Monthly Accomplishments

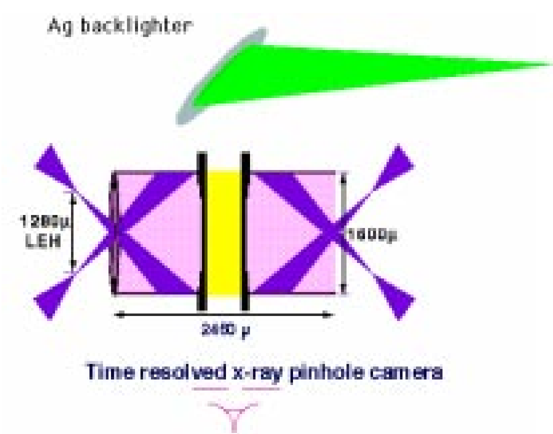
Los Alamos
Inertial Confinement Fusion

No. 5 *December 1997*

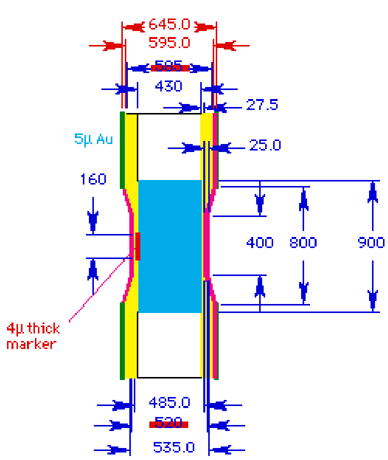
Observations of Nonlinear Mode Coupling in Cylindrical Implosions

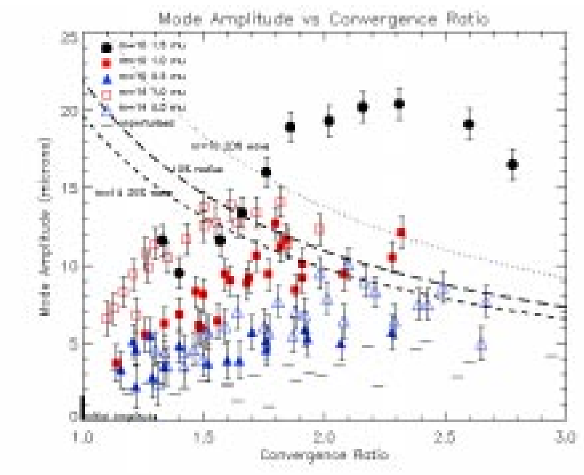
Cris W. Barnes, W. Hsing, J. Beck, N. Hoffman, H. Bush, R. Day, P. Gobby, D. Hatch, J. Moore, V. Gomez, G. Rivera, J. Salzer

Understanding hydrodynamic instability in convergent and compressible systems is important for ICF ignition and nuclear weapons. Cylindrical implosions can provide physical insight into hydrodynamics issues because cylindrical geometry allows for excellent diagnostic access along a line of sight and simplifies modeling implosions to two dimensions.



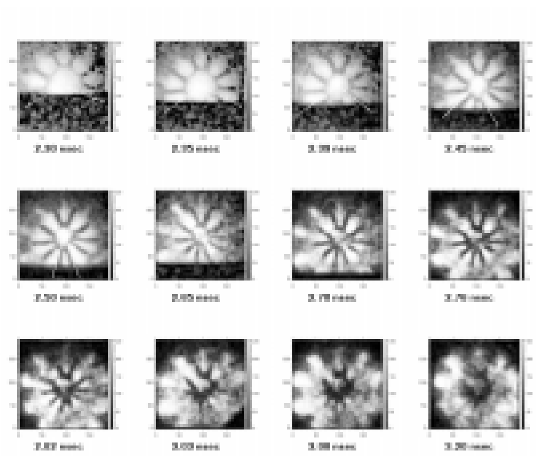
Cylindrical implosions using indirect-drive have been developed using the Nova laser at the Lawrence Livermore National Laboratory. [Hsing and Hoffman, *Phys. Rev. Lett.*, **78** (20):3876, 1997; Hsing *et al.*, *Phys. Plasmas*, **4** (5):1832, 1997.] The cylinder extends in length transversely across the entire diameter of Scale-1 Nova hohlraum, which is driven using pulse shape 26 (a shaped pulse with 2.2-ns duration and a 5-to-1 peak-to-foot contrast) with eight Nova beams with 24 kJ total energy. The eight beams are arranged symmetrically around the cylinder in the hohlraum to provide the best drive symmetry possible, but still give an initial m=4 azimuthal variation of illumination. The implosions are radiographed axially by a gated x-ray pinhole imaging system using a silver backlighter on the far side. The cylinder of the target, 472 microns in outer diameter, has a brominated polystyrene ablator over a plain polystyrene pusher with a 60 mg/cc CH foam insert of 430 microns inner diameter. The cylinder is shielded by gold coating at its ends and is tapered along its length so that only about a 300 micron waist region implodes. The axial length is further defined by a thin 160 micron long chlorinated polystyrene marker layer between the plain plastic and the foam; however, a recent test has confirmed that most of the radiographic contrast comes from radial densification of the implosion and not from the opacity of the chlorinated marker. Perturbations are machined azimuthally on the outside of the ablator. A sequence of over 15 targets has now been shot with nearly identical conditions with only the mode number (either m=10 or 14) or amplitude of the machined perturbation varied. Perturbations on the marker layer





can only be measured after the cylinder has imploded by over 20%.

Our physical understanding of instabilities in cylindrical implosioins falls into three phases:
(1) Initial ablative Rayleigh-Taylor (ART) instability growth at the ablation front occurs, and the perturbations feed-in to the marker region (of higher compressed density at the plastic-foam interface). In these experiments the acceleration tends to occur only while the convergence ratio is less than about 1.5. Hence the ART growth sets the initial amplitude observed in the experiment. The mode m=14 grows faster from the ART than the m=10.
(2) The perturbations continue to grow during convergence even in the absence of acceleration. This "crenulation" effect attributed to Bell [Bell, Technical Report LA-1321, Los Alamos Scientific Laboratory, Nov. 1951.] and Plesset [Plesset, *J. Appl. Phys.*, **25** (1):96, 1954.] is a feature of all convergent implosions that act incompressibly. As a ring or shell of material converges, to maintain its volume at reduced radius it must thicken and its wrinkles must grow. In these cylindrical experiments, all the perturbations appear to grow at the same rate independent of size, even when the perturbations exceed usual "nonlinearity conditions" such as the amplitude being a significant fraction of the wavelength or radius. All these perturbations remain linear during the ART phase, and the growth factors for the same mode number are the same during the entire implosion.
(3) There is second-order weakly nonlinear mode coupling between the machined perturbations and the m=4 illumination asymmetry caused by the eight laser beams in the hohlraum. This leads to m=10+4=14 and m=10-4=6 modes, whose phase and amplitude appear consistent (within factors of two) with theory [Haan, *Phys. Fluids B*, **3** (8):2349, 1991.] when derived for convergent geometry.



These nonlinear effects recently were studied in detail using a target with the largest initial amplitude yet tried, a m=10, five micron perturbation. This amplitude was chosen to go nonlinear during the ART phase. The figure below shows a montage of images from this shot. Several features can be seen: rod-like spikes have steepened, and for the first time in these experiments, developed observable harmonics of the fundamental; clear phase reversal at the ablation surface (the outer dark region); and late in time the spikes "crush in" from compressibility effects of the Bell-Plesset growth.

The physics studies of convergent hydrodynamics will continue using direct-drive illumination at the Omega at the University of Rochester. The increased efficiency of coupling energy into direct-drive implosions along with advances in smooth beam illumination should allow cylinders twice as large to be imploded with corresponding increase in growth factors and resolution.

Los Alamos
Inertial Confinement Fusion