



Press Release

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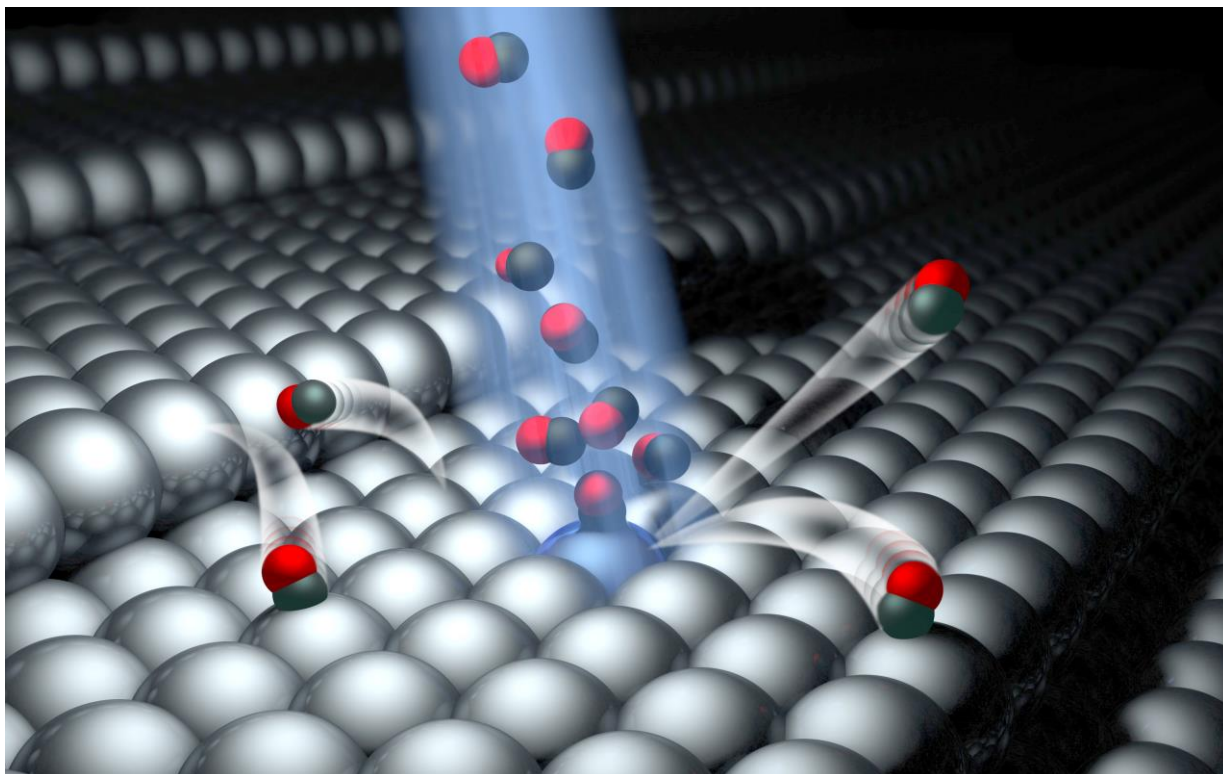
Bunching atoms together

To reach ever higher time-resolution when investigating chemical reactions is an ongoing challenge for scientists. Especially reactions that cannot be initiated by light are difficult to monitor on a short time scale. A team of researchers working with Alec Wodtke of the Max Planck Institute (MPI) for Biophysical Chemistry and the University of Göttingen have now succeeded in generating ultra-short pulses of atoms. This “bunch-compression photolysis” method might help to carry out time-resolved experiments initiated by atomic collisions. (*Nature Communications*, November 5, 2014)

We learn at an early age that atoms and molecules like to fly apart. If you open the door between two rooms in a house, it never happens that all the air suddenly bunches together in one of the rooms, leaving you with nothing to breathe in the other. This is due to entropy, the tendency of all matter to disorganize. Entropy is always around unless the temperature is cooled down to absolute zero, where atoms no longer move at all. If you want to make really short pulses of atoms and molecules (a billionth of a second long or shorter), you have to overcome the atomic desire to fly apart. Scientists have been doing this for a long time already with light – thanks to lasers. But how can it work with atoms? “To do this you have to find a way to turn entropy on its head,” explains Alec Wodtke, Director at the MPI for Biophysical Chemistry and Professor at the Institute for Physical Chemistry at the University of Göttingen. “One could say: You have to find a way to make the atoms behave backwards. You have to make them want to bunch together instead of fly apart.”

Wodtke and his team at the Department of Dynamics at Surfaces at the MPI for Biophysical Chemistry have recently discovered how to do just this, as they now report in the journal *Nature Communications*. Using a technique called “bunch-compression photolysis”, they fired a very short laser light pulse to dissociate a simple diatomic molecule, HI, which consists of a hydrogen and an iodine atom. This HI molecule had been cooled to about five degrees above absolute zero in a molecular beam to first reduce its entropy. In this setting, the frequencies in the light pulse are ordered on a line so that high energy photons (that is, the blue ones) are on the left and low energy photons (the red ones) are on the right. When this specially prepared light pulse dissociates the HI, the hydrogen atoms emerge in a bunch where the fast atoms are on the left and the slow ones are on the right. “They remember the energy of the photon that dissociated them,” says Sven Kaufmann, PhD student with Alec Wodtke. “This means that – just as in a Grand Prix car race – a situation is produced where the fast atoms must overtake the slow ones.”

“This leads to a bunching of the hydrogen atoms,” adds Dirk Schwarzer, staff scientist at the MPI for Biophysical Chemistry and one of the researchers who helped demonstrate and understand this new technique. “In fact, this effect produces hydrogen atom pulses that are already 100 times shorter than any previously produced. And according to calculations we can make them even much shorter.”



Scientists at the MPI for Biophysical Chemistry envision initiating reactions at surfaces with ultra-short pulses of atoms and molecules. (Image: Max Planck Institute for Biophysical Chemistry)

“The hope is that we will be able to carry out time-resolved experiments initiated by collisions,” co-worker Oliver Bünermann points out. He is already investigating the collisions of hydrogen atoms with metal surfaces. “Scientists have known for a long time how to study really fast processes that take place in photochemical reactions – being able to use ultra-short laser pulses to start the reaction is the trick here. But most reactions in chemistry do not need light; they take place even ‘in the dark’ and they are initiated by collisions. Bunch-compression photolysis gives us a chance to carry out a new kind of experiment altogether, where reactions are started by collisions of an ultra-short pulse of atoms.” (amw)

Original publication

Sven Kaufmann, Dirk Schwarzer, Christian Reinhardt, Alec M. Wodtke, Oliver Bünermann: Generation of ultra-short hydrogen atom pulses by bunch-compression photolysis. *Nat Commun* 5:5373, doi: 10.1038.ncomms6373 (2014).

Further information

<http://www.mpibpc.mpg.de/wodtke> – Website of the Department for Dynamics at Surfaces, Max Planck Institute for Biophysical Chemistry, Göttingen

<http://www.uni-goettingen.de/en/211983.html> – Website of the Research Group Dynamics at Surfaces, Institute for Physical Chemistry, University of Göttingen

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