

Attosecond 'lighthouses': A simple method for generating isolated ultrashort pulses

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Electrons move extremely rapidly inside atoms and molecules (the order of magnitude is the attosecond, i.e. 10^{-18} of a second). One way to observe these phenomena is to use isolated ultrashort pulses of light, which are successfully characterized at this time scale. As demonstrated by researchers at CEA-IRAMIS and the Applied Optics Laboratory (LOA, CNRS/ENSTA-Paris Tech/École Polytechnique), there is a particularly well-adapted light source that can be used to carry out such research into how matter behaves. The results are published in *Nature Photonics* on December 1, 2012.

To observe the extremely rapid motion of [electrons](#) in the core of atoms and molecules we require pulses in the attosecond range, allowing us to carry out "pump-probe" experiments in which an initial pulse excites the system, and a second allows us to observe the effect of this excitation, following a variable time delay.

The current method and its limitations

It is not possible to generate the kind of pulse required using standard laser optics technology. Until now, the only method that has been demonstrated to achieve such short lengths of time, utilizes the interaction between ultra-intense [femtosecond](#) (10^{-15} s) [laser pulses](#) and matter: as it interacts with the target, this pulse is deformed, producing a train of pulses of the order of a few tens of attoseconds each. These pulses follow each other at extremely short intervals, making them

difficult to use in experiments, and, over the last ten years or so, various methods for generating an isolated attosecond pulse have been suggested.

Innovative approach of this study

To produce isolated attosecond pulses, the scientists came up with the much simpler and more easily exploitable idea of spatially scattering the train of pulses, just like the [beam of light](#) from a lighthouse. Each attosecond pulse is thus emitted in a slightly different direction, giving a series of attosecond pulses that are clearly distinct in terms of the direction in which they propagate.

At a distance from the solid target, the successive attosecond pulses are distinct and, since they are several millimeters apart, can be isolated from one another.

The principle behind this new approach, initially put forward by the team at IRAMIS, was first validated theoretically by numerical simulation, using France's HPC facility, GENCI (Grand équipement national de calcul intensif). The experimental demonstration was then performed at LOA, the [Applied Optics](#) Laboratory (École Polytechnique-CNRS-ENSTA-ParisTech) on a laser chain delivering pulses close to the ultrashort optical cycle, thanks to very close collaboration between the two laboratories.

The effect observed opens up a world of new possibilities for attosecond science, a new science that has developed rapidly in the last 10 years. Using a single laser pulse to generate a number of isolated attosecond pulses, in the form of perfectly synchronous beams at distinct angles, the attosecond "lighthouses" are the ideal [light source](#) for future pump-probe experiments designed for studying electronic motion in mater.

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