Attenuator Design at TPS and SPring-8 12B2

Attenuators are commonly used to decrease the power of a light source and prevent damage to detector sensors and other optical components. For different beamlines and attenuation requirements, the primary challenge in this work is designing the **TPS 31A** attenuator.

The **TPS 31A** insertion device is a wiggler, and the white-beam size is 25 mm × 50 mm. The radiated power in white-beam operation mode is 1000 W, necessitating the use of an attenuator to absorb excess beam power. The **TPS 31A** attenuator is equipped with 12 foil carriers. The clear aperture is 46 mm × 56 mm, accommodating the beam in different operation modes. The system vacuum level reaches 1×10^{-7} mbar, and the cooling capacity exceeds 1000 W.

To address the thermal dissipation issue, this project employs a magnetic-coupling-type attenuator system with foil-carrier cooling through the side chamber walls, without introducing water feedthroughs into the vacuum chamber. In double-crystal monochromator (DCM) and double multilayer monochromator (DMM) modes, the **TPS 31A** beam's vertical position shifts. The foil window of the attenuator is therefore designed to be 56 mm (H) × 46 mm (V), allowing all operation modes (DCM, DMM, and white-beam mode) to pass through the attenuator. The foil carrier design is shown in **Fig. 1**.

The ball-bearing slide assembly uses six ball bearings, each lubricated with a fluoropolymer coating. With this configuration, the system can achieve a vacuum pressure of 1×10^{-7} mbar. If required, the ball bearings can be replaced with high-vacuum types, enabling the attenuator system to reach a pressure of 1×10^{-12} mbar. The pneumatic actuator provides 100 mm of travel and moves the outer chamber to position the magnet, thereby driving the foil carrier inside the vacuum chamber. The magnetic drive consists of two neodymium magnets. The frame and foil clamp are fabricated from 6061 aluminum alloy.

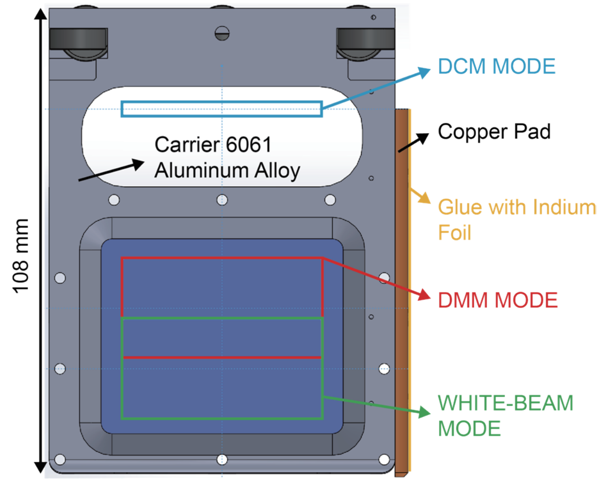

Fig. 1: Diagram of the foil carrier and beam footprint of the foil carrier in different operation modes: (1) DCM mode, (2) DMM mode, and (3) white-beam mode.

Increasing the absorption foil size helps reduce the maximum temperature in the foil and increases the contact area between the foil and the foil carrier. A copper contact pad interfaces the foil carrier with the cooling wall. The contact pad area is 87 mm × 23 mm, and this large contact area enhances heat transfer to the cooling wall. The thermal transfer path is from the foil to the carrier frame, then to the copper pad, glue, indium foil, vacuum chamber wall, and finally to the water-cooling plate.

TPS 31A is one of the most powerful projection X-ray microscope beamlines in the world. The high photon flux makes heat management a critical issue. In this work, a previous magnetic-coupling-type attenuator design, which lacked an integrated cooling system,[1–3] is improved by incorporating an efficient thermal path from the absorption foil to a water-cooled pad outside the vacuum chamber. As a result, the attenuator system remains compact, while the large absorption foil and foil carrier dimensions reduce both the thermal load density and the maximum system temperature. The **TPS 31A** attenuator system installed on the beamline is shown in **Fig. 2**.

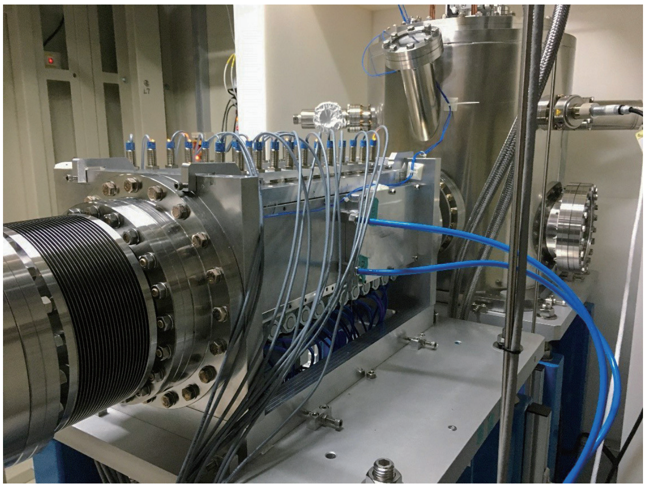

Fig. 2: Attenuator system installed on the **TPS 31A** beamline.

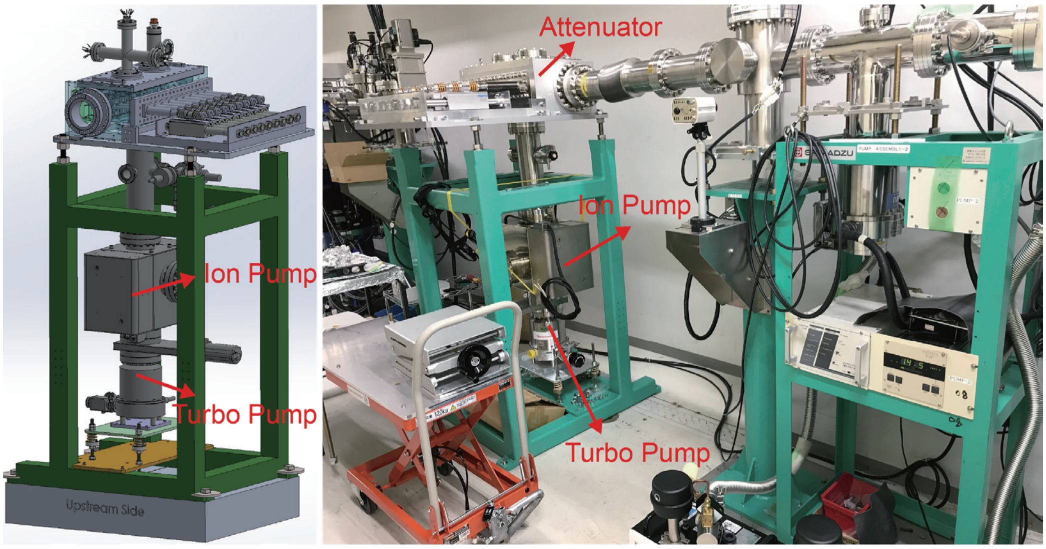

Fig. 3: The attenuator system installed in the SPring-8-II **BL12B2** beamline.

The light source for the **BL12B2** beamline at SPring-8-II is a bending magnet. This beamline enables X-ray absorption spectroscopy, high-resolution X-ray scattering, protein crystallography, and micro-beam scattering experiments. For the planned upgrade of **BL12B2**, an attenuator with nine filters has been designed. The filters are cooled through the chamber wall.

Each filter carrier is designed to absorb up to 100 W while keeping the maximum carrier temperature below 75 °C when the chamber wall temperature is 25 °C. The attenuator also functions as a pumping station and includes a 6-inch port that accommodates both an ion pump and a turbomolecular pump. The attenuator filters are driven by a pneumatic actuator, which positions each filter either in the beam path or in a cooling position. This attenuator was installed on the **BL12B2** beamline at SPring-8-II in April 2025.

The attenuator body is fabricated from 6061 aluminum alloy, which provides high thermal conductivity. The filter carriers are also made from 6061 aluminum alloy. When the filter foil absorbs energy from the light source, the filter carrier effectively dissipates heat and limits the temperature rise. The carrier clamps the foil and conducts heat to a copper pad, while the aluminum chamber wall provides additional cooling. On the outside of the chamber, a mini-channel fin water-cooling plate is attached. This plate incorporates rectangular mini-channels with a width of approximately 240 μm.

At a flow rate of 3.7 L/min (1 gallon/min), the pressure drop across the mini-channel plate is 5.998 kPa. Cooling water circulates through the plate, which is bolted to the chamber wall to improve heat dissipation. At the bottom of the attenuator, a 6 inch ConFlat flange is installed, providing the interface for both the ion pump and the turbo-molecular pump to maintain the beamline vacuum level. The overall attenuator system layout for **BL12B2** is shown in **Fig. 3**. (Reported by Ming-Ying Hsu)

References

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