HIGH-POWER LASER PROTOTYPE FOR SOFT TISSUE SURGERY IN DENTISTRY

PROTOTIPO LÁSER DE ALTA POTENCIA PARA CIRUGÍA DE TEJIDOS BLANDOS EN ODONTO-ESTOMATOLOGÍA

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The first Cuban prototype of a state-of-the-art surgical semiconductor laser for dentistry is presented. Aimed at soft tissue surgery and mucosal treatments, its performance matches that of analogous equipment in the market. The prototype underwent electrical safety and parametric testing, showing high repeatability and reproducibility of the measured optical power values. The equipment is currently being introduced in Havana's Faculty of Dentistry.

Se reporta el desarrollo del primer prototipo cubano de láser semiconductor quirúrgico "estado-del-arte", para uso dental. Enfocado hacia la cirugía y los tratamientos de la mucosa dental, su comportamiento es comparable al de equipos análogos existentes en el mercado. El prototipo sufrió exámenes de seguridad eléctrica y parámetros relevantes, y demostró alta repetibilidad y reproducibilidad en los valores de su potencia óptica. Actualmente el equipo está siendo introducido en la Facultad de Estomatología de La Habana.

Keywords: Lasers and their applications (láseres y sus aplicaciones), biomedical devices (Dispositivos biomédicos), laser-assisted surgery (cirugía asistida por láser)

I. INTRODUCTION

Laser applications in dentistry are based on knowledge of a series of physical and biological processes, which depend on several factors. Depending on the wavelength (λ) of the laser and where it is applied, different optical phenomena and diverse effects on the tissue will occur. The absorption of light depends primarily on two factors: the λ of the laser and the optical characteristics of the tissue being irradiated. Low-power lasers are primarily used for their biostimulating, analgesic, and anti-inflammatory properties [1]. The best known examples are helium-neon (HeNe), gallium arsenide (GaAs), and aluminum gallium arsenide (AlGaAs).

On the other hand, high-power lasers are used as alternatives for scalpels and other conventional instruments. In dentistry, argon ion (Ar^+) lasers, with visible emissions at 488.0 nm (blue) and 514.5 nm (blue-green), are used as alternatives to halogen lamps for photopolymerization and teeth whitening. All other high-power lasers emit infrared (IR) light: carbon dioxide (CO_2, 10.6 μm and 9.6 μm), for the treatment of pulp exposures and for coagulating and decontaminating exposed areas. The coagulation laser par excellence is the Nd:YAP (1064 nm), whose surgery is performed in a microorganism-free area, where clean incisions can be made, and less local anesthesia is required, or only topical anesthesia. Suturing is generally not necessary, postoperative periods are almost painless and edema-free, healing is rapid, and there is no evidence of recurrence. The Nd:YAP (1340 nm) behaves similarly to the above mentioned laser.

Er,Cr:YSGG (2.796 μm) and Er:YAG (2.94 μm) lasers, which emit in pulsed mode, are very well absorbed by water and can be used on both soft and hard tissues of the oral cavity [2]. They produce photoablative effects (photothermal and thermoablative). They allow cavity preparation without local or regional anesthesia, making them increasingly recommended in pediatric dentistry and for the treatment of special patients. Semiconductor laser diodes have a bactericidal effect, with specific indications in periodontics and endodontics. They are also used for tooth whitening and soft tissue surgery. The development of high-power diode lasers for soft tissue surgery and oral mucosal treatments [3] has had a significant impact on patients compared to the traditional technique of using the scalpel [4].

Because of the laser's bactericidal effect, the procedure can be performed in an operative field with reduced microbial activity. This reduces surgical time and tissue time healing. Furthermore, patients experience less pain during and after the procedure, so lower doses of analgesics are usually prescribed for pain relief. The laser should operate at wavelengths between 810 nm and 980 nm, as these wavelengths are highly absorbed by soft tissue [5], but not by dental or bone tissue.

A wide variety of high-power semiconductor laser equipment [6] is available on the market for dental applications. Examples include the Biolase Dental Soft Tissue Laser, Biolase EpicX, Smart Deka Laser, Orotig Med Pocket Laser, and the SIROLaser Advance. This type of equipment is not produced in Cuba. In this article, we introduce an in-house high-power laser prototype that has been developed for use in soft tissue surgery (curettage, cutting of the gingival and oral mucosa)

[7], incision and drainage of abscesses, biopsies, to obtain hemostasis in surgical procedures with excessive bleeding, in the treatment of peri-implantitis, among other applications [8]. It is also used in periodontics (gingival incisions and excisions) [9] and in endodontics (as a disinfection system: decontamination and removal of bacteria). The main function of the prototype is to generate an IR laser emission, through an optical fiber, with enough power to evaporate the mucosal tissue.

II. RESULTS

II.1. *Description of the prototype.*

The *FISSERHighBeam*$_{10}$ prototype consists of a central unit with a touch screen display that shows and controls various operating parameters (laser power, fiber optic connection status, etc.). The following are connected to the unit: the external power supply, the footswitch, and the fiber optic applicator (figure 1). Laser specific safety goggles are shown.

Figure 1. Laser prototype *FISSERHighBeam*$_{10}$.

The central unit of the prototype is composed of the following interacting elements: laser module, laser driver, TEC (Thermo Electrical Cooler) driver, power card, control card [10], laser card, single-board computer, two fans, touch screen, keyswitch, footswitch and power connectors, emergency stop button, and LED indicator.

The laser module (Laser Components, BLD-98-tt-10W-14-C) is composed of the following internal elements, which form a single physical object: high-power laser, power photodiode, thermistor, TEC, aiming laser (650 nm, red), and fiber optic coupling detector circuit. The fundamental element is an IR semiconductor laser (976 nm), with power up to 7 W (class 4 laser), which is regulated by a driver (PicoLAS, LDP-CW 18-05) controlled by the control card. The laser card, soldered onto the laser module itself (figure 2), facilitates its connection to the rest of the modules, especially the control card.

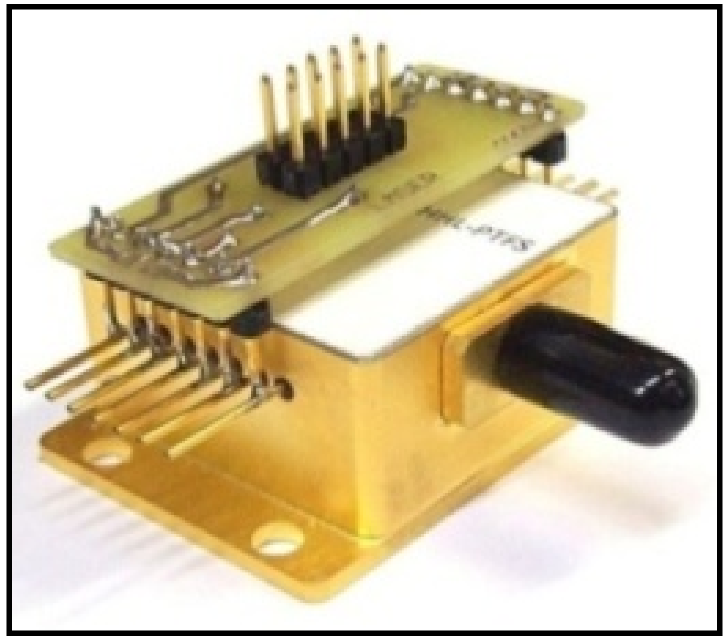

Figure 2. View of the laser module, with the laser card on top.

During operation, the high-power laser heats up and must be cooled by the TEC, controlled by another driver configured from the same control card. Additional circuits, located on this card, also monitor the status of the fiber optic connection and the footswitch action (see figure 3).

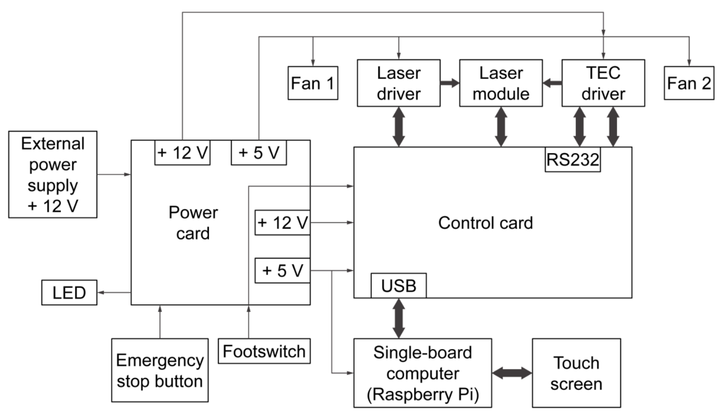

Figure 3. Block diagram of the *FISSERHighBeam*$_{10}$.

The TEC driver (PicoLAS, PL-TEC-2-1024) is a temperature controller for Peltier effect thermoelectric coolers. It is equivalent to the laser driver, but its function is to control the temperature of the laser itself by adjusting the current flowing through the TEC. It is a standalone PID (proportional-integral-derivative) controller, whose sensing element is a thermistor located in the laser module, which manipulates the current output sent to the TEC. The control card, whose fundamental element is a PIC18F4550 microcontroller, manipulates the functions and controls the states of the laser, the laser driver, and the TEC driver. This card responds to commands sent by a Raspberry Pi 2 single-board computer (SBC). Communication is established through one of the computer's USB (Universal Serial Bus) interfaces.

The general power supply comes from an external switched-mode power supply (XP Power, AKM90PS12), designed for medical use, autovolt, which provides a voltage of +12 V and a current of 7 A, while the power card generates the voltages required for all the prototype elements.

The footswitch is basically a normally open switch that changes its state to close when pressed. Its function is to activate the laser emission. The applicator contains a flexible, operator-friendly optical fiber that conducts the radiation exiting the laser module. It is not an electronic component.

A Raspberry Pi 7 touchscreen display is used as the user interface. The touchscreen allows for entering operating data or configuring the equipment. The high-power laser emission is generated by pressing the footswitch attached to the central unit, which is energized through a low-voltage key-operated switch on the front panel. On the same panel is an emergency stop button, which the operator can press if necessary for suddenly interrupt the general power supply. A two-color LED indicates whether the prototype is connected to the power supply or if it was energized via the key switch. Two low-voltage fans were installed to extract the heat generated by the different modules.

II.2. *Prototype evaluation.*

Prior to its practical introduction, the prototype underwent rigorous measurements to ensure its stability in laser power emission.

The high-power laser prototype, manufactured at CEADEN, has successfully completed electrical safety tests conducted at the Testing Laboratory of the Professional and Technical Services Company (ESAC, Havana), in compliance with current international standards.

Figure 4. Experimental setup for the evaluation of the*FISSERHighBeam*$_{10}$. The multimeter, with a connected thermocouple, monitors the temperature.

For further evaluation, the behavior of the optical power values at the applicator output (a fundamental parameter) was determined, as shown in the experimental setup in figure 4. An Ophir Optronics (Israel) digital power meter, LaserStar model was used, closely monitoring the temperature, the variable that could most affect the operation of semiconductor laser devices.

Observing the results of the output power measurements (see table 1), the standard deviations (STD) are very small, and both the percentage relative errors (Erel.) and coefficients of variation (CV) were very good, with maximum values below 5 % in both cases.

Table 1. Statistical behavior of final output power measurements. Pnom.: nominal power, Pavg.: average measured power, STD: standard deviation, Erel. (%): percentage relative error, CV (%): coefficient of variation.

Pnom. (W)	Pavg. (W)	STD	Erel. (%)	CV (%)
0.5	0.51	0.02	3.0	4.25
1.0	0.96	0.02	4.1	2.08
1.5	1.55	0.02	3.6	1.34
2.0	2.06	0.02	2.9	0.93
2.5	2.55	0.02	1.8	0.75
3.0	3.05	0.02	1.5	0.60
3.5	3.52	0.02	0.6	0.52
4.0	4.07	0.02	1.8	0.58
4.5	4.54	0.02	0.8	0.40
5.0	5.05	0.02	0.9	0.41
5.5	5.57	0.02	1.2	0.35
6.0	6.07	0.02	1.1	0.31
6.5	6.61	0.02	1.7	0.34
7.0	7.04	0.01	0.6	0.19
			Max.: 4.1	4.25

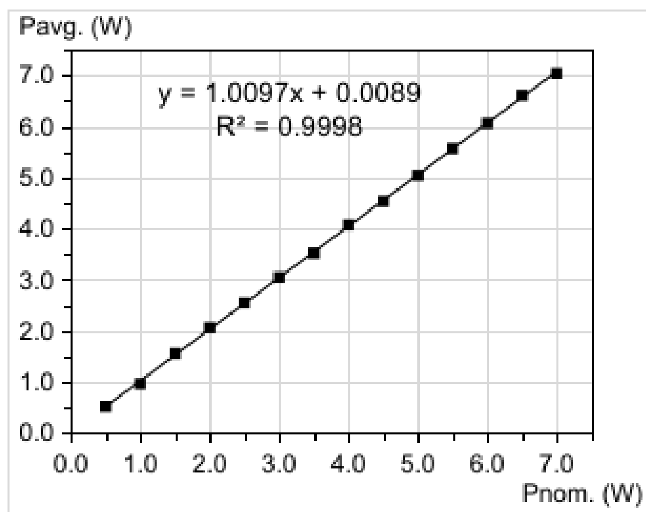

Figure 5. Calibration curve for the prototype: average measured power (Pavg.) vs. nominal power (Pnom.).

Regarding the respective graph (figure 5), adjusted using the least squares method, a correlation coefficient $R^2 = 0.9998$ (three nines) was obtained, with a slope very close to unity (1.0097) and an intercept almost zero (0.0089). In other words, there is a correlation almost 1:1.

Through a general analysis of the measurements, it is possible to affirm that there is a good correspondence (linear correlation) between the nominal values and those obtained experimentally. Throughout the entire pre-adjustment and calibration process, good reproducibility was achieved (with three operators, over several days, and using two different power meters). Furthermore, the results showed high repeatability ensuring the correct calibration of the prototype's output power, suitable for its intended implementation. For the same purpose, the *FISSERHighBeam*$_{10}$ prototype was delivered to the Faculty of Dentistry in Havana for practical implementation, with positive results so far.

III. CONCLUSION

The first prototype of a state-of-the-art surgical semiconductor laser for dentistry was developed in Cuba. Intended for soft tissue surgery and mucosal treatments, its performance is equivalent to that of existing lasers on the market. The prototype underwent electrical safety and parametric testing, demonstrating high repeatability and reproducibility of the measured optical power values. These results are in compliance with international standards.

Introducing this technique at the Faculty of Dentistry in Havana, for teaching and scientific research purposes will improve the training of new professionals. Its prac-tical application will benefit patients with oral health issues.

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