PERFORMANCE OF THE NBS-LANL RTM INJECTION LINE VACUUM SYSTEM*

R. I. Cutler
National Bureau of Standards
Washington, DC 20234

Abstract

A 1000 l/sec cryopump is used to provide the hydrocarbon-free vacuum required for the 100 keV electron beam transport line of the NBS-LANL Racetrack Microtron. The beam line is 3.5 cm in diameter and 4 m long. To overcome the low vacuum conductance of the beam line, it is pumped every 1/2 meter by a 15 cm diameter vacuum manifold which is connected to the cryopump. A single cryopump is used rather than several ion pumps to reduce costs and to provide easier starting. An oil-free roughing pump and sorption pump are used in the initial pumpdown. The vacuum system is all metal sealed. Vacuums of 3 x 10^{-6} Pa are reached in 8 hours from atomospheric pressure without baking out the system, and ultimate vacuums of 5 x 10^{-7} Pa are achieved.

Introduction

The 100 keV beam line[1] of the NBS-LANL Racetrack Microtron (RTM) provides a 550 μA, chopped and bunched continuous wave (cw) electron beam of low emittance for acceleration by the linac sections of the RTM. The beam line, illustrated in figure 1, is approximately 4 meters long. It contains a large number of beam handling components which limit the beam tube diameter to 3.5 cm. Since many of these components are not bakeable, it is not practical to outgas the beam line by heating. The electron gun, which has a thoriated cathode, requires an uninterrupted, hydrocarbon-free vacuum of 1 x 10^{-6} Pa or better for optimum lifetime, emission, and brightness.

The vacuum in the beam line must be sufficient to prevent significant deterioration of the beam emittance through small angle scattering. The rms scattering angle is given by the equation[2]

$$\langle\theta_s^2\rangle^{1/2} = \frac{21\ \mathrm{MeV}}{\beta cp}\sqrt{x/x_0}$$

where x is the thickness (in g/cm^2) and x_0 is the scattering length (38g/cm^2 for air). A beam line vacuum of better than 7 x 10^{-5} Pa is required to keep emittance growth below 5%.

The RTM is a developmental accelerator. Fast pumpdowns are desired to facilitate testing new components. Quick recovery from catastrophic (i.e., up-to-air) accidents is also needed, as the 500 watt beam can burn through the beam pipe in seconds. This rules out the use of diffusion or turbomolecular pumps, which can be damaged by such an event. Furthermore, backstreaming of diffusion pump and/or backing pump oil in such an accident would ruin the electron gun cathode and require disassembly of the entire vacuum system for cleaning. Two pump types were considered for use in the vacuum system, ion pumps and cryopumps. The decision was made to use a cryopump instead of several ion pumps for the main beam line based on the lower initial cost of the cryopump, its high gas throughput capabilities, and its higher starting and cross over pressures [1 Pa vs. 10^{-2} Pa for ion pumps]. An ion pump is used to maintain the electron gun vacuum when the cryopump is to be serviced, or the beam line is let up to air.

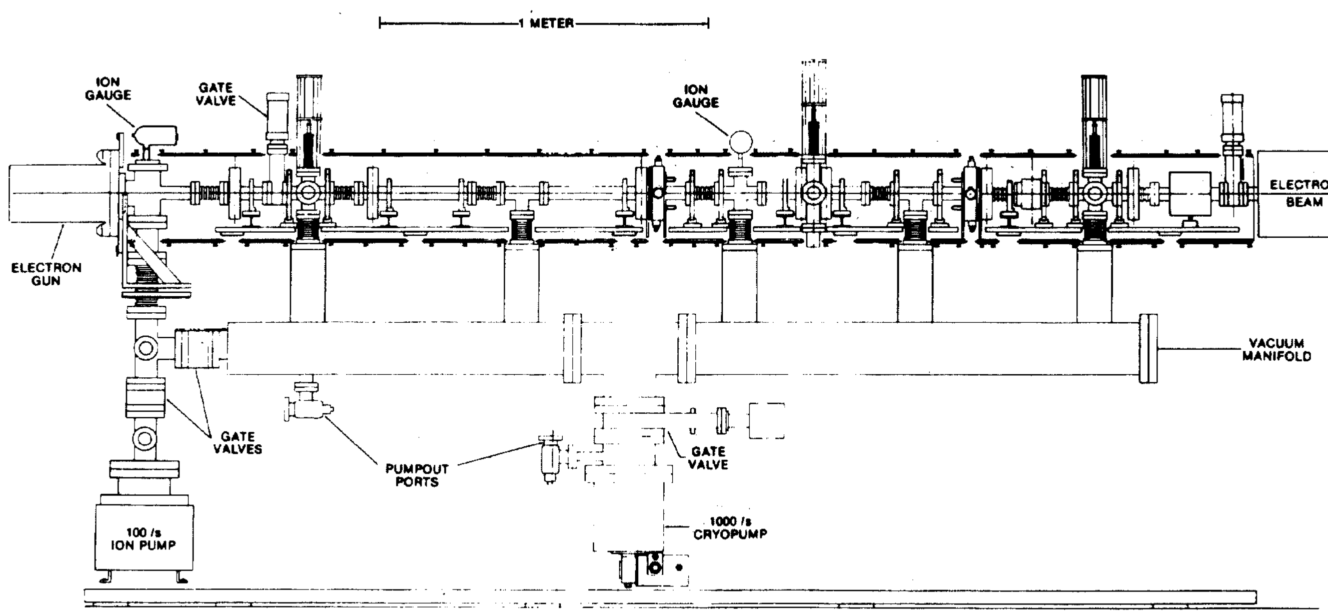

FIGURE 1. Chopper-buncher beam line vacuum system.

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Vacuum System Description

Detailed vacuum conductance and pumping speed calculations were performed for the beam line to design a system which pumps down from atmosphere to 10^{-5} Pa in 8 hours. The outgassing load was assumed to be clean, unbaked stainless steel[3]. A pumping speed of 50 l/sec is needed every 1/2 meter along the beam line to satisfy the 8 hour pump-down time requirement. To achieve this economically, a single 1000 l/sec closed cycle, helium refrigerator-expander cryopump is connected to a 15 cm diameter manifold. The manifold connects to the beam line at about 1/2 meter intervals. The actual location of the manifold-beam line interconnections was determined by the location of such devices as constricting apertures in the beam line. The combination of a manifold and a cryopump is less expensive than individual small pumps and simplifies control and gauging.

Commercially available, conflat-compatible, stainless steel components are used wherever possible in the beam line and manifold vacuum system. Seals to atmosphere are all metal, and internal gate valve seals are either viton or copper. All non-demountable joints are either welded or brazed with high vacuum materials and fillers. The volume of the total system (including manifolds) is about 200 liters. The surfaces are predominantly types 304 and 316 stainless steel and copper. Surface area is about $4m^2$. One large ceramic insulator (20 cm diameter, 30 cm long) is used in the electron gun.

Vacuum measurements are made using wide range thermocouple gauges for rough vacuum and nude Bayard-Alpert type ion gauges for high vacuum.

A portable roughing stand is used to rough the vacuum system to the crossover pressure of 1 Pa, where the valve to the cryopump is opened. The stand consists of an oil-free carbon vane pump for use from atmospheric pressure to 10^4 Pa, and three liquid-nitrogen chilled sorption pumps for pumping between 10^4 Pa and 1 Pa.

Performance

The entire beam line and electron gun system is roughed out from atmospheric pressure to 1 Pa in under 10 min. The cryopump is then opened to the system, and a vacuum of 1×10^{-5} Pa is achieved in less than 5 hours. Backfilling the system upon opening with dry nitrogen reduces this to 3 hours. Ultimate vacuums of 5×10^{-7} Pa are routinely achieved.

The cryopump has been in almost continuous use for over a year with no problems. Two large vacuum accidents occurred in this period. In the first, the electron beam burned a visible hole through a bellows assembly. Beam line pressure remained below 0.1 Pa, and the cryopump continued to pump. The damaged section was replaced and vacuum was restored to 10^{-5} Pa within one day. In the second accident, the beam melted a brazed water-vacuum joint and water leaked into the vacuum system. The cryopump held the beam line vacuum at 1 Pa. In neither of these vacuum accidents was the cryopump damaged, nor was it necessary to regenerate the cryopump.

References

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