COMPACT HIGH–EFFICIENCY METAL–VAPOR LASER FOR MEDICAL AND OTHER APPLICATIONS

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This paper presents a description of a compact sealed off Cu– *and* Au–*laser. It can be used for studies in atmospheric optics, medicine, navigation, and other applications. The laser power supply uses energy conversion at enhanced frequency. Stabilization of output high voltage and control of output current are provided.*

A compact metal–vapor laser based on the "Coulomb" active element has been developed for applications in experimental and clinical medicine. Experiments conducted at the Research Institute of Oncology of the Academy of Medical Sciences of the USSR indicated a retarding influence the 510.6 nm radiation on tumour growth and provided a basis for treatment of ulcer and aftereffects of radical lung and stomach cancer operations.[1] The compact laser can be used in atmospheric optics, navigation, for medical and other applications including show–business.

For active element we used the Coulomb tube, its optical working frequency is in the range of 8.2–8.6 kHz at pumping power within 1 kW. Such a tube needs a following power supply:

storage capacitance	3.3 nF
peak voltage at storage capacitor (peak value)	9.5 ± 0.5 kV
discharge build–up rate current pulse no less than	3500 A/μs
pulse repetition rate	8.4 ± 0.2 kHz

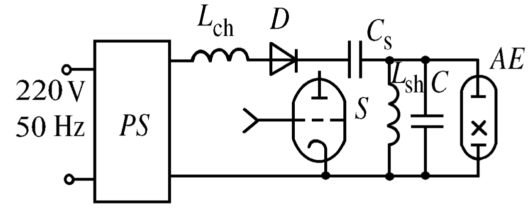

FIG. 1. Charging flow–chart for metal–vapor laser.

Figure 1 gives a typical flow–chart for resonant charging of a metal–vapor laser. Storage capacitor C_s is charged by the power supply *PS* through protective diode *D,* and the charging, L_{ch}, and (hunting, L_{sh} inductances. Capacitor *C* serves to sharpen the pump pulse. Capacitor C_s discharges into the active element *AE* when switch *S* is on. Hydrogen thyratrons of the TGI1–1000/25, TGI1–500/16 or TGI1–500/20 type are most often used for a switch. The main disadvantages of power supplies for metal–vapor lasers of earlier design were their great overall dimensions and weight, resulting from energy transformation at common circuitry frequency. Figure 2 shows the distribution of consumed power between different structural units of the power supply system for a MILAN–M/2E copper-vapor laser.[2] One can see immediately from the diagram that only 72% of the consumed power is used to excitate the active element. The rest is spent on energizing auxiliary circuits. That is why each functional unit should be carefully examined when designing a laser power supply.

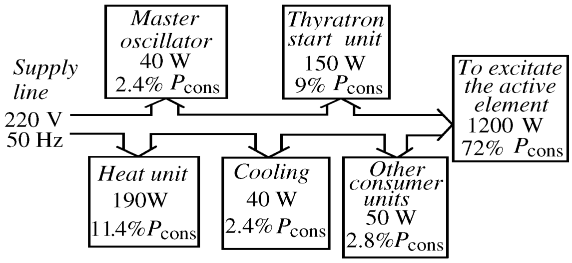

FIG. 2. Distribution of consumed power for the MILAN–M/2E copper–vapor laser.

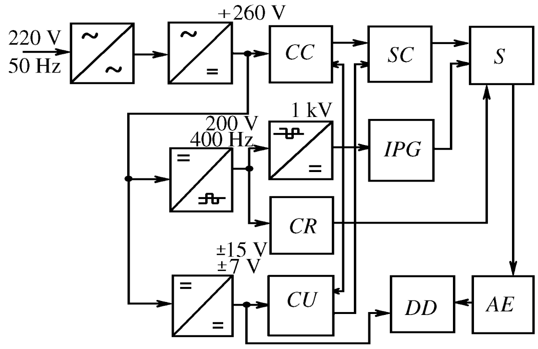

FIG. 3. Block diagram of the compact metal–vapor laser.

The flow–chart of the designed metal-vapor laser is presented in Fig. 3. The device feeds from 220 V, 50 Hz circuitry. The voltage is fed to interference suppressing filter which protects the supply line from the surge when switch *S* is put "on". An AC/DC converter is used to generate 260 V of voltage. Rectified voltage is fed to input of the high–frequency charge converter *CC* loaded by the storage capacitor *SC.* When initiating pulses from the initiating pulse generator *IPG* are fed to switch (the TGI1–1000/25 hydrogen thyratron), the storage capacitor discharges into the Coulomb–AE active element. Control unit *CU* controls the charge converter. A current regulator *CR* was designed to supply the thyratron filament circuit which stabilizes and regulates heating of the cathode filament and the current of the hydrogen generator. It appeared possible to improve the weight-size characteristics of the *CR* proceeding to convert energy at 400 Hz with conventional transformers. A DC/AC converter is used to yield 400 Hz of voltage. Both the control unit and all the auxiliary circuits are fed from a high–frequency voltages converter generating the

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necessary voltage of ± 15 V and ± 7 V. The power supply also includes a digital display, DD which displays the average power of laser radiation.

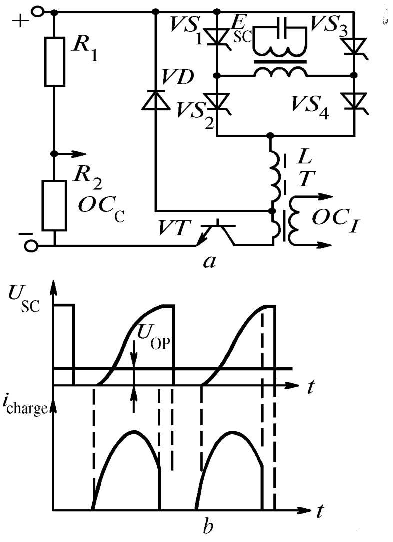

FIG. 4. Power circuit of charge converter (a) and diagram of its operation (b).

High–frequency charge converter is connected to a bridge resonance invertor with series choke[3] (Fig. 4). Capacitors SC are used as circuitry capacitance of the resonance invertor. Circuitry inductance is derived from leakage inductance of the step-up transformer and from additional inductance L (Fig. 4*a*). The resonance invertor circuit is initially triggered pressing the "Start" button; at that point thyristors VS_1 and VS_4 and transistor VT turn on. Transistor VT will turn off in the event that:

current through the transistor exceeds a prescribed level (current protection);

voltage at storage capacitor exceeds a prescribed level (voltage protection);

power consumed from rectifier exceeds the required value.

If none of the above is found, thyristors VS_1, VS_4 turn off then after a half-period and VS_2, VS_3 turn on. The storage capacitor charges for a single period, then its charging stops until discharged. After a 10–15 μsec delay to deionize the thyratron, all of the above processes repeat.

One of the problems arising in designing laser power supply systems is that of miniaturizing their input filters. The size of charge converter may be diminished increasing conversion frequency; however the choke operates at a frequency of 100 Hz and its overall dimensions remain large for the regime of continuous current. The input filter suggested below (Fig. 5) differs from the classic bridge circuit with LC–filter by a decreased calculated power of its choke and an increased power coefficient. Diodes V_1 and V_4 function within the positive half-wave of the input voltage U_{in}, while V_2 and V_3 take care of the other half–wave. Besides, an additional filter capacitor C_{add} is connected to thyristor V_7 through diodes V_5 and V_6 and to the L_fC_f–filter. When input voltage becomes equal to $U_{C_{add}}$ at angle α, (Fig. 5*b*), capacitor C_{add} starts to recharge through diodes V_5, V_6 and V_4, V_2. Thyristor V_7 turns off in the range of $\alpha \le \Theta \le \beta$, and the current of smoothing choke goes through the respective bridge diodes and the supply line. When thyristor V_7 switching on at angle β, the capacitor C_{add}, charged to input voltage, is hooked to filter input. The diodes of the rectifier bridge cut off and the choke current is sent through C_{add}. When the decreasing voltage of the additional capacitor equals the input one ($\Theta = \beta + \gamma$), thyristor V_7 cuts off and the described processes are repeated. As is seen from the diagrams, the choke voltage is of decreased amplitude and increased frequency as compared to voltage in a classic circuit. The input current is intermittent. Moreover, it is the sum of the falling off current from the additional capacitor and the building up current from the choke in the range of $\alpha \le \Theta \le \pi/2$. Therefore, even in the critical regime of choke operation the first harmonic of the input current features a small phase shift off the supply voltage, resulting in a high power coefficient of the input filter.

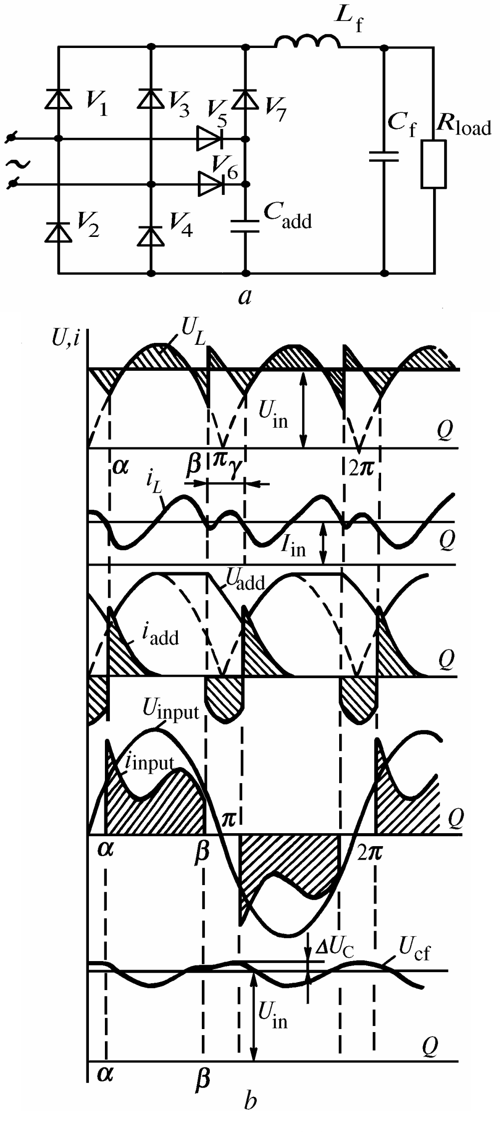

FIG. 5. Circuit of input filter (a) and diagram of its operation (b), where U_L i_L are instantaneous values of voltage and current through inductance L_f; $U_{C_{add}}$, $i_{C_{add}}$ are instantaneous values of voltage at additional capacitor C_{add} and its charging current; U_{in}, i_{in} are tht instantaneous values of input voltage and current; U_{out}, i_{out} are the mean output voltage and load current; U_{Cf}, ΔU_C are the instantaneous values of voltage at filter capacitor and its pulsation amplitude.

Our calculations show the optical angle of turn-on for thyristor V_7 to depend but slightly on the capacitance of the additional capacitor and to equal $\beta_{\text{opt}} \approx 0.84\pi$. Increasing the capacitance of C_{add} the rectifier transformation coefficient increases, while the demanded product of LC–filter decreases. To halve that parameter from its value in a classic circuit an additional capacitor is needed, with a capacitance of $C_{\text{add}} \sim 2/\omega R_1$, where ω is the supply line frequency; R_1 is the load resistance. The coefficient of voltage transformation is $K_U \approx 0.81$ then. As follows from our experimental studies the power coefficient of 0.9 may actually be reached for reasonable volume of smoothing choke.

The compact laser is designed in two separate units: the laser head and the power supply. The laser head unit includes the Coulomb active element, the TGI1–1000/25 thyratron with a filament transformer, a stepwise attenuator of radiation power and a transducer to control radiation power. Overall dimensions of the laser head are 700×300×200 mm. Average radiation power is 3 W.

The power supply has following technical characteristics: its output voltage varies from 6 to 10 kV at a conversion frequency of 8.4 kHz if output power is 1.2 kW. The unit needs a single–phase 220 V, 50 Hz supply line and has a mean service life exceeding 5000 h.

The compact metal-vapor laser described differs from the similar designs[2,4] in that:

a) energy is converted at a higher frequency, making possible a reduction of the unit mass to 20 kg at an output power of 1.2 kW;

b) the bulky charge choke is dropped from the high-voltage circuit;

c) high–voltage stabilization is provided;

d) adjustment of charge current is available;

e) digital indicator of radiation power is introduced;

f) stepwise attenuator of radiation power (1:5; 1:10; 1:20) is used;

g) service life counter is introduced.

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