$\mathcal{P},\mathcal{T}$-odd Faraday effect in heavy neutral atoms

Chubukov D.V.[a,b], Skripnikov L.V.[a,b], Labzowsky L.N.[a,b]
[a] *St. Petersburg State University, Oulianovskaya 3, 198504, St. Petersburg, Petrodvorets, Russia*
[b] *National Research Centre "Kurchatov Institute" B.P. Konstantinov Petersburg Nuclear Physics Institute, 188300,Gatchina, Leningrad district, Russia*

Theoretical study of discrete symmetry (e.g. spatial parity $\mathcal{P}$ and time-reversal parity $\mathcal{T}$) violation effects in atomic systems plays an important role in developing theories and models of fundamental interaction physics. The existence of the $\mathcal{T}$-noninvariant interactions in the nature is one of the most important fundamental problems which has to be solved by the modern physics. The $\mathcal{CP}$-violation ($\mathcal{C}$ - charge conjugation) discovered in [1] in the exotic reaction with K-mesons means, according to the $\mathcal{CPT}$-theorem that such interactions in principle exist. However a search for the more universal $\mathcal{T}$-violating interactions has been continued from 1950 up to now without success.

This contribution is devoted to the proposal to observe the $\mathcal{P},\mathcal{T}$-odd Faraday effect, i.e. rotation of the polarization plane of the light propagating through a medium in presence of an electric field in the intra-cavity absorption spectroscopy (ICAS) experiments [2]. The $\mathcal{P},\mathcal{T}$-odd Faraday effect may be caused by $\mathcal{CP}$ violation within the Standard Model. It is demonstrated that the observation of the $\mathcal{P},\mathcal{T}$-odd Faraday effect may compete with the observation of the $\mathcal{P},\mathcal{T}$-odd electron spin rotation in an external electric field which provides now the most stringent bounds for the $\mathcal{P},\mathcal{T}$-odd effects in atomic physics. We revisit the $\mathcal{P}$,$\mathcal{T}$-odd Faraday effect in view of a serious progress in the ICAS made during the last few decades [3]-[5]. For the Faraday rotation (ordinary or $\mathcal{P}$,$\mathcal{T}$-odd) the maximum of the effect coincides with the maximum of absorption what prevents usually the work off-line and employment of the large optical path length. However our proposal is based on working off-resonance using second Faraday rotation maximum existing both for the ordinary and $\mathcal{P}$,$\mathcal{T}$-odd Faraday effects. This would allow to employ very large optical path length (up to hundred kilometres) corresponding to the recent ICAS experiments and greatly enhance the $\mathcal{P}$,$\mathcal{T}$-odd Faraday rotation signal. Here we present the accurate calculations and a detailed analysis of the possible ICAS-type experiment. The calculations are performed for the heavy metal atoms Cs, Tl, Pb, Bi where the $\mathcal{P}$,$\mathcal{T}$-odd effects are most pronounced. The results of the calculations demonstrate that with that large optical path length the ICAS experiments will be able to fix the possible $\mathcal{P}$,$\mathcal{T}$-odd effects at the level several orders of magnitude lower than the other most advanced modern experiments.

[1] J.H. Christenson, J.W. Cronin, V.L. Fitch and R. Turlay, Phys. Rev. Lett. **13**, 138 (1964)
[2] D.V. Chubukov and L.N. Labzowsky, Phys. Rev. A **96**, 052105 (2017)
[3] L. Bougas, G.E. Katsoprinakis, W. von Klitzing and T.P. Rakitzis, Phys. Rev. A **89**, 052127 (2014)
[4] V.M. Baev, T. Latz and P.E. Toschek, Appl. Phys. B **69**, 171 (1999)
[5] M. Durand, J. Morville and D. Romanini, Phys. Rev. A **82**, 031803 (2010)