Spin polarization by strong field ionization

August 16 2016

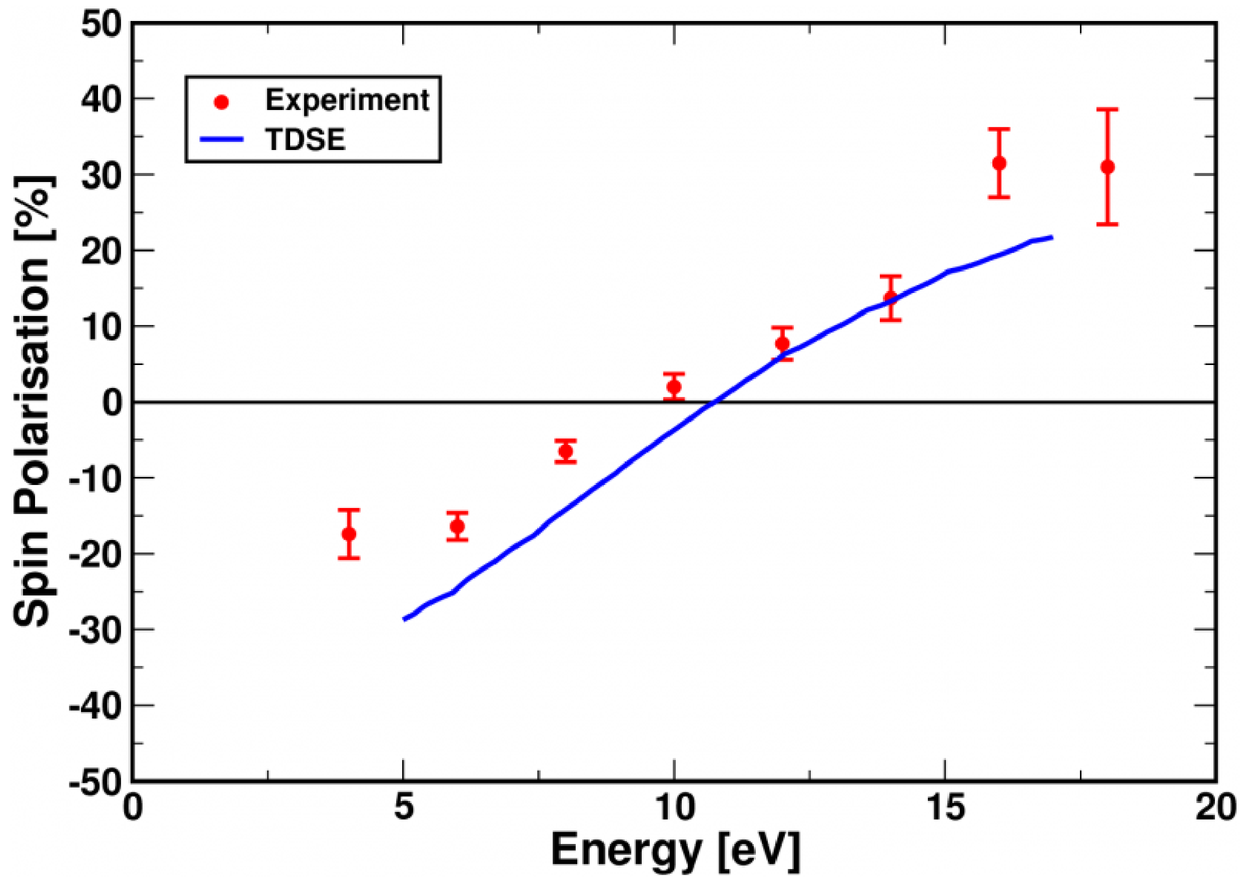

Fig. 1: Spin polarization measured as a function of electron energy. The blue curve is a theoretical prediction, while the red dots with error-bars show experimental results. The measurement was done for Xe atom. Credit: MBI

Strong field ionization has been studied for over half a century. Yet, the role of electron spin during this process has been largely overlooked.

Surprisingly, our joint experimental and theoretical study shows that a chance of detaching spin-up or spin-down electron from an atom can be very different.

As a fundamental property of the electron, the spin plays a decisive role in the electronic structure of matter, from molecules and atoms to solids, where it determines, for example, the magnetic properties of matter. Ultrashort pulses of electrons are unique tools for studying materials, both their structure and dynamics, opening a rich field of ultrafast diffraction imaging. Since electron spin is an essential variable in diffraction, ultrashort pulses of spin-polarized electrons would add a completely new dimension to this field. But where could one get such pulses?

One way is to use ionization in strong laser fields. This process naturally produces electrons in ultrashort bursts. The bursts last only a small fraction of the laser cycle when they are released from the confines of the binding potential. But would these electron bursts be spin-polarized? Surprisingly, until very recently, this question has never been asked.

This situation has now changed with the joint experimental and theoretical work of Alexander Hartung et al, inspired by the earlier theoretical prediction of I. Barth and O. Smirnova (Phys. Rev. A 88, 013401, 2013). Using the gas of Xe atoms, the authors present the first experimental detection of electron spin polarization created by strong-field ionization. The measured spin-polarization, shown in Fig.1, was found to be as high as 30%, changing its sign with the electron energy. This work opens the new dimension of spin to strong-field physics. It paves the way to the production of sub-femtosecond spin-polarized electron pulses with applications ranging from probing the magnetic properties of matter at ultrafast timescales to testing chiral molecular systems with sub-femtosecond temporal and sub-ångström spatial resolutions.

The paper also shows that spin polarization is important during laser-driven electron recollision with the parent ion, when such recollision is induced by the elliptical laser field. Since in the laser-driven electron collision with the parent ion the electron is fully controlled by the laser field, the dynamics can now be studied not only with attosecond temporal and angstrom spatial resolution, but also with spin sensitivity. This would allow chiral molecules to be probed with sub-femtosecond temporal resolution and sub-ångström spatial resolution. Finally, spin polarization of the ejected electron is firmly linked to the creation of the parent ion in an initially spin-polarized state. Spin-orbit coupling then leads to internal circular electron and spin currents.

More information: Alexander Hartung et al. Electron spin polarization in strong-field ionization of xenon atoms, *Nature Photonics* (2016). DOI: 10.1038/nphoton.2016.109

Provided by Forschungsverbund Berlin e.V. (FVB)