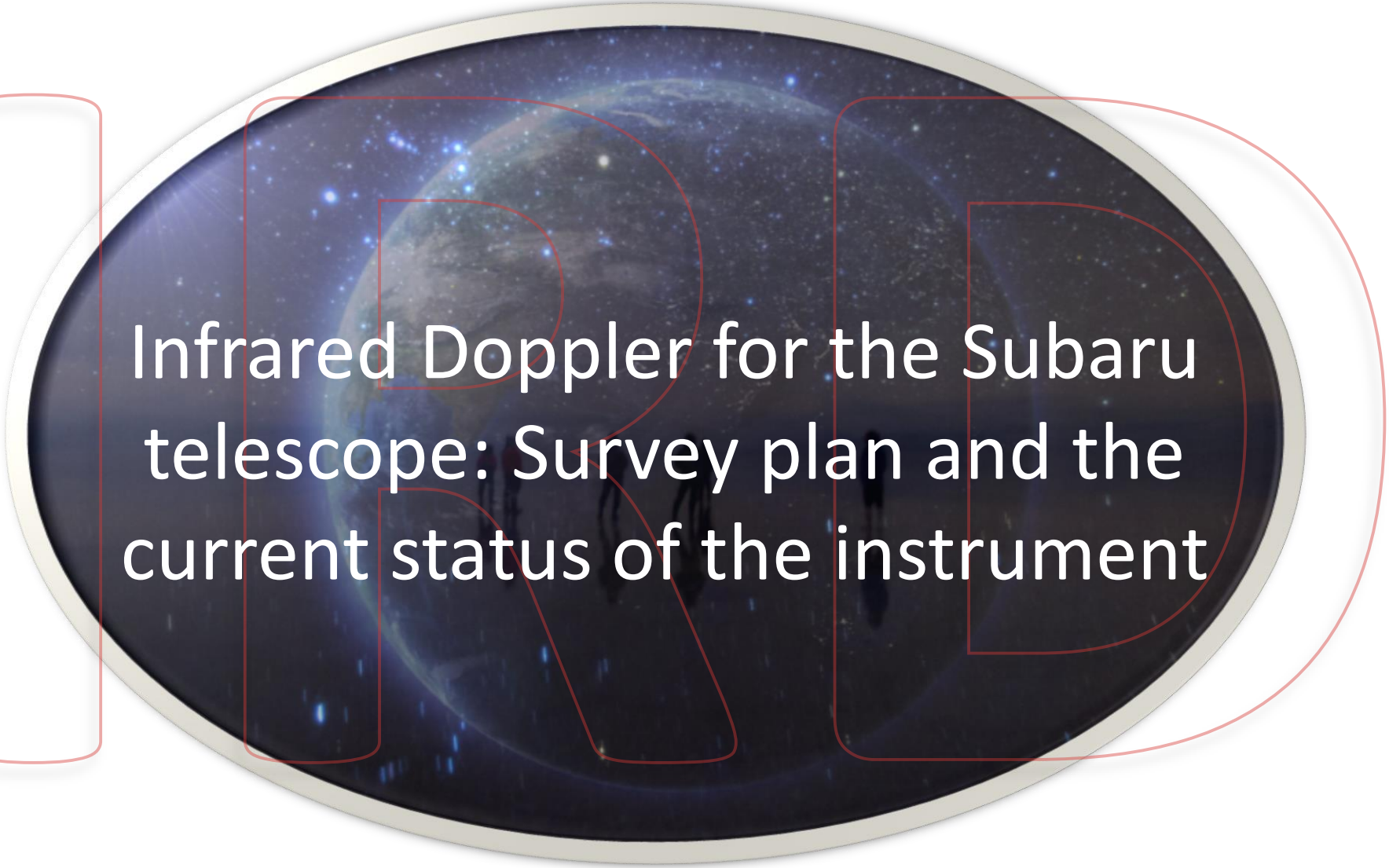


Infrared Doppler for the Subaru telescope: Survey plan and the current status of the instrument

Takayuki Kotani (ABC/NAOJ) and IRD team

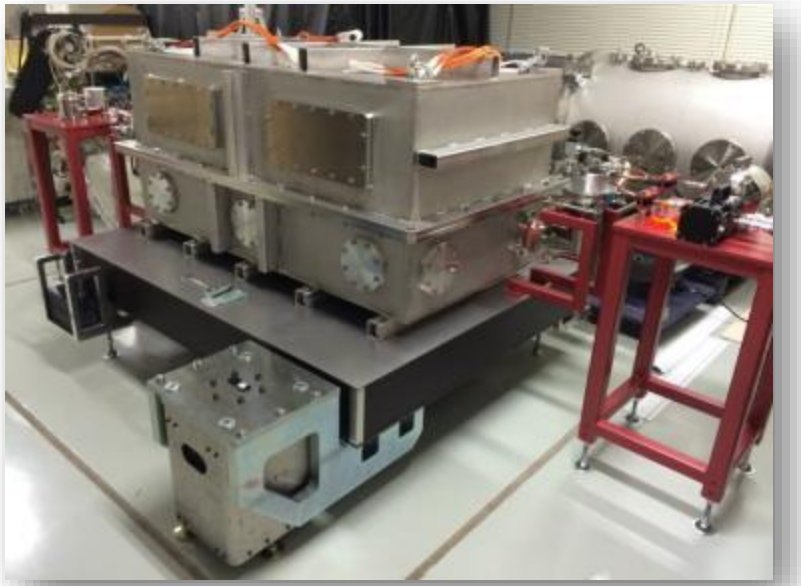
Infrared Doppler (IRD) for the Subaru telescope

What is IRD?

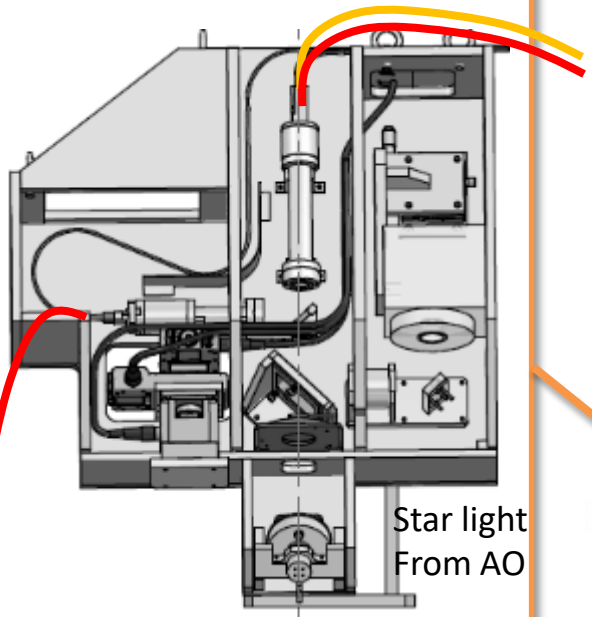
- High-resolution, NIR spectrometer for the Subaru for planet detection by radial velocity method (Rmax=70,000, Y,J,H)
- First light: early 2017, Start of survey from S18A

Goal of IRD

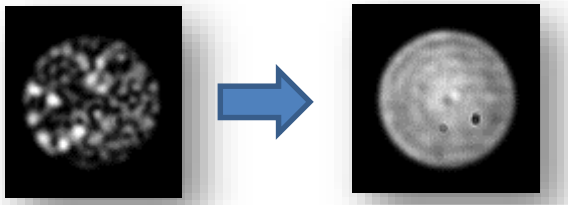
- Detection of ~ 50 planets around nearby M dwarfs, including ~10 Earth-like planets in their habitable zone
- Characterization of planet atmospheres



Overview of the IRD instrument

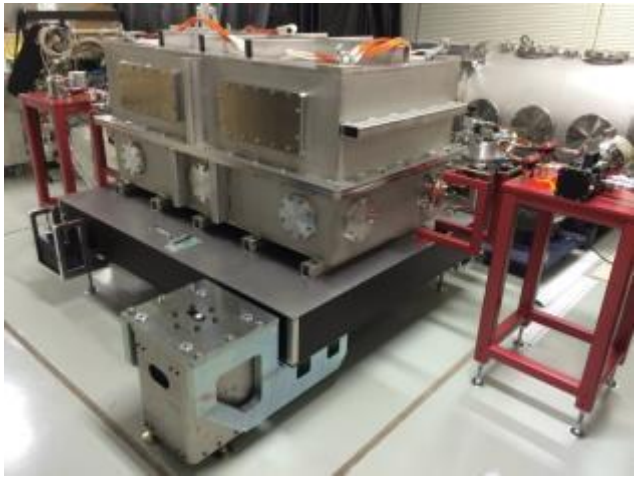


Fiber injection system
(AO bench)

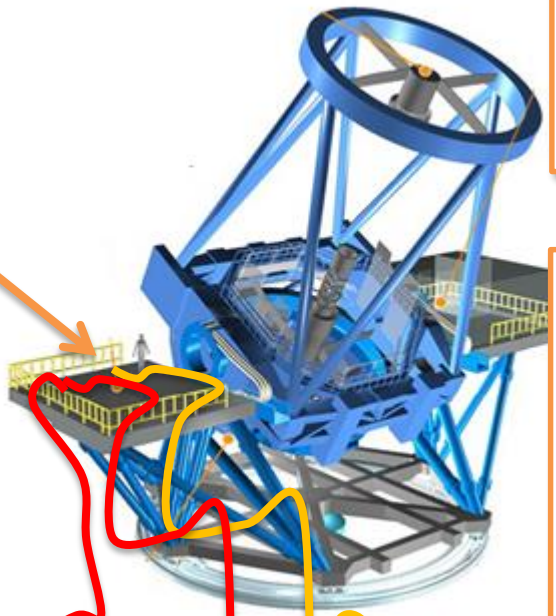


Mode scrambler

Resolution: R=70000
Wavelength: 0.97-1.75um
Cryo: 70K (detector), 200K (optics)



Spectrometer system
(Coudé room)

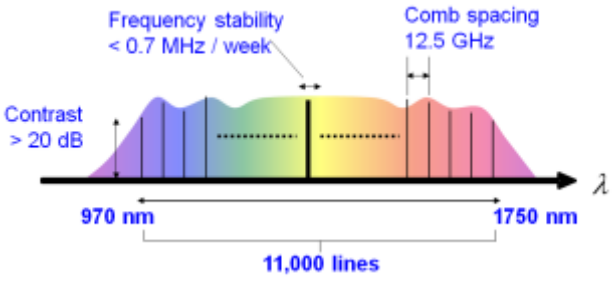


Fiber
(Comb)

Fiber
(star)

spectrometer

Coudé Room

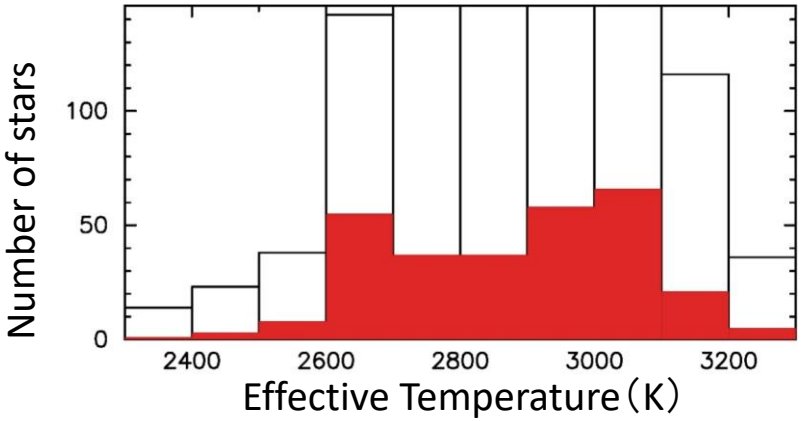


Laser frequency comb
(IR Observing floor)

Why late M dwarfs?

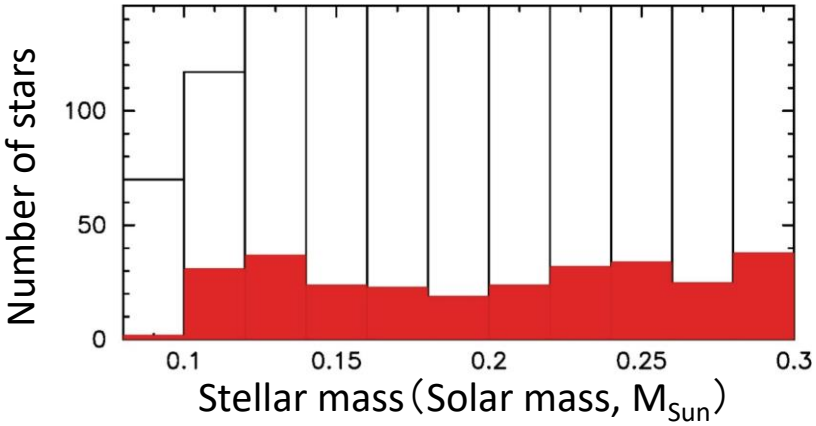
Late-M type dwarfs (M4V-M9V, 0.1-0.3 M_{sun})

- Large RV amplitude, short orbital period
  - Easier to detect Earth–mass planets in HZ with 1m/s RV precision
- Flux peak in NIR
  - Difficult for the optical surveys
- Faintness of the objects
  - Advantage of a large collecting area of a 8-meter telescope



But, many late M dwarfs are active, rapid rotator…

- Careful target selection (XUV, H-alpha, vsin*i,* variability, etc.)
- High cadence observations to reduce stellar noises from activities
- (Quasi) Simultaneous photometric measurements for diagnostics of activities, spots, etc.



Science goals of IRD

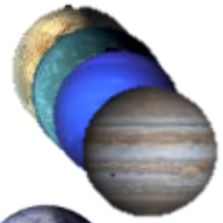
1. **Detection of habitabile Earth-like planets around nearby M dwarfs**
   - Minimum Success
     - Detection of at least 1, one Earth-mass planet in their HZ
   - **Full Success**
     - **Unveiling frequency and properties of habitable Earth**

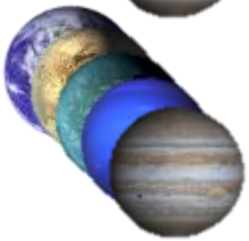
2. **Statistical understandings of planet formation around low-mass stars**
   - Minimum Success
     - 25 > Super-Earth - Jupiter-mass planets around low-mass s stars
   - **Full Success**
     - **50> planets including Earth-mass planets**

Number of Detection


× >1

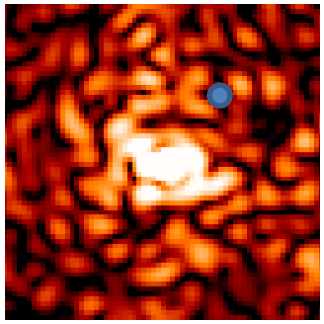

× >10

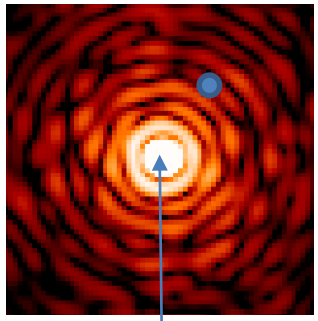

× >25

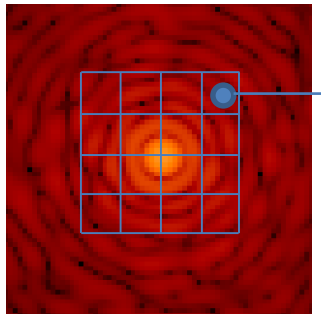

× >50

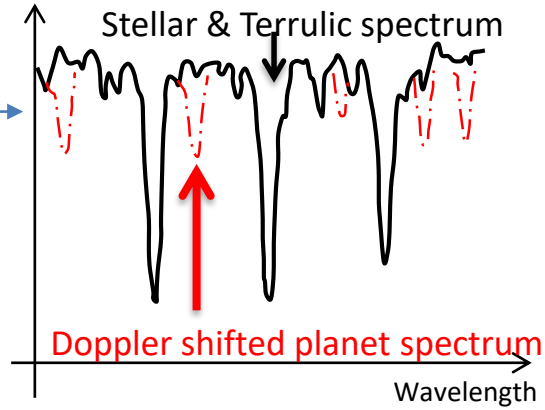
The expected number of planets is estimated by planet population synthesis and with observing schedule simulation

Coronagraphic High-dispersion Spectroscopy with IRD-SCExAO









SCExAO (Extreme AO)

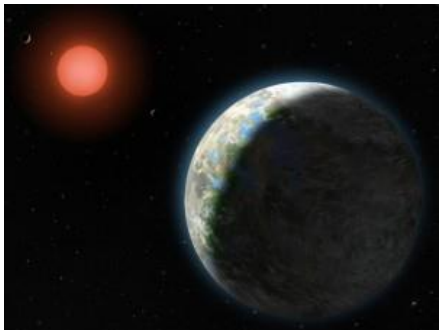
Wavefront Correction

Coronagraph

Star light Reduction

Spatially resolved, High dispersion Spectrograph

Post-process & Characterization



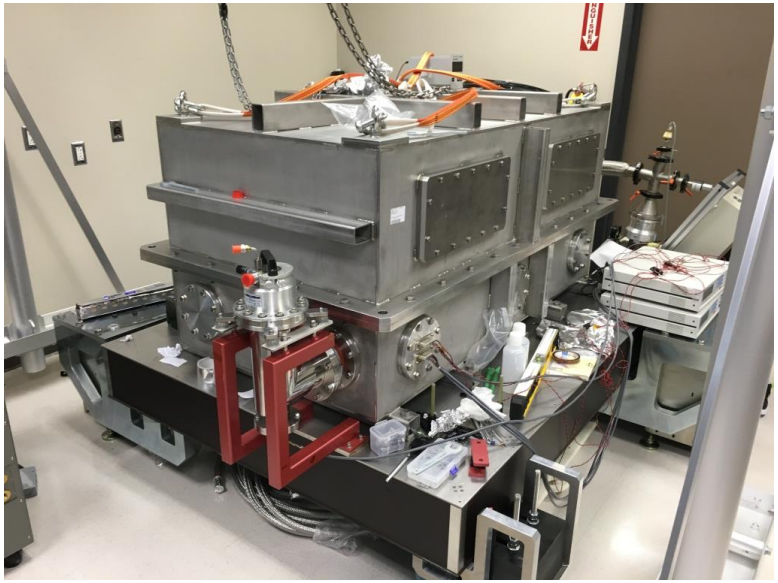
Reconstructed planetary system

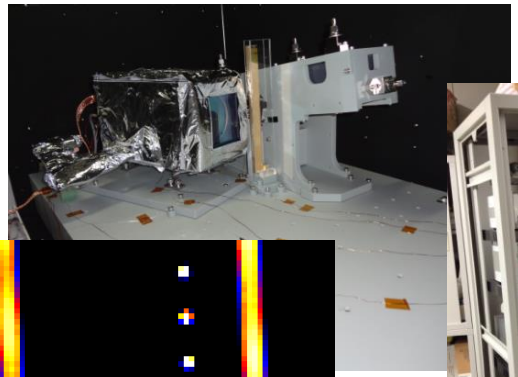
- Planetary radial velocity (mass, orbit)
- Planet spectrum
- Atmospheric characterization
- Albedo, etc

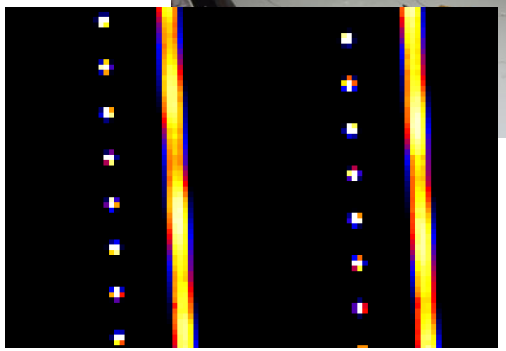
H.Kawahara, N. Murakami, T.Matsuo, T. Kotani 2014, ApJS,212,27

Current status of the instrument

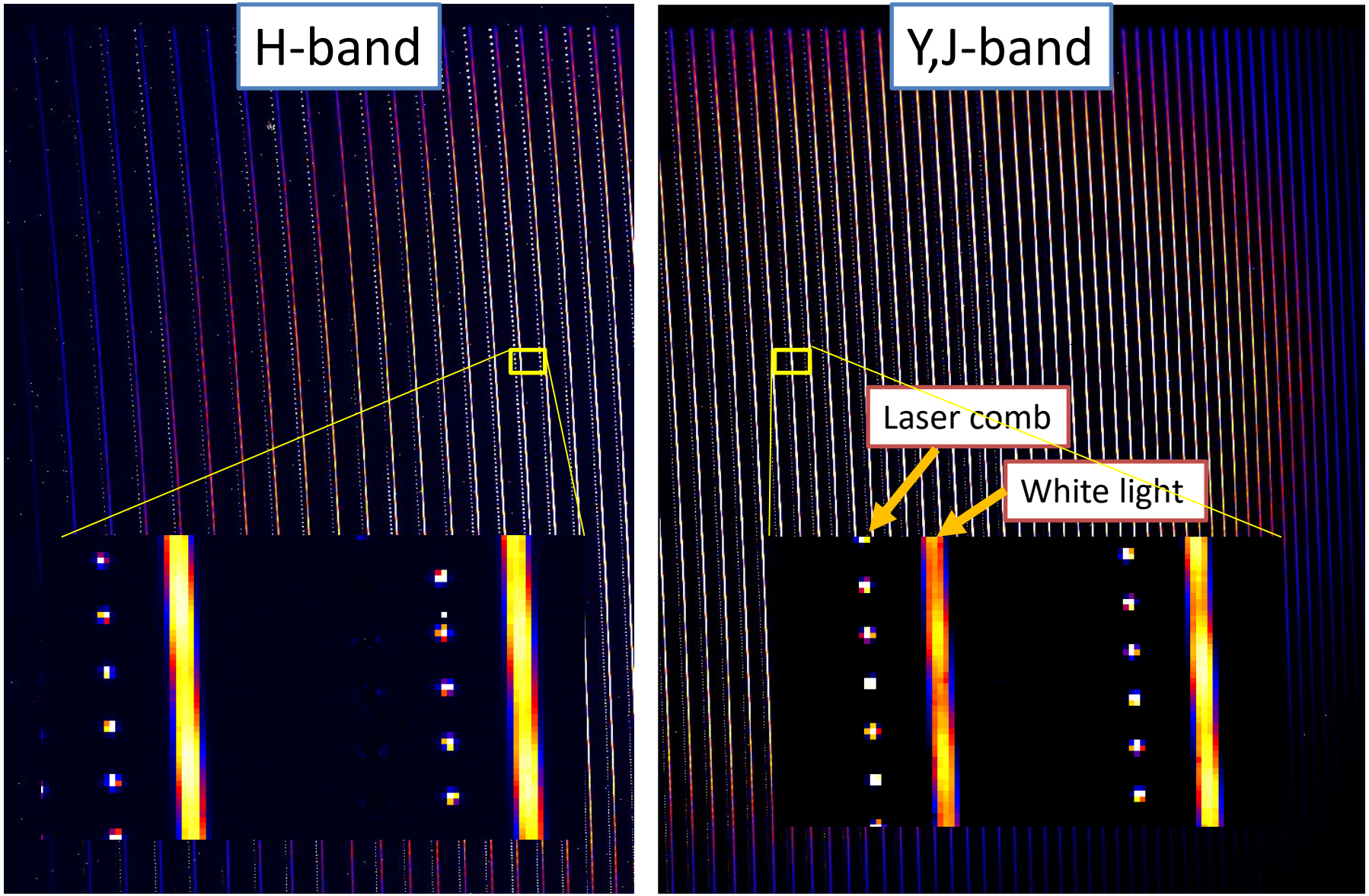
- All instruments are being tested at IfA, UH
  - Optical performance is almost OK
  - Cryogenic system with a 0.01K stability (camera lens 60K, optical bench 180K)
  - Detector (2xH2RG) noise: achieved less than 20e-
  - Laser frequency comb: 0.3m/s stability, wavelength coverage: 1050-1750nm (to be down to 970nm)
  - Scrambler system to eliminate a modal noise
- Radial velocity stability test is ongoing
- Delivery to the summit: early 2017



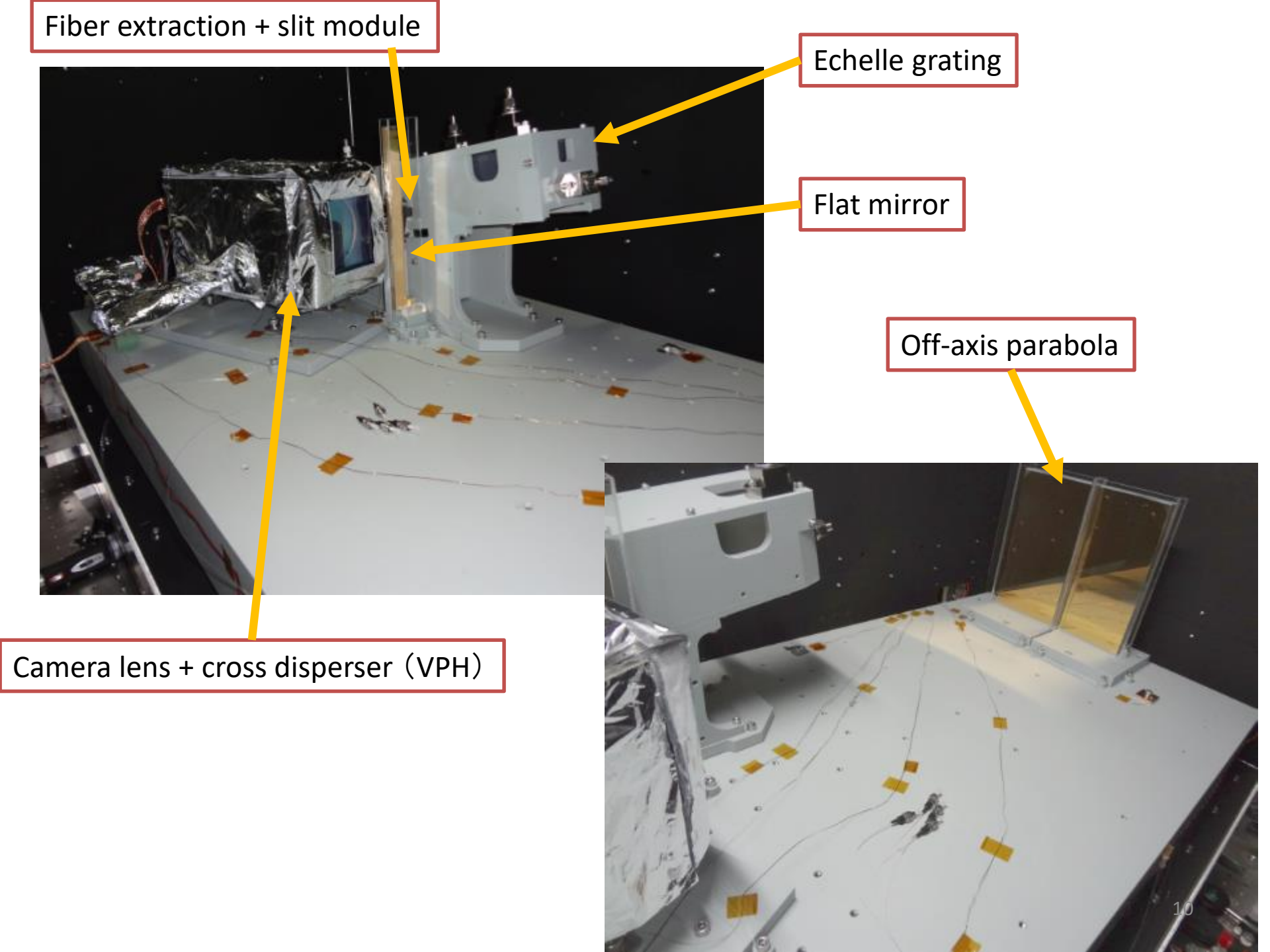




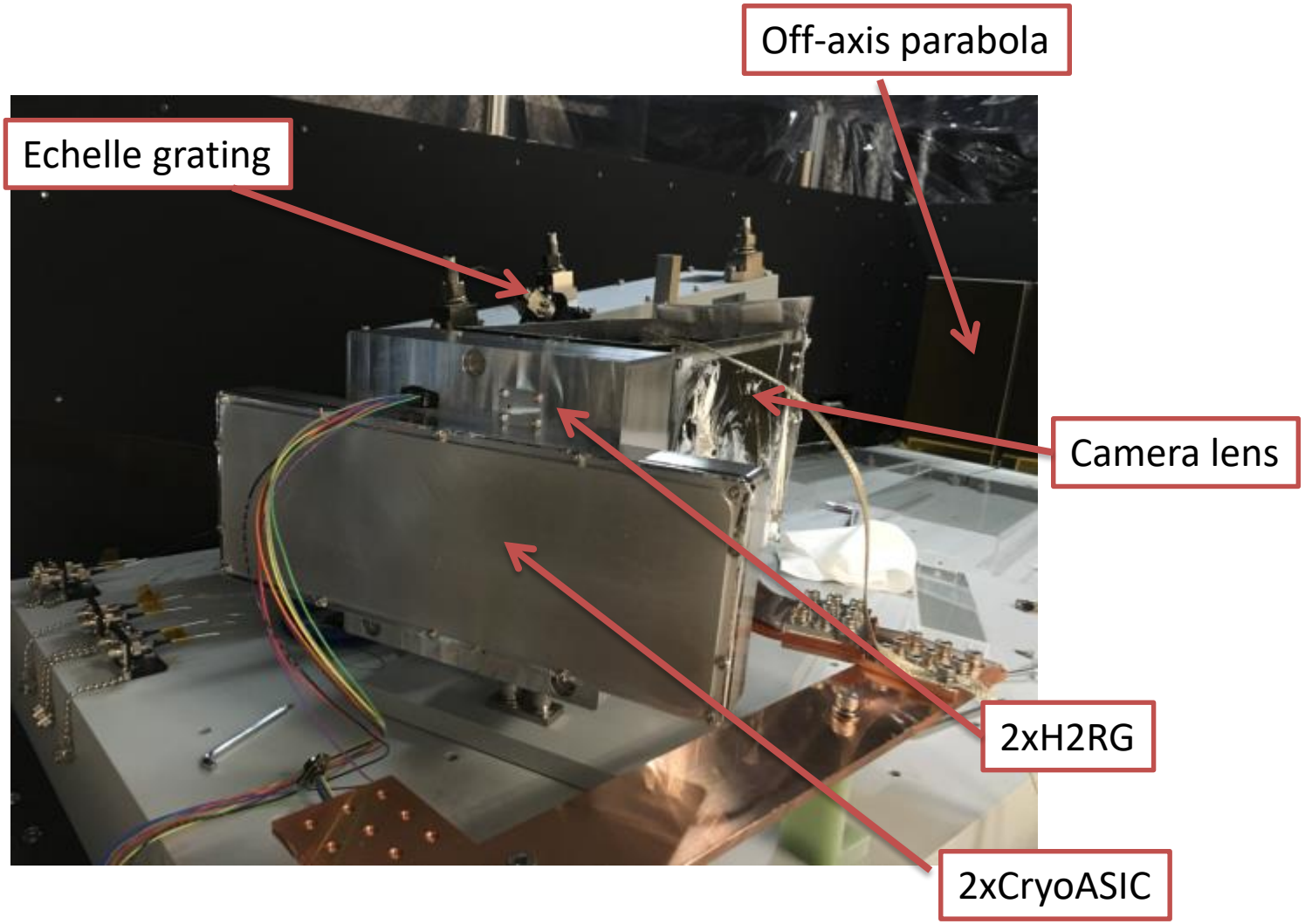
Spectrum obtained with 2xH2RG



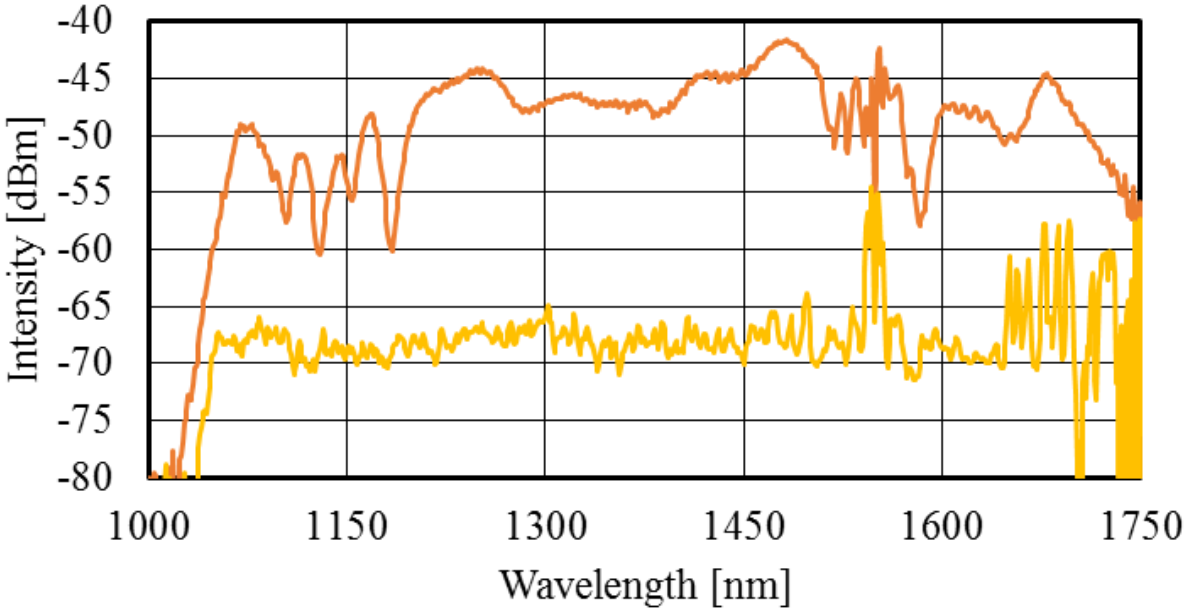
IRD acceptance at IfA


Fiber extraction + slit module
Echelle grating
Flat mirror
Off-axis parabola
Camera lens + cross disperser（VPH）

IRD detector module



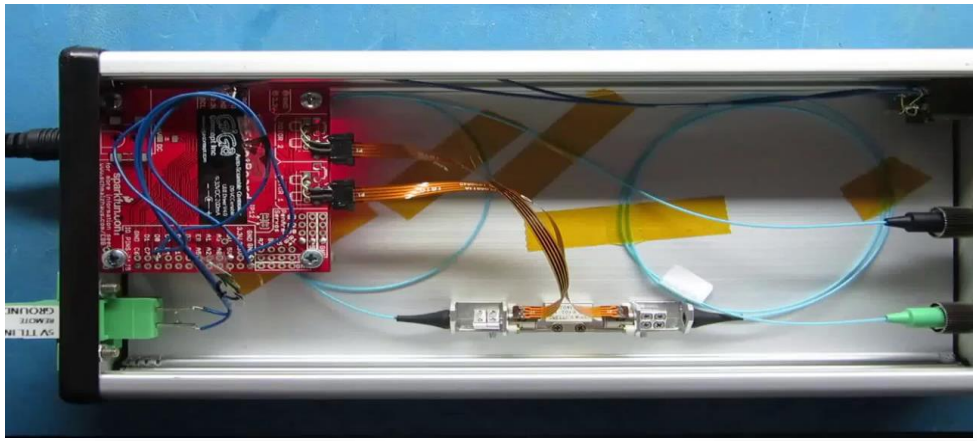
Original Laser frequency comb

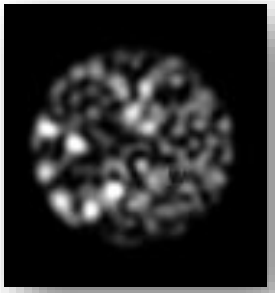


- Our original laser frequency comb will cover Y, J, H-band simultaneously
- Sufficiently wide frequency span(12.5GHz, 0.09nm @ 1.5um)
- Developed by the group at Tokyo University of Agriculture and Technology

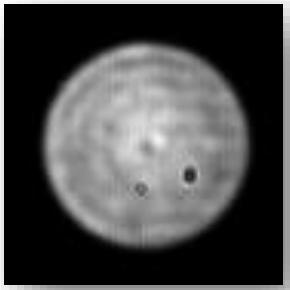
Mode scrambler

- Mode scrambler
  - Dynamic scrambler: Fiber shaker + rapidly twisting fibers
  - Static scrambler: long fiber (250m) for a star
  - Rotating ground glass scrambler and polarization scrambler for laser comb





Without any Scrambler, WFE



With Dynamic Mode Scrambler

Thank you for you attention!