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INERTIAL CONFINEMENT FUSION AND FAST IGNITOR STUDIES

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The paper reviews inertial confinement fusion research carried out at several different laser facilities including the VULCAN laser at the Rutherford Appleton Laboratory, the TRIDENT laser at the Los Alamos National Laboratory and the PHEBUS laser at Limeil. Experimental investigations using laser and x-ray drives have been performed.

For laser fusion, it is essential that a high degree of symmetry is maintained during the implosion phase. Asymmetries in the ablation pressure must be smaller than a few precent, otherwise an unacceptable level of instability growth occurs, reducing the fusion gain. In direct drive laser fusion, laser imprinting is a serious problem as any perturbation is a seed for the Rayleigh-Taylor instability [1]. Imprinting has been studied both computationally and experimentally. In particular, the saturation of areal density perturbations induced by near-single mode laser imprinting has been observed experimentally in polystyrene foam targets using face-on, soft x-ray radiography at a photon energy of 250eV [2]. In response to spatially modulated irradiation, the initially uniform foams exhibited near-linear growth of perturbations, which subsequently saturated and decayed prior to the end of the laser pulse. 2D numerical simulations agree well with the experimental results and predict that saturation occurs prior to shock breakout. The numerical and experimental results are compared with scaling laws.

Laser driven shock waves propagating in foam targets have been diagnosed by side on time resolved K-shell absorption spectroscopy obtaining ionization and density distributions in the shocked material [3]. A detailed atomic physics model was matched to the absorption spectra to infer the temperature distribution. 2D radiation-hydrodynamic modelling reproduced the experimental results.

Laser heated targets of comprising layers of gold, low density foam and plastic with an embedded aluminium tracer layer have been used to study radiation waves, shock waves and ablation fronts. The ionization in the aluminium layer was used as a diagnostic of the target conditions. The resulting temporal ionization profiles were compared to the predictions of a radiation hydrodynamics code running an in line non local thermodynamic equilibrium (non-LTE) atomic physics model. Modelling of the radiative heating and emission were in reasonable agreement with the experimental measurements.

The ablation pressure scaling of soft x-ray irradiated brominated plastic targets was obtained for different soft x-ray fluxes and pulse shapes with radiation temperatures between 70 and 200eV. The rear side trajectory of driven foil targets was observed using soft x-ray radiography at a photon energy of 250eV and was compared to hydrodynamic simulations allowing the ablation pressure to be obtained. The experimental results are compared to published scaling laws.

The transition from super- to subsonic propagation of an ionization front has been observed in low density clorinated foam targets irradiated by an intense soft x-ray pulse using time resolved, K-shell x-ray absorption spectroscopy. Density and temperature profiles were obtained from the absorption spectra. The experimental observations were compared to radiation hydrodynamic simulations.

The Rayleigh-Taylor instability was studied in the short wavelength regime using single mode targets which were driven by hohlraum radiation allowing the Takabe-Morse roll-over due to ablative stabilisation to be determined. A cylindrical hohlraum was heated with a number of laser beams. A radiation temperature of about 130 eV was obtained. Targets with sinusoidal modulations with wavelengths between 6 and 24 μm were used. The targets were probed at an x-ray energy of 250 eV with a spatial resolution < 2μm. The backlighter was either the hohlraum radiation itself or a laser irradiated gold target.

Relativisitic self-channeling of a picosecond laser pulse in a preformed plasma near critical density has been observed using optical probing [4]. Intense, localised second harmonic emission and interferometric measurements indicate the formation of a single pulsating propagation channel, typically less than 5 μm in diameter and extending over several Rayleigh lengths. A three-dimensional particle-in-cell code has been used to model the experimental results. The simulations reveal that the relativistic electrons are comoving with the light pulse and generating multi-Megagauss magnetic fields that pinch the electrons.

Magnetic fields in the Megagauss range have been measured, with a polarimetric technique, during and after propagation of relativistically intense picosecond pulses through preionised plasmas [5]. Two type of toroidal fields, of opposite orientation, generated through different mechanisms, were detected. A three dimensional Particle in Cell code was used to simulate the field generation during the interaction. Also, important indications about the plasma behaviour after the interaction were given by 1-D magneto-hydrodynamic simulations, that confirmed some of the experimental observations.

Efficient guiding of 1 ps infrared laser pulses with power exceeding 10 TW has been demonstrated through hollow capillary tubes with 40 and 100 μm internal diameters and lengths up to 10 mm, with transmittivity higher than 80% of the incident energy. The beam is guided via multiple reflections off a plasma formed on the walls of the guide by the pulse's rising edge, as inferred from optical probe measurements.

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