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NDCX-II project commencing at LBNL

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NDCX-II is the second-generation Neutralized Drift Compression eXperiment, capable of accelerating and strongly bunching tens of nanoCoulombs of non-relativistic ions, for applications requiring nanosecond-scale pulses with short stopping ranges. As with the existing NDCX-I at Lawrence Berkeley National Laboratory (LBNL), the new machine is based on the technique of neutralized drift compression, whereby a head-to-tail velocity gradient is imparted to the beam, which then shortens as it drifts in a neutralizing plasma that suppresses space-charge forces.

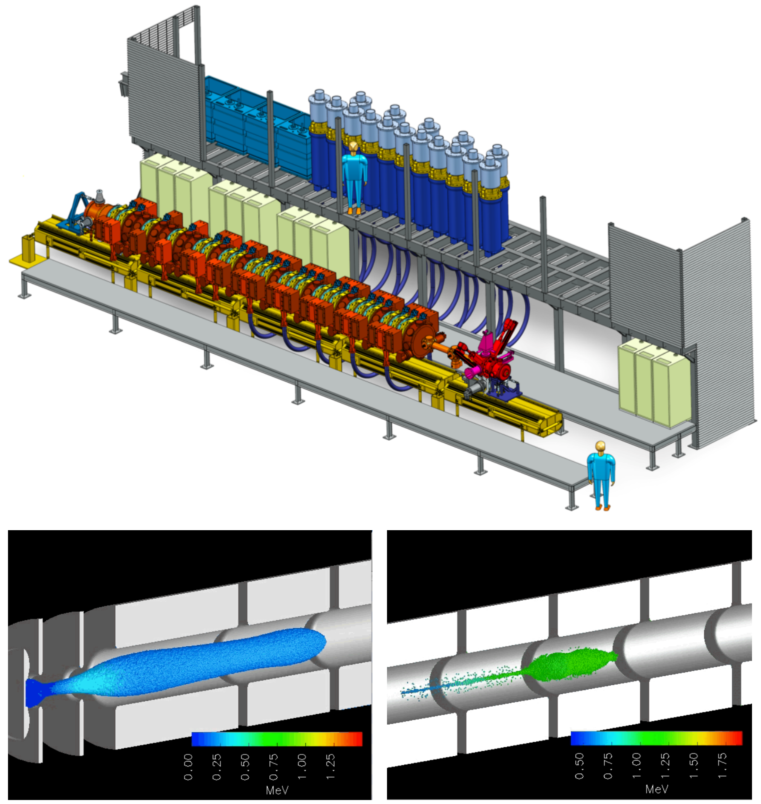
The figure shows the layout of the machine, to be sited at LBNL. It will make extensive use of induction cells and other parts from the decommissioned Advanced Test Accelerator (ATA) at Lawrence Livermore National Laboratory (LLNL). It will be extensible and reconfigurable; in the configuration that has received the most emphasis, each pulse will deliver 30-50 nC of Li^+ ions at 3 MeV into a mm-scale spot onto a thin-foil target. Pulse compression to ~ 1 ns begins in the accelerator and finishes in the drift compression line; the beam is manipulated using suitably tailored voltage waveforms in the accelerating gaps.

NDCX-II employs novel beam dynamics. To use the 200 kV Blumlein pulsed power from ATA (blue cylinders in the figure), the pulse duration must first be reduced from an initial 500 ns to less than 70 ns. This shortening is accomplished in an initial stage of non-neutral drift compression, downstream of the injector and the first few induction cells (note the spaces between induction cells at the left end of the figure). The compression is rapid enough that fewer than ten long-pulse waveform generators are needed, with Blumleins powering the rest of the acceleration.

Extensive particle-in-cell simulation studies have enabled an attractive physics design that meets the stringent cost goal. Snapshots from a simulation video are shown in the figure. Studies on a dedicated test stand are characterizing the performance of the ATA hardware, and of pulsed solenoids that will provide transverse beam confinement (ions require much stronger fields than the electrons accelerated by ATA).

Applications of this facility will include studies of: the basic physics of the poorly understood “warm dense matter” regime of temperatures around 10,000 K and densities near solid, using uniform, volumetric ion heating of thin foil targets; ion energy coupling into an ablating plasma (such as that which occurs in an inertial fusion target) using beams with time-varying kinetic energy; space-charge-dominated ion beam dynamics; and beam focusing and pulse compression in neutralizing plasma. The machine will complement facilities at GSI in Darmstadt, Germany, but will employ lower ion kinetic energies and commensurately shorter stopping ranges in matter.

Much of this research will contribute directly toward the collaboration's ultimate goal of electric power production via heavy-ion beam-driven inertial confinement fusion (“Heavy-Ion Fusion,” or HIF). In inertial fusion, a target containing fusion fuel is heated by energetic “driver” beams, and undergoes a miniature thermonuclear explosion. Currently the largest U.S. research program in inertial confinement is at Livermore’s National Ignition Facility (NIF), a multibillion-dollar, stadium-sized laser facility that was developed for studying physics relevant to nuclear stockpile stewardship. NIF is expected to establish the fundamental feasibility of fusion ignition on the laboratory scale, and to thereby advance this approach to fusion energy. Heavy ion accelerators offer efficiency and longevity, and can use magnetic fields for final focusing onto a target. These attributes make them attractive candidates as inertial fusion energy drivers. The space-charge-dominated beams in such a system will require manipulation and control similar to that being pioneered on NDCX-II.



Computer-aided-design of NDCX-II, and simulation of its ion beam. The ion source and injector are at left; voltage sources (blue) reside on a mezzanine; the induction cells are in yellow-orange; and the drift-compression line and target chamber are at right. The lower images (from a 3-D simulation video using the Warp code) show the beam at the injector and farther on, undergoing inductive acceleration.

NDCX-II is sponsored by the U.S. Department of Energy Office of Fusion Energy Sciences, and has received $11 M of funding from the American Recovery and Reinvestment Act; construction commenced in July, 2009, with completion anticipated in March, 2012. The project is being developed by a formal collaboration known as the Virtual National Laboratory for Heavy Ion Fusion Science (HIFS-VNL), including LBNL, LLNL, and the Princeton Plasma Physics Laboratory (PPPL).

Further reading

A recent article in the Berkeley Lab News is available at http://newscenter.lbl.gov/feature-stories/2009/10/14/warm-dense-matter; see also references therein. The video can be viewed at http://hifweb.lbl.gov/public/movies/ICAP09.

Joe Kwan is the NDCX-II project manager and Alex Friedman is the leader for the physics design.

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