



Canadian Association  
of Physicists

Association canadienne  
des physiciens et physiciennes

Contribution ID: 65

Type: **Invited Speaker / Conférencier(ère) invité(e)**

## Warm dense matter studies using ultrafast optical and extreme ultraviolet laser pulses

*Tuesday 9 June 2020 16:15 (35 minutes)*

Materials under high intensity femtosecond laser irradiation yield extreme material conditions called warm dense matter (WDM) with thermal energy comparable with the Fermi energy and the ion-ion coupling parameter exceeding unity. The WDM state exists in a variety of processes ranging from laser micromachining to inertial confinement fusion experiments. The WDM exists as transient states including as nonthermal WDM in the first few hundred femtoseconds when the electron thermalization is important and as two temperature WDM with high electron temperature and relatively low ion temperature in the first few picoseconds. The WDM subsequently transits into the plasma state. We have used pump-probe techniques [1-5] to study WDM produced by irradiating few ten's of nanometers thick free-standing metal foils with high intensity femtosecond laser pulses. In this talk I will focus on our studies using ultrafast optical Frequency Domain Interferometry to study the disassemble processes [2] and ultrafast electron diffraction technique to study the structural changes [1] of the laser heated foils. I will also present the results of broadband AC conductivity measurements of the warm dense gold generated with 245eV, 70fs pulses to selectively excite 4f electrons using the XUV-FEL at FLASH. The AC conductivity was measured at different wavelengths (485nm, 520nm, 585nm, 640nm and 720nm) to cover the range from 5d-6s/p interband transitions to 6s/p intraband transitions.

1. M. Z. Mo, et al, "Heterogeneous to Homogeneous Melting Transition visualized with Ultrafast Electron Diffraction", *Science* 360, 1451 (2018).
2. Z. Chen, et al. "Interatomic Potential in the Nonequilibrium Warm Dense Matter Regime", *Phys. Rev. Lett.* 121, 075002 (2018).
3. M. Z. Mo, et al, "Measurements of Ionization States in Warm Dense Aluminum with Betatron Radiation", *Phys. Rev. E* 95, 053208 (2017).
4. Z. Chen, et al, "Evolution of ac Conductivity in Nonequilibrium Warm Dense Gold", *Phys. Rev. Lett* 110, 135001 (2013).
5. Z. Chen, "Flux-limited Non-equilibrium Electron Energy Transport in Warm Dense Gold", *Phys. Rev. Letts* 108, 165001 (2012).

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**Session Classification:** DPP-1 : Plasma Physics Symposium

**Track Classification:** Symposia Day (DPP) - Plasma Physics