Heavy Ion Fusion Sciences Virtual National Laboratory

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HIFS News

Progress in beam compression and target physics on NDCX-I

Fig 1: NDCX-I facility and HIFS-VNL staff at LBNL.

Intense ion beams have several attractive features as a technique for generating warm dense matter (WDM): i) precise control of local beam energy deposition dE/dx, nearly uniform throughout a given volume, and not strongly affected by target temperature, ii) large heated sample sizes (about 1 micron thick by 0.2-0.5 mm diameter), iii) the ability to heat any target material, for example, foams, powders, conductors, insulators, solid, gas, etc.

The WDM conditions are achieved by combined longitudinal and transverse space-charge neutralized drift compression of the ion beam to provide a hot spot on the target with a beam spot size of about 1 mm, and compressed pulse length about 2 ns. The experiments use a ~0.3 MeV, ~30-mA K^+ beam (below the Bragg peak) from the NDCX-I accelerator to heat foil targets such as Au, Al and Si. The NDCX-I beam contains an uncompressed pulse length up to 20 µs with an energy flux ≈600 kW/cm^2, and a compressed pulse of fluence ~10 mJ/cm^2. The required beam intensity calls for space charge neutralization, which is achieved with a background plasma through which the beam passes while it is focusing transversely and bunching longitudinally [1]. The plasma density in the target chamber has been increased and now mostly exceeds the on-axis beam density. The cathodic arc plasma yields a plasma density of $0.9 – 6 \times 10^{13}$ /cm^3.

For 330 kV diode extraction voltage the uncompressed beam current is 36 mA. Thus, the beam is delivering 12 kW beam power over the flattop region. For a tune that optimizes the compressed beam fluence, the variation of spot radius with beam current (and power) is shown in Fig 2. Here the changes to the spot radius and transverse distribution are evident in this time scan across the compression peak. The peak beam current is 1.5 A. At peak compression, 50% of the beam flux is within a radius of 1.5 mm, a radius approximately 2x smaller than results prior to installation of the final focusing solenoid and improvements to the plasma sources in the target chamber.

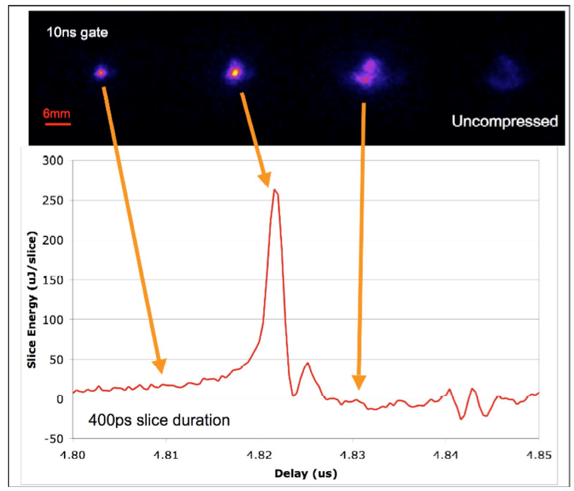

Fig. 2: Time-dependent transverse beam distributions demonstrating the simultaneous transverse focusing at the time of peak compression. The peak is ≈2.5 ns FWHM.

The WDM target diagnostics include a high-speed multi-channel optical pyrometer, optical streak camera, VISAR, and high-speed gated cameras [2-4]. The fast optical pyrometer is a unique and significant new diagnostic providing valuable information on the temperature evolution of the heated target. In those experiments, the beam heated 150-nm Au targets above 3000 K. The new target holder includes remote controlled motor drives for two degrees of freedom of remote positioning of the target. These include 2 axes on the target positioner and 2 axes on the light collection optics table (previously there was only 1 axis of motor drive on the light collection optics table). This improvement allows us to remotely position the target and target assembly without breaking vacuum to move the target to an undamaged spot. The target contains a set of improved fiducials and alignment aids for speeding up the process of alignment of the target and light collection optics. In the first test of the new remote-controlled target positioning system, we completed three successful target physics shots in less than two hours. We have also installed a new beam current monitor downstream of the target, for measuring beam current transmitted through the target as a function of time, which provides information on time evolution of the internal structure of the target foil.

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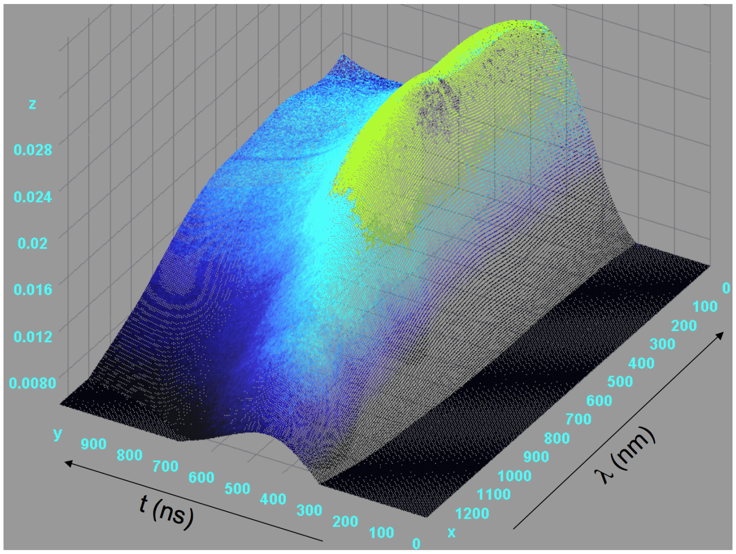

Fig. 3: Surface plot of absolute spectrum of optical emission from heated carbon target.

Based on fast optical pyrometer data, thin gold and carbon foil targets are heated to the temperature range 3000-4000 K by the portion of the uncompressed beam (1 μs) that precedes the bunched beam. Additional heating by the compressed pulse is observed.

Continued improvements in beam tuning, bunch compression, and other upgrades are expected to yield higher temperature and pressure in the WDM targets. Beam shots using the new NDCX-I configuration have been performed using a 400-nm carbon foil target. Streak-spectrometer data (Fig. 3) indicate a peak target temperature of 4000 K [3].

Since these preliminary target heating experiments, we have installed a new induction bunching module (IBM) with 20 induction core units and nearly twice the Volt-seconds of the previous IBM. The drift compression distance was doubled via extension of the ferro-electric plasma source (FEPS), to limit chromatic aberrations. This is expected to lead to higher intensities and a wide variety of target physics experiments.

- F.M. Bieniosek and P.A. Seidl

[1] P.A. Seidl et al., Nucl. Inst. and Meth., A 606 (2009)
http://dx.doi.org/10.1016/j.nima.2009.03.254

[2] HIFS-VNL 3rd Quarter 2008 milestone report, June 12, 2008
http://hifweb.lbl.gov/hifnews/attachments2009/FY08Q3reportHIFSVNL.pdf

[3] HIFS-VNL 4th Quarter 2008 milestone report, Sept. 16, 2008
http://hifweb.lbl.gov/hifnews/attachments2009/FY08Q4reportHIFSVNL.pdf

[4] HIFS-VNL 2nd Quarter 2009 milestone report, March 31, 2009
http://hifweb.lbl.gov/hifnews/attachments2009/FY09Q2reportHIFSVNL.pdf

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