migration causes the amplification-line contour to stay undeformed, the line behaves like a homogeneously-broadened one, and narrowing of the spectrum is observed, in accord with [5]. At a definite value of the migration rate, however, there exist such values of the pumping rate and of the radiation-field density, that the amplification-line contour becomes deformed and broadening of the spectrum is possible. On the other hand, when the migration rate in a neodymium laser decreases, this critical value of the pumping rate can approach the threshold, and then the spectrum should broaden during the course of lasing in almost the entire pumping range. It is this circumstance which explains, apparently, the broadening of a neodymium-laser spectrum at 4.2°K, observed in [7], since the rate of energy migration in neodymium glass is greatly reduced at these temperatures. From this point of view, the use of materials with high migration rate promises to yield single-mode generation in a wide range of pump energies.

[1] T. I. Kuznetsova and S. G. Rautian, Fiz. Tverd. Tela 5, 2105 (1963) [Sov. Phys.-Solid State 5, 1535 (1964)].
[2] V. I. Malyshev, A. S. Markin, and A. A. Sychev, ZhPS (J. of Appl. Spectr.) 7, 662 (1967).
[3] V. I. Malyshev, A. S. Markin, and A. A. Sychev, Zh. Tekh. Fiz. 39, 334 (1969) [Sov. Phys. Tech. Phys. 14 (1969)].
[4] A. M. Bonch-Bruevich, V. Yu. Petrun'kin, N. A. Esepkina et al. ibid. 37, 2031 (1967) [12, 1495 (1968)].
[5] C. L. Tang, H. Statz, et al. Phys. Rev. 136, 1A (1964).
[6] V. D. Katsubanov, Yu. V. Naboikin, A. M. Ratner, and I. A. Rom-Krichevskaya, Zh. Eksp. Teor. Fiz. 53, 807 (1967) [Sov. Phys.-JETP 26, 534 (1968)].
[7] M. N. Tolstoi and V. N. Shapovalov, Opt. i spektr. 23, 648 (1967).

RADIATIVE PERTURBATION OF POTASSIUM TERMS IN A RUBY-LASER RADIATION FIELD

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In [1 - 4] they observed intense directional glow of potassium vapor following irradiation with a giant ruby-laser pulse (ν = 14 399 cm^{-1}) and with the Stokes SRS of this pulse in nitrobenzene (ν = 13 054 cm^{-1}). The frequencies of the potassium transitions $4S_{1/2} - 4P_{3/2}$ (ν_{no} = 13 042 cm^{-1}) and $4P_{3/2} - 6S_{1/2}$ (ν_{mn} = 14 407.8 cm^{-1}) are very close to the SRS and laser frequencies, respectively, thus explaining the population of the excited levels, the feasibility of negative absorption, and the powerful stimulated emission observed in [1 - 4] for many transitions. In Fig. 1 these transitions are marked by arrows.

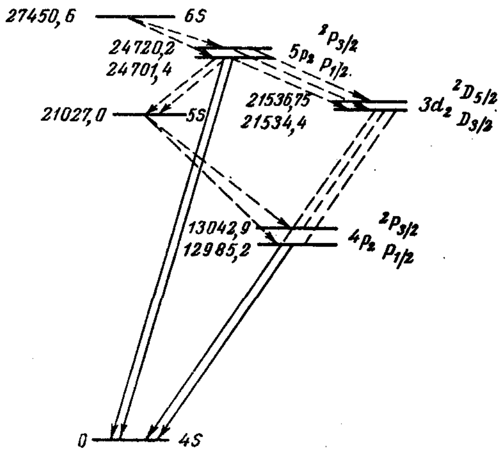

Fig. 1. Potassium terms

We investigated the radiation in the visible part of the spectrum connected with the transitions $4S_{1/2}$ - $4P_{3/2,\ 1/2}$ (λ = 7665/99 Å) and $4S_{1/2} - 5P_{3/2,1/2}$ (λ = 4044/47 Å). We were interested in the fine structure of these lines (which was not investigated in [1 - 4]), since the potassium terms should be strongly disturbed in the laser-emission field.

The potassium vapor was contained in a glass cell with end windows. The cell temperature, which determined the vapor pressure, varied in different experiments in the interval 150 - 250°C. The ruby-laser and SRS radiation were directed along the cell axis. The observation was made in the same direction, with the aid of a DFS-8 spectrograph (1200 lines/mm, dispersion 1.40 and 2.80 Å/mm, apparatus-function width $\Delta\nu_a = 0.17$ and 0.10 cm^{-1} for the violet and red lines, respectively).

The most significant experimental results are as follows:

1. Each of the $4S_{1/2} - 5P_{3/2,1/2}$ lines has a narrow "dip" (Fig. 2a) whose center coincides with the transition frequency. The total width, including both components, increased with increasing laser power and reached 3 cm^{-1} in our experiments.

2. The resonant-transition lines have no doublet structure. Both, however, have an appreciable width (0.5 - 1.0 cm^{-1}) and are shifted (by 0.7 - 1.7 cm^{-1}) to the red side relative to the transition frequency (Fig. 2b).

3. The absorption band first observed in [3] against the background of a broad SRS line in nitrobenzene is most pronounced at moderate laser power (∿1 mW, Fig. 2c). The band disappears gradually with increasing power. The frequency ν_1 of the center of the band changed following temperature scanning of the ruby frequency ν, with $\Delta\nu_1 = -\Delta\nu$ (accurate to 0.05 cm^{-1}). The absolute values of ν_1 and ν, as measured by us (with accuracy 0.1 cm^{-1}) satisfy the equation $\nu = \nu_{mo} - \nu_1$. The absorption line width is ∿1 cm^{-1}.

To interpret these facts, we shall assume that the wave function of the atom in the field of the ruby laser is given by [5]

$$\psi = \psi_m[A_1 e^{-i(\omega_m + \epsilon_1)t} + A_2 e^{-i(\omega_m + \epsilon_2)t}] + \psi_n[B_1 e^{-i(\omega_n - \epsilon_1)t} + B_2 e^{-i(\omega_n - \epsilon_2)t}]; \qquad (1)$$

$$\epsilon_{1,2} = \frac{\Omega}{2} \pm \sqrt{\left(\frac{\Omega}{2}\right)^2 + G^2}; \quad \Omega = \omega - \omega_{mn}; \quad G = \left|\frac{p_{mn}E}{2\hbar}\right|. \qquad (2)$$

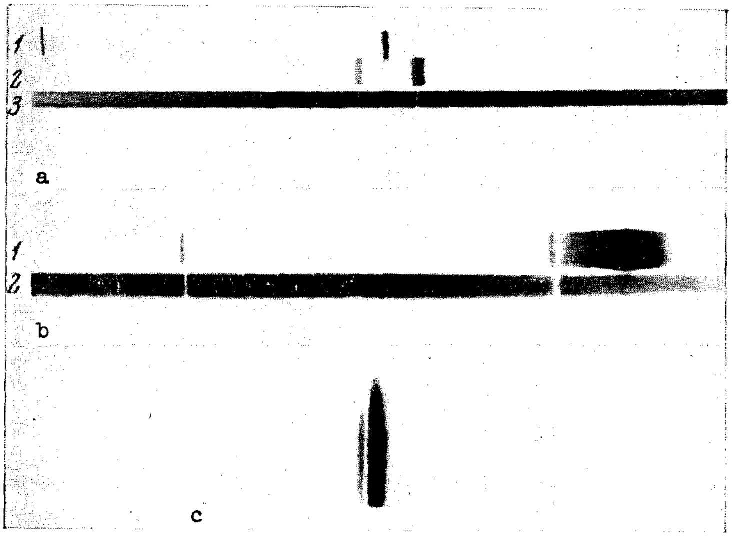

Fig. 2. Emission and absorption spectra of potassium vapor: a - region of 4044/47 Å lines: 1) iron-spectrum lines in second order of the diffraction grating, 2) emission of potassium under laser and SRS radiation, 3) potassium vapor absorption spectrum. b - region of 7665/99 Å lines: 1) emission of potassium under laser and SRS radiation, b) potassium vapor absorption spectrum. c - absorption line against the background of the Stokes SRS line.

Expression (1) for ψ can be interpreted as the spliting of the nondegenerate states of the atom (Fig. 3), due to the external field [6 - 9]. For the $4P_{3/2} - 6S_{1/2}$ transition, the numerical parameters are

$$\Omega = -8 \text{ cm}^{-1}; \quad G = 0.70\sqrt{P} \text{ cm}^{-1},$$

where P is the radiation power in MW/cm^2. For moderate powers we have $G \ll |\Omega|$, and then

$$\epsilon_1 \cong G^2/|\Omega|; \ \epsilon_2 = -|\Omega| = G^2/|\Omega|. \qquad (3)$$

According to this scheme, the absorption line corresponds to the transition of the atom from the ground state to the component ε_2 of the doublet[1] of the state (Fig.3). It is easy to show with the aid of (3) that the maximum of the absorption should take place at the frequency $\nu_1 = \nu_{mo} - \nu + G^2/|\Omega|$. Such a relation is obtained experimentally, with the exception of the term $G^2/|\Omega|$, which was small in these measurements (see Sec. 3).

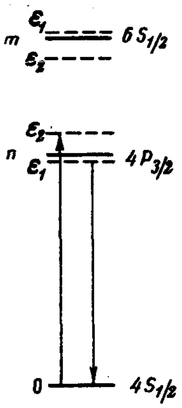

Fig. 3. Splitting of the terms $m(6S_{1/2})$ and $n(4P_{3/2})$ of potassium in the giant pulse field. The arrows denote the transitions that account for the absorption and emission lines.

The 7665 Å emission line can be interpreted as the result of induced transitions from the component ε_1 of the $4P_{3/2}$ doublet to the ground state[2] (Fig. 3). This agrees with the direction and with the order of magnitude of the shift ($\varepsilon_1 \sim 1$ cm^{-1} for $P \sim 20$ mW/cm^2), and with the increase of the shift with increasing P. The width of the 7665 Å line can be related to the spatial and temporal inhomogeneities of the giant pulse.

Thus the 7660 Å absorption line and the 7665 Å emission line are a manifestation of the radiative splitting of the potassium terms $4P_{3/2}$ and $6S_{1/2}$.

The origin of the shift of the 7669 Å line is less clear. Direct interaction with the emission of the ruby laser can lead only to an insiginficant shift of the line, one order of magnitude smaller than the observed one. The process of population of the $4P_{1/2}$ level apparently relates it coherently with the $4P_{3/2}$ term, whose structure it transfers to the $4P_{1/2}$ term.

The symmetrical broadening of the 4044/47 Å lines suggests a new type of perturbation

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[1] Under nonresonant conditions, this "transition" is connected with two-quantum absorption and with the transition 0 → m.

[2] An analogous effect in absorption was observed in [10].

of the 5P atomic states. Apparently the cascade population 6S → 5P of the 5P levels occurs with the aid of two fields that differ in frequency by an amount on the order of ε_1. This should lead to an effect analogous to phase modulation, which is characterized by a broad and symmetrical spectrum.

In spite of the few unclear aspects, it can be regarded as established that the observed effects are connected with the splitting of the atomic levels in the external field.

[1] S. Yatsiv, W. G. Wagner, G. S. Picus, and F. J. McClung, Phys. Rev. Lett. 15,614 (1965).
[2] M. Rokni and S. Yatsiv, Phys. Lett. 24A, 277 (1967).
[3] M. E. Movsesyan, N. N. Badalyan, and V. A. Iradyan, ZhETF Pis. Red. 6, 631 (1967) [JETP Lett. 6, 127 (1967)].
[4] P. P. Sorokin, N. S. Shiren, J. R. Lankard, E. C. Hammond, and T. G. Kazyaka, Appl. Phys. Lett. 10, 44 (1967).
[5] L. D. Landau and E. M. Lifshitz, Kvantovaya mekhanika (Quantum Mechanics), Sec. 40, Fizmatgiz, 1948 [Addison-Wesley, 1958].
[6] S. H. Autler and C. H. Townes, Phys. Rev. 100, 73 (1955).
[7] V. M. Kontorovich and A. M. Prokhorov, Zh. Eksp. Teor. Fiz. 33, 1428 (1957) [Sov. Phys.-JETP 6, 1100 (1958)].
[8] S. G. Rautian and I. I. Sobel'man, ibid. 41, 456 (1961) [14, 328 (1962)].
[9] A. M. Bonch-Bruevich and V. A. Khodovoi, Usp. Fiz. Nauk 93, 71 (1967) [Sov. Phys.-Usp 10, 637 (1968)].
[10] E. B. Aleksandrov, A. M. Bonch-Bruevich, N. N. Kostin, and V. A. Khodovoi, ZhETF Pis. Red. 3, 85 (1966) [JETP Lett. 3, 53 (1966)].

FORMATION OF POWERFUL NANOSECOND PULSES WITH THE AID OF MANDEL'SHTAM-BRILLOUIN SCATTERING AND STIMULATED RAMAN SCATTERING

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We observed self-excitation and the time evolution of stimulated Mandel'shtam-Brillouin scattering (SMBS) in compressed nitrogen gas in a cell placed in a ruby-laser cavity (Fig. 1). Powerful pulses (∿100 MW) were then simultaneously generated at two wavelengths, λ = 6943 Å (SMBS) and λ_1 = 8280 Å (first Stokes component of SRS in nitrogen).

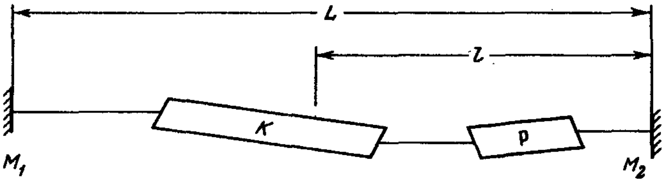

Fig. 1. Block diagram of setup: M_1 and M_2 - mirrors with reflection coefficients R_1 (99% and 12% at 6943 and 8280 Å, respectively) and R_2 (60% and 97% at 6943 and 8280 Å), C - cell 1 m long with nitrogen compressed to 500 atm, R - ruby 23 cm long and 1.5 cm in diameter, L = 4 + 13.5 m, ℓ = 2.5 m.

The time evolution of the process is shown in Fig. 2. Generation is first produced at mirrors M_1 and M_2 (Fig. 1). A microsecond pulse is produced, having a regular structure with period 2L/c (Fig. 2a). Its power is ∿10 kW and the line width is < 0.01 cm^{-1}. The radiation passing through the cell with the nitrogen is partly reflected as a result of the Mandel'shtam-Brillouin scattering and goes over into its first Stokes component. This leads to the appearance of additional spikes (Fig. 2b) together with regular pulsations. The maxima of the additional