Spin-Dependent Electron Diffraction in the Two-Photon Kapitza-Dirac Effect

S Ahrens[1], Z F Liang[1], T Cadez[2], and B F Shen[1]

[1] *Department of Physics, Shanghai Normal University, Shanghai, China*
[2] *Center for Theoretical Physics of Complex Systems, Institute for Basic Science, Daejeon, South Korea*
Contact Email: ahrens@shnu.edu.cn

It is possible to observe electron diffraction in the optical grating of a standing light wave, which is formed from two counter-propagating laser beams [1]. This effect has been first proposed by Kapitza and Dirac and is therefore commonly referred to as the Kapitza-Dirac effect [2,3]. We demonstrate the possibility of spin-dependent electron diffraction in a two-photon interaction in the Kapitza-Dirac effect, for which only the observation of the emerging Bragg peak is necessary [4]. This allows us to choose parameters that are sufficiently suitable for considering an experimental implementation, as illustrated in Fig. 1. In our contribution, we will discuss the experimental parameters of our estimation. Note that *spin-dependent* means in our context that the electron dynamics (diffraction into the Bragg peak B) is depending on the initial electron spin state.

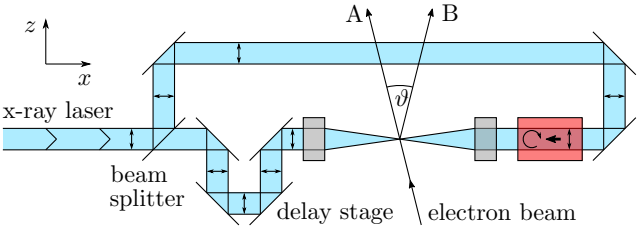

Figure 1: Illustration of a possible experimental setup for a spin-dependent Kapitza-Dirac effect by using intense X-ray laser beams. The diffraction probability of beam B depends on the initial spin state of the electrons in A

We also mention that the electron spin-dynamics in the field of two counter-propagating beams can be matched with the formula of Compton scattering, where the incoming and outgoing photon states are identified with the classical strong field counterparts in the context of the Furry picture [4]. This identification can be established by solving a quantized electron-photon system with old-fashioned perturbation theory [5]. We can therefore relate the electron spin dynamics with an analog process in Compton scattering, in which a discrepancy of the net amount of intrinsic angular momentum of the constituting particles before and after scattering remains an interesting question in the theoretical description [6].

References

[1] D L Freimund, K Aflatooni and H Batelaan, Nature **413**, 142 (2001)

[2] P L Kapitza and P A M Dirac, Math. Proc. Cambridge Philos. Soc. **29**, 297 (1933)

[3] H Batelaan, Rev. Mod. Phys. **79**, 929 (2007)

[4] S Ahrens, Z F Liang, T Cadez and B F Shen, Phys. Rev. A **102**, 033106 (2020)

[5] F Halzen and A D Martin, Quarks and Leptons (Wiley, New York, 1984)

[6] S Ahrens and C-P Sun, Phys. Rev. A **96**, 063407 (2017)