DARHT SECOND AXIS – STATUS AND PLANS*

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Abstract

The second axis of the Dual Axis Radiographic Hydrotest Facility (DARHT) is nearing the end of the construction phase. DARHT Axis 2 is designed to accelerator a 2-kA electron beam with a 2-µs flat-top up to 18.4 MeV with final delivery of four variable-length short pulses to the firing point for x-ray production. Commissioning of the induction accelerator is divided into several parts to facilitate completion of construction as well as to permit physicists to study beam properties and performance of the machine at various points along the accelerator. There are four commissioning phases for the accelerator that include study of the injector high-voltage column performance, injector short-pulse beam commissioning up to 4.6 MeV, accelerator commissioning up to 18.4 MeV, followed by long-pulse injector and accelerator commissioning. At each stage, readiness to perform the operation must be demonstrated prior to receiving approval to continue with commissioning.

1 INTRODUCTION

DARHT consists of two linear induction accelerators at right angles to produce intense x-rays for dense-object radiographic high explosive tests. Phase 1 was completed in July 1999 and consists of a single-pulse accelerator. Phase 2 consists of a long-pulse, 2000-ns electron accelerator that produces four micropulses with a fast kicker.

We are completing construction of the DARHT Axis 2 (DARHT-2) accelerator and have begun beam commissioning activities. Readiness to perform commissioning must be demonstrated prior to receiving approval to commission the beam at each stage. The commissioning phases, readiness process, and initial results for high-voltage column conditioning and beam from the injector are presented below.

2 COMMISSIONING PHASES AND INITIAL RESULTS

The DARHT-2 accelerator will be commissioned in several phases, to facilitate understanding of the beam physics in a systematic manner, to optimize installation of beam line components with commissioning activities, and to meet U. S. Department of Energy (DOE) project milestone requirements. The three major areas for commissioning activities (injector, accelerator, and downstream transport) are depicted in Figure 1.

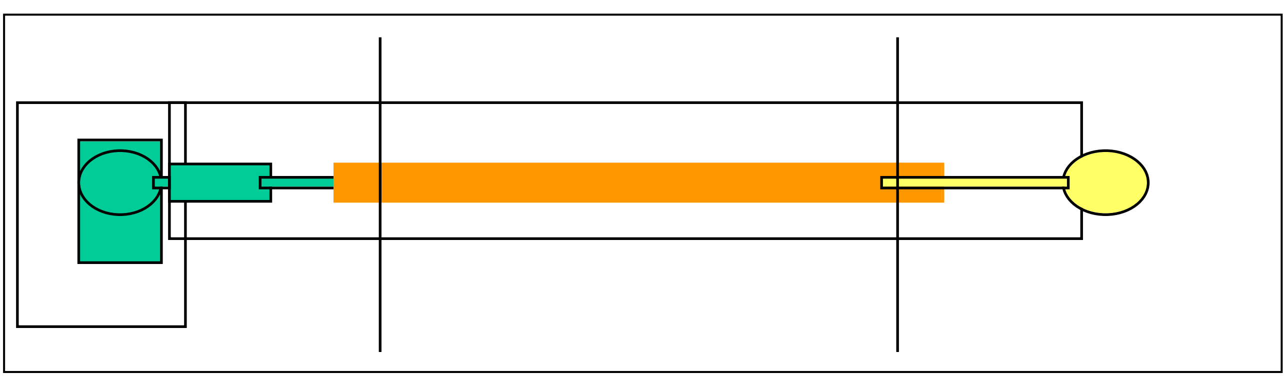

Figure 1: Generic depiction of three major phases to be used in Axis 2 commissioning.

2.1 Injector Commissioning

The injector consists of a Marx generator, a high-voltage dome, a high-voltage insulator column, and electron-source diode, an accelerator interface, and a block of eight special induction cells. The Marx generator serves as the prime power source and has been designed to deliver a variable load current with a voltage up to 3.5 MV. The Marx was tested by Lawrence Berkeley National Laboratory personnel prior to delivery at Los Alamos National Laboratory. The high-voltage dome connects to the Marx and houses various electronic and mechanical systems required to operate and diagnose the injector

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operation. The injector diode is driven by a vertical current fee through a high-voltage column connecting the diode to the Marx bank. The high-voltage column is a hollow cylinder constructed of a combination of ceramic and Mycalex (glass-bonded mica) insulator rings.

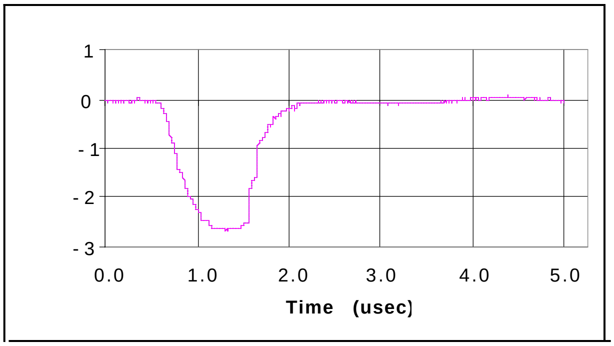

Figure 2: DARHT Axis 2 voltage on column with 400 ns crowbar

Injector commissioning has begun. The first activity was to high-voltage condition the injector insulating column. The goal of the test was to demonstrate that the injector subsystems functioned properly and that the system passes high voltage from the Marx generator, through the column, and on to the cathode dome. A conservative limit of 2.6 MV was chosen for this activity to ensure that the system operates properly without subjecting the system to undue stress prior to completion of the project and demonstration of the initial operation of the accelerator. Figure 2 shows the voltage as measured on the Marx dome for a 2.6 MV pulse with a crowbar-limited pulse length of 400 ns.

The injector with commissioning stations is shown in the layout in Figure 3. Beam has been transported from the diode through the Beam Clean-Up Zone (BCUZ) into the commissioning station. The purpose of the BCUZ is to strip the beam of the head and tail so that beam transport through the accelerator is limited to the flattop portion of the beam pulse. A special diagnostics beam line was designed and built to support beam commissioning at this phase. Beam with a pulse length of up to 400 ns will be characterized and problems resolved in the injector region prior to transporting beam through the remainder of the accelerator.

Beam from the cathode at 2.6 MeV has been detected in the BCUZ with induction cells shorted to meet a project milestone. The detected beam pulse is shown in Figure 4. The pulse was required to have 250 A of current and a beam voltage of at least 2.0 MeV. Approximately 1 kA of beam at 2.6 MeV was achieved in July.

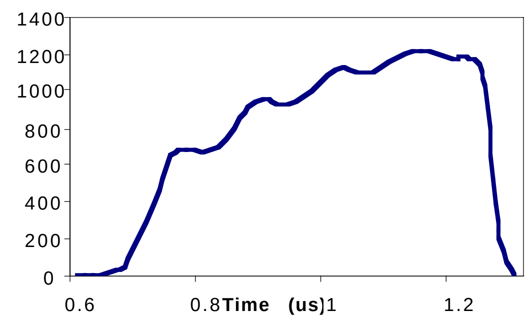

Figure 4: Beam current measured at entrance to the injector induction cells

The accelerator will be reconfigured to transport beam through the remainder of the induction cells to meet a project milestone. Then the injector configuration will be re-established to characterize and resolve problems with the long-pulse beam of 2000 ns.

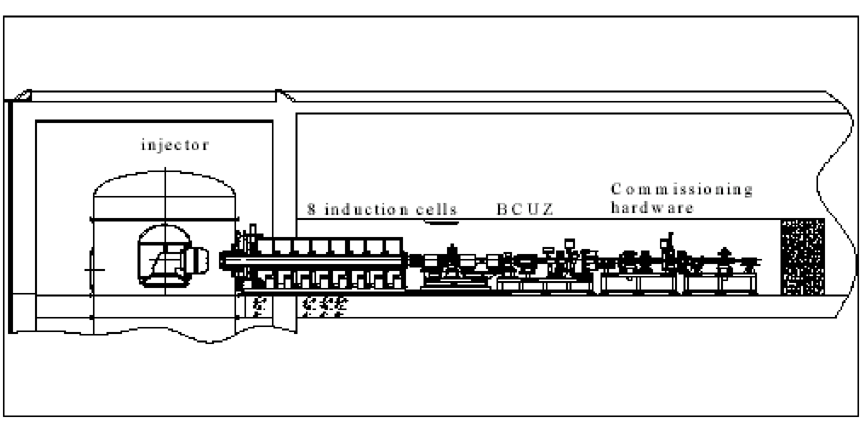

Figure 3: Injector configuration with commissioning station

2.2 Accelerator Commissioning

The initial accelerator commissioning will be to produce a burst of electrons at the end of the accelerating cells. Beam must have a 400-ns pulse, have current of at least 1 kA, and be within 20% of 15 MeV. The purpose of this commissioning activity will be to conclude the project portion of the activities for Axis 2.

A second pass of commissioning to provide high beam quality through the accelerator will occur after the injector commissioning with a 2000-ns pulse. The purpose of the second phase of accelerator commissioning is to ensure proper transport of the DARHT-2 long pulse and ensure adequate preparation of the pulse before injection into the downstream transport.

2.3 Downstream Transport Commissioning

Finally, downstream transport commissioning will provide beam characterization and proper performance of the kicker system, designed to break the long pulse into four smaller pulses. These four pulses will be focused onto an x-ray target and used for radiography. Commissioning activities are expected to take approximately two more years before the full four-pulse radiographic capability is realized.

3 READINESS REVIEWS

Prior to commencement of any commissioning activities, reviews of readiness to operate were conducted. The purpose of the reviews are to confirm that the organization is prepared to operate the equipment safely. To date, three readiness assessments (RAs) have been conducted – an independent LANL RA for conditioning the column, a DOE RA for conditioning the column, and an independent LANL RA for injector commissioning.

Readiness reviews focus on seven guiding principles [1].

- Management is responsible for the protection of employees, the public, and the environment.
- Clear and unambiguous lines of authority and responsibility for ensuring Environment, Safety and Health (ES&H) are established and maintained at all organizational levels.
- Personnel possess the experience, knowledge, skills, and abilities that are necessary to discharge their responsibilities.
- Resources are effectively allocated to address ES&H, programmatic, and operational considerations. Protecting employees, the public, and the environment is a priority whenever activities are planned and performed.
- Before work is performed, the associated hazards are evaluated and an agreed-upon set of standards and requirements is established which, if properly implemented, provide adequate assurance that employees, the public, and the environment are protected from adverse consequences.
- Administrative and engineering controls to prevent and mitigate hazards are tailored to the work being performed and associated hazards. Emphasis should be on designing the work and/or controls to reduce or eliminate the hazards and to prevent accidents and unplanned releases and exposures.
- The conditions and requirements to be satisfied for operations to be initiated and conducted are established and agreed upon by DOE and the contractor. The extent of documentation and level of authority for agreement shall be tailored to the complexity and hazards associated with the work and shall be established in a Safety Management System.

The guidelines are then broken down into several specific areas for assessment, including safety basis, systems engineering, conduct of operations, configuration management, electrical safety, industrial safety, radiological protection, training and qualification, and emergency preparedness. The reviews have each taken from three to five days with approximately eight reviewers each.

Initial results of RAs indicated that DARHT-2 was seriously deficient in the area of configuration management, training, and conduct of operations (specifically, operational procedures). Improvements were noted by the injector RA team, particularly in the area of configuration management.

Three additional RAs are planned – an independent LANL RA for accelerator commissioning, an independent LANL RA for downstream transport operation, and a DOE RA for overall DARHT-2 operations.

4 CONCLUSIONS

DARHT Axis 2 is a state-of-the-art induction accelerator that is just coming on-line. Commissioning activities are expected to take approximately two more years before the full four-pulse radiographic capability is realized.

5 REFERENCES

[1] DOE Order 425.1B.