

Sounding rocket experiment CLASP2: Development of the UV high-precision polarization spectroscopy device

R. Ishikawa⁽¹⁾ R. Kano⁽¹⁾ D. Song⁽¹⁾ M. Yoshida⁽²⁾ T. Tsuzuki⁽¹⁾
F. Uraguchi⁽¹⁾ M. Kubo⁽¹⁾ N. Narukage⁽¹⁾ H. Hara⁽¹⁾ K. Shinoda⁽¹⁾
Y. Nodomi⁽¹⁾ Y. Suematsu⁽¹⁾ T. Okamoto⁽¹⁾ S. Ishikawa⁽³⁾ T. Sakao⁽⁴⁾
D. McKenzie⁽⁵⁾ L. Rachmeler⁽⁵⁾ F. Auchere⁽⁶⁾
J. Trujillo Bueno⁽⁷⁾ CLASP1 & 2 team

(1) National Astronomical Observatory of Japan (2) Sokendai (3) Nagoya University
(4) ISAS / JAXA (5) NASA / MSFC (6) IAS (7) IAC

CLASP missions: CLASP (2015) & CLASP2 (2019)

~Toward the mechanism elucidation of dynamics and heat of the sun outer atmosphere~

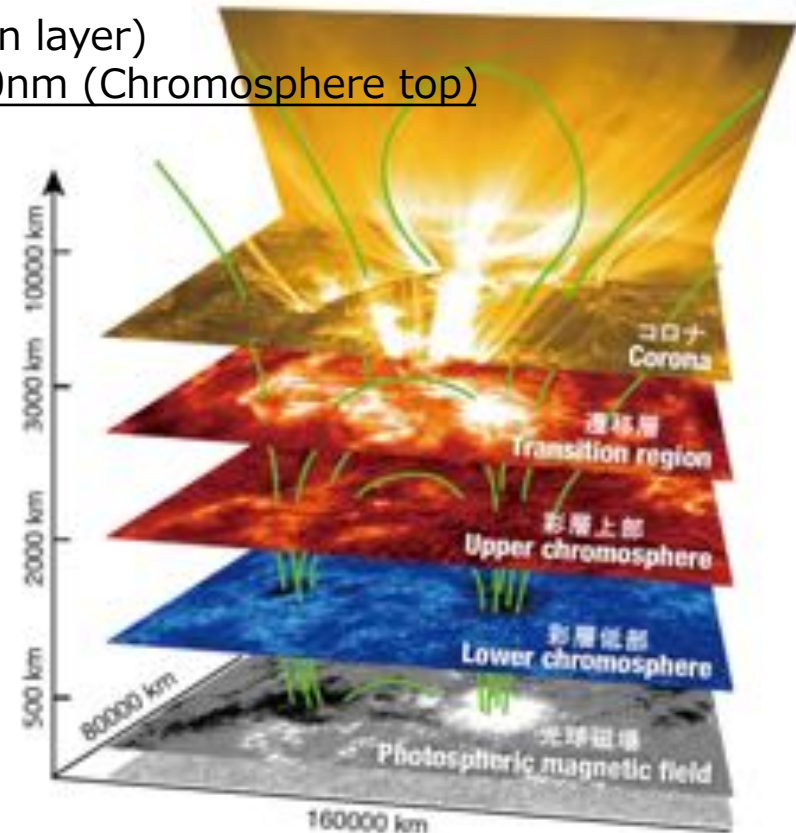
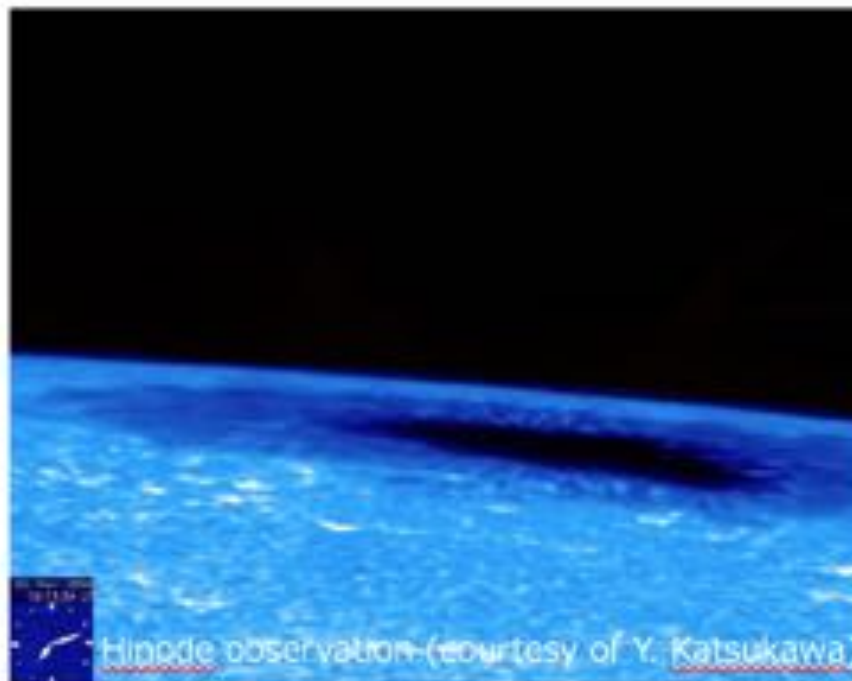


Measure the magnetic field directly from chromosphere to corona!

- Realization of high-precision polarization spectroscopy in UV
- Establishment of magnetic field diagnosis method using the "Hanle effect"

CLASP: HI Ly α line @ 122 nm (Transition layer)

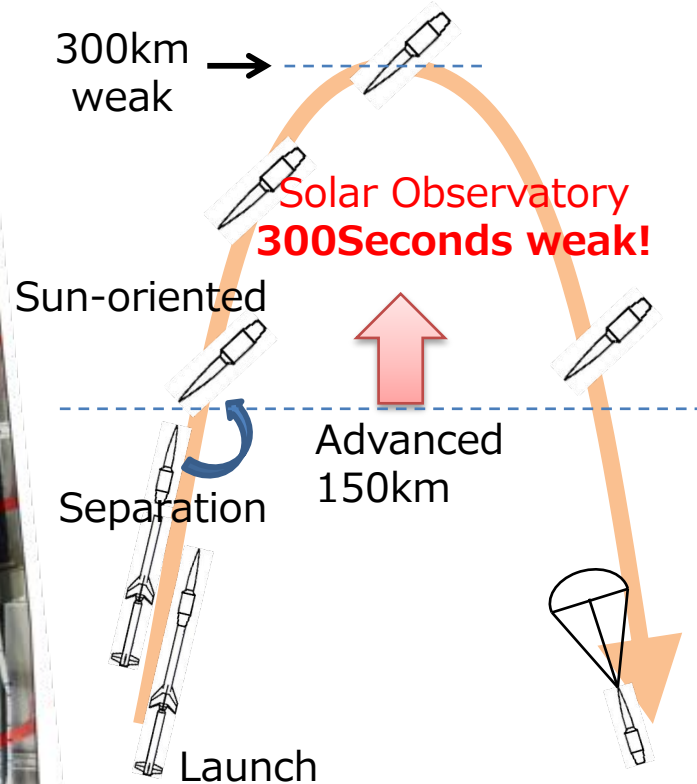
CLASP2: Ionizing magnesium line @ 280nm (Chromosphere top)



Re-flying and observation rocket experiment

CLASP2: Chromospheric **L**ayer **S**pectro-**P**olarimeter 2

NASA Sounding Rocket



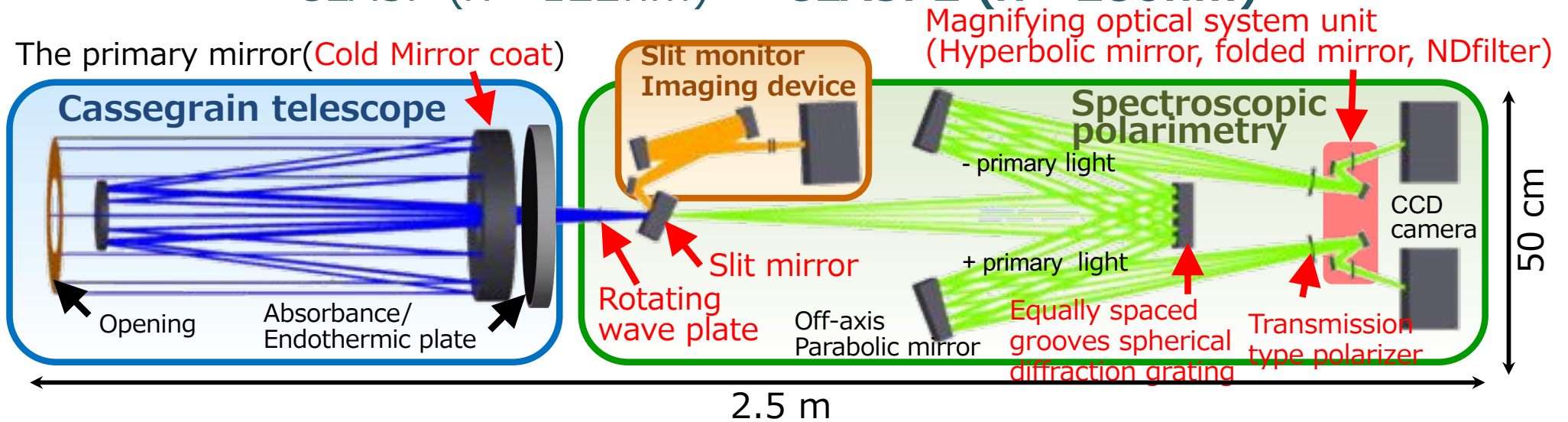
Sep 2015 CLASP launch
@ White Sands launch site



- Safely recovered after the launch.
 - Visually confirmed and optical test that there is no damage to the observation apparatus.
- CLASP2!

CLASP2 Observation apparatus

CLASP ($\lambda = 122\text{nm}$) \rightarrow CLASP2 ($\lambda = 280\text{nm}$)



Slit monitor imaging apparatus (SJ)

wavelength	Lya (122nm) filter
Field of vision	527 x 527 arcsec
resolution	2 arcsec (space)
Time interval	0.6 s

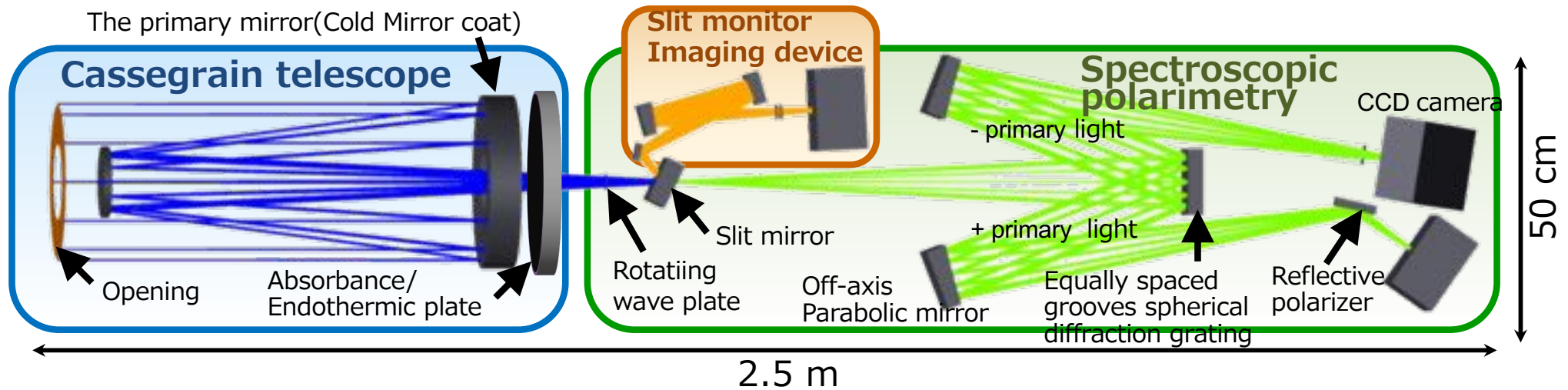
Spectroscopic polarimetry (SP)

wavelength	Mg II h & k line (280 nm)
Field of vision	200 arcsec (Slit length)
resolution	2 arcsec (space) & 0.01 nm (wavelength)
Time interval	3.2 s (Wave plate one revolution)
Polarization precision	0.1% at 3σ

- Observation equipment development:
 - Led by Japan with the supply of diffraction grating [France], CCD camera [USA]
- Sounding rocket, avionics and flight operations: the United States

CLASP Observation apparatus

CLASP ($\lambda = 122\text{nm}$) \rightarrow CLASP2 ($\lambda = 280\text{nm}$)



Slit monitor imaging apparatus (SJ)

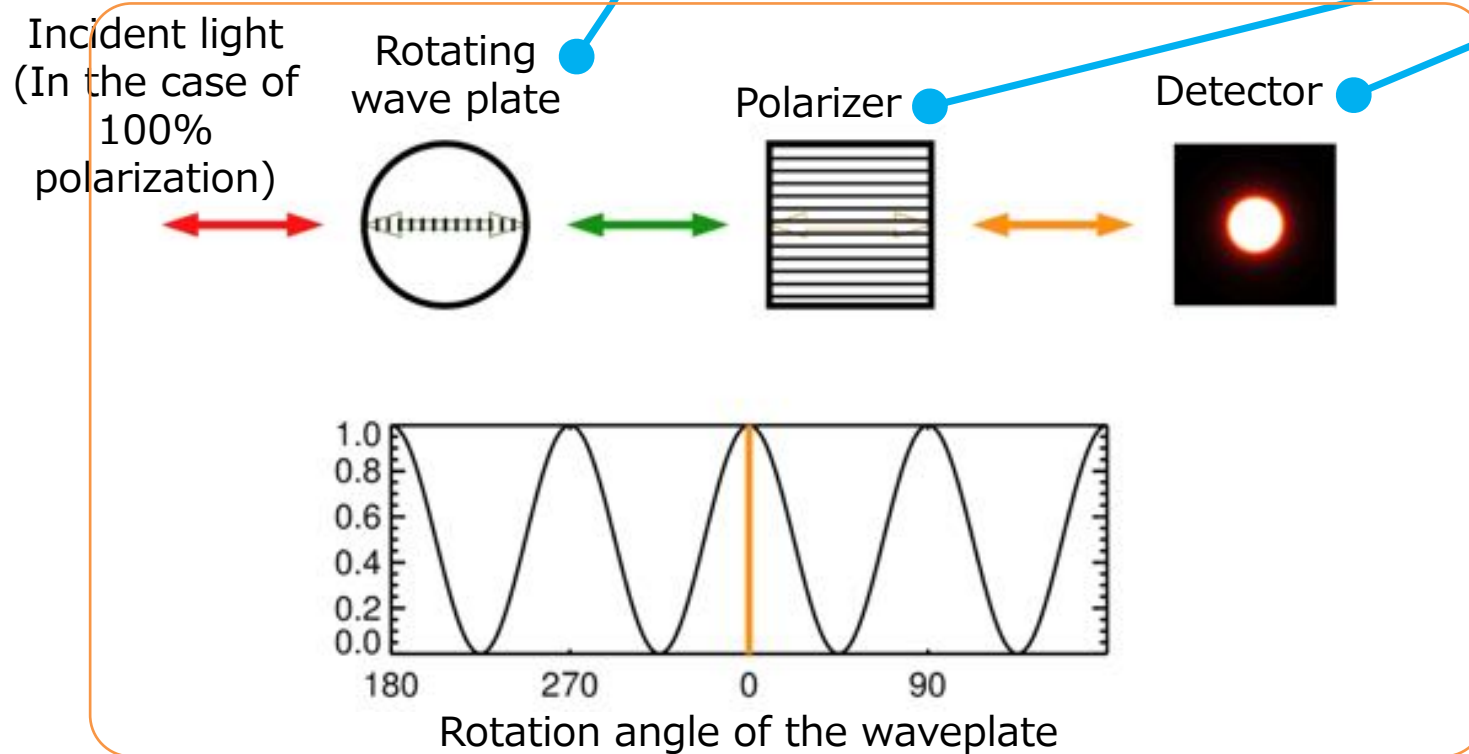
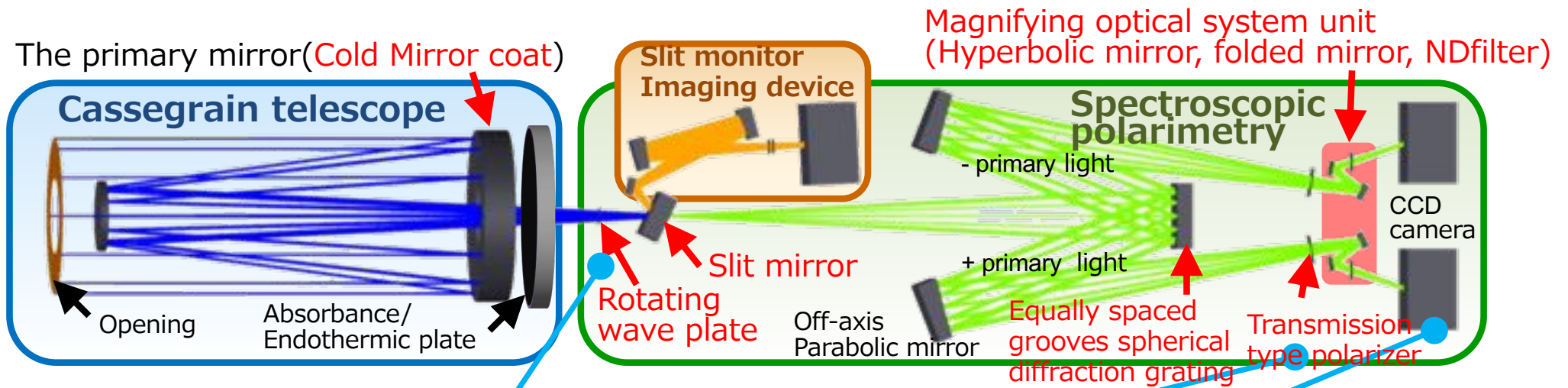
wavelength	Lya (122nm) filter
Field of vision	527 x 527 arcsec
resolution	2 arcsec (space)
Time interval	0.6 s

Spectroscopic polarimetry (SP)

wavelength	HI Lya (122 nm)
Field of vision	400 arcsec (Slit length)
resolution	3 arcsec (space) & 0.01 nm (wavelength)
Time interval	4.8 s (Wave plate one revolution)
Polarization precision	0.1% at 3σ

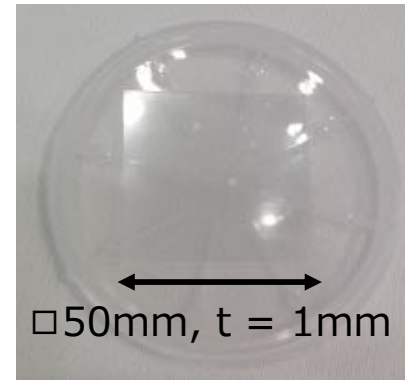
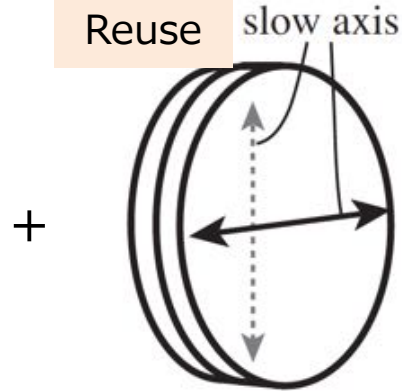
- Observation equipment development:
 - Led by Japan with the supply of diffraction grating [France], CCD camera [USA]
- Sounding rocket, avionics and flight operations: the United States

CLASP2 Polarization analyzer (Polarimeter)

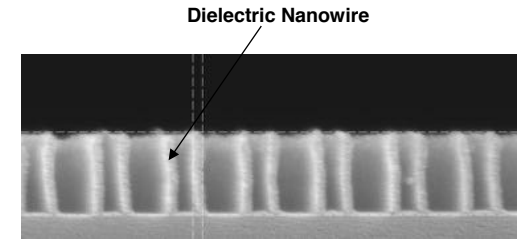


High precision (0.1%) In order to realize

Rotation speed up by software update



New development



Extinction ratio: > 400

Motor pursuing rotation uniformity
(S. Ishikawa et al. 2015, 2016)

MgF₂ Wavelength plate
 $\delta = 234^\circ @ 280\text{nm}$
(R. Ishikawa et al. 2013)

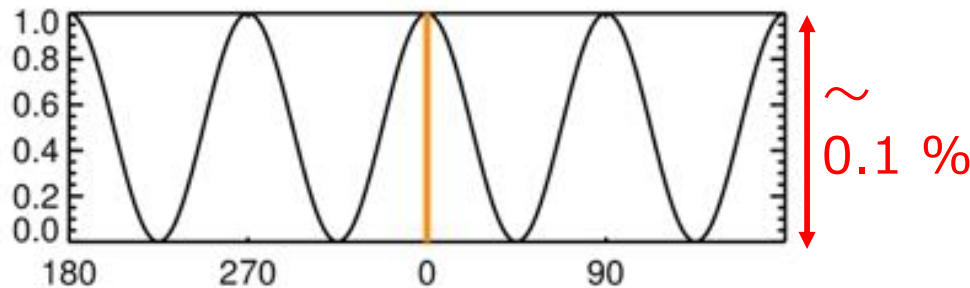
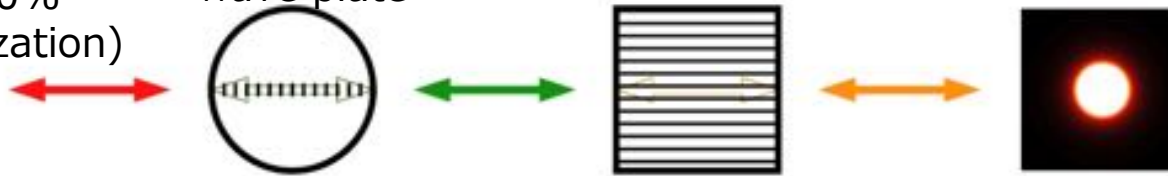
Wire grid polarizer for 280nm
(Berger et al. 2012)

Incident light
(In the case of 100% polarization)

Rotating wave plate

Polarizer

Detector



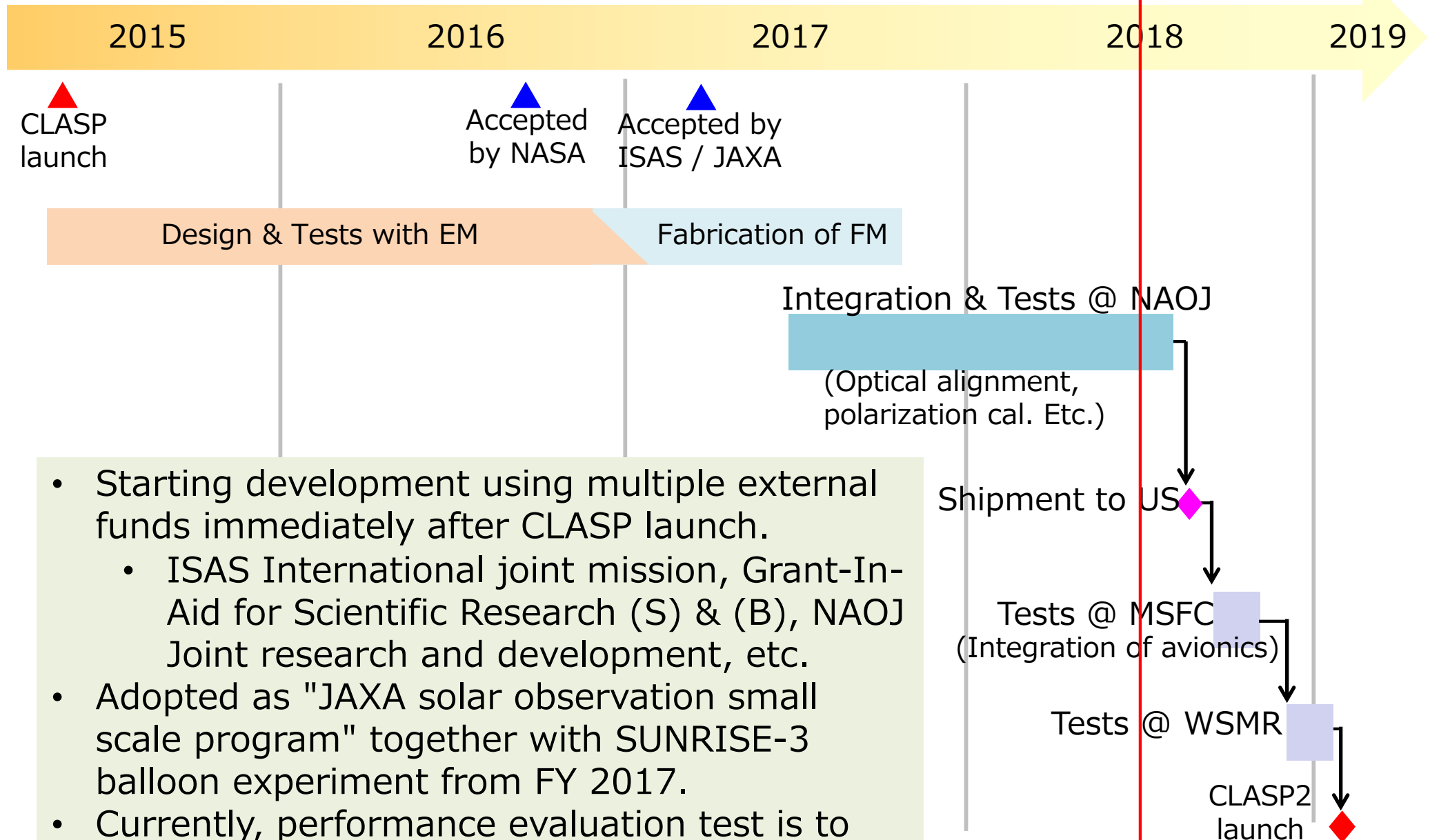
Rotation angle of the waveplate

- High throughput
 - Minimum number of elements
 - High-reflection coating
- Simultaneous measurement of two orthogonal polarization
- Polarization calibration test

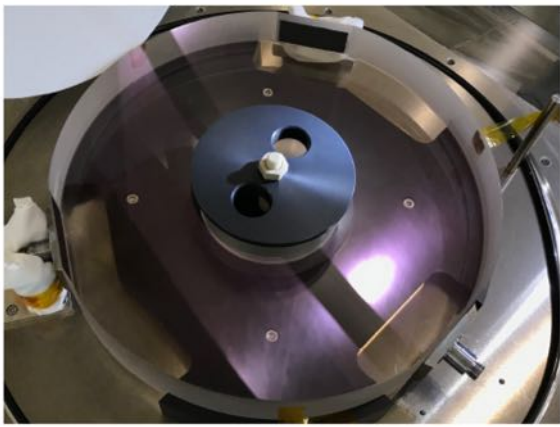
Development progress

NOW!

FY

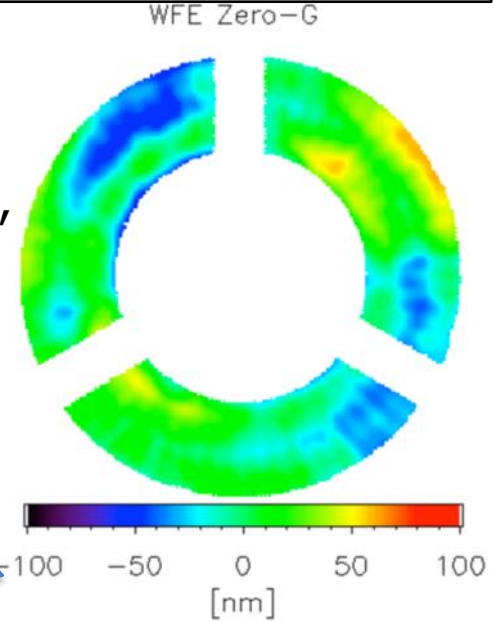


- Starting development using multiple external funds immediately after CLASP launch.
 - ISAS International joint mission, Grant-In-Aid for Scientific Research (S) & (B), NAOJ Joint research and development, etc.
- Adopted as "JAXA solar observation small scale program" together with SUNRISE-3 balloon experiment from FY 2017.
- Currently, performance evaluation test is to climax.



Telescope alignment

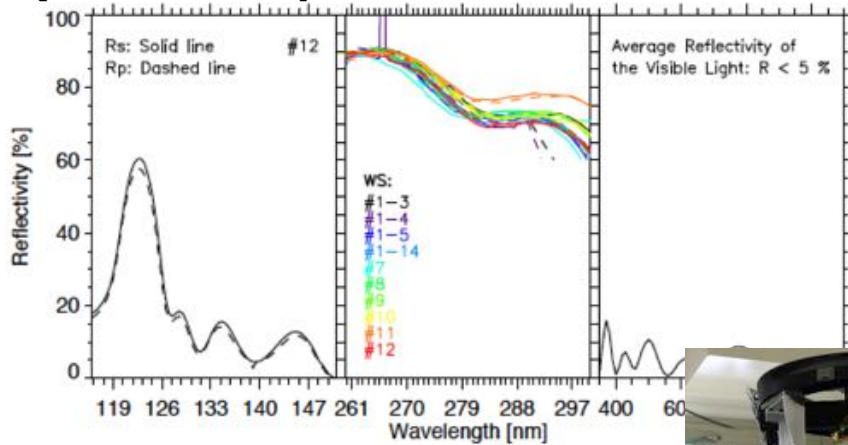
Wavefront error map of the telescope



Review the evaluation methods, performance improvement.

- 37.4 nm RMS (CLASP) → 23.9 nm RMS (CLASP2)

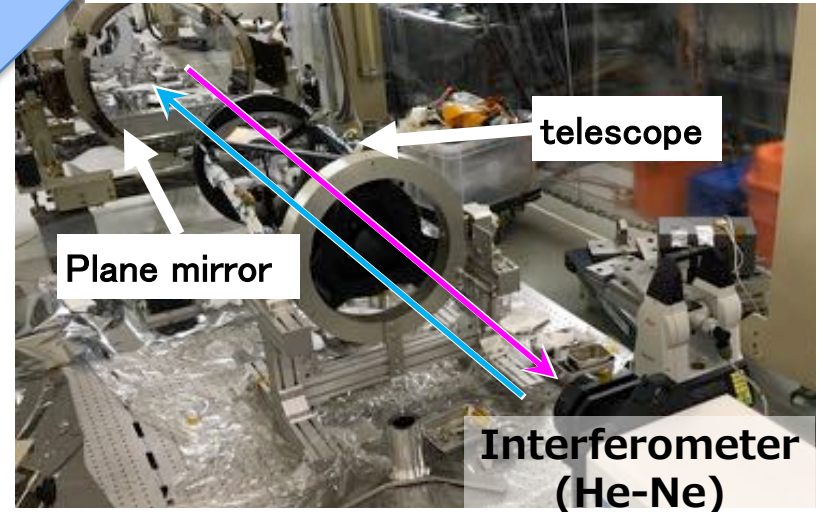
Re-coating of the primary mirror (Dual bandpass cold mirror coating)



The primary mirror re-install

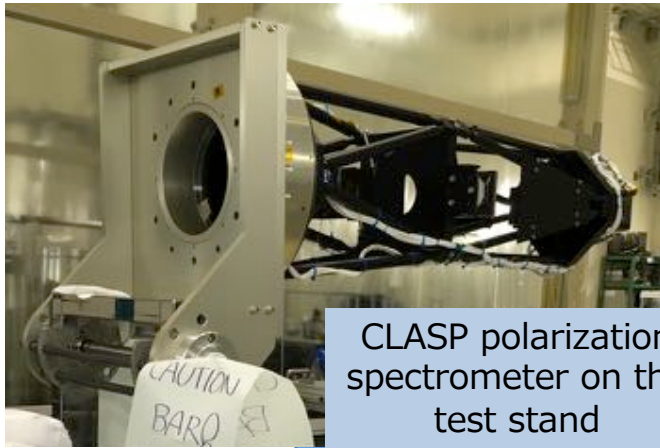


By Double Path interferometry
Wavefront error measurement
⇔ Secondary mirror adjustment



Alignment in VL (He-Ne 632.8nm) & Adjustment in the air

(Adjustment of the mirror other than the diffraction grating)

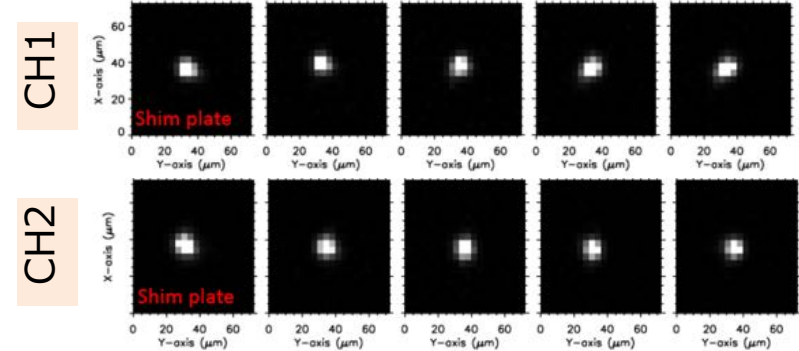


CLASP polarization spectrometer on the test stand

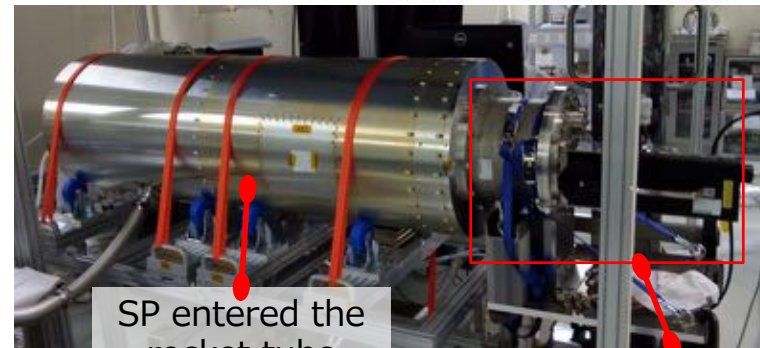
Spectroscope (SP) alignment

Flight camera focus adjustment in vacuum

Final spot diagram

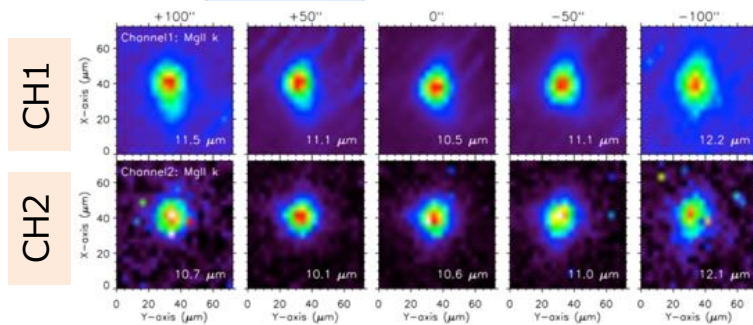


Alignment with Mg Hollow cathode lamp in the air (Flight diffraction grating and mirror adjustment)



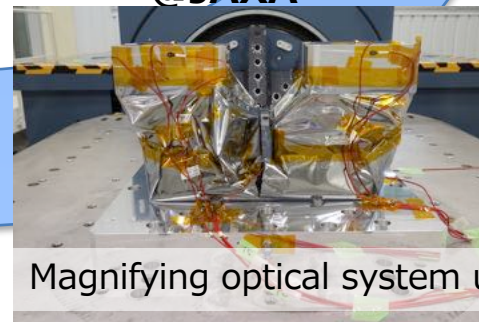
SP entered the rocket tube

light source(Hollow cathode lamp)

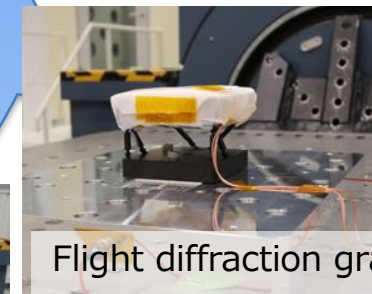


Vibration test of a new structure and newly adhered optical element @JAXA

Spot diagram by GSE camera :
RMS radius <12.2 μm (Request value: <13 μm)



Magnifying optical system unit



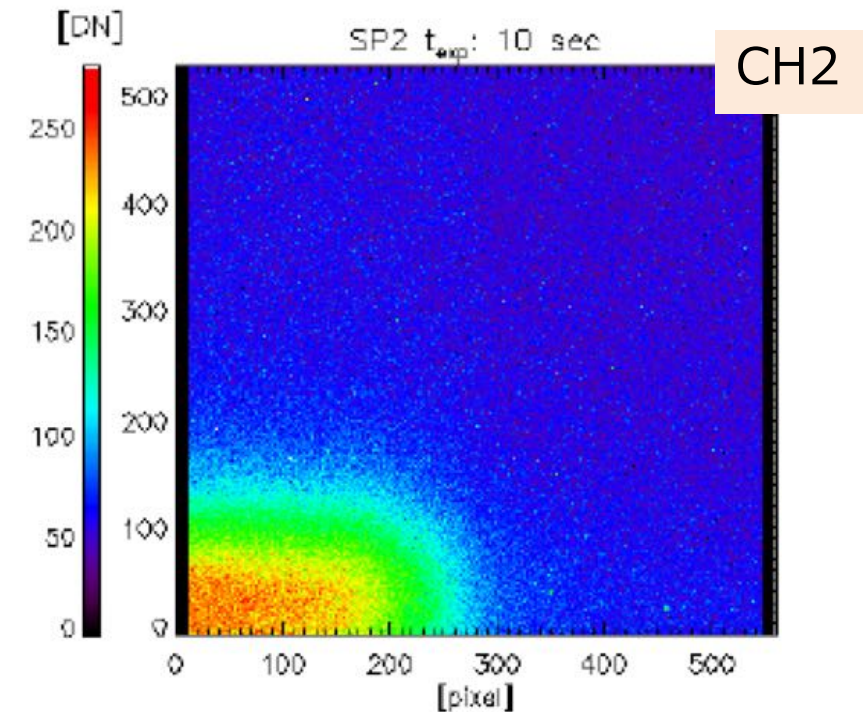
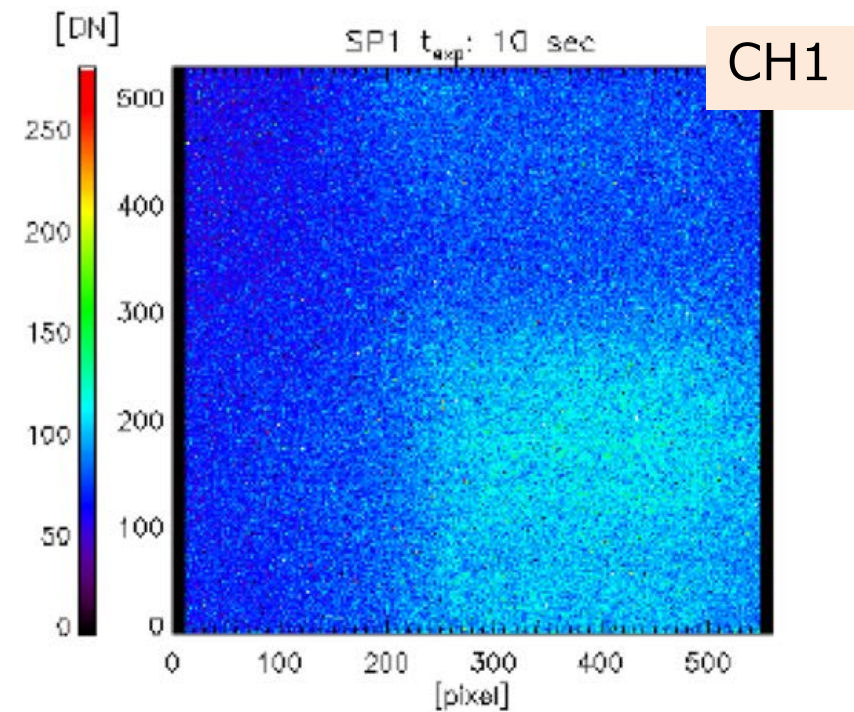
Flight diffraction grating

Stray light (visible light) test

Heliostats
@ NAOJ Clean room rooftop

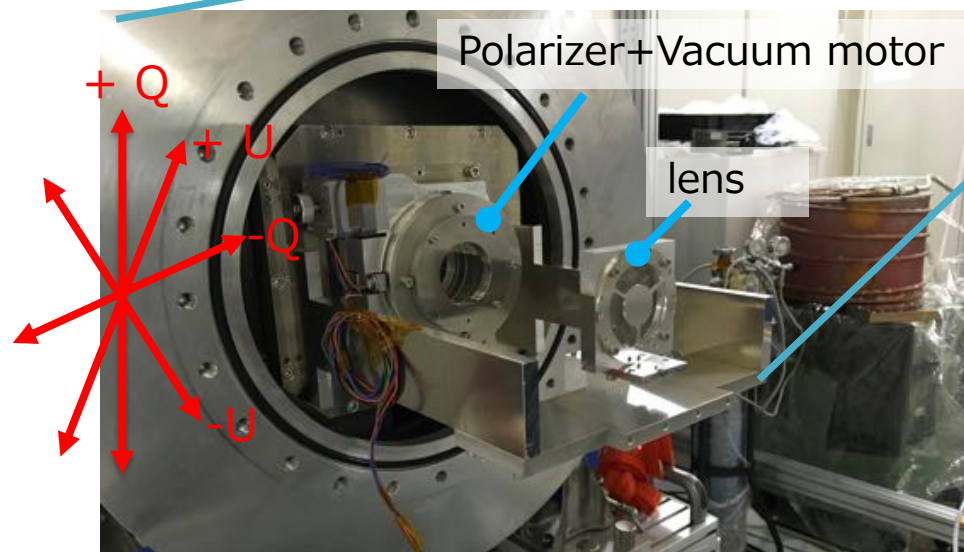
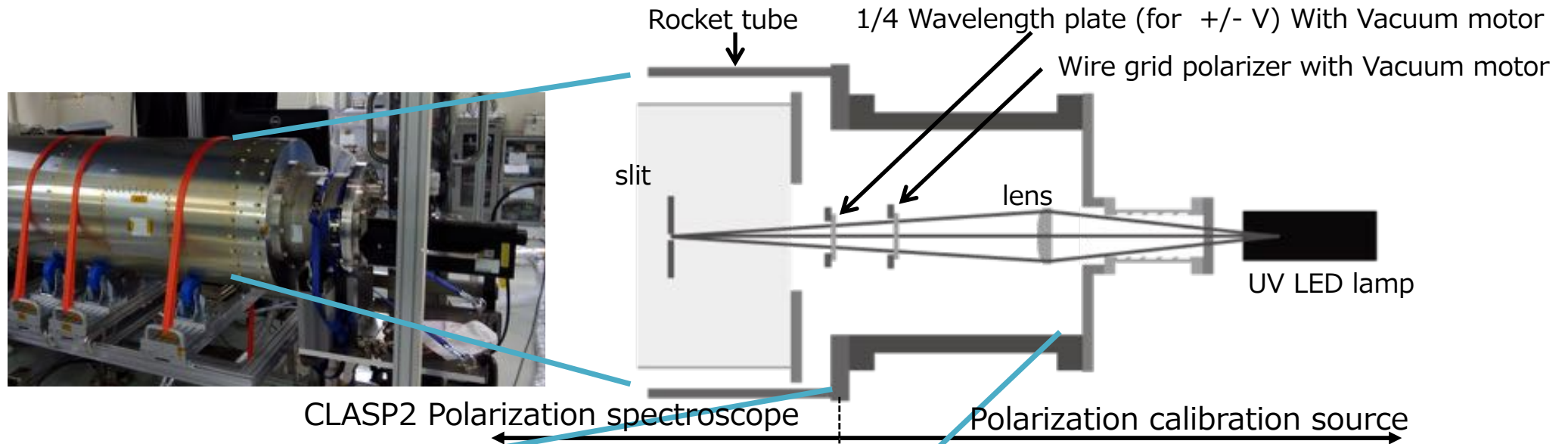


$$I_{\text{VIS}} / I_{280\text{nm}} < 0.2\% \\ (\text{request: } < 4\%)$$



Evaluate how much the VL is detected by feeding from the telescope entrance

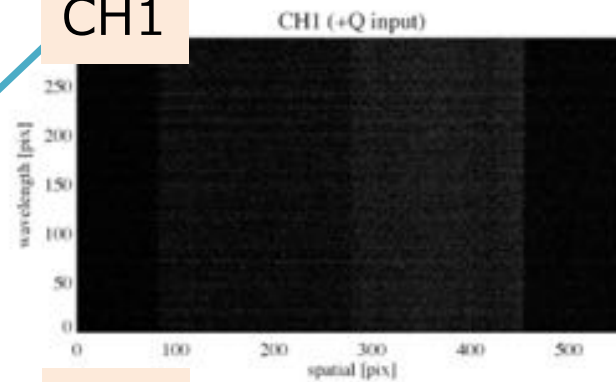
Polarization calibration test (Currently in progress!)



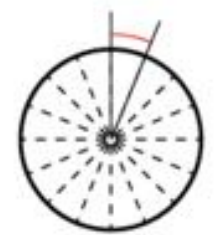
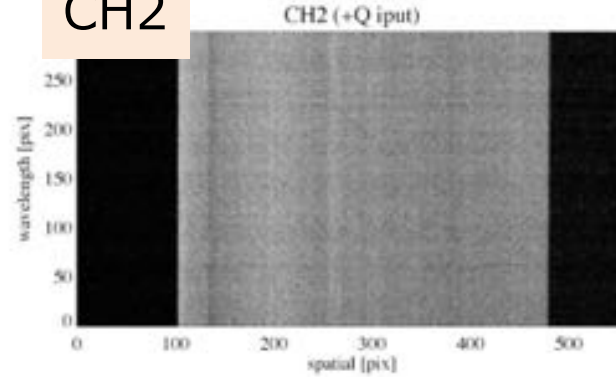
Apply known polarization (+/- Q, +/- U, +/- V) and investigate the polarization characteristics of the observation device

Modulation at + Q incidence

CH1



CH2



Rotation-wave plate
(Exposure / imaging every 22.5 ° / 0.2 s)

Summary

CLASP2

- It aimed to acquire new field diagnosis method by ultraviolet, high-precision polarization spectroscopy
Solar sounding rocket experiment

Progress of observation equipment development

- Flight model of production & assembled & optical adjustment completion
- To leave, polarization calibration test and throughput evaluation test at E2E

Future plans

- 2018 November: Shipped to NASA / MSFC (USA)
- 2019 spring: launch in the United States White Sands launch site!