Optical device to control power and exposure time, select the wavelength and handle the copper vapor laser beam

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Abstract

In spite of the improvements that copper vapor laser has obtained in the 90’s years, some applications need the ability to control power and select the desired wavelength. The power that these laser systems can deliver is defined by its design, and it is not possible to set it to other values by controlling the electric power supply. In this work we describe and show the results obtained from an optical device developed to control power and exposure time and select the wavelength of a copper vapor laser.

Introduction

Copper vapor laser is a gas laser excited by electric discharge. Its active medium is generated by evaporation of pieces of metallic copper placed inside the laser tube, and a buffer gas (Ne or He) is added to sustain the discharge. The same electric discharge that excites the Cu atoms heats the solid copper to about 1500 °C to generate Cu vapor. The laser action occurs, simultaneously, in two different lines, with \( \lambda = 510.6 \) nm (green) and \( \lambda = 578.2 \) nm (yellow), with pulse width of 30-50 ns, pulse repetition frequency around 5 kHz and peak power that easily exceeds 10 kW. For both lines it is a typical three level laser with the following kinetics: impact with electrons excites the copper atoms from the ground state to the upper laser level and the transition from the upper to the lower laser level generates the laser radiation [1]. For a good overview on CVL, see the special issue of the Optical Quantum Electronics by Kim (1991) [2]. For a good theoretical discussion about the CVL kinetics, see Kushner (1981) [3].

A great improvement was obtained by the researchers of Saint Andrews University who developed a new technology of copper lasers, combining advantages of technologies: high average powers of CVLs and low working temperature and high pulse repetition frequency (PRFs) of Copper Halide Lasers (CHL) [4, 5]. The authors named this technology HyBrID laser (Hydrogen Bromide In Discharge). In this kind of laser, copper halide molecules are formed in situ by reaction of HBr with metallic copper pieces in the discharge at temperatures between 400 °C and 900 °C. Unlike CHLs, the HyBrID laser can be operated at a very wide input power and tube temperature range because copper atom concentration in the discharge is controlled by the concentration of HBr mixed with neon buffer gas passing through the discharge region instead of by vapor in equilibrium. Laser average power of 200 W and conversion efficiency of 3 % were obtained with a HyBrID laser of 60 mm in diameter discharge tube [6]. Comparing with a CVL of the same active volume, there was a three times increase on laser average power.

Some applications need the ability to control power and select the desired wavelength. The power that these laser systems can deliver is defined by its design, and it is not possible to set it to other values by controlling the electric power supply. In this work we describe and show the results obtained from an optical device developed to allow selection of the laser wavelength and control its power and its exposure time. This optical device is assembled in the line of laser beam, as ones can see bellow.
Optical Device Description

Considering our laser and its potential applications, we have developed a special optical device. This optical system delivery can control the laser power and its exposure time, and provides a way to select the copper laser wavelengths; in addition it is a useful beam handle device.

It can be split into three sub-systems: the wavelength selection system, the power control and launch system and the fiber and optical pen system. Figure 1 show: (a) the optical system diagram and (b) a optical system picture.

![Figure 1: (a) optical system device diagram: BS= short wavelength pass beamsplitter; MS = mechanical selector and (b) optical system device prototype picture.](image)

The wavelength selection system consists of four short pass filters (BS), placed at 45° with the optical axis, and a mechanical selector system that permits to block the undesirable wavelength. Each BS transmits more than 90% at 510.6 nm (green) and reflects more than 97% at 578.2 nm (yellow). This system has been designed in such a way that the laser beam that impinges on it and, then, it is split into two beams (green and yellow). These beams can be combined again on the same optical axis. The mechanical selector allows ones to have whether only the green, only the yellow, or both beams are being launched into the fiber optics.

The power control and launch system is composed by a 16 mm iris used to reduce the laser amplified spontaneous emission that comes together with the laser beam, and a 200 mm focal lens, that focuses the beam onto a pinhole of 400 µm in diameter. This lens is mounted on a motor translation stage that adjusts the separation between the lens and the pinhole in order to provide a control of the transmitted power. Furthermore, this system can control the exposure time and the burst frequency of laser pulses, using a mechanical shutter controlled by an electronic device. The exposure time range is 10 ms to 1 s and the burst frequency is controlled from 1 Hz to 100 Hz.

Figure 2(a) shows the optical fiber beam delivery system. A three meter long silica/silica optical fiber FG-400-UAT has been used. This fiber has a numerical aperture of $0.16 \pm 0.02$, core diameter of $400 \pm 8 \mu m$ and cladding diameter of $500 \pm 10 \mu m$. Its attenuation is lower than 0.5 % per meter at the copper vapor laser wavelengths. The output end of this fiber is coupled to an optical pen device. Figures 2 (b) – (d) show details of this optical pen device. The pen has been specially designed to image the fiber output end at 24 mm of its extremity. Its main body, the cylinder at right in Figure 2 (c), that looks like a pen, is assembled on a support to allow the pen to slide in order to adjust the focus image on a desired surface.
Figure 2: (a) optical fiber beam delivery system; (b) pen components; (c) pen assembled and (d) optical pen set.

Results and Discussions

Figure 3 shows the typical laser power transmission (a) through the pinhole; (b) at the fiber output, with its input end as near as possible the pinhole and (c) theoretical transmission fit at output of the optical system device, concerning the transmission loss due a pinhole, reflections loss at fiber ends and fiber transmission loss using a Gaussian beam [7]. So, using this device one can control the laser power from 10 up to 80 percent of impinging laser power just by changing the separation between the launch lens and pinhole.

![Graph showing laser power transmission](image)

Figure 3: Laser power transmission as a function of lens position up to pinhole measured: (a) just after the pinhole; (b) at the fiber output (c) theoretical fit at output of the optical system device.

Figure 4 shows the intensity profile that can be obtained using this beam delivery system. As ones can see an approximately 0.9 mm laser beam diameter with top hat intensity distribution profile which is obtained at the optical pen image plane.
Conclusions

Many applications can be performed using the optical device developed, from medical up to material processing treatment. This device has been used to control power and exposure time, select the wavelength and handle the copper laser beam. Using this device one can control the laser power from 10 up to 80 percent of impinging laser power just by changing the separation between the launch lens and the pinhole. The exposure time and the burst frequency of laser pulses are controlled by using an electronic device and a mechanical shutter. The exposure time range can be controlled from 10 ms to 1 s while the burst frequency from 1 Hz to 100 Hz. The wavelength selection system consists on four short pass filters, placed at 45° with the optical axis, and a mechanical selector system that permits to block the undesirable wavelength. So, using this wavelength selector system one is able to launch whether only the green, only the yellow, or both, yellow and green, lights beam into the optical fiber beam delivery system. This last component allows handling a 0.9 mm laser beam diameter with a top hat intensity distribution profile obtained at the optical pen image plane.

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References