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Press Release

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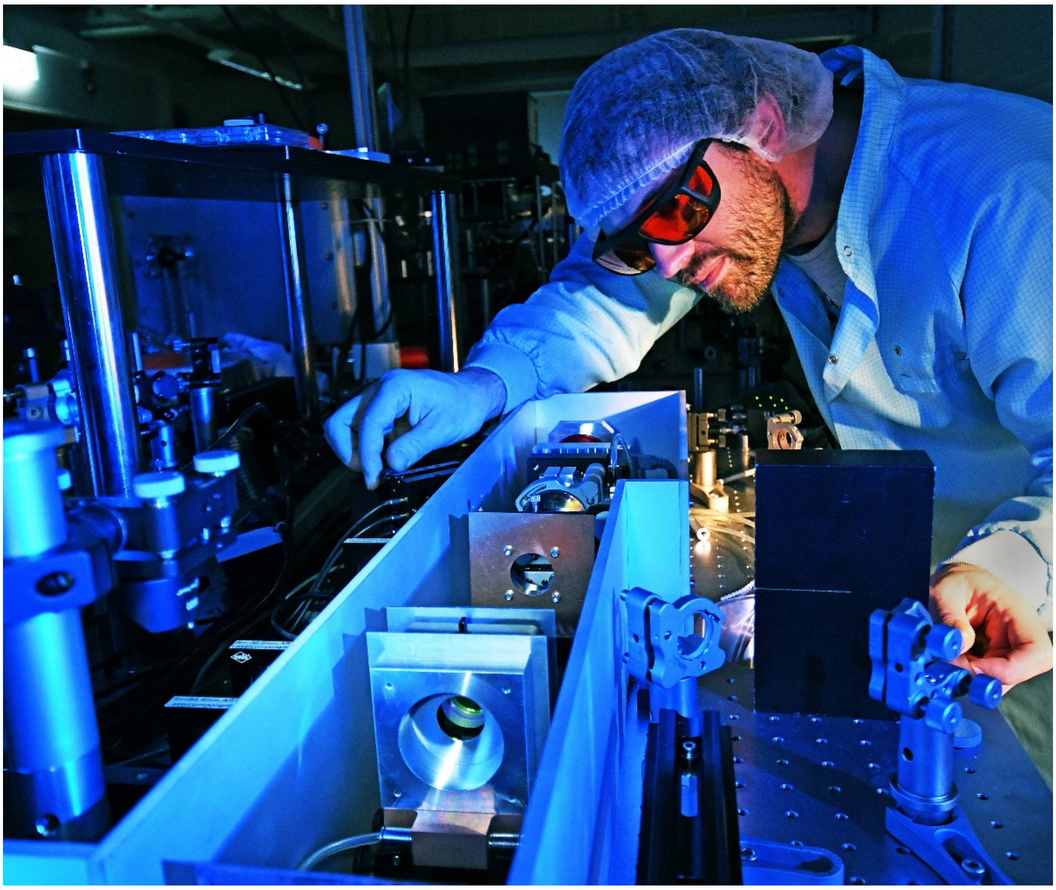
Attosecond Photoelectron Spectroscopy Accelerated

The laser physicists involved in the MEGAS collaboration have succeeded in reducing the acquisition time for data required for reliable characterization of multidimensional electron motions by a factor of 1000.

Garching, 5 February 2019 – **It may sound paradoxical, but capturing the ultrafast motions of subatomic particles is actually very time-consuming. Experiments designed to track the dynamics of electrons often take weeks. Mapping the frantic gyrations of elementary particles entails the use of extraordinarily brief laser pulses, and low signal-to-noise ratios necessitate the accumulation of huge datasets over long periods. Now members of the MEGAS project – a research collaboration between the Laboratory of Attosecond Physics (LAP) at the Max Planck Institute of Quantum Optics (MPQ), the Ludwig Maximilians University Munich (LMU), and the Fraunhofer Institutes for Applied Optics and Precision Engineering and for Laser Technology – have significantly reduced the duration of such experiments.**



The core element of their new technique is a novel enhancement resonator. Ultrashort, near-infrared laser pulses delivered to the cavity at a rate of 18.4 million per second are converted into extreme ultraviolet attosecond pulse trains, which are ideally suited for experiments in electron dynamics. | Photo: Thorsten Naeser

The advent of ultrafast photoelectron spectroscopy some two decades ago made it possible to observe the motions of electrons in atoms, molecules and solid-state materials on attosecond scales (an attosecond lasts for a billionth of a billionth of a second). However, application of the technique has been limited by the need to collect large datasets. This restriction has precluded many experiments on the dynamics of electron emission – in particular, efforts to determine their energies and momenta, and localize their sites of origin. Electrons are negatively charged particles and therefore repel each other. Consequently, precise measurements of their dynamics can best be carried out if each ultrashort light pulse results the photoemission of only a few electrons from the sample under investigation.

Now scientists involved in the MEGAS project, which forms part of the wider programme of cooperation between the Max Planck Society and the Fraunhofer Society, have overcome this obstacle. Together, groups working at the Max Planck Institute of Quantum Optics, the LMU Munich and the Fraunhofer Institutes for Laser Technology and for Applied Optics and Precision Engineering have developed a new source of attosecond laser pulses in the extreme ultraviolet (XUV) region of the electromagnetic spectrum. The set-up allows them to generate trains of high-intensity attosecond pulses at a rate of 18.4 million per second. These pulse sequences are used to trigger the emission of electrons from metal surfaces and "film" their behavior. "The new laser source generates pulses at rates that are about 1000-fold higher than was previously feasible in this spectral range, which reduces the measurement times required by the same factor," as the leader of the project, Ioachim Pupeza, explains.

The breakthrough was made possible by the use of a high-efficiency enhancement resonator cavity, in which trains of input pulses are passively enhanced, before being focused on a sample of argon gas. The upshot of the process is to convert the incoming sub-40-femtosecond near-infrared pulses into XUV pulses of attosecond duration, each containing up to 500,000 photons with energies of between 25 and 60 electron volts (eV). Given their repetition rate of 18.4 million per second, these pulses have an unprecedentedly high energy density. To demonstrate this, the attosecond pulse train was directed onto a tungsten target, detaching electrons from its surface by the photoelectric effect. The team was then able to analyze the properties of these electrons by means of attosecond-resolved photoelectron spectroscopy.

"The lower repetition rates available up to now meant that one had to wait a while for the next laser pulse in this type of experiment. But the new configuration allows us to detect the virtually continuous release of photoelectrons from the tungsten sample," as Stephan Heinrich and Tobias Saule, joint first authors of the study, point out. This reduces the times required to determine the spatial distribution of photoelectrons from several days to a matter of minutes. "This advance is of considerable significance for research on condensed-matter systems. It also opens up new opportunities for the investigation of local electric fields in nanostructures, which are of great interest for applications in future information processing with lightwaves," Pupeza adds. (Thorsten Naeser)

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