STATUS OF THE NEUTRALIZED DRIFT COMPRESSION EXPERIMENT (NDCX-II)*

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Abstract

The Neutralized Drift Compression Experiment (NDCX-II) is an 11 M$ induction accelerator project currently in construction at Lawrence Berkeley National Laboratory for warm dense matter (WDM) experiments investigating the interaction of ion beams with matter at elevated temperature and pressure. The machine consists of a lithium injector, induction accelerator cells, diagnostic cells, a neutralized drift compression line, a final focus solenoid, and a target chamber. The induction cells and some of the pulsed power systems have been reused from the decommissioned Advanced Test Accelerator at Lawrence Livermore National Laboratory after refurbishment and modification. The machine relies on a sequence of acceleration waveforms to longitudinally compress the initial ion pulse from 600 ns to less than 1 ns in ~ 12 m. Radial confinement of the beam is achieved with 2.5 T pulsed solenoids. In the initial hardware configuration, 50 nC of Li^+ will be accelerated to 1.25 MeV and allowed to drift-compress to a peak current of ~40 A. The project started in the summer of 2009. Construction of the accelerator will be completed in the fall of 2011 and will provide a worldwide unique opportunity for ion-driven warm dense matter experiments as well as research related to novel beam manipulations for heavy ion fusion drivers.

INTRODUCTION

The Heavy Ion Fusion Science Virtual National Laboratory (HIFS-VNL) is currently building NDCX-II, the second phase of the Neutralized Drift Compression Experiment, which will use an ion beam to explore Warm Dense Matter (WDM) and Inertial Fusion Energy (IFE) target hydrodynamics [1, 2]. The first phase of the Neutralized Drift Compression Experiment (NDCX-I) has successfully demonstrated simultaneous radial and longitudinal compression using a technique of imparting a velocity ramp on the ion beam, letting the beam drift through a neutralizing plasma to offset space-charge forces, and applying a high solenoidal field before the target [3, 4]. The NDCX-II ion induction accelerator includes a new short pulse lithium injector and modified induction cells and pulsed power systems from the decommissioned Advanced Test Accelerator (ATA) at Lawrence Livermore National Laboratory (LLNL) [5]. The pulsed power systems from ATA generate up to 250 kV pulses with a fixed FWHM pulsewidth of 70 ns from a Blumlein. Because the flat-top beam pulsewidth out of the injector is 600 ns, there are custom pulsed power systems to generate the required waveforms to quickly compress the beam down to 70 ns. After this compression has been achieved, the fixed volt-seconds of the ferrite cores can then be used to efficiently add energy to the beam.

Table 1: NDCX-I and NDCX-II Parameters

	NDCX-I (typical bunched beam)	NDCX-II 12-cell (r,z simulation)
Ion species	K^+ (A=39)	Li^+ (A=7)
Total charge	15 nC	50 nC
Ion kinetic energy	0.3 MeV	1.25 MeV
Focal radius (containing 50% of beam)	2 mm	0.6 mm
Bunch duration (FWHM)	2 ns	0.6 ns
Peak current	3 A	38 A
Peak energy fluence (time integrated)	0.03 J/cm^2	8.6 J/cm^2

BASELINE HARDWARE CONFIGURATION

The baseline hardware configuration shown in Figures 1 and 2 include 27 lattice periods between the injector and the neutralized drift compression section and target chamber. There are 12 energized induction cells (red) which impart voltage waveforms for compression and acceleration, 9 inactive accelerator cells (pink) which are used for drift space, and 6 diagnostic cells (blue) which provide vacuum pumping ports as well as beam diagnostics. After the last induction cell, there is a neutralized drift section and target chamber configuration very similar to NDCX-I.

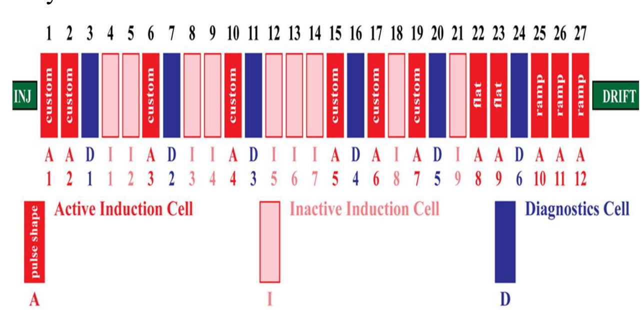

Figure 1: NDCX-II baseline hardware configuration.

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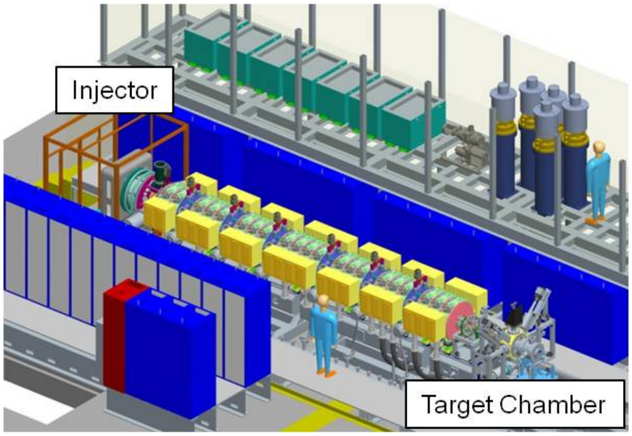

Figure 2: NDCX-II CAD model.

FACILITY PREPARATION

The power for the facility is provided by two 225 kVA transformers. The installation of these transformers and the associated distribution panels is almost complete. This will be followed by installing the power distribution from these main panels to the 22 equipment platform racks and the 28 solenoid pulser racks.

The large volume of high voltage insulating oil contained in the induction cells and pulsed power systems requires secondary containment. This has been accomplished by installing a birm around the beamline and pulsed power systems, and sealing the floor with a polyurea/polyurethane coating. A copper ground plane is currently being installed under the beamline and will be followed by the accelerator support and alignment structure.

Because the ATA Blumleins use deionized water as a dielectric, a water processing system to recirculate and filter the water to achieve 18 Mohm-cm resistivity is required. An oil processing system is also required to recirculate, filter, and degas the high voltage insulating oil. These two systems have been utilized over the last few years for tests on individual induction cells and pulsed power systems and are ready to be installed.

ION SOURCE AND INJECTOR

The fabrication and installation of the lithium ion source and the 130 keV injector are the critical path activities for the project. Small diameter (0.64 cm) lithium doped alumino-silicate ion sources have been produced and have demonstrated the required current density and acceptable lifetime [6]. A 7.6 cm diameter source has been successfully produced to verify that the coating method can be applied to a larger area source. The tungsten substrate for the full size (10.9 cm diameter) ion source has been delivered and the surface is currently being etched in preparation for coating.

The injector design is complete and the long lead components have been ordered. The design consists of the ion source and heater assembly, a graded ceramic high voltage column, high voltage electrodes, a segmented Rogowski coil, and a pulsed solenoid to prevent radial beam expansion before the first induction cell [7]. A significant effort has been made to manage the 4 kW required to heat the source to 1275 °C.

INDUCTION CELLS, DIAGNOSTIC CELLS, AND PULSED POWER SYSTEMS

A major effort associated with this project has been to modify the ATA induction cells to replace the DC solenoids with 2.5 T pulsed solenoids as shown in Figure 3. The beampipe diameter has been decreased to reduce the axial extent of the solenoid fringe fields and to make room for the water-cooled pulsed solenoid and a water-cooled copper cylinder to exclude the solenoid magnetic flux from the ferrite cores. Testing of the first article induction cell and solenoid identified the need to also include forced air cooling of the solenoid assembly and beampipe because of excessive eddy current heating. All of the induction cells have been modified and the solenoids are being wound and potted. The 28 pulser racks which drive the solenoids have been assembled and will be installed after the floor has been prepared.

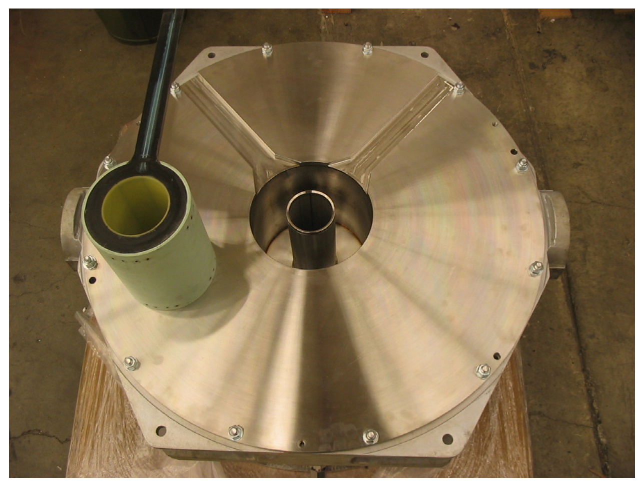
Figure 3: Modified ATA induction cell and potted 2.5 T pulsed solenoid assembly.

There are 6 diagnostic cells which serve as vacuum pumping ports and contain a transport solenoid and beam position monitors. There is an upgrade plan to implement a removable solenoid design to allow the insertion of intercepting beam diagnostics such as scintillators and faraday cups. Several of the diagnostic cells have been received.

The compression section pulsers for the first 7 energized induction cells are in production assembly. The ATA Blumlein pulsed power systems to drive the last 5 induction cells have been partially refurbished. The switch chassis which charge the Blumleins have been modified for DC charging and are installed. The Blumleins will be refurbished after the last induction cells are assembled and installed on the beamline. Blumlein refurbishment includes disassembly and cleaning as well as replacing the cast epoxy insulators with Rexolite.

NEUTRALIZED DRIFT COMPRESSION SECTION AND TARGET CHAMBER

The neutralized drift compression region after the last induction cell is approximately 1.2 m long and consists of ferroelectric plasma sources (FEPS) which have been fabricated by Princeton Plasma Physics Laboratory (PPPL). The FEPS design has been developed and proven on NDCX-I to fill the beampipe with a plasma to neutralize the beam. After the NDCX-II beamline is operational, the 8 T final focus pulsed solenoid, filtered cathodic arc plasma source (FCAPS), and target chamber from NDCX-I will be relocated to NDCX-II.

CONCLUSION

The NDCX-II project is approximately 70% complete. The baseline hardware configuration for NDCX-II will be completely installed and checked out with beam in fall of 2011. At that point, a significant commissioning effort will begin to tune the voltage waveforms and manipulate the beam to optimize the spot size and pulsewidth for warm dense matter and inertial fusion energy target experiments. As funding becomes available, additional induction cells and pulsed power systems will be added to increase the beam energy.

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