Real-Time Observation and Control of Electron Motion

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The symbiosis of electrons and light forms the basis of life: The microscopic motion of electrons creates light which supplies our globe with life-giving energy from the sun. Electrons transform light into biological energy during photosynthesis and into biological signals endowing us with the capability of seeing the world around us. Upon their motion inside and between atoms electrons emit light, carry and process information in biological systems and manmade devices, create, destroy, or modify molecules and thereby affect biological function. Consequently, they are key players in physical, chemical or life sciences as well as information, industrial and medical technologies likewise.

Motion of electrons at the atomic scale and light wave oscillations (being mutually the cause of each other) occur at an inconceivable pace and are measured in billionths of a billionth of a second, i.e. in attoseconds. By drawing on their interaction, attosecond science aims at measuring, controlling and exploiting these processes: Electron motion and light waves thereby extend the symbiosis of light and electrons from nature to technology.

Recent advances in laser science have opened the door to watching and controlling these hitherto inaccessible microscopic dynamics [1]-[14]. Key tools include waveform-controlled few-cycle laser light [3,5,15] and attosecond pulses of extreme ultraviolet and soft-X-ray light [1,4,11]. They provide a force capable of steering electrons inside and between atoms and a probe for tracking their motion [15]. Insight into and control over microscopic electron motion are likely to be important for developing brilliant sources of X-rays, understanding molecular processes relevant to the curing effects of drugs, the transport of bioinformation or the damage and repair mechanisms of DNA at the most fundamental level where the borders between physics, chemistry and biology disappear. Once implemented in condensed matter the new technology will be instrumental in advancing electronics and electron-based information technologies to their ultimate speed: From microwave towards light wave frequencies.

[1] M. Hentschel et al., Nature 414, 509 (2001);
[8] M. Kling et al., Science 312, 246 (2006);
[10] E. Goulielmakis et al., Science 317, 769 (2007);

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Research
Ultrashort-pulse lasers, ultrafast spectroscopy, high-field physics, attosecond physics: Control and real-time observation of atomic-scale motion of electrons, development of compact laser-driven sources of brilliant X-ray and particle beams for medical applications.