THE DARHT-II DOWNSTREAM TRANSPORT BEAMLINE*

G. A. Westenskow, L. R. Bertolini, P.T. Duffy, A. C. Paul
Lawrence Livermore National Laboratory, Livermore, CA 94550 USA

Abstract.

This paper describes the mechanical 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 down-stream beam transport line is approximately 22-meter long region extending from the end of the accelerator to the bremsstrahlung target. Within this proposed transport line there are 12 conventional solenoid, quadrupole and dipole magnets; as well as several speciality magnets, which transport and focus the beam to the target and to the beam dumps. There are two high power beam dumps, which are designed to absorb 80-kJ per pulse during accelerator start-up and operation. Aspects of the mechanical design of these elements are presented.

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 is 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 is also presented in these 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 bias dipole, and the steering coils). The magnets are listed in Table 1.

The transport solenoids have external iron shrouds with water-cooled copper coils. Solenoid coils are wound into individual two-layer "pancakes." Each magnet has an even number of these pancakes. The pancakes are installed in an A-B-A-B orientation to minimize axial field errors. The single Cruncher solenoid magnet was constructed in a similar manner to the transport solenoids.

The septum quadrupole and dipole magnets have solid iron cores with water-cooled copper coils. The Septum Quadrupole Magnet is a four-piece, solid-core construction. The Collins Quadrupole Magnets are two-piece solid cores with non-magnetic support. The dipole magnet is a three-piece, solid-core, "C" magnet.

The alignment requirement for the transport magnets are ±0.4-mm positional tolerance and ±3-mrad angular tolerance. Steering corrector coils will be installed at 12 locations to allow for small alignment errors or stray magnetic fields.

3 VACUUM SYSTEM

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 seals are made with conflat style knife-edge flanges with annealed copper gaskets. The use of all-metal seals is driven by the potential

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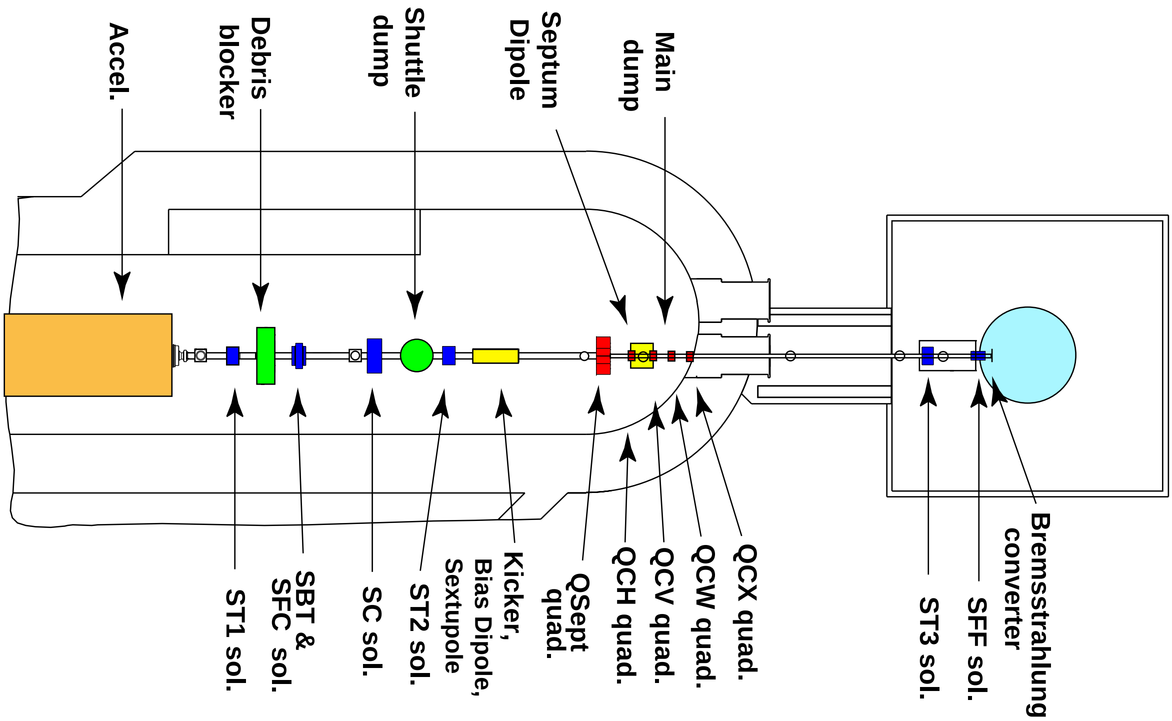

Figure 1: Layout of the transport elements.

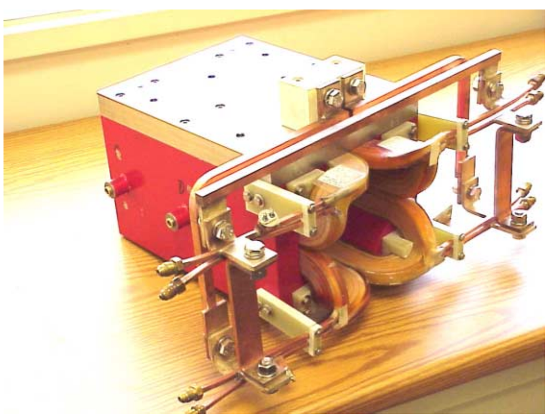

Figure 2: Picture of a Collins Quadrupole.

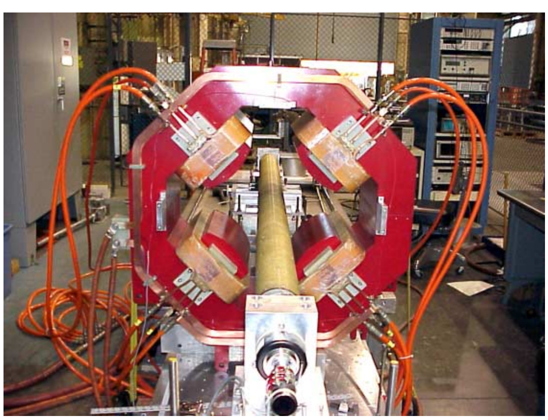

Figure 3: Picture of the Septum Quadrupole being characterised during a rotating coil test.

Transport Elements in the Downstream Beamline.

Magnet Type	Magnet Name	Max. Field (kG) or Gradient (kG/m)	Bore or Gap (cm)
Solenoid	ST1	2.5	27
Solenoid	SBT, SFC	3 - 4	27
Solenoid	SC	8	21
Solenoid	ST2	2.5	27
Dipole	Bias Dipole	0.009	41
Pulsed Dipole	Kicker	-0.009 (equivalent)	12.8
Sextupole	Sextupole Corrector	16 gauss @20.5 cm radius	41
Quadrupole	QSept	8.0	38
Quadrupole	QCH	10.0	12
Quadrupole	QCV	10.0	12
Quadrupole	QCW	10.0	12
Quadrupole	QCX	10.0	12
Solenoid	ST3	2.5	27
Solenoid	SFF	6	14
Dipole	Septum Dipole	1.0	16

Table 1: Magnet specifications

requirement to *in situ* bake the transport vacuum system. *In situ* bake-out may be required to minimize adsorbed gas on the beam tube walls, which may be desorbed by beam halo scraping the walls. 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.

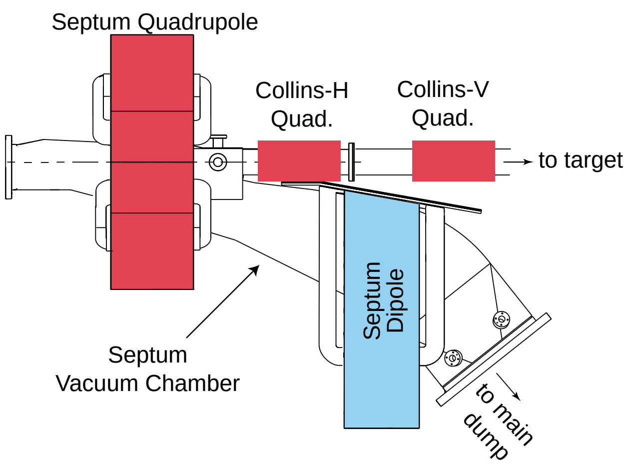

Figure 4: Arrangement of the transport elements around the septum. Horizontal view. The main part of the pulse enters the Septum Quadrupole off-axis and is bent into the Septum Dipole, it is then bent further into the main dump. The kicked portion goes straight ahead though the Collins Quadrupoles.

4 BEAM DUMPS

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.

The main beam dump absorbs the portion of the beam that is not kicked by the kicker system. At 1 pulse per minute repetition rate we can manage the average temperature increase. We also desire to keep the neutron yield low to minimize activation of components and simplify radiation shielding. The construction of the beam dump must be compatible with high vacuum as explained in the previous section.

Test have shown that we can maintain good thermal contact between the graphite and the cooling channels. The outgassing rate of the graphite drops rapidly during the first 48 hours of pumpout. By having a large pumping capacity near the dump we expect to achieve the require pressure profile.

5 DIAGNOSTICS

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 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.

During early commissioning we plan to remove the Cruncher Solenoid (SC) to allow insertion of the DARHT energy analyser. During the next stage of commissioning the beam will only be transported to the “Shuttle Dump”. This line has a large acceptance and will allow us to characterise the beam [5]. During characterization, the field at the center of the second magnetic element in the downstream transport line has contributions from a conventional solenoid operating at about 4 kGauss and a pulsed 1 kGauss field from the “fast coil” in the opposing direction. The windings of the “fast coil” are within the vacuum walls to avoid issues with field penetration though the vacuum walls. The temporal waveform is sinoiusal with ~100 ns half width. The DC solenoid will form a small waist in front of the radius monitor. We desire that the beam passes through a tight focus before the diagnostic so that trajectories have a stronger dependence on the beam’s emittance. When the “fast coil” is pulsed, the beam’s waist moves to the diagnostic location, and the radius at the diagnostic changes from around 4 cm to 1 cm. From the dependence of the radius on the magnetic field we will extract the beam’s emittance, radius and tilt near the end of the accelerator[6].

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