THE VACUUM SYSTEM FOR THE SYNCHROTRON RADIATION SOURCE ANKA

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Abstract

ANKA, a 2.5 GeV Synchrotron Radiation (SR) source with a circumference of 110.4 m, an emittance of 40-73 nmrad and a nominal current of 200 mA, is dedicated for micro-fabrication and analytics purposes. The vacuum chamber will be made of stainless steel. An in situ bake out is not foreseen. Most of the synchrotron radiation will be absorbed by discrete absorbers (two per bend) in ante chambers. Here 500 l/s and 300 l/s diode pumps will be installed. The pumping will be done by lumped ion pumps (diodes) with a total nominal pumping speed of 18800 l/s, respectively 13000 l/s at 10^{-9} mbar. The installation of Titanium sublimator or NEG pumps is foreseen as back up. Assuming a desorption coefficient of 10^{-6} mol/ph the expected gas load is 1.5 10^{-5} mbar l/s. Pressure profile calculations show that the foreseen pumping speed should be sufficient to obtain a pressure of 3 10^{-9} mbar, necessary to get a lifetime of more than 12 h.

1 GENERAL REQUIREMENTS

In ANKA the lifetime of the electron beam is mainly determined by the scattering of the electrons at the residual gas. A status report of ANKA is given in a separate contribution to this conference[1]. Measurement at KEK showed that a pressure of 10^{-9} mbar is necessary in order to get a lifetime of about 20 h [2], in accordance with own calculations. Most of the gas load is produced during operation, when the synchrotron radiation hits the wall of the vacuum chamber. The number of molecules N_{mol} desorbed by the synchrotron radiation is proportional to the number of the emitted photons N_{ph} and to the desorption coefficient η, which depends on the wall material and decreases as a function of the absorbed photon dose (d).

$N_{mol} = N_{ph}\ \eta(\text{mat., dose})$

Desorbed molecules are mainly H_2, CO, CO_2 and CH_4. In general the H_2 gas load is by an order of magnitude larger than the gas load from CO and CO_2 and by two orders of magnitude larger than the gas load of CH_4. The desorption coefficient of aluminum is at least at the beginning an order of magnitude larger compared to stainless steel and copper [3].The number of photons is given by the following formula [3]:

$N_{ph} = 8\ 10^{+17}$ I (mA) E (GeV) 1Ah ~ 7 10^{24} ph

Desorption coefficient for stainless steel measured at the 2.5 GeV e-storage ring at KEK [4] were extrapolated for the calculations given in Table 1 (η (7 10^{23} ph/m) = 10^{-4} mol/ph). Furthermore the following assumptions were used:

a) 90% of the photons hit the main absorbers (10m) in the bend, 10% hit the vacuum wall (100m) in the straight sections. Thus the dose for the main absorbers in the bend is a factor 10 higher compared to the straight sections and the desorption coefficient is a factor five lower.

b) The effective pumping speed (S) is about 10^4 l/s.

c) $\eta \sim d^{-0.7}$

1Ah ~ 7 10^{23} ph/m (bend) → $\eta_b = 10^{-4}$
7 10^{22} ph/m (straight) → $\eta_s = 5\ 10^{-4}$

p[mbar] = 3.7 10^{-20} $N_{ph}(0.9\ \eta_b + 0.1\ \eta_s)$ / S[l/s]

Table 1 Expected pressure and lifetime behavior for ANKA, η is given for the main absorbers.

dose[Ah]	η_b[mol/ph]	p/I[mbar/A]	τI[Ah]
0,01	2,50E-03	2,6E-05	0,001
0,1	5,00E-04	5,2E-06	0,004
1	1,00E-04	1,0E-06	0,02
10	2,00E-05	2,1E-07	0,1
100	4,00E-06	4,1E-08	0,5
1000	8,00E-07	8,3E-09	2,4

The thermal desorption for prebaked stainless steel after 1000 h pumping time is in the order of 10^{-11} mbar l / (s cm^2). A surface of the vacuum system of about 3 10^5 cm^2 thus leading to an additional gas flow of 4 10^{-6} mbar l / s and an additional pressure rise of 3 10^{-10} mbar.

2 MATERIAL FOR THE VACUUM CHAMBERS

As material for the vacuum chamber of SR sources stainless steel, aluminum and copper is used. The advantages and disadvantages of these materials are well known and discussed. The final decision using stainless steel 316 LN for ANKA was done since almost all possible manufacturers in Europe are experienced in this material.

3 DESIGN OF THE VACUUM CHAMBER

The design of the vacuum chamber of ANKA follows the ante chamber concept of the recently built SR sources. In the region of the dipole and the following sextupole, respectively quadrupole, the e-beam is circulating in one chamber and the synchrotron radiation passes through a small gap into the ante chamber where it is absorbed by discrete absorbers. Since the length of these absorbers are small compared to the circumference of the ring, the outgassing is obtained in a shorter time. Furthermore the desorbed gases are immediately pumped away by a pump close to the absorber.

Figure 1 shows the design of the dipole vacuum chamber consisting of the e-beam chamber, the ante chamber at the dipole and the ante chamber at the following sextupole, respectively quadrupole. The e-beam chamber and the ante chamber are separated by a slot 10 mm high and 30 mm wide. The chamber is welded out of 3 mm thick stainless steel plates. The e-beam chamber is 70 mm wide and 32 mm high. Most of the synchrotron radiation is absorbed by two discrete absorbers made of OFHC copper, the first positioned in the ante chamber of the dipole covers the radiation from 0° to 11°, the second in the adjacent ante chamber covers the range from 11° to 20°. Close to the absorbers diode pumps are installed with a nominal pumping speed of 500 and 300 l/s, respectively. In addition a small 150 l/s ion pump is installed in the middle of the chamber for pumping the e-beam chamber.

In the following section the vacuum chamber is a straight tube and the synchrotron radiation is absorbed on the wall of the chamber which is indirectly cooled. A copper plating of a 1m long section behind the dipole is foreseen in order to reduce the temperature step.

The disadvantage of the ante chamber design is the large width of the vacuum chamber which has to sustain the atmospheric pressure, especially in the case of ANKA, where the width is up to 500 mm. An unsupported chamber with a wall thickness of 3 mm would result in an unacceptable large deformation. Thus the chamber must have supporting ribs. The deformation and the stress of chamber have been calculated by means of finite elements (ANSYS) and the geometry of the chamber is optimized in order to get a deformation of less than 0.5 mm.

4 VACUUM PUMPS FOR STORAGE RINGS

Generally ion and getter pumps are used at storage rings. Concerning ion pumps, two types exist: diodes and triodes. The pumping speed of a diode in the 10^{-9} mbar range is nearly twice as large as a triode for all reactive gases (CO, CO_2, H_2). Noble gases are not pumped by conventional diodes. But diode pumps with tantalum electrodes can pump noble gases. Since noble gases are not desorbed by synchrotron radiation conventional diode pumps are foreseen close to the absorbers. Using noble

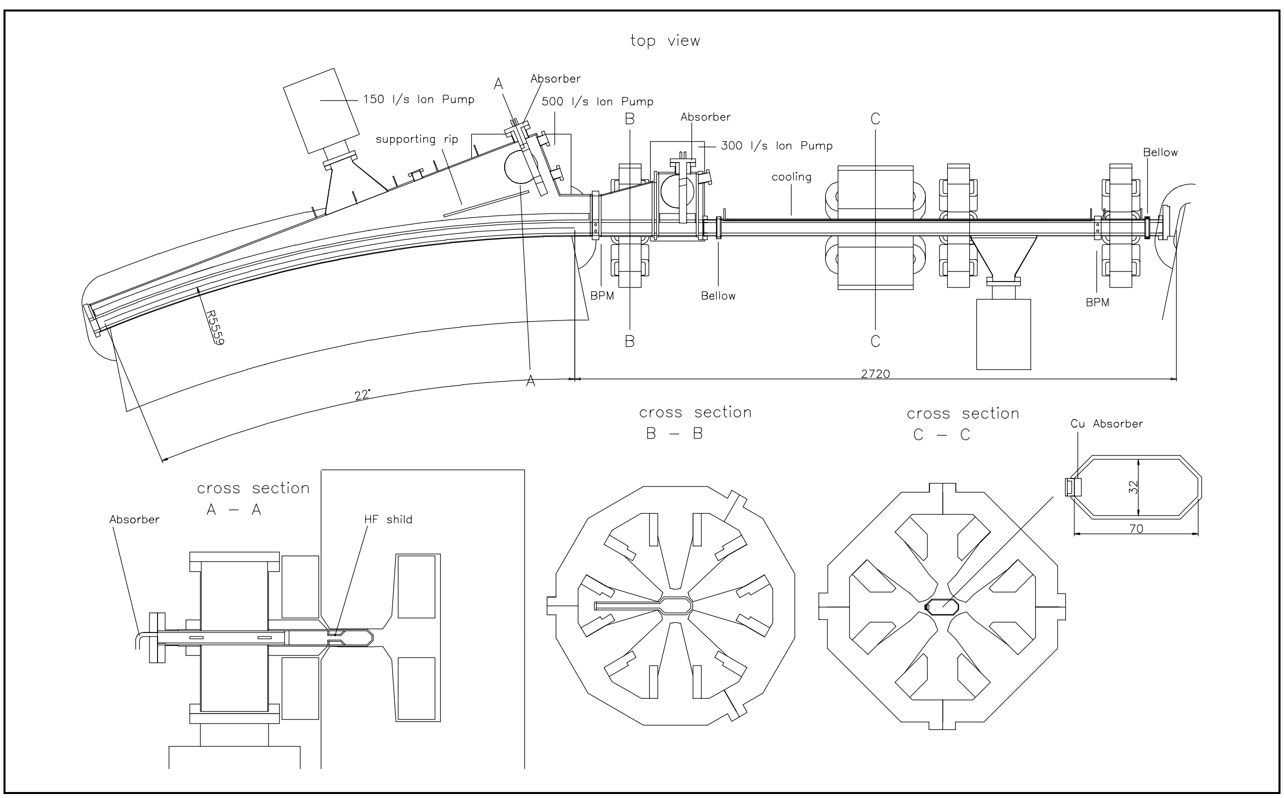

Figure: 1 Topview and cross sections of the dipole vacuum chamber.

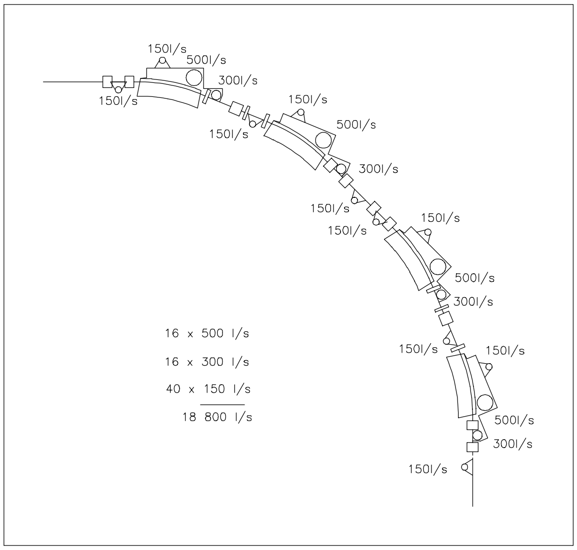

Figure: 2 Pumping scheme for a quarter of ANKA.

diodes elsewhere might be a compromise between optimum pumping speed and not excludable leaks.

Concerning getter pumps both titanium sublimator (TS) and NEG pumps (Non Evaporable Getter) are used at storage rings. Both pumps have a considerable pumping speed for hydrogen, they pump all reactive gases but do not pump noble gases and hydro carbons at all. Since the pumping speed decreases when a certain amount of gases has covered the surface of the pump, (After 10 h for a TS at 3 10^{-9} mbar) the getter must be regenerated periodically.

At ANKA only diode ion pumps will be used at the beginning. It is foreseen to install lumped NEG's or titanium sublimator on top of the ion pumps later on if this turns out to be necessary. The foreseen pumping scheme is shown in Figure 2.

5 PRESSURE PROFILE

For calculating the pressure profile of the vacuum chambers and optimizing the pumping configuration a program similar to the one described by P.C.Chen et.al.[5] was used. Figure 3 shows the pressure profile in the e-beam chamber for one quarter of ANKA. A gas load of 3.5 10^{-5} mbar l/s and an effective pumping speed of 15000 l/s (both numbers refer to the complete ring) were used for this calculation.

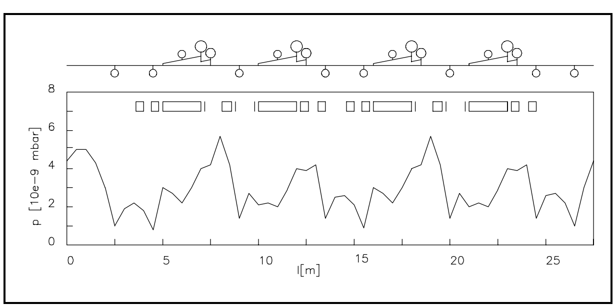

Figure: 3 Pressure profile for one quarter of ANKA.

6 THERMAL LOAD

The total power of the synchrotron radiation (2.5 GeV, 200 mA) of 123 kW leads to a power per length of 130 W/cm for the main absorbers. The maximum wall temperature, calculated with ANSYS is in the order of 95°C.

Behind the second absorber the synchrotron radiation is absorbed on the wall of the e-beam chamber. The thermal conditions of this wall are shown in Figure 4 as a function of the distance from the dipole.

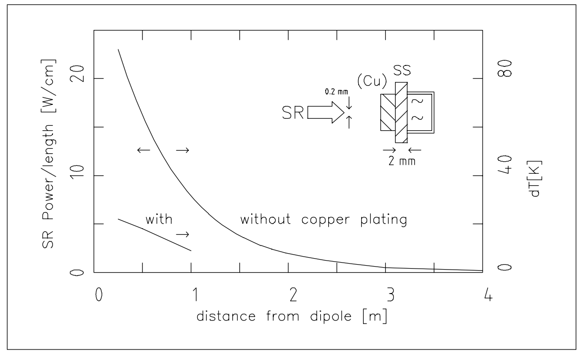

Figure: 4 Absorbed power and temperature step inside the vacuum wall (E=2.5 GeV, I=200mA).

7 BAKING

Nearly all SR sources have an insitu baking system. It's merits: getting a cleaner vacuum (i.e. no water content), having a faster commissioning and a faster recovery after vacuum break down are well established. On the other hand due to the experiences at ELETTRA it's necessity is now discussed [6]. Costs for heating jackets and insulation can be saved, the gap of the magnets can be made smaller and thus the current reduced. The bellows need only compensate the mechanical tolerances. Due to the budget limitations of ANKA, it was decided not to install an insitu baking system. Instead the chambers will be cleaned and only be baked before installation.

[**1**]D.Einfeld et al, this conference

[**2**] Y.Hori, M.Kobayashi,Y.Takiyama, Vacuum47(1996)617

[**3**] O.Grödner, A.G.Mathewson, H.Störi, P.Strubin, R.Souchet, Vacuum 33(1983)397

[**4**] S.Ueda, M.Matsumoto, T.Kobari, T.Ikeguchi, M.Kobayashi, Y.Hori, Vacuum 41(1990)1928

[**5**] P.C.Chen,G.Y.Hsing and J.R.Chen, J.of Vac.Soc.R.O.C. 1(1987)24

[**6**] J.Miertusova, F.Giacuzzo, 5.EPAC(1996)2527