Warm Dense Matter and Plasma Related Studies with Short Pulse X-ray Light Sources

R. W. Lee
LLNL / L-411 P.O. Box 808 Livermore, CA 94551

Warm Dense Matter refers to that part of the density-temperature phase space where the standard theories of condensed matter physics and/or plasma statistical physics are invalid. Thus, warm dense matter refers, on the one hand, to states from liquid to greater than solid density with temperatures comparable to the Fermi energy. On the other hand, it includes those states of matter that are plasma-like, but are too dense and/or too cold to admit to standard solutions used in plasma physics. This is the region where plasmas become strongly coupled and perturbation approaches fail as no small expansion parameters exist. Warm dense matter therefore defines a region between solids and plasmas. Experiments in the warm dense matter regime represent some of the most straightforward applications of short duration pulse light sources as it can employ the source directly as the heating mechanism in a manner that is elegant yet unachievable with any other sources. The areas we will discuss can be separated broadly into warm dense matter (WDM) research, laser probing of near solid density plasmas, and laser-plasma spectroscopy of ions in plasmas.

The study of dense plasmas has been severely hampered by the fact that laser-based methods have been unavailable. The single most useful diagnostic of local plasma conditions, *e.g.*, the temperature (T_e), the density (n_e), and the ionization (Z) has been Thomson scattering. However, due to the fact that the critical electron density where visible light will not propagate, is ~ 10^{22} cm^{-3} indicates that near-solid density plasmas can not be probed. The future short pulse x-ray light sources will remove this impediment by making high density plasmas accessible for the first time. Moreover, as plasmas become denser one reaches regime where ideal plasma theories break down and this will certainly occur in cool dense plasmas. Thus, by probing different scattering angles one can move from non-collective to collective regimes where plasma theory remains to be tested.

Laser based plasma spectroscopic techniques other than Thomson scattering have been used with great success to determine the line shapes of atomic transitions in plasmas, study the population kinetics of atomic systems embedded in plasmas, and look at redistribution of radiation. However, as with Thomson scattering the possibilities end at plasmas with electron densities > 10^{21} since light propagation through the medium is severely altered by the plasma. This will change when we have intense x-ray sources that have short pulse length. The entire field of high Z plasma kinetics from laser produced plasma will then be available to study with the tunable source. As an example, one can study the underlying mechanisms that are currently used to produce soft x-ray lasers. Probing the kinetics of ion stages to test the gain of a potential laser scheme represents one of the most exacting tests of our ability to understand the kinetics of ions embedded in plasmas.

These areas will be discussed with a view to explaining the applicability of these future sources to these problems