M1-E2 interference in the Zeeman spectra of Bi I

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The $6s^26p^3$ ground configuration of bismuth gives rise to five levels $^4S_{3/2}$, $^2P_{3/2,1/2}$ and $^2D_{5/2,3/2}$. We report studies [1] of the interference effect in mixed-type forbidden lines: 461.5nm ($^2P_{1/2} \rightarrow ^4S_{3/2}$), 647.6nm ($^2D_{5/2} \rightarrow ^4S_{3/2}$) and 875.5nm ($^2D_{3/2} \rightarrow ^4S_{3/2}$) of Bi I. In the past, the mixed M1+E2 type lines 647.6nm and 875.5nm in bismuth were intensely exploited in PNC (atomic parity nonconservation) experiments [2]. In order to extract the electroweak quantity of interest, the 'weak charge', from the PNC experiment, atomic structure calculations of comparable precision are necessary. The measurement of the ratio $D = A^{E2}/(A^{E2} + A^{M1})$ of the electric-quadrupole (E2) and magnetic-dipol (M1) transition probabilities in mixed forbidden lines can provide stringent test of theoretical wave-function calculations; accurate knowledge of this quantity is essential for existing and future measurements of parity nonconserving optical rotation.

In the Zeeman effect of mixed multipole lines, the intensities of patterns are not a simple sum of two contributions for M1 and E2 radiations taken in proportion to their transition probabilities, but should be modified by an interference term. The spontaneous transition probability for a single photon emission in the presence of the magnetic field can be expressed, according to

$$a_{ab} = (1-D)a_{ab}^{M1} + Da_{ab}^{E2} \pm 2\sqrt{D(1-D)}a_{ab}^{M1-E2}, \tag{1}$$

where D is percentage admixture of E2 radiation, a_{ab}^{M1} and a_{ab}^{E2} are pure magnetic-dipol and electric-quadrupole components, respectively, and the cross term a_{ab}^{M1-E2} describes the interference effect. The interference effect in emission spectra causes the difference between the intensities of $\Delta M{=}\pm 1$ Zeeman patterns observed in longitudinal and transverse directions of observation. This phenomenon, in a series of experiments, was used for precise determination of the electric-quadrupole admixture D in forbidden lines.

A special computer program considering the M1-E2 interference was design to obtain the predicted contour of the Zeeman structure of the line. By variation of free parameters, describing the line shape and electric-quadrupole admixtures, the calculated profiles were fitted into the experimental spectra recorded by CCD detector. The E2 admixtures found are: $(7.84 \pm 0.14)\%$, $(17.5 \pm 0.4)\%$ and $(0.70 \pm 0.11)\%$ for 461.5nm, 647.6nm and 875.5nm lines, respectively. Our results were compared with recent theories and other experiments.

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