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DESIGN OF THE EBIS VACUUM SYSTEM*

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Abstract

At Brookhaven National Laboratory the Electron Beam Ion Source (EBIS) is presently being commissioned. The EBIS will be a new heavy ion pre-injector for the Relativistic Heavy Ion Collider (RHIC). The new pre-injector has the potential for significant future intensity increases and can produce heavy ion beams of all species including uranium. The background pressure in the ionization region of the EBIS required to be low enough that it does not produce a significant number of ions from background gas. The pressure in the regions of the electron gun and electron collector can be higher than in the ionization region provided there is efficient vacuum separation between the sections. For injection the ions must be accelerated to 100KV by pulsing the EBIS platform. All associated equipment including the vacuum equipment on the platform is at a 100KV potential.

The vacuum system design and the vacuum controls for the EBIS platform and transport system will be presented as well as the interface with the Booster Ring which has a pressure 10^{-11} Torr.

Figure 1: EBIS High Voltage Platform

INTRODUCTION

The Electron Beam Ion Source (EBIS) consists of multiple vacuum chambers which make up the high voltage platform (Figure 1). The system consists of an Electron Gun chamber, main solenoid chamber and an Electron collector chamber. The main solenoid chamber has vacuum chamber tees on each end which provide ports for mounting vacuum pumps, valves and electrical feedrthroughs. A load lock chamber is installed between the upstream pumping tee on the main solenoid chamber and the electron gun chamber which allows a spare electron gun chamber to be installed under UHV by baking only the small load lock chamber. .

The background pressure in the trap region and the central solenoid chamber is required to be 10^{-11} Torr so that there are not a significant number of ions generated from background gasses. To achieve a vacuum pressure of low 10^{-11} Torr, the entire vacuum system on the platform needs to be baked in-situ.

The balance of the EBIS system is at ground potential and consists of two ion sources, a switching chamber in the Low Energy Beam Transport (LEBT), an RFQ, LINAC and a High Energy Beam Transport (HEBT) line. The HEBT system provides beam transport from LINAC to the Booster ring which interfaces to a pressure of low 10^{-11} Torr. These sections of the EBIS are unbaked, except for the later part of HEBT, which is baked to provide a transition vacuum to the Booster ring.

VACUUM CHAMBER DESIGN

The vacuum chambers are fabricated from either 304 or 316 stainless steel depending on the location and bake out requirements. Chambers with higher bakeout temperature requirements, such as the central drift tube and pump tees, are fabricated from 316 stainless steel, all other chambers are 304. The flanges however, are all 316LN stainless steel Conflat flanges with 90° knife edges. The 90° knife edges are used to prevent the knife edges from rolling over from repeated bake cycles.

The vacuum chambers are mounted on a rail system which allows the chambers to be separated for repairs and re-assembled together without being resurveyed once the system has gone through the initial alignment procedure. The rails also provide linear expansion between chambers during the bakeout cycles.

Other vacuum sections such as LEBT, RFQ, LINAC, MEBT and HEBT use all standard 304 Conflat flanges since there are no stringent baking requirements.

VACUUM PUMPING

There are several different types of vacuum pumps mounted on the platform (Figure 2) which provide pumping for different modes of operation. Cyopumps, turbomolecular pumps, NEG pumps, titanium sublimation pumps and ion pumps make up the pumping system.

The Electron Gun Chamber has a permanently mounted turbomolecular pump backed with a dry scroll pump.

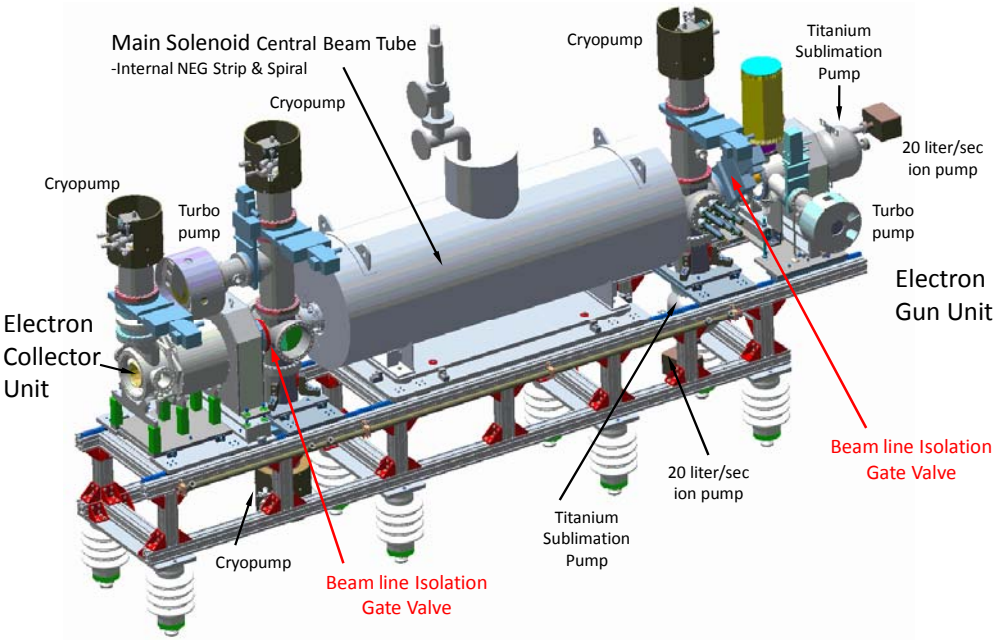

Figure 2: EBIS High Voltage Platform Layout and Pumping Arrangements

A gate valve separates the pump from the chamber. In addition, a titanium sublimation pump with a 20 L/sec ion pump is also mounted on the gun chamber which gives approximately 1,000 L/sec of pumping speed for H_2.

The main solenoid chamber has crosses mounted on each end that provide ports for pumps and gauges. Each pump cross also has a set of gauges. The main solenoid chamber is pumped with two 8" cryopumps, one titanium sublimation pump, and one permanently mounted turbomolecular pump backed with a dry scroll pump. In addition to these pumps the main solenoid chamber has St 707 NEG strip mounted on an insulated frame along the length of the chamber. The drift tubes have St 707 NEG strip spiralled along the inside diameter along the entire length of each drift tube. A perforated screen is used to retain the NEG strip in the drift tube and allow for pumping through the screen. The NEG strips are powered using an external power supply connected to vacuum feedthroughs on each end of the strip. The spiralled NEG strip is activated from an elevated bakeout temperature of 450° C for 1 hour.

The turbomolecular pumps and the cryopumps mounted near the solenoid magnet have magnetic shields fabricated from ½" thick steel to shield the electric motors of the pumps from the fringe field of the solenoid magnet. The fringe field of the solenoid magnet in the vicinity of the pumps ranges from 500-1,000 gauss. The shields were designed to cut the fringe field to the pump motors to less than 50 gauss. Gate valve solenoid blocks were remoted from the valve due to fringe field interference.

The collector chamber is pumped by to 8" cryopumps. A large electrical break is located just downstream of the collector chamber and provides electrical isolation from ground to the 100 KV platform potential. A gate valve installed between the collector and the break separates the baked platform from the standard unbaked vacuum system in LEBT.

Aside from the LEBT and RFQ which are pumped with a turbomolecular and cryopump respectively, the balance of the system which includes LINAC, MEBT and HEBT are pumped with conventional diode type ion pumps. The HEBT also has St707 NEG strip and St185 NEG cartridges to provide additional pumping in order to transition to the Booster ring pressure of low 10^{-11} Torr.

BAKEOUT SYSTEM

The EBIS platform vacuum system is required to be baked in order to minimize number of ions produced from residual background gasses. All chambers are designed to be baked to 250° C except for the central drift tube chamber which is designed to be baked at 500° C in order to activate the spiralled NEG strip in the drift tube region.

Custom heating jackets were designed and installed on all vacuum components with each blanket having a thermocouple to control the temperature. The only exception to this is the central drift tube chamber which uses fire bars instead of heating jackets due to the higher temperature required to activate the NEG strip. Fire bars are specified to achieve the 500° C temperature for the entire central drift tube chamber. The fire bars were wired so that there are 4 zones of paired fire bars in parallel. The superconducting solenoid is protected from the extreme heat from the fire bars with a water cooled heat shield.

The bakeout system is a portable multi-zone PID controller based cart that uses SCR racks to power each heating zone. A heating zone is generally one 110 volt heating jacket and one thermocouple. PID controllers are individually programmed via computer to provide a specific temperature versus time profile for each component. Ramp rates are set to 50° C/hr to promote even heating and expansion of vacuum chambers made from various materials. The programming allows for soak times at a desired temperature and can include additional ramps and soaks for specific zones such as the central drift tube chamber. This chamber, heated with the fire bars, soaks at 300° C for most of the bake out and is subsequently ramped to 450° C for one hour to activate the spiralled NEG strip and then ramped back down to room temperature to complete the bake out.

INSTRUMENTATION & CONTROL

The vacuum instrumentation and controls (Figure 3) in EBIS use Programmable Logic Controllers (PLCs), gauge, and ion pump controllers that are deployed in many of the vacuum systems in the Collider-Accelerator complex. Unique to the EBIS is the requirement that a portion of the vacuum equipment be operated at up to 100 KV potential difference from ground. Fiber-optic cables with media converters provide the voltage isolation for remote control of the vacuum systems.

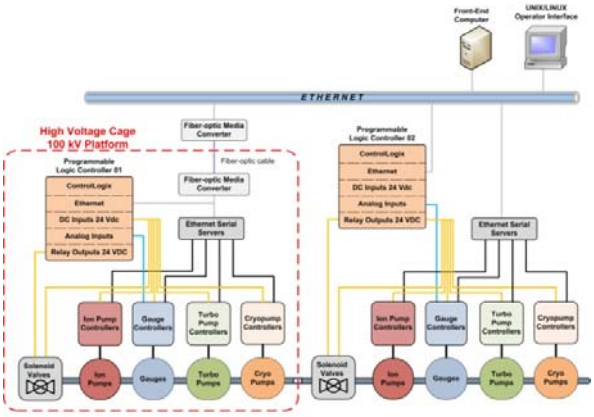

Figure 3: I&C Schematic.

PLC Systems

Both the 100 kV platform and ground potential PLC systems comprise a programmable automation controller, an Ethernet communication module, dc voltage input modules, an analog input module, relay contact output modules, and a 24 volt power supply. The 24 Vdc control power is used for all dc inputs to the PLC from the gauge, ion pump, turbo, and cryo controllers. Active high logic is used: acceptable vacuum, cold cryo temperature, and normal turbo speed each result in a 24 Vdc PLC input. Analog 0-10 V gauge signals are fed to the analog input modules. The relay contact output modules provide contact closures for equipment interlocks and valve operation. The beamline and pump isolation electro-pneumatic valves have 24 Vdc solenoids and both open & closed position indicator limit switches.

PLC Ladder Logic

The PLC controller runs several ladder logic programs organized by function: sector valve operation, turbo pump isolation valve operation, cryopump isolation valve operation, communication to and from the Controls system, and equipment interlocks. The PLC reads commands from the Controls system through the Ethernet module and acts on them according to the system status. Logic in the PLC prevents the beam line sector valves from opening, and closes them when vacuum conditions are poor. The PLC generates outputs to o the RF system and the global interlock system, which is designed to link interlocks across the spectrum of voltage platforms in EBIS. The PLC also writes a time stamp that is displayed on the Controls System data viewing application.

Ethernet-Serial Communication

The gauge and pump controllers have RS-232 serial communication interfaces through which programmable parameters are read and set. Ethernet serial servers provide the communication connection between the Controls System data applications and the controllers. Pressure, current, voltage, and temperature values are read through RS-232 interfaces on all gauge, ion pump, turbo and cryo pump controllers. Most parameters are recorded at 1 s intervals. Data from the PLC, which includes valve position and equipment interlock status information, is transmitted via Ethernet to the Controls system LINUX computers for data display and logging.

CONCLUSION

Achieving a pressure of low 10^{-11} Torr in the ionization region was a key factor during the early commissioning stage of EBIS since the beam was sensitive to ion created from residual gas molecules. The vacuum system has operated reliably since installation.

REFERENCES

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