The Design of HEPS Front Ends

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MEDSI PARIS 2018
MECHANICAL ENGINEERING DESIGN OF SYNCHROTRON RADIATION EQUIPMENT AND INSTRUMENTATION

Abstract

High Energy Photon Source (HEPS) is a 6GeV synchrotron radiation facility to be built in Huairou, Beijing, with a perimeter of 1390.6m and 48 straight sections. In the phase I, 16 front ends will be installed, including 15 ID front ends and 1 BM front end. These front ends are divided into three categories: the standard undulator front end, the wiggler front end, and the BM front end. The peak power density that the front end accepts is about 868kW/mrad^2, the total power is about 47kW. This paper describes the general layout design of the three different types of front ends, the functions of the main components, the finite element analysis of key devices and the general layout of the vacuum devices in the HEPS front end.

Introduction

The HEPS storage ring consists of 48 straight sections, of which 41 sections can be installed with insertion device and the length of the straight section is 5m. The bending magnet in the middle of each two IDs leads to a BM beam line. In the phase I, 15 ID beam lines and q BM beam line are constructed. One of the 15 ID beam lines is a test beam line. CPMU 13.5 using the HEPS pre-research project is used as a light source. A 300m long hard X-ray imaging beam line uses a Wiggler as light source. Table 1 summarizes the IDs parameters.

Table 1: the Typical Light Source Parameters of Phase I ID Beam line at HEPS

ID Type	CPMU	IAU	IVU	Wiggler
Length [mm]	21	33.7	22.4	100
Nu	199	148	187	21
B_0 [T]	1.57	0.83	1.13	1.80
Total Power [kW]	46.7	15.7	24.3	31.0
Power Density [kW/mrad^2]	868	341	584	106

Front ends layout

The front end is divided into three categories: the Undulator front end, the Wiggler front end, and the Bending Magnet front end. In order to reduce costs, front ends are standardized. The device arrangement in the three types of front end is basically the same.

The ID front end begins with a vacuum isolation valve at the end of the storage ring branch pipe and terminates at a Be window outside the ratchet wall. The overall length is 14.9m. Acceptance angle is 2/0.7mrad (H/V), general departure angle is 0.180/0.180mrad (H/V) (adjustable according to beam line requirements). The main equipment (Figure 1) is: fixed mask 1, XBPM1, fixed mask 2, photon shutter 1, lead collimator 1, slow valve, fast valve, XBPM2, photon shutters 2, Filters, Slits, lead collimators 2, safety shutters, Ratchet wall, fixed mask 3, and Be window.

The Wiggler front end and the Undulator front end are basically the same in structure, except that apertures of the wiggler front end is relatively large. Full length 12.7m, acceptance/departure angle is 2/0.7mrad (H/V). The main components in the front end are: fixed mask 1, XBPM1, fixed mask 2, photon shutter 1, lead collimator 1, slow valve, fast valve, XBPM2, photon shutter 2, Filters, lead collimator 2, safety shutter, ratchet walls, fixed mask 3 and Be window.

There is no Filter and Slits in the BM front end, and the absorber of the fixed mask and the photon shutter is far shorter than the ID front end. The main components in the front end are: fixed mask 1, XBPM1, fixed mask 2, photon shutter 1, lead collimator 1, slow valve, fast valve, XBPM2, photon shutter 2, lead collimator 2, and safety Shutters, ratchet wall, fixed mask 3.

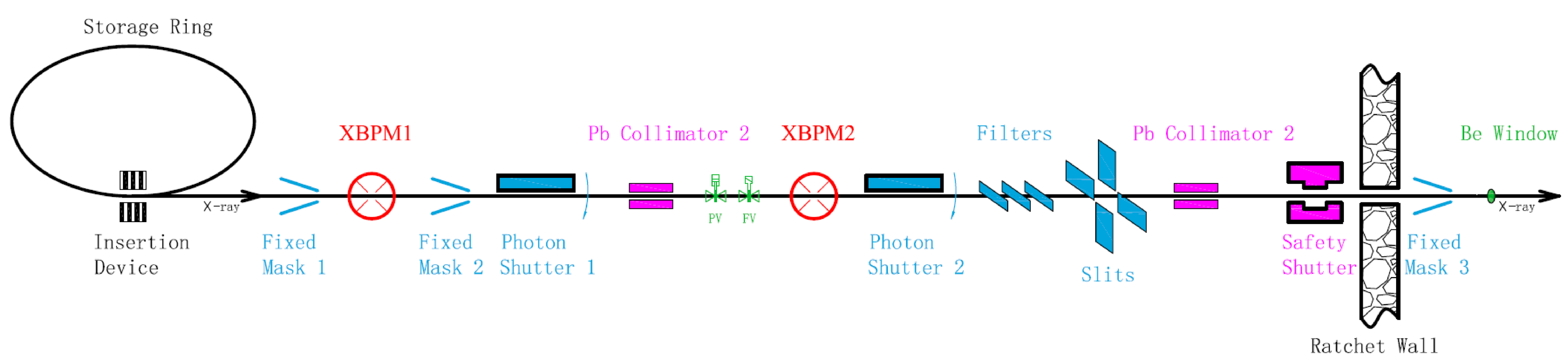

Figure 1: the Layout of Front End

Components description

Fixed Mask

The fixed mask (Figure 2) is used to define the synchrotron radiation angle. It is a parallelepiped with a rectangular through hole in the centre. The absorber material is Glidcop® AL-15. The mask uses an inclined surface to absorb the heat load, and cooling channels are distributed around the aperture.

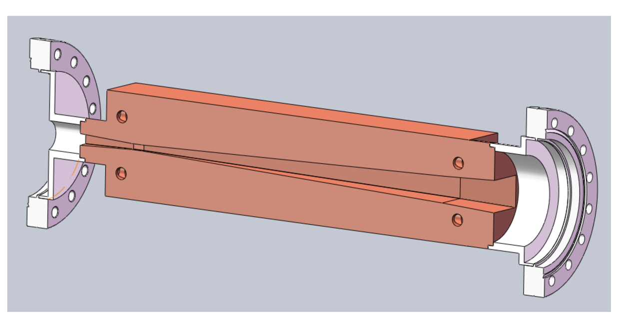

Figure 2: the Section View of Fixed Mask

Photon Shutter

Each front end contains two photon shutters. The first photon shutter (PS1) is placed in front of the equipment protection system and only operates when the equipment protection signal is triggered. The second photon shutter can be controlled by a safety interlock system. The absorber of the photon shutter is a copper block with a rectangular through hole inside and cooling water channels are near the incident plane. In the closed state, the absorber is rotated by a small angle so that the incident plane just blocks the synchrotron radiation.

Slits

Due to the unified consideration of standardized design, the design of other parts of the front-end area is the same. Beam line requirements lead to different angles, which need to be achieved through slits. The slits are used to adjust the synchrotron radiation receiving angle of the beam line and consists of two "L" shaped absorbers. Each absorber can independently move in the vertical and horizontal directions. The two absorbers are overlap and block the light separately.

Filters

Filters is used to reduce the thermal load of the first optical element of the beam line. A water-cooled copper frame is used to clamp the graphite film into X-ray and absorb the low-energy part of the synchrotron radiation.

Safety Shutter

The safety shutter (Figure 3) is an important part of the bremsstrahlung shield, which protects downstream safety. The main block is made of high-density metal tungsten alloy.

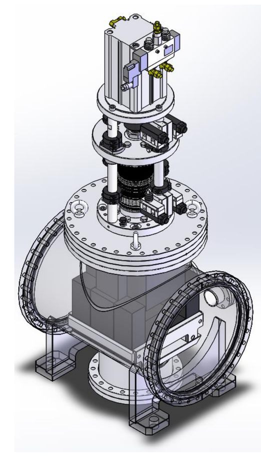

Figure 3: Safety Shutter

Lead Collimator

The Lead collimator is a rectangular section tube surrounded by lead bricks. The lead collimator and the safety shutter constitute a complete bremsstrahlung radiation shield.

XBPM

Two XBPMs are installed in the front end, placed on a temperature-stable and vibration-isolated support to monitor the X-ray's position and angle.

Beryllium Window

The water-cooled Be window is usually placed at the end of the front end and plays a role in isolating the vacuum between the front end and the beam line. It also has the ability to block the shock wave. The centre of the window is a 200 μm thick beryllium film, polished surface that is slightly larger than the spot size. Electron beam welding is used to connect the film to a water-cooled oxygen-free copper frame

Fast Valve

It is used to quickly isolate the vacuum connection between the beam line and the storage ring when a vacuum accident is detected.

FEA

The fixed mask absorber uses Glidcop® AL-15, and the cooling water channel uses enhanced heat transfer technology to achieve a heat transfer coefficient of 15,000 W/(K•m^2). Under normal operation, the maximum temperature of the incident surface is approximately 140°C (Fig. 4) at the front end of the nano-focused beam line with a peak power density of 868 kW/mrad^2, and the fixed mask can operate safely.

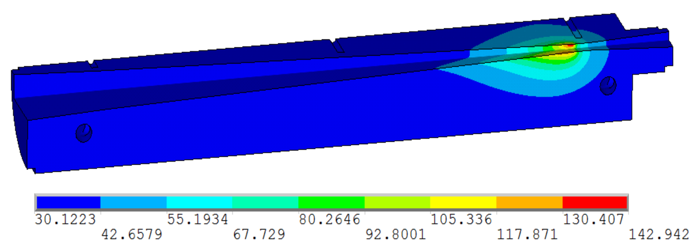

Figure 4: FEA of Fixed Mask

Vacuum Components Layout

The front end is an ultra-high vacuum chamber, which is better than 5x10^{-10} Torr in the absence of synchrotron radiation. Due to the special structure of the front end, ion pumps are deployed in various locations, and ion pumps and sublimation pumps are installed near components with a large amount of gas discharge. In order to obtain greater pumping speeds for hydrogen, NEG pumps are also installed in place. The front end vacuum components layout is shown in Figure 5. Upstream of the front end, an all-metal ultra-high vacuum valve isolates the vacuum from the storage ring and the front end, and an ion pump and a getter pump are placed immediately after it to maintain good vacuum near the end of the storage ring. The radiation-resistant cold cathode gauges are installed in place for vacuum degree monitoring. In addition, a full metal angle valve is installed near this part of the pipe to connect a vacuum unit(dry pump and turbo pump). The slow valve divides the vacuum in the front end into two sections. An angle valve is also installed before the fixed mask 3 in the experiment hall.

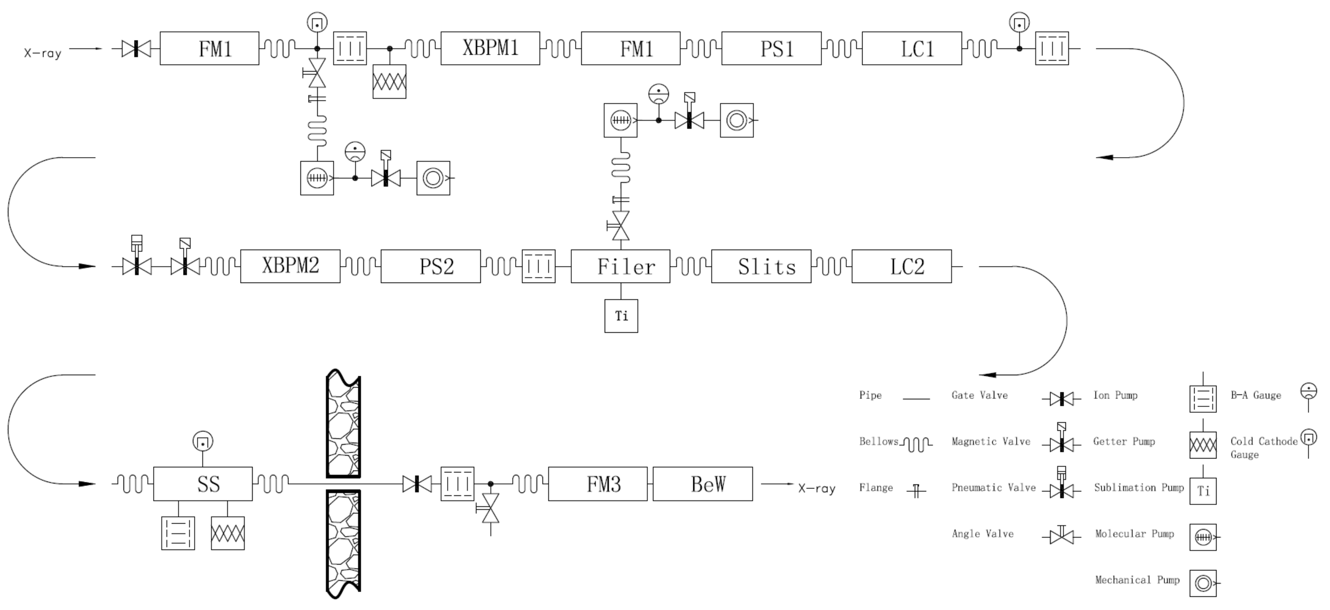

Figure 5: Vacuum Components Layout

Summary

This article describes the design of front end layout at HEPS, main components functions, finite element analysis of key components, and vacuum components layout. At present, aperture design and bremsstrahlung radiation shied design are in progress, and the finite element analysis of key components will be further refined.