# Time-resolved atomic and molecular dynamics in XUV and IR laser fields

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**Abstract**

Recent experiments with atoms and small molecules interacting with femtosecond IR and/or XUV laser pulses provided by high-power table-top lasers, high-harmonic sources, or free-electron lasers will be presented. Emphasis is given to the time-resolved many-particle dynamics of ionization and fragmentation in ultrashort and strong fields recorded with Reaction-Microscopes.

Many-particle spectrometers (COLTRIMS / Reaction-Microscopes) combined with modern short-pulse IR and XUV radiation sources are ideally suited to unravel the correlated multi-particle dynamics in ultrafast processes occurring in atoms and molecules (Fig. 1). For example, pump-probe experiments allow the observation of moving electronic wave-packets in bound sates of atoms and, in case of molecular targets, vibrational and electronic excitations can be imaged with unprecedented resolution and in real time.

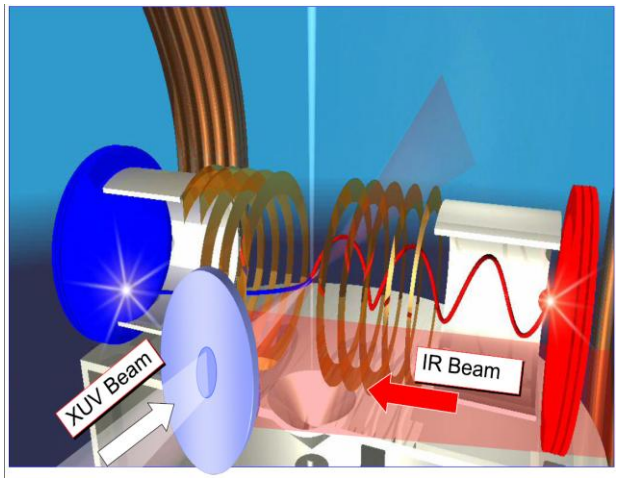


**Fig. 1**. Sketch of the spectrometer with incoming XUV and IR laser beams.

Exemplarily, in a pump-probe experiment an XUV-pulse interacts with $O_2$ molecules simultaneously ionizing them and thereby initiating an oscillating nuclear wave-packet in the cationic state of the $O_2^+$ molecules. After a variable time delay the molecule is dissociated by an IR pulse (12 fs duration, $10^{12}$ W/cm$^2$ intensity). The 3D momenta of the created photo-ions and photo-electrons are recorded and analyzed.

The experimental yield of $O^+$ ions with low kinetic energies (< 0.08 eV) is plotted as a function of the time delay in Fig. 2. Clearly visible is an oscillation of the vibrational wave-packet with a period of 40 fs. Moreover, the anharmonicity of the molecular potential curve causes a dephasing and a revival of the wave-packet with a period of about 1270 fs.

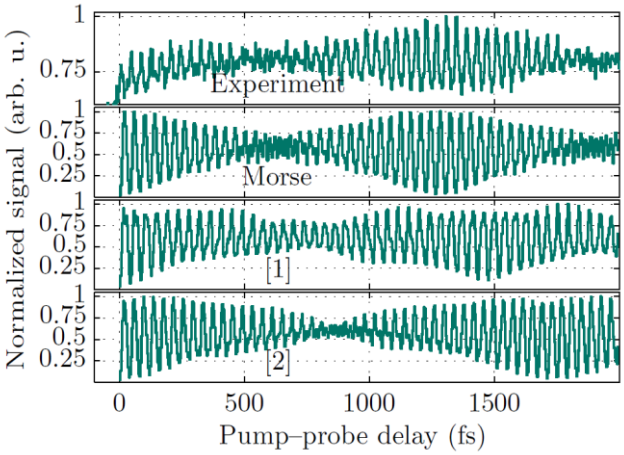


**Fig. 2**. Yield of low-energy $O^+$-ions from dissociation of $O_2^+$ as a function of the time. Experimental data (top) and three simulated spectra using a Morse potential as well as the calculated molecular potentials (see [1]).

The data provide insight into the ionization and fragmentation dynamics and, by comparison of experiment and theory, they serve as a test of molecular structure calculations, because the wave-packet evolution depends very sensitively on the shape of the molecular energy potential-curve. This way information obtained in time-resolved experiments is complementary to those of conventional spectroscopy methods.

## References

[1] P. Cörlin *et al* 2015 *Phys. Rev. A* **91**, 043415
[2] M. Magrakvelidze *et al* 2012 *Phys. Rev. A* **86**, 023402