Development of the Extreme Ultraviolet Spectrometer: EXCEED

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ABSTRACT

The extreme ultraviolet (EUV) telescope EXCEED (Extreme Ultraviolet Spectroscope for Exospheric Dynamics) onboard the Japan's small satellite SPRINT-A will be launched in August 2013. The EXCEED instrument will observe tenuous gases and plasmas around the planets in the solar system (e.g., Mercury, Venus, Mars, Jupiter, and Saturn). One of the primary observation targets is Jupiter, whose magnetospheric plasma dynamics is dominated by planetary rotation. In the EUV range, a number of emission lines originate from plasmas distributed in Jupiter's inner magnetosphere. The EXCEED instrument is designed to have a wavelength range of 55-145 nm with a spectral resolution of 0.4-1.0 nm. The spectrograph slits have a field of view of 400 x 140 arc-seconds (maximum), and the attitude fluctuations are stabilized within 5 arc-seconds. The optics of the instrument consists of a primary mirror with a diameter of 20cm, a laminar type grating, and an EUV detector using microchannel plates (MCPs). The surfaces of the primary mirror and the grating are coated with CVD-SiC.

We have finished the final integration and ground calibration of the EXCEED instrument. We performed optical tests of EXCEED and measured the following performances.

1. Quantum efficiency of the detector: >10%
2. Spectral resolution: 0.3 nm (10” slit) and 1.0 nm (60” slit)
3. Spatial resolution: 6-10”

We have confirmed that all of these results satisfied the specifications. Now EXCEED is ready for launch.

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Symposium on Planetary Science 2013

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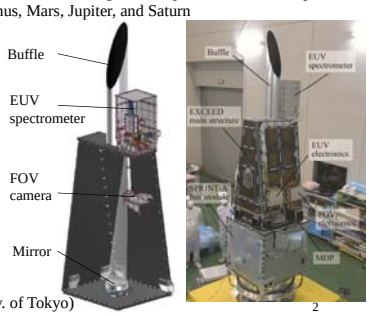
Overview of the EXCEED mission

(EXtreme ultraviolet spectrosCope for ExosphEric Dynamics)

- An earth-orbiting Extreme Ultraviolet (EUV) spectroscopic mission
- The first mission of the ISAS/JAXA small scientific satellite series (Sprint-A)
- EXCEED measures EUV emissions from tenuous gases and plasmas around the planets
- Observation targets : Mercury, Venus, Mars, Jupiter, and Saturn

Major specifications
- Launching : 12 August 2013
- Weight : 330kg
- Size : 1m × 1m × 4m
- Orbit : 950km × 1150km (LEO)
- Inclination: 31 deg ± a few deg.
- Mission life : >1 year
- Pointing accuracy : ±2 arc-min (improved to ±5arc-sec by FOV camera)

(Yoshikawa et al. AdGeo 2010,2011)



SPRINT-A/EXCEED

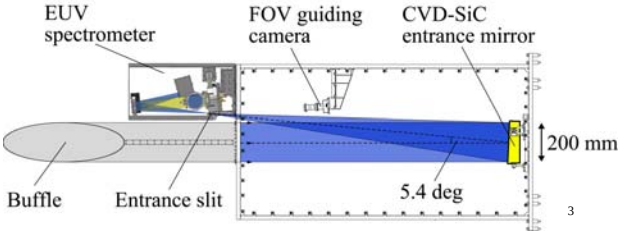
Project scientist : I. Yoshikawa (The Univ. of Tokyo)

Instrument overview

Specifications

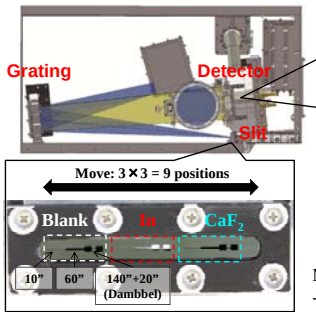
Wavelength range	60 – 145 nm
Spatial resolution	10 arc-sec
Field of view	400 arc-sec.
Spectral resolution (FWHM)	0.4 – 1.0 nm (depends on slit)
Primary mirror	20 cm diameter, f = 160 cm (F/8)

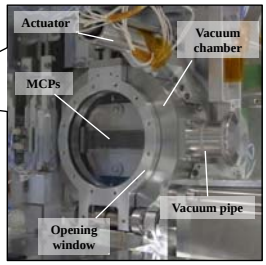
Optical layout



EUV spectrometer

1. Slits and filters
Selectable by stepping motor, **3 types of shape**, **2 types of filter + blank**
2. Grating
Laminar type, toroidal, CVD-SiC coated, D = 50 mm, f ~ 400 mm
3. EUV detector
5-stage microchannel plate (MCP) + resistive anode encoder (RAE), **CsI coated**



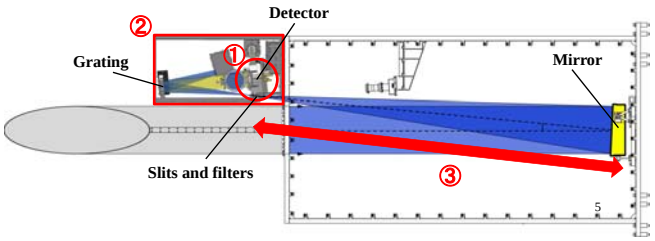


MCPs should be kept under vacuum
-> The window must be opened after launch

Ground calibrations of EXCEED

Sensitivity
-Mirror (reflectivity)
-Grating (diffraction efficiency)
-Filter (transmittance)
① **Detector** (quantum efficiency)

Resolution
-Detector (spectral and spatial resolution)
② **EUV spectrometer** (spectral and spatial resolution)
③ **Mirror and slit** (spatial resolution)



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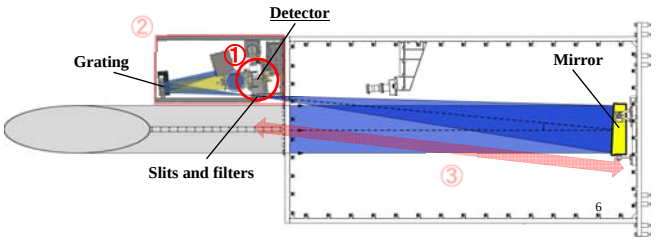
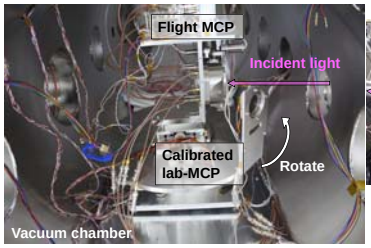
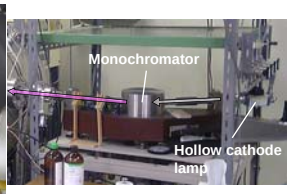


① Quantum efficiency of the detector

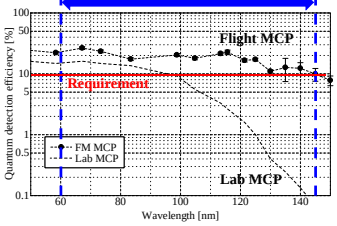
-Set the flight detector (**MCP with CsI photocathode**) and a calibrated detector (**MCP without photocathode**) on a rotation gimbal
-Compare the quantum efficiencies at various wavelengths
-Light source: hollow cathode lamp + monochromator
(Gas: He, Ne, Ar, and O)
-Open and close the window under vacuum





① Quantum efficiency of the detector

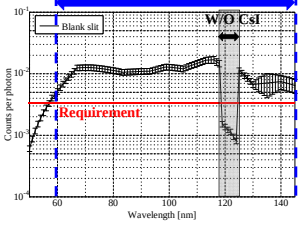
Detector



Flight MCP achieved **2~100 times** higher efficiency than Lab-MCP

Quantum efficiency: 10~30%

Total sensitivity



Total sensitivity: ~1%
(-> Effective area: ~3 cm^2)

Ground calibrations of EXCEED

Sensitivity
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① **Detector** (quantum efficiency)

Resolution
-Detector (spectral and spatial resolution)
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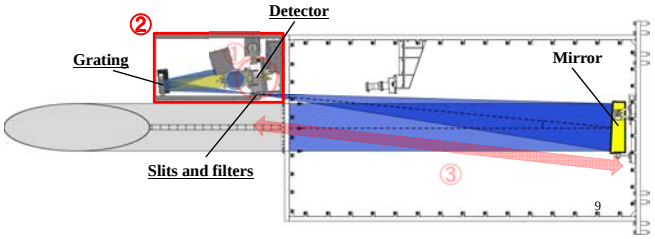
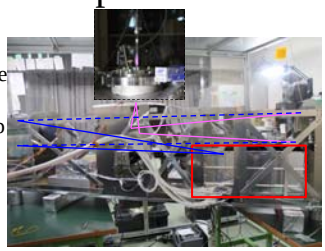
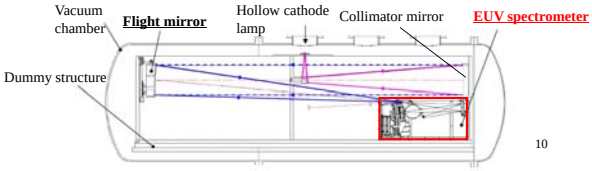


② Calibration of the spectrometer

-EUV spectrometer and the flight mirror are set on a dummy structure
-Incident light: F/8
-Light source: hollow cathode lamp

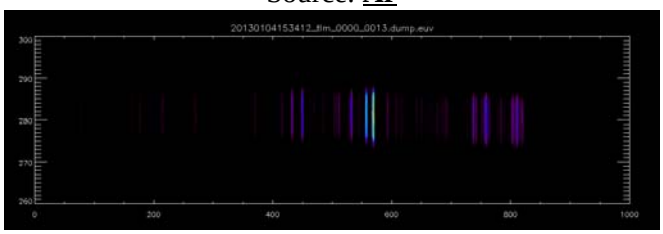
We have obtained spectrums of various gases and measured the spectral and spatial resolution





② Calibration of the spectrometer

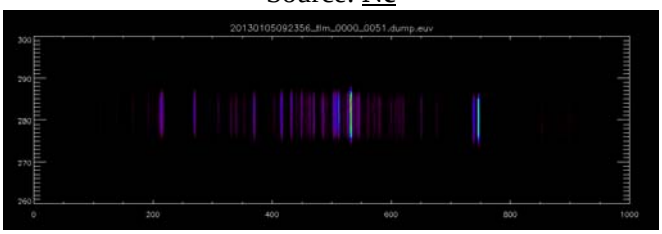
Spectrum obtained by the EUV spectrometer
Source: **Ar**



Slit: 10''
Filter: none

② Calibration of the spectrometer

Spectrum obtained by the EUV spectrometer
Source: **Ne**

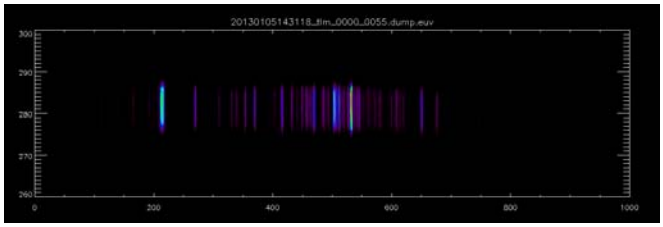


Slit: 10''
Filter: none

② Calibration of the spectrometer

Spectrum obtained by the EUV spectrometer

Source: **O**



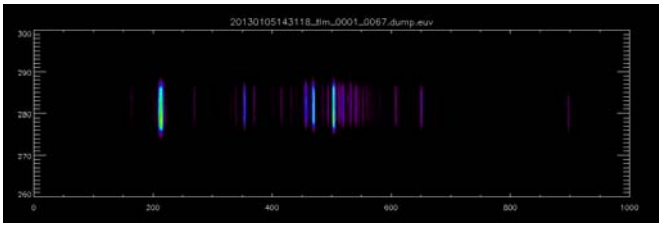
Slit: 10”

Filter: none

② Calibration of the spectrometer

Spectrum obtained by the EUV spectrometer

Source: **He**



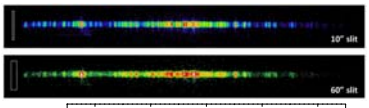
Slit: 10”

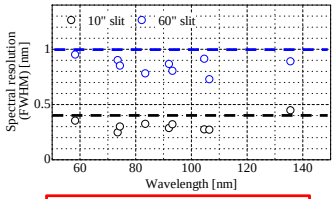
Filter: none

② Calibration of the spectrometer

Spectral resolution

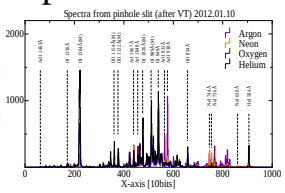
We measured the FWHM of each line

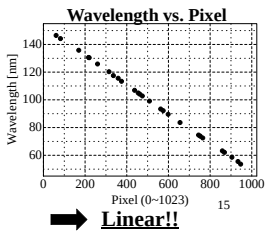




10” slit: FWHM < **0.4 nm**

60” slit: FWHM < **1.0 nm**





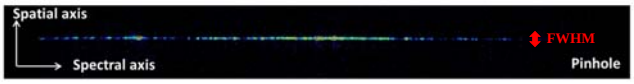
➡ **Linear!!**

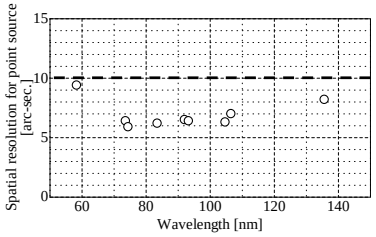
② Calibration of the spectrometer

Spatial resolution

-We used a pinhole instead of a slit (included in the flight slit plate)

-The FWHM for the spatial axis was measured at each wavelength





Test pinhole (size: 40 um = 5”)

Spatial resolution of 10” is achieved!!

Ground calibrations of EXCEED

Sensitivity

-Mirror (reflectivity)

-Grating (diffraction efficiency)

-Filter (transmittance)

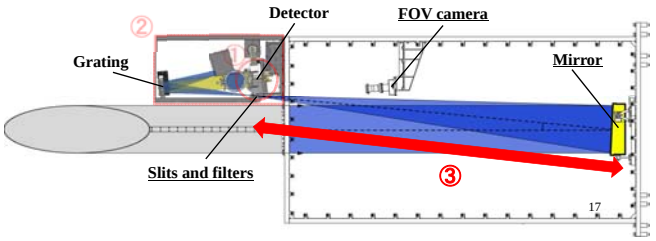
① **Detector** (quantum efficiency)

Resolution

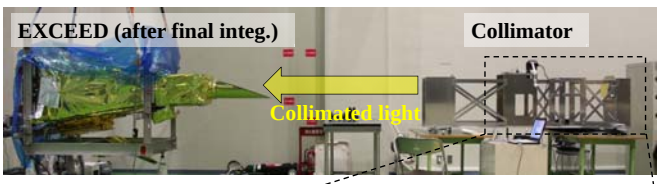
-Detector (spectral and spatial resolution)

② **EUV spectrometer** (spectral and spatial resolution)

③ **Mirror and slit** (spatial resolution)



③ Optical test of the whole instrument



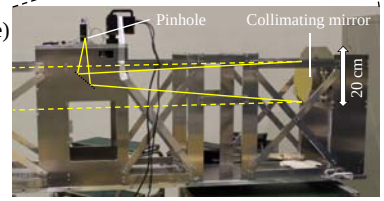
-Input collimated light (visible) to whole EXCEED

D = 20 cm

-Take a slit image by FOV

-Measure the FWHM of the pinhole image on the slit

-Before/after vibration test



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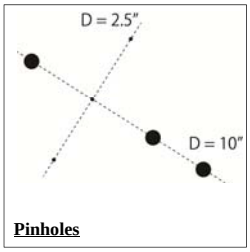
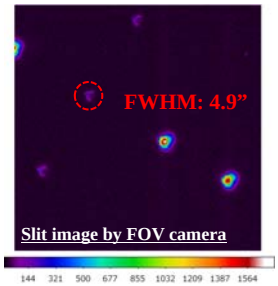


Pinholes



Slit image by FOV camera

Spatial resolution at the slit: **FWHM = 4.9"**

Spatial resolution of whole instrument: FWHM < 10" is achieved!!

Summary

- EXCEED will be soon launched in August 2013!
- We have finished the final integration and ground calibrations of EXCEED
- **Quantum efficiency of the detector: >10%**
  -> Total sensitivity: ~1% (effective area ~3 cm^2)
- **Spectral resolution: 0.3 nm (10" slit)**
  1.0 nm (60" slit)
- **Spatial resolution: 6~10"**

Thank you!

よくわかるEXCEED