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THE PRECISION ADJUSTMENT HOLDER FOR MONTEL MIRRORS

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Abstract

The focusing of X-ray nanoprobeat Taiwan Photon Source (TPS) relay upon the special designed Montel mirrors and its adjustment holder, which significantly shorten the length of beamline to 75 meters. Moreover, the focal spot size and working distance are expected to be 40 nm and 55 mm, respectively. To achieve this, the precision adjustment holder was designed and made to align Montel mirrors. The holder includes two major parts: (1) fundamental-position alignment part and (2) relative-position adjustment part.

The fundamental-position alignment part has the ability to adjust the two mirrors together in six degree of freedoms, such as X, Y, Z, pitch, roll, and yaw. These translation stages have several-tens mm travel range and nm resolution, while the rotational stages have around 40 mrad azimuthal angular range and 0.1~0.01 µrad resolution.

The relative-position adjustment part can further adjust the two mirrors to minimize the focal spot. During the pre-alignment process, one of the mirrors can be manual adjusted by micrometer heads (Mitutoyo®) in three translation directions with several mm travel range and micrometers resolution. These micrometer heads also provide this mirror three rotational degree of freedoms with sub-mrad resolution. For the further alignment in vacuum chamber, the additional four piezo-motor (PiezoMotors®) actuators can precisely adjust the other Montel mirror in the Y and Z direction with several nm resolution, and its pitch and roll with 1 urad and 0.05 urad resolution, respectively.

The precision adjustment holder will be installed in TPS-23A endstation and start commission before the end of this year.

MONTEL MIRRORS FOR HARD X-RAY FOCUSING

The Montel mirrors were adopted to focus the hard x-ray down to hundreds even tens of nano-meters in synchrotron beamlines[1-4]. There many nano-focusing optics, such as K-B mirror, Zone Plate, refractive lens, and Montel KB mirror. Different optics have different focusing ability.

According to the study done by Gene E Ice et. al [1], The numerical aperture is limited by the critical angles of the mirrors. Besides, the numerical aperture can be enlarged if more reflections are accompanied for focusing. Therefore, it is very clear that the numerical aperture is enlarged by factor of root 2 theoretically, because the Montel mirrors consists two reflections from identical two plane-ellipse mirrors close to each other. The focus principle is to hit one side of the mirror than the other side.

The Montel KB mirror has better chromatic dependence, higher flux and longer working distance. For the application in TPS-23A, we adapt the Montel mirror as the nano-focusing optics, which gives a larger numerical aperture as well as higher flux than conventional K-Bs.

TPS-23A BEAMLINE

There are two horizontal focusing mirrors and one horizontal DCM in the beamline. In order to preserve the coherent in vertical direction, there no other focusing optics before montel KB mirrors, and it is windowless. Finally, we use montel KB mirror to focus the beam down to 40 nm, and the photon flux can be larger than ten to the power of 10. The length of this beam line is less than 70 m. In order to fully use the symmetrical manner of the Montel mirrors, the horizontal optics is more complicated. The HFM1 focuses the horizontal beam at slits3 and he HFM2 defocuses and pull back the source back to the center of the undulator. With this plan, the source becomes a symmetrical source. The sketch of TPS-23A is shown in Fig. 1.

According to the ray tracing simulation results, if the beam energy is 10 keV and average reflection coefficient is 0.83, the source is 65m up stream to the mirrors, the source size is 12.5 µm x 12.5µm, and the source divergence is 6µrad x 6µrad, we can found that the final spot size is around 40 nm and the divergence is 6.29 mrad. The flux is estimated to be 2x1010 Photon/second.

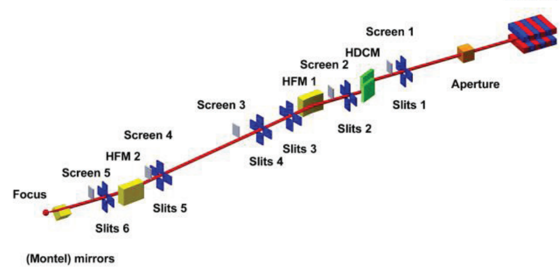

Figure 1: The beamline sketch of TPS-23A.

MONTEL MIRRORS OF TPS-23A

The specification of Montel mirrors adopted in TPS-23A is described as following. The length of the mirror is 110 mm, and the working distance is 55 mm. The very high demand on the slope error is 0.05 µrad, which is the best quality that can be made which is limited by the

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minimum radius of the mirror, which is 20 meter. The material of mirror is silica and coated with rhodium.

The Montel mirrors are placed on the top of mirror holder, as shown in Fig. 2. With the precise alignment of two mirrors, the focal spot size can down to 40 nm. At the same time, the working distance is around 55 mm, which provides the more space and probability to assemble variable detectors, probes and instruments into the endstation.

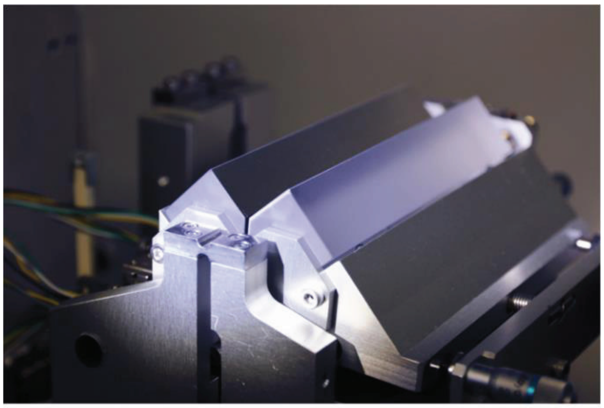

Figure 2: The Montel mirrors of TPS-23A.

TPS-23A ENDSTATION

TPS at NSRRC is already successful for the test operation at the end of 2014. So, at this time our goal is to construct the phase I beamline of TPS. There are seven beamlines in the phase I. And the Nanoprobe project is one of them. This nanoprobe beamline will be delivered at the end of 2016. Due to the cite condition, some part of the TPS storage ring is constructed underground, therefore the length of the beamline is limited. The longest beamline is actually only 75 meters. It is a big challenge to build a modern x-ray nanoprobe beamline with only 75 meters. Therefore, we need a special focusing device, that is Montel mirros.

The X-ray nanoprobe (TPS-23A) is designed to use TPS light source to resolve the atomic, chemical and electronic structures of the semiconductor-based nanodevices in tomographic and nondestructive manners. The Montel KB mirror is adopted to focus the beam down to 40 nm.

Then the end station can provide x-ray probes of imaging, spectroscopy and diffraction, and coherent way. In addition, the station will equipped with SEM, photoluminescense and a stream camera to perform the time-resolved measurement. The sample environment of this beamline is : the sample is in vacuum, and we have a load lock system, the sample can be heat up or cool down, measure some electrical property in our main chamber or preparation chamber. The sketch of TPS-23A endstation is shown in Fig. 3.

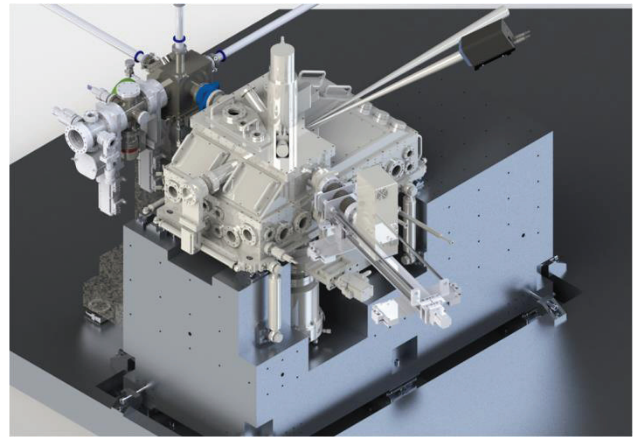

Figure 3: The Sketch of TPS-23A Endstation.

PRECISION ADJUSTMENT MIRROR HOLDER

The idea of Montel nested mirrors has been tested at APS, and a focal spot of 150 nm has been achieved [1]. However, the Montel is not been commonly used as an optics for a nano-focusing beamline for two reasons: first, the gap between the two mirrors is very difficult to control and second, the slope error requirement is very hard to achive. The issue of slop error have been overcome in last two years, by adapting Elastic emission machining(EEM) techniques, which was developed by Osaka University. In this status, the key issue of nano-focusing is how to align and adjust the Montel mirrors. The sketch of the mirror holder is shown in Fig. 4.

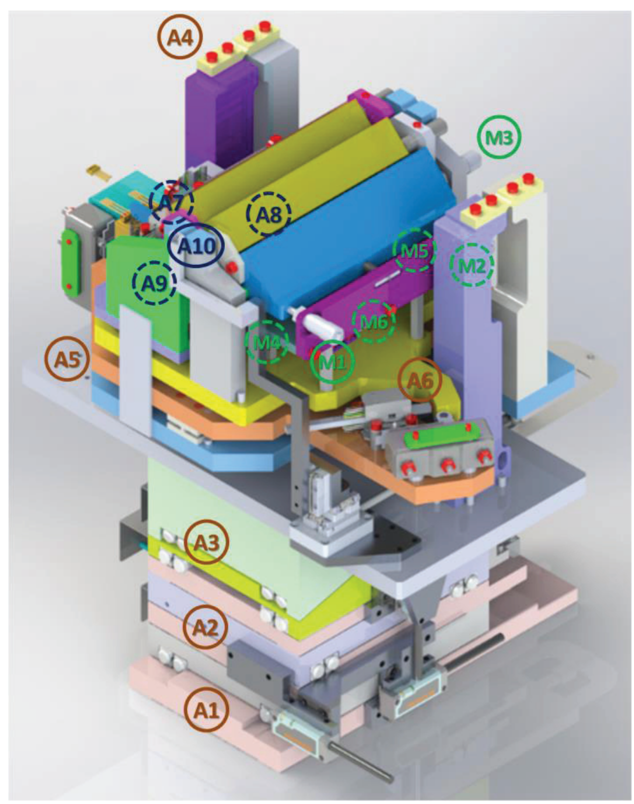

Figure 4: The Sketch of Mirror Holder.

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As shown in Fig. 4, the mirror holder is designed to precisely adjust the Montel mirror simultaneously and independently in three translation and three rotational directions. The adjustment mechanism A1~A6 can be used to move the two mirrors together in six degree of freedoms. The other four motorized axis: A7~A10 can further align the relative position between two mirrors, which is very important to focus the spot size down to tens of nano-meters. Moreover, to roughly define the position of mirror, one of the mirrors can be manual adjust its position by micrometer heads (Mitutoyo®) in three translation directions with several mm travel range and micro-meters resolution. These micrometer heads also provide this mirror three rotational degree of freedoms with sub-mrad resolution.

Before the holder assembling with the endstation, the relative position of two Montel mirrors should be pre-alignment by the tilt sensor and two optical microscopes, as shown in Fig. 5. The orthogonality of the two mirrors can be adjusted in the range of $90^{o} \pm 15$ min and the gap between two mirrors is less than 10 um. The resolution and travel range of this mirror holder is listed in Table 1.

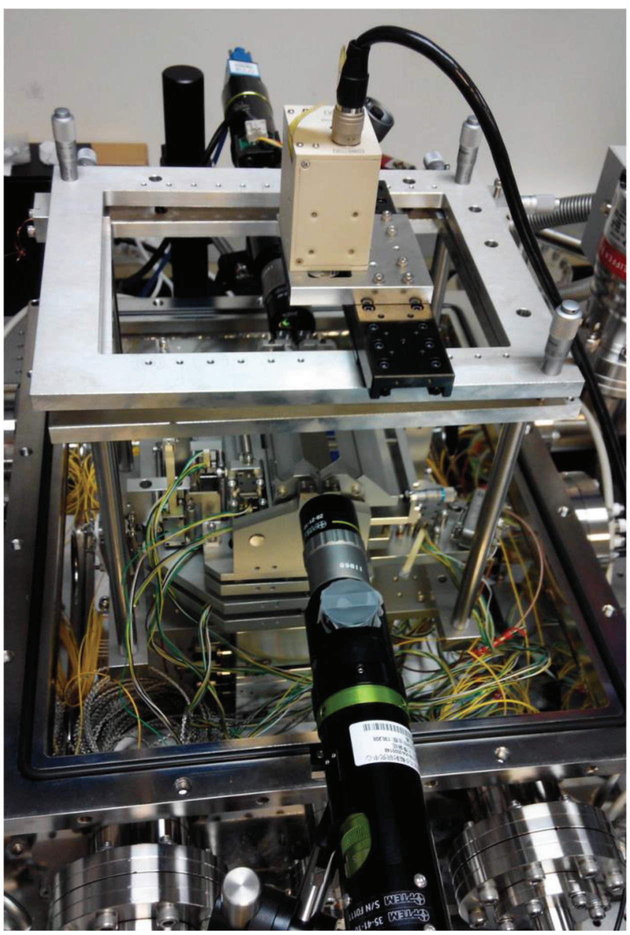

Figure. 5 The Pre-alignment System.

CONCLUSION

In this work, the precision mirror older for the Montel mirrors were designed and made. The two mirrors can be adjusted and aligned simultaneously and independently by micrometers and piezomotors. The adjustable ranges are around 1~24 mm and 1~50 mrad for translation and rotational degree of freedom, respectively. Moreover, the minimum step size is about 1 nm and 0.01 urad .

The precision adjustment holder will be installed in TPS-23A endstation and start commission before the end of 2016.

Table 1: The Resolution and Travel Range of Holder

NO.	**Translation/** Rotaiton	**Resolution** (um/urad)	**Travel range** (mm/mrad)
A1	Y	0.002	24
A2	X	0.002	10
A3	Z	0.001	10
A4	Pitch	0.01	40
A5	Roll	0.05	50
A6	Yaw	0.01	40
A7	Top-Y	0.01	1
A8	Top-Z	0.01	1
A9	Top-Pitch	0.05	1
A10	Top-Roll	1	1
M1	Top-X	5	1
M2	Top-Yaw	50	10
M3	Top-Y	5	1
M4	Top-Z	5	1
M5	Top-Pitch-II	50	10
M6	Top-Roll-II	100	5

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