
L A S E R C O L L O Q U I U M

Tracing Coherent Electron Dynamics in Molecules: Novel Approaches and Application to Chiral Control

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ABSTRACT

Attosecond light sources have given direct access to electron dynamics in matter and opened the field of attochemistry, which aims to control chemical reactivity through coherent electronic motion [1,2]. I will present our recent ultrafast sources from the UV to the soft x-ray [3,4], including an integrated high-harmonic source that reaches beyond the C K-edge. I will then show a site-specific study of charge migration in phenylalanine and tryptophan at the O and N K edges. It uses attosecond time-resolved x-ray absorption spectroscopy at LCLS-II in an $\omega/2\omega$ XLEAP configuration [5]. Preliminary results at the N K edge in tryptophan reveal a 0.58 PHz oscillation, which also appears in the immonium dication yield. Finally, I will show that sub-2-fs UV pulses launch chiral currents in methyl lactate. A circularly polarized NIR pulse can probe these currents and control the molecule's fragmentation, establishing a new route to enantioselective charge-directed reactivity [6].

References

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 - [5] Driver, T., Guo, Z., Isele, E. et al. *Nat. Phys.* 22, 1459–1466 (2026).
 - [6] V. Wanie et al., *Nature* 630, 109–115 (2024).
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ABOUT THE SPEAKER

Francesca Calegari leads the Attosecond Science group at the Center for Free-Electron Laser Science (CFEL) at DESY. She is also Professor of Physics at the University of Hamburg. Among other distinctions, she received the ICO Prize and the Ernst Abbe Medal from the International Commission of Optics, and she is a Fellow of the Optical Society (Optica).

The main focus of her research is to track and ideally control in real time the electron dynamics occurring in systems with increasing complexity, from simple molecules to molecules of biological interest and nanostructured materials. To this purpose, her group develops state-of-the-art table-top light sources providing extreme time resolution (from a few femtoseconds down to attoseconds) and spanning wavelengths from the infrared to the ultraviolet and then further down to the soft X-ray spectral range. In her group, attosecond technology is used to understand the role of the electron dynamics in the photo-induced chemical changes that occur in our own biomolecules (e.g. DNA and proteins) in a bottom-up approach. Her research will allow not only to disclose the physical origin of a variety of light-driven processes of crucial importance in photo-chemistry, but also to mimic and optimise those process for artificial light harvesting. Her approach is synergetic with the possibility to resolve structural changes in biomolecules through femtosecond time-resolved X-ray diffraction using extreme-ultraviolet/X-ray free-electron lasers.