DESIGN ASPECTS OF UHV SYSTEM FOR INDUS-2

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Abstract

INDUS-2, a dedicated synchrotron radiation source operating in X-ray range, is a 2 GeV, 300 mA electron storage ring being developed at CAT Indore. Present paper describes the details of its ultra high vacuum system, designed to achieve ultimate vacuum of $2X10^{-10}$ mbar without beam and $1X10^{-9}$ mbar with beam. Circumference of the ring is 172.278 meters, divided into 8 unit cells. Aluminium alloys are chosen as construction material of vacuum envelope. Each unit cell has two bending magnet (BM) chambers, interspersed with straight section (SS) chambers. SS chambers are extruded while BM chambers are machined ones. Synchrotron radiation (SR), except that going in the beam lines, is mostly incident on photon absorbers mounted on ante-chambers and direct incidence of SR is avoided on chamber walls. Main gas loads are due to photon induced desorption ($3.02x10^{-5}$ torr lit/sec) and thermal desorption ($0.7x10^{-5}$ torr lit/sec). Triode Sputter Ion Pumps (112 no.) and Titanium Sublimation pumps (128 no.) are main pumps. Non evaporable Getter strips (16 no.) will be used for pumping dynamic gas load, when the ring operates at the specified beam current. Moveable turbo molecular pump stations fitted with pirani gauges, are used for sector-wise roughing and baking. Total pressure measurement is done by 25 nude BA gauges. Sixteen quadrupole mass analysers are used for residual gas analysis and leak detection. The interlocking and control of the seven sector valves is done through BA Gauges.

1 INTRODUCTION

INDUS-2 is designed to store electrons upto a beam intensity of 300 mA at 2 GeV. Booster synchrotron is used to inject 700 MeV electrons into the storage ring, where the energy is increased to 2GeV. The storage ring is divided into 8 unit cells, each having 2 dipole, 9 quadrupole and 6 sextupole magnets. Total Synchrotron radiation power, from dipole magnets, is 76.45 kW and its critical wave length is 3.87 A^o. 22 beam lines are planned to tap synchrotron radiation (SR) from bending magnet and 5 beam lines are planned for radiation from insertion devices like wigglers and undulators, located in long straight sections. The vacuum envelope consists of 16 BM chambers, 8 long straight section and 8 short straight section chambers. From beam lifetime considerations, pressure less than $1X10^{-9}$ torr is needed when the beam is on and the partial pressures of high mass gas species are also required to be below $1X10^{-10}$ torr. For INDUS-2 the beam life time is 18 hours [1].

2 DESIGN APPROACH

The cross section of the vacuum chamber is a trade off between aperture needed for beam excursion and the pole gap of magnets. Minimum requirement for beam excursion is 34mm(vertical) and 64mm(horizontal). To minimise HOM losses, abrupt changes in cross section are avoided.

Photons are brought out of electron beam channel and dealt with in an ante-chamber, using photons absorbers. Sufficient pumping speed is provided just below the photon absorbers to take care of photon induced desorption gas load. Ante chamber is provided only in BM chamber. But the electron beam channel has same cross section throughout the storage ring except r.f cavities, septum and kicker magnet chambers.

Triode type Sputter ion pumps (SIP) and Titanium sublimation pumps (TSP) are the main pumps. Their choice is mainly decided by their in-house production. Turbo molecular pumps are used during roughing and baking. NEG strips are planned in BM chamber, but they will be used only at the end of commissioning.

Due to its inherent advantages [2], aluminium alloys are used as construction material for vacuum envelope. Pump bodies, septum & kicker magnet chambers, bellows, valves etc will be fabricated from austenitic stainless steel of grades 304 LN and 316 LN as they have excellent mechanical and vacuum properties and meet the requirements like very low magnetic permeability (<1.005), highly reliable welding joints etc.

3 VACUUM ENVELOPE

Bending magnet chamber is extended to cover upto first quadrupole magnet down the beam path. Photon exit ports are incorporated in BM chamber to tap SR for beam line experiments. Considering the characteristics of circulating electrons and minimum lateral separation required between two adjacent beam lines, it is decided to have photon exit ports at 5^o & 10^o in each dipole chamber. To facilitate tapping of SR generated by ID's, a 0^o port is also provided in each BM chamber. All the BM chambers are identical. Unused ports are blanked off and provided with cooling on blanking flanges. The length of the BM chamber is 3.597 m and its width is 0.62 m. Figure-1 shows a cross section of BM chamber. These chambers are fabricated from aluminium alloy 5083 H321, by machining the chamber in two halves and lip welding all around the perimeter. The weld sizes are kept small and welding is done by TIG. The potential virtual leaks between the perimeter weld and the main vacuum volume are ventilated by a groove.

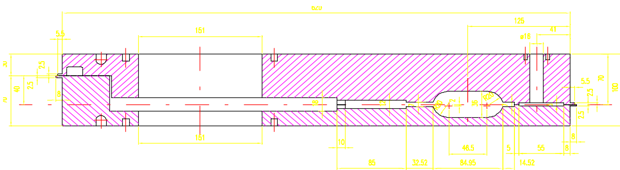

Figure 1: A Cross Section of BM chamber.

The straight section chambers are extruded from aluminium alloys A6063-T6. Inner dimensions of straight section chamber are identical to the electron beam chamber in bending section. The ante-chamber is omitted in straight section of the ring because of aperture limitations imposed by conventional design of quadrupole and sextupole magnets. Figure-2 shows the cross section of extruded straight section chamber.

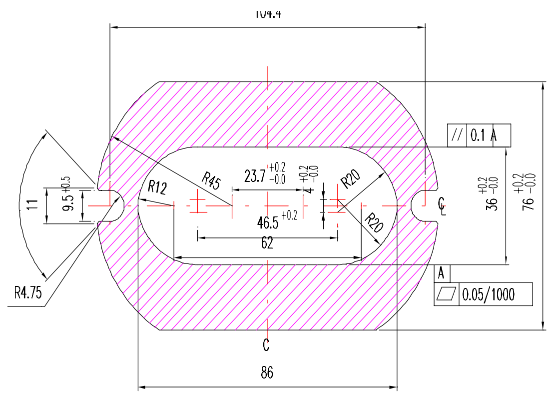

Figure 2: Cross Section of Extruded chamber.

Ports are provided for installing pumps, photon absorbers, gauges etc. R.F shielded bellows are provided to take care of thermal expansion during bakeout. Baking of the Aluminium chamber is envisaged by circulating pressurised hot water at 150^{o}C through the pipes fitted in the grooves provided on the chambers. The Pumps and other stainless steel chambers are baked at 300^{o}C by heating tapes and jackets.

4 PHOTON ABSORBERS

Water cooled photon absorbers fabricated from OFHC copper are used to stop most of the non-experimental facility synchrotron radiation and to direct the desorbed gas molecules into the pump. A 7.5 degree wedge shaped absorber performs this function very well [3]. There are three absorbers in each BM chamber. SR power incident on these absorbers is 0.94, 0.94, 1.54 kW respectively. 0.584 kW power falls on the downstream end of BM chamber, making it necessary to provide cooling arrangement there. Approximately 0.41 kW power is channelled into the straight section and 0.08 kW power hits the next BM Chamber. Approximately 0.01 kW of SR power from dipole magnets may go into the 0^o beam line meant for SR from ID's. Figure-3 shows the SR fan in a unit cell.

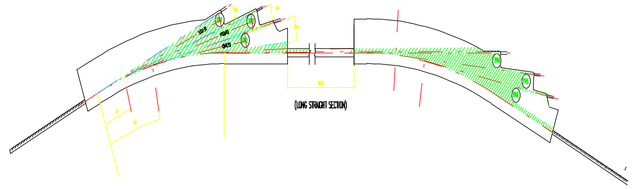

Figure 3: Synchrotron Radiation from Dipole Magnet.

A 3-D model of the crotch was used to compute the temperature distribution using COSMOS/M FEM software. The hot spot temperature is 80°C and at the cooling wall, the maximum temperature is 47°C, which is quite low . Assembly of one of the crotches is shown in figure-4.

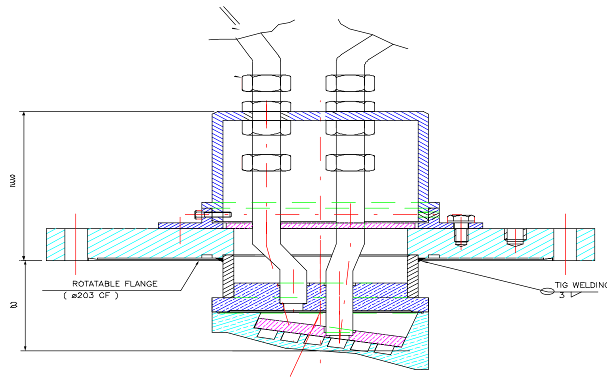

Figure 4: Assembly drawing for a Photon Absorber.

5 GAS DESORPTION

Thermal outgassing from the surfaces exposed to vacuum and the photon induced desorption constitutes main gas load. The gas load due to photon induced desorption, Q_{SR}, is given by [4]

$$Q_{SR} = 2n^o \eta K$$

where, the number of photons emitted per sec, n^o is given by, $n^o = 9.5 \times 10^{17}$ IE $[1- (0.01/ \varepsilon_c)^{1/3}]$

Empirically for an Aluminium chamber with copper absorbers, the molecular desorption yield, η, is given by,

$$\eta = 5 \times 10^{-6} \times D^{-1/2} \text{ molecules/photon.}$$

For Indus-2, Molecular desorption yield, $\eta = 1 \times 10^{-6}$ molecules per photon and after 25 Amp.hrs,

$Q_{SR} = 3.02 \times 10^{-5}$ Torr lit/sec,

Assuming specific outgassing rate, $q = 5 \text{ X } 10^{-12}$ torr.l /sec/ cm^2 , thermal outgassing rate, $Q_{th} = 0.7 \times 10^{-5}$ torr.l /sec/ cm^2.

Therefore, the total gas load for INDUS-2 , Q_{total} is ,

$Q_{total} = Q_{SR} + Q_{th} = 3.72 \times 10^{-5}$ Torr lit/sec

6 PUMPING SYSTEM

The ring is divided in 7 sectors, by using r.f contact valves for isolation. Pump down scheme for INDUS-2, involves sector-wise roughing and baking of ring by using TMP carts, attaining 10^{-9} torr by using SIP's and then to fire TSP's to attain the ultimate vacuum. To attain 10^{-10} torr, effective speed of 70000 l/s is required. But the specific conductance of the electron beam channel is 24 l.m/s. Therefore, it is necessary to distribute the pumps properly. Each unit cell is provided with three ports for TMP carts; 7 SIP's of 140 l/s, 6 SIP's of 270 l/s and 15

TSP's.of 1000 l/s. Two NEG strips of 500l/s are also proposed in BM chambers of each unit cell. Additional pumps are installed at the site of larger gas loads like septum magnet chamber, r.f cavity etc. Table -1 lists the pumps and their effective speeds, installed in INDUS-2.

TABLE -1

Type of Pump	Effective Speed (l/s)	No of Pumps	Total Speed (l/s)
140 l/s SIP	38	54	2052
270 l/s SIP	96	2	192
270 l/s SIP	102	48	4896
500 l/s SIP	182	8	1456
1000 l/s TSP	133	54	6418
1000 l/s TSP	803	2	1606
1000 l/s TSP	624	72	44928
1000 l/s TSP	500	16	8000
TOTAL AVAILABLE SPEED = 70312 l/s			

Simulations were carried out by computer program 'Pressure Distribution 2.0', obtained from CERN. Results show that an average pressure 2.25x 10^{-10} torr without beam and 5.7 x 10^{-10} torr with beam is obtained for the installation of pumps as shown in fig 5.

7 PRESSURE MEASUREMENT

UHV compatible Pirani/Pening gauges are mounted on each TMP station to monitor vacuum during roughing and baking. In addition to SIP current, 25 nude type BA gauges are used monitor total pressure at various locations on the ring. These gauges are also used as sensors to close ring sector valves and beam line front end valves. 16 Quadrupole Mass Analysers (QMA's) are installed along the ring to continuously monitor the residual gas composition, to protect the ring from contamination and for leak detection.

8 CONCLUSION

Vacuum system for INDUS-2 was designed to provide the beam life time of 18 hours for 300 mA electron beam of 2 GeV, assuming photo desorption yield of $1X10^{-6}$ mole/photon and specific thermal outgassing rate of $5x10^{-12}$ torr.l/s/cm^2. This value of photo desorption yield may only be obtained after 25 Amp-.hrs of dose. Initially, photo desorption yield may be as high as 10^{-1}. This will lead to short beam lifetime. But sufficiently large pumping speed provided in the design will take care of gas loads and quickly augment beam life time and the stored beam current. Self cleansing effects of beam will further reduce the gas loads and the specified vacuum parameters will be easily achieved.

9 REFERENCES

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[3] "Vacuum System for the LBL Advanced Light source (ALS)" by Kurt Kennedy, AIP, Conference Proceedings No. 171,1988,52.

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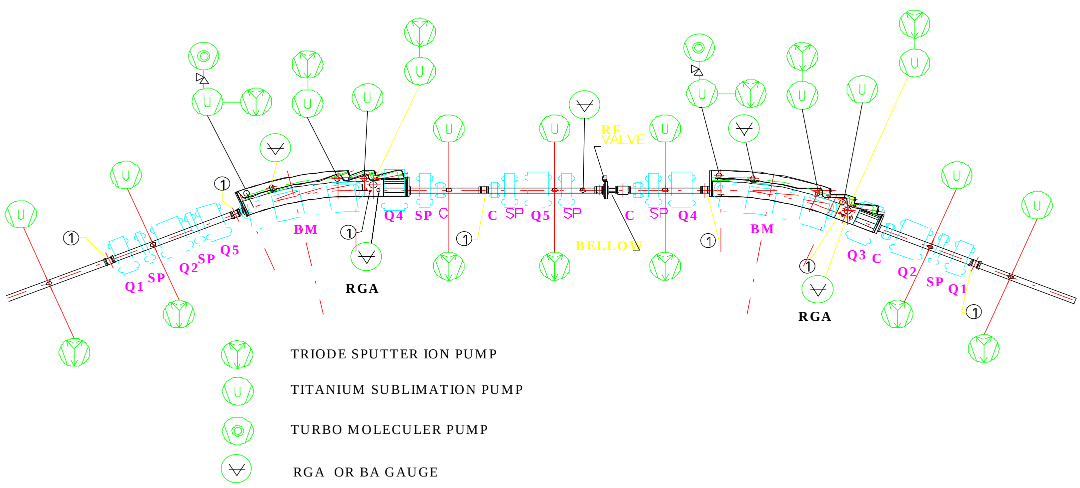

Figure 5: Layout of vacuum components in a unit cell of INDUS-2.