

## Design of Compact Absorbers for High-Heat-Load X-ray Undulator Beamlines at SPring-8

T. Mochizuki,<sup>a\*</sup> Y. Sakurai,<sup>b</sup> D. Shu,<sup>c</sup> T. M. Kuzay<sup>c</sup> and H. Kitamura<sup>b</sup>

<sup>a</sup>The Japan Synchrotron Radiation Research Institute (JASRI), Kamigori-cho, Ako-gun, Hyogo 678-12, Japan, <sup>b</sup>The Institute of Physical and Chemical Research (RIKEN), Kamigori-cho, Ako-gun, Hyogo 678-12, Japan, and <sup>c</sup>Argonne National Laboratory, Advanced Photon Source, Argonne, Illinois 60439, USA. E-mail: mochizut@spring8.or.jp

(Received 3 October 1997; accepted 6 January 1998)

A compact and high-heat-load absorber for the SPring-8 X-ray undulator beamline has been developed and installed. It consists of an upper heat-absorber part and a lower photon duct part, which are configured together in a water-cooled GlidCop body. The absorber part has a horizontal notch shape and the photon duct part forms a rectangular open channel under the absorber part. Two types of absorber are designed: one, with wire mesh channels, is 486 mm long, 70 mm high and 64 mm wide; the other, with smooth-bore channels, is 610 mm long, 75 mm high and 70 mm wide. Thermal and stress analyses show that they withstand the 12.3 kW heat load and the maximum heat flux of  $940 \text{ W mm}^{-2}$  at normal incidence.

**Keywords:** undulator beamlines; front ends; high-heat-load components; absorbers.

### 1. Introduction

The SPring-8 standard undulator produces synchrotron radiation with a total power of 12.3 kW and a peak power density of  $497 \text{ kW mrad}^{-2}$ . The high heat load causes thermal engineering problems of the beamline components. The photon absorber in the front end of the beamline fully intercepts the synchrotron radiation at a distance of 23 m from the source point and receives almost the full power and the maximum heat flux of  $940 \text{ W mm}^{-2}$  at normal incidence. The design of the high-heat-load absorbers is based on the uses of a tilted surface and enhanced heat-transfer coolant channels. The tilted surface is effective in reducing the maximum heat flux but it leads to a large absorber and an increase of scattered X-rays to the downstream components (Munekawa *et al.*, 1992). The surface of the SPring-8 undulator absorber is set at an angle of  $0.88^\circ$  to the beam; therefore, the maximum heat flux is reduced to  $14.4 \text{ W mm}^{-2}$  and the beam footprint length on the surface is about 550 mm.

The SPring-8 undulator absorber consists of an upper horizontal notch-shape synchrotron-radiation-receiving part and a lower square synchrotron-radiation-transporting-channel part, which are formed in a water-cooled GlidCop (SCM metal Products, Inc.) body. The synchrotron-radiation-receiving surfaces block the scattered X-rays from each other to protect the downstream components from the X-rays. Two types of coolant channel were employed. One was a coolant channel filled with copper wire mesh (Kuzay, 1992) with a convective heat-transfer coefficient of  $0.03 \text{ W mm}^{-2} \text{ K}^{-1}$ . The other was a smooth bore channel with  $0.02 \text{ W mm}^{-2} \text{ K}^{-1}$  at a water

velocity of  $5 \text{ m s}^{-1}$ . Adopting both the notch-shape heat absorber and the enhanced heat transfer, the compact absorber, equivalent to the synchrotron radiation footprint length, is realized.

By thermal and stress analysis, as well as by considering the manufacturing processes, the two types of absorber with different coolant channels have been designed, fabricated and installed. At a ring stored current of 17 mA, measurements of the absorber temperatures were carried out. They showed good agreement with the finite-element-method computer-code (ANSYS; Swanson Analysis Systems, Inc., Champaign, Illinois, USA) simulation result.

### 2. Conceptual design

The design of the absorber is subject to the criteria of the SPring-8 front-end components. All water joints and connections must be isolated from UHV with venting to the atmosphere. The absorber will be baked at 473 K. Therefore, its surface exposed to the beam must be kept under the baking temperature of 473 K to avoid vacuum degradation due to outgassing from the heated surface. The absorber, as well as the other front-end components, is set on the common support which consists of two parallel I-shape channels with a space of 240 mm.

Since an ordinary designed absorber, which consists of a heat absorber, an actuator and a vacuum chamber, is too large to be set on the support, a compact absorber unit has been devised. It is an absorber block supported with an actuator unit. The absorber block consists of a horizontal notch-shape synchrotron radiation receiver, a beam-trans-

**Table 1**

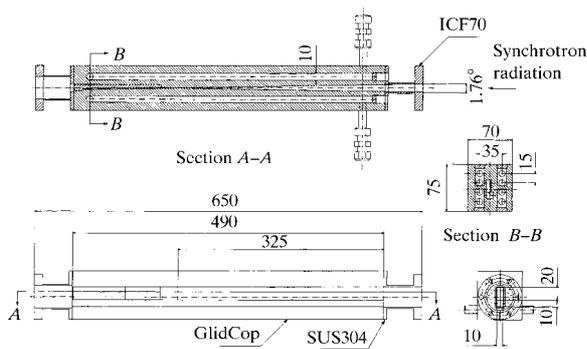
SPring-8 standard undulator (BL47XU) radiation power and power density.

	Design value	In commissioning
Beam energy	8 GeV	8 GeV
Beam current	100 mA	17 mA
Period	3.2 cm	3.2 cm
Number of periods	37	37
$K_{max}$	2.46	2.46
Total power	12.3 kW	2.2 kW
Maximum power density	497 kW mrad <sup>-2</sup>	84.5 kW mrad <sup>-2</sup>
Distance from source	23 m	23 m
Heat flux	940 W mm <sup>-2</sup>	160 W mm <sup>-2</sup>

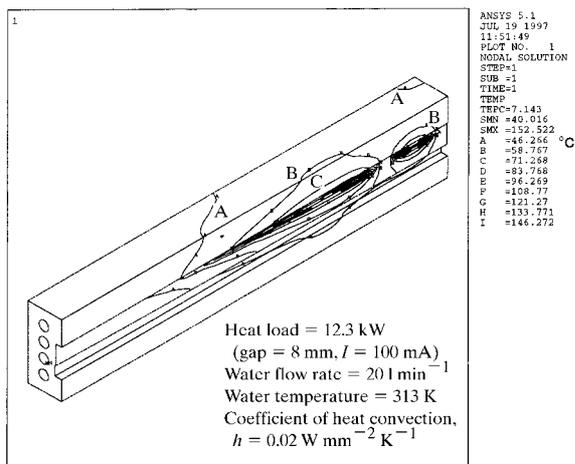
porting channel and water channels. The absorber block moves up vertically with the pneumatic actuator to open the beamline and down to close the beamline. The absorber closes within 2.0 s.

**3. Numerical analysis**

The radiation power of the BL47XU undulator and the heat load on the absorber are shown in Table 1. The angle of the surface to the beam, the heat-transfer coefficient and



**Figure 1** Design of the absorber for the SPring-8 standard undulator beamline (type-B straight-water-channel model).

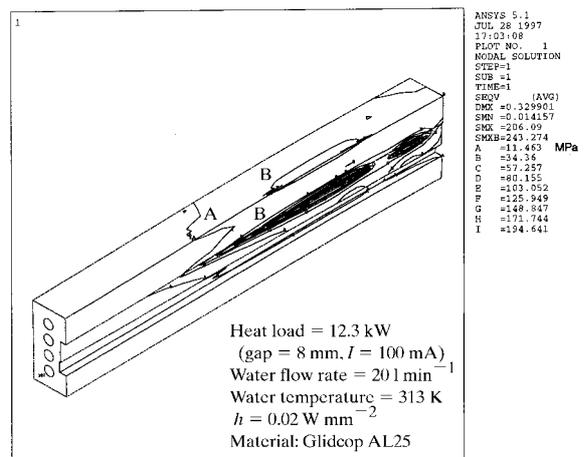


**Figure 2** Result of ANSYS thermal analysis for the type-B GlidCop (AL25) absorber.

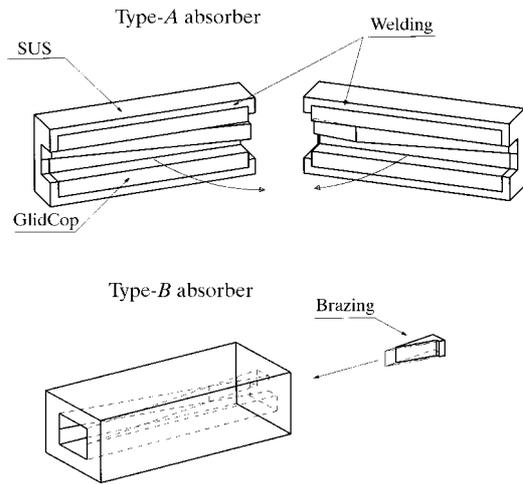
the distance between the surface and the water channels are optimized through the three-dimensional thermal and stress analysis with the ANSYS code. Fig. 2 shows the thermal analysis result at the maximum heat load. The surfaces cut the beam at an angle of 0.88° and are followed by 10 mm-diameter straight channels containing 313 K water for cooling by forced convection, as shown in Fig. 1. For a convective heat-transfer coefficient of 0.02 W mm<sup>-2</sup> K<sup>-1</sup>, the maximum value is 426 K, which satisfies the design criterion of the UHV surface temperature (473 K). Fig. 3 shows the thermal stress analysis results. It shows that the maximum Mises stress is 206 MPa, which is 100 MPa lower than the yield stress of GlidCop. The other model with 8 mm-diameter wire-mesh-brazed water channels shows that the maximum temperature is 442 K and the maximum Mises stress of the GlidCop body is 240 MPa. These two models are sufficient for use in standard undulator beamlines.

**4. Fabrication**

The fabrication procedures of the notch-shape synchrotron radiation receiver and a synchrotron-radiation-transporting channel are shown in Fig. 4. The type-A absorber with wire-mesh water channels is made of two halves. A notch-shape surface and a synchrotron-radiation-transporting channel are machined on each half and the two halves are welded together. The type-B absorber has smooth-bore water channels. The synchrotron-radiation-receiving surfaces and synchrotron-radiation-transporting channel are formed in one GlidCop block by a wire-cutting process. The downstream notch-shape opening is blazed with a solid notch and blocked up. Since the distances between the outer surfaces of the body and the centreline of the synchrotron radiation receiver or the transporting channel are precisely determined, the accurate position of the centreline can be marked on the outer surfaces of the



**Figure 3** Result of ANSYS thermal stress analysis for the type-B GlidCop (AL25) absorber.

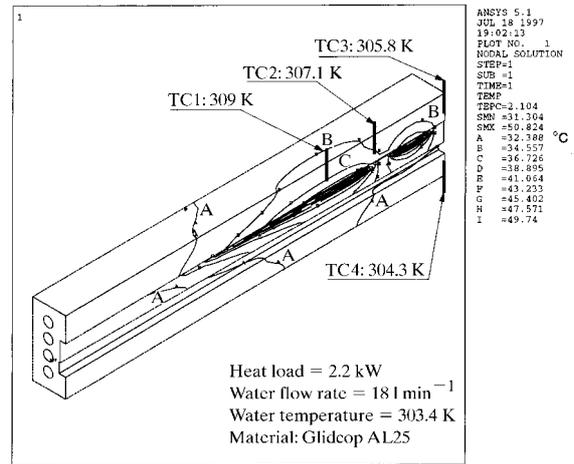


**Figure 4**  
Conceptual design for the manufacturing of a notch opening and beam-transfer channel.

body. The marks simplify the accurate alignment of the absorber.

## 5. Discussion

Two types of absorbers were set on the beamline front ends. Four type-*A* and four type-*B* absorbers are installed in the SPring-8 undulator beamlines. At the commissioning of the beamlines, the temperature measurement of the absorber type-*B* was carried out in the BL47XU beamline at a ring stored current of 17 mA. The total heat load was 2.2 kW and the maximum power density was  $84.5 \text{ kW mrad}^{-2}$ . Fig. 5 shows a comparison between the measurement and a numerical simulation. The temperature of thermocouple No. 1 (TC1) is 309 K and that of the simulation result is 310.6 K. Considering the uncertainty of the coefficient of



**Figure 5**  
Simulation results of ANSYS for the BL47XU absorber at the commissioning.

heat transfer, the position error of the thermocouples, and the measurement error of the temperature, it is concluded that the measurement agrees with the simulation.

Another three type-*B* absorbers and four type-*A* absorbers will be commissioned in Autumn 1997 at 20 mA and in 1998 at 100 mA. The temperature of all undulator absorbers, the water temperature and the water flow rate will be measured and recorded. The verification of the absorber thermal design will be carried out during the commissioning.

## References

- Kuzay, T. M. (1992). *Rev. Sci. Instrum.* **63**, 468–472.
- Munekawa, S., Sakurai, Y., Tong, X. M. & Nagasawa, H. (1992). *Rev. Sci. Instrum.* **63**, 376–379.