

# Physical Chemistry Colloquium

INSTITUTE  
FOR PHYSICAL  
CHEMISTRY



UNIVERSITÄT  
HEIDELBERG  
ZUKUNFT  
SEIT 1386

## High-brightness, high-throughput, ultrashort keV and MeV electrons for femtochemistry studies in photoexcited matter

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Ultrafast electron diffraction (UED) is the method of choice for studying femtosecond structural dynamics in photoexcited matter [1-5]. Compact keV instruments complement facility-based 8-30 fs MeV sources [6,7] but are constrained by space-charge effects: high-charge operation at 1 kHz limits pulse durations to 150-240 fs [4,5,8], while single-electron modes sacrifice throughput [9]. We present a 90 keV UED platform that overcomes these limitations using RF compression synchronized to the drive laser with <6 fs precision [10], achieving 26–114 fs pulses [11] at 40–100 kHz with direct electron detection, as confirmed by THz electron streaking [12] - combining femtosecond resolution with unprecedented throughput in the keV regime. Using uncompressed electron beams with 300 fs resolution, we have also measured non-thermal dynamics in aluminium [13,14].

Complementing this approach, we have performed MeV UED experiments using 30 fs MeV sources [6,7] to disentangle coupled electronic-nuclear dynamics in gas-phase molecules and liquids in highly polar environments. Together, these capabilities enable high-sensitivity studies of gases, nanostructures, photoinduced phase transitions, and ultrafast solvation dynamics with among the brightest electron pulses and highest usable throughput available worldwide.

- [1] G. Mourou and S. Williamson, *Appl. Phys. Lett.* **41**, 44-45 (1982).
- [2] J. C. Williamson *et al.*, *Nature* **386**, 159-162 (1997).
- [3] X. Shen *et al.*, *Struct. Dyn.* **6**, 054305 (2019).
- [4] T. Xiong *et al.*, *Phys. Rev. Res.* **2**, 043064 (2020).
- [5] D. Filippetto *et al.*, *Rev. Mod. Phys.* **94**, 045004 (2022).
- [6] F. Qi *et al.*, *Phys. Rev. Lett.* **124**, 134803 (2020).
- [7] Y. Yang *et al.*, arXiv:2508.03946 (2025).
- [8] T. van Oudheusden *et al.*, *Phys. Rev. Lett.* **105**, 264801 (2010).
- [9] C. Kealhofer *et al.*, *Science* **352**, 429 (2016).
- [10] M. R. Otto *et al.*, *Struct. Dyn.* **4**, 051101 (2017).
- [11] K. Amini *et al.*, arXiv:2601.02597 (2026).
- [12] A. Ryabov and K. Amini, arXiv:2601.02333 (2026).
- [13] F. Rodriguez Diaz *et al.*, *Struct. Dyn.* **11**, 054302 (2024).
- [14] F. Rodriguez Diaz and K. Amini, arXiv:2601.02055 (2026).

**Date:** Wednesday, March 18

**Time:** 16:15

**Place:** INF 236 (Geologie hinter Museum) Großer Hörsaal

**Speaker:** Dr. Kasra Amini, Max-Born Institute, Berlin

**97 ± 3 fs FWHM or  
41 ± 1 fs RMS**

