Nanosecond and femtosecond pulsed laser ablation of metals: Plume characterisation and nanomaterial synthesis

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Laser ablation at intensities just above the threshold for bulk material removal (~10^8 W cm^{-2} for nanosecond ablation and ~10^{12} W cm^{-2} for femtosecond ablation) is used to remove material from a solid target which can be deposited on an acceptor substrate in a process that is known as pulsed laser deposition (PLD). PLD has been extensively used for the growth of complex multi-component thin films as well as different nanomaterial configurations. Although PLD has seen widespread use for materials research the ablation mechanisms and the expansion dynamics of the laser removed material are not fully understood. Many fundamental laser ablation studies are performed for simple ablation geometries in vacuum and use low-Z targets for which atomic data is readily available. More often, however new functional material synthesis involves complex ablation geometries in non-vacuum environments using high-Z and/or multi-component target materials for which atomic data is not readily available.

I will describe the results of some recent experiments on nanosecond and femtosecond laser ablation of different metals. We have studied the dynamics of both the plasma and nanoparticle components of the laser ablation plume using a combination of Langmuir ion probes, optical emission spectroscopy and time-resolved optical absorption. For femtosecond laser ablation it is shown that only a small fraction of the ablated material is removed as plasma which moves at ~10^6 cm s^{-2}. A larger fraction leaves the target as a hot nanoparticle mist moving at ~2×10^4 cm s^{-2}. The optical emission and absorption properties of the nanoparticle mist are analysed by taking account of the wavelength dependence of the nanoparticle emissivity. The nanoparticle plume density and temperature is extracted from absolutely calibrated emission spectra and the density measurements are compared to nanoparticle density measurements made using a novel time and space resolving laser absorption technique. Different behaviour in the synthesis of nanomaterial using nanosecond and femtosecond laser ablation will be highlighted.