DESIGN OF THE DARHT-II DOWNSTREAM BEAMLINE[*]

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Abstract.

This paper describes the design of the downstream beam transport line for the second axis of the Dual Axis Radiographic Hydrodynamic Test (DARHT-II) Facility. The DARHT-II project is a collaboration between LANL, LBNL and LLNL. DARHT II is a 18.4-MeV, 2000-Amperes, 2-μsec linear induction accelerator designed to generate short bursts of x-rays for the purpose of radiographing dense objects. The downstream beam transport line is approximately 22-meter long region extending from the end of the accelerator to the bremsstrahlung target. The principal element of the beam transport section is the fast deflector, or kicker system, used to generate four micropulses from the primary accelerator beam. Within this proposed transport line there are also several conventional solenoid, quadrupole and dipole magnets which transport and focus the beam to the target and to the beam dumps.

1 INTRODUCTION

We are completing the construction of the downstream beam transport components for the DARHT II Accelerator [1]. Beam transport studies for this design have been performed [2]. Figure 1 shows the layout for the downstream elements. The beamline from the exit of the accelerator to the target is about 22 meters long. In the accelerator the pulse length is about 2 μsec. However, only four short (20 to 100 nsec) pulses separated by about 600 nsec are desired at the bremsstrahlung target. The function of the kicker septum system is to "kick" four short pulses out from the main 2-μsec beam. The kicker includes a bias dipole operated so that the non-kicked parts are deflected off the main line into the main beam dump, while the kicked pulses are sent straight ahead. Focusing elements between the kicker and the septum would complicate operation. Therefore, to achieve a narrow beam waist at the septum, solenoid ST2 must "throw" a waist to the septum. The first 6 meters of beamline allow the beam to expand from its 5-mm matched radius in the accelerator to ~3 cm at solenoid ST2. The system is designed to have a 20% energy acceptance to transport the main beam and most of the leading and falling edge of the pulse exiting the accelerator. The proposed system using a quadrupole magnet [2] allows for a larger beam pipe radius than the more conventional septum dipole magnet studied earlier. This increases the energy acceptance of the transport line to the main beam dump.

Work on the kicker system has been described elsewhere[3]. After the septum, there are four Collins style quadrupole magnets to restore the beam to a round profile. Finally the beam will be pinched to a tight focus at the target to provide an intense spot of x-rays for radiographic purposes. Work on the target has been presented in other proceedings [4].

2 TRANSPORT ELEMENTS

The magnets within the DARHT II transport line are all water-cooled conventional dc electromagnets (except the SFC “fast coil”, the Kicker, the Kicker bias dipole, and the steering coils)[5]. Steering corrector coils will be installed at 12 locations to allow for small alignment errors or stray magnetic fields.

The beam pipes used for the DARHT II Transport Line are constructed from Aluminium to reduce the resistive wall instability. The region from the end of the accelerator through the septum has a 16-cm bore diameter. From the septum to the target, the bore diameter is reduced to 10 cm. The vacuum design requirement for the transport line is an average pressure less than 10^{-7} Torr (N_2 equivalent).

Figure 4 shows a side view of the septum vacuum chamber. The chamber resides in the region were the beamline splits between the line going to the target and the line going to the main dump. The chamber is formed by two aluminium halves that are then welded together at the midplane.

There are two beam dumps included in the DARHT II downstream transport system; a main beam dump, and a shuttle dump. The purpose of the shuttle dump is to allow accelerator operations while personnel are working in the target area outside the accelerator hall. The shuttle dump will have a composite absorber, made up of a 8-cm thick graphite block, backed by 30 cm of tungsten. The composite absorber has the ability to be translated in and out of the beam line

Throughout the beamline there are beam position monitors (BPMs) to measure the location and angle of trajectory of the beam. The BPMs mount between the flanges of adjacent transport beam tubes. The accurate

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[*] This work was performed under the auspices of the U.S. Department of Energy by University of California Lawrence Livermore National Laboratory under contract No. W-7405-Eng-48.

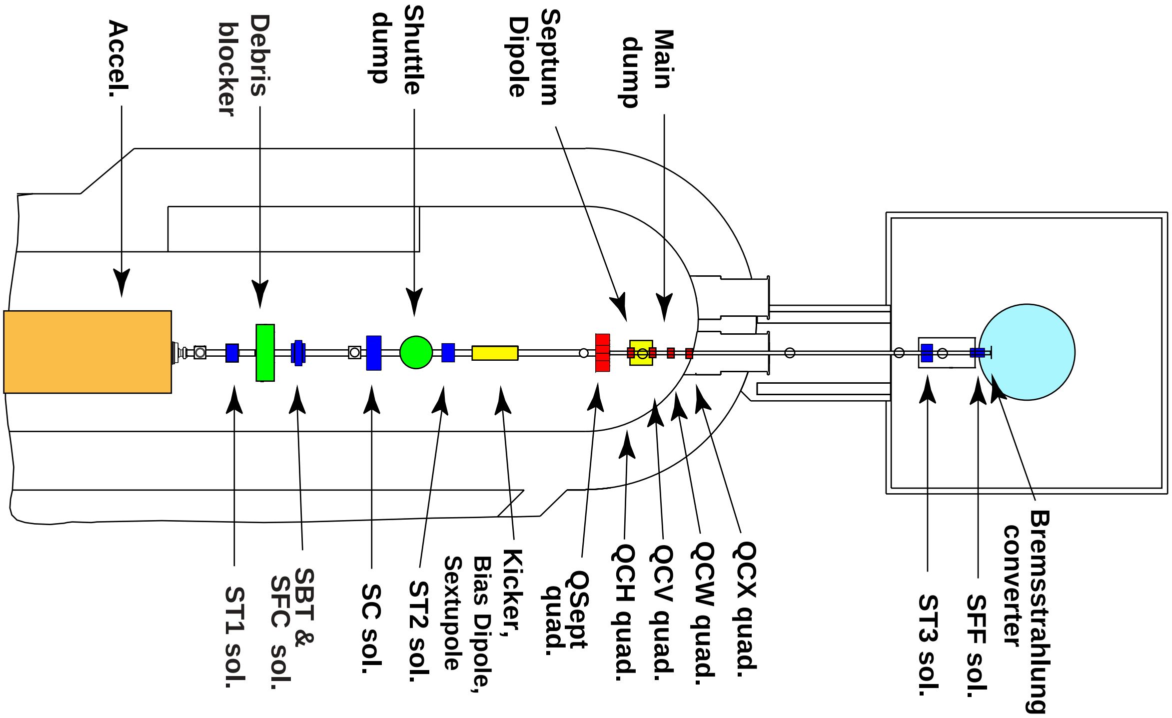

Figure 1: Layout of the transport elements.

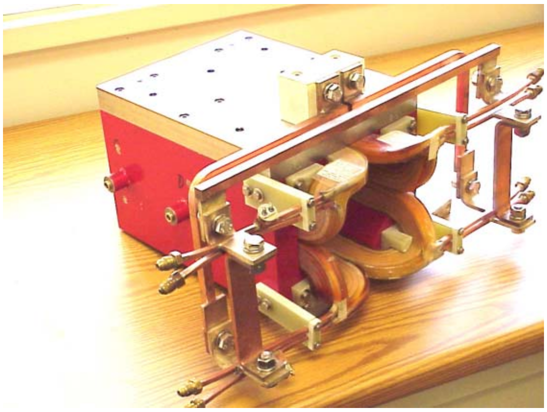

Figure 2: Picture of a Collins Quadrupole.

Figure 3: Picture of the transport elements around the septum region.

transverse location of the BPMs is critical to the operation of the transport line and it is their positional requirements, which set the alignment tolerances for the beam line vacuum system.

3 KICKER

The principal element of the beam transport section is the fast deflector, or kicker system, used to generate four micropulses from the primary accelerator beam. It is similar in design to stripline beam position monitors.

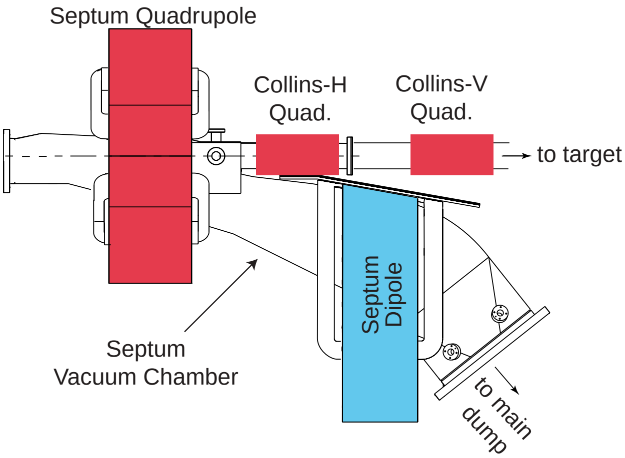

Figure 4: Arrangement of the transport elements around the septum. Horizontal view. The main part of the pulse enters the Septum Quadrupole off-axis and is bent into the Septum Dipole, it is then bent further into the main dump. The kicked portion goes straight ahead though the Collins Quadrupoles.

There are four equal size electrodes enclosed within a vacuum housing that has a DC bias magnetic dipole wound over the enclosure. An opposite pair of electrodes is driven by a fast amplifier through transit time isolated 50-Ω cables to provide beam deflection. The other two electrodes are terminated at their 50-Ω matched impedance. A subsequent drift space of several meters allows a substantial relative deflection to develop between the output beam positions of the kicker and drift. During most of the pulse, the bias dipole will deflect the beam off-axis into a large-bore, weak quadrupole magnet septum beampipe. This magnet deflects the off-axis beam into a strong dipole magnet that transports the beam into a dump. When an x-ray pulse is desired the kicker pulsers are activated and overcome the bias field allowing a short segment of beam to travel down the axis through the null field region of the quadrupole magnet and on to the x-ray converter target. Fig. 5 shows the Kicker installed on the LLNL ETA-II accelerator for testing.

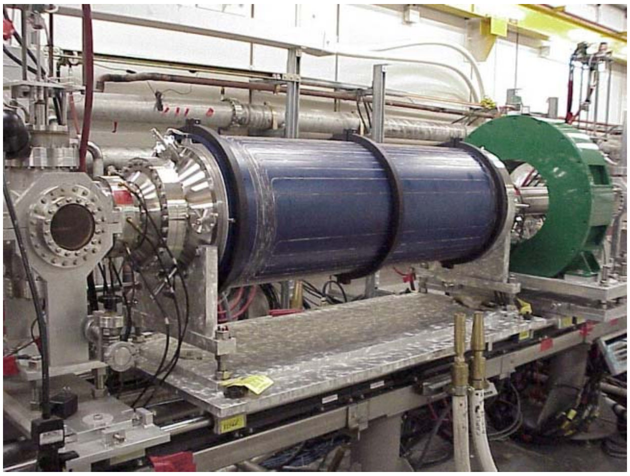

Figure 5: The DARHT Kicker installed on ETA-II

The Kicker modulator is a solid-state inductive adder with a nominal output voltage of ±18 kV. Corrections for beam/Kicker interactions and the details of the power feed to the Kicker requires the ability to place fine modulation onto each Kicker pulse. In addition, micropulse width and spacing must be adjustable from the control room. Figure 6 demonstrates the ability of the Kicker modulator to meet these needs. This is a measured 4-pulse output overlaid onto a typical, pre-programed pulse train.

4 ENERGY ANALYSER

Although still not part of the official beamline, we have complete the design of an energy analyser that could be included in the beamline between the end of the accelerator and the Shuttle Dump. The design was based on an analyser used on the Astron Accelerator [6]. A small fraction of the electrons in the main beam are scattered by a wire (see Figure 7). We analyse those electrons scattered by about 11 degrees. This diagnostics would allow the machine operators to adjust the energy of the beam to within about 0.1% of a previous setting.

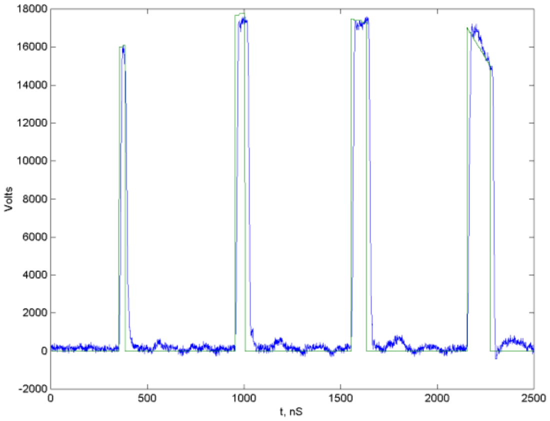

Figure 6: Kicker pulser output demonstrating a 4-pulse train and the ability to generate arbitrary modulation to each micropulse.

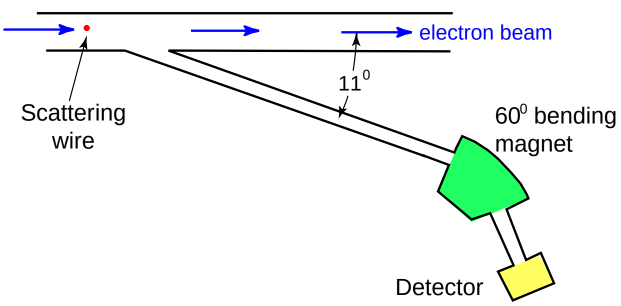

Figure 7: Layout of the proposed energy analyser .

5 REFERENCES

[1] M.J. Burns, et al., “Status of the DARHT Phase 2 Long-Pulse Accelerator”, Proc. of the 2001 Particle Accelerator Conference, Chicago, IL, (2001).

[2] A. Paul, et al., “The Beamline for the Second Axis of the Dual Axis Radiographic Hydrodynamic Test Facility”, Proc. of the 1999 Particle Accelerator Conference, New York, NY, (1999).

[3] J. Watson, et al., “A Solid-State Modulator for High Speed Kickers”, Proc. of the 2001 Particle Accelerator Conference, Chicago, IL, (2001).

[4] S. Sampayan, “Beam-Target Interactions Experiments For Bremsstrahlung Converters Applications”, Proc. of the 2001 Particle Accelerator Conference, Chicago, IL, (2001).

[5] G.A. Westenskow, et al., “The DARHT-II Downstream Transport Beamline”, Proc. of the 2001 Particle Accelerator Conference, Chicago, Ill., (2001).

[6] T.J. Fessenden, “The Astron On-Line Beam Energy Analyzer,” Rev. of Sci. Instru., 43, 1090, (1972).