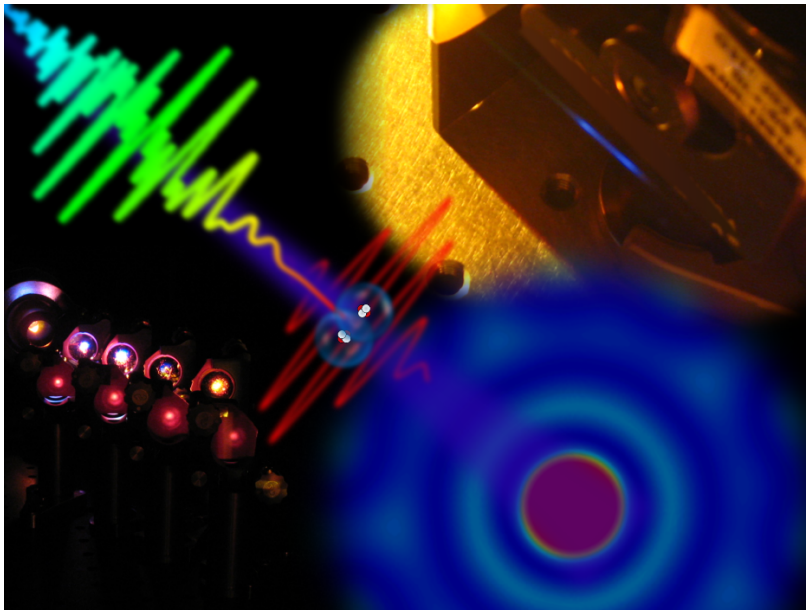
Atoms and molecules in taylored laser fields

Thomas Pfeifer

Course description:

An ongoing revolution in laser science nowadays provides coherent light throughout a large range of the electromagnetic spectrum, spanning all the way from THz via infrared and optical into the (extreme) UV and the x-ray range. These laser fields also reach intensities that allow not only to perform single-photon ionization, (linear) excitation, and spectroscopy of materials but unlock the manipulation of matter directly on the level of individual nuclei and electrons in molecules and atoms.

Imagine a general matter synthesizer, or an atomic 3D printer, for any molecular structure and even supramolecular assemblies. In principle, the full control over the electric field in space and time across all electromagnetic frequencies allows to steer nuclei and their electrons from any supplied form into a desired molecular target structure. But for this, we need a kind of four-dimensional "arbitrary-waveform synthesizer" for optical light to generate electromagnetic fields of a specific shape "taylor-made" to generate a specific outcome of the synthesis of the molecular printing process.



This course provides an overview of the fundamentals and current state of the art in the generation and manipulation of intense laser light fields, both in time and in space, and the corresponding scientific and technological applications. It starts out with the basics of laser pulse shaping, various shaping techniques and metrology. Field shaping on a sub-cycle basis, i.e. phase-control of multi-octave spanning spectra currently opens new routes in the control of electron dynamics. Control over the spatial properties of light will also be covered, including the polarization state of light as well as the spatial structure, both in free space as well as near-field geometries, including the angular momentum and topological states of light.