

## Attosecond transient absorption spectroscopy of molecular hydrogen

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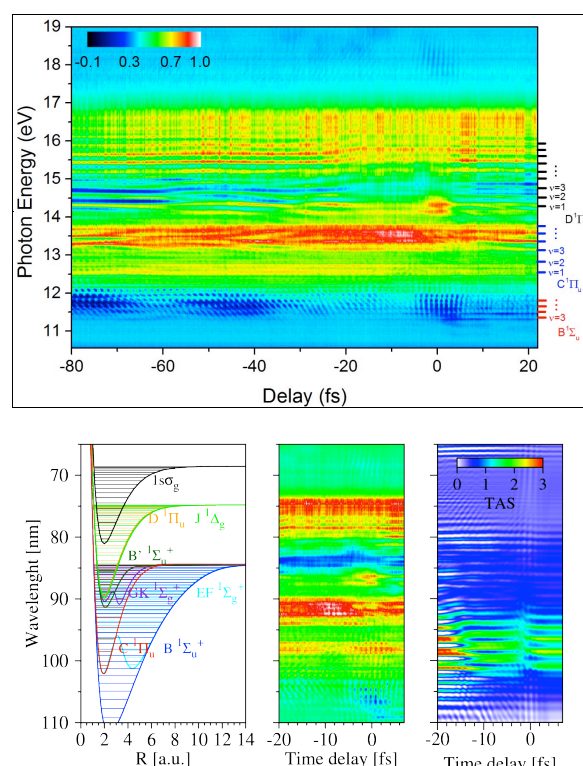
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**Synopsis** We extend attosecond transient absorption spectroscopy (ATAS) to the study of hydrogen molecules, demonstrating the potential of the technique to resolve – simultaneously and with state resolution – both the electronic and nuclear dynamics.

Attosecond pulses promise to allow new forms of quantum control in which a broadband isolated attosecond pulse excites a wave packet, which is a coherent superposition of multiple excited electronic states. In molecules, this electronic excitation triggers nuclear motion on the molecular manifold of coupled potential energy surfaces and can result in permanent rearrangement of the constituent atoms. The ability to steer reaction outcomes by controlling the exciting light field will enable attosecond photochemistry [1,2]. In this communication, we demonstrate attosecond transient absorption spectroscopy as a viable probe of the coupled electronic and vibrational wave packet dynamics initiated by an isolated attosecond pulse in the vacuum ultraviolet (VUV) spectral region in neutral hydrogen molecules. The technique allows high-resolution and state-resolved measurements of electronic and nuclear dynamics without the need for inducing subsequent ionization [3] or dissociation [4]. The addition of a moderately intense few-cycle laser field allows control over the subsequent evolution of the molecule. An illustration of the ATAS for the H<sub>2</sub> molecule obtained from experiment and a solution of the time-dependent Schrödinger equation is shown in Figure 1. The origin of the different structures will be discussed at the conference.



**Figure 1.** Measured (central panel) and calculated (right panel) ATAS for the H<sub>2</sub> molecule. The time-resolved absorption spectra uniquely encode the molecular dynamics in the vicinity of the B <sup>1</sup>Σ<sub>u</sub><sup>+</sup> ← X <sup>1</sup>Σ<sub>g</sub><sup>+</sup>, C <sup>1</sup>Π<sub>u</sub> ← X, and D <sup>1</sup>Π<sub>u</sub> ← X transition bands of H<sub>2</sub>. The corresponding potential energy curves are shown on the left panel.

## References

- [1] F. Lépine, G. Sansone, and M. J. J. Vrakking, *Chem. Phys. Lett.* **578**, 1 (2013).
- [2] F. Lépine, M. Y. Ivanov, and M. J. J. Vrakking, *Nat. Photon.* **8**, 195 (2014).
- [3] P. Ranitovic, *et al.*, *Proc. Natl. Acad. Sci.* **111**, 912 (2014).
- [4] G. Sansone, *et al.*, *Nature* **465**, 763-766 (2010).

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