Electron Beam Ion Source Pre-Injector Diagnostics*

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Abstract. A new ion pre-injector line is currently under design at Brookhaven National Laboratory (BNL) for the Relativistic Heavy Ion Collider (RHIC) and the NASA Space Radiation Laboratory (NSRL). Collectively, this new line is referred to as the EBIS project. This pre-injector is based on an Electron Beam Ion Source (EBIS), a Radio Frequency Quadrupole (RFQ) accelerator, and a linear accelerator. The new EBIS will be able to produce a wide range of heavy ion species as well as rapidly switching between species. To aid in operation of the pre-injector line, a suite of diagnostics is currently proposed which includes faraday cups, current transformers, profile monitors, and a pepperpot emittance measurement device.

Keywords: diagnostics, instrumentation, faraday cup, profile monitor, current transformer, pepperpot, electron beam ion source
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INTRODUCTION

The EBIS pre-injector is being constructed as a replacement to the Collider-Accelerator Department's (CAD) present pre-injector, the Tandem Van de Graaff. The Tandem was built around 1970 and is showing signs of age. Significant upgrades are required to allow the Tandem to maintain reliable operation and to be able to produce the types and intensities of ions that both RHIC and NSRL are requesting. An EBIS test stand was constructed for development and experimental results have proven that an EBIS meeting beam requirements can be successful[1,2]. The EBIS project received DOE critical decision 1 (CD-1) approval in September 2005 and is expected to obtain critical decisions 2 and 3 this year (2006).

TABLE 1. EBIS Parameters and Specifications.

Parameter	Specification
Electron Beam Current	10A
Ion Beam Pulse Width	10 - 40 μs
Intensity in Desired Charge State	$\geq 1 \times 10^{11}$ charges/pulse
Repetition Rate	5 Hz
Switching Time Between Species	1 second
Output Energy	2 MeV/amu
Emittance (Full Beam, Normalized)	$\leq 1.4\ \pi$ mm mrad

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Table 1 gives a list of some relevant specifications for the EBIS pre-injector[3]. The transport line will be approximately 30m and will inject full intensity beam into Booster over 1-4 turns, as opposed to the 30-40 turns that it takes presently. Booster injection from the EBIS transfer line will be situated in the same place as the present Tandem injection location. The EBIS is capable of producing any ion species in contrast with the present Tandem which can only produce negative ion species. EBIS will have the potential to run species ranging from helium to uranium. A future upgrade may allow polarized ^{3}He beams as well. Beam current ranges from 10uA at EBIS injection to 15mA at the EBIS source extraction.

With the improvements of species switching time and the wide range of species that will be available with the new EBIS, the RHIC and NSRL programs will be able to operate in an increasingly efficient manner by reducing delays in switching time and tuning. Both programs will also be able to take advantage of the capability of EBIS to produce ions that the Tandem cannot currently generate.

DIAGNOSTICS

Figures 1 and 2 depict the locations of the diagnostics that will be used in the EBIS pre-injector. A standard set of diagnostics will be installed and include faraday cups (FC), a fast faraday cup (FFC), current transformers (CT), profile monitors (PM), and an emittance pepperpot (PP).

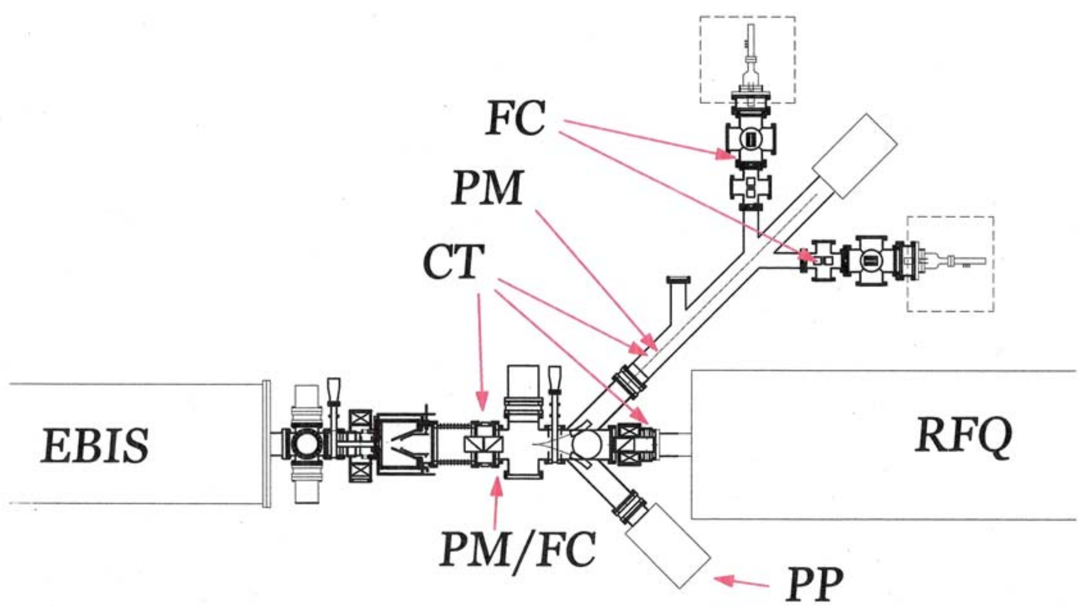

FIGURE 1. Layout of diagnostics in the external ion injection lines (EIL) and in the low energy beam transport (LEBT)

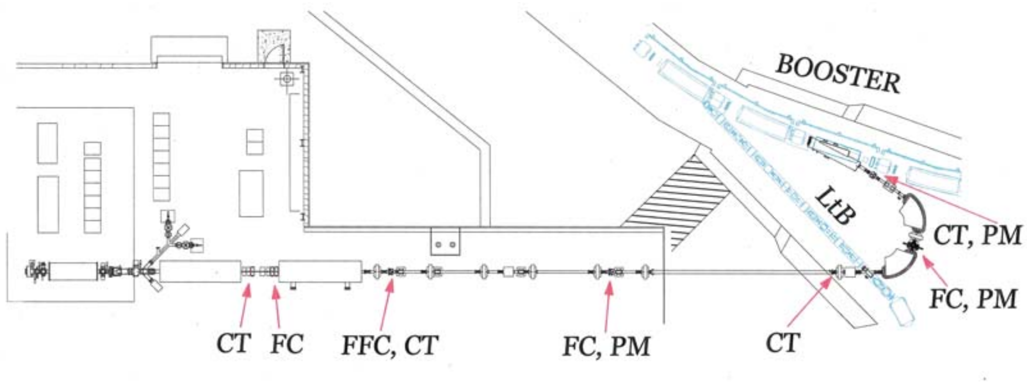

FIGURE 2. Layout of diagnostics in the transfer line to Booster

Faraday Cups

Six faraday cups and one fast faraday cup will be distributed among the pre-injector and transfer line.

The faraday cups are pneumatically inserted into the beamline aperture to make a measurement. The accumulated electric charge is detected as a current and then processed by front end electronics. It is desired for the current measurement to have a resolution of 0.1uA. The resulting current measurement and pulse waveform will be digitized and input into the Controls system for distribution, viewing, and logging. An oscilloscope will be used for digitizing the fast analog pulse waveforms and an MADC will be used to digitize the current measurement. Since the insertion of the faraday cup is a destructive measurement device, it can also be used as a beam stop.

The fast faraday cup installation will make use of an existing unit that was removed from another beamline. This unit has bandwidth in the GHz range that will allow the 100MHz bunch structure of the beam to be observed. A scope will be used to digitize this signal.

Current Transformers

Seven current transformers will be installed as shown previously in Figures 1 and 2. The transformers will be fabricated at BNL and be similar to the transformers currently installed in the Tandem to Booster (TTB) and test EBIS lines. Six of the transformers will be identical in size with the seventh transformer at the entrance to the EBIS trap being slightly larger to accommodate the beamline components. At present, two transformers in the EIL and the one transformer at the exit of the RFQ will be mechanically mounted inside conflat flanges which will help in keeping the space requirements low. The remainder of the transformers in the transport line will have specially designed enclosures.

A one turn calibration winding will be installed around each transformer to assist in measuring each transformer's response independent of beam conditions. Electronics similar to those used for the TTB transformers will be used. The signals will be digitized using an oscilloscope and input into the Controls system for remote viewing. Data will be taken on a pulse by pulse basis, if possible. Otherwise, light averaging will be done to obtain the measurements with resolution of 0.1uA.

Figure 3 depicts the progressive fabrication of the transformers beginning at the bottom right with the bare high permeability ferrite core. Moving towards the left in the bottom row, the picture shows the core being wound with 28 gauge insulated wire. Moving on to the top right, the core is shown with kapton tape and continuing left displaying the TTB style mechanical enclosures.

FIGURE 3. Fabrication of current transformers

Profile Monitors

Beam profile measurements will be made at four locations and be installed in conjunction with the faraday cups on dual feedthroughs at two locations. A fifth profile monitor is already installed at a location in the existing TTB line, just past the transport line bending magnets. Two 32H x 32V multiwire assemblies will be moved from the TTB line and installed in EBIS. The required remaining multiwire assemblies will be purchased. The 0.1mm thick wires in the units are made of Tungsten-Rhenium (W-Re). Units will be pneumatically inserted into the beamline when profile measurements are needed.

The profile measurements are obtained by processing the current signal that is generated when the beam interacts with the wires, with a resolution of 1mm. These currents are processed by integrators and then input into an MADC for digitization and display of the results.

Emittance Pepperpot

A pepperpot device that can measure the emittance of an ion beam in a single pulse is being developed on the EBIS test stand for eventual use in the EBIS pre-injector[4]. The pepperpot schematic is shown in Figure 4. A mask with an array of small holes is inserted into the beam. An image of the beam passing through the small holes is generated on a phosphor screen behind the mask which is then digitized and captured by a CCD camera. In addition, a microchannel plate can be placed between the mask and phosphor screen to enhance the image intensity and to gate the measurement such that measurements can be made at a specific time by pulsing the voltage on the microchannel plate. The two dimensional profiles captured by the camera are then used to calculate a four dimensional beam emittance by use of software.

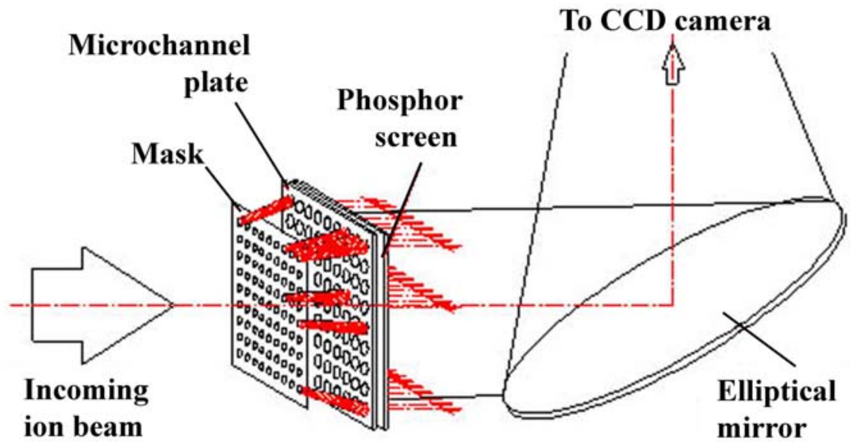

FIGURE 4. Schematic of the Pepperpot device

With a nominal beam diameter of 50mm, it was determined that the array of holes will be 25 x 25 with a distance between the individual holes around 2mm. By using a CCD camera with resolution of 1000 x 1000, each small beamlet that travels through the mask hole will cover 40 channels on the camera. Calibration can be performed by shining a laser beam through the mask. Initial results from the pepperpot installed on the EBIS test stand have been very good. Figure 5 shows a calculated horizontal emittance of Xe-132. Resolution of the measurements is expected to be around 0.5 mrad in divergence and 0.1mm in size.

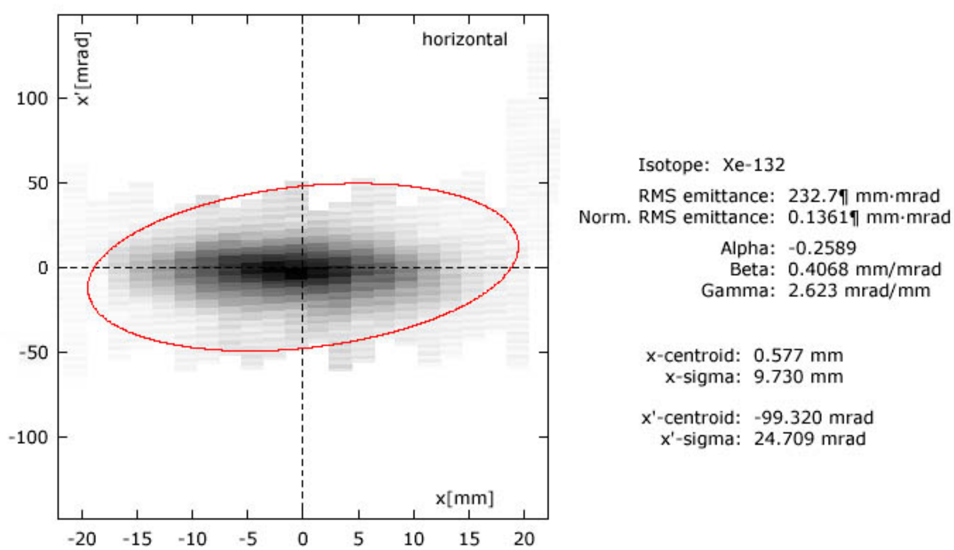

FIGURE 5. Results from the EBIS Test Stand Pepperpot

CONTROLS INTERFACE

In general, the EBIS Controls system will be an extension of the existing RHIC Controls system. The Diagnostics-Controls interface is no exception and will make use of the VME-based standard RHIC system. Hardware control will be provided by digital output boards, trigger boards, and timing distribution boards. Status information and signal monitoring will be done by digital input boards, MADCs, and an oscilloscope. Multiplexers will be used for the scope input channels as all signals will not need to be viewed at the same time. For example, if a faraday cup is inserted into the beamline aperture, devices downstream of that cup will not measure any useful signal. A software user interface will be provided through the BNL-developed *pet* program. Standard software programs for displaying and logging data already exist for most of the diagnostics with the exception of the pepperpot. These existing programs will simply need the addition of the new devices into the programs' databases for proper operation. The pepperpot has a standalone software program which could eventually be integrated into the Controls system.

CONCLUSION

The new EBIS pre-injector will provide many additional benefits to the RHIC and NSRL programs. As with any pre-injector line, a set of diagnostics will be crucial to determining proper operation of the EBIS. The proposed suite of diagnostics will be similar to diagnostics used elsewhere in the facility wherever possible to maximize value.

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