Observation of parity nonconservation in atomic transitions

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Parity nonconservation in atomic transitions has been observed. The rotation of the plane of polarization of light was measured on the components of the hyperfine splitting of the 6477 Å line of bismuth.

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Search for effects of parity conservation in atomic transitions was undertaken in our institute in 1974, prompted by a discussion with I. B. Khriplovich. The first to call attention to the possible existence of such effects was Ya. B. Zel'dovich in 1959,[1] and these effects have since been discussed many times.[2-6] Similar studies with a different procedure are being carried out at Oxford and in Seattle.[7-12]

Figure 1 shows a block diagram of our setup for the measurement of the plane of polarization of light passing through bismuth vapor. The measurements were performed on the 6477 Å line corresponding to the magnetic-dipole transition. The light source was a model-375 Spectra Physics dye laser. An element was introduced into the laser to permit operation in the single-frequency lasing regime and scanning the laser wavelength at a frequency of 1 kHz. The radiation power in the single-frequency regime was 15 mW.

Light modulated at the emission frequency passed through a polarizer, a cell with bismuth vapor, and an analyzer. The polarizer and the analyzer were situated inside the vacuum volume of the cell. To protect them against sputtering and to maintain a

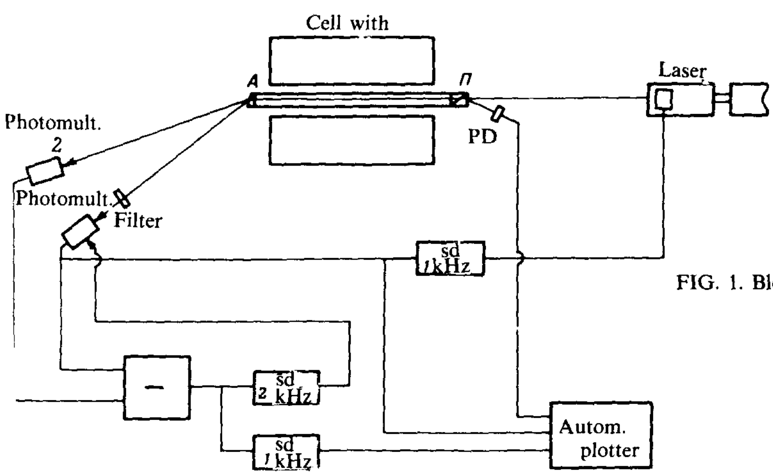

FIG. 1. Block diagram of setup.

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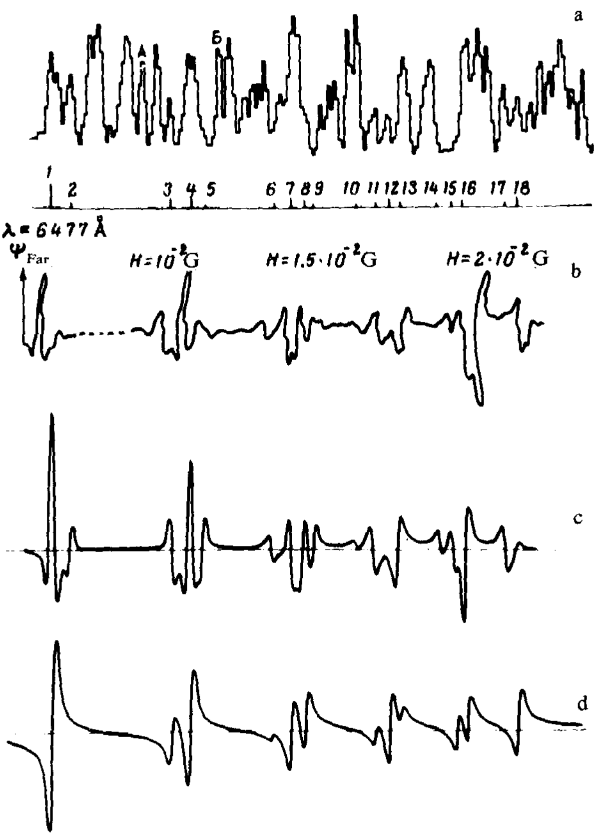

FIG. 2. a) Absorption spectrum of bismuth vapor; b) experimentally measured Faraday rotation on the hyperfine structure line; c) theoretical curve for the Faraday rotation[13]; d) rotation of plane of polarization calculated in accordance with the Weinberg-Salam model.

constant vapor pressure, helium was used as a buffer gas. The axes of the polarizer and the analyzer made an angle θ_0. The mounting for the polarizer was designed to be able to vary this angle in the course of operation.

Two light beams with orthogonal polarizations emerge from the analyzer. The angle between the analyzer axis and the light polarization is $\theta=\theta_0+\psi$, where ψ is the angle of rotation of the plane of polarization by the bismuth vapor. The expected value was $\psi\sim10^{-7}$ rad, and θ_0 was chosen to be $\sim10^{-3}$ rad. Thus, the intensity of the light in one of the channels is

$$I \approx I_0\theta^2 \approx I_0\theta_0^2(1+2\psi/\theta_0),$$

and in the other channel it is $I_0\cos^2\theta\approx I_0$. Since the expected effect if proportional to the real part of the refractive index, in the course of scanning of the laser emission wavelength relative to the absorption line center, the light intensity in the first channel should contain the first harmonic of the scanning frequency.

The two signals from the photodetectors are fed to the subtraction circuit and are detected synchronously with respect to the first harmonic of the scanning frequency To maintain equality of the levels of the subtracted signals, feedback based on the second harmonic of the scanning frequency was used.

TABLE I.

Line	$F \to F'$	$\psi_{exp} \cdot 10^8$	$\psi_{theor} \cdot 10^8$
1	6 – 7	–11,8 ± 5,5	– 12.2
3	6 – 6	–4,7 ± 2.2	– 3,1
7	5 – 5	–3,6 ± 4,0	– 4,2
10	6 – 4	0,0 ± 1,8	+ 0,1
12	4 – 4	–11,3 ± 3.2	–4,2
A	–	+11,9 ± 11,9	+0,1
B	–	+6,6 ± 2,8	+0,1

1)The calculated curves shown in Fig. 2 were kindly provided by V. I. Novikov and O. P. Sushkov.

The feedback with respect to the first harmonic in the signal of the channel with the higher intensity of the light was used to maintain the correct position of the scanner relative to the bismuth-vapor absorption line.

The cell with the bismuth vapor is located inside a double magnetic screen. The average magnetic field along the light beam axis is 2×10^{-5} G. The cell can operate at temperatures up to 1500 K. At these temperatures, the partial pressures of the atomic and molecular bismuth vapor are approximately equal and the vibrational-rotational spectrum of the molecule is superimposed on the absorption line of the hyperfine structure of the investigated atomic line.

Figure 2a shows the spectrum of the absorption line of the bismuth vapor. The ntervals in the histogram correspond to the distance between the neighboring longitulinal modes of the laser resonator and is equal 400 MHz. Measurements of the Faralay rotation of the plane of polarization of the light, shown in Fig. 2b, and their :omparison with the theoretical calculations[13] (see Fig. 2c)[1)] have made it possible to dentify uniquely the hyperfine structure of the 6477 Å line of atomic bismuth. The esults of these measurements agree also with the results obtained in Oxford (P. andars, private communication).

Measurements of the rotation of the plane of polarization were carried out on the nes 1, 3, 7, 10, 12, A, and B. The results of the measurements are shown in Table I. 'he measurements were made at a total bismuth-vapor pressure 24 Torr and an effecve cell length on the order of 30 cm. The scanning amplitude corresponded to one or vo Doppler widths. The values of the rotation angle given in the table were defined as $\psi/\partial\omega\Delta\omega$, where $\Delta\omega > 0$ is the scanning amplitude. We used the standard optics defi-

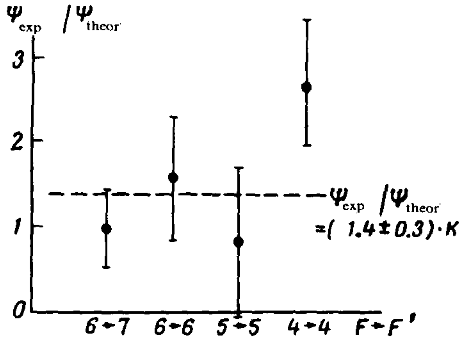

FIG. 3. Ratio of the experimentally measured rotational angles of the plane of polarization to those calculated by the Weinberg-Salam model.

nition, whereby positive rotation is clockwise as seen by an observer looking at the source. The theoretical values given in the table for the rotation angle of the plane of polarization of the light, for the Weinberg model, are based on the results of [14].

As seen from the table, rotation of the polarization plane is observed for all the working lines 1, 3, 7, and 12. The average rotation angle for these lines is $\bar{\psi}_{exp} = (-6.7 \pm 1.6) \times 10^{-8}$ rad, whereas the average rotation angle on the control lines 10, A, and B is $(+2.1 \pm 1.5) \times 10^{-8}$ rad. Figure 3 shows the ratio of the experimentally measured angle of rotation of the plane of polarization of the light to the value predicted for the Weinberg–Salam model. The mean value of this ratio is

$$\overline{\psi_{exp} / \psi_{W-S}} = (+ 1.4 \pm 0,3)\ k\ .$$

The factor k was introduced because of inexact knowledge of the bismuth vapor, and also because of some uncertainty in the relative positions of the resonator modes and the absorption-line contours. According to our estimates, this factor lies in the interval from 0.5 to 1.5.

Figure 4 shows a comparison of the results of the present work at $k=1$ with the

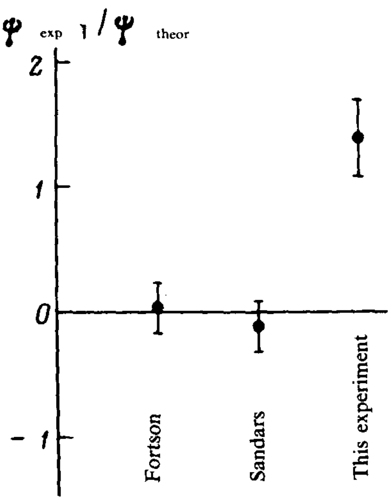

FIG. 4. Comparison of the results of the present paper (a $k=1$) with the results of [11,12].

results obtained in Seattle and Oxford. The results testify to the existence of parity nonconservation in atomic transitions and does not contradict the predictions of the Weinberg–Salam model.

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