Notes on PNC in DR
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G. F. GRIBAKIN AND M. G. KOZLOV

1. Introduction

In our paper Gribakin et al. (2005) on PNC in DR we derived several expressions for PNC cross section and for PNC strength of the resonance, which can be used for the analysis of the general situation with PNC in DR. Here is one of the questions which can be addressed: *Is there any additional enhancement for weak resonances similar to* $\frac{E1}{M1}$ *enhancement in optics?*

The answer to this question can be given with the help of Eqs. (37, 38) from Gribakin et al. (2005):

$$S_P = \frac{\pi^2}{2p^2} \frac{\Gamma_P^{(r)}\Gamma_P^{(a)}}{\Gamma_P}, \tag{1}$$

$$S_P^{\rm PNC} = -\frac{\pi^2}{p^2} \frac{h^{\rm PNC}\sqrt{\Gamma_P^{(a)}\Gamma_{-P}^{(a)}}\,\frac{\Gamma_P^{(r)}}{\Gamma_P}}{\left[\Delta^2 + \frac{1}{4}(\Gamma_P+\Gamma_{-P})^2\right]} \left[\Delta\cos\delta_{sp} + \tfrac{1}{2}(\Gamma_P+\Gamma_{-P})\sin\delta_{sp}\right], \tag{2}$$

where P is the parity of the resonant state and $\Delta = E_P - E_{-P}$. Note that here we assume that the resonances of the opposite parity do not overlap. Because of that, here we do not sum the PNC effect over two resonances of the opposite parity as it was done in the paper.

Let us rewrite (2) for $|\Delta| \gg \frac{1}{2}(\Gamma_P + \Gamma_{-P})$:

$$S_P^{\rm PNC} \approx -\frac{\pi^2}{p^2}\sqrt{\Gamma_P^{(a)}\Gamma_{-P}^{(a)}}\,\frac{\Gamma_P^{(r)}}{\Gamma_P}\frac{h^{\rm PNC}}{\Delta}\cos\delta_{sp} \tag{3}$$

$$= -2S_P\sqrt{\frac{\Gamma_{-P}^{(a)}}{\Gamma_P^{(a)}}}\,\frac{h^{\rm PNC}}{\Delta}\cos\delta_{sp}. \tag{4}$$

We can define PNC rate as a ratio

$$\mathcal{P} \equiv \frac{S_P^{\rm PNC}}{S_P} = -2\sqrt{\frac{\Gamma_{-P}^{(a)}}{\Gamma_P^{(a)}}}\,\frac{h^{\rm PNC}}{\Delta}\cos\delta_{sp}. \tag{5}$$

Alternatively, we can rewrite Eq. (39) from the paper in a form:

$$I_{\rm av} > \frac{1}{2}\frac{S_P}{(S_P^{\rm PNC})^2} = \frac{1}{2S_P}\left(\frac{\Gamma_P^{(a)}}{\Gamma_{-P}^{(a)}}\right)\left(\frac{\Delta}{2h^{\rm PNC}\cos\delta_{sp}}\right)^2$$
$$= \frac{1}{4\pi^2}\frac{\Gamma_P}{\Gamma_P^{(r)}\Gamma_{-P}^{(a)}}\left(\frac{p\Delta}{h^{\rm PNC}\cos\delta_{sp}}\right)^2. \tag{6}$$

Eq. (5) shows that PNC rate for the weak resonance P is enhanced by the factor $\sqrt{\frac{\Gamma_{-P}^{(a)}}{\Gamma_P^{(a)}}}$, which is similar to the factor $\frac{E1}{M1}$ in optics. On the other hand, statistical sensitivity for PNC effect is given by Eq. (6), where this factor is absent.

Eq. (6) shows that for the PNC experiment the optimal case is when $\Gamma_{-P}^{(a)}$ is large and $\Gamma_P \approx \Gamma_P^{(r)}$. The latter condition, as we saw in the paper, is automatically met for large Z. Then, the former condition simply means that mixed resonance of the opposite parity is strong.

Let us compare this picture with optics, where one looks for the rotation of the plane of polarization of light traveling through atomic gas. If L is the length of the cavity, the phase of the light exiting the cavity is

$$\phi_\pm = \frac{L\omega}{c}\, n_\pm, \tag{7}$$

where $\pm$ corresponds to the circular polarization. The plane of polarization of the linear polarized light will rotate by the angle

$$\chi = \tfrac{1}{2}(\phi_+ - \phi_-) = \frac{L\omega}{2c}\,(n_+ - n_-). \tag{8}$$

The optimal signal to noise ratio is achieved for $L = L_0$, where absorption length $L_0 = \frac{c}{(n_0-1)\omega}$. If we substitute L_0 in (8), we get an alternative expression in terms of the PNC rate $\mathcal{P} = \frac{n_+-n_-}{n_0-1}$:

$$\chi = \mathcal{P}\frac{L}{L_0}. \tag{9}$$

If we can take $L = L_0$, then we use Eq. (9) and get $\chi = \mathcal{P}$. If we have fixed length L, then we use (8), where $\chi \propto n_+ - n_-$. This regime is similar to the DR case, given by (6), where parameters of the target are fixed. In this case, there is no particular reason to look for the weak resonances.

References

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QUB, PNPI
E-mail address: mgk@MF1309.spb.edu