Thesis outline

Title: ?

Target completion: December 2016

1. Introduction:
    a. Physics of the warm dense matter regime is interesting and has relevance to several fields of basic and applied science, such as astrophysics, geophysics, and efforts to achieve inertial confinement fusion.
    b. Define WDM as matter at solid densities and temperatures within an order of magnitude (or so) of the Fermi energy. kT in WDM is too small compared to the coulomb interaction between neighboring atoms to adopt plasma physics treatments wherein interionic interactions are introduced perturbatively. WDM is Fermi degenerate but, similarly, too hot to treat as a solid state system. In addition to these theoretical challenges there are a host of experimental ones: e.g. how does one produce uniform WDM in the lab; how does probe its bulk properties; how does one ensure local thermal (or deal with the lack of it) when generating WDM and interpreting its thermodynamic properties?
    c. Introduce techniques for generating WDM. Short-pulse laser, long-pulse laser, free-electron laser and the corresponding regimes (energy density, timescale). Introduce X rays as the probe of choice for studying WDM. Various techniques: XRTS, XES, XRD, XRF.
    d. This thesis introduces a few new approaches to studying WDM using XRD and emission spectroscopy as probes. The proposed techniques aim to increase the information content of WDM measurement in such a to improve experimental data's discrimination between different theoretical models. In section 1, …… etc.
2. EDXRD measurements of laser-generated WDM
    a. Laser-shock and ramp compression experiments are central to inertial confinement fusion and studies of the thermodynamic equation of state of warm dense matter. The low repetition rate and shot-to-shot variations in these studies impart high value on measurements that can be done in a single shot. In this section we discuss a configuration for single-shot XRD measurements using broadband backlighters. We present results of a photometric study that demonstrate its feasibility using established technology at large-scale laser facilities.
    b. Use content of the EDXRD paper, adapting the introduction and conclusion to fit the context of this thesis.
3. Probing the fs-scale relaxation cascade of solid state systems heated to eV temperature
    a. Introduce the X ray free electron laser as a tool for producing and characterizing WDM. Its primary advantages over laser heating are the shorter accessible timescale and ability to do two-color pump-probe.
    b. Scientific motivations for studying WDM at the XFEL
        i. Understanding the onset of electronic heating and (thermal or nonthermal) lattice deformation in x-ray heated solid state systems. One of the basic

questions is that of the time scales involved in each constituent process of the relaxation cascade.

    ii. Testing finite-T DFT (contingent on being able to heat electrons before the lattice, thus tied to the previous question).
    iii. Revisit certain suggestive, but ambiguous, experimental results in the existing literature using higher-information diagnostics (for example, Hau Riege's observation of possible nonthermal melting in graphite).

  c. Design of an XFEL heating experiment:
    i. Diagnostics: XRD, specifically wide-angle XRD
    ii. How does one design a target? Introduce hot electron furnace concept.
    iii. PENELOPE physics models
    iv. PENELOPE simulation results validate the HEF concept
  d. Experimental results
    i. Lack of lattice thermalization in solid-state targets (Fe_3O_4 from LD67).
    ii. Valence reorganization upon x-ray heating (LK20 MgO and Fe_3O_4)
    iii. Time evolution of electronic reorganization (LK20 Fe_3O_4 long pulse vs. short pulse)
    iv. Nonlocal heat transport: LD67 micro/nano Fe_3O_4.
    v. HEF qualitative result: SEM of clad/unclad LK20 mica samples.
    vi. What else? Depends on outcome of analysis for LK20 graphite, HEF oxides.

4. Appendix: instrument development for laser plasma physics and lab spectroscopy
  a. CMOS camera RSI
  b. Minisoft?