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MECHANICAL DESIGN OF THE HIGH-ENERGY BEAM-TRANSPORT LINE FOR THE FMIT 2-MeV ACCELERATOR*

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Summary

The beam-transport line for the high-power 2-MeV Fusion Materials Irradiation Test (FMIT) accelerator is one of the most heavily instrumented ever designed. A wide variety of diagnostics is required to accurately determine the characteristics of the beam that will ultimately be used. Because the machine is only 2 MeV, the packing factor in the high-energy beam transport (HEBT) is high, especially since full-scale FMIT-grade components are used where possible. The HEBT's mechanical design aspects and its instrumentation are described.

Introduction

A 2-MeV FMIT accelerator is being installed at Los Alamos and will go into operation later this year. The technical objective of the program is to test design concepts and components. The program will be conducted in two phases: the first is to match a low-energy beam into a radio-frequency quadrupole (RFQ) and determine accurately the performance of the RFQ at 2 MeV; the second will be to match the RFQ beam into a drift-tube linac and assess performance at 5 MeV.[1] The 5-MeV accelerator awaits future funding and will be installed later.

A major design goal is to develop a HEBT that can accommodate all present and future needs with only minor changes. The same beamline components must work for both the 2- and 5-MeV systems. The same diagnostic devices located in the same relative positions must provide adequate beam data to provide assurance that the difficult low-energy end of the FMIT accelerator will function properly. This goal has been met.

The beam from the 2-MeV accelerator is 100 mA cw with an 80-MHz microstructure and about 1 A per micropulse. The beam power at the RFQ output is 200 kW. Because the HEBT is designed to handle the 5-MeV accelerator system, the beamstop must be able to absorb 500-kW average. An additional complication is the fact that the FMIT accelerator is a heavy-ion machine and will use a deuteron beam. The accelerator can run on deuterium, but to avoid unnecessary activation from neutron stripping, singly ionized hydrogen (H_2^+) will be used instead. These low-energy heavy ions have a very short range in normal accelerator materials. This means that beamstop heating will be a surface effect and that the diagnostics must be noninterceptive to avoid destruction by the beam.

Finally, at the beam power involved in the FMIT accelerator program, very little sustained or concentrated beam loss can be tolerated. For this reason, special precautions must be taken to avoid hot spots caused by beam mishandling.

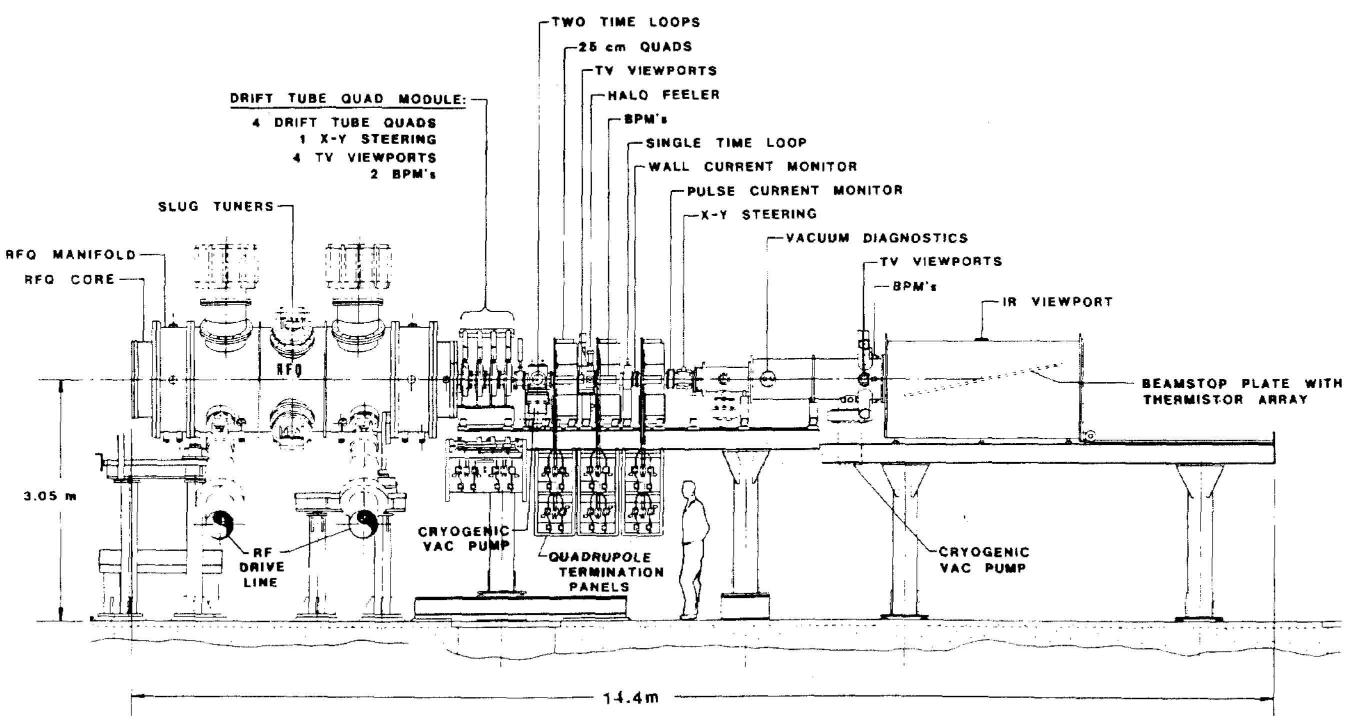

Fig. 1. HEBT system for 2-MeV accelerator.

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HEBT Design Description

The HEBT system for the 2-MeV accelerator is shown in Fig. 1. On the left is the RFQ that is installed 304.8 cm above the floor. The RFQ output beam is well bunched, well focused, and parallel as it leaves the RFQ. It enters an array of four matching quadrupoles forming a periodic focusing system using the same magnets and spacing that applies in the drift tube linac. However, because no accelerating fields are present, the spacing is held constant. Within this matching array, a number of TV diagnostic ports are included, one at the upstream face of each quadrupole. The beam is visible through these ports by virtue of the light emitted from excited residual gas in the beamline. It can be scanned by low-level TV cameras, digitized and reconstructed into profile and emittance plots.[2] Also located in the matching section are beam position monitors (BPMs) built into the beam tube at two positions. These are four magnetic pickup loops in quadrature that detect the 80-MHz magnetic field of the beam microstructure. The beam tube in the matching section has a 4.75-cm aperture and is double walled for flood cooling with water. Also, the tube sections are copper plated to a thickness of 0.75 mm to better distribute beam-loss heating. Then they are oxidized to a flat-black surface to eliminate reflections and provide better beam viewing.

Downstream of the matching section the beam tube opens to a 12.7-cm aperture. Again it is double walled water-cooled and heavy-copper plated. A large beam box and valve separate the matching section from the three large-bore quadrupoles. This beam box contains a pair of pickup loops that allows energy measurements to be made by micropulse time-of-flight determination. The quadrupoles themselves are FMIT-rated radiation-hardened units with 25-cm effective length. They are used in the program to develop FMIT engineering concepts. Between the quads is a TV and halo-feeler beam box. This is the only interceptive diagnostic component and is designed to probe the beam halo, a valuable guide to RFQ transmission efficiency. The halo-feeler beam box also is equipped with TV view ports for additional optical diagnostics.

Inserted into the beam tube in the central 25-cm quadrupole is another BPM and, downstream of that, a second time-loop beam box, thus completing the energy-measurement circuit. At this same position is the first of two current-measuring devices, a wall-current monitor capable of determining beam current by its associated image currents. Downstream of the last 25-cm quadrupole is an X-Y steering magnet and a second inductive-type current monitor. Thus, through the last magnet in the HEBT, the RFQ output beam will be exposed to five optical view ports for profile and emittance measurements, three BPMs, two current monitors, energy-determination time loops, and a halo detector. The 25-cm quadrupoles now expand the beam onto the beamstop in an ~50-cm-diam spot. Just before entering the beamstop vacuum chamber, a last view with TV ports is obtained and the beam also passes through one last set of BPMs.

Beam Control and Beamstop

The quadrupoles in the HEBT are interfaced with the power supplies and cooling water by remotely connected termination panels. This is an FMIT concept for placing the critical connections outside the shield wall. Steering coils are provided on the pole tips of the small-bore matching quadrupoles. The 25-cm quadrupoles are mineral-insulated for radiation resistance and fabricated as dowel-located breakaway units to test the FMIT concept of replaceable beam-tube sections using remote maintenance.

All the quadrupoles used in the HEBT are FMIT rated. The small-bore drift-tube quadrupoles are operated at field levels required for the FMIT accelerator but the 25-cm quadrupoles require only about half the fields. Beam control through the HEBT restricts the beam size to the beam-tube's central portion to reduce aberration effects. The beam profile is shown in Fig. 2 with quadrupole strengths listed.

Adequate beam-spot size on the beamstop is essential to prevent damage to the beamstop plates. The beam is expanded to a 50 by 45-cm ellipse and then strikes the plates angled back at 11.5° to produce a 50- by 226-cm spot size. This keeps peak power density on the copper surface below 500 W/cm^2 at 500 kW. Beam-spot control is maintained by the TV view ports and BPMs at the entrance to the beamstop vacuum chamber, and also by a view port directy over

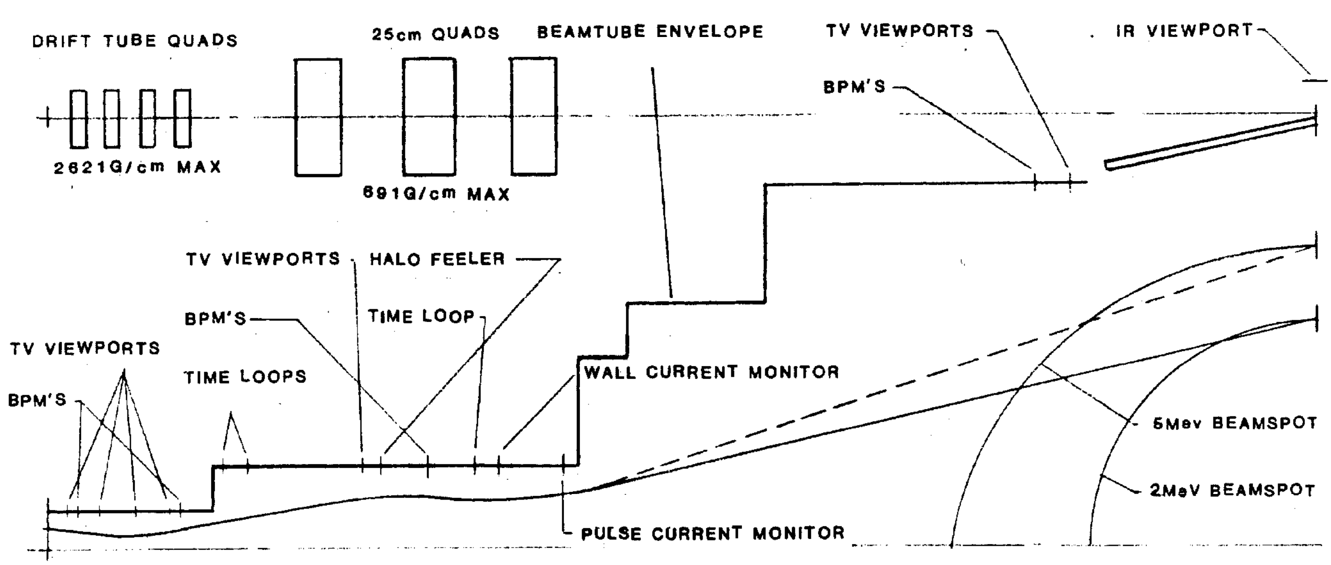

Fig. 2. Profile of 200/500-kW beams through HEBT.

the center of the plate that allows infrared TV scans to be made. In addition, the beamstop is equipped with an array of thermistors, embedded in the copper, that can be read by computer and the data reconstructed into a beam-spot ellipse.

The beamstop also is an FMIT-rated component. It will be used at the FMIT facility to absorb the energy of the 3.5-MW beam during accelerator tune-up but only at low duty factor. The only major modification for the 35-MeV accelerator (that will also be required for the 5-MeV accelerator) will be the addition of a graphite sheath. This will prevent the straggling protons in both the 5- and 35-MeV test beams from reaching and activating the copper plate.

Conclusion

The heavily instrumented HEBT for the FMIT accelerator program meets the objectives for both the 2- and 5-MeV systems. In addition, it uses FMIT-rated quadrupoles and beamstop, equipment that has been developed for ultimate use on the final version of the FMIT accelerator. Certain FMIT concepts, such as remotely located termination panels and breakaway quadrupole designs for replacing burned-out beam tubes can be tested on the prototype HEBT. Graphite plating of the beamstop, an FMIT requirement, also will be developed in the prototype HEBT. Finally, the diagnostic devices are, in many cases, directly applicable to the FMIT accelerator because of their noninterceptive nature; the design philosphy developed in the program ultimately will be used on the final version of the FMIT accelerator.

References

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