Beam Transport Testing for the Production Accelerator Arrangement

Chemical Science and Engineering Division

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by

Roman Gromov and Sergey Chemerisov

Chemical Science and Engineering Division, Argonne National Laboratory

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BEAM TRANSPORT TESTING FOR THE PRODUCTION ACCELERATOR ARRANGEMENT

1. INTRODUCTION

The beam transport system is designed to deliver an electron beam from the accelerator to the target. The design of the beam line depends on beam parameter (energy, energy spread, etc.) and target geometry. Elements of the beam transport system should provide transportation, focusing, and positioning of the beam onto the target surface.

Main elements of the transport line are shown in Figure 1. These include the following:

- FODO¹-doublet;
- 10° bending magnet; and
- Raster magnet.

In Figure 1, the beam travels from left to right. The first element shown is a regular vacuum valve connecting the beamline to the accelerator. The second element is fast-action vacuum valve (FAV); it should isolate the accelerator from target area to prevent contamination in case of target damage. The next element is FODO-doublet of two magnetostatic quadrupole lenses. The raster magnet is positioned after the doublet. A 10°-bending magnet directs a beam into the experimental area. The additional magnetostatic quadrupole is placed after the bending magnet to compensate for beam dispersion. The vacuum sensor for FAV is positioned at the end of the beam line.

The pair of FODO magnetostatic quadrupoles are used to focus the beam. An additional magnetostatic quadrupole is installed in the beam line after a 10° bending magnet to compensate for beam dispersion due to energy spread. Since the target area is bigger than the transverse beam size, the raster magnet is used to evenly raster the beam on the target area. The last 2 m of the beam line have no magnetic elements. This space is reserved for a concrete shielding wall for radiation protection.

¹ “FODO” is an acronym in accelerator physics, which means “focusing–open space–defocusing–open space” for a setup of two quadrupole magnets. The first one has a horizontal focusing field, and the second one has a horizontal defocusing field. Spaces between and behind them are “open” spaces without a magnetic field.

FIGURE 1. Schematic of the Transport Beam Line (all lengths are in centimeters)

2. RASTER MAGNET

The raster magnet is designed to provide uniformity of the magnetic field in the beam area. The magnet has no yoke, in order to avoid hysteresis problems. A prototype of the raster magnet consists of two pairs of rectangular coils (Figure 2). Preliminary experiments were performed using the Van de Graaff generator. In these tests, the beam parameters were:

- Beam energy 3 MeV
- Average beam current 1.5 μ A
- Average beam diameter 0.3 in.
- Repetition rate 120 Hz
- Beam length 55 ns

The coils were powered by alternating current (AC) with an amplitude of about 2.5 A. The initial beam spot diameter was about 0.3 in. when the raster magnet was off (Figure 3). With the magnet on, the coils of the raster magnet were powered by an alternating current with a frequency of 21 Hz. The coils were fed by the sinusoidal current and the vertical coils had a 90° phase shift. Under these conditions, the beam made a circular path across the target point with a displacement of about 0.15 in. from the center (Figure 4). The resulting spot has an average diameter of about 0.6 in. with 15% top roughness.

FIGURE 2. Prototype of the Raster Magnet

FIGURE 3. Initial Beam Profile with Magnet Off

FIGURE 4. Beam Profile with the Raster Magnet On

3. MAGNETIC ELEMENTS OF THE TRANSPORT BEAM LINE

Argonne National Laboratory's current linac beamline (ATLAS: Argonne Tandem Linac Acceleration System) is composed of several focusing magnetostatic quadrupoles, steering coils, and two 10° -bending magnets (Figure 5). It is close to the designed beam line; therefore, the transport parameters are expected to be similar. The accelerated beam with energy of about 35 MeV was directed to the 10° line. The efficiency of the beam transport was measured by the beam current monitors (BCMs). One of them is installed between FODO focusing magnetostatic quadrupoles and first 10° magnet, and another one is about 3 m after the 10° bending magnet. The water-cooled aperture with a 0.6-in. hole was installed before the second BCM. A comparison of pulse currents from the BCMs (Figures 6 and 7) has demonstrated the transport efficiency of the proposed beam line. The beam transportation is close to 100% for the 30-MeV beam and energy spread up to ± 0.8 MeV.

In these experiments, the second magnetostatic quadrupole after the bending magnet was zeroed to emulate the proposed beam line geometry. The first FODO doublets were used for beam focusing. The initial beam was stretched in the horizontal plane because of the accelerator geometry. The experiment demonstrated that an electron beam with a large energy spread (up to $\pm 3\%$) can be focused by the proposed beam transport geometry without horizontal stretching on the target surface. Figure 7 shows the beam transverse profile at the target area. The final beam shape is not round because the initial (accelerated beam) is not round; it has an elliptical cross-section.

FIGURE 5. Current Argonne Linac Beam Line in the Experimental Cell

FIGURE 6. Beam Pulse Profile (red line—gun current; white line—beam current at the first BCM; green line—beam current at the second BCM)

FIGURE 7. Beam Transverse Profile at the Target Surface

4. TEN-DEGREE BENDING MAGNET

The prototype of the bending magnet was installed and tested on the existing 10° beam line at ATLAS (Figure 8). Uniformity of its magnetic field is good. Since the bending radius is small, its poles do not have to be curved to accommodate the beam trajectory. The power consumption is less than 400 W, and it does not require water cooling. Currently, it is used as a regular second bending magnet at the 10° beam line.

FIGURE 8. Prototype of the 10° Bending Magnet

5. CONCLUSION

The proposed beam transport line design is able to satisfy beam transportation, focusing, and rastering onto the target area. Separate magnetic elements are easy manufacture. The raster magnet is sensitive to AC noise; the power cords should be a shielded twisted pair. Power consumption is low, and no cooling water is required for regular performance.

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Argonne National Laboratory
9700 South Cass Avenue, Bldg. 205
Argonne, IL 60439-4837

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