Performance of the JEBIS for Heat Load Test on SR Optical Elements

Shinya HASHIMOTO[1] and Haruhiko MOTOHASHI[2]

1) Japan Synchrotron Radiation Research Institute, Kamigori, Ako-gun, Hyogo 678-12, Japan
2) SPring-8, Kamigori, Ako-gun, Hyogo 678-12, Japan

1. Introduction

First optical elements on the beamlines of undulators or wigglers will suffer heat loads of high power synchrotron radiation (SR). Water cooling method will be the most ordinary cooling method. The cooling efficiency largely depends on the geometrical structure of water-guide, but heat transfer coefficients precise enough to design a cooling system with would not easily be obtained from theoretical calculations. A modification of the water-guide structure might cause an unexpected drastic change in the mode of water flow, and big errors will accompany the calculation of heat transfer coefficient.

The Japan Atomic Energy Research Institute has an electron beam facility dedicated to the research and development of the high heat flux components for fusion experimental reactors, which is called 'JAERI Electron Beam Irradiation Stand (JEBIS)'. It is well equipped for measuring temperature-rises of the components and cooling water during the electron irradiation in a real time fashion.

We made a performance test of the JEBIS on water-cooled heat heads simulating the SR optical elements (supposed to be monochromators).

2. Features of the JEBIS and its operation conditions

Fig. 1 shows a vertical cross-section of the JEBIS. Major features are as follows;

1) A new plasma electron gun can be operated at 100 keV and 4 A at maximum.
2) The SR photon power can be simulated with a heat flux of less than 2 kW/mm^2 and a pulse width of more than 1 msec.
3) Various beam profiles can be produced without a beam sweeping, that is, from a pencil beam with a FWHM of ϕ9 mm to a sheet-like beam with FWHMs of 100mm× 200mm.
4) A large area of 300mm×600mm is irradiated with a beam sweeping.
5) High speed beam switching is possible within ~200 μsec by using high frequency invertors.
6) There are two kinds of water pumps of flow rates above and below 15 l/min, which are at present tubed to the test beds #1 and #3, respectively.

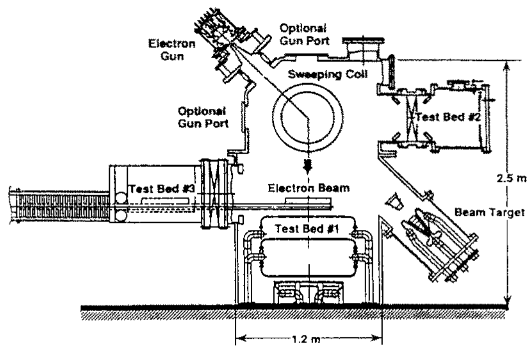

Fig. 1 JAERI electron beam irradiation stand.

3. Performance Test with Cu Heat Heads Simulating Water-Cooled Monochromators

3-1. Preparation of heat heads

We adopted three kinds of copper test heads to simulate the SR irradiation on the optical elements;

a) Coarse fin structure with hemicylindrical water path:Fin thickness=1mm, maximum fin length=9.5 mm, fin-fin gap=1mm.
b) Fine fin structure with straight water path:Fin thickness=0.4mm, fin length=7mm, fin-fin gap=0.4 mm.
c) Fine pipe structure : Pipe diameter =1.5mm, inter-pipe distances (x=1.8mm, y=1.6mm:four layered)].

The cooling manifold, on which the test heads were mounted, was commonly used and has a basic structure as shown in Fig. 2. Beam mask had a circular aperture of ϕ20 mm. The area to be irradiated was over ϕ30 mm. The heat heads had a thermocouple soldered with silver at the center to precisely measure the temperature-rise of the head surface. An IR camera was monitoring the sample position, but it was not able to be used, because the mask aperture was too small.

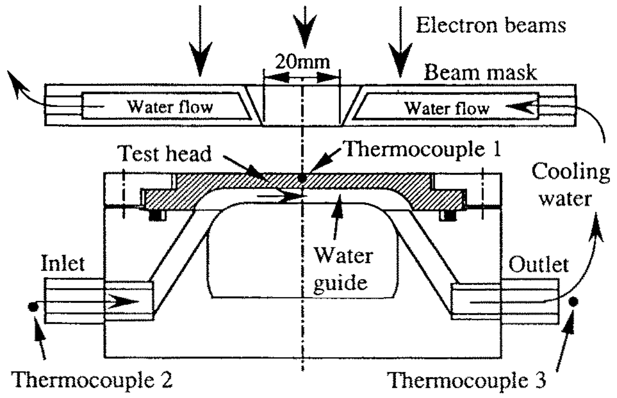

Fig. 2 Basic structure of the cooling manifold adopted.

3-2. Operating conditions of JEBIS

The JEBIS was operated at 35 keV accelerating voltage and about 1A arc current. The voltage was determined so as to give a uniform beam flux. The power density was controlled with changing the arc current in plasma. The power of the electrons effectively absorbed in the heat head was monitored with a calorimeter as shown in Fig. 3. Fig. 4 shows a calibration curve of the power vs. the applied arc current.

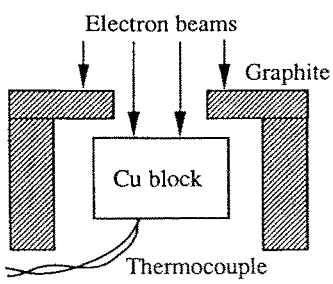

Fig. 3 Calorimeter

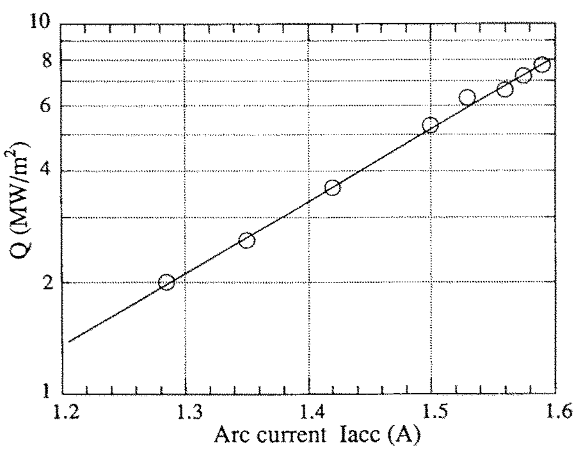

Fig. 4 Calibration curve for Q vs. Iacc.

3-3. Records of temperature data

The temperature data were acquired and recorded on a floppy disk, which can be plotted as in Fig. 5. It is an example of 3sec exposure to the electrons. The data for the arc current and the temperatures of other sampling points are also included. A, B and C in the figure indicate the temperatures of the head center, outlet water, and the arc current, respectively. The present test heads were heated as shown in Fig. 6 depending on the effective electron power density.

3-4. ANSYS calculation for heat transfer coefficient

We simulated the experimental heating processes (Fig. 6) with ANSYS. We obtained heat transfer coefficients of a)35, b)8.5 and c)14 kW/(m^2 K) for the three geometries, respectively. On the other hand, their theoretical (phenomenological) values are 20 (straight path), 14 and 20 kW/(m^2 K), respectively.

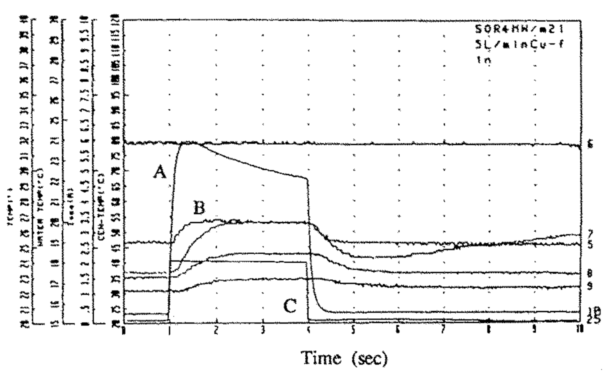

Fig. 5 Temperature changes after the irradiation.

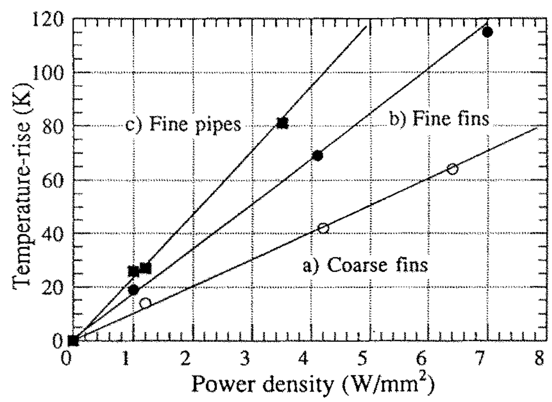

Fig. 6 Power density dependence of the temperature-rises of the test heads.

4. Conclusion

We found that the JEBIS was well established for high heat load tests and that it can be ideally applied to the R&D of the optical elements in the third generation SR facilities.