A Design of an X-Ray Pink Beam Integrated Shutter for HEPS

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Mechanical Engineering Design of Synchrotron Radiation Equipment and Instrumentation

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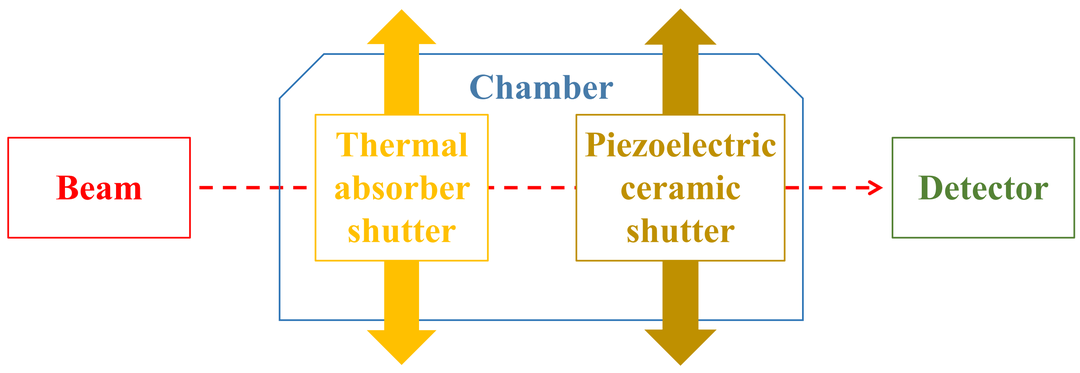
1. Introduction of the Integrated Shutter

The integrated shutter is designed for the small angle X-ray scattering station, which is under construction at HEPS and characterized by a pink beam with enormous high photon flux. In order to solve the vacuum heat dissipation problem and at the same time ensure a fast response, we proposed the following schematic design. Firstly, the integrated shutter is comprised of a thermal absorber shutter in series with a piezoelectric ceramic fast shutter. By coordinating their different opening and closing times, the exposure time of the sample can be controlled. Secondly, it is suitable for both monochromatic and pink beam operation with a horizontal pitch of 15mm. In addition, the thermal absorber shutter is also able to function as a beam profile monitor, and the position of the spot can be monitored through a viewing window on the cavity. Finally, all functional modules are integrated into a fixed chamber, which avoids recalibration after changing the module.



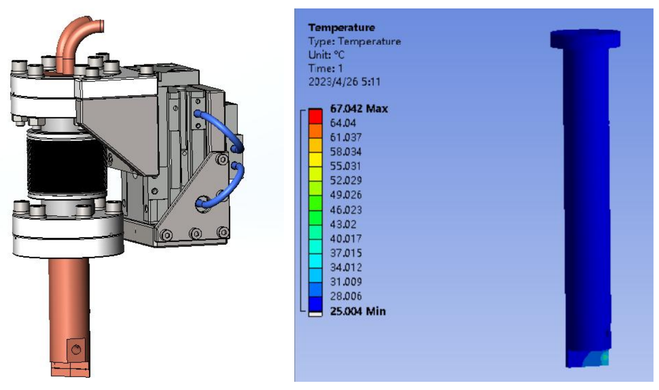
Schematic diagram of integrated shutter

2. Main specifications

X-Ray Pink Beam Integrated Shutter		
Operating condition	Energy range	8-30 keV
	Flux at sample	~10^{15} ph/s@200 mA
	Vacuum requirements	rough vacuum & atmosphere
Beam size	max. 500×500 μm²	
Thermal power	Pink beam: 16 W Monochromatic beam: <1 W	
Response time	Thermal absorber shutter: <0.1 s Fast shutter: <1 ms	
Function module integration	Thermal absorber shutter, Piezoelectric ceramic fast shutter, Beam profile monitor	

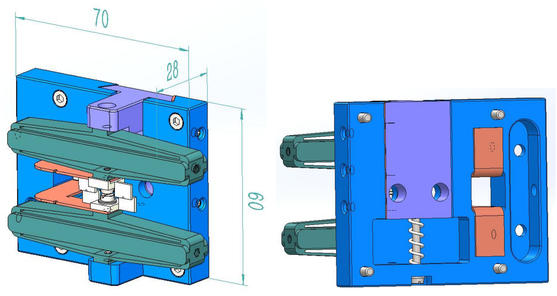
3. Structural design and functional description

The thermal absorber shutter is driven by an LCG cylinder slide with a stroke of 5 mm and the opening time is less than 0.1 s. The water-cooled absorber is made of OFHC, which has a steady-state temperature of 67 ℃ at a power density of 64 W/mm².



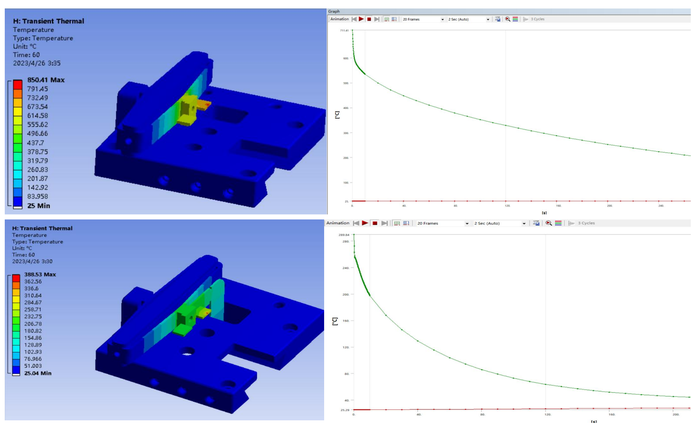
Assembly of thermal absorber shutter and steady-state thermal simulation results based on Ansys

Due to the characteristics of very fast response, compact structure and small stroke, piezoelectric ceramic actuator is very suitable as a driving part of the fast shutter. The material for blocking photons of the piezoelectric ceramic shutter is tungsten alloy. The maximum opening range of the shutter is 1 mm and the response time is less than 1 millisecond. There is a horizontally distance of 15 mm between the monochromatic beam and the pink beam in the SAXS station. Considering this, two through-holes with the same distance are designed on the fast shutter, which ensure that both kinds of beams can pass through.

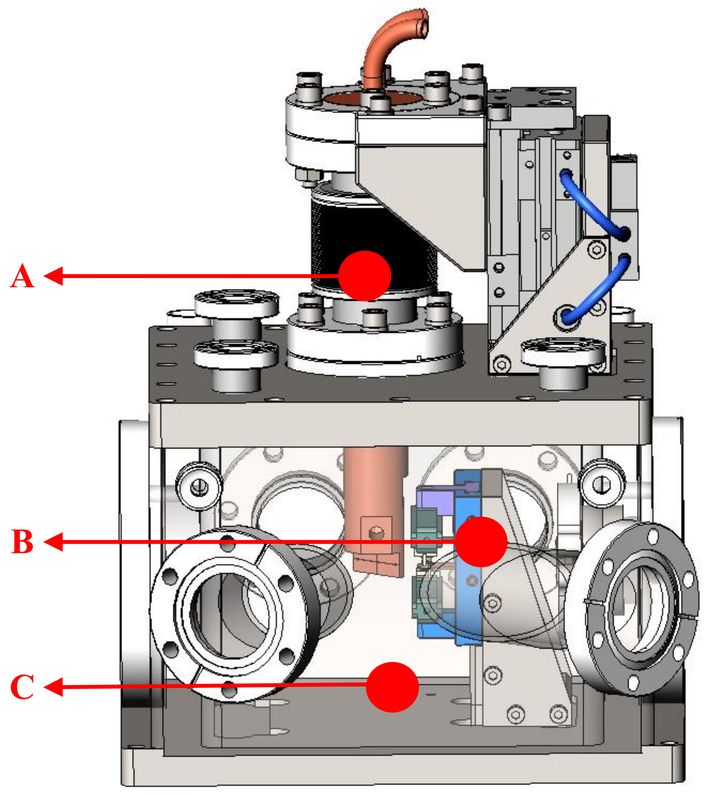


Schematic Design of Piezo Ceramic Fast Shutter

Although most of the heat has been taken away by the upstream absorber shutter, there will still be heat accumulation after a long period of operation in a vacuum environment. This will seriously affect the working life of piezoelectric ceramics. For this reason, we have added a copper braid connected to the tungsten alloy, which can transfer the heat to the environment through the cavity. The simulation results show that the highest temperature, cooling temperature and cooling speed of the shutter with copper braid are far superior to those without that.

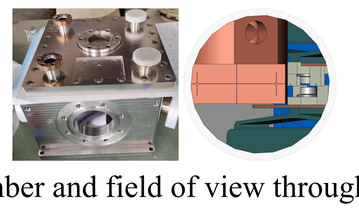


Simulation results of shutter with and without copper braid after heating for 60 s and then naturally cooling



X-Ray Pink Beam Integrated Shutter
A. thermal absorber shutter B. piezoelectric ceramic shutter C. vacuum chamber

After being coated with fluorescent powder, the absorber can be used as a beam monitor. The spot position can be viewed through the reserved observation window. In addition, the cavity can also be compatible with Uniblitz using in Atmosphere.



Welding chamber and field of view through the window

4. Conclusion and contact

The integrated shutter incorporates many functional modules, which means that the corresponding control system and collimation calibration work will be challenging. At present, the machining of shutter parts is in progress, and we will carry out further work on the collimation calibration, motion control and accurate response time test of equipment in the future.

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