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Title:

LOW INDUCTANCE PULSER SYSTEM DRIVES A FAST MAGNET AT DARHT

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LOW INDUCTANCE PULSER SYSTEM DRIVES A FAST MAGNET AT DARHT

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Abstract

The DARHT facility [Dual Axis Radiographic Hydrodynamic Test] uses bremsstrahlung radiation from focused electron beams to produce radiographs. To produce a smaller spot size and, thus, a higher quality radiograph, one must be able to control the emittance of the electron beam. To that end, it is necessary to measure emittance. Emittance is measured by focusing the electron beam to a small size, such that the size is dominated by the emittance, as opposed to the space charge. Our electron beam, at 2 kA, 18 MV and 2 μs, would destroy any imaging target, were the full beam to be focused to minimal spot size for the full beam duration. The solution is to focus the beam for a short duration, a few tens of nanoseconds, using a fast solenoid magnet.

This paper reports details of the pulsed power system used to drive the segmented magnet. The system consists of twenty pulsers, driving 60 cables to feed two headers on the magnet. The magnet itself consists of 12 individual loops, each segmented in three parts, for inductance reduction. The system is designed to produce one kilogauss over a 15-cm diameter and 60-cm length. The pulsers incorporate spark gaps that produce the main pulse with a half sine period of 125 ns and also clip the tail of the pulse to prevent refocusing of the beam. A five-to-one ratio between the first and second current peaks has been demonstrated [same polarity peaks].

I. PRINCIPAL OF OPERATION

The fast solenoid magnet is a key component of a diagnostic that measures the emittance of the DARHT electron beam [1, 2, 3]. The emittance-measuring diagnostic uses a thin plate to intercept the electron beam and produce light by Cerenkov or optical transition radiation. This light is captured by an imaging system, using a framing camera or a streak camera. Analysis of the image yields the beam current profile. Focusing the beam to a small diameter produces a condition where the beam diameter is dominated by the emittance. In practice, a series of magnet settings is used to produce a curve of the beam diameter versus the focal length of the magnetic solenoidal lens. The results are fit to the beam envelope equation to measure the emittance.

DARHT has two electron accelerators, used to produce x-rays for radiography. The first accelerator, in operation, produces a 2 kA, 20 MV beam with 60 ns duration. Emittance measurements of the electron beam produced by the first accelerator allow the beam to strike the light producing target for the full beam duration.

The second electron accelerator, under construction, will produce a 2 kA, 18 MV beam with 2 μs duration. That electron beam will destroy the light producing target, if it is focused on the target for the full beam duration. We are pursuing a pulsed solenoid magnet as a solution to this problem. The pulsed magnet will allow one to focus the electron beam on the target, get the emittance data and then defocus the beam. The short period of focused beam will limit the heating of the target and limit beam disrupting ion production and avoid melting of the target. Calculations indicate that a solenoid magnet with a 125-ns half period will meet requirements.

II. FAST SOLENOID MAGNET

Our goal is to produce a fast solenoidal magnetic lens. The solenoid will generate a peak field of 1 kilogauss with a half period of 125 ns. The length of the magnetic field will be 60 cm and the inside diameter of the solenoid will be 15 cm. Refer to figure 1 below.

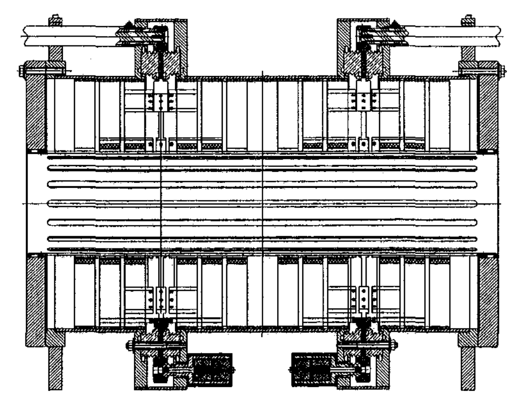

Figure 1. Fast solenoid magnet assembly.

To achieve a low inductance architecture, the solenoid has been divided into many twelve parallel turns. Each turn has been subdivided into three partial turns. Two headers provide current to the solenoid. Each header provides current to eighteen partial turns [nine on each side of the header] using vacuum strip lines. The strip lines run axially from the header to the position of the partial turn, then radially to the partial turn. Each radial section of the strip line is closely coupled to a radial section from another partial turn, carrying current in the opposite direction. Refer to figure 2 below.

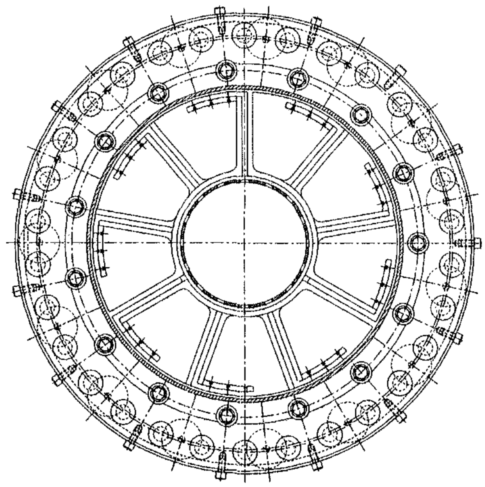

Figure 2. End view of the solenoid magnet.

Figure 2 shows nine of the strip lines. Each strip line provides current to one 120-degree partial turn. The sets of strip lines for each turn are clocked to avoid interference. Nine partial turns are shown in figure 2, constituting one quarter of the total turns in the solenoid.

Thirty cables feed each header. Those thirty cables originate in ten pulsers. There are a total of twenty pulsers in the full system. There is a provision for fifteen R-C snubbers on each header to reduce voltage spikes from impedance mismatches.

Figure 1 shows a slotted tube that extends the DARHT beamline through the solenoid magnet. The return current of the electron beam flows on the slotted tube. The axially oriented slots permit the magnet field of the solenoid to penetrate and filters non-axial field components produced by the strip lines.

One feature of the fast magnet system is not shown in figures 1 or 2. A solenoid magnet that is operated at constant magnet field encircles the fast solenoid magnet. The fast solenoid magnet, when pulsed, either shortens the focal length [when its polarity matches the DC magnet] or lengthens the focal length [when its polarity opposes the DC magnet]. The DC magnet is positioned between the headers. That magnet constrains the design of the fast solenoid magnet.

III. HIGH VOLTAGE PULSERS

There are twenty high voltage pulsers to drive the fast solenoid magnet. A pulser is illustrated in figure 3. Each pulser contains two spark gaps [Titan part number 40044I]. The top spark gap drives three RG220 cables that connect to the header of the solenoid magnet. It discharges the six or seven ceramic capacitors [Murata 2.7 nF] that are charged to 40 kV nominal. The bottom spark gap diverts the current after the first half-period. Six 4-ohm resistors absorb the energy during the diverting action.

Each pulser is required to deliver 10 kA, for a total of 100 kA delivered to each header, or 200 kA for the full solenoid magnet.

Measurements indicate that the inductance of the pulser is 40 nH when driving a load. Another 40 nH is associated with the three parallel cables that will connect each pulser to the header. Each pulser drives 95 nH, associated with the header and the solenoid magnet.

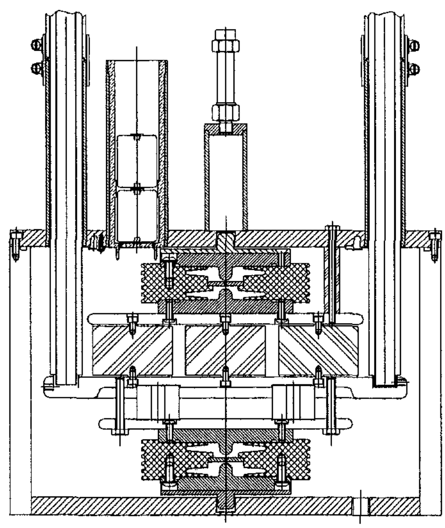

Figure 3. High voltage pulser.

IV. PULSER TESTS

The prototype pulser was tested into a dummy load, consisting of a set of shorted cables that simulated the inductance of the solenoid and the three feed cables to the solenoid header. Current viewing resistors were installed on the pulser to measure the driving and diverting currents, and one of the dummy load cables was instrumented to measure load current.

Earlier tests established the ability to achieve a 125-ns half period pulse. Recent tests were conducted to find a combination of timing for the diverting spark gap and resistance for the diverter load to optimize the effect of the diverter. Our goal was to maximize the ratio between the first and second positive polarity current peaks in the load current.

We achieved a 5:1 ratio in current peaks by using a 2/3 ohm diverter resistor and a 120-ns delay between triggers to the driving and diverting spark gaps. The current peak is 10 kA, and the half period is 250 ns, as required. Refer to figure 4.

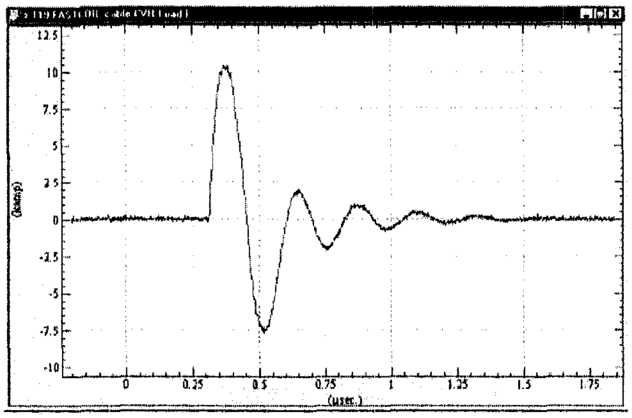

Figure 4. Load current with diverter.

V. CONCLUSION

The fast solenoid magnet will be a critical element of a new diagnostic, capable of measuring the emittance of the two-microsecond duration electron beam produced by the second accelerator at DARHT.

Calculations have been performed to predict the performance of the low inductance pulser system connected to the solenoid magnet. Calculations predict the behavior of the electron beam and the heating of the light producing target. Experiments on the first accelerator of DARHT have proven details of the emittance measurement concept.

Models of the header and coil geometries have been built and operated under constant and pulsed high voltage conditions to predict and ensure reliability under operating conditions [4].

Prototypes of the pulsers have been built and operated to predict circuit operation. The circuit has achieved a 5:1 ratio in current peaks and reached the design goal.

Procurement of the complete fast magnet system is proceeding. Assembly and operation of the complete diagnostic system will occur in FY2003.

VI. REFERENCES

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VII. ACKNOWLEDGEMENT

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