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SUMMARY OF RLA BEAM TRANSPORT EXPERIMENTS USING A 1.5 MV INJECTOR*

Michael D. Haworth†, Robert C. Platt†, David L. Smith, Michael G. Mazarakis, James W. Poukey, Gordon T. Leifeste, David E. Hasti, Lawrence F. Bennett, and Samuel J. Lucero‡

Sandia National Laboratories
Albuquerque, New Mexico

†Science Applications International Corporation
Albuquerque, New Mexico

‡Diversus, Inc.
Albuquerque, New Mexico

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ABSTRACT

Beam transport experiments on Sandia's Recirculating Linear Accelerator (RLA) using a 1.5–MV injector with and without an additional 1.0 MV of acceleration provided by the ET–2 accelerating cavity were concluded this year. Our experimental results show that an injected beam of only 1.5 MeV requires too large an f–value in the IFR channel to effectively propagate a 10–kA beam. Dramatic improvement in current transport was seen for the higher–γ 2.5 MeV beam. Based on these results plus computer simulation results, the 4.0 MeV IBEX accelerator is now being used as the RLA injector.

INTRODUCTION

The Sandia RLA concept involves recirculating a high current (≈ 10 kA) relativistic electron beam (REB) guided by an IFR channel past one or more accelerating cavities in order to reach a higher final beam energy [1]. The experimental layout used during this past year to test this concept is shown in Fig. 1. Here a 1.5–MV isolated Blumlein (IB) injector [2] with a planar diode configuration injects the beam into a 1.2–m long IFA–type [3] gas transport cell used to match the REB to the Racetrack IFR channel [see Ref. 4 for further details]. A 1.0–MV dielectric cavity (ET–2 [2]) is located ≈ 1.0 m from the exit of the IFA cell to provide post–acceleration of the REB. Typical IB and ET–2 waveforms are shown in Fig. 2.

This paper summarizes our experimental beam transport results both with and without application of the ET–2 accelerating pulse. We report on REB and IFR channel characterization measurements made at the exit of the IFA cell plus on REB current transport measurements made along the Racetrack. Included are the major conclusions drawn from our experimental results and how they have led to design changes implemented on the 4.0–MeV RLA experiment presently underway on IBEX [5].

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DISCLAIMER

REB AND IFR CHANNEL CHARACTERIZATION AT EXIT OF IFA CELL

The IB planar diode configuration consisting of a 1.6–cm O.D. straight cathode shank and a 1.0–cm to 1.3–cm A–K gap produces a very hot, shank current dominated beam which is evident in the MAGIC simulation results shown in Fig. 3. Various types of beam conditioning cells (including electrostatic wire, classical IFR, and higher pressure gas cells [4]) were tested for producing a beam well–matched to the IFR channel. The best results were obtained using a 2.2–cm I.D., 1.2–m long IFA–type gas cell [3] statically filled with 1.0 Torr of argon.

The beam profile at the exit of the IFA cell was obtained from open–shutter photographs of Cherenkov emission from a 5–mil Teflon foil and is shown in Fig. 4. A radial slice of this data is shown in Fig. 4a and is best fit by a Gaussian profile with a 0.75–cm radius. Fig. 4b shows an overlay of this REB profile with that of the Racetrack IFR channel, which was measured using a cylindrical Langmuir probe. Notice that the beam and channel radii are well matched and yield an f–value of 0.41 when integrated over the radial extent of the REB.

BEAM CURRENT TRANSPORT AROUND THE RACETRACK

After producing a beam that was well matched to the Racetrack IFR channel, we next made a series of current transport measurements around the Racetrack while varying the IFR plasma parameters. In addition, we tested the effect on current transport due to the additional 1.0 MeV of beam energy provided by ET–2. Typical peak current values as a function of length around the Racetrack are shown in Fig. 5.

One striking feature of this data is that there is virtually no loss from the exit of the IFA cell at L = 1.2 m to the end of the first straight section at L = 8 m for the 2.5 MeV beam but substantial loss for the 1.5 MeV beam. The principal reason for this is seen in Fig. 6. The beam front erosion from the exit of the IFA cell (I_3) to the end of the first straight section (I_6) is clearly increased in the lower–γ beam. The amount of beam front erosion for both the 1.5 MeV and 2.5 MeV cases agrees quite well with the simple analytical expression for inductive erosion given by [6]

$$\frac{dx}{dz} = f \frac{\nu}{\gamma} [1 + 2 \ln(b/a)]$$

This demonstrated lower erosion rate for the higher–γ beam plus extensive computer simulation results [7] were the primary reasons for choosing to use the 4.0 MV IBEX as the injector for present–day RLA experiments [5] as well as to design a new compact 4.0 MV injector [8] for future RLA experiments.

A second striking feature of the 2.5–MeV data in Fig. 5 is that there was little current loss along the straight sections of the Racetrack (L = 2–8 m and L = 10–17 m), while there was substantial loss around the first 180° turn. This loss was much greater than could be expected due to erosion or to emittance growth in the turns [9] and remained puzzling for some time. The answer became apparent when we measured the IFR channel profile at several axial locations around the Racetrack (see Fig. 7 and Ref. 10). In particular, the plasma profile at Port 3 at the beginning of the first 180° turn showed severe asymmetry, while the peak density of the channel varied by over a factor of 3 around the Racetrack. The reason for this axial variation in the IFR plasma profiles turned out to be due to poor alignment of the 200–G field coils at the ports. The flimsy coil supports used during these experiments have since been replaced on the IBEX experiment with rigidly mounted coils which also have improved field uniformity across the ports [5,10].

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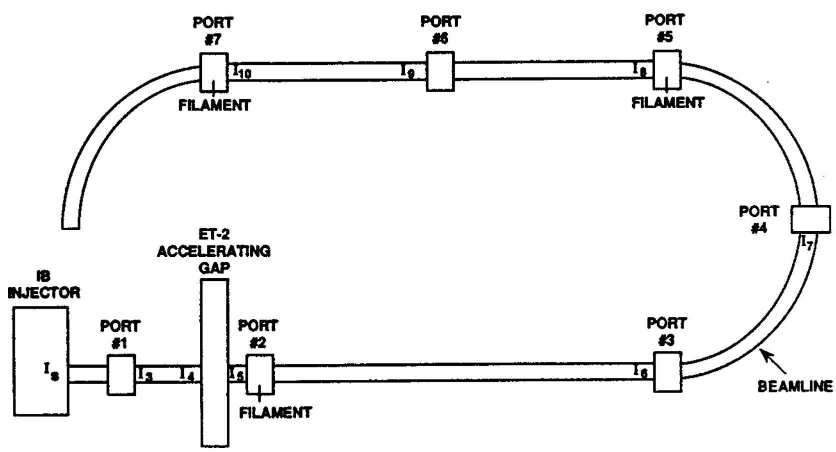
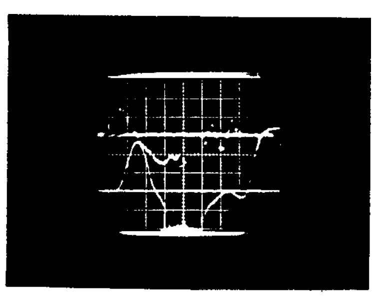
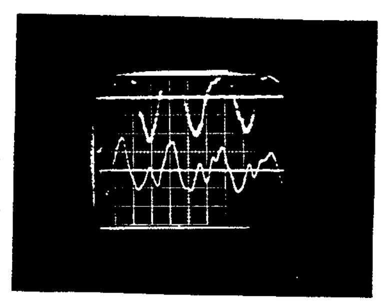


Fig. 1. Experimental layout used during this past year to test the Sandia RLA concept.



Top: Diode Voltage (0.98 MV/div, 20 ns/div)

Bottom: Shank Current (9.4 kA/div, 20 ns/div)



Bottom: Acceleration Voltage (0.57 MV/div, 50 ns/div)

Fig. 2. Typical IB and ET–2 waveforms.

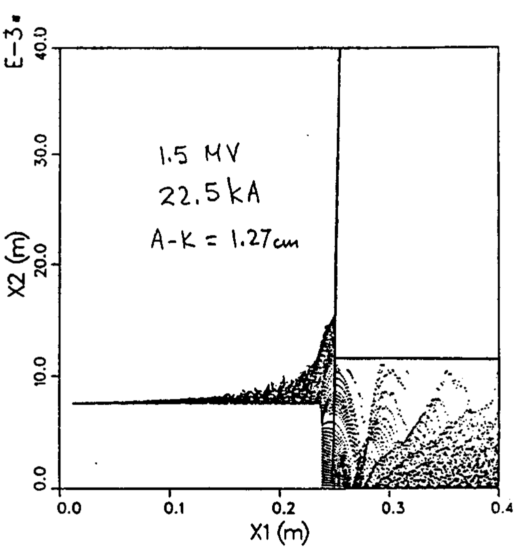


Fig. 3. MAGIC simulation results for the IB injector diode configuration.

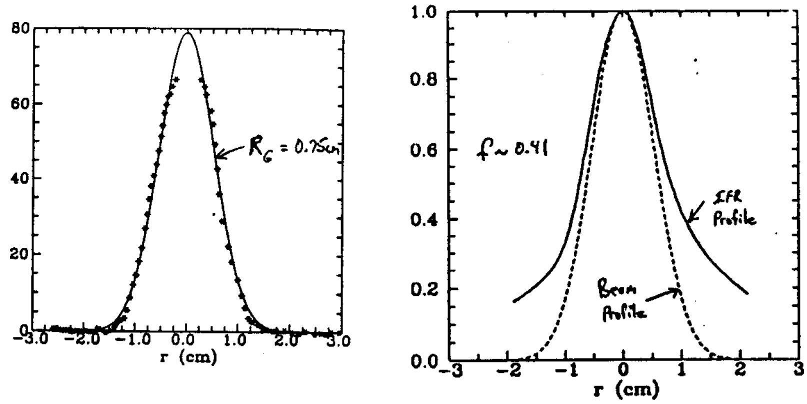


Fig. 4. Cherenkov emission data taken at the exit of the IFA cell showing (a) a Gaussian fit to the data and (b) an overlay of it with the IFR plasma profile.

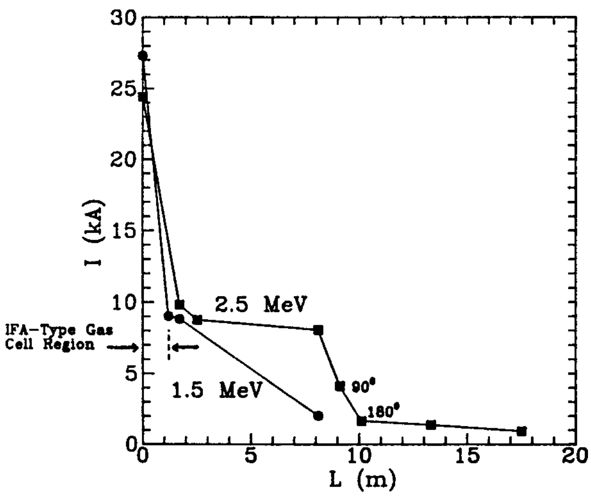


Fig. 5. Peak beam current transport results around the Racetrack.

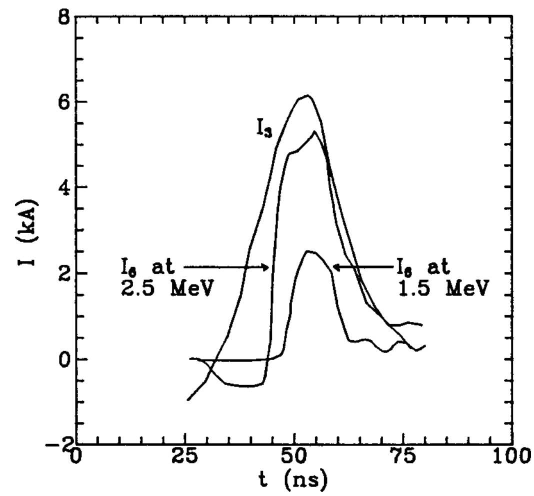


Fig. 6. Beam erosion results after the first 8 m of transport.

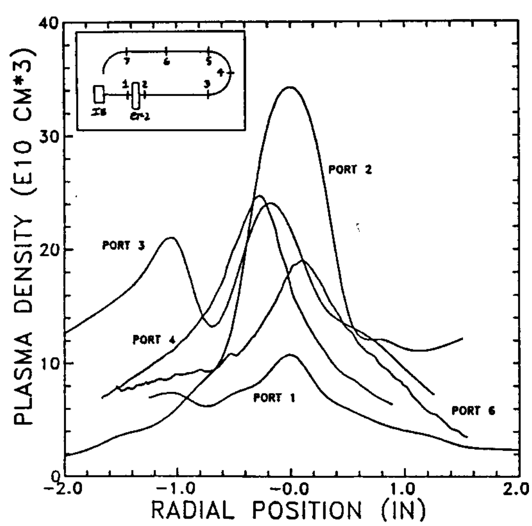


Fig. 7. IFR plasma radial profiles at various axial locations around the Racetrack.