A VACUUM SYSTEM FOR THE ARGONNE 6 GeV SYNCHROTRON LIGHT SOURCE*

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Abstract: The ANL vacuum system for the 6 GeV light source storage ring features non-evaporable strip getter pumps for uniform pumping around the ring within a gas desorption antechamber, and it also features lumped getter pumping directly under and above crotch radiation absorbers that are positioned after each bending magnet. Based on experiments at ANL in 1980 and by others, the technical and economical advantages have been established for the use of the distributed NeG pumps of non-magnetic strips coated with a non-evaporable Zr Al getter matrix. The NeG strip pump lifetime approaches ten years. The antechamber improves the isolation of the gas desorption process from the main beam chamber and beam. The combination of these vacuum techniques; the NeG strip getter pumps, the gas desorption antechambers, and the lumped ion and lumped getter pumping provide a unique and reliable system for maintaining long beam lifetime.

Introduction

A design study is being carried out at Argonne National Laboratory for a 6 GeV synchrotron light source containing a vacuum system for a positron storage ring that has a circumference of ~ 800 meters. The light source storage ring will be an extremely intense dedicated source of hard x-ray photons. Some of these x-ray photons strike the vacuum chamber absorbers causing indirect desorption of gases. The 100 mA beam current of the positrons stored in the storage ring diminishes with time due to interactions with the desorbed residual gases. High mean lifetime of the storage ring beam is required for the most effective operation of the light source. For a beam lifetime of 20 hours, an average pressure of 1×10^{-9} Torr or better is necessary within the beam chamber while beam is circulating. To realize such an operating pressure, base pressures in this chamber (I = 0) must be 1×10^{-10} Torr or less.

Desorption

The circulating positron beams produce the intense synchrotron light which strikes the absorbers and the chamber walls. This increases the wall temperature which causes increased thermal outgassing. Furthermore, secondary electrons are produced which, upon hitting the chamber wall again, desorb more adsorbed gas molecules from the surface.

Experience demonstrates these residual gases cause time delays of many months in bringing light source storage rings up to full coasting beam intensity for useful lifetimes. The desorbed gases cause Coulomb scattering and bremsstrahlung beam loss interactions. Many procedures for precleaning chamber walls of absorbed gases such as baking, glow discharges, and chemical washes are rightly employed to obtain a headstart. However, the photon produced electrons remain as the best desorption agents and so relatively large amounts of gas are still desorbed. Therefore a large pumping capacity judiciously distributed is considered an economical necessity for efficient long run operation of the storage ring.

The specific gas desorption rate determined for PETRA[1] as a function of the operation dose can be generalized for all electron storage rings, considering the number of photoelectrons produced and the area of the inside chamber surface of the vacuum structure. Determination of the specific desorption rate can be done by the following equation:

$$\frac{dQ}{dt} = 1.55 \times 10^{-8} \times C \times I \left(\frac{C \times D}{F}\right)^{-0.63}, \qquad (1)$$

where $\frac{dQ}{dt}$ = the desorption rate in mbar l/s/m; I = beam current in mA; F = inside surface of vacuum chamber effected by the radiation in cm^2/m; C = photoelectron current in mA per meter and per mA beam current; and D = dosage in mA hours.

For the proposed ANL positron storage ring, a photoelectron current C of 1.2 mA is assumed as being most representative for the 6 GeV Light Source. The inside surface area of the vacuum chamber affected by synchrotron radiation, F, is 3828 cm^2/m. Figure 1

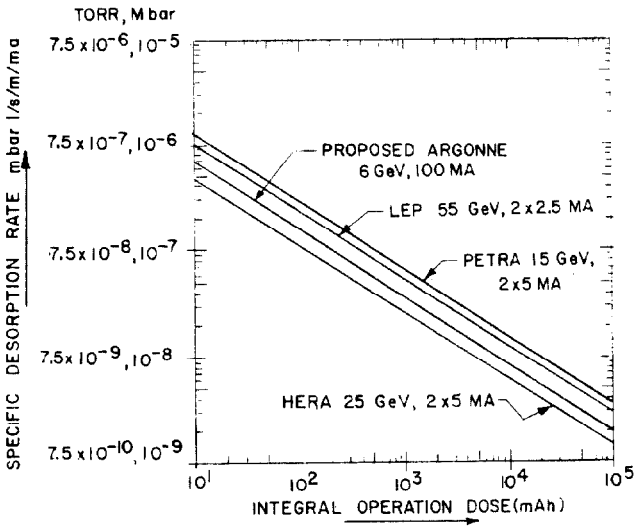

Figure 1 Specific Desorption Rates

shows the calculated specific desorption rate for the proposed 6 GeV, 100 mA light source compared to PETRA, HERA, AND LEP.

The Vacuum Chamber

The chamber that is intended to pass through the dipole, quadrupole, and sextupole magnets is shown in Fig. 2. This chamber, which is to be an aluminum

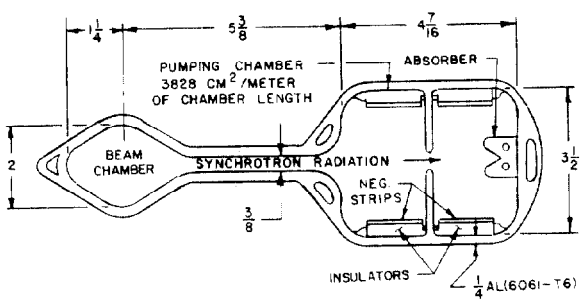

Figure 2 Vacuum Chamber

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extrusion, is patterned after a chamber designed by the Lawrence Berkeley Laboratory for light source use.

The unique design of this chamber allows the synchrotron radiation to be transferred from the beam chamber to an antechamber and onto a water-cooled copper target strip. Absorbed gas molecules liberated from the walls of the antechamber by photoelectrons produced by the photons of the synchrotron radiation are captured within the antechamber by non-evaporable getter (NeG) strips distributed along its length. This design approach should improve beam lifetime considerably since the increased pumping speed and better control of synchrotron radiation could reduce operating pressures approaching a hundred fold below that of existing electron storage rings. Dividing the antechamber as shown in Fig. 2 confines the synchrotron radiation into a smaller volume. Pumping on both sides of the divider suggests differential pumping within the antechamber and will result in still lower operating pressures within the beam chamber.

Pumping

Pumping of the vacuum chamber will be done with a combination of pumps. Integrated antechamber pumping will be done with NeG, ST 101[2] or ST 707[2] as indicated previously. Immediately following each dipole magnet, a water cooled absorber, Fig. 3, patterned after the

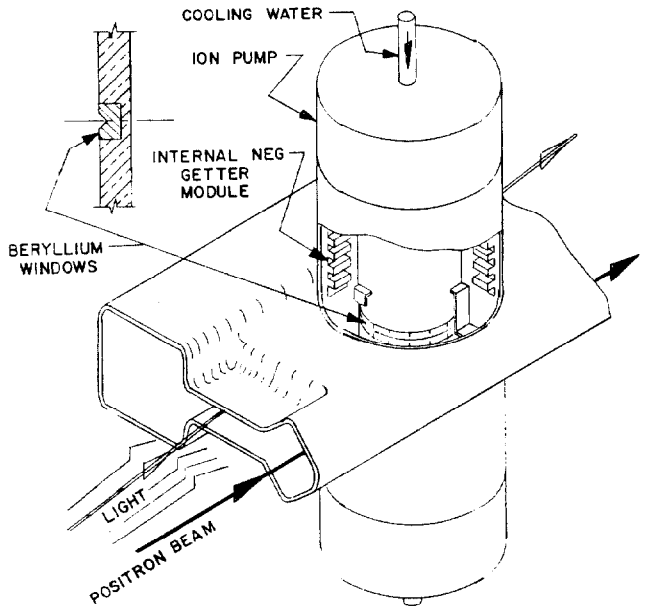

Figure 3 Crotch Absorber Lumped NeG Pumping

synchrotron radiation exit lines "crotch" absorber[3] for the Cornell electron storage ring, will intercept about 75% of the light energy contained within the vacuum chambers. Lumped NeG pumps will collect most of the gases desorbed directly below and above each absorber. Almost all of the remaining 25% of the contained light energy is deposited downstream in a continuous distribution on the target strips in the afore noted antechambers. At predetermined intervals around the ring, ion pumps will collect methane and noble gases which are not pumped by the NeG pumps. Turbomolecular pumps will be used exclusively for pumpdown, baking, and conditioning and activation of the NeG pumps.

The technical and economical advantages have been established[1,4,6] for the use of the NeG pump. It readily absorbs hydrogen at room temperatures as well as at temperatures of 200 to 400° C. However, it adsorbs other gases such as O_2, CO_2, and CO only on its surfaces at the room temperatures of the operating storage ring. In time, depending upon the amount present, these other adsorbed gases will prevent efficient pumping of themselves as well as disrupting the absorption of H_2. When this occurs, conditioning the NeG (ST 707) at ~ 400° C for a few minutes is necessary to absorb the adsorbed gases and thus clean the surfaces for renewed efficient pumping. Activation of the NeG on the other hand is normally done under vacuum only after the system has been up to atmosphere. Activation of ST 707 is done under vacuum at 500° C for about 15 minutes. Based on the data from PETRA, Fig. 4 illustrates the expected conditioning periods for both the NeG strips and the NeG lump pumps in the proposed Argonne light source storage ring.

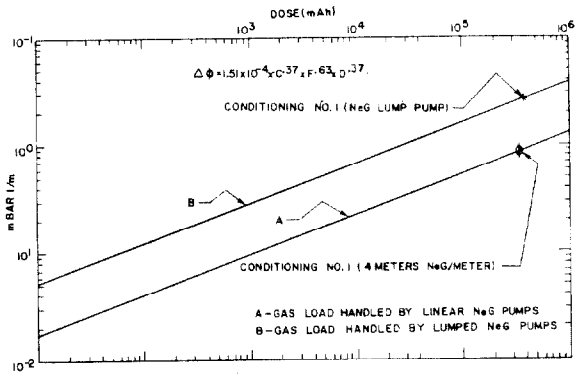

Figure 4 NeG Conditioning Periods

By integrating the desorption rate, Equation (1) above, with time, the expected gas loads can be determined at any given beam dose (mAh). Figure 5

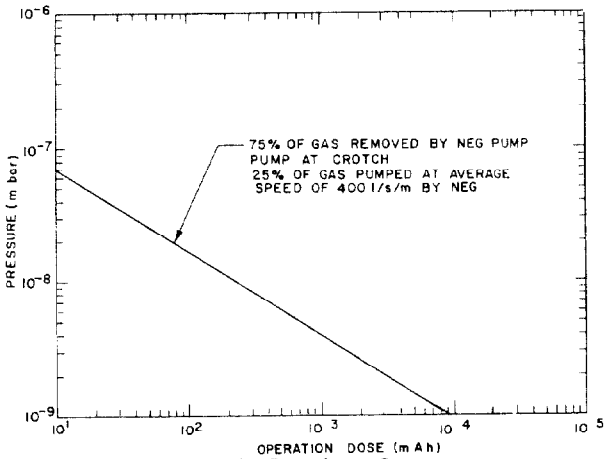

Figure 5 Pumpdown Curve

illustrates a possible pumpdown curve using "crotch" absorbers and NeG lump pumps following each dipole magnet and four one meter strips of NeG per meter of chamber. Should higher pumping speeds be required, NeG modules, Fig. 6, as used in the lump pump beneath the "crotch" absorber, can be substituted in the antechamber in place of the NeG strips.

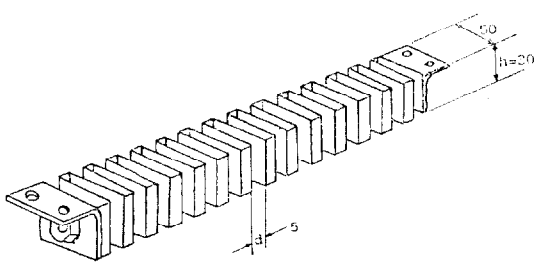

Figure 6 NeG Modules

Lifetime

It is important to restate that residual gas pressures of 1 x 10^{-9} Torr or less are extremely necessary to minimize the Coulomb scattering and bremsstrahlung effects on beam lifetime. Bremsstrahlumg effects on beam lifetime depend on the composition of the gas, and the gas partial pressure, molecular weight and radiation length of each gas species. Lifetime in a given gas due to this effect can be demonstrated by the equation:

$$\tau = 2.82 \times 10^{-8} \frac{X_o}{MP}, \quad (2)$$

where τ = lifetime in hours; X_o = radiation length in g/cm^2; M = molecular weight; and P = pressure in mbar. Effective lifetimes for a composition of gases is given by:

$$\frac{1}{\text{effective lifetime}} = \frac{1}{\text{lifetime gas A}} + \frac{1}{\text{lifetime gas B}} + \text{---, etc.} \quad (3)$$

For operating pressures of 3.75 x 10^{-9} Torr with 80% H_2 and 20% CO, the beam lifetime due to bremsstrahlung effects alone would calculate to 33 hours as shown in Fig. 7. Figure 7 demonstrates the critical need of

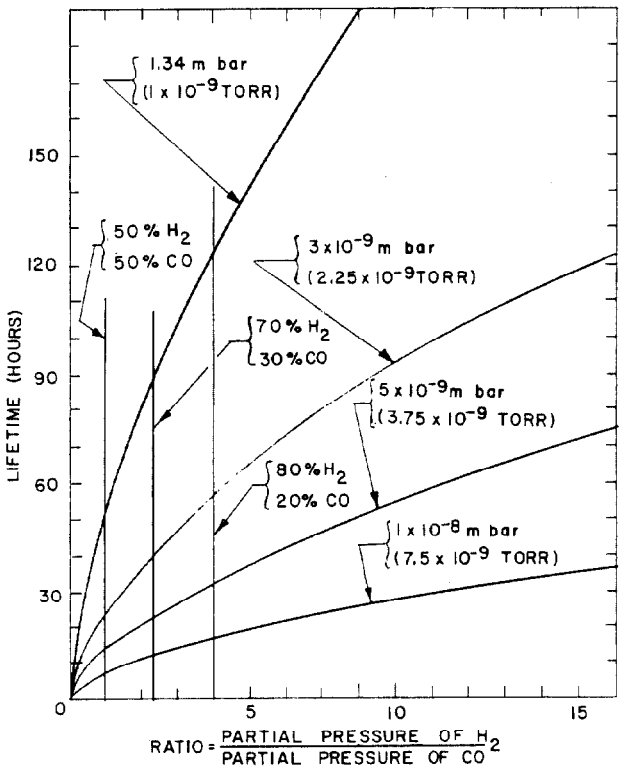

Figure 7 Beam Lifetimes for CO and H_2 Mixtures at Different Pressures

low operating pressures below 1 x 10^{-9} Torr since additional losses due to Coulomb scattering could approach those due to these bremsstrahlung effects and reduce these lifetimes by as much as half.

Research

Extensive research studies will be conducted to insure longer lifetimes in the proposed Argonne light source storage ring. These R&D studies will include 1) pretreatment and in-situ treatments of vacuum surfaces including chemical and vapor cleaning, electropolishing, plating, etching, baking, and glow discharge cleaning; 2) desorption rate tests on vacuum chamber interior surfaces such as gold, silver, copper, aluminum, and titanium; and 3) tests on surface finishes and various NeG pumping combinations among others and arrangements to identify the most promising. A prototype chamber 64 inches long with cross section as Fig. 2 shows has been constructed and is being used for these studies.

Another aluminum prototype chamber with the same cross section and length is currently undergoing testing for rf characteristics.

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