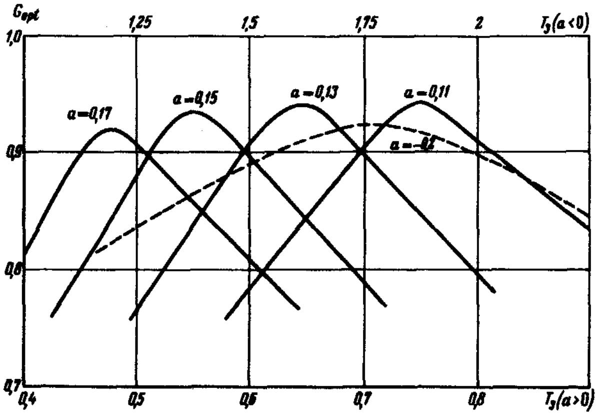

Fig. 2

oscillators with residual energy, the current again interacts with the field in the last active section ΔT_4. The length of the latter is chosen such as to optimize the conversion coefficient G.

The described model was analyzed by solving numerically, with a computer, the nonlinear equations of weakly-relativistic motion of charged oscillators in a piecewise homogeneous field of the type shown in Fig. 1. All the parameters of the problem were chosen such as to obtain the optimal value of G. The inhomogeneity of the magnetic field separating the active sections was specified in the form

$$\phi(T) = \frac{B(T)}{B_s} - 1 = a \sin^2\left(\frac{\pi T}{T_1}\right), \quad T = \frac{e}{m_0} E_\perp \frac{1}{v_{t_0}} \frac{z}{v_{\ell_0}},$$

where v_{t_0} and v_{ℓ_0} are the transverse and longitudinal velocities of the electron at the start of the section ΔT_1.

The calculation results are shown in Fig. 2 in the form of plots of $G(T_3)$ at the optimal values of all other parameters (E, ΔT_1, ΔT_2, ΔT_3, ΔT_4, T_1, T_2, etc.). $G_{opt} \to 1$ for both $a > 0$ and $a < 0$ (lowering of the field induction) in the optimal variants. This conclusion, on the one hand, demonstrates qualitatively the feasibility of coherent synchrotron radiation under natural conditions [3], and on the other hand is of interest for practical utilization (generation of microwaves with high efficiency).

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[2] V.P. Grigor'ev and A.P. Privezentsev, Izv. Vuzov Fizika 11, 154 (1968).
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NONLINEAR PHENOMENA IN THE PASSAGE OF BROAD-SPECTRUM LASER EMISSION THROUGH ATOMIC POTASSIUM VAPOR

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We observed a change in the angular distribution of the intensity of light with spectral components near the lines D_1 (λ = 7699 Å) and D_2 (λ = 7665 Å) of the principal doublet of potassium following the passage of an intense light beam through vapor of this metal.

The source of the intense radiation was a dye-solution (DS) laser with intensity $I_0 = 10^7$ W/cm^2 (Δt = 20 nsec, beam divergence angle $\alpha = 10^{-3} - 10^{-2}$ rad). The radiation was linearly polarized, and its spectrum was located in the 7600 - 8000 Å band that includes the potassium absorption D lines (transitions $4S_{1/2} - 4P_{1/2,\ 3/2}$). The STE-1 spectrograph (dispersion 13 Å/mm) was used to register the spectral and angular distributions of the laser emission passing through a cell with potassium vapor (ℓ = 6 cm).

It was observed that at radiation intensities $I_0 > 10^4$ W/cm^2 (beam diameter 5 mm) the laser beam divergence increased with increasing potassium vapor pressure near the absorption D lines. Figure 1 shows spectrograms of the radiation passing through the cell at T = 20°C (a) and at 240°C (b) (the vertical dimension of the spectrogram is proportional to the divergence angle of the transmitted beam, and the angle scale is indicated on the figure). A point at which the angular distribution does not change is located between the D lines. At this point, the refractive index is equal to unity and does not depend on the potassium vapor pressure in the cell. If the beam is limited by two diaphragms spaced 500 mm apart, the angular distribution changes appreciably when the temperature is raised to 300 - 330°C, namely, a "splitting" of the beam, corresponding to an axially-symmetrical spreading at a definite angle relative to the incident-beam direction (Fig. 1c), takes place in the long-wave region. This was confirmed by direct photography, at the focus of a lens with f = 100 mm, of the distribution of the intensity of the laser radiation passing through the beam, in the case when its spectrum consisted of one narrow band of width ~5 Å, overlapping the D_2 line (Fig. 2). Subsequent experiments have revealed that this effect has the following features: 1) There is no spreading of the beam at low laser intensities ($I_0 < 10^3$ W/cm^2). In the potassium vapor-pressure range 10^{-3} - 10^{-1} mm Hg, the angle of the beam spreading first increases with increasing I_0, and then drops to zero with the absorption line saturates. 2) The spread increases when the radiation wavelength approaches the wavelengths of the D lines, and depends strongly on the presence of wavelengths resonant to one of the D lines in the laser spectrum. Thus, if the laser spectrum consists of two bands of width ~5 Å spaced ~100 Å apart and one of the bands overlaps the D_2 line, a distinct spreading is observed even in the second band (Fig. 1c). In the absence of a resonant overlap, there is no such spreading in either band (Fig. 1e). The magnitude of the spread remains practically unchanged on going over from linear to elliptic polarization of the laser beam. 3) If the laser beam is sufficiently homogeneous in cross section and has a relatively large diameter (5 mm) and high intensity ($I_0 \sim 10^7$ W/cm^2), there is practically no spreading of the beam (Fig. 1f, T = 320°C). On the other hand, if the upper (or lower) half of the incident beam is covered under these conditions by an opaque screen, then an upward (Fig. 1f) or downward (Fig. 1g) spreading of the beam passing through the cell is observed. If the central part of the beam is blocked by a horizontal strip 1 mm wide, the spreading is directed both downward and upward (Fig. 1h).

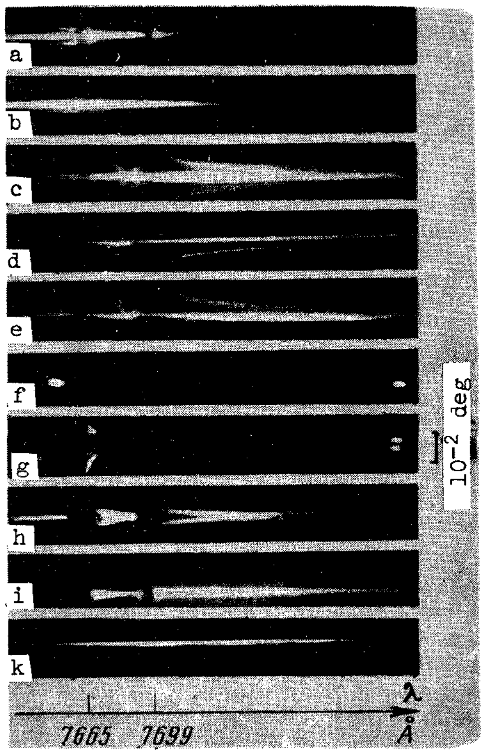

Fig. 1

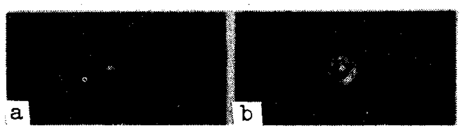

Fig. 2. Intensity distribution, at the focus of a lens with f = 100 mm, of laser radiation passing through potassium vapor: a - T = 20°C, b - T = 310°C.

To elucidate the role of the "bare" radiation, the experimental setup was modified somewhat. The diaphragm-limited laser beam was split by passing through a substrate inclined at a small angle. One side of the substrate was coated with a dielectric having a reflection coefficient of 50%. After bringing the two beams together with a lens of f = 550 mm, two beams propagated in the cell with an intensity ratio $I_1(0):I$ = 1:50. The angle between the beams could be rotated in the range $\theta_1 = 10^{-3} - 10^{-2}$ rad by rotating the substrate. No significant change of the effect occurred in the long-wave region, but at certain short wavelengths the weak beam is intensified and an additional beam appears at an angle $\theta_2 = -\theta_1$ in the plane of the incident beams (Fig. 1i, T = 250°C). This effect depends strongly on the intensity of the incident radiation I_0 and is observed at $I_0 = (0.3 - 1) \times 10^7$ W/cm^2 in the temperature range 200 - 270°C. The region of intensified wavelengths moves away from the absorption line with increasing potassium pressure or with decreasing θ_1, and expands with increasing I_0. The maximum gain under our conditions is ~10, and the intensity of the additional beam $I_2(\ell)$ practically coincides with the intensity of the enhanced weak beam $I_1(\ell)$ (Fig. 1k). The maximum gain depends little on the vapor pressure and remains practically unchanged on going from linear to elliptic polarization of the laser beam. By placing a second cell with potassium vapor (T = 330°C, ℓ = 2 cm) in the path of the laser beam, prior to its splitting, we have established that the effect observed in the short-wave region remains unchanged or even increases slightly when the components resonant to the D lines are "eliminated" from the spectrum of the incident beam. The spread of the beam in the long wave region, on the other hand, decreases sharply.

We assume that the observed spread of the beam is connected with the change of the refractive index of the potassium vapor as a result of the absorption of resonant photons and as a result that the non-uniform distribution of the intensity over the cross section of the beam produces a lens that scatters the non-resonant part of the radiation. In the particular case when the refractive index of the medium varies linearly along the beam radius, the lens turns into a conical prism, corresponding to the spread of the beam at definite angles. It was verified that the sign of the equivalent lens is negative in the long-wave region, and its maximal focal length is of the order of 100 mm. The second effect - the enhancement of the weak beam and the appearance of the additional beam in the short-wave regions of the D lines - is connected, in our opinion, with stimulated four-photon scattering [1]. If we assume that the stimulated four-photon scattering in each spectral component of the beam occurs independently of the presence of the other components, then the condition for the synchronism of the scattering is satisfied in the short-wave side of the absorption line for definite angles θ_1^m. For these angles, neglecting the attenuation of the strong beam, (i.e., far from the absorption line), the change of the intensities of the weak and additional beam $I_1(\omega)$ and $I_2(\omega)$ is given by the formulas

$$I_1(\omega, \ell) = I_1(0)\,[\mathrm{ch}\, g\ell/2]^2 \exp[-k(\omega)\ell],$$

$$I_2(\omega, \ell) = I_1(0)\,[\mathrm{sh}\, g\ell/2]^2 \exp[-k(\omega)\ell],$$

$$g = k(\omega)\, d^2 E_\omega^2\, \tau \hbar^{-2} (\omega - \omega_0)^{-1} [1 - \exp(-t/\tau)], \quad \theta_1^m = \sqrt{cg/\omega}.$$

Here $k(\omega)$ is the coefficient of linear absorption in the case of infinitesimally low intensities, τ is the lifetime of the excited state, d and ω_0 are the dipole moment and the frequency of the transition, E_ω is the amplitude of the harmonic of the strong beam, $\hbar$ is Planck's constant divided by 2π, and c is the speed of light. Estimates obtained with these formulas are in satisfactory agreement with the experimental data.

It is our pleasant duty to express deep gratitude to N.N. Kostin for very useful discussion of the results.

[1] R.L. Carman, R.Y. Chiao, and P.L. Kelley, Phys. Rev. Lett. 17, 1281 (1966).

E R R A T U M

In the article by A.M. Bonch-Bruevich et al., Vol. 11, No. 9, p. 291, the letter sequence in Fig. 1 reads downward, but should read upward. In the same figure, on the right side, read 10^{-2} rad in place of 10^{-2} deg.