The extraordinary nature of magnetic rotation of the polarization plane of monochromatic radiation inside the spectral line absorption contour

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The magnetic rotation of the polarization plane of a highly monochromatic radiation inside a Doppler-broadened absorption-line contour, $3S_{1/2}(F=2) - 3P_{3/2}$, of sodium atoms has been observed experimentally. This magnetic rotation differs qualitatively from the Macaluso-Corbino effect.

In this letter we report an experimental study of the rotation of the polarization plane of a monochromatic radiation with $\lambda \approx 589$ nm in a beam of sodium atoms in the transition $3S_{1/2}(F=2) - 3P_{3/2}$ in weak magnetic fields (on the order of the Earth's magnetic field). The angle of rotation was measured in longitudinal magnetic fields of strength in the range from 0 to ± 5 Oe for a radiation with a spectral width $\Delta\nu \cong 1$ MHz and intensity I from 0.01 to 100 mW/cm^2. The experimental arrangement is shown in Fig. 1. The radiation is aimed at a beam of atoms (A) through a window (O_1) of the vacuum chamber and polarizer (P_1), which establishes the polarization plane of the wave along the z axis. The degree of polarization (the ratio I_z/I_y) is no less than 10^4. At the point where the beam of light crossed the beam of atoms the components of the Earth's magnetic field were $H_{x3} \cong 0.49$ Oe, $H_{y3} \cong 0.27$ Oe, and $H_{z3} \cong 0.31$ Oe. The use of two Helmholtz coils (H) allowed us to cancel the H_{y3} component and to vary the H_x component.

The state of polarization of the radiation transmitted through a beam of atoms was analyzed by making use of a second polarizer (P_2). The radiation power was recorded by a photodetector (Ph). The optical thickness of the beam of atoms, κl, at the absorption maximum of the transition was on the order of unity and its nonuni-

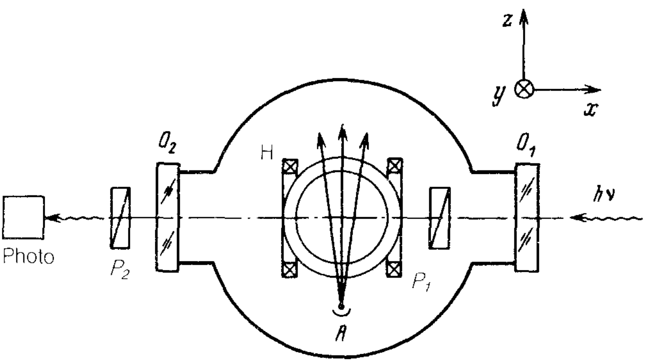

FIG. 1. Experimental arrangement.

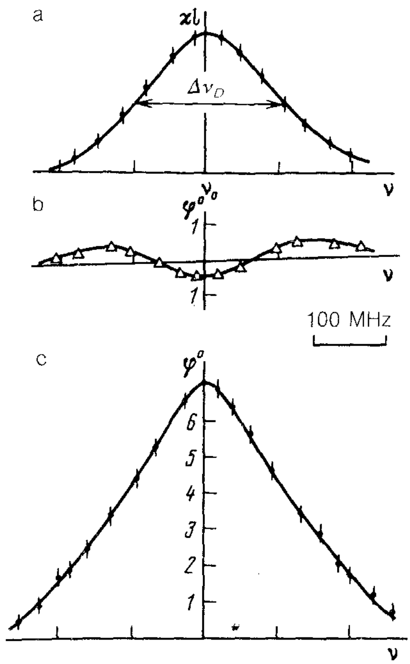

FIG. 2. (a) Absorption contour of a working transition; (b) the $\varphi(\nu)$ curve for $I \simeq 0.5$ mW/cm^2, $\kappa l \approx 2$, $H_x \simeq 1$ Oe; (c) the $\varphi(\nu)$ curve for $I \simeq 20$ mW/cm^2, $\kappa l \approx 1.1$, $H_x \simeq 1$ Oe. The values of κl are given for the center of the transition.

form (Doppler) width was $\Delta\nu_D \approx 200$ MHz. The light beam crossed the beam of atoms at a distance of 5 cm. However, the length of the luminescence region, which is determined by the spectral radiation width, was only 5 mm.

The spectral dependences of the rotation angle φ of the polarization plane were

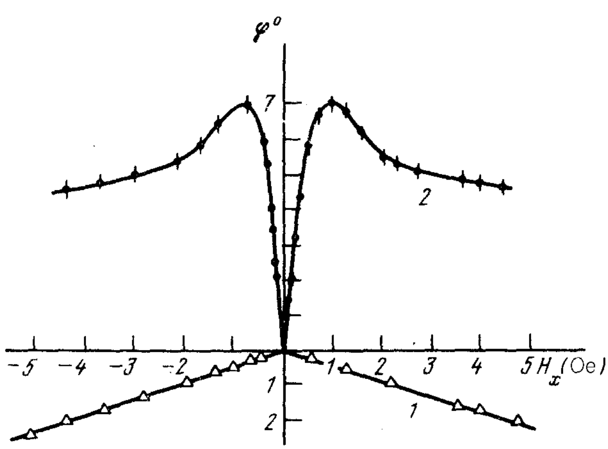

FIG. 3. The plot of φ vs H_x. The radiation frequency $\nu = \nu_0$. 1—$I \simeq 0.01$ mW/cm^2, $\kappa l \approx 1.1$; 2—$I \simeq 30$ mW/cm^2, $\kappa l \approx 1.08$ (the clockwise rotation is assumed to be the positive rotation direction when viewing in the same direction as the magnetic field).

obtained experimentally for various radiation intensities (Fig. 2). At $I \ll I_{sat}$ ($I_{sat} \cong 40$ mW/cm^2 is the saturation rate) the shape of the $\varphi(\nu)$ curve is typically that of a Faraday rotation[1–5] (Fig. 2b). The rotation angle is positive on the wings and negative at the center of the absorption line. The rotation changes appreciably as a result of increasing the radiation power to the transition saturation rate (Fig. 2c). The value of φ, which increased to 7° in a field $H_x \cong 1$ Oe, was positive over the entire variation range of ν.

The angle of rotation of the polarization plane is plotted in Fig. 3 as a function of the intensity of the longitudinal magnetic field H_x for $I \cong 30$ mW/cm^2. Also plotted, for comparison, in this figure is the $\varphi(H_x)$ curve for the saturation rates $I \ll I_{sat}$. As can be seen from Fig. 3, not only the sign and the magnitude of the effect are different but also the nature (the presence of a peak) of the $\varphi(H_x)$ curve itself.

We have thus determined experimentally that the rotation of the polarization plane of a highly monochromatic radiation which passes through a resonant medium in a magnetic field changes considerably upon transition from low intensities ($I \ll I_{sat}$) to high intensities ($I \sim I_{sat}$).

The effect observed experimentally is attributable, in our view, to the burnt-out Bennett hole in a non-uniformly broadened working-transition absorption contour and to the formation of nonuniformities in the refractive index associated with this hole.

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