First step taken to image ultra-fast movements in chemical reactions

March 15 2012

A team of international researchers have fired ultra-fast shots of light at oxygen, nitrogen and carbon monoxide molecules as part of a development aimed at mapping the astonishingly quick movements of atoms within molecules, as well as the charges that surround them.

The ultra-short laser that spans only a few hundred attoseconds – an attosecond is equivalent to one quintillionth of a second – was fired in a sample of molecules and could pave the way towards imaging the movement of atoms and their electrons as they undergo a chemical reaction – one of the holy grails of chemistry research.

This latest study has been published today, 16 March, as part of a special issue on attosecond science, in IOP Publishing's *Journal of Physics B: Atomic, Molecular and Optical Physics* to mark the 10th anniversary of the first ever attosecond laser pulse.

Previous research has been able to probe the structure of molecules using a variety of techniques; however, the inherent challenge is to perform these experiments in systems where changes are rapidly occurring on very small time scales.

The researchers used two lasers in their experiments: the first held the molecule in place whilst the second was fired at it. The second laser operated in the extreme ultra-violet region of the electromagnetic spectrum as this is one of only two regions – x-ray being the other – where the laws of physics allow laser pulses to be produced on an

attosecond timescale.

Once the target molecule was in place, short pulses of the laser were fired at in an attempt to dislodge an electron. This process, known as photoionization, allows atoms and molecules to be imaged in unprecedented detail as the ejected electrons carry crucial information about where it came from.

In this experiment, the samples, which existed as a gas, were stable, meaning no reactions were taking place; however, the major goal of the research team is to monitor the electrical and molecular changes, in real-time, that occur as atoms undergo a chemical reaction.

They intend to do this by triggering a reaction with the laser, breaking a chemical bond that holds molecules together, and then using the described technique to image the changes that occur in the molecule as they happen.

Lead author of the study Dr Arnaud Rouzée from the Max-Born-Institute said: "We show that the photoelectron spectra recorded for a small molecule, such as oxygen, nitrogen and carbon monoxide contains a wealth of information about electron orbitals and the underlying molecular structure.

"This is a proof-of-principle experiment that electrons ejected within the molecule can be used to monitor ultrafast electronic and atomic motion."

The researchers are from the Max-Born-Institute, FOM-Institute AMOLF and Texas A&M University.

More information: "Photoelectron kinetic and angular distributions for the ionization of aligned molecules using a HHG source" A Rouzée et al 2012 *J. Phys. B: At. Mol. Opt. Phys.* 45 074016.