Upgrade the RIXS Beamline to Ultrahigh Resolution at NSRRC: Mechanical Stability Issues

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outline

- 1. Introduction (optical layout, stability issues)
- 2. Original design and setup
- 3. Measurement instruments
- 4. Upgraded design and engineering
- 5. Performance of the upgrade
- 6. Summary

High-Resolution, High-Efficiency Beamline and Spectrometer for Reasonace Inelastic Soft X-ray Scattering (RIXS)

C. H. Lai, H. S. Fung, W. B.Wu, H. Y. Huang, H.W. Fu, S.W. Lin,C. C. Chiu, D. J. Wang, L. J. Huang, T. C. Tseng, S. C. Chung, C.T. Chen and D. J. Huang

Through this new system, the commissioning results successfully showed spin-flip, dd, and charge-transfer excitations of NiO. These results are consistent with previous published results, while maintaining a better spectral resolution and a higher measurement efficiency. The best energy resolution of our setup in terms of full width at half maximum is 77 meV at the incident photon energy tuned about the Ni L3-edge.

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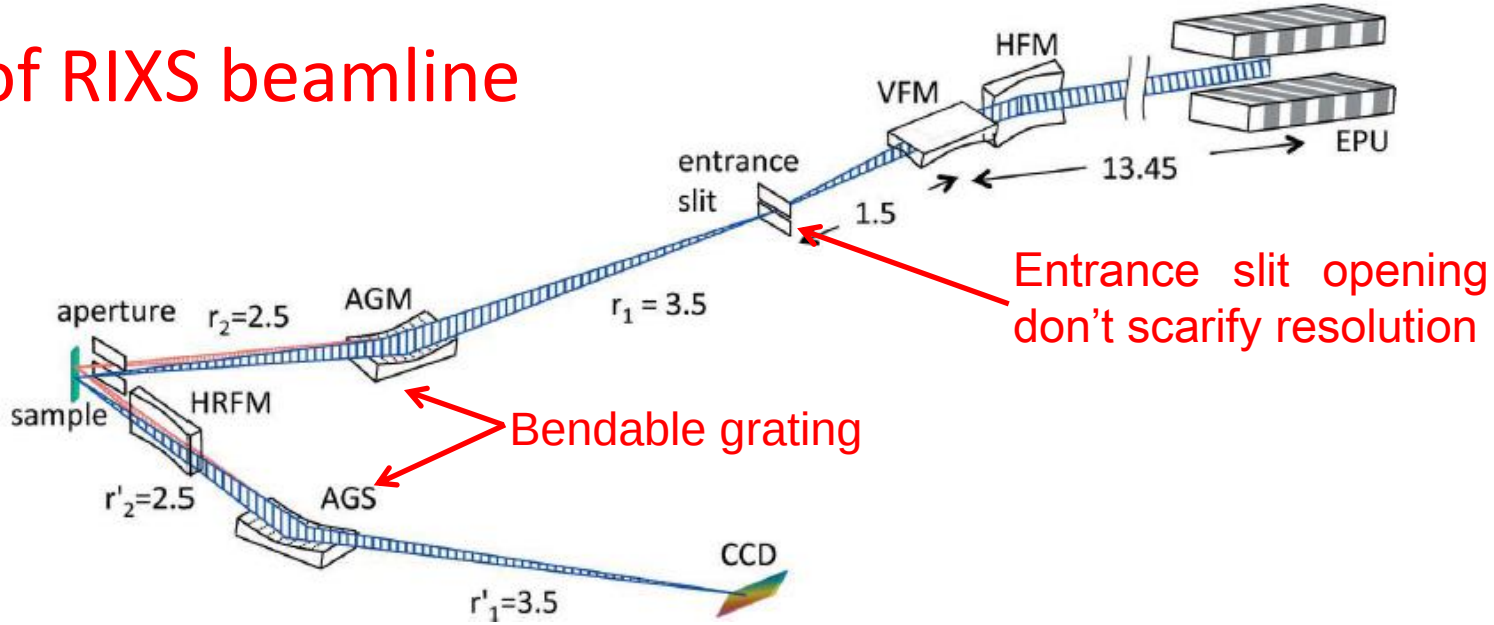
Layout of RIXS beamline

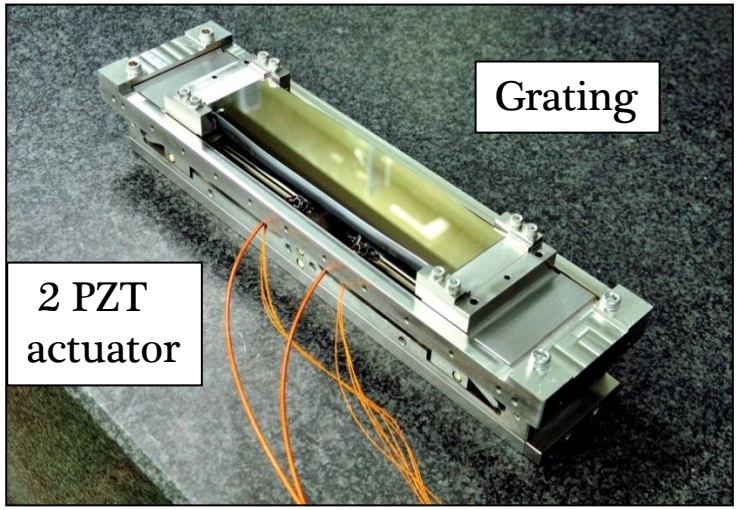


- Base on the energy compensation principle, we build the AGM –AGS beamline for **RIXS**.
- The first optical element is a **horizontal focusing mirror (HFM)** located at distance 12.05m from the center of an **elliptically polarized undulator (EPU**), which is the source of X ray.
- A **vertical focusing mirror (VFM)** is located at distance 1.4 m from the HFM to focus the X-ray beam onto an entrance slit.
- The light is further focused and dispersed onto the sample by the **active-grating monochromator (AGM)**.
- An aperture is placed just before the sample to define the energy spread of the incident photons.
- After the sample, a **horizontal refocusing mirror (HRFM)** enhances the efficiency of collection of scattered X-rays in the horizontal direction.
- An **active-grating spectrometer (AGS)** is used also to disperse and to focus the scattered light onto a two-dimensional **charge-coupled device (CCD)**.

Anticipation of Beamline User : High resolution and High Stability

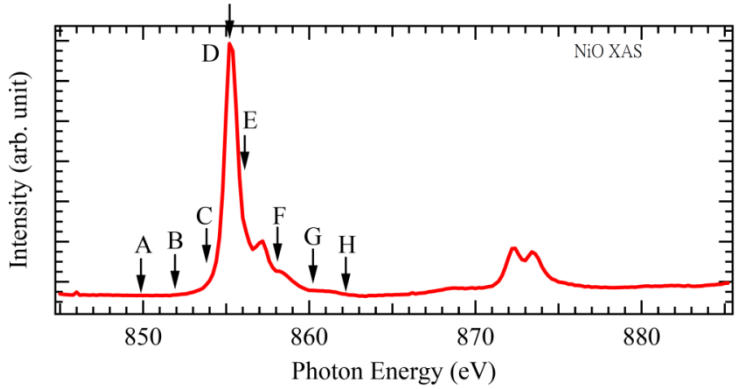
In this innovative optical design,
theoretical resolution is very high but limited by the realistic optics quality. (so far 0.5urad rms slope error, A)

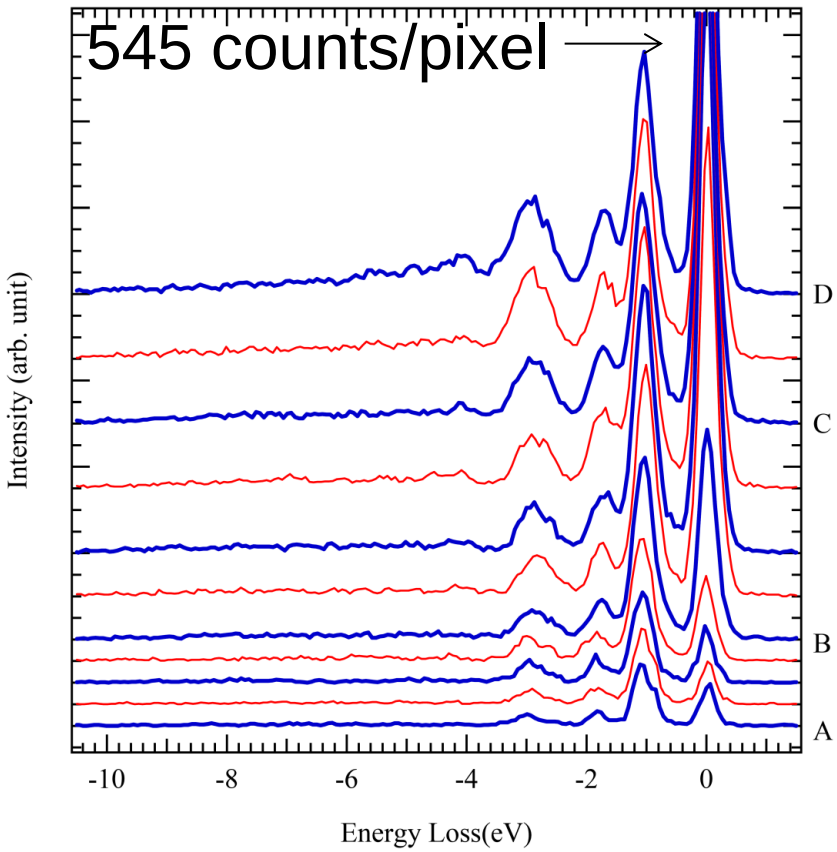
High stability is related from source through each optical component and CCD. (below 0.1urad p-p, B)



Real resolution～ $\left[(A^2 + B^2 + \cdots) \right]^{1/2}$

Why is the stability sensitive for this experiment





NiO RIXS (energy loss) Spectra

Spectrometer @ 90 degrees

3 minutes/spectrum

(weak photon signal expt)

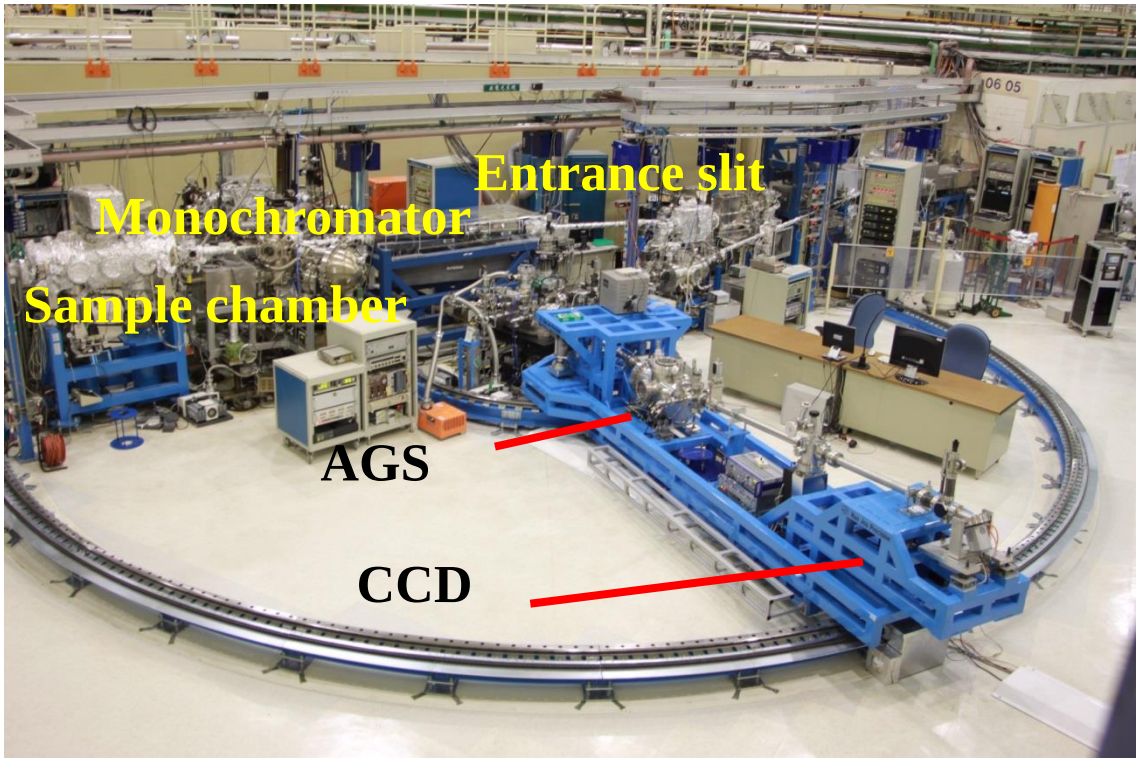
For the energy of point A, CCD takes the energy loss spectrum 3 min to get FWHM, and further to determine the resolution.

Due to Low stability of AGM, AGS and CCD will then deteriorate the resolution

Typical RIXS original Setup

To collect RIXS signal at different scattering angle, AGS could be moved to different location.

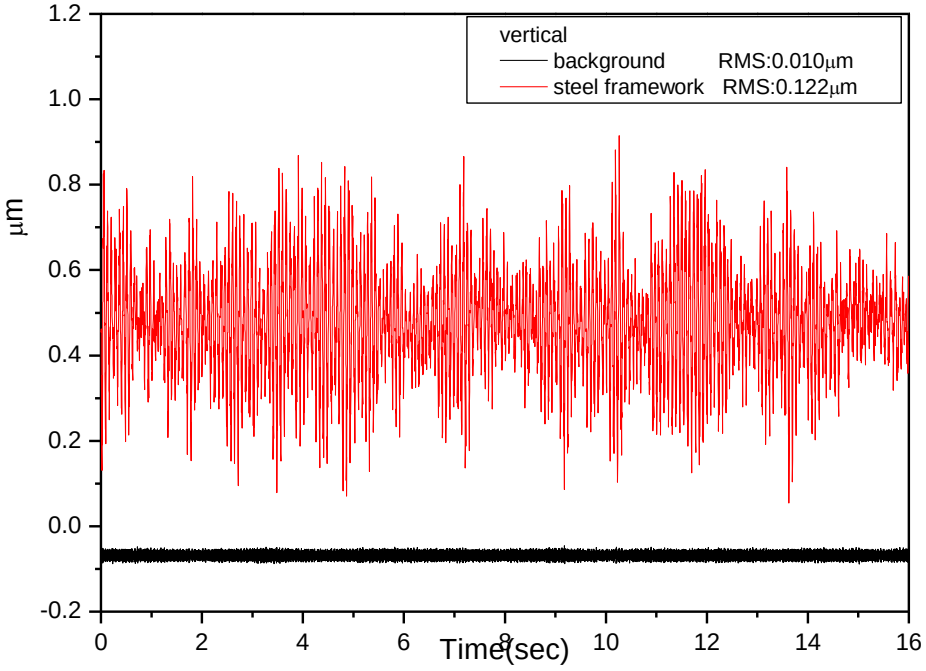
Blue steel frame moves along the circle trace and carries the AGS and CCD to desired location.

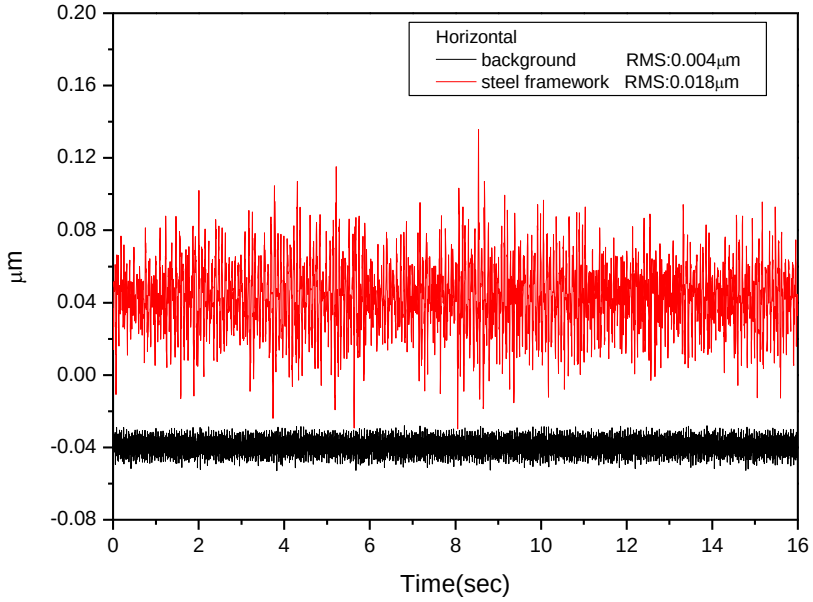


How to stably support the movable AGS and CCD?

Before 2013 Feb

Vertical and horizontal vibration of original steel frame



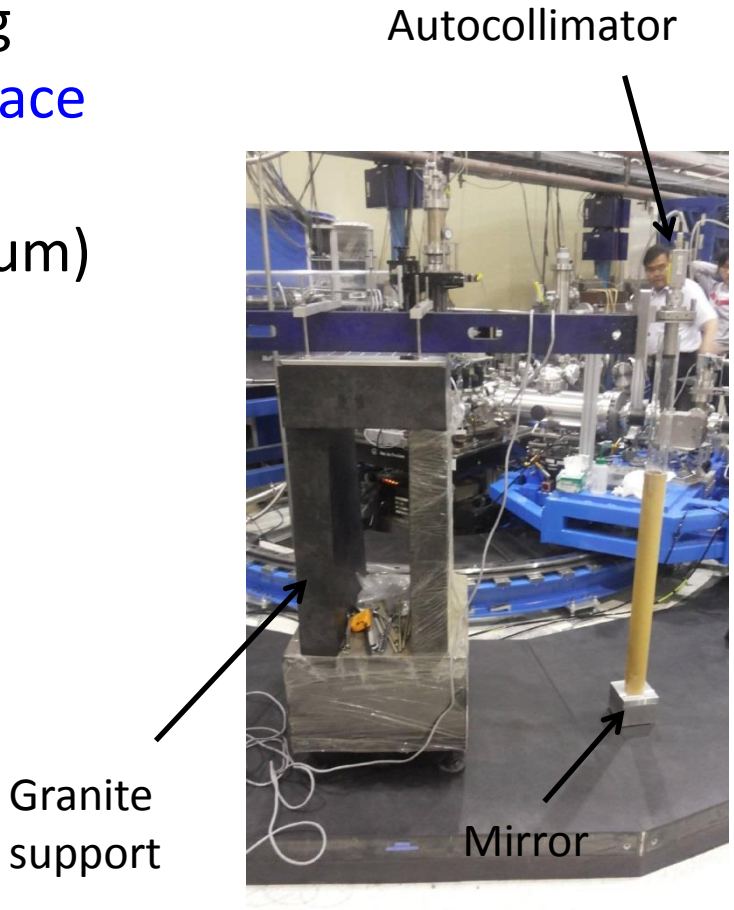


Vertical vibration is 10 times higher than background

Instrument: Lion precision capacitive sensor relative to ground

Measurement instruments

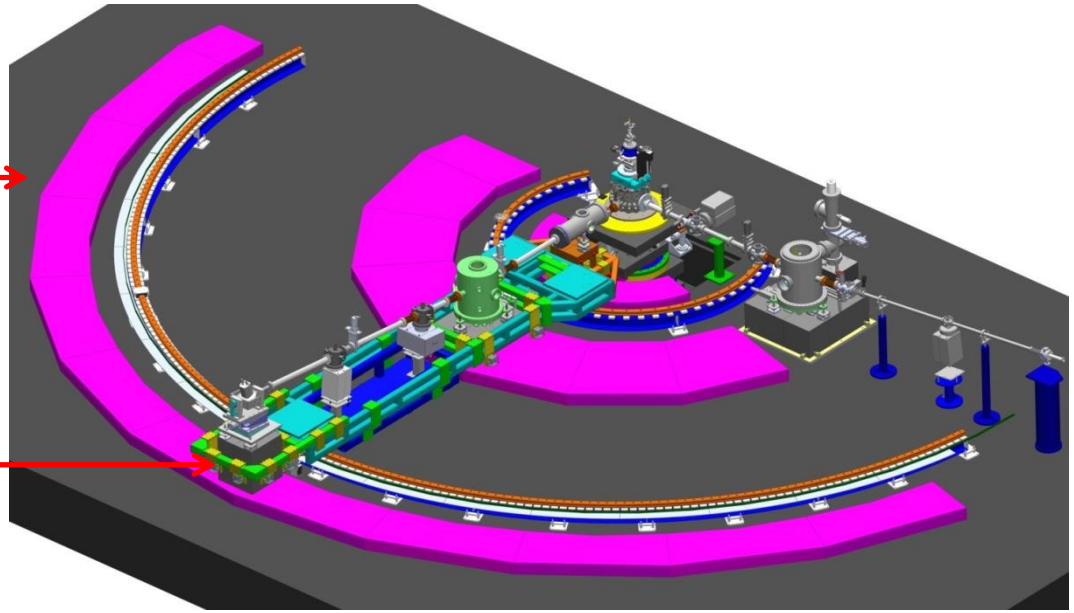
- High-resolution autocollimator and stable support for measuring grating angle (20Hz, 0.1urad) on grating surface
- Capacitive sensor for measuring displacement of support (1Kz, 0.001um)
- Linear encoder of grating actuator (20Hz, 2nm)
- PCB accelerometer for measuring chamber (4-100HZ)



Upgraded engineering

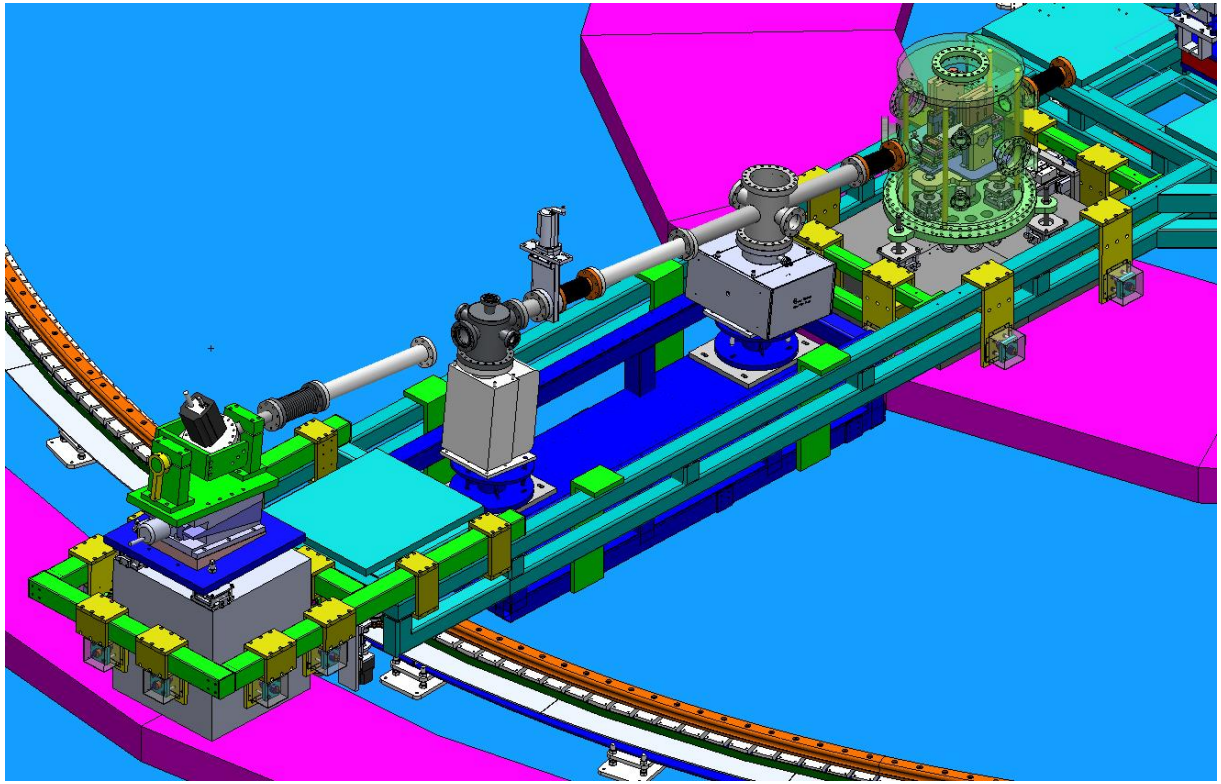
- AGS, CCD granite engineering and air floating.
- AGM and AGS chamber will be rebuilt.

Granite engineering

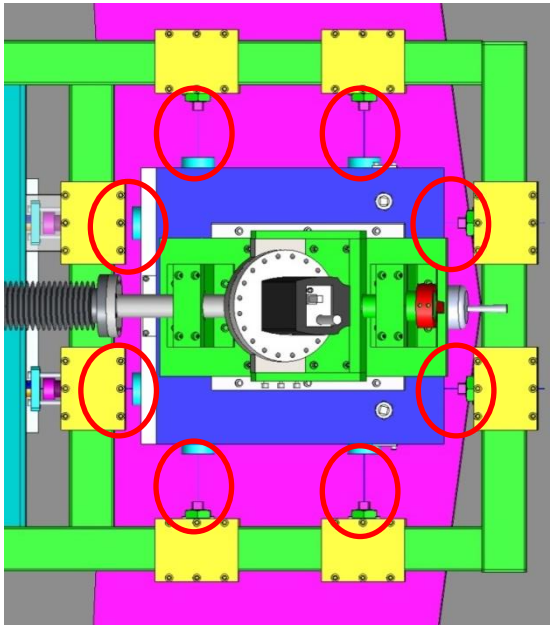


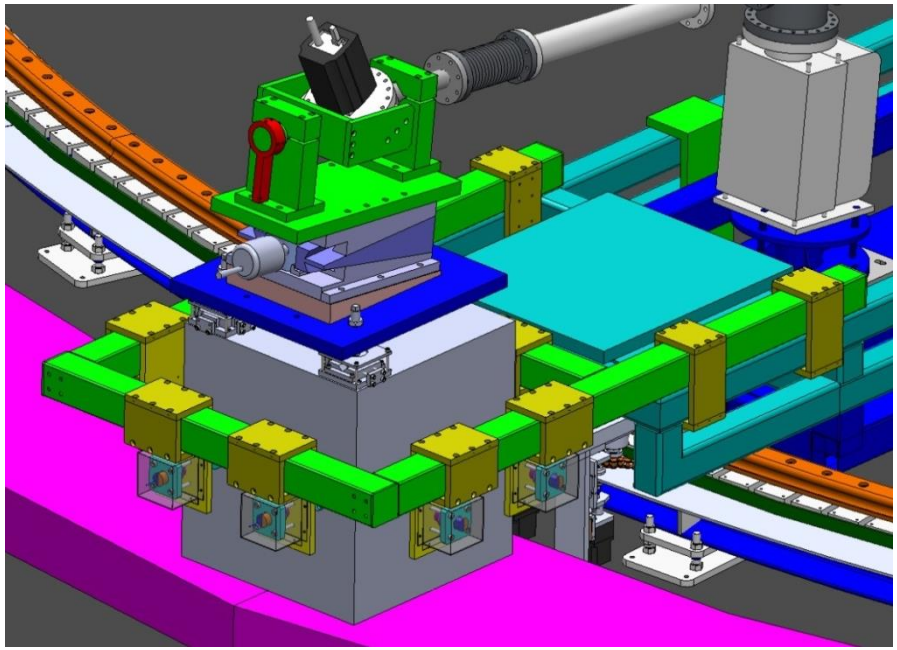
- AGS & CCD are located on granite base with flatness = 5um. The granite base will be lifted height 30um @3Kg/cm^2 when operating 4 air purge holes.
- Each granite platform segment was polished at a factory in advance. The installation flatness is about 50um/10m, and pitch direction is below 20urad.
- Slow curing epoxy was used to fill with the gap between granite and ground.
- Repeatability of sliding granite in pitch direction is about 1 urad by lifting it up and down.

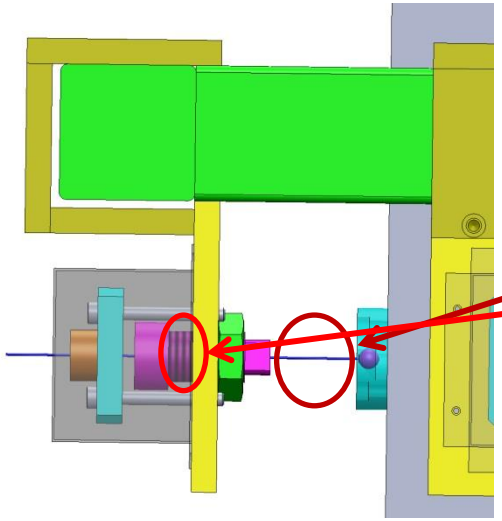
Wire pulling mechanism of the sliding granite



AGS & CCD sliding granite base moving mechanism

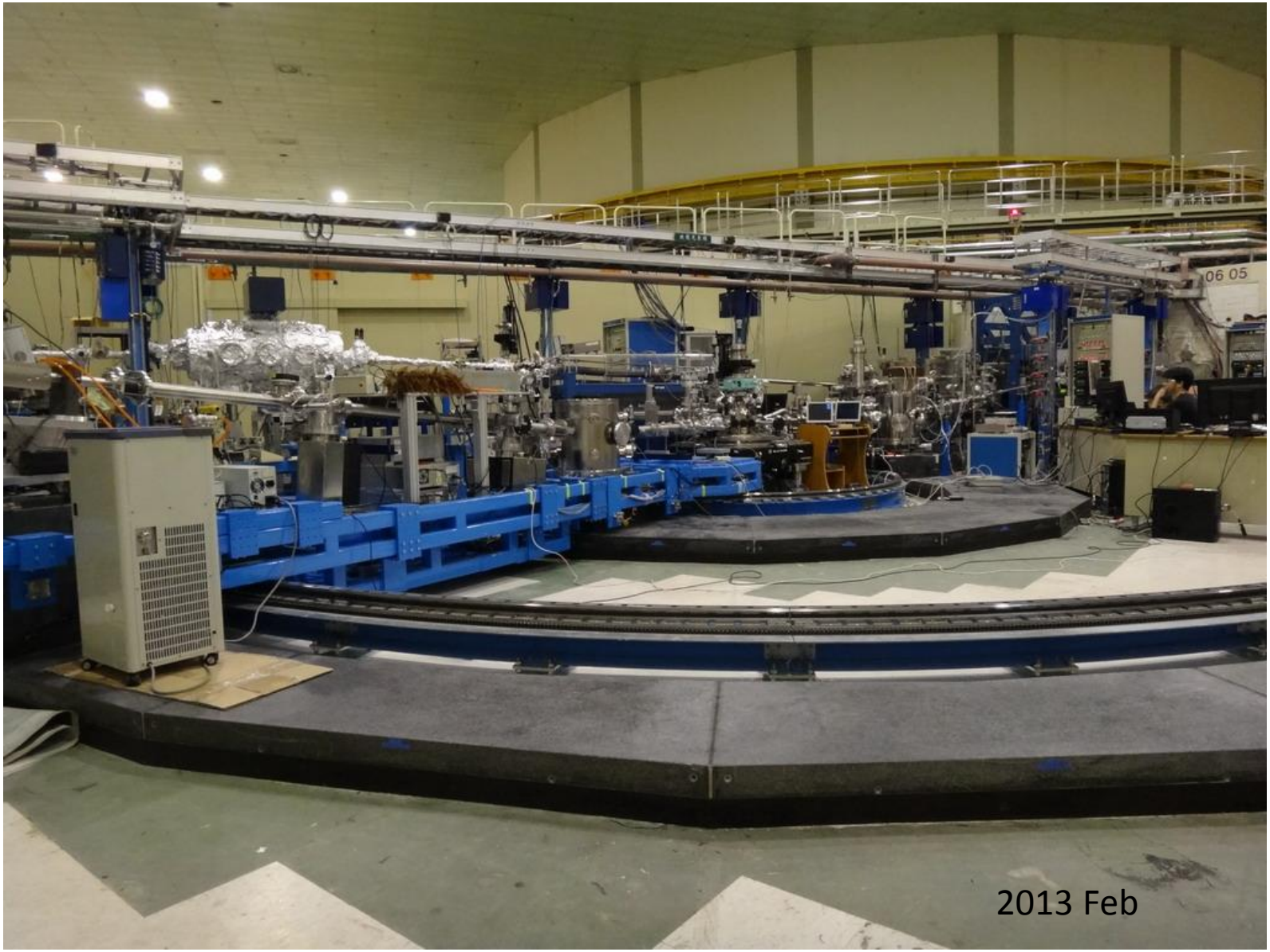






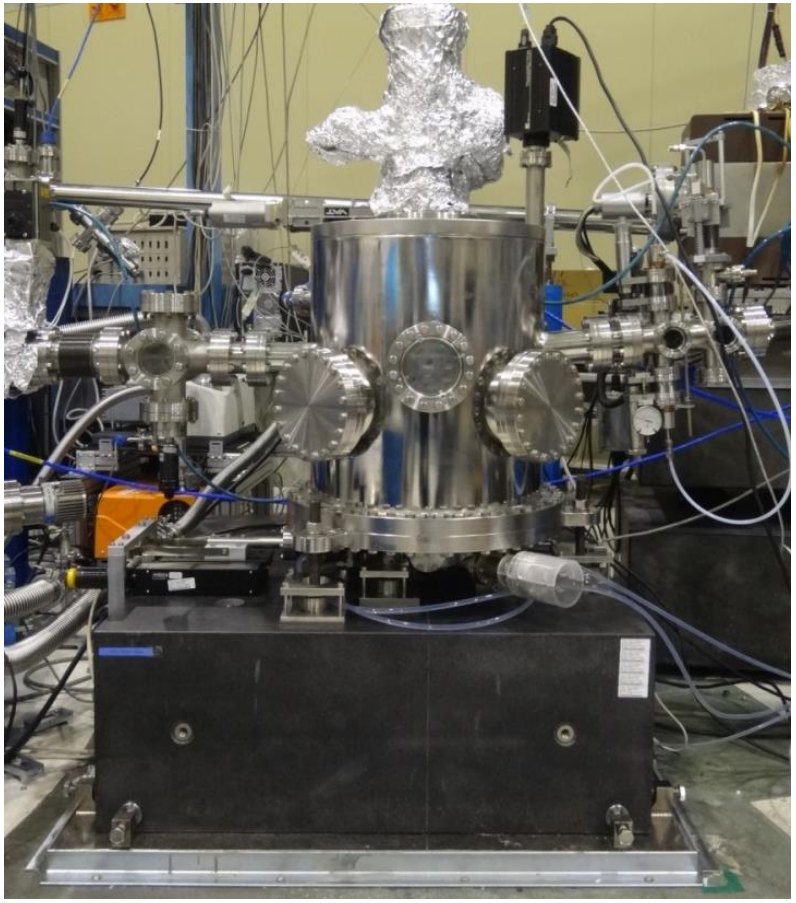
Using **8 steel wires** with **spring force** to pull the granite base, and then to prevent it from distortion by steel frame

TLS RIXS BL upgrade



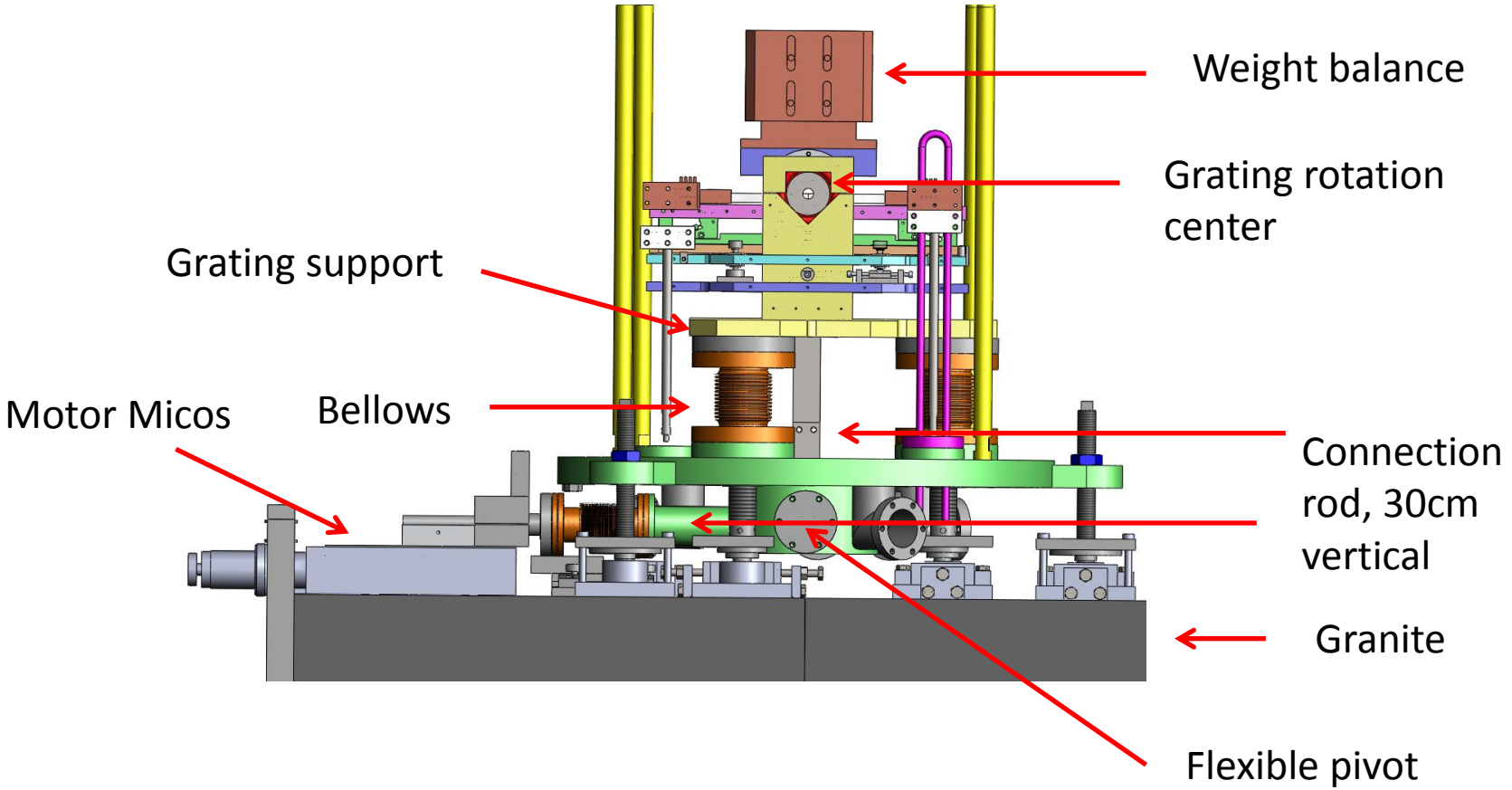
New AGM chamber system

New system



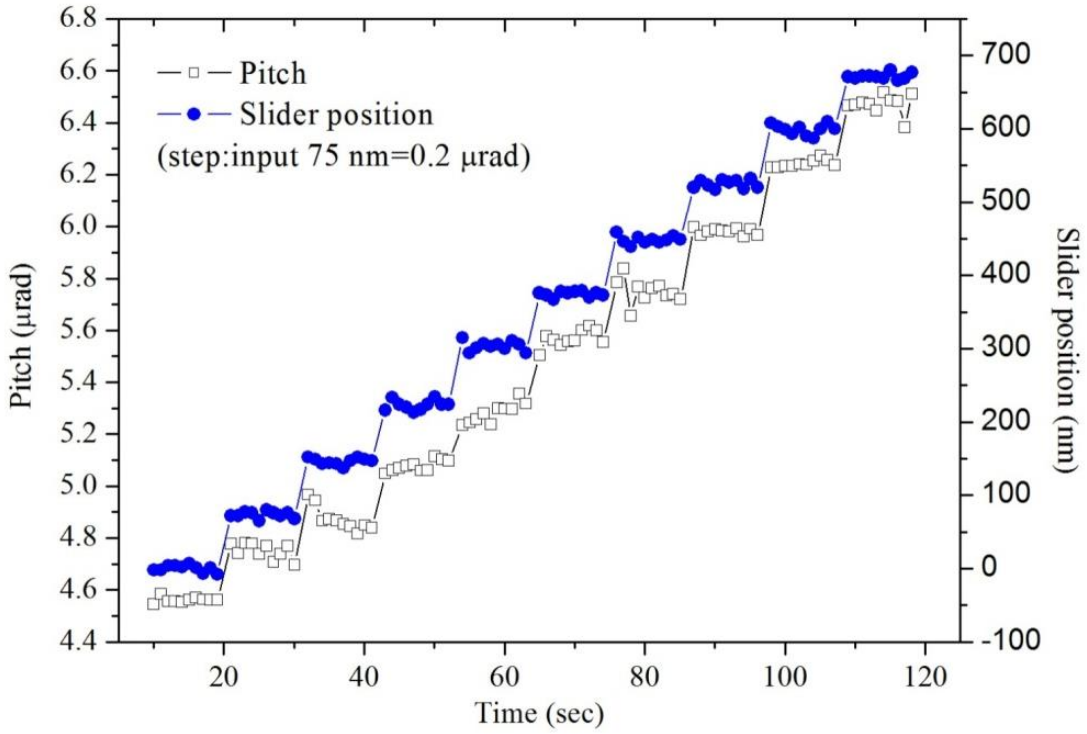
- Using Stable granite base to support chamber
- Introducing Vertical big chamber
- Decoupling Grating adjusting mechanism with Vertical big chamber

AGM design



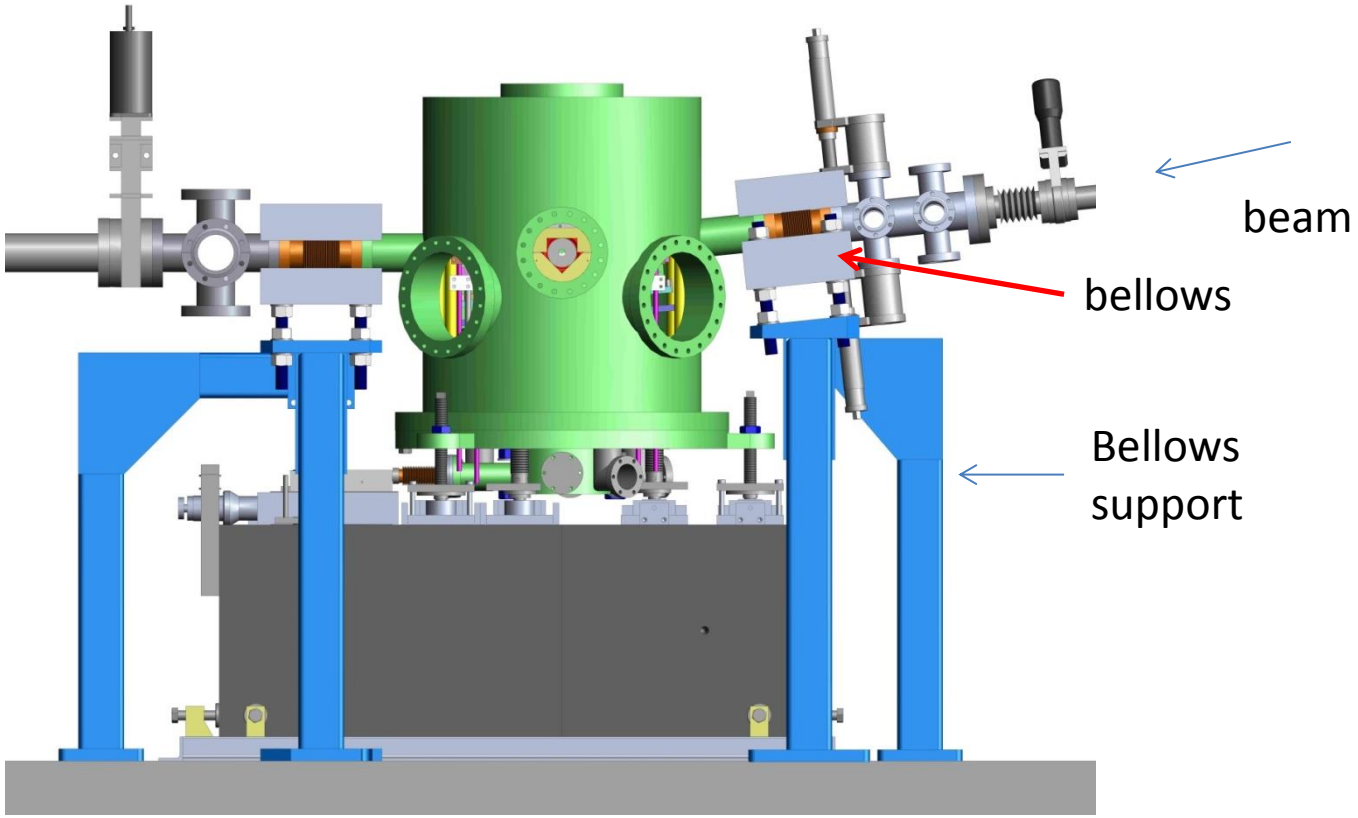
The grating support is mounted to granite and decouple with chamber via bellows, and therefore prevents the vibration from both sides of the chamber

Resolution of AGM by Micos motor



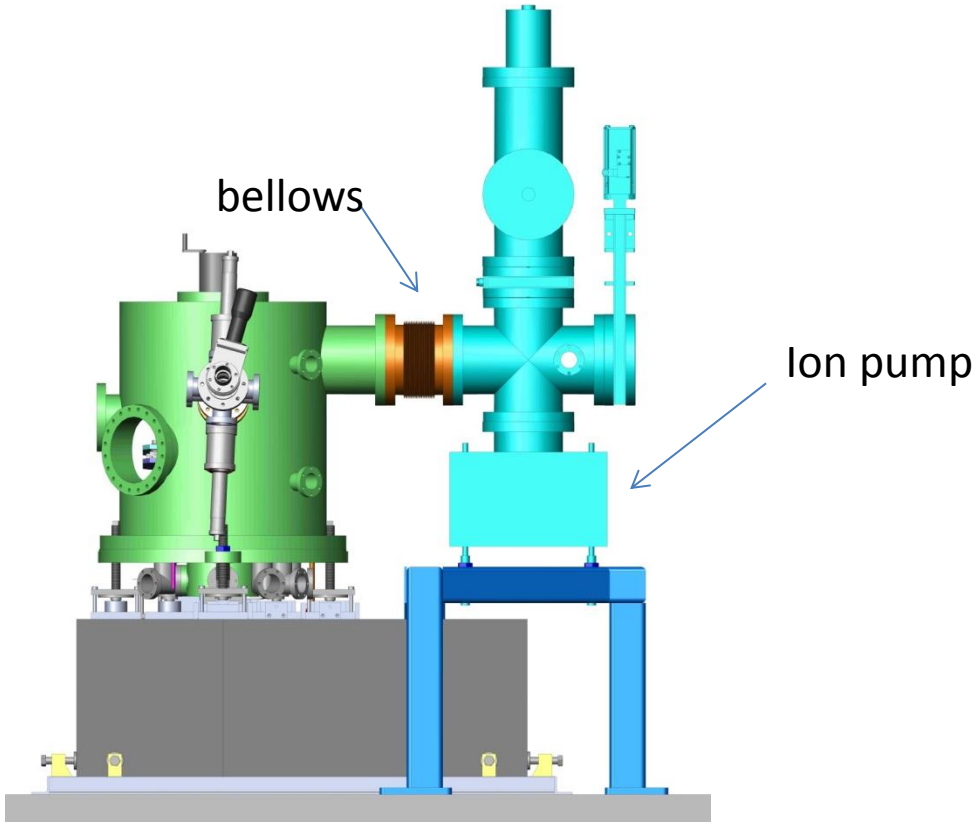
Resolution is good enough for the grating

Refine chamber mounting



Because the weight and vacuum force are different on both sides of the chamber, we will introduce bellows support to reduce extra moment on the chamber.

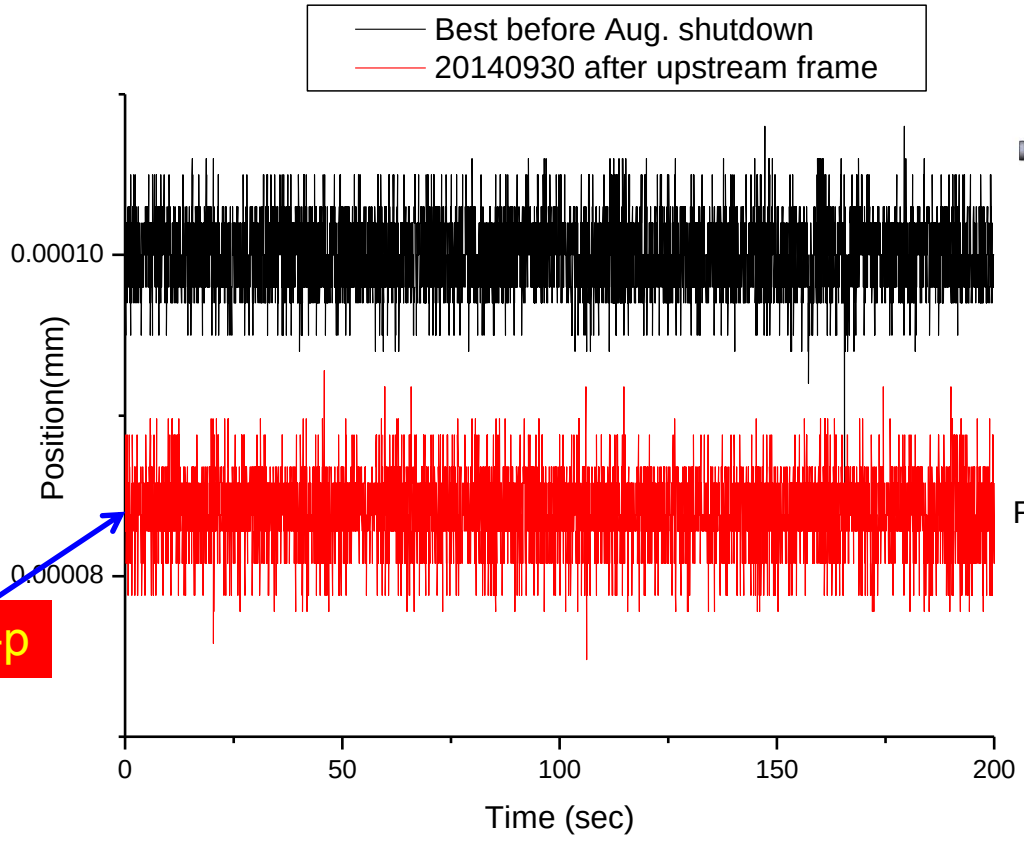
Chamber mounting from view of beam direction

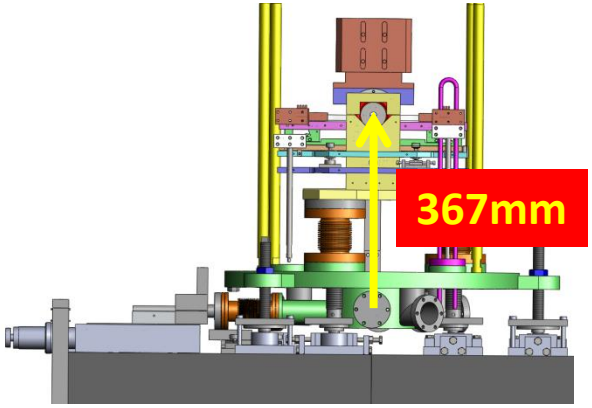


Due to Weight of IP and GV is more than AGM chamber, we use bellows to decouple with the chamber to further prevent the indeterminate supporting points of this system.

AGM chamber with bellows support

Data obtained from Micos motor encoder





RMS= 2.33 nm

Without bellows support

RMS= 2.30 nm

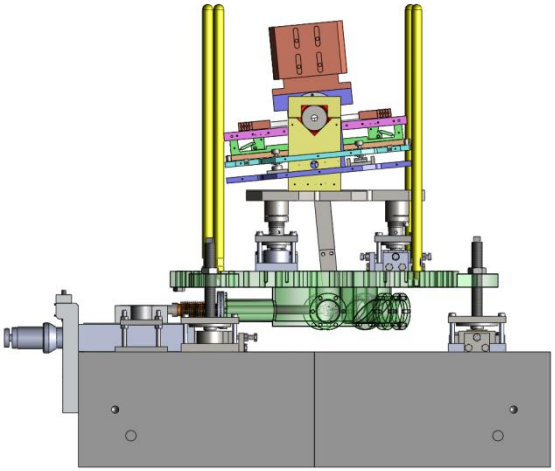
Bellows support

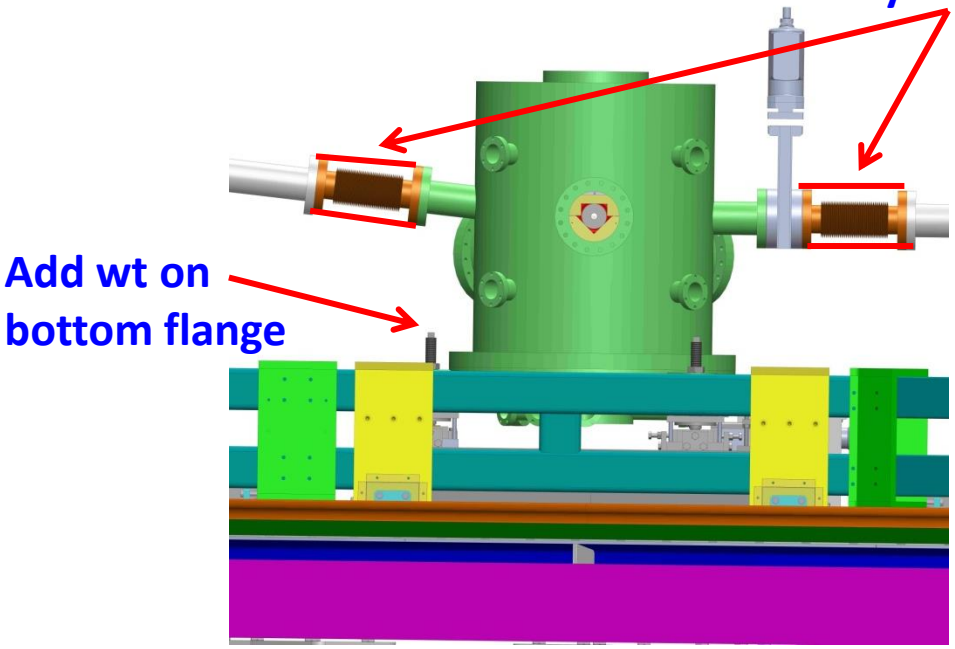
10nm p-p

10nm p-p/367mm
≈ 27.2nrad

User response: Bellows support help shorten the pendulum-phenomenon duration of grating holder in the chamber of AGM subjected to external excitation

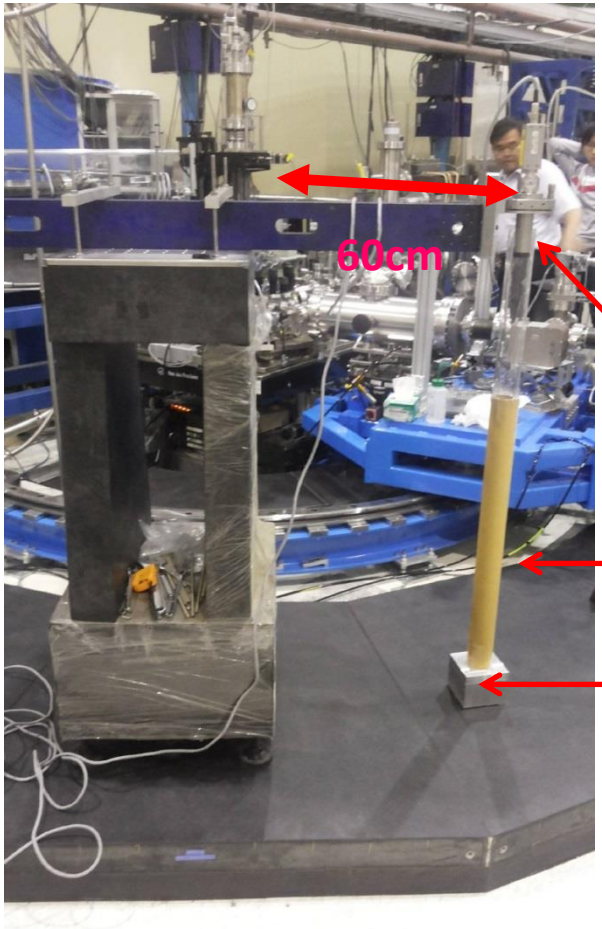
AGS design

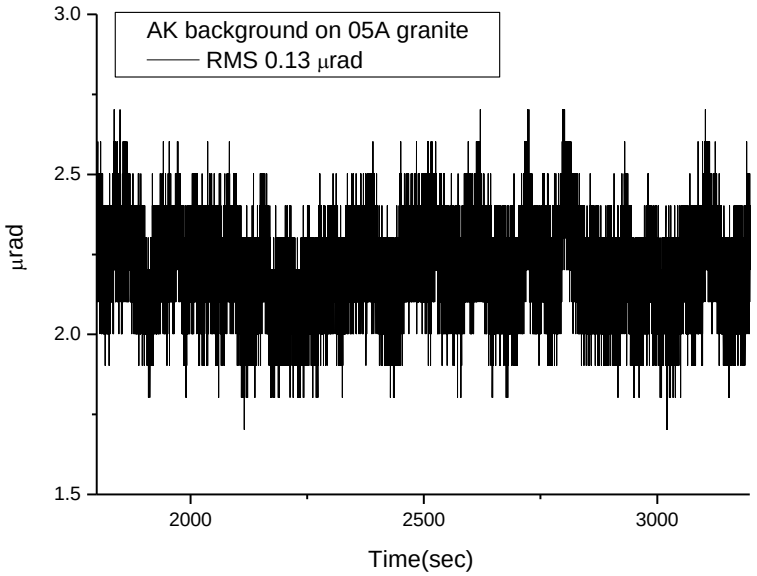




- AGS is mounted on the bottom flange due to height limitation
- The adjusting mechanism for angle driving of AGS is the same as the one of AGM

Stability test of Autocollimator



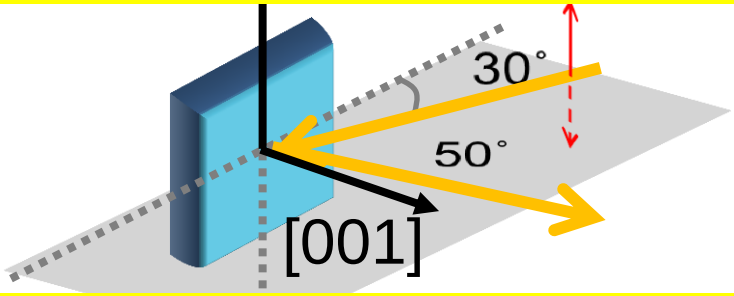


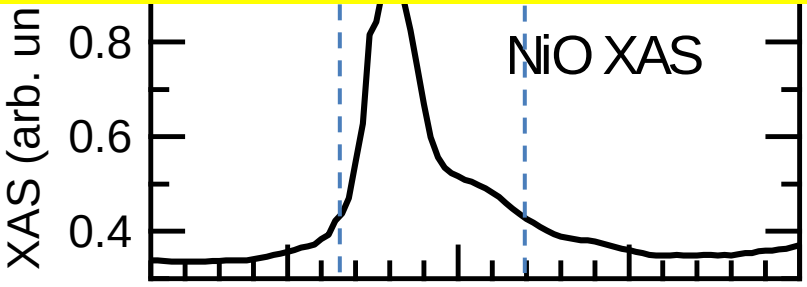
AGS chamber mounting stability

	No bellows support No wt	**No bellows support Wt 80Kg**	**1 bellows support Wt 80Kg**	**2 bellows support Wt 80Kg**
Grating encoder (nm rms)	3.6	2.3	2.2	2.18
Autocollimator (urad)	0.38	0.178	0.187	0.167

The bellows support are tentative, and just shows the trend

- We chose NiO as a test sample for high resolution RIXS measurements using a side branch of the EPU beamline at the TLS.
- NiO is a prototypical system of strongly correlated electrons that exhibit many-body characteristic properties.



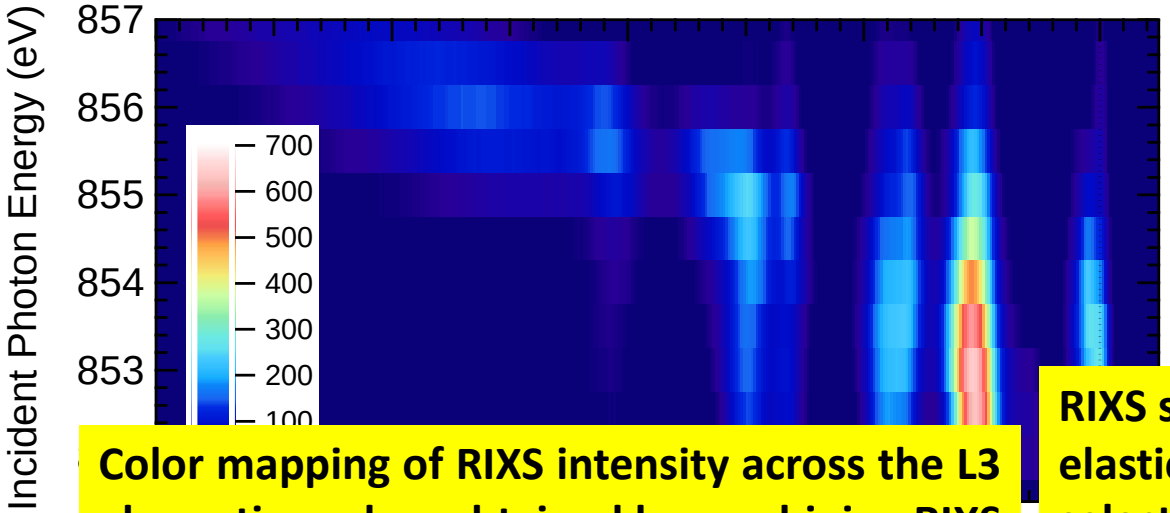


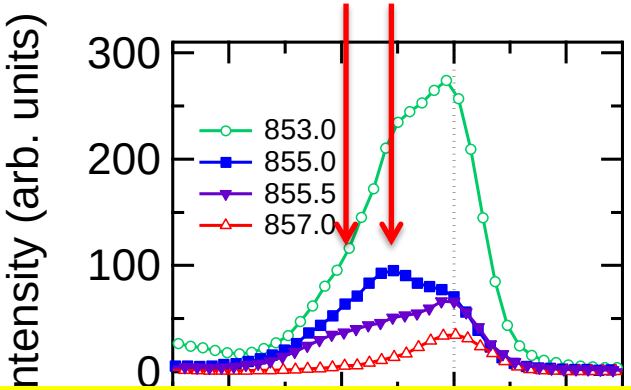
The surface normal of the NiO sample was along the [001] direction; the incident angle was 30 from the sample surface.

RIXS spectra excited with incident photons of energies 853, 855 and 857 eV.

CT *d-d* Spin

Excitation of local spin-flip





Color mapping of RIXS intensity across the L3 absorption edge, obtained by combining RIXS spectra excited every 500 meV.

RIXS spectra in an energy range near the elastic scattering excited with of selected incident energies labeled in units of eV.

Summary

- After upgrading the stability of RIXS beamline, users are satisfied with the resolution and stability of RIXS system.
- From grating encoder reading, it seems that we can attain below 30nrad p-p mechanical stability (corresponding to 10nm obtained from Micos motor encoder) p-p mechanical stability for RIXS system, and this mechanical stability can last for several hours.
- Beamline signals obtained from CCD are more sensitive than most commercial measurement tools.