Attosecond physics: A switch for light-wave electronics

May 23 2016

Light waves could in principle be used to drive future transistors. Since the electromagnetic waves of light oscillate approximately one million times in a billionth of a second, i.e. at petahertz (PHz) frequencies, optoelectronic computers could attain switching rates 100,000 times higher than current digital electronic systems. However, to achieve this goal, we will need a better understanding of the sub-atomic electron motion induced by the ultrafast electric field of light. Now a team led by Ferenc Krausz, who holds a Chair in Experimental Physics at LMU and is a Director of the Max Planck Institute for Quantum Optics in Garching, in collaboration with theorists from Tsukuba University in Japan, has used a novel combination of experimental and theoretical techniques, which for the first time provides direct access to the dynamics of this process.

The new findings are reported in the journal *Nature*.

Insights into attosecond electron dynamics

Electron movements form the basis of electronics, as they facilitate the storage, processing and transfer of information. State-of-the-art electronic circuits have reached their maximum clock rates at some billion switching cycles per second, as any further increase is limited by the heat generated in the process of switching power on and off. The electric field of light changes its direction a trillion times per second and is able to mobilize electrons in solids at this rate. This means that light waves can form the basis for future electronic switching, provided the induced electron motion and its influence on heat accumulation is precisely understood. In two papers published back-to-back in *Nature* in 2012, Krausz and his team had already shown that it is possible to manipulate the electronic properties of matter at optical frequencies (DOI: 10.1038/nature11567, DOI: 10.1038/nature11720).

As in these earlier experiments, the researchers have now employed extremely intense laser pulses, each lasting for a few femtoseconds (1 fs is a millionth of a billionth of a second) to perturb electrons in glass (silicon dioxide). The light pulse consists of a single oscillation of the field, so the electrons are moved left and right only once. The full temporal characterization of the light field after transmission through the thin glass plate for the first time yields direct insight into the electron dynamics induced by the light pulse in the solid on an attosecond scale.

Optimizing the interaction of light and matter

This measurement technique reveals that electrons react to the incoming light within a few tens of attoseconds (1 as is a billionth of a billionth of a second). The duration of the delay in the response in turn determines the amount of energy transferred between light and matter. Since it is possible to measure the energy exchanged within one light cycle for the first time, the parameters of the light-matter interaction can be precisely determined and optimized for ultrafast signal processing. The greater the degree of reversibility in the exchange and the smaller the amount of energy left behind in the medium after passage of the light pulse, the more suitable the interaction becomes for future light field-driven electronics.

To obtain a detailed understanding of the observed phenomena, and identify the most appropriate set of experimental parameters for that purpose, the experiments were backed up by a novel simulation method based on first principles developed at the Center for Computational Sciences at University of Tsukuba. The theorists there used the K computer, currently the fourth fastest supercomputer in the world, to compute electron motions within solids with unprecedented accuracy.

The researchers succeeded in optimizing the energy consumption by carefully tuning the amplitude of the light field. At certain field strengths energy is transferred from the field to the solid during the first half of the pulse cycle and is almost completely re-emitted during in the second half of the oscillation period. These findings confirm that a potential switching medium for future light-driven electronics would not overheat. The 'cool relationship' between glass and light might thus provide an opportunity to dramatically accelerate electronic signal- and data processing to its ultimate limits.

More information: Attosecond nonlinear polarization and light-matter energy transfer in solids, *Nature*, DOI: 10.1038/nature17650

Provided by Ludwig Maximilian University of Munich

Citation: Attosecond physics: A switch for light-wave electronics (2016, May 23) retrieved 25 April 2024 from https://phys.org/news/2016-05-attosecond-physics-light-wave-electronics.html