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Development of High Power Density Photon Absorber for Super-B Sections in SSRF

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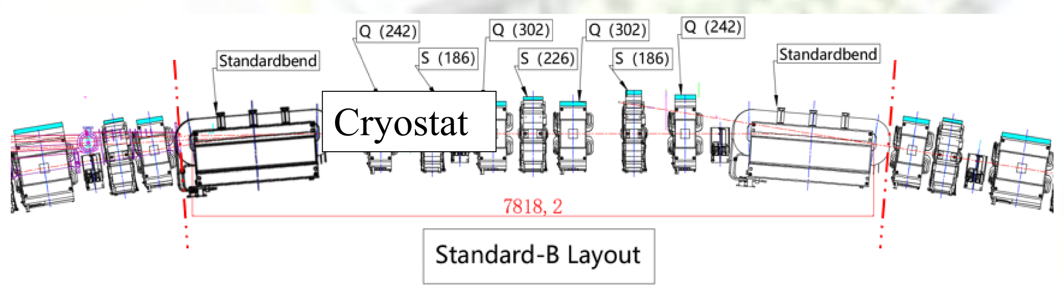
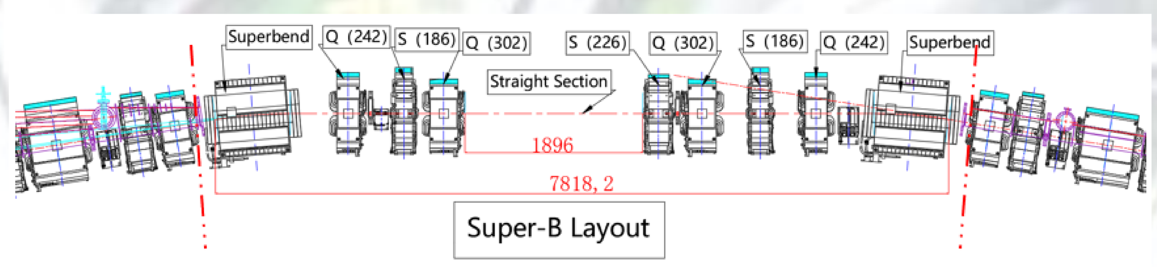
Abstract:

There are two symmetrical standard bend(standard-B) sections been upgraded to super-B sections in the storage of Shanghai Synchrotron Radiation Facility(SSRF). Photon absorbers made up of CuCrZr were used for absorbing radiation with very high power density in the super-B sections. Meanwhile, CuCrZr absorbers were also used as beam chamber and pump port for the lattice of super-B section is very compacted. The absorbing surface was designed as serrate structure in order to diminish the power density. CuCrZr was cold-forged before machining to enhance its strength, thermal conductivity and hardness. Friction welding is adopted for absorber fabrication to avoid material properties deterioration. Rectangle flanges of absorbers were designed as step rather than knifer for vacuum seal. These high power density photon absorbers have been installed on the storage ring, both pressure and temperature being in accordance with design anticipation under the condition of 240 mA beam.

Introduction

The purpose of upgrading stand-B sections to super-B sections is to provide hard X-ray with the energy of 18.7keV for users in SSRF. Moreover, The short straight sections in which insert devices can be installed to provide photon for beamline laboratories were added in super-B sections of which the total length is same with that of stand-B sections. Compare to stand-B, much stronger magnetic field can be generated by super-B, the power of synchrotron radiation being much higher. Furthermore, the majority of synchrotron radiation has to be absorbed in more compact space.



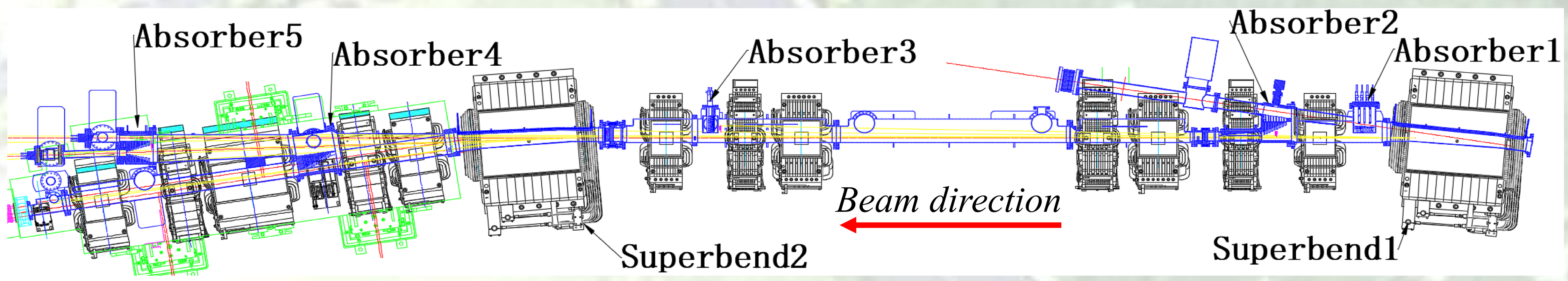


The density of photon power is much higher because of limited absorbing space and much stronger magnetic field. CuCrZr photon absorbers were developed to absorb photon with high power density in super-B sections. Friction welding was adopted to fabricate these absorbers with complex structure.

	Standard-B	Super-B
Arc Length（mm）	1440	832.5
Magnetic Field（T）	1.27	2.29
Gap(mm)	50	30
Bending Angle（°）	9	9
Radiation Power(kW) @300mA	10.9	18.8

Absorbers Distribution and Material

There are just five absorbers distributed in each super-B section and downstream because of very limited available installing space. The lattice of super bend 2 downstream haven't been changed. However, original absorbers have been replaced by two new absorbers (absorber 4 and absorber 5) to absorb high power density photon from super bend 2 as shown followed figure, vacuum chambers also being redesigned.



All absorbers were installed at clearance of each couple of magnets. Ion pumps were installed next to these absorbers to enhance pumping efficiency. The maximum heat flux density on absorber 2 is yet up to 43W/mm^2 @300mA after structure optimization.

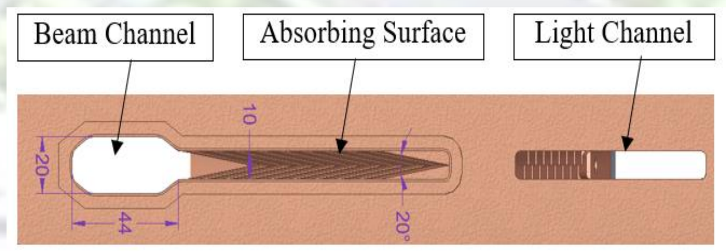
	Absorbing Power（kW）	Max. Power Density（W/mm²）
Absorber1	4.3	16
Absorber 2	11.7	43
Absorber 3	1.1	8
Absorber 4	9.5	34
Absorber 5	5.4	15

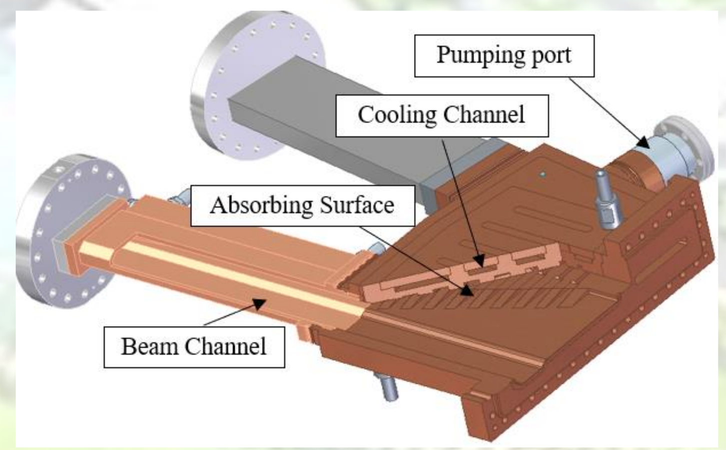
Oxygen free copper(OFHC) can't endure so high heat flux density, while Glidcop inported are very expensive. Domestic CuCrZr was chosen as material for these absorbers finally. Properties of the CuCrZr are improved apparently after cold forging.

	CuCrZr Properties	Before Cold Forging	After Cold Forging
Mechanical Properties	Young's Modulus E（GPa）	85.3	119.0
	Yield Strength $R_{p0.2}$（MPa）	111.6	400.6
	Ultimate Limit R_m（MPa）	239.3	434.7
	Elongation A（%）	48.7	11.6
	Hardness（HBW5/250/30）	61.0	151.7
Thermal Properties	Expansion at 100℃（10^{-6}/K）	15.9	16.6
	Conductivity at 100 ℃（W/(m·K)）	283.5	358.5

Absorbers Structure and Fabrication

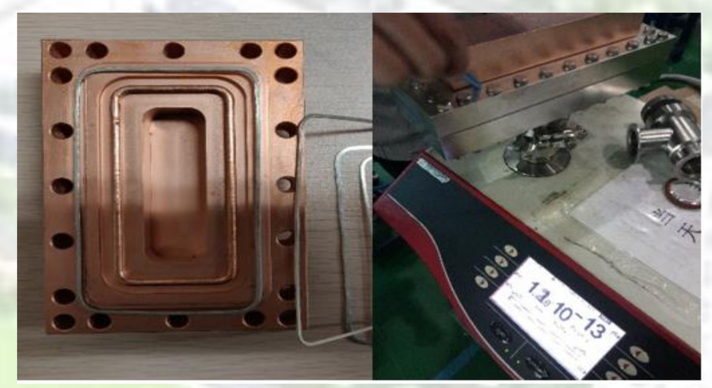
The absorbing face of absorbers were designed as slope with comb shape to dilute heat flux density. The typical structure of absorbers was made up of up-absorbing body and down-absorbing body, both of which having comb shaped absorbing face. Up-body and down-body were assembled by friction-welding, their comb teeth engaging together to complete absorbing face.

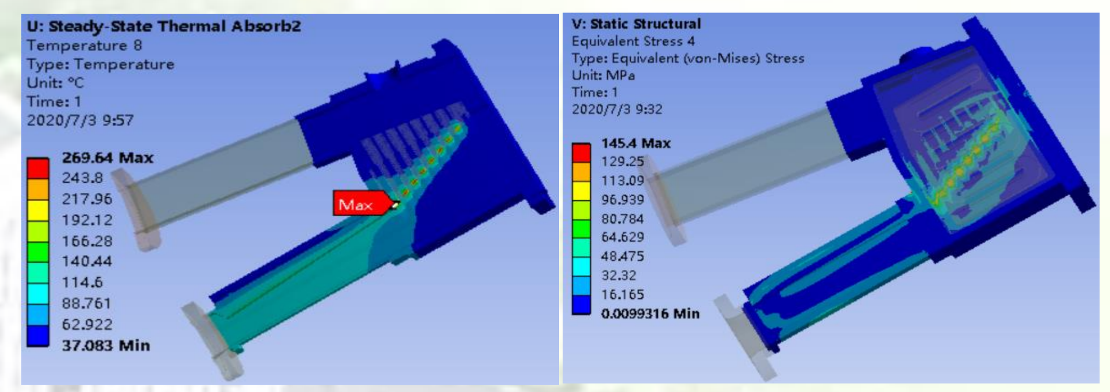




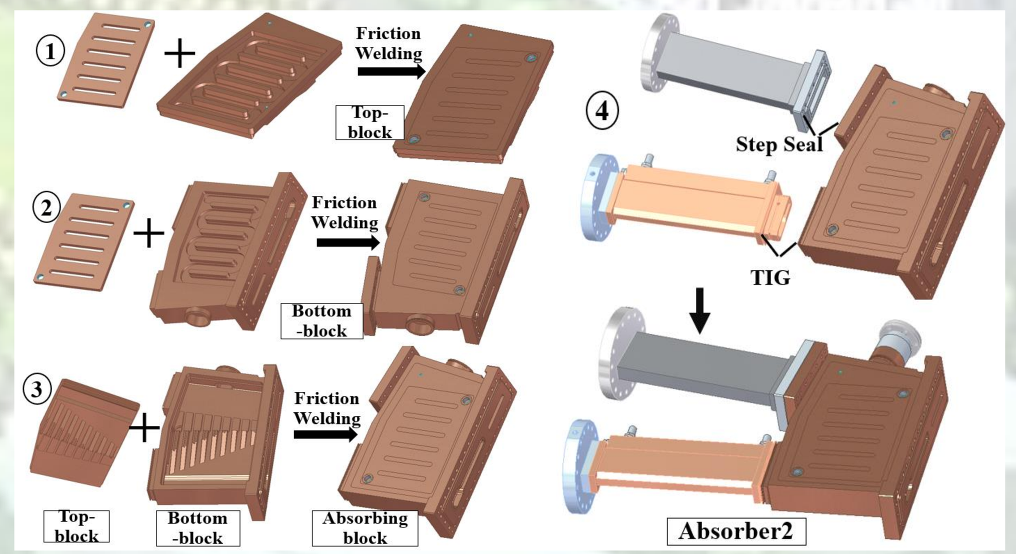
Step flange directly machined on CuCrZr down-body is used for vacuum seal. Flange sample was test for several times before formal fabrication, the result showing this type of flange is suitable for ultra high vacuum seal.

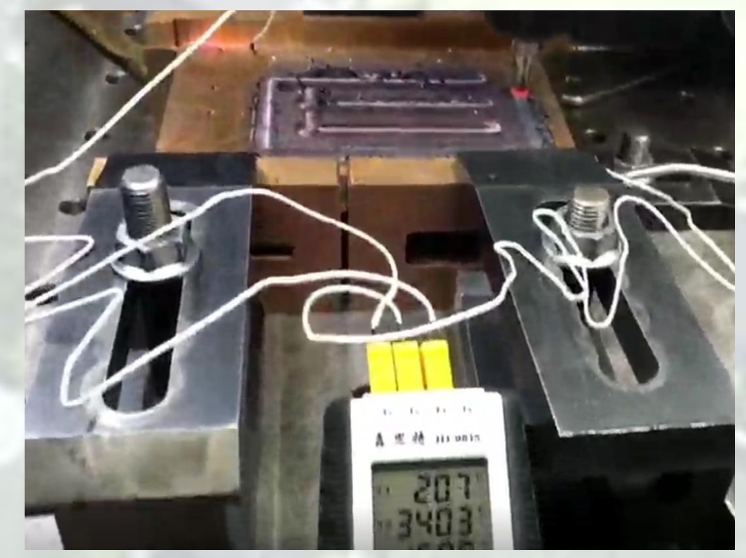
Cooling channels were formed by grooves on the back of absorbing bodies welding with CuCrZr cover plates. The maximum temperature on absorbing face is about 270℃ under the situation of beam of 300mA by simulation .





Several welding process were carried out to complete photon absorber 2 fabrication because of complex structure. Friction welding was mainly adopted for absorbers fabrication to keep the temperature of absorbing face bellow 500 ℃ , avoiding deterioration of material properties.

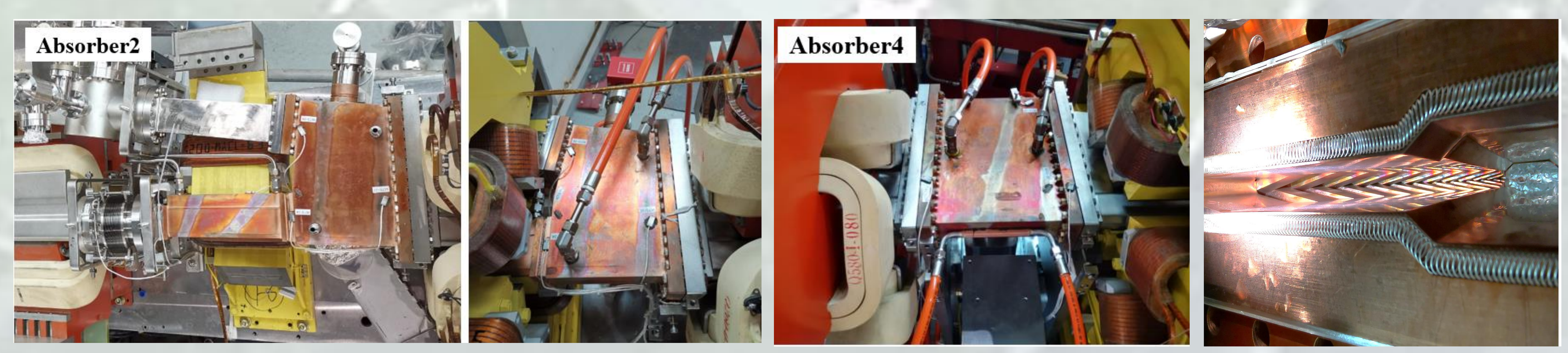


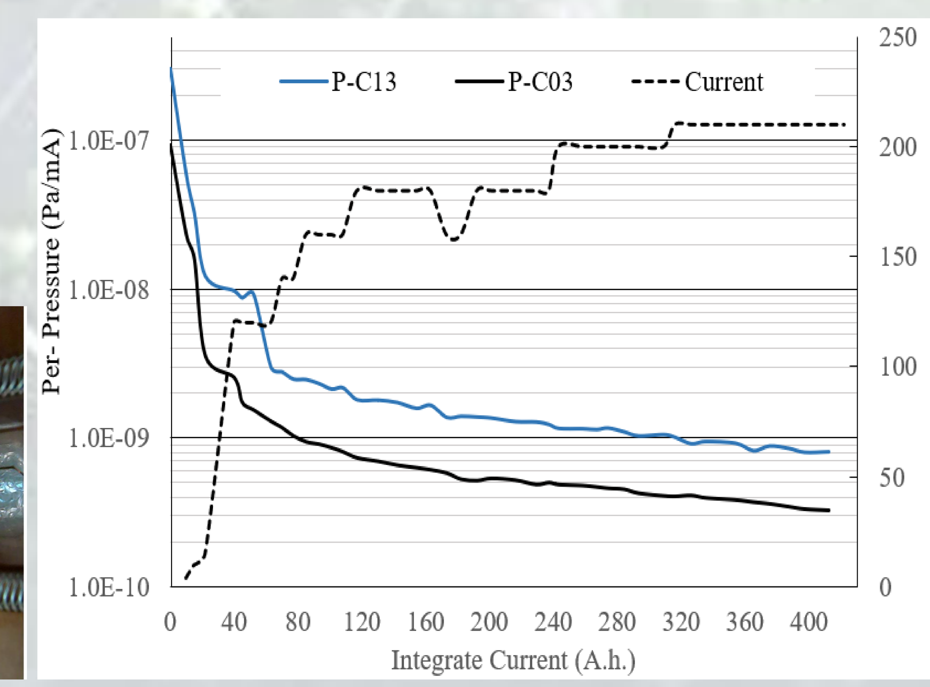


Vacuum Performance

CuCrZr absorbers have been installed on the storage ring in August 2019. Static average pressure of super-B sections was about 3.3×10^{-8}Pa after vacuum baking in site. Dynamic average pressure have reduced from 1×10^{-6}Pa at the beginning of beam operation to 1.5×10^{-7}Pa @260mA after 100A.H of integral current. These CuCrZr absorbers have been on the storage ring for several years, Dynamic average pressure being lower than 6×10^{-8}Pa @200mA now.

The temperature on these CuCrZr absorbers rise proportionally to the beam current. The highest temperature measured on outer surface of absorber 2 is about 80℃ @240mA, which is accordance with the result of simulation. It is concluded that the structure of the face of oblique teeth engaged on CuCrZr body for diluting power density and step flange on the body for vacuum seal is feasible from the result of operation in site for several years.





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