Er:Cr:YSGG Laser Beam Characterization

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Abstract

In this work it was used a simple and inexpensive method for laser beam characterization: the knife-edge technique. To characterize a multimode pulsed laser beam. The laser used was a pulsed Er:Cr:YSGG laser. The beam waist and the M^2 parameter were determined using the knife-edge technique in x and y directions for three different sapphire tips to the fiber deliver system: G6, S75, and Z4, with 600, 750, and 400 micrometers of diameter, respectively.

Introduction

Accurate characterization of laser beams has become an important procedure for many laser applications. The well-known knife-edge technique allows the determination of Gaussian beam profiles in a simple and inexpensive way. The measurement could be performed by using only an energy detector and a knife coupled to a micrometer. [1]

For symmetric Gaussian beams, the beam diameter (w) and its bending radius (R) are given by [2]:

$$w^2 = w_0^{\;2}\left[1+\left(\frac{\lambda}{\pi w_0^{\;2}}\right)z^2\right] \qquad (1)$$

$$R = z\left[1+\left(\frac{\pi w_0^{\;2}}{\lambda z}\right)^2\right] \qquad (2)$$

where w_0 is the waist , and λ the laser wavelength.

The radius of curvature is a measurement of the beam divergence in the propagation direction. Considering the propagation of the beam as in direction z, the measurement is: $R(z)=z-z_0$, where z_0 is the smaller diameter.

The laser beam resonator can emit many simultaneous modes, producing a superposition in the exiting beam. When it happens, there is a multimode beam. A multimode beam is not a Gaussian beam, because it has a beam enlargement when compared with a Gaussian one, as it is observed in Figure 1, and decrypts in equation 3:

$$w_0 = \frac{w_0^{\;*}}{M^2} \qquad \text{where} \qquad w_0^{\;*} = M^2\frac{4\lambda f}{\pi D_{in}} \qquad (3)$$

where w_0 is the waist (smaller beam diameter in the focus region) of the Gaussian beam, w_0^* is the waist of the multimode beam, λ the laser wavelength, D_{in} the initial diameter, and M^2 is the qualitative factor of the beam.

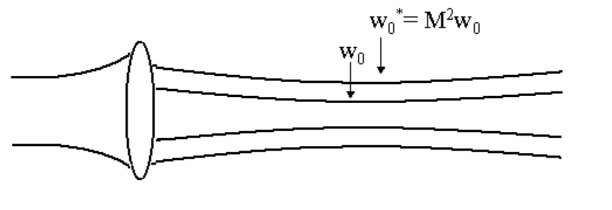

Figure 1 - Focalization of the Gaussian beam and multimode beam

To get an equation that describes the diameter of a multimode beam, an equation that describes any point z the multimode beam behavior, it is incorporated in the equation (1) a correction factor in beam diameter. The multimode beam diameter is M^2 times bigger than de Gaussian beam, as it is illustrated in figure 1. Incorporating this variable in equation (1), we have:

$$w^2 = w_0^2\left[1+\left(M^2\frac{\lambda}{\pi w_0^2}\right)^2 (z-z_0)^2\right] \qquad (4)$$

where z_0 is a position of the smaller beam diameter in the focus region.
M^2 is a positive number ,and when it is close to one, it means that the profile of the characterized beam is similar to the profile of Gaussian beam.
The knife-edge technique correlates the knife displace in the transversal position with the transmission energy. The technique correlates the energy detected with the obstructed area. To measure it is necessary that the knife is by displaced a micrometer, as represented in Figure 2, and an energy detector.

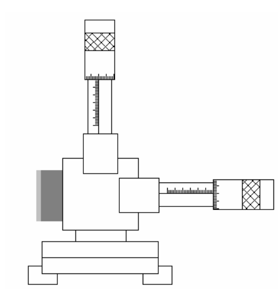

Figure 2- displacing system

The knife is displaced throughout axes x and y, starting at the point where the knife began to obstruct the beam until this was totally obstructed. The movement occurs in small intervals, with 0,005mm of precision. The energy versus displacements graphs allows the determinations of the beam waist (w_x) and the beam position (x_0).
The normalized energy of a multimode laser is:

$$\overline{P}(x) = \frac{1}{1+\exp[-(a_0 + a_1 t + a_2\, t^2 + a_3\, t^3)]} \qquad (5)$$

where the values of the constants are: a_0=-6,71387x10^{-3}, a_1=-1,55115, a_2= 5,13306x10^{-2}, a_3= -5,49164x10^{-2}, and t is the variable, a relation between the radios and the position, given by:

$$t = \left(\frac{2}{w_x}\right)(x - x_0) \qquad (6)$$

Knowning the energy experimental values and the knife position (x), it is possible to perform an adjustment using the equation (5), and to determine the beam position (x_0) and the beam width (w_x).
This procedure is repeated several times, with the equipment in different positions of the z axis. From these data the M^2 factor can be determined using the equation (4), as weel as the beam waist.

Experimental Setup

The laser beam studied was from a Er:Cr:YSGG laser (Waterlase/ Biolase-EUA), emitting at 2,78 μm. This is a commerciallaser for clinical use in Dentistry.

The beam energy was measured using a piroelectric detector (FieldMaster-Coherent). The measurements of the z values had an error of 5 μm.

The output laser beam was characterized byfor three different sapphire tips: G6, S75, and Z4, with 600, 750, and 400 micrometers of diameter, respectively.

Results and Discussions

Initially the knife was displaced transversally to the laser beam in x and y axis, using an energy meter measure the energy not obstructed by the knife. The resulting area was plotted against the measured energy and the equation (5) allow the fitting to the experimental data. From this fitting w_x and x_0 can be determined (Figura 3).

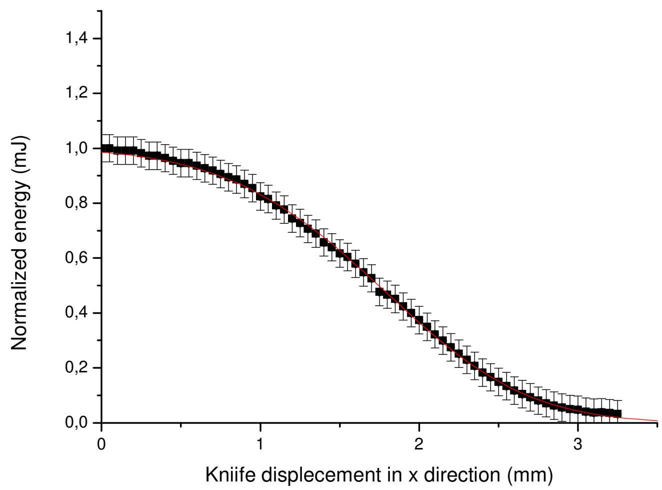

Figure 3 - Normalized transmitted power measurement as a function of the knife-edge position in the x direction.

The plot of w_x by z position, allow fitting the equation (4). From this fitting z_0, w_0, and M^2 can be determined (Figure 4).

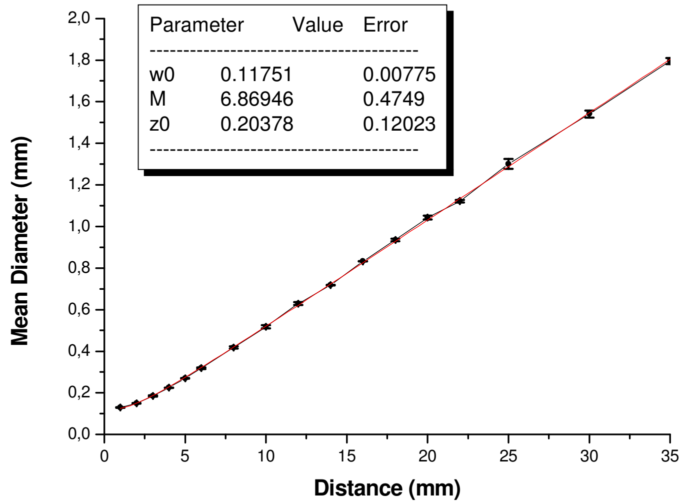

Figure 4 - Set of wx data obtained by the knife-edge measurements and equation 4 with fitted parameters for the G6 tip.

Conclusions

By using the simple knife-edge technique described, it was possible to characterize the beam from the pulsed Er:Cr:YSGG laser. This characterization is very useful for the clinicians that often operates the laser with the beam in positions other then focus.

Acknowledgements

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References

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[2] Bachmann, L. Sistema de entrega de Feixe para Laser de Hólmio e Aplicações em endodontia. 2000. Dissertação (Mestrado) – Instituto de Pesquisa Energéticas Nucleares, São Paulo.