MASSIVE TITANIUM SUBLIMATION PUMPING IN THE CESR INTERACTION REGION*

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*Abstract**

The residual gas pressure within 30 m of the interaction point (IP) at the $e^{\pm}$ collider CESR is maintained in the low nanotorr range, despite the high gas loads produced by the intense flux of synchrotron radiation, in order to minimize the experimental backgrounds due to beam gas scattering. Within 12 m of the IP, the vacuum chambers incorporate large pumping plenums with massive titanium sublimation pumping to provide the necessary pumping speed and capacity. Operating experience over the last two years has shown that this method of pumping is efficient and inexpensive.

1. INTRODUCTION.

Lost particles generated by the 5.3 GeV $e^{\pm}$ beams in the collider CESR interacting with the residual gas are a major source of background in the CLEO High Energy Physics detector. They could also lead to radiation damage of sensitive components such as the new Silicon Vertex Detector (SVX) electronics installed around a two-centimeter radius thin beryllium beampipe.[1]

An aggressive R&D program to increase the luminosity of CESR has led to successive upgrades of the storage ring, which is now producing peak luminosities of $4\text{x}10^{32}$ $\text{cm}^{-2}\,\text{s}^{-1}$ at a beam energy of 5.3 GeV, well beyond its original design specification. The main objective of the 1995 upgrade to Phase-II was to allow storage of up to 300 mA per beam. Increased current produces increased desorption of gases by synchrotron radiation (SR), so that the beam-gas background in the detector could increase proportional to the *square* of the current if the pressure were allowed to increase in proportion. The detector at the interaction point (IP) is most sensitive (in the present optics) to lost particles produced by beam-gas bremssstrahlung in the region up to about 30 m from the IP. The region up to 12 m was in particular need of increased pumping, to keep the pressure below about 2 ntorr at 300 mA.

For Phase-II, the vacuum chambers from the IP up to 12 m were replaced by new chambers, most of them incorporating massive titanium sublimation pumping (TiSP) plenums. The secret to maintaining high distributed pumping speed is, of course, large conductance to the pumping surfaces. The SR is absorbed on water-cooled copper bars and high-conductance slots lead to the pumping surfaces lining the plenum in each chamber. Right after flashing fresh Ti, the sticking coefficient is about 0.7 for CO. The net pumping speed is dominated by the slot conductance and gradually decreases as the Ti surface saturates. The TiSP speed is quite appreciable even when the sticking coefficient has fallen to 0.1. However, we flash again when the operating pressure with beams is about 2 ntorr.

There is another factor that affects the dynamic pressure rise and the flashing interval. It is well known[2] that the SR induced desorption coefficient η_{SR} decreases steadily from its initial high value after intervention. Thus the dynamic pressure rise, dP/dI , expressed in nanotorr per mA of beam, continues to decrease with beam dose D, expressed in Amp-hours. Correspondingly, the flashing interval increases steadily. Eventually, we find that η_{SR} levels off due to the overall equilibrium between desorption and readsorption of the molecules on the cleaned surfaces during steady operation at a particular beam current. This phenomenon has also been observed directly as "wall-pumping", contributing very significant distributed pumping in regions of intense SR flux.

The variation in desorption yield at any given location is well described by a power law $\eta_{SR} = \eta_{in} D^{\alpha}$, with α of order -1. The initial yield, η_{in}, immediately after start up of the accelerator can be as high as 0.1 molecule/photon and η_{SR} reaches values as low as $2\text{x}10^{-6}$ mol/photon after exposure to 10^{24}photons/m.

2. CHAMBERS NEAR THE IR.

Immediately surrounding the IP is a 50 cm long, 2 cm radius thin beryllium beam-pipe. A silicon vertex detector, the most sensitive part of the detector, surrounds this pipe. The first pump is the Q1 TiSP at 2.3 m from the IP. A tapered, slotted beam-pipe incorporates water-cooled copper absorber bars in the horizontal plane and is surrounded by a 20 cm radius TiSP plenum. The total conductance of the slots leading to the plenum is 620 l/s for N_2. Three Ti-sublimation cartridges, each with three filaments, are installed on demountable conflat flanges, baffled from each other and from direct line-of-sight to the beam tube. The next pump is a 220 l/s "noble-diode" sputter-ion pump (SIP) at 6 m. This serves to keep the partial pressure of noble gases and methane in control. Although methane is desorbed by the beam, the intense photon and electron flux is efficient at cracking methane (CH_4) to CH_3 and H which are then pumped by the TiSP, and no buildup of CH_4 is observed.

Figure 1 shows the "ISP chamber" which occupies the region from 6.4 m to about 8.6 m. From the end nearest the IP, there is a section of 1 m long

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copper beam chamber with pumping slots and holes (of total conductance 9,000 l/s) surrounded by a cylindrical pumping plenum of 0.4 m diameter with three Ti-filament cartridges. A total surface of about 10^4 cm^2 is covered by Ti during flashing. A CCG is installed on top of the pumping plenum.

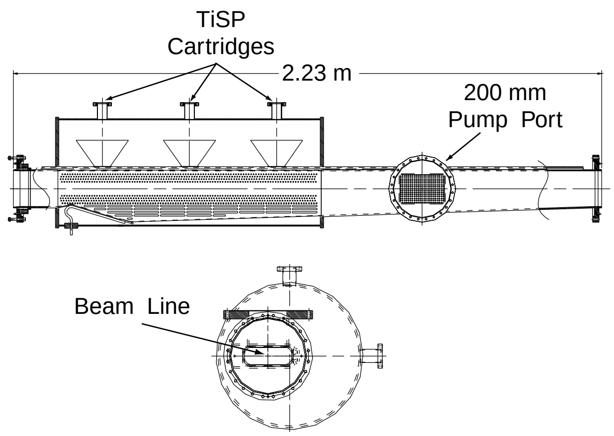


Figure 1. The ISP Chamber with Ti pumping plenum.

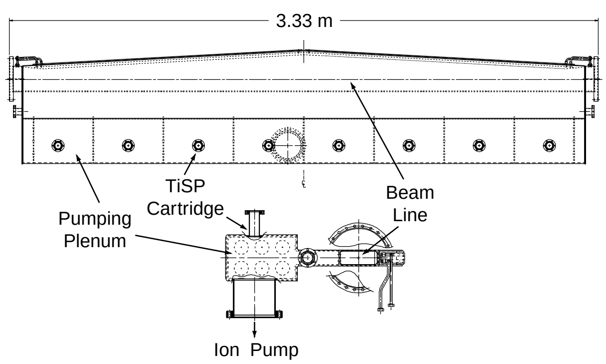


Figure 2. The Soft-Bend Chamber. Top view (above) and cross-section showing Ti pumping plenum.

The 3.3 m long "Soft-Bend" vacuum chamber, (Figure 2) sees the intense SR radiated by the beam in the "Hard Bend" (HB) magnets upstream. The absorber is a 3.2 m long copper bar bent to a chevron shape, with wedge-shaped absorbing steps. A slotted wall of about 7,800 l/s conductance leads to a large rectangular copper pumping plenum, 15 cm high by 25 cm wide, running the full length of the chamber. Nine vertical baffles give rigidity and increase the surface covered by titanium. Eight Ti-filament cartridges are equally spaced in the pumping plenum, covering about 25,000 cm^2 with Ti during flashing. A 110 l/s noble-diode sputter-ion pump is mounted on the pumping plenum. A CCG is installed near the beam line.

In Table 1 we give an estimate of the CO gas load obtained in different regions of the IR when the photodesorption yield in the HB region of most intense flux gets down to $\eta_0 = 1.8 \cdot 10^{-6}$ mol/photon. We use this "ultimate" value of η_{SR} to predict the vacuum performance of CESR when the vacuum system is fully conditioned and use it to model pressure profiles below.

TABLE I. Synchrotron Radiation Flux and Gas Load in the CESR IR for 300 mA $e^{\pm}$ Stored Beams.

Location	Flux Density (Photon/s/m)	Total Flux (Photons/s)	CO GasLoad [Torr-l/s]
Q1-Pump	$1.3 \cdot 10^{18}$	$2.5 \cdot 10^{17}$	$7.9 \cdot 10^{-8}$
ISP absorb.	$1.1 \cdot 10^{19}$	$1.9 \cdot 10^{18}$	$2.0 \cdot 10^{-7}$
Soft-Bend	$3.3 \cdot 10^{18}$	$3.5 \cdot 10^{18}$	$6.7 \cdot 10^{-7}$
Hard-Bend	$6.9 \cdot 10^{18}$	$2.3 \cdot 10^{19}$	$1.3 \cdot 10^{-6}$

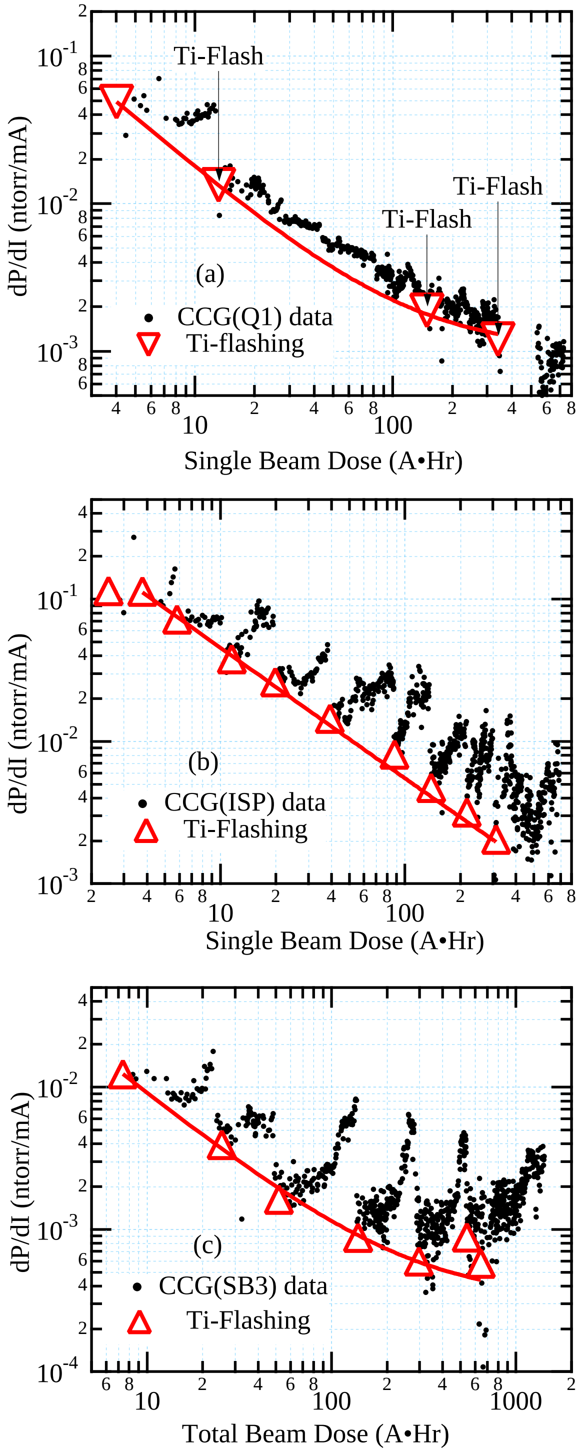
3. PUMPING SPEED AND CAPACITY.

Each pumping chamber was treated as follows before installation in CESR: leak check; bakeout and degassing of all Ti filaments and gauges; saturation of the bare walls with either CO or N_2 using calibrated leaks; flashing of Ti cartridges; slow saturation of the Ti surface using CO and/or nitrogen calibrated leaks with continuous monitoring of pressure and gas composition. The effective pumping speeds at each stage were determined from the data. The experience obtained with the Soft-Bend chamber is quite illustrative and typical. After bakeout and degassing of filaments, initial pumping speeds of the *bare walls* were S_{N2}= 957 l/s and S_{CO}= 4,400 l/s and absorbed a dose of 0.29 torr-liter of nitrogen! Significant partial pressure peaks of CH_3, CH_4 and Argon showed clear evidence of passive gettering action. After flashing all eight Ti -cartridges for 2 minutes each at 220 W, the pumping speeds for CO and N_2 were measured as a function of nitrogen load. Initial pumping speeds at zero load were: S_{N2}= 1,571 l/s and S_{CO}= 8,420 l/s (higher sticking coefficient for CO). After absorbing 2.2 torr-liters of N_2 S_{CO} was still as high as 3,500 l/s and decreased to 1,500 l/s after 0.4 torr-liter of CO was absorbed.

Saturation of the Q1 pump chamber with CO showed that the pumping speed falls by five at about 0.6 torr-l/s. In CESR, this is a region of low SR gasload, 8 x 10^{-8} torr-l/s with 300 mA beams, so the ultimate flashing interval for Q1 should be ~ 90 days. The data for the ISP chamber show that saturation occurs at 1.0 torr-liter of CO. The ultimate expected SR-induced gasload at 300 mA per beam is 2 x 10^{-7} torr-l/s, so we expect a flashing interval of about 60 days to maintain pressures below a few nanotorr.

4. DYNAMIC PRESSURE RISE IN CESR.

The new IR chambers were installed and Phase-II operation started in November 1995. The dynamic pressure rise with beam, (*dP/dI*), at various locations in the IR is shown in the Figure 3 as a function of beam dose in Amp-hrs. Single beam dose or total beam dose is used as appropriate for each geometry. Ti-flashing points are shown (triangles) and the subsequent points show the slow saturation of the TiSP. The plots include data recorded up to March 3, 1997, representing approximately 14 months of operation. The clean-up due to the beams is very apparent in all plots and shows the characteristic dose dependence of the gas load, $N_{gas} = N_{phot} \bullet (\eta_0 + \varepsilon\eta_{in} D^{\alpha})$, with $\alpha \approx -1$ for all plots. Here ε is the fraction of photons scattered from the primary SR stripe which is assumed to have reached the ultimate coefficient η_0.



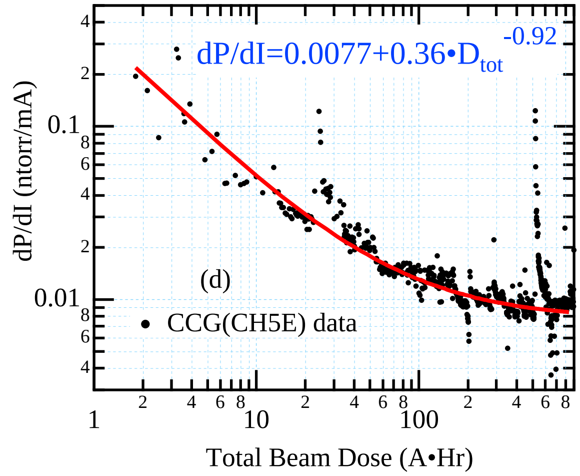


Figure 3. The beam induced dynamic pressure rise, (*dP/dI*), at various locations in the IR. (a) At Q1E chamber; (b) on the beamline next to the ISP chambers, and (c) for the soft-bend chambers. (d) shows *dP/dI* for a gauge within the hard-bend sector pumped only by distributed ion pumps, where the SR flux and gas load are the most intense.

The scattered photons then continue to clean up the rest of the chamber. In the high-intensity HB region (Figure 3d) we see that after about 100 Amp-hrs of total beam, the dynamic pressure rise has levelled off to $N_{phot}\eta_0$, indicating the equilibrium between desorption by the beam and readsorption by the cleaned surfaces, leading to a constant effective η_{SR}.

5. CONCLUSIONS.

Ti sublimation pumping on an extensive scale has been used successfully in the interaction region of CESR, to keep pressures at a few nantorr level despite the intense SR flux. Present operation of CESR with two beams of 150 mA each results in operating pressures of between 1.5 ntorr and 3.5 ntorr in most of the IR. This pressure profile is sufficient to keep detector backgrounds at acceptable levels. In the near future, we will install more chambers similar in design to the soft-bend chambers further down the line in the bend region. We expect the pressures to be maintained at the low nanotorr level as the beam currents are raised to 300 mA and beyond.

6. REFERENCES.

[1] S.Henderson, “The CESR High Luminosity IR”, these Proceedings.

[2] O.Groebner et al., Vacuum **33**, 397 (1983).

[3] R. Kersevan, “MOLFLOW, a 3D Monte-Carlo Code for the simulation of molecular flow”, available from the author, Laboratory of Nuclear Studies, Cornell University, Ithaca, NY, 14853.