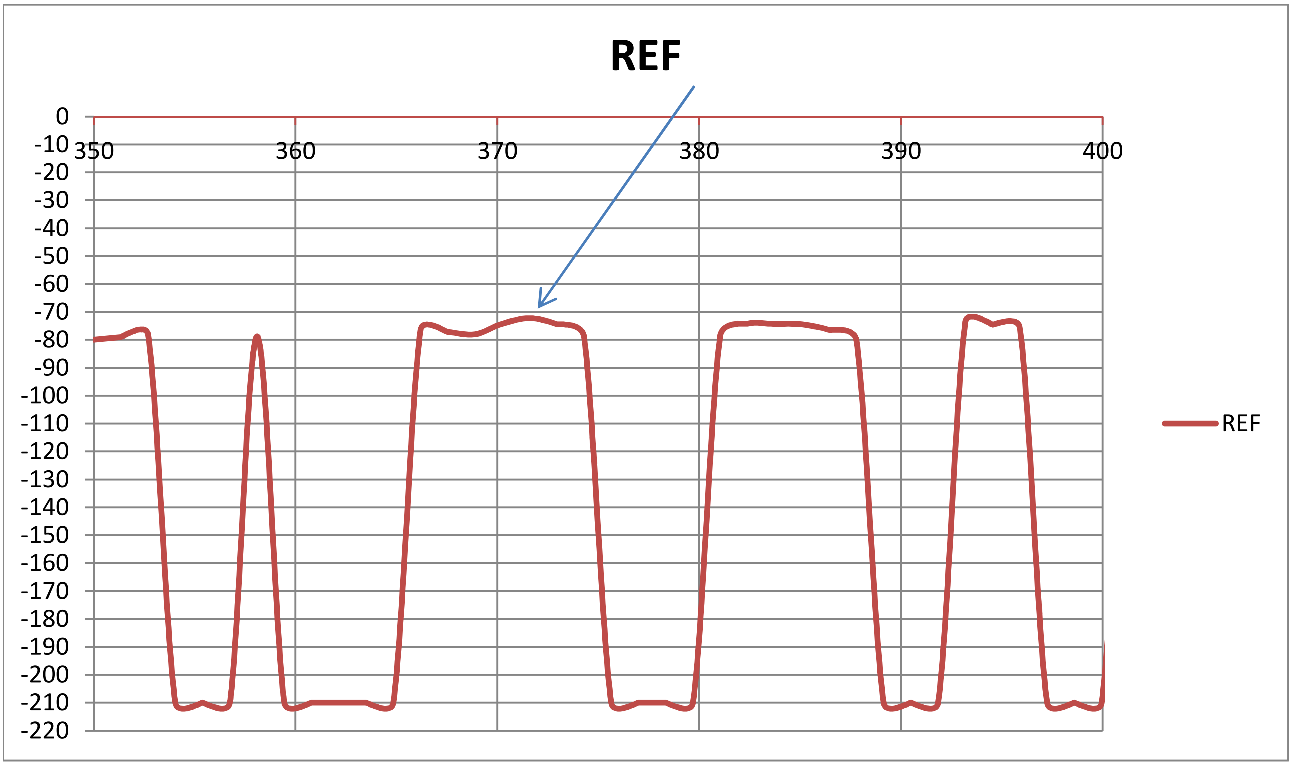

Fig. 22 – Graph recorded by the spectrum analyzer using sensor and fiber, 1.350 nm step, without light input source with the exception of the ambient light. Graph from 350 nm to 400 nm with maximum value of -72.250 dBm at 371.600 nm (arrow).

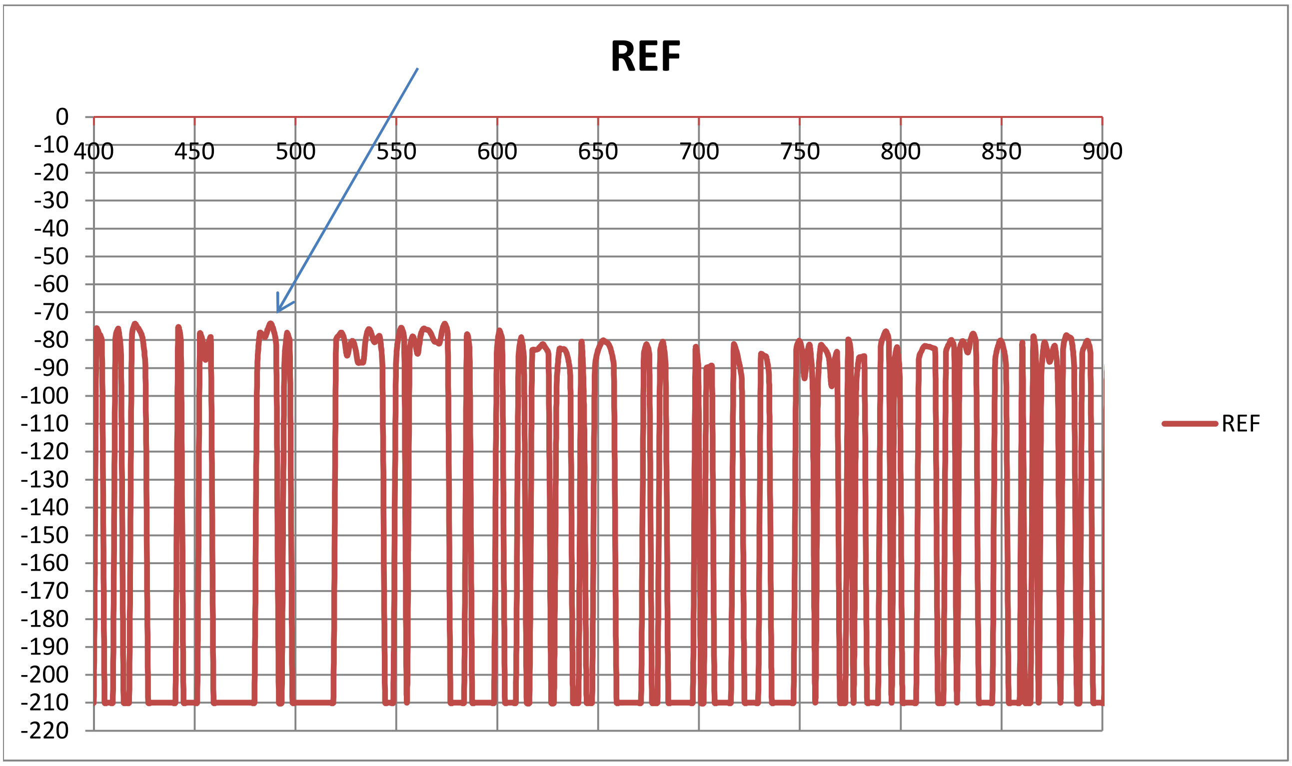

Fig. 23 – Graph recorded <u>by the spectrum analyzer using sensor and fiber</u>, 1.350 nm step, without light input source with the exception of the ambient light. Graph from 400 nm to 900 nm with maximum value of -74.010 dBm at 487.700 nm (arrow).

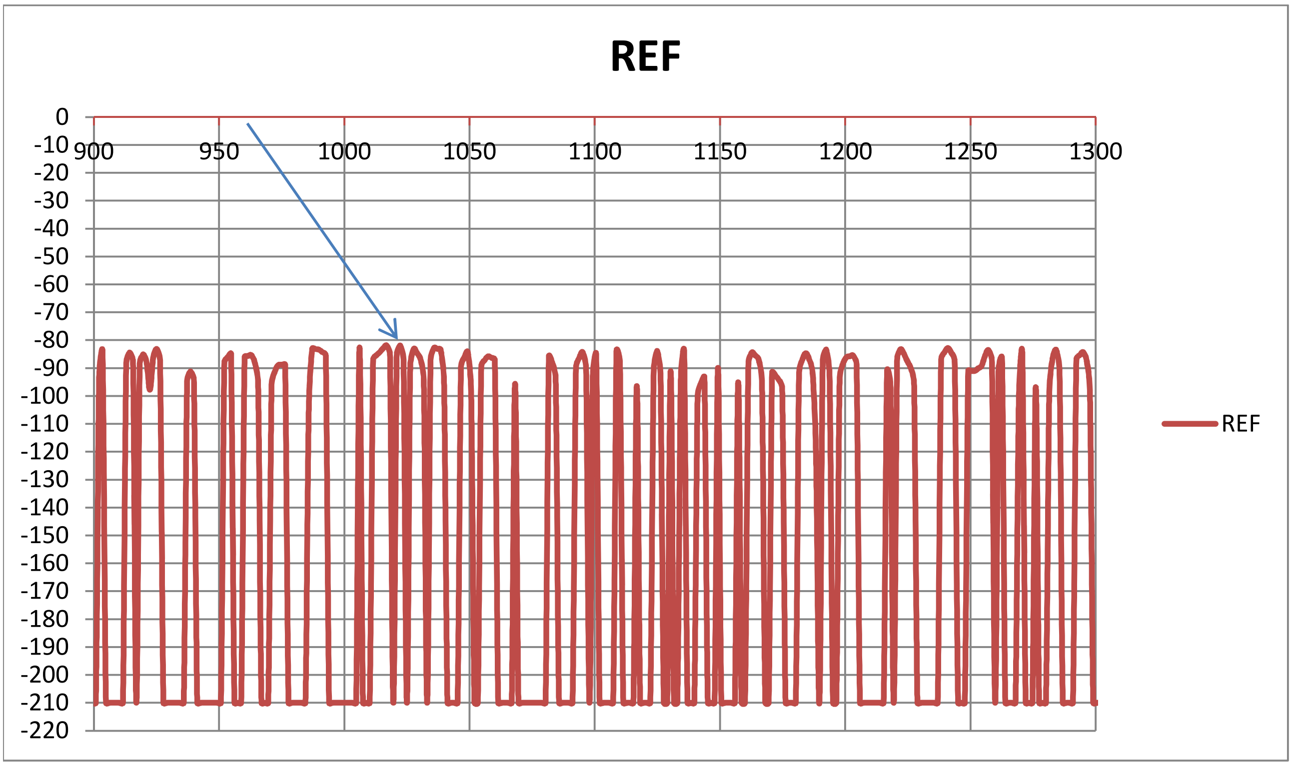

Fig. 24 – Graph recorded <u>by the spectrum analyzer using sensor and fiber</u>, 1.350 nm step, without light input source with the exception of the ambient light. Graph from 900 nm to 1300 nm with maximum value of -81.878 dBm at 1022.300 nm (arrow).

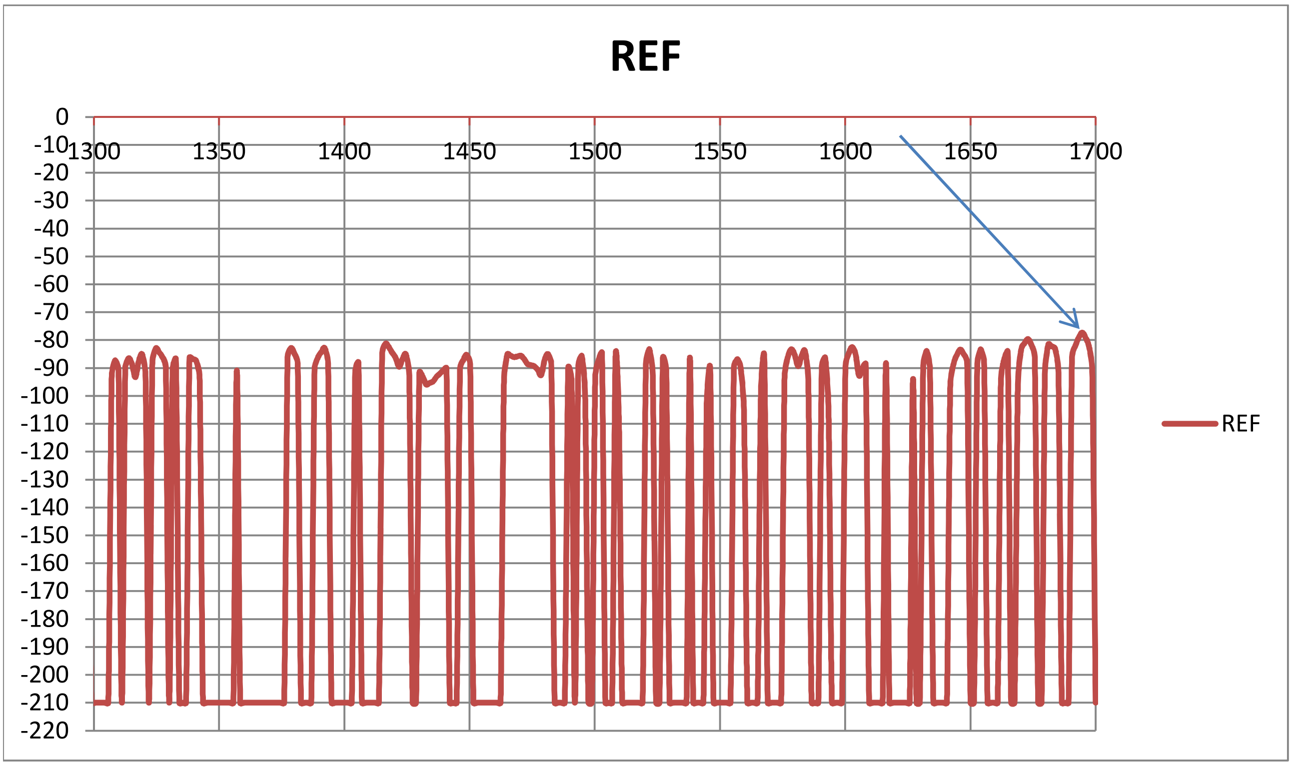

Fig. 25 – Graph recorded <u>by the spectrum analyzer using sensor and fiber</u>, 1.350 nm step, without light input source with the exception of the ambient light. Graph from 1300 nm to 1700 nm with maximum value of -77.319 dBm at 1694.600 nm (arrow).

What exhibited in this chapter leads to think that if the intensity of the generated radiation is too small, lower than a limit value, the spectrum analyzer cannot be trusted. In fact, the spectrum analyzer reveals input power for the whole wavelength range even when the light source is not emitting. What now affirmed is valid for all tests reported following in this study.

The ambient light was present during all our measurement campaign and in this study we wanted to make sure we properly performed each and every measure.

At the light of the results reported in this chapter, it can be assumed that it exists a lower bound value or a minimum valid value below which we must assume that light is totally absorbed. When performing measures on specific tissue the spectrum analyzer reveal a power lower which is almost equal to the power measured in presence of ambient light only, we have to conclude that no light could pass through the tissue.

In our test we begin to consider as reliable measure, the light passing through the tissue starting from these values and above.
For the whole test campaign we fixed -80 dBm as lower bound threshold to discriminate reliable values.

Results

1. Nerve
2. Skin
3. Small intestine
4. Lung
5. Esophagus
6. Stomach
7. Kidney
8. Heart
9. Spleen
10. Liver 1 (sample 1)
11. Liver 2 (sample 2)
12. Liver 3 (sample 3)
13. Muscle 1 (sample 1)
14. Muscle 2 (sample 2)
15. Bone

1 Nerve

The first tissue under analysis is the sciatic nerve of the sprague dawley rat (Fig. 1). It has a thickness of 0.2 mm, it is positioned between the smaller plates with a central hole having a diameter of 1.5 mm in order to cover the entire hole (Fig. 2). The source emits the light with the values and the sequence already described (Fig. 3).

Fig. 1 – Sciatic nerve vision after the sample taking.

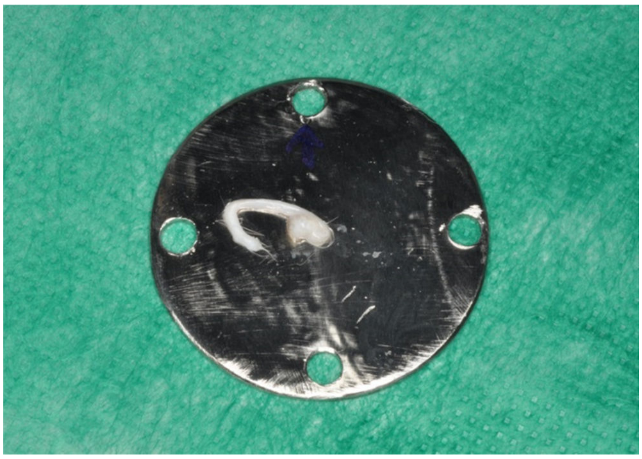

Fig. 2 – Sciatic nerve vision positioned on the plate.

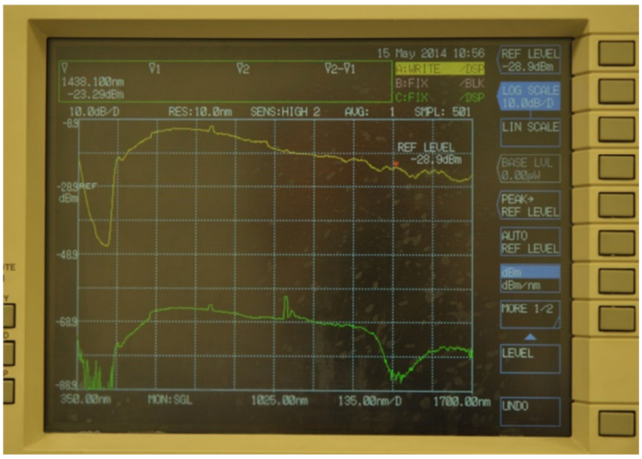

Fig. 3 – Graph of measurement taken in the sprague dawley rat sciatic nerve shown by Spectrum Analyzer display.

The values of the light which crosses the tissue (Nerve) are represented in Fig. 4 along with to the values of light emitted through the air without anything interposed (reference or calibration path, REF).

In the same figure you see also the graph of nerve light absorption (Absorption). Its value is the difference between the emitted light and the passing light through the tissue (transmitted).

From the graph of Fig. 4 and in particular from Fig. 6 you could postulate that radiation from 350.00 nm till 378.350 nm wavelength can pass through the nerve. Instead the values analysis shows that at those wavelengths the received power level is close or less than -80 dBm (Table 1). In this study -80 dBm is considered as lower limit for reliable power values. Most of the power values in this range are much lower than or very close to -80 dBm. Only very few values are greater than the limit of acceptable reliability, equal to-80 dBm, and there is no certainty of the measurement reliability within this range of wavelengths. Hence these values are considered to be invalid and it is assumed that these wavelengths are completely absorbed by tissue.

From the wavelength of 379.700 nm till 466.100 nm included (Fig. 4, Fig. 6), the passing light values in the tissue are very variable. They may look like light absence spikes (-210.000 dBm) followed by partially absorbed light whose value is less than or close to -80 dBm. Again, for the reasons already stated they represent the wavelengths at which radiation is completely absorbed. A vision of the same wavelengths range (Fig. 6) using a more detailed scale, would seem to show that the light at wavelength higher than 467.450 nm passes in the tissue. Instead, the analysis shows that from 467.450 nm till 475.550 nm included, the passing radiation measurement through the nerve still has a power level less than -80 dBm (Fig. 4, Fig. 6, Table 2). So also for these range it can be considered that the radiation is completely absorbed by the nerve.

From wavelength of 476.900 nm till 1401.650 nm included, the passing light values are greater than -80 dBm. Hence, being the values reliable, we can say that in this wavelengths portion, the light can effectively pass through the nerve (Fig. 4, Fig. 5).

From wavelengths from 1403.000 nm till 1519.100 nm included, measure values are all less than -80 dBm. Again, for the reasons already stated, the transmitted light values in this wavelength range are discarded. These values cannot be listed in a table being too numerous and the table size would be too big.

Finally, from 1520.450 nm till 1700.000 nm included, the passing radiation values are greater than -80 dBm. So we can say that in this range of wavelengths the light can pass through the nerve.

It thus appears that the light effectively passes through the sciatic nerve between 476.900 nm and 1401.650 nm and from 1520.450 nm till 1700.000 nm (Table 3).

In the figures are represented graphically the instrument reference values (REF), the passing light values through the tissue (Nerve) and absorbed light values by the nerve (Absorption).

If we exclude an transmitted light increase, not real, which we will discuss in a few lines, around 800 nm, on first analysis it can be seen that the light pass through from 476.900 nm has a slight increase till 620.000 nm then remain fairly constant till 1057.400 nm (Fig. 4, Fig. 5). Starting from this latter wavelength (Fig. 7) the passing light amount through the nerve has a significant increase till 1062.800 nm, where received power reaches its local maximum value, and then decreases till 1070.900 nm (Table 5).

Accordingly, in the range of these wavelengths, the absorption in the tissue has a drastic decrease. From the wavelength of 1070.900 nm onwards the transmission remains again fairly constant till the wavelength of 1295.000 nm (Fig. 9) and then progressively it decreases till 1401.650 nm.

At first sight (Fig. 4, Fig. 5), from the wavelength of 798.200 nm till 815.750 nm there is an radiation increase through the tissue, with a local maximum at 809.000 nm. This draws in deception. In fact, this variation in the path of light through (Nerve) is also present in the reference (REF) (Fig. 4, Fig. 5, Fig. 8).

So, at those wavelengths values, the transmitted power increase is the same source light, without reduction of absorbed radiation that, for those wavelengths, is pretty much constant (Fig. 8).

In this regard see the particular shown by the graph (Fig. 8) and the values for that range of wavelengths shown in Table 4.

A summary is shown in Table 6.

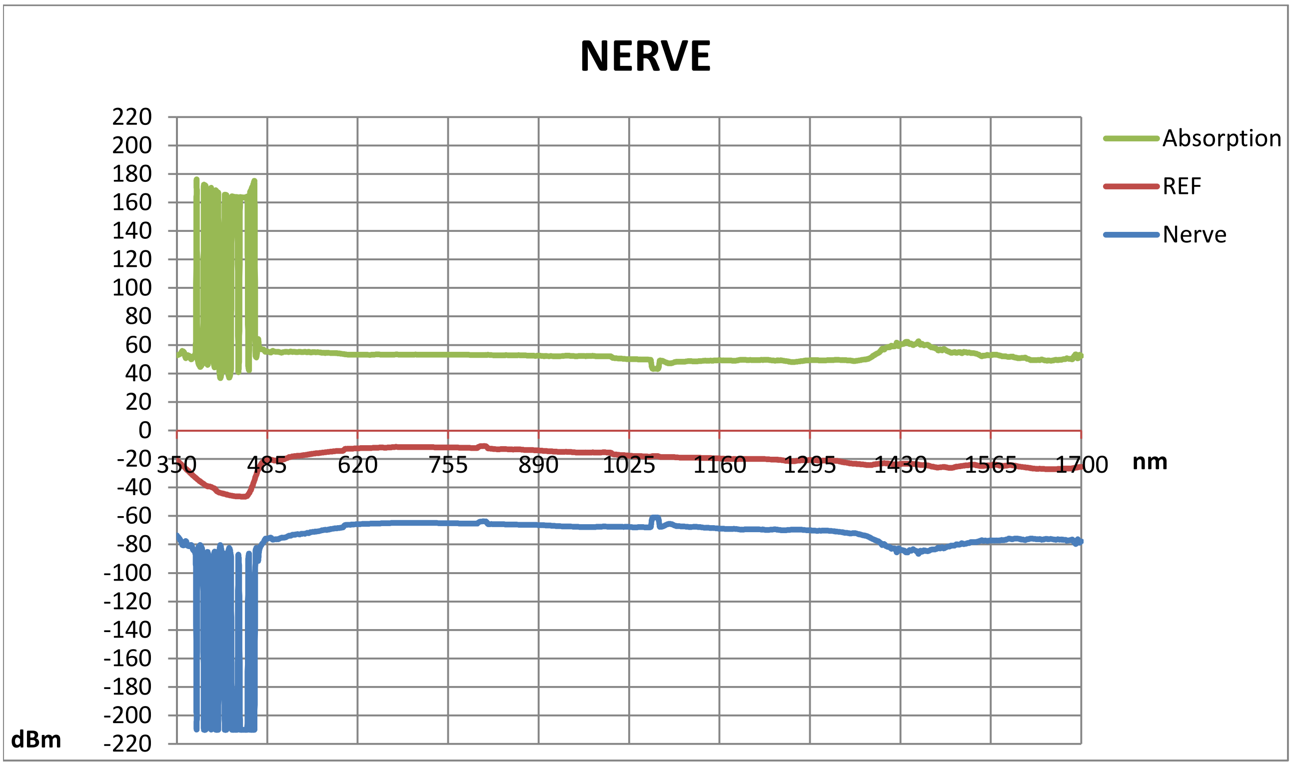

Fig. 4 – Graph of the reference radiation source (REF), the radiation that passes through the tissue (Nerve) and absorption (Absorption) in sprague dawley rat sciatic nerve.

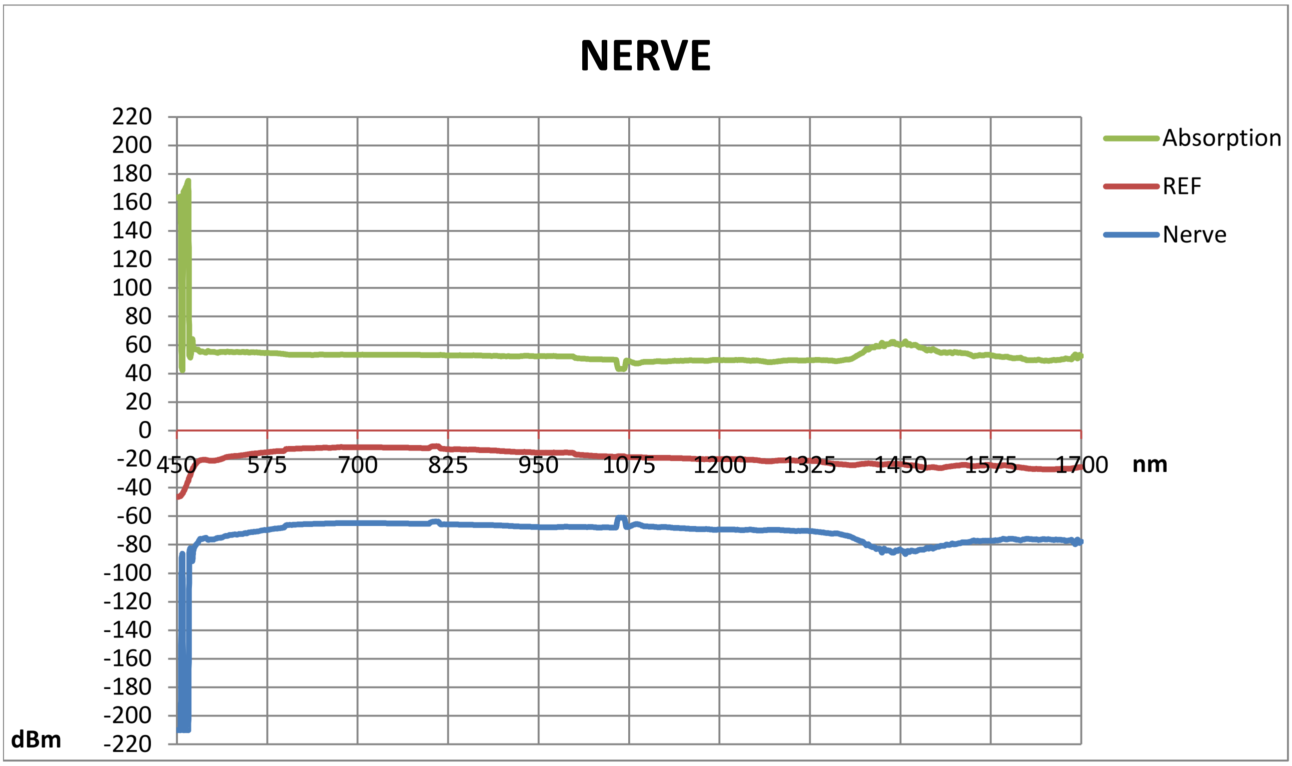

Fig. 5 – Graph of the reference radiation source (REF), the radiation that passes through the tissue (Nerve) and absorption (Absorption) in sprague dawley rat sciatic nerve for wavelengths from 450 nm till 1700 nm.

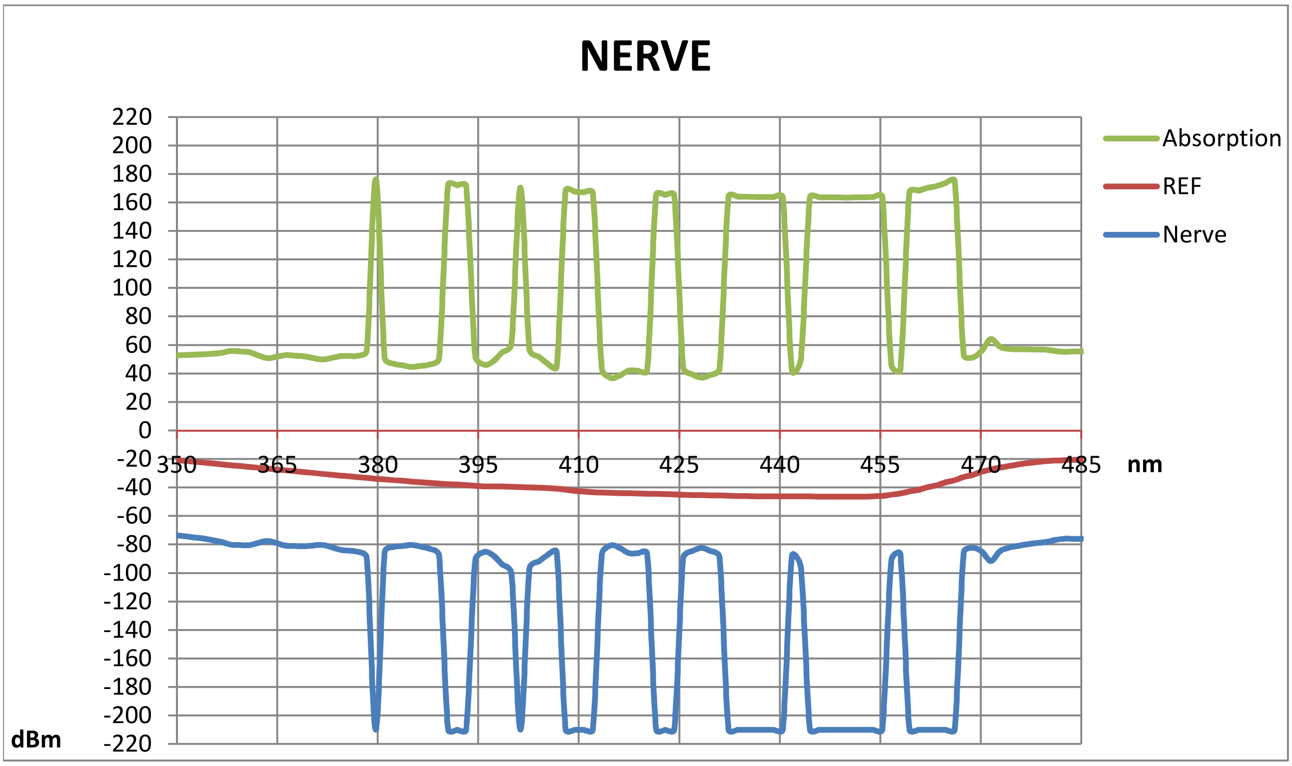

Fig. 6 – Graph of the reference radiation source (REF), the radiation that passes through the tissue (Nerve) and absorption (Absorption) in sprague dawley rat sciatic nerve for wavelengths from 350 nm till 485 nm.

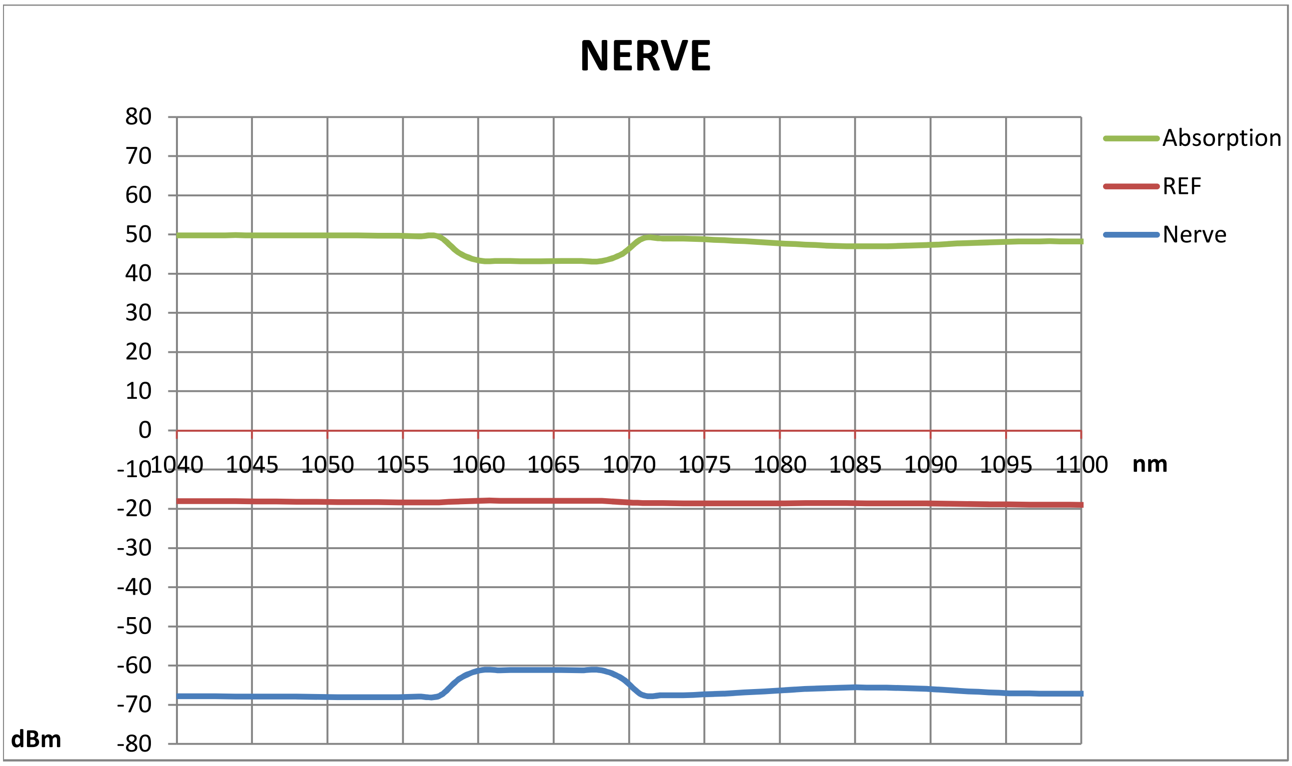

Fig. 7 – Graph of the reference radiation source (REF), the radiation that passes through the tissue (Nerve) and absorption (Absorption) in sprague dawley rat sciatic nerve for wavelengths from 1040 nm till 1100 nm.

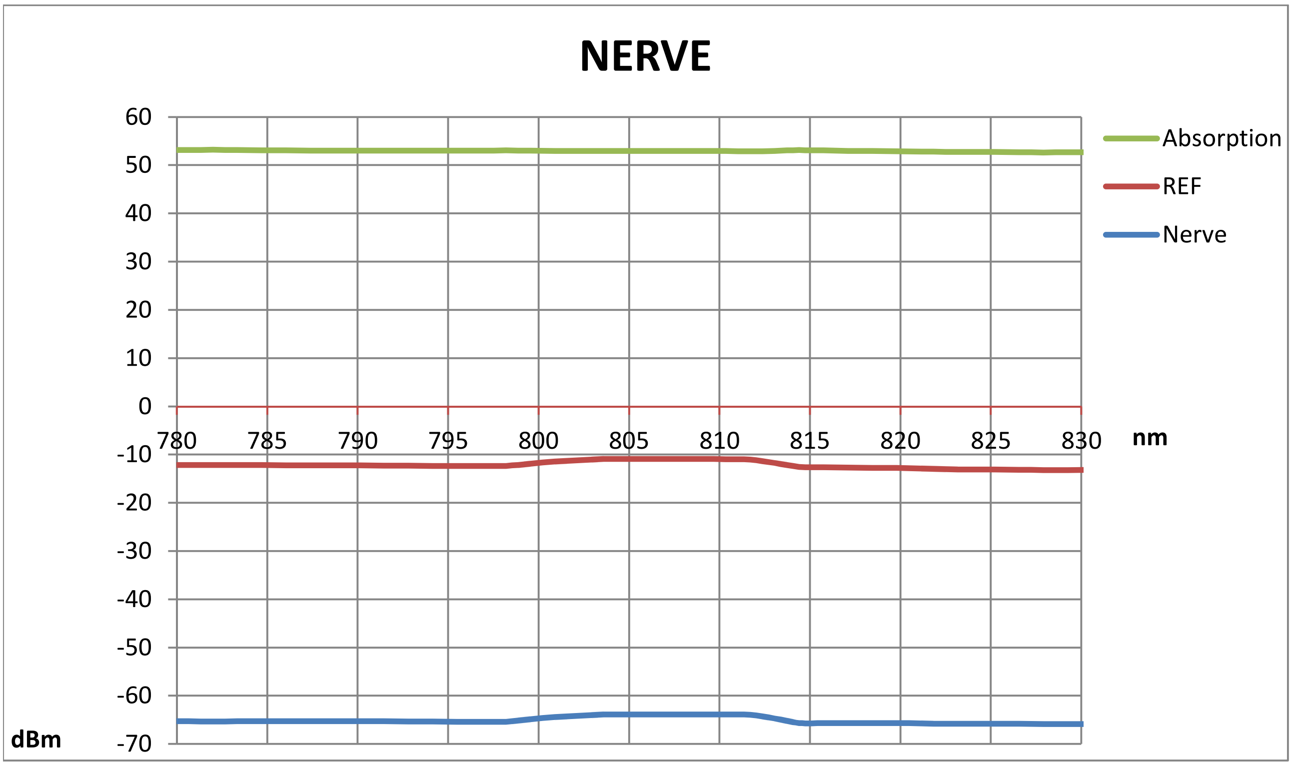

Fig. 8 – Graph of the reference radiation source (REF), the radiation that passes through the tissue (Nerve) and absorption (Absorption) in sprague dawley rat sciatic nerve for wavelengths from 780 nm till 830 nm.

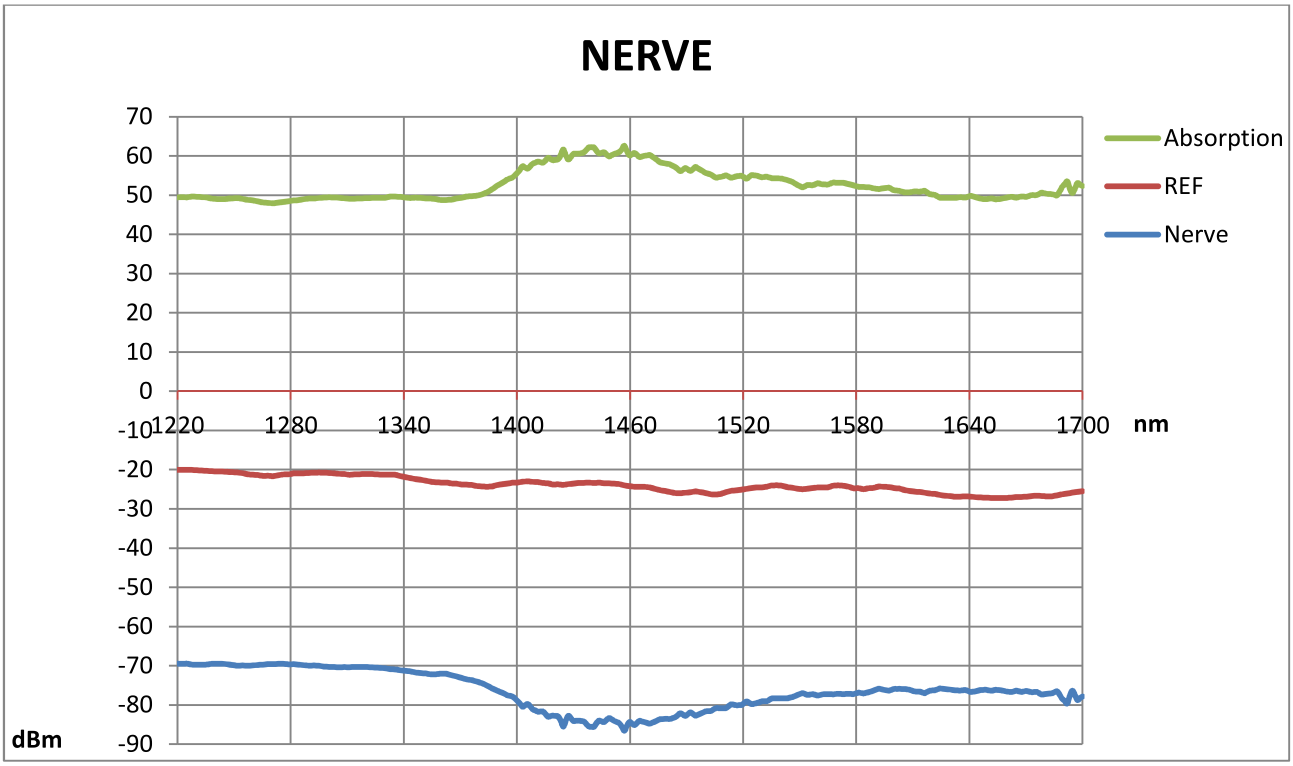

Fig. 9 – Graph of the reference radiation source (REF), the radiation that passes through the tissue (Nerve) and absorption (Absorption) in sprague dawley rat sciatic nerve for wavelengths from 1220 nm till 1700 nm.

Wavelength (nm)	Nerve Measure (dBm)	Wavelength (nm)	Nerve Measure (dBm)
350.000	-73.601	364.850	-78.906
351.350	-74.291	366.200	**-80.797**
352.700	-75.110	367.550	**-81.044**
354.050	-75.957	368.900	**-81.306**
355.400	-77.011	370.250	**-80.757**
356.750	-78.326	371.600	**-80.270**
358.100	**-80.220**	372.950	**-81.648**
359.450	**-80.393**	374.300	**-83.678**
360.800	**-80.572**	375.650	**-84.366**
362.150	-78.832	377.000	**-85.185**
363.500	-77.593	378.350	**-89.199**

Table 1 - Values of measured light from spectrum analyzer in sprague dawley rat sciatic nerve at wavelengths from 350 nm till 378.350 nm. The values lower than -80 dBm are in red. For the reasons illustrated in this chapter it is believed that the light is completely absorbed at these wavelengths.

Wavelength (nm)	Nerve Measure (dBm)	Wavelength (nm)	Nerve Measure (dBm)
467.450	**-85.580**	472.850	**-84.792**
468.800	**-82.400**	474.200	**-82.261**
470.150	**-84.917**	475.550	**-80.949**
471.500	**-91.592**		

Table 2 - Values of measured light from spectrum analyzer in sprague dawley rat sciatic nerve at wavelengths from 467.450 nm till 475.550 nm. The values lower of -80 dBm are in red. For the reasons illustrated in this chapter it is believed that the light is completely absorbed at these wavelengths.

Wavelength (nm)		Nerve Measure (dBm)	Nerve Absorption (dB)
from	**till**		
350.000	**378.350**	**values < -80**	**full absorption**
379.700	**466.100**	**spikes < -80**	**full absorption**
467.450	**475.550**	**values < -80**	**full absorption**
476.900	**1401.650**	**values > -80**	**valid values**
1403.000	**1519.100**	**values < -80**	**full absorption**
1520.450	**1700.000**	**values > -80**	**valid values**

Table 3 - Summary of wavelengths where light is completely absorbed in sprague dawley rat sciatic nerve. Values lower than -80 dBm are deemed too small because they are not read by the spectrum analyzer. So those wavelengths light are considered completely absorbed.

Wavelength (nm)	REF (dBm)	Nerve Measure (dBm)	Nerve Absorption (dB)
798.200	-12.350	-65.399	53.049
799.550	-11.882	-64.874	52.992
800.900	-11.459	-64.406	52.947
802.250	-11.187	-64.139	52.952
803.600	-10.931	-63.888	52.957
804.950	-10.930	-63.871	52.941
806.300	-10.929	-63.855	52.926
807.650	-10.913	-63.857	52.944
809.000	**-10.897**	-63.859	52.962
810.350	-10.977	-63.893	52.916
811.700	-11.058	-63.928	52.870
813.050	-11.737	-64.707	52.970
814.400	-12.543	-65.657	53.114
815.750	-12.615	-65.663	53.048

Table 4 - The table shows that the value of absorption in sprague dawley rat sciatic nerve remains almost constant for wavelength from 798.200 nm till 815.750 nm. At 809.000 nm the value of source is maximum (in red), but despite this absorption is almost constant.

Wavelength (nm)	REF (dBm)	Nerve Measure (dBm)	Nerve Absorption (dB)
1045.250	-18.102	-67.884	49.782
1046.600	-18.139	-67.882	49.743
1047.950	-18.178	-67.936	49.758
1049.300	-18.217	-67.990	49.773
1050.650	-18.250	-68.026	49.776
1052.000	-18.284	-68.061	49.777
1053.350	-18.324	-68.045	49.721
1054.700	-18.364	-68.028	49.664
1056.050	-18.349	-67.900	49.551
1057.400	-18.334	-67.776	49.442
1058.750	-18.123	-63.375	45.252
1060.100	-17.921	-61.234	43.313
1061.450	-17.932	-61.183	43.251
1062.800	-17.942	**-61.132**	43.190
1064.150	-17.941	-61.138	43.197
1065.500	-17.939	-61.145	43.206
1066.850	-17.964	-61.185	43.221
1068.200	-17.988	-61.226	43.238
1069.550	-18.255	-63.319	45.064
1070.900	-18.540	-67.512	48.972
1072.250	-18.565	-67.538	48.973
1073.600	-18.590	-67.564	48.974
1074.950	-18.604	-67.368	48.764
1076.300	-18.618	-67.182	48.564
1077.650	-18.597	-66.863	48.266

Table 5 - Values of radiation passing through and of radiation absorbed in sprague dawley rat sciatic nerve in relation to radiation emitted at wavelengths from 1045.250 nm till 1077.650 nm. The maximum light value passing through the tissue is in red.

Wavelength (nm)		dBm or dB	Light
809.000		-10.897 dBm	maximum value of light source
1065.500		42.824 dB	minimum absorption
1065.500		-60.763 dBm	maximum transmission
449.900		-46.547 dBm	minimum value of light source
from	till		
350.000	378.350	values < -80	full absorption
379.700	466.100	spikes < -80	full absorption
467.450	475.550	values < -80	full absorption
476.900	1401.650	values > -80	valid values
1403.000	1519.100	values < -80	full absorption
1520.450	1700.000	values > -80	valid values

Table 6 – Summary table.

2 Skin

Similarly a flap skin of sprague dawley rat, with his hair, is subjected to radiation (Fig. 1). It has a thickness of 0.3 mm and it is positioned between the larger plates with a central hole having a diameter of 3.8 mm (Fig. 2). The source emits the light with the values and the sequence already described (Fig. 3).

Fig. 1 – Skin vision after the sample taking.

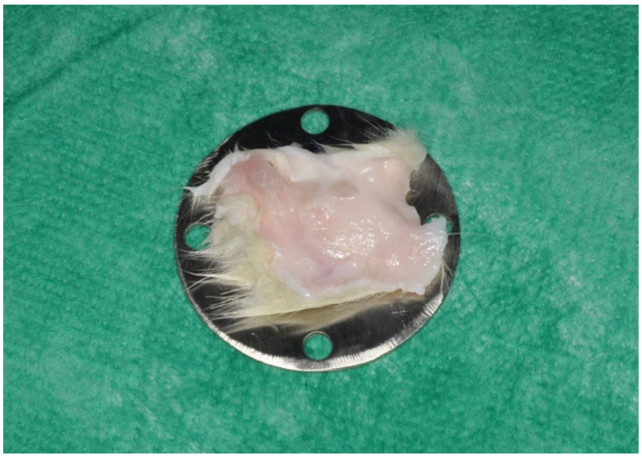

Fig. 2 – Skin vision positioned on the plate.

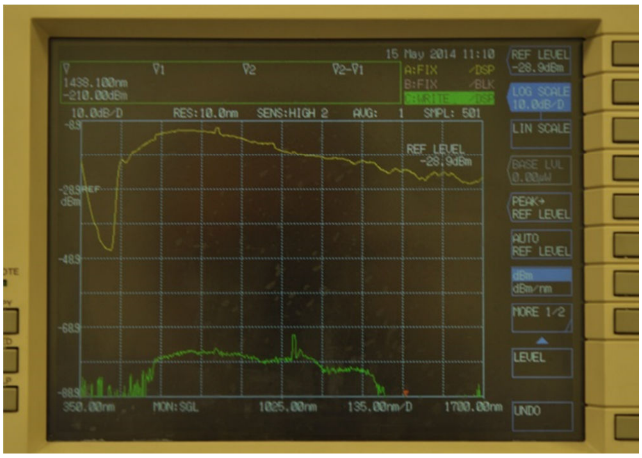

Fig. 3 - Graph of measurements made on the skin shown by Spectrum Analyzer display.

The values of the light, which crosses the tissue (Skin), are represented in Fig. 4 along with the values of light emitted freely through the air without anything interposed (reference or calibration path, REF). In the same figure you see also the graph of skin light absorption (Absorption). Its value is the difference between the emitted light and the passing light through the tissue (transmitted).

Also in this case (Fig. 4) you see that from 350.000 nm till 555.200 nm included (Fig. 6), and from 1388.150 nm till 1700.000 nm included (Fig. 8), the passing light values in the tissue are very variable. They may look like light absence spikes (-210.000 dBm) followed by partially absorbed light whose value is less than or close to -80 dBm. Again, for the reasons already stated they represent the wavelengths at which radiation is completely absorbed. A vision of the same wavelengths range (Fig. 6), using a more detailed scale, would seem to show that the light pass into the tissue at wavelength higher than 556.550 nm. Instead the values analysis shows that from 556.550 nm till 594.350 nm included, the passing radiation measurement through the skin still has a power level less than -80 dBm (Table 1). So also for these range it can be considered that the radiation is completely absorbed by the skin.

From wavelength of 595.700 nm till 1147.850 nm included, the passing light values are greater than -80 dBm. Hence, being the values reliable, we can say that in this wavelengths portion, the light can effectively pass through the skin (Fig. 5, Fig. 7).

The second group of spikes begins at 1388.150 nm and lasts till 1700.000 nm (Fig. 8). In this range the light is completely absorbed in the skin. However, also in this case, the numbers analysis shows that the passing radiation values begin to be less than -80 dBm already at wavelength of 1149.250 nm. The radiation values continue to be very low till 1386.800 nm after which, at 1388.150 nm, the already mentioned spikes start. For the reasons already stated, starting from 1149.250 nm till to 1386.800 nm (Fig. 7), also these radiation values must be discarded and, therefore, in this range of wavelength, we conclude that the radiation is completely absorbed by the skin. These values cannot be listed in a table being too numerous and the table size would be too great.

It thus appears that the light effectively passes through the skin between 595.700 nm and 1147.850 nm (Table 2).

In the figures are represented graphically the instrument reference values (REF), the passing light values through the tissue (Skin) and absorbed light values by the skin (Absorption).

On first analysis it can be seen that the passing light through the tissue has practically constant value from 620.000 nm till 1057.400 nm (Fig. 4, Fig. 5). Starting from this latter wavelength (Fig. 9) the passing light amount through the skin has a significant increase till 1062.800 nm, to which transmission is the highest, then it decreases till the wavelength of 1070.900 nm (Table 4).

Accordingly, in the range of these wavelengths the absorption in the tissue has a drastic decrease. From the wavelength of 1070.900 nm onward, the transmission remains again fairly constant till the wavelength of 1147.850 nm (Fig. 4, Fig. 5, Fig. 7) and then at 1149.200 nm it decreases below -80 dBm, when at 1388.150 nm absorbed light spikes are present again. These spikes continue till wavelength of 1700 nm.

Also in this case, by examining the graph of Fig. 4 and Fig. 5, it would seem that significant radiation values pass through the examined tissue at wavelengths around 800 nm.

But in this case, as well as in the previous, the transmitted power increase follows the source light increase, without reduction of absorbed radiation that, for those wavelengths, is almost constant. In this regard see the detail shown in the graph of Fig. 10 and the values for that field of wavelengths shown in Table 3.

The maximum value of source light it is revealed at 809.000 nm, but for this wavelength the transmission is neither the highest nor the absorption is the minimum.

A summary is shown in Table 5.

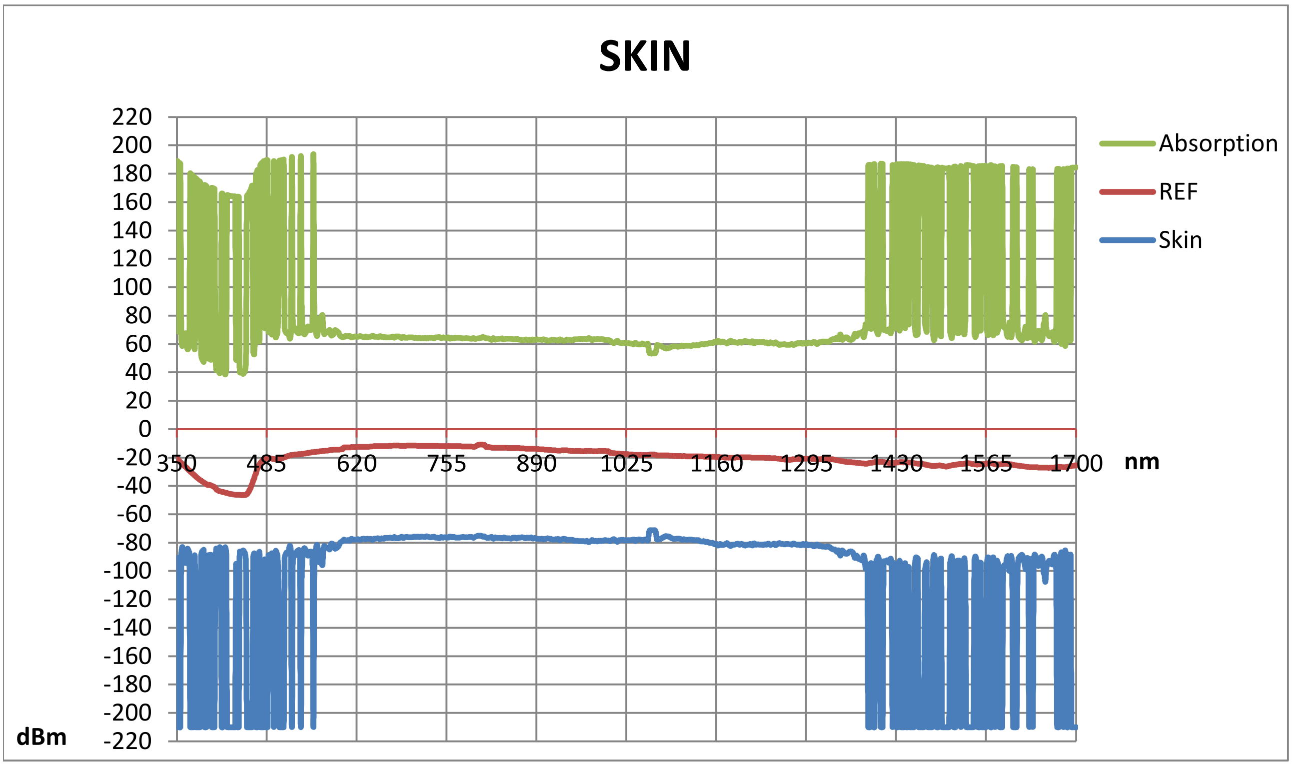

Fig. 4 – Graph of reference radiation source (REF), the radiation that passes through the tissue (Skin) and absorption (Absorption) in sprague dawley rat skin.

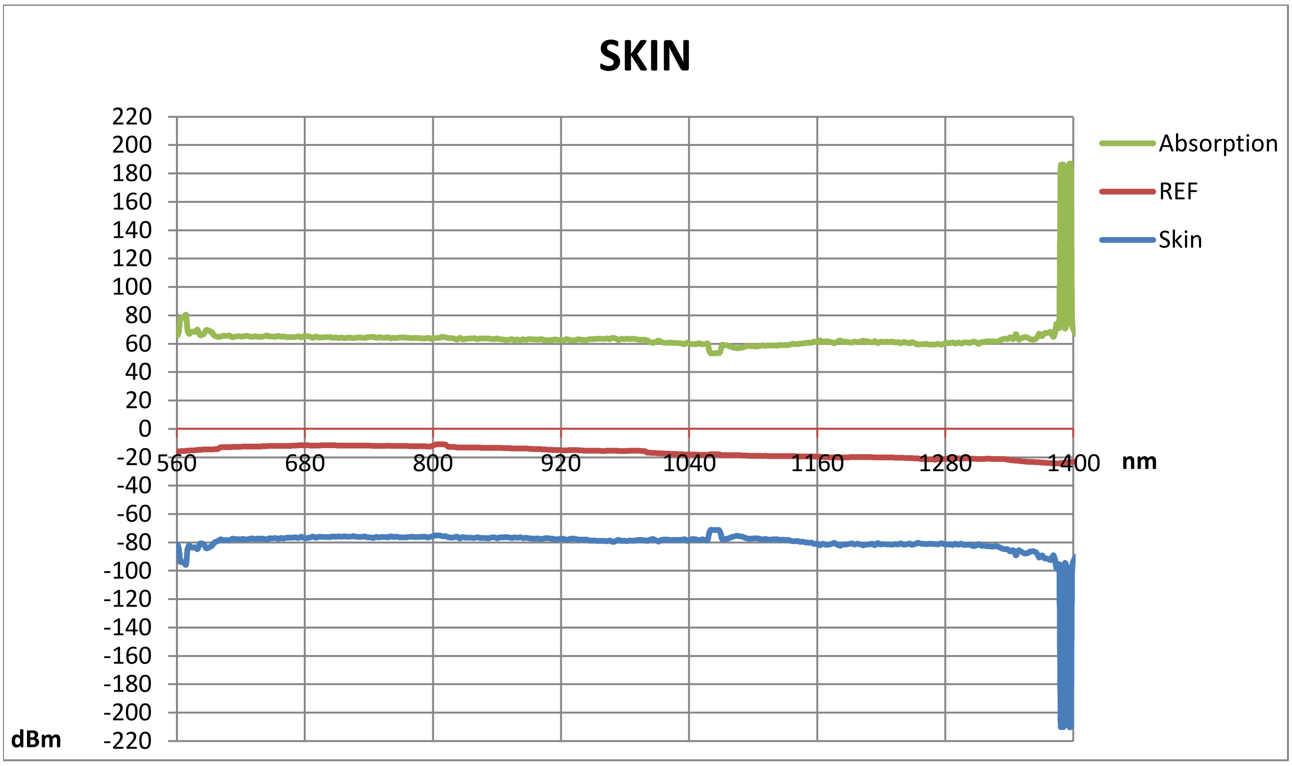

Fig. 5 – Graph of the reference radiation source (REF), the radiation that passes through the tissue (Skin) and absorption (Absorption) in sprague dawley rat skin for wavelengths from 560 nm till 1400 nm.

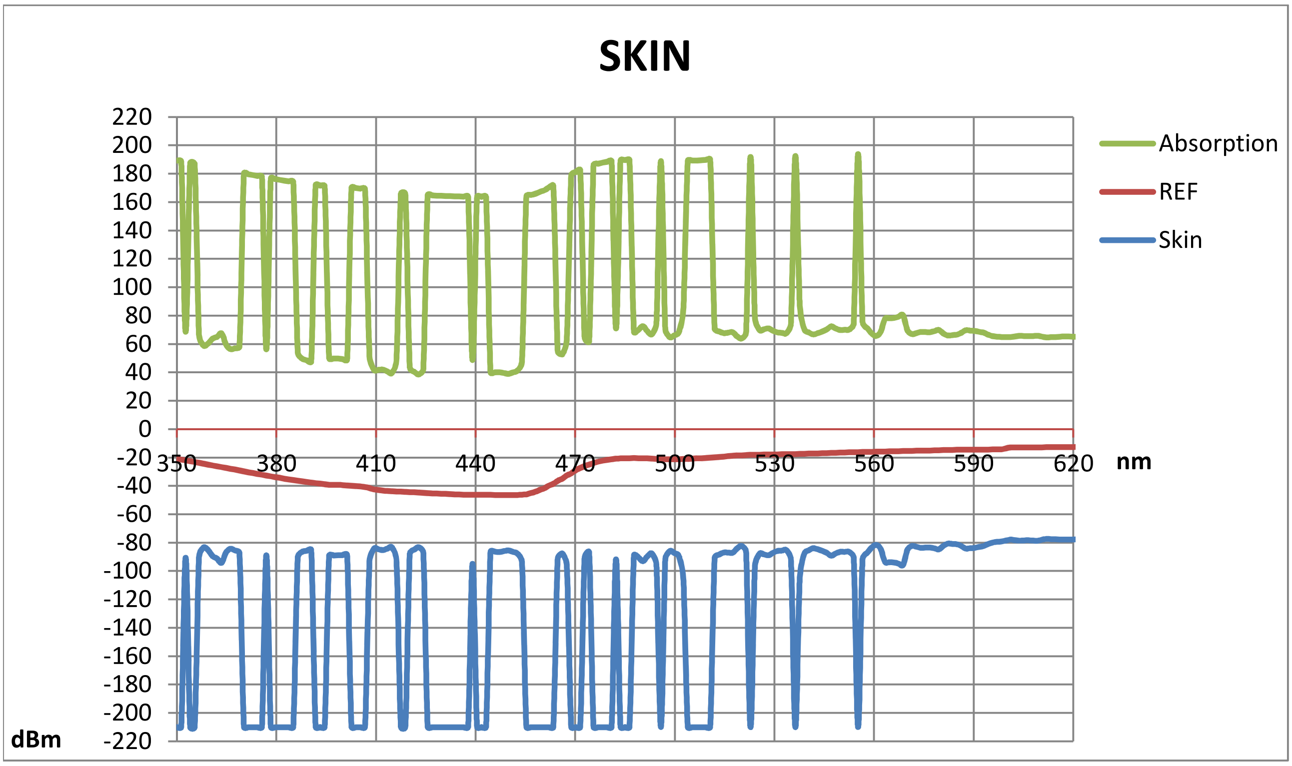

Fig. 6 – Graph of the reference radiation source (REF), the radiation that passes through the tissue (Skin) and absorption (Absorption) in sprague dawley rat skin for wavelengths from 350 nm till 620 nm.

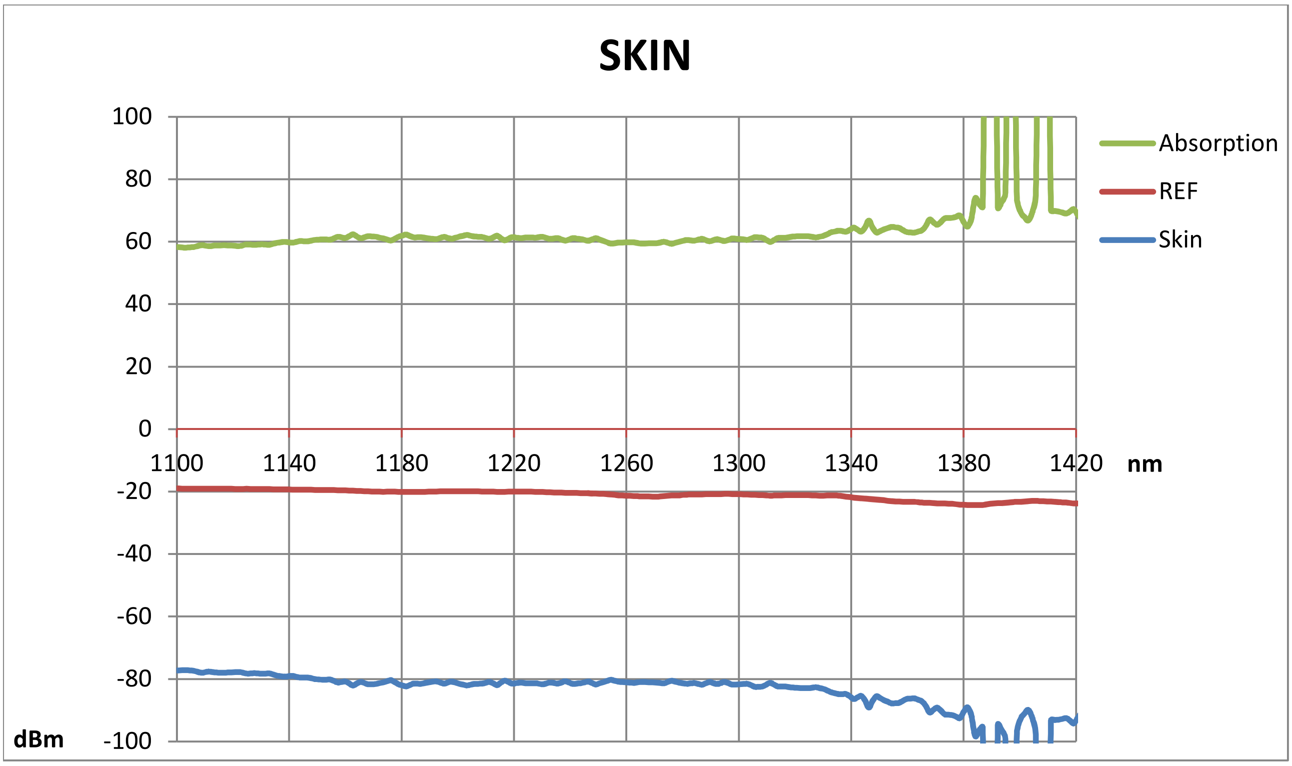

Fig. 7 – Graph of the reference radiation source (REF), the radiation that passes through the tissue (Skin) and absorption (Absorption) in sprague dawley rat skin for wavelengths from 1100 nm till 1420 nm.

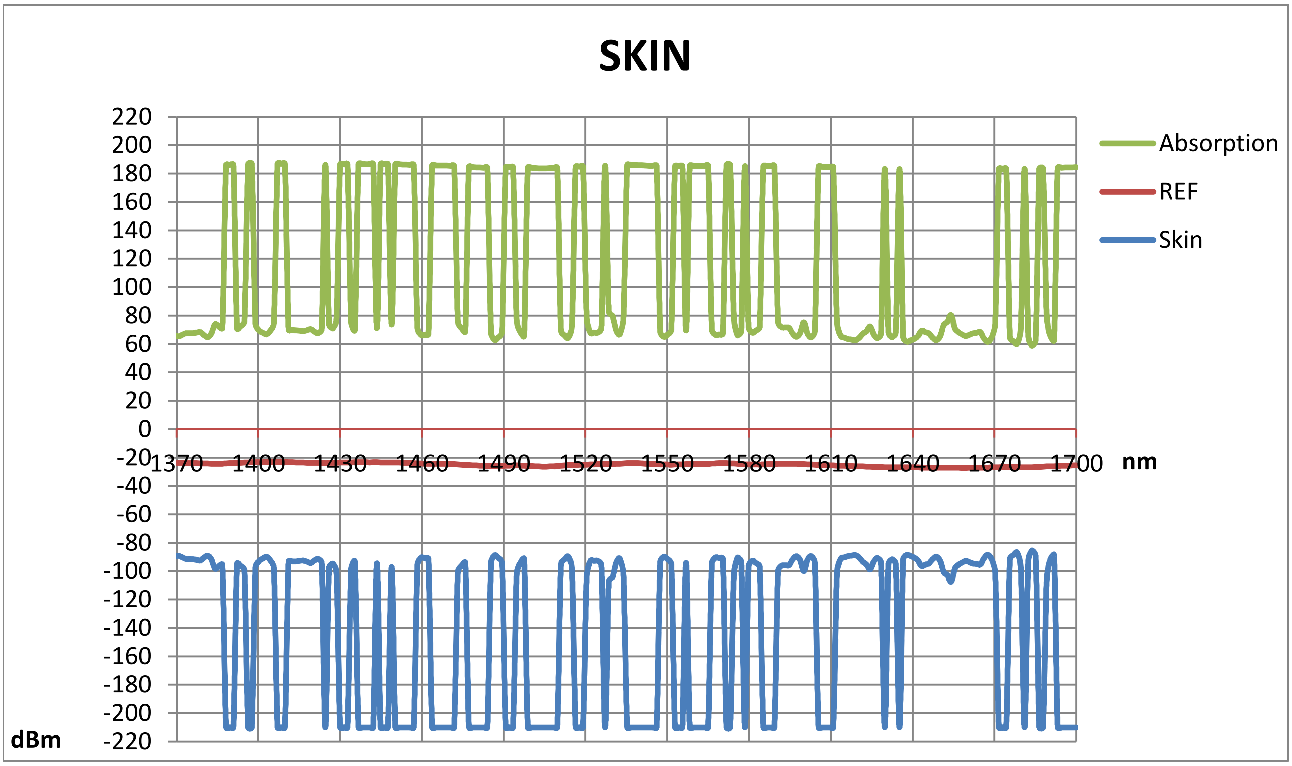

Fig. 8 – Graph of the radiation source (REF), the radiation that passes through the tissue (Skin) and absorption (Absorption) in sprague dawley rat skin for wavelengths from 1370 nm till 1700 nm.

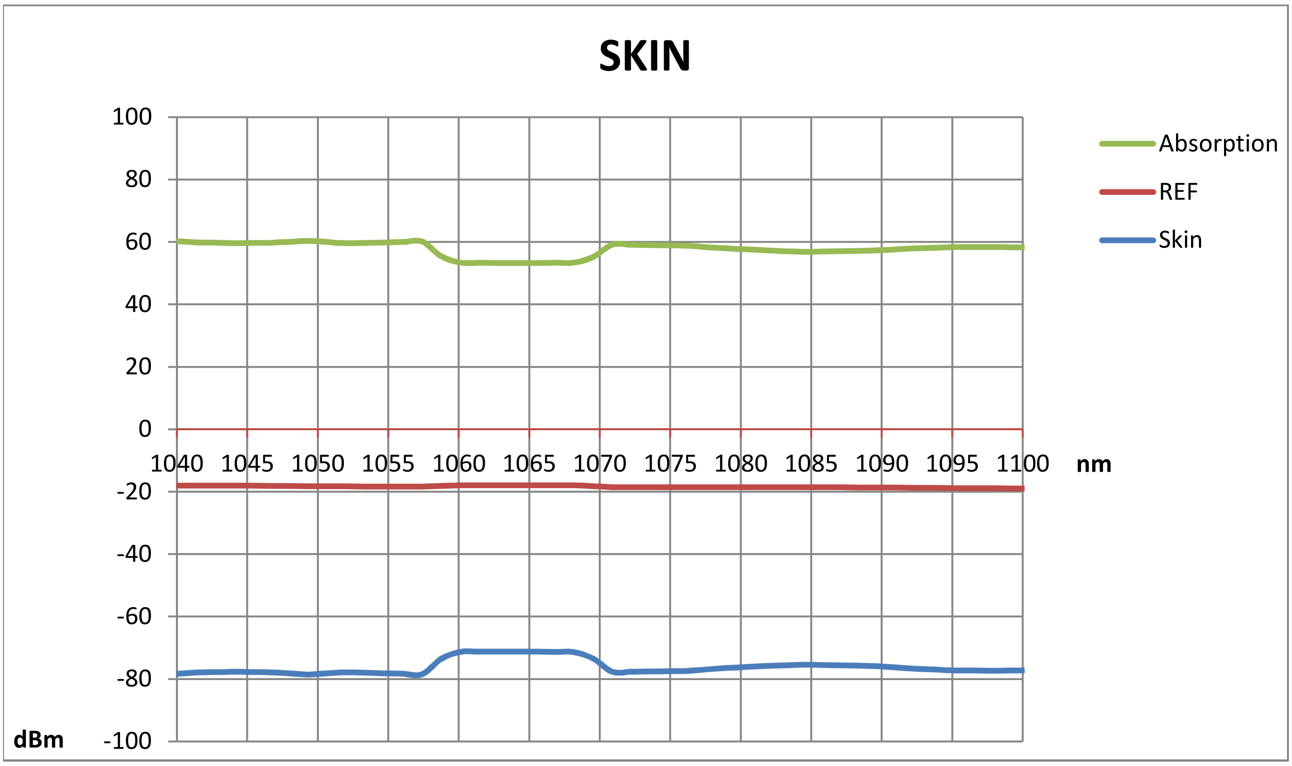

Fig. 9 – Graph of the reference radiation source (REF), the radiation that passes through the tissue (Skin) and absorption (Absorption) in sprague dawley rat skin for wavelengths from 1040 nm till 1100 nm.

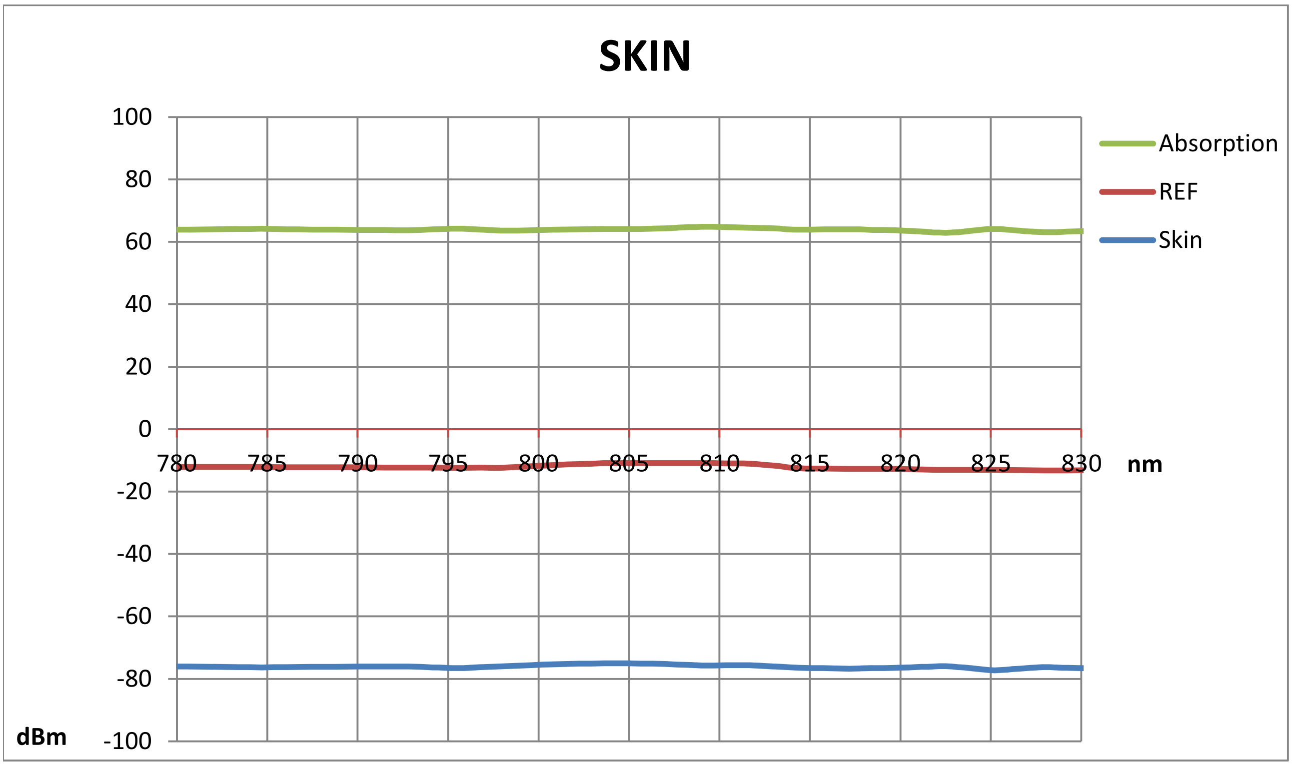

Fig. 10 – Graph of the reference radiation source (REF), the radiation that passes through the tissue (Skin) and absorption (Absorption) in sprague dawley rat skin for wavelengths from 780 nm till 830 nm.

Wavelength (nm)	Skin Measure (dBm)	Wavelength (nm)	Skin Measure (dBm)
556.550	**-91.484**	576.800	**-83.392**
557.900	**-87.218**	578.150	**-84.022**
559.250	**-83.526**	579.500	**-84.759**
560.600	**-81.560**	580.850	**-82.253**
561.950	**-84.307**	582.200	**-80.674**
563.300	**-93.600**	583.550	**-80.892**
564.650	**-93.775**	584.900	**-81.121**
566.000	**-93.958**	586.250	**-82.386**
567.350	**-94.757**	587.600	**-84.179**
568.700	**-95.739**	588.950	**-83.902**
570.050	**-85.118**	590.300	**-83.641**
571.400	**-82.300**	591.650	**-82.963**
572.750	**-82.928**	593.000	**-82.376**
574.100	**-83.664**	594.350	**-80.943**
575.450	**-83.526**		

Table 1 - Values of measured light from the spectrum analyzer in sprague dawley rat skin at wavelengths from 556.550 nm to 594.350 nm. The values lower of -80 dBm are in red. For the reasons illustrated in this chapter it is believed that the light is completely absorbed at these wavelengths.

Wavelength (nm)		Skin Measure (dBm)	Skin Absorption (dB)
from	till		
350.000	**555.200**	**spikes < -80**	**full absorption**
556.550	**594.350**	**values < -80**	**full absorption**
595.700	**1.147.850**	**values > -80**	**valid values**
1149.200	**1.86.800**	**values < -80**	**full absorption**
1388.150	**1700.000**	**spikes < -80**	**full absorption**

Table 2 – Summary of wavelengths where light is completely absorbed in the sprague dawley rat skin. Values lower than -80 dBm are deemed too small because they are not read by the spectrum analyzer. So those wavelengths light are completely absorbed.

Wavelength (nm)	REF (dBm)	Skin Measure (dBm)	Skin Absorption (dB)
798.200	-12.350	-75.905	63.555
799.550	-11.882	-75.606	63.724
800.900	-11.459	-75.327	63.868
802.250	-11.187	-75.166	63.979
803.600	-10.931	-75.011	64.080
804.950	-10.930	-75.057	64.127
806.300	-10.929	-75.104	64.175
807.650	-10.913	-75.398	64.485
809.000	**-10.897**	-75.712	64.815
810.350	-10.977	-75.668	64.691
811.700	-11.058	-75.624	64.566
813.050	-11.737	-76.004	64.267
814.400	-12.543	-76.420	63.877
815.750	-12.615	-76.569	63.954

Table 3 - The table shows that the value of absorption in the sprague dawley rat skin remains almost constant for wavelength from 798.200 nm till 815.750 nm. At 809.000 nm the value of source is maximum (in red), but despite this absorption is almost constant.

Wavelength (nm)	REF (dBm)	Skin Measure (dBm)	Skin Absorption (dB)
1045.250	-18.102	-77.779	59.677
1046.600	-18.139	-77.869	59.730
1047.950	-18.178	-78.207	60.029
1049.300	-18.217	-78.575	60.358
1050.650	-18.250	-78.214	59.964
1052.000	-18.284	-77.880	59.596
1053.350	-18.324	-78.018	59.694
1054.700	-18.364	-78.160	59.796
1056.050	-18.349	-78.321	59.972
1057.400	-18.334	-78.488	60.154
1058.750	-18.123	-73.572	55.449
1060.100	-17.921	-71.325	53.404
1061.450	-17.932	-71.251	53.319
1062.800	-17.942	**-71.179**	53.237

1064.150	-17.941	-71.200	53.259
1065.500	-17.939	-71.221	53.282
1066.850	-17.964	-71.305	53.341
1068.200	-17.988	-71.390	53.402
1069.550	-18.255	-73.485	55.230
1070.900	-18.540	-77.690	59.150
1072.250	-18.565	-77.653	59.088
1073.600	-18.590	-77.616	59.026
1074.950	-18.604	-77.492	58.888
1076.300	-18.618	-77.373	58.755
1077.650	-18.597	-76.907	58.310

Table 4 - Values of radiation passing through and of radiation absorbed in the sprague dawley rat skin in relation to radiation emitted at wavelengths from 1045.250 nm till 1077.650 nm. The maximum light value passing through the tissue is in red.

Wavelength (nm)		dBm or dB	Light
809.000		**-10.897 dBm**	**maximum value of light source**
1062.800		**53.237 dB**	**minimum absorption**
1062.800		**-71.179 dBm**	**maximum transmission**
449.900		**-46.547 dBm**	**minimum value of light source**
from	**till**		
350.000	**555.200**	**spikes < -80**	**full absorption**
556.550	**594.350**	**values < -80**	**full absorption**
595.700	**1147.850**	**values > -80**	**valid values**
1149.200	**1386.800**	**values < -80**	**full absorption**
1388.150	**1700.000**	**spikes < -80**	**full absorption**

Table 5 – Summary table.

3 Small intestine

It is used small intestine of sprague dawley rat, emptied of its content. It has a thickness of 0.1 mm and it is positioned (Fig. 1) between the smaller plates with a central hole having a diameter of 1.5 mm in order to cover the entire hole. The source emits light with the values and the sequence already described (Fig. 2).

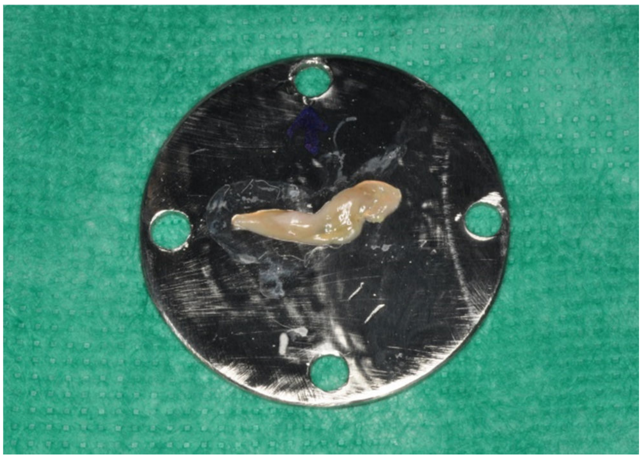

Fig. 1– Sprague dawley rat small intestine vision positioned on the plate.

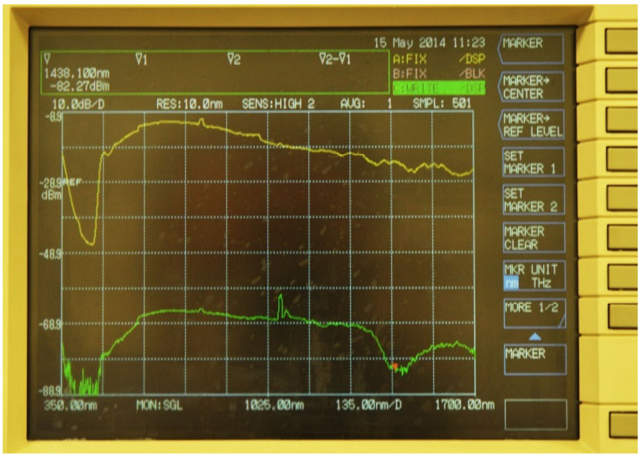

Fig. 2 - Graph of measurements taken on sprague dawley rat small intestine shown by spectrum analyzer display.

The values of the light which crosses the tissue (Small intestine), are represented in Fig. 3 along with to the values of light emitted through the air without anything interposed (reference or calibration path, REF). In the same figure you see also the graph of small intestine light absorption (Absorption). Its value is the difference between the emitted light and the passing light through the tissue (transmitted).

From the graph of Fig. 3 and particularly from Fig. 5 you could assume that radiation from 350.00 nm till 394.550 nm wavelength can pass through the small intestine. Instead the values analysis shows that at those wavelengths the received power level is close or less than -80 (Table 1). In this study -80 dBm is considered as lower limit for reliable power values. Most of the power values in this range are much lower than or very close to -80 dBm.

So there is no certainty of the measurement reliability within this range of wavelengths and so these values are considered invalid. Hence, it is assumed that these wavelengths are completely absorbed by tissue.

From the wavelength of 395.900 nm till 467.450 nm included (Fig. 3, Fig. 5) passing light values in the tissue are very variable. They may look like light absence spikes (-210.000 dBm) followed by partially absorbed light whose value is less than or close to -80 dBm. Again, for the reasons already stated they represent the wavelengths at which radiation is completely absorbed. A vision of the same range of wavelengths (Fig. 5), using a more detailed scale, would seem to show that the light at wavelength higher than 468.800 nm passes through the tissue. Instead, the analysis shows that from 468.800 nm till 476.900 nm included, the passing radiation measurement through the small intestine still has a power level less than -80 dBm (Fig. 3, Fig. 5, Table 2). So also for these range it is considered that the radiation is completely absorbed by the small intestine.

From the wavelength of 478.250 nm till 1411.100 nm included, the passing light values are greater than -80 dBm. Hence, being the values reliable, we can say that in this wavelengths portion, the light can effectively pass through the small intestine (Fig. 4).

From the wavelength of 1412.450 nm till 1490.750 nm included, measure values are all less than -80 dBm. Again, for the reasons already stated, the transmitted light values in this wavelength range are discarded. These values cannot be listed in a table being too numerous and the table size would be too big.

From the wavelength of 1492.100 nm till 1700.000 nm included, the passing light values are greater than -80 dBm. So we can say that in this range of wavelengths the light can pass through the small intestine.

It thus appears that the light effectively passes through the small intestine between 478.250 nm and 1411.100 nm and from 1492.100 nm till 1700.000 nm (Table 3).

In the figures are represented graphically the instrument reference values (REF), the passing light values through the tissue (Small intestine) and absorbed light values by the small intestine (Absorption).

From the wavelength of 489.050 nm passing light values has a slight increase till 620.000 nm then remain fairly constant till 1057.400 nm (Fig. 3, Fig. 4). Starting from this latter wavelength (Fig. 6) the passing light amount through the small intestine has a significant increase till 1065.500 nm, to which transmission is the highest, then it decreases till the wavelength of 1070.900 nm (Table 5).

Accordingly, in the area of these wavelengths, absorption by the tissue has a drastic decrease. From the wavelength of 1070.900 nm onward, the transmission remains fairly constant till the wavelength of 1354.400 nm (Fig. 3, Fig. 4, Fig. 8) and then it decreases till 1411.100 nm when at 1412.450 nm it decreases under the -80 dBm, and at 1492.100 nm the radiation begins again to pass through the tissue till the wavelength of 1700 nm.

Also in this case, by examining the graph of Fig. 3 and Fig. 4, it would seem that significant radiation values pass through the examined tissue at wavelengths around 800 nm.

But in this case, as well as in the previous, the transmitted power increase follows the source light increase, without reduction of absorbed radiation that, for those wavelengths, is almost constant. In this regard see the detail shown in the graph of Fig. 7 and the values for that field of wavelengths shown in Table 4. The maximum value of source light is revealed at 809.000 nm, but for this wavelength the transmission is neither the highest nor the absorption is the minimum.

A summary is shown in Table 6.

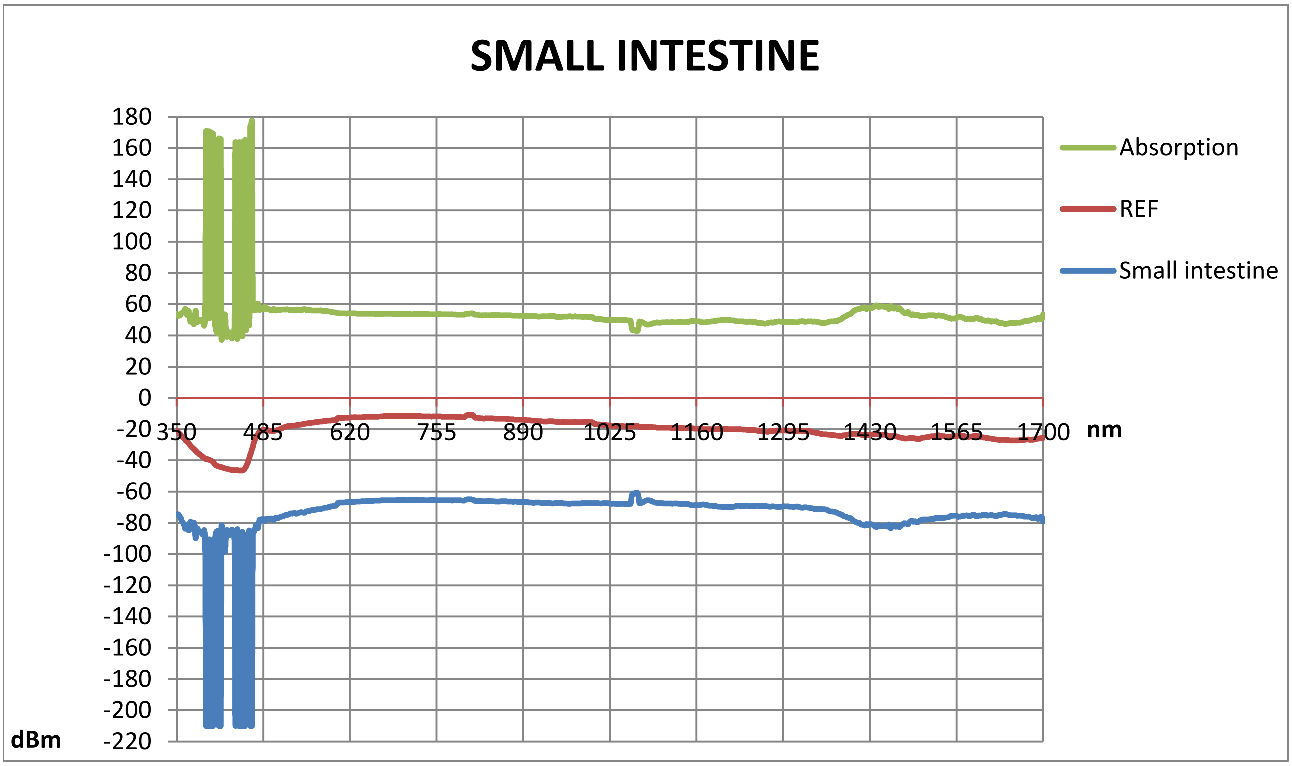

Fig. 3 - Graph of the reference radiation source (REF), the radiation that passes through the tissue (Small intestine) and absorption (Absorption) in sprague dawley rat small intestine.

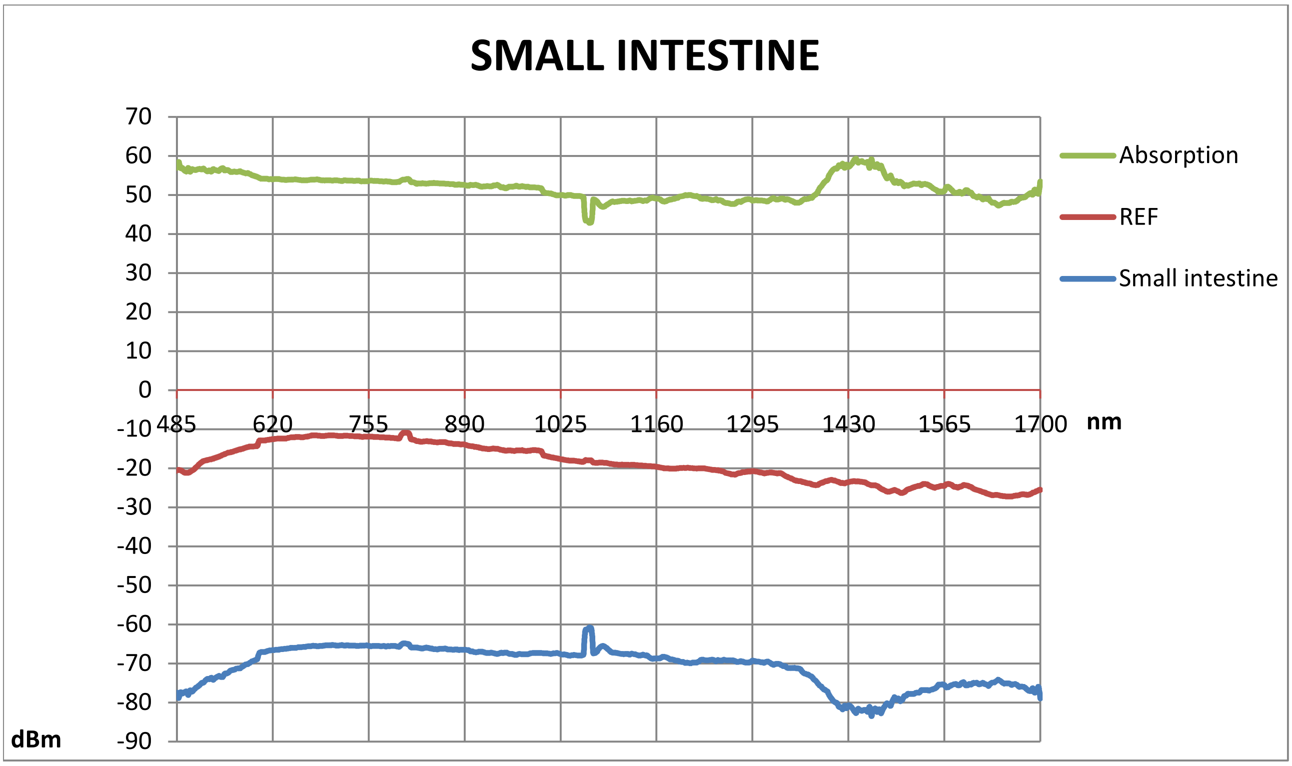

Fig. 4 - Graph of the reference radiation source (REF), the radiation that passes through the tissue (Small intestine) and absorption (Absorption) in sprague dawley rat small intestine for wavelengths from 485 nm till 1700 nm.

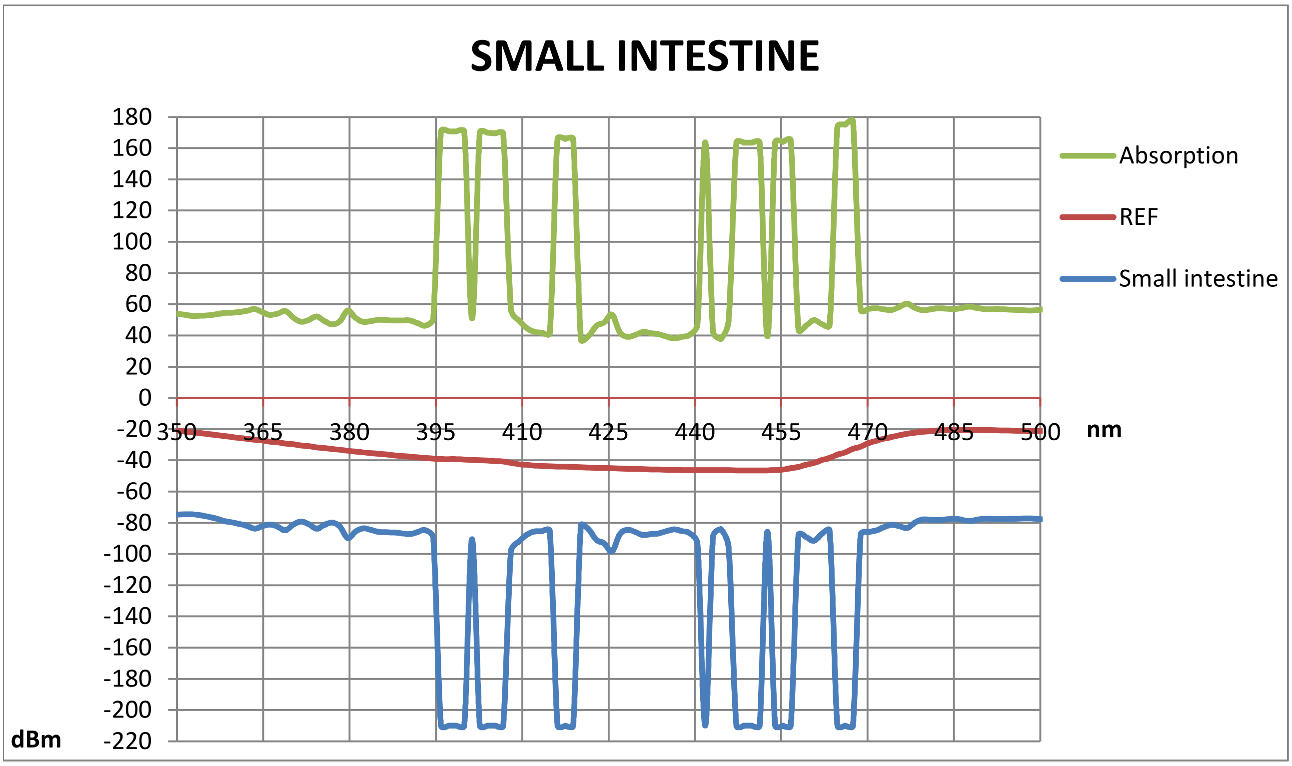

Fig. 5 - Graph of the reference radiation source (REF), the radiation that passes through the tissue (Small intesine) and absorption (Absorption) in sprague dawley rat small intestine for wavelengths from 350 nm till 500 nm.

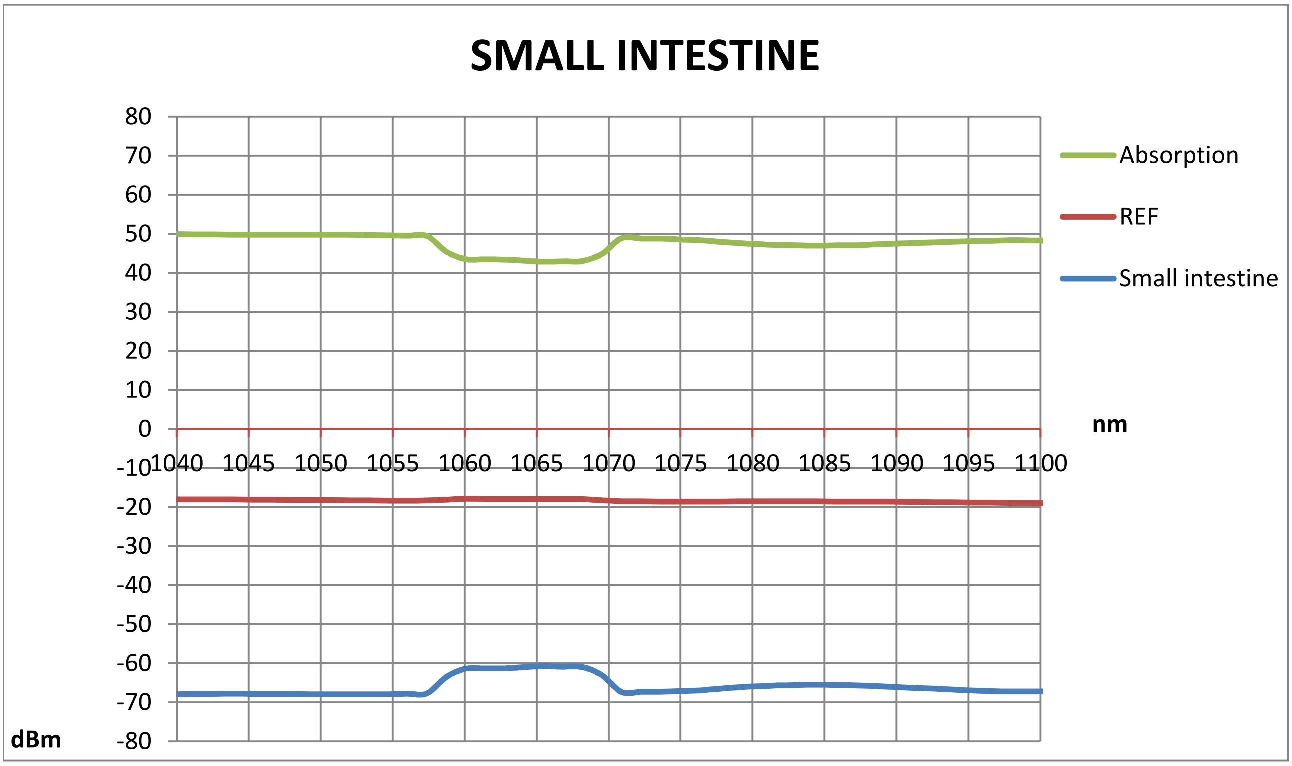

Fig. 6 - Graph of the reference radiation source (REF), the radiation that passes through the tissue (Small intestine) and absorption (Absorption) in sprague dawley rat small intestine for wavelengths from 1040 nm till 1100 nm.

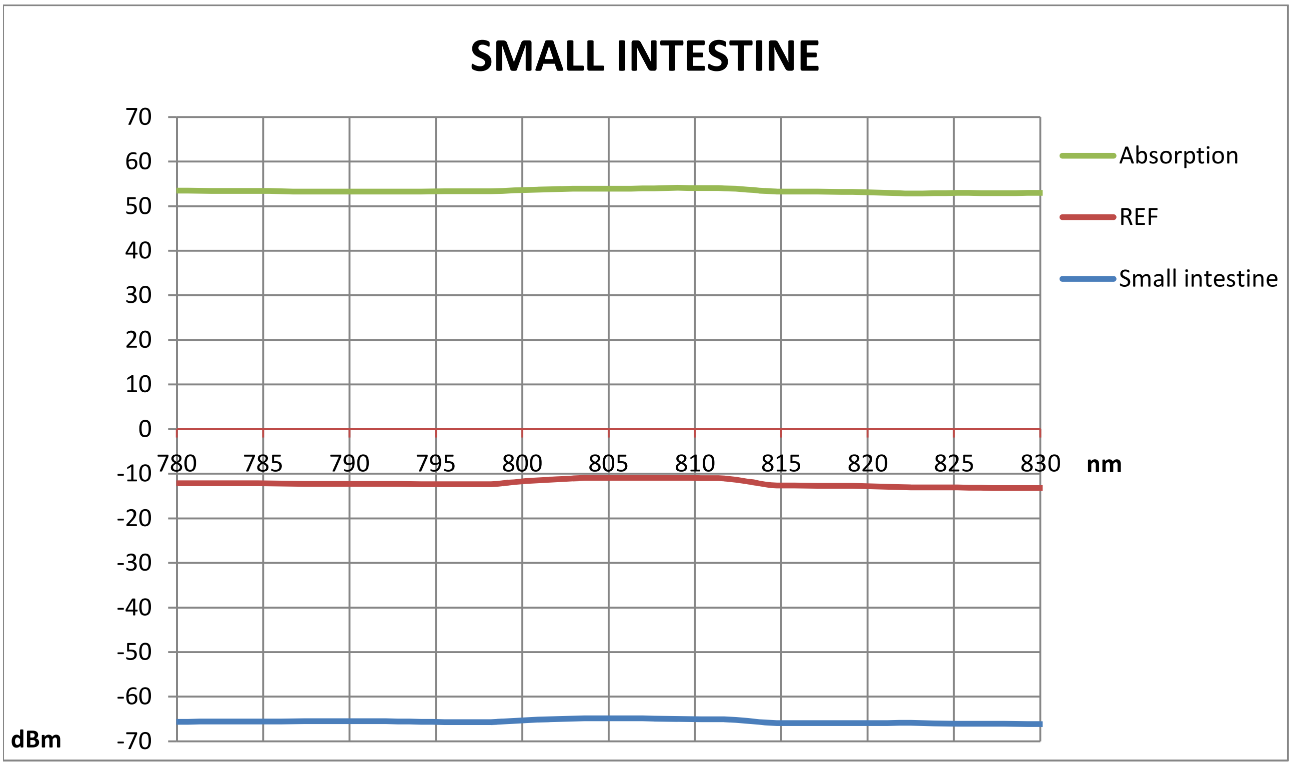

Fig. 7 - Graph of the reference radiation source (REF), the radiation that passes through the tissue (Small intestine) and absorption (Absorption) in sprague dawley rat small intestine for wavelengths from 780 nm till 830 nm.

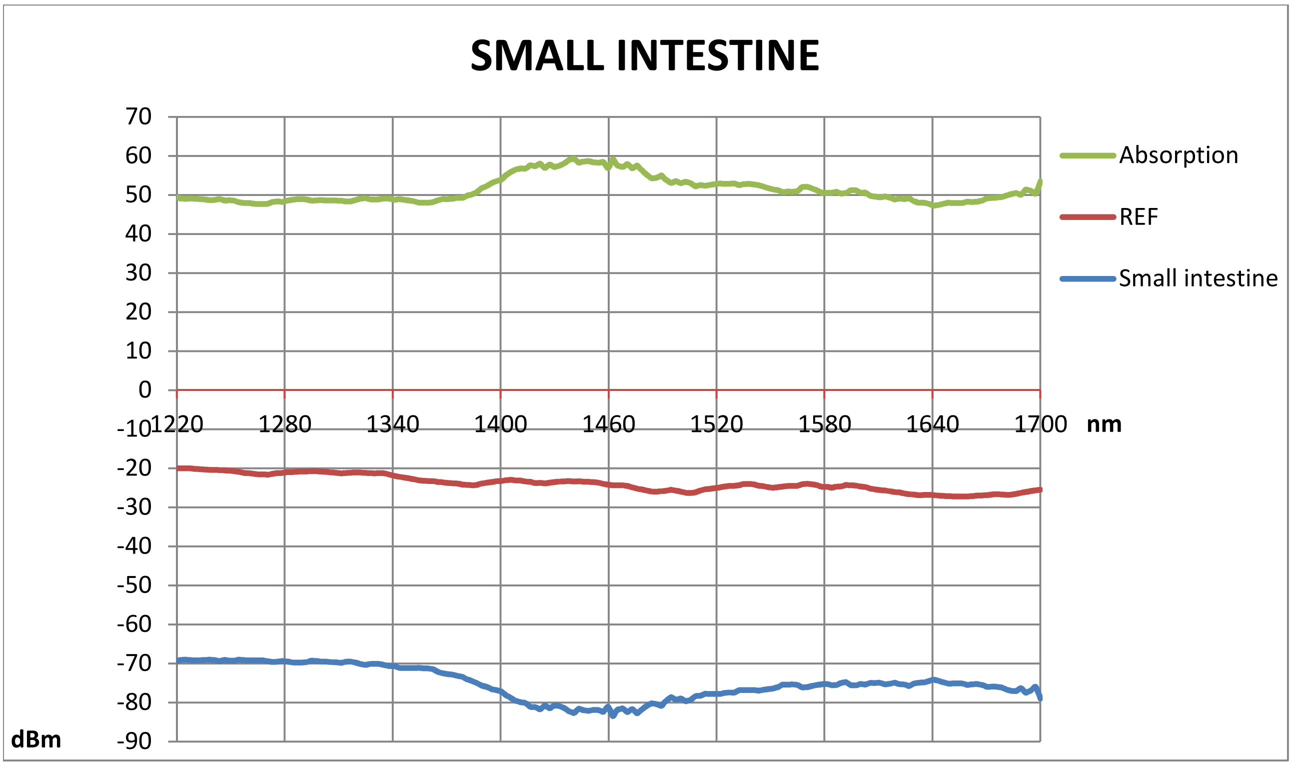

Fig. 8 - Graph of the reference radiation source (REF), the radiation that passes through the tissue (Small intestine) and absorption (Absorption) in sprague dawley rat small intestine for wavelengths from 1220 nm till 1700 nm.

Wavelength (nm)	Small intestine Measure (dBm)	Wavelength (nm)	Small intestine Measure (dBm)
350.000	-74.727	372.950	**-80.950**
351.350	-74.630	374.300	**-83.825**
352.700	-74.536	375.650	**-81.395**
354.050	-75.232	377.000	-79.846
355.400	-76.063	378.350	-82.440
356.750	-77.198	379.700	**-89.819**
358.100	-78.739	381.050	**-85.654**
359.450	-79.590	382.400	**-83.568**
360.800	**-80.649**	383.750	**-84.572**
362.150	**-81.927**	385.100	**-85.882**
363.500	**-83.748**	386.450	**-86.085**
364.850	**-82.237**	387.800	**-86.299**
366.200	**-81.119**	389.150	**-86.778**
367.550	**-82.586**	390.500	**-87.318**
368.900	**-84.817**	391.850	**-85.862**
370.250	**-81.185**	393.200	**-84.774**
371.600	-79.235	394.550	**-89.642**

Table 1 - Values of measured light from spectrum analyzer in sprague dawley rat small intestine at wavelengths from 350 nm till 394.550 nm. The values lower than -80 dBm are in red. For the reasons illustrated in this chapter it is believed that the light is completely absorbed at these wavelengths.

Wavelength (nm)	Small intestine Measure (dBm)	Wavelength (nm)	Small intestine Measure (dBm)
468.800	**-87.457**	474.200	**-81.356**
470.150	**-85.984**	475.550	**-82.242**
471.500	**-84.886**	476.900	**-83.357**
472.850	**-82.772**		

Table 2 - Values of measured light from spectrum analyzer in sprague dawley rat small intestine at wavelengths from 468.800 nm till 476.900 nm. The values lower than -80 dBm are in red. For the reasons illustrated in this chapter it is believed that the light is completely absorbed at these wavelengths.

Wavelength (nm)		Small intestine Measure (dBm)	Small intestine Absorption (dB)
from	**till**		
350.000	**394.550**	**values < -80**	**full absorption**
395.900	**467.450**	**spikes < -80**	**full absorption**
468.800	**476.900**	**values < -80**	**full absorption**
478.250	**1411.100**	**values > -80**	**valid values**
1412.450	**1490.750**	**values < -80**	**full absorption**
1492.100	**1700.000**	**values > -80**	**valid values**

Table 3 - Summary of wavelengths where light is completely absorbed in sprague dawley rat small intestine. Values lower than -80 dBm are deemed too small because they are not read by the spectrum analyzer. So those wavelengths light are considered completely absorbed.

Wavelength (nm)	REF (dBm)	Small Intestine Measure (dBm)	Small Intestine Absorption (dBm)
798.200	-12.350	-65.706	53.356
799.550	-11.882	-65.425	53.543
800.900	-11.459	-65.161	53.702
802.250	-11.187	-65.003	53.816
803.600	-10.931	-64.850	53.919
804.950	-10.930	-64.847	53.917
806.300	-10.929	-64.843	53.914
807.650	-10.913	-64.918	54.005
809.000	**-10.897**	-64.994	54.097
810.350	-10.977	-65.031	54.054
811.700	-11.058	-65.069	54.011
813.050	-11.737	-65.441	53.704
814.400	-12.543	-65.849	53.306
815.750	-12.615	-65.893	53.278

Table 4 - The table shows that the value of absorption in sprague dawley rat small intestine remains almost constant for wavelength from 798.200 nm till 815.750 nm. At 809.000 nm the value of source is maximum (in red), but despite this absorption is almost constant.

Wavelength (nm)	REF (dBm)	Small intestine Measure (dBm)	Small intestine Absorption (dBm)
1045.250	-18.102	-67.841	49.739
1046.600	-18.139	-67.869	49.730
1047.950	-18.178	-67.919	49.741
1049.300	-18.217	-67.969	49.752
1050.650	-18.250	-67.979	49.729
1052.000	-18.284	-67.989	49.705
1053.350	-18.324	-67.966	49.642
1054.700	-18.364	-67.943	49.579
1056.050	-18.349	-67.825	49.476
1057.400	-18.334	-67.711	49.377
1058.750	-18.123	-63.477	45.354
1060.100	-17.921	-61.375	43.454
1061.450	-17.932	-61.344	43.412
1062.800	-17.942	-61.314	43.372
1064.150	-17.941	-61.030	43.089
1065.500	-17.939	-60.763	42.824
1066.850	-17.964	-60.875	42.911
1068.200	-17.988	-60.989	43.001
1069.550	-18.255	-63.100	44.845
1070.900	-18.540	-67.369	48.829
1072.250	-18.565	-67.342	48.777
1073.600	-18.590	-67.315	48.725
1074.950	-18.604	-67.136	48.532
1076.300	-18.618	-66.964	48.346
1077.650	-18.597	-66.537	47.940
1045.250	-18.102	-67.841	49.739
1046.600	-18.139	-67.869	49.730
1047.950	-18.178	-67.919	49.741
1049.300	-18.217	-67.969	49.752
1050.650	-18.250	-67.979	49.729
1052.000	-18.284	-67.989	49.705
1053.350	-18.324	-67.966	49.642
1054.700	-18.364	-67.943	49.579

1056.050	-18.349	-67.825	49.476
1057.400	-18.334	-67.711	49.377
1058.750	-18.123	-63.477	45.354
1060.100	-17.921	-61.375	43.454
1061.450	-17.932	-61.344	43.412
1062.800	-17.942	-61.314	43.372
1064.150	-17.941	-61.030	43.089
1065.500	-17.939	**-60.763**	42.824
1066.850	-17.964	-60.875	42.911
1068.200	-17.988	-60.989	43.001
1069.550	-18.255	-63.100	44.845
1070.900	-18.540	-67.369	48.829
1072.250	-18.565	-67.342	48.777
1073.600	-18.590	-67.315	48.725
1074.950	-18.604	-67.136	48.532
1076.300	-18.618	-66.964	48.346
1077.650	-18.597	-66.537	47.940

Table 5 - Values of radiation passing through and of radiation absorbed in sprague dawley rat small intestine in relation to radiation emitted at wavelengths from 1045.250 nm till 1077.650 nm. The maximum light value passing through the tissue is in red.

Wavelength (nm)		dBm or dB	Light
809.000		-10.897 dBm	maximum value of light source
1062.800		43.190 dB	minimum absorption
1062.800		-61.132 dBm	maximum transmission
449.900		-46.547 dBm	minimum value of light source
from	till		
350.000	394.550	values < -80	full absorption
395.900	467.450	spikes < -80	full absorption
468.800	476.900	values < -80	full absorption
478.250	1411.100	values > -80	valid values
1412.450	1490.750	values < -80	full absorption
1492.100	1700.000	values > -80	valid values

Table 6 – Summary table.

4 Lung

It is used sprague dawley rat lung. It has a thickness of 0.3 mm and it is positioned between the smaller plates (Fig. 1), with the center hole having a diameter of 1.5 mm in order to cover the entire hole. The source emits the light with the values and the sequence already described (Fig. 2).

Fig. 1 - Sprague dawley rat lung vision positioned on the plate.

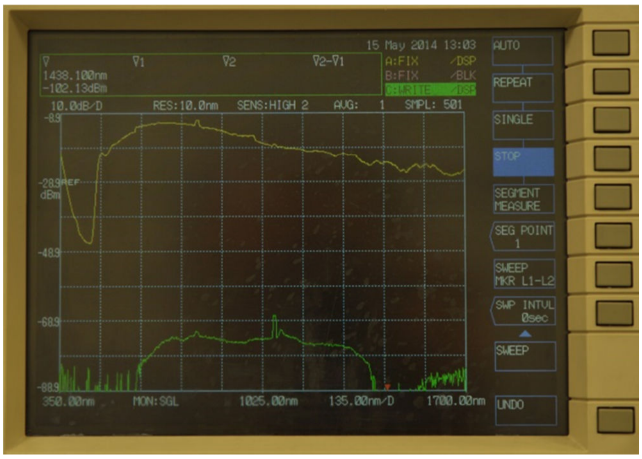

Fig. 2 – Graph of measurements made on sprague dawley rat lung shown by Spectrum Analyzer display.

The values of the light, which crosses the tissue (Lung), are represented in Fig. 3, along with to the values of light emitted through the air without anything interposed (reference or calibration path, REF). In the same figure you see also the graph of the light absorption in the lung (Absorption). Its value is the difference between the emitted light and the passing light through the tissue (transmitted).

Also in this case (Fig. 3) you see that from 350.000 nm till 598.400 nm included (Fig. 5), and from 1400.300 nm till 1535.300 nm included (Fig. 9), the passing light values in the tissue are very variable. They may look like light absence spikes (-210.000 dBm) followed by partially absorbed light whose value is less than or close to -80 dBm. Again, for the reasons already stated they represent the wavelengths at which radiation is completely absorbed. A vision of the same range of wavelengths, using a more detailed scale (Fig. 5), would seem to show that the light pass into the tissue at wavelengths greater than 599.750 nm. Instead the values analysis shows that from 599.750 nm till 637.550 nm included, the passing radiation measurement through the lung still has a power level less than -80 dBm (Fig. 5, Table 1).

So also for these wavelengths it can be considered that the radiation is completely absorbed by the lung.

From the wavelength of 638.900 nm till 1358,450 nm included, the passing light values are greater than -80 dBm. Hence, being the values reliable, we can say that in this wavelengths portion, the light can effectively pass through the lung (Fig. 3, Fig. 4).

The second group of spikes begins at 1400.300 nm and lasts till 1535.300 nm (Fig. 3, Fig. 8, Fig. 9). In this range the light is completely absorbed by the lung. However, also in this case, the numbers analysis shows that the passing radiation values begin to be less than -80 dBm already at wavelength of 1359.800 nm till 1398.950 nm (Fig. 9, Table 2) after which, at 1400.300 nm the already mentioned spikes start. For the reasons already stated, starting from 1359.800 nm till 1398.950 nm

(Fig. 8, Fig. 9) also these radiation values must be discarded and, therefore, in this range of wavelength, we conclude that the radiation is completely absorbed by the lung (Table 2).

The spikes terminate at wavelength of 1535.300 nm, but all passing light values from 1536.650 nm till 1700.000 nm included are not reliable because below -80 dBm (Fig. 10).

For the reasons already stated the transmitted light values in this wavelength range are discarded. So all the radiation from wavelength of 1535.300 nm till 1700.000 nm is completely absorbed by the lungs. These values cannot be listed in a table being too numerous and the table size would be too big.

It thus appears that the light effectively passes through the lung between the 638.900 nm and 1358.450 nm (Table 3).

In the figures are represented graphically the instrument reference values (REF), the passing light values through the tissue (Lung) and absorbed light values by the lung (Absorption).

On first analysis it can be seen that the passing light through the tissue has practically constant value from 638.900 nm till 1057.400 nm (Fig. 3, Fig. 4). Starting from this latter wavelength (Fig. 6) the passing light amount through the lung has a significant increase till 1065.500 nm, to which transmission is the highest, then it decreases till the wavelength of 1070,900 nm (Table 5).

Accordingly, in the range of these wavelengths the absorption in the tissue has a drastic decrease. From the wavelength of 1070,900 nm onward, the transmission remains again fairly constant till the wavelength of 1358.450 nm (Fig. 8, Fig. 9)   at 1359.800 nm it decreases below -80 dBm.

Also in this case, by examining the graph of Fig. 3 e Fig. 4, it would seem that significant radiation values pass through the examined tissue at wavelengths around 800 nm.

But in this case, as well as in the previous, the transmitted power increase follows the source light increase, without reduction of absorbed radiation that, for those wavelengths, is almost constant. In this regard see the detail shown in the graph of Fig. 7 and the values for that field of wavelengths shown in Table 4. The maximum value of source light it is revealed at 809.000 nm, but for this wavelength the transmission is neither the highest nor the absorption is the minimum.

A summary is shown in Table 6.

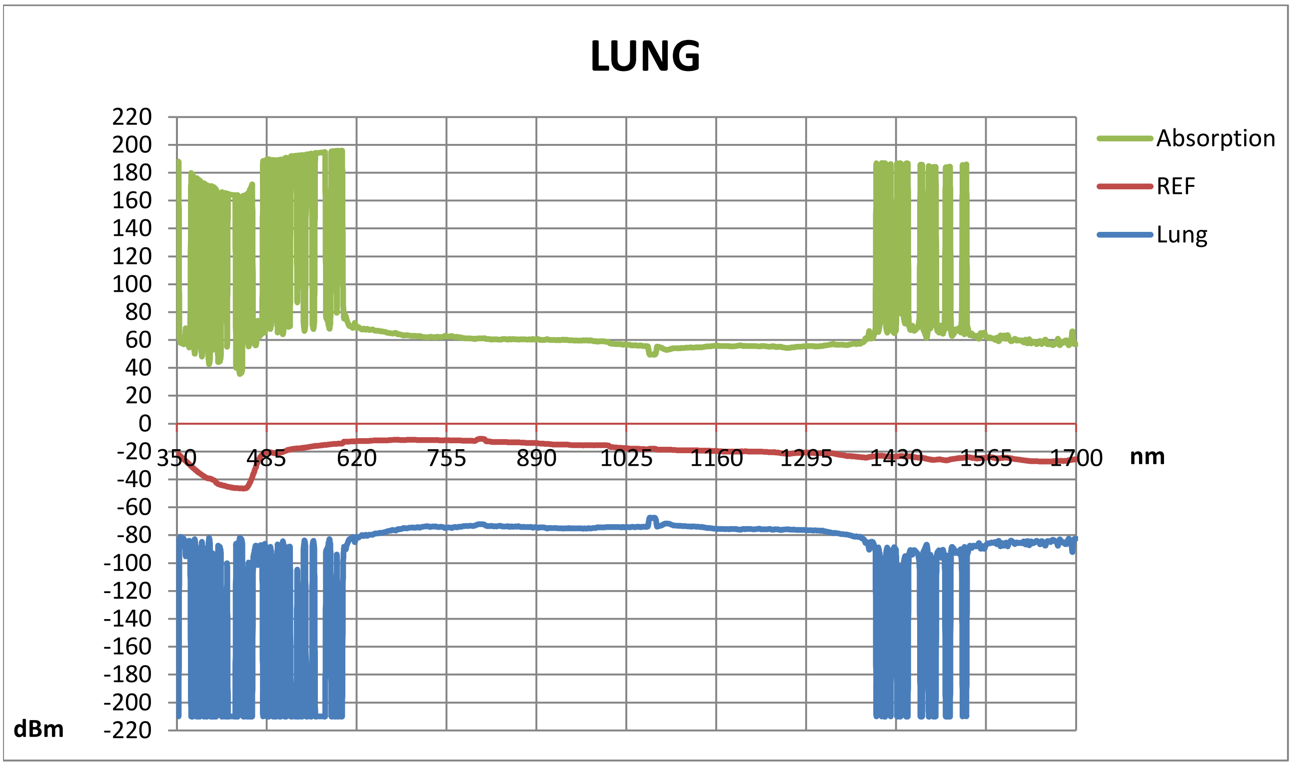

Fig. 3 – Graph of the reference radiation source (REF), the radiation that passes through the tissue (Lung) and absorption (Absorption) in sprague dawley rat lung.

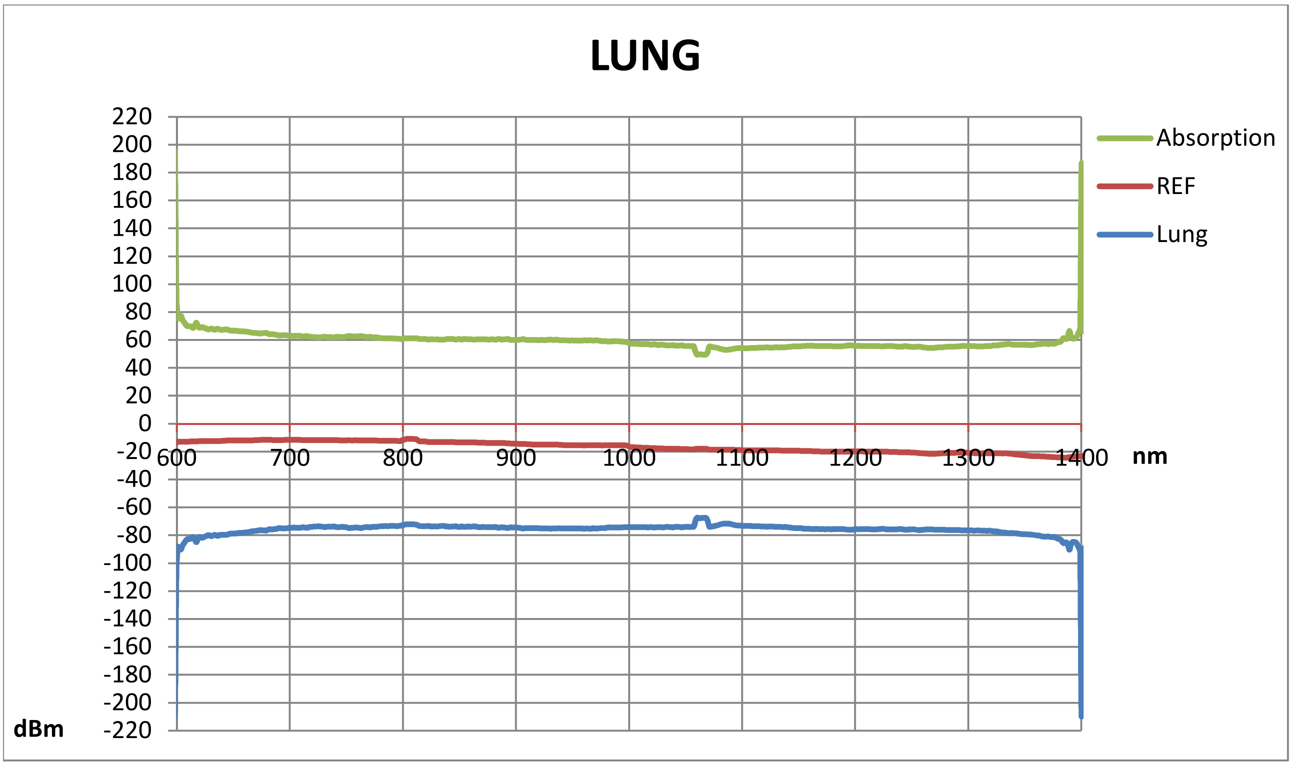

Fig. 4 – Graph of the reference radiation source (REF), the radiation that passes through the tissue (Lung) and absorption (Absorption) in sprague dawley rat lung for wavelengths from 600 nm till 1400 nm.

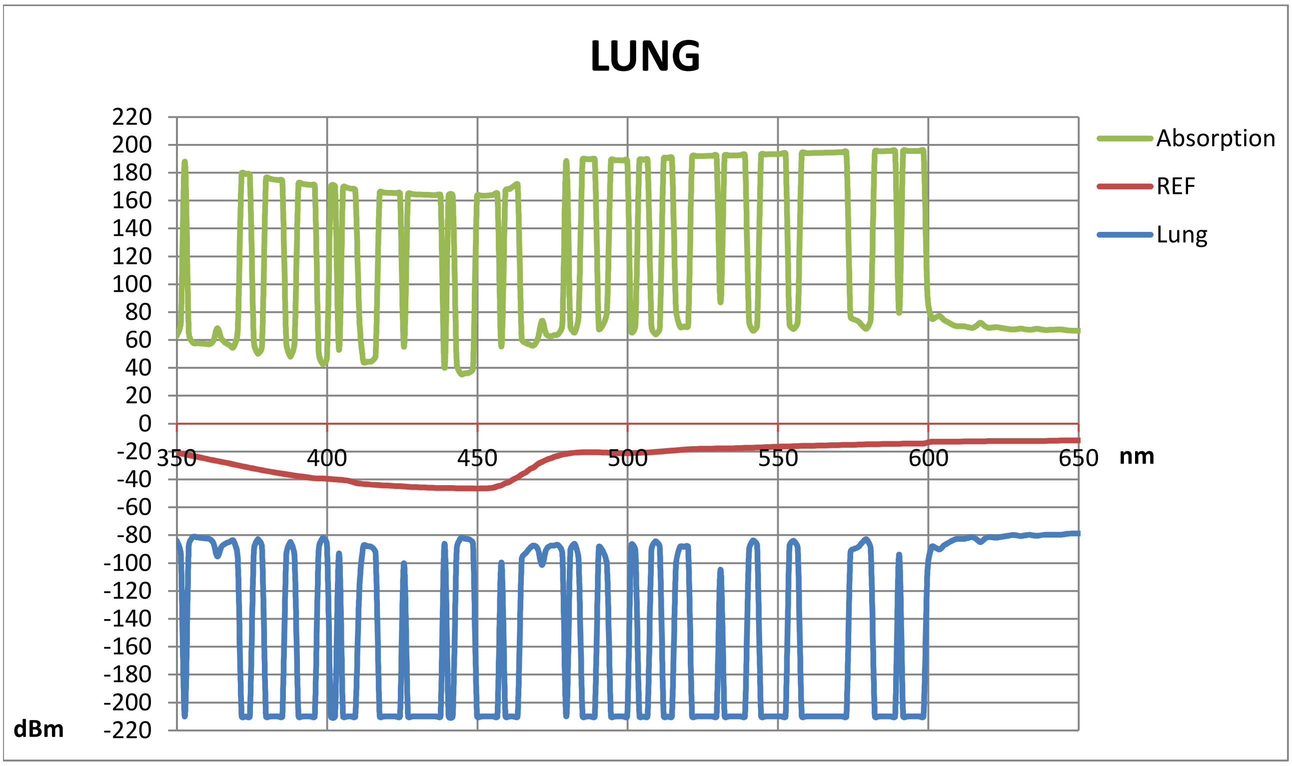

Fig. 5 – Graph of the reference radiation source (REF), the radiation that passes through the tissue (Lung) and absorption (Absorption) in sprague dawley rat lung for wavelengths from 350 nm till 650 nm.

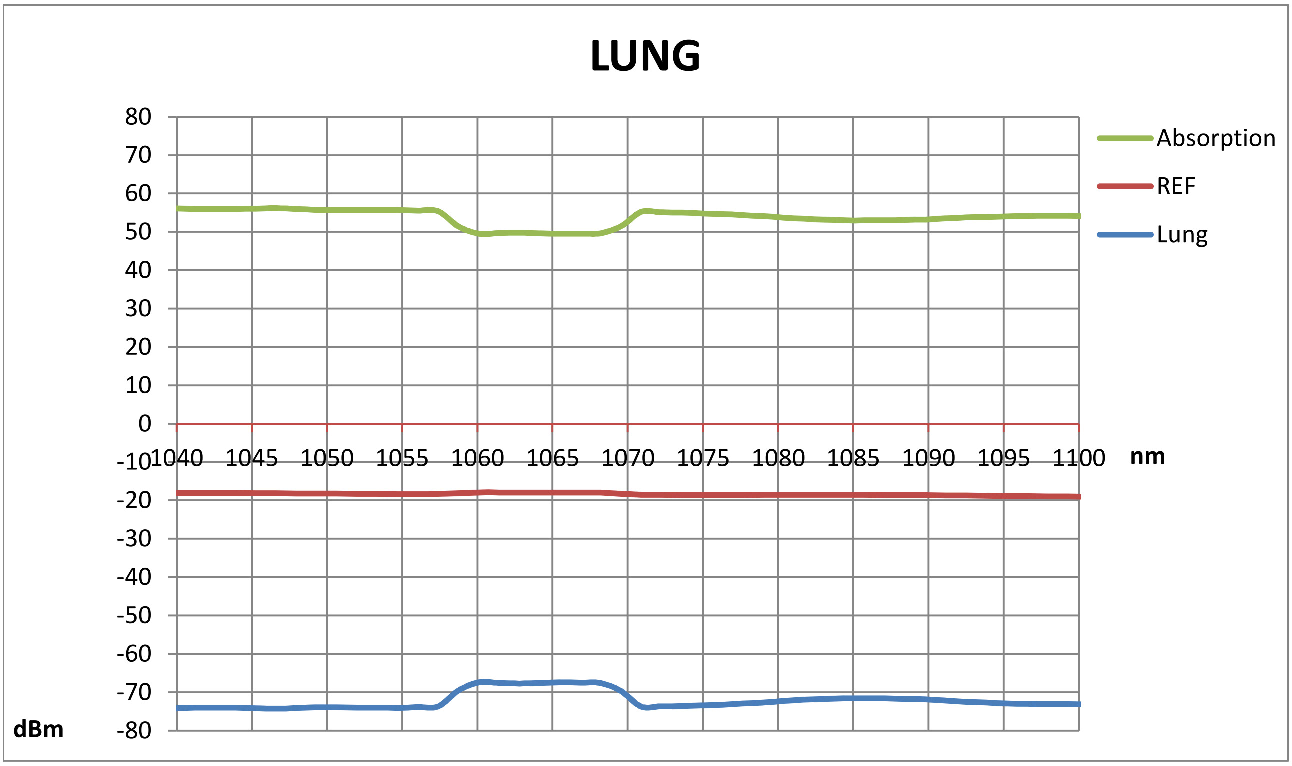

Fig. 6 – Graph of the reference radiation source (REF), the radiation that passes through the tissue (Lung) and absorption (Absorption) in sprague dawley rat lung for wavelengths from 1040 nm till 1100 nm.

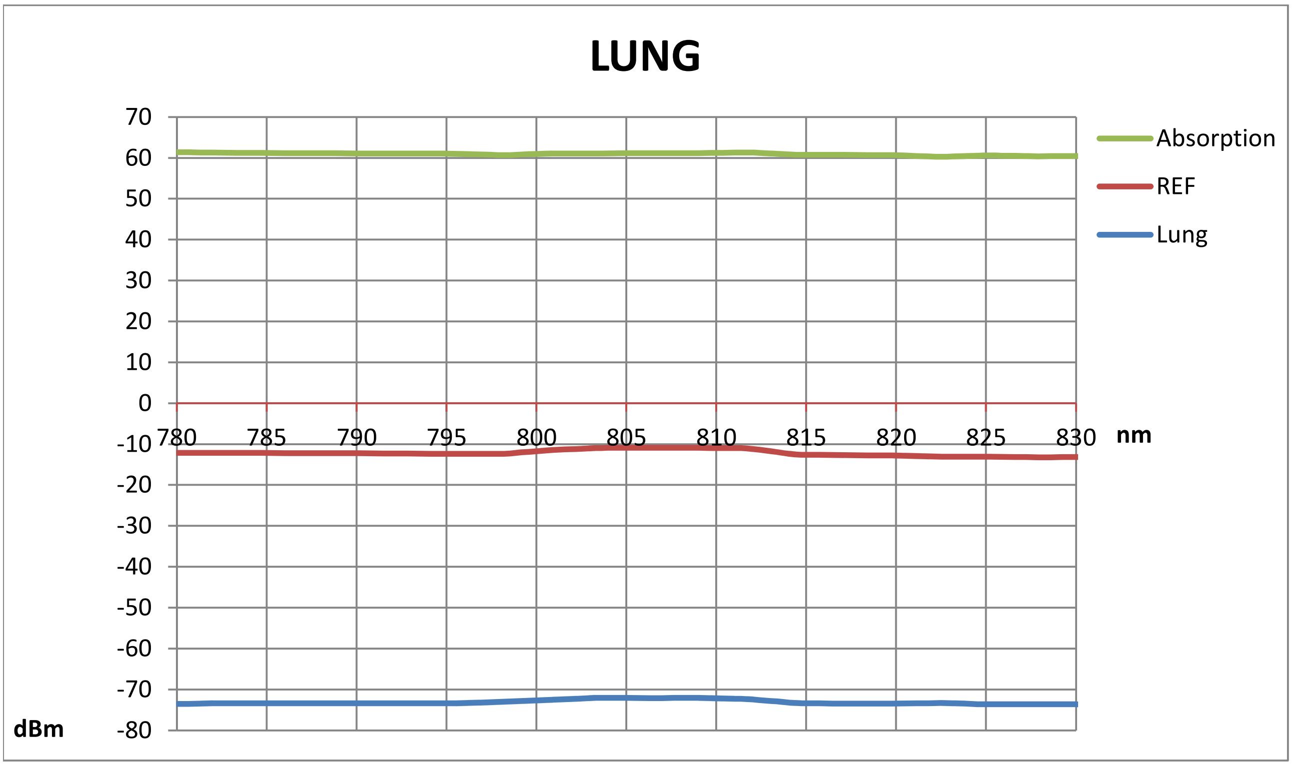

Fig. 7 – Graph of the reference radiation source (REF), the radiation that passes through the tissue (Lung) and absorption (Absorption) in sprague dawley rat lung for wavelengths from 780 nm till 830 nm.

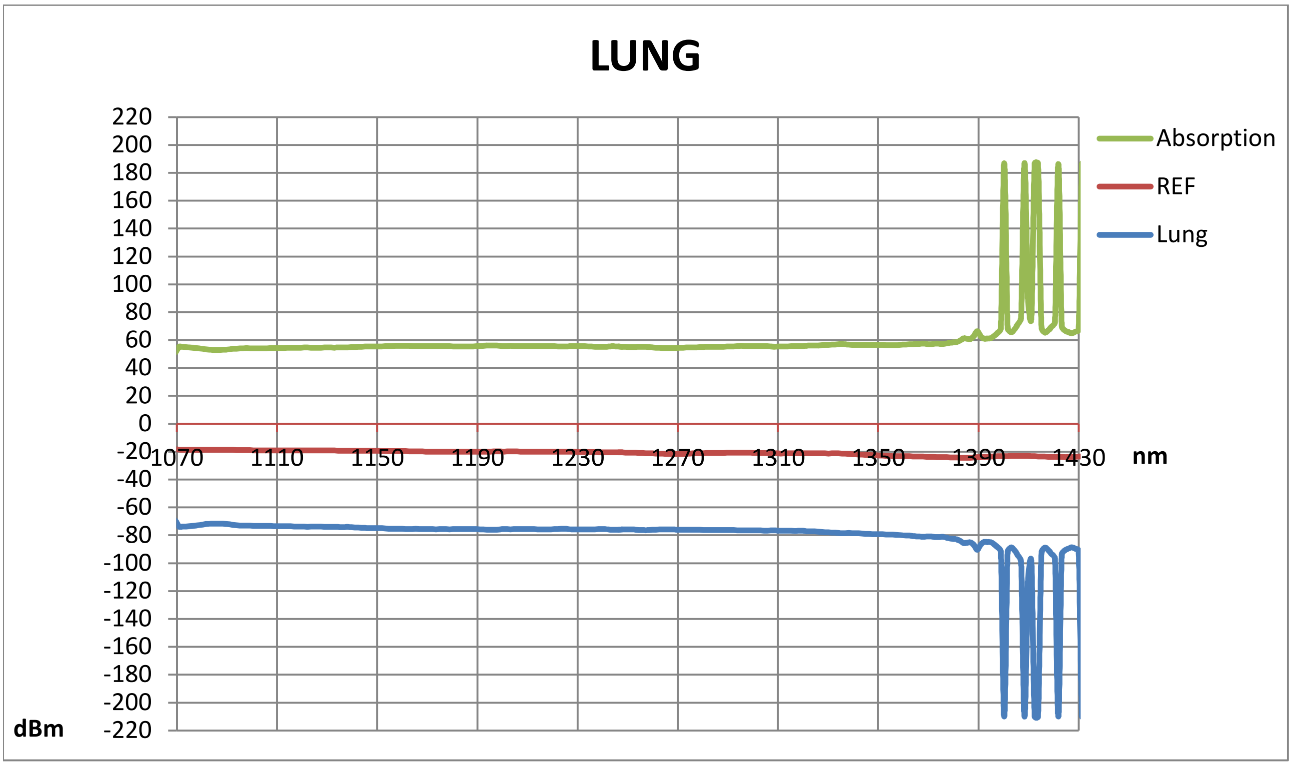

Fig. 8 – Graph of the reference radiation source (REF), the radiation that passes through the tissue (Lung) and absorption (Absorption) in sprague dawley rat lung for wavelengths from 1070 nm till 1430 nm.

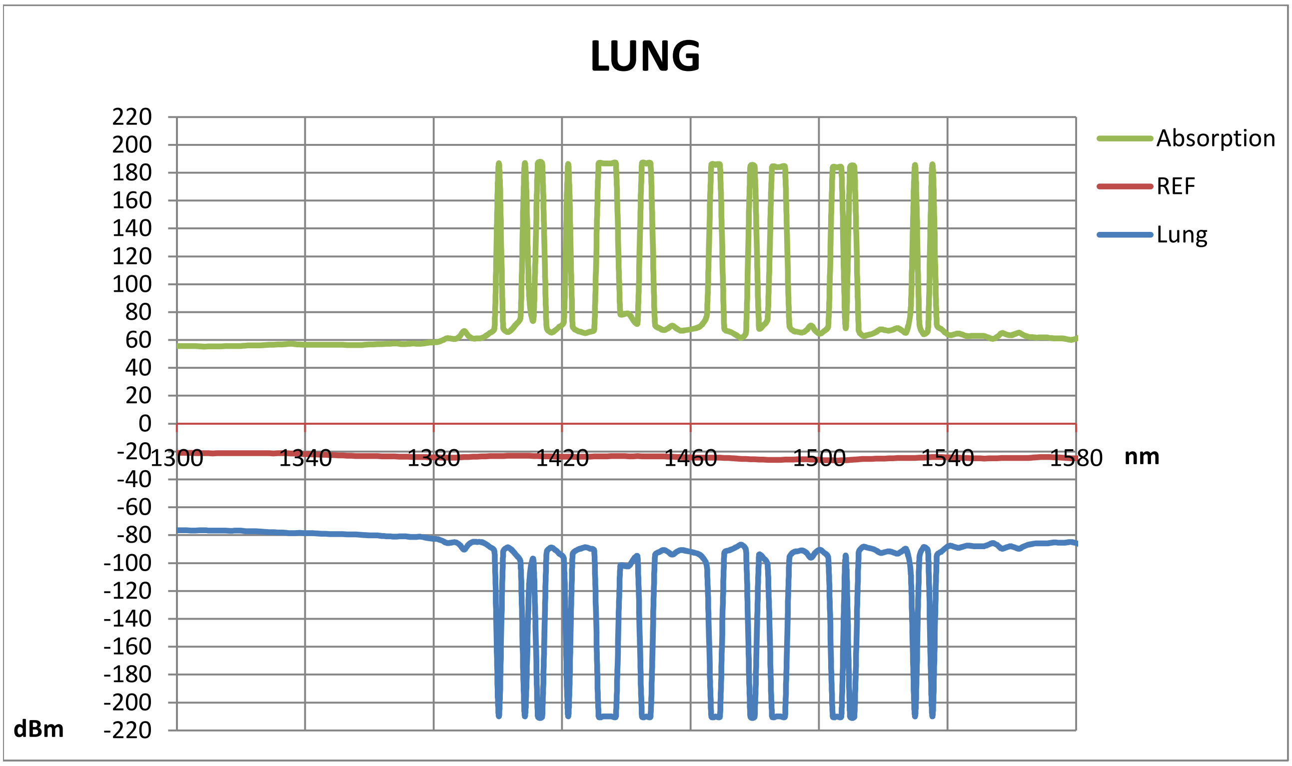

Fig. 9 – Graph of the reference radiation source (REF), the radiation that passes through the tissue (Lung) and absorption (Absorption) in sprague dawley rat lung for wavelengths from 1300 nm till 1580 nm.

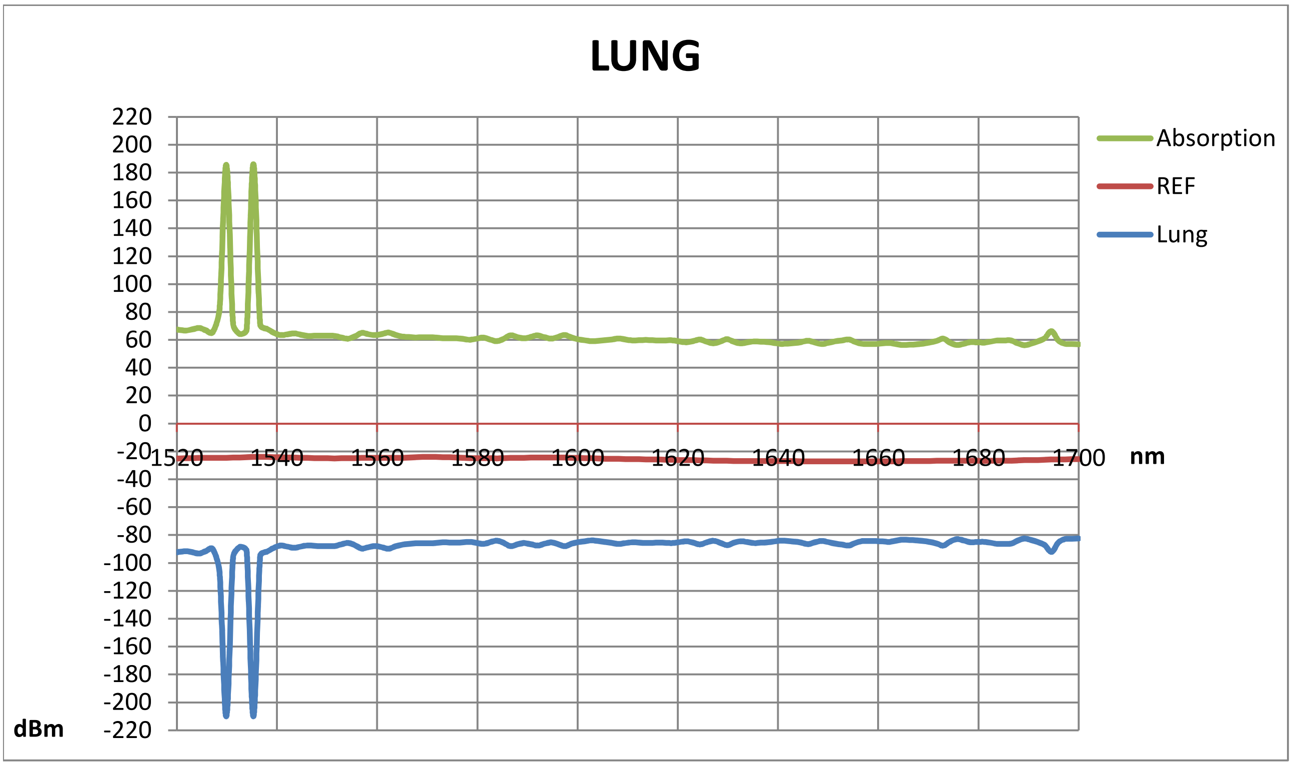

Fig. 10 – Graph of the reference radiation source (REF), the radiation that passes through the tissue (Lung) and absorption (Absorption) in sprague dawley rat lung for wavelengths from 1520 nm till 1700 nm.

Wavelength (nm)	Lung Measure (dBm)	Wavelength (nm)	Lung Measure (dBm)
599.750	**-103.660**	620.000	**-81.323**
601.100	**-88.355**	621.350	**-81.556**
602.450	**-89.152**	622.700	**-81.801**
603.800	**-90.128**	624.050	**-81.255**
605.150	**-87.376**	625.400	**-80.770**
606.500	**-85.705**	626.750	**-80.299**
607.850	**-84.051**	628.100	-79.873
609.200	**-82.856**	629.450	**-80.219**
610.550	**-82.743**	630.800	**-80.594**
611.900	**-82.633**	632.150	**-80.137**
613.250	**-81.928**	633.500	-79.725
614.600	**-81.323**	634.850	**-80.068**
615.950	**-82.776**	636.200	**-80.440**
617.300	**-84.976**	637.550	**-80.007**
618.650	**-82.777**		

Table 1 - Values of measured light from spectrum analyzer in sprague dawley rat lung at wavelengths from 599.750 nm till 637.550 nm. The values lower than -80 dBm are in red. For the reasons illustrated in this chapter it is believed that the light is completely absorbed at these wavelengths.

Wavelength (nm)	Lung Measure (dBm)	Wavelength (nm)	Lung Measure (dBm)
1359.800	**-80.023**	1380.050	**-82.608**
1361.150	**-80.122**	1381.400	**-82.921**
1362.500	**-80.223**	1382.750	**-84.066**
1363.850	**-80.506**	1384.100	**-85.624**
1365.200	**-80.809**	1385.450	**-85.329**
1366.550	**-80.935**	1386.800	**-85.053**
1367.900	**-81.065**	1388.150	**-86.942**
1369.250	**-80.936**	1389.500	**-90.358**
1370.600	**-80.810**	1390.850	**-86.734**
1371.950	**-81.057**	1392.200	**-84.786**
1373.300	**-81.318**	1393.550	**-84.874**
1374.650	**-81.236**	1394.900	**-84.964**
1376.000	**-81.155**	1396.250	**-86.403**
1377.350	**-81.697**	1397.600	**-88.570**
1378.700	**-82.317**	1398.950	**-91.781**

Table 2 - Values of measured light from spectrum analyzer in sprague dawley rat lung at wavelengths from 1359.800 nm till 1398.950 nm. The values lower than -80 dBm are in red. For the reasons illustrated in this chapter it is believed that the light is completely absorbed at these wavelengths.

Wavelength (nm)		Lung Measure (dBm)	Lung Absorption (dB)
from	till		
350.000	598.400	spikes < -80	full absorption
599.750	637.550	values < -80	full absorption
638.900	1358.450	values > -80	valid values
1359.800	1398.950	values < -80	full absorption
1400.300	1535.300	spikes < -80	full absorption
1536.650	1700.000	values < -80	full absorption

Table 3 - Summary of wavelengths where light is completely absorbed in sprague dawley rat lung. Values lower than -80 dBm are deemed too small because they are not read by the spectrum analyzer. So those wavelengths light are considered completely absorbed.

Wavelength (nm)	REF (dBm)	Lung Measure (dBm)	Lung Aborption (dB)
798.200	-12.350	-72.996	60.646
799.550	-11.882	-72.758	60.876
800.900	-11.459	-72.533	61.074
802.250	-11.187	-72.269	61.082
803.600	-10.931	-72.020	61.089
804.950	-10.930	-72.059	61.129
806.300	-10.929	-72.097	61.168
807.650	-10.913	-72.077	61.164
809.000	**-10.897**	-72.056	61.159
810.350	-10.977	-72.203	61.226
811.700	-11.058	-72.355	61.297
813.050	-11.737	-72.803	61.066
814.400	-12.543	-73.302	60.759
815.750	-12.615	-73.375	60.760

Table 4 - The table shows that the value of absorption in sprague dawley rat lung remains almost constant for wavelength from 798.200 nm till 815.750 nm. At 809.000 nm the value of source is maximum (in red), but despite this absorption is almost constant.

Wavelength (nm)	REF (dBm)	Lung Measure (dBm)	Lung Aborption (dB)
1045.250	-18.102	-74.152	56.050
1046.600	-18.139	-74.301	56.162
1047.950	-18.178	-74.119	55.941
1049.300	-18.217	-73.944	55.727
1050.650	-18.250	-73.961	55.711
1052.000	-18.284	-73.979	55.695
1053.350	-18.324	-74.022	55.698
1054.700	-18.364	-74.065	55.701
1056.050	-18.349	-73.875	55.526
1057.400	-18.334	-73.693	55.359
1058.750	-18.123	-69.526	51.403
1060.100	-17.921	-67.439	49.518
1061.450	-17.932	-67.582	49.650

1062.800	-17.942	-67.731	49.789
1064.150	-17.941	-67.576	49.635
1065.500	-17.939	**-67.427**	49.488
1066.850	-17.964	-67.523	49.559
1068.200	-17.988	-67.622	49.634
1069.550	-18.255	-69.684	51.429
1070.900	-18.540	-73.749	55.209
1072.250	-18.565	-73.675	55.110
1073.600	-18.590	-73.601	55.011
1074.950	-18.604	-73.418	54.814
1076.300	-18.618	-73.243	54.625
1077.650	-18.597	-72.947	54.350

Table 5 - Values of radiation passing through and of radiation absorbed in sprague dawley rat lung in relation to radiation emitted at wavelengths from 1045.250 nm till 1077.650 nm. The maximum light value passing through the tissue is in red.

Wavelength (nm)		dBm or dB	Light
809.000		-10.897 dBm	maximum value of light source
1065.500		49.488dB	minimum absorption
1065.500		-67.427dBm	maximum transmission
449.900		-46.547 dBm	minimum value of light source
from	till		
350.000	598.400	spikes < -80	full absorption
599.750	637.550	values < -80	full absorption
638.900	1358.450	values > -80	valid values
1359.800	1398.950	values < -80	full absorption
1400.300	1535.300	spikes < -80	full absorption
1536.650	1700.000	values < -80	full absorption

Table 6 – Summary table.

5 Esophagus

In this case, we use sprague dawley rat esophagus emptied of its content (Fig. 1). It has a thickness of 0.4 mm (Fig. 4) and it is positioned between the smaller plates, with a central hole having a diameter of 1.5 mm (Fig. 2), in order to cover the entire hole. The source emits light with the values and the sequence already described (Fig. 3).

Fig. 1 – End sprague dawley rat esophagus and stomach vision immediately after the sample taking.

Fig. 2 – Sprague dawley rat esophagus vision positioned on the plate.

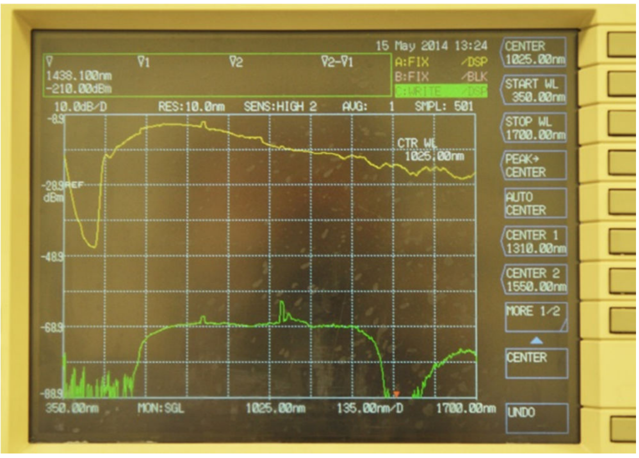

Fig. 3 – Graph of measurements taken on sprague dawley rat esophagus shown by Spectrum Analyzer display.

The values of the light, which crosses the tissue (Esophagus), are represented in Fig. 5, along with the values of light emitted freely through the air without anything interposed (reference or calibration path, REF). In the same figure you see also the graph of esophagus light absorption (Absorption). Its value is the difference between the emitted light and the passing light through the tissue (transmitted).

Also in this case (Fig. 5) you see that the values from 350.000 nm till 545.750 nm (Fig. 7) included, and from 1420.550 nm till 1489.400 nm included (Fig. 8), the passing light values in the tissue are very variable. They may look like light absence spikes (-210.000 dBm) followed by partially absorbed light whose value is less than or close to -80 dBm. Again, for the reasons already stated they represent the wavelengths at which radiation is completely absorbed. A vision of the same wavelengths range (Fig. 7), using a more detailed scale, would seem to show that the light pass in the tissue at wavelengths higher than 545.750 nm. Instead the values analysis shows that from 547.100 nm till 588.950 nm included, the passing radiation measurement through the esophagus still has a power level less than -80 dBm (Table 1).

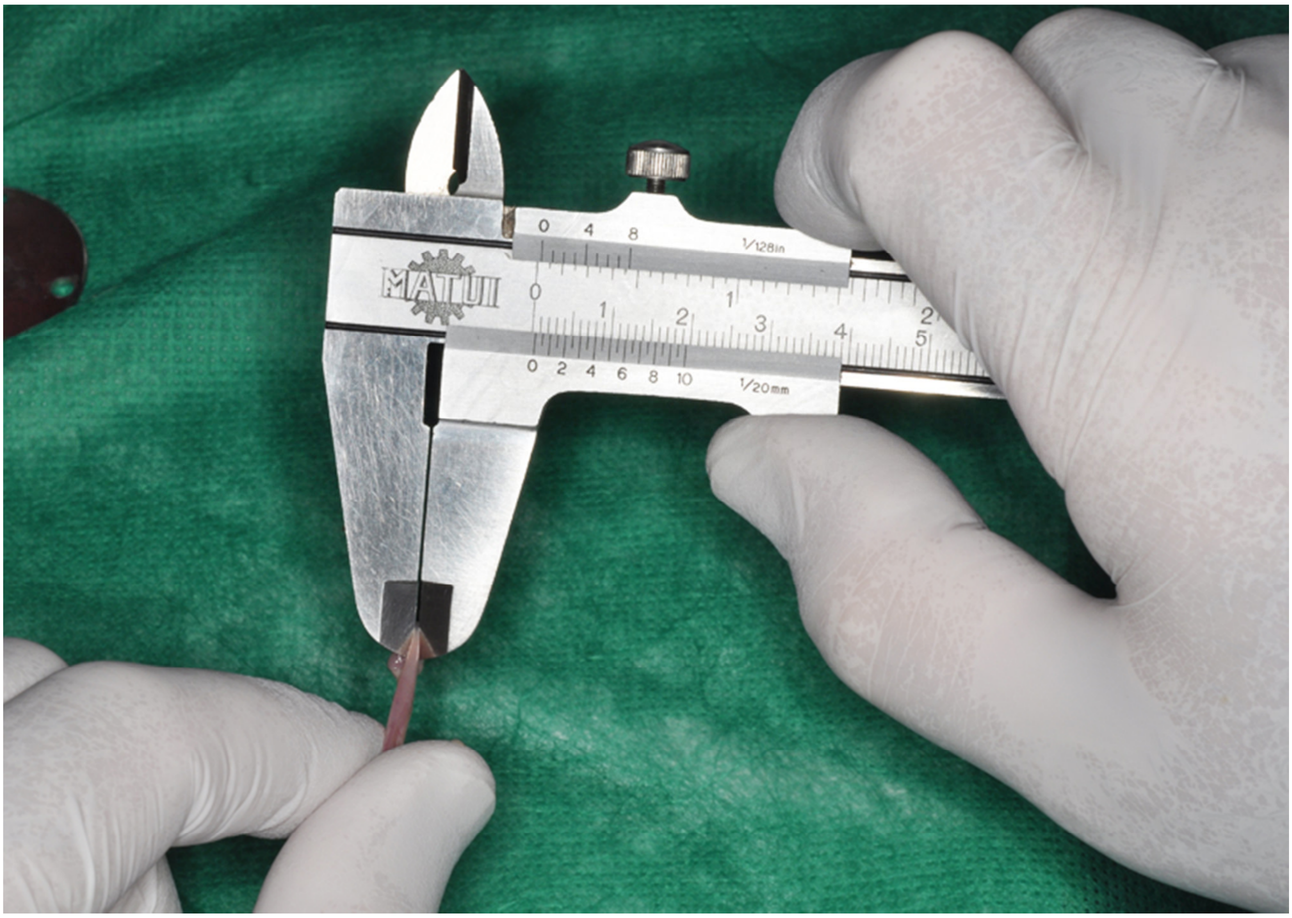

Fig. 4 – Detecting the thickness of the esophagus before the test.

So also for these range it can be considered that the radiation is completely absorbed by the esophagus.

From the wavelength of 590.300 nm till 1388.150 nm included, the passing light values are greater than -80 dBm. Hence, being the values reliable, we can say that in this wavelengths portion, the light can effectively pass through the esophagus (Fig. 6).

The second group of spikes begins at 1420.550 nm and lasts till 1489.400 nm (Fig. 5, Fig. 6, Fig. 8). In this range the light is completely absorbed in the esophagus. However, also in this case, the numbers analysis shows that the passing radiation values begin to be less than -80 dBm already at wavelength of 1389.500 nm till 1419.200 nm (Fig. 6, Fig. 8) after which, at 1420.550 nm, the already mentioned spikes start (Fig. 8). For the reasons already stated, starting from 1389.500 nm till 1419.200 nm also these radiation values must be discarded and, therefore, in this range of wavelength, the radiation is completely absorbed by the esophagus (Table 2).

The spikes terminate at the wavelength of 1489.400 nm (Fig. 8), but all passing light values from 1490.750 nm till 1577.150 nm included are not reliable because below -80 dBm (Fig. 11).

For the reasons already stated the transmitted light values in this wavelength range are discarded. So all the radiation between wavelength of 1490.750 nm till 1577.150 nm are completely absorbed by the esophagus (Table 3).

From the wavelength of 1578.500 nm till 1700 nm included, the passing light values are again greater than -80 dBm. So we can say that in this area of wavelengths the light can pass through the esophagus.

It thus appears that the light effectively passes through the esophagus between 590.300 nm and 1388.150 nm and from 1578.500 nm till 1700 nm (Table 4).

In the figures are represented graphically the instrument reference values (REF), the passing light values through the tissue (Esophagus) and absorbed light values by the esophagus (Absorption).

On first analysis it can be seen that the transmitted light, apart a small increase from 590.300 nm until till 690.000 nm, has practically constant value till 1057.400 nm (Fig. 5, Fig. 6). Starting from this latter wavelength (Fig. 9) the passing light amount through the esophagus has a significant increase till 1062.800 nm, to which transmission is the highest, then it decreases till the wavelength of 1070.900 nm (Table 6).

Accordingly, in the range of these wavelengths the absorption into the tissue has a drastic decrease. From the wavelength of 1070.900 nm onward, the transmission remains again fairly constant till the wavelength of 1388.150 nm (Fig. 6) and then at 1389.500 nm it decreases under the -80 dBm.

Also in this case, by examining the graph of Fig. 5 and Fig. 6, it would seem that significant radiation values pass through the examined tissue at wavelengths around 800 nm.

But in this case, as well as in the previous, the transmitted power increase follow the source light increase, without reduction of absorbed radiation that, for those wavelengths, is almost constant. In this regard see the detail shown in the graph of Fig. 10 and values for that field of wavelengths shown in Table 5. The maximum value of source light it is revealed at 809.000 nm, but for this wavelength the transmission is neither the highest nor the absorption is the minimum.

A summary is shown in Table 7.

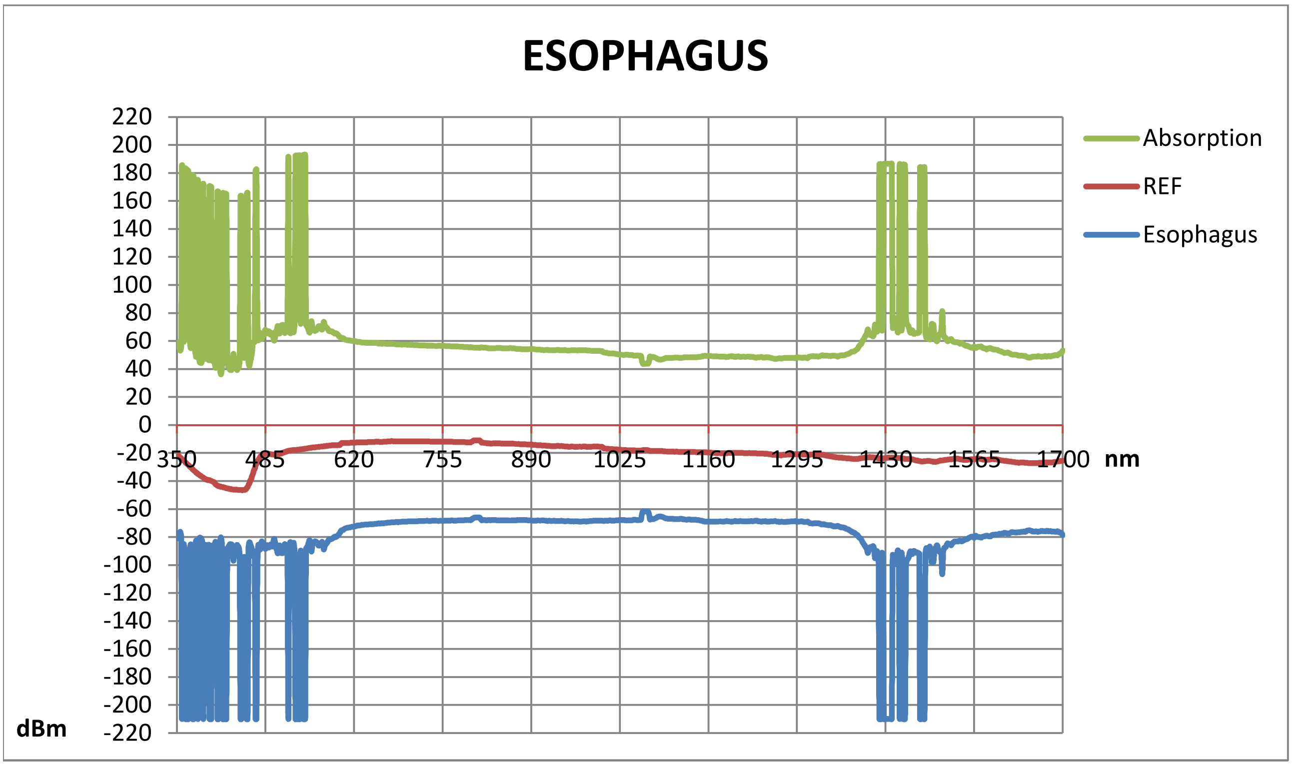

Fig. 5 – Graph of the reference radiation source (REF), the radiation that passes through the tissue (Esophagus) and absorption (Absorption) in sprague dawley rat esophagus.

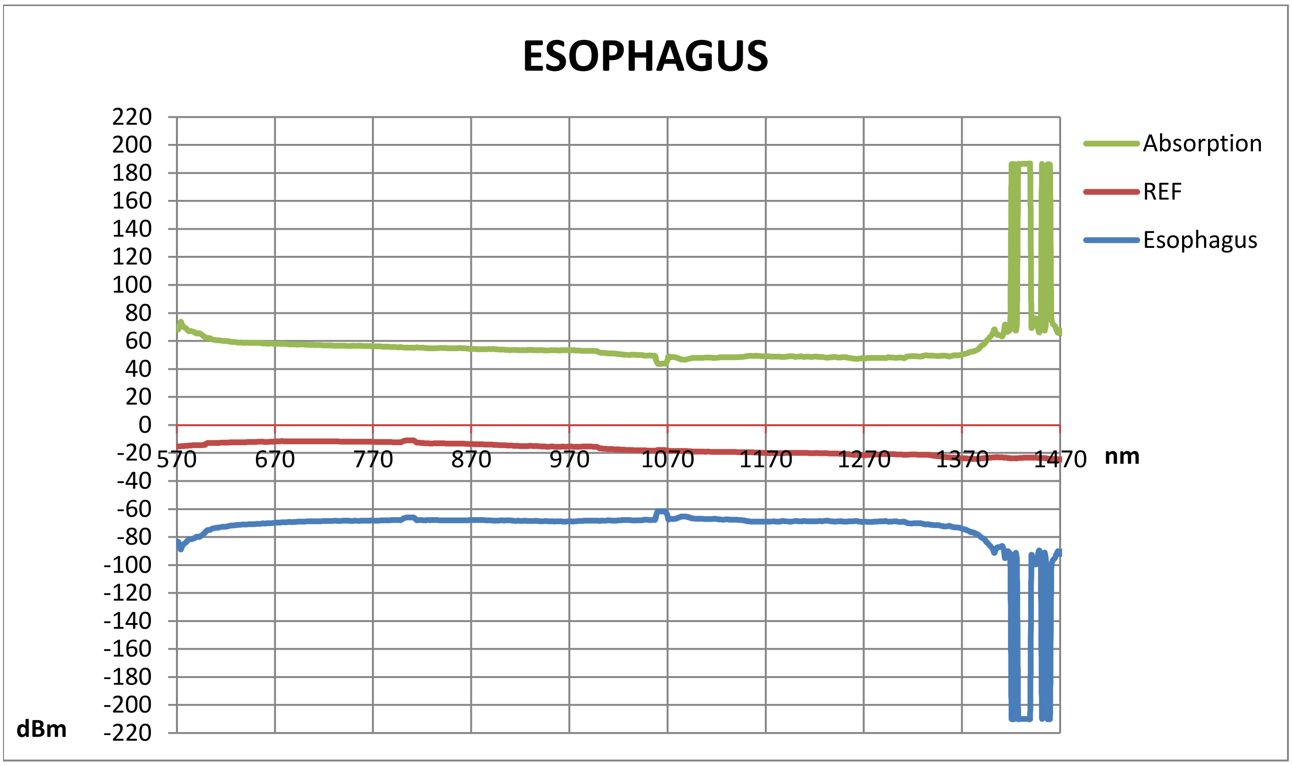

Fig. 6 – Graph of the reference radiation source (REF), the radiation that passes through the tissue (Esophagus) and absorption (Absorption) in sprague dawley rat esophagus for wavelengths from 570 nm till 1470 nm.

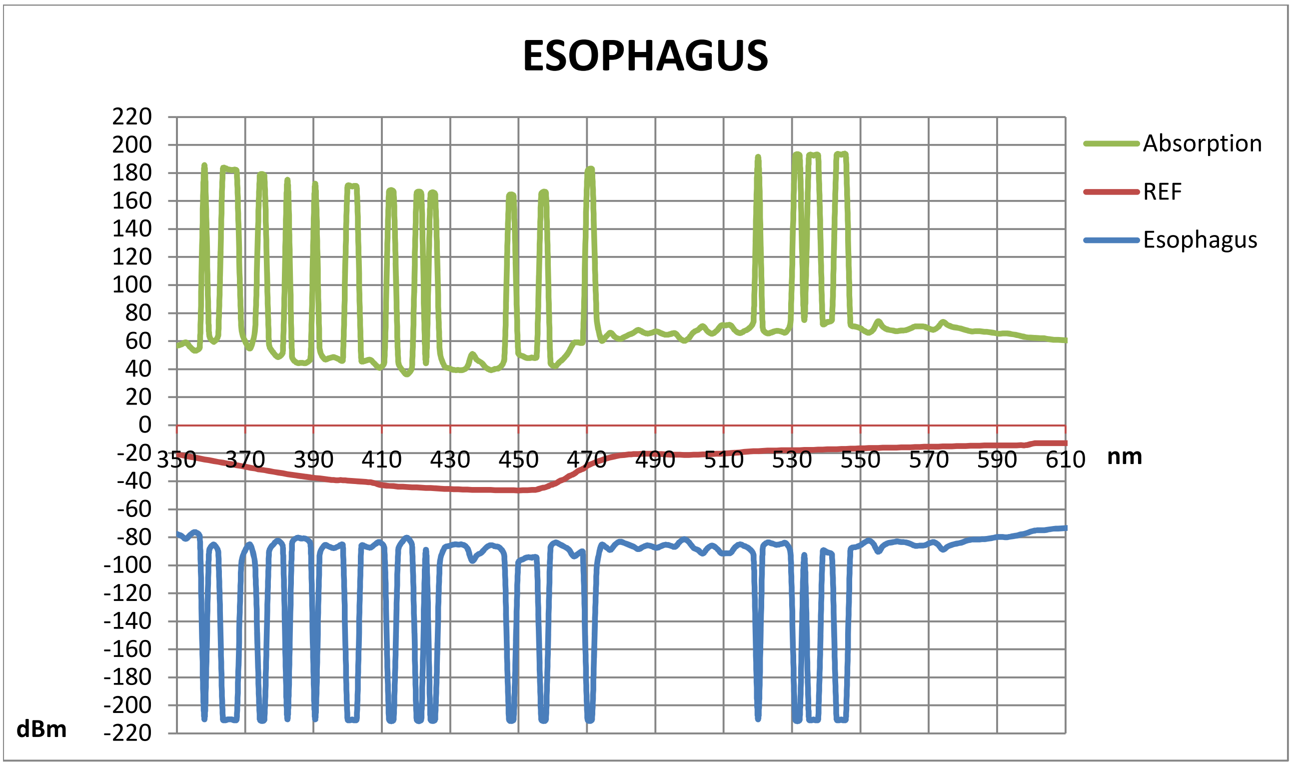

Fig. 7 – Graph of the reference radiation source (REF), the radiation that passes through the tissue (Esophagus) and absorption (Absorption) in sprague dawley rat esophagus for wavelengths from 350 nm till 610 nm.

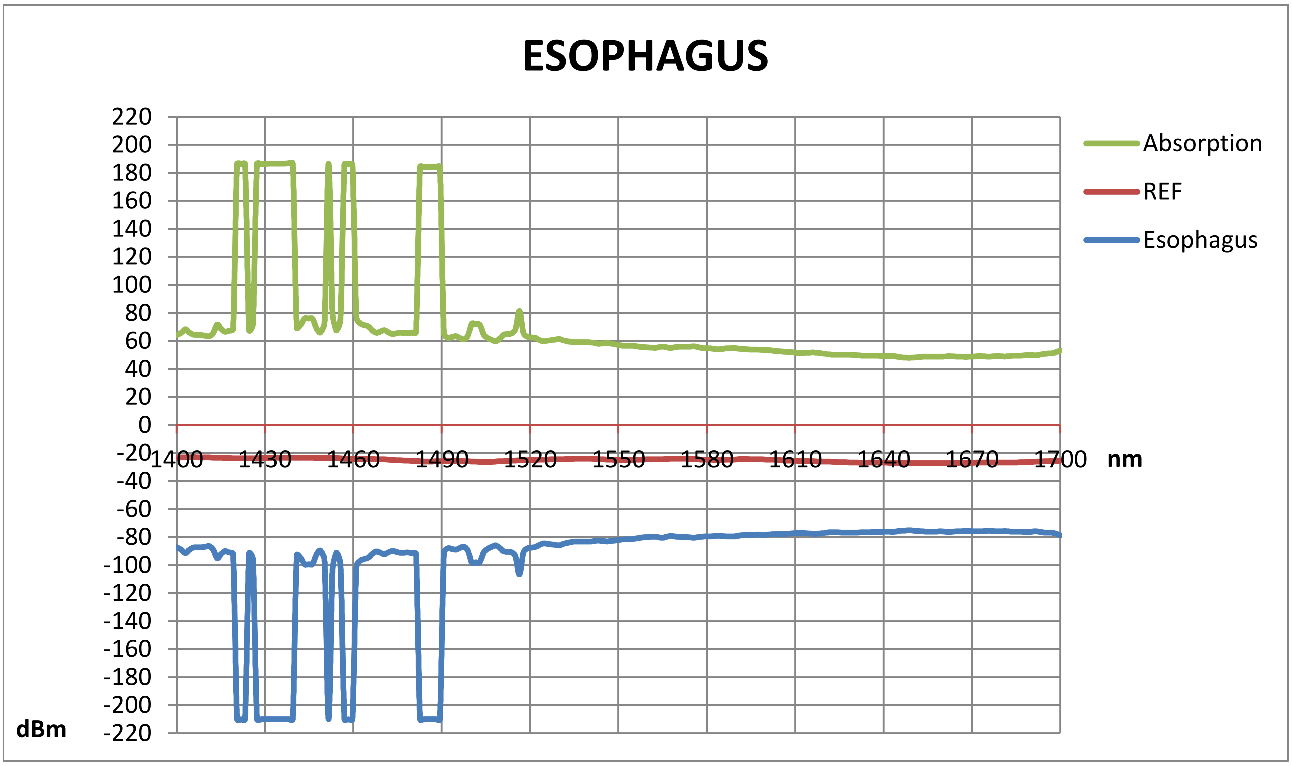

Fig. 8 – Graph of the reference radiation source (REF), the radiation that passes through the tissue (Esophagus) and absorption (Absorption) in sprague dawley rat esophagus for wavelengths from 1400 nm till 1700 nm.

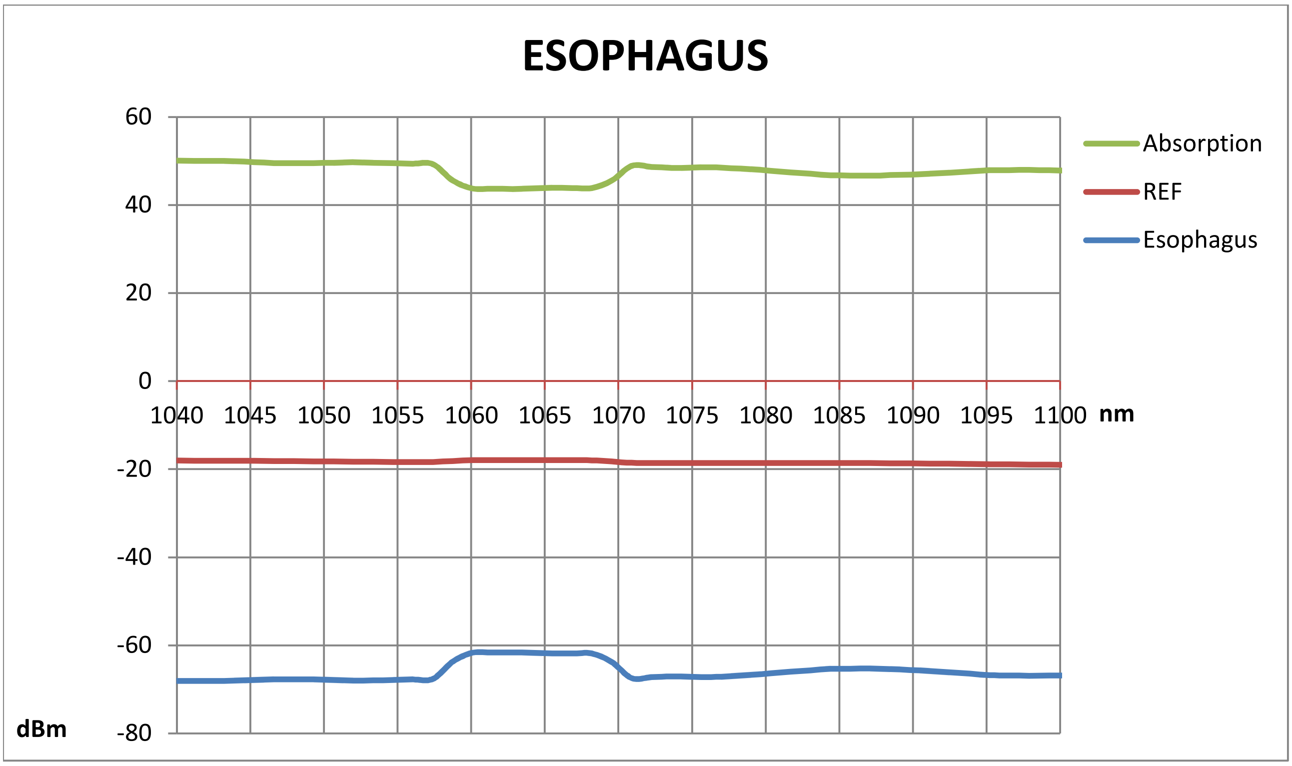

Fig. 9 – Graph of the reference radiation source (REF), the radiation that passes through the tissue (Esophagus) and absorption (Absorption) in sprague dawley rat esophagus for wavelengths from 1040 nm till 1100 nm.

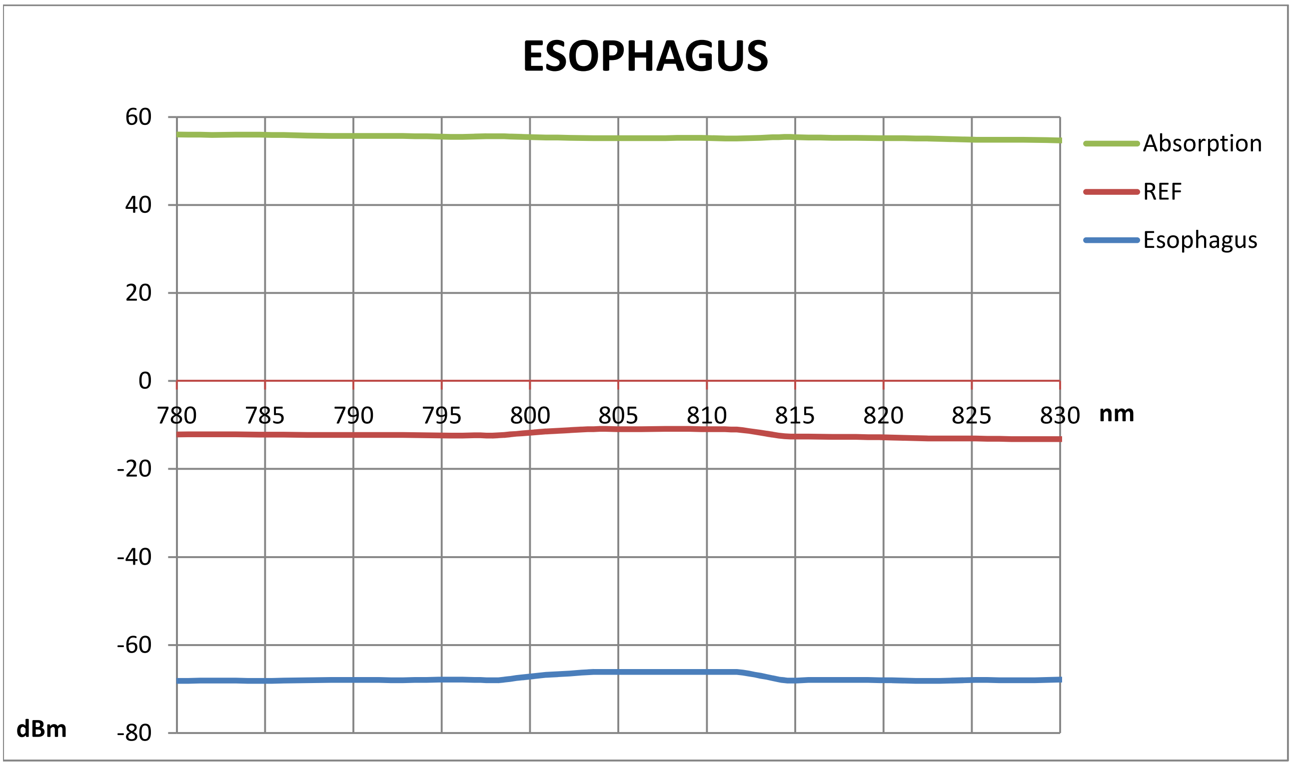

Fig. 10 – Graph of the reference radiation source (REF), the radiation that passes through the tissue (Esophagus) and absorption (Absorption) in sprague dawley rat esophagus for wavelengths from 780 nm till 830 nm.

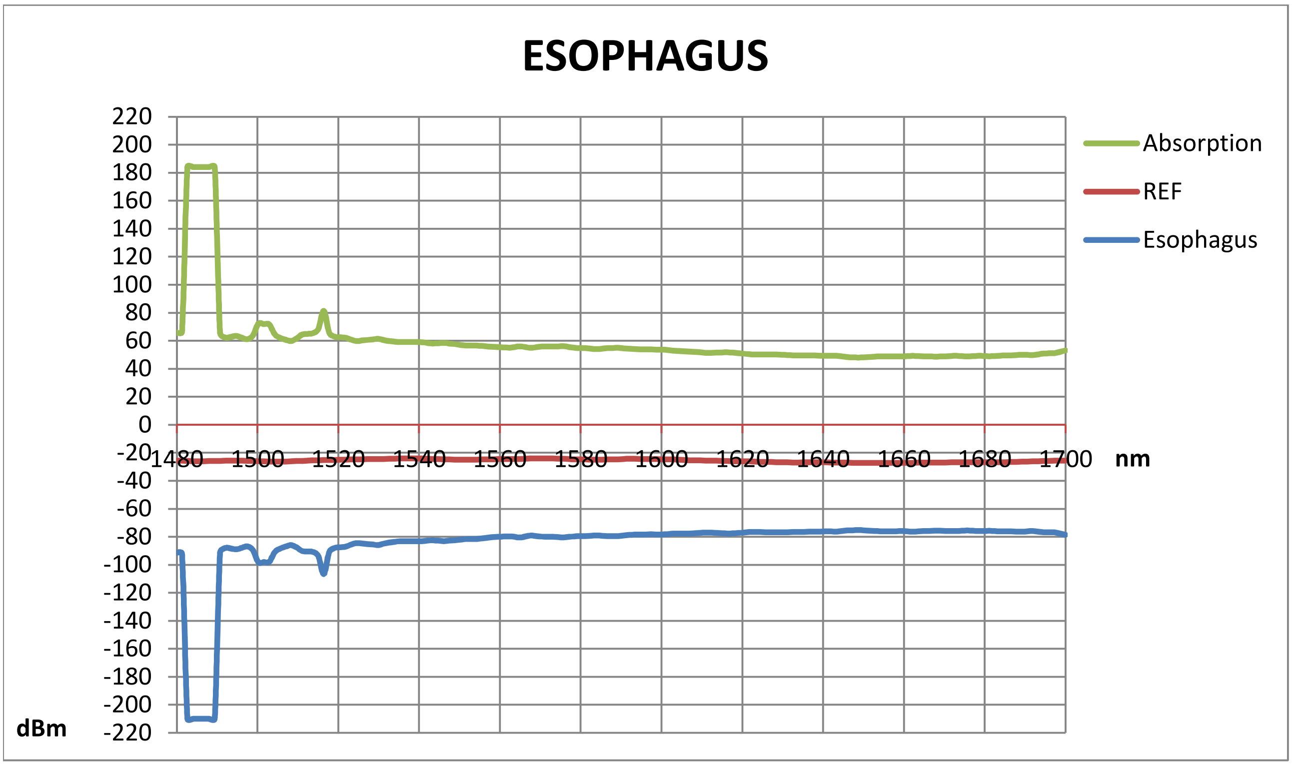

Fig. 11 – Graph of the reference radiation source (REF), the radiation that passes through the tissue (Esophagus) and absorption (Absorption) in sprague dawley rat esophagus for wavelengths from 1480 nm till 1700 nm.

Wavelength (nm)	Esophagus Measure (dBm)	Wavelength (nm)	Esophagus Measure (dBm)
547.100	**-88.749**	568.700	**-85.793**
548.450	**-87.132**	570.050	**-84.442**
549.800	**-85.957**	571.400	**-83.412**
551.150	**-83.775**	572.750	**-85.332**
552.500	**-82.329**	574.100	**-88.859**
553.850	**-84.706**	575.450	**-86.735**
555.200	**-90.366**	576.800	**-85.315**
556.550	**-86.370**	578.150	**-84.527**
557.900	**-84.325**	579.500	**-83.860**
559.250	**-83.639**	580.850	**-82.692**
560.600	**-83.046**	582.200	**-81.773**
561.950	**-83.330**	583.550	**-81.665**
563.300	**-83.634**	584.900	**-81.560**
564.650	**-84.700**	586.250	**-81.260**
566.000	**-86.116**	587.600	**-80.980**
567.350	**-85.952**	588.950	**-80.347**

Table 1 - Values of measured light from spectrum analyzer in sprague dawley rat esophagus at wavelengths from 547.100 nm till 588.950 nm. The values lower than -80 dBm are in red. For the reasons illustrated in this chapter it is believed that the light is completely absorbed at these wavelengths.

Wavelength (nm)	Esophagus Measure (dBm)	Wavelength (nm)	Esophagus Measure (dBm)
1389.500	**-80.313**	1405.700	**-87.498**
1390.850	**-80.764**	1407.050	**-87.350**
1392.200	**-81.268**	1408.400	**-87.207**
1393.550	**-82.258**	1409.750	**-86.846**
1394.900	**-83.544**	1411.100	**-86.512**
1396.250	**-84.460**	1412.450	**-88.961**
1397.600	**-85.621**	1413.800	**-95.109**
1398.950	**-86.501**	1415.150	**-91.863**
1400.300	**-87.606**	1416.500	**-90.026**
1401.650	**-89.101**	1417.850	**-91.012**
1403.000	**-91.402**	1419.200	**-92.289**
1404.350	**-89.025**		

Table 2 - Values of measured light from spectrum analyzer in sprague dawley rat esophagus at wavelengths from 1389.500 nm till 1419.200 nm. The values lower than -80 dBm are in red. For the reasons illustrated in this chapter it is believed that the light is completely absorbed at these wavelengths.

Wavelength (nm)	Esophagus Measure (dBm)	Wavelength (nm)	Esophagus Measure (dBm)
1490.750	**-91.137**	1535.300	**-83.077**
1492.100	**-87.965**	1536.650	**-83.142**
1493.450	**-88.425**	1538.000	**-83.207**
1494.800	**-88.939**	1539.350	**-83.153**
1496.150	**-87.774**	1540.700	**-83.099**
1497.500	**-86.857**	1542.050	**-82.792**
1498.850	**-89.555**	1543.400	**-82.506**
1500.200	**-98.127**	1544.750	**-82.813**

1501.550	**-98.030**	1546.100	**-83.144**
1502.900	**-97.935**	1547.450	**-82.807**
1504.250	**-90.955**	1548.800	**-82.494**
1505.600	**-88.403**	1550.150	**-82.071**
1506.950	**-86.998**	1551.500	**-81.685**
1508.300	**-85.939**	1552.850	**-81.585**
1509.650	**-87.544**	1554.200	**-81.488**
1511.000	**-90.118**	1555.550	**-81.063**
1512.350	**-90.455**	1556.900	**-80.677**
1513.700	**-90.820**	1558.250	**-80.301**
1515.050	**-93.718**	1559.600	-79.955
1516.400	**-106.618**	1560.950	-79.807
1517.750	**-90.936**	1562.300	-79.664
1519.100	**-87.985**	1563.650	**-80.076**
1520.450	**-87.512**	1565.000	**-80.532**
1521.800	**-87.086**	1566.350	-79.741
1523.150	**-85.590**	1567.700	-79.072
1524.500	**-84.480**	1569.050	-79.447
1525.850	**-84.805**	1570.400	-79.858
1527.200	**-85.157**	1571.750	-79.951
1528.550	**-85.512**	1573.100	**-80.047**
1529.900	**-85.899**	1574.450	**-80.225**
1531.250	**-84.901**	1575.800	**-80.410**
1532.600	**-84.090**	1577.150	**-80.041**
1533.950	**-83.554**		

Table 3 - Values of measured light from spectrum analyzer in sprague dawley rat esophagus at wavelengths from 1490.750 nm till 1577.150 nm. The values lower than -80 dBm are in red. For the reasons illustrated in this chapter it is believed that the light is completely absorbed at these wavelengths.

Wavelength (nm)		Esophagus Measure (dBm)	Esophagus Absorption (dB)
from	till		
350.000	545.750	spikes < -80	full absorption
547.100	588.950	values < -80	full absorption
590.300	1388.150	values > -80	valid values
1389.500	1419.200	values < -80	full absorption
1420.550	1489.400	spikes < -80	full absorption
1490.750	1577.150	values < -80	full absorption
1578.500	1700.000	values > -80	valid values

Table 4 - Summary of wavelengths where light is completely absorbed in sprague dawley rat esophagus. Values lower than -80 dBm are deemed too small because they are not read by the spectrum analyzer. So those wavelengths light are considered completely absorbed.

Wavelength (nm)	REF (dBm)	Esophagus Measure (dBm)	Esophagus Absorption (dB)
798.200	-12.350	-67.981	55.631
799.550	-11.882	-67.348	55.466
800.900	-11.459	-66.795	55.336
802.250	-11.187	-66.451	55.264
803.600	-10.931	-66.132	55.201
804.950	-10.930	-66.107	55.177
806.300	-10.929	-66.082	55.153
807.650	-10.913	-66.114	55.201
809.000	**-10.897**	-66.146	55.249
810.350	-10.977	-66.147	55.170
811.700	-11.058	-66.147	55.089
813.050	-11.737	-66.975	55.238
814.400	-12.543	-67.999	55.456
815.750	-12.615	-67.963	55.348

Table 5 - The table shows that the value of absorption in sprague dawley rat esophagus remains almost constant for wavelength from 798.200 nm till 815.750 nm. At 809.000 nm the value of source is maximum (in red), but despite this absorption is almost constant.

Wavelength (nm)	REF (dBm)	Esophagus Measure (dBm)	Esophagus Absorption (dB)
1045.250	-18.102	-67.855	49.753
1046.600	-18.139	-67.679	49.540
1047.950	-18.178	-67.709	49.531
1049.300	-18.217	-67.739	49.522
1050.650	-18.250	-67.864	49.614
1052.000	-18.284	-67.993	49.709
1053.350	-18.324	-67.934	49.610
1054.700	-18.364	-67.875	49.511
1056.050	-18.349	-67.743	49.394
1057.400	-18.334	-67.615	49.281
1058.750	-18.123	-63.695	45.572
1060.100	-17.921	-61.669	43.748
1061.450	-17.932	-61.631	43.699
1062.800	-17.942	-61.594	43.652
1064.150	-17.941	-61.704	43.763
1065.500	-17.939	-61.816	43.877
1066.850	-17.964	-61.835	43.871
1068.200	-17.988	**-61.855**	43.867
1069.550	-18.255	-63.803	45.548
1070.900	-18.540	-67.430	48.890
1072.250	-18.565	-67.223	48.658
1073.600	-18.590	-67.026	48.436
1074.950	-18.604	-67.110	48.506
1076.300	-18.618	-67.197	48.579
1077.650	-18.597	-66.957	48.360

Table 6 - Values of radiation passing through and of radiation absorbed in sprague dawley rat esophagus in relation to radiation emitted at wavelengths from 1045.250 nm till 1077.650 nm. The maximum light value passing through the tissue is in red.

Wavelength (nm)		dBm or dB	Light
809.000		-10.897 dBm	maximum value of light source
1068.200		43.867 dB	minimum absorption
1068.200		-61.855 dBm	maximum transmission
449.900		-46.547 dBm	minimum value of light source
from	till		
350.000	545.750	spikes < -80	full absorption
547.100	588.950	values < -80	full absorption
590.300	1388.150	values > -80	valid values
1389.500	1419.200	values < -80	full absorption
1420.550	1489.400	spikes < -80	full absorption
1490.750	1577.150	values < -80	full absorption
1578.500	1700.000	values > -80	valid values

Table 7 – Summary table.

6 Stomach

It is used sprague dawley rat stomach (cardias) emptied of its content (Fig. 1). It has a thickness of 0.8 mm and is positioned between the smaller plates, with the central hole having a diameter of 1.5 mm in order to cover the entire hole (Fig. 2). The source emits light with the values and the sequence already described (Fig. 3).

Fig. 1 – End sprague dawley rat esophagus and stomach vision immediately after the sample taking.

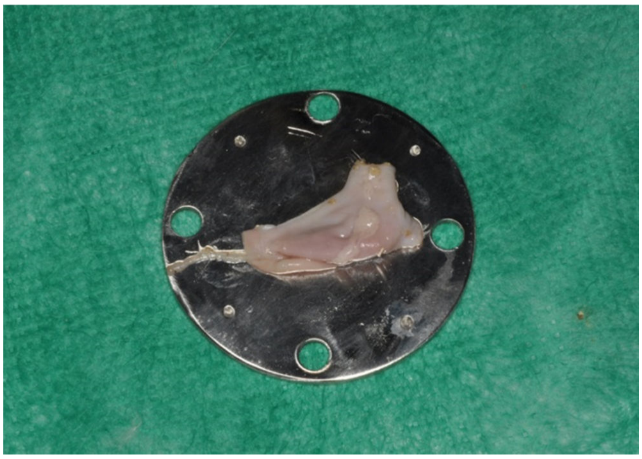

Fig. 2 – Sprague dawley rat stomach vision positioned on the plate.

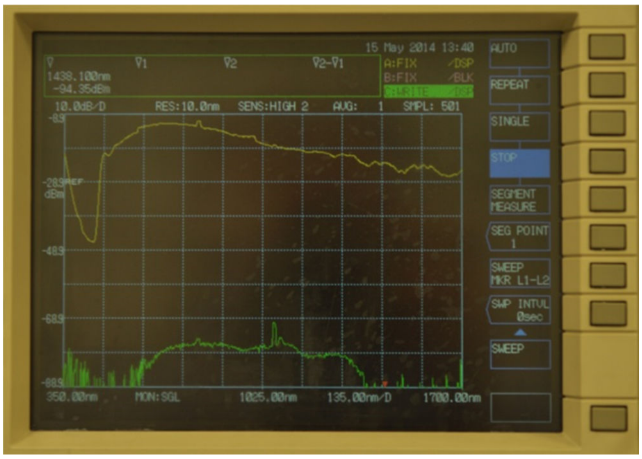

Fig. 3 – Graph of measurements taken on sprague dawley rat stomach shown by Spectrum Analyzer display.

The values of the light, which crosses the tissue (Stomach), are represented in Fig. 4, along with the values of light emitted freely through the air without anything interposed (reference or calibration path, REF).

In the same figure you see also the graph of stomach light absorption (Absorption). Its value is the difference between the emitted light and the passing light through the tissue (transmitted).

Also in this case (Fig. 4) you see that the values from 350.000 nm till 591.650 nm included (Fig. 6), and from 1389.500 nm till 1700.000 nm included (Fig. 7), the passing light values in the tissue are very variable. They may look like light absence spikes (-210.000 dBm) followed by partially absorbed light whose value is less than or close to -80 dBm. Again, for the reasons already stated they represent the wavelengths at which radiation is completely absorbed. A vision of the same wavelengths range (Fig. 6), using a more detailed scale, would seem to show that the light pass in the tissue at wavelengths higher than 591.650 nm. Instead the values analysis shows that from 593.000 nm to 667.250 nm included, the passing radiation measurement through the stomach still has a power level less than -80 dBm (Table 1).

So also for these range it can be considered that the radiation is completely absorbed by the stomach.

From the wavelength of 668.600 nm till 1176.200 nm included, the passing light values are greater than -80 dBm. Hence, being the values reliable, we can say that in this wavelengths portion, the light can effectively pass through the stomach (Fig. 4, Fig. 5).

The second group of spikes begins at 1389.500 nm and lasts till 1700.000 nm (Fig. 4, Fig. 7). In this range the light is completely absorbed in the stomach. However, also in this case, the numbers analysis shows that the passing radiation values begin to be less than -80 dBm already at wavelength of 1177.550 nm till 1388.150 nm (Fig. 4, Fig. 5, Fig. 8) and all, or almost all, the passing radiation values through the stomach are below -80 dBm. In this study -80 dBm is considered as lower limit for reliable power values. Most of the power values in this range are much lower than or too close to -80 dBm. So there is no certainty of the measurement reliability within this range of wavelengths and so these values are considered to be invalid and it is assumed that these wavelengths are completely absorbed by tissue. For the reasons already stated, starting from 1177.550 nm to 1388.150 nm, also these radiation values must be discarded and, therefore, in this range of wavelength, the radiation is completely absorbed by the stomach. These values cannot be listed in a table being too numerous and the table size would be too great.

It thus appears that the light effectively passes through the stomach between 668.600 nm and 1176.200 nm (Table 2).

In the figures are represented graphically the instrument reference values (REF), the passing light values through the tissue (Stomach) and absorbed light values by the stomach (Absorption).

On first analysis it can be seen that the light passing through has practically constant value from 668.600 nm till 1057.400 nm (Fig. 4 e Fig. 5). Starting from this latter wavelength (Fig. 9) the passing light amount through the stomach has a significant increase till 1062.800 nm, to which transmission is the highest, then it decreases till the wavelength of 1070.900 nm (Table 4).

Accordingly, in the range of these wavelengths the absorption in the tissue has a drastic decrease. From the wavelength of 1070.900 nm onward, the transmission remains again fairly constant till the wavelength of 1176.200 nm (Fig. 4, Fig. 5). From the wavelength 1177.550 nm till 1388.150 nm, for the reasons already stated, also these radiation values must be discarded and, therefore, in this wavelength range, the radiation is completely absorbed by the stomach.

Also in this case, by examining the graph of Fig. 4, Fig. 5, it would seem that significant radiation values pass through the examined tissue at wavelengths around 800 nm.

But in this case, as well as in the previous, the transmitted power increase follow the source light increase, without reduction of absorbed radiation that, for those wavelengths, is almost constant. In this regard see the detail shown in the graph of Fig. 10 and values for that field of wavelengths shown in Table 3. The maximum value of source light it is revealed at 809.000 nm, but for this wavelength the transmission is neither the highest nor the absorption is the minimum.

A summary is shown in Table 5.

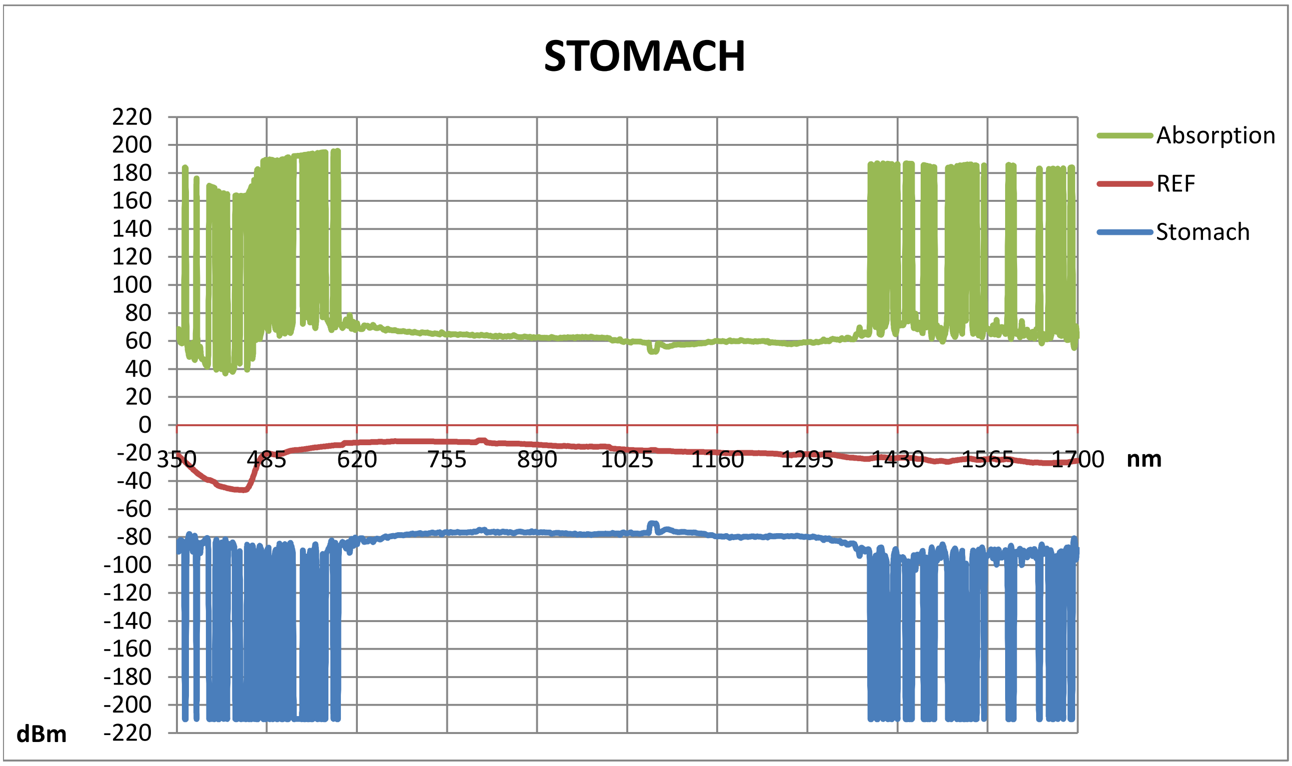

Fig. 4 – Graph of the reference radiation source (REF), the radiation that passes through the tissue (Stomach) and absorption (Absorption) in sprague dawley rat stomach.

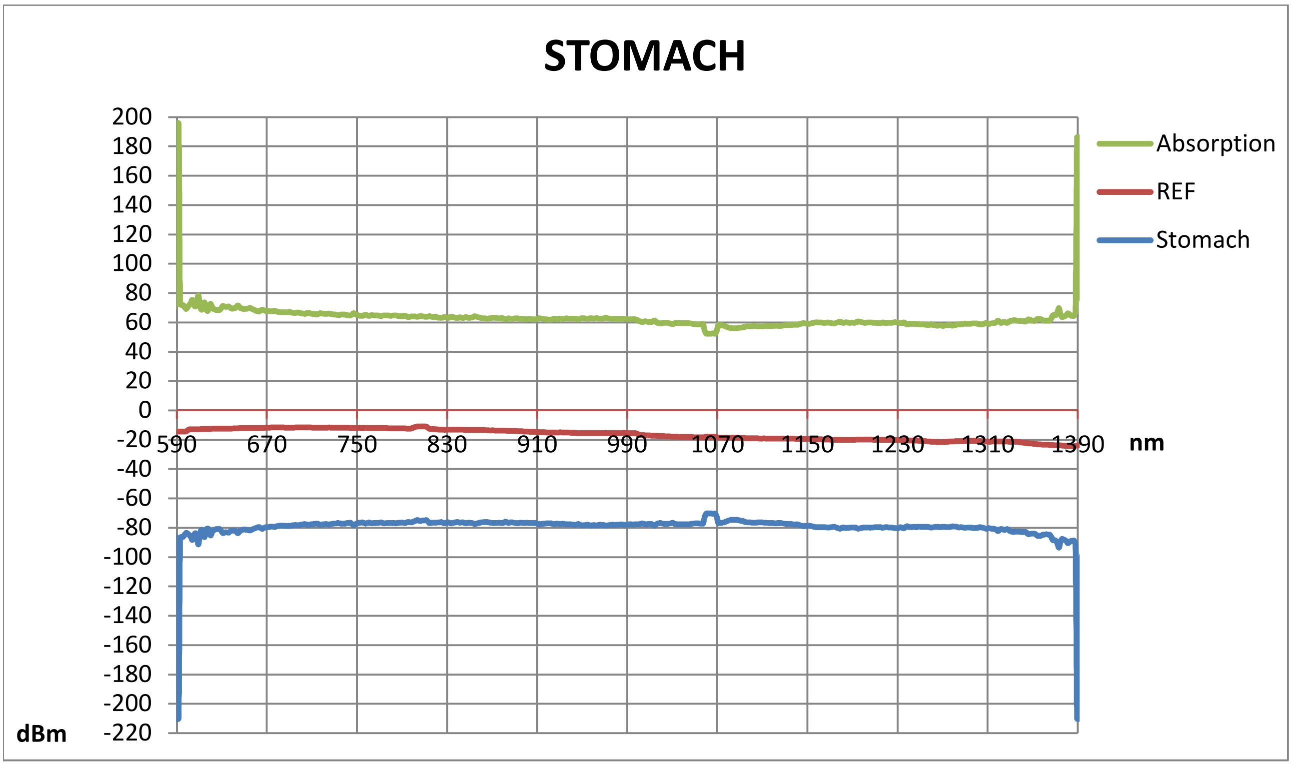

Fig. 5 – Graph of the reference radiation source (REF), the radiation that passes through the tissue (Stomach) and absorption (Absorption) in sprague dawley rat stomach for wavelengths from 590 nm till 1390 nm.

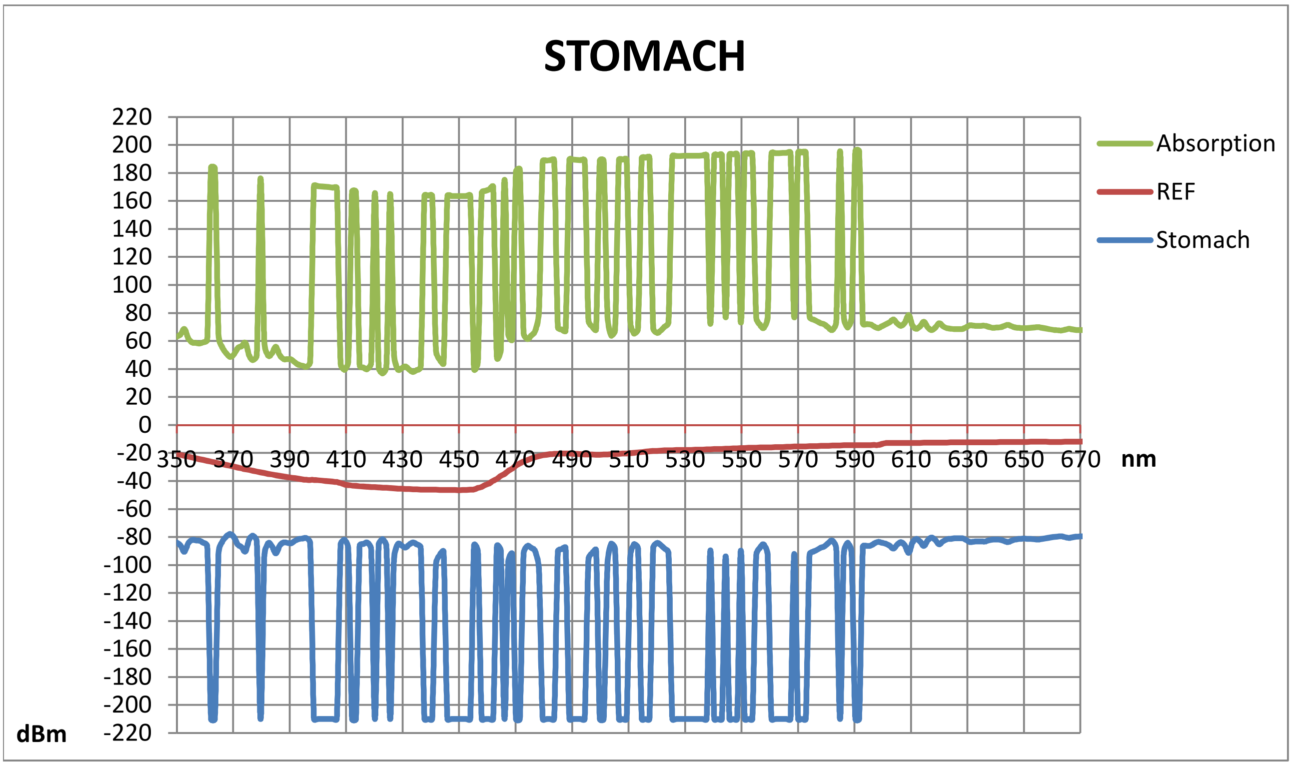

Fig. 6 – Graph of the reference radiation source (REF), the radiation that passes through the tissue (Stomach) and absorption (Absorption) in sprague dawley rat stomach for wavelengths from 350 nm till 670.

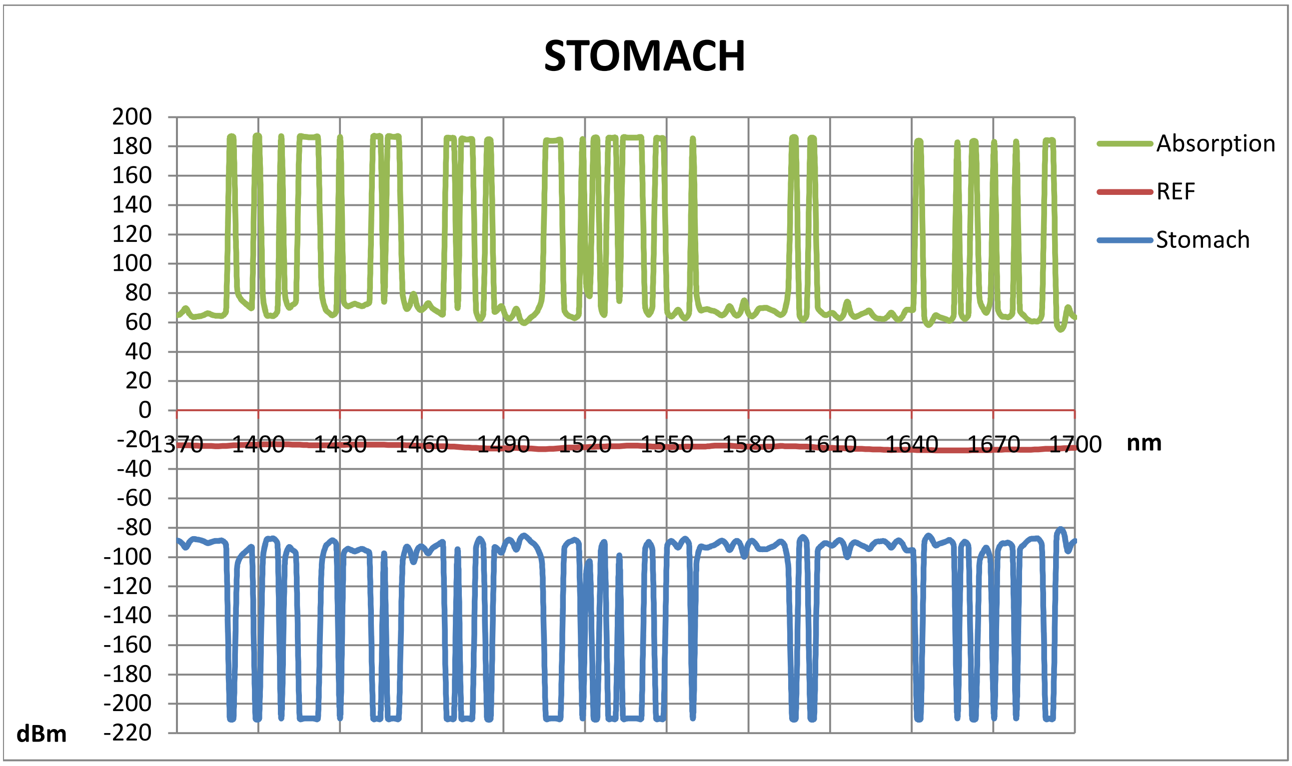

Fig. 7 – Graph of the reference radiation source (REF), the radiation that passes through the tissue (Stomach) and absorption (Absorption) in sprague dawley rat stomach for wavelengths from 1370 nm till 1700 nm.

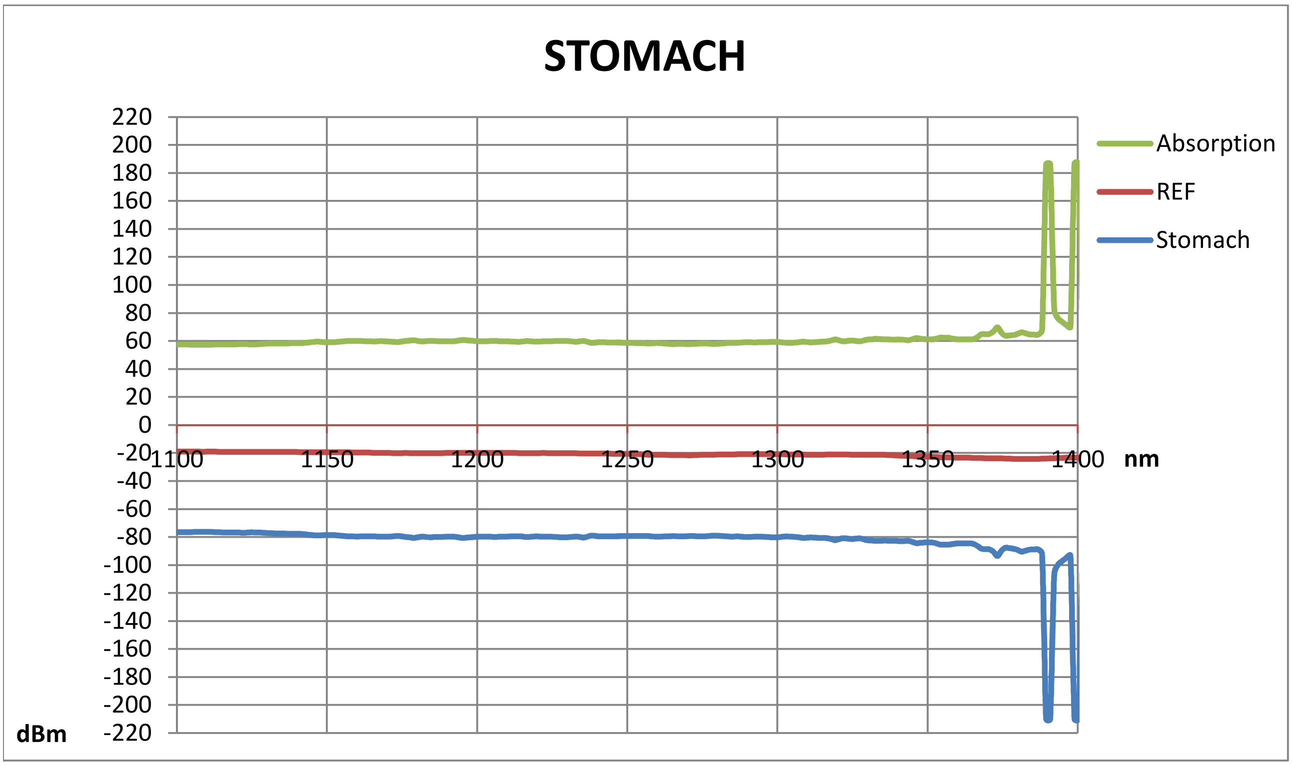

Fig. 8 – Graph of the reference radiation source (REF), the radiation that passes through the tissue (Stomach) and absorption (Absorption) in sprague dawley rat stomach for wavelengths from 1100 nm till 1400 nm.

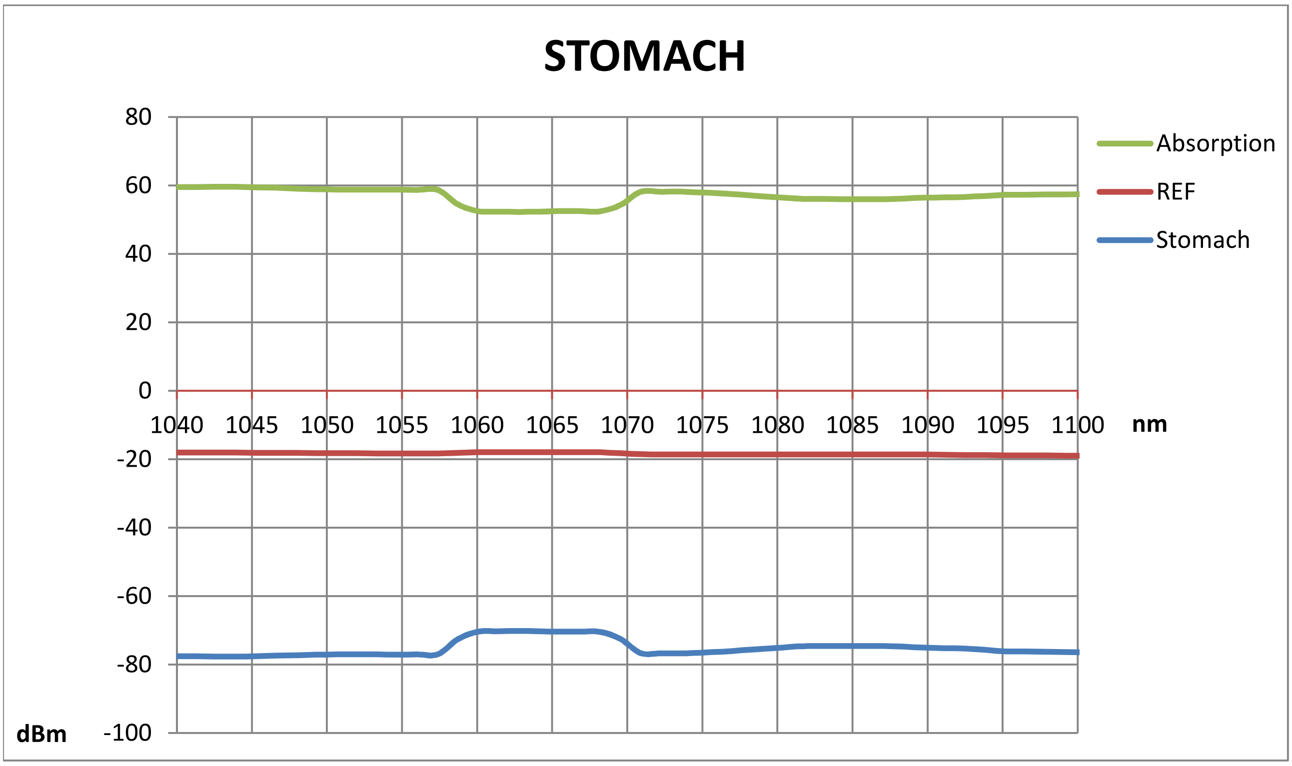

Fig. 9 Graph of the reference radiation source (REF), the radiation that passes through the tissue (Stomach) and absorption (Absorption) in sprague dawley rat stomach for wavelengths from 1040 nm till 1100 nm.

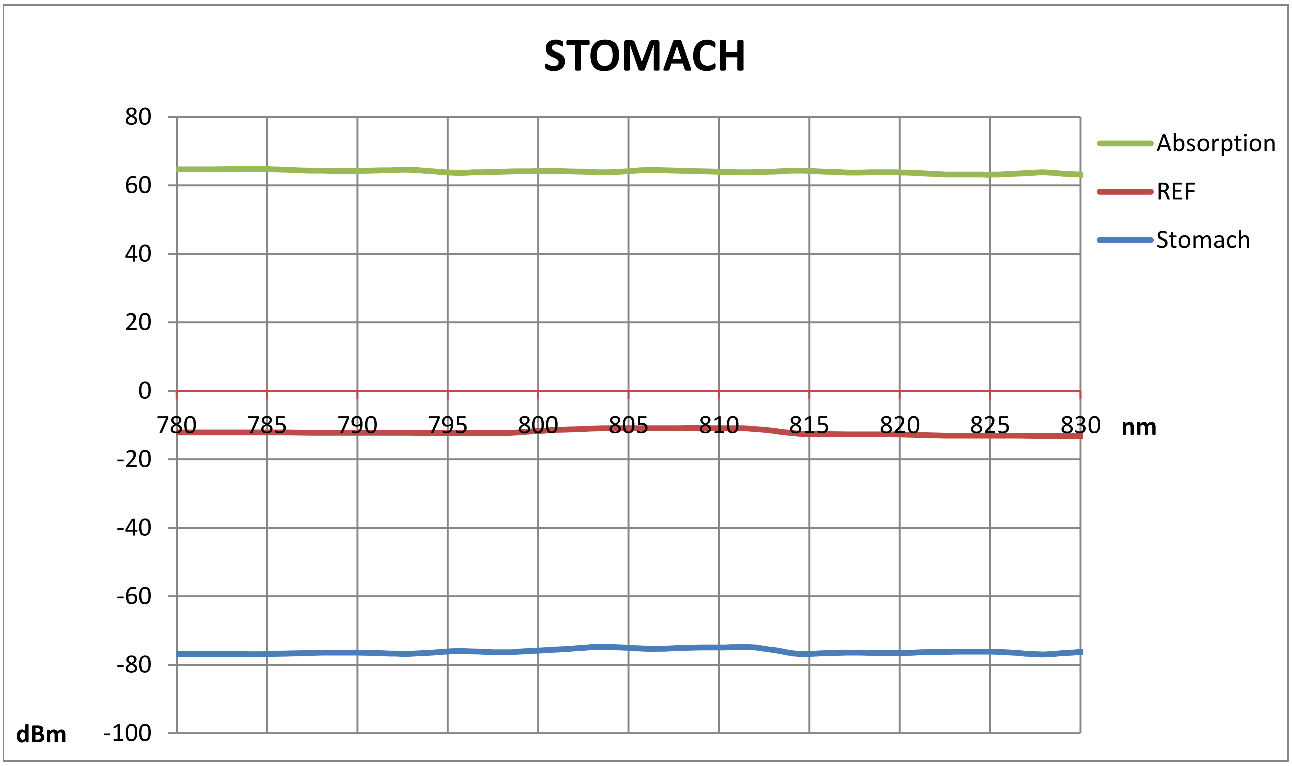

Fig. 10 – Graph of the reference radiation source (REF), the radiation that passes through the tissue (Stomach) and absorption (Absorption) in sprague dawley rat stomach for wavelengths from 780 nm till 830 nm.

Wavelength (nm)	Stomach Measure (dBm)	Wavelength (nm)	Stomach Measure (dBm)
593.000	**-86.776**	630.800	**-83.554**
594.350	**-86.440**	632.150	**-83.321**
595.700	**-86.128**	633.500	**-83.099**
597.050	**-84.613**	634.850	**-83.179**
598.400	**-83.491**	636.200	**-83.261**
599.750	**-84.092**	637.550	**-82.467**
601.100	**-84.789**	638.900	**-81.796**
602.450	**-86.191**	640.250	**-81.882**
603.800	**-88.272**	641.600	**-81.971**
605.150	**-85.407**	642.950	**-82.735**
606.500	**-83.696**	644.300	**-83.663**
607.850	**-86.012**	645.650	**-82.589**
609.200	**-91.307**	647.000	**-81.729**
610.550	**-83.995**	648.350	**-81.451**
611.900	**-81.407**	649.700	**-81.189**
613.250	**-83.222**	651.050	**-81.292**
614.600	**-86.398**	652.400	**-81.396**
615.950	**-82.452**	653.750	**-81.620**
617.300	**-80.419**	655.100	**-81.856**
618.650	**-82.194**	656.450	**-81.356**
620.000	**-85.246**	657.800	**-80.908**
621.350	**-83.129**	659.150	**-80.429**
622.700	**-81.712**	660.500	-79.997
624.050	**-81.278**	661.850	-79.739

625.400	**-80.882**	663.200	-79.496
626.750	**-80.883**	664.550	**-80.050**
628.100	**-80.884**	665.900	**-80.686**
629.450	**-82.017**	667.250	**-80.191**

Table 1 - Values of measured light from spectrum analyzer in sprague dawley rat stomach at wavelengths from 593.000 nm till 667.250 nm. The values lower than -80 dBm are in red. For the reasons illustrated in this chapter it is believed that the light is completely absorbed at these wavelengths.

Wavelength (nm)		Stomach Measure (dBm)	Stomach Absorption (dB)
from	till		
350.000	**591.650**	**spikes < -80**	**full absorption**
593.000	**667.250**	**values < -80**	**full absorption**
668.600	**1176.200**	**values > -80**	**valid values**
1177.550	**1388.150**	**values < -80**	**full absorption**
1389.500	**1700.000**	**spikes < -80**	**full absorption**

Table 2 – Summary of wavelengths where light is completely absorbed in sprague dawley rat stomach. Values lower than -80 dBm are deemed too small because they are not read by the spectrum analyzer. So those wavelengths light are considered completely absorbed.

Wavelength (nm)	REF (dBm)	Stomach Measure (dBm)	Stomach Absorption (dB)
798.200	-12.350	-76.367	64.017
799.550	-11.882	-75.992	64.110
800.900	-11.459	-75.646	64.187
802.250	-11.187	-75.166	63.979
803.600	-10.931	-74.733	63.802
804.950	-10.930	-75.048	64.118
806.300	-10.929	-75.388	64.459
807.650	-10.913	-75.173	64.260
809.000	**-10.897**	-74.969	64.072
810.350	-10.977	-74.909	63.932
811.700	-11.058	-74.851	63.793
813.050	-11.737	-75.725	63.988
814.400	-12.543	-76.819	64.276
815.750	-12.615	-76.623	64.008

Table 3 - The table shows that the value of absorption in sprague dawley rat stomach remains almost constant for wavelength from 798.200 nm till 815.750 nm. At 809.000 nm the value of source is maximum (in red), but despite this absorption is almost constant.

Wavelength (nm)	REF (dBm)	Stomach Measure (dBm)	Stomach Absorption (dB)
1045.250	-18.102	-77.546	59.444
1046.600	-18.139	-77.411	59.272
1047.950	-18.178	-77.247	59.069

1049.300	-18.217	-77.088	58.871
1050.650	-18.250	-77.051	58.801
1052.000	-18.284	-77.014	58.730
1053.350	-18.324	-77.053	58.729
1054.700	-18.364	-77.091	58.727
1056.050	-18.349	-77.045	58.696
1057.400	-18.334	-76.998	58.664
1058.750	-18.123	-72.521	54.398
1060.100	-17.921	-70.364	52.443
1061.450	-17.932	-70.269	52.337
1062.800	-17.942	**-70.176**	52.234
1064.150	-17.941	-70.287	52.346
1065.500	-17.939	-70.401	52.462
1066.850	-17.964	-70.415	52.451
1068.200	-17.988	-70.429	52.441
1069.550	-18.255	-72.512	54.257
1070.900	-18.540	-76.664	58.124
1072.250	-18.565	-76.706	58.141
1073.600	-18.590	-76.749	58.159
1074.950	-18.604	-76.501	57.897
1076.300	-18.618	-76.267	57.649
1077.650	-18.597	-75.813	57.216

Table 4 - Values of radiation passing through and of radiation absorbed in sprague dawley rat stomach in relation to radiation emitted at wavelengths from 1045.250 nm till 1077.650 nm. The maximum light value passing through the tissue is in red.

Wavelength (nm)		dBm or dB	Light
809.000		-10.897 dBm	maximum value of light source
1062.800		52.234 dB	minimum absorption
1062.800		-70.176 dBm	maximum transmission
449.900		-46.547 dBm	minimum value of light source
from	till		
350.000	591.650	spikes < -80	full absorption
593.000	667.250	values < -80	full absorption
668.600	1176.200	values > -80	valid values
1177.550	1388.150	values < -80	full absorption
1389.500	1700.000	spikes < -80	full absorption

Table 5 – Summary table.

7 Kidney

It is used sprague dawley rat kidney. This has a thickness too large (Fig. 1). So the test is performed on the kidney cut in half in the sense of its length (Fig. 2). Now it has a thickness of 2.4 mm. The sample is positioned between the smaller plates, with a central hole having a diameter of 1.5 mm in order to cover the entire hole. The source emits the light with the values and the sequence already described (Fig. 3).

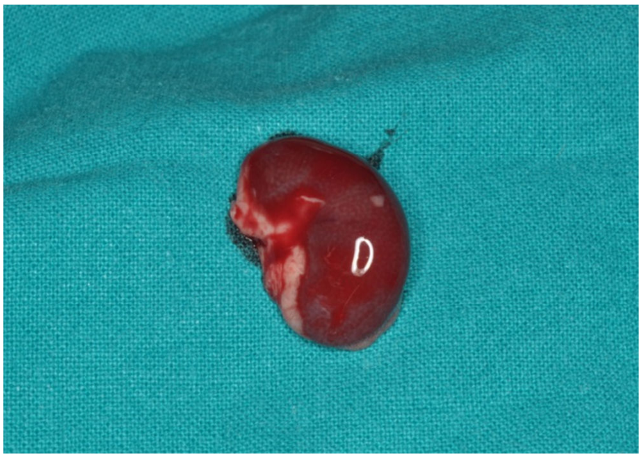

Fig. 1 – Sprague dawley rat kidney vision immediately after the sample taking.

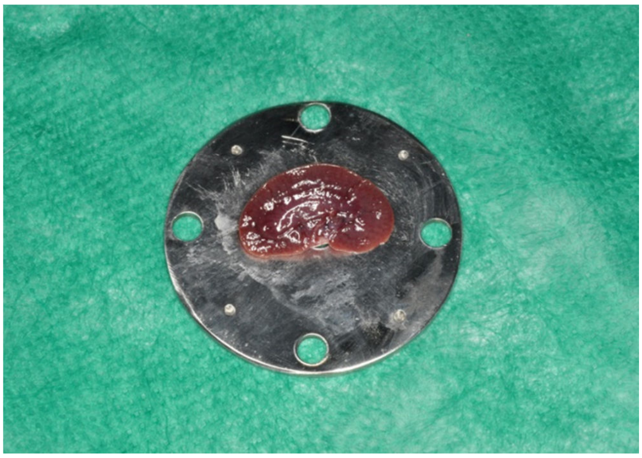

Fig. 2 – Sprague dawley rat kidney vision positioned on the plate.

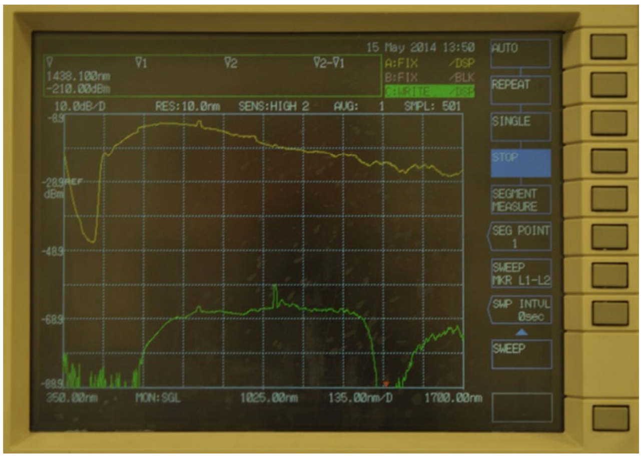

Fig. 3 – Graph of measurements taken on sprague dawley rat kidney shown by Spectrum Analyzer display.

The values of the light, which crosses the tissue (Kidney), are represented in Fig. 4, along with the values of light emitted freely through the air without anything interposed (reference or calibration path, REF).

In the same figure you see also the graph of kidney light absorption (Absorption). Its value is the difference between the emitted light and the passing light through the tissue (transmitted).

Also in this case (Fig. 4) you see that the values from da 350.000 nm till 602.450 nm included (Fig. 6), and from 1420.550 nm till 1478.600 nm included (Fig. 7), the passing light values in the tissue are very variable. They may look like light absence spikes (-210.000 dBm) followed by partially absorbed light whose value is less than or close to -80 dBm. Again, for the reasons already stated they represent the wavelengths at which radiation is completely absorbed. A vision of the same wavelengths range (Fig. 6), using a more detailed scale, would seem to show that the light pass in the tissue at wavelengths higher than 603.800 nm. Instead the values analysis shows that from 603.800 nm till 615.950 nm included, the passing radiation measurement through the kidney still has a power level less than -80 dBm (Table 1).

So also for these range it can be considered that the radiation is completely absorbed by the kidney.

From the wavelength of 617.300 nm till 1394.900 included, the passing light values are greater than -80 dBm. Hence, being the values reliable, we can say that in this wavelengths portion, the light can effectively pass through the kidney (Fig. 4, Fig. 5).

The second group of spikes begins at 1420.550 nm and lasts till 1478.600 nm (Fig. 4, Fig. 7). In this range the light is completely absorbed in the kidney. However, also in this case, the numbers analysis shows that the passing radiation values begin to be less than -80 dBm already at wavelength of 1396.250 nm till 1419.200 nm (Fig. 7, Table 2) after which, at 1420.550 nm, the already mentioned spikes start (Fig. 7). For the reasons already stated, starting from 1396.250 nm till 1419.200 nm also these radiation values must be discarded and, therefore, in this range of wavelength, the radiation is completely absorbed by the kidney (Table 2).

The spikes terminate at the wavelength of 1478.600 nm (Fig. 7), but all passing light values from 1479.950 nm till 1524.500 nm included are not reliable because below -80 dBm (Fig. 10). For the reasons already stated the transmitted light values in this wavelength range are discarded. Therefore all the radiations between wavelength 1479.950 nm till 1524.500 nm are completely absorbed by the kidney (Table 3).

From the wavelength of 1525.850 nm till 1700 nm included, the passing light values are again greater than -80 dBm (Fig. 10). So we can say that in this area of wavelengths the light can pass through the kidney.

It thus appears that the light effectively passes through the kidney between 617.300 nm and 1394.900 nm and from 1525.850 nm till 1700 nm (Table 4).

In the figures are represented graphically the instrument reference values (REF), the passing light values through the tissue (Kidney) and absorbed light values by the kidney (Absorption).

On first analysis it can be seen that the passing light through the tissue increase progressively from 617.300 nm till 1057.400 nm (Fig. 4, Fig. 5). Starting from this latter wavelength (Fig. 8) the passing light amount through the kidney has a significant increase till 1060.100 nm, at which transmission is the highest, then it decreases till the wavelength of 1070.900 nm (Table 6).

Accordingly, in the range of these wavelengths the absorption in the tissue has a drastic decrease. From the wavelength of 1070.900 nm onward, the transmission remains again fairly constant till the wavelength of 1394.900 nm (Fig. 5) and then at 1396.250 nm it decreases under the -80 dBm (Table 2) till 1420.550 nm when the absorbed light spikes start (Fig. 7).

Also in this case, by examining the graph of Fig. 4 e Fig. 5, it would seem that significant radiation values pass through the examined tissue at wavelengths around 800 nm.

But in this case, as well as in the previous, the transmitted power increase follow the source light increase, without reduction of absorbed radiation that, for those wavelengths, is almost constant. In this regard see the detail shown in the graph of Fig. 9 and values for that field of wavelengths shown in Table 5. The maximum value of source light it is revealed at 809.000 nm, but for this wavelength the transmission is neither the highest nor the absorption is the minimum.

A summary is shown in Table 7.

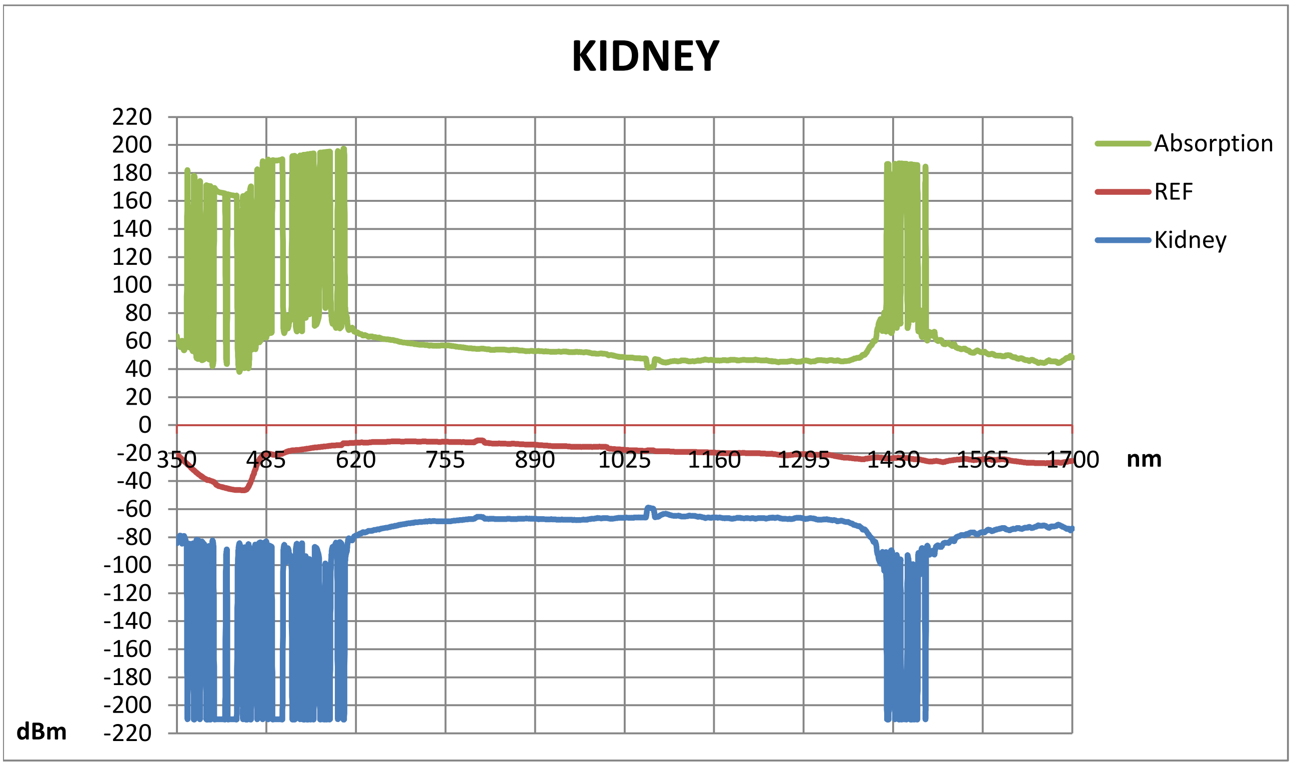

Fig. 4 – Graph of the reference radiation source (REF), the radiation that passes through the tissue (Kidney) and absorption (Absorption) in sprague dawley rat kidney.

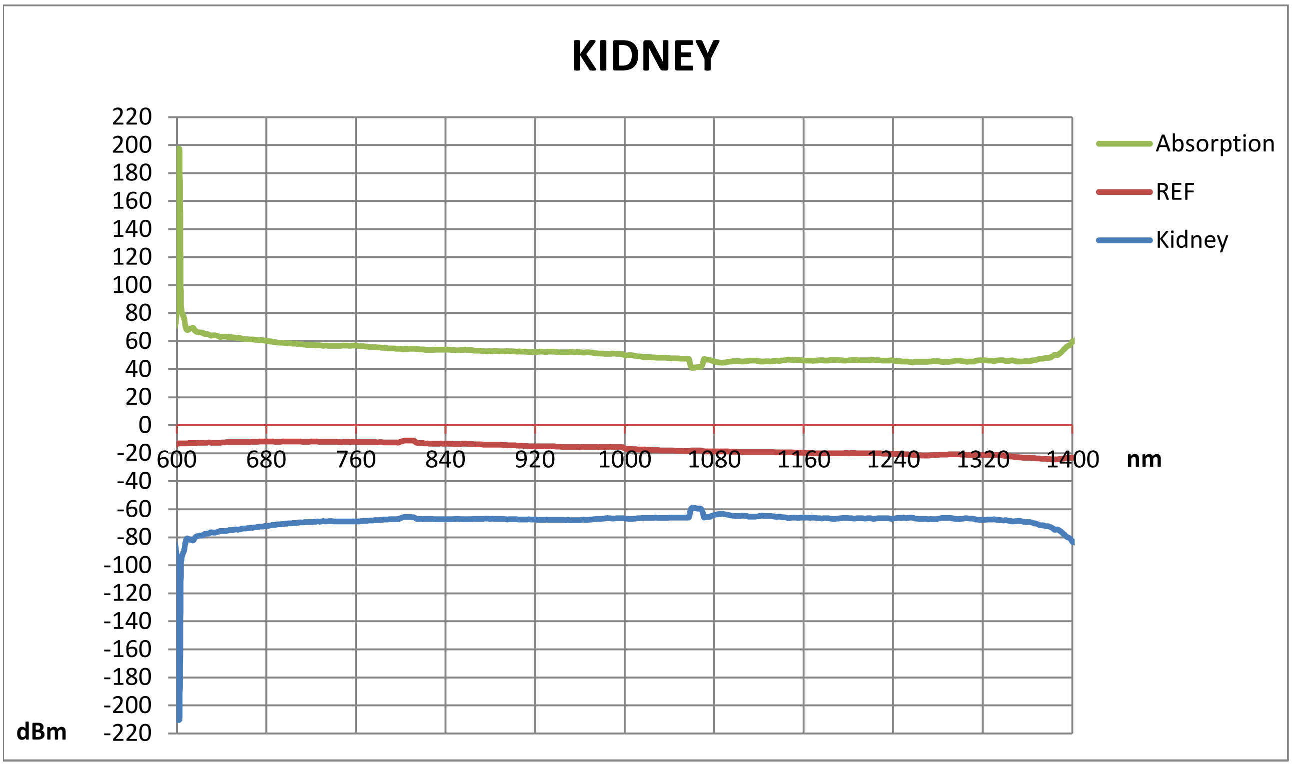

Fig. 5 – Graph of the reference radiation source (REF), the radiation that passes through the tissue (Kidney) and absorption (Absorption) in sprague dawley rat kidney for wavelengths from 600 nm till 1400 nm.

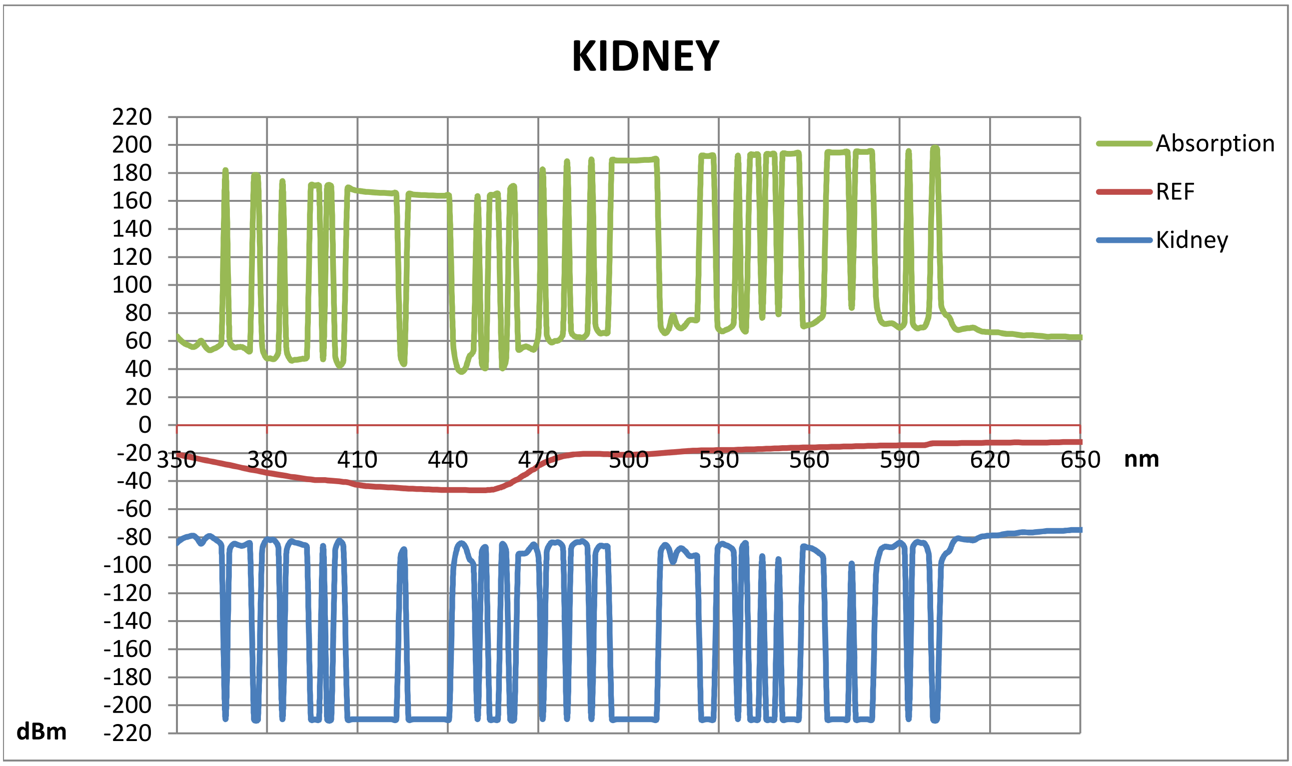

Fig. 6 – Graph of the reference radiation source (REF), the radiation that passes through the tissue (Kidney) and absorption (Absorption) in sprague dawley rat kidney for wavelengths from 350 nm till 650 nm.

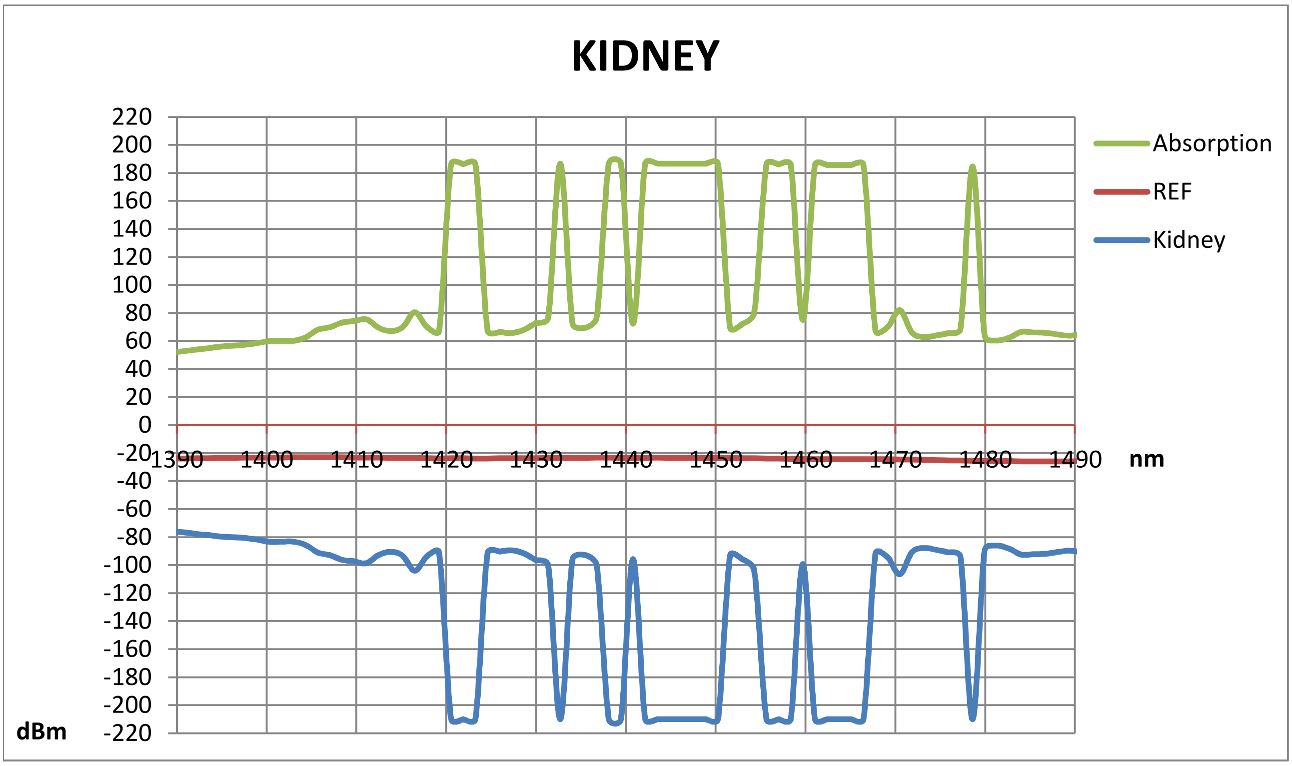

Fig. 7 – Graph of the reference radiation source (REF), the radiation that passes through the tissue (Kidney) and absorption (Absorption) in sprague dawley rat kidney for wavelengths from 1390 nm till 1490 nm.

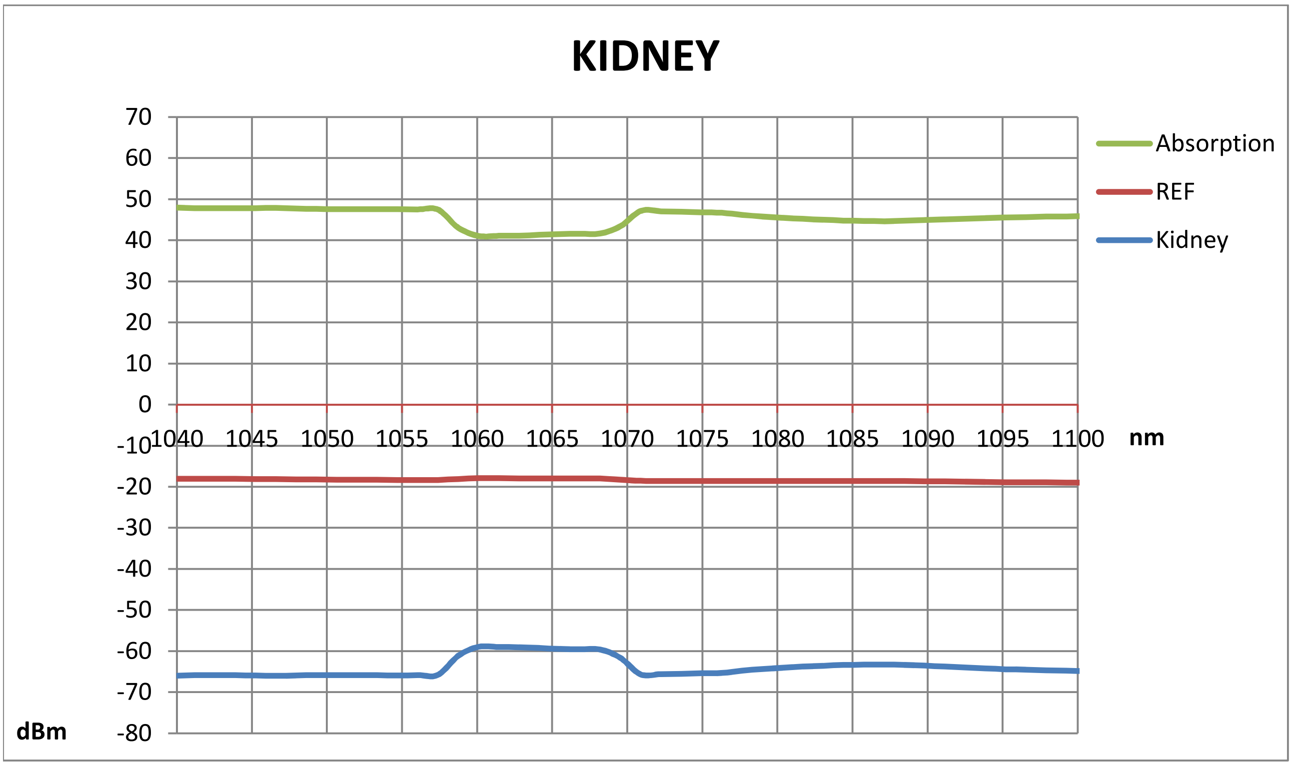

Fig. 8 – Graph of the reference radiation source (REF), the radiation that passes through the tissue (Kidney) and absorption (Absorption) in sprague dawley rat kidney for wavelengths from 1040 nm till 1100 nm.

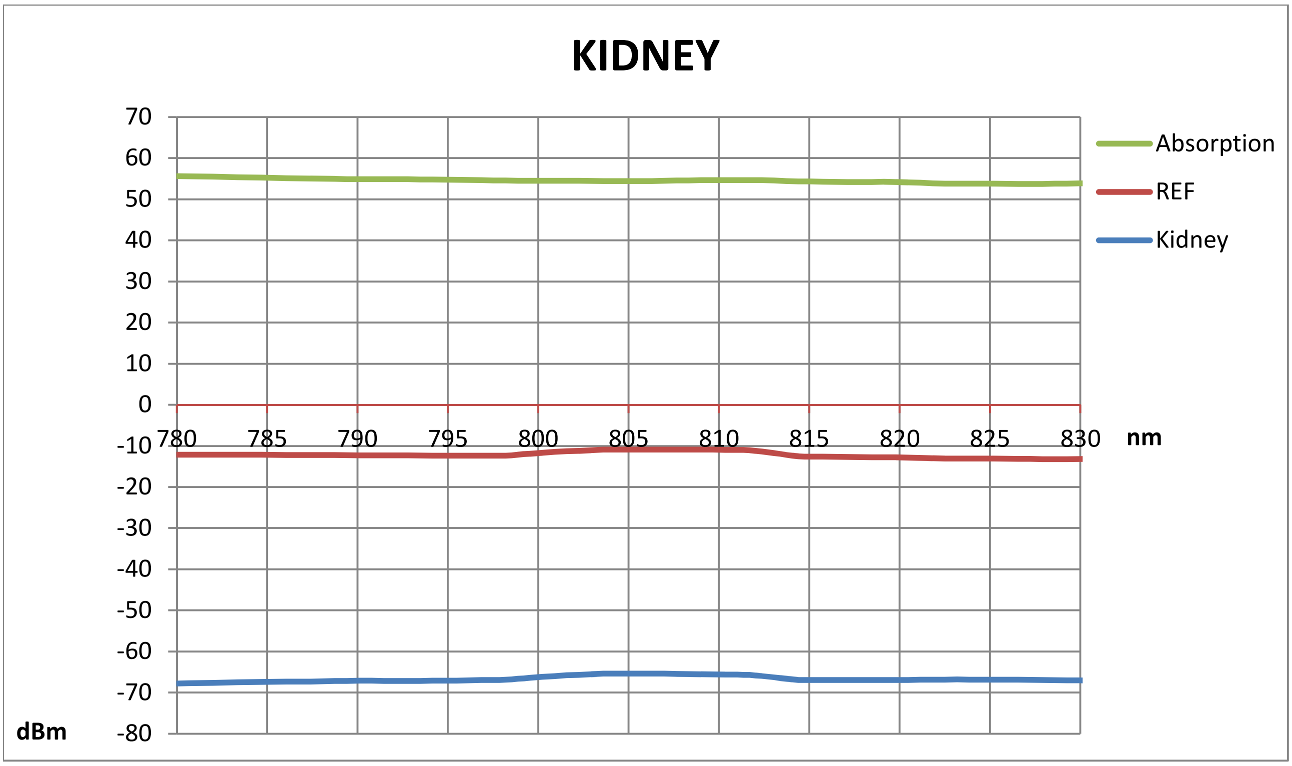

Fig. 9 – Graph of the reference radiation source (REF), the radiation that passes through the tissue (Kidney) and absorption (Absorption) in sprague dawley rat kidney for wavelengths from 780 nm till 830 nm.

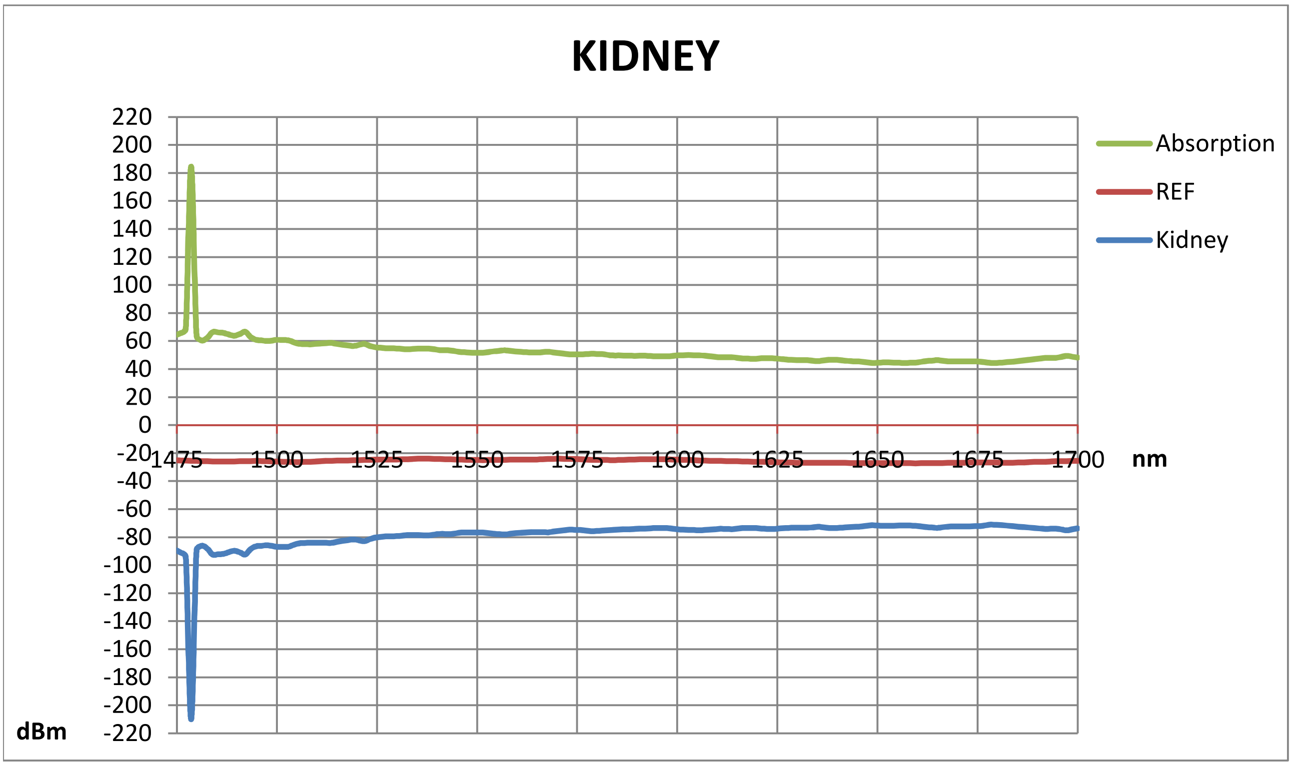

Fig. 10 – Graph of the reference radiation source (REF), the radiation that passes through the tissue (Kidney) and absorption (Absorption) in sprague dawley rat kidney for wavelengths from 1475 nm till 1700 nm.

Wavelength (nm)	Kidney Measure (dBm)	Wavelength (nm)	Kidney Measure (dBm)
603.800	-98.879	610.550	-81.289
605.150	-92.201	611.900	-81.805
606.500	-89.685	613.250	-82.009
607.850	-83.307	614.600	-82.223
609.200	-80.828	615.950	-80.664

Table 1 - Values of measured light from spectrum analyzer in sprague dawley rat kidney at wavelengths from 603.800 nm till 615.950 nm. The values lower than -80 dBm are in red. For the reasons illustrated in this chapter it is believed that the light is completely absorbed at these wavelengths.

Wavelength (nm)	Kidney Measure (dBm)	Wavelength (nm)	Kidney Measure (dBm)
1396.250	-80.096	1408.400	-96.238
1397.600	-80.632	1409.750	-97.295
1398.950	-81.783	1411.100	-98.695
1400.300	-83.356	1412.450	-92.888
1401.650	-83.318	1413.800	-90.489
1403.000	-83.280	1415.150	-93.311
1404.350	-85.608	1416.500	-104.040
1405.700	-90.976	1417.850	-93.755
1407.050	-92.855	1419.200	-90.953

Table 2 - Values of measured light from spectrum analyzer in sprague dawley rat kidney at wavelengths from 1396.250 nm till 1419.200 nm. The values lower than -80 dBm are in red. For the reasons illustrated in this chapter it is believed that the light is completely absorbed at these wavelengths.

Wavelength (nm)	Kidney Measure (dBm)	Wavelength (nm)	Kidney Measure (dBm)
1479.950	**-89.201**	1502.900	**-86.826**
1481.300	**-86.112**	1504.250	**-85.433**
1482.650	**-88.213**	1505.600	**-84.380**
1484.000	**-92.438**	1506.950	**-84.107**
1485.350	**-92.148**	1508.300	**-83.851**
1486.700	**-91.876**	1509.650	**-83.953**
1488.050	**-90.638**	1511.000	**-84.057**
1489.400	**-89.677**	1512.350	**-84.061**
1490.750	**-90.814**	1513.700	**-84.065**
1492.100	**-92.359**	1515.050	**-83.267**
1493.450	**-88.507**	1516.400	**-82.593**
1494.800	**-86.498**	1517.750	**-82.047**
1496.150	**-86.127**	1519.100	**-81.562**
1497.500	**-85.784**	1520.450	**-82.185**
1498.850	**-86.290**	1521.800	**-82.911**
1500.200	**-86.862**	1523.150	**-81.430**
1501.550	**-86.844**	1524.500	**-80.327**

Table 3 - Values of measured light from spectrum analyzer in sprague dawley rat kidney at wavelengths from 1479.950 nm till 1524.500 nm. The values lower than -80 dBm are in red. For the reasons illustrated in this chapter it is believed that the light is completely absorbed at these wavelengths.

Wavelength (nm)		Kidney Measure (dBm)	Kidney Absorption (dB)
from	till		
350.000	**602.450**	**spikes < -80**	**full absorption**
603.800	**615.950**	**values < -80**	**full absorption**
617.300	**1394.900**	**values > -80**	**valid values**
1396.250	**1419.200**	**values < -80**	**full absorption**
1420.550	**1478.600**	**spikes < -80**	**full absorption**
1479.950	**1524.500**	**values < -80**	**full absorption**
1525.850	**1700.000**	**values > -80**	**valid values**

Table 4 - Summary of wavelengths where light is completely absorbed in sprague dawley rat kidney. Values lower than -80 dBm are deemed too small because they are not read by the spectrum analyzer. So those wavelengths light are considered completely absorbed.

Wavelength (nm)	REF (dBm)	Kidney Measure (dBm)	Kidney Absorption (dB)
798.200	-12.350	-66.875	54.525
799.550	-11.882	-66.396	54.514
800.900	-11.459	-65.964	54.505
802.250	-11.187	-65.657	54.470
803.600	-10.931	-65.370	54.439

804.950	-10.930	-65.365	54.435
806.300	-10.929	-65.361	54.432
807.650	-10.913	-65.443	54.530
809.000	**-10.897**	-65.527	54.630
810.350	-10.977	-65.623	54.646
811.700	-11.058	-65.722	54.664
813.050	-11.737	-66.270	54.533
814.400	-12.543	-66.898	54.355
815.750	-12.615	-66.898	54.283

Table 5 - The table shows that the value of absorption in sprague dawley rat kidney remains almost constant for wavelength from 798.200 nm till 815.750 nm. At 809.000 nm the value of source is maximum (in red), but despite this absorption is almost constant.

Wavelength (nm)	REF (dBm)	Kidney Measure (dBm)	Kidney Absorption (dB)
1045.250	-18.102	-65.927	47.825
1046.600	-18.139	-66.002	47.863
1047.950	-18.178	-65.915	47.737
1049.300	-18.217	-65.829	47.612
1050.650	-18.250	-65.839	47.589
1052.000	-18.284	-65.850	47.566
1053.350	-18.324	-65.879	47.555
1054.700	-18.364	-65.910	47.546
1056.050	-18.349	-65.844	47.495
1057.400	-18.334	-65.780	47.446
1058.750	-18.123	-61.146	43.023
1060.100	-17.921	**-58.955**	41.034
1061.450	-17.932	-59.002	41.070
1062.800	-17.942	-59.049	41.107
1064.150	-17.941	-59.251	41.310
1065.500	-17.939	-59.463	41.524
1066.850	-17.964	-59.533	41.569
1068.200	-17.988	-59.605	41.617
1069.550	-18.255	-61.653	43.398
1070.900	-18.540	-65.663	47.123
1072.250	-18.565	-65.598	47.033
1073.600	-18.590	-65.533	46.943
1074.950	-18.604	-65.409	46.805
1076.300	-18.618	-65.288	46.670
1077.650	-18.597	-64.784	46.187

Table 6 - Values of radiation passing through and of radiation absorbed in sprague dawley rat kidney in relation to radiation emitted at wavelengths from 1045.250 nm till 1077.650 nm. The maximum light value passing through the tissue is in red.

Wavelength (nm)		dBm or dB	Light
809.000		-10.897 dBm	maximum value of light source
1068.200		41.034 dB	minimum absorption
1068.200		-58.955 dBm	maximum transmission
449.900		-46.547 dBm	minimum value of light source
from	till		
350.000	602.450	spikes < -80	full absorption
603.800	615.950	values < -80	full absorption
617.300	1394.900	values > -80	valid values
1396.250	1419.200	values < -80	full absorption
1420.550	1478.600	spikes < -80	full absorption
1479.950	1524.500	values < -80	full absorption
1525.850	1700.000	values > -80	valid values

Table 7 – Summary table.

8 Heart

It is used sprague dawley rat heart (Fig. 1). This has a thickness enough large. So the test is performed on the heart cut in half in the sense of its length (Fig. 2). Now it has a thickness of 2.2 mm. The sample is positioned between the smaller plates with a central hole having a diameter of 1.5 mm in order to cover the entire hole. The source emits light with the values and the sequence already described (Fig. 3).

Fig. 1 – Sprague dawley rat heart vision immediately after the sample taking.

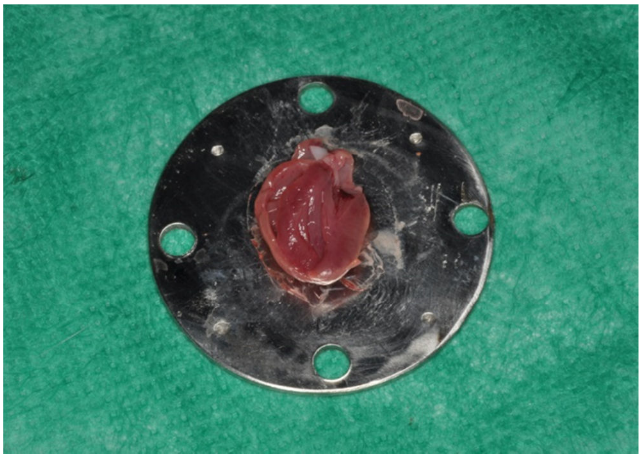

Fig. 2 – Sprague dawley rat heart vision positioned on the plate.

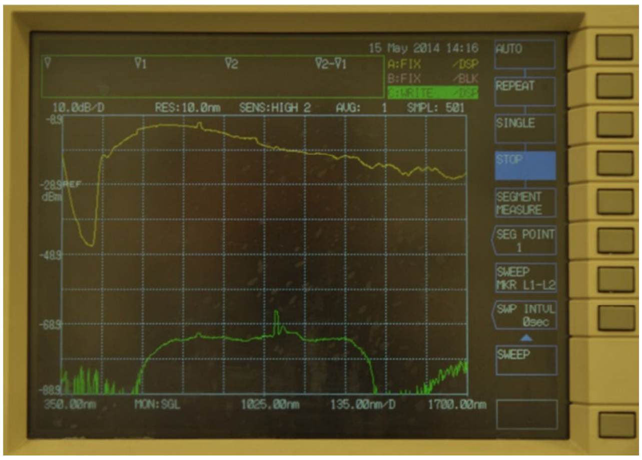

Fig. 3 – Graph of measurements taken on sprague dawley rat heart shown by Spectrum Analyzer display.

The values of the light, which crosses the tissue (Heart), are represented in Fig. 4, along with the values of light emitted freely through the air without anything interposed (reference or calibration path, REF).

In the same figure you see also the graph of heart light absorption (Absorption). Its value is the difference between the emitted light and the passing light through the tissue (transmitted).

From the graph of Fig. 4, and in particular from Fig. 6, you could suppose that radiation passes through the heart from 350.00 nm till 367.550 nm. Instead the values analysis shows that at those wavelengths all the passing radiation measurement through the heart are below than -80 dBm (Table 1).

Also in this case (Fig. 4) you see that the values from da 367.550 nm till 603.800 nm included (Fig. 6), and from 1400.300 nm till 1520.450 nm included (Fig. 7), the passing light values in the tissue are very variable. They may look like light absence spikes (-210.000 dBm) followed by partially absorbed light whose value is less than or close to -80 dBm. Again, for the reasons already stated they represent the wavelengths at which radiation is completely absorbed.

A vision of the same wavelengths range (Fig. 6), using a more detailed scale, would seem to show that the light pass in the tissue at wavelengths higher than 605.150 nm. Instead the values analysis shows that from 605.150 nm till 629.450 nm included, the passing radiation measure through the heart still has a power level less than -80 dBm (Fig. 4, Fig. 6, Table 2).

So also for these range it can be considered that the radiation is completely absorbed by the heart.

From the wavelength of 630.800 nm till 1374.650 nm included, the passing light values are greater than -80 dBm. Hence, being the values reliable, we can say that in this wavelengths portion, the light can effectively pass through the heart (Fig. 5).

The second group of spikes begins at 1400.300 nm till 1520.450 nm (Fig. 4, Fig. 5, Fig. 7). In this range the light is completely absorbed in the heart. However, also in this case, the numbers analysis shows that that the passing radiation values begin to be less than -80 dBm already at wavelength of 1376.000 nm till 1398.950 nm (Fig. 7) after which, at a 1400.300 nm, the already mentioned spikes start (Fig. 7). For the reasons already stated, starting from 1376.000 nm till 1398.950 nm also these radiation values must be discarded and, therefore, in this range of wavelength, the radiation is completely absorbed by the heart (Table 3).

The spikes terminate at the wavelength of 1520.450 nm (Fig. 7), but all passing light values from 1521.800 nm till 1700.000 nm included are not reliable because below -80 dBm (Fig. 10). For the reasons already stated the transmitted light values in this range wavelength are discarded. Therefore all the radiation between wavelength of 1521.800 nm till 1700.000 nm are completely absorbed by the heart. These values cannot be listed in a table being too numerous and the table size would be too great.

It thus appears that the light effectively passes through the heart between 630.800 nm and 1374.650 nm (Table 4).

In the figures are represented graphically the instrument reference values (REF), the passing light values through the tissue (Heart) and absorbed light values by the heart (Absorption).

On first analysis it can be seen that the light passing through increase progressively from 630.800 nm till 1057.400 nm (Fig. 4, Fig. 5). Starting from this latter wavelength (Fig. 8) the passing light amount through the heart has a significant increase till 1060.100 nm, to which transmission is the highest, then it decreases till the wavelength of 1070.900 nm (Table 6).

Accordingly, in the range of these wavelengths the absorption in the tissue has a drastic decrease. From the wavelength of 1070.900 nm onward, the transmission remains again fairly constant till the wavelength of 1289,600 nm (Fig. 5) when it starts to decrease, and at 1376.000 nm it decreases below -80 dBm and at 1400.300 nm the absorbed light spikes start (Fig. 7).

Also in this case, by examining the graph of Fig. 4 e Fig. 5, it would seem that significant radiation values pass through the examined tissue at wavelengths around 800 nm.

But in this case, as well as in the previous, the increase of power transmitted follow the source light increase, without reduction of absorbed radiation that, for those wavelengths, is almost constant. In this regard see the detail shown in the graph of Fig. 9 and values for that field of wavelengths shown in Table 5. The maximum value of source light it is revealed at 809.000 nm, but for this wavelength the transmission is neither the highest nor the absorption is the minimum.

A summary is shown in Table 7.

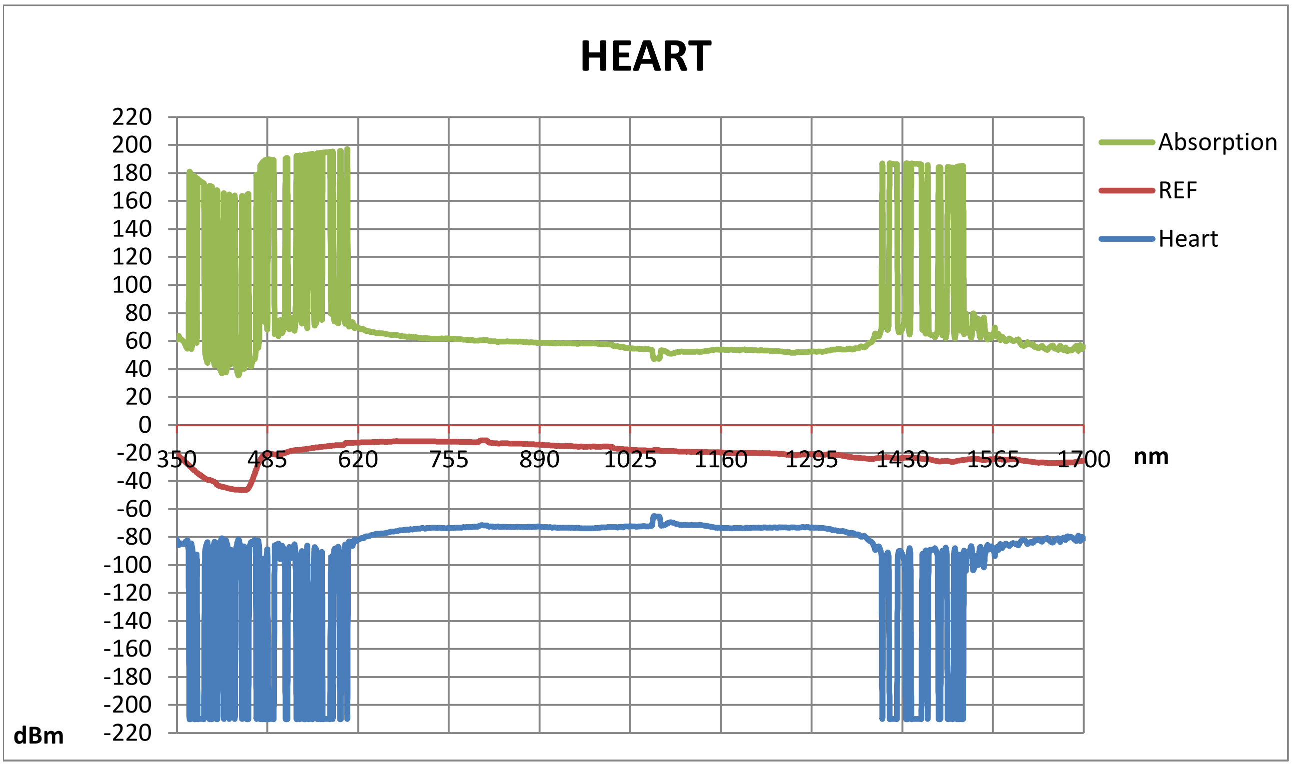

Fig. 4 – Graph of the reference radiation source (REF), the radiation that passes through the tissue (Heart) and absorption (Absorption) in sprague dawley rat heart.

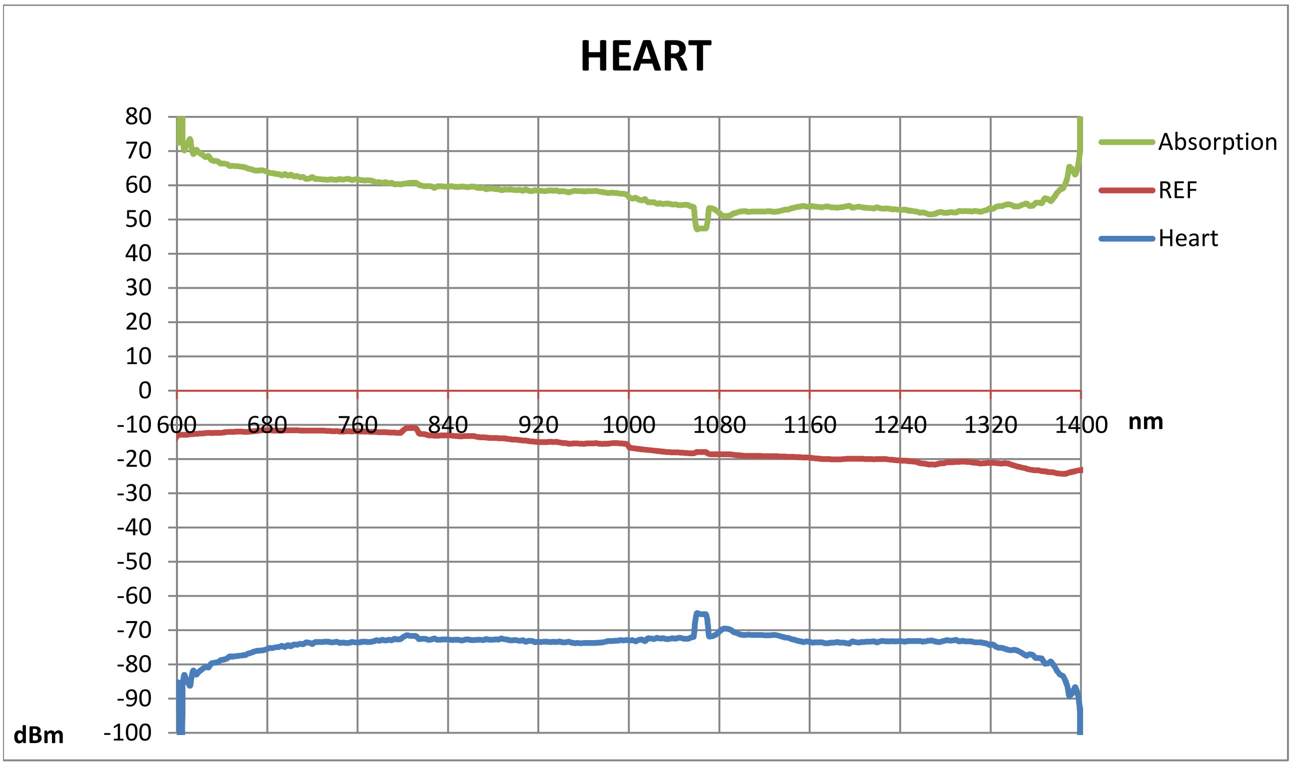

Fig. 5 – Graph of the reference radiation source (REF), the radiation that passes through the tissue (Heart) and absorption (Absorption) in sprague dawley rat heart for wavelengths from 600 nm till 1400 nm.

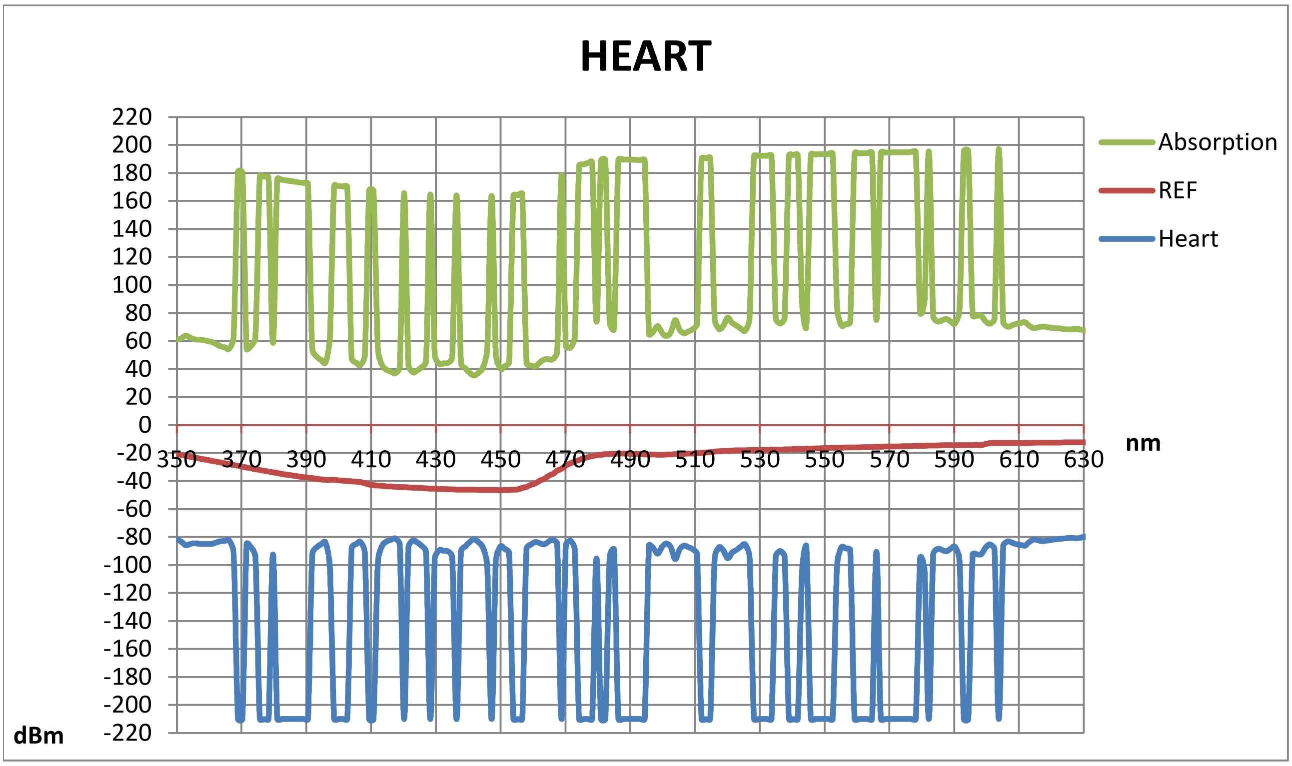

Fig. 6 – Graph of the reference radiation source (REF), the radiation that passes through the tissue (Heart) and absorption (Absorption) in sprague dawley rat heart for wavelengths from 350 nm till 630 nm.

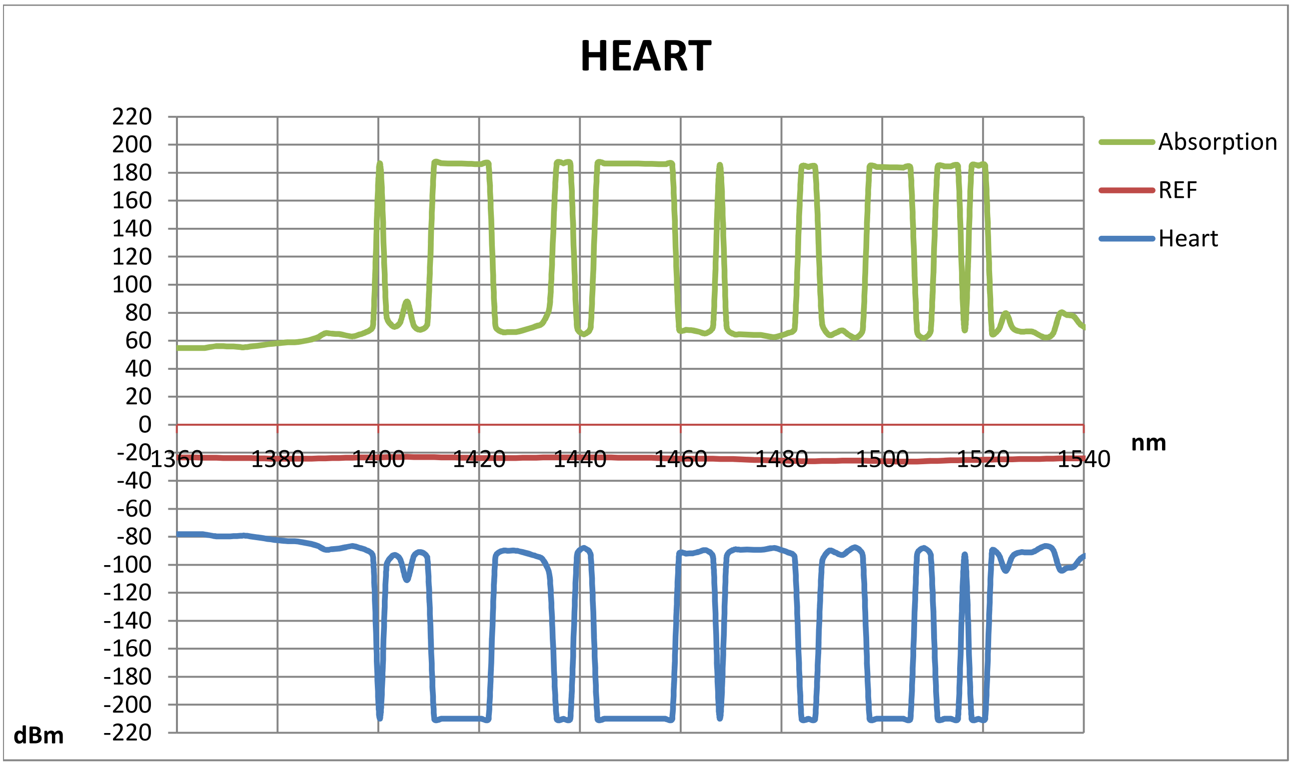

Fig. 7 – Graph of the reference radiation source (REF), the radiation that passes through the tissue (Heart) and absorption (Absorption) in sprague dawley rat heart for wavelengths from 1360 nm till 1540 nm.

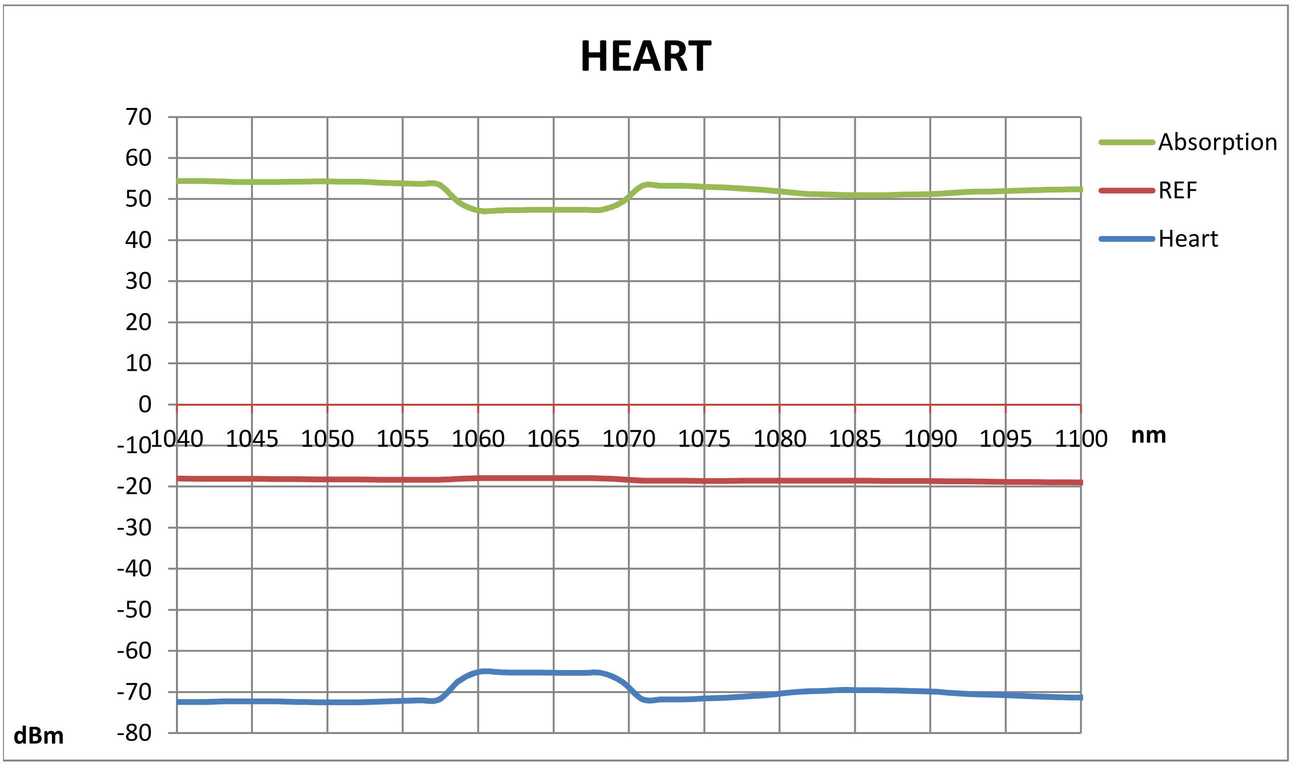

Fig. 8 – Graph of the reference radiation source (REF), the radiation that passes through the tissue (Heart) and absorption (Absorption) in sprague dawley rat heart for wavelengths from 1040 nm till 1100 nm.

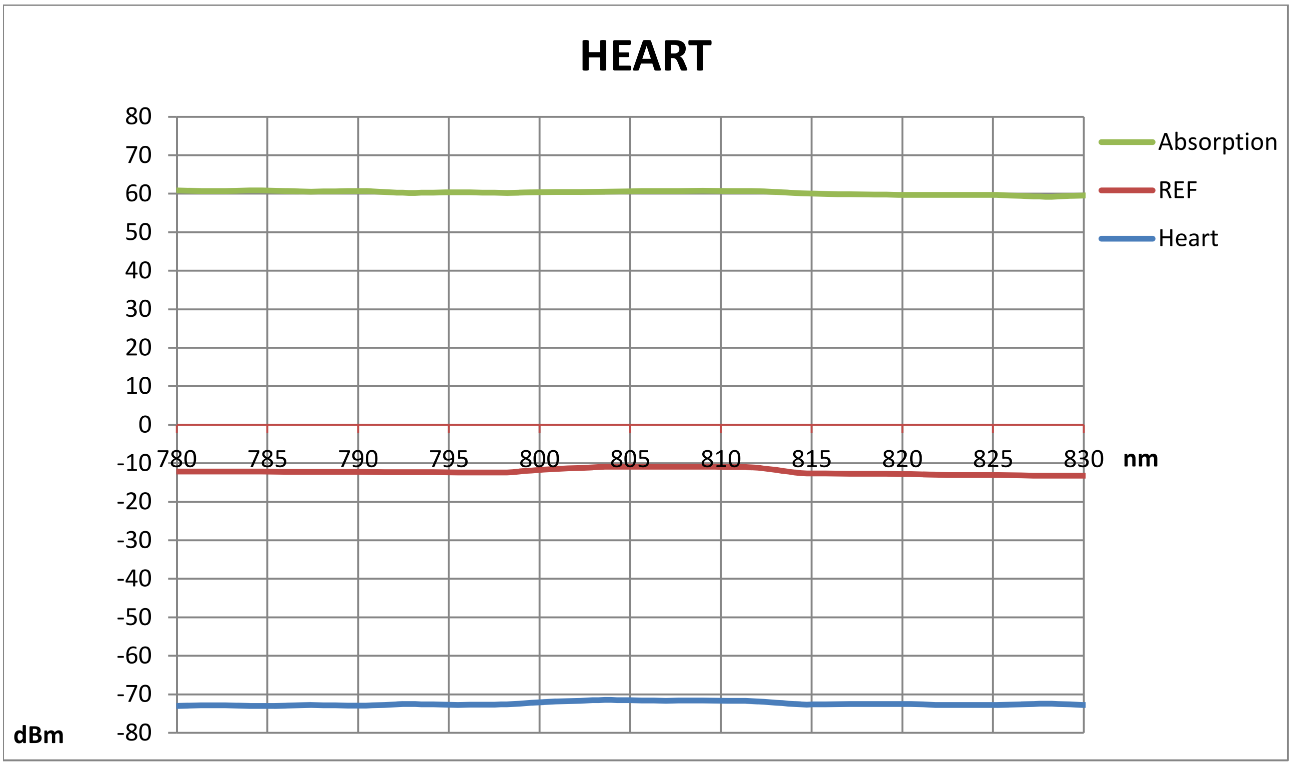

Fig. 9 – Graph of the reference radiation source (REF), the radiation that passes through the tissue (Heart) and absorption (Absorption) in sprague dawley rat heart for wavelengths from 780 nm till 830 nm.

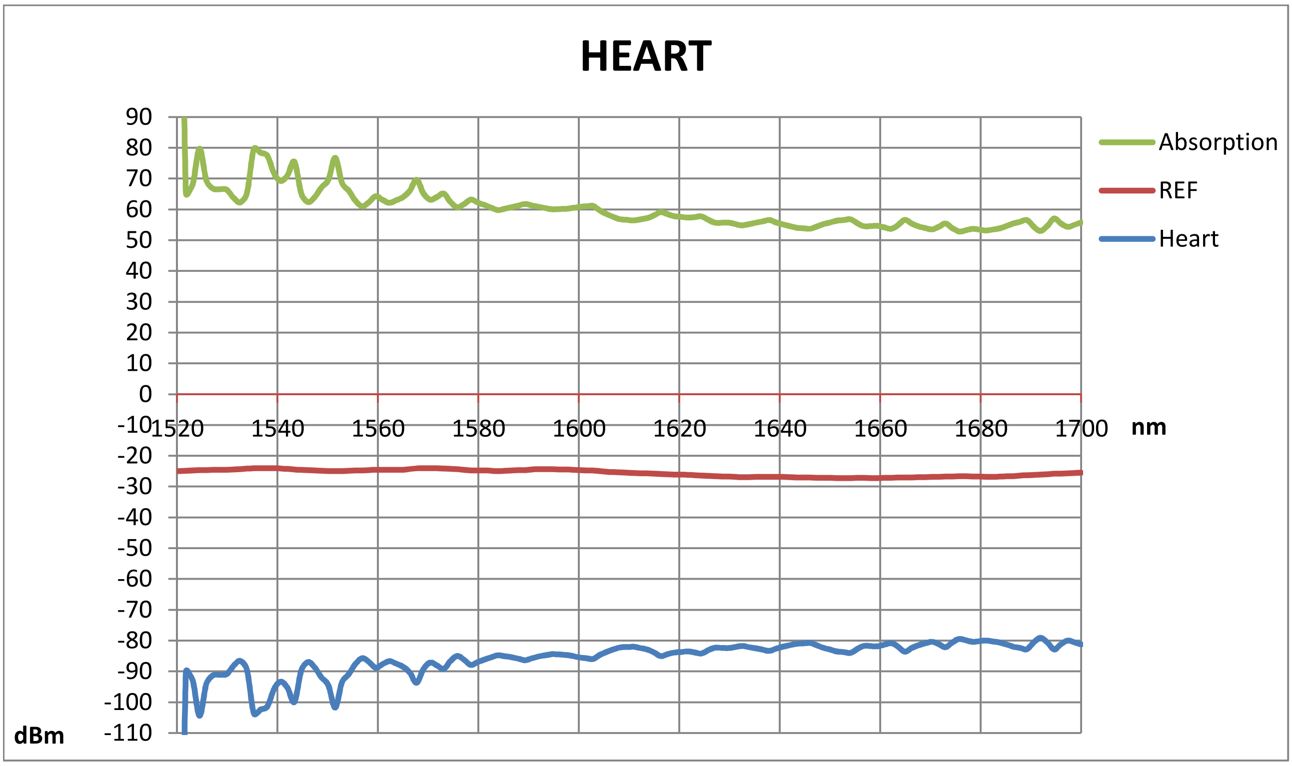

Fig. 10 – Graph of the reference radiation source (REF), the radiation that passes through the tissue (Heart) and absorption (Absorption) in sprague dawley rat heart for wavelengths from 1520 nm till 1700 nm.

Wavelength (nm)	Heart Measure (dBm)	Wavelength (nm)	Heart Measure (dBm)
350.000	**-81.604**	359.450	**-85.022**
351.350	**-83.221**	360.800	**-84.947**
352.700	**-85.824**	362.150	**-83.886**
354.050	**-85.073**	363.500	**-83.034**
355.400	**-84.432**	364.850	**-82.749**
356.750	**-84.753**	366.200	**-82.481**
358.100	**-85.099**	367.550	**-91.126**

Table 1 - Values of measured light from spectrum analyzer in sprague dawley rat heart at wavelengths from 350 nm till 367.550 nm. The values lower than -80 dBm are in red. For the reasons illustrated in this chapter it is believed that the light is completely absorbed at these wavelengths.

Wavelength (nm)	Heart Measure (dBm)	Wavelength (nm)	Heart Measure (dBm)
605.150	**-86.526**	618.650	**-82.491**
606.500	**-83.153**	620.000	**-82.037**
607.850	**-84.022**	621.350	**-81.684**
609.200	**-85.109**	622.700	**-81.358**
610.550	**-85.611**	624.050	**-80.996**
611.900	**-86.179**	625.400	**-80.661**
613.250	**-83.472**	626.750	**-80.771**
614.600	**-81.817**	628.100	**-80.884**
615.950	**-82.368**	629.450	**-80.244**
617.300	**-82.999**		

Table 2 - Values of measured light from spectrum analyzer in sprague dawley rat heart at wavelengths from 605.150 nm till 629.450 nm. The values lower of -80 dBm are in red. For the reasons illustrated in this chapter it is believed that the light is completely absorbed at these wavelengths.

Wavelength (nm)	Heart Measure (dBm)	Wavelength (nm)	Heart Measure (dBm)
1376.000	**-80.339**	1388.150	**-86.826**
1377.350	**-81.052**	1389.500	**-89.279**
1378.700	**-81.905**	1390.850	**-88.857**
1380.050	**-82.405**	1392.200	**-88.473**
1381.400	**-82.969**	1393.550	**-87.470**
1382.750	**-83.201**	1394.900	**-86.656**
1384.100	**-83.446**	1396.250	**-87.869**
1385.450	**-84.262**	1397.600	**-89.557**
1386.800	**-85.268**	1398.950	**-93.974**

Table 3 - Values of measured light from spectrum analyzer in sprague dawley rat heart at wavelengths from 1376.000 nm till 1398.950 nm. The values lower of -80 dBm are in red. For the reasons illustrated in this chapter it is believed that the light is completely absorbed at these wavelengths.

Wavelength (nm)		Heart Measure (dBm)	Heart Absorption (dB)
from	till		
350.000	**367.550**	**values < -80**	**full absorption**
368.900	**603.800**	**spikes < -80**	**full absorption**
605.150	**629.450**	**values < -80**	**full absorption**
630.800	**1374.650**	**values > -80**	**valid values**
1376.000	**1398.950**	**values < -80**	**full absorption**
1400.300	**1520.450**	**spikes < -80**	**full absorption**
1521.800	**1.700.000**	**values < -80**	**full absorption**

Table 4 - Summary of wavelengths where light is completely absorbed in sprague dawley rat heart. Values lower than -80 dBm are deemed too small because they are not read by the spectrum analyzer. So those wavelengths light are considered completely absorbed.

Wavelength (nm)	REF (dBm)	Heart Measure (dBm)	Heart Absorption (dB)
798.200	-12.350	-72.593	60.243
799.550	-11.882	-72.222	60.340
800.900	-11.459	-71.880	60.421
802.250	-11.187	-71.663	60.476
803.600	-10.931	-71.456	60.525
804.950	-10.930	-71.551	60.621
806.300	-10.929	-71.649	60.720
807.650	-10.913	-71.649	60.736
809.000	**-10.897**	-71.649	60.752
810.350	-10.977	-71.700	60.723
811.700	-11.058	-71.751	60.693
813.050	-11.737	-72.171	60.434
814.400	-12.543	-72.636	60.093
815.750	-12.615	-72.581	59.966

Table 5 - - The table shows that the value of absorption in sprague dawley rat heart remains almost constant for wavelength from 798.200 nm till 815.750 nm. At 809.000 nm the value of source is maximum (in red), but despite this absorption is almost constant.

Wavelength (nm)	REF (dBm)	Heart Measure (dBm)	Heart Absorption (dB)
1045.250	-18.102	-72.282	54.180
1046.600	-18.139	-72.306	54.167
1047.950	-18.178	-72.407	54.229
1049.300	-18.217	-72.511	54.294
1050.650	-18.250	-72.516	54.266
1052.000	-18.284	-72.521	54.237
1053.350	-18.324	-72.368	54.044
1054.700	-18.364	-72.221	53.857
1056.050	-18.349	-72.029	53.680
1057.400	-18.334	-71.845	53.511
1058.750	-18.123	-67.259	49.136
1060.100	-17.921	**-65.078**	47.157
1061.450	-17.932	-65.182	47.250
1062.800	-17.942	-65.288	47.346
1064.150	-17.941	-65.307	47.366
1065.500	-17.939	-65.326	47.387
1066.850	-17.964	-65.365	47.401
1068.200	-17.988	-65.404	47.416
1069.550	-18.255	-67.514	49.259
1070.900	-18.540	-71.778	53.238
1072.250	-18.565	-71.796	53.231
1073.600	-18.590	-71.814	53.224
1074.950	-18.604	-71.621	53.017
1076.300	-18.618	-71.436	52.818
1077.650	-18.597	-71.093	52.496

Table 6 - Values of radiation passing through and of radiation absorbed in sprague dawley rat heart in relation till radiation emitted at wavelengths from 1045.250 nm till 1077.650 nm. The maximum light value passing through the tissue is in red.

Wavelength (nm)		dBm or dB	Light
809.000		**-10.897 dBm**	**maximum value of light source**
1065.500		**42.824 dB**	**minimum absorption**
1065.500		**-60.763 dBm**	**maximum transmission**
449.900		**-46.547 dBm**	**minimum value of light source**
from	**till**		
350.000	**367.550**	**values < -80**	**full absorption**
368.900	**603.800**	**spikes < -80**	**full absorption**
605.150	**629.450**	**values < -80**	**full absorption**
630.800	**1374.650**	**values > -80**	**valid values**
1376.000	**1398.950**	**values < -80**	**full absorption**
1400.300	**1520.450**	**spikes < -80**	**full absorption**
1521.800	**1700.000**	**values < -80**	**full absorption**

Table 7 – Summary table.

9 Spleen

It is used sprague dawley rat spleen. It has a thickness of 1.2 mm. The sample is positioned between the smaller plates with a central hole having a diameter of 1.5 mm in order to cover the entire hole (Fig. 1). The source emits light with the values and the sequence already described (Fig. 2).

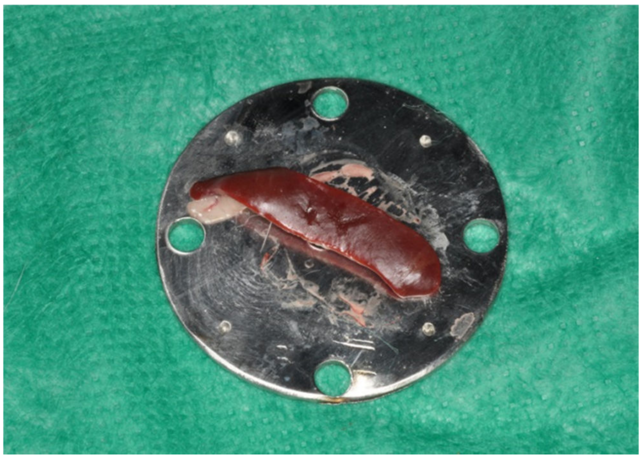

Fig. 1 – Sprague dawley rat spleen vision positioned on the plate.

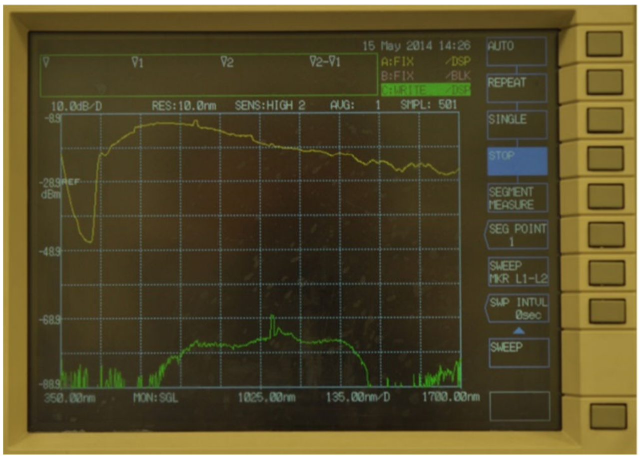

Fig. 2 – Graph of measurements taken on sprague dawley rat spleen shown by Spectrum Analyzer display.

The values of the light, which crosses the tissue (Spleen), are represented in Fig. 3, along with the values of light emitted freely through the air without anything interposed (reference or calibration path, REF).

In the same figure you see also the graph of spleen light absorption (Absorption). Its value is the difference between the emitted light and the passing light through the tissue (transmitted).

Also in this case (Fig. 3) you see that the values from 350.000 nm till 676.700 nm included (Fig. 5), and from 1397.600 nm till 1556.900 nm included (Fig. 6), the passing light values in the tissue are very variable. They may look like light absence spikes (-210.000 dBm) followed by partially absorbed light whose value is less than or close to -80 dBm. Again, for the reasons already stated they represent the wavelengths at which radiation is completely absorbed.

A vision of the same wavelengths range (Fig. 5), using a more detailed scale, would seem to show that the light pass in the tissue at wavelengths higher than 678.050 nm. Instead the values analysis shows that from 678.050 nm till 752.300 nm included, the passing radiation measurement through the tissue still has a power level less than -80 dBm (Fig. 4, Fig. 5, Table 1).

So also for these range it can be considered that the radiation is completely absorbed by the spleen (Table 1).

From the wavelength of 753.650 nm till 1350.350 nm included, the passing light values are greater than -80 dBm. Hence, being the values reliable, we can say that in this wavelengths portion, the light can effectively pass through the spleen (Fig. 3, Fig. 4).

The second group of spikes begins at 1397.600 nm till 1556.900 nm (Fig. 3, Fig. 4, Fig. 6). In this range the light is completely absorbed in the spleen. However, also in this case, the numbers analysis shows that the passing radiation values begin to be less than -80 dBm already at wavelength of 1351.700 nm till 1396.250 nm (Fig. 6, Table 2) after which, at 1397.600 nm, the already mentioned spikes start. For the reasons already stated, starting from 1351.700 nm till 1396.250 nm also these radiation values must be discarded and, therefore, in this range of wavelength, the radiation is completely absorbed by the spleen (Table 2).

The spikes terminate at the wavelength of 1556.900 nm (Fig. 6), but all passing light values from 1558.250 nm till 1700.000 nm included are not reliable because lower than -80 dBm (Fig. 6, Fig. 9). For the reasons already stated the transmitted light values in this wavelength range are discarded. So all the radiation in this range wavelength are completely absorbed by the spleen. These values cannot be listed in a table being too numerous and the table size would be too great.

It thus appears that the light effectively passes through the spleen between 753.650 nm and 1350.350 nm (Table 3).

In the figures are represented graphically the instrument reference values (REF), the passing light values through the tissue (Spleen) and absorbed light values by the spleen (Absorption).

On first analysis it can be seen that the transmitted light increase progressively from 753.650 nm till 1057.400 nm (Fig. 3, Fig. 4). Starting from this latter wavelength (Fig. 7) the passing light amount through the spleen has a significant increase till 1060.100 nm, to which transmission is the highest, then it decreases till the wavelength of 1070.900 nm (Table 5).

Accordingly, in the range of these wavelengths the absorption in the tissue has a drastic decrease. From the wavelength of 1070.900 nm onward, the transmission remains again fairly constant till the wavelength of 1308.500 nm (Fig. 3, Fig. 4) when it starts to decrease, and at 1351.700 nm it decreases below -80 dBm, and at 1397.600 nm absorbed light spikes start (Fig. 6, Table 2).

Also in this case, by examining the graph of Fig. 3 e Fig. 4, it would seem that significant radiation values pass through the examined tissue at wavelengths around 800 nm.

But in this case, as well as in the previous, the transmitted power increase follow the source light increase, without reduction of absorbed radiation that, for those wavelengths, is almost constant. In this regard see the detail shown in the graph of Fig. 8 and values for that field of wavelengths shown in Table 4. The maximum value of source light it is revealed at 809.000 nm, but for this wavelength the transmission is neither the highest nor the absorption is the minimum.

A summary is shown in Table 6.

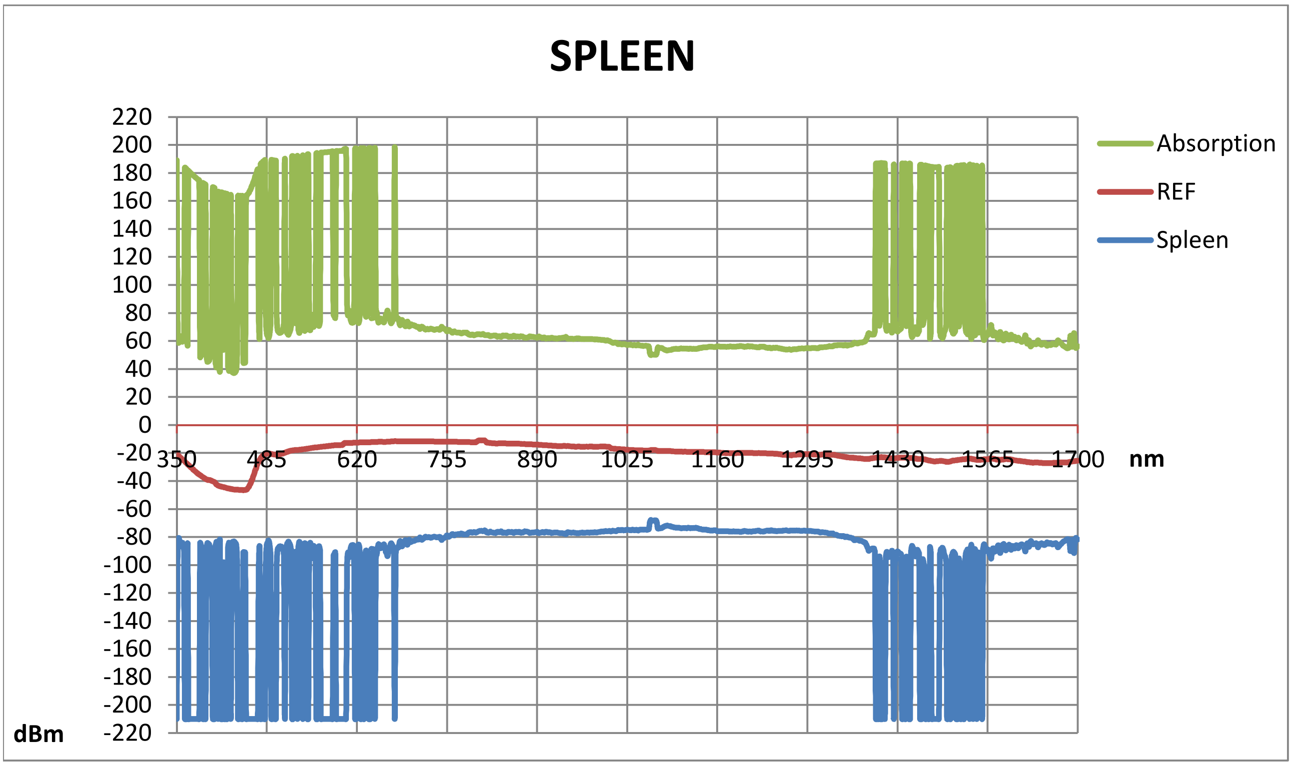

Fig. 3 – Graph of the reference radiation source (REF), the radiation that passes through the tissue (Spleen) and absorption (Absorption) in sprague dawley rat spleen.

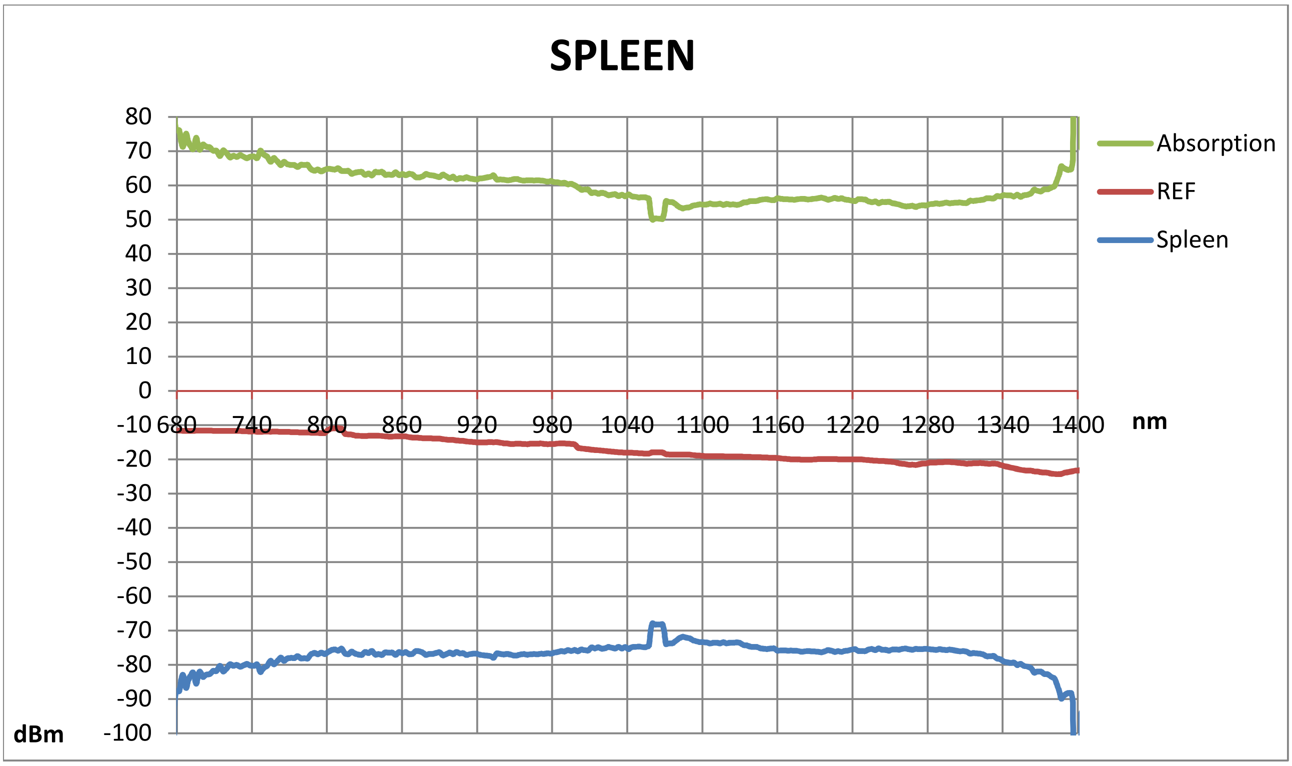

Fig. 4 – Graph of the reference radiation source (REF), the radiation that passes through the tissue (Spleen) and absorption (Absorption) in sprague dawley rat spleen for wavelengths from 680 nm till 1400 nm.

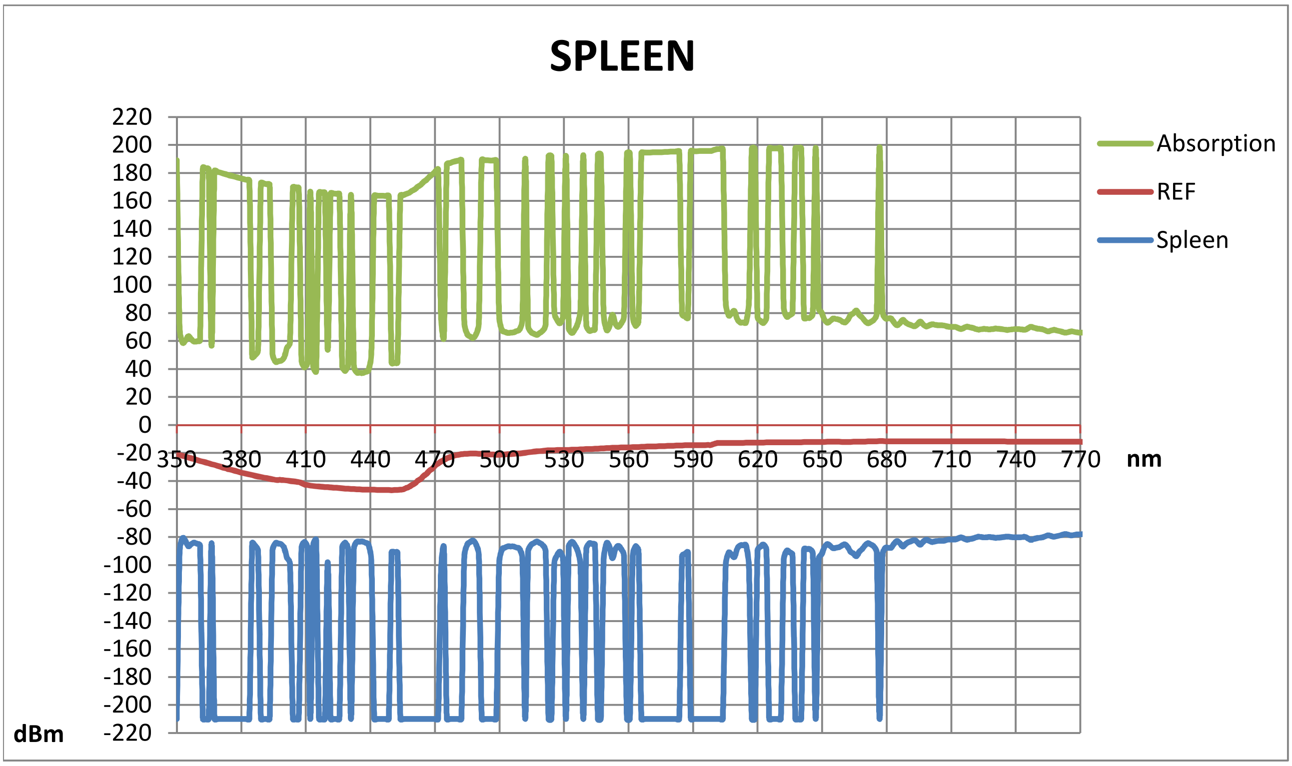

Fig. 5 – Graph of the reference radiation source (REF), the radiation that passes through the tissue (Spleen) and absorption (Absorption) in sprague dawley rat spleen for wavelengths from 350 nm till 770 nm.

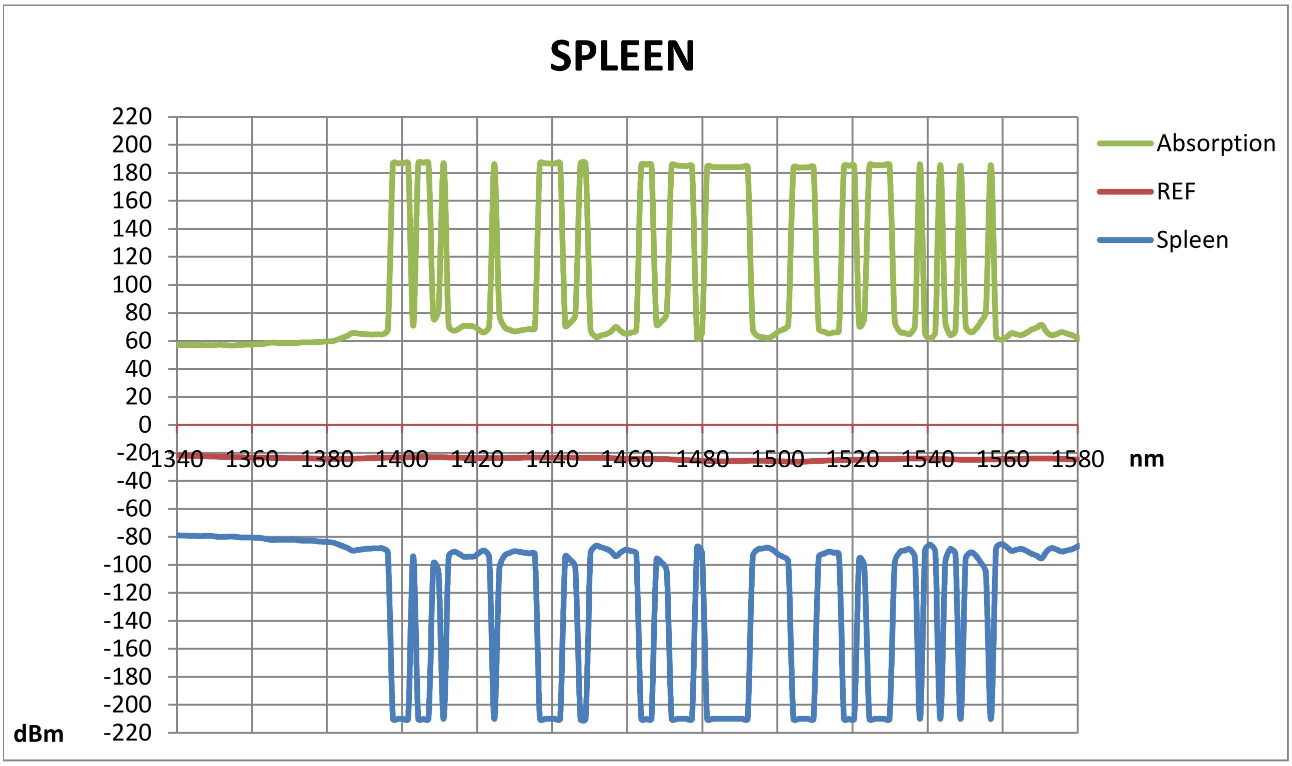

Fig. 6 – Graph of the reference radiation source (REF), the radiation that passes through the tissue (Spleen) and absorption (Absorption) in sprague dawley rat spleen for wavelengths from 1340 nm till 1580 nm.

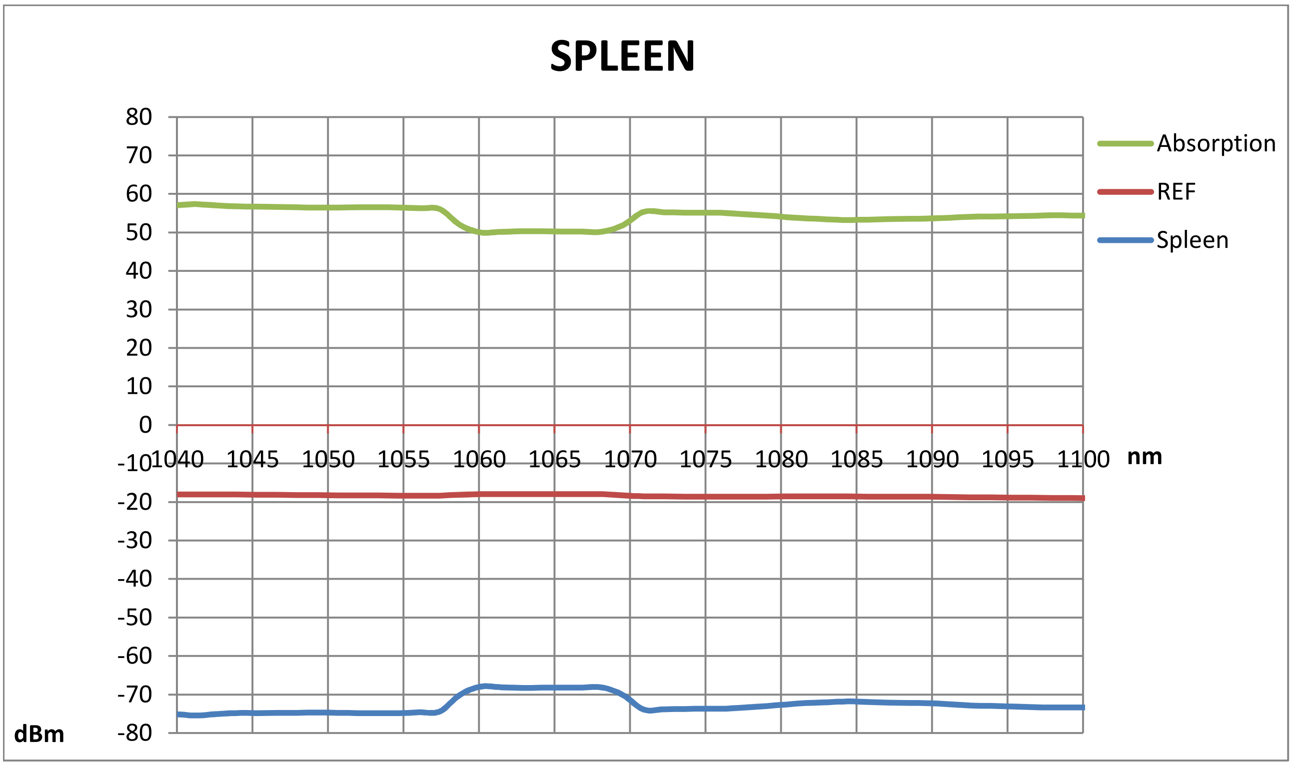

Fig. 7 – Graph of the reference radiation source (REF), the radiation that passes through the tissue (Spleen) and absorption (Absorption) in sprague dawley rat spleen for wavelengths from 1040 nm till 1100 nm.

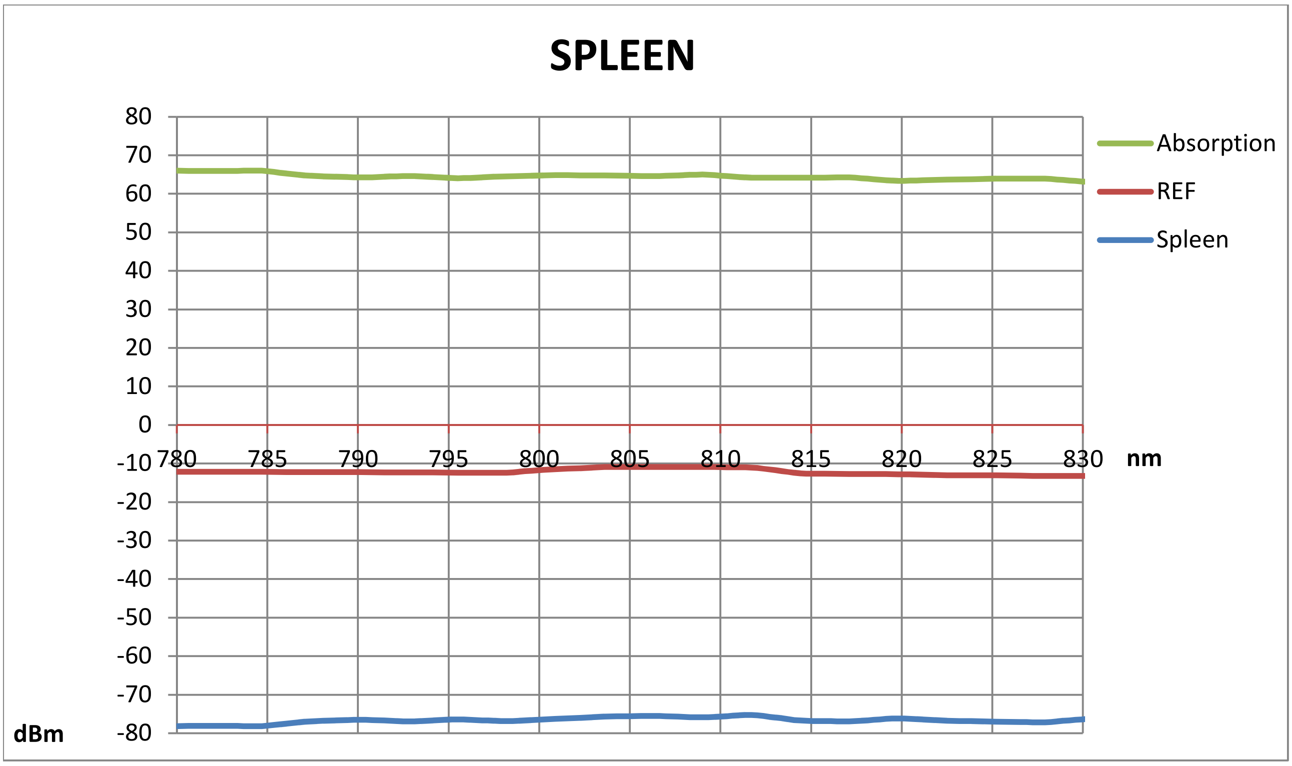

Fig. 8 – Graph of the reference radiation source (REF), the radiation that passes through the tissue (Spleen) and absorption (Absorption) in sprague dawley rat spleen for wavelengths from 780 nm till 830 nm.

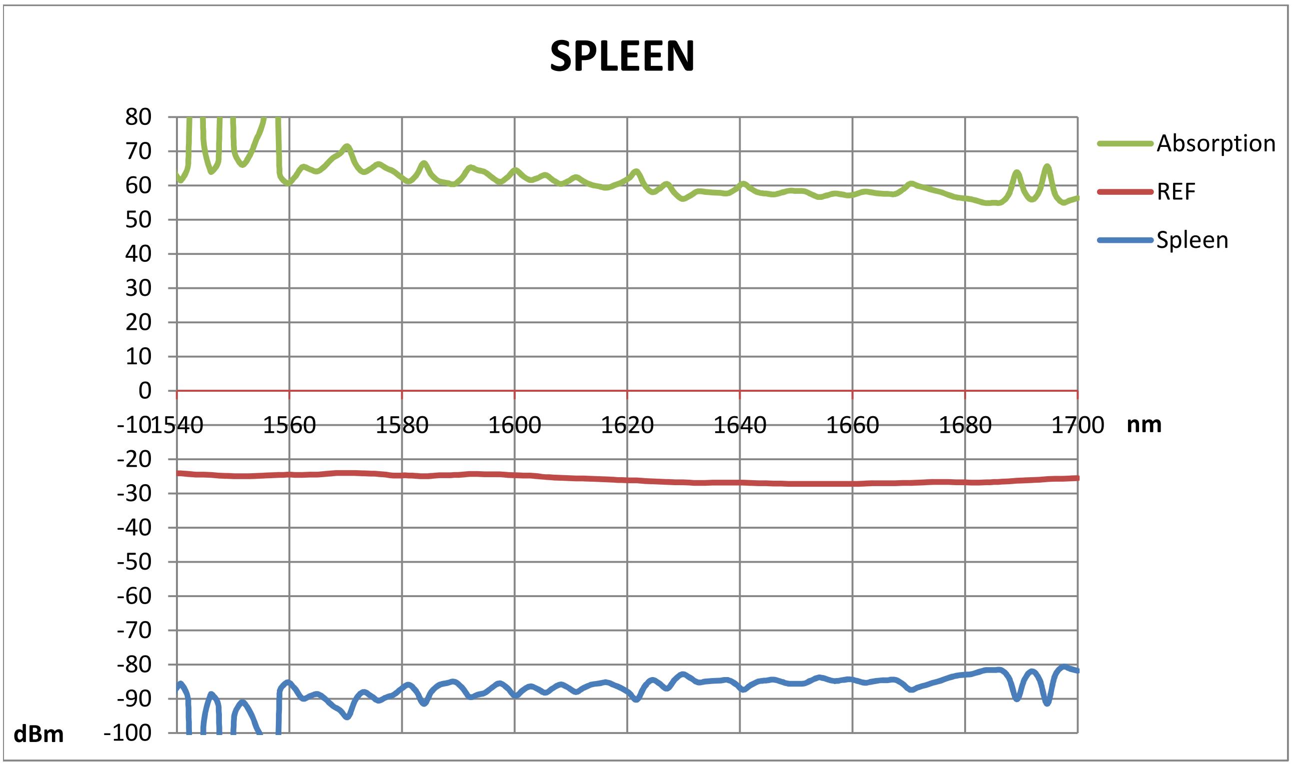

Fig. 9 – Graph of the reference radiation source (REF), the radiation that passes through the tissue (Spleen) and absorption (Absorption) in sprague dawley rat spleen for wavelengths from 1540 nm till 1700 nm.

Wavelength (nm)	Spleen Measure (dBm)	Wavelength (nm)	Spleen Measure (dBm)
678.050	**-92.441**	715.850	**-81.043**
679.400	**-87.779**	717.200	**-81.957**
680.750	**-87.701**	718.550	**-81.493**
682.100	**-87.625**	719.900	**-81.074**
683.450	**-84.649**	721.250	**-80.393**
684.800	**-82.899**	722.600	-79.805
686.150	**-84.420**	723.950	**-80.052**
687.500	**-86.782**	725.300	**-80.315**
688.850	**-84.954**	726.650	**-80.165**
690.200	**-83.671**	728.000	**-80.020**
691.550	**-82.879**	729.350	**-80.288**
692.900	**-82.210**	730.700	**-80.572**
694.250	**-83.562**	732.050	**-80.367**
695.600	**-85.538**	733.400	**-80.172**
696.950	**-83.397**	734.750	-79.942
698.300	**-81.970**	736.100	-79.725
699.650	**-82.693**	737.450	-79.969
701.000	**-83.561**	738.800	**-80.227**
702.350	**-83.194**	740.150	**-80.260**
703.700	**-82.855**	741.500	**-80.294**
705.050	**-82.776**	742.850	**-80.080**
706.400	**-82.698**	744.200	-79.876
707.750	**-82.197**	745.550	**-80.851**
709.100	**-81.748**	746.900	**-82.111**

710.450	**-81.790**	748.250	-81.439
711.800	**-81.832**	749.600	-80.857
713.150	**-80.992**	750.950	-80.562
714.500	**-80.289**	752.300	-80.285

Table 1 - Values of measured light from spectrum analyzer in sprague dawley rat spleen at wavelengths from 678.050 nm till 752.300 nm. The values lower than -80 dBm are in red. For the reasons illustrated in this chapter it is believed that the light is completely absorbed at these wavelengths.

Wavelength (nm)	Spleen Measure (dBm)	Wavelength (nm)	Spleen Measure (dBm)
1351.700	**-80.088**	1374.650	**-82.717**
1353.050	-79.895	1376.000	**-82.749**
1354.400	-79.710	1377.350	**-83.082**
1355.750	**-80.014**	1378.700	**-83.444**
1357.100	**-80.341**	1380.050	**-83.707**
1358.450	**-80.425**	1381.400	**-83.988**
1359.800	**-80.512**	1382.750	**-85.060**
1361.150	**-80.690**	1384.100	**-86.487**
1362.500	**-80.876**	1385.450	**-87.850**
1363.850	**-81.532**	1386.800	**-89.847**
1365.200	**-82.305**	1388.150	**-89.313**
1366.550	**-82.136**	1389.500	**-88.838**
1367.900	**-81.974**	1390.850	**-88.516**
1369.250	**-81.976**	1392.200	**-88.216**
1370.600	**-81.979**	1393.550	**-88.250**
1371.950	**-82.318**	1394.900	**-88.285**
1373.300	**-82.686**	1396.250	**-91.507**

Table 2 - Values of measured light from spectrum analyzer in sprague dawley rat spleen at wavelengths from 1351.700 nm till 1396.250 nm. The values lower than -80 dBm are in red. For the reasons illustrated in this chapter it is believed that the light is completely absorbed at these wavelengths.

Wavelength (nm)		Spleen Measure (dBm)	Spleen Absorption (dB)
from	**till**		
350.000	**676.700**	**spikes < -80**	**full absorption**
678.050	**752.300**	**values < -80**	**full absorption**
753.650	**1350.350**	**values > -80**	**valid values**
1351.700	**1396.250**	**values < -80**	**full absorption**
1397.600	**1556.900**	**spikes < -80**	**full absorption**
1558.250	**1700.000**	**values < -80**	**full absorption**

Table 3 Summary of wavelengths where light is completely absorbed in sprague dawley rat spleen. Values lower than -80 dBm are deemed too small because they are not read by the spectrum analyzer. So those wavelengths light are considered completely absorbed.

Wavelength (nm)	REF (dBm)	Spleen Measure (dBm)	Spleen Absorption (dB)
798.200	-12.350	-76.873	64.523
799.550	-11.882	-76.577	64.695
800.900	-11.459	-76.299	64.840
802.250	-11.187	-75.981	64.794
803.600	-10.931	-75.683	64.752
804.950	-10.930	-75.597	64.667
806.300	-10.929	-75.513	64.584
807.650	-10.913	-75.694	64.781
809.000	**-10.897**	-75.882	64.985
810.350	-10.977	-75.561	64.584
811.700	-11.058	-75.261	64.203
813.050	-11.737	-75.925	64.188
814.400	-12.543	-76.708	64.165
815.750	-12.615	-76.821	64.206

Table 4 - The table shows that the value of absorption in sprague dawley rat spleen remains almost constant for wavelength from 798.200 nm till 815.750 nm. At 809.000 nm the value of source is maximum (in red), but despite this absorption is almost constant.

Wavelength (nm)	REF (dBm)	Spleen Measure (dBm)	Spleen Absorption (dB)
1045.250	-18.102	-74.809	56.707
1046.600	-18.139	-74.796	56.657
1047.950	-18.178	-74.724	56.546
1049.300	-18.217	-74.652	56.435
1050.650	-18.250	-74.735	56.485
1052.000	-18.284	-74.819	56.535
1053.350	-18.324	-74.836	56.512
1054.700	-18.364	-74.854	56.490
1056.050	-18.349	-74.621	56.272
1057.400	-18.334	-74.399	56.065
1058.750	-18.123	-70.060	51.937
1060.100	-17.921	**-67.933**	50.012
1061.450	-17.932	-68.101	50.169
1062.800	-17.942	-68.276	50.334
1064.150	-17.941	-68.240	50.299
1065.500	-17.939	-68.205	50.266
1066.850	-17.964	-68.197	50.233
1068.200	-17.988	-68.189	50.201
1069.550	-18.255	-70.168	51.913
1070.900	-18.540	-73.907	55.367
1072.250	-18.565	-73.818	55.253
1073.600	-18.590	-73.731	55.141
1074.950	-18.604	-73.710	55.106
1076.300	-18.618	-73.689	55.071
1077.650	-18.597	-73.324	54.727

Table 5 - Values of radiation passing through and of radiation absorbed in sprague dawley rat spleen in relation to radiation emitted at wavelengths from 1045.250 nm till 1077.650 nm. The maximum light value passing through the tissue is in red.

Wavelength (nm)		dBm or dB	Light
809.000		-10.897 dBm	maximum value of light source
1060.100		50.012 dB	minimum absorption
1060.100		-67.933 dBm	maximum transmission
449.900		-46.547 dBm	minimum value of light source
from	till		
350.000	676.700	spikes < -80	full absorption
678.050	752.300	values < -80	full absorption
753.650	1350.350	values > -80	valid values
1351.700	1396.250	values < -80	full absorption
1397.600	1556.900	spikes < -80	full absorption
1558.250	1700.000	values < -80	full absorption

Table 6 – Summary table.

10 Liver 1

It is used sprague dawley rat liver. It has a thickness too large (Fig. 1). The test is performed on this entire sample, with thickness of the 5.7 mm, called LIVER 1. Later on this tissue will run the test in the part most thin, of 2.3 mm, called LIVER 2 (see next chapter). In the first two cases the light passes from the outer surface to outer surface, by the cortical surface to cortical surface, and passes through the entire liver. Later performed a section thickness of 0.6 mm, called LIVER 3 (see next chapter) and the radiation will be passed, not as in the first two samples through the entire liver, but directly through the parenchyma. The LIVER 1 sample is positioned between the smaller plates with a central hole having a diameter of 1.5 mm in order to cover the entire hole (Fig. 2). The source emits light with the values and the sequence already described (Fig. 3).

Fig. 1 – Sprague dawley rat liver vision immediately after the sample taking.

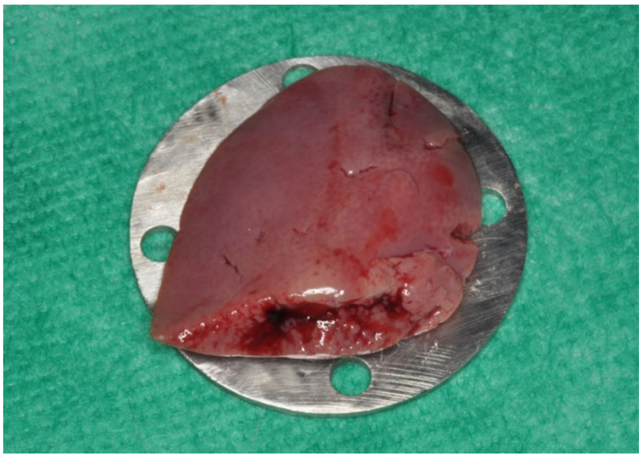

Fig. 2 – Sprague dawley rat liver vision (sample 1, Liver 1) positioned on the plate.

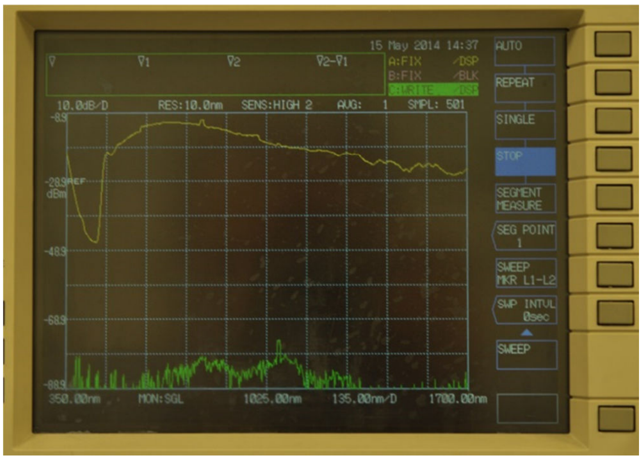

Fig. 3 – Graph of measurements taken on sprague dawley rat liver (sample 1, Liver 1) shown by Spectrum Analyzer display.

The values of the light, which crosses the tissue (Liver 1), are represented in Fig. 4, along with the values of light emitted freely through the air without anything interposed (reference or calibration path, REF).

In the same figure you see also the graph of liver light absorption (Absorption). Its value is the difference between the emitted light and the passing light through the tissue (transmitted).

Also in this case (Fig. 4) you see that the values from 350.000 nm and 674.000 nm included (Fig. 8), and from 1331.450 nm till 1700.000 nm included (Fig. 9), the passing light values in the tissue are very variable. They may look like light absence spikes (-210.000 dBm) followed by partially absorbed light whose value is less than or close to -80 dBm. Again, for the reasons already stated they represent the wavelengths at which radiation is completely absorbed.

The values analysis shows that from 675.350 nm till 1057.400 nm included, the passing radiation measurement through the liver (sample 1, Liver 1) still has a power level less than -80 dBm (Fig. 5, Fig. 6, Fig. 7, Fig. 11).

From the wavelength of 1058.750 nm till 1069.550 nm included, the passing light values are greater than -80 dBm (Fig. 10). Hence, being the values reliable, we can say that in this wavelengths portion, the light can effectively pass through the liver (sample 1, Liver 1).

From the wavelength of 1070.900 nm till 1081.700 nm included the light values are slightly lower than -80 dBm. From 1083.050 nm till 1091.150 nm included the light values are greater than -80 dBm (Fig. 10). Hence, being the values reliable, we can say that in this wavelengths portion, the light can effectively pass through the liver (sample 1, Liver 1).

From the wavelength of 1092.500 nm till 1330.100 nm all measured values from the Spectrum Analyzer are less than -80 dBm (Fig. 5, Fig. 7, Fig. 11). Hence also for these wavelengths we can be considered that the radiation is completely absorbed in the liver (sample 1, Liver 1).

The second group of spikes begins at the wavelength of 1331.450 nm till 1700 nm (Fig. 9). In this range the light is completely absorbed in the liver (sample 1, Liver 1).

It thus appears that the light passes, validly, through the liver (sample 1, Liver 1), just from 1058.750 nm till 1069.550 nm and 1083.050 nm till 1091.150 nm (Fig. 10).

In the figures are represented graphically the instrument reference values (REF), the passing light values through the tissue (sample 1, Liver 1) and absorbed light values by the liver (Absorption)

How much stated is shown in the graphs.

A summary is shown in the Table 1, Table 2, Table 3 e Table 4.

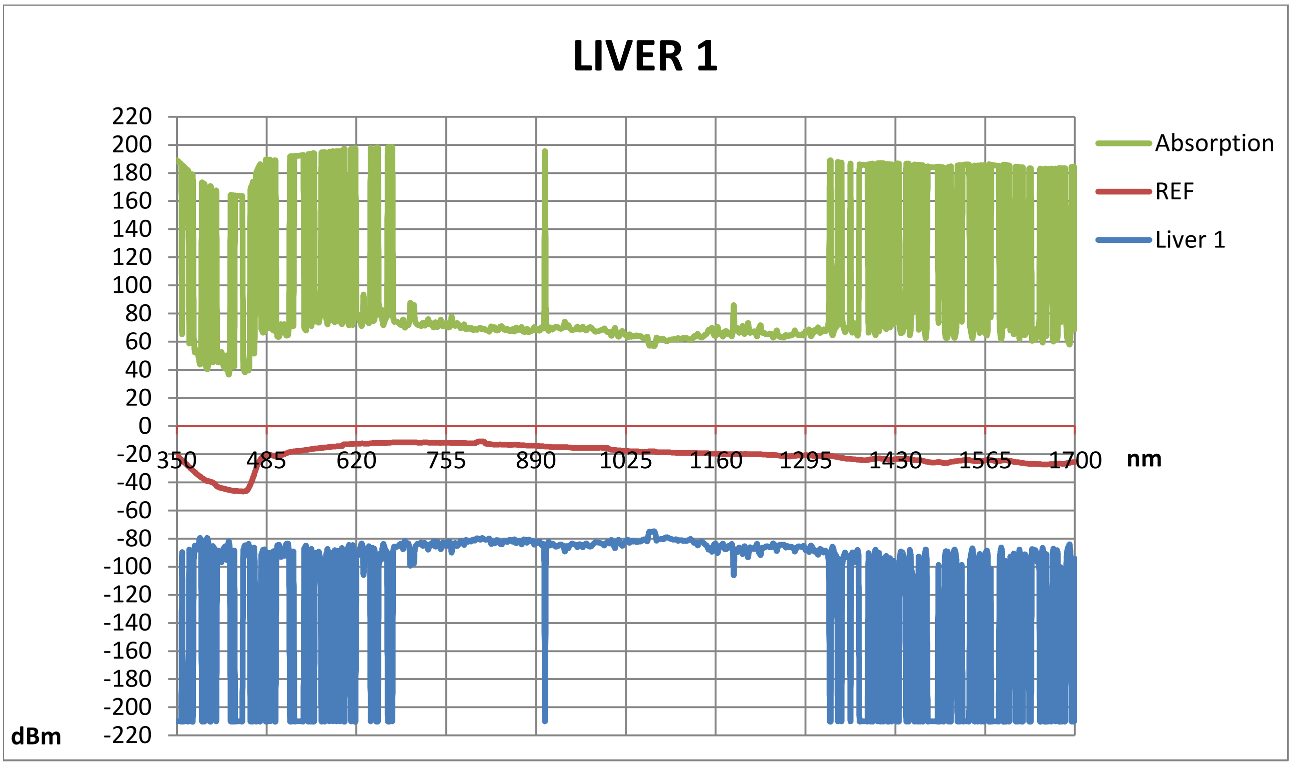

Fig. 4 – – Graph of the reference radiation source (REF), the radiation that passes through the tissue (Liver 1) and absorption (Absorption) in sprague dawley rat liver (sample 1, Liver 1).

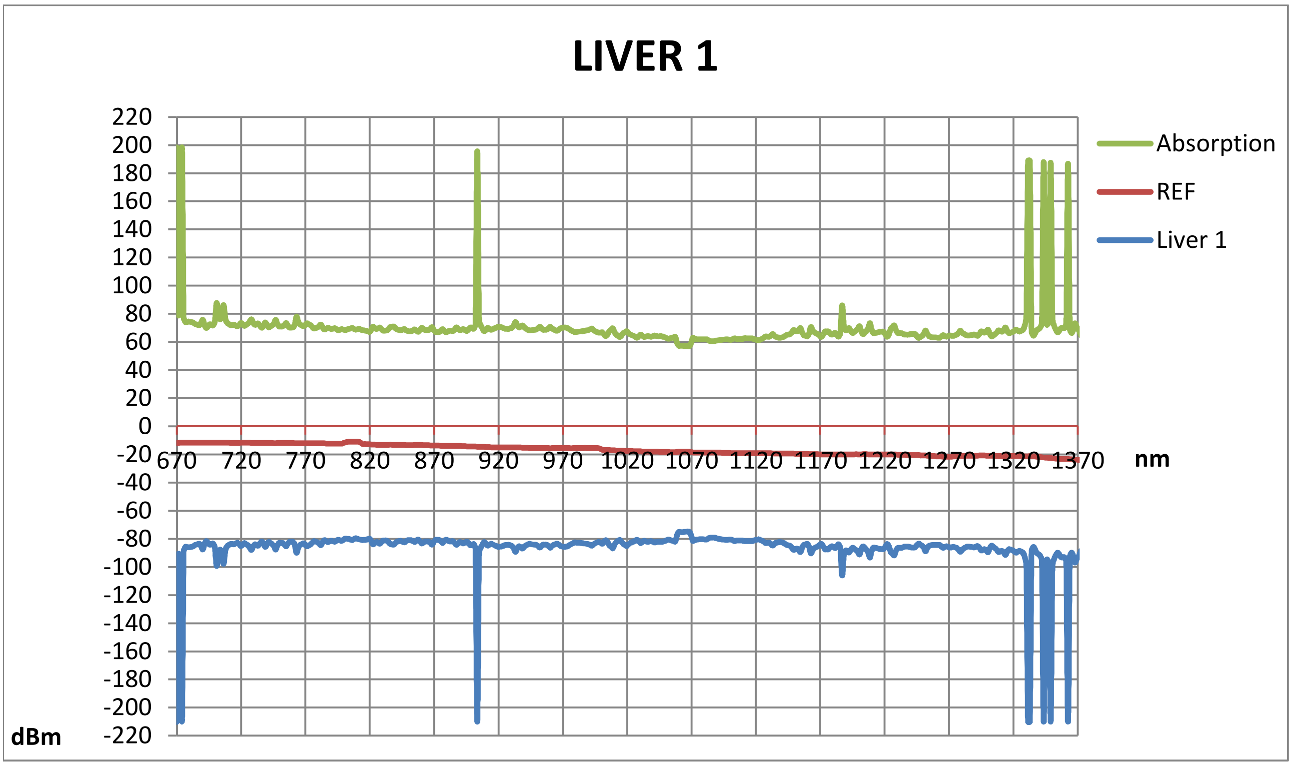

Fig. 5 – Graph of the reference radiation source (REF), the radiation that passes through the tissue (Liver 1) and absorption (Absorption) in sprague dawley rat liver (sample 1, Liver 1) for wavelengths from 670 nm till 1370 nm.

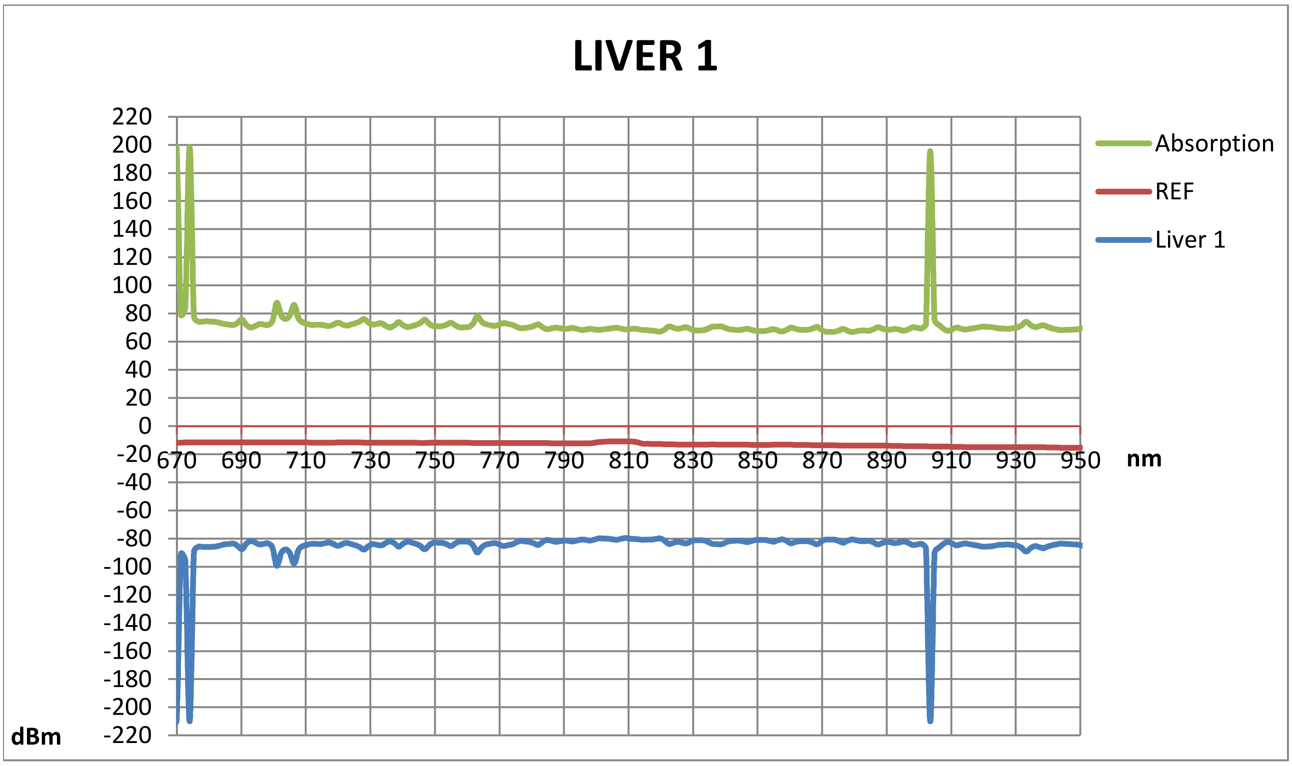

Fig. 6 – Graph of the reference radiation source (REF), the radiation that passes through the tissue (Liver 1) and absorption (Absorption) in sprague dawley rat liver (sample 1, Liver 1) for wavelengths from 670 nm till 950 nm.

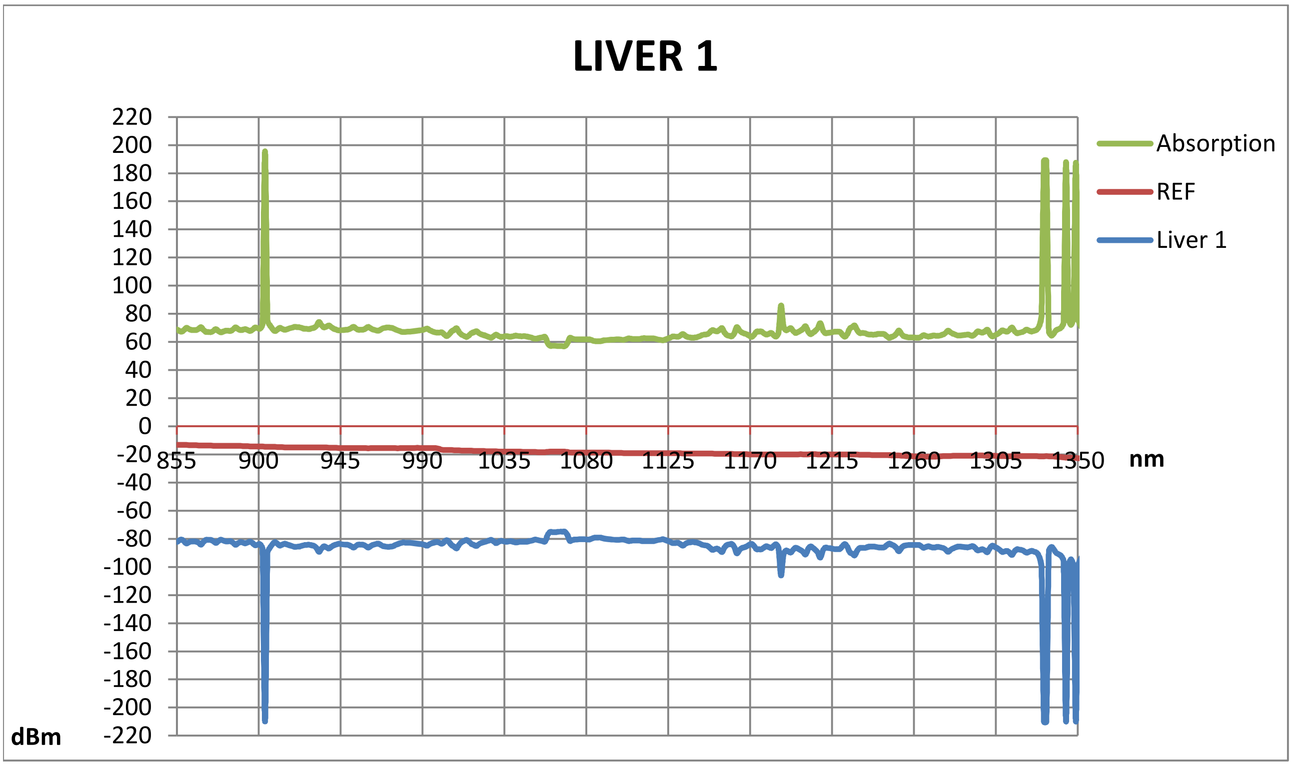

Fig. 7 – Graph of the reference radiation source (REF), the radiation that passes through the tissue (Liver 1) and absorption (Absorption) in sprague dawley rat liver (sample 1, Liver 1) for wavelengths from 855 nm till 1350 nm.

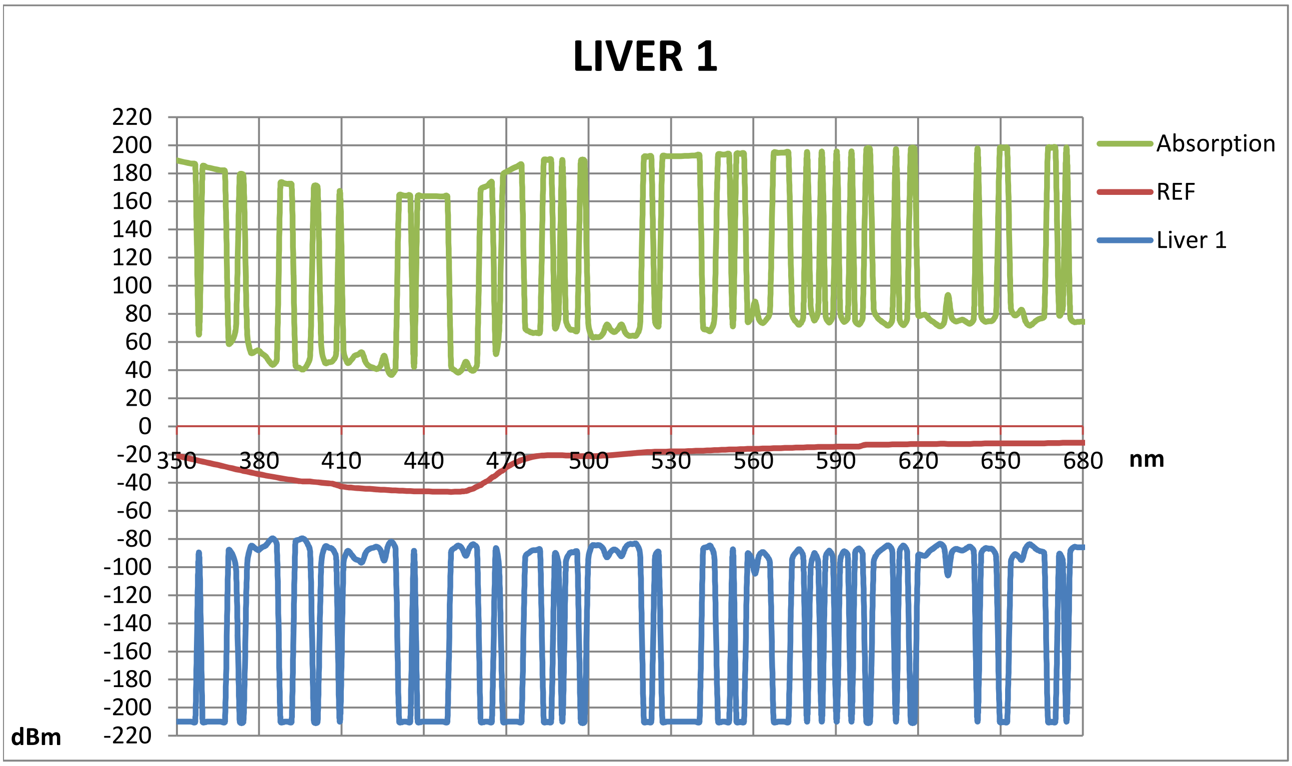

Fig. 8 – Graph of the reference radiation source (REF), the radiation that passes through the tissue (Liver 1) and absorption (Absorption) in sprague dawley rat liver (sample 1, Liver 1) for wavelengths from 350 nm till 680 nm.

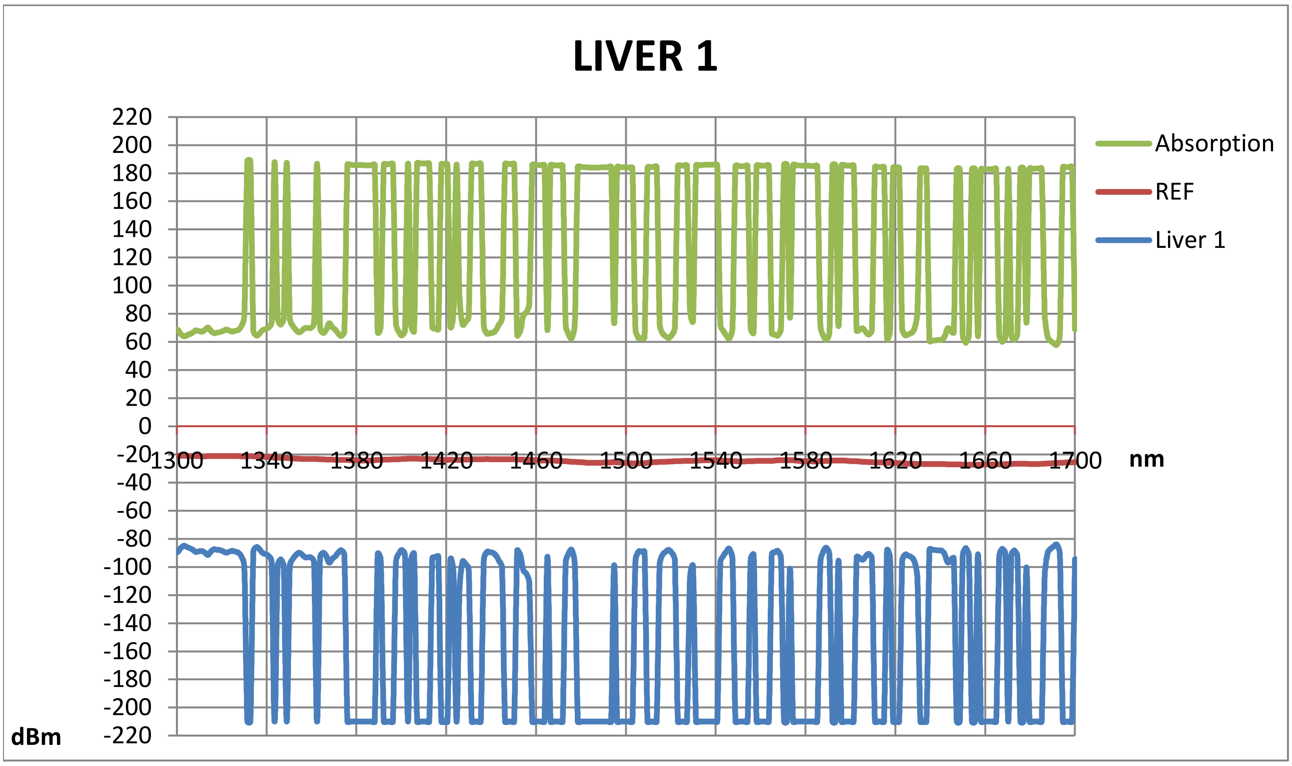

Fig. 9 – Graph of the reference radiation source (REF), the radiation that passes through the tissue (Liver 1) and absorption (Absorption) in sprague dawley rat liver (sample 1, Liver 1) for wavelengths from 1300 nm till 1700 nm.

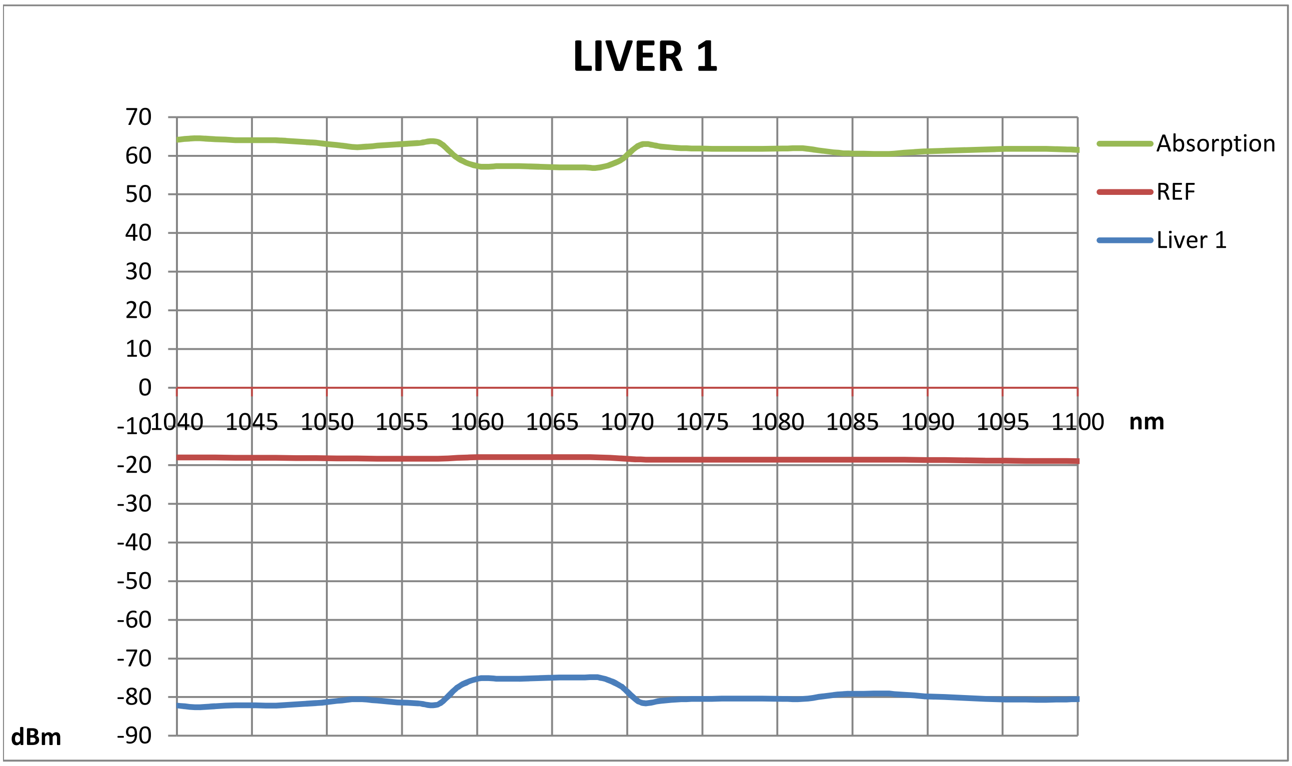

Fig. 10 – Graph of the reference radiation source (REF), the radiation that passes through the tissue (Liver 1) and absorption (Absorption) in sprague dawley rat liver (sample 1, Liver 1) for wavelengths from 1040 nm till 1100 nm.

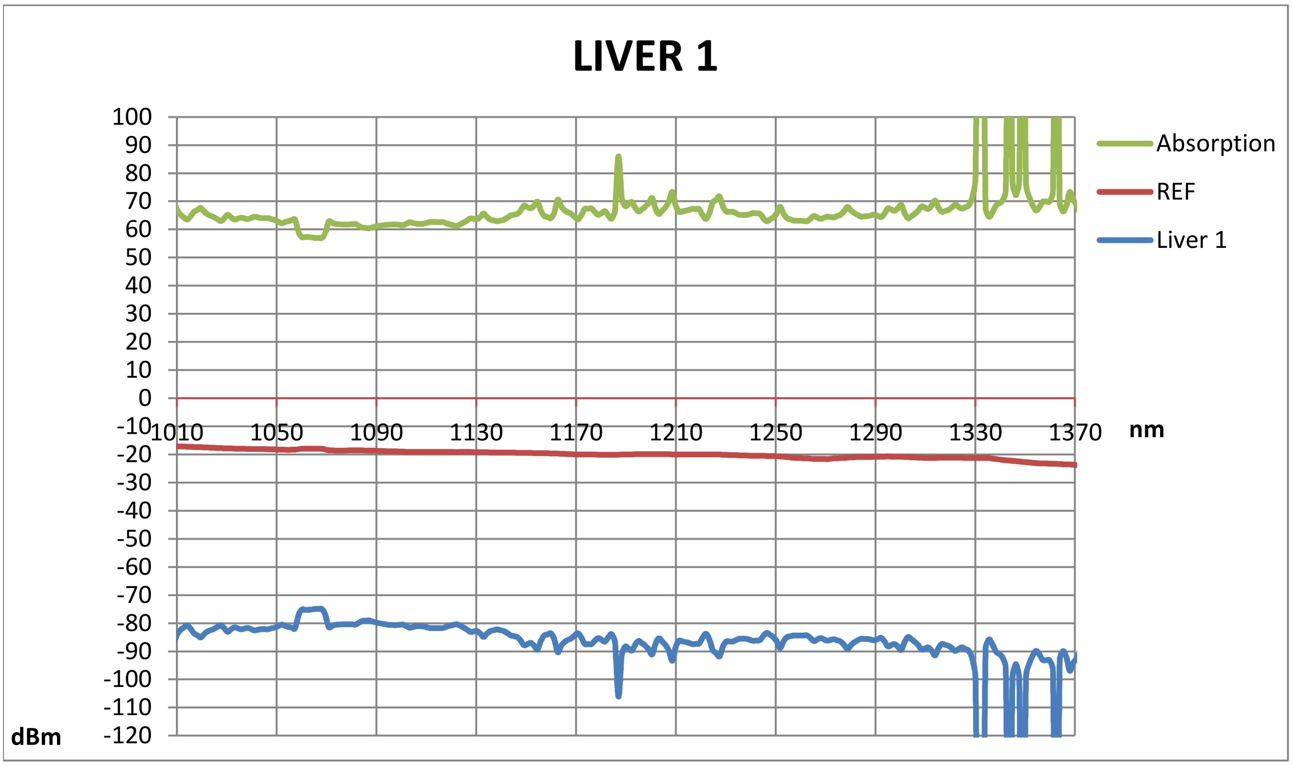

Fig. 11 – Graph of the reference radiation source (REF), the radiation that passes through the tissue (Liver 1) and absorption (Absorption) in sprague dawley rat liver (sample 1, Liver 1) for wavelengths from 1010 nm till 1370 nm.

Wavelength (nm)	Liver 1 Measure (dBm)	Wavelength (nm)	Liver 1 Measure (dBm)
1058.750	-77.362	1065.500	**-74.930**
1060.100	-75.198	1066.850	-74.952
1061.450	-75.237	1068.200	-74.974
1062.800	-75.275	1069.550	-77.089
1064.150	-75.099		

Table 1 - Values of measured light from spectrum analyzer in sprague dawley rat liver (sample 1, Liver 1) at wavelengths from 1058.750 nm till 1069.550 nm. The maximum light value passing through the tissue is in red.

Wavelength (nm)	Liver 1 Measure (dBm)	Wavelength (nm)	Liver 1 Measure (dBm)
1083,050	-79,808	1088,450	-79,382
1084,400	-79,227	1089,800	-79,762
1085,750	-79,129	1091,150	-79,990
1087,100	**-79,033**		

Table 2 - Values of measured light from spectrum analyzer in sprague dawley rat liver (sample 1, Liver 1) at wavelengths from 1083.050 nm till 1091.150 nm. The maximum light value passing through the tissue is in red.

Wavelength (nm)		Liver 1 Measure (dBm)	Liver 1 Absorption (dB)
from	till		
350.000	674.000	spikes < -80	full absorption
675.350	902.150	values < -80	full absorption
	903.500	single spike < 80	full absorption
904.850	1057.400	values < -80	full absorption
1058.750	1069.550	values > -80	valid values
1070.900	1081.700	values < -80	full absorption
1083.050	1091.150	values > -80	valid values
1070.900	1330.100	values < -80	full absorption
1331.450	1700.000	spikes < -80	full absorption

Table 3 Summary of wavelengths where light is completely absorbed in sprague dawley rat liver (sample 1, Liver 1). Values lower than -80 dBm are deemed too small because they are not read by the spectrum analyzer. So those wavelengths light are considered completely absorbed.

Wavelength (nm)		dBm or dB	Light
809.000		-10.897 dBm	maximum value of light source
1065.500		56.991 dB	minimum absorption
1065.500		-74.930 dBm	maximum transmission
449.900		-46.547 dBm	minimum value of light source
from	till		
350.000	674.000	spikes < -80	full absorption
675.350	902.150	values < -80	full absorption
	903.500	single spike < 80	full absorption
904.850	1057.400	values < -80	full absorption
1058.750	1069.550	values > -80	valid values
1070.900	1081.700	values < -80	full absorption
1083.050	1091.150	values > -80	valid values
1070.900	1330.100	values < -80	full absorption
1331.450	1700.000	spikes < -80	full absorption

Table 4 – Summary table.

11 Liver 2

Also in this case it is used sprague dawley rat liver. As already stated in the previous chapter, the test is performed on the same sample, but by crossing the radiation through thinner area than the first trial, equal to 2.3 mm, called LIVER 2. The surface of that thickness is positioned between the smaller plates with a central hole having a diameter of 1.5 mm in order to cover the entire hole (Fig. 1). The source emits light with the values and the sequence already described (Fig. 2).

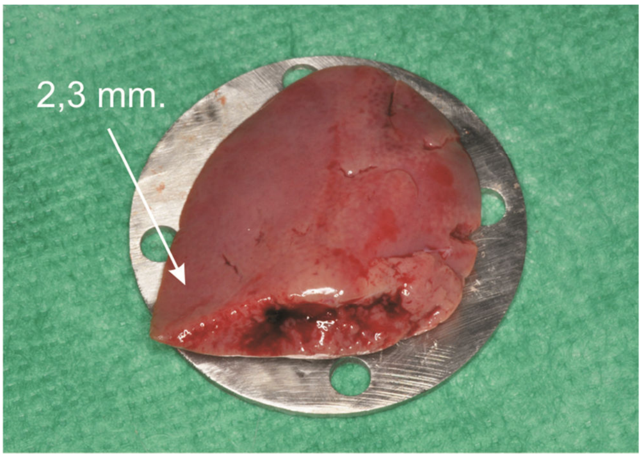

Fig. 1 – Sprague dawley rat liver vision (sample 2, Liver 2) positioned on the plate. The thickness part of 2.3 mm is positioned on the central hole.

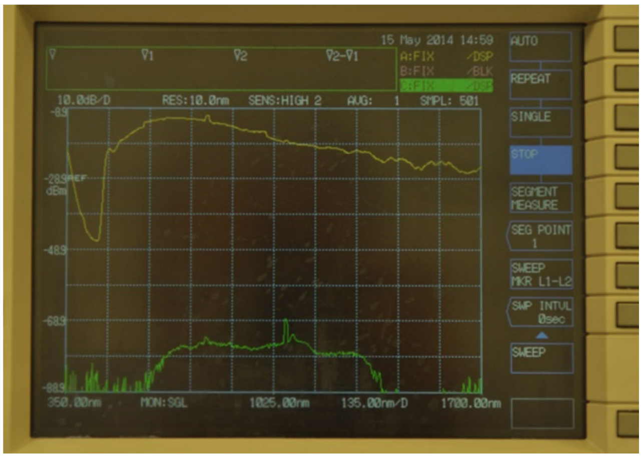

Fig. 2– Graph of measurements taken on sprague dawley rat liver (sample 2, Liver 2) shown by Spectrum Analyzer display.

The values of the light, which crosses the tissue (Liver 2), are represented in Fig. 3, along with the values of light emitted freely through the air without anything interposed (reference or calibration path, REF). In the same figure you see also the graph of liver light absorption (Absorption). Its value is the difference between the emitted light and the passing light through the tissue (transmitted).

Also in this case (Fig. 3) you see that the values from 350.000 nm and 606.500 nm included (Fig. 5), and from 1396.250 nm till 1700.000 nm included (Fig. 6), the passing light values in the tissue are very variable. They may look like light absence spikes (-210.000 dBm) followed by partially absorbed light whose value is less than or close to -80 dBm. Again, for the reasons already stated they represent the wavelengths at which radiation is completely absorbed.

A vision of the same wavelengths range, using a more detailed scale (Fig. 5), would seem to show that the light pass in the tissue at wavelengths higher than 607.850 nm. Instead the values analysis shows that from 607.50 nm till 667.250 nm included, the passing radiation measurements through the liver (sample 2, Liver 2) still has a power level less than -80 dBm (Table 1). So also for these range it can be considered that the radiation is completely absorbed by the liver (sample 2, Liver 2).

From the wavelength of 668.600 nm till 1322.000 nm included, the passing light values are greater than -80 dBm. Hence, being the values reliable, we can say that in this wavelengths portion, the light can effectively pass through the liver (Fig. 3, Fig. 4).

The second group of spikes begins at 1396.250 nm till 1700.000 nm (Fig. 3, Fig. 4, Fig. 6). In this range the light is completely absorbed in the liver (sample 2, Liver 2). However, also in this case, the numbers analysis shows that the passing radiation values begin to be less than -80 dBm already at wavelength between of 1323,350 nm till 1394.900 nm after which, at 1396.250 nm, the already mentioned spikes start (Fig. 3, Fig. 4, Fig. 6, Table 2). For the reasons already stated, starting from 1323.350 nm till 1394.900 nm, also these radiation values must be discarded and, therefore, in this range of wavelength, we conclude the radiation is completely absorbed by the liver (Table 2).

It thus appears that the light effectively passes through the liver (sample 2, Liver 2) between 668.600 nm and 1322.000 nm (Table 3).

In the figures are represented graphically the instrument reference values (REF), the passing light values through the tissue (Liver 2) and absorbed light values by the liver (Absorption).

On first analysis it can be seen that the transmitted light increase progressively from 668.600 nm till 1057.400 nm (Fig. 3, Fig. 4). Starting from this latter wavelength (Fig. 7) the passing light amount through the liver has a significant increase till 1062.800 nm, to which transmission is the highest, then decrease till the wavelength of 1070.900 nm (Table 5).

Accordingly, in these wavelengths range the absorption in the tissue has a drastic decrease. From the wavelength of 1070.900 nm onward, the transmission remains again fairly constant till the wavelength of 1322.000 nm (Fig. 3, Fig. 4, Fig. 5, Fig. 9) when it starts to decrease below -80 dBm till 1396.250 nm when absorbed light spikes start (Fig. 9).

Also in this case, by examining the graph of Fig. 3 e Fig. 4, it would seem that significant radiation values pass through the examined tissue at wavelengths around 800 nm.

But in this case, as well as in the previous, the transmitted power increase follow the source light increase, without reduction of absorbed radiation that, for those wavelengths, is almost constant. In this regard see the detail shown in the graph of Fig. 8 and values for that field of wavelengths shown in Table 4. The maximum value of source light it is revealed at 809.000 nm, but for this wavelength the transmission is neither the highest nor the absorption is the minimum.

A summary is shown in Table 6.

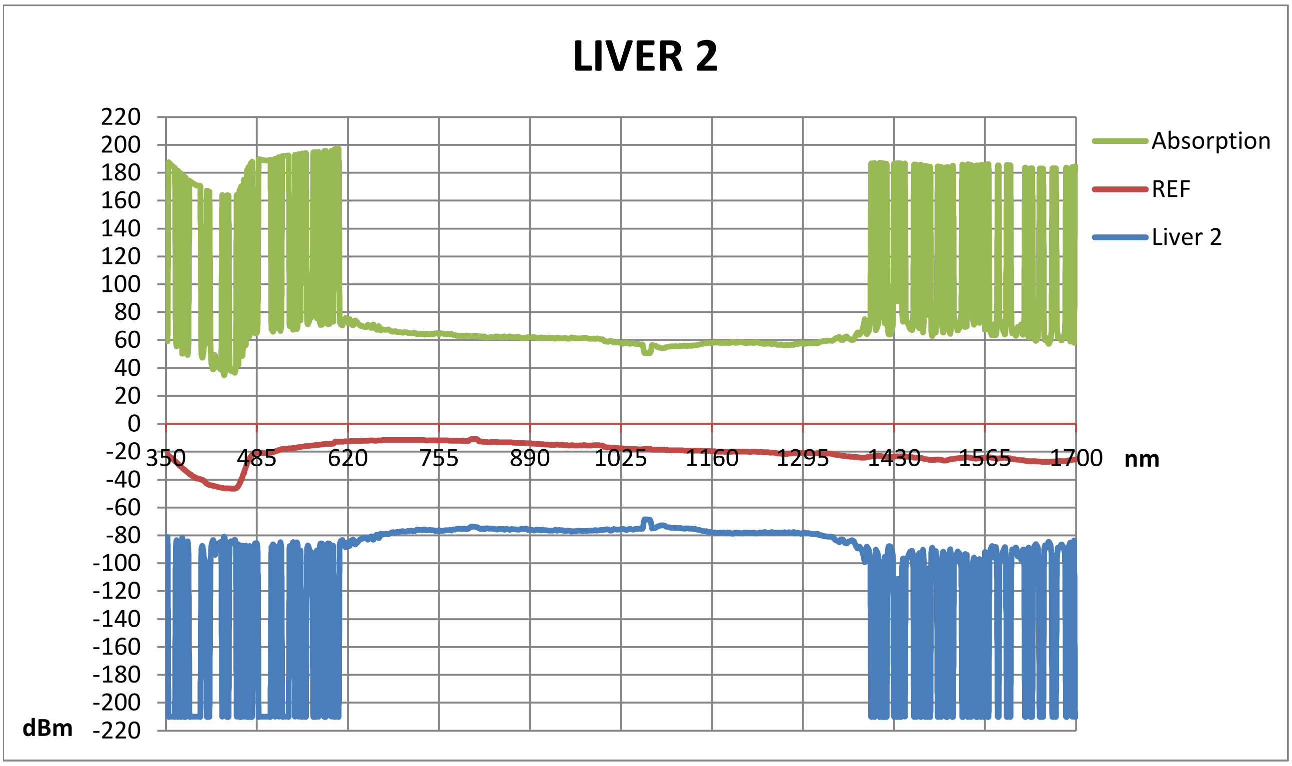

Fig. 3 – Graph of the reference radiation source (REF), the radiation that passes through the tissue (Liver 2) and absorption (Absorption) in sprague dawley rat liver (sample 2, Liver 2).

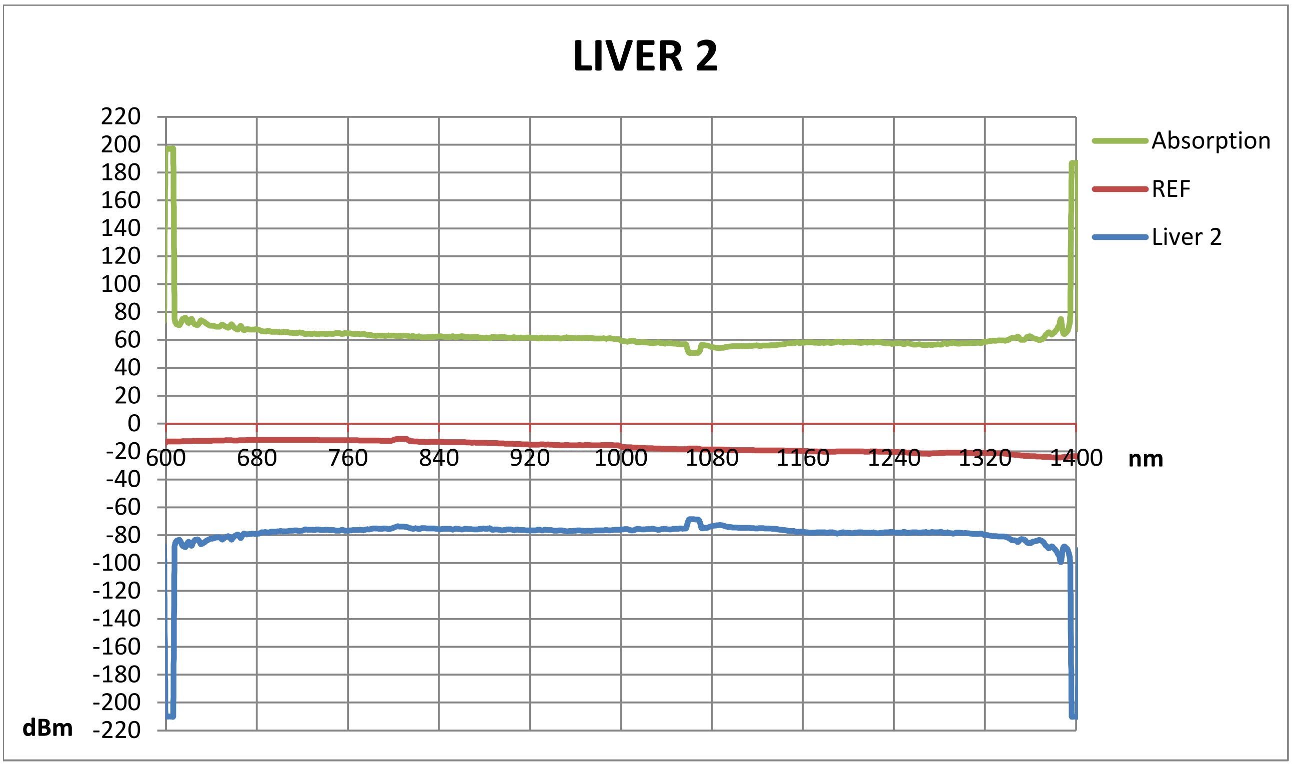

Fig. 4 – Graph of the reference radiation source (REF), the radiation that passes through the tissue (Liver 2) and absorption (Absorption) in sprague dawley rat liver (sample 2, Liver 2) for wavelengths from 600 nm till 1400 nm.

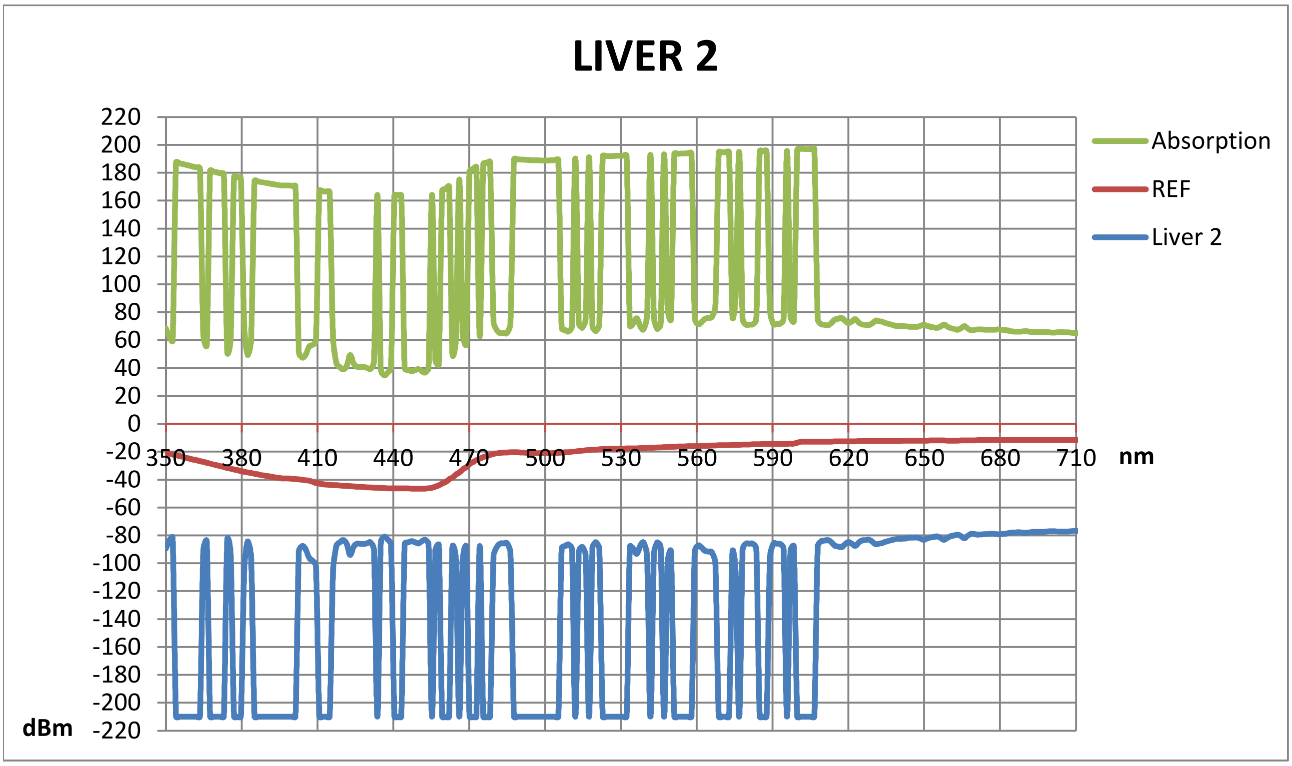

Fig. 5 – Graph of the reference radiation source (REF), the radiation that passes through the tissue (Liver 2) and absorption (Absorption) in sprague dawley rat liver (sample 2, Liver 2) for wavelengths from 350 nm till 710 nm.

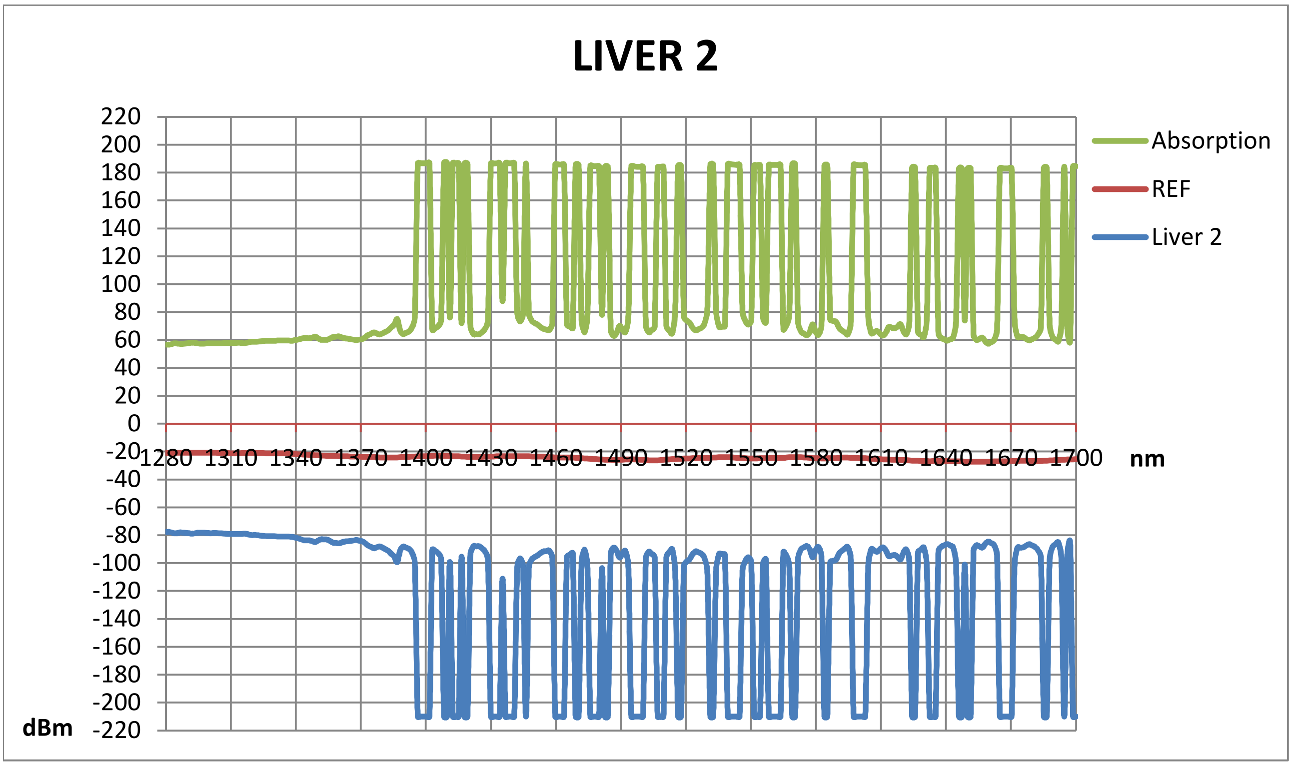

Fig. 6 – Graph of the reference radiation source (REF), the radiation that passes through the tissue (Liver 2) and absorption (Absorption) in sprague dawley rat liver (sample 2, Liver 2) for wavelengths from 1280 nm till 1700 nm.

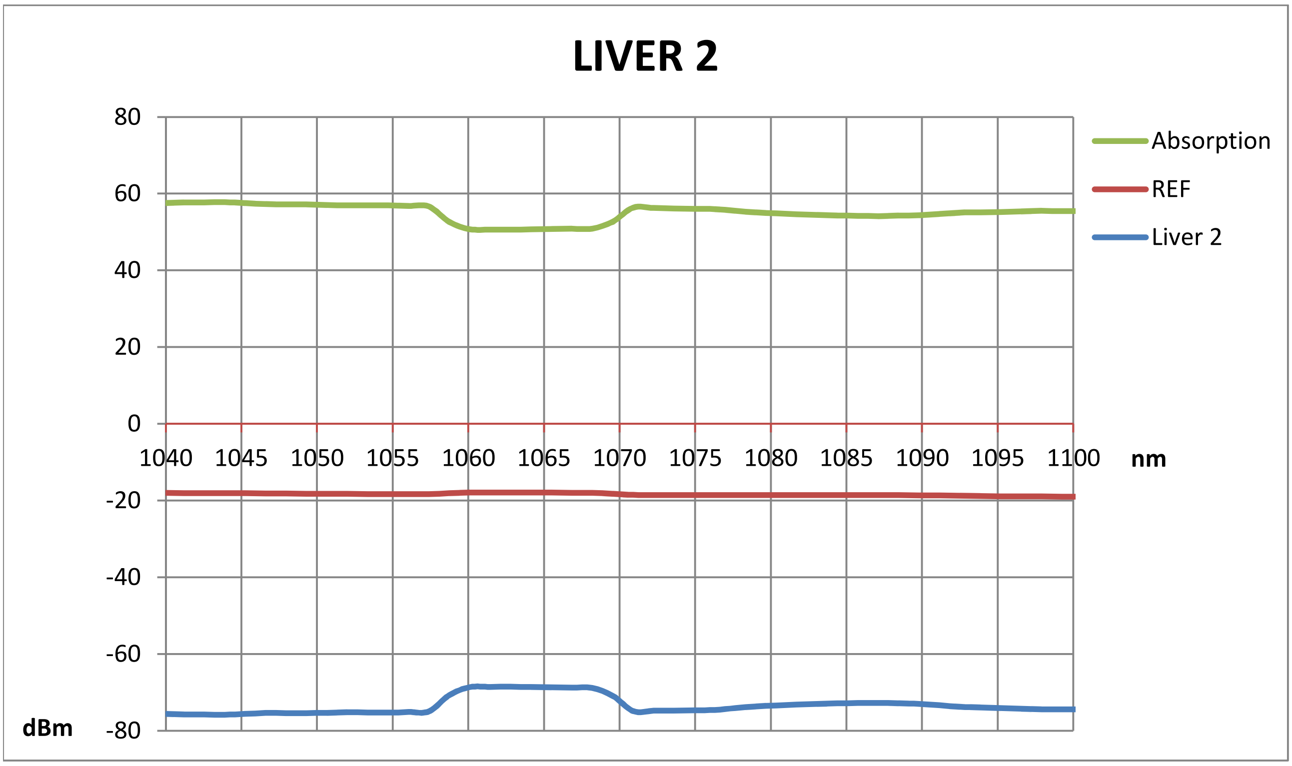

Fig. 7 – Graph of the reference radiation source (REF), the radiation that passes through the tissue (Liver 2) and absorption (Absorption) in sprague dawley rat liver (sample 2, Liver 2) for wavelengths from 1040 nm till 1100 nm.

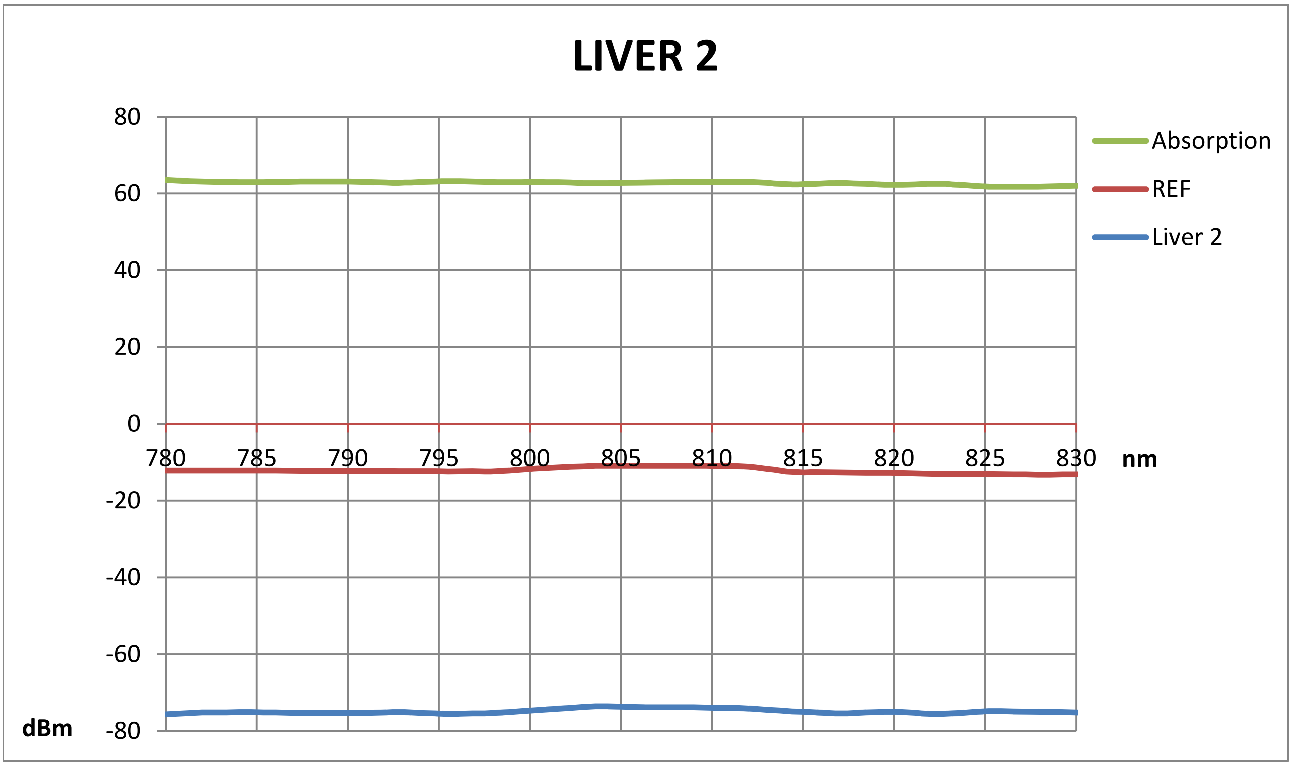

Fig. 8 – Graph of the reference radiation source (REF), the radiation that passes through the tissue (Liver 2) and absorption (Absorption) in sprague dawley rat liver (sample 2, Liver 2) for wavelengths from 780 nm till 830 nm.

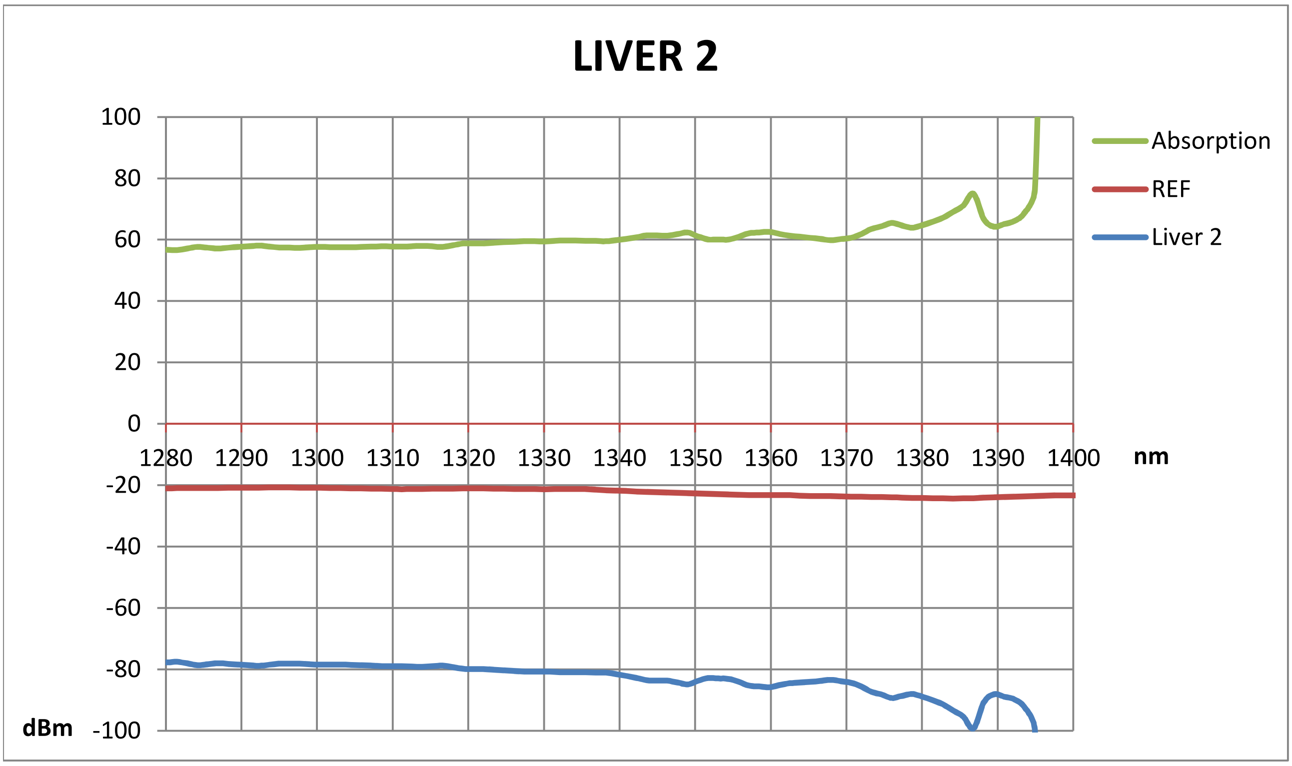

Fig. 9 – Graph of the reference radiation source (REF), the radiation that passes through the tissue (Liver 2) and absorption (Absorption) in sprague dawley rat liver (sample 2, Liver 2) for wavelengths from 1280 nm till 1400 nm.

Wavelength (nm)	Liver 2 Measure (dBm)	Wavelength (nm)	Liver 2 Measure (dBm)
607.850	**-87.925**	638.900	**-82.642**
609.200	**-84.282**	640.250	**-82.521**
610.550	**-83.782**	641.600	**-82.403**
611.900	**-83.334**	642.950	**-82.001**
613.250	**-84.926**	644.300	**-81.633**
614.600	**-87.466**	645.650	**-81.573**
615.950	**-87.964**	647.000	**-81.515**
617.300	**-88.527**	648.350	**-82.248**
618.650	**-86.264**	649.700	**-83.130**
620.000	**-84.784**	651.050	**-82.267**
621.350	**-85.960**	652.400	**-81.547**
622.700	**-87.578**	653.750	**-81.139**
624.050	**-85.161**	655.100	**-80.765**
625.400	**-83.618**	656.450	**-81.812**
626.750	**-83.350**	657.800	**-83.193**
628.100	**-83.098**	659.150	**-81.704**
629.450	**-84.448**	660.500	**-80.598**
630.800	**-86.417**	661.850	**-80.017**
632.150	**-85.915**	663.200	-79.504
633.500	**-85.465**	664.550	**-80.585**
634.850	**-84.520**	665.900	**-82.027**
636.200	**-83.745**	667.250	**-80.153**
637.550	**-83.159**		

Table 1 - Values of measured light from spectrum analyzer in sprague dawley rat liver (sample 2, Liver 2) at wavelengths from 607.850 nm a 667.250 nm. The values lower than -80 dBm are in red. For the reasons illustrated in this chapter it is believed that the light is completely absorbed at these wavelengths.

Wavelength (nm)	Liver 2 Measure (dBm)	Wavelength (nm)	Liver 2 Measure (dBm)
1323.350	**-80.143**	1359.800	**-85.847**
1324.700	**-80.390**	1361.150	**-85.154**
1326.050	**-80.575**	1362.500	**-84.556**
1327.400	**-80.768**	1363.850	**-84.342**
1328.750	**-80.767**	1365.200	**-84.139**
1330.100	**-80.766**	1366.550	**-83.769**
1331.450	**-80.873**	1367.900	**-83.428**
1332.800	**-80.983**	1369.250	**-83.881**
1334.150	**-80.981**	1370.600	**-84.386**
1335.500	**-80.979**	1371.950	**-85.616**
1336.850	**-81.033**	1373.300	**-87.339**
1338.200	**-81.088**	1374.650	**-88.235**
1339.550	**-81.597**	1376.000	**-89.366**
1340.900	**-82.175**	1377.350	**-88.662**
1342.250	**-82.817**	1378.700	**-88.057**
1343.600	**-83.570**	1380.050	**-88.948**
1344.950	**-83.641**	1381.400	**-90.070**
1346.300	**-83.713**	1382.750	**-91.433**
1347.650	**-84.282**	1384.100	**-93.431**
1349.000	**-84.937**	1385.450	**-95.433**
1350.350	**-83.783**	1386.800	**-99.259**
1351.700	**-82.872**	1388.150	**-90.847**
1353.050	**-82.994**	1389.500	**-88.161**
1354.400	**-83.120**	1390.850	**-88.908**
1355.750	**-84.082**	1392.200	**-89.811**
1357.100	**-85.319**	1393.550	**-92.387**
1358.450	**-85.575**	1394.900	**-99.588**

Table 2 - Values of measured light from spectrum analyzer in sprague dawley rat liver (sample 2, Liver 2) at wavelengths from 1323.350 nm a 1394.900 nm. The values lower than -80 dBm are in red. For the reasons illustrated in this chapter it is believed that the light is completely absorbed at these wavelengths.

Wavelength (nm)		Liver 2 Measure (dBm)	Liver 2 Absorption (dB)
from	till		
350.000	**606.500**	**spikes < -80**	**full absorption**
607.850	**667.250**	**values < -80**	**full absorption**
668.600	**1322.000**	**values > -80**	**valid values**
1323.350	**1394.900**	**values < -80**	**full absorption**
1396.250	**1700.000**	**spikes < -80**	**full absorption**

Table 3 – Summary of wavelengths where light is completely absorbed in sprague dawley rat liver (sample 2, Liver 2). Values lower than -80 dBm are deemed too small because they are not read by the spectrum analyzer. So those wavelengths light are considered completely absorbed.

Wavelength (nm)	REF (dBm)	Liver 2 Measure (dBm)	Liver 2 Absorption (dB)
798.200	-12.350	-75.325	62.975
799.550	-11.882	-74.869	62.987
800.900	-11.459	-74.457	62.998
802.250	-11.187	-74.023	62.836
803.600	-10.931	-73.628	62.697
804.950	-10.930	-73.733	62.803
806.300	-10.929	-73.839	62.910
807.650	-10.913	-73.870	62.957
809.000	**-10.897**	-73.902	63.005
810.350	-10.977	-74.008	63.031
811.700	-11.058	-74.117	63.059
813.050	-11.737	-74.497	62.760
814.400	-12.543	-74.913	62.370
815.750	-12.615	-75.175	62.560

Table 4 - The table shows that the value of absorption in sprague dawley rat liver (sample 2, Liver 2) remains almost constant for wavelength from 798.200 nm till 815.750 nm. At 809.000 nm the value of source is maximum (in red), but despite this absorption is almost constant.

Wavelength (nm)	REF (dBm)	Liver 2 Measure (dBm)	Liver 2 Absorption (dB)
1045.250	-18.102	-75.618	57.516
1046.600	-18.139	-75.398	57.259
1047.950	-18.178	-75.419	57.241
1049.300	-18.217	-75.441	57.224
1050.650	-18.250	-75.327	57.077
1052.000	-18.284	-75.216	56.932
1053.350	-18.324	-75.268	56.944
1054.700	-18.364	-75.320	56.956
1056.050	-18.349	-75.149	56.800
1057.400	-18.334	-74.985	56.651
1058.750	-18.123	-70.748	52.625
1060.100	-17.921	-68.645	50.724
1061.450	-17.932	-68.591	50.659
1062.800	-17.942	**-68.537**	50.595
1064.150	-17.941	-68.626	50.685
1065.500	-17.939	-68.716	50.777
1066.850	-17.964	-68.800	50.836
1068.200	-17.988	-68.885	50.897
1069.550	-18.255	-70.925	52.670
1070.900	-18.540	-74.900	56.360
1072.250	-18.565	-74.822	56.257
1073.600	-18.590	-74.746	56.156
1074.950	-18.604	-74.671	56.067
1076.300	-18.618	-74.597	55.979
1077.650	-18.597	-74.113	55.516

Table 5 - Values of radiation passing through and of radiation absorbed in sprague dawley rat liver (sample 2, Liver 2) in relation to radiation emitted at wavelengths from 1045.250 nm till 1077.650 nm. The maximum light value passing through the tissue is in red.

<table>
<tr><th colspan="2">Wavelength (nm)</th><th>dBm or dB</th><th>Light</th></tr>
<tr><td colspan="2"></td><td></td><td></td></tr>
<tr><td colspan="2">809.000</td><td>-10.897 dBm</td><td>maximum value of light source</td></tr>
<tr><td colspan="2">1062.800</td><td>50.595 dB</td><td>minimum absorption</td></tr>
<tr><td colspan="2">1062.800</td><td>-68.537 dBm</td><td>maximum transmission</td></tr>
<tr><td colspan="2">449.900</td><td>-46.547 dBm</td><td>minimum value of light source</td></tr>
<tr><td>from</td><td>till</td><td></td><td></td></tr>
<tr><td>350.000</td><td>606.500</td><td>spikes < -80</td><td>full absorption</td></tr>
<tr><td>607.850</td><td>667.250</td><td>values < -80</td><td>full absorption</td></tr>
<tr><td></td><td></td><td></td><td></td></tr>
<tr><td>668.600</td><td>1322.000</td><td>values > -80</td><td>valid values</td></tr>
<tr><td></td><td></td><td></td><td></td></tr>
<tr><td>1323.350</td><td>1394.900</td><td>values < -80</td><td>full absorption</td></tr>
<tr><td>1396.250</td><td>1700.000</td><td>spikes < -80</td><td>full absorption</td></tr>
</table>

Table 6 – Summary table.

12 Liver 3

Also in this case it is used sprague dawley rat liver. As already stated in the previous chapter, the test is performed on the same sample, dissected from cortical to cortical, obtaining a thickness portion 0.6 mm, called LIVER 3. The radiation crosses the sample directly through the parenchyma. It is positioned between the smaller plates with central hole having a diameter of 1.5 mm in order to cover the entire hole (Fig. 1). The source emits light with the values and the sequence already described (Fig. 2).

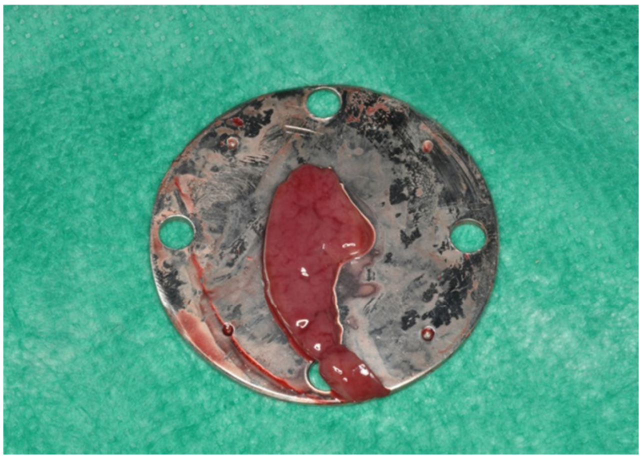

Fig. 1 – Sprague dawley rat liver vision (sample 3, Liver 3) positioned on the plate. The cutted part through the parenchyma, with a thickness of 0.6 mm, is positioned on the central hole.

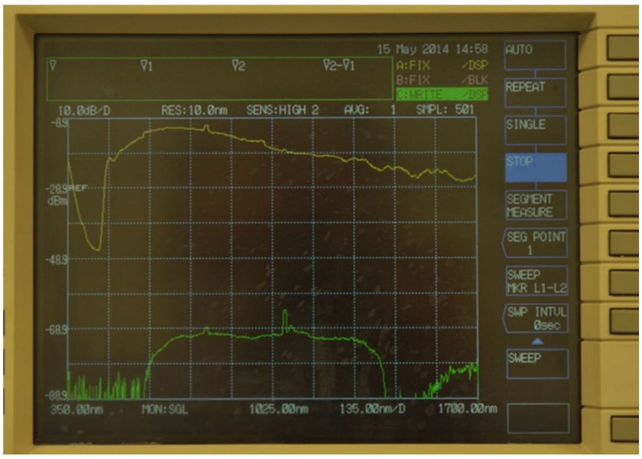

Fig. 2 – Graph of measurements taken on sprague dawley rat liver (sample 3, Liver 3) shown by Spectrum Analyzer display.

The values of the light, which crosses the tissue (Liver 3), are represented in Fig. 3, along with the values of light emitted freely through the air without anything interposed (reference or calibration path, REF). In the same figure you see also the graph of liver light absorption (Absorption). Its value is the difference between the emitted light and the passing light through the tissue (transmitted).

Also in this case (Fig. 3) you see that the values from 350.000 nm till 599.750 nm included (Fig. 5), and from 1415.150 nm till 1532.600 nm included (Fig. 6), the passing light values in the tissue are very variable. They may look like light absence spikes (-210.000 dBm) followed by partially absorbed light whose value is less than or close to -80 dBm. Again, for the reasons already stated they represent the wavelengths at which radiation is completely absorbed.

A vision of the same wavelengths range, using a more detailed scale (Fig. 5), would seem to show that the light pass in the tissue at wavelengths higher than 601.100 nm. Instead the values analysis shows that from 601.100 nm till 617.300 nm included, the passing radiation measurement through the liver (sample 3, Liver 3) still has a power level less than -80 dBm (Table 1). So also for these range it can be considered that the radiation is completely absorbed by the liver (sample 3, Liver 3).

From the wavelength of 618.650 nm till 1380.050 nm included, the passing light values are greater than -80 dBm. Hence, being the values reliable, we can say that in this wavelengths portion, the light can effectively pass through the liver (Fig. 3, Fig. 4).

The second group of spikes begins at 1415.150 nm and lasts till 1532.600 nm (Fig. 3, Fig. 6). In this range the light is completely absorbed in the liver (sample 3, Liver 3). However, also in this case, the numbers analysis shows that the passing radiation values begin to be less than -80 dBm already at wavelength of 1381.400 nm till 1413.800 nm (Fig. 6, Table 2) after which, at 1415.150 nm, the already mentioned spikes start. Again, for the reasons already stated, also these radiation values must be discarded and, therefore, in this range of wavelength, the radiation is completely absorbed by the liver (Table 2).

The spikes terminate at the wavelength of 1532.600 nm (Fig. 6), but all passing light values from 1533.950 nm till 1700.000 nm included are not reliable because below -80 dBm (Fig. 9). For the reasons already stated the transmitted light values in this wavelength range are discarded. Hence all the wavelength radiations from 1533.950 nm till 1700.000 nm are completely absorbed by the liver. These values cannot be listed in a table being too numerous and the table size would be too great.

It thus appears that the light effectively passes through the liver (sample 3, Liver 3) between 618.650 nm and 1380.050 nm (Table 3).

In the figures are represented graphically the reference instrument values (REF), the passing light values through the tissue (Liver 3) and absorbed light values by the liver (Absorption).

On first analysis it can be seen that the passing light through the tissue increase progressively from 601.100 nm till 1057.400 nm (Fig. 3, Fig. 4, Fig. 7). Starting from this latter wavelength (Fig. 7) the passing light amount through the liver has a significant increase till 1065.500 nm, to which transmission is the highest, then it decreases till the wavelength of 1070.900 nm (Table 5).

Accordingly, in these wavelengths range the absorption in the tissue has a drastic decrease. From the wavelength of 1070.900 nm onward, the transmission remains again fairly constant till the wavelength of 1323.350 nm (Fig. 3, Fig. 4) when it starts to decrease, and at 1381.400 nm it decreases below -80 dBm and at 1415.150 nm absorption light spikes start (Fig. 6).

Also in this case, by examining the graph of Fig. 3 e Fig. 4, it would seem that significant radiation values pass through the examined tissue at wavelengths around 800 nm.

But in this case, as well as in the previous, the transmitted power increase follow the source light increase, without reduction of absorbed radiation that, for those wavelengths, is almost constant. In this regard see the detail shown in the graph of Fig. 8 and values for that field of wavelengths shown in Table 4. The maximum value of source light it is revealed at 809.000 nm, but for this wavelength the transmission is neither the highest nor the absorption is the minimum.

A summary is shown in Table 6.

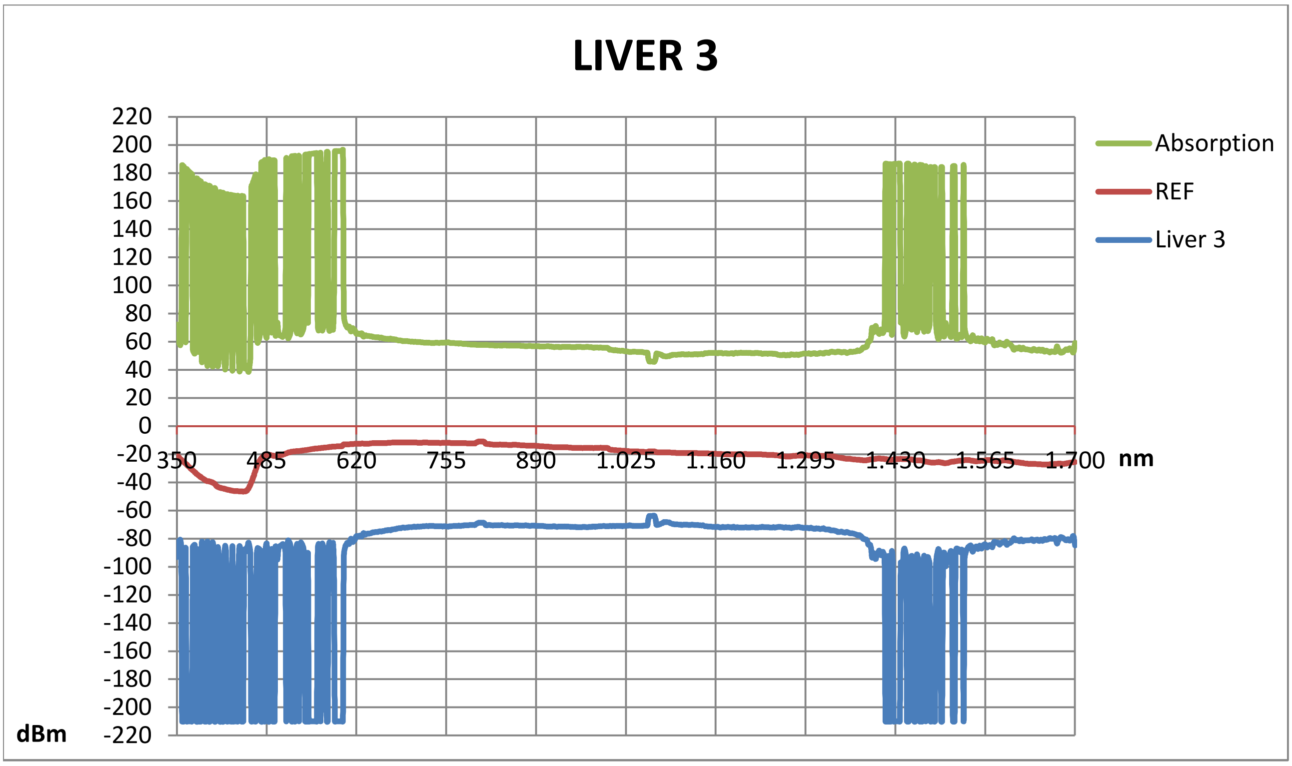

Fig. 3 – Graph of the reference radiation source (REF), the radiation that passes through the tissue (Liver 3) and absorption (Absorption) in sprague dawley rat liver (sample 3, Liver 3).

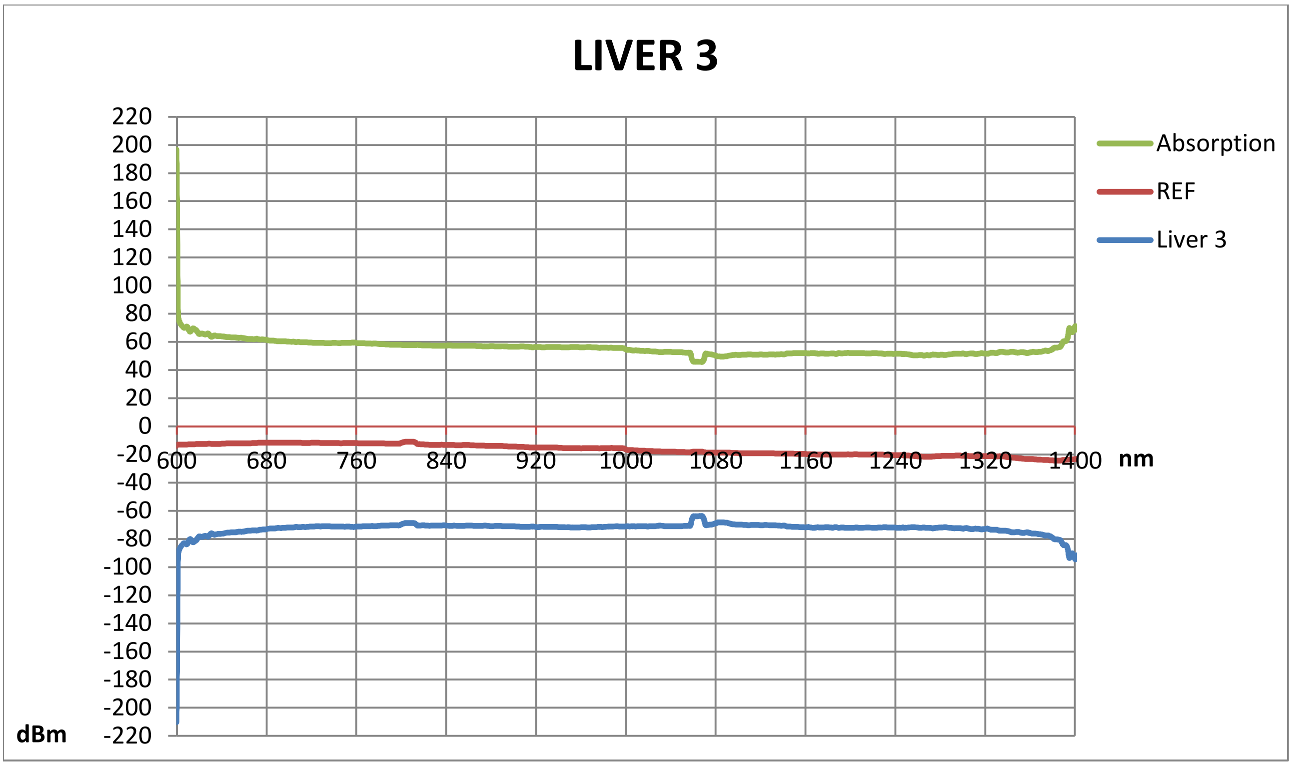

Fig. 4 – Graph of the reference radiation source (REF), the radiation that passes through the tissue (Liver 3) and absorption (Absorption) in sprague dawley rat liver (sample 3, Liver 3) for wavelengths from 600 nm till 1400 nm.

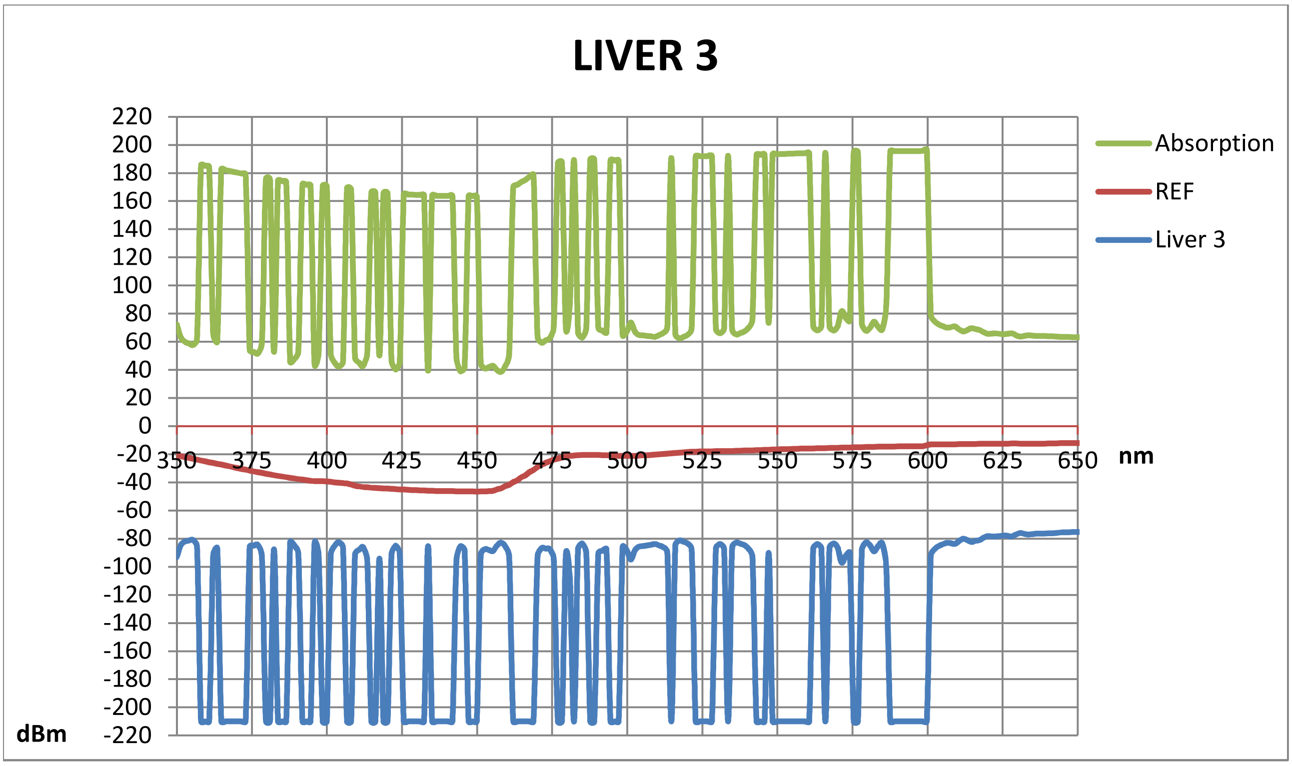

Fig. 5 – Graph of the reference radiation source (REF), the radiation that passes through the tissue (Liver 3) and absorption (Absorption) in sprague dawley rat liver (sample 3, Liver 3) for wavelengths from 350 nm till 650 nm.

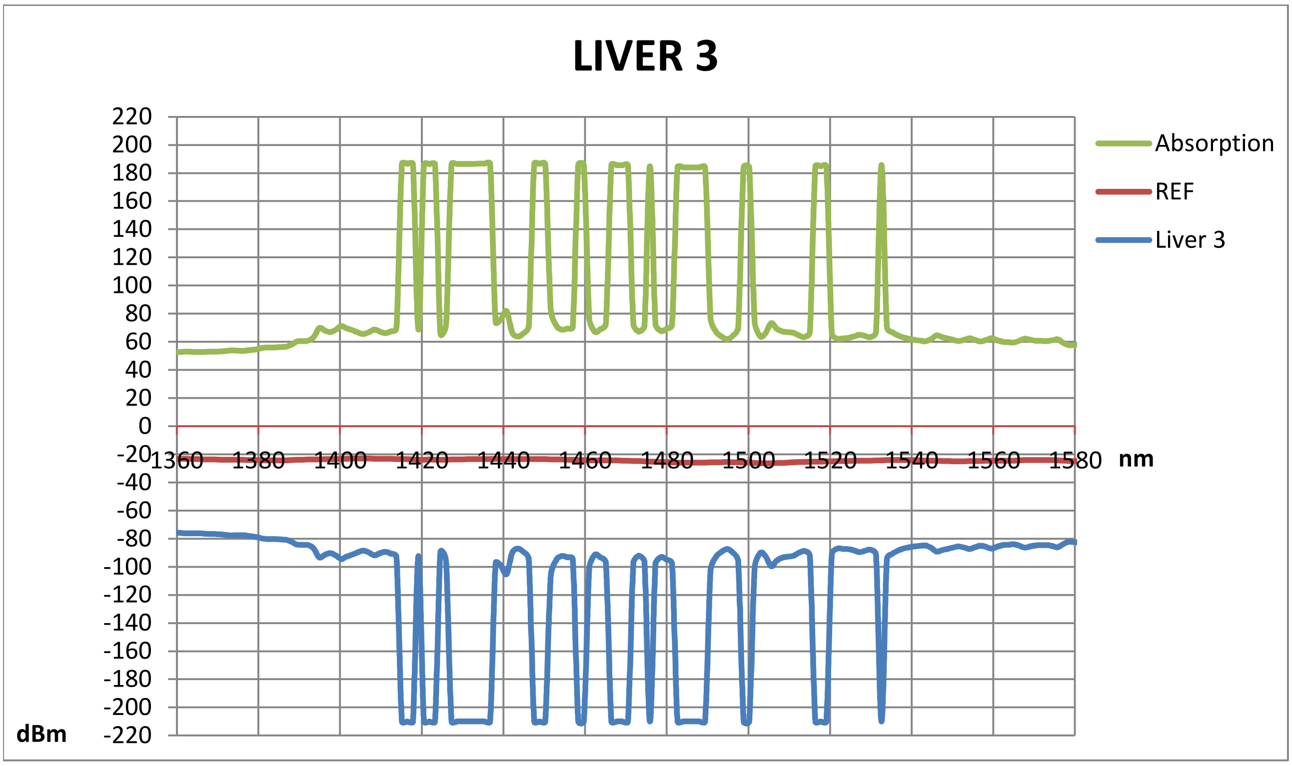

Fig. 6 – Graph of the reference radiation source (REF), the radiation that passes through the tissue (Liver 3) and absorption (Absorption) in sprague dawley rat liver (sample 3, Liver 3) for wavelengths from 1360 nm till 1580 nm.

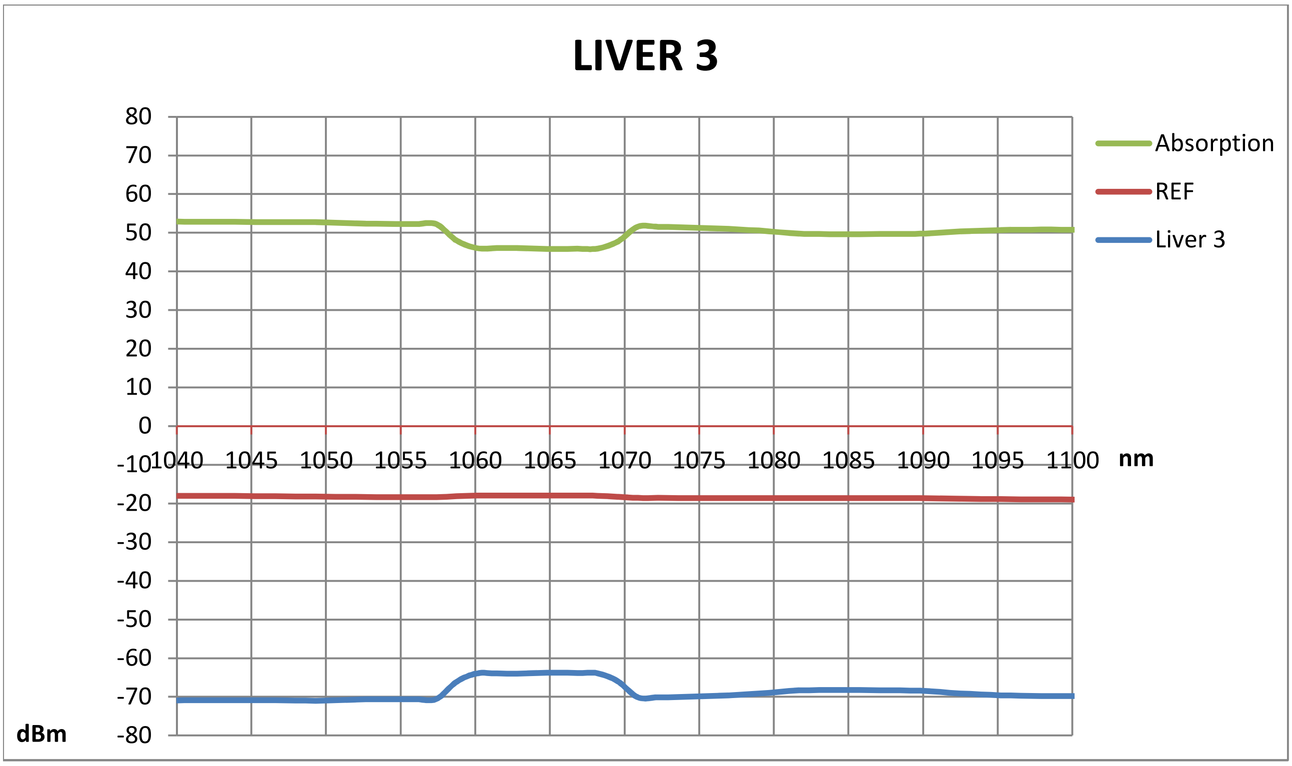

Fig. 7 – Graph of the reference radiation source (REF), the radiation that passes through the tissue (Liver 3) and absorption (Absorption) in sprague dawley rat liver (sample 3, Liver 3) for wavelengths from 1040 nm till 1100 nm.

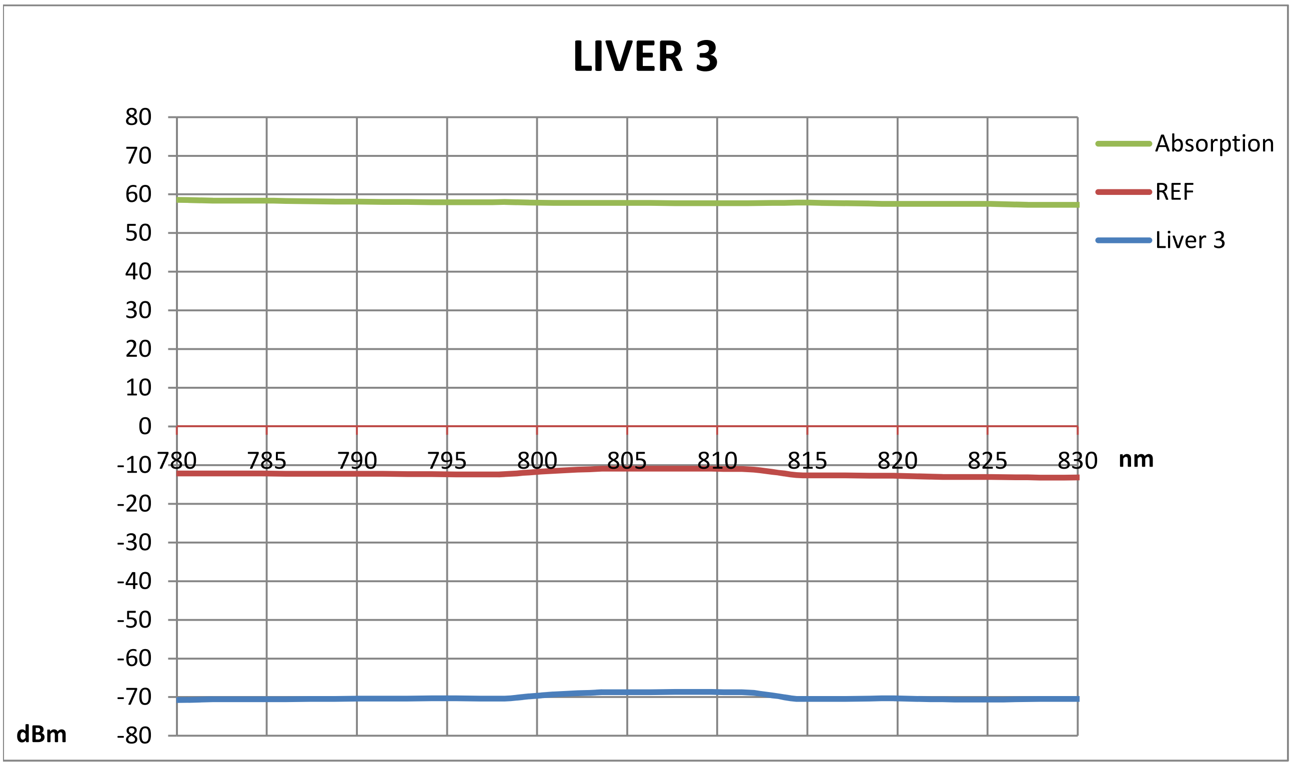

Fig. 8 – Graph of the reference radiation source (REF), the radiation that passes through the tissue (Liver 3) and absorption (Absorption) in sprague dawley rat liver (sample 3, Liver 3) for wavelengths from 780 nm till 830 nm.

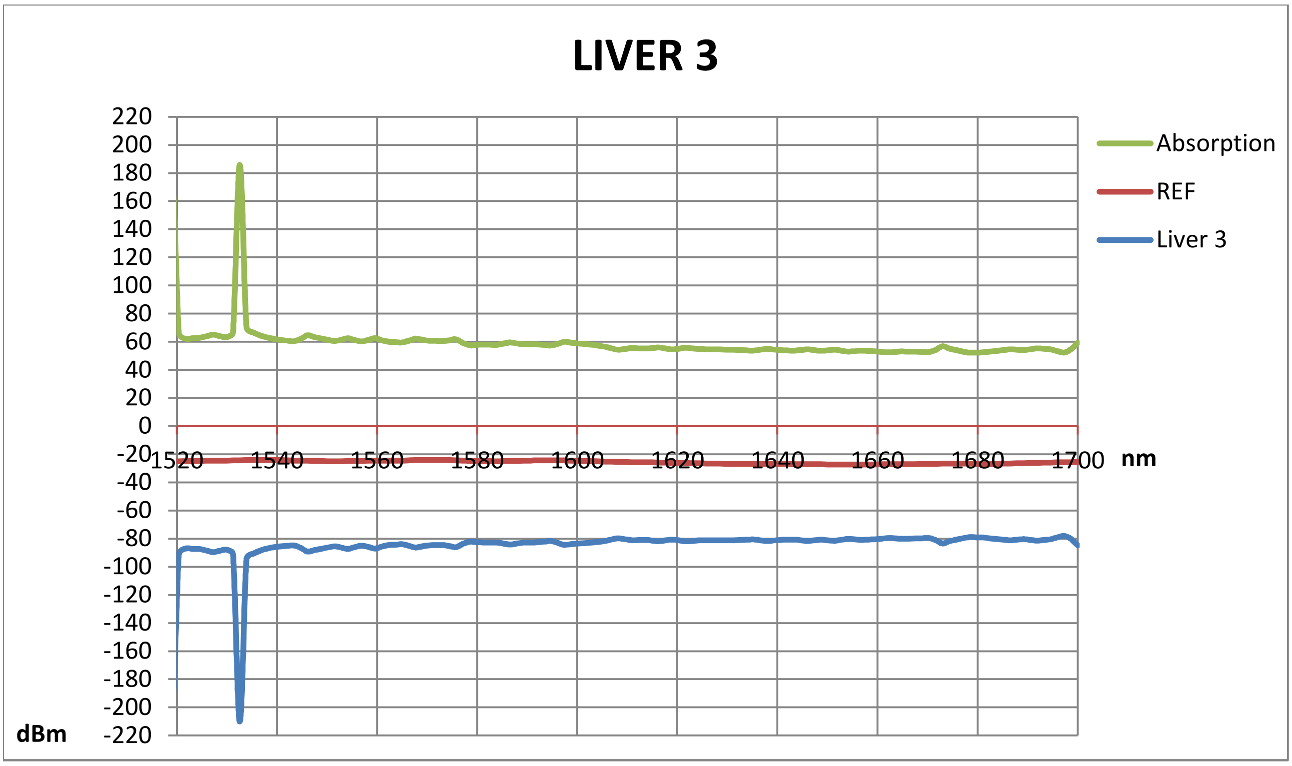

Fig. 9 – Graph of the reference radiation source (REF), the radiation that passes through the tissue (Liver 3) and absorption (Absorption) in sprague dawley rat liver (sample 3, Liver 3) for wavelengths from 1520 nm till 1700 nm.

Wavelength (nm)	Liver 3 Measure (dBm)	Wavelength (nm)	Liver 3 Measure (dBm)
601.100	**-92.002**	610.550	**-81.534**
602.450	**-87.360**	611.900	**-80.077**
603.800	**-85.168**	613.250	**-81.068**
605.150	**-83.890**	614.600	**-82.353**
606.500	**-82.904**	615.950	**-81.627**
607.850	**-83.303**	617.300	**-81.005**
609.200	**-83.742**		

Table 1 - Values of measured light from spectrum analyzer in sprague dawley rat liver (sample 3, Liver 3) at wavelengths from 601.100 nm till 617.300 nm. The values lower than -80 dBm are in red. For the reasons illustrated in this chapter it is believed that the light is completely absorbed at these wavelengths.

Wavelength (nm)	Liver 3 Measure (dBm)	Wavelength (nm)	Liver 3 Measure (dBm)
1381.400	**-80.088**	1398.950	**-91.885**
1382.750	**-80.196**	1400.300	**-94.517**
1384.100	**-80.308**	1401.650	**-92.686**
1385.450	**-80.560**	1403.000	**-91.402**
1386.800	**-80.828**	1404.350	**-89.707**
1388.150	**-82.206**	1405.700	**-88.491**
1389.500	**-84.236**	1407.050	**-89.844**
1390.850	**-84.379**	1408.400	**-91.819**
1392.200	**-84.527**	1409.750	**-90.396**

1393.550	-87.001	1411.100	-89.326
1394.900	-93.341	1412.450	-90.712
1396.250	-91.531	1413.800	-92.759
1397.600	-90.258		

Table 2 - Values of measured light from spectrum analyzer in sprague dawley rat liver (sample 3, Liver 3) at wavelengths from 1381.400 nm till 1413.800 nm. The values lower than -80 dBm are in red. For the reasons illustrated in this chapter it is believed that the light is completely absorbed at these wavelengths.

Wavelength (nm)		Liver 3 Measure (dBm)	Liver 3 Absorption (dB)
from	till		
350.000	599.750	spikes < -80	full absorption
605.150	617.300	values < -80	full absorption
618.650	1380.050	values > -80	valid values
1381.400	1413.800	values < -80	full absorption
1415.150	1532.600	spikes < -80	full absorption
1533.950	1700.000	values < -80	full absorption

Table 3 Summary of wavelengths where light is completely absorbed in sprague dawley rat liver (sample 3, Liver 3). Values lower than -80 dBm are deemed too small because they are not read by the spectrum analyzer. So those wavelengths light are considered completely absorbed.

Wavelength (nm)	REF (dBm)	Liver 3 Measure (dBm)	Liver 3 Absorption (dB)
798.200	-12.350	-70.377	58.027
799.550	-11.882	-69.807	57.925
800.900	-11.459	-69.303	57.844
802.250	-11.187	-69.007	57.820
803.600	-10.931	-68.730	57.799
804.950	-10.930	-68.722	57.792
806.300	-10.929	-68.714	57.785
807.650	-10.913	-68.665	57.752
809.000	-10.897	-68.617	57.720
810.350	-10.977	-68.693	57.716
811.700	-11.058	-68.770	57.712
813.050	-11.737	-69.522	57.785
814.400	-12.543	-70.432	57.889
815.750	-12.615	-70.426	57.811

Table 4 - The table shows that the value of absorption in sprague dawley rat liver (sample 3, Liver 3) remains almost constant for wavelength from 798.200 nm till 815.750 nm. At 809.000 nm the value of source is maximum (in red), but despite this absorption is almost constant.

Wavelength (nm)	REF (dBm)	Liver 3 Measure (dBm)	Liver 3 Absorption (dB)
1045.250	-18.102	-70.900	52.798
1046.600	-18.139	-70.898	52.759
1047.950	-18.178	-70.951	52.773
1049.300	-18.217	-71.004	52.787
1050.650	-18.250	-70.839	52.589
1052.000	-18.284	-70.681	52.397
1053.350	-18.324	-70.654	52.330
1054.700	-18.364	-70.628	52.264

1056.050	-18.349	-70.586	52.237
1057.400	-18.334	-70.544	52.210
1058.750	-18.123	-66.101	47.978
1060.100	-17.921	-63.951	46.030
1061.450	-17.932	-63.959	46.027
1062.800	-17.942	-63.967	46.025
1064.150	-17.941	-63.858	45.917
1065.500	-17.939	**-63.751**	45.812
1066.850	-17.964	-63.829	45.865
1068.200	-17.988	-63.908	45.920
1069.550	-18.255	-65.989	47.734
1070.900	-18.540	-70.134	51.594
1072.250	-18.565	-70.099	51.534
1073.600	-18.590	-70.064	51.474
1074.950	-18.604	-69.897	51.293
1076.300	-18.618	-69.737	51.119
1077.650	-18.597	-69.443	50.846

Table 5 - Values of radiation passing through and of radiation absorbed in sprague dawley rat liver (sample 3, Liver 3) in relation to radiation emitted at wavelengths from 1045.250 nm till 1077.650 nm. The maximum light value passing through the tissue is in red.

Wavelength (nm)		dBm or dB	Light
809.000		**-10.897 dBm**	**maximum value of light source**
1065.500		**45.812 dB**	**minimum absorption**
1065.500		**-63.751 dBm**	**maximum transmission**
449.900		**-46.547 dBm**	**minimum value of light source**
from	**till**		
350.000	**599.750**	**spikes < -80**	**full absorption**
601.100	**617.300**	**values < -80**	**full absorption**
618.650	**1380.050**	**values > -80**	**valid values**
1381.400	**1413.800**	**values < -80**	**full absorption**
1415.150	**1532.600**	**spikes < -80**	**full absorption**
1533.950	**1700.000**	**values < -80**	**full absorption**

Table 6 – Summary table.

13 Muscle 1

It uses the left femur muscle of sprague dawley rat (Fig. 1). By this it is taken a part, with thickness of 2.5 mm, called MUSCLE 1, on which it is performed the first test (Fig. 2). Later it is taken another part, called MUSCLE 2, with thickness of 0.3 mm, on which it is performed another test. The first sample is positioned between the smaller plates with a central hole having a diameter of 1.5 mm in order to cover the entire hole (Fig. 2). The source emits the light with the values and the sequence already described (Fig. 3).

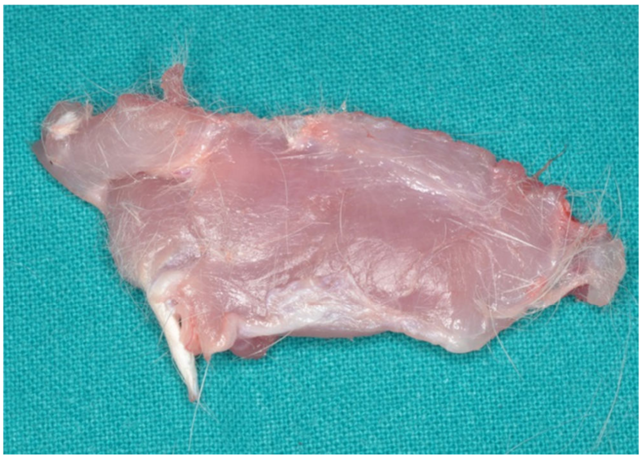

Fig. 1 Sprague dawley rat left femur muscle vision immediately after the sample taking.

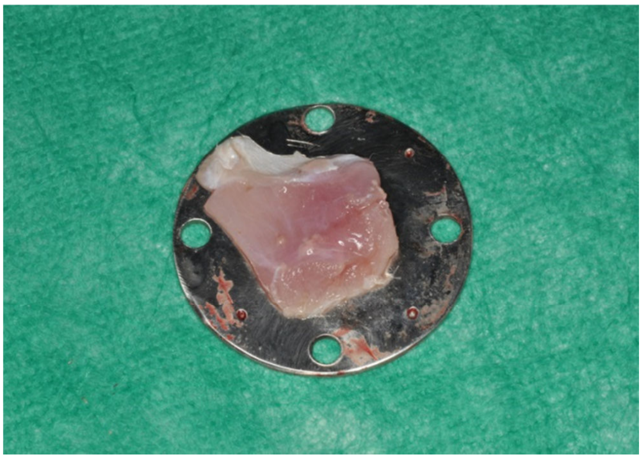

Fig. 2 – Sprague dawley rat muscle vision (sample 1) positioned on the plate. The part, with thickness of 2.5 mm, is positioned on the central hole.

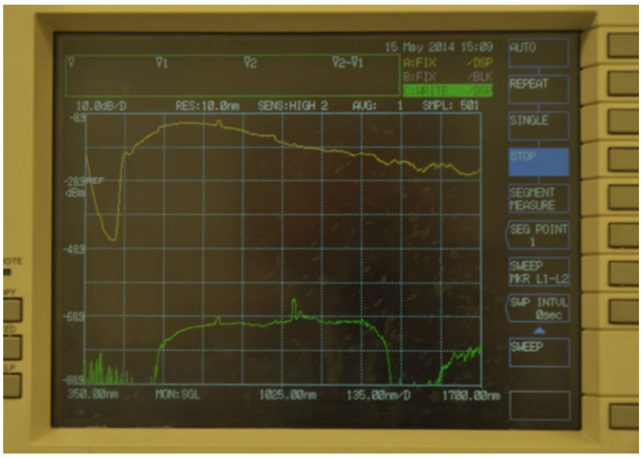

Fig. 3 – Graph of measurements taken on sprague dawley rat muscle (sample 1) shown by Spectrum Analyzer display.

The values of the light, which crosses the tissue (Muscle 1), are represented in Fig. 4, along with the values of light emitted freely through the air without anything interposed (reference or calibration path, REF).

In the same figure you see also the graph of the muscle light absorption (Absorption). Its value is the difference between the emitted light and the passing light through the tissue (transmitted).

Also in this case (Fig. 4) you see that the values from 350.000 nm till 590.300 nm included (Fig. 6), and from 1397.600 nm till 1538.000 included (Fig. 7), the passing light values in the tissue are very variable. They may look like light absence spikes (-210.000 dBm) followed by partially absorbed light whose value is less than or close to -80 dBm. Again, for the reasons already stated they represent the wavelengths at which radiation is completely absorbed.

A vision of the same wavelengths range, using a more detailed scale (Fig. 6), would seem to show that the light pass in the tissue at wavelengths higher than 591.650 nm. Instead the values analysis shows that from 591.650 nm till 602.450 nm included, the passing radiation measurement through the muscle (sample 1, Muscle 1) still has a power level less than -80 dBm (Fig. 4, Fig. 5,

Table 1). So also for these range it can be considered that the radiation is completely absorbed by the muscle.

From the wavelength of 603.800 nm till 1381.400 nm included, the passing light values are greater than -80 dBm. Hence, being the values reliable, we can say that in this wavelengths portion, the light can effectively pass through the muscle (Fig. 4, Fig. 5).

The second group of spikes begins at 1397.600 nm and lasts till 1538.000 nm (Fig. 4, Fig. 7). In this range the light is completely absorbed in the muscle (sample 1, Muscle 1). However, also in this case, the numbers analysis shows that the passing radiation values begin to be less than -80 dBm already at wavelength of 1382.750 nm till 1396.250 nm (Fig. 7, Table 2) after which, at 1397.600 nm, the already mentioned spikes start. Again, for the reasons already stated, also these radiation values must be discarded and, therefore, in this range of wavelength, the radiation is completely absorbed by the muscle (Fig. 7, Table 2).

The spikes terminate at the wavelength of 1538.000 nm (Fig. 7), but the passing light values from 1539.350 nm till 1700.000 nm included, are not reliable because almost all are below -80 dBm (Fig. 10). In this range of wavelengths there are only some values slightly greater to -80 dBm. The difference between the minimum value considered valid (-80 dBm) and the measured value in this field of wavelengths is less only of -1 dBm or -2 dBm, or even less than -1 dBm.

These values are not continuous and sequential, but scattered from 1539.350 nm till 1700.000 nm. Therefore with a big margin of reliability can be discarded. Hence, all the values in this range are values in which radiation is completely absorbed by the muscle. These values cannot be listed in a table being too numerous and the table size would be too great.

It thus appears that the light effectively passes through the muscle (sample 1, Muscle 1) from 603.800 nm till 1381.400 nm (Table 3).

In the figures are represented graphically the reference values of the instrument (REF), the passing light values through the tissue (Muscle 1) and absorbed light values by the muscle (Absorption).

On first analysis it can be seen that the passing light through the tissue increase progressively from 603.800 nm till 1057.400 nm (Fig. 4, Fig. 5). Starting from this latter wavelength (Fig. 8) the passing light amount through the muscle has a significant increase till 1065.500 nm, to which transmission is the highest, then it decreases till the wavelength of 1070.900 nm (Table 5).

Accordingly, in these wavelengths range the absorption in the tissue has a drastic decrease. From the wavelength of 1070.900 nm onward, the transmission remains again fairly constant till the wavelength of 1297.700 nm (Fig. 4, Fig. 5) when it starts to decrease, and at 1382.750 nm it decreases below -80 dBm and at 1397.600 nm light absorption spikes start (Fig. 7).

Also in this case, by examining the graph of Fig. 4 e Fig. 5, it would seem that significant radiation values pass through the examined tissue at wavelengths around 800 nm.

But in this case, as well as in the previous, the transmitted power increase follow the increase of the light source, without reduction of absorbed radiation that, for those wavelengths, is almost constant. In this regard see the detail shown in the graph of Fig. 9 and values for that field of wavelengths shown in Table 4. The maximum value of source light it is revealed at 809.000 nm, but for this wavelength the transmission is neither the highest nor the absorption is the minimum.

A summary is shown in Table 6.

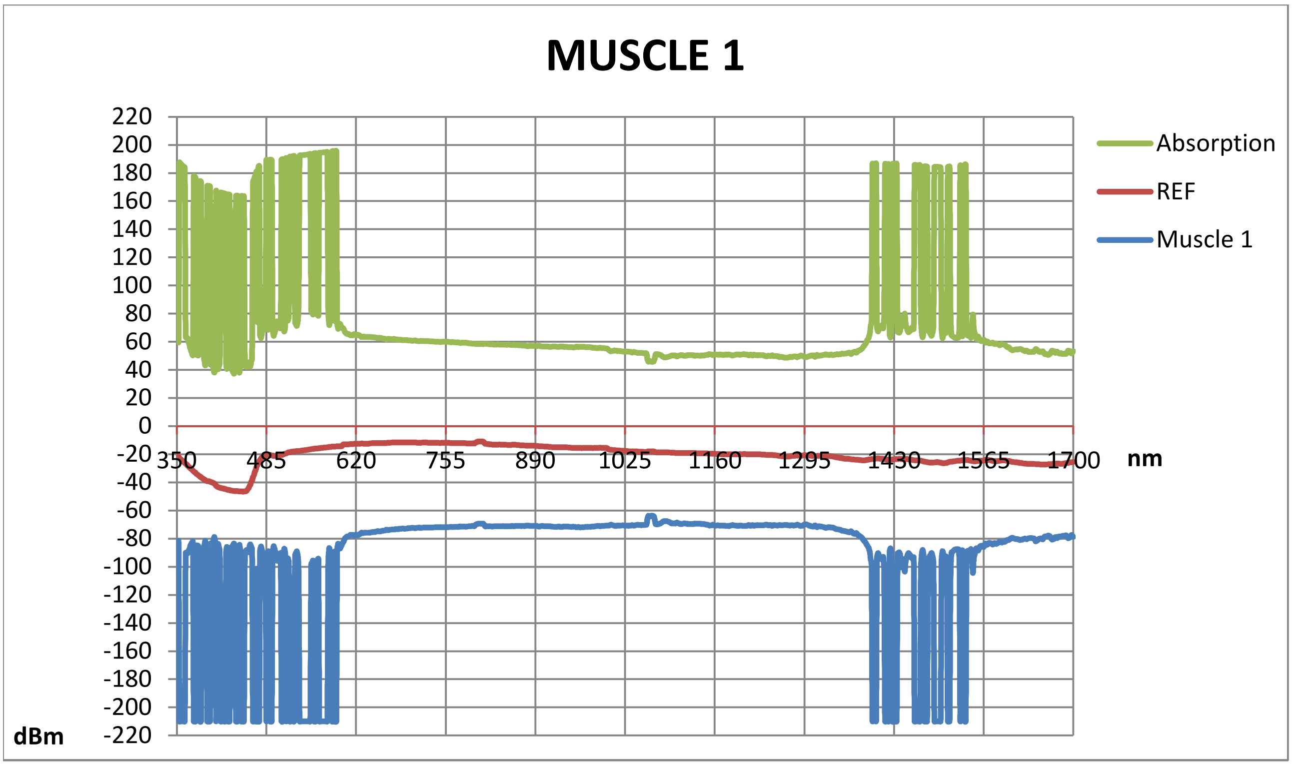

Fig. 4 – Graph of the reference radiation source (REF), the radiation that passes through the tissue (Muscle 1) and absorption (Absorption) in sprague dawley rat muscle (sample 1, Muscle 1).

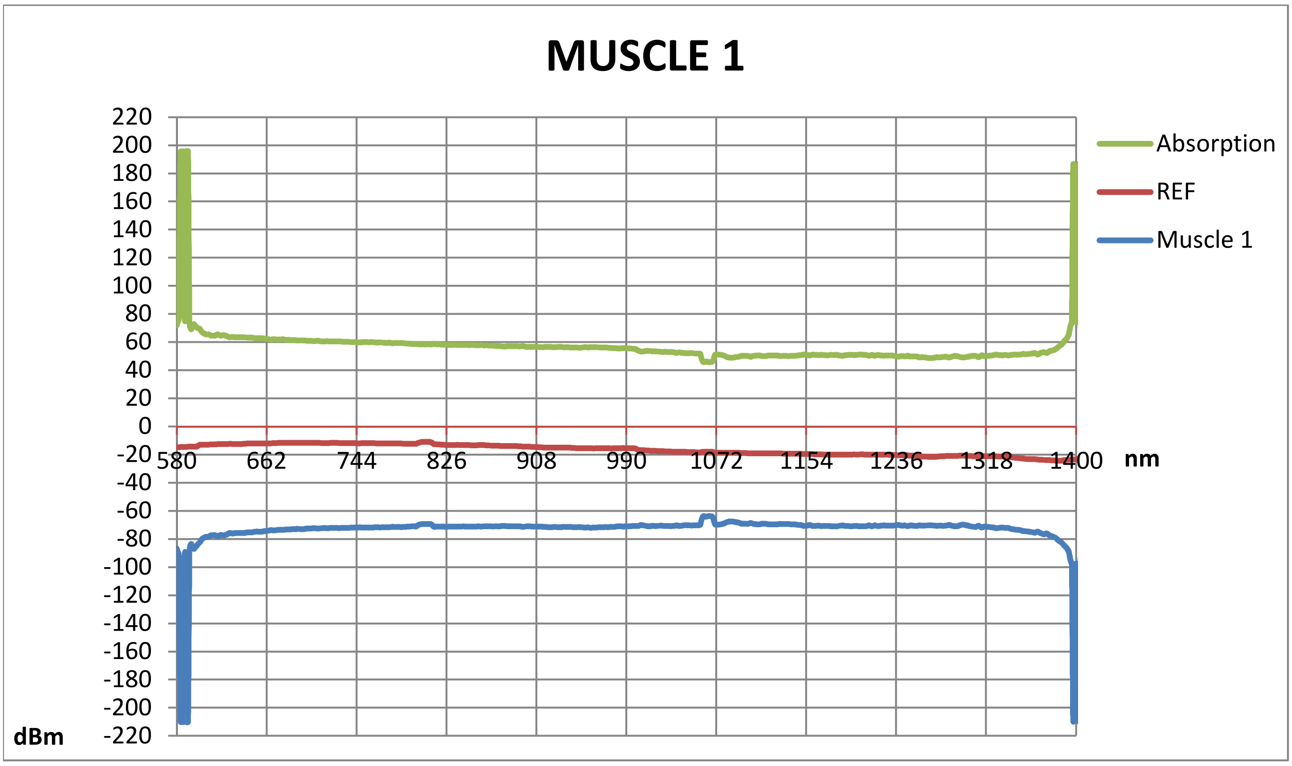

Fig. 5 – Graph of the reference radiation source (REF), the radiation that passes through the tissue (Muscle 1) and absorption (Absorption) in sprague dawley rat muscle (sample 1, Muscle 1) for wavelengths from 580 nm till 1400 nm.

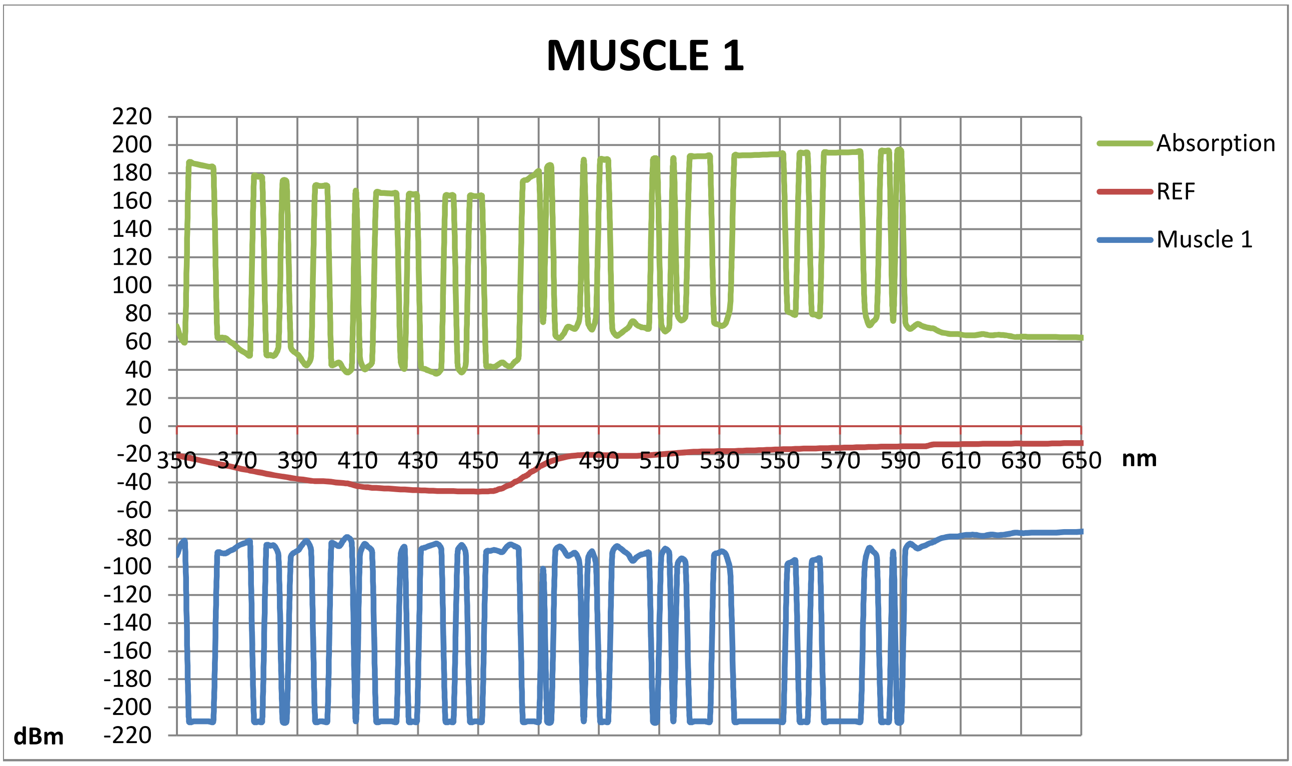

Fig. 6 – Graph of the reference radiation source (REF), the radiation that passes through the tissue (Muscle 1) and absorption (Absorption) in sprague dawley rat muscle (sample 1, Muscle 1) for wavelengths from 350 nm till 650 nm.

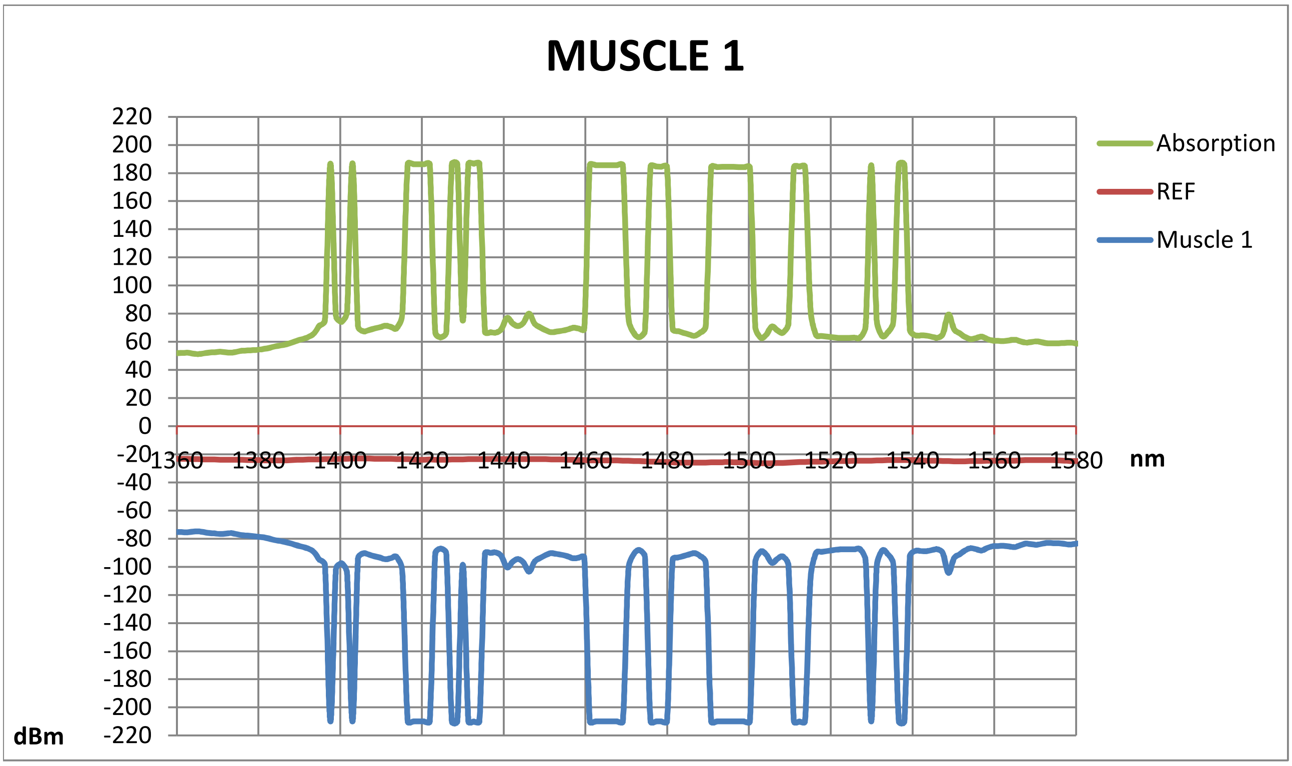

Fig. 7 – Graph of the reference radiation source (REF), the radiation that passes through the tissue (Muscle 1) and absorption (Absorption) in sprague dawley rat muscle (sample 1, Muscle 1) for wavelengths from 1360 nm till 1580 nm.

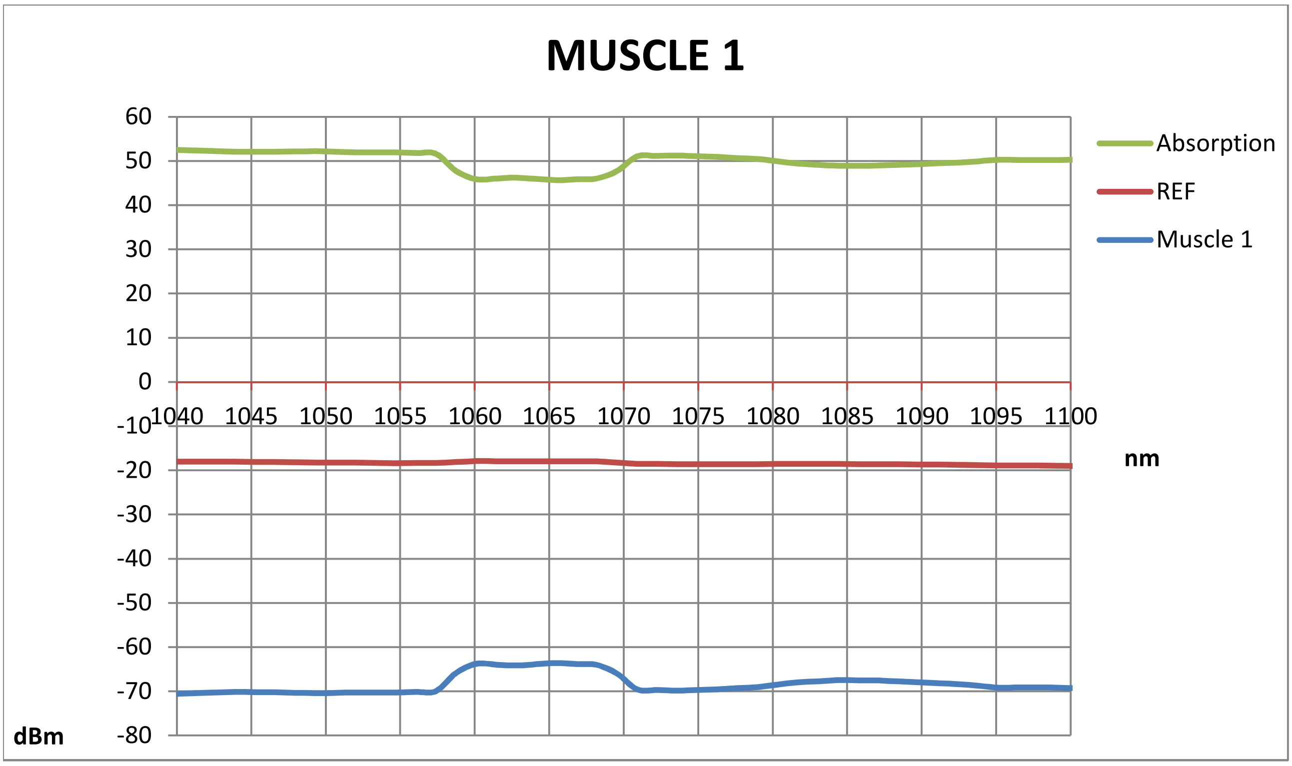

Fig. 8 – Graph of the reference radiation source (REF), the radiation that passes through the tissue (Muscle 1) and absorption (Absorption) in sprague dawley rat muscle (sample 1, Muscle 1) for wavelengths from 1040 nm till 1100 nm.

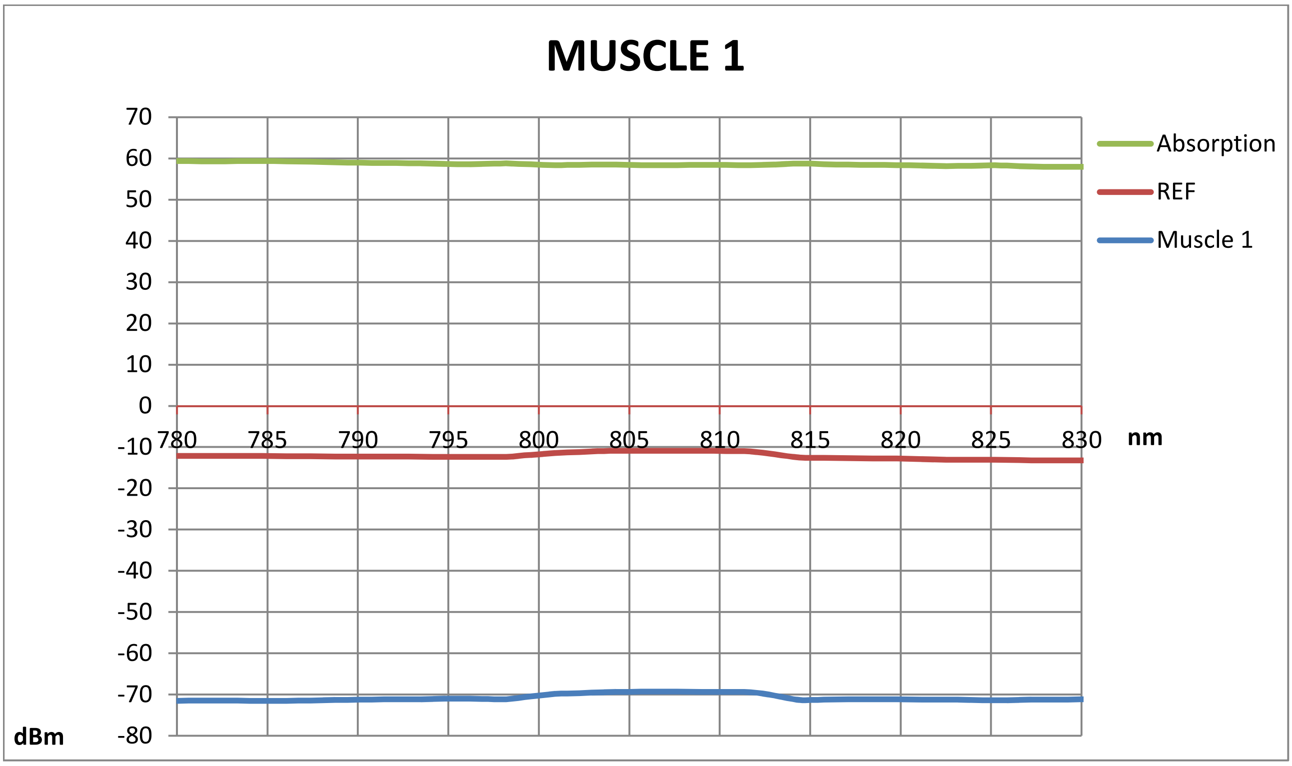

Fig. 9 – Graph of the reference radiation source (REF), the radiation that passes through the tissue (Muscle 1) and absorption (Absorption) in sprague dawley rat muscle (sample 1, Muscle 1) for wavelengths from 780 nm till 830 nm.

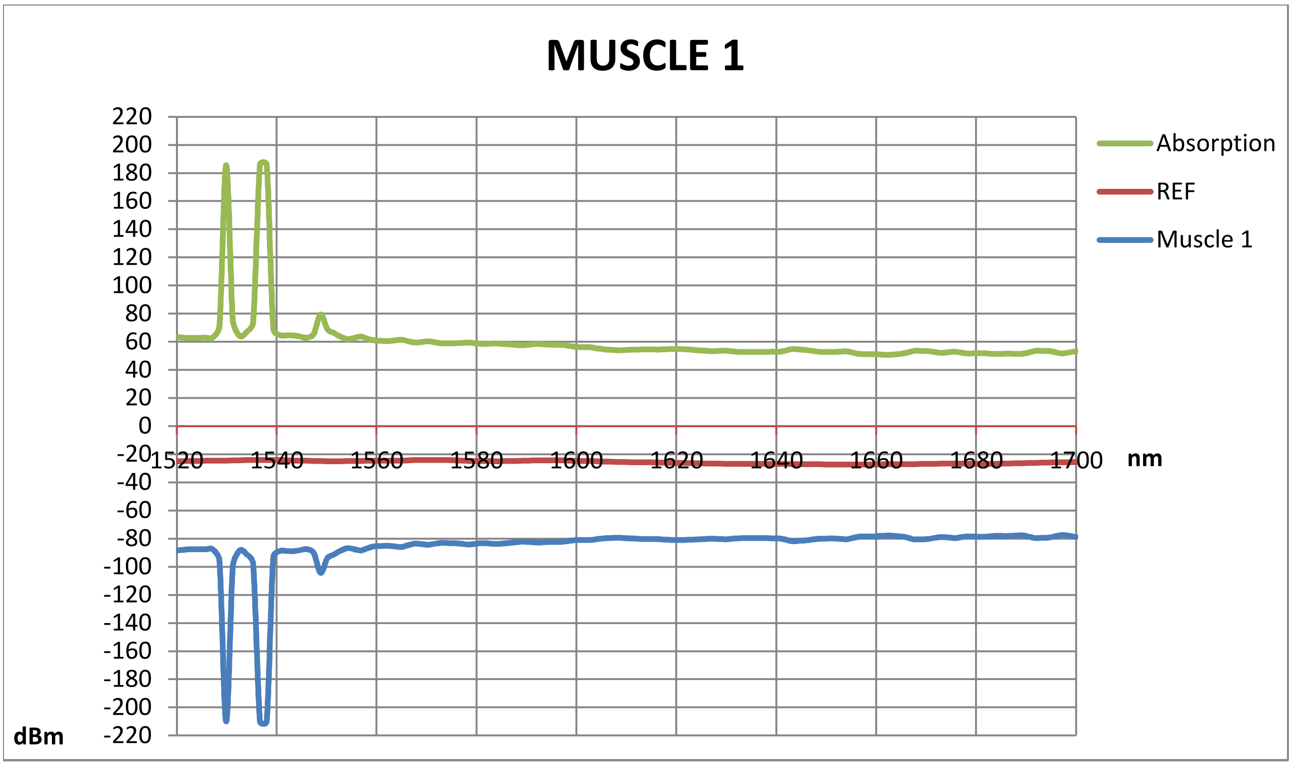

Fig. 10 – Graph of the reference radiation source (REF), the radiation that passes through the tissue (Muscle 1) and absorption (Absorption) in sprague dawley rat muscle (sample 1, Muscle 1) for wavelengths from 1520 nm till 1700 nm.

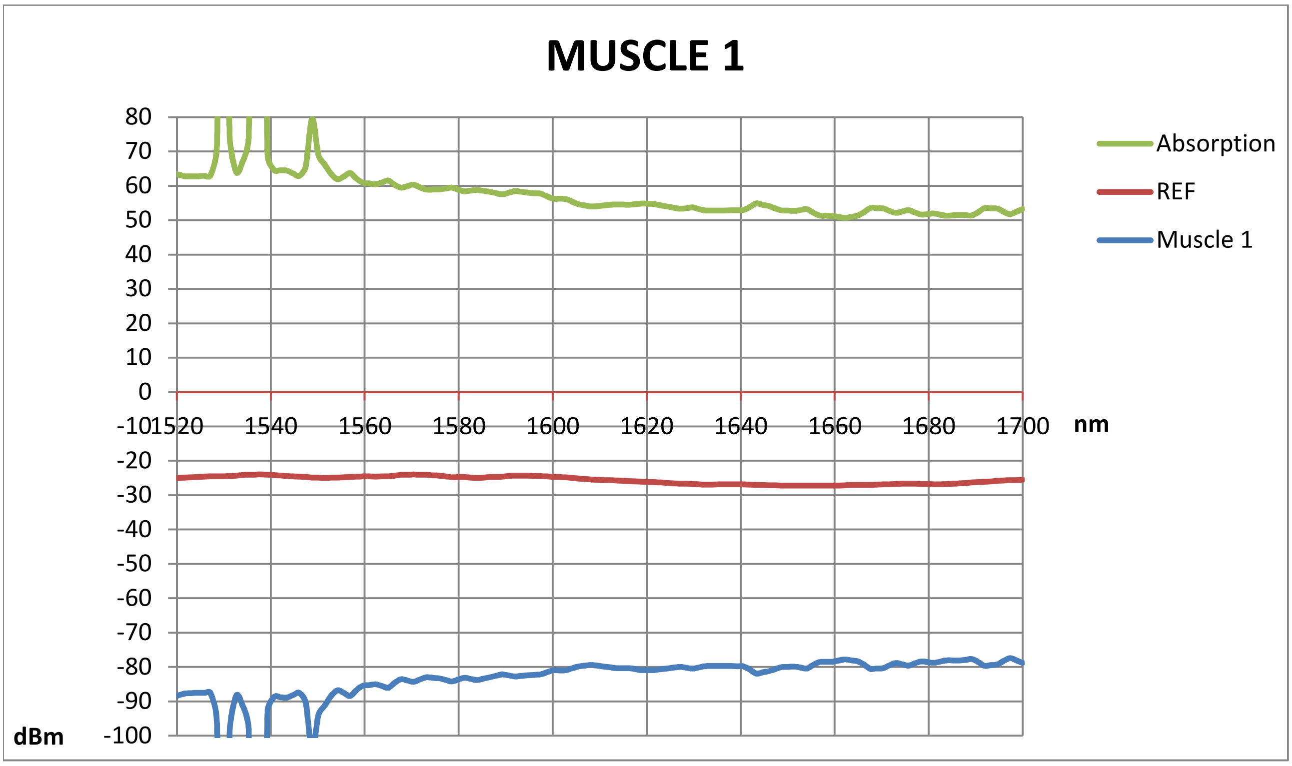

Fig. 11 – Graph at most magnification of the reference radiation source (REF), the radiation that passes through the tissue (Muscle 1) and absorption (Absorption) in sprague dawley rat muscle (sample 1, Muscle 1) for wavelengths from 1520 nm till 1700 nm.

Wavelength (nm)	Muscle 1 Measure (dBm)	Wavelength (nm)	Muscle 1 Measure (dBm)
591.650	**-88.322**	598.400	**-84.662**
593.000	**-83.660**	599.750	**-83.297**
594.350	**-85.023**	601.100	**-82.261**
595.700	**-87.021**	602.450	**-80.695**
597.050	**-85.683**		

Table 1 - Values of measured light from spectrum analyzer in sprague dawley rat muscle (sample 1, Muscle 1) at wavelengths from 591.650 nm till 602.450 nm. The values lower than -80 dBm are in red. For the reasons illustrated in this chapter it is believed that the light is completely absorbed at these wavelengths.

Wavelength (nm)	Muscle 1 Measure (dBm)	Wavelength (nm)	Muscle 1 Measure (dBm)
1382.750	**-80.055**	1390.850	**-85.838**
1384.100	**-81.117**	1392.200	**-87.140**
1385.450	**-81.762**	1393.550	**-89.496**
1386.800	**-82.519**	1394.900	**-95.029**
1388.150	**-83.526**	1396.250	**-98.745**
1389.500	**-84.838**		

Table 2 - Values of measured light from spectrum analyzer in sprague dawley rat muscle (sample 1, Muscle 1) at wavelengths from 1382.750 nm till 1396.250 nm. The values lower than -80 dBm are in red. For the reasons illustrated in this chapter it is believed that the light is completely absorbed at these wavelengths.

Wavelength (nm)		Muscle 1 Measure (dBm)	Muscle 1 Absorption (dB)
from	till		
350.000	**590.300**	**spikes < -80**	**full absorption**
591.650	**602.450**	**values < -80**	**full absorption**
603.800	**1381.400**	**values > -80**	**valid values**
1382.750	**1396.250**	**values < -80**	**full absorption**
1397.600	**1538.000**	**spikes < -80**	**full absorption**
1539.350	**1700.000**	**values < -80**	**full absorption**

Table 3 - Summary of wavelengths where light is completely absorbed in sprague dawley rat muscle (sample 1, Muscle 1). Values lower than -80 dBm are deemed too small because they are not read by the spectrum analyzer. So those wavelengths light are considered as completely absorbed.

Wavelength (nm)	REF (dBm)	Muscle 1 Measure (dBm)	Muscle 1 Absorption (dB)
798.200	-12.350	-71.119	58.769
799.550	-11.882	-70.425	58.543
800.900	-11.459	-69.827	58.368
802.250	-11.187	-69.625	58.438
803.600	-10.931	-69.431	58.500
804.950	-10.930	-69.340	58.410
806.300	-10.929	-69.250	58.321
807.650	-10.913	-69.291	58.378
809.000	**-10.897**	-69.333	58.436
810.350	-10.977	-69.361	58.384
811.700	-11.058	-69.389	58.331
813.050	-11.737	-70.234	58.497
814.400	-12.543	-71.285	58.742
815.750	-12.615	-71.221	58.606

Table 4 - The table shows that the value of absorption in sprague dawley rat muscle (sample 1, Muscle 1) remains almost constant for wavelength from 798.200 nm till 815.750 nm. At 809.000 nm the value of source is maximum (in red), but despite this absorption is almost constant.

Wavelength (nm)	REF (dBm)	Muscle 1 Measure (dBm)	Muscle 1 Absorption (dB)
1045.250	-18.102	-70.191	52.089
1046.600	-18.139	-70.230	52.091
1047.950	-18.178	-70.325	52.147
1049.300	-18.217	-70.421	52.204
1050.650	-18.250	-70.334	52.084
1052.000	-18.284	-70.248	51.964
1053.350	-18.324	-70.276	51.952
1054.700	-18.364	-70.305	51.941
1056.050	-18.349	-70.123	51.774
1057.400	-18.334	-69.949	51.615
1058.750	-18.123	-65.848	47.725
1060.100	-17.921	-63.777	45.856
1061.450	-17.932	-63.964	46.032
1062.800	-17.942	-64.160	46.218
1064.150	-17.941	-63.871	45.930
1065.500	-17.939	**-63.601**	45.662
1066.850	-17.964	-63.810	45.846
1068.200	-17.988	-64.030	46.042
1069.550	-18.255	-65.969	47.714
1070.900	-18.540	-69.560	51.020
1072.250	-18.565	-69.694	51.129
1073.600	-18.590	-69.833	51.243
1074.950	-18.604	-69.685	51.081
1076.300	-18.618	-69.541	50.923
1077.650	-18.597	-69.271	50.674

Table 5 - Values of radiation passing through and of radiation absorbed in sprague dawley rat muscle (sample 1, Muscle 1) in relation to radiation emitted at wavelengths from 1045.250 nm till 1077.650 nm. The maximum light value passing through the tissue is in red.

Wavelength (nm)		dBm or dB	Light
809.000		-10.897 dBm	maximum value of light source
1065.500		45.662dB	minimum absorption
1065.500		-63.601 dBm	maximum transmission
449.900		-46.547 dBm	minimum value of light source
from	till		
350.000	590.300	spikes < -80	full absorption
591.650	602.450	values < -80	full absorption
603.800	1381.400	values > -80	valid values
1382.750	1396.250	values < -80	full absorption
1397.600	1538.000	spikes < -80	full absorption
1539.350	1700.000	values < -80	full absorption

Table 6 – Summary table.

14 Muscle 2

It uses the sprague dawley rat muscle. As already stated in the previous paragraph, this test is performed on the same sample of sprague dawley rat left femur (Fig. 1). By this is taken a part, with a thickness of 0.3 mm, called MUSCLE 2. The sample is positioned between the smaller plates with a central hole having a diameter of 1.5 mm in order to cover the entire hole (Fig. 2). The source emits the light with the values and the sequence already described (Fig. 3).

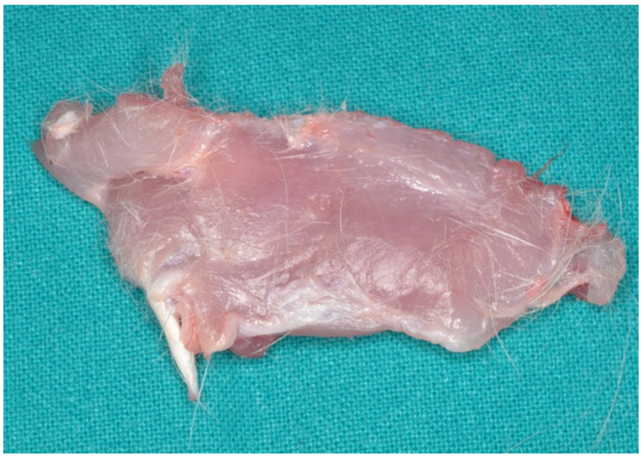

Fig. 1 Sprague dawley rat left femur muscle vision immediately after the sample taking.

Fig. 2 – Sprague dawley rat muscle vision (sample 2) positioned on the plate. The part thickness of 0.3 mm is positioned on the central hole.

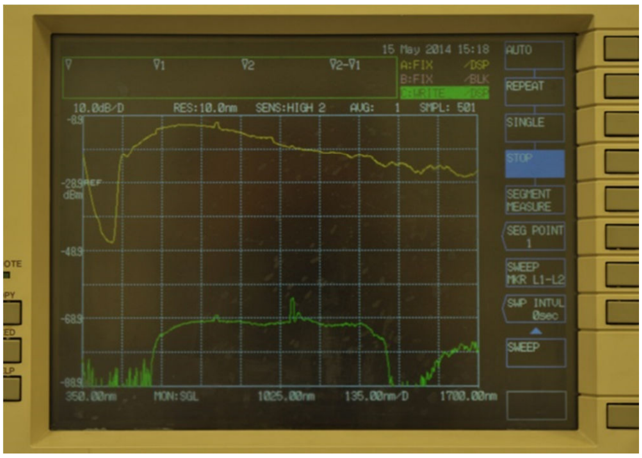

Fig. 3 – Graph of measurements taken on sprague dawley rat muscle (sample 2) shown by Spectrum Analyzer display.

The values of the light which crosses the tissue (Muscle 2), are represented in Fig. 4, along with the values of light emitted freely through the air without anything interposed (reference or calibration path, REF).

In the same figure you see also the graph of muscle light absorption (Absorption). Its value is the difference between the emitted light and the passing light through the tissue (transmitted).

Also in this case (Fig. 4) you see that the values from 350.000 nm till 582.200 nm included (Fig. 6), and from 1413,800 nm till 1498,850 nm included (Fig. 7), the passing light values in the tissue are very variable. They may look like light absence spikes (-210.000 dBm) followed by partially absorbed light whose value is less than or close to -80 dBm. Again, for the reasons already stated they represent the wavelengths at which radiation is completely absorbed.

A vision of the same wavelengths range, using a more detailed scale (Fig. 6), would seem to show that the light pass in the tissue at wavelengths higher than 583.550 nm. Instead the values analysis shows that from 583.550 nm till 590.300 nm included, the passing radiation measurement through the muscle (sample 2, Muscle 2) still has a power level less than -80 dBm (Fig. 4, Fig. 5,

Table 1). So also for these range it can be considered that the radiation is completely absorbed by the muscle.

From wavelength of 591.650 nm till 1386.800 nm included, the passing light values are greater than -80 dBm. Hence, being the values reliable, we can say that in this wavelengths portion, the light can effectively pass through the muscle (Fig. 4, Fig. 5).

The second group spikes begins at 1413.800 nm and lasts till 1498.850 nm (Fig. 4, Fig. 7). In this range the light is completely absorbed in the muscle (sample 2, Muscle 2). However, also in this case, the numbers analysis shows that the passing radiation values begin to be less than -80 dBm already at wavelength of 1388.150 nm till 1412.450 nm (Fig. 7, Table 2) after which, at 1413.800 nm, the already mentioned spikes start. Again, for the reasons already stated, also these radiation values must be discarded and, therefore, in this range of wavelength, the radiation is completely absorbed by the muscle (Fig. 7, Table 2).

The spikes terminate at the wavelength of 1498.850 nm (Fig. 7), but the passing light values from 1500.200 nm till 1600.100 nm included, are not reliable because almost all are below -80 dBm (Fig. 10, Fig. 11). In this range of wavelengths there are only some values slightly greater to -80 dBm. The difference between the minimum value, considered valid (-80 dBm), and the measured value in this field of wavelengths is less only of -1 dBm o -1,5 dBm or even less than -1 dBm.

These values are not continuous and sequential, but scattered from 1500.200 nm till a 1600.100 nm. Therefore with a big margin of reliability can be discarded. Hence, all the values in this range are values in which radiation is completely absorbed by muscle. These values cannot be listed in a table being too numerous and the table size would be too great.

From 1601.450 nm till 1700.000 nm the passing radiation values are greater than -80 dBm. So we can say that in this range of wavelengths the light can pass through the muscle.

It thus appears that the light effectively passes through the muscle (sample 2, Muscle 2) between 591.650 nm and 1386.800 nm and between 1601.450 nm and 1700.000 nm (Table 3).

In the figures are represented graphically the reference values for the instrument (REF), the values of the light that passes through the tissue (Muscle 2) and absorbed light values by the muscle (Absorption).

On first analysis it can be seen that the passing light through the tissue increase progressively from 583.550 nm till 1057.400 nm (Fig. 4, Fig. 5). Starting from this latter wavelength (Fig. 9) the passing light amount through the muscle has a significant increase till 1068.200 nm, to which transmission is the highest, then it decreases till the wavelength of 1070.900 nm (Table 5).

Accordingly, in these wavelengths range, the absorption in the tissue has a drastic decrease. From the wavelength of 1070.900 nm onwards, the transmission remains again fairly constant till the wavelength of 1305.800 nm (Fig. 4, Fig. 5) when it starts to decreases and at 1388.150 nm it decreases below -80 dBm and at 1413.800 nm light absorption spikes start (Fig. 7).

Also in this case, by examining the graph of Fig. 4 e Fig. 5, it would seem that significant radiation values passes through the examined tissue at wavelengths around 800 nm.

But in this case, as well as in the previous, the transmitted power increase follow the increase of the light source, without reduction of absorbed radiation that, for those wavelengths, is almost constant. In this regard see the detail shown in the graph of Fig. 8 and values for that field of wavelengths shown in Table 4. The maximum value of source light it is revealed at 809.000 nm, but for this wavelength the transmission is neither the highest nor the absorption is the minimum.

A summary is shown in Table 6.

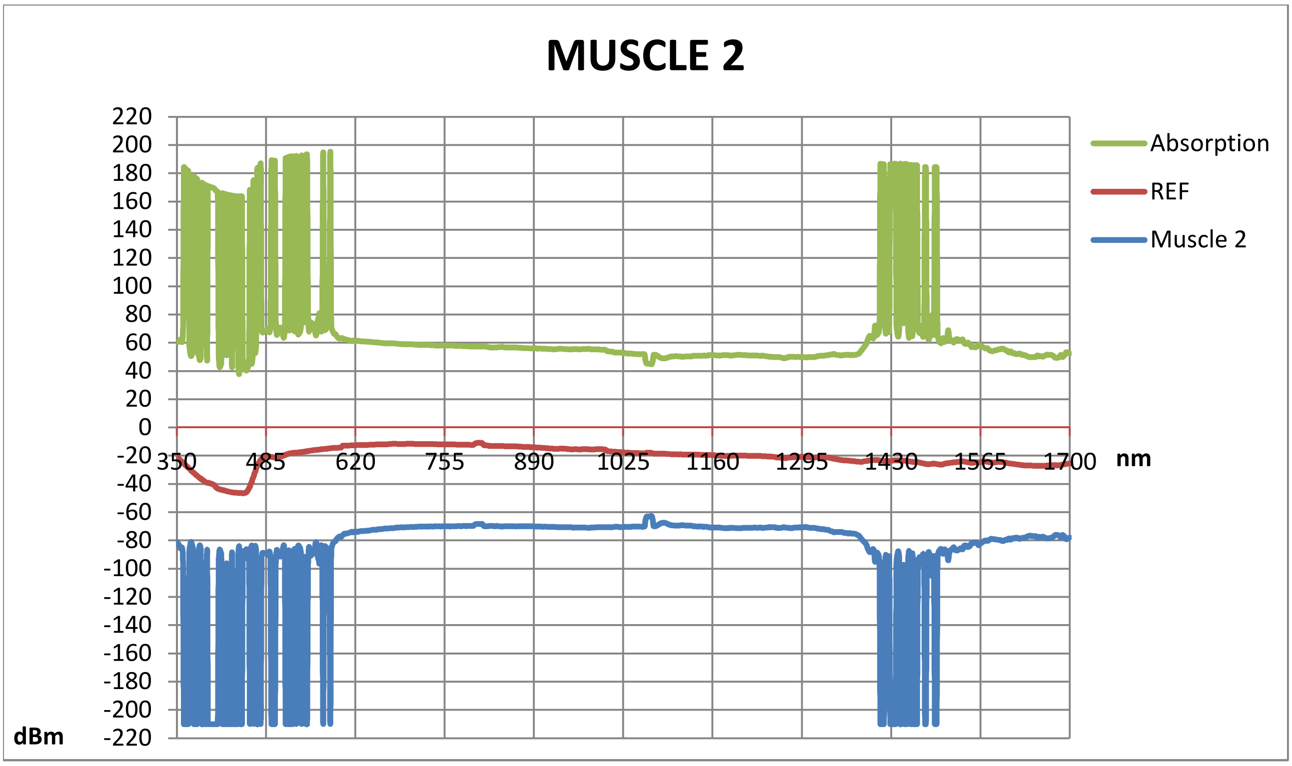

Fig. 4 – Graph of the reference radiation source (REF), the radiation that passes through the tissue (Muscle 2) and absorption (Absorption) in sprague dawley rat muscle (sample 2, Muscle 2).

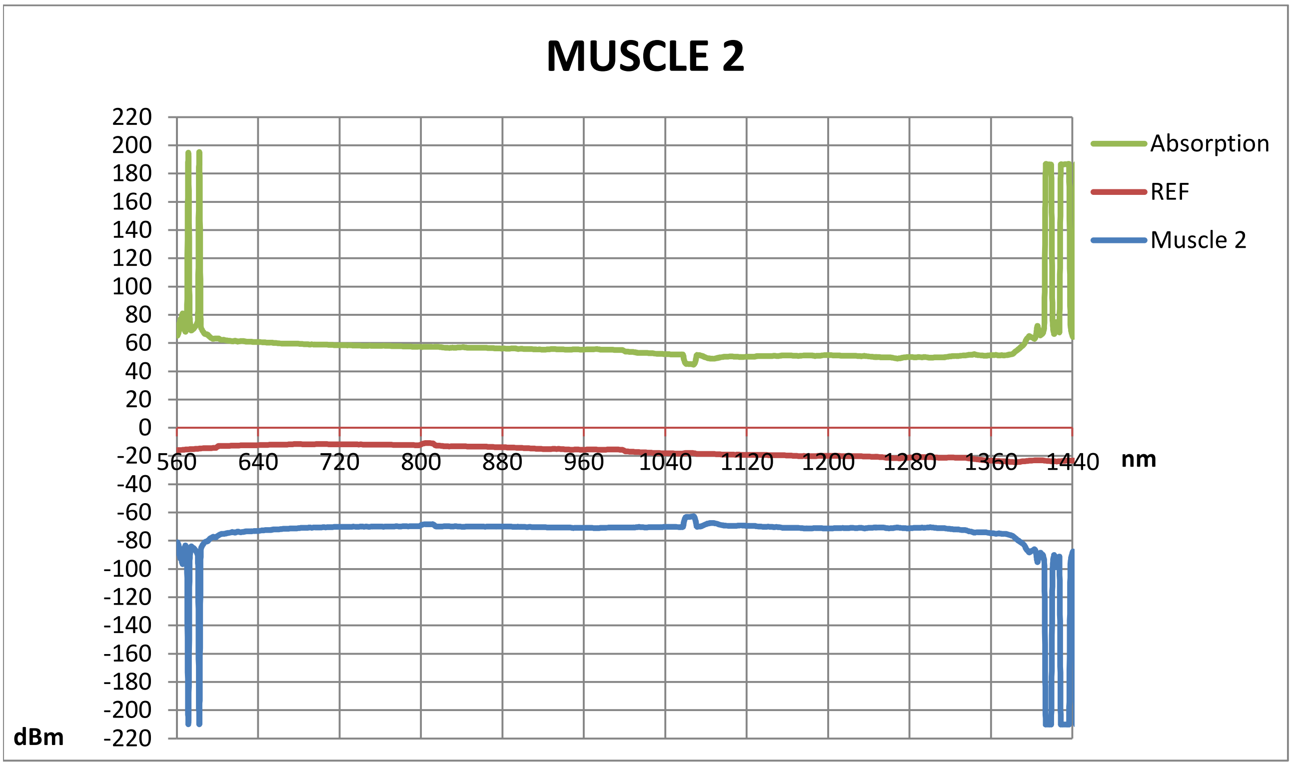

Fig. 5 – Graph of the reference radiation source (REF), the radiation that passes through the tissue (Muscle 2) and absorption (Absorption) in sprague dawley rat muscle (sample 2, Muscle 2) for wavelengths from 560 nm till 1440 nm.

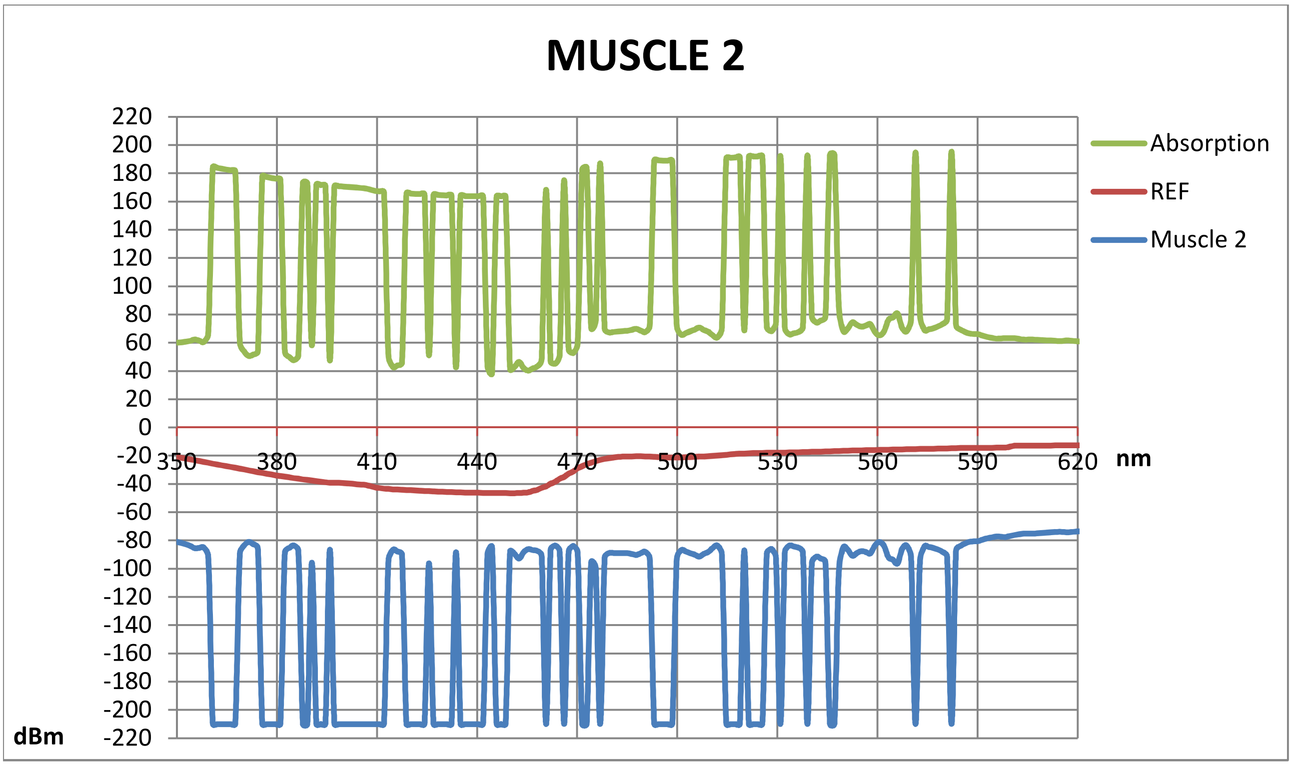

Fig. 6 – Graph of the reference radiation source (REF), the radiation that passes through the tissue (Muscle 2) and absorption (Absorption) in sprague dawley rat muscle (sample 2, Muscle 2) for wavelengths from 350 nm till 620 nm.

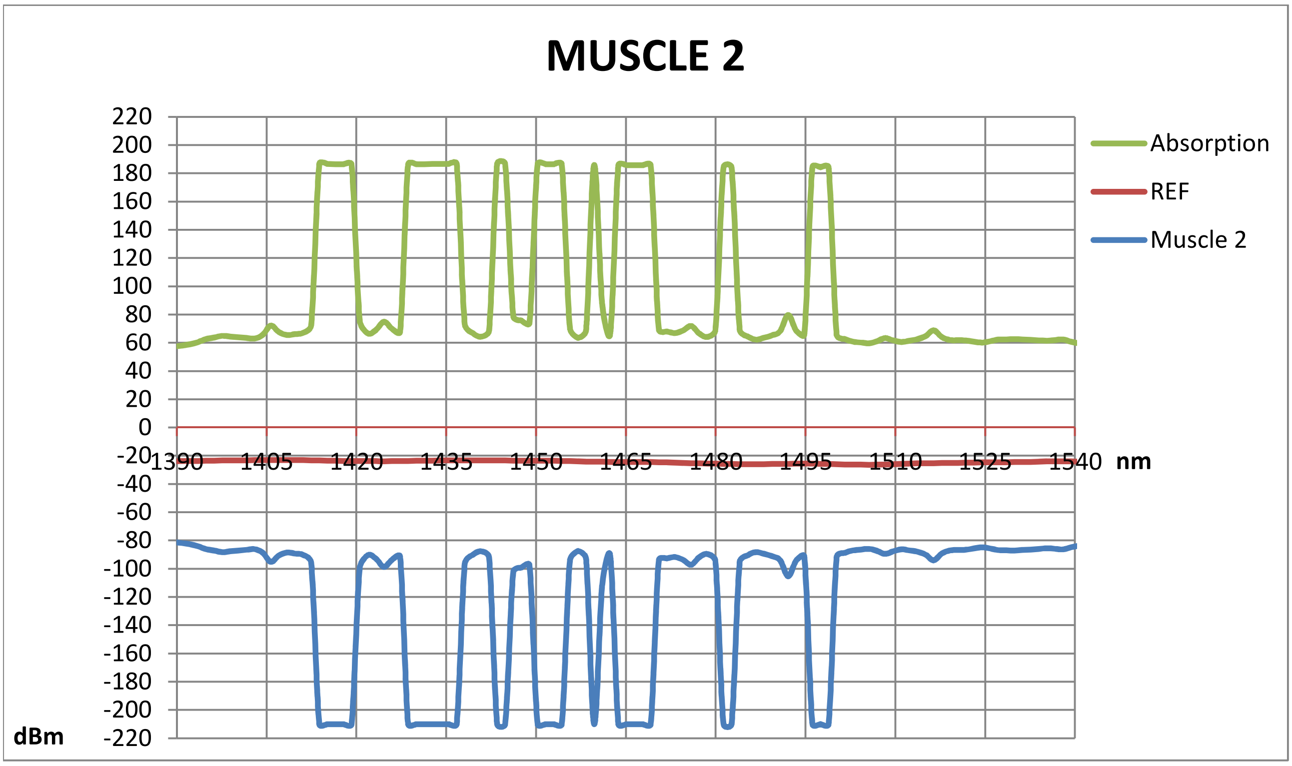

Fig. 7 – Graph of the reference radiation source (REF), the radiation that passes through the tissue (Muscle 2) and absorption (Absorption) in sprague dawley rat muscle (sample 2, Muscle 2) for wavelengths from 1390 nm till 1540 nm.

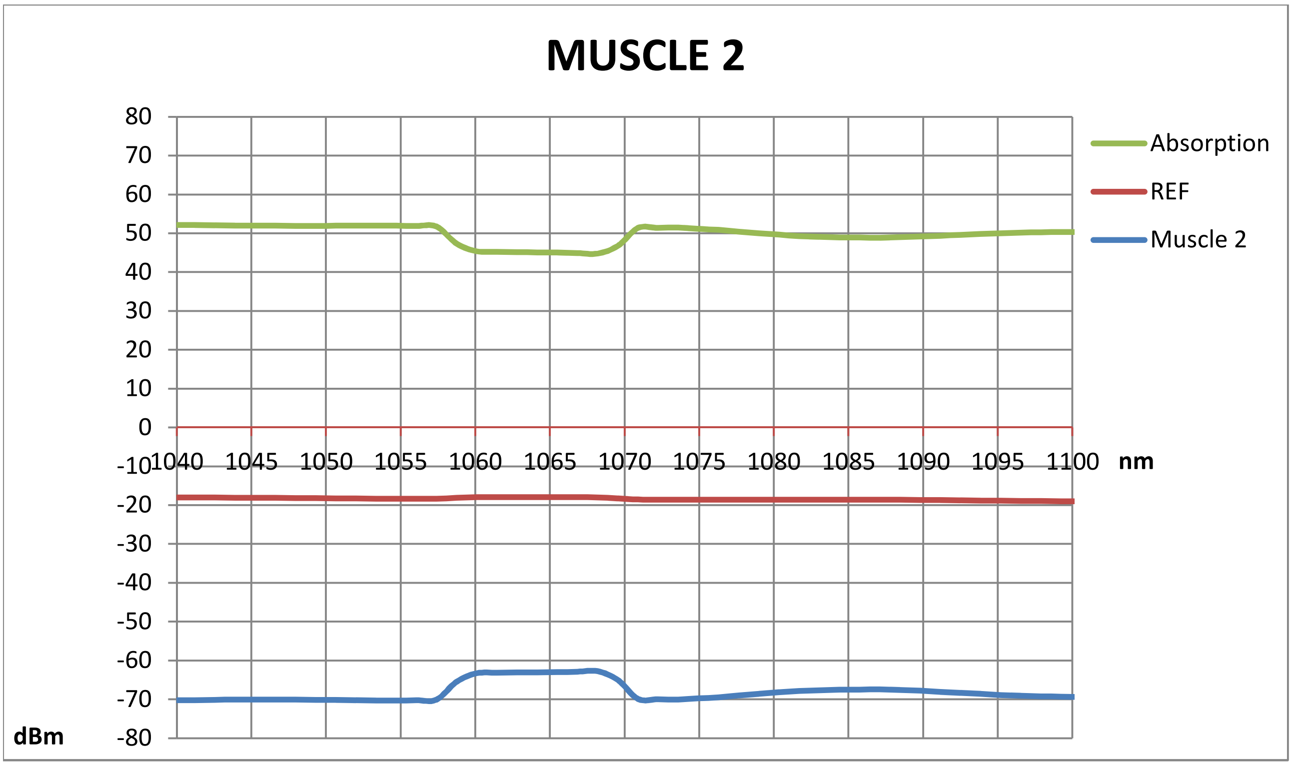

Fig. 8 – Graph of the reference radiation source (REF), the radiation that passes through the tissue (Muscle 2) and absorption (Absorption) in sprague dawley rat muscle (sample 2, Muscle 2) for wavelengths from 1040 nm till 1100 nm.

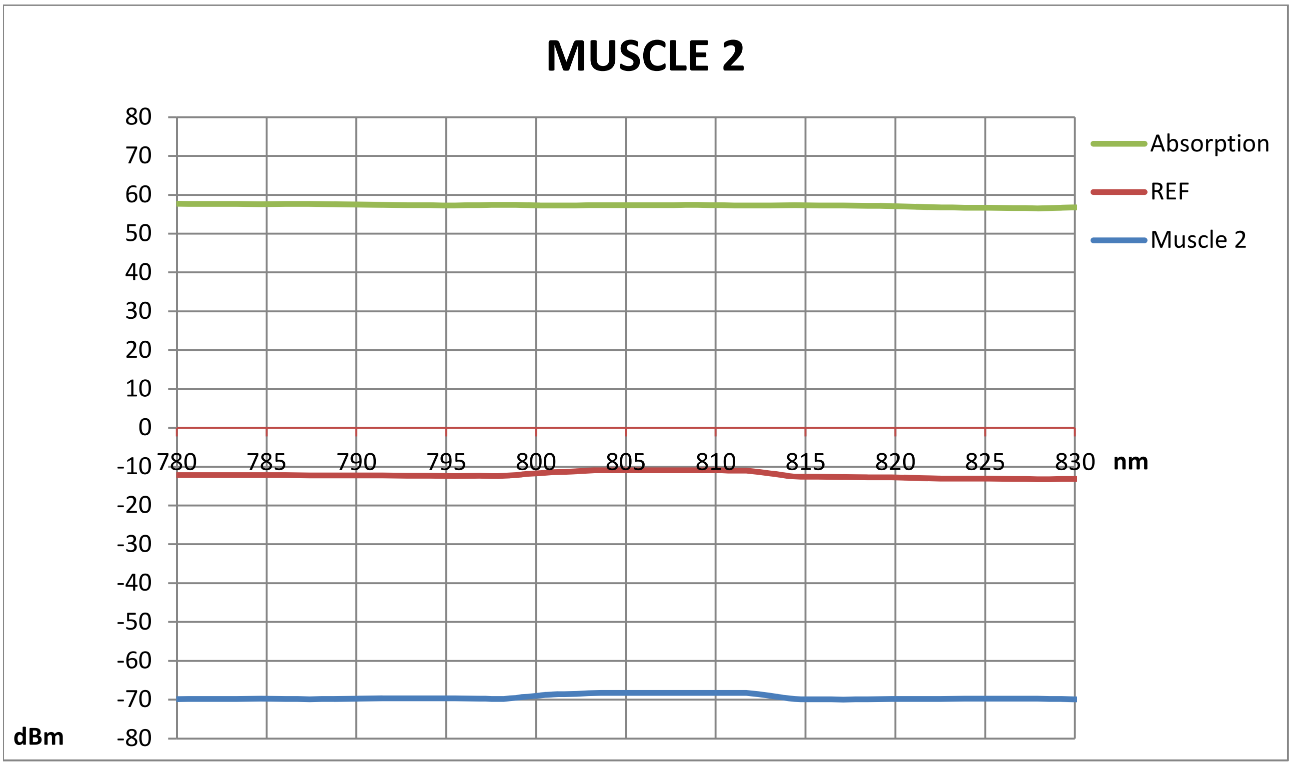

Fig. 9 – Graph of the reference radiation source (REF), the radiation that passes through the tissue (Muscle 2) and absorption (Absorption) in sprague dawley rat muscle (sample 2, Muscle 2) for wavelengths from 780 nm till 830 nm.

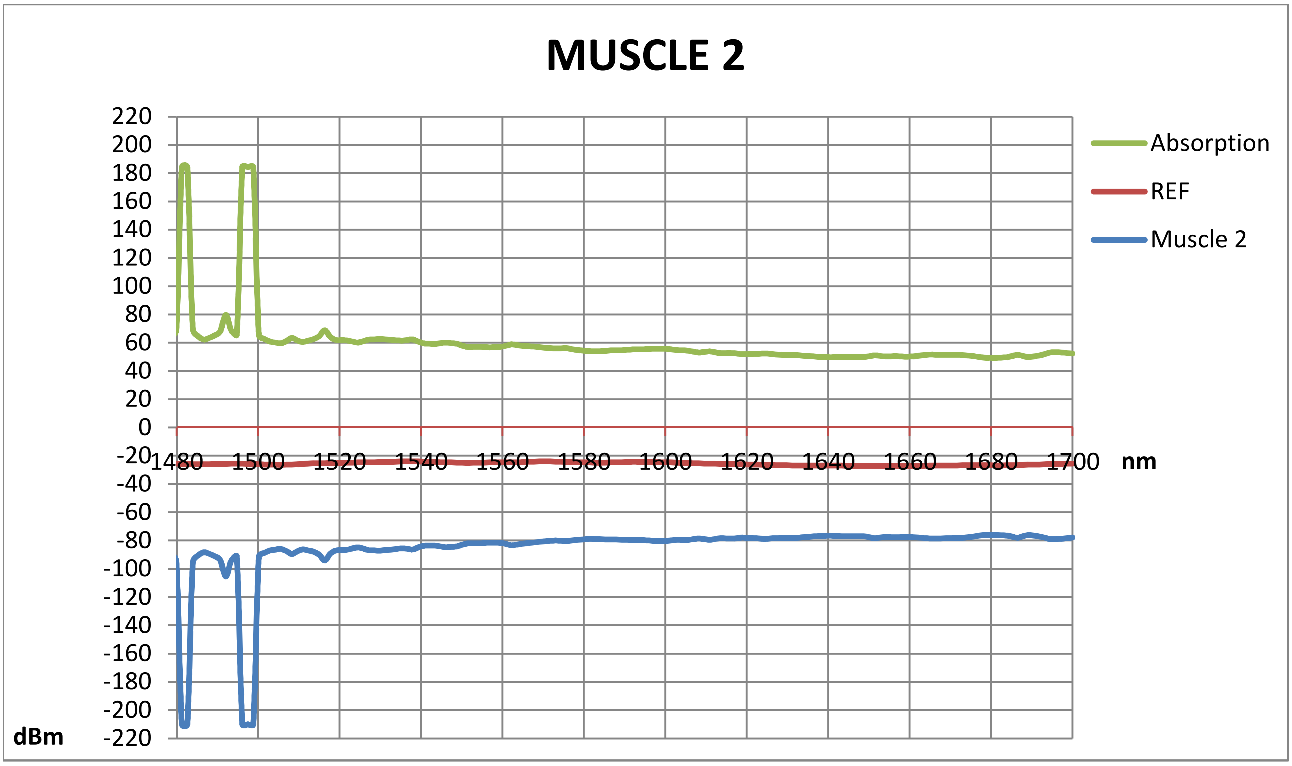

Fig. 10 – Graph of the reference radiation source (REF), the radiation that passes through the tissue (Muscle 2) and absorption (Absorption) in sprague dawley rat muscle (sample 2, Muscle 2) for wavelengths from 1480 nm till 1700 nm.

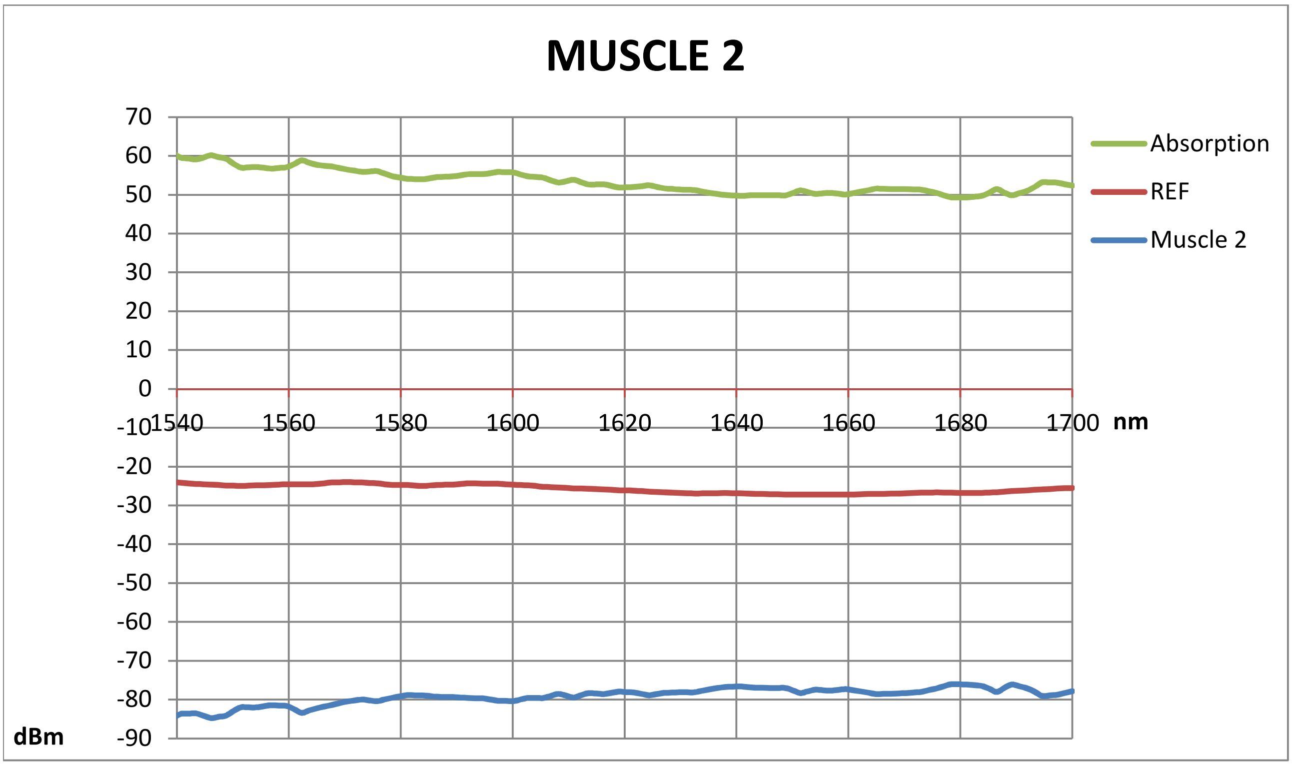

Fig. 11 – Graph at most magnification of the reference radiation source (REF), the radiation that passes through the tissue (Muscle 2) and absorption (Absorption) in sprague dawley rat muscle (sample 2, Muscle 2) for wavelengths from 1540 nm till 1700 nm.

Wavelength (nm)	Muscle 2 Measure (dBm)	Wavelength (nm)	Muscle 2 Measure (dBm)
583.550	**-86.938**	587.600	**-80.944**
584.900	**-83.856**	588.950	**-80.654**
586.250	**-82.160**		

Table 1 - Values of measured light from spectrum analyzer for sprague dawley rat muscle (sample 2, Muscle 2) at wavelengths from 583.550 nm till 588.950 nm. The values lower than -80 dBm are in red. For the reasons illustrated in this chapter it is believed that the light is completely absorbed at these wavelengths.

Wavelength (nm)	Muscle 2 Measure (dBm)	Wavelength (nm)	Muscle 2 Measure (dBm)
1388.150	**-80.396**	1401.650	**-86.588**
1389.500	**-81.123**	1403.000	**-86.126**
1390.850	**-81.822**	1404.350	**-88.619**
1392.200	**-82.655**	1405.700	**-95.109**
1393.550	**-84.073**	1407.050	**-90.677**
1394.900	**-86.192**	1408.400	**-88.530**
1396.250	**-87.105**	1409.750	**-89.288**
1397.600	**-88.262**	1411.100	**-90.208**
1398.950	**-87.645**	1412.450	**-95.669**
1400.300	**-87.105**		

Table 2 - Values of measured light from spectrum analyzer for sprague dawley rat muscle (sample 2, Muscle 2) at wavelengths from 1382.750 nm till 1396.250 nm. The values lower than -80 dBm are in red. For the reasons illustrated in this chapter it is believed that the light is completely absorbed at these wavelengths.

Wavelength (nm)		Muscle 2 Measure (dBm)	Muscle 2 Absorption (dB)
from	to		
350.000	**582.200**	**spikes < -80**	**full absorption**
583.550	**590.300**	**values < -80**	**full absorption**
591.650	**1386.800**	**values > -80**	**valid values**
1388.150	**1412.450**	**values < -80**	**full absorption**
1413.800	**1498.850**	**spikes < -80**	**full absorption**
1500.200	**1600.100**	**values < -80**	**full absorption**
1601.450	**1700.000**	**values > -80**	**valid values**

Table 3 - Summary of wavelengths where light is completely absorbed in sprague dawley rat muscle (sample 2, Muscle 2). Values lower than -80 dBm are deemed too small because they are not read by the spectrum analyzer. So those wavelengths light are considered as completely absorbed.

Wavelength (nm)	REF (dBm)	Muscle 2 Measure (dBm)	Muscle 2 Absorption (dB)
792.800	-12.300	-69.608	57.308
794.150	-12.339	-69.629	57.290
795.500	-12.379	-69.650	57.271
796.850	-12.364	-69.716	57.352
798.200	-12.350	-69.784	57.434
799.550	-11.882	-69.191	57.309

800.900	-11.459	-68.670	57.211
802.250	-11.187	-68.468	57.281
803.600	-10.931	-68.275	57.344
804.950	-10.930	-68.260	57.330
806.300	-10.929	-68.245	57.316
807.650	-10.913	-68.263	57.350
809.000	**-10.897**	-68.281	57.384
810.350	-10.977	-68.281	57.304
811.700	-11.058	-68.281	57.223
813.050	-11.737	-68.988	57.251
814.400	-12.543	-69.834	57.291
815.750	-12.615	-69.891	57.276

Table 4 - The table shows that the value of absorption in sprague dawley rat muscle (sample 1, Muscle 1) remains almost constant for wavelength from 792.800 nm till 815.750 nm. At 809.000 nm the value of source is maximum (in red), but despite this absorption is almost constant.

Wavelength (nm)	REF (dBm)	Muscle 2 Measure (dBm)	Muscle 2 Absorption (dB)
1045.250	-18.102	-70.080	51.978
1046.600	-18.139	-70.088	51.949
1047.950	-18.178	-70.098	51.920
1049.300	-18.217	-70.108	51.891
1050.650	-18.250	-70.183	51.933
1052.000	-18.284	-70.260	51.976
1053.350	-18.324	-70.303	51.979
1054.700	-18.364	-70.346	51.982
1056.050	-18.349	-70.215	51.866
1057.400	-18.334	-70.087	51.753
1058.750	-18.123	-65.470	47.347
1060.100	-17.921	-63.283	45.362
1061.450	-17.932	-63.179	45.247
1062.800	-17.942	-63.079	45.137
1064.150	-17.941	-63.035	45.094
1065.500	-17.939	-62.993	45.054
1066.850	-17.964	-62.875	44.911
1068.200	-17.988	**-62.760**	44.772
1069.550	-18.255	-65.003	46.748
1070.900	-18.540	-69.901	51.361
1072.250	-18.565	-69.965	51.400
1073.600	-18.590	-70.030	51.440
1074.950	-18.604	-69.750	51.146
1076.300	-18.618	-69.486	50.868
1077.650	-18.597	-69.021	50.424

Table 5 - Values of radiation passing through and of radiation absorbed in sprague dawley rat muscle (sample 2, Muscle 2) in relation to radiation emitted at wavelengths from 1045.250 nm till 1077.650 nm. The maximum light value passing through the tissue is in red.

Wavelength (nm)		dBm or dB	Light
809.000		-10.897 dBm	maximum value of light source
1068.200		44.772 dB	minimum absorption
1068.200		-62.760 dBm	maximum transmission
449.900		-46.547 dBm	minimum value of light source
from	to		
350.000	582.200	spikes < -80	full absorption
583.550	590.300	values < -80	full absorption
591.650	1386.800	values > -80	valid values
1388.150	1412.450	values < -80	full absorption
1413.800	1498.850	spikes < -80	full absorption
1500.200	1600.100	values < -80	full absorption
1601.450	1700.000	values > -80	valid values

Table 6 – Summary table.

15 Bone

It uses the left femur bone of sprague dawley rat. The sample is positioned between the smaller plates with a central hole having a diameter of 1.5 mm in order to cover the entire hole. We used the femur proximal part to approximately 8 mm from articulation (Fig. 1). The source emits the light with the values and the sequence already described (Fig. 2).

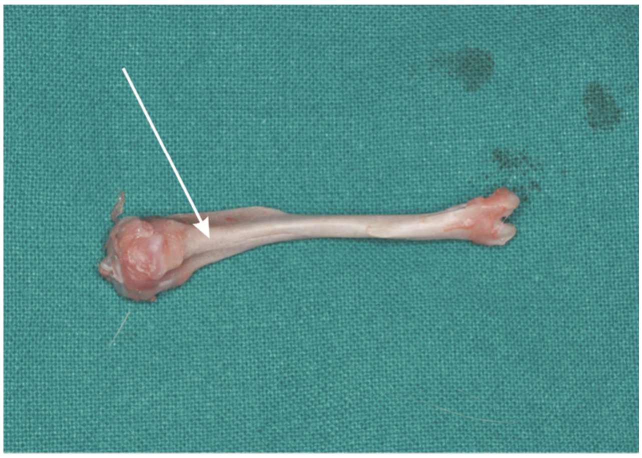

Fig. 1 Sprague dawley rat left femur vision immediately after the sample taking.

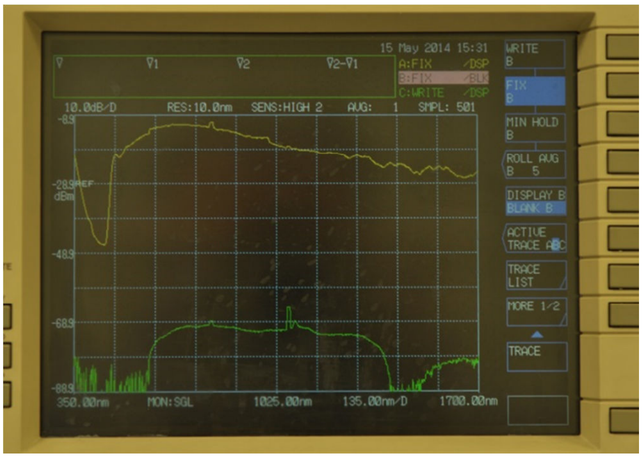

Fig. 2 – Graph of measurements taken on sprague dawley rat femur bone shown by Spectrum Analyzer display.

The values of the light, which crosses the tissue (Bone), are represented in Fig. 3, along with the values of light emitted through the air without anything interposed (reference or calibration path, REF).). In the same figure you see also the graph of bone light absorption (Absorption). Its value is the difference between the emitted light and the passing light through the tissue (transmitted).

From the graph of Fig. 3 and in particular from Fig. 5 you could postulate that radiation from 350.00 nm till 375.650 nm wavelength can pass through the bone. Instead the values analysis shows that at those wavelengths the received power level is close or less than -80 dBm (Table 1). In this study -80 dBm is considered as lower limit for reliable power values. Most of the power values in this range are much lower than or very close to -80 dBm. Only very few values are greater than the limit of acceptable reliability, equal to -80 dBm, and there is no certainty of the measurement reliability within this range of wavelengths. Hence, also for the reasons already stated, these values are considered to be invalid and it is assumed that these wavelengths are completely absorbed by tissue. Also in this case from the wavelength of 377.000 nm to 572.750 nm included (Fig. 3**,** Fig. 5**)** and from 1450.250 nm to 1469.150 nm light passing values in the tissue are very variable. They may look like light absence spikes (-210.000 dBm) followed by partially absorbed light whose value is less than or close to -80 dBm. Again, for the reasons already expressed they represent the wavelengths at which radiation is completely absorbed. A vision of the same wavelengths range (Fig. 5) using a more detailed scale, would seem to show that the light pass in the tissue at wavelengths higher than 574.100 nm.

Instead, the analysis shows that from 574.100 nm to 599.750 nm included, the measurement of the radiation passing through the bone still has a power level less than -80 dBm (Fig. 3, Fig. 5, Table 2). So also for these range it can be considered that the radiation is completely absorbed by the bone.

From wavelength of 601.100 nm to 1386.800 nm included, the passing light values are greater than -80 dBm. So, being the values reliable, we can say that in this wavelengths portion the light can effectively pass through the bone (Fig. 3, Fig. 4).
The second group spikes begins at 1450.250 nm and lasts 1469.150 nm (Fig. 3, Fig. 6). In this range the light is completely absorbed in the bone. However, also in this case, the number analysis shows that the radiation values passing begin to be less than -80 dBm already from wavelength of 1388.150 nm till 1448.900 nm (Fig. 6, Table 3) after which, at 1450.250 nm, the already mentioned spikes start. Again, for the reasons already stated they represent the wavelengths at which radiation is completely absorbed (Table 3).
The spikes terminate at the wavelength of 1469.150 nm (Fig. 6), but all passing light values from 1470.500 nm to 1700.000 nm included, are not reliable because almost all are less than -80 dBm (Fig. 9).
For the reasons already stated the values of transmitted light in this wavelength range are discarded. Therefore all the radiation in this range wavelength are completely absorbed by the bone. These values cannot be listed in a table being too numerous and the table size would be too great.
It thus appears that the light effectively passes through the bone between 601.100 nm and 1386.800 nm (Table 4).
In the figures are represented graphically the instrument reference values (REF), the passing light values through the tissue (Bone) and absorbed light values by the bone (Absorption).
On first analysis it can be seen that the passing light through the tissue, increase progressively from 601.100 nm till 1057.400 nm (Fig. 3, Fig. 4, Fig. 7). Starting from this latter wavelength (Fig. 7) the passing light amount through the bone has a significant increase till 1062.800 nm, at which transmission is the highest, then it decreases till the wavelength of 1070.900 nm (Table 6).
Accordingly, in the range of these wavelengths, the absorption in the tissue has a drastic decrease. From the wavelength of 1070.900 nm onwards the transmission remains again fairly constant till the wavelength of 1301.750 nm (Fig. 3, Fig. 4, Fig. 7) when it decreases, and then at 1388.150 nm it decreases under -80 dBm, and at 1450.250 nm light absorption spikes start (Fig. 6).
Also in this case, by examining the graph of Fig. 3 e Fig. 4, it would seem that significant radiation values passes through the examined tissue at wavelengths around 800 nm.
But in this case, as well as in the previous, the increase of power transmitted follow the increase of the light source, without reduction of absorbed radiation that, for those wavelengths, is almost constant. In this regard see the detail shown in the graph of Fig. 8 and values for that field of wavelengths shown in Table 5.

A summary is shown in Table 7.

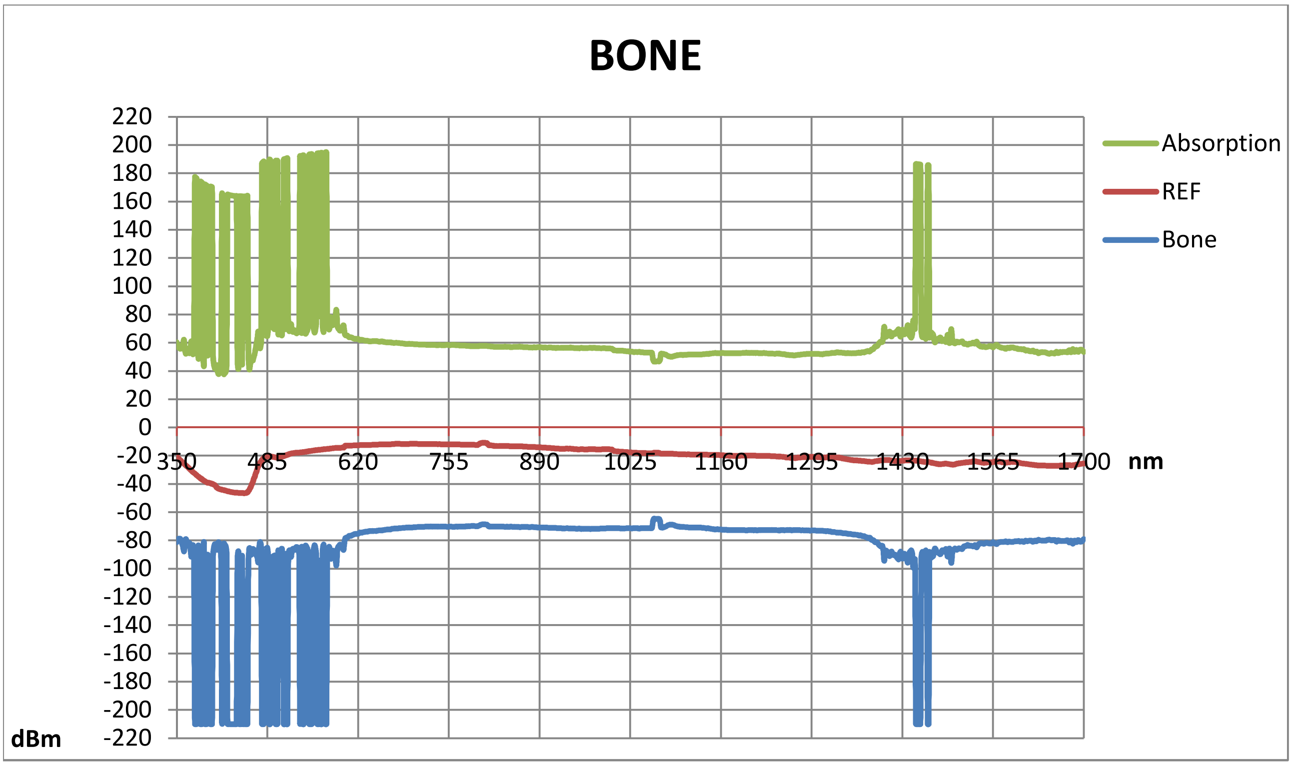

Fig. 3 – Graph of the reference radiation source (REF), the radiation that passes through the tissue (Bone) and absorption (Absorption) in sprague dawley rat femur bone.

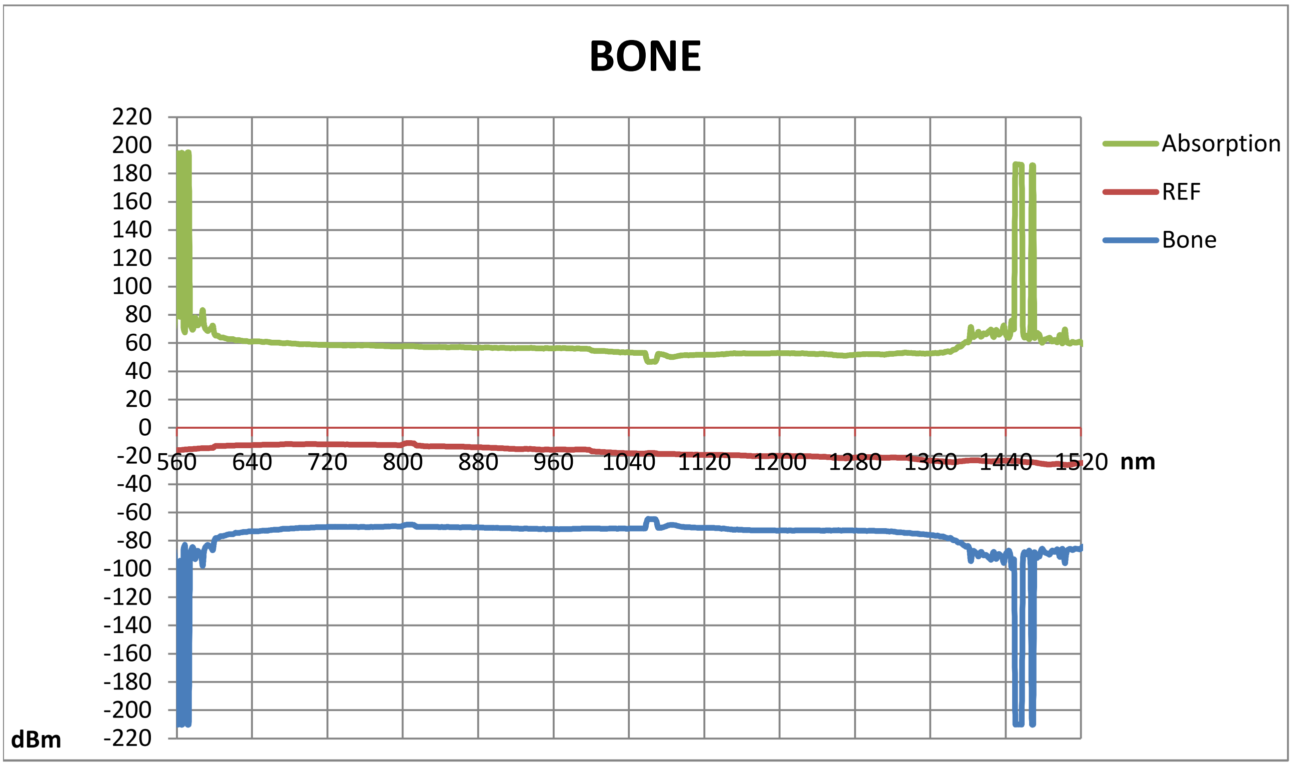

Fig. 4 – Graph of the reference radiation source (REF), the radiation that passes through the tissue (Bone) and absorption (Ab-sorption) in sprague dawley rat femur bone for wavelengths from 560 nm till 1520 nm.

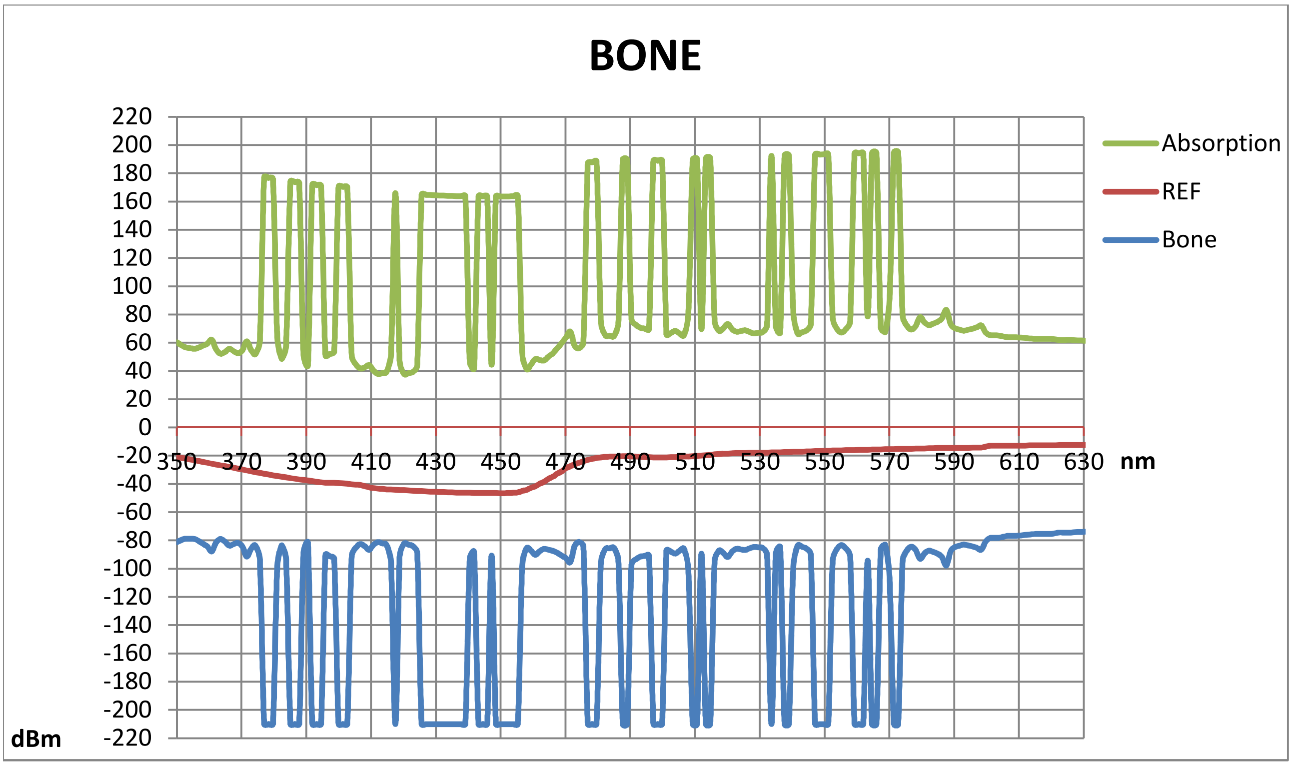

Fig. 5 – Graph of the reference radiation source (REF), the radiation that passes through the tissue (Bone) and absorption (Ab-sorption) in sprague dawley rat femur bone for wavelengths from 350 nm till 630 nm.

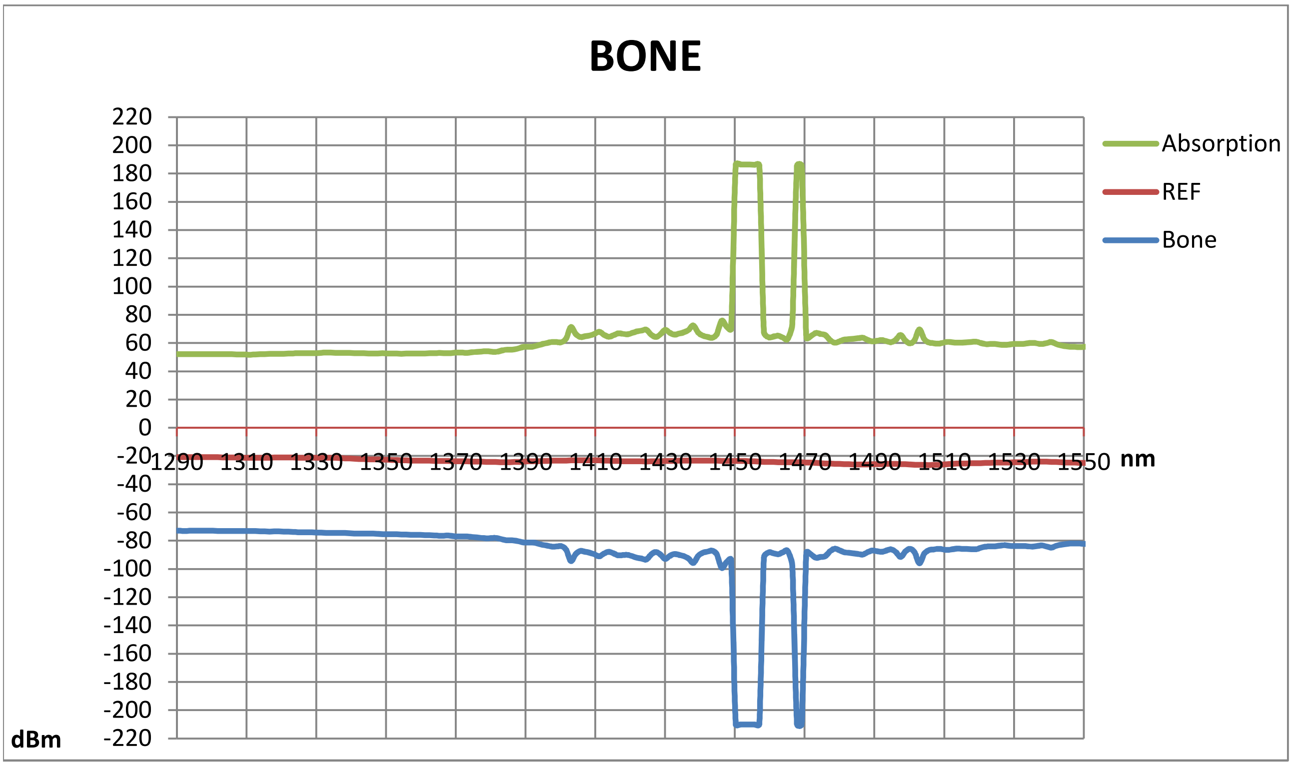

Fig. 6 – Graph of the reference radiation source (REF), the radiation that passes through the tissue (Bone) and absorption (Ab-sorption) in sprague dawley rat femur bone for wavelengths from 1290 nm till 1550 nm.

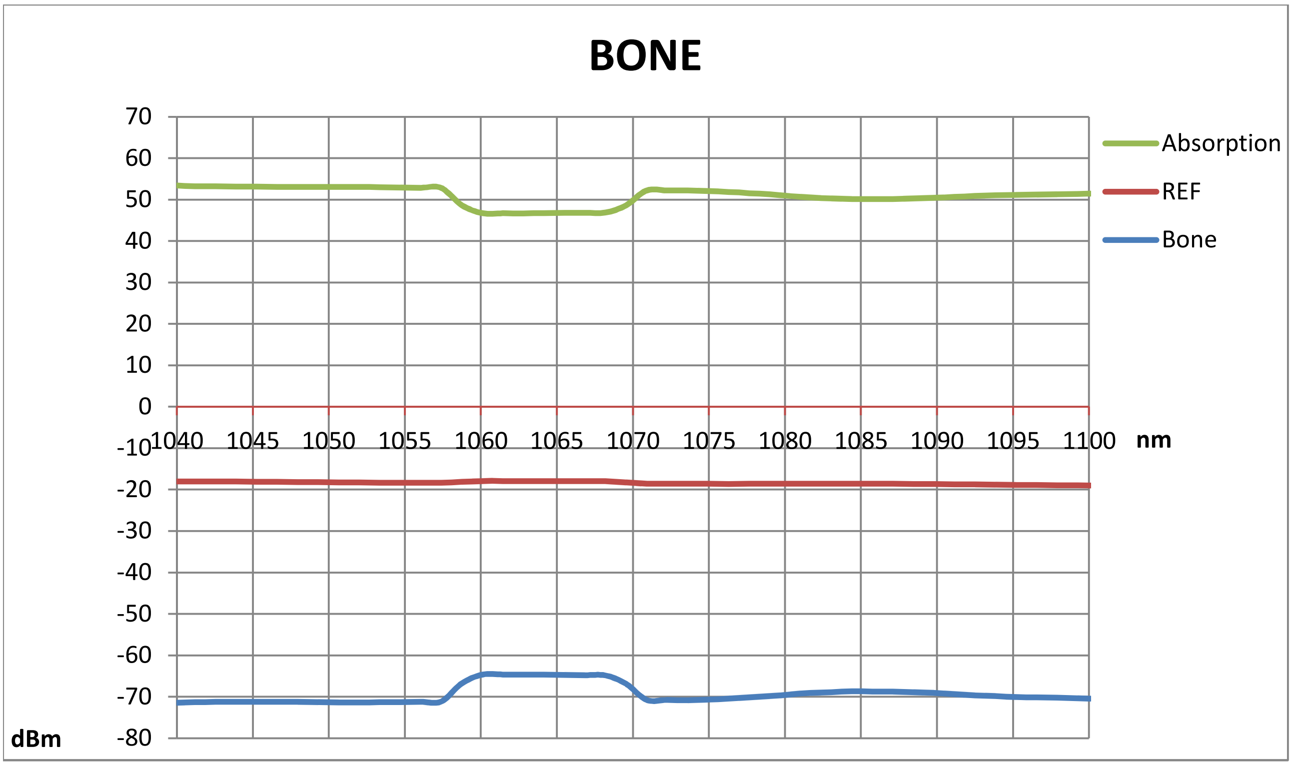

Fig. 7 – Graph of the reference radiation source (REF), the radiation that passes through the tissue (Bone) and absorption (Ab-sorption) in sprague dawley rat femur bone for wavelengths from 1040 nm till 1100 nm.

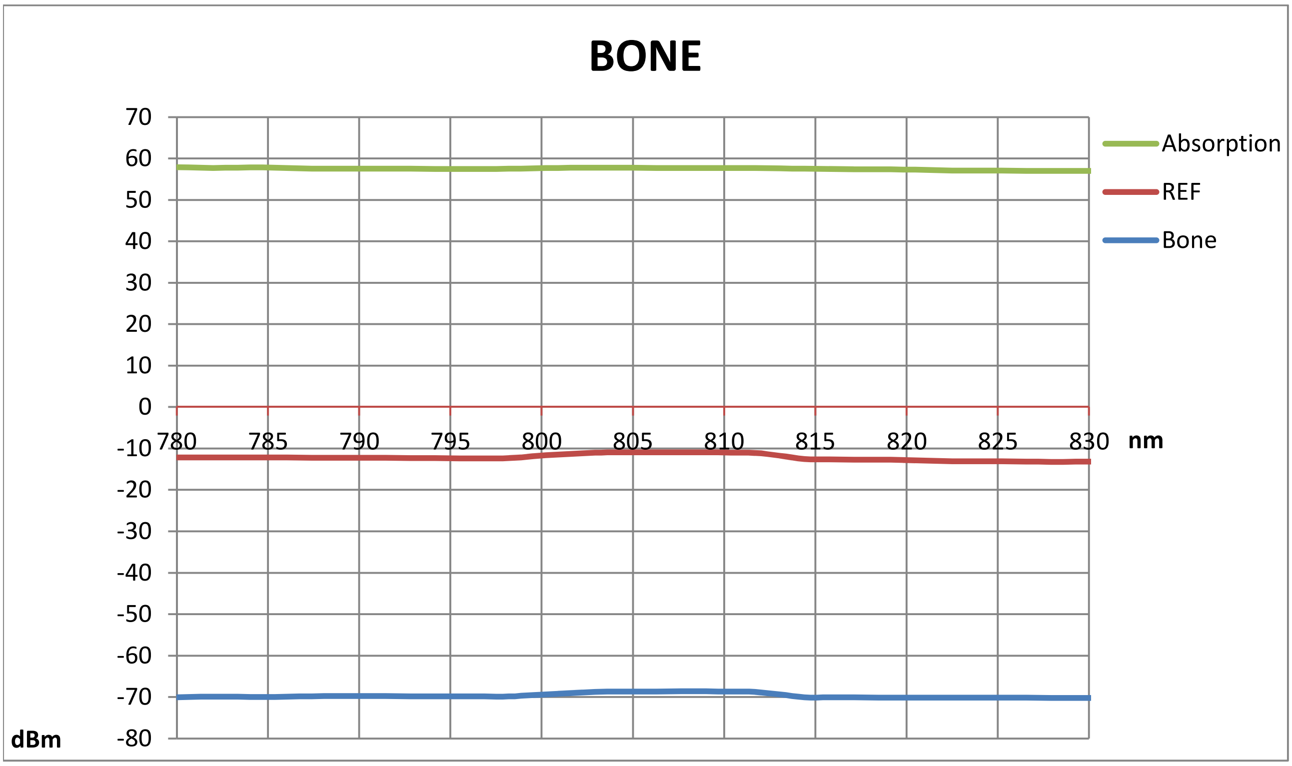

Fig. 8 – Graph of the reference radiation source (REF), the radiation that passes through the tissue (Bone) and absorption (Ab-sorption) in sprague dawley rat femur bone for wavelengths from 780 nm till 830 nm.

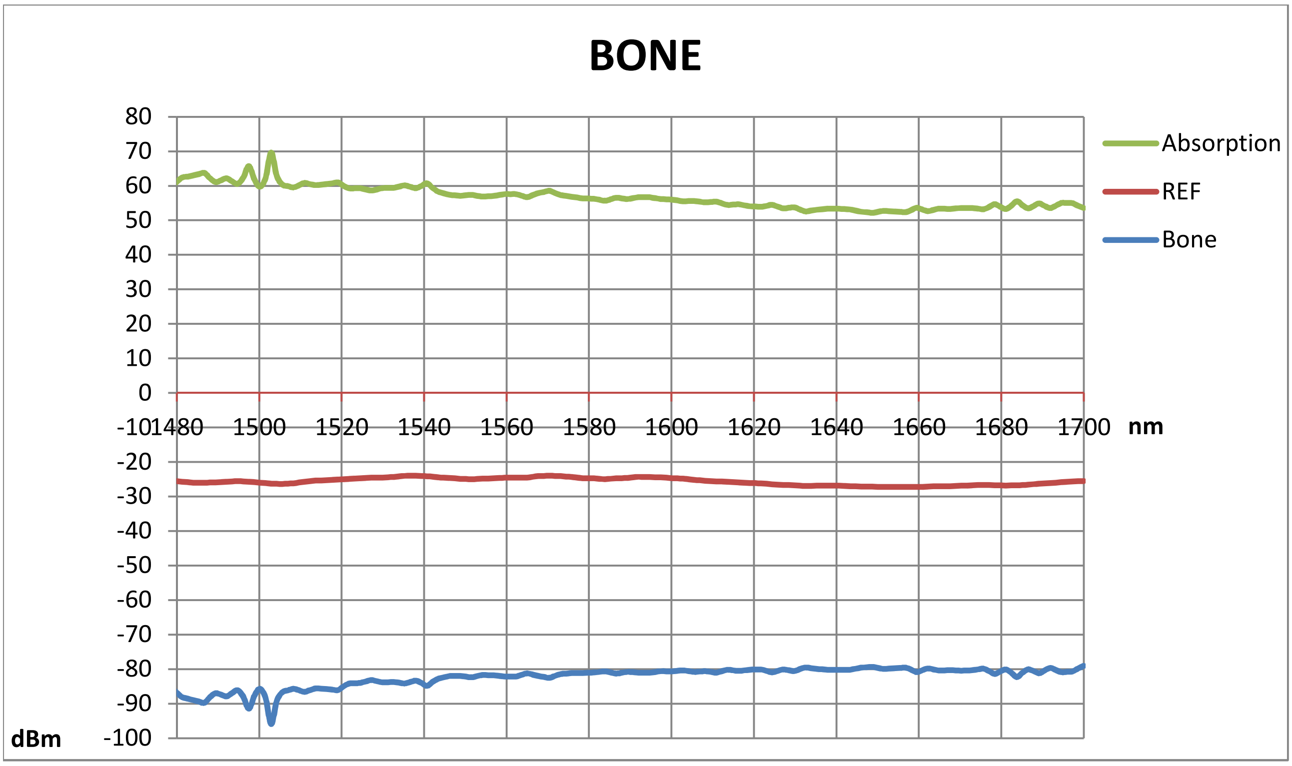

Fig. 9 – Graph of the reference radiation source (REF), the radiation that passes through the tissue (Bone) and absorption (Ab-sorption) in sprague dawley rat femur bone for wavelengths from 1480 nm till 1700 nm.

Wavelength (nm)	Bone Measure (dBm)	Wavelength (nm)	Bone Measure (dBm)
350.000	**-81.172**	363.500	-79.002
351.350	-79.798	364.850	**-80.733**
352.700	-78.756	366.200	**-83.655**
354.050	-78.833	367.550	**-82.604**
355.400	-78.911	368.900	**-81.759**
356.750	**-80.304**	370.250	**-84.322**
358.100	**-82.369**	371.600	**-91.409**
359.450	**-84.276**	372.950	**-85.950**
360.800	**-87.755**	374.300	**-83.606**
362.150	**-81.469**	375.650	**-93.793**

Table 1 - Values of measured light from spectrum analyzer in sprague dawley rat femur bone at wavelengths from 350.000 nm to 375.650 nm. The values lower than -80 dBm are in red. For the reasons illustrated in this chapter it is be-lieved that the light is completely absorbed at these wavelengths.

Wavelength (nm)	Bone Measure (dBm)	Wavelength (nm)	Bone Measure (dBm)
574.100	**-94.356**	587.600	**-97.720**
575.450	**-87.015**	588.950	**-87.438**
576.800	**-84.425**	590.300	**-84.636**
578.150	**-86.871**	591.650	**-83.698**
579.500	**-92.999**	593.000	**-82.927**
580.850	**-89.181**	594.350	**-83.553**

582.200	-87.181	595.700	-84.286
583.550	-88.152	597.050	-85.267
584.900	-89.405	598.400	-86.536
586.250	-91.818	599.750	-80.683

Table 2 - Values of measured light from spectrum analyzer in sprague dawley rat femur bone at wavelengths from 574.100 nm to 599.750 nm. The values lower than -80 dBm are in red. For the reasons illustrated in this chapter it is believed that the light is completely absorbed at these wavelengths.

Wavelength (nm)	Bone Measure (dBm)	Wavelength (nm)	Bone Measure (dBm)
1388.150	-80.459	1419.200	-90.001
1389.500	-81.226	1420.550	-90.877
1390.850	-81.226	1421.900	-91.975
1392.200	-81.227	1423.250	-92.586
1393.550	-81.983	1424.600	-93.298
1394.900	-82.900	1425.950	-89.840
1396.250	-83.472	1427.300	-87.940
1397.600	-84.130	1428.650	-89.737
1398.950	-83.978	1430.000	-92.859
1400.300	-83.831	1431.350	-90.772
1401.650	-86.477	1432.700	-89.369
1403.000	-94.412	1434.050	-90.061
1404.350	-89.469	1435.400	-90.886
1405.700	-87.217	1436.750	-92.663
1407.050	-87.803	1438.100	-95.719
1408.400	-88.481	1439.450	-90.802
1409.750	-89.591	1440.800	-88.555
1411.100	-91.087	1442.150	-87.734
1412.450	-89.152	1443.500	-87.043
1413.800	-87.818	1444.850	-89.797
1415.150	-88.888	1446.200	-99.198
1416.500	-90.311	1447.550	-95.353
1417.850	-90.153	1448.900	-93.346

Table 3 - Values of measured light spectrum analyzer in sprague dawley rat femur bone at wavelengths from 1388.150 nm to 1448.900 nm. The values lower than -80 dBm are in red. For the reasons illustrated in this chapter it is believed that the light is completely absorbed at these wavelengths.

Wavelength (nm)		Bone Measure (dBm)	Bone Absorption (dB)
from	to		
350.000	375.650	values < -80	full absorption
377.000	572.750	spikes < -80	full absorption
574.100	599.750	values < -80	full absorption
601.100	1386.800	values > -80	valid values
1388.150	1448.900	values < -80	full absorption
1450.250	1469.150	spikes < -80	full absorption
1470.500	1700.000	values < -80	full absorption

Table 4 - Summary of wavelengths where light is completely absorbed in sprague dawley rat femur bone. Values lower than -80 dBm are deemed too small because they are not read by the spectrum analyzer. So those wavelengths light are considered as completely absorbed.

Wavelength (nm)	REF (dBm)	Bone Measure (dBm)	Bone Absorption (dB)
798.200	-12.350	-69.864	57.514
799.550	-11.882	-69.514	57.632
800.900	-11.459	-69.190	57.731
802.250	-11.187	-68.926	57.739
803.600	-10.931	-68.677	57.746
804.950	-10.930	-68.667	57.737
806.300	-10.929	-68.658	57.729
807.650	-10.913	-68.633	57.720
809.000	-10.897	-68.609	57.712
810.350	-10.977	-68.687	57.710
811.700	-11.058	-68.767	57.709
813.050	-11.737	-69.364	57.627
814.400	-12.543	-70.057	57.514
815.750	-12.615	-70.072	57.457

Table 5 - The table shows that the value of absorption in sprague dawley rat femur bone remains almost constant for wavelength from 798.200 nm to 815.750 nm. At 809.000 nm the value of source is maximum (in red), but despite this absorption is almost constant.

Wavelength (nm)	REF (dBm)	Bone Measure (dBm)	Bone Absorption (dB)
1045.250	-18.102	-71.212	53.110
1046.600	-18.139	-71.200	53.061
1047.950	-18.178	-71.256	53.078
1049.300	-18.217	-71.312	53.095
1050.650	-18.250	-71.343	53.093
1052.000	-18.284	-71.375	53.091
1053.350	-18.324	-71.334	53.010
1054.700	-18.364	-71.294	52.930
1056.050	-18.349	-71.221	52.872
1057.400	-18.334	-71.149	52.815
1058.750	-18.123	-66.780	48.657
1060.100	-17.921	-64.646	46.725
1061.450	-17.932	-64.635	46.703
1062.800	-17.942	**-64.623**	46.681
1064.150	-17.941	-64.688	46.747
1065.500	-17.939	-64.755	46.816
1066.850	-17.964	-64.802	46.838
1068.200	-17.988	-64.850	46.862
1069.550	-18.255	-66.865	48.610
1070.900	-18.540	-70.741	52.201
1072.250	-18.565	-70.779	52.214
1073.600	-18.590	-70.817	52.227
1074.950	-18.604	-70.646	52.042
1076.300	-18.618	-70.482	51.864
1077.650	-18.597	-70.155	51.558

Table 6 - Values of radiation passing through and of radiation absorbed in sprague dawley rat femur bone in relation to radiation emitted at wavelengths from 1045.250 nm to 1077.650 nm. The maximum light value passing through the tissue is in red.

Wavelength (nm)		dBm or dB	Light
809.000		-10.897 dBm	maximum value of light source
1062.800		46.681 dB	minimum absorption
1062.800		-64.623 dBm	maximum transmission
449.900		-46.547 dBm	minimum value of light source
from	to		
350.000	375.650	values < -80	full absorption
377.000	572.750	spikes < -80	full absorption
574.100	599.750	values < -80	full absorption
601.100	1386.800	values > -80	valid values
1388.150	1448.900	values < -80	full absorption
1450.250	1469.150	spikes < -80	full absorption
1470.500	1700.000	values < -80	full absorption

Table 7 – Summary table.

Discussion

The purpose of this study is to analyze the amount of light that can pass through a tissue and the radiation absorption inside it at different wavelengths.

After accomplishing the measurements on each tissue, recording data, building graphic and understanding the numbers, we must now observe carefully and objectively the measures graphs and their values.

All the graphs show that at low wavelengths, up to about 400-600 nm, and at high wavelengths above 1300 nm, whether they are at the spikes not transmitted light (-210.000 dBm) or not, the radiation does not pass through used tissues. In these areas the light is completely absorbed. Of course, this statement must be evaluated case by case.

For lack of space and for much better clarity, the data collected were inserted all together in two separate graphs. The first eight tissue, reported in Table 1 have been included in the first graph (Fig. 1) and the other seven of the Table 1, in the second graph (Fig. 2).

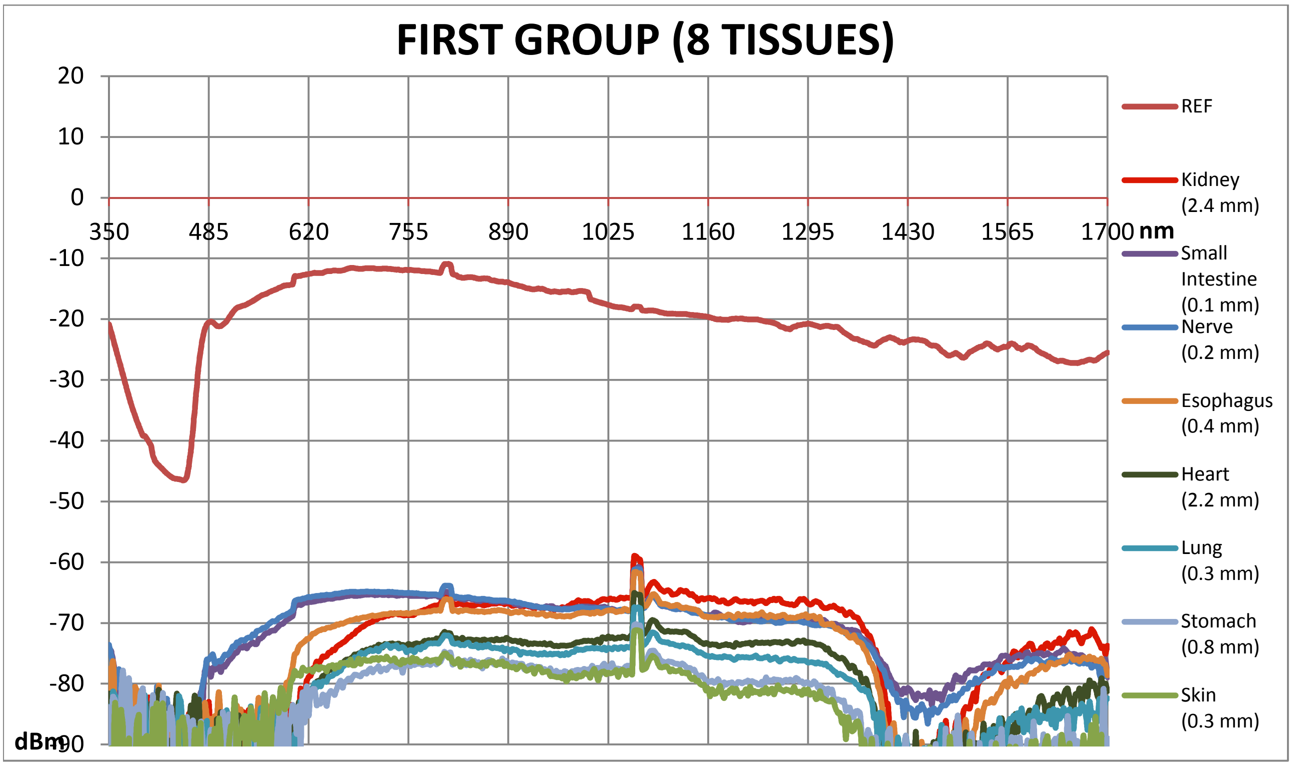

Fig. 1 – Graph of the measures on first group of analyzed tissues. The order is listed in the legend from top to bottom starting from higher to lower passing light measure values at 1160 nm.

At first glance it would seem obvious and logical that the thinner the tissue, the more will be the light passing through it. Hence the following questions arise:

- Is it really true that the thinner the tissue the more will be the light passing through it?
- For a given wavelength and for a given thickness, will the light pass in the same way and in the same amount in all the analyzed tissues?

- Is the thickness affecting the light ability to pass through the tissue? Is it the only variable, or does the thickness influence the light transmission differently from one wavelength to another?
- Can the tissue intrinsic features like nature, color and histology influence the amount of light through or how much light the tissue can hold back?

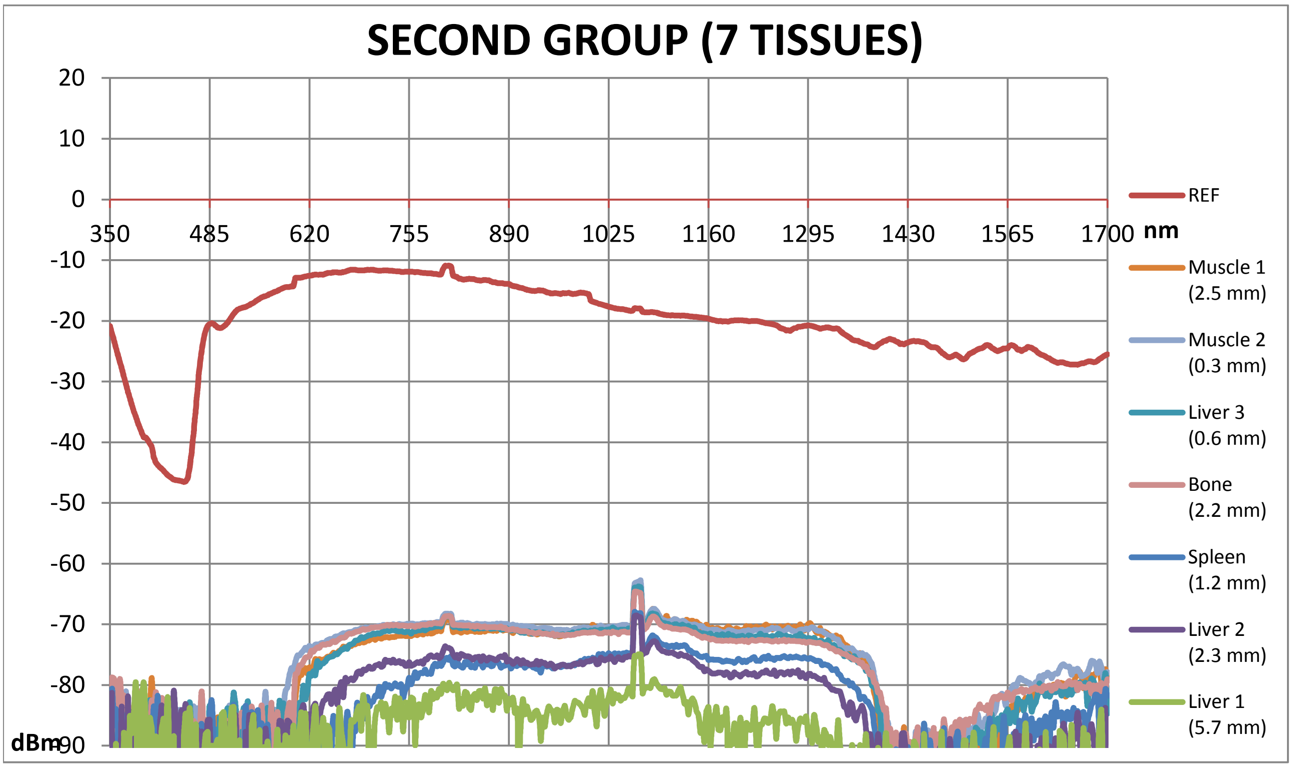

Fig. 2 – Graph of the measures on second group of analyzed tissues. The order is listed in the legend from top to bottom starting from higher to lower passing light measure values at 1160 nm.

In Table 1 are listed the tissues separated per group of analysis:

Group	Order	Tissue	Thickness
1st group	1	Nerve	0.2 mm
	2	Skin	0.3 mm
	3	Small Intestine	0.1 mm
	4	Lung	0.3 mm
	5	Esophagus	0.4 mm
	6	Stomach	0.8 mm
	7	Kidney	2.4 mm
	8	Heart	2.2 mm
2nd group	9	Spleen	1.2 mm
	10	Liver 1	5.7 mm
	11	Liver 2	2.3 mm
	12	Liver 3	0.6 mm
	13	Muscle 1	2.5 mm
	14	Muscle 2	0.3 mm
	15	Bone	2.2 mm

Table 1 – List used tissue in order to the study.

For the reader convenience, in Table 2 are also listed all used tissue and sorted from the thinner to the thicker:

Order	Tissue	Thickness
1	Small Intestine	0.1 mm
2	Nerve	0.2 mm
3	Skin	0.3 mm
4	Lung	0.3 mm
5	Muscle 2	0.3 mm
6	Esophagus	0.4 mm
7	Liver 3	0.6 mm
8	Stomach	0.8 mm
9	Spleen	1.2 mm
10	Heart	2.2 mm
11	Bone	2.2 mm
12	Liver 2	2.3 mm
13	Kidney	2.4 mm
14	Muscle 1	2.5 mm
15	Liver 1	5.7 mm

Table 2 – List used tissue in order to the thickness.

To answer the questions raised above we analyzed each tissue values at specific wavelengths and for each of them a ranking was defined. The chosen wavelengths are:

- 620.000 nm
- 755.000 nm
- 890.000 nm
- 1060.100 nm
- 1160.000 nm
- 1295.000 nm

We consider the eight first tissue of our study (Fig. 1). The thinnest tissue is the small intestine (0.1 mm). If it were true that the more the tissue is thin, the more the light will pass through it, the small intestine should be always at the first place. Instead it is always at the second or third place and, in Fig. 1, at a wavelength of 1160 nm (Table 7, Table 19) it is at second place, after the kidney (thickness 2.4 mm), which has a thickness of twenty-four times greater than the small intestine.

The skin has a thickness of only three times the small intestine but, at the same wavelength of 1160 nm it is eighth place (Table 7, or the 14th Table 19) and the light at this wavelength, even does not pass through it, because the measured value (-80.800 dBm) is less than the acceptable limit of -80 dBm.

As another example of how thinner thickness not always implies more light to pass, we have small intestine and nerve. At wavelength of 620 nm (Table 3, Table 15) the small intestine (thickness 0.1 mm) is still in second place, but after the nerve, which is thicker (0.2 mm). At this same wavelength, the skin, which at 1160 nm was at eighth place, now it is in fourth (Table 3) (from 14th

to 7th in the Table 15). Moreover, at 620 nm, the skin lets the light passing, while at 1160 nm it didn't.

Other interesting examples exist. The lung, which has the same thickness of the skin, at 1160 nm is in 6th place (Table 3, or the 10th in Table 19), but the light does not even pass through it because the measured value (-81.323 dBm) is less than the limit value considered acceptable.

At wavelength of 755 nm (Table 16), even though not inversely proportional to the thickness, light passes through all listed tissues, except Liver 1, which is the thickest.

So we can think that the possibility of the light to pass through a tissue, at a certain wavelength, is not strictly depending on the thickness, but also on the wavelength and on the nature of the tissue. This is confirmed by analysis of other tables.

The following tables list the tissues in the order in which the light passes through them while providing their thickness and the corresponding measured value. In these chapters we always spoke of passing light, but the absorption is related to it and decreases when its increases. So the light passing through the tissue and absorption are related one another. In fact in the graphs we note that absorption is the mirror image of the transmitted light.

Order	Tissue	Thickness	dBm at 620,000 nm
1	Nerve	0.2 mm	-65.709
2	Small intestine	0.1 mm	-66.573
3	Esophagus	0.4 mm	-72.584
4	Skin	0.3 mm	-77.708
5	Kidney	2.4 mm	-78.856
6	Lung	0.3 mm	**-81.323**
7	Heart	2.2 mm	**-82.037**
8	Stomach	0.8 mm	**-85.246**

Table 3 – List of first group of tissues sorted by amount of transmitted light at 620.000 nm along with their thickness. The values less than -80 dBm, expression of full absorption, are in red.

Order	Tissue	Thickness	dBm at 755,000 nm
1	Nerve	0.2 mm	-65.037
2	Small intestine	0.1 mm	-65.477
3	Esophagus	0.4 mm	-68.511
4	Kidney	2.4 mm	-68.710
5	Heart	2.2 mm	-73.441
6	Lung	0.3 mm	-74.587
7	Skin	0.3 mm	-76.154
8	Stomach	0.8 mm	-76.402

Table 4 – List of first group of tissues sorted by amount of transmitted light at 755.000 nm along with their thickness.

Order	Tissue	Thickness	dBm at 890,000 nm
1	Nerve	0.2 mm	-66.370
2	Small intestine	0.1 mm	-66.470
3	Kidney	2.4 mm	-66.748
4	Esophagus	0.4 mm	-68.126
5	Heart	2.2 mm	-72.664
6	Lung	0.3 mm	-74.402
7	Stomach	0.8 mm	-76.611
8	Skin	0.3 mm	-77.142

Table 5 – List of first group of tissues sorted by amount of transmitted light at 890.000 nm along with their thickness.

Order	Tissue	Thickness	dBm at 1060.100 nm
1	Kidney	2.4 mm	-58.955
2	Nerve	0.2 mm	-61.234
3	Small intestine	0.1 mm	-61.375
4	Esophagus	0.4 mm	-61.669
5	Heart	2.2 mm	-65.078
6	Lung	0.3 mm	-67.439
7	Stomach	0.8 mm	-70.364
8	Skin	0.3 mm	-71.325

Table 6 – List of first group of tissues sorted by amount of transmitted light at 1060.100 nm along with their thickness.

Order	Tissue	Thickness	dBm at 1160.000 nm
1	Kidney	2.4 mm	-65.911
2	Small intestine	0.1 mm	-68.685
3	Nerve	0.2 mm	-68.900
4	Esophagus	0.4 mm	-69.067
5	Heart	2.2 mm	-73.431
6	Lung	0.3 mm	-75.423
7	Stomach	0.8 mm	-79.661
8	Skin	0.3 mm	**-80.800**

Table 7 – List of first group of tissues sorted by amount of transmitted light at 1160.000 nm along with their thickness. The value less than -80 dBm, expression of full absorption, is in red.

Order	Tissue	Thickness	dBm at 1295.000 nm
1	Kidney	2.4 mm	-66.778
2	Esophagus	0.4 mm	-69.145
3	Small intestine	0.1 mm	-69.266
4	Nerve	0.2 mm	-70.017
5	Heart	2.2 mm	-73.114
6	Lung	0.3 mm	-76.530
7	Stomach	0.8 mm	-79.802
8	Skin	0.3 mm	**-80.942**

Table 8 – List of first group of tissues sorted by amount of transmitted light at 1295.000 nm along with their thickness. The value less than -80 dBm, expression of full absorption, is in red.

Let us now look at the second group of the other seven tissues of our study (Fig. 2). Also in this case we examined values at the same wavelength of the previous ones and for each of them a ranking was defined.

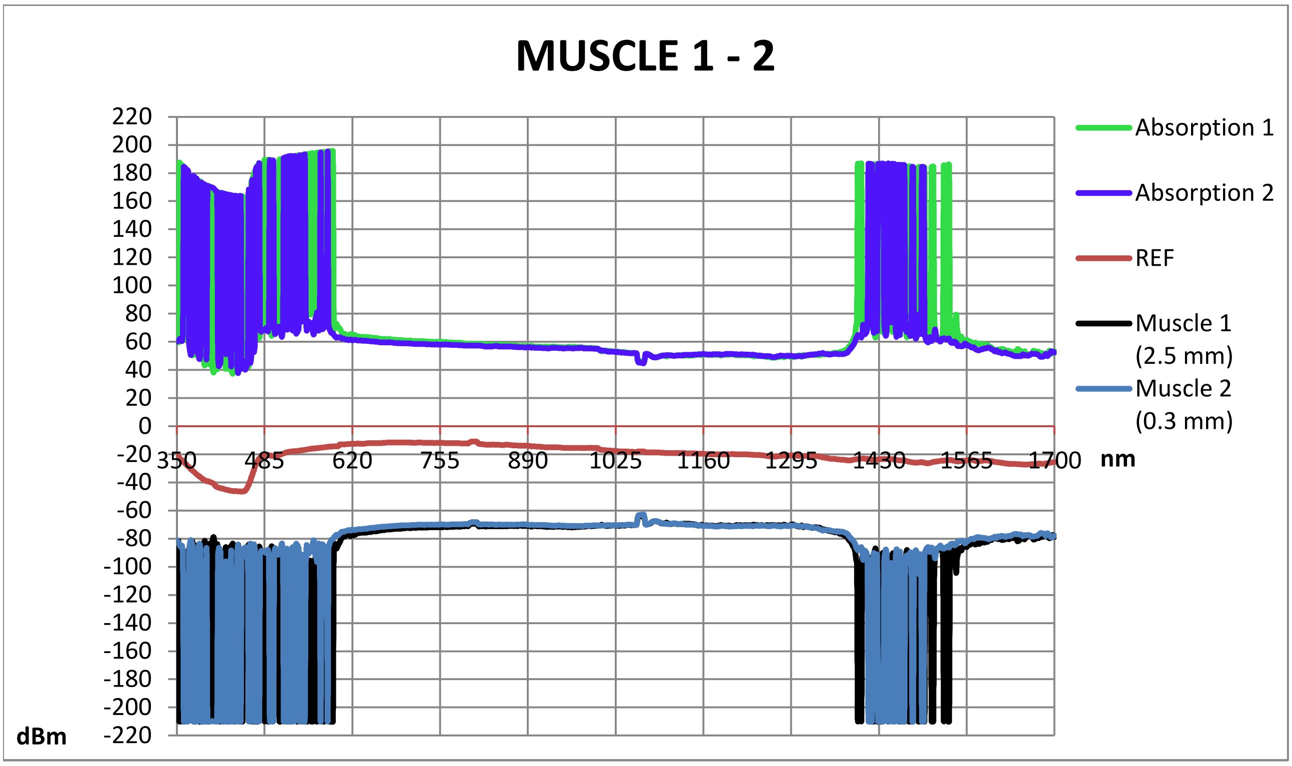

Fig. 3 – Comparison graphs of measurements on Muscle 1 and Muscle 2. You note that the paths have the same shape and Muscle 2, thinner, at certain wavelengths, allows more light to pass than Muscle 1.

The thinnest tissue, equal to 0.3 mm, is the Muscle 2. If we extend the same reasoning made with previous tissues, we see that Muscle 2 (see second group tables) is always at first place except at wavelengths 1160.000 nm and 1295.000 nm. At these wavelengths Muscle 2 is preceded by Muscle 1, which is eight times thicker. This priority surely is not due to the thickness, since Muscle 1 is much thicker than Muscle 2. It cannot even be due to the nature or the characteristic of the tissue, because they are identical.

Analyzing the transmitted light numbers of Muscle 1 and Muscle 2 we noted that, excluding the spikes area, starting from the wavelength of 350 nm up to 1700 nm, the value of the transmission is always higher for the thinner muscle (Muscle 2) except for some wavelengths to which the values are bigger for the thicker muscle. These specific wavelengths are 1160 nm and 1295 nm, but we have to considered that the difference of such measured values is in the range of few tenths of dBm. Therefore the transmission values (or absorption values) shall be considered almost equal. From the wavelength of 1025 nm up to 1350 nm the two paths are overlapped.

These reasonings are performed on tissues of the same kind and the comparison performed here is very simple, because the only variable between the two tissues is their thickness. Hence for tissues of the same kind, certainty the thinner one lets pass more light than the thicker one (Fig. 3).

Moving forward with the analysis, the thickest tissue in the second group is Liver 1. The light passes through it only at wavelengths between 1058.750 nm and 1069.550 nm and between

1083.050 nm and 1091.150 nm (Fig. 4). At other wavelengths the light is completely absorbed (see chapter Liver 1).

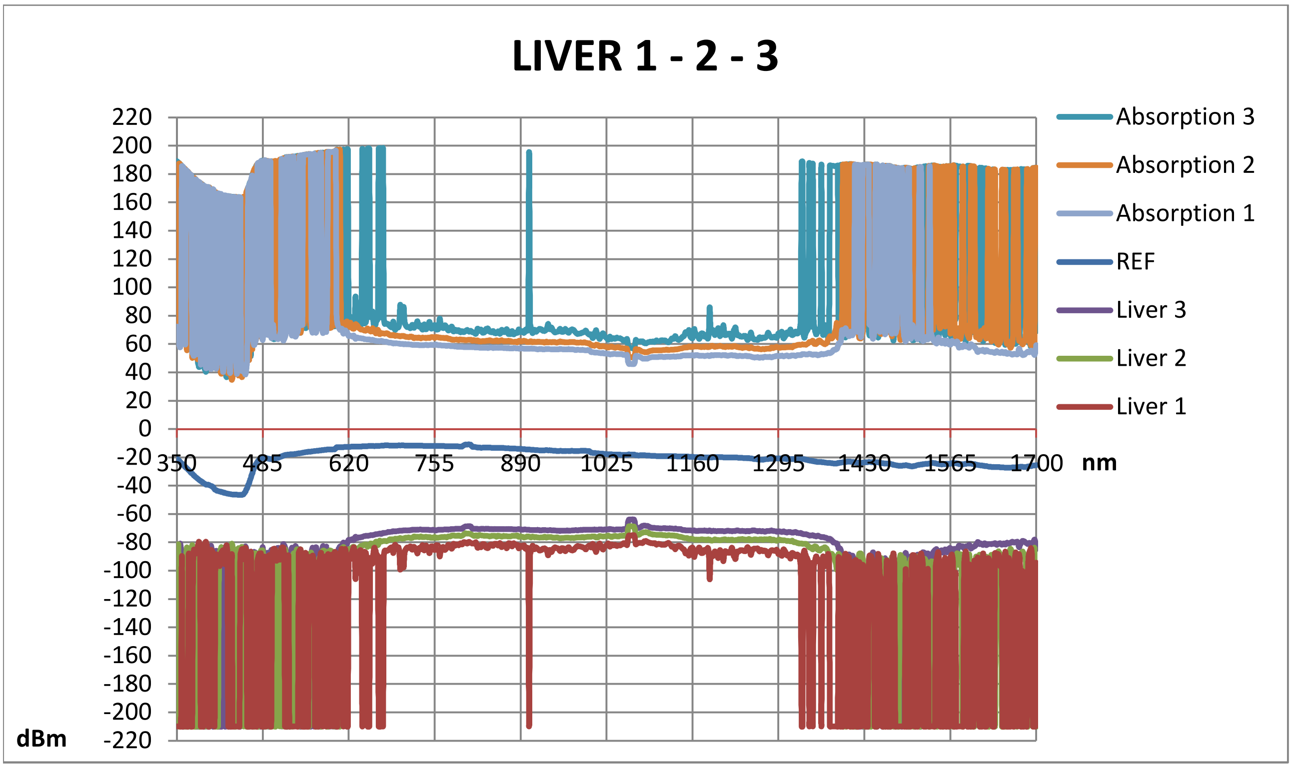

Fig. 4 – Comparison graphs of measurements on Liver 1, Liver 2 and Liver 3. You note that the tracks have the same form and that the thicker the tissue the less light can pass through it.

Analyzing the second group tissues, the competition of first places in our ranking is between Muscle 1, Bone, Muscle 2 and Liver 3. At wavelength of 620 nm the passing light values in these tissues differ only for some dBm from one tissue to another one (Table 9). These values are not inversely proportional to tissue thickness. Therefore we can say that the light passes due to an intrinsic tissue ability to let pass light at that specific wavelength.

It can also be noticed from tables that include all the tissues measures (Table 15, Table 16, Table 17, Table 18, Table 19, Table 20).

The last three tissues in the ranking, Spleen, Liver 2 and Liver 1, at 620 nm do not even allow light to pass through them, but instead, at wavelength of 755 nm (Table 10), only Liver 2 and Spleen allow light to pass. Specifically, spleen lets pass less light than Liver 2, even if it is thinner. Considering that spleen is darker than the liver, then we can think that it absorbs more, and the value of light passing through it is less than Liver 2, most likely for this reason. So we can suppose that at low wavelengths, the dark chromophore absorbs more, while this does not occur at higher wavelengths. In fact at 1060.100, at 1160 and at 1295 (Table 12, Table 13, Table 14) the spleen lets pass more light than Liver 2. At support of this consideration, the bone, which is more compact than the spleen and has approximately twice the thickness, it is always higher in our ranking order.

At a wavelength between 1057.400 nm to 1070.900 nm, range in which there is a passing light increase, all tissues have shown that in this area the light pass more easily through them.

So we can conclude that it is not always true that the thicker the tissue the less light will pass through it. This is true only if the tissues are of the same kind: in such tissues, transmitted light is effectively inversely proportional to their thickness (Fig. 3 e Fig. 4).

If the tissues instead are different, at a certain wavelength, the light will pass, more or less, in a manner dependent on the intrinsic affinity of that tissue at that wavelength. There are wavelengths that pass better in a thicker tissue than a thinner one (Table 10, comparison between Muscle 1 and Spleen), but the spleen is darker than the muscle and perhaps absorbs more, precisely because it is dark. It is known that at this wavelength (755 nm) light still has a high affinity with hemoglobin and melanin.

Perhaps not even this statement is completely true, because the kidney is darker than the esophagus, which is clear (Table 5), but the kidney, at 890 nm wavelength, lets pass more light than the esophagus and it absorbs more, although it is much lighter and thinner than kidney.

Also the lung is clearer than the kidney, but it is at the sixth place in our ranking, preceded by the kidney and by the heart despite they are darker and thicker than the lung (Table 4, Table 5, Table 6).

At wavelengths of 890 nm light still has affinity with melanin and hemoglobin and starts the affinity with water. Beyond this wavelength, the transmitted light order is subverted, and passes more light in the kidney than in other tissues rich in water, lighter and thicker, such as the small intestine, esophagus, or nerve (Table 7, Table 8).

The values reported in all the tables in this chapter allows the reader to perform many other comparisons and understand or integrate if necessary what illustrated in this study..

Order	Tissue	Thickness	dBm at 620.000 nm
1	Muscle 2	0.3 mm	-73.553
2	Bone	2.2 mm	-75.282
3	Muscle 1	2.5 mm	-77.101
4	Liver 3	0.6 mm	-78.199
5	Liver 2	2.3 mm	**-84.784**
6	Spleen	1.2 mm	**-89.412**
7	Liver 1	5.7 mm	**-91.560**

Table 9 – List of second group of tissues sorted by amount of transmitted light at 620.000 nm along with their thickness. The values less than -80 dBm, expression of full absorption, are in red.

Order	Tissue	Thickness	dBm at 755.000 nm
1	Muscle 2	0.3 mm	-70.046
2	Bone	2.2 mm	-70.268
3	Liver 3	0.6 mm	-71.296
4	Muscle 1	2.5 mm	-71.856
5	Liver 2	2.3 mm	-76.229
6	Spleen	1.2 mm	-78.804
7	Liver 1	5.7 mm	**-85.364**

Table 10 – List of second group of tissues sorted by amount of transmitted light at 755.000 nm along with their thickness. The value less than -80 dBm, expression of full absorption, is in red.

Order	Tissue	Thickness	dBm at 890.000 nm
1	Muscle 2	0.3 mm	-70.089
2	Liver 3	0.6 mm	-70.878
3	Bone	2.2 mm	-70.882
4	Muscle 1	2.5 mm	-70.970
5	Liver 2	2.3 mm	-75.813
6	Spleen	1.2 mm	-76.308
7	Liver 1	5.7 mm	**-82.309**

Table 11 – List of second group of tissues sorted by amount of transmitted light at 890.000 nm along with their thickness. The value less than -80 dBm, expression of full absorption, is in red.

Order	Tissue	Thickness	dBm at 1060.100 nm
1	Muscle 2	0.3 mm	-63.283
2	Muscle 1	2.5 mm	-63.777
3	Liver 3	0.6 mm	-63.951
4	Bone	2.2 mm	-64.646
5	Spleen	1.2 mm	-67.933
6	Liver 2	2.3 mm	-68.645
7	Liver 1	5.7 mm	-75.198

Table 12 – List of second group of tissues sorted by amount of transmitted light at 1060.100 nm along with their thickness.

Order	Tissue	Thickness	dBm at 1160.000 nm
1	Muscle 1	2.5 mm	-70.723
2	Muscle 2	0.3 mm	-70.946
3	Liver 3	0.6 mm	-71.773
4	Bone	2.2 mm	-72.271
5	Spleen	1.2 mm	-75.869
6	Liver 2	2.3 mm	-77.622
7	Liver 1	5.7 mm	**-83.649**

Table 13 – List of second group of tissues sorted by amount of transmitted light at 1160.000 nm along with their thickness. The value less than -80 dBm, expression of full absorption, is in red.

Order	Tissue	Thickness	dBm at 1295.000 nm
1	Muscle 1	2.5 mm	-69.960
2	Muscle 2	0.3 mm	-70.858
3	Liver 3	0.6 mm	-72.249
4	Bone	2.2 mm	-72.911
5	Spleen	1.2 mm	-75.715
6	Liver 2	2.3 mm	-78.194
7	Liver 1	5.7 mm	**-88.231**

Table 14 – List of second group of tissues sorted by amount of transmitted light at 1295.000 nm along with their thickness. The value less than -80 dBm, expression of full absorption, is in red.

We place now all the tissues in the same table for each wavelength considered. Each of these tables shows the tissues capability to allow the light to pass through and their sequence at each wavelength considered.

Order	Tissue	Thickness	dBm at 620.000 nm
1	Nerve	0.2 mm	-65.709
2	Small intestine	0.1 mm	-66.573
3	Esophagus	0.4 mm	-72.584
4	Muscle 2	0.3 mm	-73.553
5	Bone	2.2 mm	-75.282
6	Muscle 1	2.5 mm	-77.101
7	Skin	0.3 mm	-77.708
8	Liver 3	0.6 mm	-78.199
9	Kidney	2.4 mm	-78.856
10	Lung	0.3 mm	**-81.323**
11	Heart	2.2 mm	**-82.037**
12	Liver 2	2.3 mm	**-84.784**
13	Stomach	0.8 mm	**-85.246**
14	Spleen	1.2 mm	**-89.412**
15	Liver 1	5.7 mm	**-91.560**

Table 15 – List of all the tissues sorted by amount of transmitted light at 620.000 nm along with their thickness. The tissues of the first group and the values less than -80 dBm, expression of full absorption, are in red.

Order	Tissue	Thickness	dBm at 755.000 nm
1	Nerve	0.2 mm	-65.037
2	Small intestine	0.1 mm	-65.477
3	Esophagus	0.4 mm	-68.511
4	Kidney	2.4 mm	-68.710
5	Muscle 2	0.3 mm	-70.046
6	Bone	2.2 mm	-70.268
7	Liver 3	0.6 mm	-71.296
8	Muscle 1	2.5 mm	-71.856
9	Heart	2.2 mm	-73.441
10	Lung	0.3 mm	-74.587
11	Skin	0.3 mm	-76.154
12	Liver 2	2.3 mm	-76.229
13	Stomach	0.8 mm	-76.402
14	Spleen	1.2 mm	-78.804
15	Liver 1	5.7 mm	**-85.364**

Table 16 – List of all the tissues sorted by amount of transmitted light at 755.000 nm along with their thickness. The tissues of the first group and the value less than -80 dBm, expression of full absorption, are in red.

Order	Tissue	Thickness	dBm at 890.000 nm
1	Nerve	0.2 mm	-66.370
2	Small intestine	0.1 mm	-66.470
3	Kidney	2.4 mm	-66.748
4	Esophagus	0.4 mm	-68.126
5	Muscle 2	0.3 mm	-70.089
6	Liver 3	0.6 mm	-70.878
7	Bone	2.2 mm	-70.882
8	Muscle 1	2.5 mm	-70.970
9	Heart	2.2 mm	-72.664
10	Lung	0.3 mm	-74.402
11	Liver 2	2.3 mm	-75.813
12	Spleen	1.2 mm	-76.308
13	Stomach	0.8 mm	-76.611
14	Skin	0.3 mm	-77.142
15	Liver 1	5.7 mm	**-82.309**

Table 17 – List of all the tissues sorted by amount of transmitted light at 890.000 nm along with their thickness. The tissues of the first group and the value less than -80 dBm, expression of full absorption, are in red.

Order	Tissue	Thickness	dBm at 1060.100 nm
1	Kidney	2.4 mm	-58.955
2	Nerve	0.2 mm	-61.234
3	Small intestine	0.1 mm	-61.375
4	Esophagus	0.4 mm	-61.669
5	Muscle 2	0.3 mm	-63.283
6	Muscle 1	2.5 mm	-63.777
7	Liver 3	0.6 mm	-63.951
8	Bone	2.2 mm	-64.646
9	Heart	2.2 mm	-65.078
10	Lung	0.3 mm	-67.439
11	Spleen	1.2 mm	-67.933
12	Liver 2	2.3 mm	-68.645
13	Stomach	0.8 mm	-70.364
14	Skin	0.3 mm	-71.325
15	Liver 1	5.7 mm	-75.198

Table 18 – List of all the tissues sorted by amount of transmitted light at 1060.100 nm along with their thickness. The tissues of the first group are in red.

Order	Tissue	Thickness	dBm at 1160.000 nm
1	Kidney	2.4 mm	-65.911
2	Small intestine	0.1 mm	-68.685
3	Nerve	0.2 mm	-68.900
4	Esophagus	0.4 mm	-69.067
5	Muscle 1	2.5 mm	-70.723
6	Muscle 2	0.3 mm	-70.946
7	Liver 3	0.6 mm	-71.773
8	Bone	2.2 mm	-72.271
9	Heart	2.2 mm	-73.431
10	Lung	0.3 mm	-75.423
11	Spleen	1.2 mm	-75.869
12	Liver 2	2.3 mm	-77.622
13	Stomach	0.8 mm	-79.661
14	Skin	0.3 mm	**-80.800**
15	Liver 1	5.7 mm	**-83.649**

Table 19 – List of all the tissues sorted by amount of transmitted light at 1160.000 nm along with their thickness. The tissues of the first group and the values less than -80 dBm, expression of full absorption, are in red.

Order	Tissue	Thickness	dBm at 1295.000 nm
1	Kidney	2.4 mm	-66.778
2	Esophagus	0.4 mm	-69.145
3	Small intestine	0.1 mm	-69.266
4	Muscle 1	2.5 mm	-69.960
5	Nerve	0.2 mm	-70.017
6	Muscle 2	0.3 mm	-70.858
7	Liver 3	0.6 mm	-72.249
8	Bone	2.2 mm	-72.911
9	Heart	2.2 mm	-73.114
10	Spleen	1.2 mm	-75.715
11	Lung	0.3 mm	-76.530
12	Liver 2	2.3 mm	-78.194
13	Stomach	0.8 mm	-79.802
14	Skin	0.3 mm	**-80.942**
15	Liver 1	5.7 mm	**-88.231**

Table 20 – List of all the tissues sorted by amount of transmitted light at 1295.000 and their thickness. The tissues of the first group and the values less than -80 dBm, expression of full absorption, are in red.

Conclusions

We always talked about light transmitted or light passing through the tissue. This statement implies that its value is inversely proportional to absorption: the higher the light passing value, the lower is the light absorption value in that tissue, at a given wavelength.

From what has been stated here it can be concluded that for wavelengths from 350 nm up to about 400-600 nm, and from 1300 nm up to 1700 nm, the light does not pass through the tissues. So all these wavelengths, in these areas, are completely absorbed in the studied tissues. However, in order to resolve this claim, is correct to analyze case by case.

In the range from 400-600 nm to 1300 nm, although in different amounts, all tissues let pass the light and therefore in this range the absorption is less.

The thickness is not decisive to allow light to pass into the tissue. Indeed, at a certain wavelength, some tissues, much thicker than other (see tables), lets pass light better than others, or some thinner tissues absorb more, and in them the light passes less.

The thickness is decisive only in the analysis of the same tissue. The graphs of the same tissue, in samples of different thickness, show that the light passes in the same way. The only difference between them is the passing light value, which will be higher in thinner samples and, vice versa, it will be lower in thicker samples.

So the thickness will condition the passage of light only in the tissues of the same nature.

In tissues different, instead, the light has an unpredictable behavior. At same wavelength, light will pass in a different manner from one tissue to another.

To understand the significance of this statement we must analyze the numbers and not the order. The tissues order is determined from the light passing values through them.

The graphs observation allows to state that it is indisputable that the light passes more, in absolute terms, at wavelengths ranging from 1057.400 nm to 1070.900 nm, field in which, the passing light values show a marked increase. The wavelengths of this area, within which the light passes more, are precisely at about 1064 nm, Neodymium laser wavelength.

From what has been stated here it can be concluded also that in the same kind of tissue, the thickness affects the amount of passing light through the tissue, at the wavelengths considered, in inverse proportion fashion.

In tissues different, the light passes through them in an unpredictable manner, dependent by nature, histology, color, amount of water contained, in different magnitude, at the wavelengths considered.