IMPROVEMENT OF A FOUR-BLADE SLIT FOR SPRING-8 X-RAY BEAMLINE

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Abstract

We improved a slit for x-ray undulator beamline of SPring-8. For the improved slit, one blade is driven through two bellows mounted on the opposite sides of the chamber. Linking rods of the bellows are firmly connected each other and the atmospheric-pressure loads on the feedthroughs are cancelled. Thus, mechanical deformation on the translation stage and linking mechanism can be reduced and smooth motion of the blade can be achieved.

1. Introduction

Optics and transport channel of the SPring-8 x-ray beamline is composed of several high-vacuum compatible parts such as a double-crystal monochromator, mirror support, downstream shutter, four-blade slit, screen monitor, and beryllium window [1]. The four-blade slit is used to define the beam shape, to reduce scattered x-rays from upstream optics, and to confirm the beam position.

An existing standard four-blade slit of the SPring-8 has four translation stages outside a vacuum chamber and linear motion for each blade is driven into the chamber through bellows. Based on this basic configuration, several vacuum-component manufacturers produced similar slits. They however have some problems:

(i) Displacement of the slit blade occurs by evacuation. It is due to the atmospheric-pressure load on the feedthrough, resulting in a mechanical deformation of the stage and feedthrough.
(ii) Smooth motion of the blade cannot be achieved due to the deformation of the stage.
(iii) Some version of the slits uses a ball screw to achieve a smooth motion. A shaft of the feedthrough is pulled into the vacuum chamber by atmospheric-pressure load with the rotation of the stepping motor, when electric power fails for the motor. In this case, we may lose the present position of the blade.

In this report, we will show that a simple improvement solves the problems. Performance of the prototype will be presented on the positioning accuracy and reproducibility as well as basic design.

2. Specification of standard slit for x-ray undulator beamline

A four-blade slit was designed as a part of standard components [1]. For high-vacuum compatibility, a linear feedthrough with bellows is used and linear motion by translation stage is transmitted to the slit blade inside the vacuum chamber. For a typical slit, a 5-phase stepping motor with 0.36 degrees/step is used. A 1-mm-lead screw is directly revolved by the motor. Thus, positioning of 1 μm/step can be performed. Table 1 shows specifications of a four-blade slit for x-ray undulator beamline and figure 1 shows a configuration of the existing slit.

Table 1: Specifications of standard 4-blade slit for undulator beamline

Positioning step	*1 µm/step*
Stroke	*-5 ~ 5 mm*
Ta blade thickness	*5 mm*
Pressure	*<10^{-4} Pa*
Flange for beam axis	*ICF70*
Flange-flange distance	*280 mm*

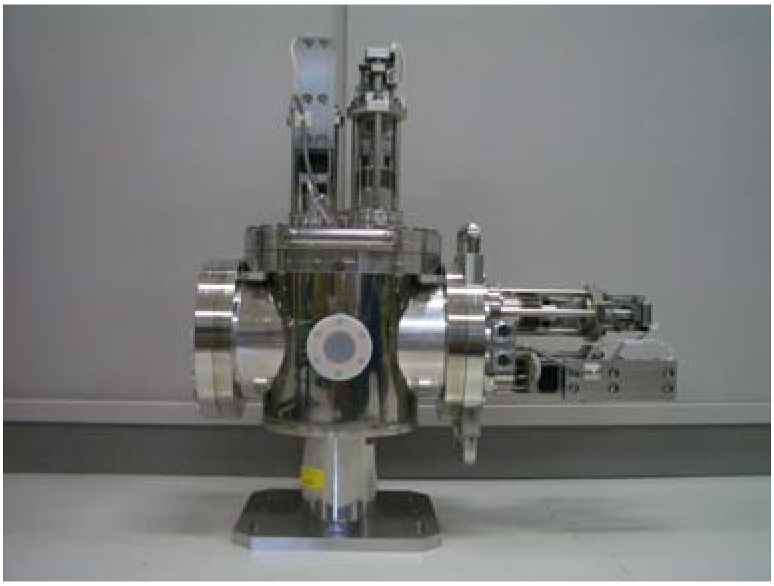


Figure 1: An existing four-blade slit for x-ray undulator beamline.

3. Improvement of the slit

Figure 2 shows prototype of improved slits. In the preliminary design phase, a vertical slit and a horizontal slit were designed individually. We adopted a double-bellows arrangement for the improved slit to avoid the mechanical deformation by atmospheric-pressure load on the feedthrough, and to achieve a smooth motion of the slit blade. In this arrangement, one blade is driven through two bellows mounted on the opposite sides of the vacuum chamber. Linking rods of the bellows (12-mm-diameter stainless steel) are firmly connected each other and the atmospheric-pressure loads of 20 N on the bellows are cancelled. Thus, mechanical deformation on the translation stage and linking mechanism can be reduced and smooth motion of the blade can be achieved. To realize a high-precision positioning, we used a commercially available translation stages (KOHZU Precision, XA07F [2]), which has a 10-nm-positioning capability [3].

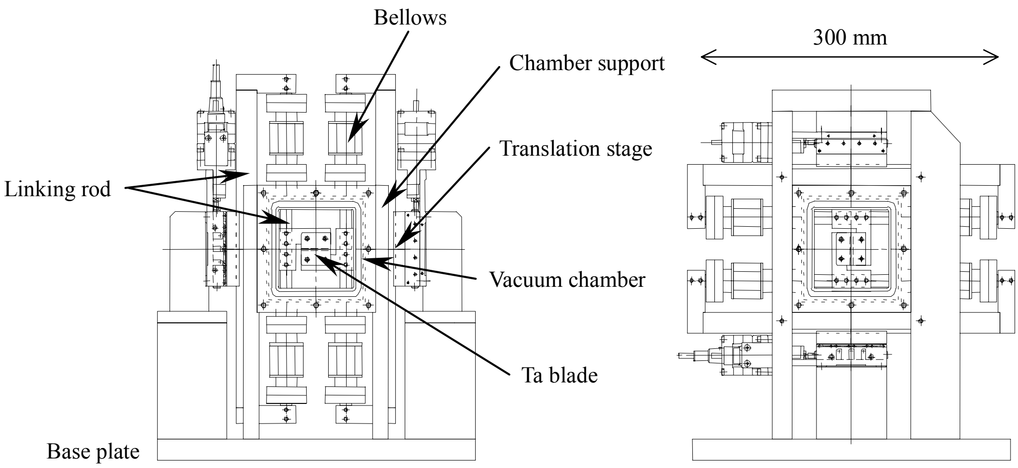
We evaluated the performances on positioning accuracy, reproducibility, and displacement by evacuation using a laser interferometer (Tokyo Seimitsu, DISTAX [4]) and a laser displacement meters (Keyence, LC-2400 [5]). Reproducibility and backlash were measured by 10-times repetition of motion in the full-stroke range. Table 2 shows the results of the reproducibility, backlash, and displacement by evacuation. Improvement of performances is clearly shown in the results. For improved slit, they agree with the catalogue specifications of the stage [2], keeping the performances by the double-bellows arrangement. Figure 3 shows linearity and positioning accuracy of the improved slit. Positioning accuracy of 1 μm (1σ) is obtained from full-stroke measurement using the laser interferometer (Fig 4 (a)). Fine step positioning was evaluated using the same interferometer and order of 10 nm can be achieved by 1/160 of full-step of the stepping motor (Fig 4 (b)). This is quite similar to the result reported by Suzuki et al. [3].

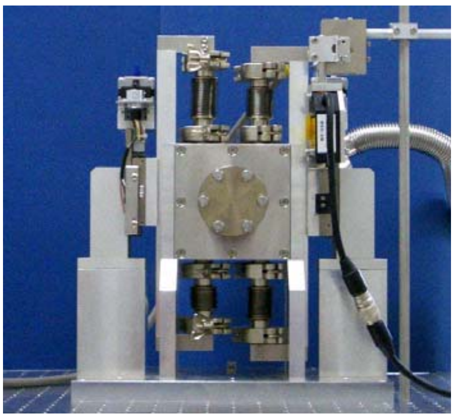
We adopted the out-of-plane arrangement of the slit blades to avoid the crunching of the blades for the existing slit. We investigated the in-plane arrangement of the slit blades to reduce a beam blurring and to improve an elimination of the scattered x-rays by facing slit blades. Figure 4 shows a no-blade-crunching circuit for the stepping motor controller. The stepping motor stops when:

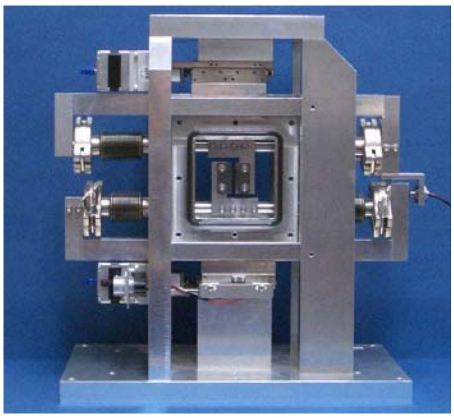
- running the proximity switch which detects the minimum opening of the blades,
- running the CW/CCW limit switch of the stage,
- power failure for proximity switch controller and relay,
- disconnection of proximity switch,

to avoid crunching the blades. The proximity switch with a 0.4-μm resolution (Keyence EX-V110, [5]) enables us to close the slit opening down to 1 μm or less.

We are monitoring the performances of the slit at the end of the optics hutch of 1-km beamline 29XU (Fig. 5).





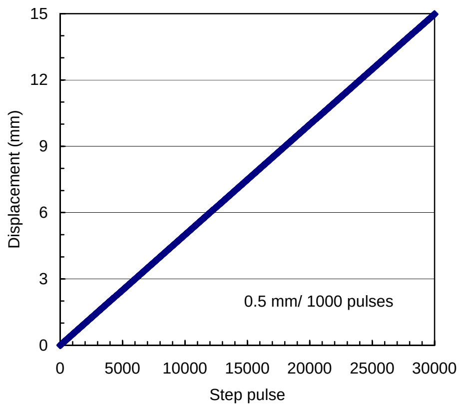


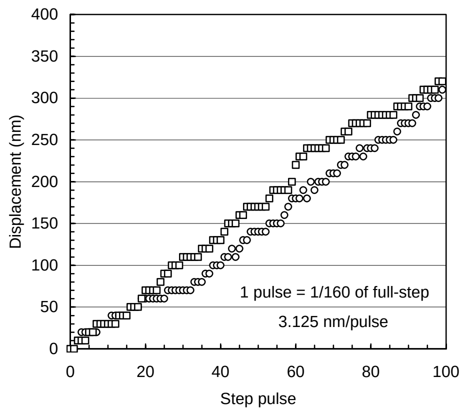
(a) Vertical slit (b) Horizontal slit

Figure 2. Prototype of improved slits

Table 2: Performances of the slits

	Existing slit	*Improved slit*
Reproducibility (1σ)	*3 μm*	*1 μm*
Backlash	*3 μm*	*0.5 μm*
Displacement by evacuation	*>50 μm*	*0.5 μm*





(a) *(b)*

Figure 3: Performance of the improved slit. (a) Positioning accuracy of 1 μm (1σ) is obtained from full-stroke measurement using a laser interferometer. (b) Fine step positioning of order of 10 nm can be achieved by 1/160 of full-step of the stepping motor. The results of different two positions are shown.

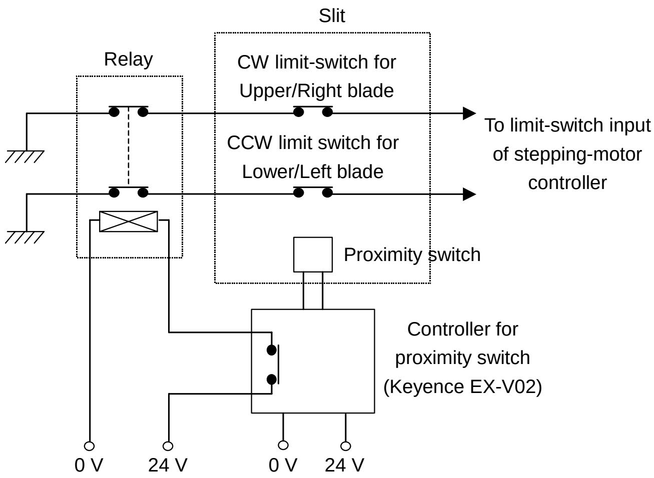


Figure 4: No-blade-crunching circuit for the stepping motor controller.

Figure 5: Prototype installed at the optics hutch of the 1-km beamline 29XU.

4. Concluding remarks

We improved the slit with the double-bellows arrangement to cancel the atmospheric-pressure loads. Prototype with this arrangement showed good capabilities on the positioning accuracy, reproducibility, and rigidity to the atmospheric-pressure load without losing the initial performances of the high-precision translation stage.

We are designing a final four-blade slit by combining the newly developed vertical and horizontal slits. The final one will be compatible with the existing slit and easily be replaced at the beamlines.

5. References

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