VISIBLE LASER LIGHT SCATTERING IN HUMAN TOOTH

*Walter Miyakawa**, *Denise Maria Zezell*
Centro de Lasers e Aplicações - Instituto de Pesquisas Energéticas e Nucleares
Jaime Tsutomu Watanuki, Rudimar Riva
Instituto de Estudos Avançados – Centro Técnico Aeroespacial
wmi@ieav.cta.br

Abstract

This work presents a simple experimental setup to imaging light penetration in human tooth and to evaluate an effective attenuation coefficient for the light propagation. In this experiment, human molar and incisive teeth were cut longitudinally and the samples were positioned so that the laser beam was incident perpendicularly to the enamel surface and tangentially to the cut. A CCD camera was placed in such a way that both the tooth section and the scattered light intensity distribution could be recorded. The obtained photograph (bitmap image) is approximately a two-dimensional light intensity distribution. The line of pixels passing the point on enamel surface that had the highest pixel intensity was analyzed. The intensity distribution in this line was fitted to an exponential decay and, although the absolute intensity distribution had been re-scaled to a 256-level pixel intensity bitmap image, it was possible to evaluate an effective attenuation coefficient. Two visible laser wavelengths were used: 632 nm from a HeNe laser and 510 nm from a Cu-HyBrID laser. The experimental intensity distribution curve for the Cu-HyBrID laser was compared with the theoretical curve obtained from Monte-Carlo computer simulation, showing good agreement.

Introduction

Formerly, applications of lasers on dental hard tissues aimed to increase the tooth resistance to caries. By efficiently transforming the laser energy into thermal energy, the dental enamel surface was fused and resolidified resulting in a surface that was less susceptible to caries decay [1,2]. When laser radiation was not well absorbed by the dental surface, a thin layer of a photoabsorber was usually deposited over the dental surface in order to artificially enhance the efficiency of heat generation. Afterwards, even low absorbed laser radiation found several other applications in Dentistry such as, for example, the use of visible laser for curing of sealants []. Since then, the interest in using visible lasers increased, particularly in applications that took advantage of their high penetration on dental tissues (selective absorption, imaging techniques of caries diagnosis, etc.). The knowledge of the optical properties (μ_a and μ_s, absorption and scattering coefficients) and consequently, the laser light distribution became fundamental to understand the interaction mechanism between the laser and the dental tissue. Hence, the objectives of this work are to present a simple experimental setup to imaging the light penetration in human tooth and to evaluate an effective attenuation coefficient for the light propagation in a similar fashion already done by other authors in rat tissues [4]. Experimental intensity distribution curve and theoretical curve obtained from Monte-Carlo computer simulation [5] are also compared.

Experimental Setup

Freshly extracted human molar and central incisive teeth were used in this experiment. The teeth were cut longitudinally from the crown to the root apex and the samples positioned so that the laser beam was incident perpendicularly to the enamel surface and tangentially to the cut. Two visible laser wavelengths were used: 632 nm from a HeNe laser (*model 05-LHR-151, 15 mW, Melles Griot, USA*) and 510 nm from a Cu-HyBrID laser (*home-made at IEAv/CTA* [6]). A CCD camera (*model DCR-TRV17, Sony, Japan*) was then placed orthogonal to the beam path in such a way that both the tooth section and the scattered light intensity distribution could be recorded, as shown in Figure 1. Some absorptive neutral density optical filters (*Newport, USA*) were also placed in front of the camera so as to avoid pixel intensity saturation. The obtained photograph (bitmap image) is approximately a map of the two-dimensional light intensity distribution in the tooth. This bitmap image was transferred to the *Mathcad Professional 2001* software (*MathSoft Engineering & Education, Inc., USA*), where the color information was separated in the corresponding constituent images of red, green and blue. Hence, only the red (HeNe laser) and the green (Cu-HyBrID laser) images were analyzed in order to determine the line of

* Institute of origin: *Instituto de Estudos Avançados – Centro Técnico Aeroespacial*

pixels passing the point on enamel surface that had the highest pixel intensity. The pixel intensity distribution in this line was then fitted to an exponential decay using the *Origin 7.0* software (*OriginLab Corporation, USA*) with the purpose of evaluating the effective attenuation coefficient.

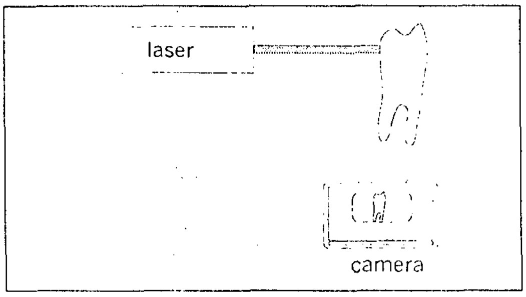

Figure 1: experimental setup showing the laser, the tooth sample and the CCD camera.

Results and Discussions

Figure 2 shows typical laser light distribution maps for the same sample irradiated by HeNe laser (a) and Cu-HyBrID laser (b). They are not the images picked up by the CCD camera, but the respective constituent images of red and green. Note that these light distributions correspond, in fact, to the scattered light and seem to present an isotropic pattern inside the dental tissues. The differences of intensity observed in (a) and (b) can be attributed to variations in the laser power and in the attenuation of the absorptive neutral density optical filters.

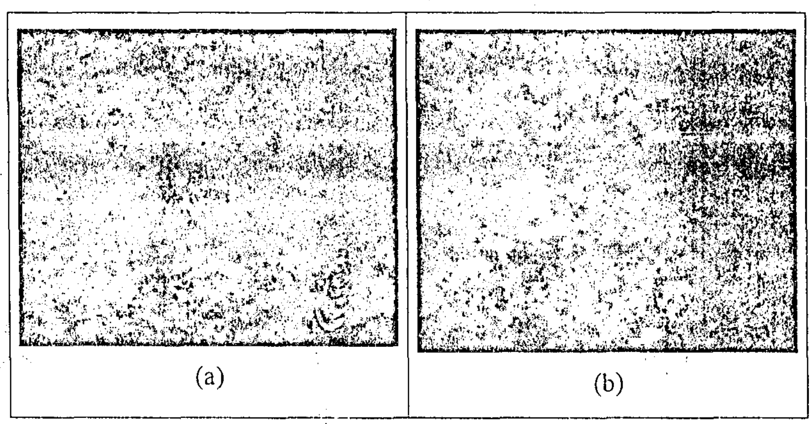

Figure 2: typical laser light distribution images recorded by the CCD camera for (a) HeNe laser and (b) Cu-HyBrID laser.

Representative experimental pixel intensity distribution (black) and fitted first order exponential decay (blue) for HeNe laser and Cu-HyBrID laser wavelengths can be seen in Figure 3 (a) and (b), respectively. The corresponding mean values of the effective attenuation coefficients were (11.8 ± 0.8) cm^{-1} and (10.5 ± 0.5) cm^{-1}. Observe that these values cannot be directly connected neither to the absolute total attenuation coefficient ($\mu_t=\mu_a+\mu_s$) of the transport theory of light propagation, nor to the effective attenuation of the diffusion theory $\{\mu_{eff}=3\mu_a[\mu_a+\mu_s(1-g)]\}$ [7, 8]. The real laser light intensity distribution follows an exponential law and, consequently, the absolute intensity is logarithmically scaled. In a conventional CCD camera like the one utilized in this work, the absolute light intensity is re-scaled to 256-level pixel intensities, which means loss of resolution in the intensity axis. Even so, it is possible to calculate an effective attenuation coefficient, which describes qualitatively the propagation of laser light in the tissue.

With the aim of evaluating this methodology, a comparison between the experimental intensity distribution curve for the Cu-HyBrID laser shown in Figure 3 (b) and a theoretical curve obtained from Monte-Carlo computer simulation [5] were made. These two curves are displayed in Figure 4, exhibiting good agreement.

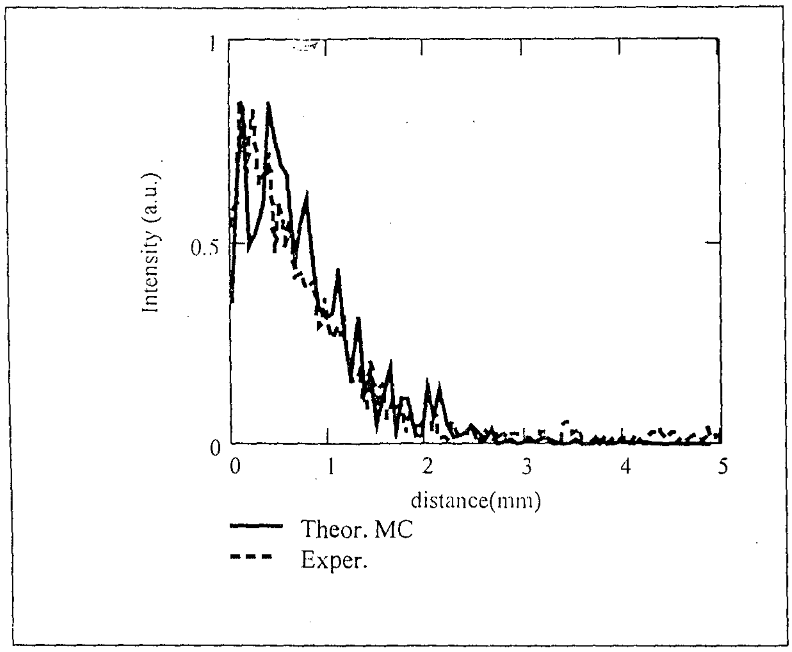

Figure 4: comparison between the experimental intensity distribution curve (blue) for the Cu-HyBrID laser shown in Figure 3 (b) and a theoretical curve (red) obtained from Monte-Carlo computer simulation [5].

Conclusions

This work presented a simple experimental setup to imaging the light penetration in human tooth and to evaluate an effective attenuation coefficient for the light propagation dental hard tissues, based on a CCD camera photograph. Although, the absolute intensity distribution had been re-scaled to a 256-level pixel intensity bitmap image, it was possible to evaluate an effective attenuation coefficient, which describes qualitatively the light propagation in dental tissues. Experimental intensity distribution curve and theoretical curve obtained from Monte-Carlo computer simulation [5] were also compared, exhibiting good agreement.

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