Copper Vapor Laser For Biological Applications

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Abstract: The paper describes studying of copper-vapor-laser development for applications. On the basic design of the single oscillator and the plan-plan resonator, copper vapor laser with an average output power of 8W and an efficiency of energy transfer about 1% at 8 - 10 KHz repetition rate have been developed. It's being evaluated as excellent light source for Biological applications.

1. Introduction

Copper vapor lasers (CVLs) as the most important kind of metal-vapor lasers, are characterized by laser transitions from an excited resonance state to a metastable state. These self-terminating lasers are distinctive because of their rather high efficiency (∼1%), high average power (>200W) and wide applications [1-3]. CVL emits in the vision region (the green 510.6 nm and the yellow 578.2 nm) with short pulse lengths and high average powers have been attractive for pumping tunable dye and Ti-Sapphire lasers. Harmonic generation can produce 255 and 289 nm from the fundamental copper lines or tunable ultraviolet light from CVL-pumped dye lasers. So we can get pico-second and femto-second pulses. They are particularly useful for studying Time-spatial resolved spectroscopy of biological processes [4-5]. In this paper we report the studies and development of a copper vapor laser system for biological applications. The Laser is designed on the basic of a single oscillator with plan-plan resonator as in ref's [6-11]. Using this approach, we have obtained 8 W average output power with an energy transfer efficiency of about 1% at 8-10 KHz repetition rate.

2. The copper vapor laser

Copper vapor laser is designed similarly as CVL systems in ref’s [1-11] with configuration of plan-plan resonator, Which comprises basic components as following: The laser head with the discharged tube is mounted in a metal frame cooling by electric fan; the power supply with triggering pulse generator and modulator; and optical systems including two mirror. Rear mirror is a high-reflector -mirror 99.8% and front mirror is an output coupler with reflector of 4%. As shows in fig 1.

The laser head is a tube has designed for low and average power laser (1 - 15 W). CVL tube is cooled by air or water and has two electrodes. The alumina plasma tube is made in Russia has internal diameter of 14 mm and 490 mm long, which is placed in ceramic insulator. The electrodes are made of niobium. They are in contact with the quartz parts and so have high mechanical hardness. The electrodes are placed in the free space of the ceramic insulator and permit the concentration of the discharge in the alumina tube.
The tube is filled with a pure Ne buffer gas at pressure of 300 mmHg and with small quantity of pure copper the tube laser was excited using a standard Thyratron-switched capacitance-transfer circuit.

This is a resonantly charged Thyratron-switched discharge device. This is a critical component of the system. Because, the life of this switch depends on the impedance offered by the discharge. Since the discharge impedance at start-up is much higher than that under normal operating conditions. The increase in this impedance depends on the presence or absence of the metal vapors. So in this system to decrease this impedance resistor, we have been used an extra inductor. Fig 2 is the modulator circuit with the component values used in our system. Under normal operating conditions $C_S$ is charged resonantly to approximately twice the DC Once $C_S$ is charged.

**Figure 1: Schema of CVL discharge**

**Figure 2: Diagram of the modulator circuit. Capacity storage $C_S = 2200\text{nF}$, Capacity peaking $C_P = 470\text{ nF}$. Charge resistance $R=1.5\text{ K}\Omega$. $L = 1000\text{mH}$, Thyratron TGI-2 500/20**
The charging current from the supply reduces to Zero. The diode D prevents $C_S$ from discharging back into the power supply. Triggering of the Thyatron now initiates the charging of $C_P$ from $C_S$.

The peaking capacitor $C_P$ is charged until the gas in discharged tube breaks down. The DC breakdown voltage under normal operating gas pressure and electrode separation is much lower than the voltage required for efficient pumping of the laser. On breakdown, the capacitor $C_P$ discharges into the tube, giving rise to lasing action. It should noted that the discharge tube impedance under normal conditions is low enough that the discharge time of $C_P$ is greater than it's charging time. The Thyatron can conduct in the reverse direction in arc mode due to high inverse voltage. Most of the energy from $C_P$ will go back into $C_S$. High reverse voltage and current through the Thyatron are known to severely reduce its life. So, an extra inductor between $C_s$ and $C_p$, have been used during set up runs. Of course it also make the charging of $C_P$ slows down.

3. Experiment results

The study of the laser performance as function of different parameters allowed the optimization output characteristics of CVL in operating.

The output powers were measured with a calibrated partial reflector and a joulemeter (Newport) connected to recorder (K201). Thus the laser period at a given out put power was recorded. The voltage and the current was monitor with high - voltage probe (Tektronix 465B). Laser pulse shapes was observed with a coaxial photocell (TF1850) connected with oscilloscope (Tektronix 465B).

Fig 3 shows the relative of the laser output power, conversion efficiency and electric input power of this CVL. The maximum output power obtained with this CVL was 8 W when discharge input power reach at 0.9 KW and repetition rate interval of 8-10 KHz, corresponding with an energy transfer efficiency of about 1%.

<table>
<thead>
<tr>
<th>Electric discharge Power(kW)</th>
<th>Average Output Power (W)</th>
<th>Efficiency (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.7</td>
<td>7.5</td>
<td>0.75</td>
</tr>
<tr>
<td>0.9</td>
<td>8</td>
<td>0.5</td>
</tr>
<tr>
<td>1.1</td>
<td>8.5</td>
<td>0.25</td>
</tr>
<tr>
<td>1.3</td>
<td>9</td>
<td></td>
</tr>
</tbody>
</table>

**Fig 3:** The output power as a function of repetition rate, electric discharge power and Efficiency

In the table 1 are some experimental results with CVL laser, which have been obtained. with the optimized parameters.
<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Output Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average Power (W)</td>
<td>8</td>
</tr>
<tr>
<td>Opt. Pulse repetition rate (kHz)</td>
<td>8</td>
</tr>
<tr>
<td>Pulse repetition rate range (kHz)</td>
<td>7-11</td>
</tr>
<tr>
<td>Green/Yellow ratio</td>
<td>1.5:1</td>
</tr>
<tr>
<td>Pulse Energy (mj)</td>
<td>1.1</td>
</tr>
<tr>
<td>Pulse width (ns)</td>
<td>25</td>
</tr>
<tr>
<td>Efficiency (%)</td>
<td>1</td>
</tr>
<tr>
<td>Warm-up time (min)</td>
<td>90</td>
</tr>
</tbody>
</table>

4. Applications in biology

CVL emit in the visible and ultraviolet region (double frequency) and has the high average power, efficiency, and repetition rate of CVL make them particularly useful in biomedicine applications such as:

In high resolve spectroscopy: CVL is used for studying very fast processes in biology by it can generate ten of thousands of pulses each second. It is also used for pumping dye laser to obtain ultrashort pulses (pico and femto second)...

In biomedicine systems: Laser beam can be absorbed by biological tissue components, which may be selectively destroyed.

In oncology, the photodynamic therapy based on the effect of simultaneous photochemical reaction between an appropriate sensitize, laser light and oxygen, is used for a selective destructions of pathologica tissues.

Laser projection microscope (LPM means using a CVL as is a microscope) with simple principle of using active medium is copper vapor for amplification of Light (up to $10^4$), Which allowed to visualize microstructure and interaction in the biological cells, With the high spacial resolution (< 1µm) and temporal resolution (~ 30 ns) and pulse repetition frequency (1 - 50 kHz), so it is also comfortable for image treatment, used to observe exploring fast moving objects and fast developing prIn

![Fig 4. The photograph of E.Coli bacteria is taken with electronic microscope and laser projection microscope. E.Coli has dimension of about 1-3 µm](image)
5. Conclusion

The CVL with a simple design, giving an average power of 8W and with an energy transfer efficiency of about 1% at 8KHz, is obtained. It's very promising future since the demand for applications, some preliminary experiments were performed with very encouraging results. This laser showed excellent prospect for investing in Biomedicine objects. Now, one of our trends studying in Vietnam is using the copper vapor laser for photodynamic therapy and treatment of telangiectasias. Beside that, CVL with double frequency is hoping for exciting luminescence of microorganisms and DNA...With version "laser projection microscope", we are hoping to use this LPM for observing and investigating some fast dynamic processes in biomedicine objects.

REFERENCES