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Original Research Article

# WATER INFLUENCE OF 1.064 µM AND 0.532 µM LIGHT WAVELENGTH PROPAGATION DIRECTED AT HUMAN TEETH

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**Abstract.**
The research was performed to calculate the amount of the loss from the light incident on the tooth structure at the 1.064µm and 0.532 µm wavelengths via reflection and transmission. The diffused scattering spectra at 400-900 µm were measured, too. The aim was to find a wavelength that possesses a stable behavior with the tooth structure. To find the suitable wavelength that is not influenced by the dryness of the tooth during laser irradiation. *Material and method*: UV/VIS/NIR spectrometer was implemented to measure the transmission and scattering spectra of.1mm thickness of wet human teeth as a function of time. The change in the light behavior was recorded during the experiment. *Results*: There was a dramatic drop in the amount of transmitted light as the tooth gets dry with time which may be due the abrupt increase in the variation in the refractive index at the interface between the incident media to the transmitted media. *Recommendation*: the presence of water at the interface between air and tooth surface influences the light behavior at 1.064µm while for 0.532 µm wavelength the light was not affected.

## I- Introduction

Since the invention of laser in 1960, there has been a worldwide growing interest in its dental applications. The first attempts to ablate dental tissues took place in 1965(1). Ever since, many publications which cover the mechanisms of tooth ablation using the photothermal effect have arisen. Several laser systems were used to achieve the aforementioned objective. Those are namely; Er:YAG (λ=2.94µm) [2][3] ,CO2 (λ=10.9µm) [4],Nd:YAG(λ=1.064µm) [5]and 532nm laser devices[6]. Furthermore, the plasma mediated ablation using the ultrashort pulse laser with the pulse durations of pico to femtoseconds regime were emerged(7,8). The work of others in this field has concentrated on monitoring and measuring the threshold power

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density needed for ablation to take place, as if the whole delivered energy to the surface is absorbed**(7,8)**..Whereas with metals and semiconductors, surface reflection measurements and calculations are of immense importance **(9,10).**

Moreover, the tooth structure is known to be inhomogeneous, birefringent**(11,12).** The coronal portion of the tooth can be regarded as a biomechanical complex of the two major tissues, enamel and dentin. Enamel is the outermost layer restricted to the coronal portion of the tooth. Enamel is composed of mineral rods which are not in direct contact with each other but are cemented together by inter prismatic substance. The latest has a slightly higher refractive index and a lower concentration of minerals than the rod itself. Each enamel rod is build-up of segment. Those segments are separated by dark lines which give them the striated appearance. These transverse striations that mark the margins of rod segments are insufficiently calcified(11,12).

The dentin which is the supporting structure consists of specialized cells and bulky intercellular substance. The latter consists of roughly the following two components; (i) the collagenous fiber and (ii) cementing substance which is mainly composed of polysaccharides **(**12**,**13**)**.

The specialized cells are the odontoblasts that lie in the pulpal side of dentin. They extend through the full thickness of the dentin (so called, Tom's fiber) in dentinal tubules. Each odontoblastic process in dentin is found to be thin walled tubes (so called Newman's sheath). It is not formed by different membrane, but is formed due to differences in the nature of the matrix at the border of the tubules or the difference in the orientation of the fiber **(11-13).** Dentinal tubules are about 1-3μm in diameter. The density of the tubules depends on their location within dentin which corresponds to 8,100-57,600 tubule per $mm^2$**(14).**

In the visible and near infra-red regions, dentin and enamel weakly absorb light. However, light scattering plays an important role in determining the deposited energy distribution on the tissue. **(15).**

The experiments of this study were carried out by measuring the scattered light intensity in order to draw conclusions regarding the amount of power density losses.

Further objective of the presently reported experiments is to understand the effect of tooth structure in homogeneities on the light beam. This is besides calculating the real amount of power density that causes changes in the structure of the tooth.

## II-Material and Methods

II-1 Sample Preparation:

Extracted human teeth, non caries molars were used in the presently reported set of experiments.

Teeth were stored in distilled water, so that the structure of the tooth will not be disturbed**(16)**. Each tooth was mounted in (Aremco-Bond 526,T-E-Klebetechnik).

Number of sections parallel to the occlusal surface were prepared by slow speed diamond disc (MTI Corporation MODEL 150). Each section was 1mm in thickness. Water was used as a coolant during the slicing of the tooth to prevent tooth damage due to the friction. Slices were stored in water till the time of the experiment. Focused ion beam/scanning electron microscope (FIB/SEM) were used in our work to scan both sides of tooth slices to discard any sample with caries lesion.

III-UV/VIS/NIR Spectrometer Systems

The functioning of UV/VIS/IR instrument is relatively straightforward. The ultraviolet (UV) region scanned is normally from 200 to 400 nm, the visible portion is from 400 to 800 nm, the IR region from 800to1200nm Figure1

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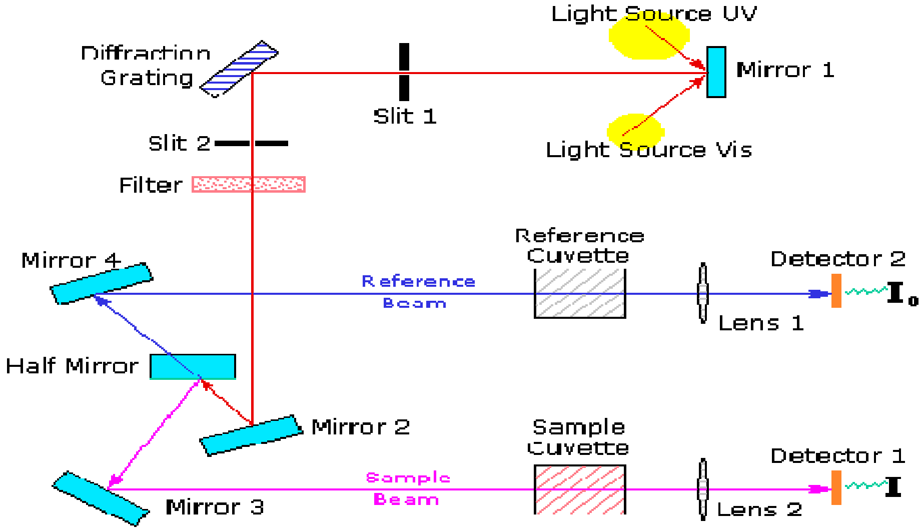


**Figure 1. Scheme diagram of the spectram**

The instrument was Lambda 900 PERKIN ELMER. It is a double beam, ratio recording spectrometer, the measurement of reflectance factor and transmittance involves the performance of the baseline correction.

Radiation from the instrument source of illumination is split into the following two different beams, the sample beam and the reference beam. Each beam is interrupted periodically by means of chopper, each that the integrating sphere is illuminated alternately by the two beams.

At any given wavelength, the instrument records the ratio of the signal produced by the detector when the sphere is illuminated by the sample beam to that when the sphere is illuminated by the reference beam.

Two radiation sources present in the instrument are deuterium lamp and a halogen lamp, cover the working length range of the spectrometer.

Number of mirrors, filters and monochromators are present in the optical path.

The source is changed automatically during the monochromator slewing.

**First Experiment**

The base line was recorded for spectrum width of (1.075-1.055) µm. The sample is a tooth slices of 1mm thickness which was stored in the water.

The diameter of the sample beam was 2mm cover the tooth slice .The tooth slice was chosen from the middle part of the crown where there is no hole of the pulp present.

The measurements were applied for the transmittance versus time i.e. measuring the transmittance while the process of drying of the tooth was carried on with time.

The same experiment was repeated but for another range of wavelength (0.520-0.540) µm.

**Second Experiment**

This experiment have dealt with measuring diffused reflectance. The tooth slice was scanned in order to obtain the correct reflectance. This was achieved by fitting it to the back side of the integrating sphere (PELA-1000) at a port which correspond to $8^0$.The port that was used in this experiment is made of plastic.

The port was fitted with light trap to exclude the specular component reflected from the tooth slice.

The measurements were done at the previously mentioned spectral range (1.075-1.055) µm, (0.520-0.540) µm.

**Third Experiment**

The beam was adjusted in the horizontal direction by watching the beam back reflection image through the holder aperture on a piece of paper to verify the alignment of the holder (port) . Recording the baseline for the wavelength spectral range (300-1200) nm was done.

The tooth slice was adjusted on the port hold by a clamp to record the diffused .reflection for the same previously mentioned spectral range.

**Result and Discussion**

The result showed low transmission at 0.532µm which about 0.28 and for 1.064µm started at 1.75.The value of the transmission for both wavelengths keep decreasing as a function of time and this may be due to the fact that the tooth is getting dry with the time and the difference in the values due to the water vaporization from the sample.

For more than two hours the transmission reaches the value of 0.15 at 0.532 µm, and 0.72 at 1.064 µm which is the real transmission of the tooth at the previously mentioned wavelengths Figure-2.

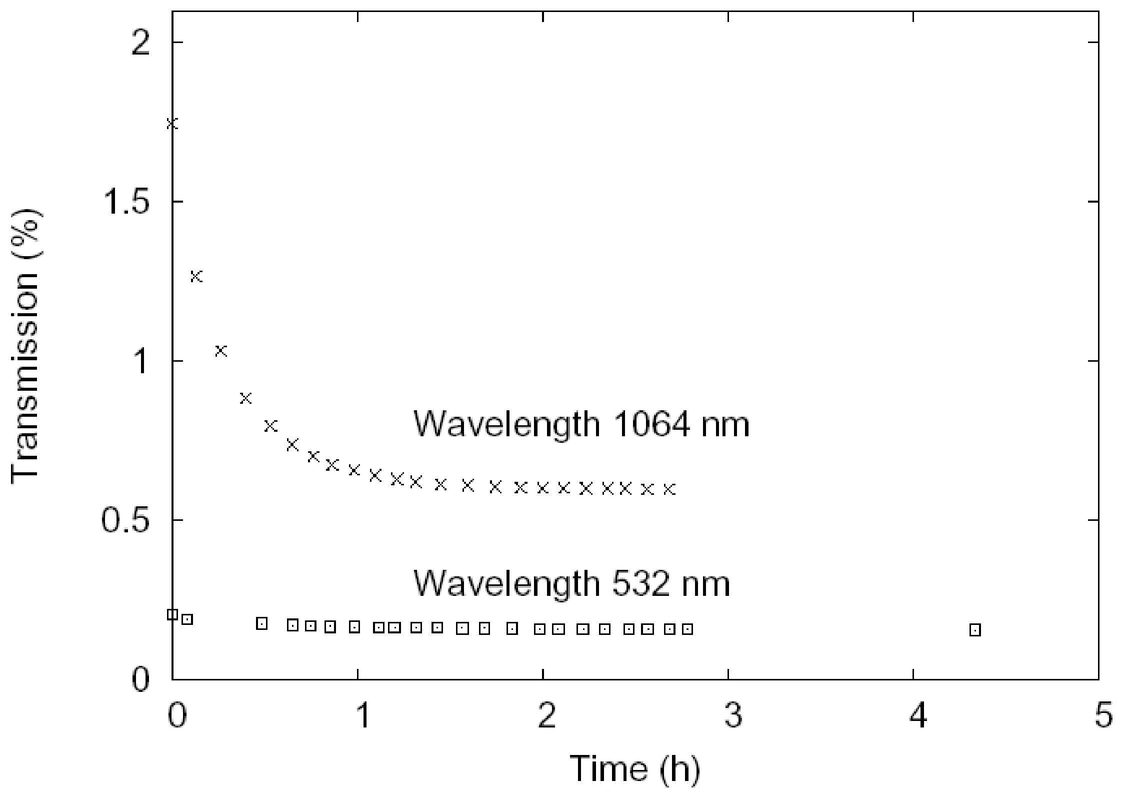


**Figure 2.Time dependence transmission of the tooth @532nm and 1064nm**

This indicates that the majority of the beam is lost as scattered beam or absorbed.

The absorption at wavelength of 1.064µm is low in dental tissue and mostly it is contributed to the water in the tissue, which is less than 1cm$^{-1}$ for the enamel and 3-4cm$^{-1}$ for dentin **(17)**. This fact makes 1.064µm wavelength is more sensitive to sample dehydration than 0.532µm wavelength, as the tooth sample gets dry the amount of reflection to 1.064µm wavelength at the first interface increases leading to decrease in the transmission.

While for the 532nm wavelength it is absorbed by the protein which is located around the dental tubule **(15)** and it is a bout less than 1cm$^{-1}$ for the enamel and 3-4cm$^{-1}$ for dentine **(17)**.

In laser ablation of tooth structure keeping a hydrated environment is essential on using 1.064µm while it is not the same when 0.532µm is used.

**Reflectivity of an uncoated surface**

$$R = 1 - T = \frac{(n_o - n_s)^2}{(n_o + n_s)^2}$$

Where, $n_o$ is the refractive index of the incident medium (which usually air), and $n_s$ is the refractive index of the dental tissues

$n_s$=1.62**(18)** and Nd:YAG (λ=1.064 μm)
Nd:YAG (λ=0.532 μm)

$$R = \frac{(1-1.62)^2}{(1+1.62)^2} = \frac{0.3844}{6.8644} = 0.05599 \rightarrow \approx 6\%$$

**Reflectivity of coated surface with one layer**

The reflectivity of a surface coated with single layer of refractive index $n_1$ is,

$$R = 1 - T = \frac{a_1 \cos^2\delta_1 + a_2 \sin^2\delta_1}{a_3 \cos^2\delta_1 + a_4 \sin^2\delta_1} \qquad 2$$

Where

$$a_1 = (n_o - n_s)^2 a_2 = (n_1 - n_o {}^{n_s}/_{n_1})^2$$

$$a_3 = (n_o + n_s)^2 a_4 = (n_1 + n_o {}^{n_s}/_{n_1})^2$$

$\delta_1$ the retardation of phase of the layer $\delta = 2\pi\, n\, t$
is the wave number of the incident light

When the $n_1 t_1 = {}^{\lambda}/_{4}, {}^{3\lambda}/_{4}, {}^{5\lambda}/_{4}$ , etc., the reflectivity is either max. Or min. And is given by

$$R_m = [\frac{n_1^2 - n_o\, n_s}{n_1^2 + n_o\, n_s}]^2 \qquad --3$$

We will only consider the case reflectivity is a min., which occurs when

$n_0 > n_1 > n_s \quad or \quad n_0 < n_1 < n_s$

The reflectivity is zero when

$n_1 = \sqrt{n_o n_s}$

=sqrt (1*1.6)=1.27

If we take $n_1$ =1.33 for water refractive index from equation (3), reflectivity is R=0.00193

**We can see from result that R reduces <u>from 6% → 0. 2%,</u> that mean that will be better 30 times.**

At 0.532μm wavelength the tooth slice shows 40% diffused reflection and low transmission Figure-2-, that is to say we may expect a considerable amount of absorption.

Dental hard tissues are anisotrophic. Absorption and scattering of light are much stronger in dentin than in enamel**(17-20).** Thus the scattering coefficient is much larger than the absorbing coefficient **(19,21).**Scattering spectra were similar for all 4 samples measured, since the samples of dentin and the location were the same. Scattering decreases continuously with increasing wavelength Figure 3. These results are in agreement with Friebel at al 2012(22), who reported the value of scattering coefficient 12mm$^{-1}$ at400nm and 4.5mm$^{-1}$ at 700nm wavelength.

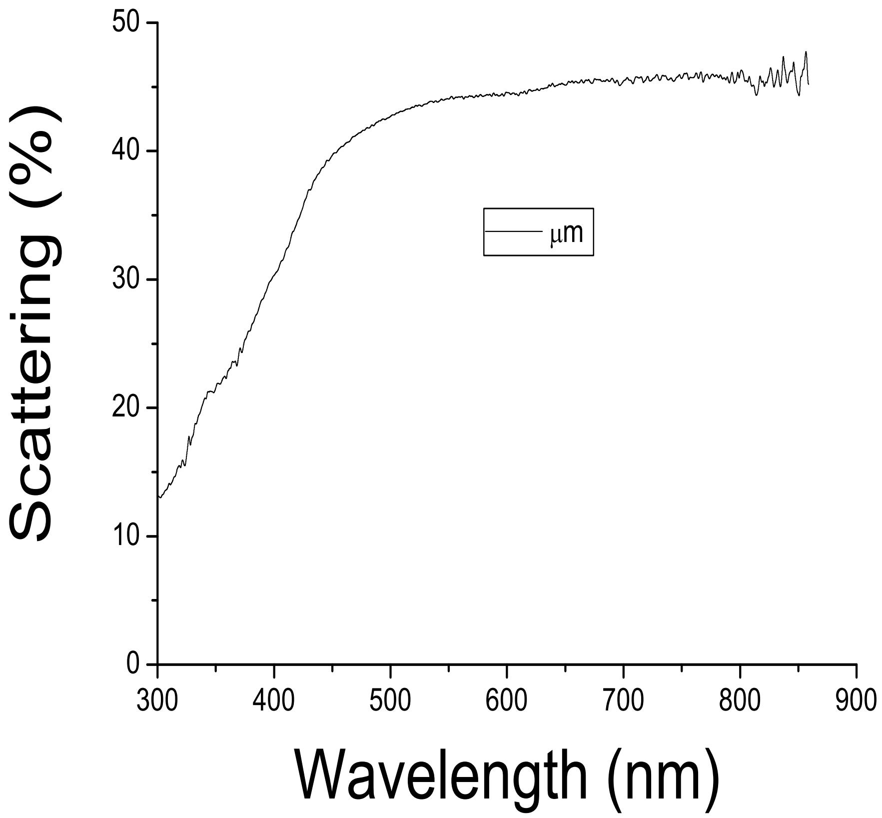


**Figure 3.Diffused reflection spectra of tooth slice**

While for the results of the time dependant diffused reflection showed that at 1.064µm was about 71% and it showed slight increasing as a function of time(as the sample gets dry) and for the 0.532 µm wasa bout56% which could be considered as constant with time, this due to the fact that the scattering process occur at the surface due to the surface roughness .Where the intertubuler dentine distance is about (5.6-6)µm, pertubular dentine average width is 0.08±0.09 µm, tubule average diameter is 1.21µm±0.08µm (18) (22). Zijp J. R.(23) considered that mineral crystals of dentin can be Rayleigh scatterers, there size is smaller than incident wavelength. While the dentinal tubules are considered to be Mie scatterers. Though these values change from sample to sample and within one sample and that is due to the distribution of Enamel rod in enamel and dentinal tubules in dentin that different in their size and distribution with variable depth.

**Conclusion**

In this study, a high precsion integrating sphere setup was used to measure the optical property of dentin at 1.064µm and 0.532µm. The transmission and scattering was very much affected at 1.064µm wavelength when the sample is wet or dry. At 1.064µm there is an increase in the transmission when the sample is wet and when it gets dry the reflection and scattering at the first interface increases as a consequence the transmission decreases. While at 532nm wavelength the behaviour was stable with wet samples or dry. In accordance the use of wet canal on using 1.064µm wavelength laser in root canal treatment to sterilize or to remove the smear layer is more preferable than having a dry canal.

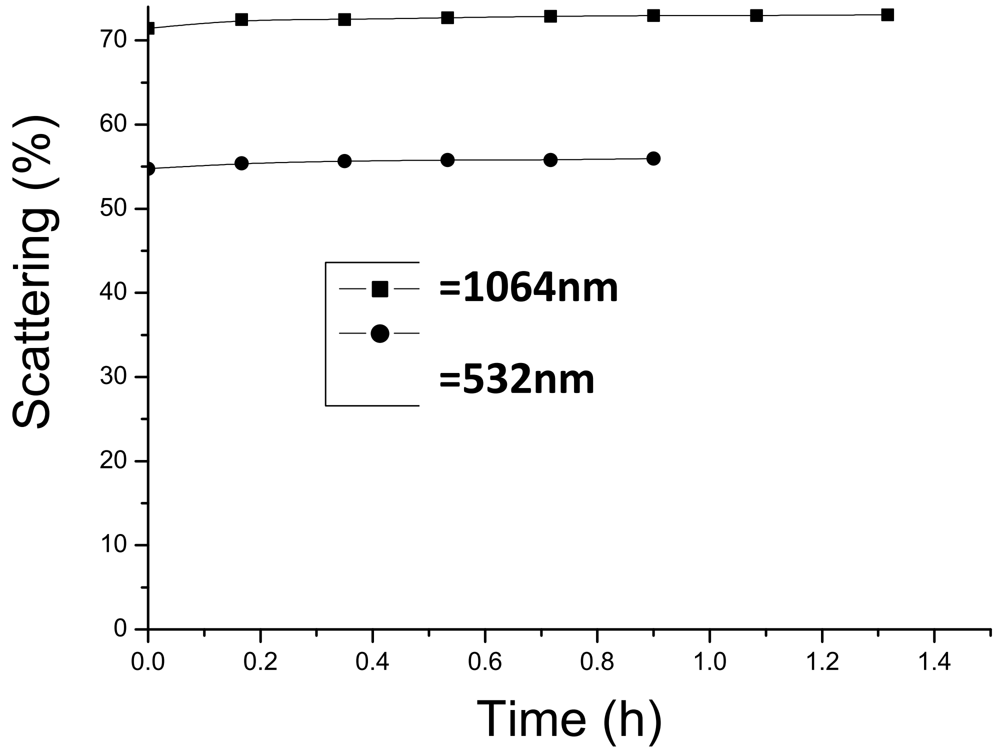


**Figure 4.Time dependence diffused reflection of the tooth @532nm and 1064nm**

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