Petahertz field reconstruction for the investigation of electron dynamics in nanostructures

R. N. Shah[a], S. Bengtsson[a], S. H. Ahmadi[a], D. Ertel[a], P. K. Maroju[a], M. Moioli[a], S. Kellerer[a], G. Sansone[a]

[a] Physikalisches Institut, Albert-Ludwigs-Universität Freiburg, Stefan-Meier-Str. 19, 79104 Freiburg, Germany.

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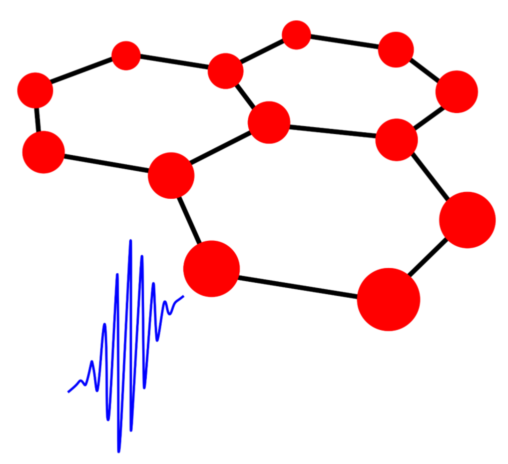
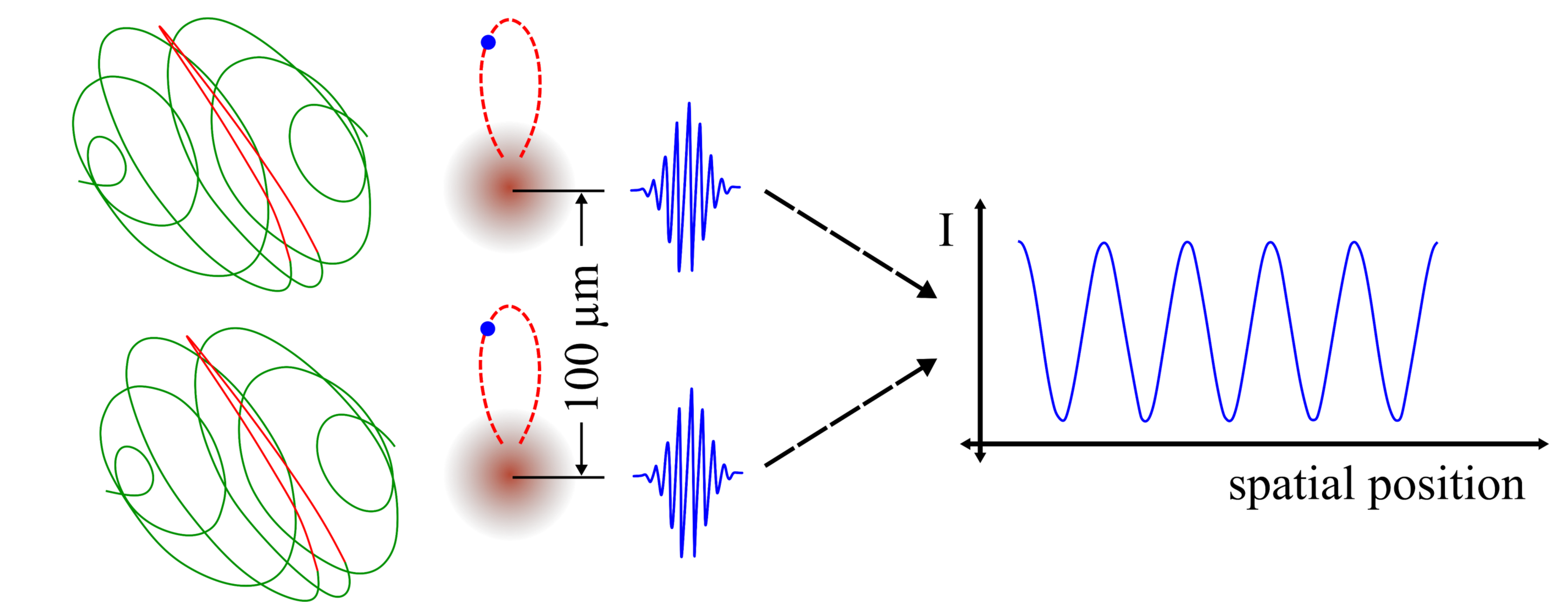
Introduction



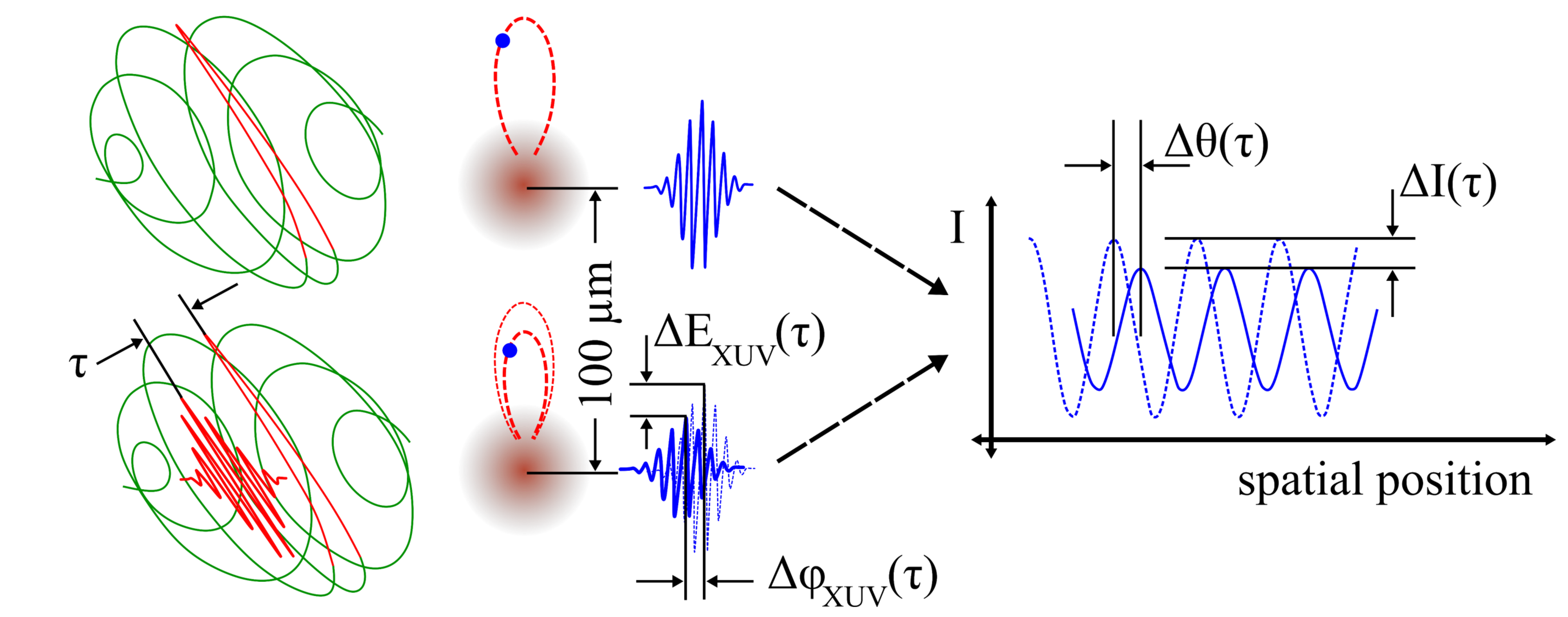
Understanding the ultrafast electron dynamics in matter, especially in nanostructures, in the presence of strong fields are a key for the development of future generation fast and compact electronics devices[1]. Using pump-probe spectroscopy to understand these dynamics requires complete characterization of optical pulses on sub-femtosecond timescales[2]. In contrast to the attosecond streak camera which needs an intense field and petahertz optical oscilloscope which suffer systematic distortion, XUV spatial interferometry which allows complete characterization at sub-femtosecond timescales of the probe pulses with energy as low as few tens of nanojoules and without distortion, is used[2,3].

Measurement principle

A binary 0-π plate introduces a π-shift between the two halves of the laser beam, thus leading to two focal spots[4]. Polarization gating (PG) these pulses before focusing, to have a small time window of linear polarization, results in the generation of isolated attosecond pulses through high-harmonic generation (HHG)[5], at the corresponding focal spots. The generated isolated attosecond pulses interfere in the far field which can be recorded by a XUV spectrometer.

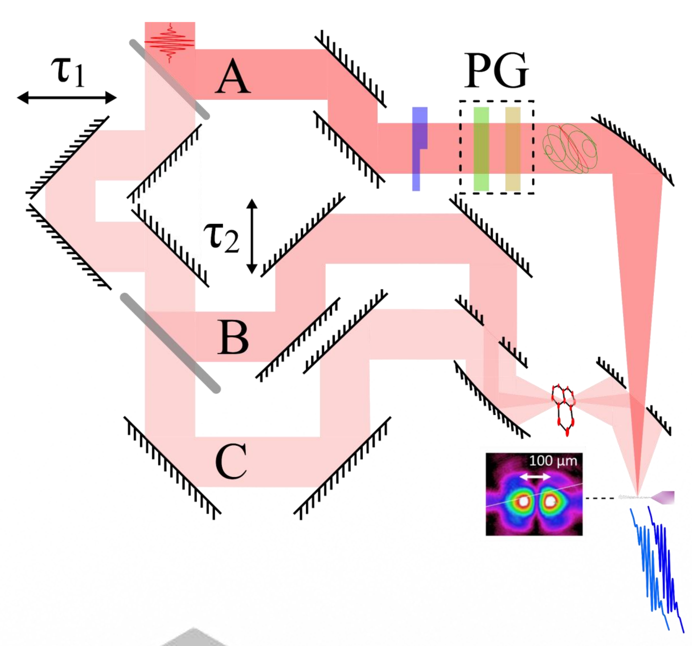


The presence of a unknown weak IR field at one of the two focal spots with a time delay τ, perturbs the process of HHG, causing a diminished amplitude ($\Delta E_{XUV}(\tau)$) and a shift in phase ($\Delta\varphi_{XUV}(\tau)$) dependent on the delay τ between the unknown weak IR pulse and the polarization gated IR pulse[2,3]. The diminished amplitude and a shift in phase in the process of HHG, manifest itself in the interference pattern in the far field as ($\Delta I(\tau)$) and ($\Delta\theta(\tau)$), respectively.

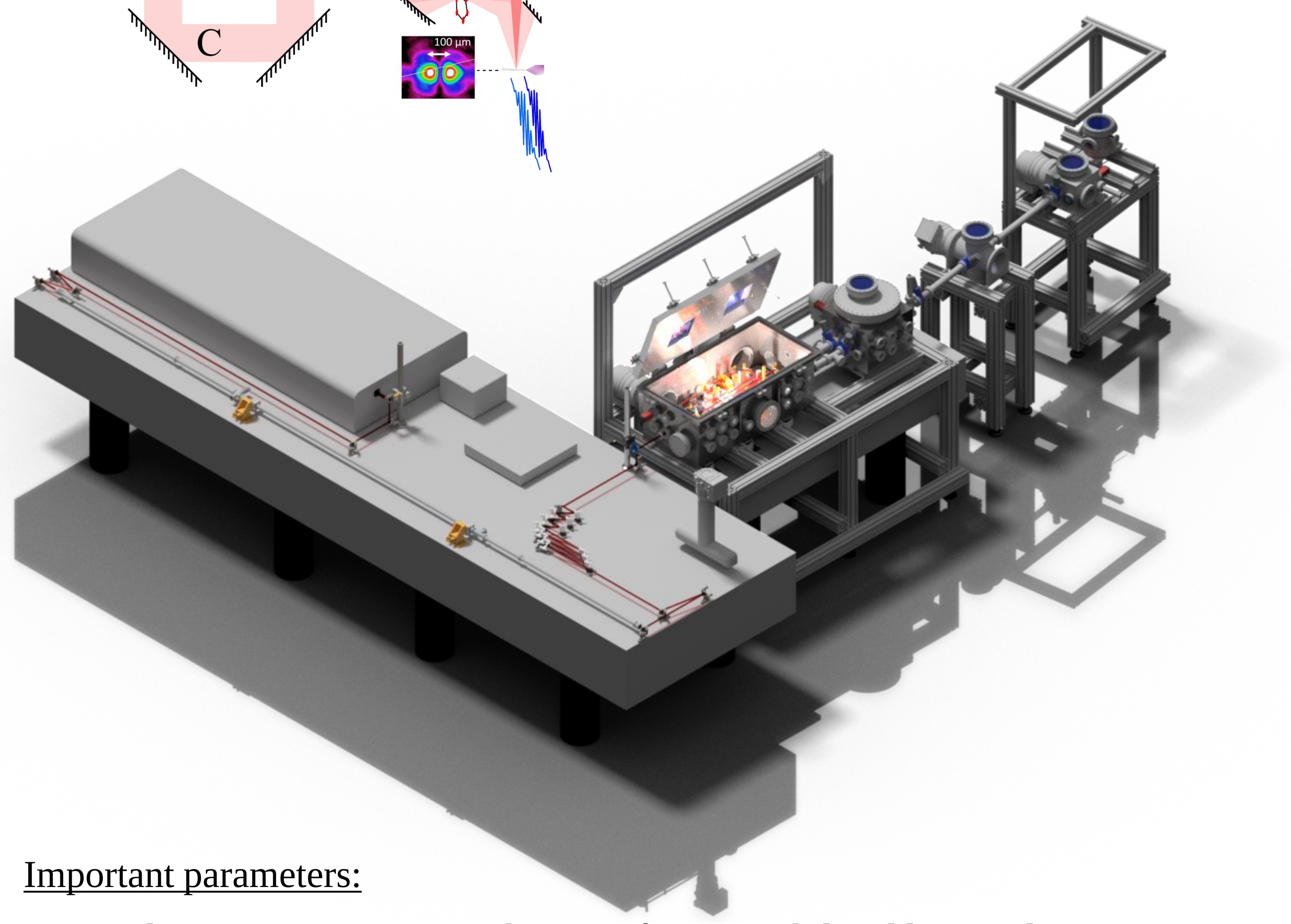


An efficient HHG process is driven by a linearly polarized IR field. It has been experimentally demonstrated that in the presence of unknown weak IR field of arbitrary polarization, the polarization component of the unknown weak field in the polarization direction of the polarization gated IR pulse perturbs the HHG process[2,3]. Thus, obtaining polarization gated IR pulse in two perpendicular direction allows a complete reconstruction with sub-femtosecond time resolution of an unknown field, irrespective of its polarization.

Proposed beamline



- Beam path A is used for XUV spatial interferometry. Beam path B and C are the pump and probe, respectively.
- τ_1 and τ_2 are the delay for the XUV spatial interferometry and pump-probe, respectively.



Important parameters:

- TiSa laser system : ~5 mJ, 1 kHz, 25 fs CEP stabilized laser pulses.
- Hollow core fiber (HCF) system: 2 m long HCF, Neon, differentially pumped.
- Beam diagnostic: FROG, Stereo ATI.

Milestones:

- Few cycle pulses having ~2 mJ pulse energy.
- Setting up the optics to generate harmonics, correspondingly making XUV interferometry and pump-probe setup for nanostructures.
- Understand the physics happening at sub-fs domain in Nanostructures.

Present work:

- Setting up of the vacuum chambers to conduct the experiments.
- Upgrading the hollow core fiber system to a 2 m long hollow core fiber to compress ~5 mJ 1 kHz laser pulses from 25 fs to close to 5 fs.

References

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