Diode Pumped Solid State Green Laser for Ophthalmology
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Abstract
This project intends to develop a green laser cavity of 2W (532nm) based on a Diode Pumped Solid State technology. The aim of this project is integrating this cavity module in a photo coagulator for use in ophthalmologic procedures. The cavity under development has a “V” shape, a Nd:YAG crystal to generate the 1064nm laser and a KTP to double the frequency and generate the green laser. This laser light penetrates the Nd:YAG crystal which energy levels generates the 1064nm by electron population inversion and stimulated degeneracy. In this process, around 60% of the light is converted into 1064nm (stimulated and spontaneous light). The stimulated fraction passes through the KTP crystal that generates a second harmonic from the incident laser having at the wavelength of 532nm (the green spectrum). The laser cavity efficiency is dependent on the mirrors quality and alignment. The maximum power output reached for this cavity architecture was 3.5W for pulses of 100ms and duty-cycle of 50%.

Introduction
The DPSS technology uses a 801nm laser diode for pumping a crystal which properties of absorption and emission allow the generation of a 1064nm infrared laser and additionally a non-linear crystal that doubles this laser frequency and generates the 532nm green laser [1]. The aim is to project a 2W output green laser (532nm) to be used in a sort of clinical procedures such as: elevated IOP, diabetic retinopathy, glaucoma, retinal tears, retinal detachment, retinal vein occlusion, retinal artery occlusion and retinopathy of prematurity [2].

The set up consists of a diode laser - 40W, 810nm-, a Nd:YAG crystal responsible for absorbing the 810nm wavelength and emitting the 1064nm wavelength and a KTP (KTiOPO4) crystal for create a second harmonic frequency of the 1064nm generating thus the green laser (532nm), as shown in figure 1. The “V” shaped cavity is composed by three mirrors: M1, M2 and M3. All of those mirrors are approximately 100% reflective at the 1064nm. The diode laser pumps the Nd:YAG laser in a transversal mode. This crystal then absorbs the 810nm and emits the 1064nm. The mirrors then close the system and a laser in 1064nm is formed inside the “V” cavity, but there is no optical window once the mirrors have high reflectance at this wavelength. Finally the KTP crystal converts the 1064nm laser that passes throw it into the 532nm wavelength, by generating the second harmonic via a non-linear effect related on the birefringence of this crystal. M2 has a special coating that is approximately 0% reflective at 532nm, in order to allow the green laser go through the cavity. M3 is approximately 100% reflective at 532nm, thus the green laser generated in the opposite direction of the output laser cavity is reflected to the output direction doubling the output green laser power [3].

![Figure 1: DPSS cavity design.](image-url)
Experimental Setup
In order to test the “V” shaped laser cavity, electronic systems were developed to support the preliminary version of the green laser cavity that has been set up in a clean room. Those electronic systems are responsible for: (a) delivering 50A to the diode laser in order to generate 40W of 810nm in a feedback closed system, monitored by a photodiode calibrated at 532nm for guaranteeing constant green laser power in the output laser cavity; (b) cooling the system based on Peltier effect that must to drive almost 80W of heat from the diode laser and assures that the temperature on his case is maintained 21°C; (c) – keeping the KTP temperature at 45ºC, once its refractive properties is quite dependable on temperature and consequently on the second harmonic conversion. The photograph of the setup of the green laser cavity is presented in figure 2.

Results and Discussions
Performing tests has shown that the temperature for the diode laser for the best performance in obtaining green power output is 21ºC. This can be explained considering that the wavelength of the laser emitted by the diode is shifted in approximated 0.2nm/ºC and the absorbing peak of the Nd:YAG is in 808.4nm, thus, at 21ºC the center of the emitted spectral laser matches with this absorbing peak. The best cooling system for this case is based on Peltier effect, because of the high quantity of heat generated by the diode (~80W). It was also observed that the beam of 1064nm laser that must pass through the KTP does not enter in the normal direction at the KTP surface, but at a determined angle manually assured for maximizing the second harmonic generation. The maximum green laser power output obtained in the cavity of picture 2 was 3.5W in pulses of 100ms and duty-cycle of 50%. It was also detected that the laser power output is lower for pulses period over 100ms. Many clinical protocols establish minimal and maximal pulse duration of 50ms and 2s, respectively, thus it is important build a cavity that provides up to 2s of pulse duration. For the cavity in the figure 2, the maximum continuous power obtained was 1.5W. Considering that 75% of the laser power can be collimated in the optical fiber, which is not an incongruous value, it’s possible provide up to 1.125W to the patients eye at this pulse duration. No problem was related associated to minimal pulse duration.

Conclusions
The obtained results are not far from the initial specification. The maximum power for narrow pulses (up to 100ms) was reached. For 2s period pulses, the output power is a bit lower (1.125W) compared to the specification. Currently we are concerned in solving the problem of the power dropping down in order to achieve the power specifications. The current electronic system came out to be very robust as well as the thermal system.

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References