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PRELIMIARY DESIGN OF HEPS STORAGE RING VACUUM CHAMBERS AND COMPONENTS

P. He, B.L. Deng, D.Z. Guo, Y.S. Ma, B.Q. Liu, Q. Li, Y.C. Yang, L. Zhang, X.J. Wang,
Institute of High Energy Physics, CAS, Beijing, P.R. China

Abstract

The 4th generation ring-based light sources, HEPS (High Energy Photon Source) 7BA lattice has been developed at IHEP. This is 6Gev, 200mA machine which has horizontal emittance ε_h around 60pm.rad to gain the high brilliance photon beam. This compact lattice bring the magnet aperture to 25mm diameter, this will place a demanding set of constraints on the storage ring vacuum system design. Hybrid design has been adopted this lattice which combines conventional chambers incorporating "antechambers" with a variety of simpler tubular chambers made variously of copper-plated stainless steel, and NEG-coated copper tube in the FODO section.

INTRODUCTION

The main issues of low emittance ring vacuum system are providing the effective pumping and handling the higher SR power. The general requirements for vacuum chamber have to be considered for the cost, performance, and required maintenance, these factors will led to a design by which the details of the chamber construction varies according to local spatial constraints and SR loading. The next-generation light source storage ring vacuum system has to be designed in such way which is compatible with a multi-bend achromat(MBA) compact lattice [1]. Three different approaches have been developed: Conventional chamber with antechamber [2], all NEG-coated copper tubes [3], and hybrid design which combines conventional chambers and tubular NEG-coated copper tube [4]. For the HEPS storage ring vacuum system, we choose the hybrid design. This option takes both advantage of type I and type II design, it has good vacuum performance and reduce the vacuum chamber impedance, and also can shorter the required installation time, and easy maintainability. Also the system cost is at the moderate level.

SYSTEM DESIGN

As presently envisioned, a 7BA lattice storage ring will store 200 mA of electron current at an energy of 6 GeV for HEPS. One cell layout of the storage ring is shown in Fig. 1. According to the difference of the magnet function, the sector is divided into four types of sections: quadrupole doublet, longitudinal gradient dipole, multipole straight, FODO (alternately of focusing and defocusing). Vacuum chamber cross-section and material selection will depend on the synchrotron radiation power distribution there and also need integrate with other components(magnet, BPM, et al.). The issues such as space between magnet pole tips, coil gaps for vacuum and photon extraction chambers, all of these need to be considered when we design the vacuum chamber. The different vacuum chamber design will be presented as below.

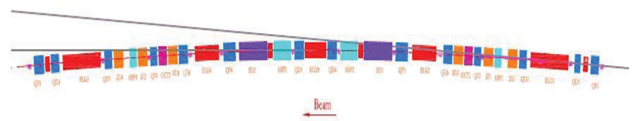

Figure 1: One sector of HEPS lattice layout.

Quadrupole Doublet Chamber

In this section, the fast corrector magnet is located between two quadrupoles, the Inconel segment will be used on this area to limit the impact of eddy current shielding by increasing electrical resistivity ($7.4\text{x}10^{-7}\ \Omega\text{m} \rightarrow 1.28\text{x}10^{-6}\ \Omega\text{m}$, 40% higher compare with 316LN stainless steel).

The interior surface, however, will be plated with copper to minimize beam impedance effects. The chamber layout is shown at Fig. 2.

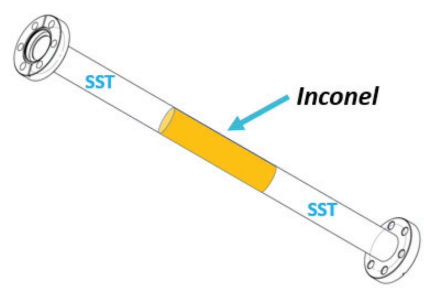

Figure 2: Quadrupole doublet chamber with Inconel segment.

LGD Chamber (Longitudinal Gradient Dipole)

Chambers here will have a 22 mm aperture for the particle beam and antechambers to allow discrete absorbers to intercept bending magnet radiation away from the stored beam (Fig. 3). In order to provide the good vacuum performance, two NEG pump will be add to the antechamber side. Finite element analysis (FEA) was used to calculate the mechanical stresses in vacuum chamber. The primary results show the max. deformation is 0.055mm and max. stress is 17.8MPa, the further optimization of the design still underway.

Straight Multiplet Chamber and X-ray Extraction Chamber

The ray trace simulation indicate that the very less bending magnet radiation shooting on the chamber wall in the straight multiplet section even without antechamber and just very simple tubular chamber. The key-hole chamber is applied here for the x-ray extraction which

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coming from the insertion device (undulator). The chambers cross section is shown in Fig. 4.

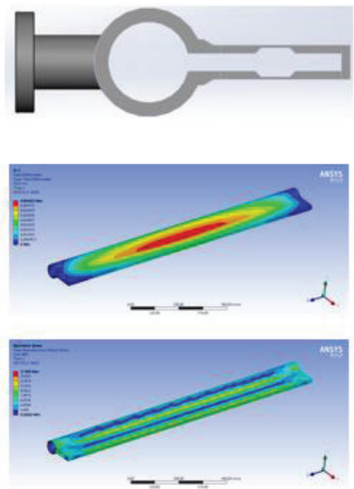

Figure 3: LDG chamber cross section.

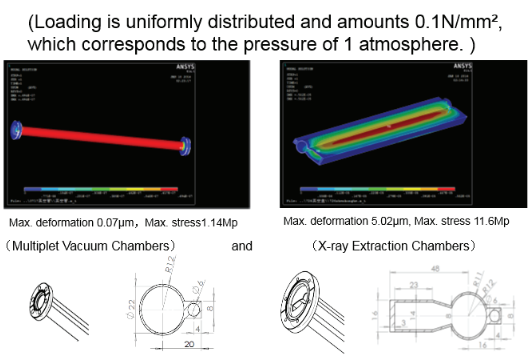

Figure 4: Multiplet chamber and X-ray extraction chamber.

FODO NEG-Coated Copper Chamber

Due to the higher synchrotron radiation power will shining on the vacuum chamber wall in this central FODO area, we design the chamber by using the oxygen-free copper material to maximize the thermal conductivity. And also a cooling water tube will adjoin the outboard wall to remove synchrotron radiation heat. The "in-line absorber" concept design will use GlidCop stub in the end of the chamber to absorb the radiation power and protect the following BPM components (see Fig. 5).

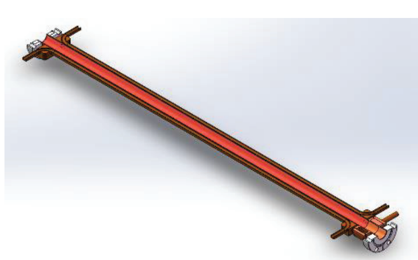

Figure 5: Copper tube in FODO section.

The mechanical stress analysis is shown in Fig. 6. The NEG coating will applied on the inner surface of the chamber to provide the distributed pumping. Getter films deposited on the inner surface of the chamber would transform the vacuum chamber from an outgassing source into a pump.

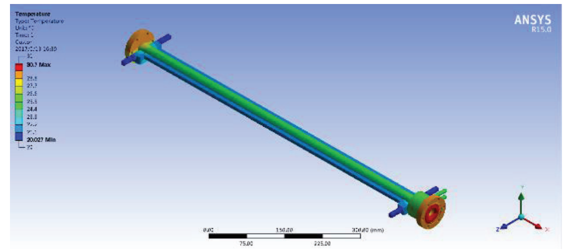

Figure 6: Mechanical analysis of copper tube.

COMPONENT DESIGNS

Zero Impedance Flange

This kind of flange means with no slit and no step between the two flanges which was developed at Sirius [3], on the basis of the model developed at KEK [5]. It is smooth inner surface, and additional effort is made so that electron beam only sees copper in traversing a flange (Fig. 7). The leak check and vacuum test shows no leaking even after 10 times assemble/disassemble and bake out up to 200° C (Fig. 8).

Figure 7: Zero impedance flange prototype.

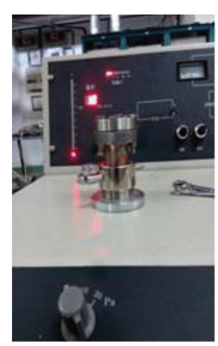

Figure 8: Flange under leak check.

RF Shielded Bellow

The bellows will be used between vacuum chambers, they have following functions:

a) Make up for transverse offsets in beamline hardware, and minor misalignments

b) Provide installation personnel with sufficient flexibility to install hardware.

c) Reduce stresses on adjacent vacuum joints.

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d) Provide adequate expansion and/or contraction ability during thermal cycles.

e) Provide required movements for functioning instruments, such as beam profile viewers.

In storage rings, bellows MUST be shielded from the beam. Otherwise, wake-field will be excited in the cavities to cause damage to the bellows. Most modern designs of RF-shielded bellows should have much smoother transitions, to reduce RF-impedance. The two different RF shielding liners have been designed here: conventional "outside finger" configuration and omega stripe RF shield. The 3D-model are shown in Fig. 9. The K loss factor and impedance will be measured after the two prototypes are delivered to IHEP.

Photon Absorbers

In addition to the "inline absorbers" built into the downstream end of many of the chambers, demountable photon absorbers are also needed at both crotch locations and at the downstream end of each bend chamber.

Preliminary designs have been established for these and analysis is underway to determine required materials, detailed geometry, and cooling water flow.

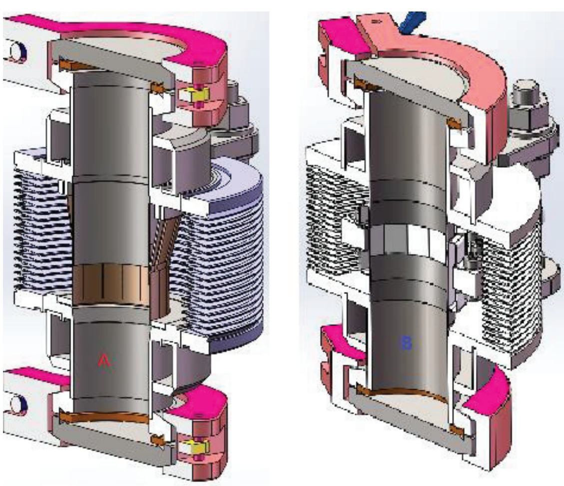

Figure 9: Two configurations of RF shielded bellows (A-outside finger; B-omega stripe).

First prototype of photon absorber was designed by using GlidCop material which has which has high thermal conductivity comparable to that of OFHC copper and can withstand higher stress(Fig. 10). This design need brazing the absorber body into stainless steel flange which show some technical difficulty even use Au-Cu 50-50 filler. While the use of GlidCop for this application is not ideal as the material is expensive, available form limited, and hard to weld. 2nd design has been developed and absorber material is changed to the CrZrCu, this design is whole block 100% machine even for the knife-edge, no braze and no weld at all (Fig. 11). CrZrCu widely available in all sizes from many suppliers and is considerably less expensive. Options to eliminate the need for GlidCop are being investigated by testing the both two types of photon absorber prototypes.

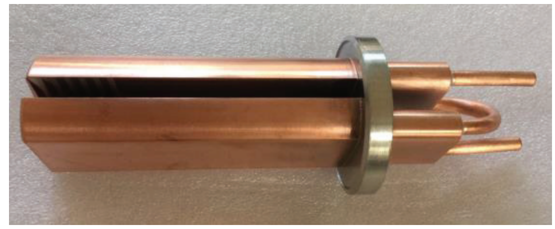

Figure 10: Brazing GlidCop_AL_15 to stainless steel (SST).

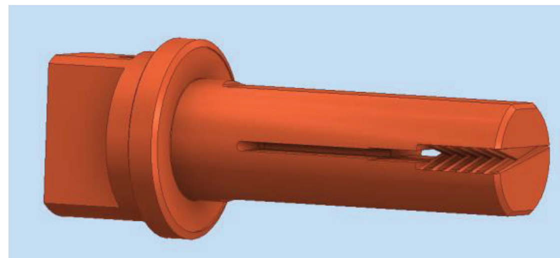

Figure 11: CrZrCu whole block machined absorber.

Synchrotron Ray Trace Analysis

A ray trace analysis (Fig. 12) by using SynRad code illustrates how synchrotron radiation distribution along the sector.

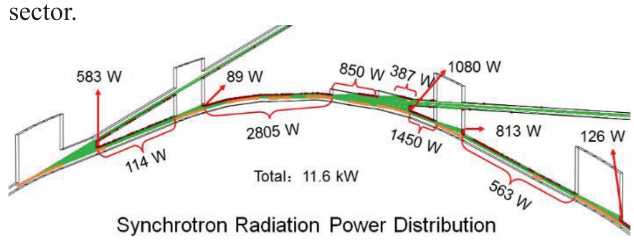

Figure 12: Distribution of bending magnet radiation.

According to SynRad simulation, we know the total bending magnet power approximately 11.6 kW. The higher power radiation generated primarily in central section and at outer ends (near ID straight section). FODO chambers receive more than half of the total power. Straight multiplet chambers receive very little power. These information will provide much help for the vacuum chamber and photon absorber design.

CONCLUSION

A conceptual design has been developed for a storage ring vacuum system of HEPS project. Chamber designs and pumping schemes are still need optimized for the four types of magnet arrangements according to the spatial allowances and synchrotron radiation power distribution there.

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