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Can ultrashort electron flashes help harvest nuclear energy?

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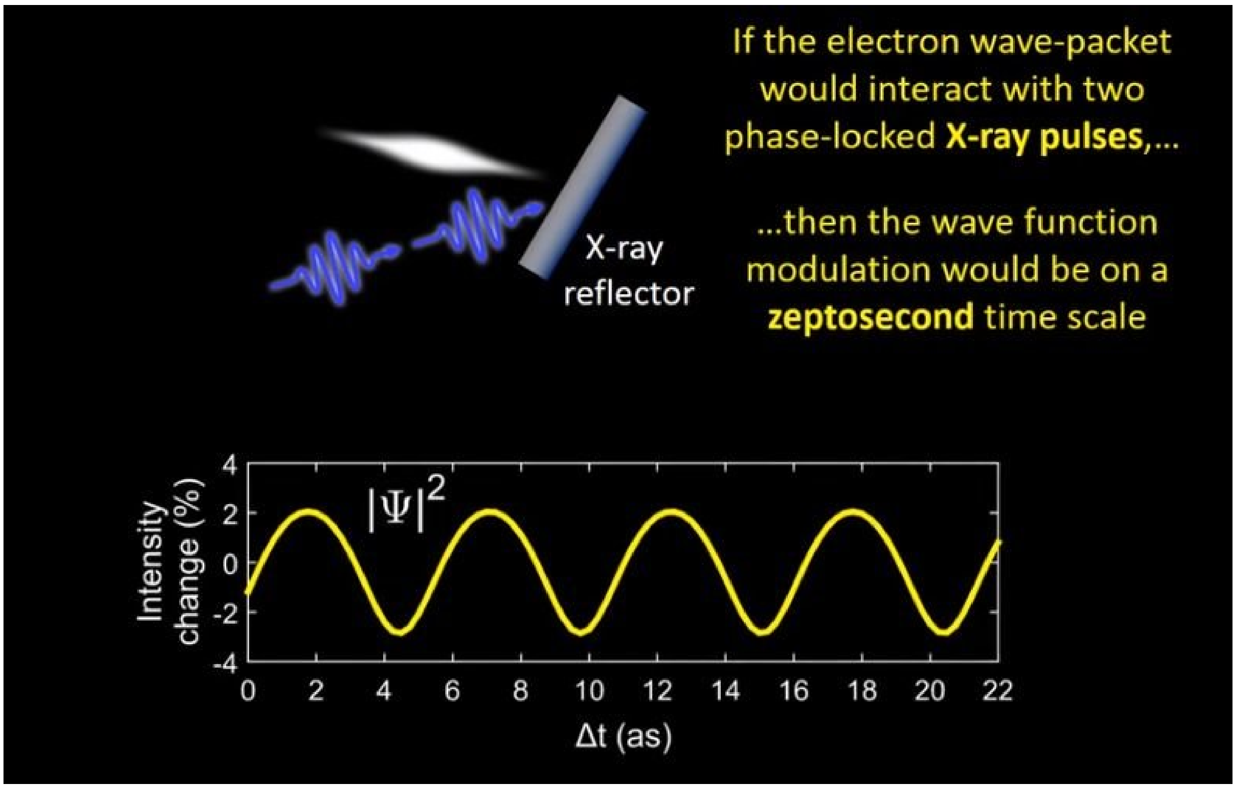

The group led by Fabrizio Carbone at EPFL and international colleagues have used ultrafast transmission electron microscopy to take attosecond energy-momentum resolved snapshots (1 attosecond = 10^{-18} or quintillionths of a second) of a free-electron wave function. Though unprecedented in itself, the scientists also used their experimental success to develop a theory of how to create electron flashes within zeptosecond (10^{-21} of a second) timeframes, using existing technology. This breakthrough could allow physicists to increase the energy yield of nuclear reactions using coherent control methods, which relies on the manipulation of quantum interference effects with lasers and which has already advanced fields like spectroscopy, quantum information processing, and laser cooling.

In fact, one of the most elusive phenomena in physics is the excitation of an atom's nucleus by absorption of an electron. The process, known as "nuclear excitation by electron capture" (NEEC), was theoretically predicted forty years ago, though it proved difficult to observe experimentally.

But in February 2018, US physicists were finally able to catch a glimpse of NEEC in the lab. The work was hailed as ushering in new nuclear energy-harvesting systems, as well as explaining why certain elements like gold and platinum are so abundant in the universe.

The EPFL researchers suggest a potential method to exploit the several orders of magnitude in energy in the nucleus of an atom via the coherent control of the NEEC effect. Such method would be enabled by the availability of ultrashort (as to zs) electron flashes. "Ideally, one would like to induce instabilities in an otherwise stable or metastable nucleus to prompt energy-producing decays, or to generate radiation," says Carbone. "However, accessing nuclei is difficult and energetically costly because of the protective shell of electrons surrounding it."

The authors write, "Our coherent control scheme with ultrashort electron pulses would offer a new perspective for the manipulation of nuclear reactions with potential implications in various fields, from fundamental physics to energy-related applications."

More information: G. M. Vanacore et al, Attosecond coherent control of free-electron wave functions using semi-infinite light fields, *Nature Communications* (2018). DOI: 10.1038/s41467-018-05021-x

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