Publishable summary: UltrafastElectrons

FP7-MC- IRG, Grant agreement number 230399

Project final report

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http:www.mpq.mpg.de/uqo-en

The project objectives of this grant were to setup an experiment aimed at controlling laser-driven electron emission with unprecedented control in both space and time. Novel emitters as well as femtosecond-laser driven emission of electron from sharp field emitters was to be and has been investigated.

Within this project we have achieved the following scientific results:

- Observation of above-threshold-photoemission (ATP). M. Schenk, M. Krüger, P. Hommelhoff, Physical Review Letters 105, 257601 (2010)
- Observation of strong-field effects in ATP, published in the above-mentioned article
- Generation of gold tips with new and simple method. M. Eisele, M. Krüger, M. Schenk, A. Ziegler, P. Hommelhoff, Rev. Sci. Instr. 82, 026101 (2011)
- Demonstration of attosecond physics at a metal nanotip. M. Krüger, M. Schenk, P. Hommelhoff, Attosecond control of electrons emitted from a nanoscale metal tip, Nature 475, 78 (2011).
- Observation and theoretical understanding of electron rescattering at a metal nanotip. G. Wachter, Chr. Lemell, J. Burgdörfer, M. Schenk, M. Krüger, P. Hommelhoff, Electron rescattering at metal nanotips induced by ultrashort laser pulses, Phys. Rev. B 86, 035402 (2012)
- In sum, 7 publication resulted. The ones that are given in the complete publication list comprise review and deeper insight articles related to the scientific results mentioned here.

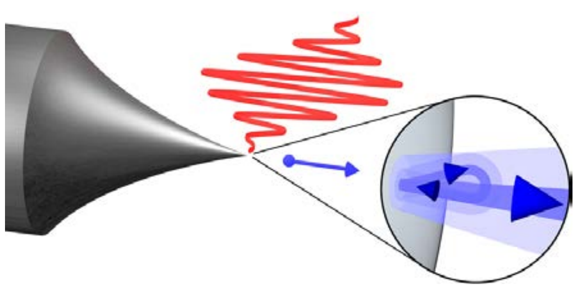

Figure2: Sketch of the experiment. Laser pulses, shown as a wavy line, are focused on a sharp metal tip. Electrons are emitted, indicated by the blue dot. Our results show that the emitted electrons undergo a process known as re-scattering, as indicated in the zoom-in. Before the electron can leave the tip-laser

interaction area, it is being driven back to the tip, scatters at the tip elastically, picks up more energy in the laser field, and is only then propagating towards the detector. This process, namely that the electron is driven back to the parent tip, is well known from strong-field physics with free atoms. In fact, it is the basis of the whole field of attosecond physics. It is therefore of utmost interest that we could observe this process at a solid for the first time. Future applications might involve an extremely fast, light-based transistor, an attosecond field effect transistor.

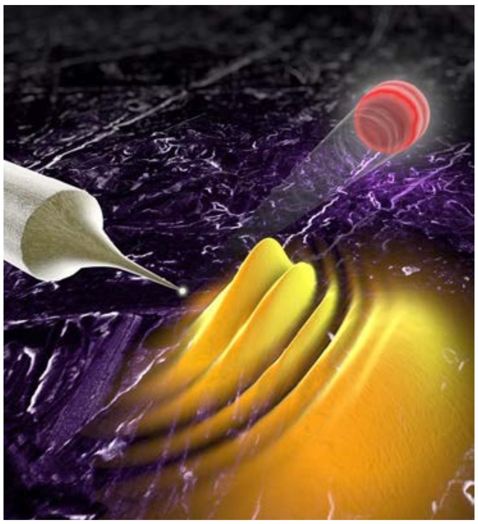

Figure 2: Artist's impression of the electron emission from the metal tip. A short laser pulse, shown in red, drives electrons from the tip. As indicated in Fig. 1, the electron undergo rescattering at the tip. While the electrons, indicated as yellow matter waves in this figure, propagate towards the tip, we observe that the matter waves overlap leading to matter wave interference. In this experiment, we hence observe the time-energy analog of Young's famous double slit experiment – with electronic matter waves.

In terms of scientific results, this is considerably more than what was initially proposed. Thus, the proposal goals have been fully met. Specifically, in terms of the goals mentioned in the grant agreement, the experiment is fully operational, has taken the mandatory steps to work on the forefront of science, and has been producing highly visible results.

Socio-economic impacts lie mostly on the training of students. Overall, about a dozens PhD, master, and bachelor students have been trained on this project. Several have graduated and found very highly regarded and highly paid jobs, for example at high-tech companies. Others have chosen to stay in science and are now working towards their PhD. Many visitors have been demonstrated what basic science is, how it relates to applications, and how taxpayer's money is converted to knowledge in cutting edge research.