



Date & Time: **THURSDAY, MARCH 12, at 15:30**

Location: **MPSD, 900 EG 136**

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**qcemd** - Seminar



## **Ultrafast Phenomena at the Nanoscale: From Photonic Temporal Structures to Strong Light–Matter Interactions and Hot Electron Dynamics**

Understanding and controlling light-matter interactions at the nanoscale on femtosecond to picosecond timescales is opening new frontiers in nanophotonics, quantum materials, and ultrafast spectroscopy [1]. This talk presents an integrated perspective on three complementary research directions that collectively illustrate how nanoscale geometry, ultrafast optical driving, and resonant electromagnetic modes can be leveraged to manipulate energy flow and electronic dynamics with high temporal precision.

First, I will discuss the generation of photonic temporal structures through femtosecond transient gratings in wide bandgap dielectric films coupled to hyperbolic metamaterials. These experiments demonstrate that spatiotemporal modulation of the permittivity can launch high-momentum Bloch modes on sub-picosecond timescales, revealing a new pathway for dynamic mode activation in nanostructured media without static patterning [2].

Then, I will showcase the ultrafast dynamics of strong light-matter interactions in plasmonic nanoantennas coupled to molecular photoswitches. Pump-probe spectroscopy, supported by quantum simulations, reveals that molecular polaritons created under strong coupling collapse to localized molecular excitations within a few hundred femtoseconds giving rise to a probe-driven non-coherent polaritonic state. These results highlight also how plasmonic confinement reshapes the ultrafast electronic landscape, offering new opportunities for manipulating photochemical pathways and accessing non-equilibrium potential energy surfaces [3].

Finally, I will present insights into hot electron dynamics in nanoporous plasmonic metamaterials, where nanoscale porosity modifies electronic temperatures, interband

thresholds, and relaxation pathways. Ultrafast measurements combined with cathodoluminescence spectroscopy and atomistic modeling show how nanoporosity redistributes intraband and interband contributions, enhancing hot carrier generation across a broad spectral range [4].

Together, these studies feature how spatial, spectral, and temporal degrees of freedom can be engineered and dynamically intertwined at the nanoscale, to eventually gain access to regimes where optical fields steer matter before dissipation sets in - paving the way for next-generation photonic circuitry, real-time control of chemical reactivity, efficient hot-carrier devices, and programmable metamaterials.

## **References**

- [1] A. N. Koya et al., *Appl. Phys. Rev.* 10, 021318 (2023).
- [2] T. Tapani et al., in preparation
- [3] J. Kuttruff et al., *Nat. Commun.* 14, 3875 (2023).
- [4] T. Tapani et al., *Nat. Commun.* 17, 829 (2026).