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Nail-like targets for laser plasma interaction experiments

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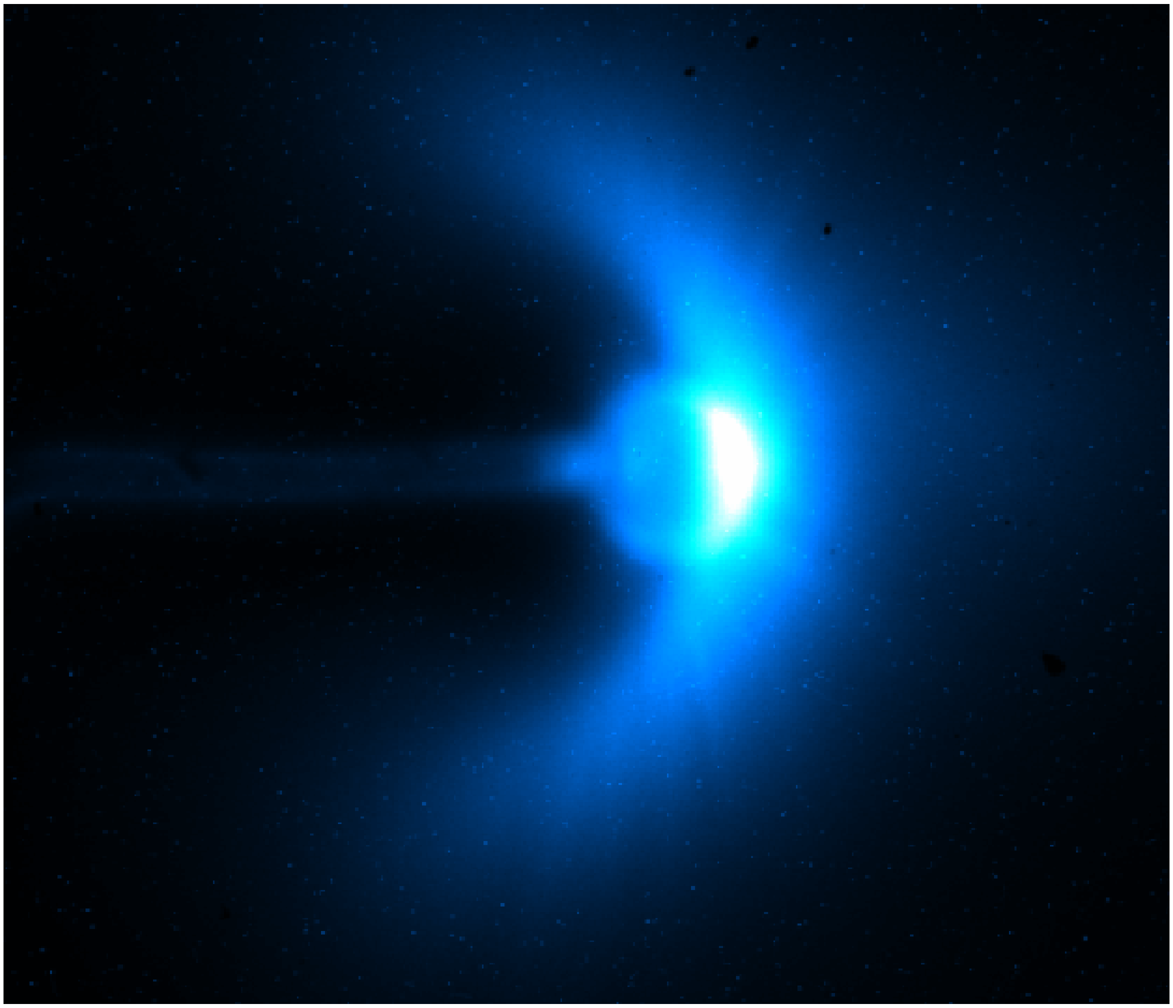

Fig. 1. Extreme Ultra Violet emission from a “nail-like” Cu/Ti target under the action of the ultra-high power picosecond arm of the Titan Laser

Abstract **– The interaction of ultra-high power picosecond laser pulses with solid targets is of interest both for benchmarking the results of hybrid particle in cell (PIC) codes and also for applications to re-entrant cone guided fast ignition. We describe the construction of novel targets in which copper/titanium wires are formed into “nail-like” objects by a process of melting and micro-machining, so that energy can be reliably coupled to a 24μm diameter wire. An extreme-ultraviolet image of the interaction of the Titan laser with such a target is shown.**

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In ultra-high power laser-solid interaction experiments it is often of interest to concentrate the energy of the laser within an object of the minimum possible mass, for a given target type. This enables the highest energy density to be achieved within the target as a whole, and thereby permits the investigation of the most extreme physical conditions [1]. However, real laser systems possess three qualities that tend to inhibit the attainment of extreme conditions by this approach. The first of these is that the real focal spot size is greater than the diffraction limited spot size, due to imperfections of the optical components in the laser chain, misalignment, and other aberrations. The second is that ultra-high power lasers based around the chirped pulse amplification (CPA) methodology present the target with a 'pre-pulse' of approximately nanosecond duration. This prepulse, given that the intensity contrast ratio with respect to the main pulse is unlikely to be better than 10^{-7}, in absence of expensive and/or energy losing mitigation approaches such as plasma mirrors or frequency doubling, will expose the target to significant photon flux given the intensity of the main pulse will typically be on the order of 10^{20}W/cm^2. The third factor is that of laser pointing stability. Pointing stability tends to limit the aiming accuracy of an ultrahigh power laser to little better than 20μm. High energy (100's of Joules) CPA lasers are invariably glass based laser systems, therefore shot rates tend to be quite low (less than 1mHz), so operating on the basis of hitting only a small percentage of targets in a desirable location is impractical. Therefore the practical limiting target dimension in the transverse plane is around 50μm, and usually rather more than this, particularly if the target is intended to be struck centrally.

In the present investigation [2], the intention is to couple a significant fraction of the laser energy into a wire of small diameter. This is of interest to explore the transport of high energy (~MeV) laser generated electrons over distances comparable to the electron mean free path (hundreds of microns) in a high density, initially cold, system, that is of sufficiently low mass to be amenable to modeling with PIC hybrid codes. Such codes must resolve the Debye length so solid targets usually place insurmountable demands on processor time if they are to be modeled in their entirety. A narrow metal wire is also interesting since it can be quasi transparent to its own K-shell radiation, permitting direct observation of emission from all depths within the target. Also, as previously discussed, low mass targets can in principle enable the exploration of the most extreme conditions, and it was of interest to explore the limiting current densities that could be produced, with a view to fast ignition applications.

To overcome the constraints imposed by the laser pointing stability, "nail-like" wire targets were proposed. The targets, manufactured by General Atomics, are 20μm diameter solid Cu wires with an approximately 80μm diameter, roughly hemispherical termination. They are fabricated by melting the tip of the wire with a pulse of Nd:YAG laser light, and then machining down the resulting melt-globule. The heating is performed in an inert atmosphere (argon) to prevent oxidation. The machined flat surface of the 'nail head' has ~80μm diameter. The Cu nail targets employed in the experiment were also sputter coated with 2μm of Ti prior to the machining. An ~ 90^{O} bend ~ 1mm from the flat face of the nail head is formed allowing the farther end of the wire to be mounted vertically on an aluminum post (with non-electrically-conducting glue) with the ~1mm long section, terminated by the nail head, horizontal. The fabrication of the targets had some irreproducibility in radius of curvature of the nail head and the hemisphere was also sometimes offset relative to the wire axis. The nail-head is approximately an order of magnitude less massive than the cones employed in the experiment described in ref. 3, and represents only around 50% of the mass of the horizontal portion of the wire.

An ~500fs, ~200J pulse of 1.053μm laser light from the Titan laser [4] is focused to an ~ 20μm diameter spot, centered with 20μm pointing accuracy [5] on the flat face of the nail head. The striking image presented in figure 1 shows such an interaction in the X-UV, at 68eV captured with a multi-layer mirror based imaging system. From this image it can be seen that the expanding plasma halo wraps around the wire, possibly due to magnetic confinement. Filamentary structures appear to extend out through the coronal plasma, reminiscent of the coronal streams seen in the solar atmosphere. Care must be taken in interpretation however, since this is a time integrated image.

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