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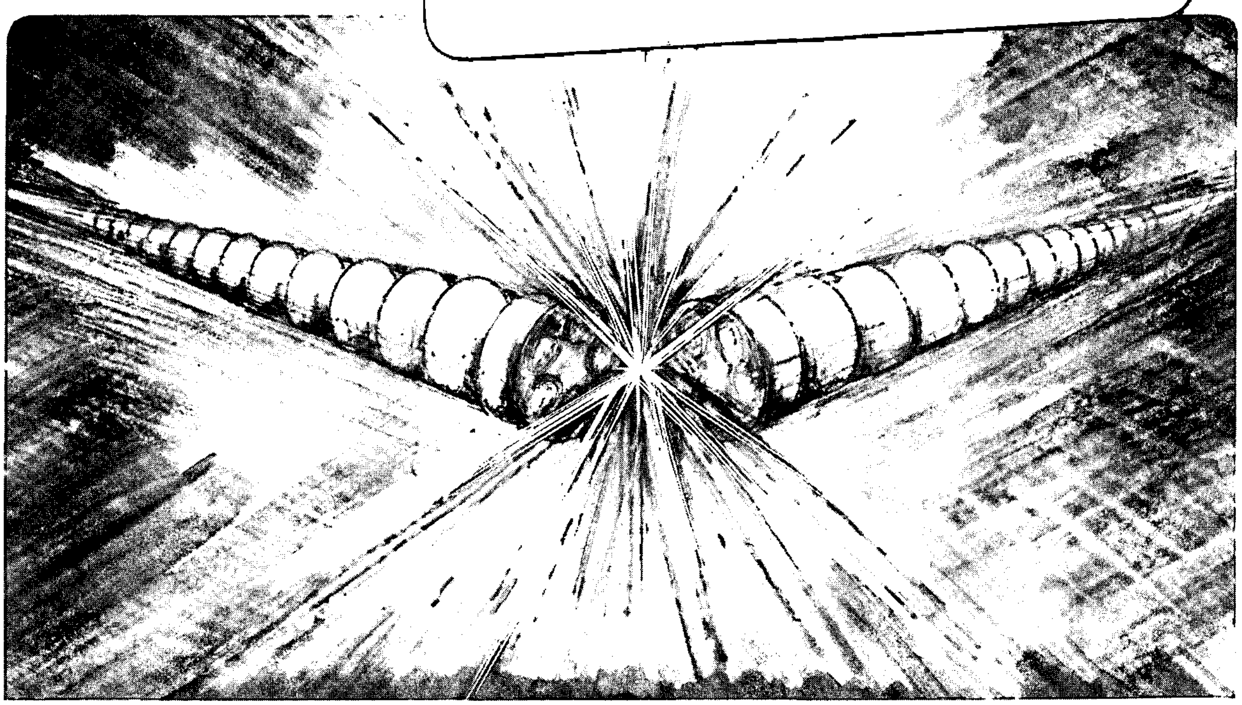

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DISCLAIMER

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VACUUM SYSTEM FOR THE LBL ADVANCED LIGHT SOURCE (ALS)

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ABSTRACT

A 1.5 to 1.9 GeV synchrotron light source is being built at LBL. The vacuum system is designed to permit all synchrotron photons on the median plane to escape the electron channel and go into an antechamber through a 10 mm high slot. This slot offers effective RF isolation between the electron duct and the antechamber. All unused synchrotron photons within a few mrad of the median plane will be stopped by 96 nearly horizontal absorbers located in the antechamber. The gas, generated by the photons hitting the absorbers, will be directed down to reactive titanium surfaces.

Twelve 10 meter long vessels constitute the vacuum chambers for all the lattice magnets. Each chamber will be machined from two thick plates of 5083-H321 aluminum and welded at the perimeter. The nominal wall thickness of the vacuum chamber is 40 mm, which makes it possible to machine a flange into the chamber without the use of welding.

INTRODUCTION

The ALS, like other new generation light sources, will have a small aperture electron channel. This small aperture makes low pressure during operation both necessary and hard to achieve. The circulating electrons will generate copious amounts of vacuum defeating photons. If these synchrotron photons were to land in the electron channel, they would be converted through photon-stimulated desorption to gas. The low conductance of the electron channel (15 l/s/m) would require many discrete vacuum pumps or distributed pumping to remove the desorbed gas.

The traditional distributed ion pump used in electron storage rings utilizes the magnetic field of the dipole magnets. This is an attractive solution, however, the ALS has been optimized for insertion devices in long straight sections. This has left only 15% of the circumference of the storage ring with a magnetic field suitable for ion pumps. Recently developed non-evaporable getters may offer a nonmagnetic alternate distributed pumping system.

DESIGN APPROACH

The photon management philosophy used in the ALS is to allow the photons out of the electron channel and deal with them in an antechamber. Figure 1 is a cross section of the storage ring at a sextupole. The vacuum chamber is typical of all chambers, showing the electron channel and the outer antechamber. The neck between these two chambers is 10 mm high and continues all around the storage ring in except at the injection and RF sections. This 10 mm slot gives good electromagnetic isolation between the electron channel and the antechamber up to 15 GHz[1].

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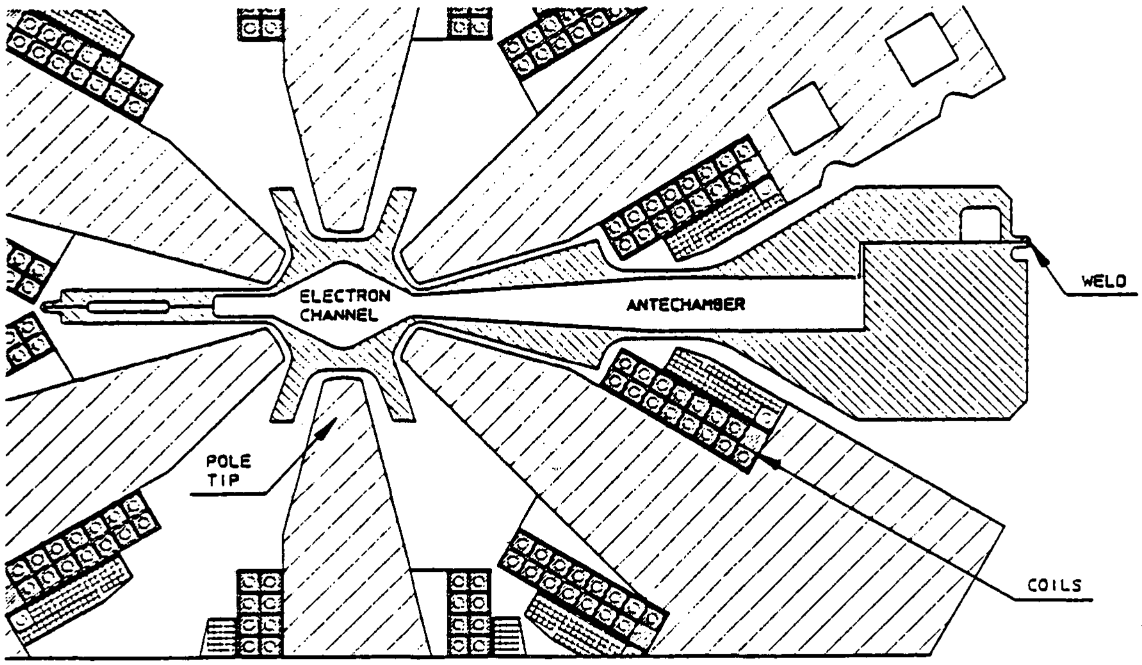

FIG. 1. CROSS SECTION AT SEXTUPOLE

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Over 99% of the dipole synchrotron photons will clear the electron channel through this slot in a nearly continuous fan around the storage ring. The vertical angle of the exiting photon fan will be only about 1 mRad high but it contains the source of most of the gas load to the vacuum system. Most dipole photons will be well clear of the electron channel and into the antechamber after traveling two meters, yet the footprint of the photons will be only 2 mm high. Photon absorbers, normal to the photon direction, can be relatively small and located near vacuum pumps. The ALS will use 96 dipole photon absorbers whose combined total length will be 16 meters. Fig. 2 is a layout for one of twelve sector chambers showing the dipole photon fans. If the dipole radiation were to strike on the outer wall of the electron channel, the total illuminated length would have been 197 meters, some of the length necessarily remote from vacuum pumps.

ANTECHAMBERS

The antechamber will be a uniform 25 mm high with a variable width depending on need. This chamber will have an average longitudinal conductance of 110 l/s/m, offering seven times the conductance of the electron channel. The higher conductances makes it possible to place appendage pumps farther apart and to rough from only one place in a sector chamber. The antechamber will contain, along with the photon absorber, 96 sputter ion pumps, 60 photon exit ports, 24 ion gauges, 12 RGAs and other vacuum hardware that has the potential for disturbing the electrical impedance of the electron channel.

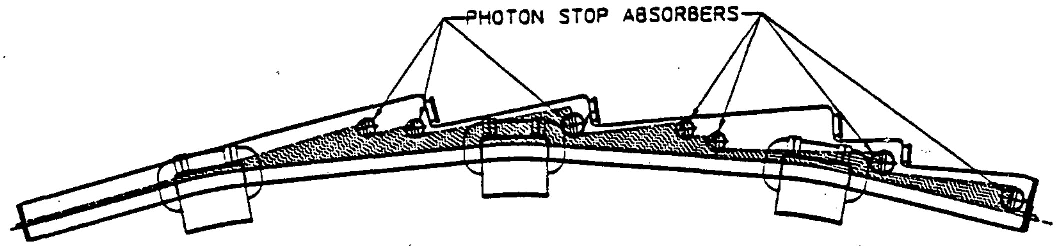

Fig. 2 PLAN VIEW SHOWING PHOTON FAN FOR ONE SECTOR

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TITANIUM SUBLIMATION PUMPS

The dipole photons will be converted into gas in the antechamber by landing on sloping photon absorbers located directly above vacuum pumps as shown in Fig. 3.

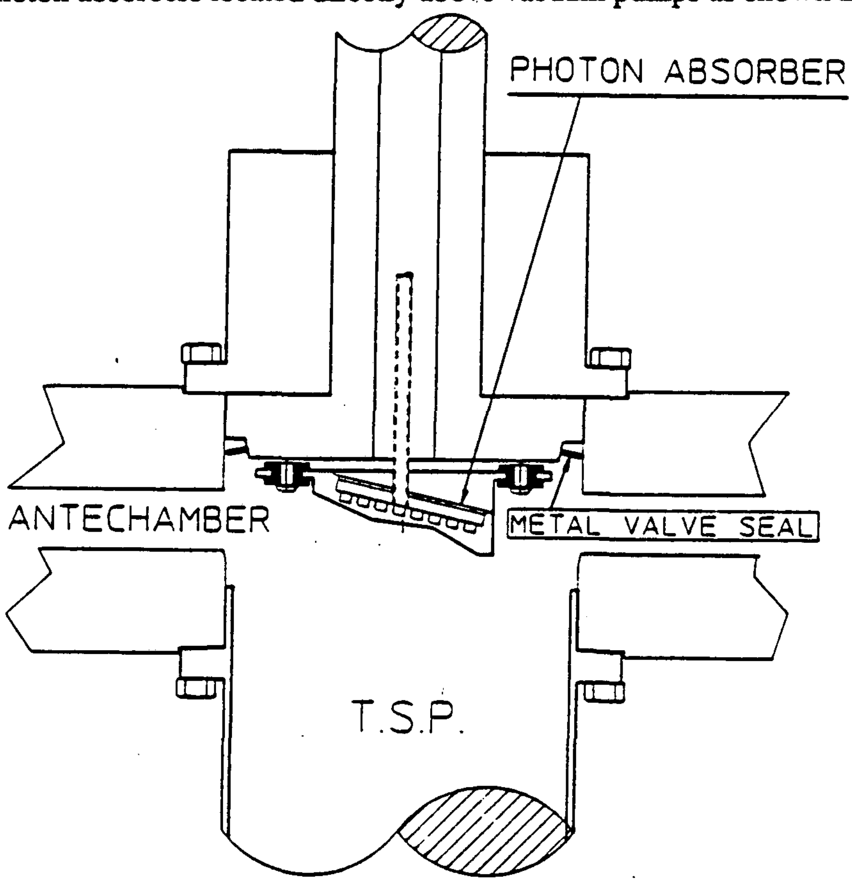

FIG. 3. PHOTON ABSORBER AND T.S.P.

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It is important that as much gas as possible go directly into the pump. The best way to achieve this goal is to have the mouth of the pump subtend a large solid angle normal to the surface where the photons land. A large number of gas molecules will thus go in a straight line from the photon impact area to the pump without becoming a random walk gas.

Once the gas molecules enter the pump it is important that they stay, i.e. the pump should be a "black hole.". Freshly vacuum deposited titanium fulfills this criterion but titanium sublimation pumps (TSP) lose their high sticking coefficient long before their potential pumping capacity has been used up. To increase the total capacity of the TSPs the condensation surfaces were extended as shown in Fig. 3. This extended surfaces not only increases the total capacity of the pump but, accord to Monto Carlo analysis, increases the probability of trapping gas molecules even when the titanium has a low sticking coefficient.

The titanium condensation surfaces will be capable of being cooled by liquid nitrogen (LN). This offers an extra 150,000 l/s of water pumping during pump down, reducing bake-out requirements. During normal operations, the LN cooling will improve the performance of titanium pumping surfaces substantially, particularly for hydrogen. After the storage ring is mature and the gas load is lower, the LN can be turned off for economic reasons.

TITANIUM SUBLIMATION PUMP ISOLATION VALVES

The dipole radiation beam lines will receive their photons through a slot in the photon absorbers. It will be desirable to change photon absorbers from solid to slotted as dipole photon lines are commissioned without letting the main vacuum chamber to air. Mounting the photon absorber on the seal plate of a poppet valve will permit the absorber to be lowered and sealed in the TSP. The TSP will be able to be let up to air and the photon absorber replaced while the main chamber remain at high vacuum.

Other benefits result from isolatable TSPs; the most obvious is maintenance. Burned out titanium filaments will be replaceable and titanium deposits will be removable before they become thick enough to flake. The TSPs will be isolatable from the main vacuum system during the sublimation cycle. This will permit the heating of the condensation surfaces, driving the hydrogen into the roughing system and improving the adhesion of the next titanium deposit.

The 96 photon absorbers will receive most of the photons that strike surfaces in the storage ring and hence are the most important to clean. The ability to move the absorbers from the main vacuum system into the TSPs under high vacuum creates an opportunity to glow discharge clean the absorbers in the TSP eliminates the hazard of contamination of the main chamber's ion pumps with argon. Freshly deposited titanium present during glow discharge cleaning will help prevent recontamination of the absorbers.

PHOTON ABSORBERS

The function of the photon absorbers will be to stop the photons and direct the desorbed gas into the pump. A six degree wedge shaped absorber performs this function well and, in addition, the power density will be reduced making cooling easier. A simple wedge will not be used because of reflected and mis-steered photons. Steeper facets must be present at the front and the rear of the wedge so that the absorber can be 25 mm high but no deeper than 75 mm. During normal operations the photon beam will be centered and will illuminate the six degree portion of the wedge face, but if vertical mis-steering occurs the photons will be stopped by the steeper facets.

Some of the photons landing on the six degree surface will be reflected, but it is important that these photons land on an appropriate surface. The steep facet at the rear of the photon absorber fulfills this role and any reflected photons from the steep facet will tend to go into the TSP. The direction of the gas emitted from this second surface will not be ideal for entering the TSP, but the amount and energy of photons landing on the second surface will be lower than those that land on the primary surface.

When bend magnet synchrotron radiation is to be used outside the storage ring, it will be channeled through the photon absorber in a slot cut in the absorber. The photons on either side of a beam that will go to a photon line will continue to be absorbed at an easy-to-cool grazing angle. This approach eliminates the hard-to-cool slender septum and thus, the name "crotch."

ANTICIPATED VACUUM PERFORMANCE

The ALS will have a total vacuum pumping speed of about 120,000 l/s. At 1.5 GeV and 400 mA the ALS will radiate about 5×10^{20} dipole photons per sec. 15.4η Torr l/s of gas is created when these photons strike a surface, where η is the conversion efficiency of photons to gas molecules. If all the dipole photons were converted to gas in the main ALS vacuum chamber and effectively pumped by the 120,000 l/s available in that chamber, then η would have to be below 7.8×10^{-6} to achieve the vacuum goal of a nano Torr. An extrapolation, from Grober et al[2], indicates that many thousands of ampere hours of electron beam current would be required to achieve $\eta < 7.8 \times 10^{-6}$.

Experiments run at NSLS[3] (Ref. 4), using apparatus similar to Fig. 3, indicate that the pressure rise associated with photons striking the absorber over TSP is much smaller than the rise is in the absence of a TSP. The combined length of all the photon stops will be 8% of the circumference of the storage ring, having the effect of increasing the rate of photon cleaning by a factor 12 over conventionally laid out storage rings. The combination of preventing gas from the photon absorber from entering the vacuum chamber and increasing the rate of clean up of the photon absorbers should reduce integrated beam required for vacuum commissioning from many thousands to a few hundred A h. The full energy injection of ALS makes high current operation possible even during the early stages of start up.

A combination of ejector pumps, LN cooled zeolite, oil free turbo pumps, and LN cryopumps will be used for roughing. Each sector chamber will have a permanent set of these pumps. The ejector and the zeolite pumps will rough the sector chamber to molecular flow pressure. The LN cooled surfaces of the TSPs will offer 10,000 l/s per sector of condensable pumping and the turbo pump will have 75 l/s for noncondensables. Because of the large water pumping speed of the LN cooled surfaces in the TSPs, the ion pumps will be able to be turned on at a safe low pressure and add 480 l/s of noncondensable pumping. Finally, at the lowest reasonable pressure, the TSPs will be started.

Based on published outgassing rates[4,5] for unbaked aluminum, the pressure at 24 hours after roughing would be somewhere between 3×10^{-9} and 2×10^{-10} Torr. The latter would be very acceptable and every effort will be made to achieve it, including off line bake. Provision will be made for *in situ* bake, but the length of the sector chambers makes baking unattractive.

FABRICATION

A continuous slot around the outer wall of the electron channel creates mechanical problems. Fig. 4 shows how the vacuum load, at the quadrupole and sextupole, can be transmitted through ribs to the outer wall of the antechamber and still maintain a thin chamber wall at the magnet pole tips. Complex shapes, such as shown in Fig. 4, suggest machining as the method of fabricating. The storage ring divides naturally into 12 sector and 12 straight vacuum chambers. The vacuum chamber can be made narrow at the entrance and exit of the sector chamber because the way the dipole radiation fans can be masked. These narrow points are the only reasonable location for flanges and, hence require that the sector chambers be made in one piece ten meters long.

Machining a ten meter part is a nontrivial enterprise; fortunately, the needs of the aircraft industry has made such machining capability widely available in California. Machining dictates that the vacuum chamber be made from an aluminum alloy. The selection of the alloy was made based on weldability and dimensional stability during machining. The stress level in the vacuum chamber will be very low so that strength of the alloy could be a secondary consideration. The alloy that was chosen was 5083-H321, which is a nonheat treatable alloy with a small amount of cold work for ease of machining. It is also stretched and stabilized to reduce residual stress.

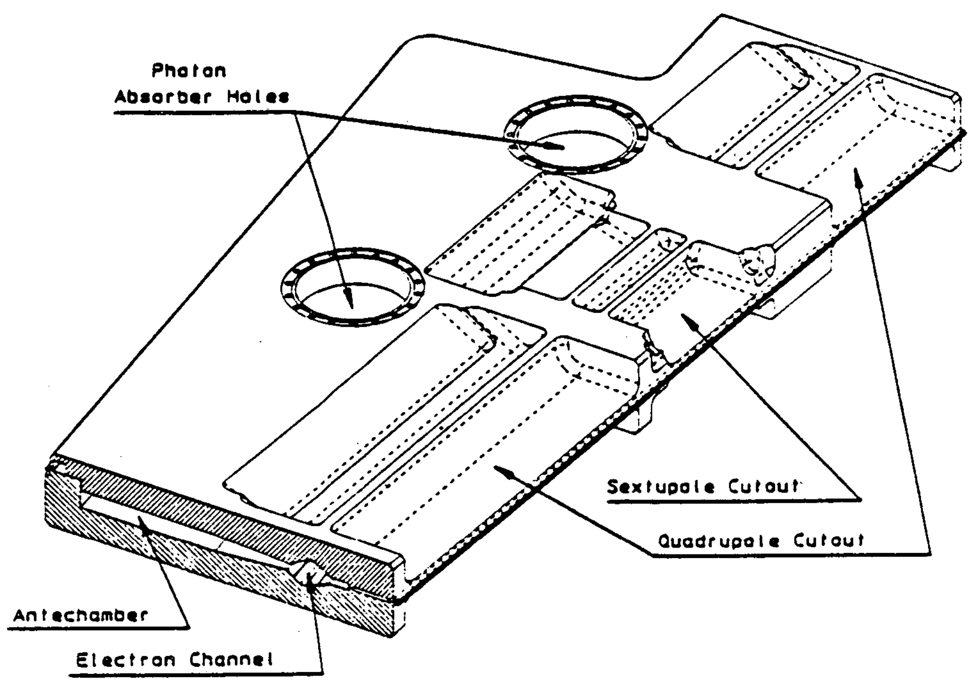

Fig 4 Section of Vacuum Chamber

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Machining vacuum chambers out of thick plate is certainly an expensive method of fabrication; however, other benefits result:

- The dimensional tolerances are those associated with machining rather than sheet metal.
- Flange surfaces can be machined directly into the outside surface. Such flanging is shown at the beam position monitors in Figure 5.
- A saw tooth texture can be machined in the top and bottom of the vacuum chamber along the path of the photons to suppress reflections.
- The very thick aluminum provides excellent heat distribution during bake
- Machining avoids complex cutting, fitting and welding with its attendant distortions.

The ALS sector chambers will be machined in two halves and welded around the perimeter. The perimeter weld will carry a small load and, therefore, can be small and weld prepped. The potential virtual leak between the perimeter weld and the main vacuum volume will be ventilated by a groove.

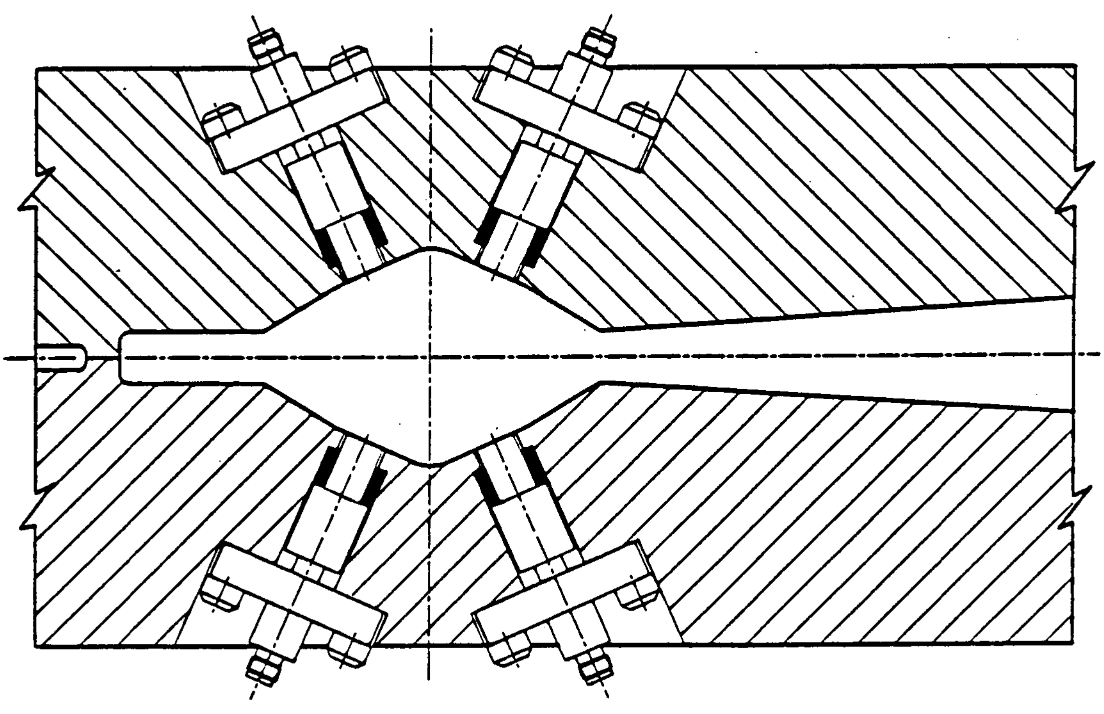

Fig. 5 BEAM POSITION MONITOR

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SUMMARY

A vacuum system is being built for the ALS that will have twelve 10 meter machined aluminum chambers. These chambers will have two parts: an electron channel and an antechamber. These two chambers will be electrodynamically isolated by a slot between them for the low frequencies effecting the stored electron orbit, but for the high frequency (short wavelength) troublesome photons, they communicate. Most of the synchrotron photons generated in the electron channel will go to photon absorbers over vacuum pumps located in the antechamber. This two chamber system will maintain an acceptably low beam impedance in the electron channel, and it is anticipated that the time to achieve the required operating pressure will be relative short.

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