the closeness of the Debye temperatures of our crystals and of the extrema of the observed $E_{thr}(T)$ plots. Mention should be make of the theoretical paper of Kiel [9], who showed that the transition probabilities in rare-earth ions should depend strongly on the thermal vibrations of the crystal, and particularly on ω_D.

In conclusion we must also note that the high-temperature spectroscopic investigation of the stimulated emission was carried out on more than 15 lasers using crystals and glasses ($Y_3Al_5O_{12}:Nd^{3+}$, $FaF_2:YF_3:Nd^{3+}$, $BaF_2:LaF_3:Nd^{3+}$, $CaWO_4:Nd^{3+}$, α-$NaCaYF_6:Nd^{3+}$, KGSS-7 and others). Besides the effects described above, the experiments confirmed the existence of autoresonant sensitization in mixed fluoride systems and glasses, and its connection with the thermal vibrations of the crystals. Figure 2c shows the high-temperature spectra of generation of KGSS-7 neodymium glass. The narrowing of the generation line at high temperatures shows that the probability of cross-relaxation of energy between different optical centers increases. Our investigations have also shown that the lasers operating at the highest temperatures are those based on fluoride crystals, and a laser based on α-gagarinite emits up to 1000°K. All this indicates that the method of high-temperature spectroscopy is very interesting and highly promising.

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SUPERRADIANCE AT TRANSITIONS TERMINATING AT METASTABLE LEVELS OF HELIUM AND THALLIUM

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It is known that pulsed population inversion can be produced at the start of an excitation pulse even without relaxation of the lower working level, by merely accelerating the excitation of the upper one. The rate of level population in the initial instants of the discharge are determined essentially by its effective cross section for excitation by electrons from the ground state. Since the largest cross sections for excitation by electrons are possessed as a rule by the resonance levels, it is preferable to use a resonant upper working level in order to obtain generation with high efficiency and high power. In this case the working transition can be a transition to a lower metastable level. Thus, pulsed generation using transitions between resonant and metastable levels is of special interest. We report here on superradiance obtained with transitions of this type in helium and in thallium.

The simplest atom in which transitions to a metastable level exist is that of helium.

The characteristics of the helium levels have been quite well investigated. The investigation of generation in the helium transitions is therefore quite intersting from the point of view of determining the physical processes that cause inversion. However, generation in helium transitions that terminate at metastable levels has not been observed before. A calculation which we performed with account taken of excitation by electrons from the ground state to the 2^1P, 2^3P, 2^1S, and 2^3S levels and for the radiative decay of the 2^1P and 2^3P levels has shown that, under perfectly feasible discharge conditions,one can expect a large gain and superradiance in the transitions $2^1S - 2^1P$ ($\lambda = 2.058\ \mu$) and $2^3S - 2^3P$ ($\lambda = 1.083\ \mu$). We used in the calcualtion data on the effective excitation cross sections taken from [1], and on the transition probabilities from [2]. We undertook to observe superradiance in the indicated transitions. The experiments were made with a quartz discharge tube of inside diameter 1.3 mm and working length 20 cm, with windows at the Brewster angle. The discharge was excited in the tube with the aid of a cable transformer with a transformation coefficient close to 3.5 [3], and the voltage pulse on the tube reached about 50 kV. The pulse repetition frequency ranged from several Herz to 10 kHz. Both cold electrodes and an oxide heated cathode were used. The tube was filled with spectrally pure helium. The radiation was registered with the IKS-6 and DFS-12 instruments. The receivers were lead-sulfide photoresistors (FS-A1), an InSb photodiode, and a photomultiplier. The results described below wer obtained using only one silver-coated mirror.

The experiments revealed superradiance at $\lambda = 2.058\ \mu$. The wavelength measurements with the DFS-12 instrument, with the gratings moved away from their usual position, yielded $\lambda = 20581.3 \pm 1$ Å. The tabulated value for the $2^1S - 2^1P$ transition is $\lambda = 20581.3$ Å. A check against the tables [4] showed that helium has no other transitions coinciding with the wavelength data within the limits of the estimated measurement accuracy.

The dependence of the superradiance power on the helium pressure is shown in Fig. 1. This dependence differs somewhat for the cold and for the oxide cathodes. It should be noted that the superradiance is much more stable when the oxide cathode is used. Figure 2 shows

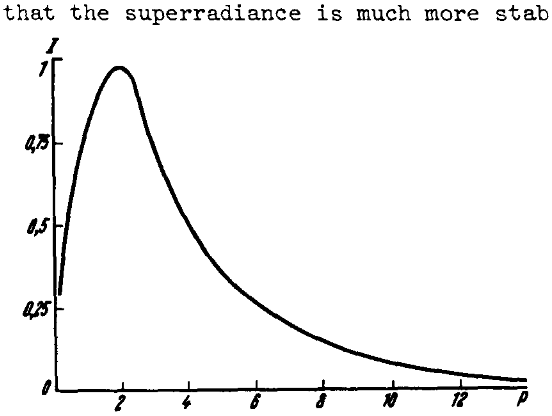

Fig. 1. Superradiance power I (arbitrary units) vs. pressure of helium. Pulsed voltage on tube approximately 36 kV, cold cathode, one mirror.

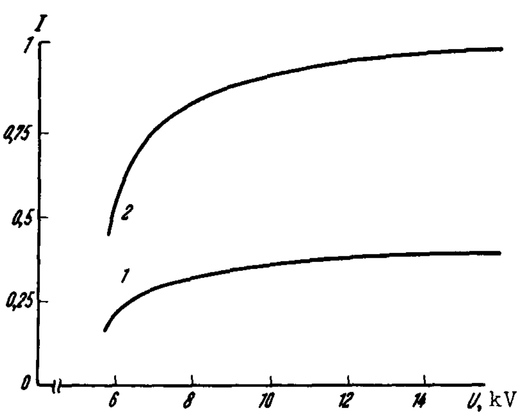

Fig. 2. Superradiance power I (arbitrary units) vs. primary voltage of pulse transformer. Helium pressure 2.7 Torr, cold cathode; curve 1 - without mirror; curve 2 - with one mirror.

the dependence of the superradiance on the voltage of the primary winding of the pulse transformer, for the case of operation without a mirror (curve 1) and with one mirror (curve 2). The helium pressure was 2.7 Torr. At higher pressures, the influence of the mirror is noticeably reduced. The peak superradiance power, estimated from the average power assuming the customary superradiance duration, on the order of 10^{-8} sec [5-7], was about one watt for the tube with 1.3 mm diameter, and about 10 W for the 5 mm tube.

Attempts were also made to observe superradiance or generation in the $2^3S - 2^3P$ transition (λ = 1.083 μ), but generation could not be observed under any experimental conditions. The population of the helium levels is apparently more complicated a process than assumed in the initial calculations.

The above-described superradiance in helium is of physical interest, but is not very promising from the point of view of high efficiency, since the ratio of the energy of the emitted quantum, $h\nu$, to the excitation energy E_b of the upper level is $h\nu/E_b = 0.29$ for λ = 2.058 μ. To obtain high efficiency it is necessary to use atoms with low-lying metastable levels. From this point of view, great interest attaches to thallium, whose atom possesses a very favorable level structure. For the thallium transition from the resonant $7^3S_{1/2}$ level to the metastable $6^2P_{3/2}$ level, the ratio $h\nu/E_b$ is equal to 0.70, so that a high efficiency can be hoped for. As far as we know, no generation in thallium line has been observed so far. We attempted to obtain generation in the green thallium line λ = 5350 Å. We used quartz tubes with inside diameters 1.3, 2, and 3 mm, discharge length 20 cm, and cold cathodes. The middle part of the discharge tube, which contained the thallium, was placed in an oven. The electrodes and the windows mounted at the Brewster angle were outside the oven. The buffer gases were neon and helium at pressures on the order of several Torr. The remaining part of the setup was the same as in the experiments with helium.

When the oven was heated to 600°C, corresponding to a thallium vapor pressure of 10^{-2} Torr, superradiance was observed at λ = 5350 Å, with an intensity that increased with increasing temperature. The superradiance was observed both with a single mirror and without any mirror. The superradiance pulse duration did not exceed 20 nsec, and the peak power was estimated by us at several watts. The dependence of the superradiance power on the pulse-transformer primary voltage is similar in the case of thallium to that shown in Fig. 2 for helium.

An investigation of the spectrum by means of a Fabry-Perot interferometer revealed an appreciable narrowing of the lines and made it possible to observe, under the most favorable conditions, four hfs lines connected with the presence of two isotopes having a nuclear angular momentum 1/2. The line splitting agreed with that known from the literature [8,9].

In conclusion we note that the largest pulse-generation efficiency can be obtained by exciting the thallium vapor with monoenergetic electrons having an energy slightly higher than the upper working level. Under these conditions, apparently, only one upper working level will be excited. The theoretical efficiency may exceed 20% in this case.

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CONTRACTION OF POSITIVE COLUMN

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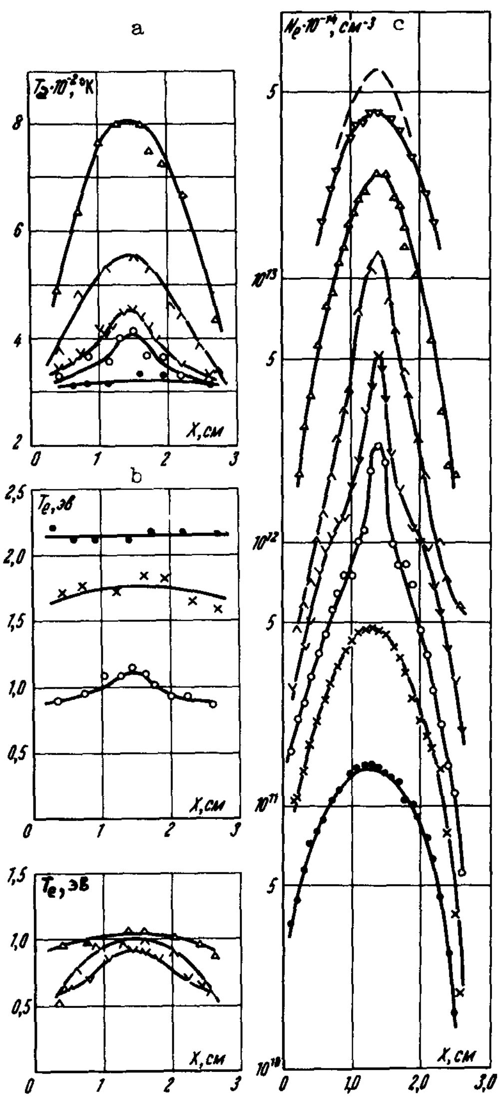
It is known that the positive column can contract at medium and high pressures. Various hypotheses were proposed to explain this phenomenon [1,2]. However, only the theory of current contraction at high pressures [3] has found experimental confirmation. The present paper is devoted to contraction of current at medium pressures ($p \sim 5 - 500$ mm Hg). The properties of the positive column were investigated in cylindrical tubes evacuated to $p < 5 \times 10^{-6}$ mm Hg and filled with spectrally pure gas (Ar and Ar + Cs). The distributions of the electron temperature T_e and density N_e over the radius were measured with double moving probes and also determined from the recombination radiation, and the distribution of the gas temperature T_a was determined by the incandescent tungsten wire method. The longitudinal electric field intensity was measured with wall probes. The electron-energy balance and the electron balance were calculated at all values of the pressure and current in six cylindrical layers.

The effective radius r_{eff} of the positive column depends on the current and on the pressure. At low argon pressure ($p < p^* \approx 5$ mm Hg) the current contracts little. At $p > p^*$ a non-contracted state exists only at currents lower than a limiting value $i < i_{lim}$, and when $i > i_{lim}$ this state becomes unstable and contraction occurs abruptly (see the figure).



Distributions of T_a (a), T_e (b), and N_e(c) over the tube diameter (i.d. 2.6 cm) at argon pressure 20 mm Hg) in currents of 5×10^{-3} (•), 1.5×10^{-2} (×), 3×10^{-2} (o), 0.1 (v), 0.5 (^), 2 (Δ), and 5 A (∇). Dashed - density determined from absolute recombination radiation at i = 2 A.

Diffusion state at low pressures ($p < p^*$). When the current is large, the inhomogeneity of the atoms $N_a(r)$ as a result of the heating leads to only a weak inhomogeneity of $T_e(r)$, since the major role in the electron-energy balance is played by the electron heat