The Creation of Radiation Dominated Plasmas using Laboratory X-ray Lasers

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Abstracts: When short wavelength extreme ultra-violet (EUV) and x-ray laser radiation is focused onto solid targets, narrow deep features are ablated and a dense, low temperature plasma is formed. We examine the radiation dominated plasma formed by 46.9 nm laser radiation focused onto solids and show that ionization is significantly modified by electron degeneracy effects. A capillary discharge laser operating at wavelength 46.9 nm is to be installed at the University of York. Some experimental and theoretical considerations for investigating the laser interaction with solid targets will be presented.

Extreme ultra-violet (EUV) and x-ray lasers can be used to generate strongly coupled plasmas and 'warm dense' matter. Targets irradiated by EUV and x-ray lasers are heated predominantly by direct photoionization. With photo-ionization as a dominant heating mechanism, lower temperature and higher particle density plasmas are produced. With all laser-produced plasmas, an expanding plume of plasma allows only absorption where the electron density drops below a critical value ($\simeq 10^{21}/\lambda^2$ μm cm^{-3}, where λ is the laser wavelength in units of microns). By reducing the wavelength into the EUV to x-ray region, the critical electron density is greater than solid and the laser photon energy E_p becomes sufficient to directly photoionize elemental components (ionization energy E_i), transferring energy ($E_p - E_i$) to the ejected electron. As the critical electron density is higher than solid, the laser is able to penetrate any expanding plasma plume and heat solid material directly throughout the duration of a laser pulse.

We explore in this talk the potential for creating narrow and deep features by EUV laser ablation of solids, and also for using the plasma created by EUV lasers as sources for warm dense matter. Our calculations show that the ionization of plasma can be affected by free electron degeneracy effects with overlap to the plasma conditions found in inertial fusion, where degenerate plasma is created during x-ray driven compression of material. The use of a capillary laser operating at 46.9 nm in producing high density degenerate plasma will be explored.