Atomic processes with twisted electron beams

V A Zaytsev[1], A Surzhykov[2,3], V G Serbo[4,5], V P Kosheleva[1], M E Groshev[1] and V M Shabaev[1]

[1]*Department of Physics, St. Petersburg State University, Universitetskaya naberezhnaya 7/9, 199034 St. Petersburg, Russia*
[2]*Physikalisch-Technische Bundesanstalt, D-38116 Braunschweig, Germany*
[3]*Technische Universität Braunschweig, D-38106 Braunschweig, Germany*
[4]*Novosibirsk State University, RUS–630090 Novosibirsk, Russia*
[5]*Sobolev Institute of Mathematics, RUS–630090 Novosibirsk, Russia*

Twisted (or vortex) electrons which have been experimentally realized less than a decade ago [1-3] currently attract great interest from both experimental and theoretical sides. In contrast to the conventional (plane-wave) electrons, these particles can carry a large value of the total angular momentum projection $\hbar m$ onto their propagation direction. Apart from being an additional degree of freedom, this projection enlarges the spin-induced magnetic moment approximately by a factor of m. Nowadays, the twisted electrons with $m \sim 1000$ can be routinely produced with existing experimental techniques [4]. The magnetic interaction with such electrons is enhanced by three orders of magnitude what makes these particles a powerful tool for the investigation of magnetic properties of materials [5] and various subtle magnetic effects [6].

Most investigations rely on the knowledge of the basic acts of interaction of the twisted electrons with ionic and atomic targets. Particular interest is related to heavy systems where relativistic and magnetic effects are strongly enhanced and, as a result, the role of the "twistedness" is expected to become the most pronounced. These systems require a fully-relativistic description with the nonperturbative treatment of the nucleus field. Here we present such descriptions of the fundamental scattering processes involving twisted electrons; namely, radiative recombination [7], elastic (Mott) scattering [8], and Bremsstrahlung.

[1] Verbeeck J *et al* 2010 *Nature (London)* **467** 301
[2] Uchida M and Tonomura A 2010 *Nature (London)* **464** 737
[3] McMorran B J *et al* 2011 *Science* **331** 192
[4] Mafakheri E *et al* 2017 *Appl. Phys. Lett.* **110** 093113
[5] Rusz J and Bhowmick S 2013 *Phys. Rev. Lett.* **111** 105504
[6] Ivanov I P and Karlovets D V 2013 *Phys. Rev. Lett.* **110** 264801
[7] Zaytsev V A, Serbo V G and Shabaev V M 2017 *Phys. Rev. A* **95** 012702
[8] Kosheleva V P, Zaytsev V A, Surzhykov A, Shabaev V M and Stöhlker Th 2018 *Phys. Rev. A* **98** 022706