Investigation of the lasing characteristics of a barium vapor laser with pulse repetition frequencies up to 320 kHz for navigation

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ABSTRACT

Results of experimental investigations into the characteristics of a laser on self-terminating transitions of the barium atom with $\lambda = 1499$ nm are presented for high pulse repetition frequencies (PRF). The frequency-energy characteristics are investigated in the self-heating mode of laser operation. Record values of PRF for the barium vapor laser, equal to ~320 kHz, have been attained.

Keywords: metal vapor laser, laser on self-terminating transitions.

INTRODUCTION

Radiation of lasers on self-terminating transitions of metal atoms and ions (MVL) cover the range of discrete lasing wavelengths from 0.31 to 6.45 μm. The MVL operate in pulsed-periodic mode with pulse repetition frequency (PRF) from several units to several ten kilohertz [1]. In a number of works the possibility of MVL operation with PRF exceeding 100 kHz was indicated. By the present time, the following maximum PRFs are attained: 230 kHz for a copper vapor laser [2], 700 kHz for a copper bromide vapor laser [3], and 830 kHz for a strontium vapor laser [4].

Investigation of maximum PRFs are important for understanding of physical processes limiting the frequency-energy characteristics (FEC) of MVL radiation. Achievement of high PRF is also attractive for laser application in various fields (for investigation of transient processes, creation of data recording systems, sensing of the parameters of the atmospheric surface layer, development of navigation systems, etc.).

One of the most efficient lasers on the self-terminating transitions is a copper vapor laser (CVL). A great number of works is devoted to the study of processes in the active medium of this laser. Among the factors limiting the maximum attainable PRR of CVL lasing are high prepulse metastable state population density leading to a decrease in the population inversion and gain and high prepulse electron concentration ne0 that does not allow fast heating of the electron gas to the temperature Te at which the population rate of the upper laser level exceeds that of the lower level. Moreover, different factors are interrelated, and their contributions depend on the conditions and methods of exciting the active medium. Ambiguous estimates of the maximum attainable frequency and energy characteristics (FEC) of even the CVL best studied in the literature call for their further investigations to elucidate the energy potential of lasers of this class and, in particular, of the laser on self-terminating barium atom transitions.

In a barium vapor laser, the maximum PRF attained by the present time is 40 kHz [5–7]. Investigation by the double-pulse method demonstrated the possibility of obtaining the PRF exceeding 100 kHz in the barium vapor laser. It should be noted that lasing at $\lambda = 1499$ nm (1P1 – 1D2 transition) in barium vapor is of special interest from the viewpoint of its application in systems of instrumental laser navigation, since radiation falls within a transparency window of the atmosphere and within the range of sensitivity of commercially available photodetectors [8]. Realization of the laser operating mode with increased frequencies will allow such parameters of navigation systems, as spatial and angular resolution and sensing range to be increased significantly.

In the present work, results of investigations of the lasing FEC ($\lambda = 1499$ nm) for a barium vapor laser are presented for PRFs > 100 kHz. Energy levels barium atom shown in Fig. 1.

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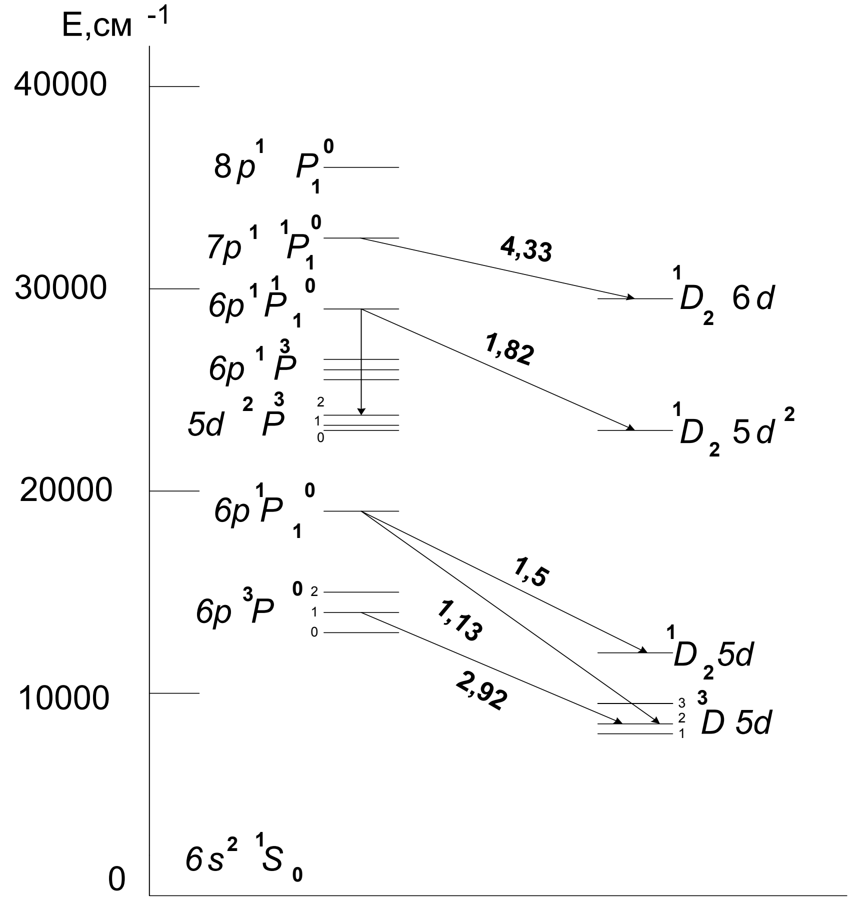

Fig. 1. Energy level diagram illustrating laser transitions for the barium atom

EXPERIMENTAL SETUP

Experiments were performed with a gas-discharge tube (GDT) whose gas-discharge channel was fabricated from BeO ceramics and had an inner diameter of 0.8 cm and a length of 18 cm. The GDT design was analogous to the laser tube of the strontium vapor laser used in experiments on investigation of the lasing FEC of the strontium vapor laser [4]. A plane-parallel resonator of the Ba laser comprised a nontransmitting mirror with aluminum coating having a reflection coefficient of ~95% at the lasing wavelength (λ = 1499 nm) and a quartz plate without coating. As a buffer gas, helium and neon were used. The range of variation of the capacitance of a storage capacitor was ~235–470 pF, the lasing PRF varied from 140 to 320 kHz, and the voltage on the rectifier changed from 0.95 to 1.25 kV. The excitation system was constructed by the scheme of direct discharge of the storage capacitor through the commutator – TGU1-60/7 tasitron. Thus, the scheme of realization of the pulsed-periodic discharge was functionally and structurally close to that used in [2, 4], where PRFs were obtained record for the copper and strontium vapor lasers.

Experimental investigations performed under above-indicated conditions allowed us to obtain a lasing PRF of 320 kHz. In this case, a decrease in the average lasing power P was observed without changes in the spectral structure of radiation with increasing excitation PRF (Fig. 2) and with increasing pressure of the buffer gas (Fig. 3).

For the He and Ne mixture of buffer gases (in the ratio 3:1 at a total pressure of ~60 Torr), the average lasing power was 160 mW, whereas for pure neon at a pressure of ~50 Torr, the average lasing power was 300 mW. A maximum average lasing power of 390 mW was obtained for the helium buffer gas (pHe=50 Torr). In all measurements of the output power depending on the composition and pressure of the buffer mixture, the PRF was 162 kHz. Table 1 summarizes the experimental data including the electric excitation parameters, pressure and composition of the buffer mixture, and values of the PRF and output power corresponding to the given conditions.

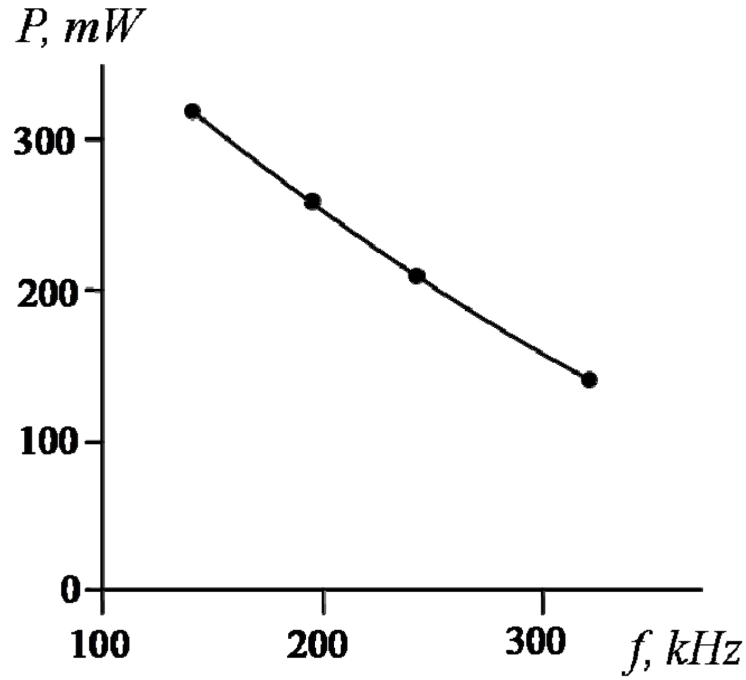

Fig. 2. Dependence of the average lasing power on the excitation pulse repetition frequency (pHe=50 Torr)

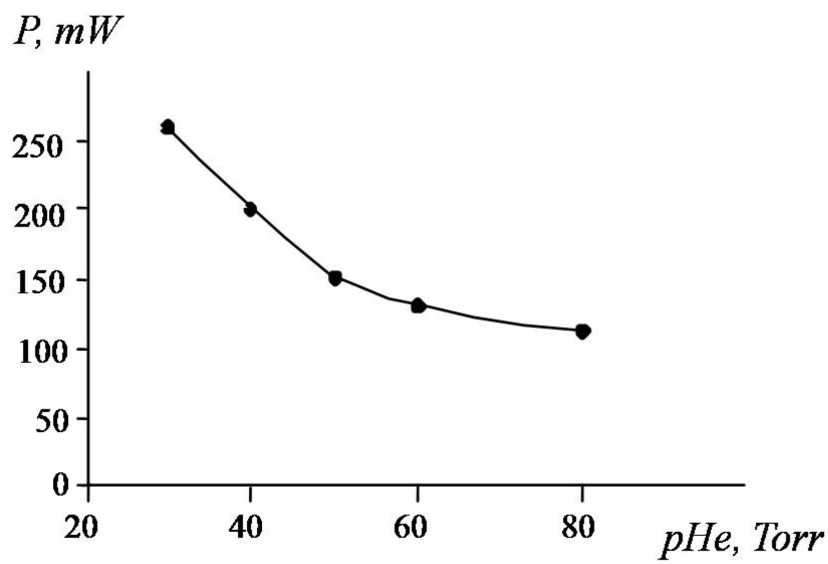

Fig. 3. Dependence of the average lasing power on the buffer gas pressure (PRF = 162 kHz)

The record PRF was attained in this work in the self-heating mode. Investigations in the range from 100 to 300 kHz were performed under conditions of reduction of the pulse energy proportional to the PRF increase (just as in [2–4]) with retention of the average energy deposition to preserve the stationary thermal mode.

We note that lasing at the wavelength $\lambda = 1499$ nm was observed in the entire range of variation of the pumping parameters. The lasing pulse waveform is shown in Fig. 4. The pulse duration at half maximum was ~15 nm, and at the base it was ~40 ns.

Table 1. Summary of the experimental data

F, kHz	U, kV	I, A	P, Torr	W, mW
100	1 .35	0.300	He = 80	250
120	1.25	0.300	Ne = 40	210
140	1.15	0.350	Ne = 35	300
162	1.2	0.300	He = 45 Ne = 15	160
194	1.25	0.300	He = 50	240
240	1.05	0.420	Ne = 35	220
242	1.1	0.340	He = 40 Ne = 10	140
320	1.15	0.350	He = 30	170

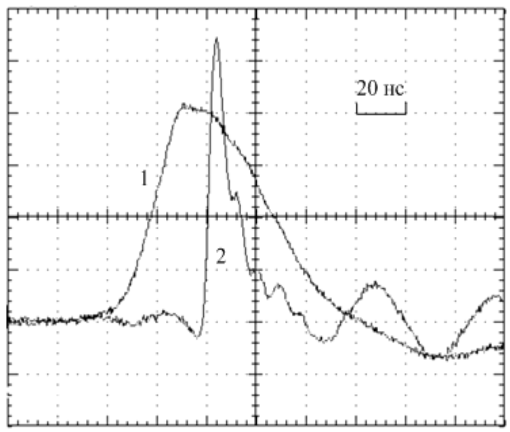

Fig. 4. Waveforms of current pulse 1 and lasing pulse 2 for excitation pulse repetition frequency of ~140 kHz. The capacitance of the storage capacitor was 470 pF, pHe = 40 Torr, and pNe = 10 Torr for an average lasing power of 130 mW

CONCLUSION

Our estimates demonstrated that the energy extracted from the Ba laser was ~20 mW/cm^3, which is comparable with the value (30–40 mW/cm^3) obtained previously for the Sr laser with the active medium having a working volume of 9 cm^3. Our investigations have confirmed the possibility of obtaining the lasing pulse repetition frequency exceeding 100 kHz. For the first time, we have obtained a lasing PRF of 320 kHz for the barium vapor laser.

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