Scientific session of the Division of General Physics and Astronomy of the Academy of Sciences of the USSR (20–21 February 1980)

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A scientific session of the Division of General Physics and Astronomy of the Academy of Sciences of the USSR was held at the P. N. Lebedev Physics Institute on 20 and 21 February 1980. The following papers were presented:

20 February

E. B. Aleksandrov and N. N. Yakobson, Optical self-pumping of atoms.

D. A. Varshalovich, Optical pumping of the OH radical masers in the space.

I. I. Sobel'man, Investigation of the effect of non-conservation of parity in atomic bismuth.

21 February

B. B. Kadomtsev, INTOR—international tokamak reactor.

V. S. Strelkov, Tokamaks: status and prospects.

G. I. Dimov, Ambipolar traps.

Brief summaries of three of these reports are presented below.

E. B. Aleksandrov and N. N. Yakobson. *Optical self-pumping of atoms*

1. It was found that in the excited (in a gas discharge or by other methods) vapors of atoms with the optically-resolved hyperfine structure (hfs) of the ground state a tendency exists to redistribute the population of the hfs sublevels; moreover, sublevels characterized by lower statistical weights become predominantly populated. This phenomenon, called optical self-pumping, was discovered for the first time in a discharge in thallium vapors by means of radio-optical spectroscopy methods.[1] Investigations of this phenomenon[2-4] have underscored its universal nature which was subsequently shown in experiments with rubidium (Rb^{871})[5] and silver (Ag^{109}) vapors.

2. Figure 1 illustrates the self-pumping mechanism. It shows an arbitrary hfs diagram of the atomic ground state (gs) which consists of two sublevels with angular momenta 0 and 1, and the first excited state. Let the gs sublevels be initially populated according to the ratio of the statistical weights (equality of the magnetic sublevel populations). A change in the populations may occur as a result of differences in the rates of excitation of atoms from these sublevels, and (or) if the sublevel population probabilities differ during deactivation. The probabilities of excitation by electron impact are equal for the two hfs sublevels as a result of their energy proximity, as are also probabilities of deactivation by collisions of the second kind. The radiative processes at low optical densities of the gas also do not alter the population ratio since, in accordance with the intensity rule, the numbers of excited atoms which spontaneously decay to the gs sublevels are in the ratio of the statistical weights of the latter.

The situation changes with a rise in the optical density of vapors. As we know, the ratio of spectral-line intensities deviates from the initial one with increasing densities of the emitting vapors, converging in the limit to the Planck distribution which, in the case of the near line components, corresponds to the convergence of intensities. This corresponds to a relative increase in the radiative relaxation of atoms to a sublevel with a smaller statistical weight, i.e., sublevel overpopulation [Fig. 1(b)]. The diagram in Fig. 1, illustrates the structure of the resonance transitions in silver; self-excitation in the silver vapor leads to population inversion of the gs sublevels.

3. The general tendency of the intensities of adjacent spectral lines to converge as the vapor densities increase ("blackening" of radiation) is realized in a combination of processes of activation, quenching and migration of excitation of atoms. Among these, the principal role in the development of self-pumping is played by a competition between resonance lines coming from a common upper level.[2,10] The competition is based on the absorption of radiation: absorption of the stronger line leads to an increase in the population of the com-

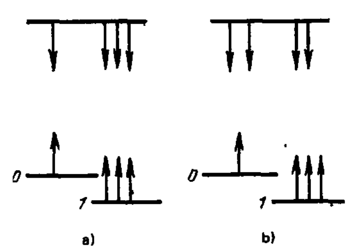

FIG. 1. Diagram of the occurrence of self-pumping. The number of arrows characterizes the intensity of the primary excitation events (upward) and radiative deactivation (downward). a. Low optical density $k \ll 1$; b. $k \gg 1$.

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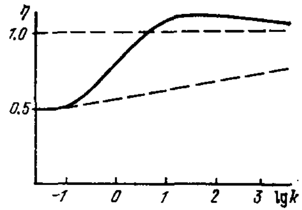

FIG. 2. Dependence of the ratio of intensities η of the resonance lines with a common upper level on the optical density k of the emitting medium. Dashed line—same dependence for uncoupled lines.

mon upper level, and to a relative increase in the intensity of the weaker and, therefore, less absorbed line which terminates at a level with a smaller statistical weight. As a result of competition the convergence of the component intensity ratio η to unity, when the optical density increases, proceeds nonmonotonically, as is schematically illustrated in Fig. 2 for the initial ratio $\eta = 0.5$. The anomalous growth of the weak spectral-line components has been spectroscopically observed earlier,[6-8] but not explained. Under the conditions of competition, sharp deviations from the intensity rule occur at moderate optical densities of the radiating volume $k \sim 3-10$; this is conducive to development of self-pumping since the rate of relaxation of the hfs sublevels which impedes self-pumping is proportional to the concentration of atoms.

4. Self-pumping may be used to conduct radio-spectroscopic studies of atoms in the ground state in a gas discharge and to extend the radio-optical spectroscopy methods to substances for which the traditional optical pumping methods[9] are ineffective (for example, halogens, oxygen). In certain substances, such as silver vapor, self-pumping may lead to maser action.

Evidently, self-pumping is not limited to the hfs of ground-state atoms. A similar process should affect the ratio of populations of arbitrary long-lived states, for example fine structure levels. It is plausible to believe that self-pumping participates in determining the populations of metastable levels of atoms and molecules in the rarefied atmospheres of stars and planets. In particular, self-pumping should contribute to populating the $^1S_0$ metastable level of oxygen which is responsible for the bright "auroral" 5577-Å line in the polar glow.

[1] E. B. Aleksandrov and N. N. Yakobson, Pis'ma Zh. Eksp. Teor. Fiz. 26, 463 (1977) [JETP Lett. 26, 333 (1977)].
[2] E. B. Aleksandrov and N. N. Bezuglov, Opt. Spektrosk. 45, 218 (1978) [Opt. Spectrosc. (USSR) 45, 121 (1978)].
[3] E. B. Aleksandrov and N. N. Yakobson, v: Tezisy 6-ĭ konfrentsii po atomnoĭ fizike (In: Proceedings of the 6th Conference on Atomic Physics), Riga, 1978, p. 59.
[4] E. B. Aleksandrov, N. N. Bezuglov, and N. N. Yakobson, Opt. Spektrosk. 46, 1061 (1979) [Opt. Spectrosc. (USSR) 46, 599 (1979)].
[5] E. B. Aleksandrov and N. N. Yakobson, [*ibid.* 48, 828 (1980) *ibid.* 48, 457 (1980)].
[6] S. É. Frish, Tr. GOI (Proceedings of the State Optical Institute), No. 71, 1 (1931); Zs. Phys. 68, 758 (1931).
[7] Yu. I. Turkin, Opt. Spektrosk. 2, 290 (1957); *ibid.* 7, 10 (1959) [*ibid.* 7, 5 (1959)].
[8] Yu. I. Turkin and M. P. Chaĭka, *ibid* 11, 695 (1961) [*ibid.* 11, 375 (1961)].
[9] W. Happer, Rev. Modern Phys. 44, 169 (1972).
[10] D. I. Nagirner and A. B. Shneĭvaĭs, Astron. Zh. 54, 162 and 367 (1977) [Sov. Astron. 21, 91, 204 (1977)].