Observation of a "magnetic" rotation of the speckle of light passed through an optical fiber

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(Submitted 15 April 1994)
Pis'ma Zh. Eksp. Teor. Fiz. **59**, No. 11, 734–736 (10 June 1994)

This rotation was observed as light propagated through a few-mode optical fiber in an external magnetic field. The speckle was observed in linearly polarized light with the same azimuthal angle as at the entrance to the fiber. The rotation angle corresponds in order of magnitude and also in sign to the angle of Faraday rotation of the polarization plane.

As linearly polarized light propagates through an optical medium in an external magnetic field, one observes a rotation of the polarization plane. This rotation results from changes induced by the magnetic field in the refractive indices for light with left- and right-hand circular polarizations. One does not observe any significant change in the trajectory of the light. As light propagates through an optical fiber, applying a magnetic field and changing the helical shape of the fiber have the same result: a rotation of the polarization plane of linearly polarized light. Guided by this analogy, we have attempted[1] to determine the effect of a magnetic field on light propagation in an optical fiber, specifically, the effect of the field on the rotation of the speckle of circularly polarized light which has passed through a multimode fiber, upon a change in the sign of the circular polarization (the optical Magnus effect.[2]). The results of numerical calculations have shown that an external magnetic field alters the magnitude of the rotation of the speckle, but to a surprisingly small extent: In a quartz fiber 1 m long, with a ≈300° Magnus effect, a change of ≈10° in the magnitude of the effect can be achieved by applying a magnetic field $\approx 10^6$ G. These calculations were carried out without consideration of meridional rays or, in terms of modes, without consideration of "hedgehog" and "steering-wheel" modes.

It was shown just recently[3] that as light propagates through an optical fiber a magnetic field can cause a significant rotation of the speckle if the modes corresponding to meridional rays are taken into account. To observe this effect, one can illuminate the entrance to the fiber with linearly polarized light; the linearly polarized component in the light which has passed through the fiber with the same azimuthal angle as at the entrance is singled out. In this letter we are reporting an experimental observation of this effect.

The experimental layout is shown in Fig. 1. In accordance with Ref. 3, polarizers which transmit the same linearly polarized component are placed at the entrance and exit of a fiber, which is at the axis of a coil with a magnetic field. We use the beam from a He–Ne laser with a wavelength $\lambda = 0.63$ μm. The speckle is observed on a semitransparent screen and can be photographed on this screen. The strength of the magnetic field is found from the angle ($\psi^+ = +3.5°$, $\psi^- = -3.5°$) through which the polarization plane of the light transmitted through a quartz rod $l = 20$ cm long is rotated. The average field $H = \varphi/(Vl)$ over the length of the coil, $L = 21.5$ cm, is ≈500 G. We use the value[4]

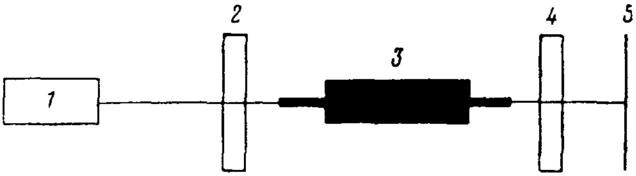

FIG. 1. Optical layout of the experimental apparatus. *1*—He–Ne laser, $\lambda=0.63$ μm; *2*—polarizer; *3*—fiber in a magnetic field; *4*—analyzer; *5*—screen.

$V=1.4\times10^{-2}$ min/(G·cm) for the Verdet constant of quartz. The light passes through a quartz fiber with a core diameter $2\rho=9.5$ μm and a difference $\Delta n=0.004$ between the refractive indices of the core and the cladding. Up to 16 modes (including a polarization degree of freedom) can be excited at the wavelength 0.63 μm in such a fiber.

The effect is seen as a rotation of the speckle when a magnetic field is turned on. When the direction of the field is changed, the speckle rotates in the opposite direction. The direction of the rotation is the same as that of the Faraday rotation of a polarization plane. A rotation of the pattern through an angle on the order of 2° can be seen visually, and quite clearly. To intensify the effect, we then used a fiber 17 m long, which was passed through the coil seven times, so that the length of the fiber in the magnetic field was ≈1.4 m.

Figure 2 shows photographs of the speckle for positive and negative polarities of the magnetic field. It can be seen from the photographs that the magnitude of the rotation is about $\varphi^+-\varphi^-\approx15°$. The magnitude of the Faraday rotation over this distance, on the other hand, is $\psi^+-\psi^-\approx40°$. These values agree in order of magnitude and—a particularly important point—in sign.

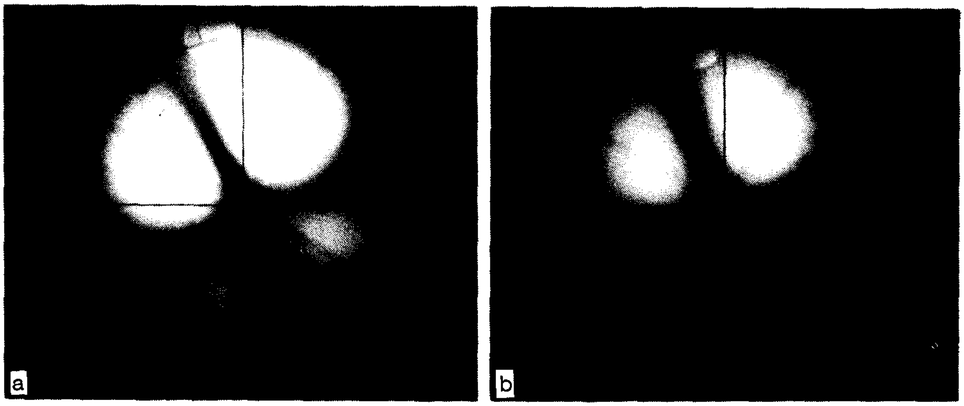

FIG. 2. Photographs of the speckle on a semitransparent screen. The observation direction is opposite the light propagation direction. a—The field direction is the same as the light propagation direction; b—the field direction is opposite the light propagation direction.

We wish to stress that the effect is quite strong. Indeed, the fiber material (quartz) which we used has a very small Verdet constant at the wavelength $\lambda = 0.63\ \mu\mathrm{m}$. (We used the first fiber we came across.) By moving into the short-wave part of the spectrum and by using other materials, one could intensify the effect by at least two orders of magnitude.

In summary, it can be asserted that we have observed a rotation of speckle caused by a magnetic field. The sign of the effect is that which is predicted. Quantitative estimates of the observed magnitude of the effect agree with the theory.[3]

This study had partial support from the Soros Foundation and the Russian Basic Research Foundation (Grant 93-02-15546).

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[2] A. V. Dooghin *et al.*, Phys. Rev. A **45**, 8204 (1992).

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[4] G. W. C. Kaye and T. H. Laby, *Tables of Physical and Chemical Constants and Some Mathematical Functions* (Longmans, Dorchester, England, 1948).

Translated by D. Parsons