Simulations of the pressure profiles of the PETRAIII frontends

C. Amann, U. Hahn, M. Hesse, H. Schulte-Schrepping
Deutsches Elektronen Synchrotron DESY, Notkestraße 85, 22603 Hamburg Germany
Christian.amann@desy.de

Abstract. PETRA III will be a high brilliance third generation synchrotron radiation source [1]. The undulators will provide photon beams with small beam size and therefore the components in the frontend are as compact as feasible. The resulting narrow cross sections of the vacuum system will yield a small conductance in the whole beamline. The design of the frontends has reached an advanced state so that the initial design of the vacuum system can be finalized now. The vacuum specification of the beamline components [2] demands for a hydrocarbon and dust free vacuum systems. To provide this, the beamline will be initially pumped down with dry pumping stations [9] to a pressure of at least 10^-6 mbar. At this pressure a set of ion pumps will be switched on to pump the beamline continuously. For lifetime reasons of the ion pumps it is necessary that during operation the pressure in the pumps is below 10^-6 mbar. During the start up of the beamline system a high amount of gas will be photo desorbed especially at the high power slit systems. To cope with this, the pumping concept of the beamline has been revised. Monte Carlo simulations of the pressure profiles in the beamline show that additional pumping near the slit systems is mandatory for a long lifetime of the ion-pumps. The paper reports the layout process of the pumping system.

1. Introduction
PETRA III [1] is a third generation synchrotron source which is currently rebuilt from the old PETRA II storage ring at DESY in Hamburg. With a particle energy of 6 GeV, up to a maximum of 200 mA stored current and an emittance of 1 nm rad 14 undulators will deliver highly brilliant photon beams. To shape these beams and to reduce the thermal load on optical components two high power slit systems (a vertical and a combined vertical and horizontal) are installed in the frontend of the beamline in the ring tunnel. The second slit system also works as photon shutter and will be able to stop the complete power of the undulator radiation.

The high photon flux of the undulators will create a huge amount of gas by photo desorption at the start of operation of new installed slit systems.

Figure 1: side view of the final frontend of a single beamline at PETRAIII
2. Vacuum requirements
The vacuum specifications for PETRA III components [2] demands a hydrocarbon and dust free vacuum in order to protect the optical components from carbon contamination. Permanent pumping with ion pumps fulfills the vacuum requirements. Additionally these pumps need the lowest amount of maintenance during operation.

3. Photo desorption and gas load
At the start of operation of PETRA III beamlines a large amount of gas will be released by photo desorption from the surfaces of the slit systems. This initial desorption rate was calculated for a closed slit system using the maximum integrated photon flux $\Phi$ of $1 \times 10^{19}$ ph/s from figure 2 and an initial value for the photo desorption yield ($\eta_0 = 0.01$ mol/ph) [10] at a critical energy of 20keV and achieve a gas load of $1.2 \times 10^{-3}$ mbarl/s. Groebner et al. [11] published a smaller photo desorption yield of $\eta_0 = 10^{-3}$ mol/ph, but at a critical energy of 3.75keV. For the calculations of the integrated photon flux of a standard PETRA III insertion device the program SPECTRA was used [4]. We calculated the photon flux for two scenarios. The first is a worst case scenario with the maximum PETRA III current of 200mA and the smallest possible gap ($k = 2.2$) (red curve in figure 2). In the second scenario we used a reduced current of 10mA and a wider gap to calculate the photon flux (green curve in figure 2).

The photon dose related development of the photo desorption yield can be written[3] as:

$$\eta(D) = \eta_0 \cdot D^\alpha$$

Used parameters are $D$ the accumulated photon dose and $\alpha$ as the decrement of the desorption yield. The value of $\alpha$ was estimated as -0.5 from ref. [3]. This approach does not account for the difference between our copper alloy (Glidcop®) system and the referenced stainless steel data. For our material there do not exist published photo desorption data. The temporal development of the photo desorption yield can be calculated using this formula by setting $D(t) = \int_0^t \Phi(t) \, dt$ assuming a constant photon flux.

![Figure 2: total flux and integrated flux of the standard undulator](image1)

![Figure 3: desorption rate versus time for two different photon fluxes](image2)
4. Pressure profile simulations

To simulate the pressure profiles we used the Monte Carlo program MOLFLOW [5]. In this type of simulation each molecule is traced separately through the system. This method is appropriate because the mean free path length of the molecules (~6400cm at 10^-6 mbar) is much bigger than the diameter of the beam pipe (~4cm). The molecules do not interact with other molecules in the volume, but only with the surfaces of the system.

The layout of the vacuum pump system is an iterative process supported by these calculations. In a first step we simulated the initial layout of the vacuum pumps. The results of these simulations are shown in Figure 4 and 5 as blue curve. The position of the beamline components corresponds to indicated ranges in Figure 1. The pronounced maxima correspond to the position of the slit system. The strong decrease around the maxima is caused by the ion pumps. The result of the first simulation shows that the ion-pumps at the slit systems can not cope with the amount of photo desorbed gases.

In two further steps we changed the size of the pump, added a titanium sublimation pump (TSP) and changed the position of an aperture in the beamline. The results of these simulations are shown in the red and the black curves in Figure 4 and 5. These curves show that the combination with TSP results in a sufficient low pressure at the ion pump.

To estimate the pressure distribution in the beamline, it is necessary to calculate also the thermal desorption. The gas load due to thermal desorption has been estimated by measurements of the thermal desorption coefficient [6]. The thermal desorption coefficient was 8*10^{-11} mbarl/s/cm². In the simulation around the vertical slit system we got a thermal gas load of 6.4*10^{-7} mbarl/s. Around the vertical/horizontal slit system 9*10^{-7} mbarl/s is calculated. The resulting pressure profiles are shown in figures 6 and 7.

The average pressure in the beamline caused by the thermal desorbed gas load will be below 10^{-7} mbar. The comparison to fig. 4 and 5 shows that at the start of operation the pressure in the beamline is mainly determined by the photo desorbed gas. After an amount of accumulated photons the determining factor for the pressure will be the thermal desorbed gas load. This behaviour is shown for an absorbed photon dose of 10^{22} photons (green curve Figure 4 and 5).
5. Conclusions
The simulations show that the first design of the vacuum system was too optimistic. The pumping speed of the ion-pumps was not sufficient for the expected gas load at the start of the system operation. The finalized frontend design with improved pumping speed can cope with the expected gas load.

References
[1] PETRAIII “A low Emittance Synchrotron Radiation Source”, Technical Design Report DESY 2004-035, 211-218
[2] U. Hahn, “Hasylab Vacuum Guidelines for Beamlines and Experiments”, http://hasylab.desy.de/infrastructure/vacuum_group/guidelines/vacuum_guidelines/index_en_g.html
[3] C.L. Foerster, Syn. Rad., News. Vol. 11, No. 5, 1998
[4] SPECTRA, Takashi Tanaka and Hideo Kitamura, SPring-8/RIKEN
[5] “MOLFLOW User’s Guide”, available from the author Roberto Kersevan
[6] “Measurement of the thermal desorption rates of vacuum tubes”, DESY, unpublished
[7] “Varian Product Catalog”, Varian, Inc. Vacuum Technologies
[8] U. Hahn, H. B. Peters, R. Röhrsberger, and H. Schulte-Schrepping The Generic Beamline Concept of the PETRA III Undulator Beamlines AIP Conf. Proc SRI 2006, VOL.879,539 – 542 (2007)
[9] M. Degenhardt, U. Hahn, M. Hesse, J. Schütt, and R. v. Staa,,”Mobile dry pumping station for PETRA III beamlines”, these proceedings
[10] R. Kersevan, private communication
[11] Groebner et al., “Gas desorption from an oxygen free high conductivity copper vacuum chamber by synchrotron radiation”, JVST A12, 1994, p.846