RESONANT BIREFRINGENCE IN THE ELECTRIC FIELD OF A LIGHT WAVE

A. M. Bonch-Bruevich, N. N. Kostin, and V. A. Khodovoi
Submitted 28 March 1966
ZhETF Pis'ma 3, No. 11, 425-429, 1 June 1966

We have observed the occurrence of birefringence in potassium vapor under the influence of the electric field of ruby-laser emission. The magnitude of the effect had a resonant dependence on the laser emission wavelength.

The experimental setup is illustrated in Fig. 1. Light from a potassium lamp 1 was passed through vessel 2 containing potassium vapor saturated at 150°C. The line width of the potassium line (principal doublet $4S_{1/2}$ - $4P_{1/2,3/2}$, λ = 7665 and 7699 Å), measured with a scanning Fabry-Perot interferometer, was 0.15 Å, i.e., approximately 4 times larger than the Doppler width of the vapor absorption line. At the chosen temperature, the vapor absorbed approximately 50% of the resonant light of the lamp. Two crossed polaroids 3 and 3' were placed in the path of the light from the lamp ahead and past the vessel with the potassium vapor. The potassium vapor was beamed with pulses from the ruby laser 7, operating with passive shutter (KS-19 glass). The laser emission intensity was registered with an F-5 photocell 8 feeding a pulsed oscilloscope (S1-7), and its wavelength was measured with the aid of an STE-1 spectrograph 9 with 13 Å/mm dispersion. The intensity of the resonance radiation passing through the vessel and the polaroids was registered with an FEU-28 photomultiplier 6 feeding a pulsed oscilloscope (S1-11); the scattered laser radiation was reliably cut off with FS-7 filters 5 and with a resonant filter 4 using the Faraday effect and having a transmission band of the order of 0.1 cm^{-1} [1,2].

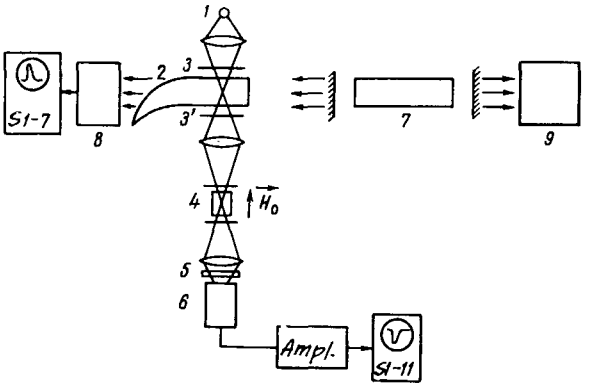

Fig. 1. Diagram of experimental setup.

During the operating time of each laser pulse (duration 20 nsec) a clear-cut signal was observed indicating an increase in the resonant radiation from the lamp passing through vessel 2. At a laser emission power density of the order of 5 MW/cm^2 the amplitude of the signal corresponded to the transmission of several times ten per cent of the intensity of the light from the lamp passing through the first polaroid. The greatest signal was observed when the angle between the lamp-radiation electric field vector $\vec{E}_r$ incident on vessel 2 and the vector of the laser emission electric field $\vec{E}_l$ was 45°; there was no signal when this angle was 0 or 90°.

It was verified that no signal was observed when the potassium vapor in vessel 2 was frozen out, when the potassium lamp was turned off, or when polaroids 3 and 3' were removed. The latter, together with the dependence of the signal on the angle between the vectors $\vec{E}_r$ and $\vec{E}_\ell$, proves that the observed effect is due to birefringence caused by the laser pulse, and not by the shift of the center of gravity of the potassium-vapor absorption line by an amount larger than the half-width of the lamp emission line [1].

The observed birefringence is caused by the fact that the shift of the absorption line in the laser-emission electric field has different values when the electric vector of the light is parallel and perpendicular to $\vec{E}_\ell$ [1)]. It is known that the refractive index near the absorption-line maximum depends strongly on how close the emission frequency is to its center of gravity. In the absence of a laser pulse the resonant potassium absorption lines D_1 and D_2 (Fig. 2) are not split, and the refractive index does not depend on the polarization of the incident radiation. Under the influence of the laser pulse the degenerate states $4P_{3/2}$ are lifted, and the center of gravity of the absorption-line components are shifted for the π and σ radiation (z axis along the vector $\vec{E}_\ell$) in such a way that the refractive indices become different for the π and σ radiation.

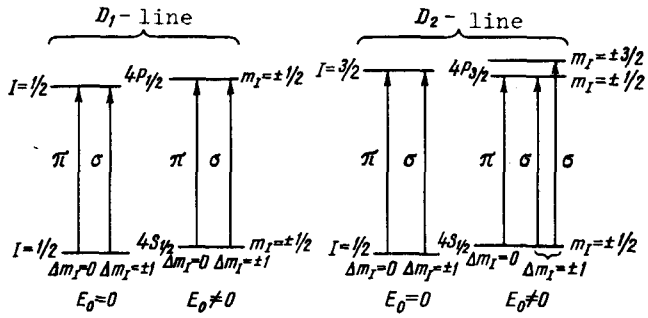

Fig. 2. Electric splitting of the potassium terms $4S_{1/2}$ and $4P_{3/2,1/2}$.

The shift ΔW_i of the energy of the level i under the influence of the electric field $\vec{E} = 2\vec{E}_0 \cos\omega t$ of the light wave is given by the formula [1,4]

$$\Delta W_i = \sum_k \left\{ \frac{|\langle i|\vec{d}\cdot\vec{E}_0|k\rangle|^2}{E_i - E_k + \hbar\omega} + \frac{|\langle i|\vec{d}\cdot\vec{E}_0|k\rangle|^2}{E_i - E_k - \hbar\omega} \right\}, \qquad (1)$$

where E_i and E_k are the energies of the states of the i-th and k-th atoms and $\langle i|\vec{d}\cdot\vec{E}_0|k\rangle$ is the matrix element of the dipole transition between the states i and k. Unlike the level shift in a constant electric field (Stark effect), the shift in the field of a light wave increases resonantly when the energy $\hbar\omega$ of the light quantum approaches the energy $E_k - E_i$ of the atomic transitions. For the $4P_{3/2}$ state of potassium the ruby-laser emission wavelength is close to the wavelength of the transition $4P_{3/2} - 6S_{1/2}$ (λ = 6939 Å); it can be shifted in the range 6935 - 6945 Å by varying the temperature of the ruby rod.

Figure 3 shows the measured dependence of the laser emission intensity required to obtain a signal of prescribed magnitude (transmission of the order of 10% of the potassium lamp light) on the laser emission wavelength. Measurement with a Fabry-Perot etalon has shown that in all the operating modes employed the total spectral width of the laser emission, consisting of several pulses in each pump pulse, was 0.15 Å. The observed linear dependence of the re-

quired laser intensity on the wavelength difference $\Delta\lambda = |\lambda - \lambda_0|$ between the resonant transition and the laser emission corresponds to the theoretically expected relation (1). It follows therefore that the resonant transition $4P_{3/2} - 6S_{1/2}$ makes the main contribution to the level splitting of the $4P_{3/2}$ state of potassium under the influence of the ruby laser emission.

The authors thank V. M. Zakharova and N. A. Vorob'eva of the Leningrad State University for the opportunity to measure with their apparatus the potassium line contour, and E. B. Aleksandrov for help with the work and a discussion of the results.

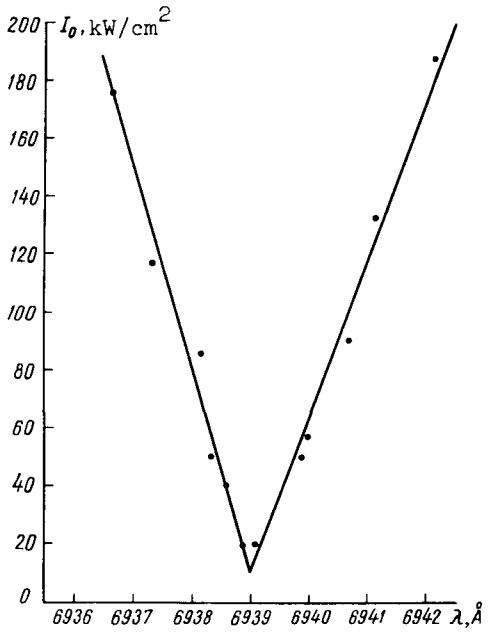

Fig. 3. Ruby laser emission power density I_0 needed to obtain a signal of specified magnitude, vs. the ruby laser wavelength λ.

[1] E. B. Aleksandrov, A. M. Bonch-Bruevich, N. N. Kostin, and V. A. Khodovoi, JETP Letters 3, 85 (1966), transl. p. 53.

[2] E. B. Aleksandrov, Optika i spektroskopiya 19, 455 (1965).

[3] H. Kopfermann and R. Ladenburg, Ann. Physik 78, 659 (1926).

[4] I. I. Sobel'man, Vvedenie v teoriyu atomnykh spektrov (Introduction to the Theory of Atomic Spectra), Fizmatgiz, 1963.

1) A similar phenomenon observed in a constant electric field is reported in [3].

COLLECTIVE EFFECTS IN VIBRON SPECTRA OF MOLECULAR CRYSTALS

V. L. Broude, E. I. Rashba, and E. F. Sheka
Physics Institute, Ukrainian Academy of Sciences
Submitted 30 March 1966
ZhETF Pis'ma 3, No. 11, 429-434, 1 June 1966

One of the authors has recently shown [1] that in the interpretation of the electron-vibrational (vibron) transitions in the absorption spectra of molecular crystals sight is lost of a very important circumstance. The point is that owing to the intermolecular resonance interaction, which is well known for purely electronic excitations, virtual decay processes become possible, wherein the electronic and vibrational excitations initially localized on a single site turn out to be separated. The decay processes should produce in the region of each vibron transition broad-band two-particle absorption in which the electronic and vibrational excitons are excited simultaneously. A branch of single-particle excitations can split