Technical University of Denmark

Ultrafast Infrared & Terahertz Science

www.fotonik.dtu.dk/ultrafast

Projects in the Ultrafast Infrared & Terahertz Science group at DTU Fotonik are focused on experimental facilities in our state-of-the-art femtosecond laboratory with a range of world-class femtosecond laser systems and experimental setups for mid-IR and terahertz-frequency experiments.

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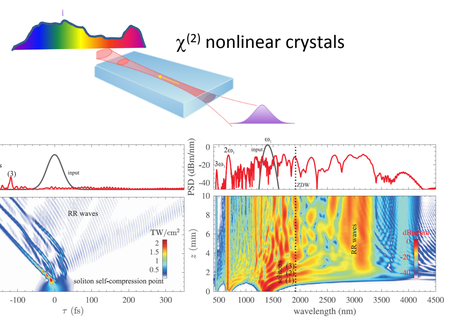
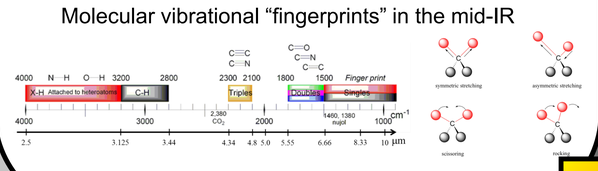
Ultrafast mid-IR nonlinear optics



$\chi^{(2)}$ nonlinear optics
- Filament-free mid-IR supercontinuum
- Parametric control over nonlinearity

Molecular vibrational "fingerprints" in the mid-IR



THz transport properties in novel 2D materials

Preparation of terahertz compatible substrates in Danchip facilities

Transfer of 2D materials from the growth substrate to the target substrates

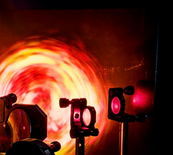
Measurement of the 2D materials response under THz light using state-of-the-art setups

Understanding properties of 2D materials

THz setups

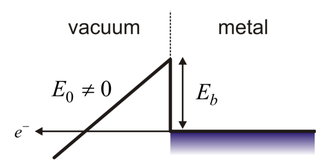
Near-field THz microscopy

Broadband THz spectroscopy

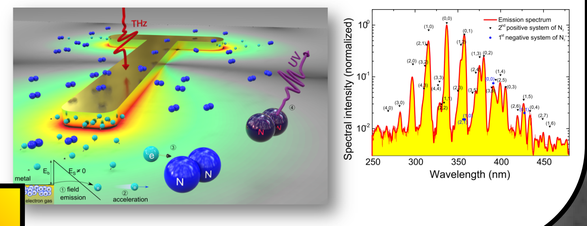


Ultra-broadband THz spectroscopy

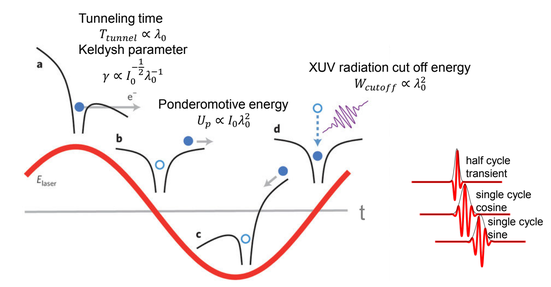
THz-induced ultrafast electron optics

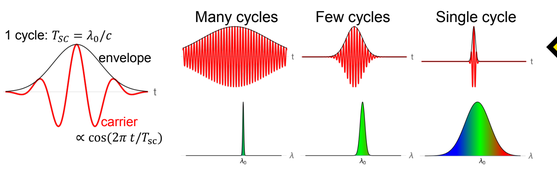


- Use strong THz pulses to induce ultrafast electron bunch emission from metals
- Understand material degradation under strong-field conditions
- Simulate and control electron behavior in strong, transient fields
- Investigate collision processes between ultrafast electron bunches and molecules



Few-cycle mid-IR pulses



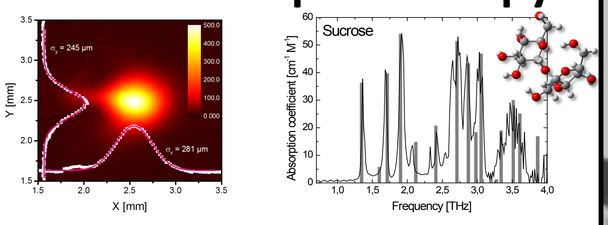


Ultrafast nonlinear optics
- generate few-cycle mid-IR pulses
- excite and control ultrafast processes on atomic and molecular level

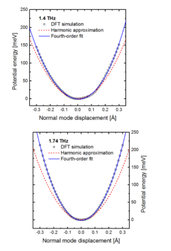
Femtosecond

laser lab

Nonlinear THz molecular spectroscopy



- Intense THz pulses for nonlinear vibrational spectroscopy
- Ab-initio density functional theory Molecular dynamics simulations
- Vibrational anharmonivity
- Energy flow in complex, coupled systems
- Time-dependent quantum mechanics

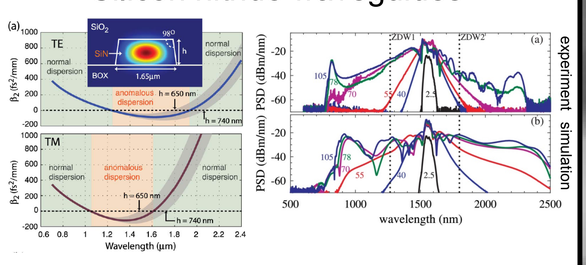


$$\tilde{H} = -\frac{\hbar^2}{2m}\frac{\partial^2}{\partial x^2} + V(x) - \mu E(t) = \tilde{H}_0 - \mu E(t)$$

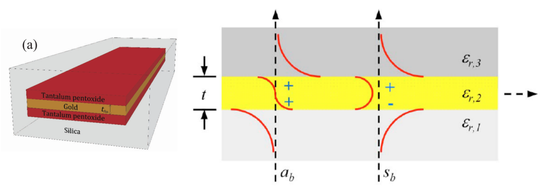
$$\frac{\partial \tilde{\rho}}{\partial t} = -\frac{i}{\hbar}[\tilde{H}, \tilde{\rho}] = -\frac{i}{\hbar}\left(\tilde{H}\tilde{\rho} - \tilde{\rho}\tilde{H}\right)$$

Ultrafast nonlinearities in nanophotonic devices

Silicon nitride waveguides

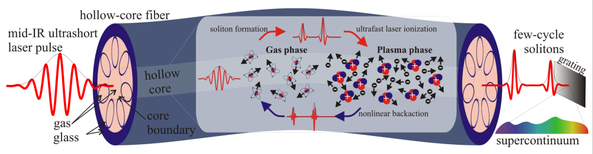


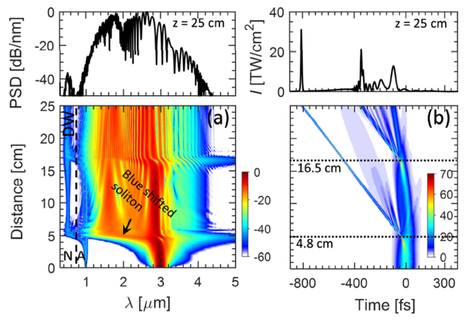
Nanoscale plasmonic waveguides



<1 fs Absorption, "cold" electrons → **~100 fs** Hot electrons $\chi^{(3)}$ nonlinearity → **>1 ps** Electrons decay to lattice

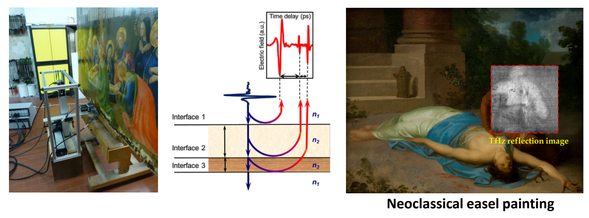
Nonlinear optics in hollow-core gas-filled fibers





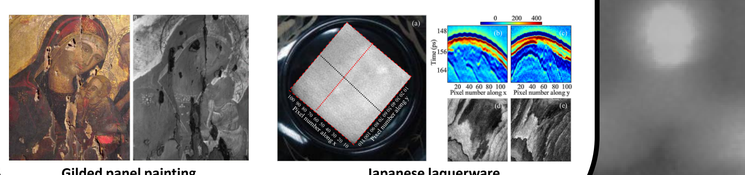
- Fundamental properties of ultrafast gas-plasma interaction in the mid-IR
- High-energy mid-IR few-cycle pulses and supercontinuum generation

THz imaging applications



Neoclassical easel painting

- THz pulses penetrate many materials that are opaque to visible and infrared wavelengths
- Use portable THz imaging system for investigation of art objects
- Develop image analysis software for detailed inspection of internal structure
- Applications also in fundamental science and industry



Gilded panel painting — Japanese laquerware

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