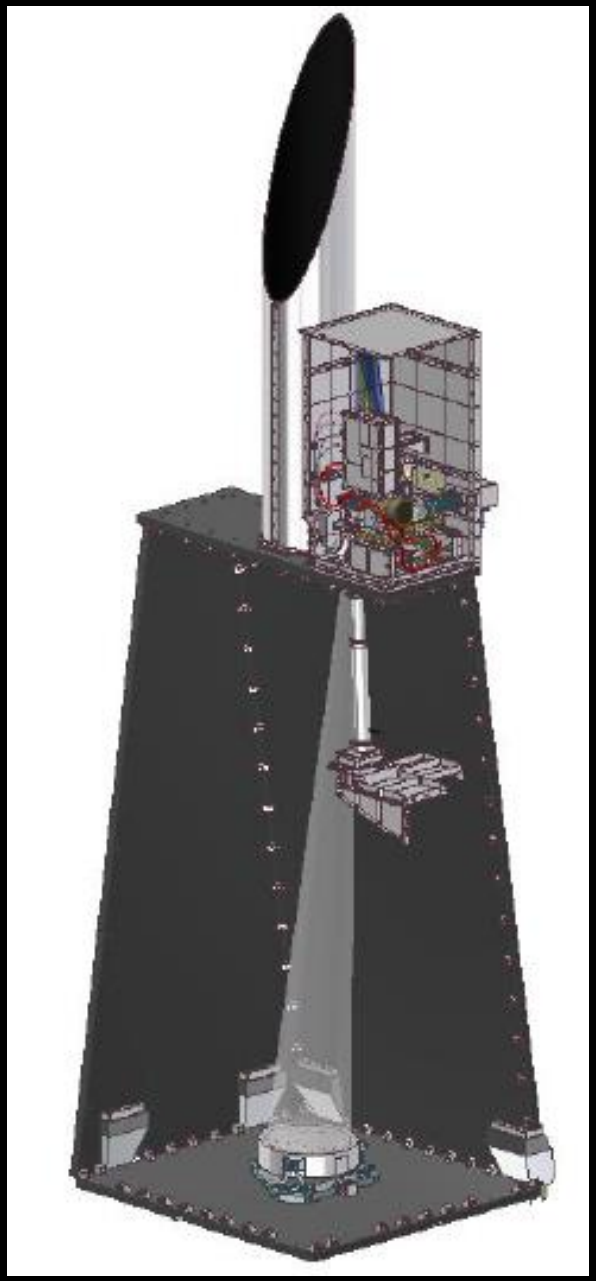
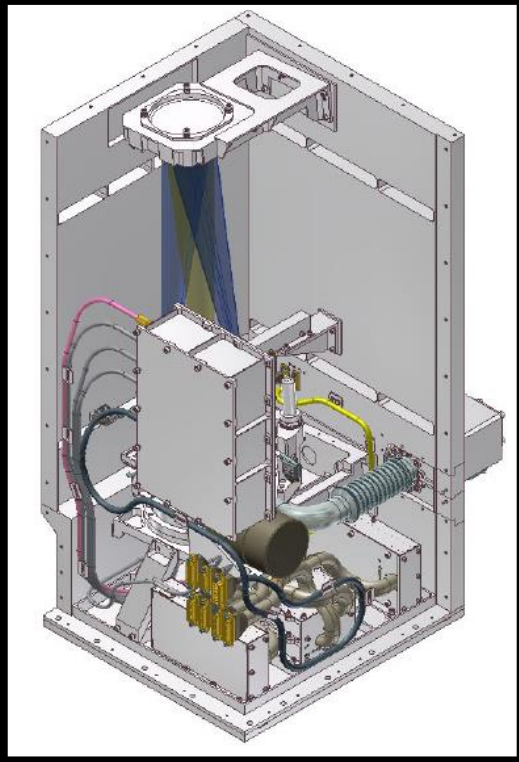
The Performance of the EUV Spectroscope (EXCEED) Onboard the SPRINT-A Mission

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

EXCEED

- The observing module contains
  - Entrance mirror
  - Spectrometer
  - Slit with filters
  - Grating
  - EUV detector
  - Light trap
  - Target finding camera
- Total weight : 99kg



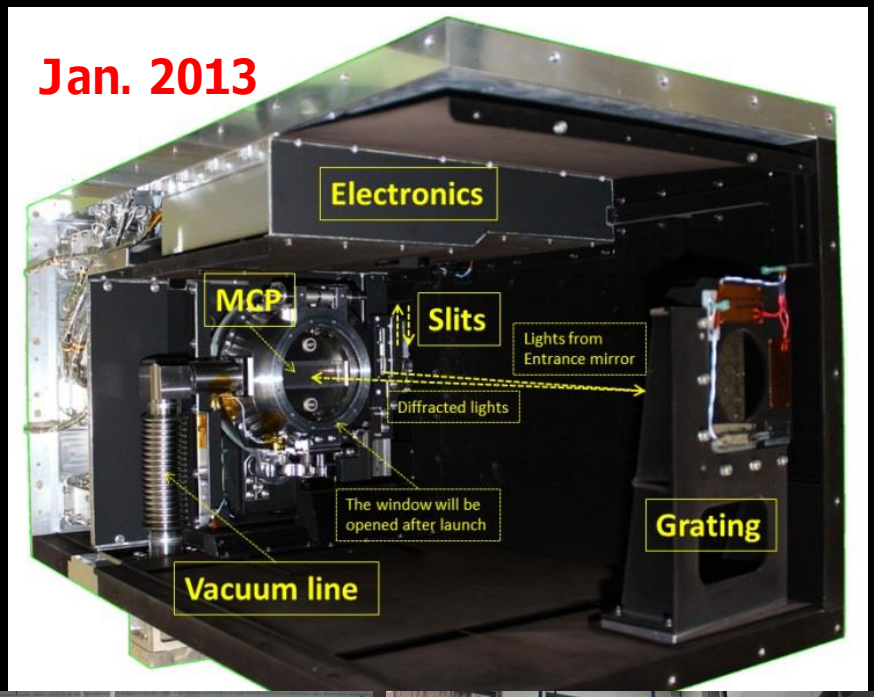


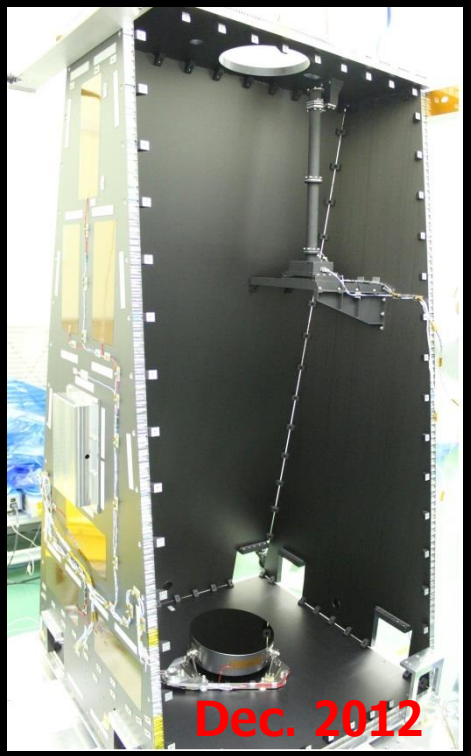
(↑) The inner part of the EUV spectrometer

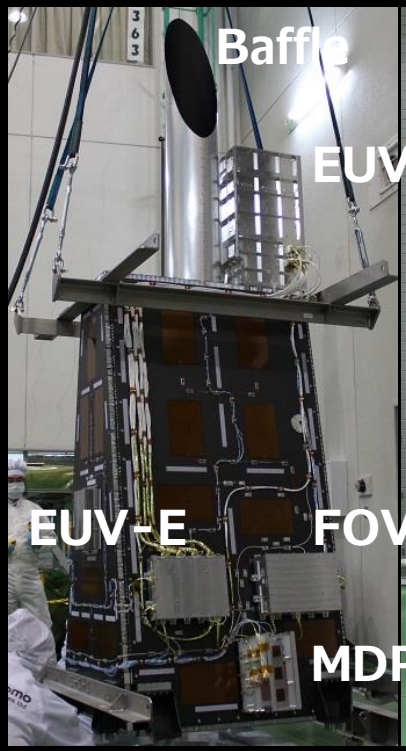
(←) The schematics of the EXCEED instrument (without bus system)

EXCEED current status

- The assembly of the spectrometer part is completed in last January.
- The main body has been constructed.
- Environmental tests have been done.
- EXCEED is integrated on the bus module ! → SPRINT-A
- SPRINT-A is under final environmental test at ISAS

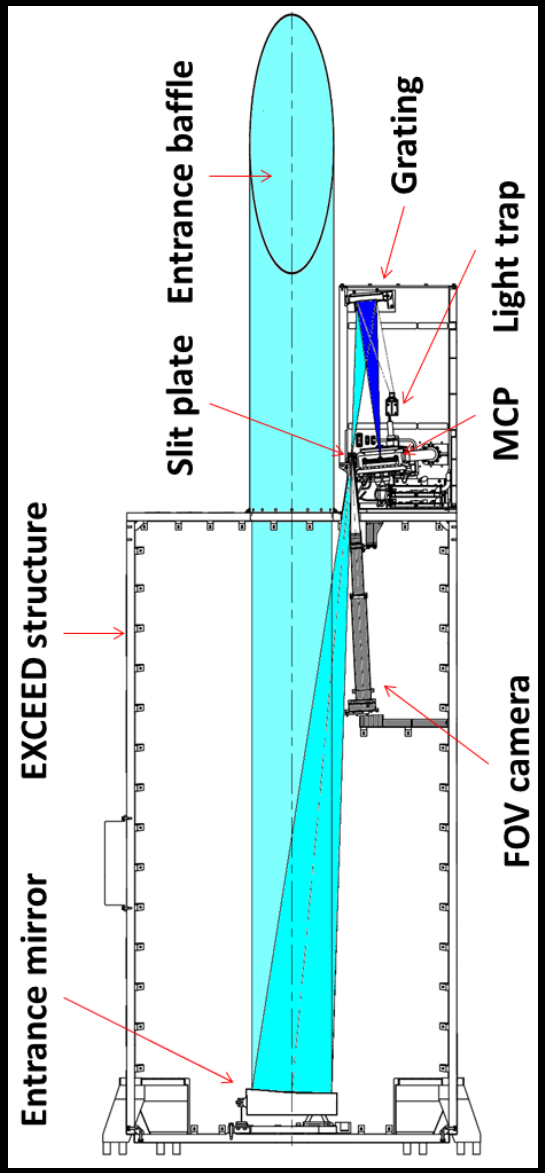




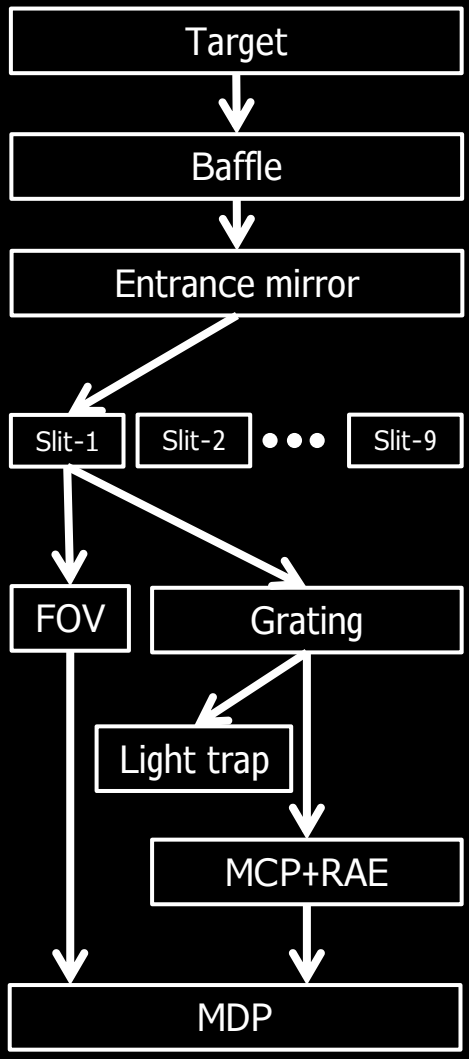


EXCEED optical layout

- **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

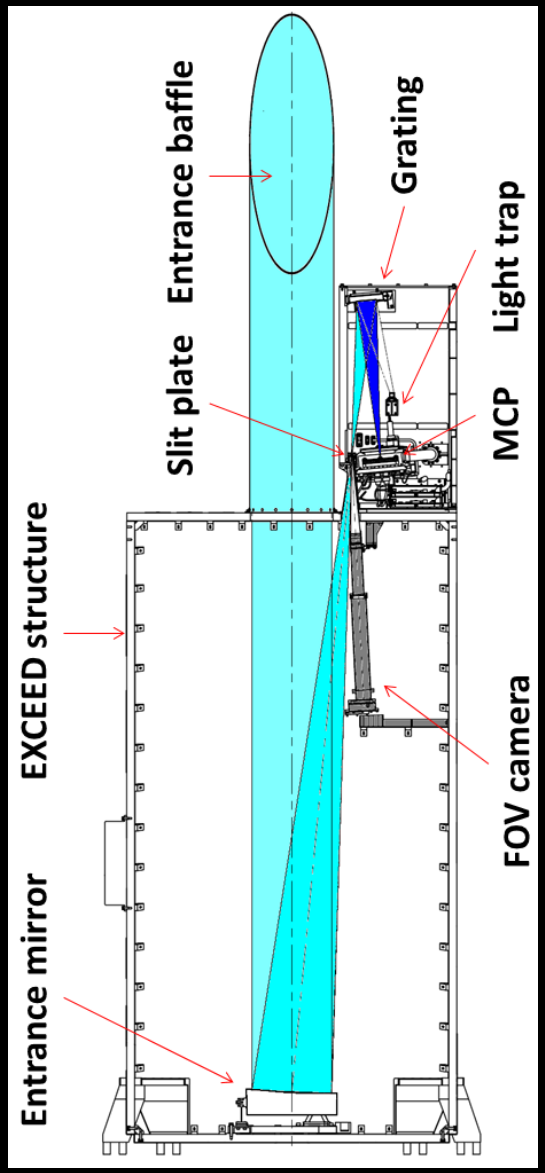


The optical layout of EXCEED

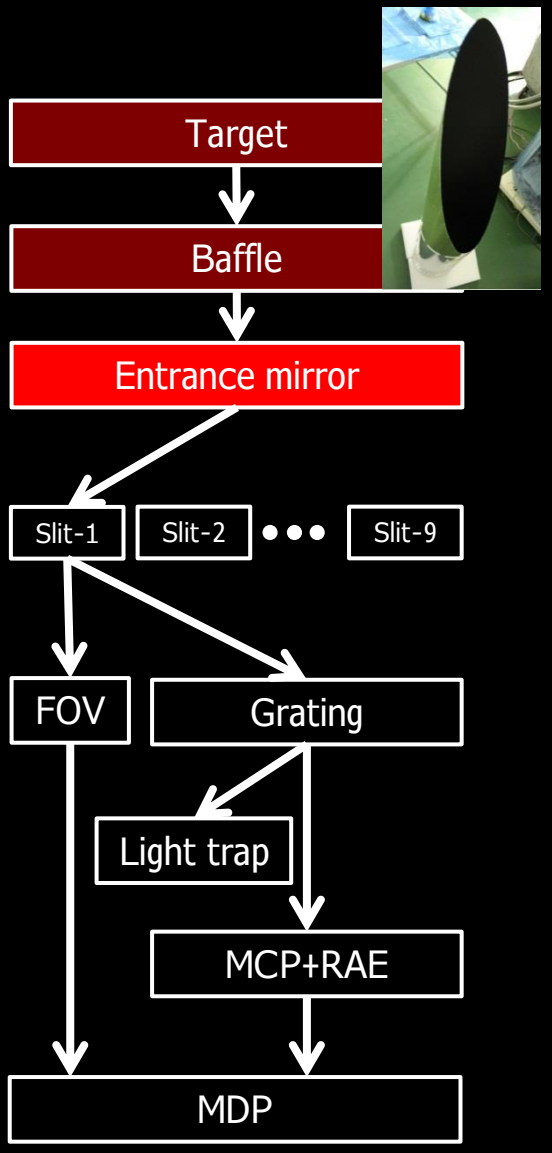


EXCEED/Entrance mirror

- **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



The optical layout of EXCEED



EXCEED/Entrance mirror

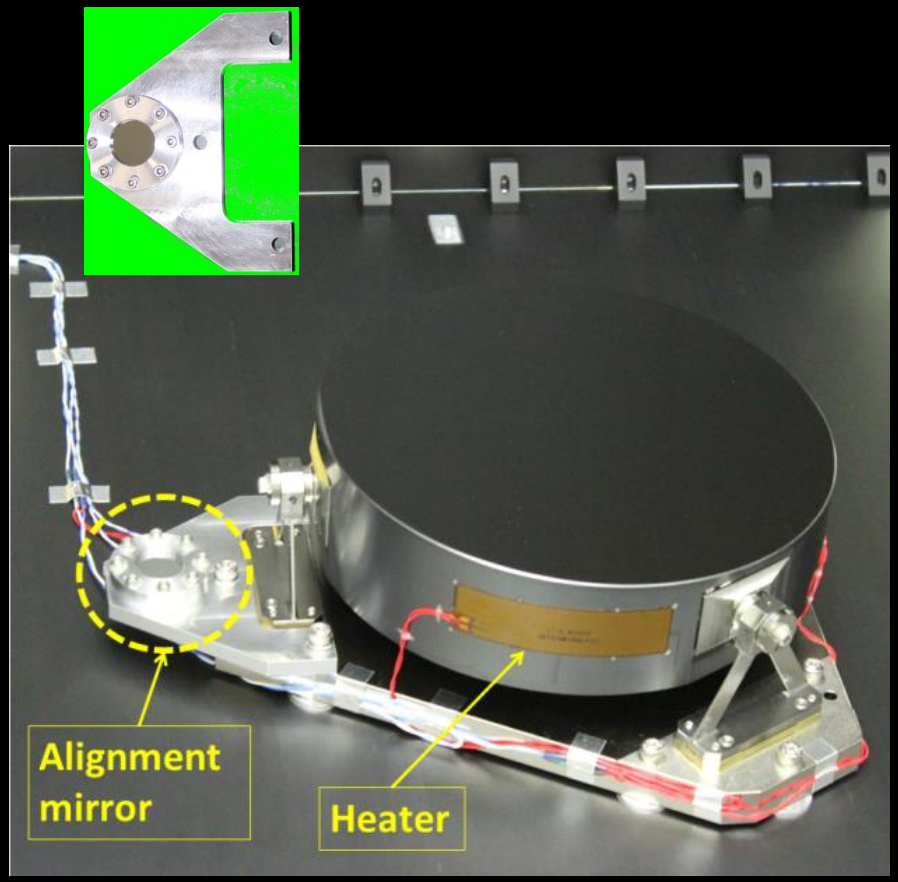
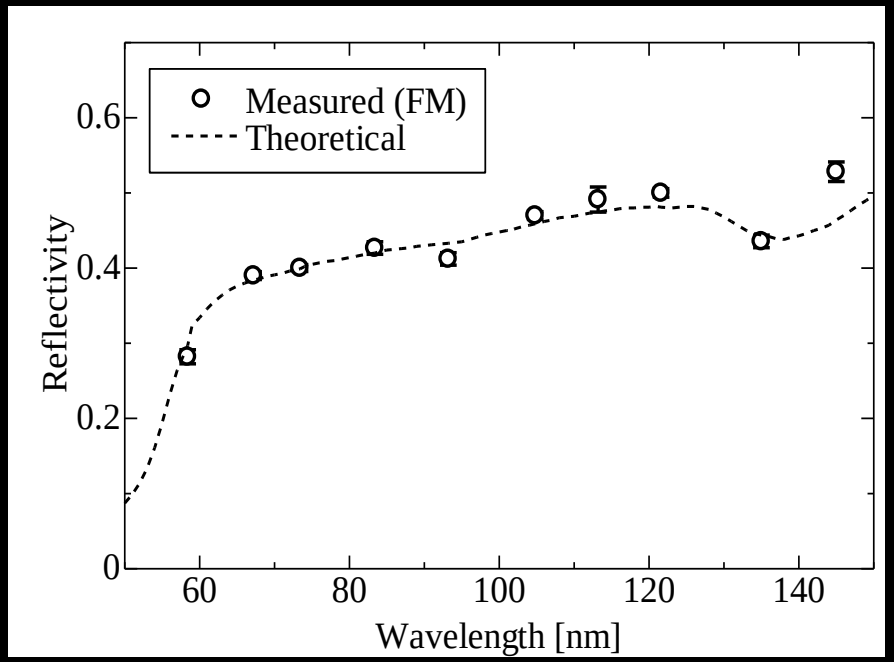


Photo of the entrance mirror with alignment mirror (FM)

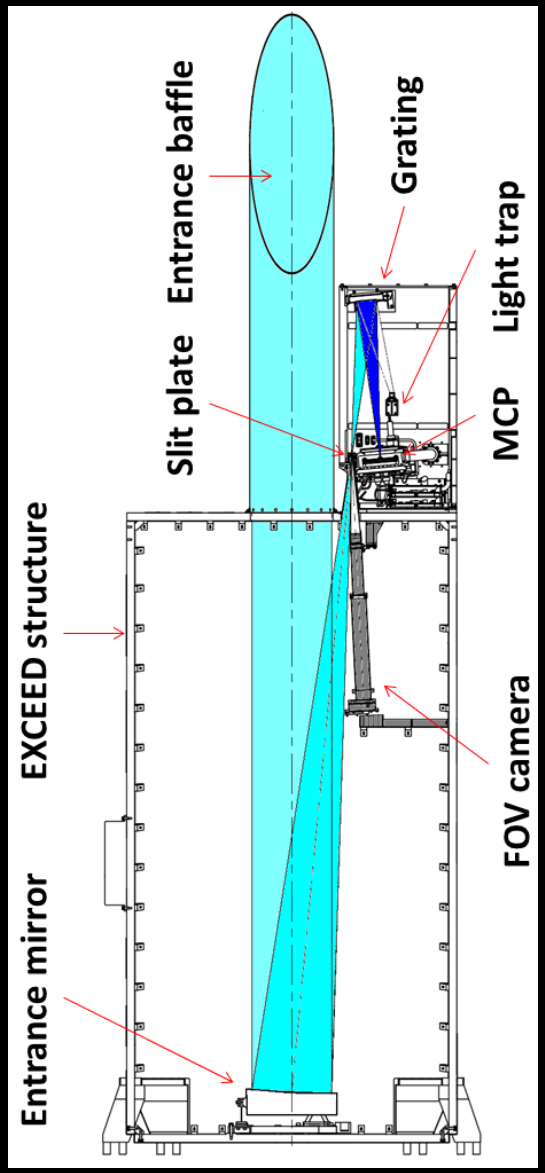


The reflectance of FM mirror

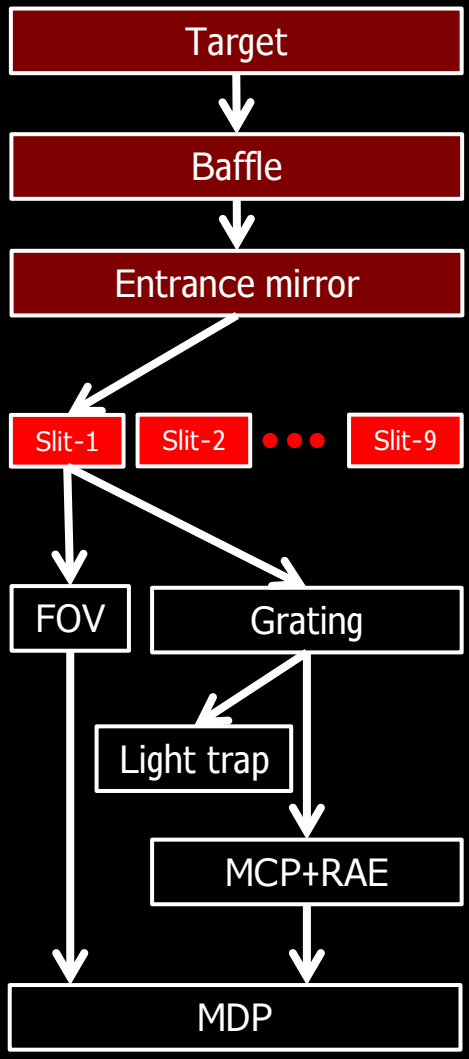
- The reflectivity of the entrance mirror has been evaluated successfully.
- The shape (optical performance) has been evaluated.

EXCEED/Slit with filters

- **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

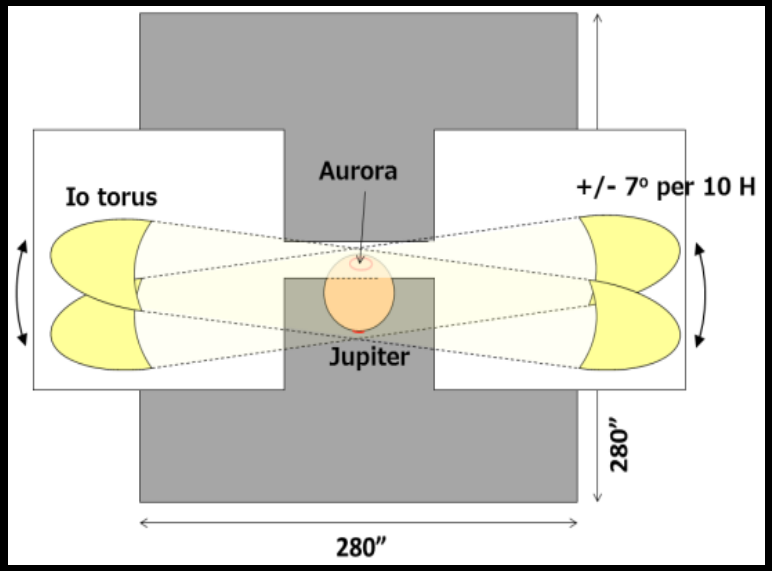


The optical layout of EXCEED

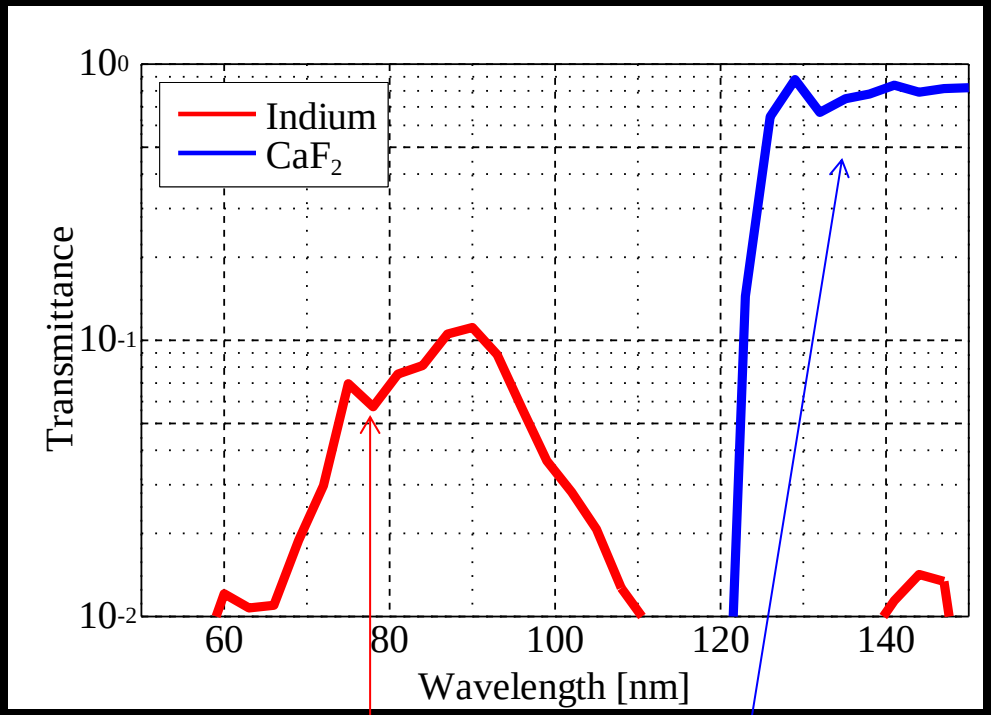


EXCEED/Slit with filters

- Three types of slit shape.
  - 10″
  - 60″
  - dumbbell
- Two types of filters and blank (without filter).
  - Blank (w.o. filter),
  - Indium t=100nm,
  - CaF_2 t=3mm
- 3 × 3 = 9 types of slits.



Io torus observation by dumbbell slit.



Transmittance of FM filters

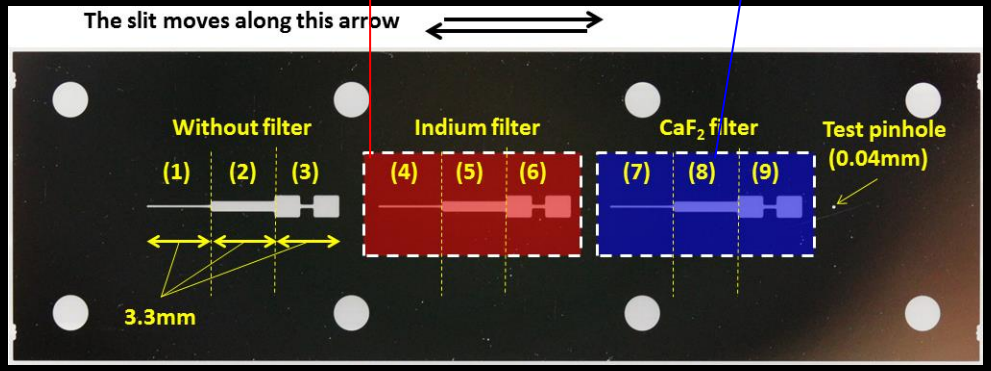
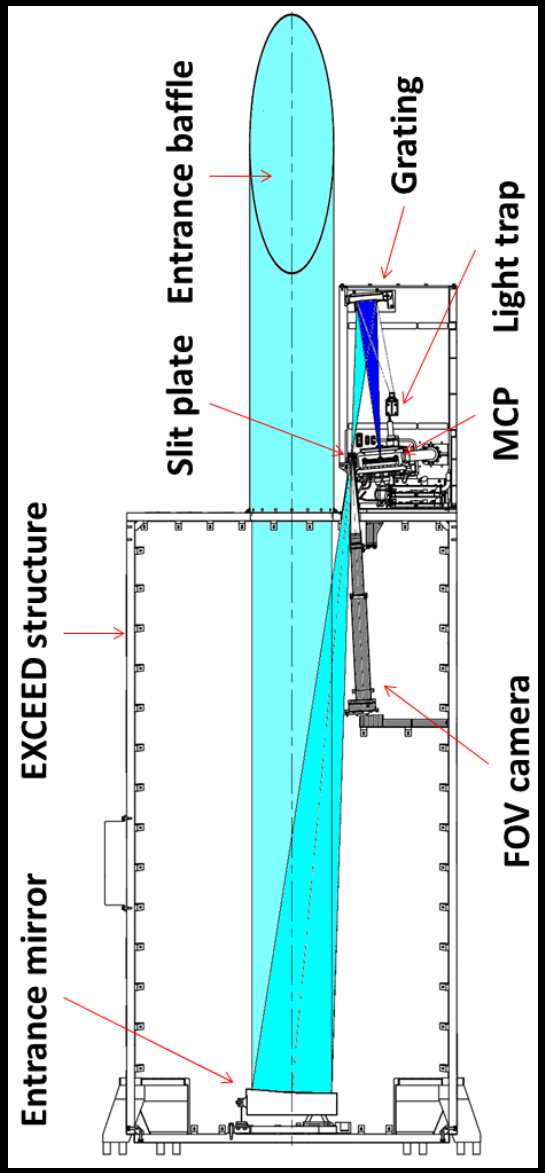


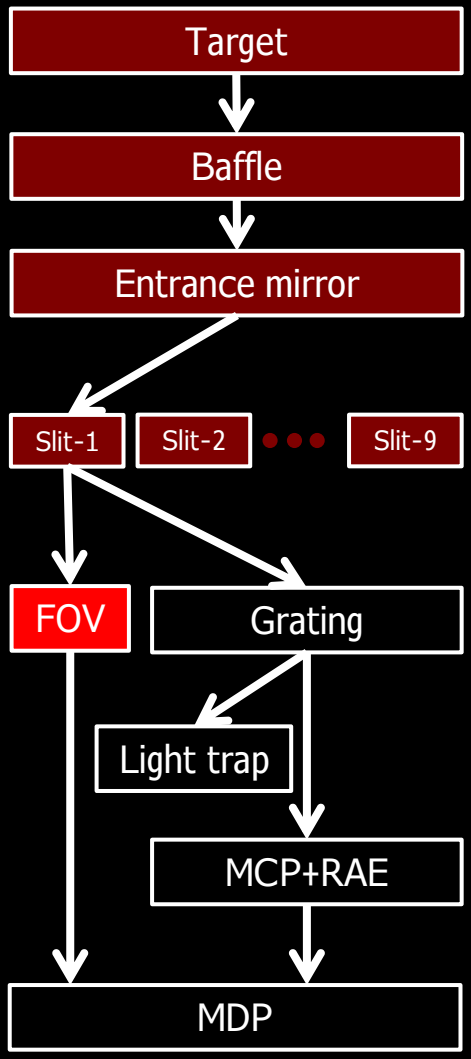
Photo of Slits plate (reflective surface)

EXCEED/FOV guiding camera

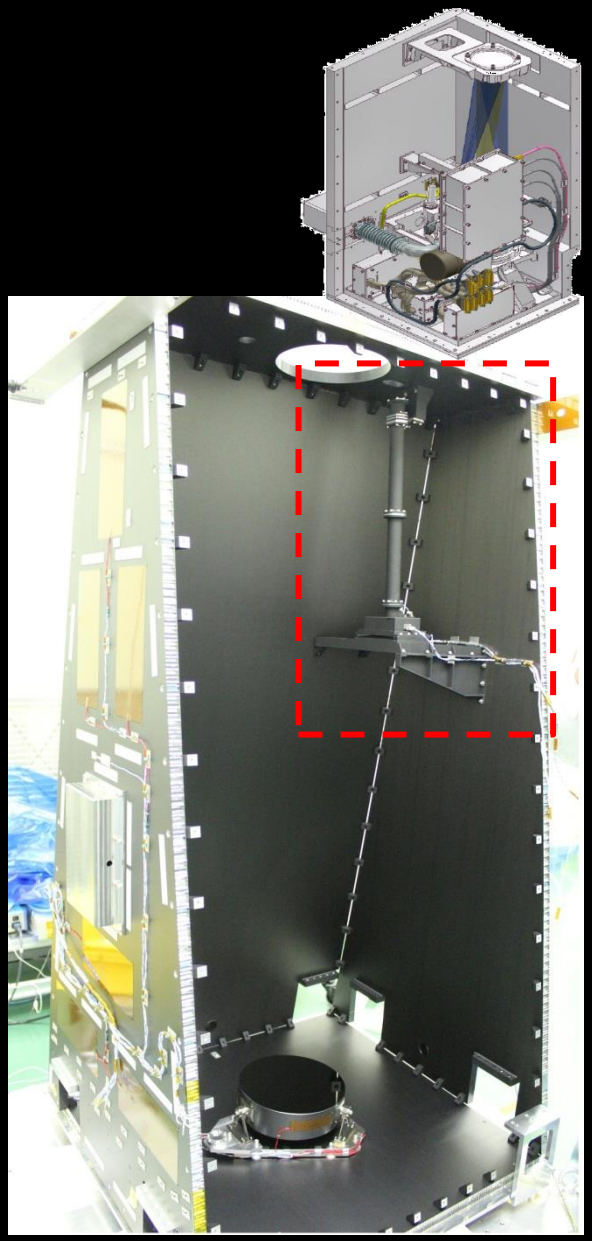
- **Entrance mirror**
  - An off-axis parabolic, CVD-SiC coated
- **Slit**
  - Three types of shape, and three types of filters
- **Grating**
  - Laminar type, toroidal, CVD-SiC coated
- **Photon detector**
  - Microchannel plate and Resistive anode

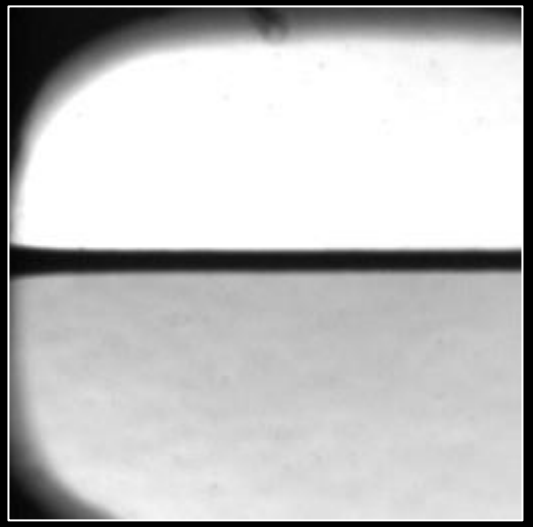


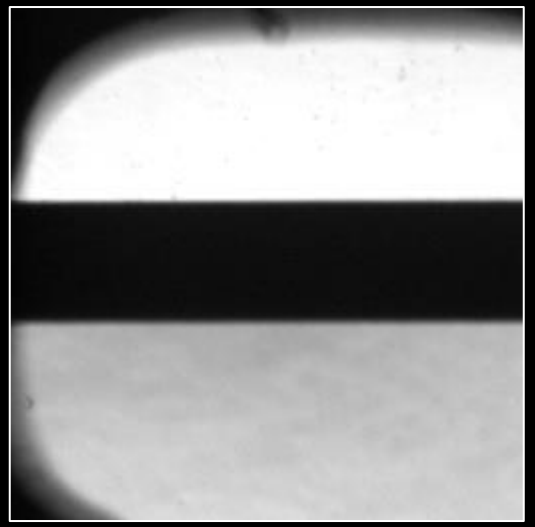
The optical layout of EXCEED

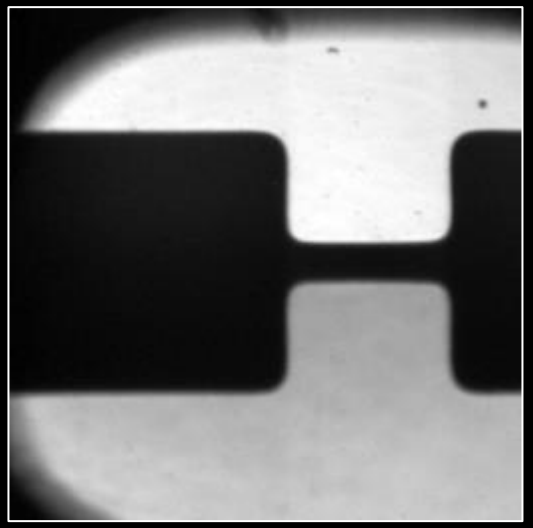


EXCEED/FOV guiding camera





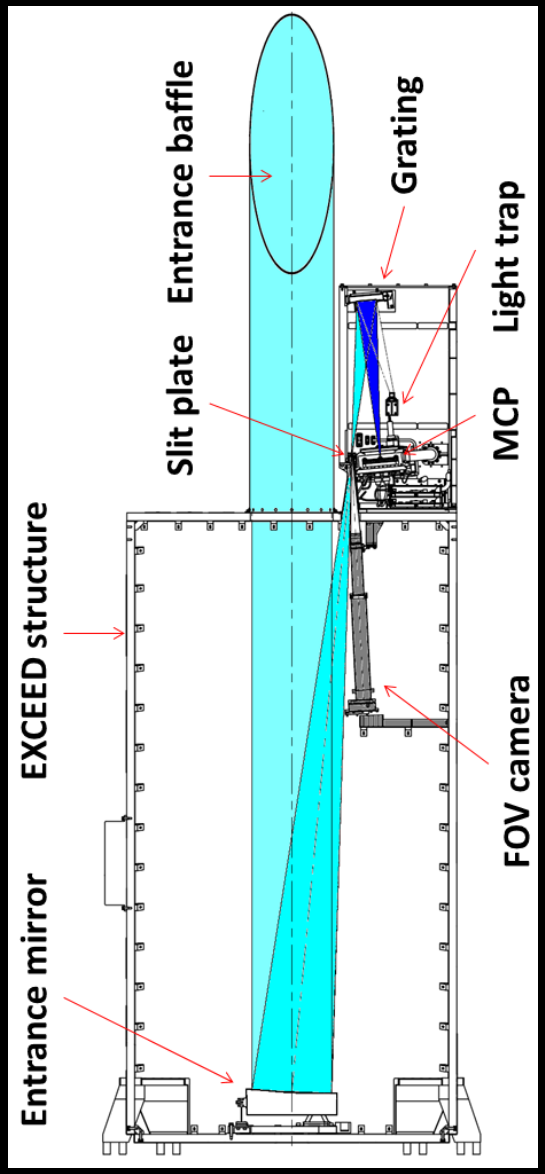




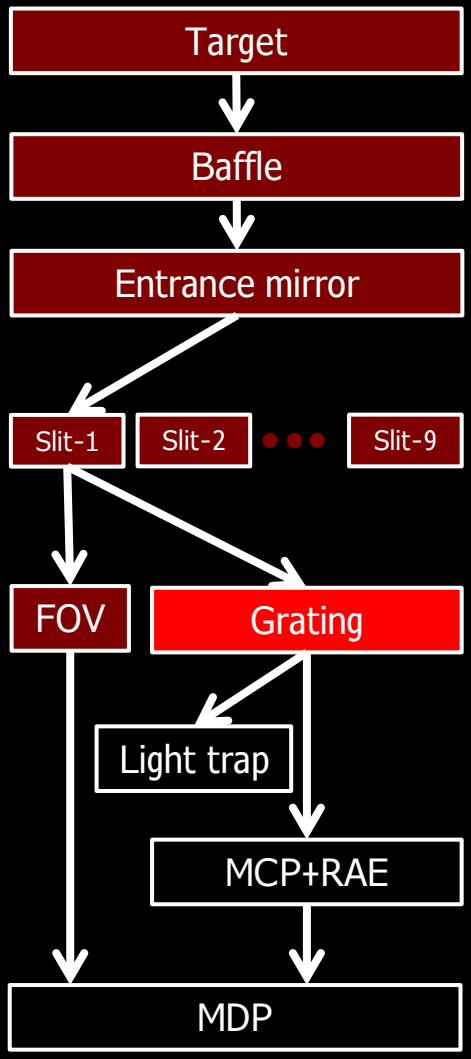
Slit images taken by FOV camera.
The focus is OK.

EXCEED/Grating

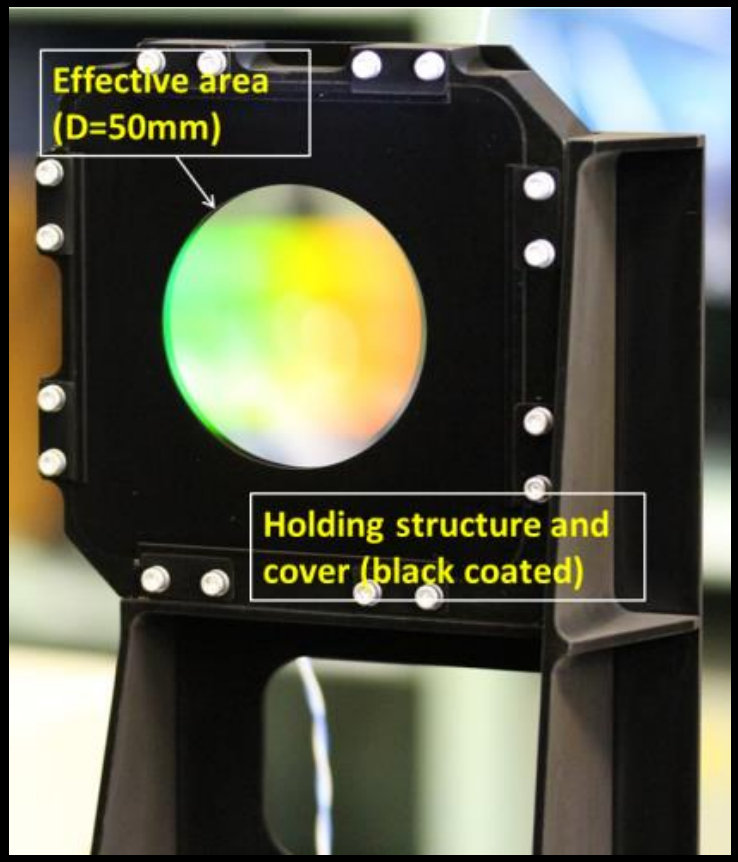
- **Entrance mirror**
  - An off-axis parabolic, CVD-SiC coated
- **Slit**
  - Three types of shape, and three types of filters
- **Grating**
  - Laminar type, toroidal, CVD-SiC coated
- **Photon detector**
  - Microchannel plate and Resistive anode

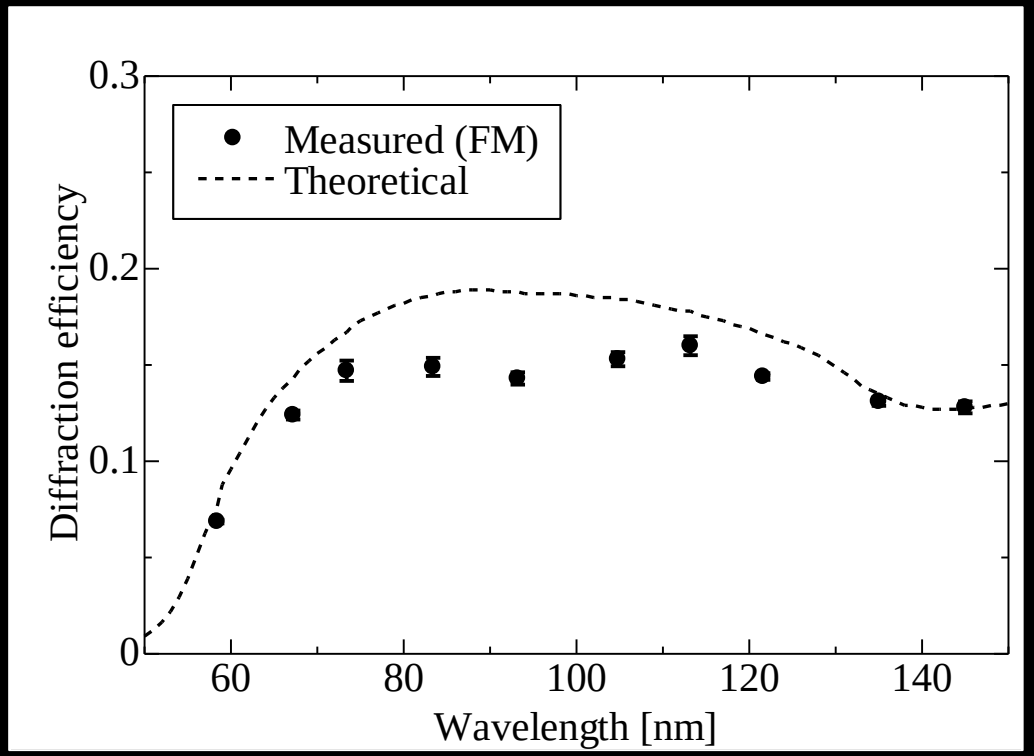


The optical layout of EXCEED



EXCEED/Grating



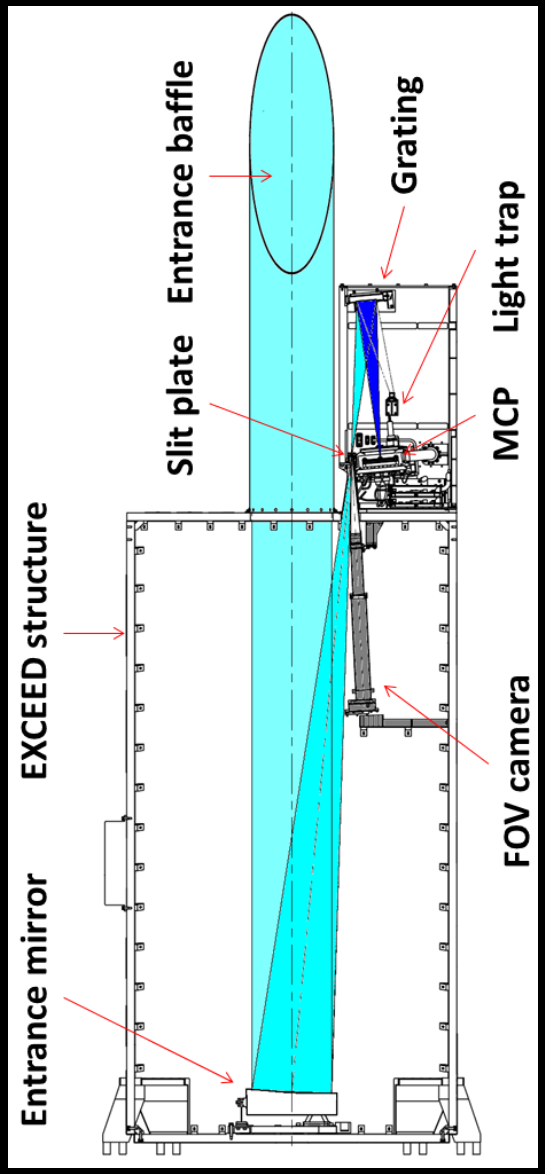


The reflectance of FM grating

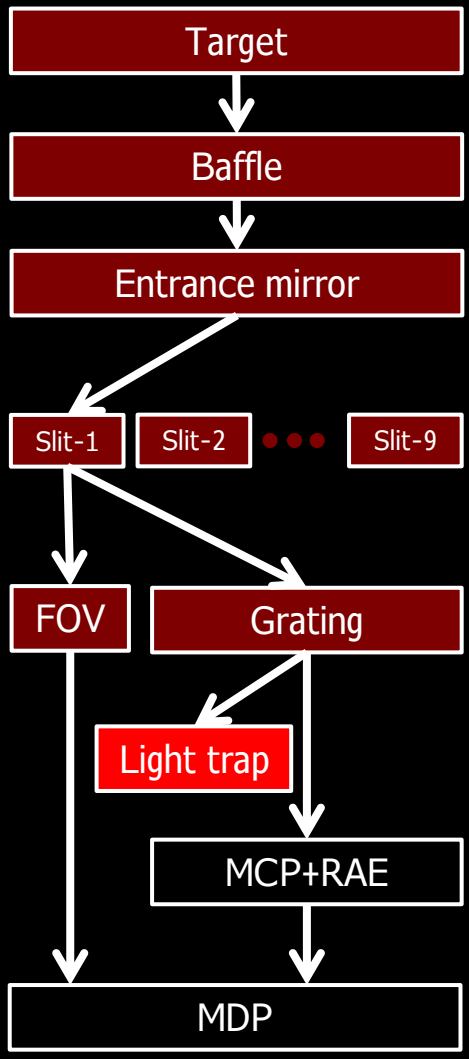
- The diffraction efficiency of FM Grating has been evaluated successfully.
- The difference between theoretical and measured values are possibly due to the surface roughness. But not critical.

EXCEED/Light trap

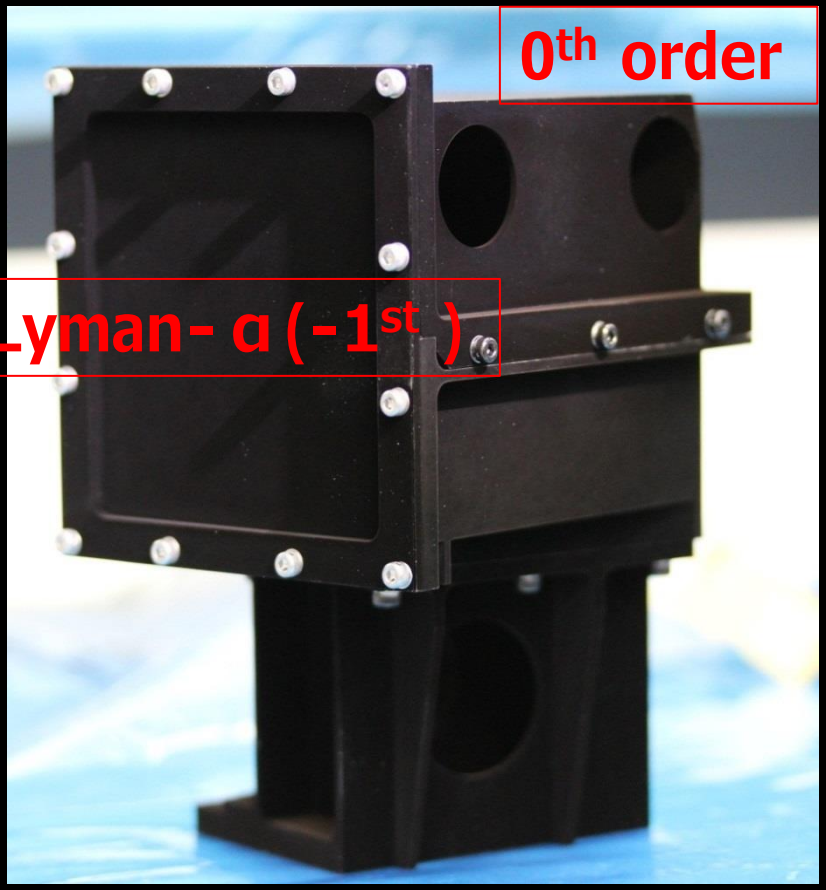
- **Entrance mirror**
  - An off-axis parabolic, CVD-SiC coated
- **Slit**
  - Three types of shape, and three types of filters
- **Grating**
  - Laminar type, toroidal, CVD-SiC coated
- **Photon detector**
  - Microchannel plate and Resistive anode



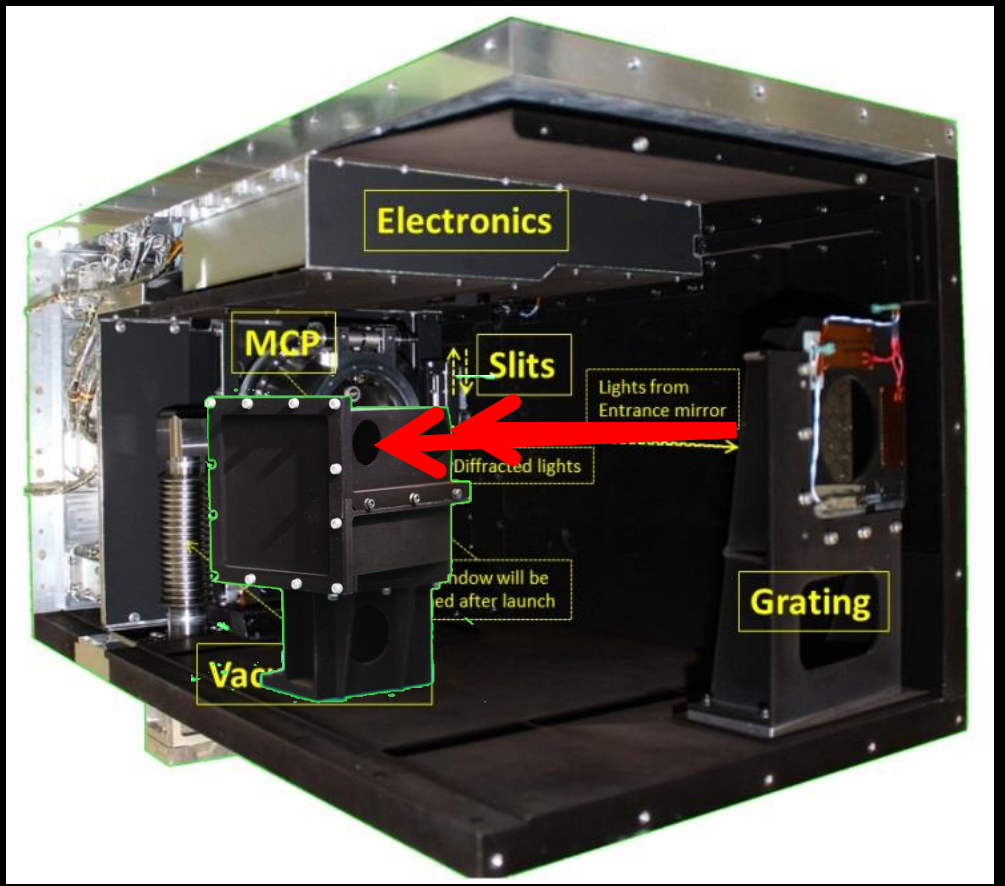
The optical layout of EXCEED



EXCEED/Light trap



The photo of the light trap (FM)

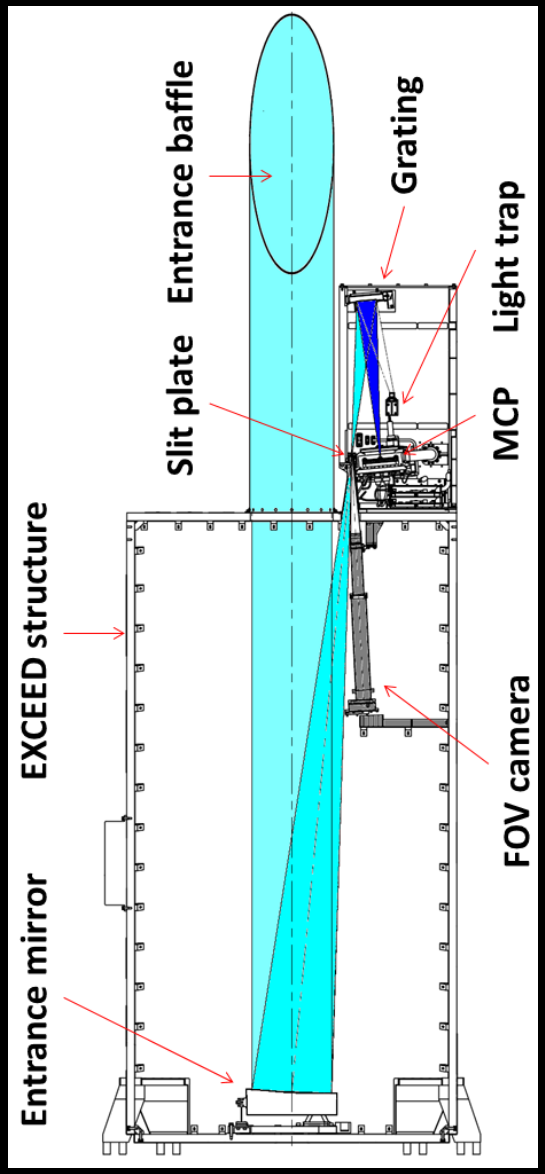


The photo of the spectrometer (FM)

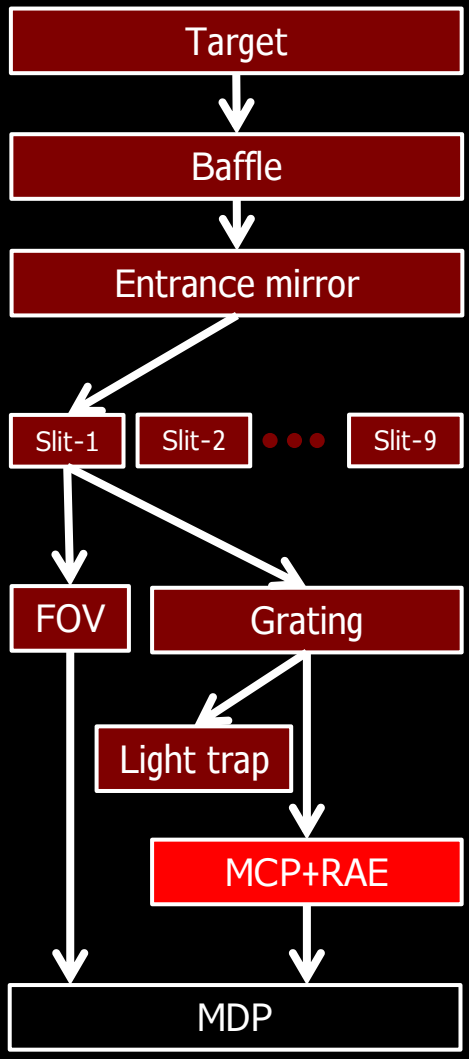
- Light trap is set in order to capture the 0th order light and -1st order Lyman alpha (121.6nm) which may cause serious stray light problem.

EXCEED/MCP+RAE

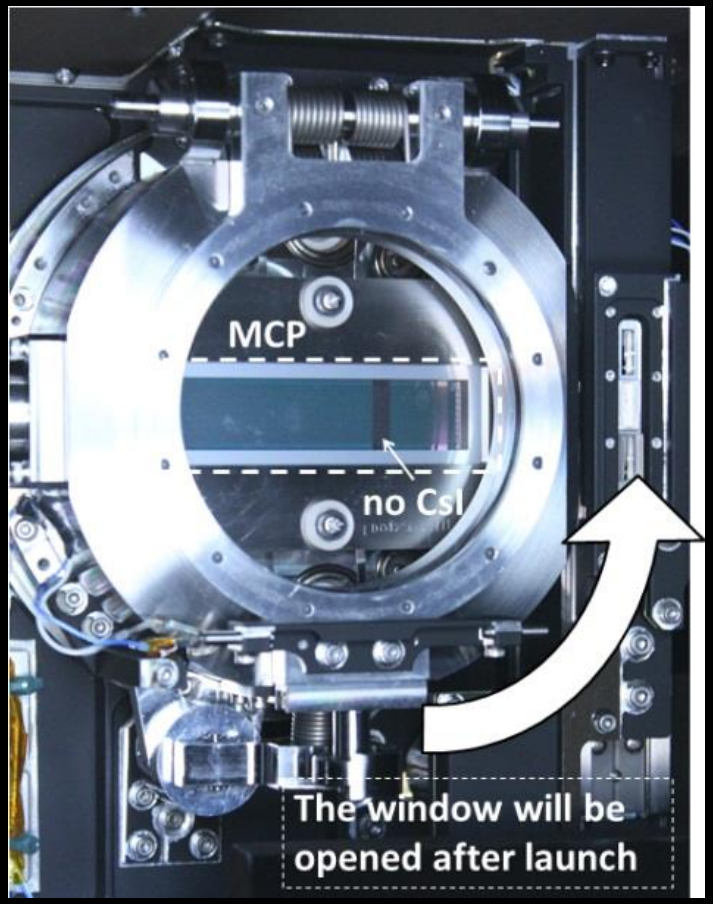
- **Entrance mirror**
  - An off-axis parabolic, CVD-SiC coated
- **Slit**
  - Three types of shape, and three types of filters
- **Grating**
  - Laminar type, toroidal, CVD-SiC coated
- **Photon detector**
  - Microchannel plate and Resistive anode

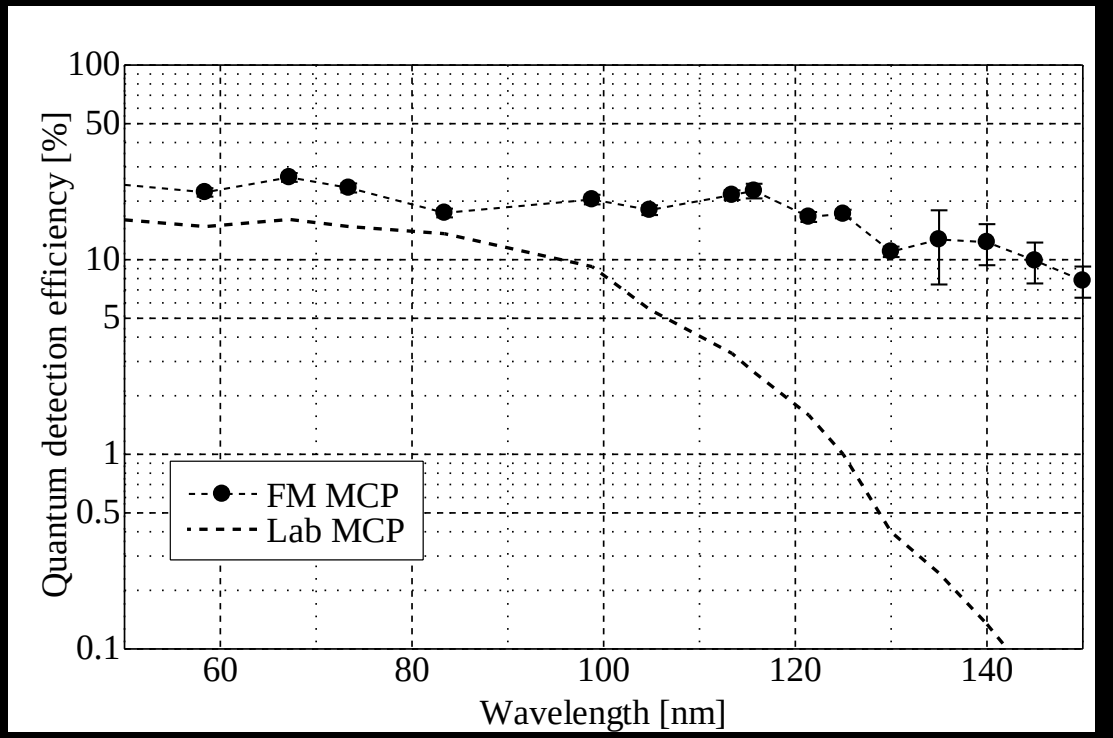


The optical layout of EXCEED



EXCEED/MCP+RAE



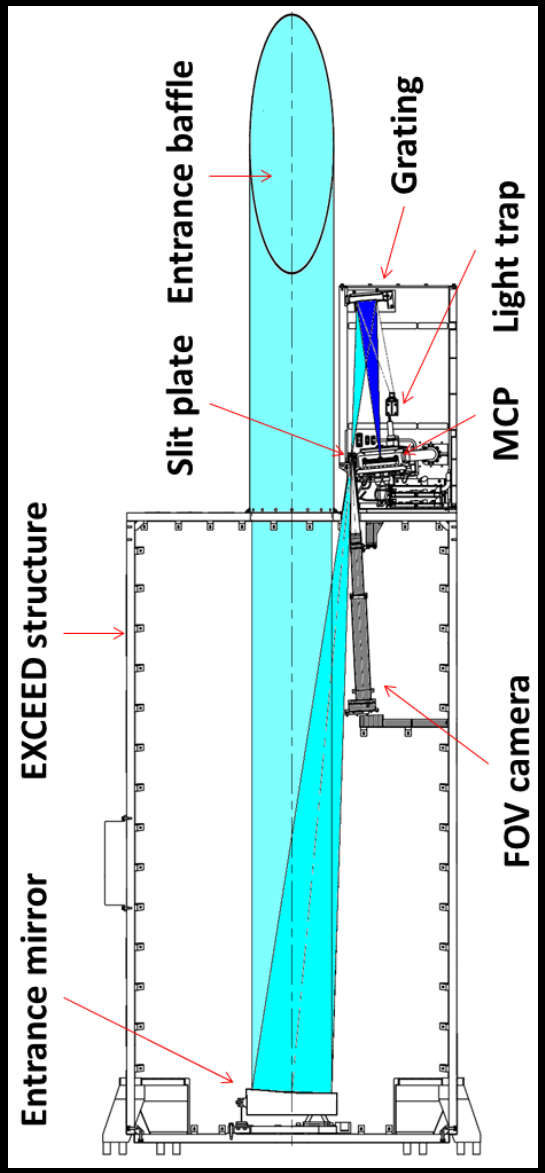


- CsI photocathode is deposited on the MCP surface
- The detection efficiency increase x1.5~x100
- The MCP should be kept under vacuum until the launch.

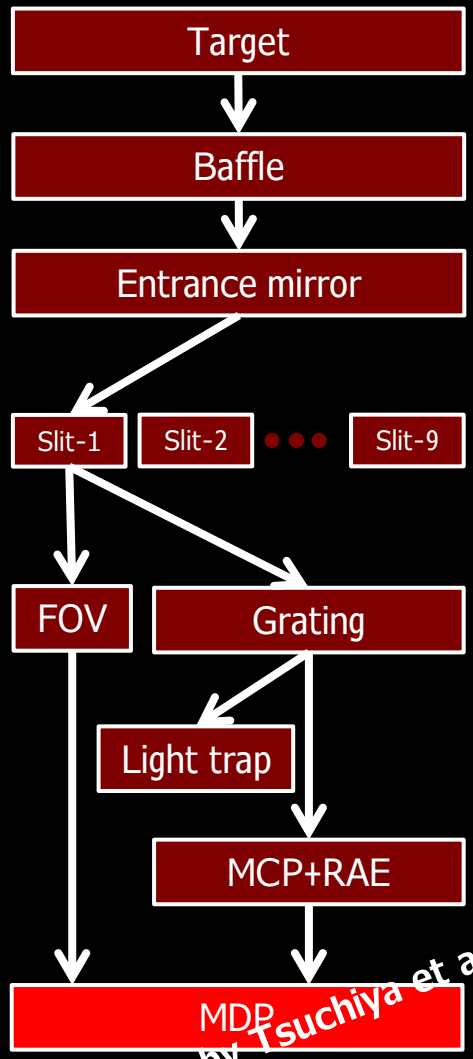
The absolute efficiency of the detector (FM) → (see the next presentation)

EXCEED/MDP

- **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

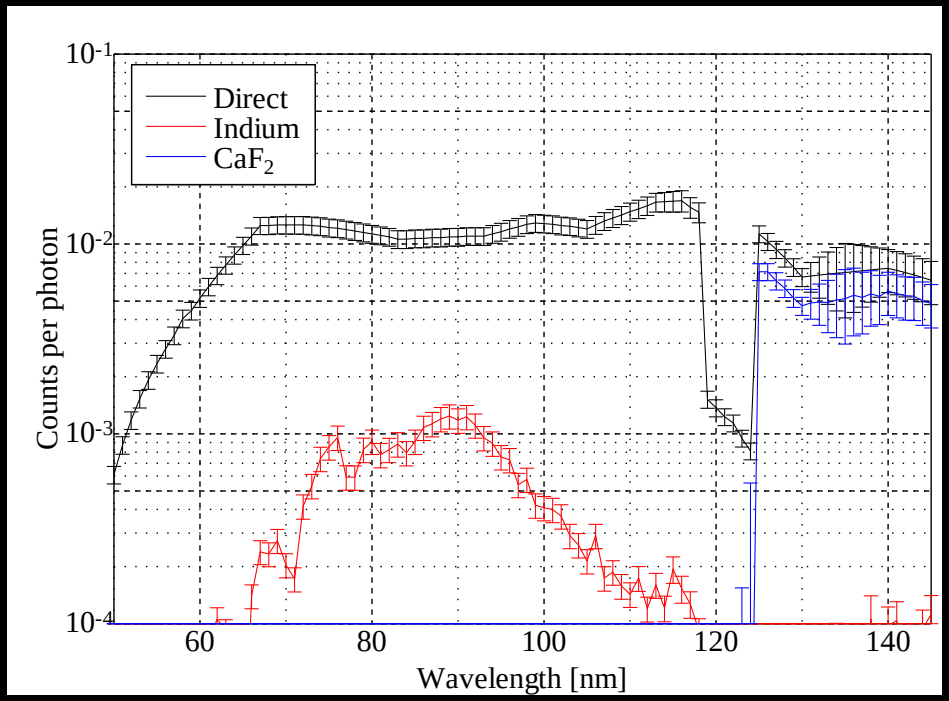


The optical layout of EXCEED

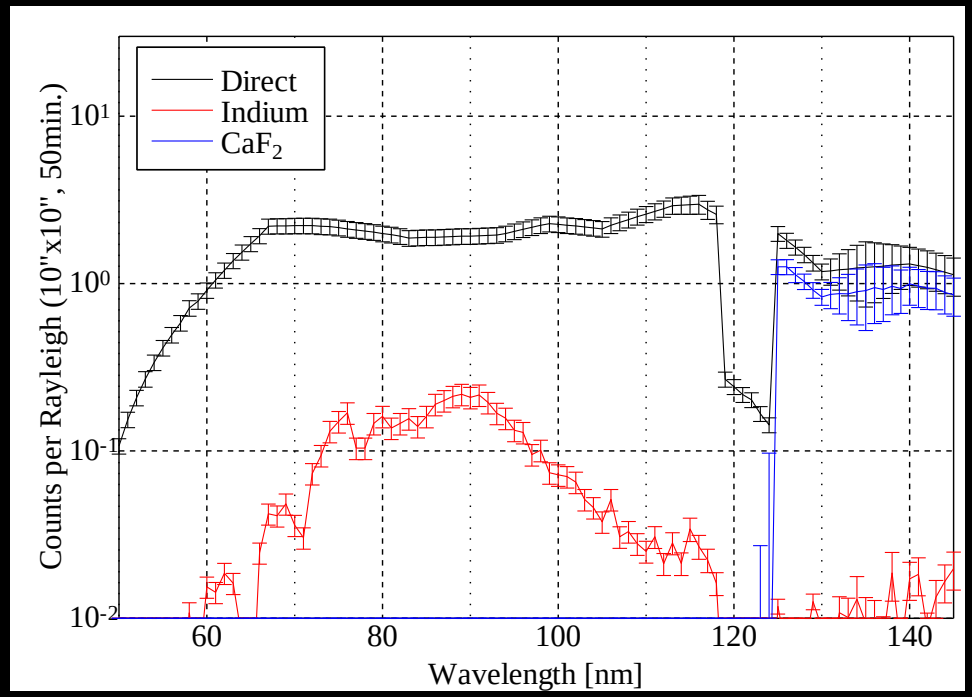


See poster by Tsuchiya et al.

Total sensitivity (with/without filters)

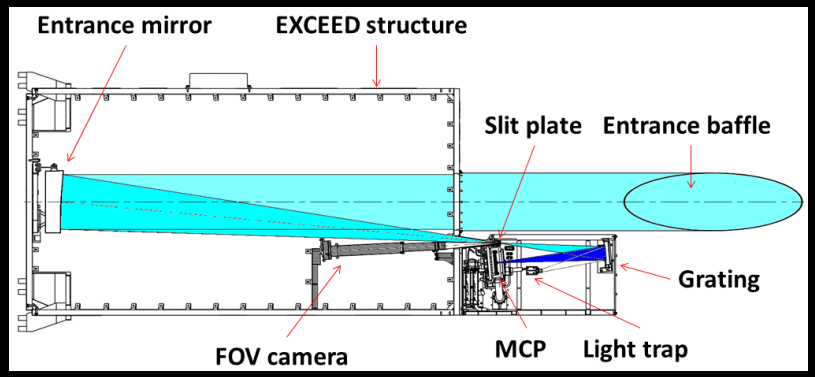


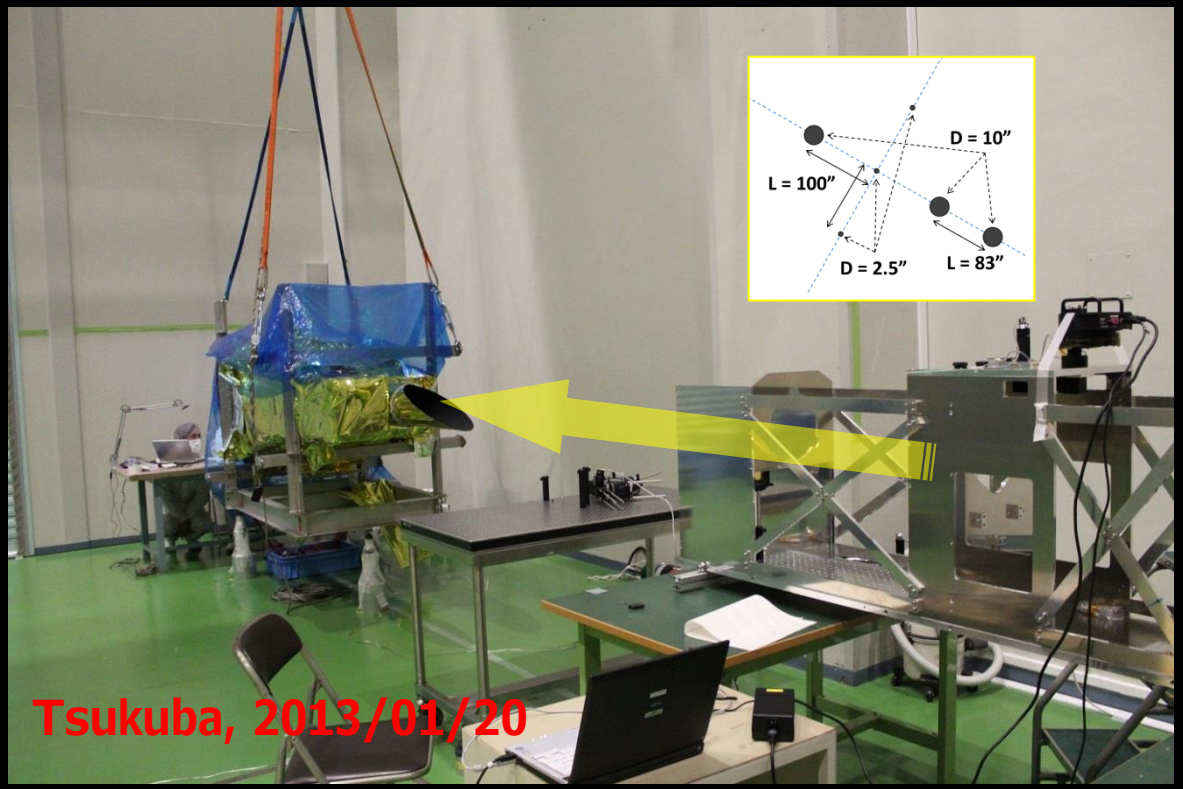
The total sensitivity (Photon to count conversion factor) as a function of wavelength. The version with Indium filter (red) and CaF2 filter (blue)

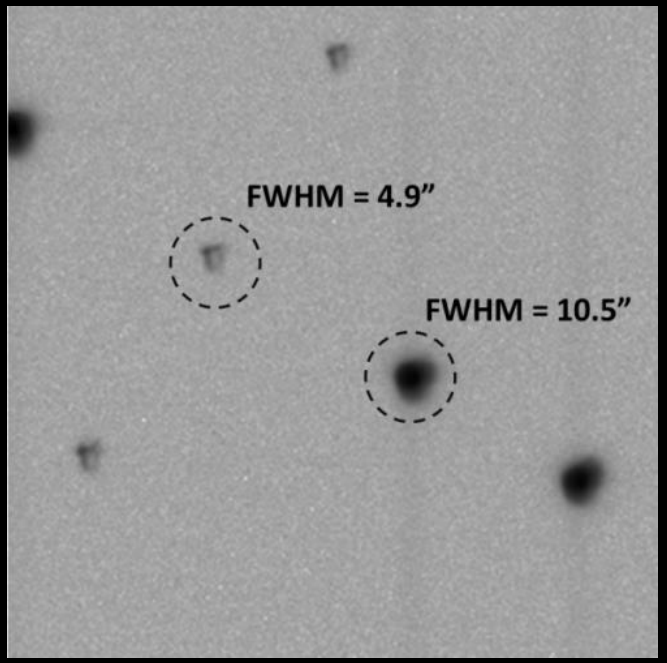


The sensitivity of EXCEED. (The integration time is assumed as 50 minutes. The field of view is assumed 10″ × 10″)

Optical performances ~Entrance mirror → slit~

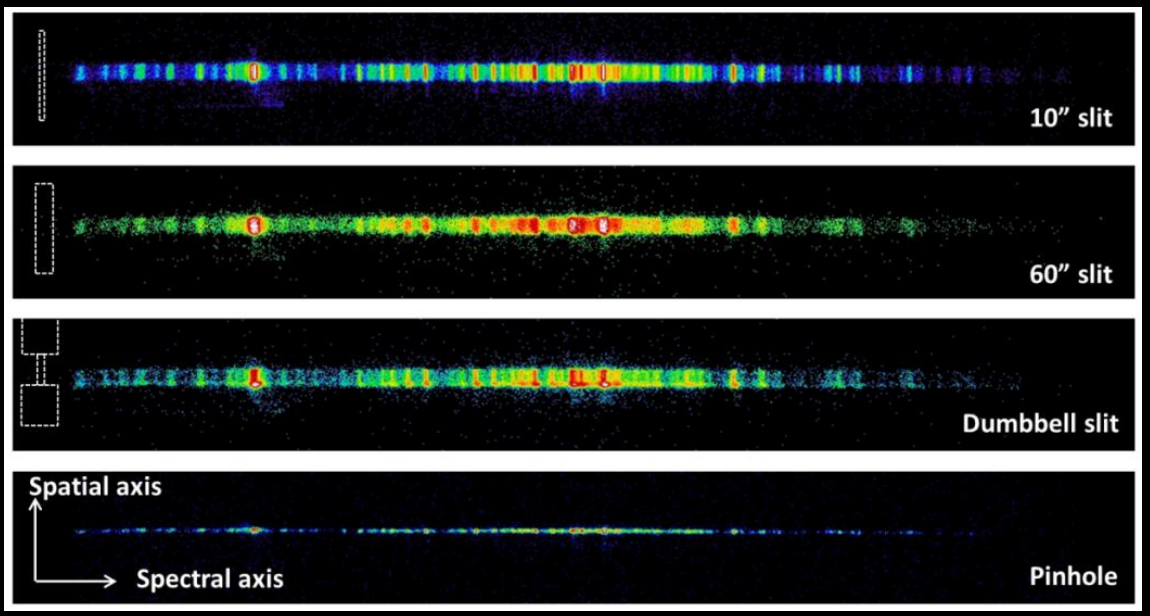


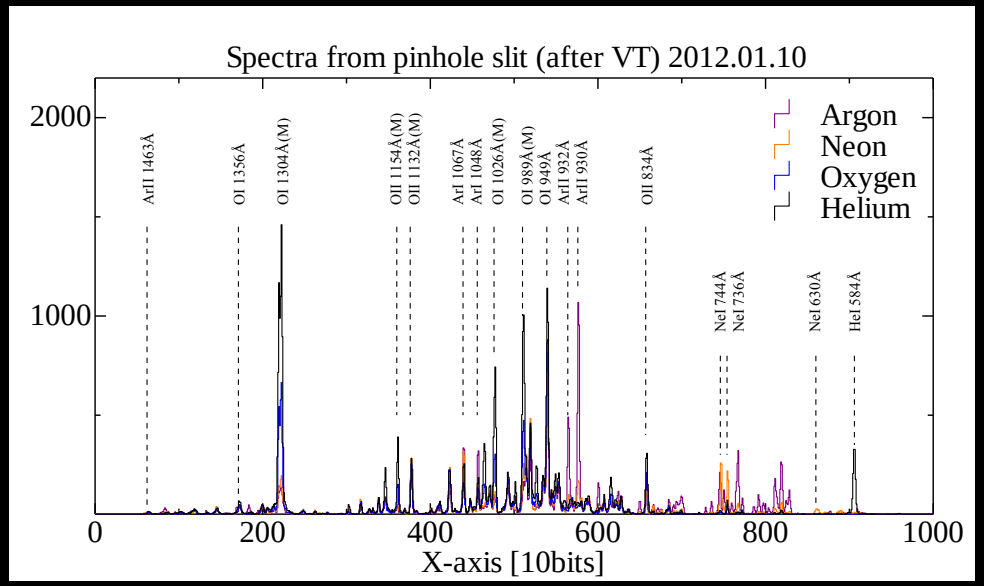




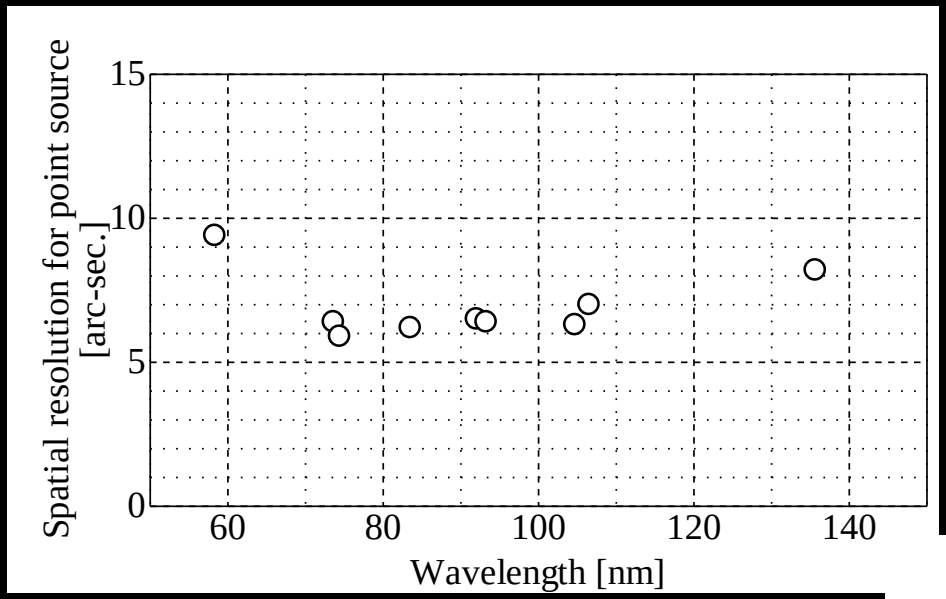
- The FWHM of the spot diagrams are smaller than 10 arc-seconds.

Optical performances «Slit → MCP»





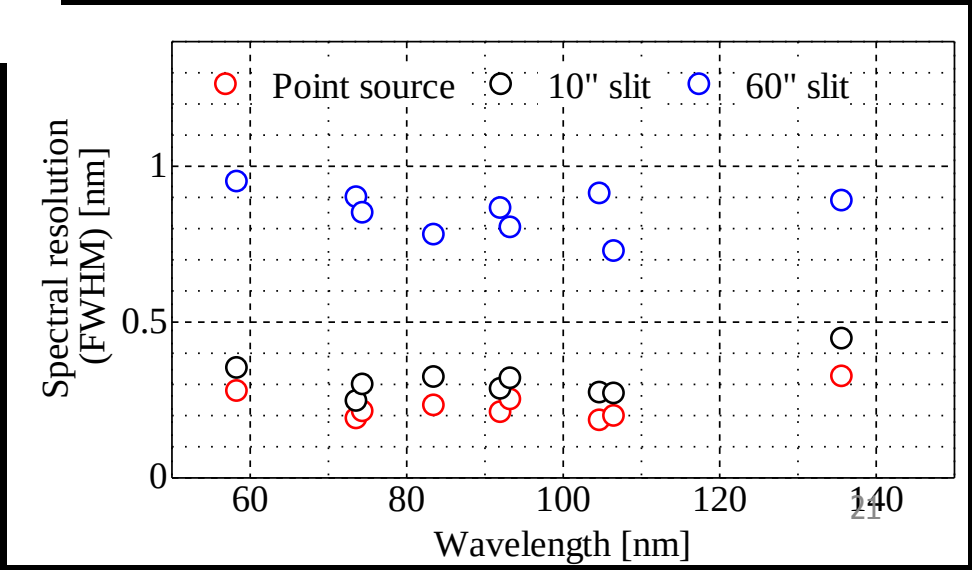
Optical performances (spatial and spectral resolutions)



Spatial resolution (FWHM) as a function of wavelength.

Spatial resolution:
6~10 arc-seconds
Spectral resolution:
0.3nm ~ 1nm.

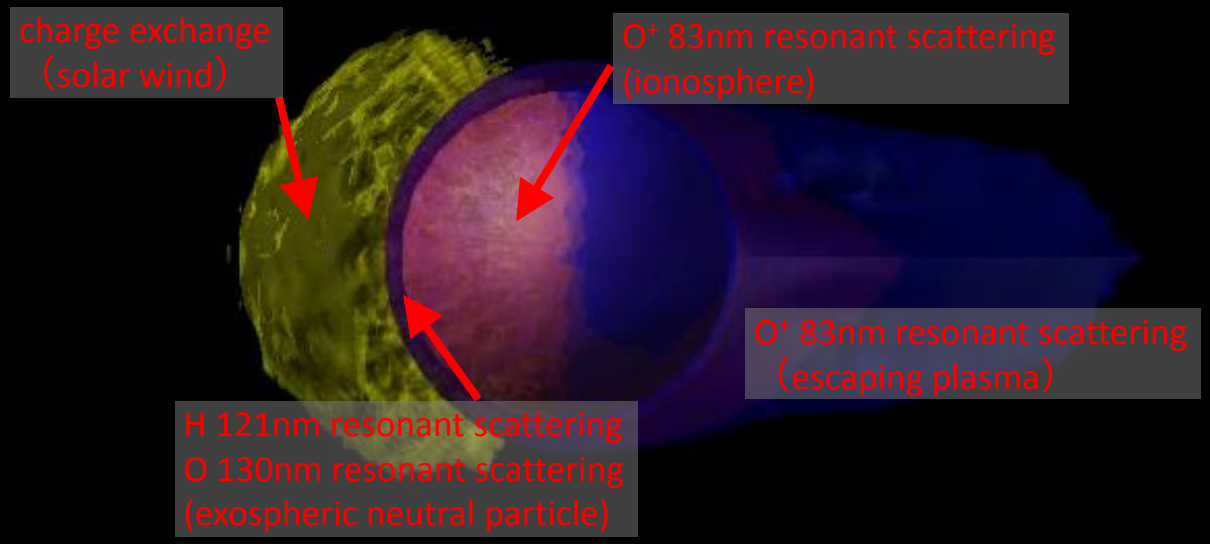
Spectral resolution (FWHM) as a function of wavelength for various slits.



Two primary science targets

(1) Simultaneous observation of exosphere, ionosphere, and **escaping plasma** down the tail.

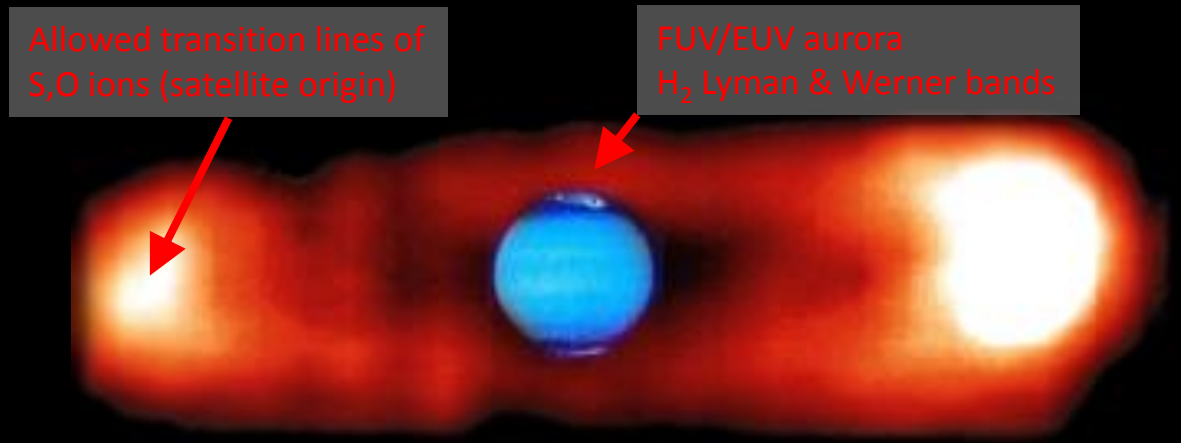
Venus, Mars, and Mercury



---

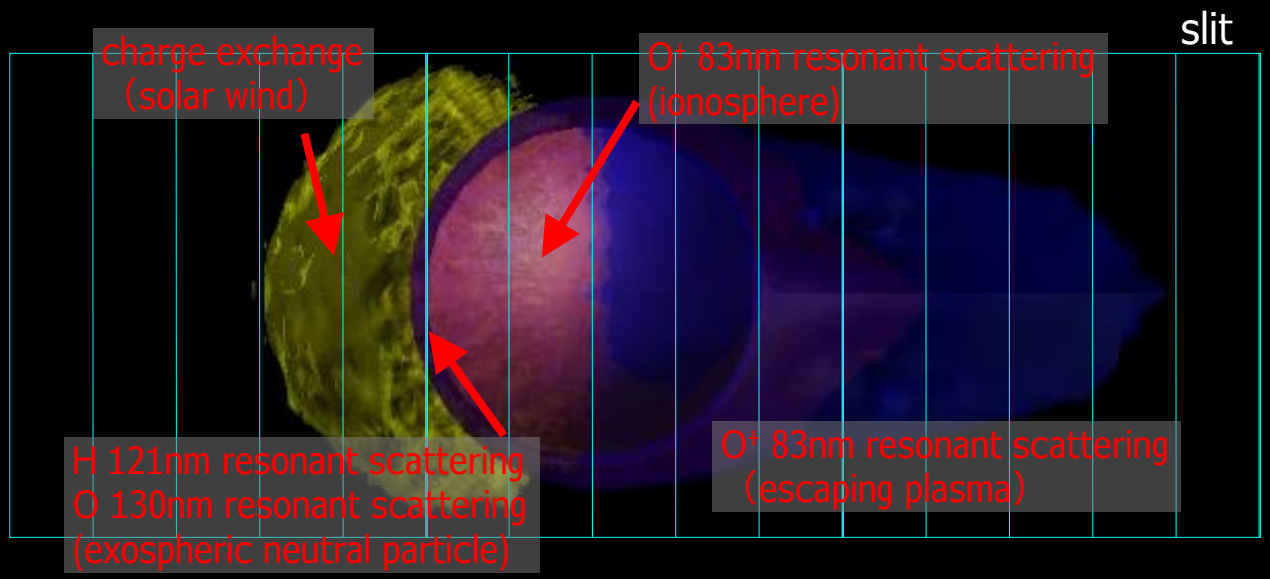
(2) Spectral analysis for aurora and gas torus.

Jupiter and Saturn



Io plasma torus : Cassini/UVIS. Jupiter's UV aurora : HST/WFPC2

Escaping atmosphere from terrestrial planets



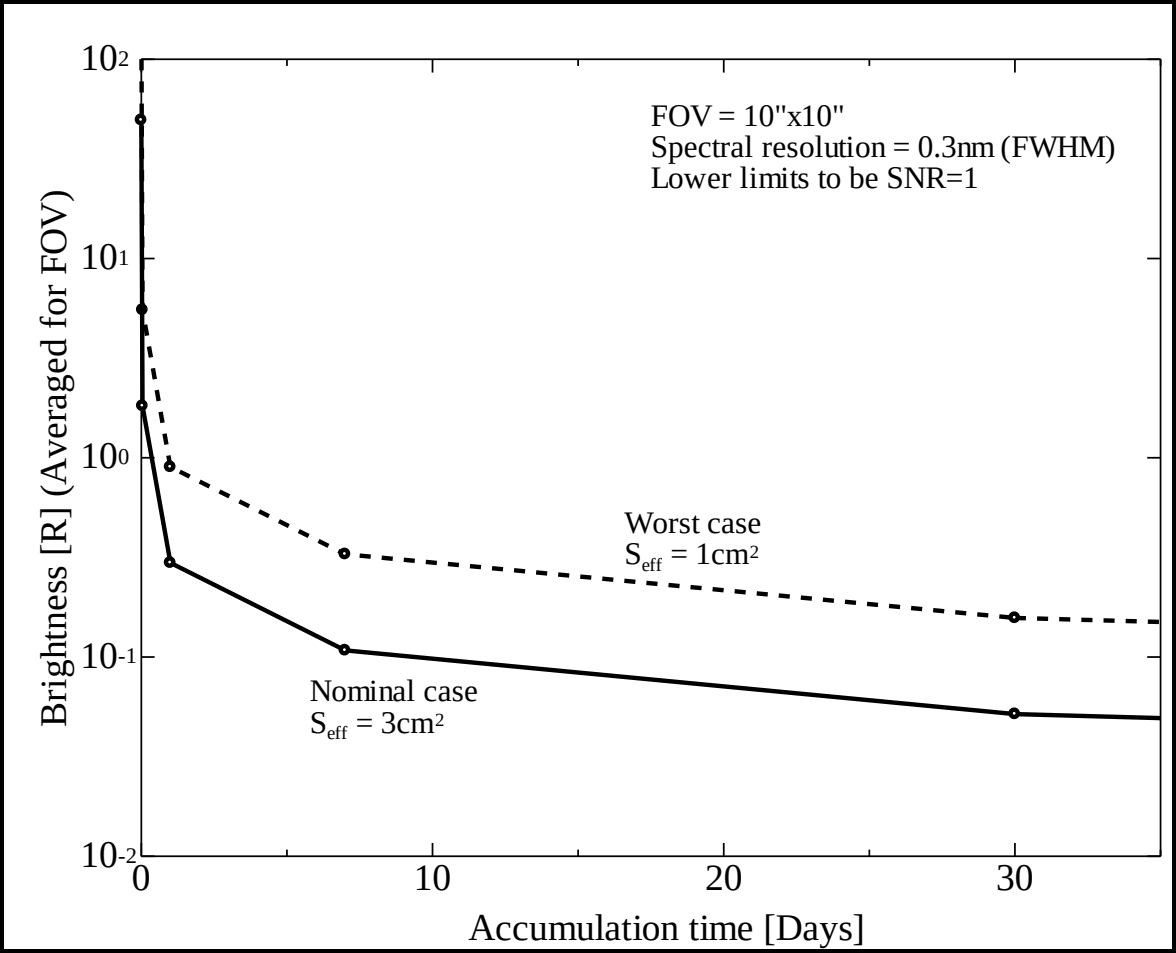
EXCEED will measure outflow rate of the atmosphere (O+. C+, N+) depending on solar (wind) conditions (short-term) from Mars and Venus

Through the simultaneous observation of exosphere, ionosphere, and **escaping plasma** down the tail, EXCEED will reveal

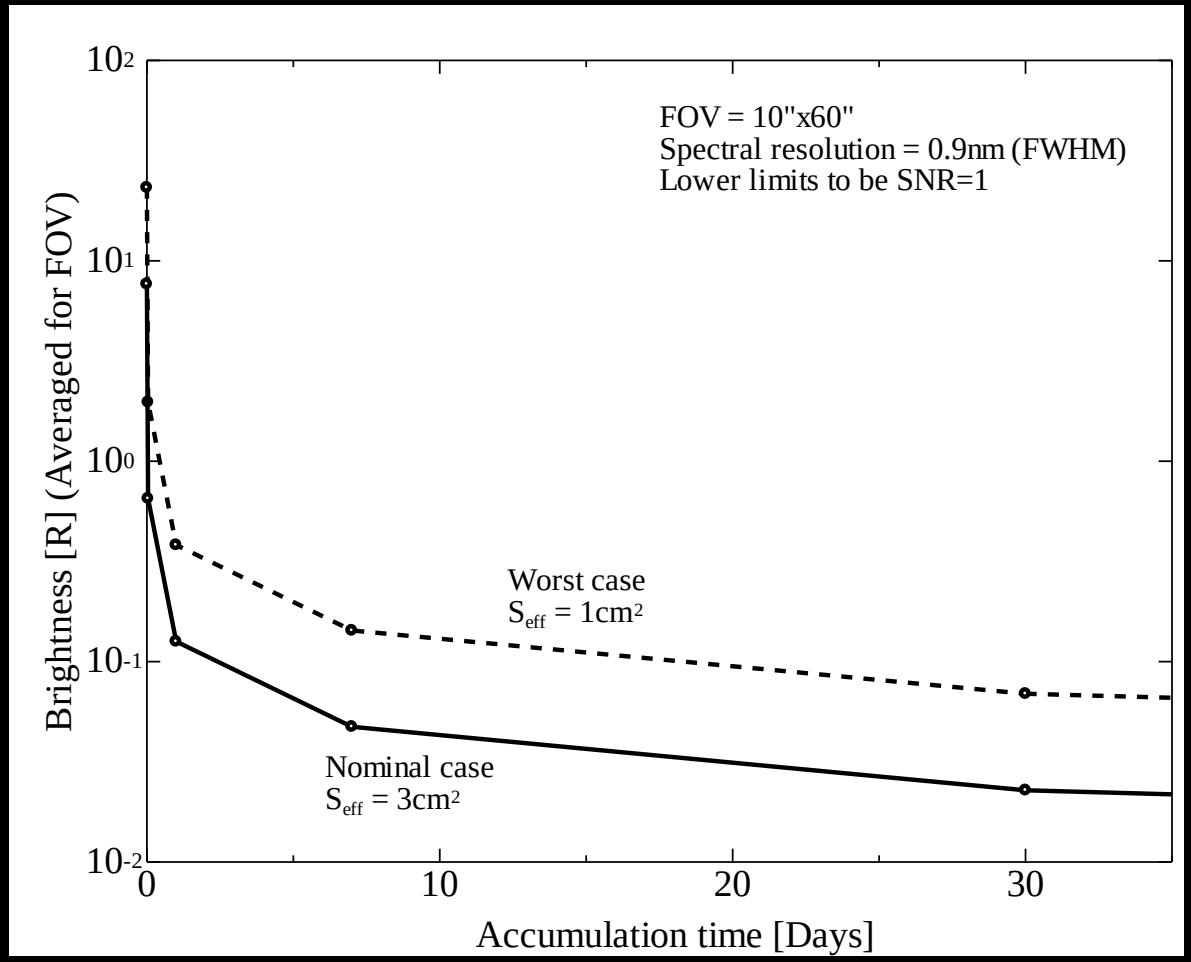
* The total amounts of escaping atmosphere
* Its dependency on Solar wind activity

The targets are Venus, Mars, and Mercury.

Can EXCEED detects the faint targets?

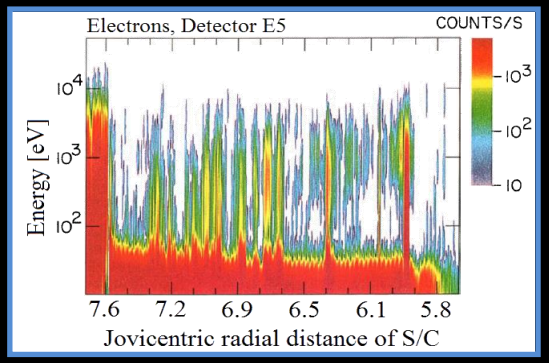


Can EXCEED detects the faint targets?



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

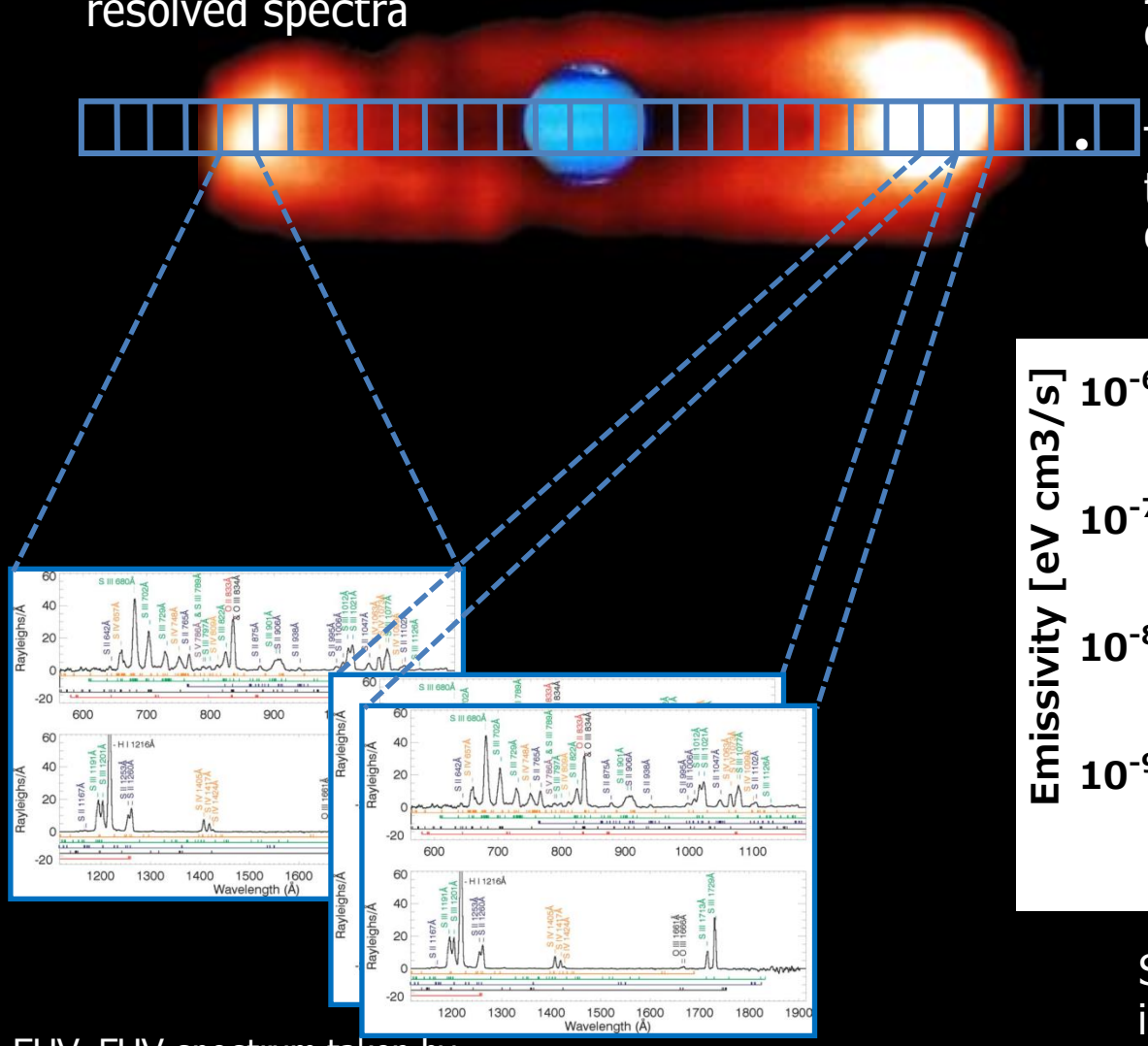
Fast neutral

Transport

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

The approach for Io plasma torus ~spectral diagnosis~

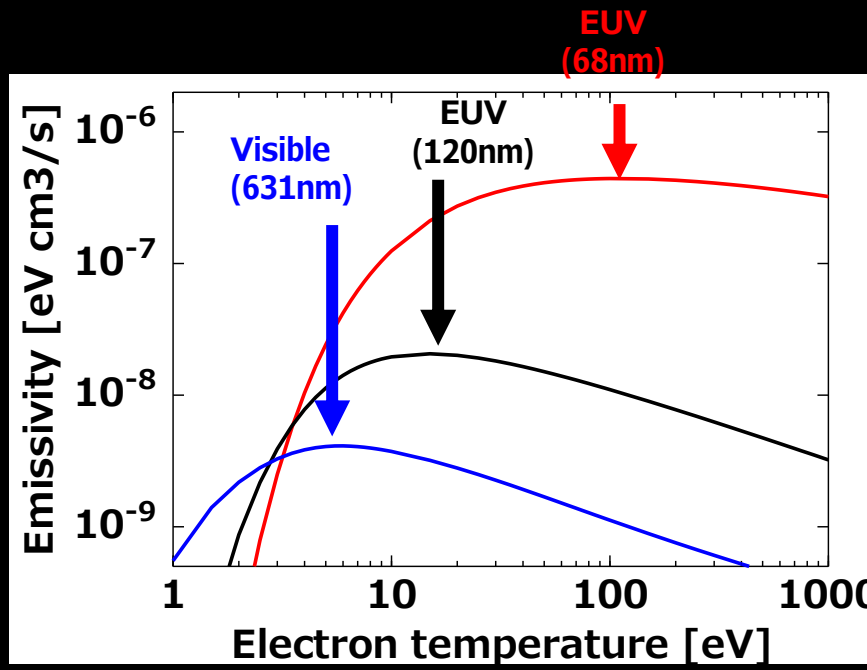
- EXCEED will take spatially resolved spectra



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

- 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.

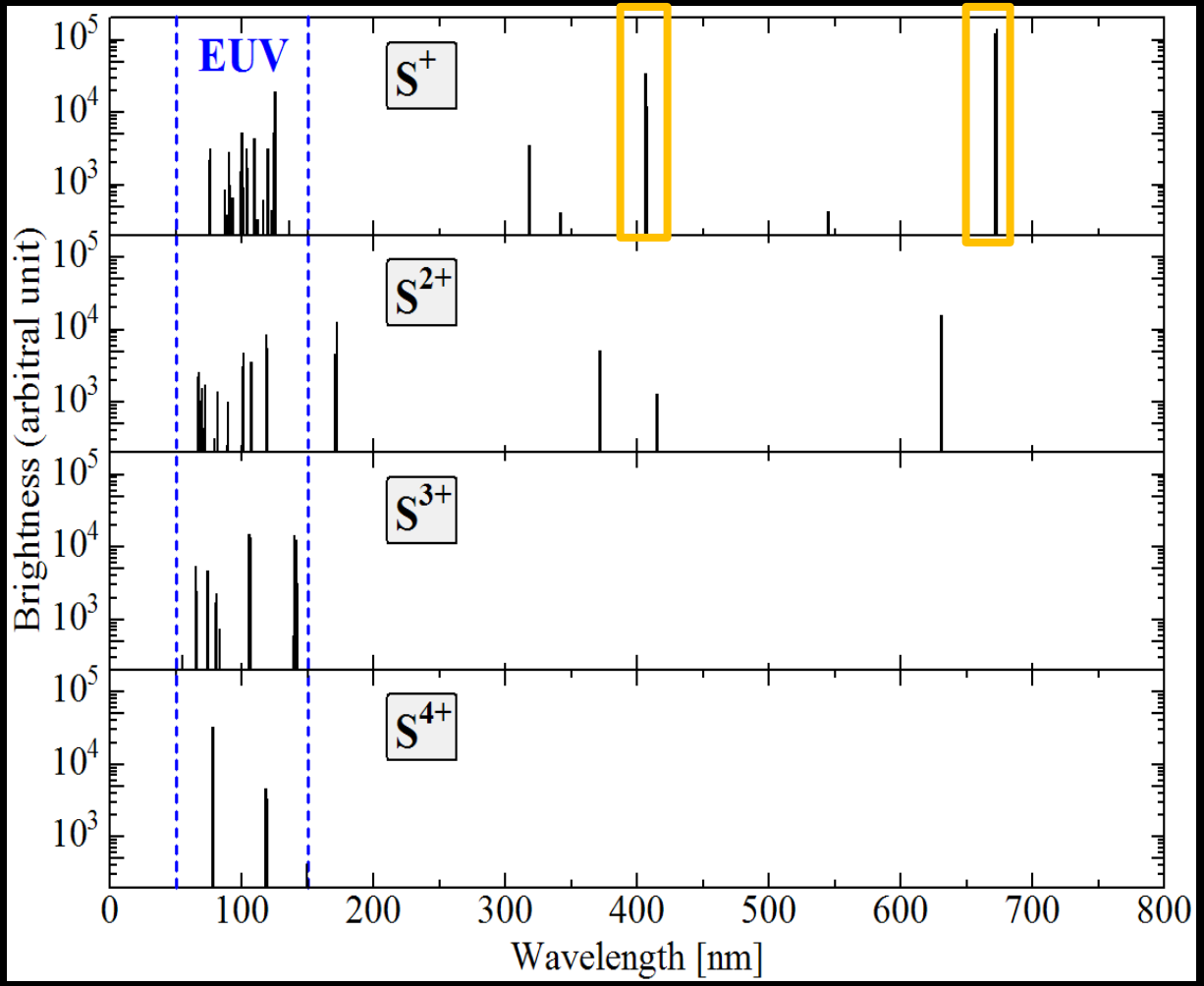


S^{++} Emissivity through the electron impact excitation. The calculation use the CHIANTI database.

EUV is the best band for spectral diagnosis

Space based obs.

Ground based obs.

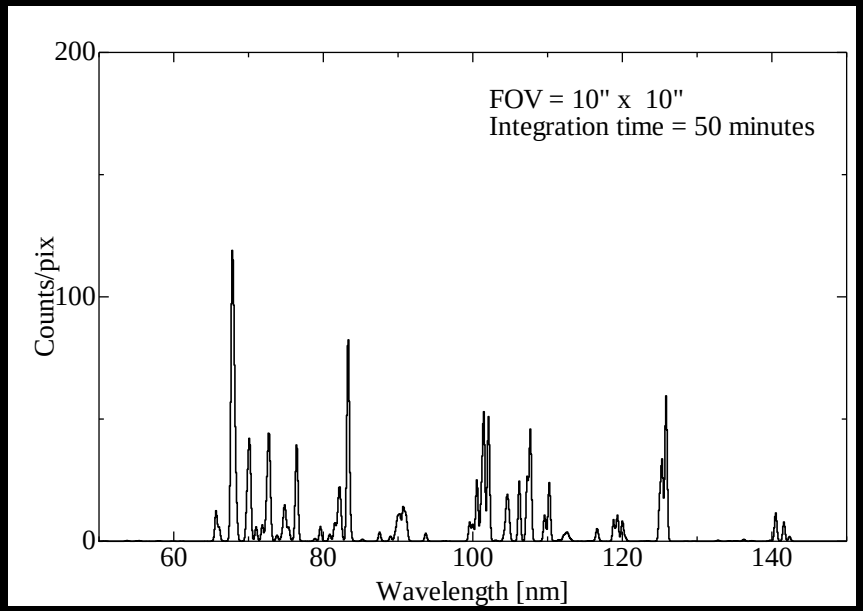


More than 80% of the lines are in the EUV region.

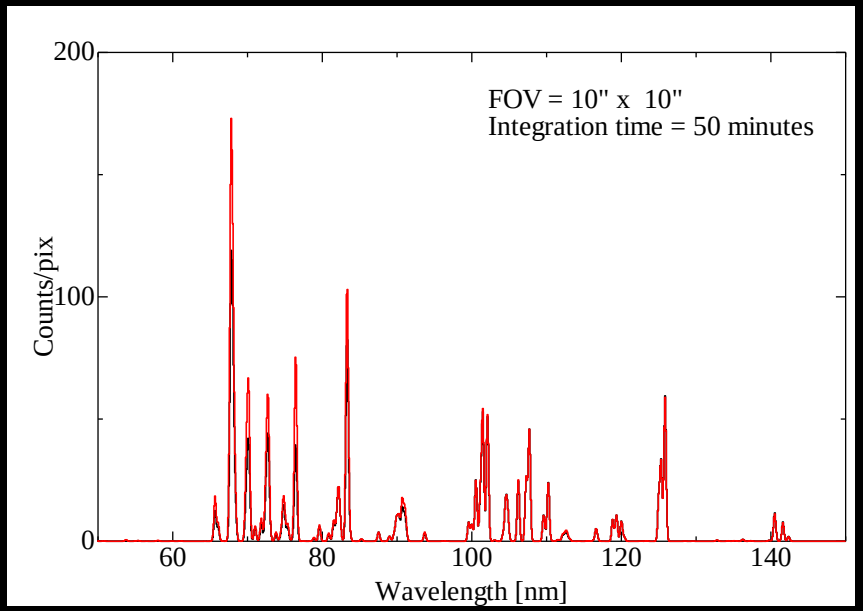
The distribution of Sulfur ion emissions. These emissivities are calculated with same plasma conditions (Yoshioka et al. 2012).

EUV observation of Io tours from EXCEED

Model spectra with hot electron 0%



Model spectra with hot electron 4.2%



- EXCEED can distinguish the spectra with and without hot component by the 1 orbit (50min.) observation..

Summary and next steps

- Flight model of the whole EXCEED instruments have been evaluated. (good!)
  - Entrance mirror, slit, filter, detector
- The EXCEED structure has been installed and the optical performances have been evaluated. (good!)
- EXCEED will be launched in next August from Uchinoura Space center.