A master oscillator-power amplifier system based on a 20 W average power strontium-vapor laser

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Investigation results on the time, space, and energy characteristics of a master oscillator-power amplifier system based on a strontium-vapor laser are presented. The experimental evidence suggests that the system under consideration holds much promise for high lasing efficiency average power operation. The space and time separation of the laser lines involved was determined. In our experimental conditions, the working aperture is uniformly filled with laser radiation for all lasing lines. Good timing of the oscillator and amplifier outputs made it possible to obtain stable multiple-wavelength laser action. For a total laser power of 21 W, the output power was found to be distributed over the operating wavelengths in the following way: 15 W at λ = 6.45 μm, 5 W at λ ~ 3 μm, and 1 W at λ ~ 1 μm. The peak average power was 22 W. Ways of improving the lasing efficiency of the master oscillator-power amplifier system are discussed.

Introduction

Strontium-vapor laser is an effective source of laser radiation in IR-range (λ ~ 6.456; 3; and 1 μm).[1] High obtainable average and peak values of generation power allow us to use these lasers for atmospheric investigations, as well as for working different materials.[2] The efficiency of the lasers depends on energy and quality characteristics of their radiation, that is, on the divergence angle, homogeneity and stability.

Laser output power can be increased at the sacrifice of the increasing active volume, as well as due to the installation of master oscillator-power amplifier system. The results of investigation of the increase of the active volume[3] demonstrate a possibility of a significant increase of both the pulse energy and the average lasing power. However, the increase of lasing power due to the increase of active volume is hard to achieve because of technical difficulties, connected with building of more powerful excitation sources, as well as decrease of operating parameters of the active elements. Therefore, we have designed a master oscillator-power amplifier system, which also allows increasing both energy and qualitative characteristics of radiation.

Experimental setup

The scheme of the experimental laser setup is illustrated in Fig. 1.

Laser strontium-vapor active elements were used as a master oscillator *1* and a power amplifier *2*. The master oscillator had a form of a cylindrical gas-discharge tube (GDT) with a volume of 540 cm^3 and an inner diameter of 2.5 cm. The mixture of He and Ne at a pressure of 100 mm Hg was used as a buffer gas. An unstable telescopic resonator *3* consisted of a nontransmitting mirror with a curvature radius of 1.8 m and exit mirror of 2 mm in diameter and 0.1 m in curvature radius. A GDT of 650 cm^3 active volume and D = 3 cm was used as an amplifier.

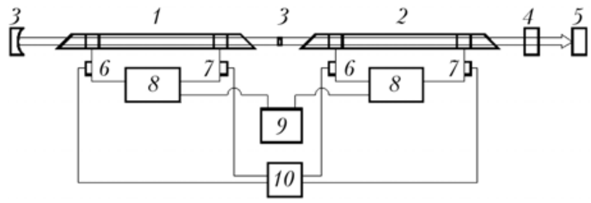

Fig. 1. A master oscillator-power amplifier system: gas-discharge tube of the oscillator (*1*); gas-discharge tube of the amplifier (*2*); unstable telescopic resonator (*3*); filter bank (*4*); power meter (*5*); current bypass (*6*); voltage divider (*7*); power source (*8*); master oscillator (*9*); oscillograph (*10*).

The active elements were heated and exited with the help of pulse power sources *8*, in which the thyratron (gas-filled triode) TGI1-1000/25 was used as a switch. Modulators were initiated by the master oscillator *9* with a variable lag between channels, which allowed synchronization of performance of the master oscillator-power amplifier system. Pulse repetition rate varied within 14–24 kHz. Average lasing power was registered by the Nova-II power meter. Low-impedance bypass was used to recorder current pulses, the voltage was recorded with the help of a divider, signals were transmitted to Tektronix TDS 2012 oscillograph. The shape of generation pulses was recorded by FSG-22 and FEC-24 photodetectors.

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Experimental results and discussion

The efficient operation of master oscillator-power amplifier system is in generation of radiation with low (close to the diffraction one) divergence angle and optimization of the moment of pulse passing through the amplifier. The radiation divergence was formed with an unstable telescopic resonator. Since the length of the total generation pulse (both from the oscillator and the amplifier) was equal to ~ 350 nanoseconds (Fig. 2*a*), the share of radiation with the diffraction divergence should be significant, because it is known that relatively long generation pulse correspond to a great number of radiation passes through the resonator.

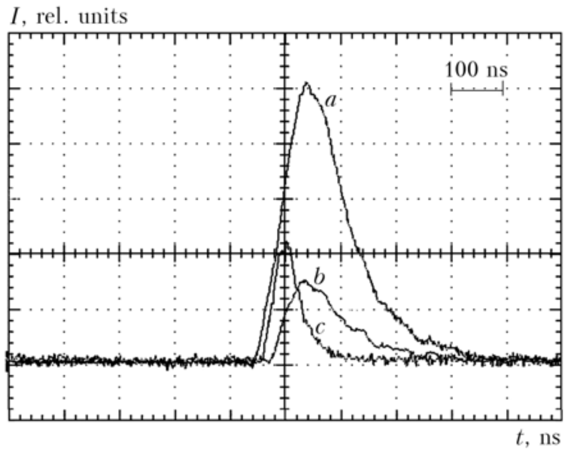

Fig. 2. The shape of strontium-vapor laser generation pulse: *a* is the total pulse; *b* is a 3 μm pulse, *c* is a 1 μm pulse.

In master oscillator-power amplifier system the part of radiation with diffraction divergence made up 75% of the total generation power corresponding to the values received in earlier investigations.[4]

The peculiarity of the strontium-vapor laser operation is generation at several wavelengths. The most efficient generation is a 6.456 μm wavelength of the SrI line. The generation at other lines is also of theoretical and practical interest. Filtering of generation lines allowed us to determine time positions of generation pulses at ~1 and ~3 μm wavelengths in total generation pulse (Fig. 2). Several lines of SrI within 3 μm region form a generation pulse (Fig. 2*b*). The pulse length in the basis makes up 250 ns.

The next pulse (Fig. 2*c*) is formed by generation on SrII transitions within 1 μm region, the length of which is 150 ns in the basis. This is sufficient for efficient operation of an unstable resonator. Thus, the radiation characteristics allow radiation with the divergence close to the diffraction one, with a high efficiency for all wavelengths.

The performance of the master oscillator-power amplifier system presumes optimization of the generator lasing pulse and the amplifier excitation pulse. Temporal and spatial adjusting of the generation pulse over the discharge channel diameter plays an important role in the process. It is important in our case, when the diameter size reached 3 cm. Relative magnitude of the pulse time shift over the beam cross-section also is of importance. It is evident that non-simultaneity of the discharge itself makes the most contribution to the mismatching of the active volume excitation.[5]

The experimental results presented in Fig. 3 demonstrate the pulse shape variability of generation lines depending on the discharge channel diameter, as well as the pulse time position.

The measurements were conducted with the help of a diaphragm and photodetectors. Total pulse radiation (Fig. 3*a*), 3-μm generation line pulse (Fig. 3*b*), and 1-μm generation line pulse (Fig. 3*c*) uniformly fill the active volume aperture. In this process the paraxial region advances the near-wall one by approximately 15 ns.

The experiments revealed that the difference of both time position of generation line pulses and their length in the multiwave laser mode provides for time matching between pumping pulses of the generator and amplifier, as well as a high stability of the system operation. Figure 4 illustrates the radiation power distribution depending on the wavelength.

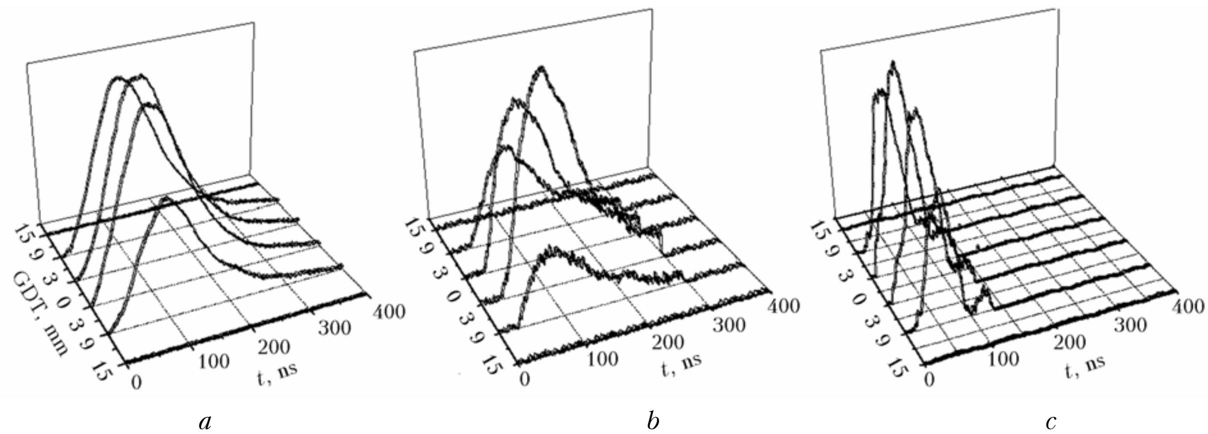

Fig. 3. Variability of generation pulse shape depending on the diameter of the discharge channel: total generation pulse (*a*); 3-μm pulse (*b*), 1-μm pulse (*c*).

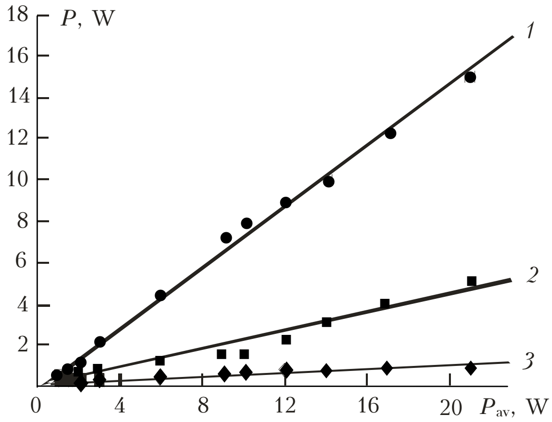

Fig. 4. Average radiation power distribution over spectral lines in the master oscillator-power amplifier system: generation power at 6.456 μm line (*1*); total generation power at 3 (*2*) and at 1 μm (*3*).

Conclusion

The investigations have proved a high efficiency of the strontium-vapor master oscillator- power amplifier system at SrI and SrII laser transitions. Spatial and time distribution of generation pulses in different spectral regions has been determined. It was revealed that uniform radiation filling of active volume aperture for all generation lines is realized experimentally. Time and spatial matching of the generator and the amplifier operation allowed obtaining of stable generation in the multiwave mode. At a total generation power of 21 W, the distribution over wavelengths is the following: 6.456 μm – 15 W, ~3 μm – 5 W, ~ 1 μm – 1 W, maximal average generation power was equal to 22 W.

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