A LEBT FOR THE 400 keV RFQ BASED NEUTRON GENERATOR AT BARC

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Abstract

A LEBT test bench has been setup at Van de Graaff Laboratory, BARC which consists of an Alphatross ion source, Einzel lens, accelerating tube and 2 solenoids. The beam line also has two Faraday cups and two BPM's for measuring the beam current and to see the beam profile, one pair after the first solenoid and the second after the second solenoid. He^+ beam has been extracted from the ion source and accelerated to 50 keV using the accelerating tube. The emittance of the He^+ beam in the LEBT test bench has been measured using the solenoid scan method.

INTRODUCTION

A 400 keV, 1 mA deuteron RFQ based neutron generator is under construction at BARC [1]. It consists of a rf ion source, a 400 keV RFQ and a low energy beam transport (LEBT) line to match the beam from the ion source to the RFQ. The LEBT has been designed using 2 solenoids for focusing the beam. Based on the simulations, a LEBT test bench has been setup at Van de Graaff Laboratory using an existing Alphatross RF ion source to validate the simulations and focusing of the solenoids that have been designed and fabricated. Experiments to measure the beam emittance and transmission in the line have been done.

LEBT TEST BENCH

The LEBT test bench (Fig.1) consists of an Alphatross ion source, Einzel lens, accelerating tube and 2 solenoids. There are 2 Faraday cups and 2 BPM's in the line to measure the beam current and size. He^+ beam has been extracted from the ion source and accelerated to 50 keV using the dc accelerating tube. This 50 keV beam is then focused with the help of the 2 solenoids in the LEBT line. Beam current of 100 µA was measured after the first solenoid and by properly tuning the second solenoid the same current was measured at the exit of solenoid 2 which implies 100% transmission through the line. The effect of changing the strengths of either solenoid on beam size and transmission was seen.

Fig.1. LEBT test bench at BARC.

The solenoids for the LEBT were designed for a peak field of 4 kG and effective length of 30 cm. Based on the design they have been fabricated and tested at RRCAT, Indore. The fabricated solenoid is shown in Fig.2. The variation in longitudinal field 3 cm away from the axis is less than 0.3%. This has been verified from magnetic field profile measurements on the solenoid (Fig.3.).

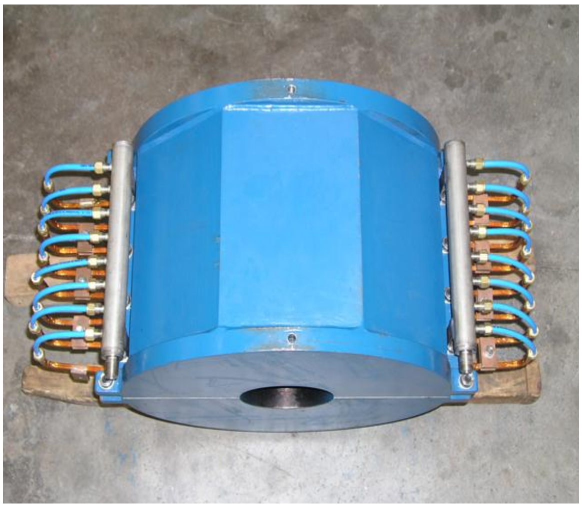

Fig.2. Solenoid magnet fabricated for the test bench.

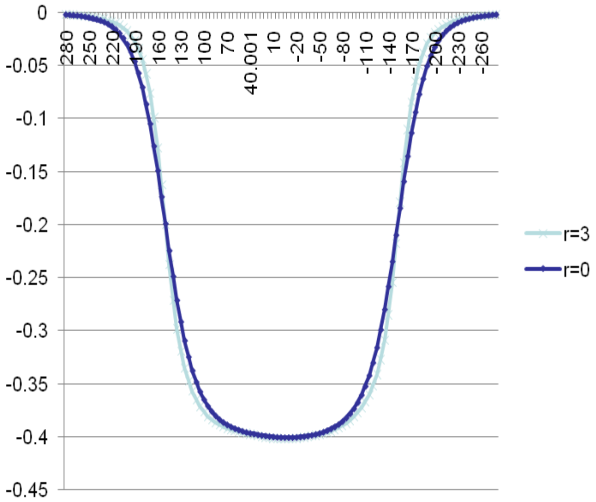

Fig.3. Magnetic field profile measurement of the LEBT solenoid.

EMITTANCE MEASUREMENT

The solenoid scan method [2] was used to calculate the emittance of the He^+ beam in the test bench. A solenoid can be considered as a focusing magnet with the normalized focusing strength

$$Q = \left(\frac{eB_z}{2p}\right)^2 l_{eff}$$

where e is the electric charge, B_z is the longitudinal solenoid field, and p is the momentum of beam. If the effective length of the solenoid l_{eff} is much shorter than its focal length f_{sol}, the solenoid can be considered as a thin focusing quadrupole and the same principle as the quadrupole scan method [3] can be applied to the solenoid scan. Measuring the beam sizes at the final position for different focusing strength of the solenoid can give the emittance and Twiss parameters at the initial position.

The solenoid scan method is very similar to the quadrupole scan method, except for the coupling between horizontal and vertical motions. Rotational coordinates can be used to decouple them for an approximately round beam. Then the transfer matrix for the solenoid-drift system can be written as:

$$R = \begin{pmatrix} 1 & L \\ 0 & 1 \end{pmatrix} \begin{pmatrix} 1 & 0 \\ -Q & 1 \end{pmatrix} = \begin{pmatrix} 1-LQ & L \\ -Q & 1 \end{pmatrix}$$

The equation for the square of the rms beam size can then be solved in the terms of focusing strength of the solenoid lens as:

$$\sigma_{11}{}^{1} = \sigma_{11}{}^{0} L^2 Q^2 - 2(L\sigma_{11}{}^{0} + L^2\sigma_{12}{}^{0})Q$$
$$+ (\sigma_{11}{}^{0} + 2\sigma_{12}{}^{0} L + L^2\sigma_{22}{}^{0})$$

Horizontal and vertical beam profiles are measured using the wire scanner. The solenoid was optimized to locate the beam waist at the wire scanner and then the beam size is scanned around that value. A gaussian distribution was fitted into the beam profile. The fitting coefficient, R^2, in all cases was greater than 0.98. At each value of the solenoid current, 10 readings of the beam profile were taken and averaged to give the beam size. The images were analyzed off line to obtain the rms beam size. After acquiring images for all solenoid scan steps, the RMS transverse emittance was calculated by a least square fitting of the square of the beamsize as a function of the solenoid focusing strength Q as shown in Fig. 4. The normalized rms emittance is calculated to be 0.178 π cm mrad by this method.

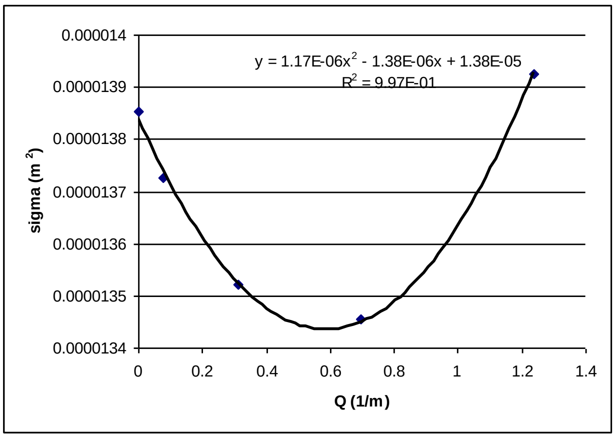

Fig.4. A square of beam radius plotted as a function of magnetic strength of solenoid lens.

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