Title

EUV observation for the Jovian inner magnetosphere from the EXCEED

Authors:

K. Yoshioka[(1)], G. Murakami[(1)], A. Yamazaki[(1)], K. Uemizu[(1)], I. Yoshikawa[(2)], H. Ishii[(2)], K. Uji[(2)], F. Tsuchiya[(3)], and M. Kagitani[(3)]

[(1)] ISAS/JAXA

[(2)] The University of Tokyo

[(3)] Tohoku University

Abstract:

The Io plasma torus is composed mainly of sulfur and oxygen ions and their compounds such as SO^{2+} derived from Io's volcanic activities, together with a background of electrons. In addition to those basic components, several in-situ observations have shown that a few percent of the electrons there have been excited to be as much as 100 times hotter than the background electrons. These hot electrons have a significant impact on the energy balance in the Jovian inner magnetosphere.

However, their generation process has not yet been elucidated. One difficulty is that the available data all comes from in-situ observations which cannot explore the temporal and spatial distributions explicitly. Therefore remote sensing which could take a direct picture of the plasma dynamics is necessary.

In order to clear up the hot electron problem, the Earth-orbiting EUV spectroscope, EXCEED will be launched in 2013. It is dedicated and optimized for observing the terrestrial planets. Because of its large effective area and the simplicity of the scientific target, better temporal resolution and more complete coverage for Io plasma torus observation is expected.

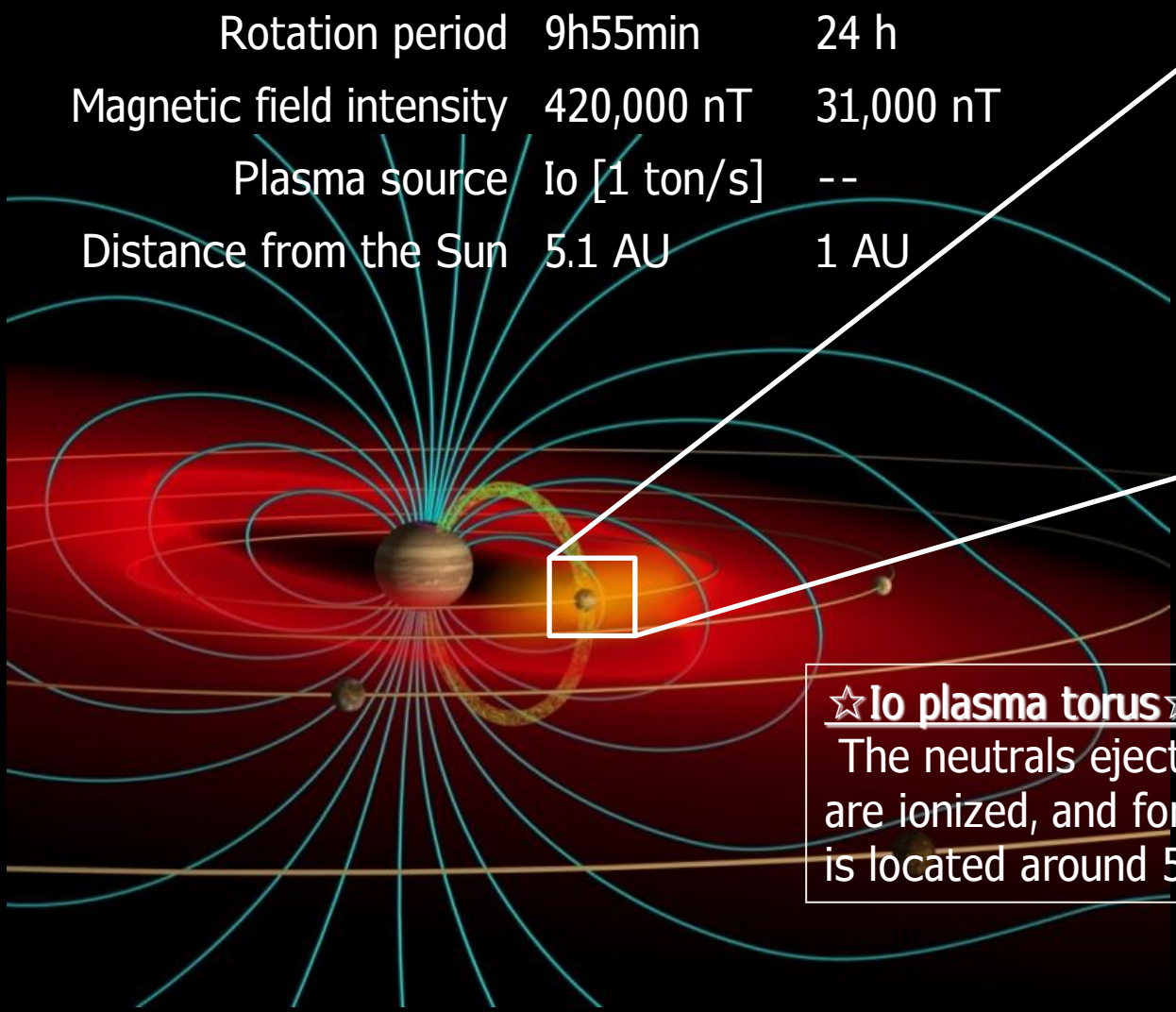
In this presentation, the optical design and efficiency performance of FM components of EXCEED are introduced. The current status of optical alignment test is also introduced.

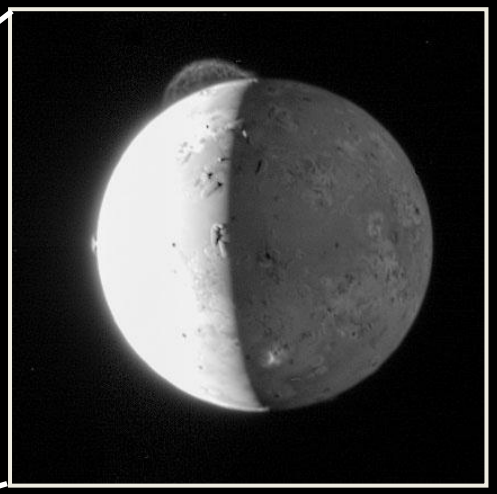
EUV observation for the Jovian inner magnetosphere from the EXCEED

K. Yoshioka, G. Murakami, A. Yamazaki, K. Uemizu (ISAS/JAXA),
I. Yoshikawa, H. Ishii, K. Uji (Univ. Tokyo)
F. Tsuchiya, and M. Kagitani (Tohoku Univ.)

Jupiter and Io plasma torus (overview)

	Jupiter	Earth
Radius	71500 km	6400 km
Rotation period	9h55min	24 h
Magnetic field intensity	420,000 nT	31,000 nT
Plasma source	Io [1 ton/s]	--
Distance from the Sun	5.1 AU	1 AU





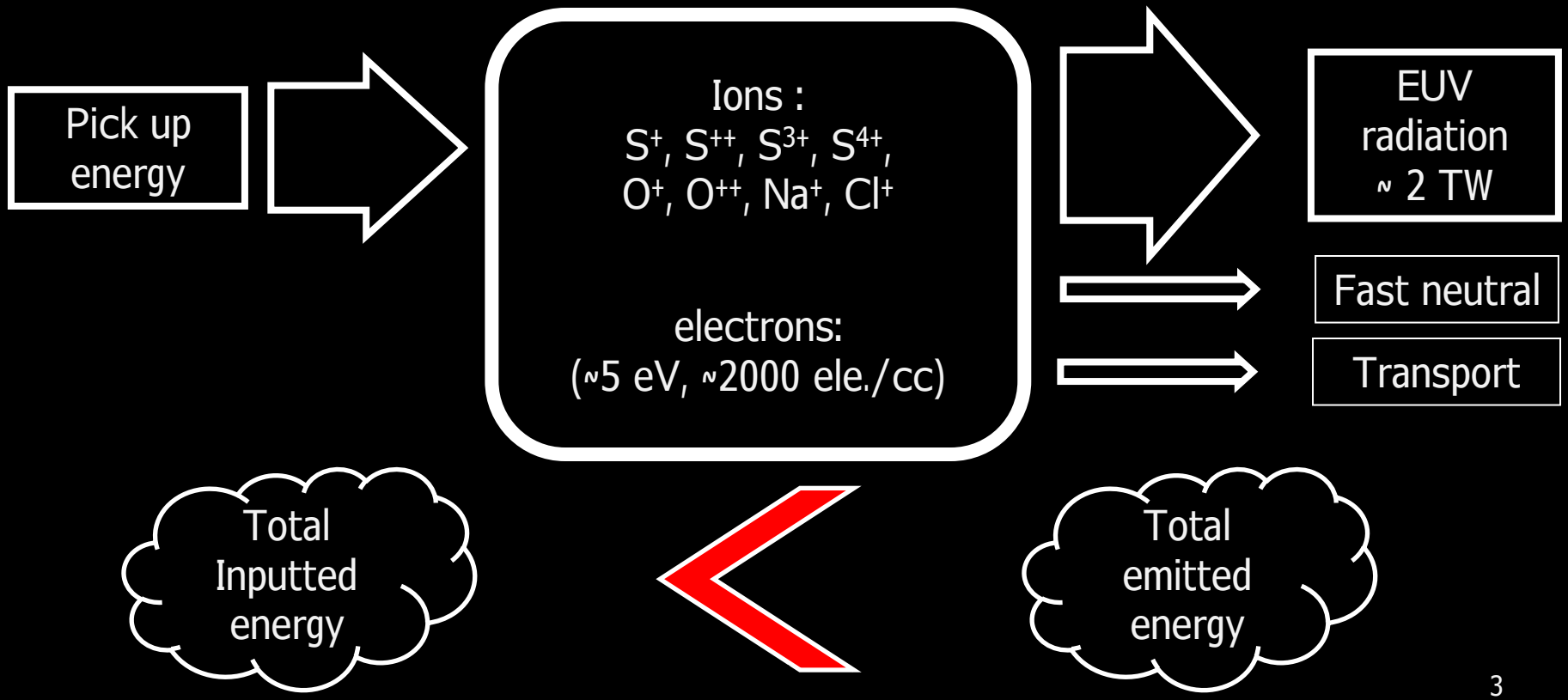
Io's volcanic activity
(NASA/NEW HORIZONS/VIS)

☆Io plasma torus☆

The neutrals ejected from the Io's volcanoes are ionized, and form a torus like structure which is located around 5 to 8 times Jupiter radius.

Energy flow through the Io plasma tours

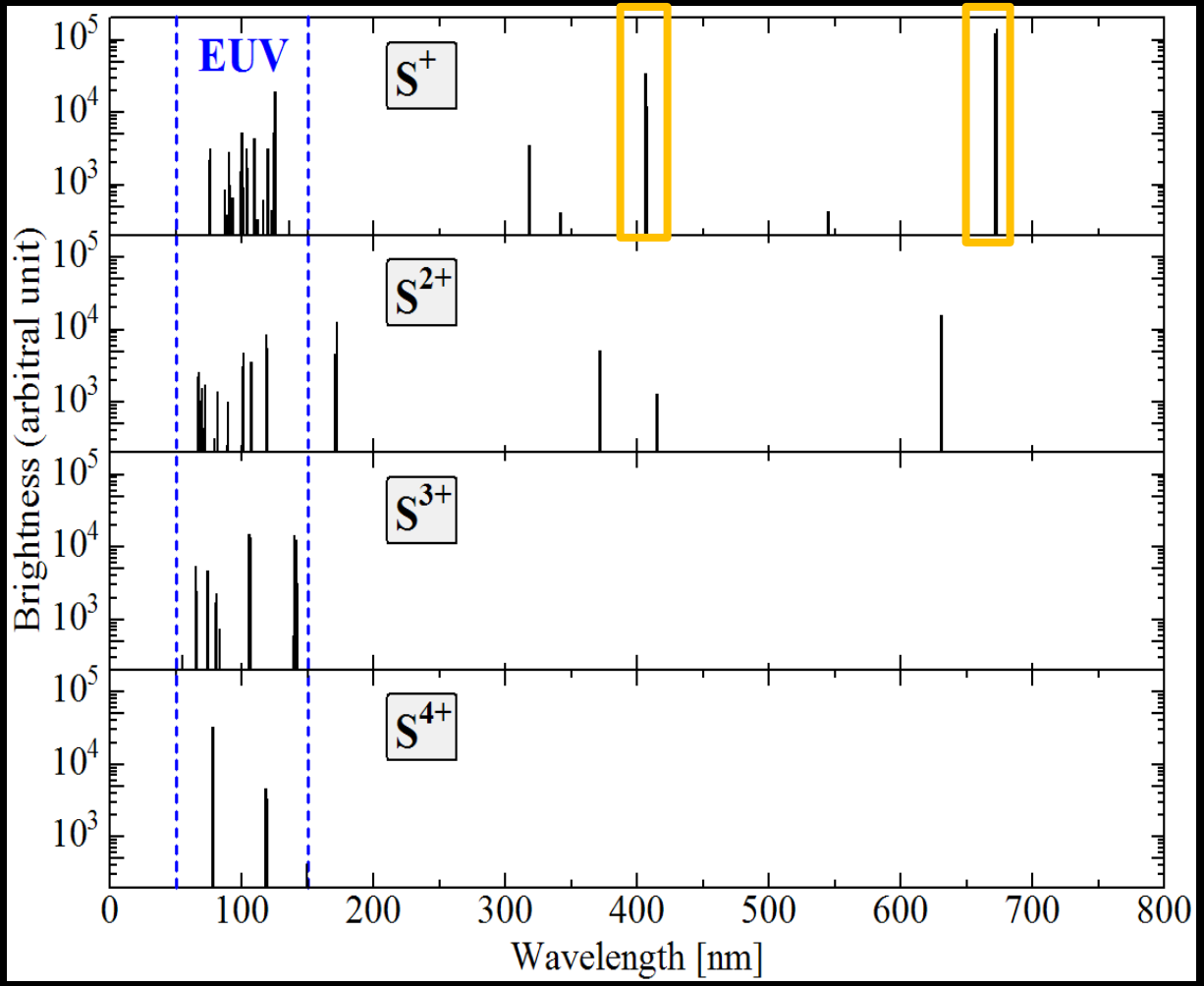
- The ionized ions are picked up by the Jupiter's magnetic field.
- The pickup energy of the ions are ~200 eV
- The inputted energy is emitted (mainly) through the EUV radiation.



Line distributions

Space based obs.

Ground based obs.

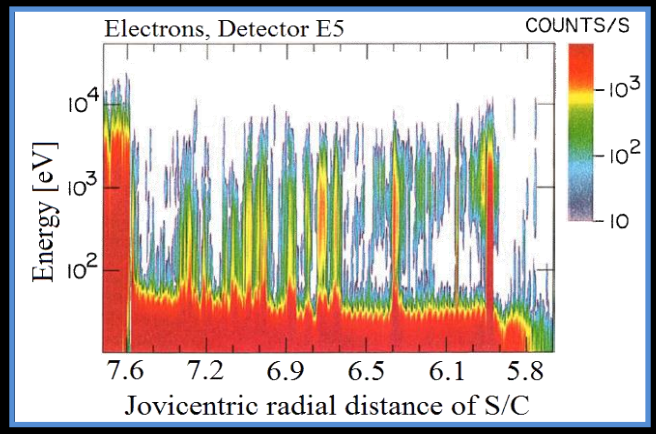


More than 80% of the lines are in the EUV region.

The distribution of Sulfur ion emissions. These emissivities are calculated with same plasma conditions (Yoshioka et al. 2012 mod.).

The energy flow around the Io plasma tours

- There must be an extra energy source.
- A small amount of hot electron is the candidate.
- The hot electron component has been detected through **in situ** observation by **Galileo** space craft.



Frank and Paterson, 1999 mod.

Pick up energy

Ions :
S^+, S^{++}, S^{3+}, S^{4+},
O^+, O^{++}, Na^+, Cl^+

electrons:
(~5 eV, ~2000 ele./cc)

Hot electrons

The extra energy source

EUV radiation ~ 2 TW

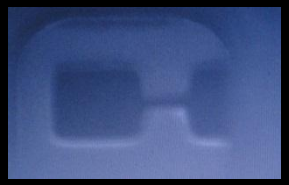
Fast neutral

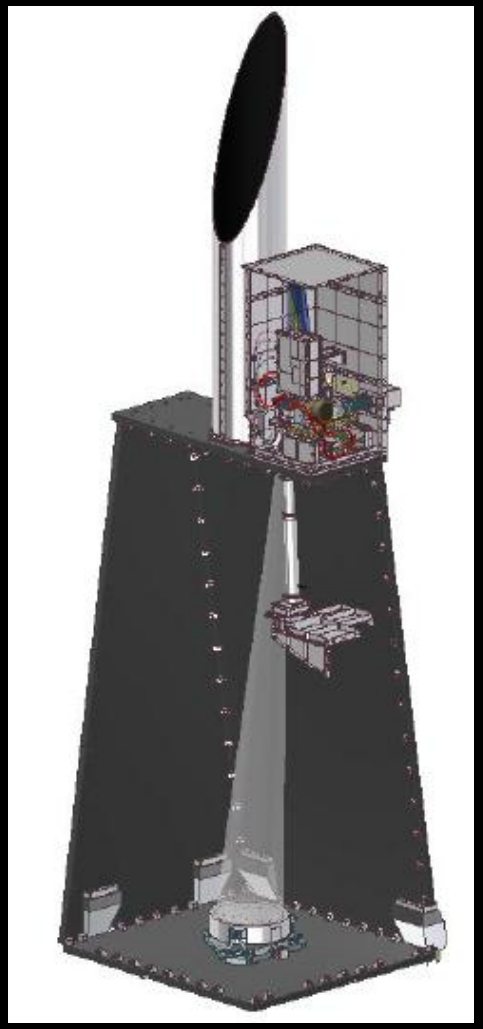
Transport

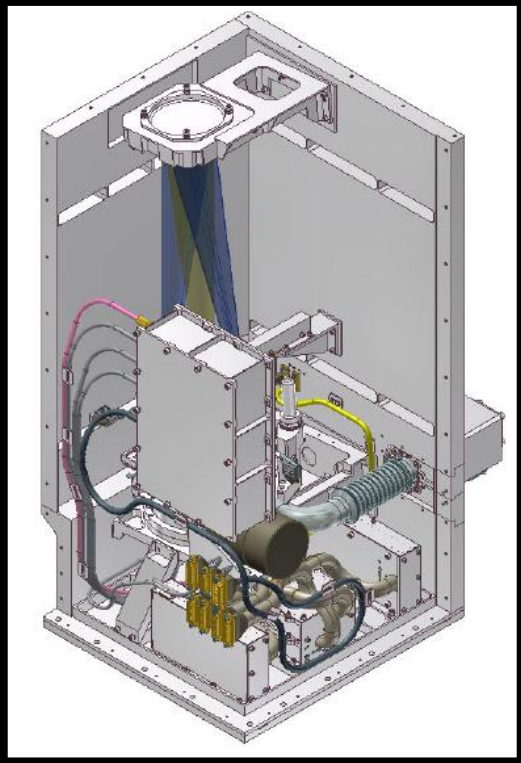
Can we detect hot electrons through **remote observation**?

The EXCEED mission

- The observing module contains
  - Entrance mirror
  - Spectrometer
    - Slit
    - Grating
    - EUV detector
    - Light trap
  - Target finding camera





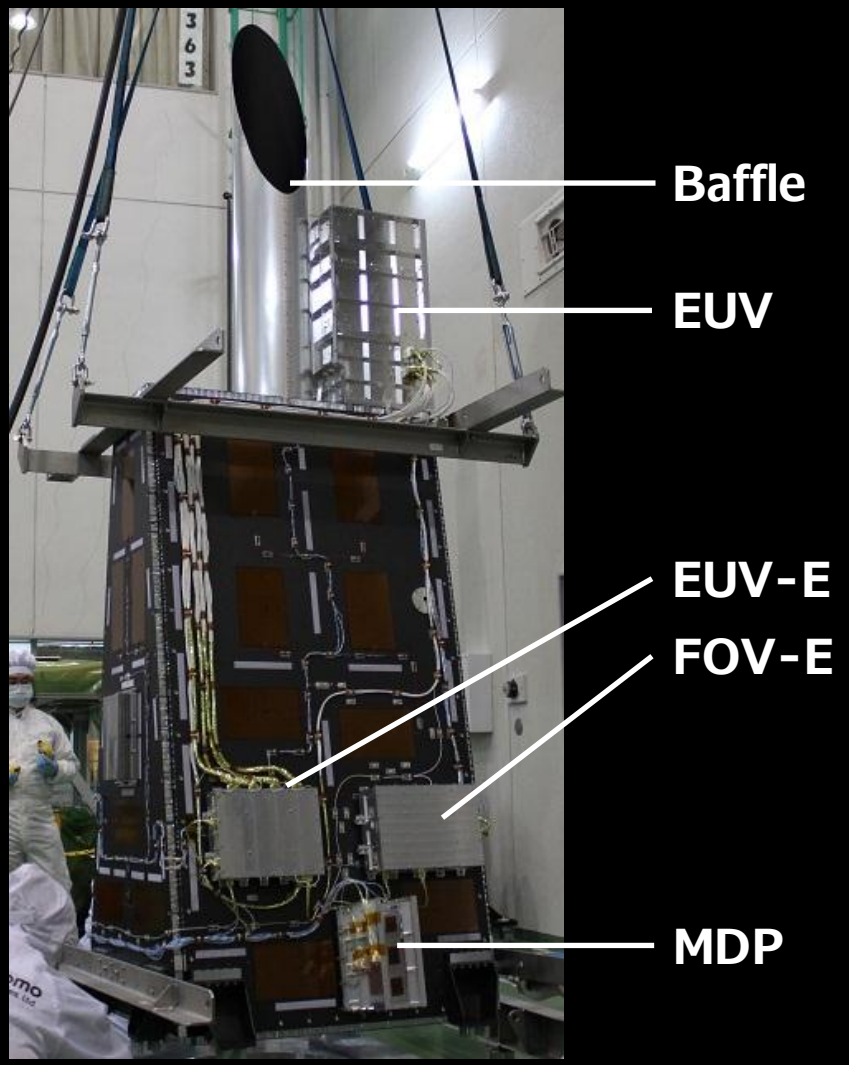


(←) The schematics of the EXCEED instrument (without bus system)
(↑) The inner part of the EUV spectrometer

- A pointing attitude accuracy
  - **±5″** with the help of the target finding camera. (≈1/5 RJ)
  - The pointing accuracy of the satellite is about ±1.5′. The target finding camera refines this and feeds the instrument pointing and attitude back to the data bus system. (Tsuchiya, et al., poster)

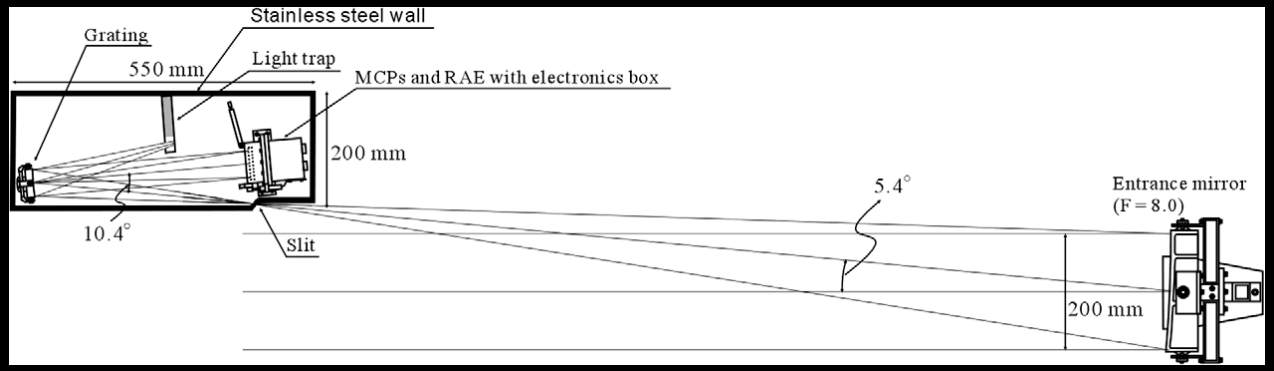
The EXCEED mission

- The observing module contains
  - Entrance mirror
  - Spectrometer
    - Slit
    - Grating
    - EUV detector
    - Light trap
  - Target finding camera



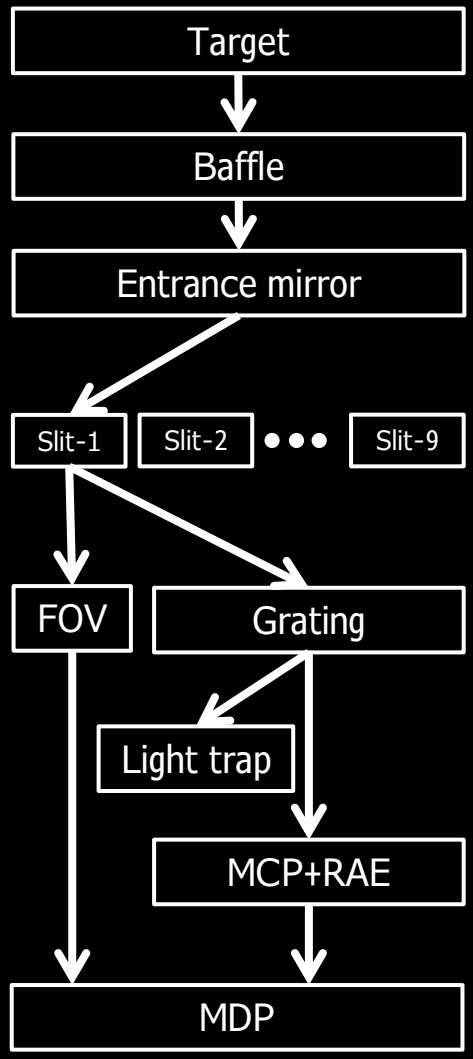
- A pointing attitude accuracy
  - **±5”** with the help of the target finding camera. (≈1/5 RJ)
  - The pointing accuracy of the satellite is about ±1.5′. The target finding camera refines this and feeds the instrument pointing and attitude back to the data bus system. (Tsuchiya, et al., poster)

The EXCEED mission (optical layout)



The optical layout of EXCEED, (Yoshioka et al. 2010)

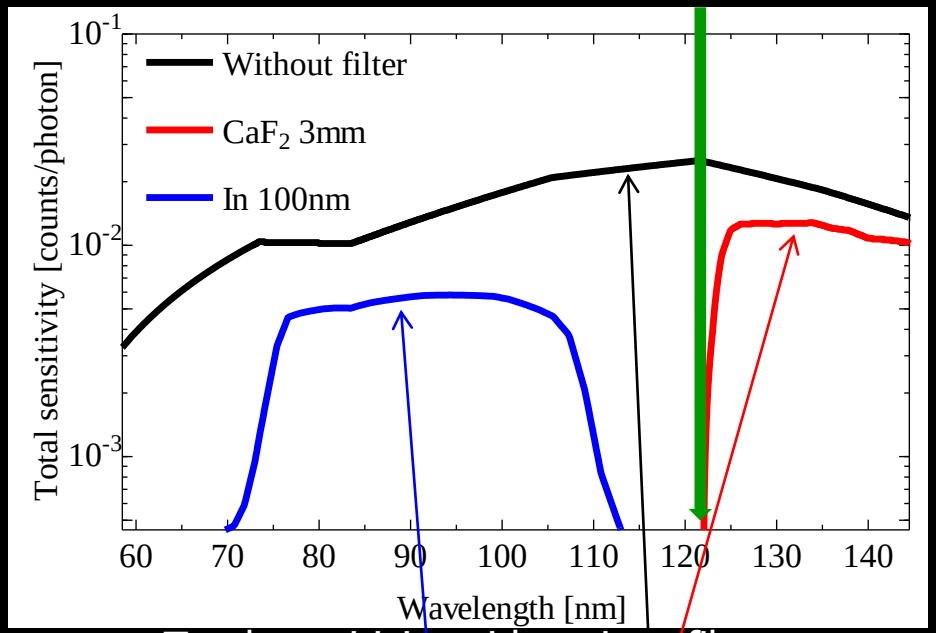
- **Entrance mirror**
  - An off-axis parabolic, CVD-SiC coated
- **Slit**
  - Three types of shape, and three types of filters
- **Grating**
  - Laminar type, toroidal, CVD-SiC coated
- **Photon detector**
  - Microchannel plate and Resistive anode



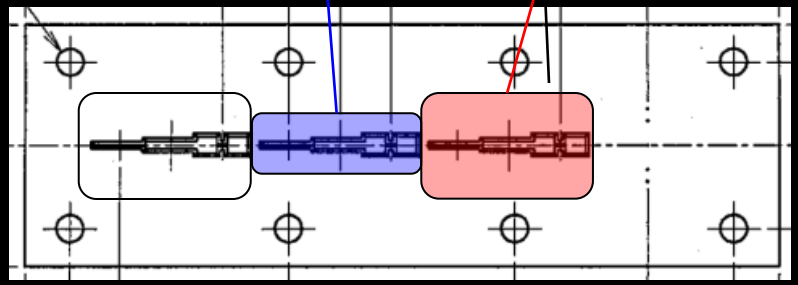
Filters (Two types)

- Two types of filters and blank (without filter).
  - CaF_2 t=3mm
  - Indium t=100nm
  - Blank (w.o. filter)
- Rejection of geocoronal Lyman- α (121.6nm)
- 3 × 3 = 9 types of slits.

Lyman- α 121.6nm



Total sensitivity with various filters.

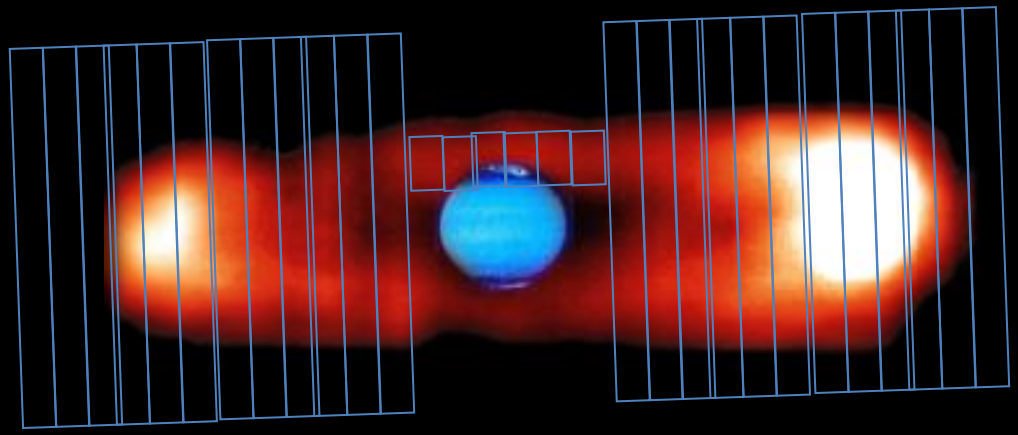


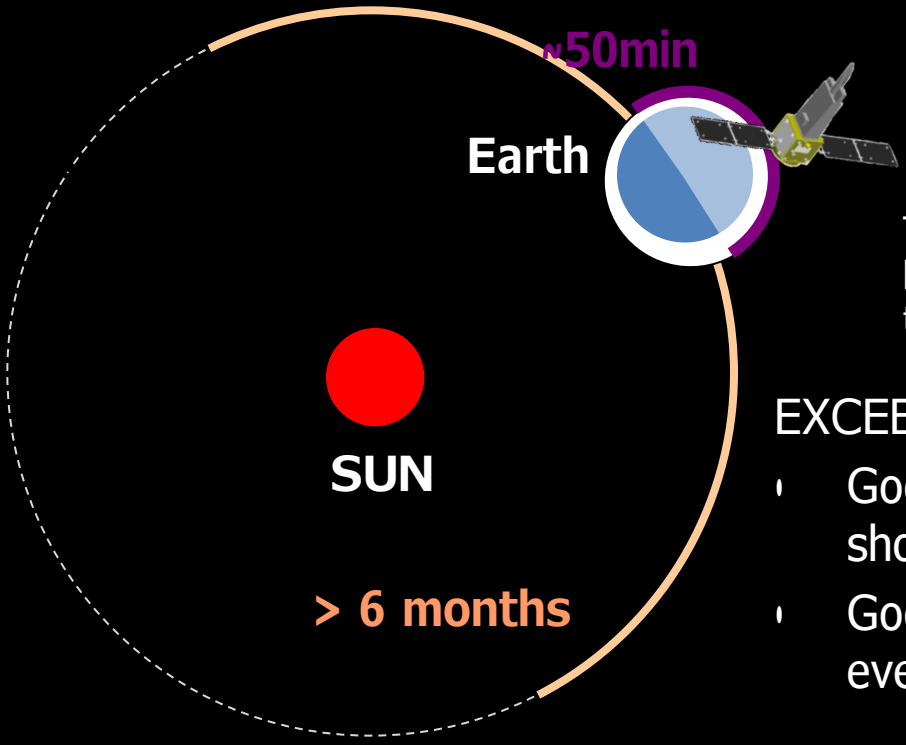
Slits and filters.

The approach for Io plasma torus I

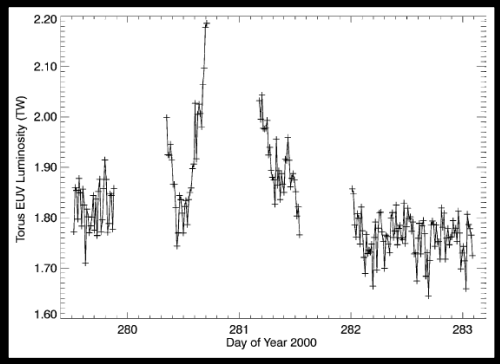
- The observation window for Jupiter is longer than 6 months.
- 50 minutes observation is available for every orbit.
- The dumbbell shaped slit takes both the dawn and dusk torus and aurora spectra.

Dumbbell slit





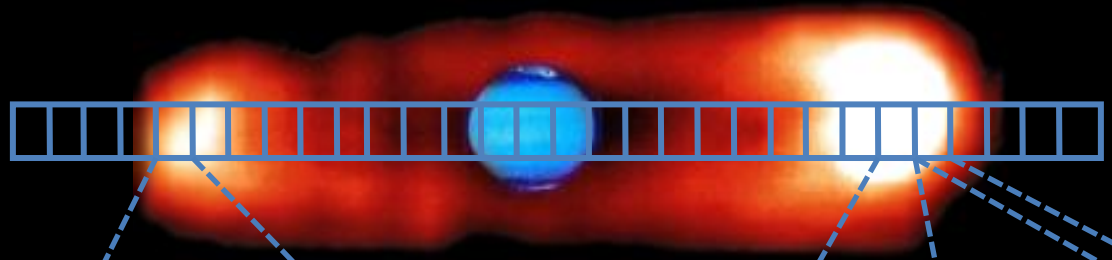
The sudden increase of EUV luminosity from the Io plasma torus. (Steffl et al. 2004a)



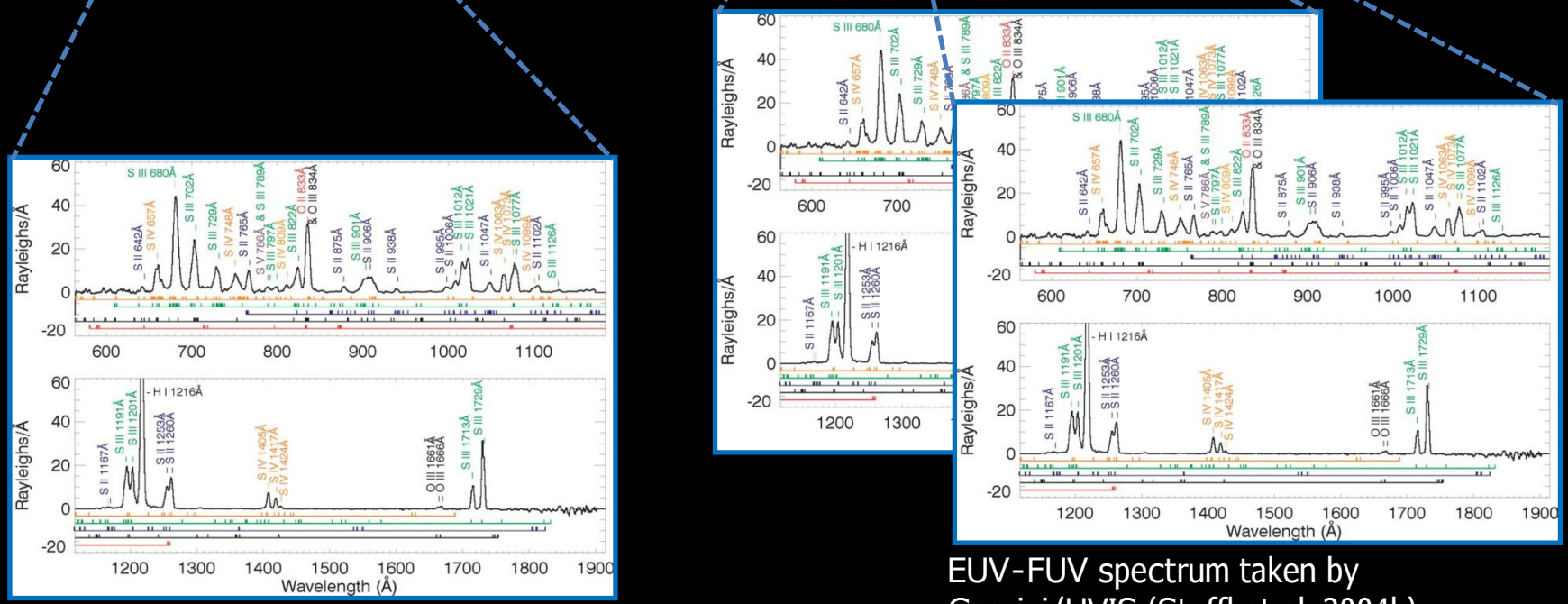
EXCEED has

- Good time resolution enough to investigate short time scale (1min~50min) phenomena.
- Good time coverage to encounter sporadic events and to find their statistical properties.

The approach for Io plasma torus II



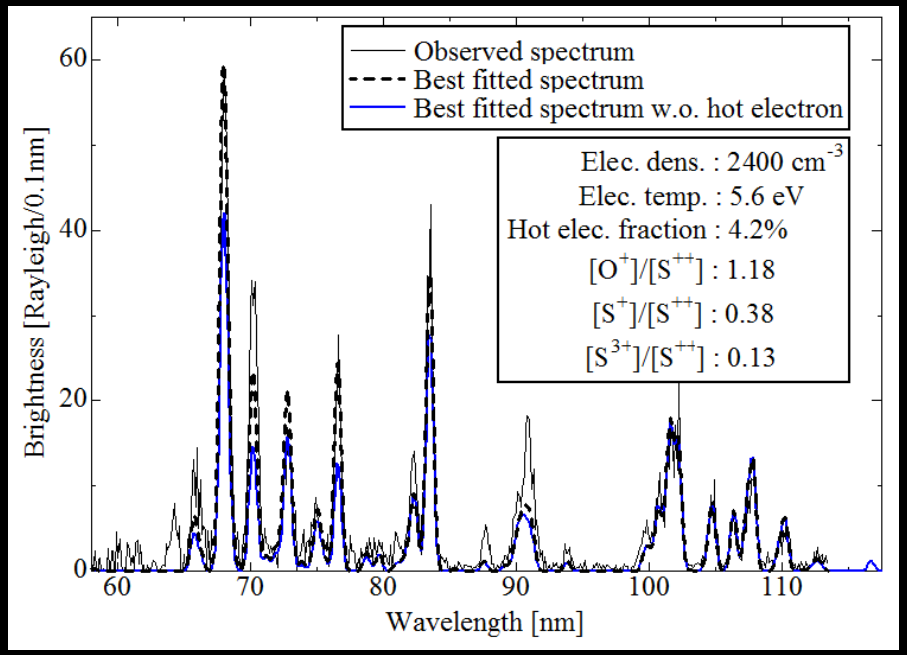
- EXCEED will take spatially resolved spectra
- The spectral resolution of 4~5 Å FWHM.



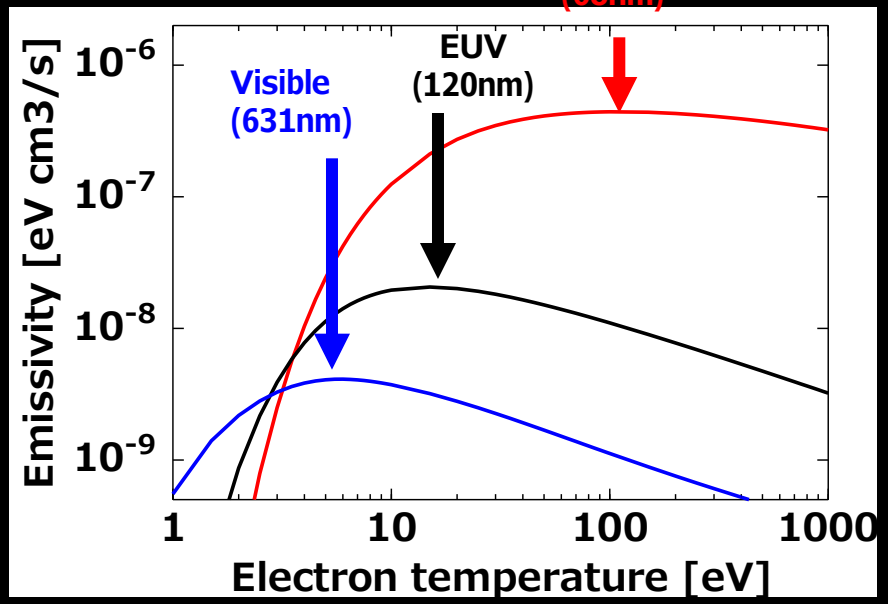
EUV-FUV spectrum taken by Cassini/UVIS (Steffl et al. 2004b)

EUV observation of Io tours

- Emission line intensities from the Io torus depend on the ambient electron temperature.
- The EUV spectra tell us not only the ion composition but also the electron temperature.

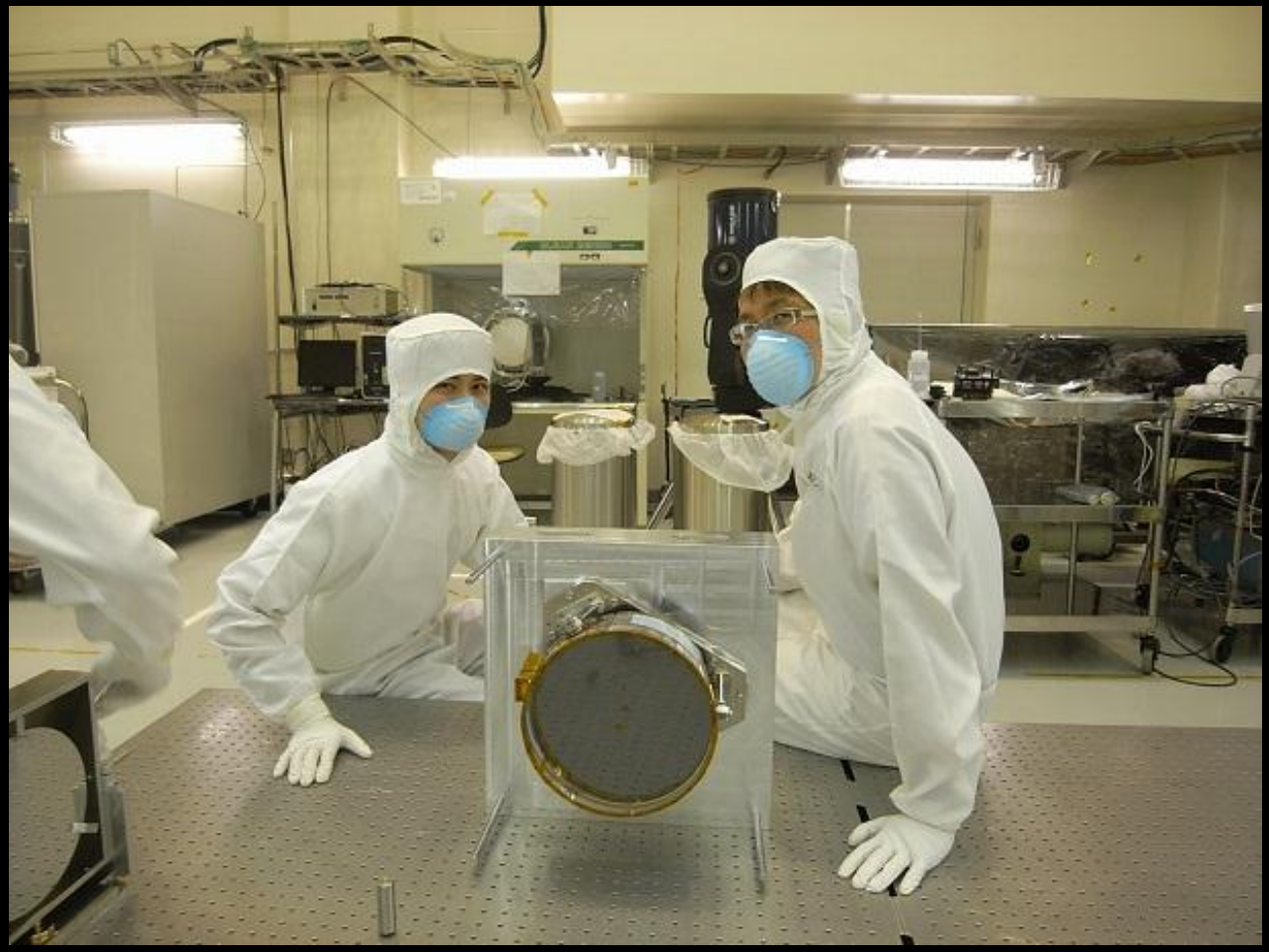


EUV spectrum taken by Cassini and model spectra. (Yoshioka et al. 2011)



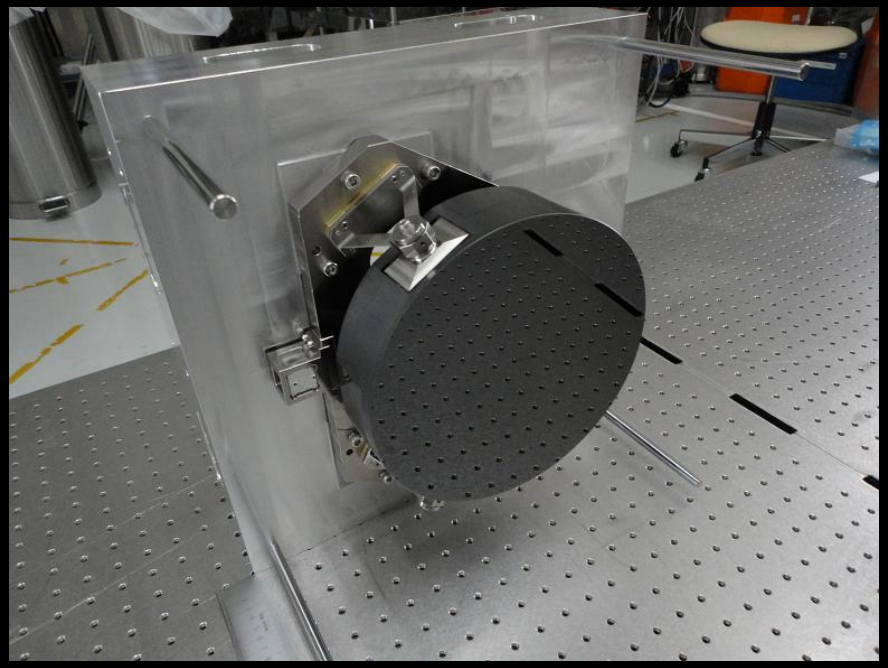
S^{++} Emissivity through the electron impact excitation. The calculation use the CHIANTI database.

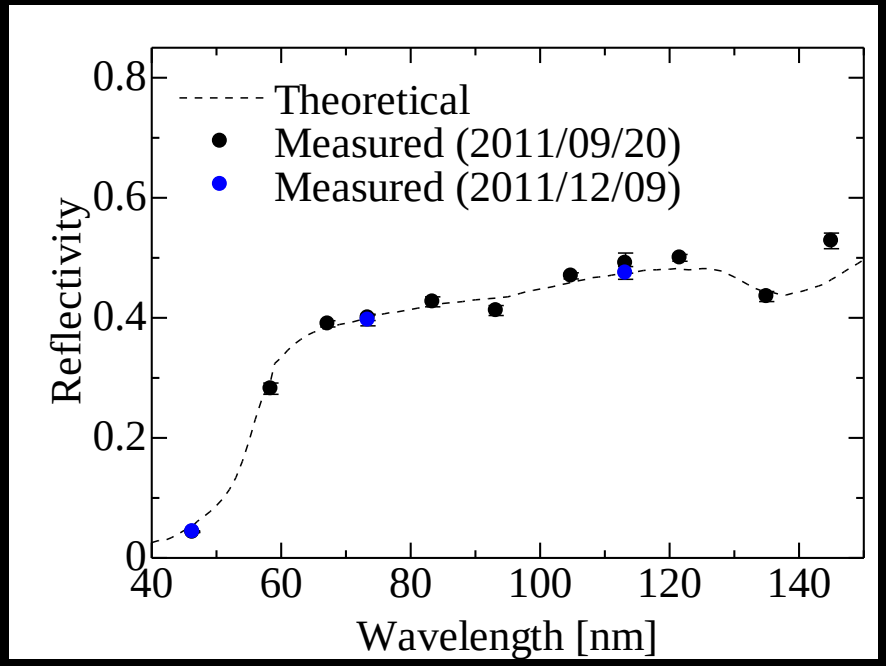
Current status of optical calibration (evaluation)



Optical alignment test for FM entrance mirror (June. 2011)

Entrance mirror: reflectance (FM)

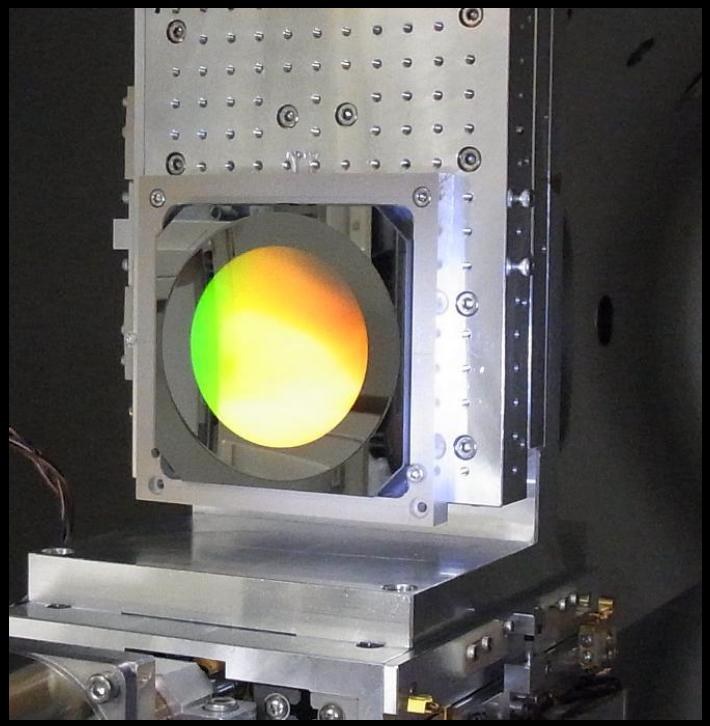


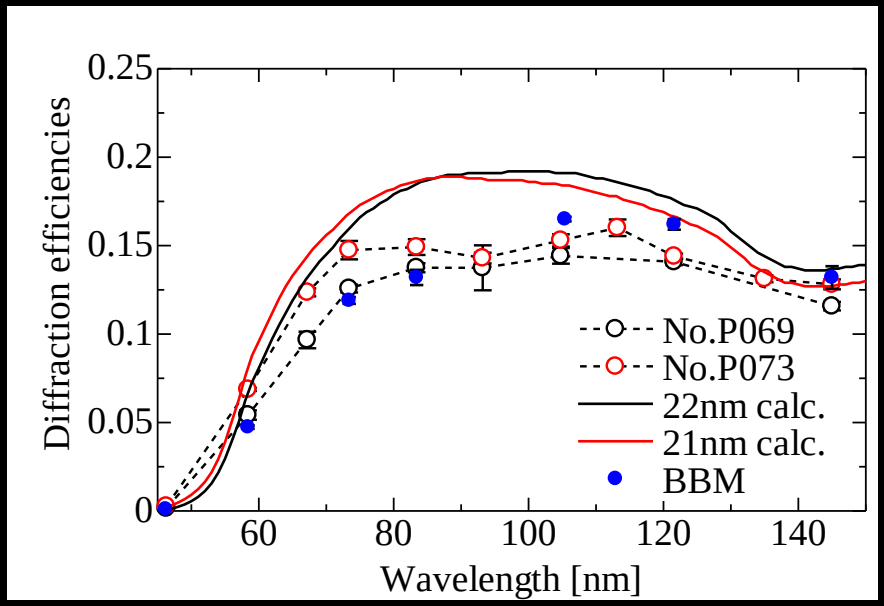


The reflectance of FM mirror

- The reflectivity of the entrance mirror is good. (same as theoretical one)
- There are no reflectance degradation during the 1st calibration campaign.

Grating: diffraction efficiency (FM)

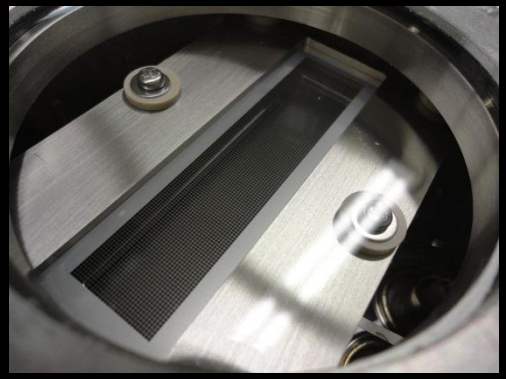


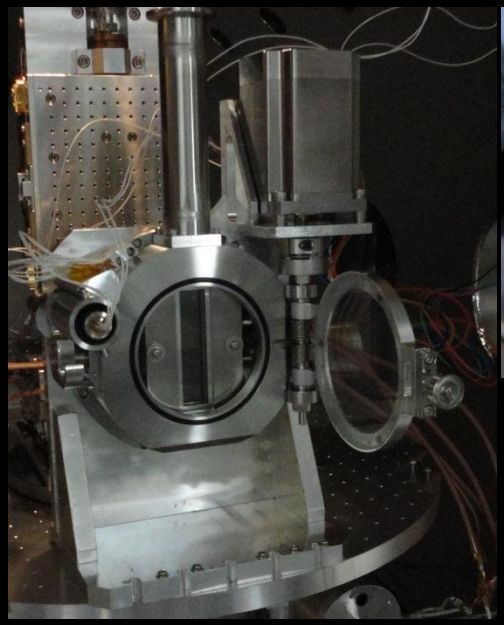


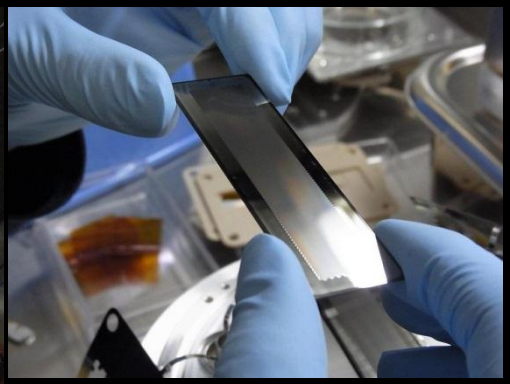
The reflectance of FM grating

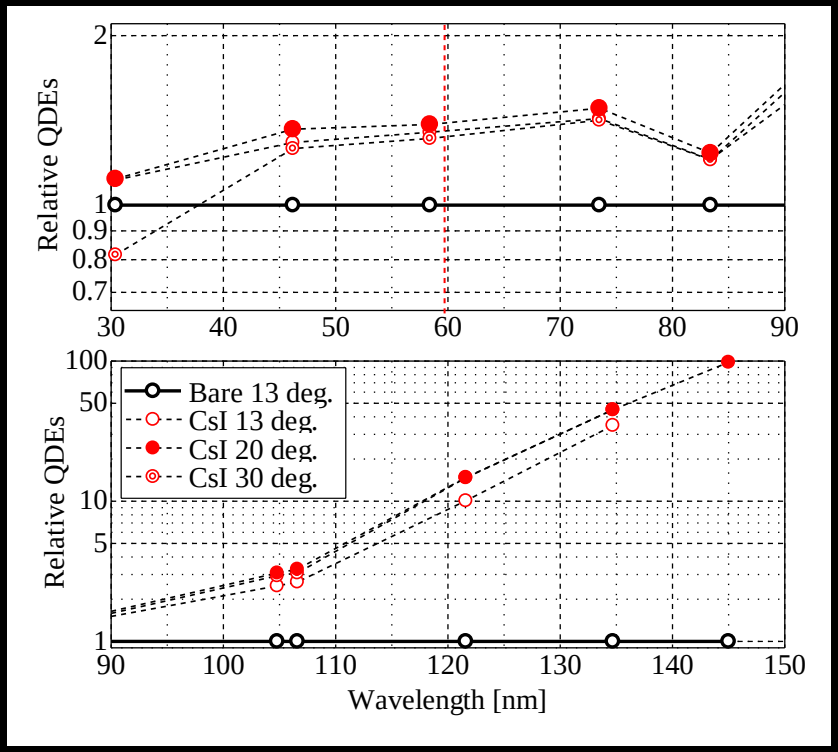
- The diffraction efficiencies of the two gratings are same as BBM.
- No. P073 shows higher efficiency than P069. Therefore, P073 is used as FM.

MCP: Quantum detection efficiency (BBM)





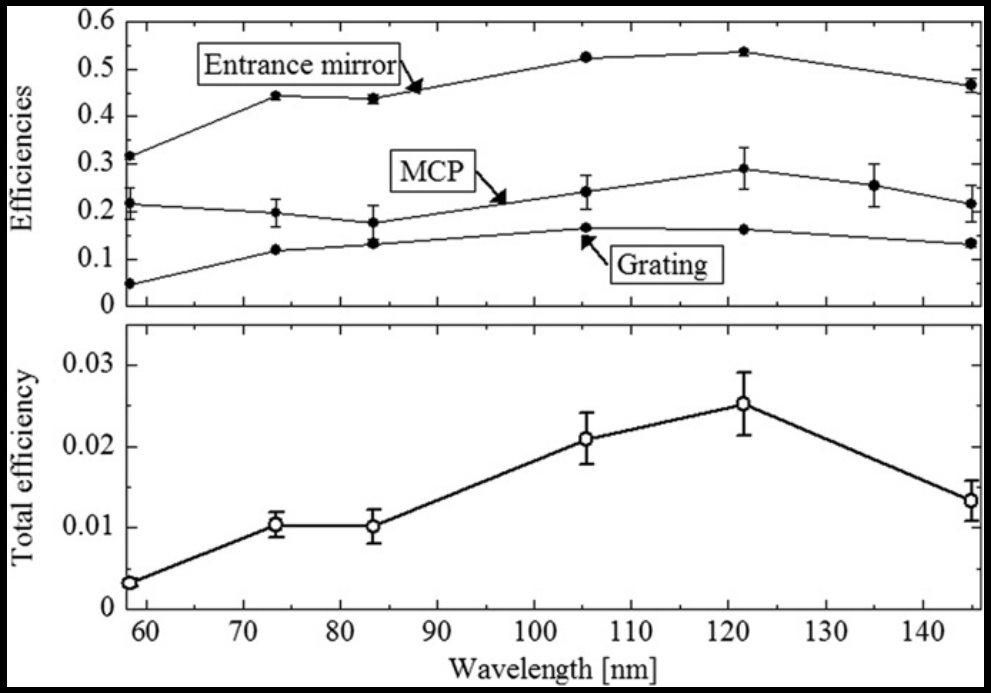




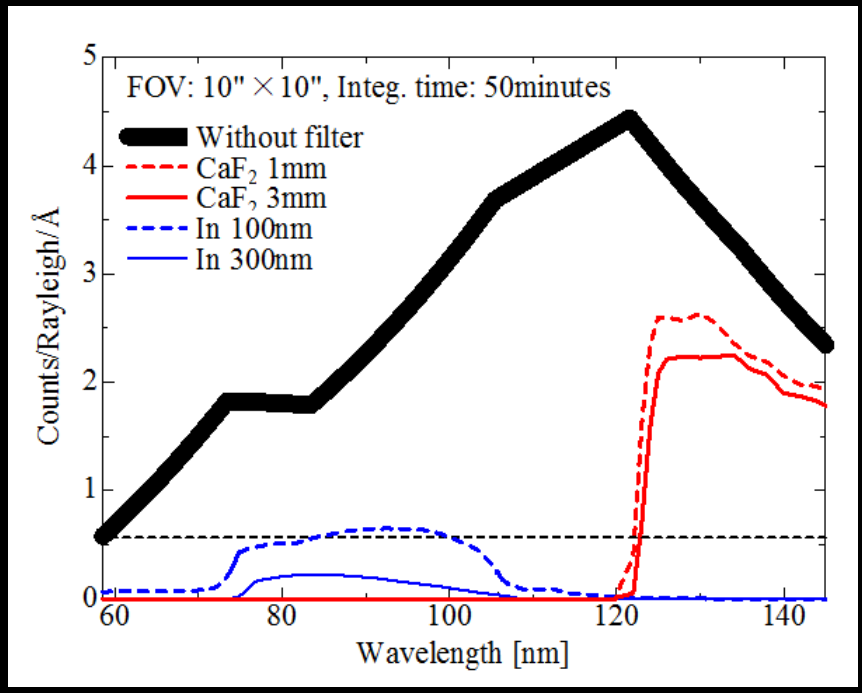
	30-84 nm	105-135 nm
CsI / Bare	**1.5 ~ 2**	**5 ~ 100**

- CsI photocathode is deposited on the MCP surface
- The detection efficiency increase x1.5~x100
- The MCP should be kept under vacuum until the launch.

Total sensitivity (with/without filters)

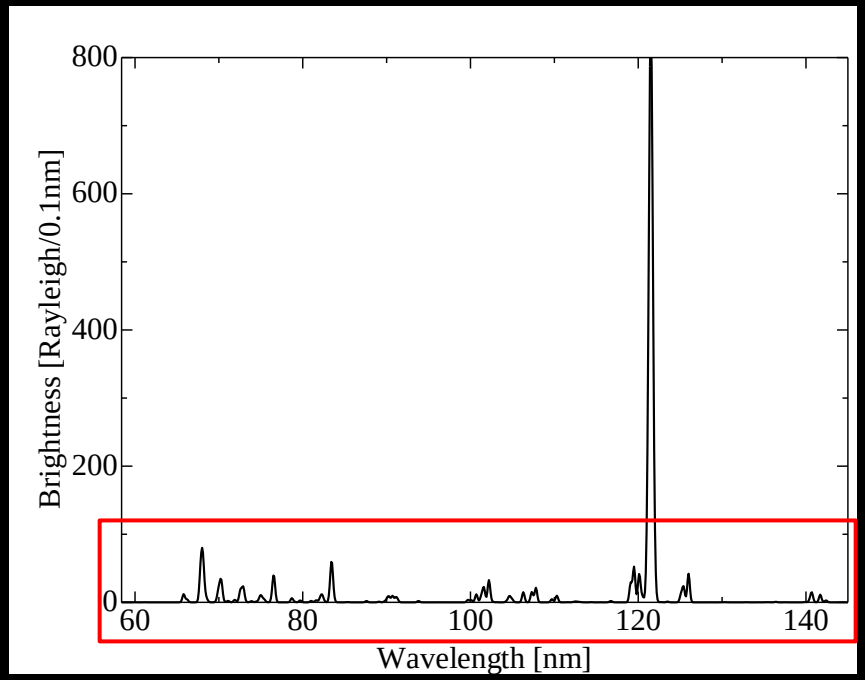


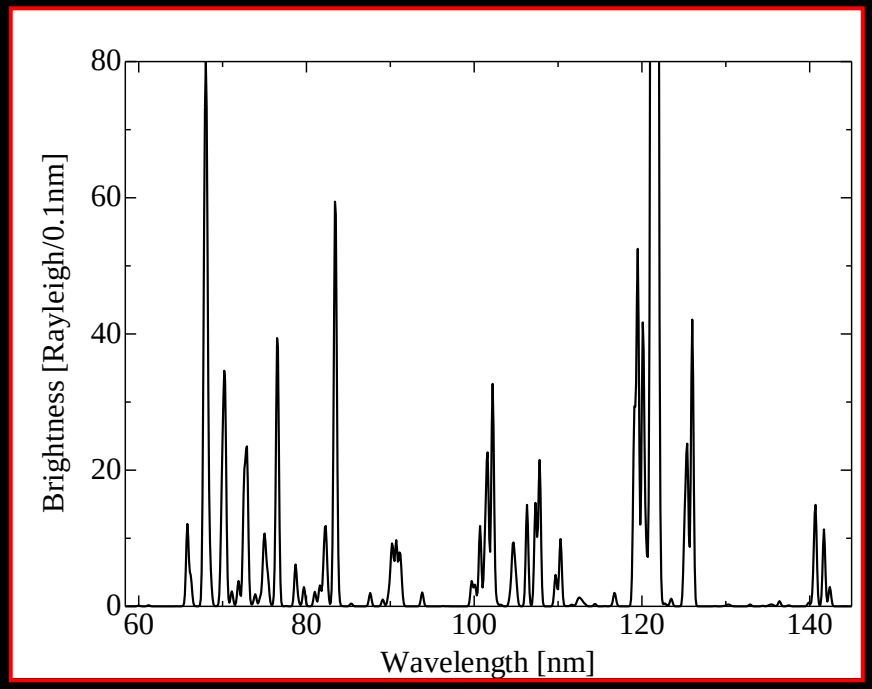
Total sensitivity of EXCEED (Yoshioka et al., 2012)



The sensitivity of EXCEED. (The integration time is assumed as 50 minutes. The field of view is assumed 10″ × 10″)

The expected spectrum from Io torus and geocorona

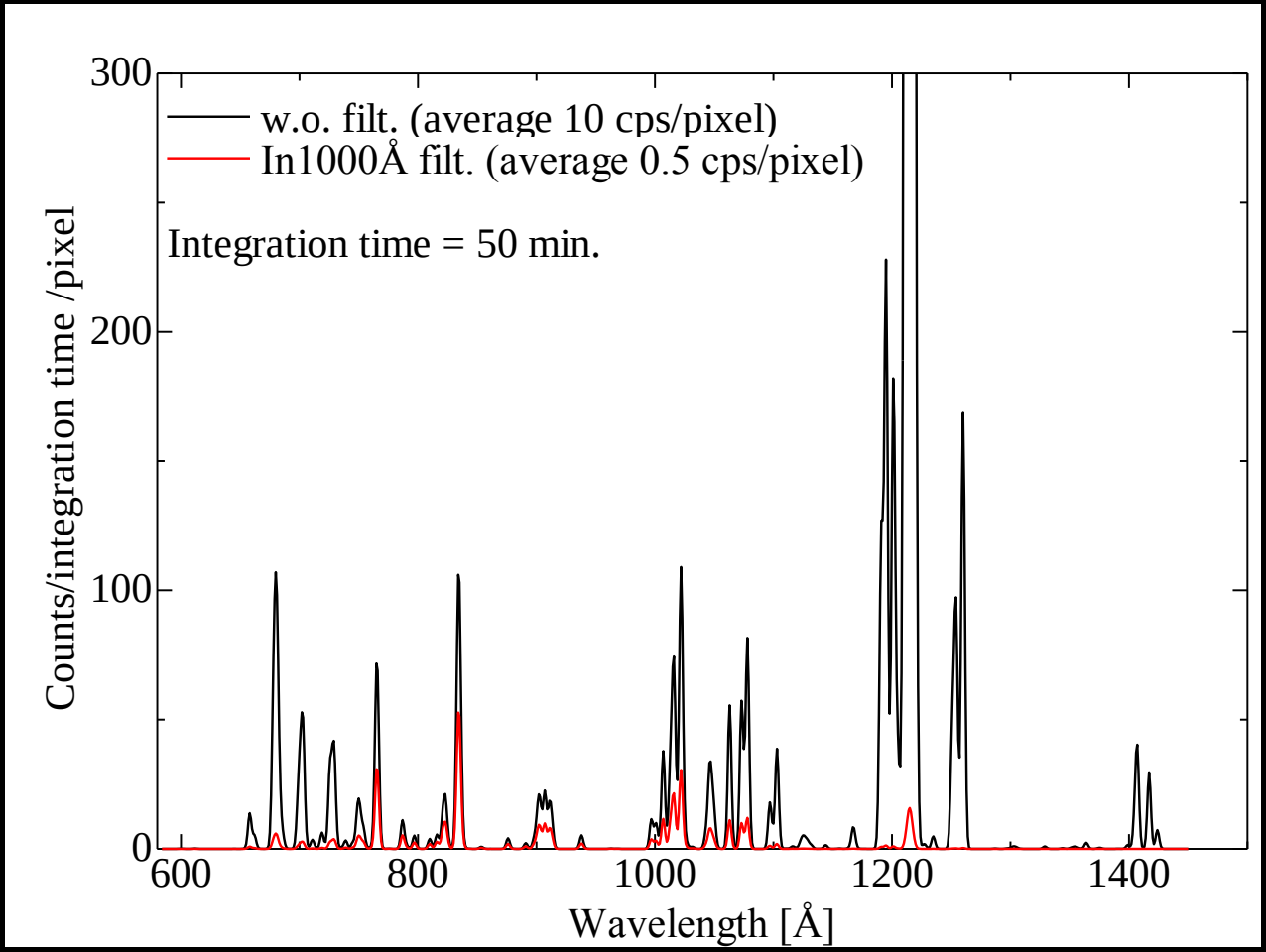




Expected spectrum from Io plasma torus.

- The ion composition are derived from Cassini observation (Steffl et al., 2004 etc.)
- The spectral resolution is assumed 5 Å FWHM

Model spectra (with and without Indium filter)

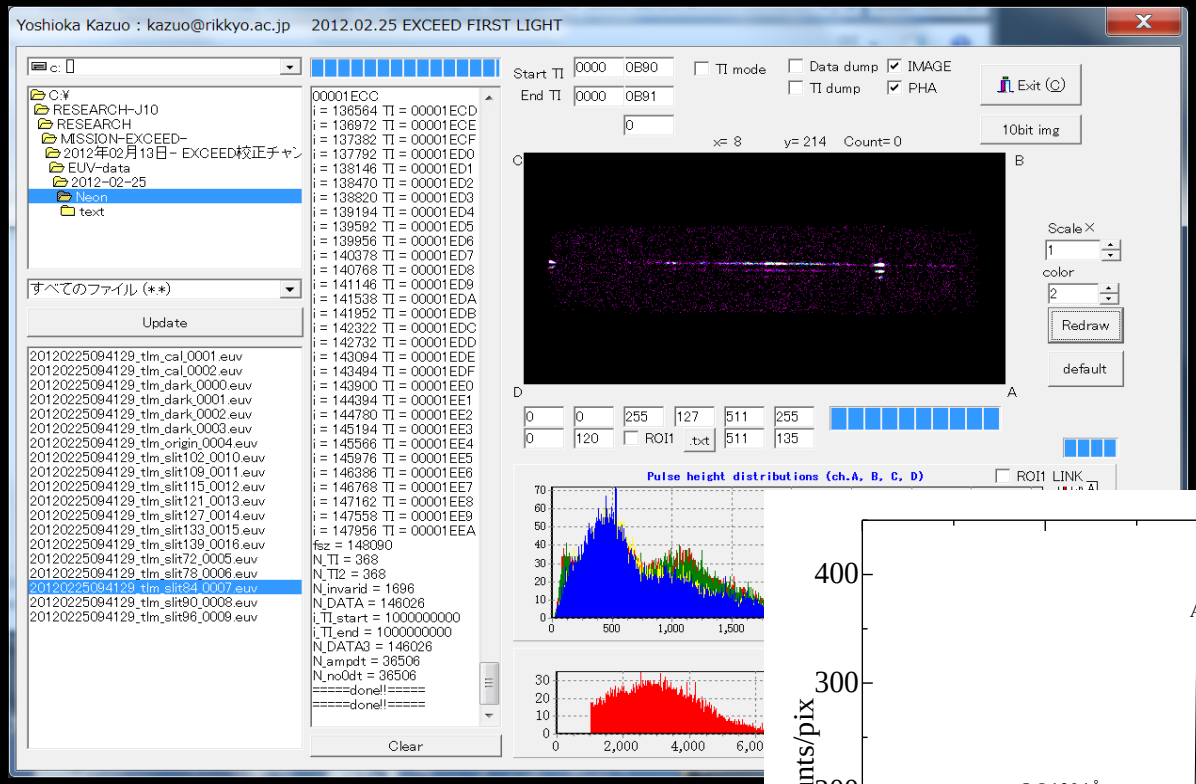


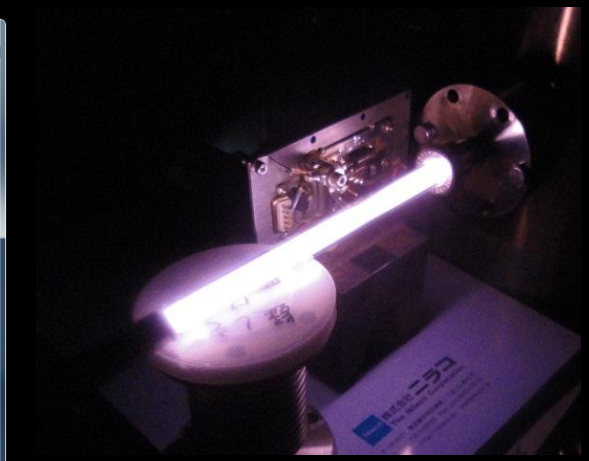
Expected spectrum from Io plasma torus.
The FOV is set 10″x10″
The integration time is 50 minutes.

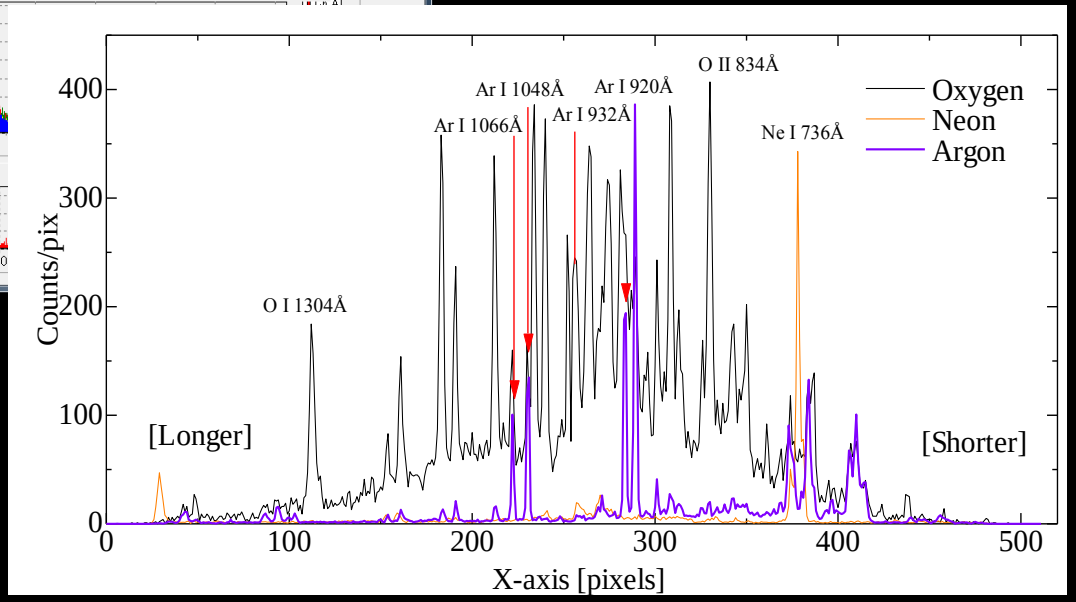
Summary and next steps

- EXCEED will observe the Io plasma torus for more than 6 months in series.
- The flight model of the entrance mirror, grating, filters have been evaluated. (good!)
- The overall optical alignment is now under evaluation.
- The quantum detection efficiency of FM detector should be evaluated.

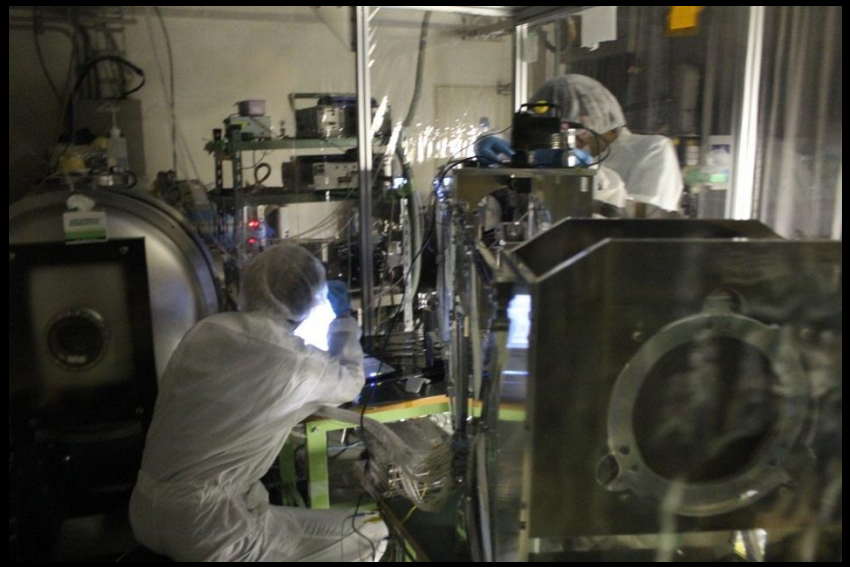
First EUV spectrum of EXCEED flight model







EXCEED first EUV spectra
Neon, Argon, Oxygen, Nitrogen….



Vacuum chamber for FM calibration.

Thank you for your attention.