Advancements in Optics Research at NARIT

Supachai Awiphan

NATIONAL ASTRONOMICAL RESEARCH INSTITUTE OF THAILAND
(PUBLIC ORGANIZATION)

Advanced Astronomy and Space Technology as a Tool for Instrumentation Development

Optics and Photonics

Radio Frequency Technology

Mechatronics

High Precision Machining

High Performance Computing and Data Science

Research & Development

- Telescopes
- Spectrograph
- Others

Commercial

- Medical Science
- Telecommunication
- Industrial Instrumentations

Objectives

1. To develop the facilities and human capabilities in optical technologies and related fields in Thailand.
2. To develop high-performance and cutting-edge technology optical instruments for astronomy, space, life science, and industry.
3. To lead research activities in innovative optical technologies to stimulate the development of high-technology companies.
4. To train Thai and/or ASEAN engineers, researchers, and entrepreneurs in optics and photonics.

Center for Optics and Photonics Sites

Princess Sirindhorn AstroPark (Chiang Mai)

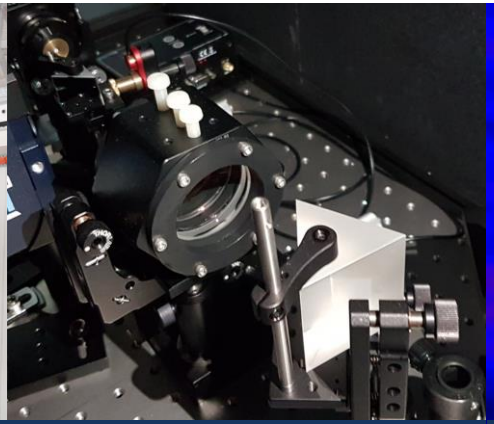
- **Clean room optical laboratory** (cleanliness class 100,000)
- **Optical design room**

Regional Observatory for the Public, Songkhla

Current activities

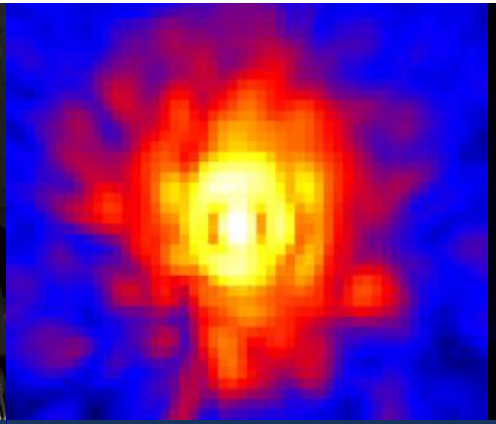
Telescope design

- TNT Prime Focus Camera
- Planetary Imaging Telescope project
- 0.6-0.8 m Telescope design
- TNT optical alignment and performance optimization



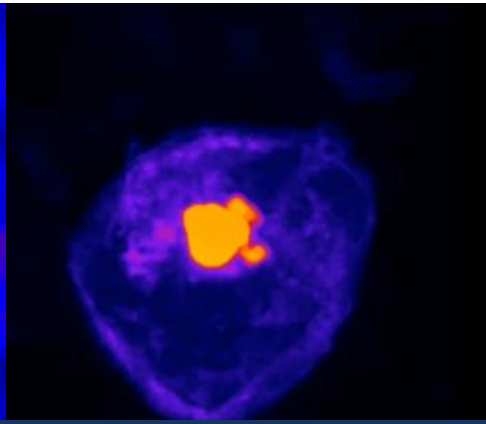
Spectrograph

- Low-Resolution Spectrograph
- EXOhSPEC
- Thai Space Consortium Hyperspectral Imager
- UV-Visible Spectrometer for Atmospheric Science
- Fourier Transform Spectrograph



Coronagraph and Adaptive Optics

- Evanescent Wave Coronagraph (EvWaCo)
- Adaptive Optics



Industry/Medical/Atmos. Science applications

- Time-Resolved Raman Spectroscopy system
  - Bench-Top for industry applications
  - Compact system for medical applications
- RAMAN Lidar (Atmospheric Science)
- Two-photon microscope system

Thai National Observatory

Thai National Telescope Instruments

Main Instruments

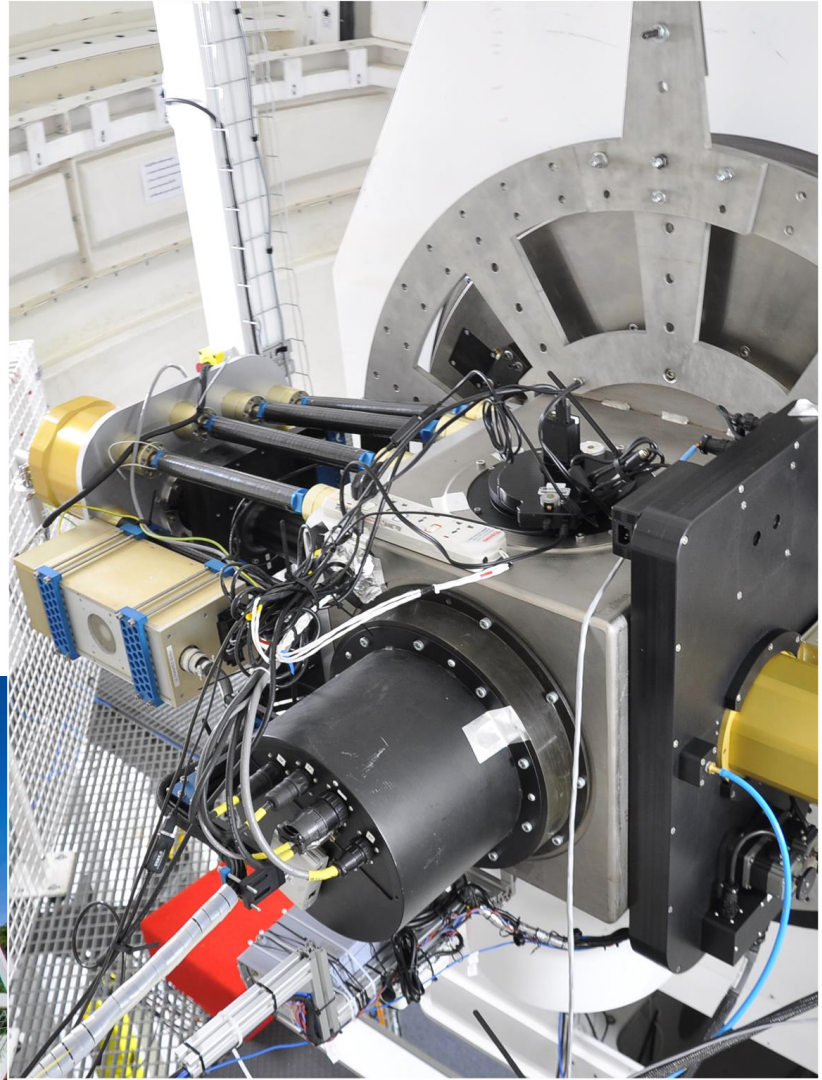
1. ARC4K Imager (2013)
2. ULTRASPEC(2013)
3. Medium Resolution Spectrograph-MRES (2014)

Future Addition Instruments

1. LRES (2024)
2. EvWaCo (2025)
3. EXOhSPEC (2027)

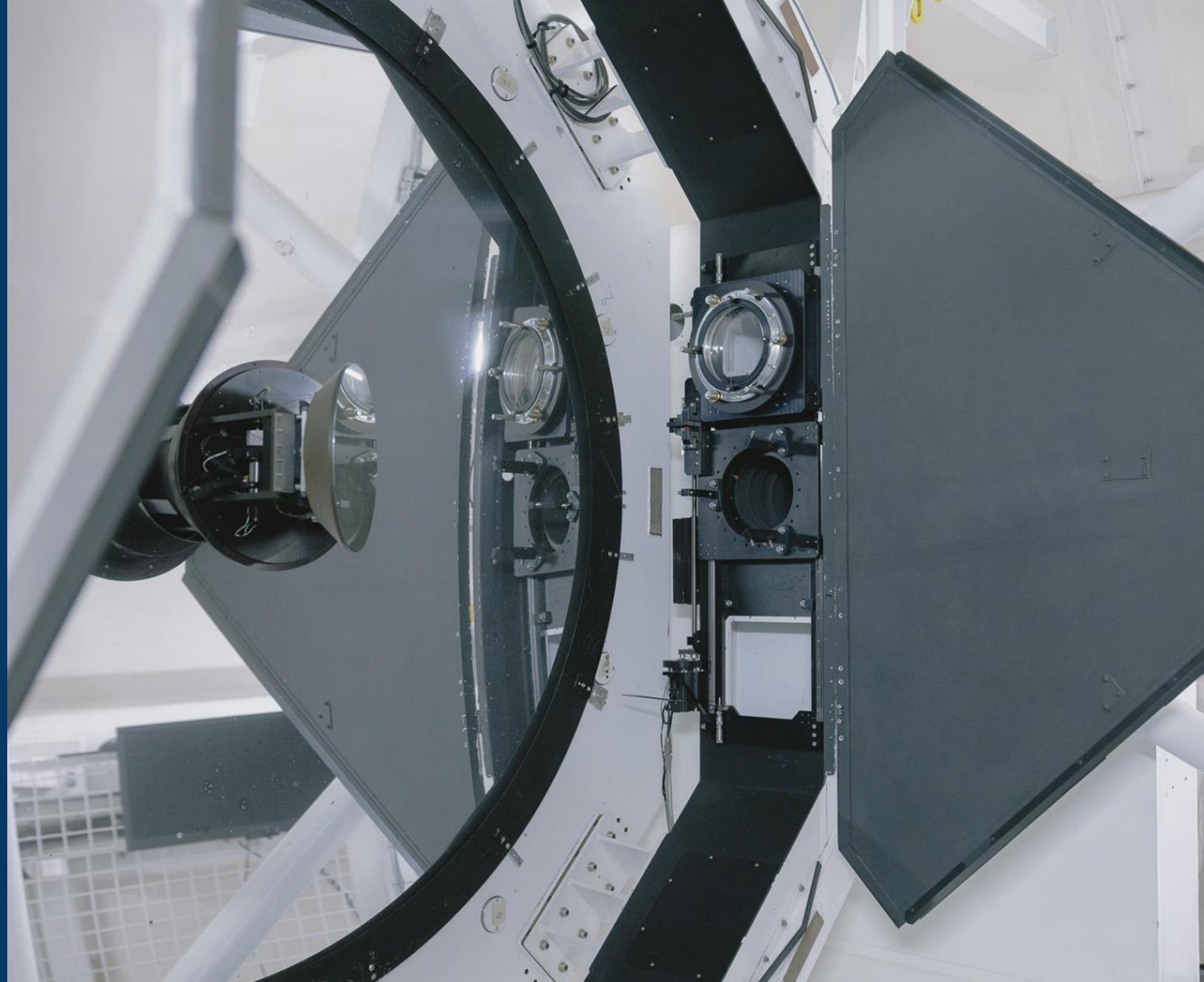
Telescope Upgrades

1. M1 Masking (2015)
2. New Baffle (2015)
3. Focal Reducer (2019)

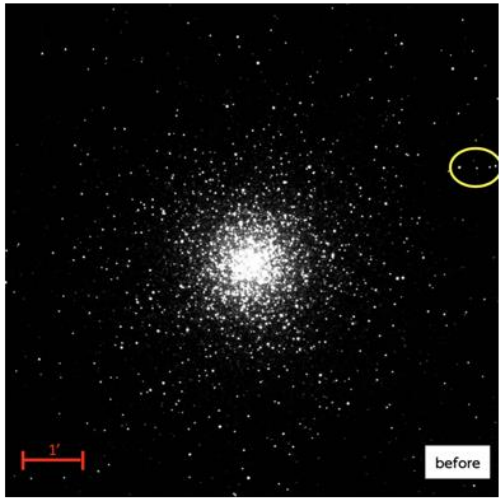


Focal Reducer

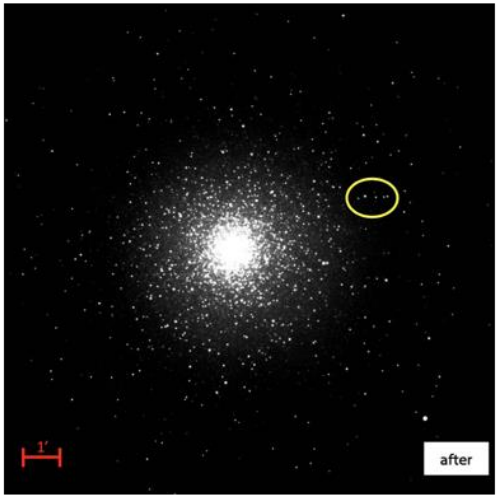
Objective: to enlarge the field of view on the 4k camera and provide image quality close to seeing limit



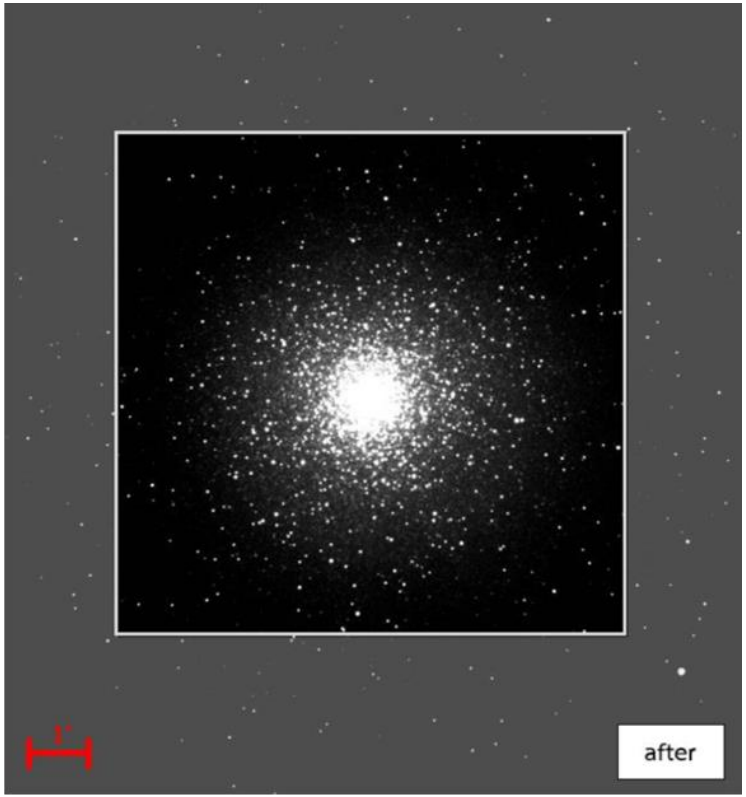
Focal Reducer



Field of View: 8.8 x 8.8 arcmins

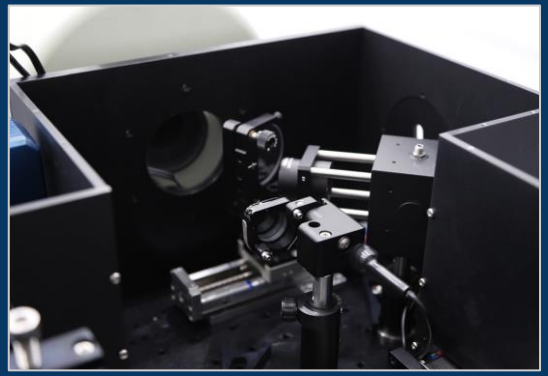


Field of View: 14.6 x 14.6 arcmins



Globular cluster M3

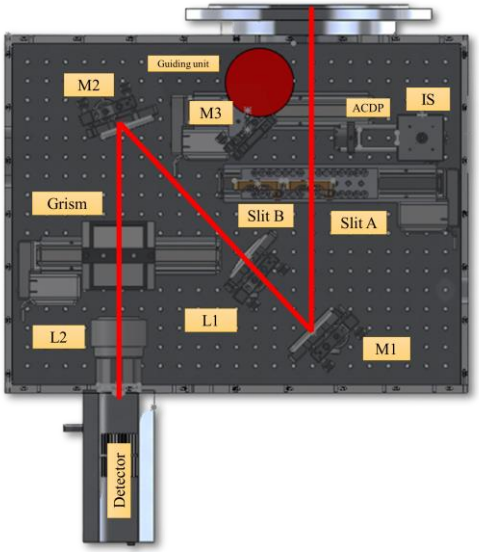
LRS
Low Resolution Spectrograph

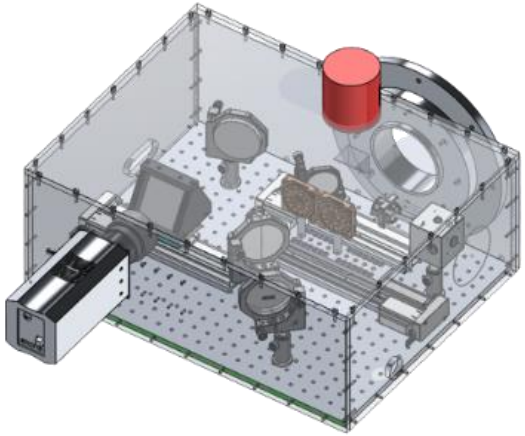


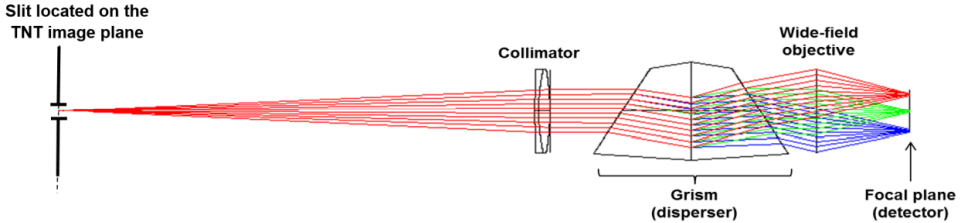
Objective: Development of low-resolution spectrograph for the 2.4 m Thai National Telescope

Specifications

- Slit less/Long slit spectrograph
- Spectral Resolution: R=1000 at 600 nm
- Spectral Domain: 400-800 nm



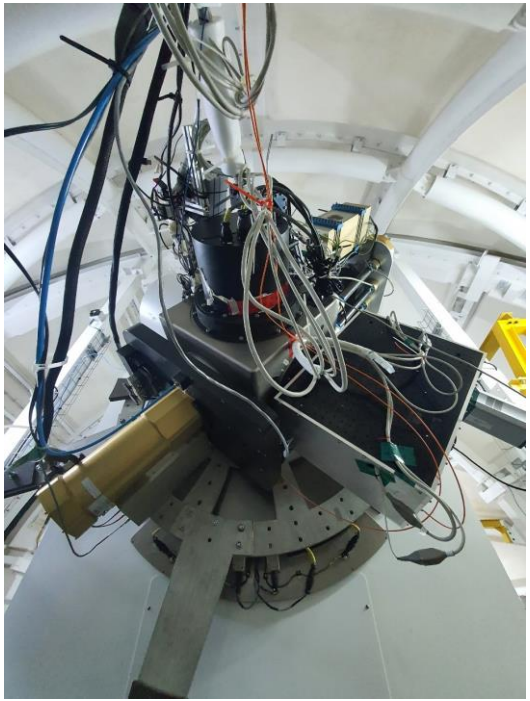


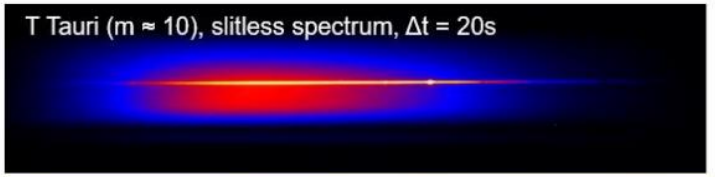


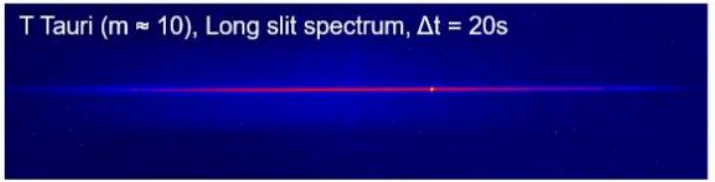
Schematic of the LRS Mark-III with the optical axis

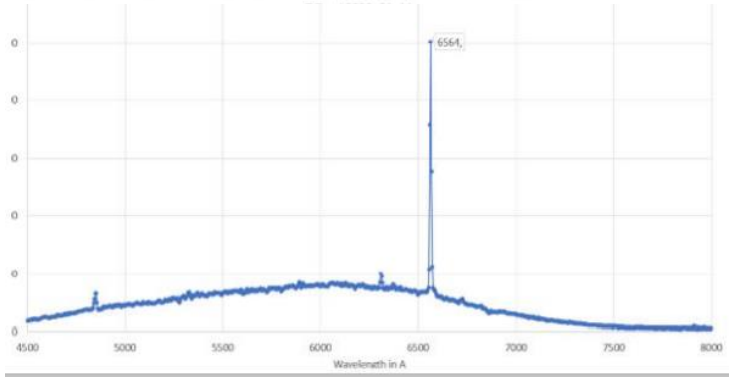
LRS
Low Resolution Spectrograph

Testing LRS at the 2.4-m Thai National Telescope



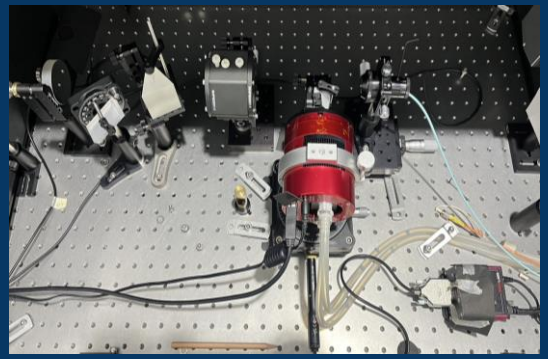






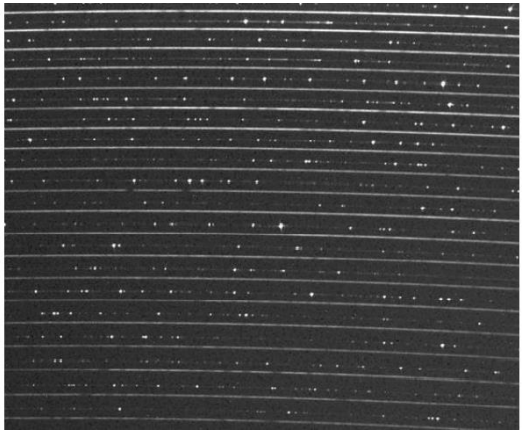
EXOhSPEC

Exoplanet High Resolution Spectrograph

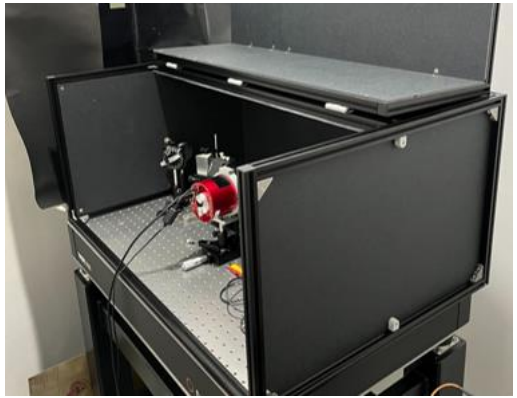


University of Hertfordshire UH

Objective: To develop a new kind of compact and cost-effective high-resolution Echelle spectrograph



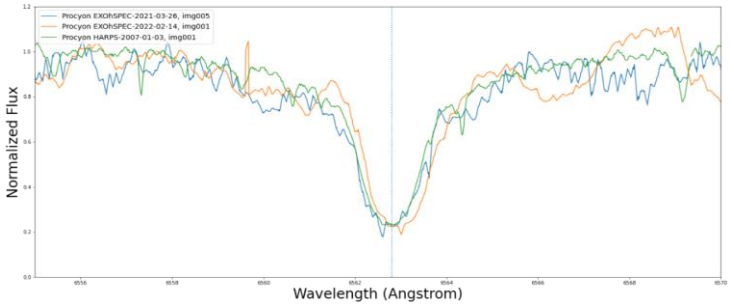
Spectra of Procyon (V_{mag} = 0.37) with an exposure time of 180 seconds



Insulation box and temperature control

Specifications

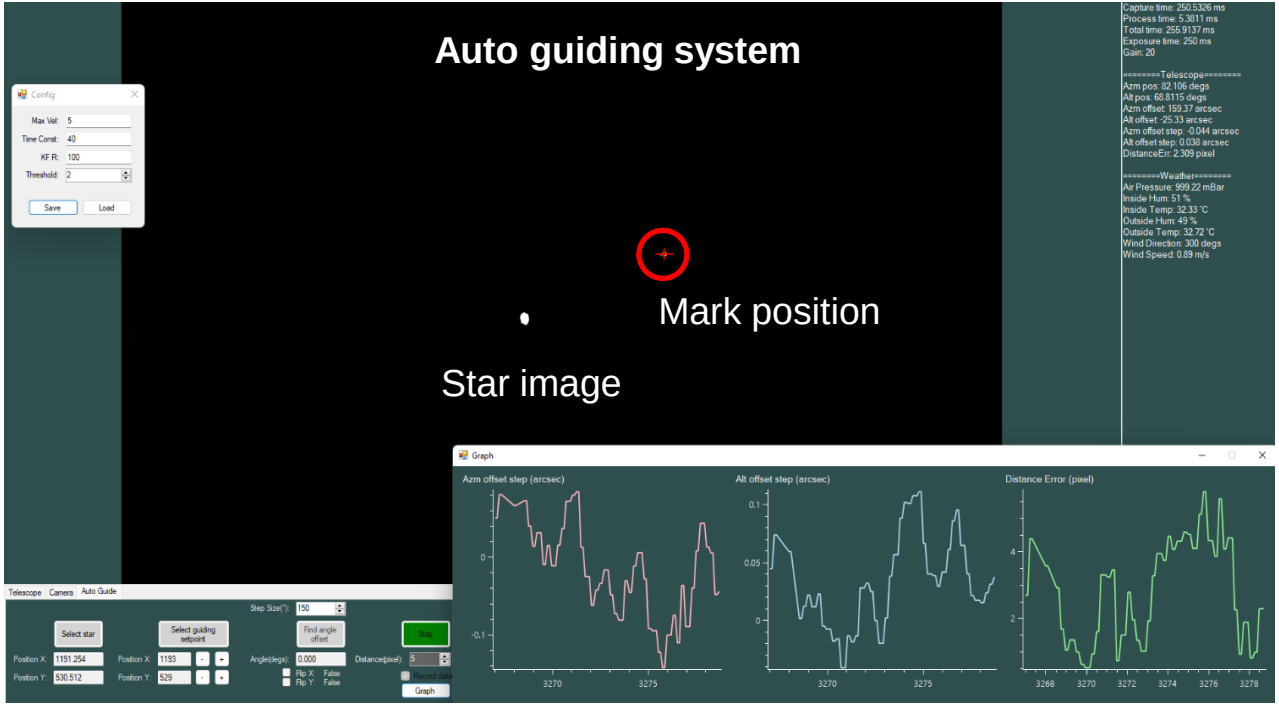
- Fiber-fed Echelle spectrograph
- Spectral Resolution: R>70000
- Spectral Domain: 400-1000 nm

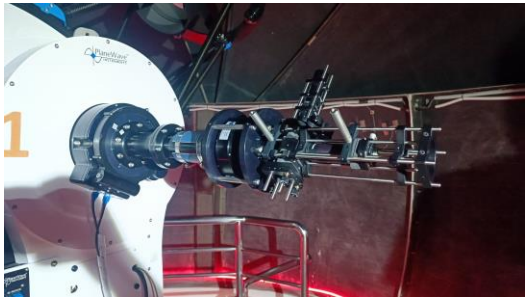


Median sp. resolution R=42,000 (FWHM = 0.01488 nm) determined from 206 ThAr lines

EXOhSPEC

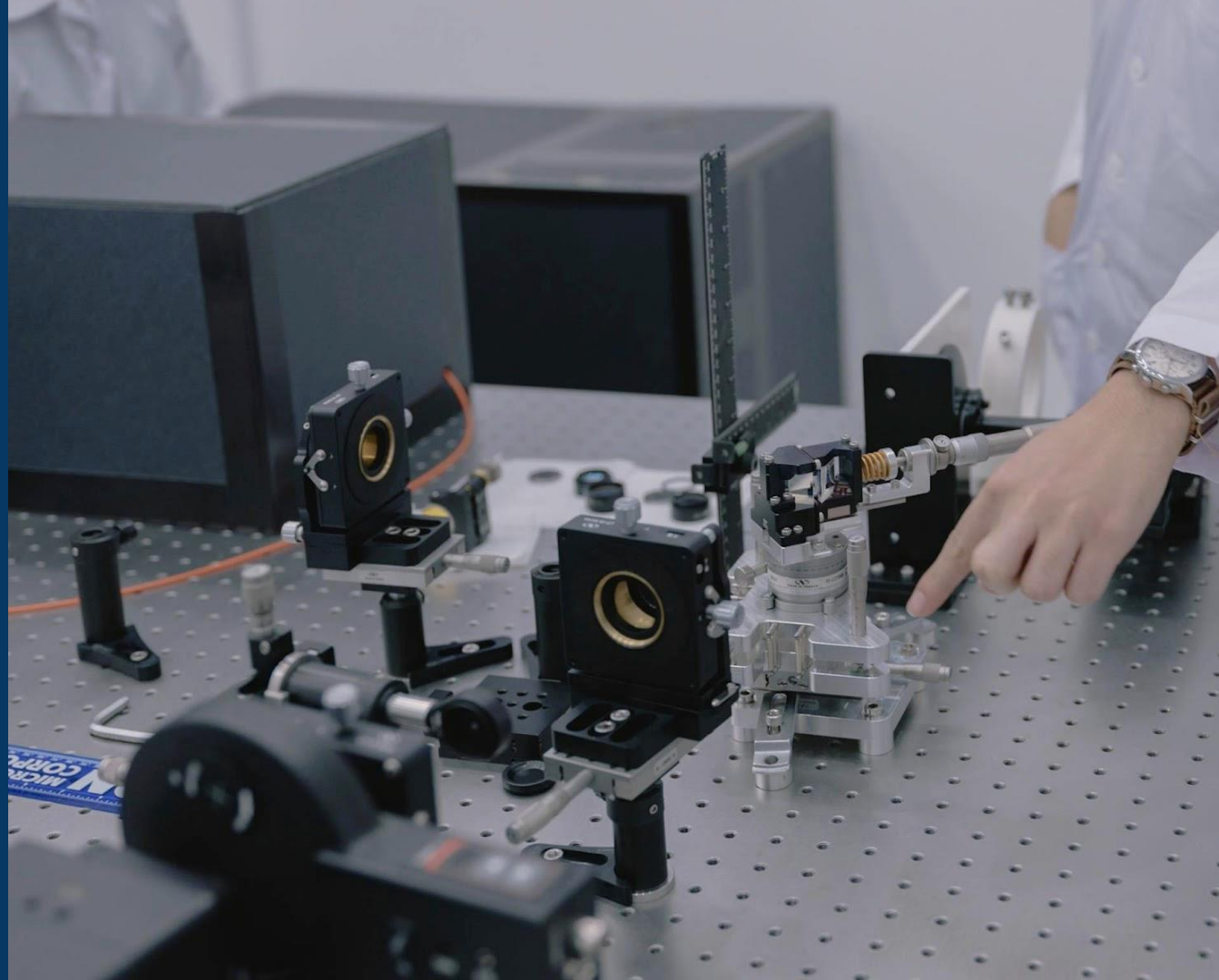
Exoplanet High Resolution Spectrograph





EvWaCo

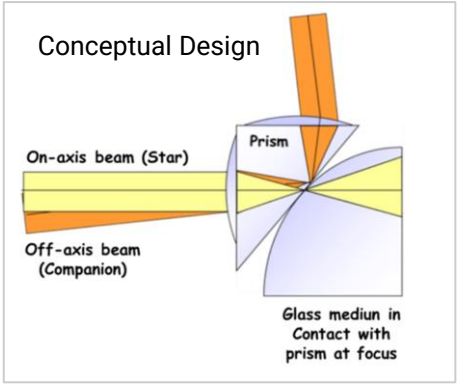
Evanescent Wave Coronagraph



Objective: Development of Evanescent Wave Coronagraph prototype

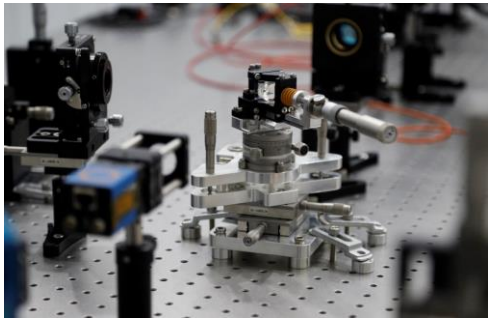
EvWaCo

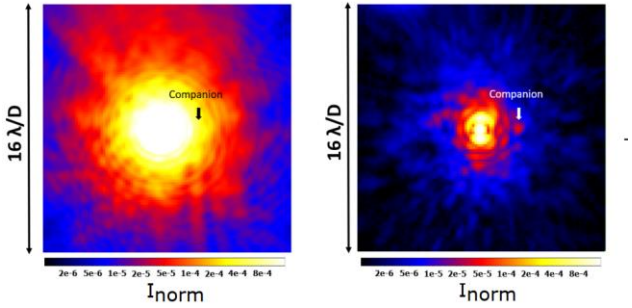
Evanescent Wave Coronagraph

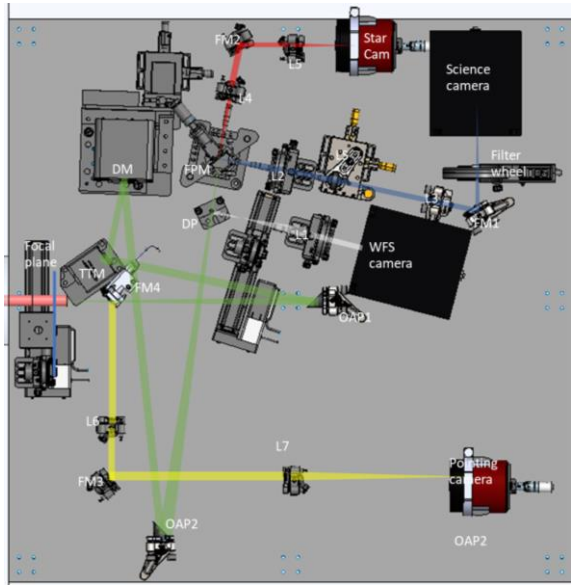


Specifications

- Evanescent Wave Coronagraph
- Spectral Domain: R- and I-bands
- Raw constrast: <10^{-4} at IWA
- Inner Working Angle: 0.5”
- FOV: 10”
- Limiting magnitude: 8

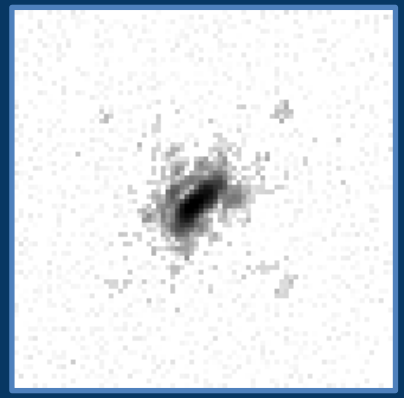


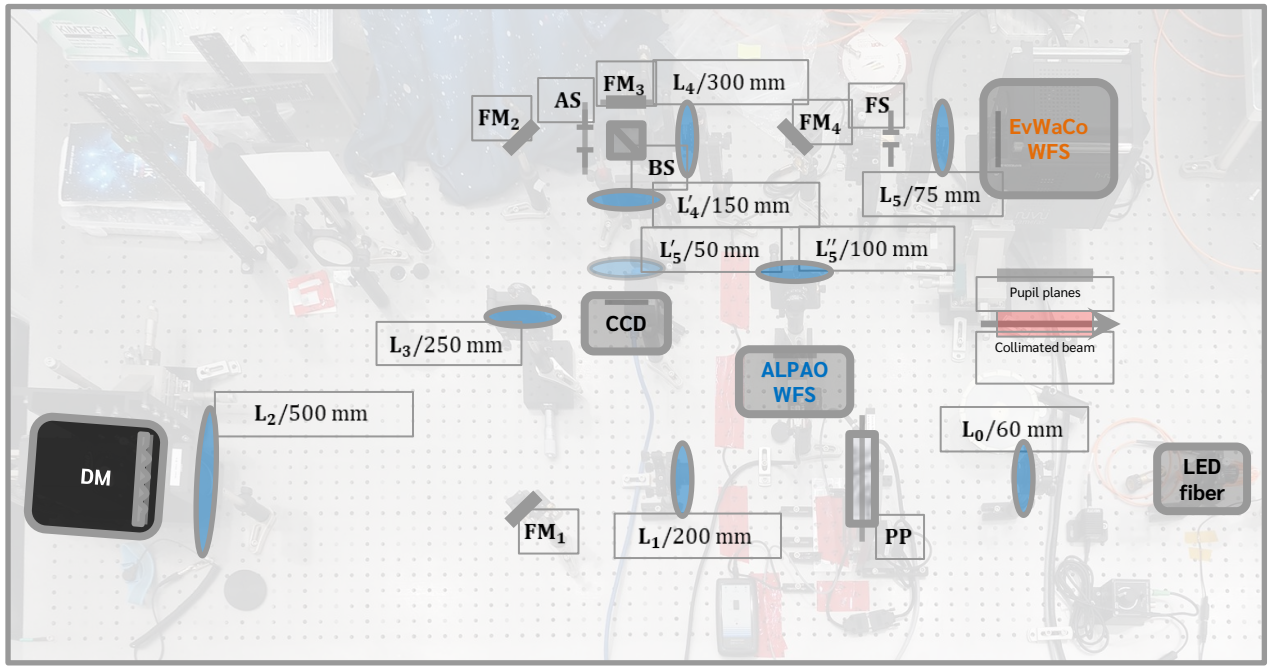


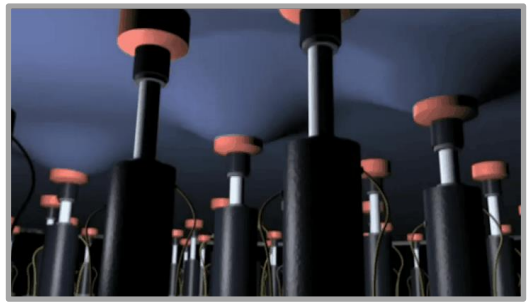


EvWaCo

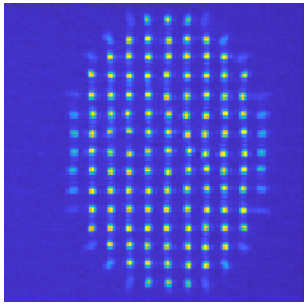
Evanescent Wave Coronagraph







Deformable mirror

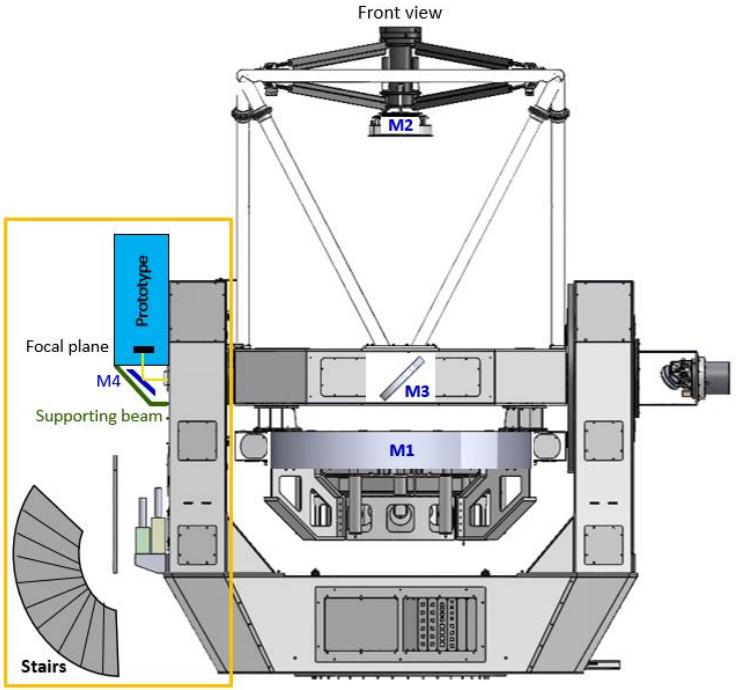


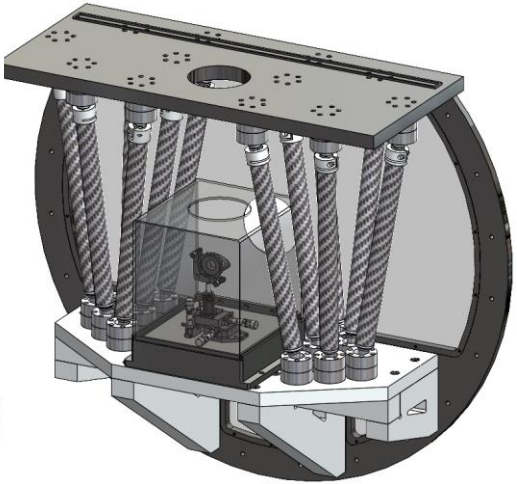
Wavefront sensor Camera

EvWaCo

Evanescent Wave Coronagraph

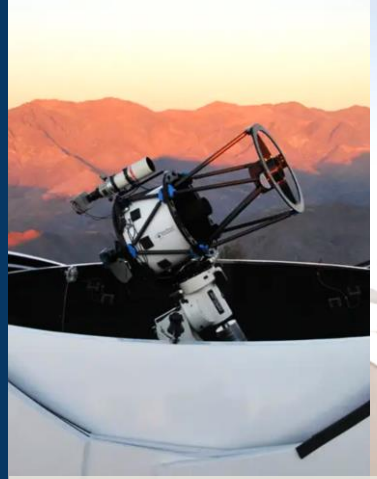
Mechanical design of EvWaCo prototype





TRT

Thai Robotic Telescope Network

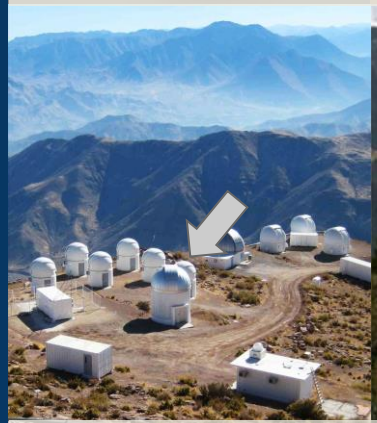


0.6 m.

0.7 m.

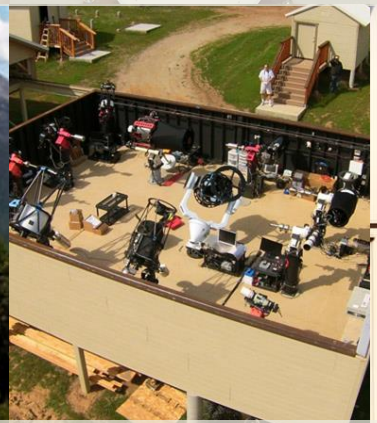
0.6 m.

0.7, 0.4 m.



CHILE

CHINA



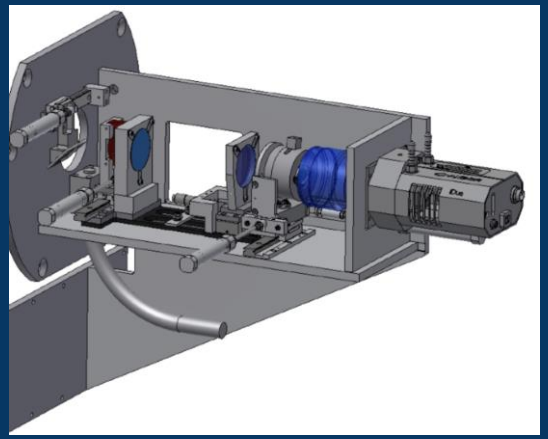
USA

AUS

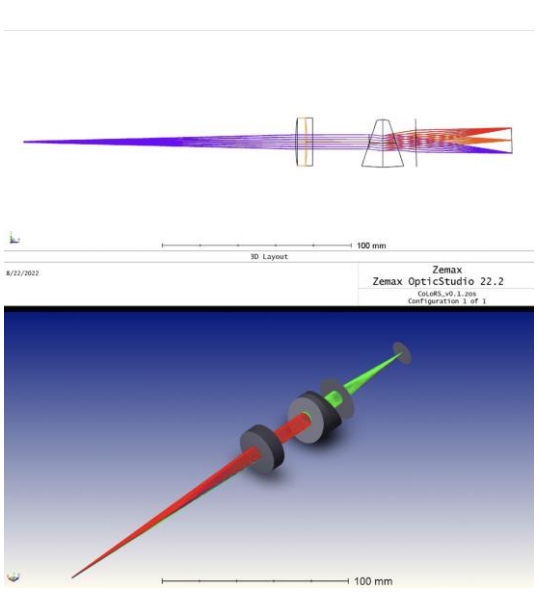
In 2024

- 0.7 m @CTIO

CoLoRS
Compact Low Resolution Spectrograph



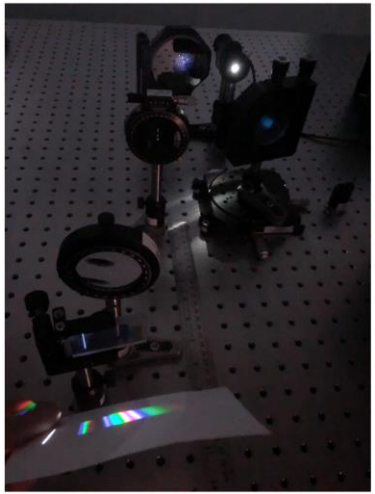
Objective: To develop a light weight compact spectrograph with robotic capability

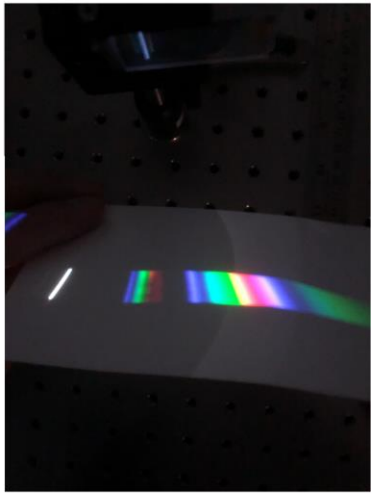


Schematic of the CoLoRS with the optical axis

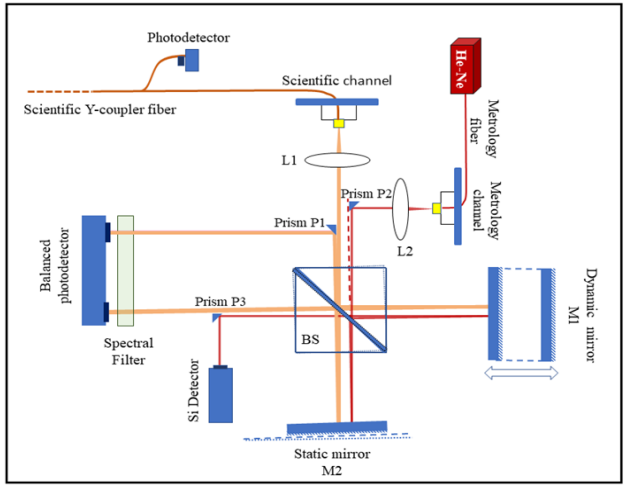
Specifications

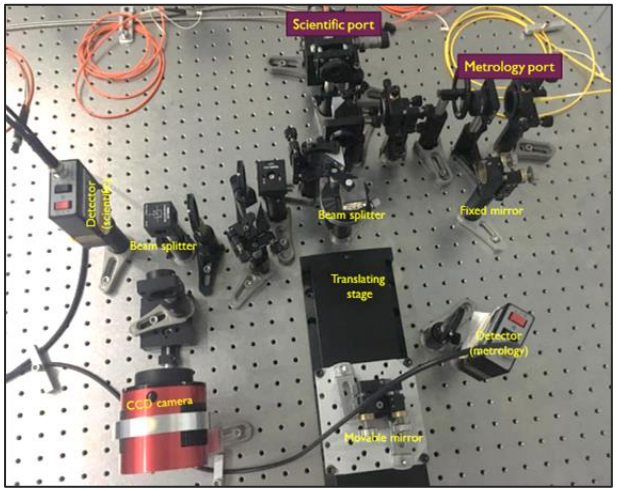
- Slit less/Long slit spectrograph
- Spectral Resolution: R=100-200
- Spectral Domain: 400-800 nm
- Robotic capability

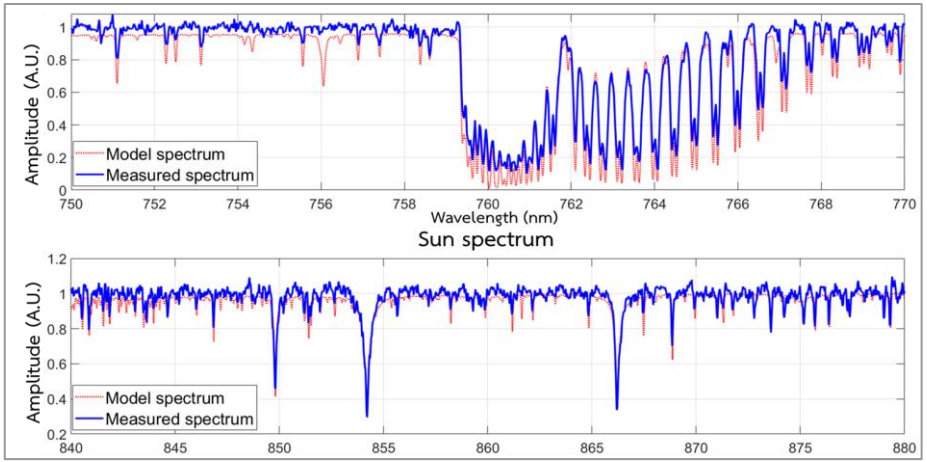




Fourier Transform Spectrograph



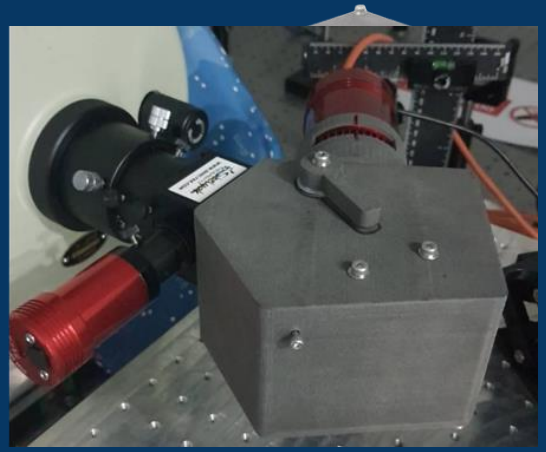




Experiment verification: Observe Sun Spectra

Objective: to develop a laboratory prototype of a fiber-fed Fourier Transform Spectrograph

UV to Visible Spectrograph

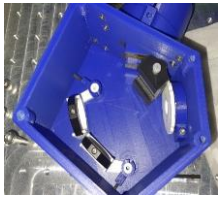


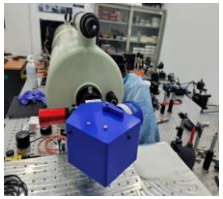
Objective: Development of spectrograph for UV to visible (350-700)

For Astronomy and Atmospheric Science purposes

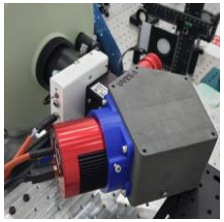
Specifications

- Spectral Resolution: R=500-3500
- Spectral Domain: 350-700 nm
- Czerny-Turner design

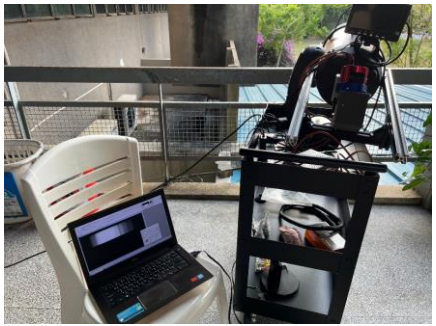


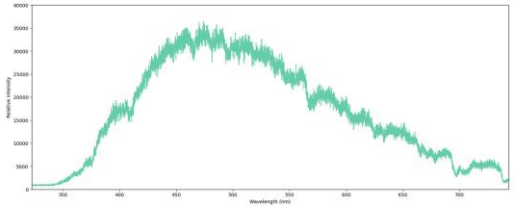


PLA 3D printed prototype

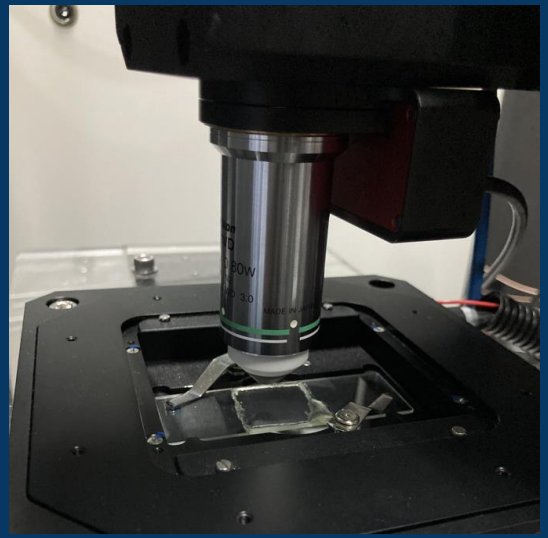


Nylon 3D printed prototype

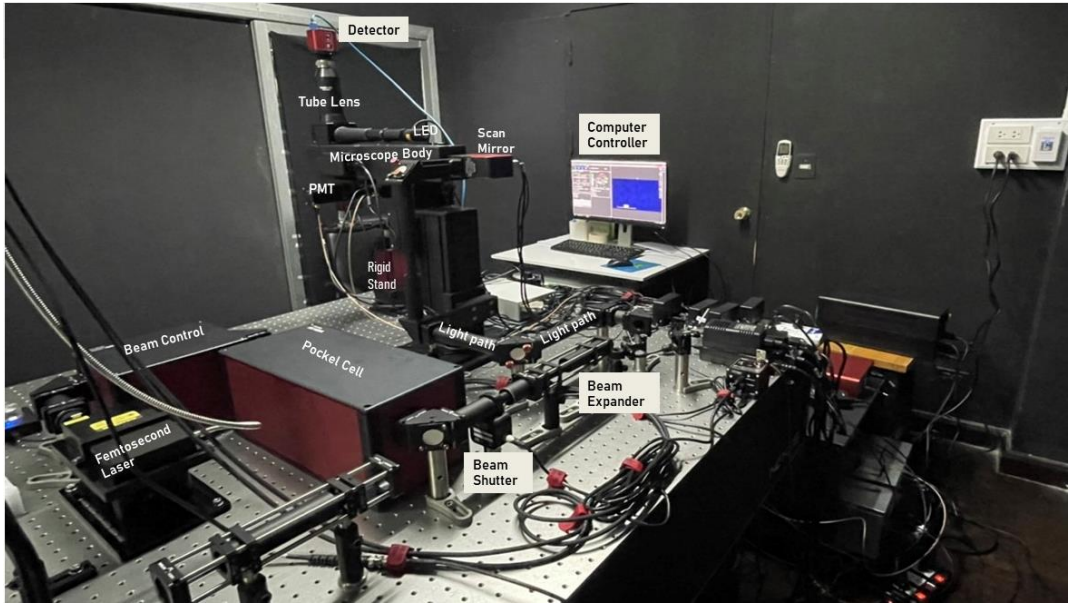


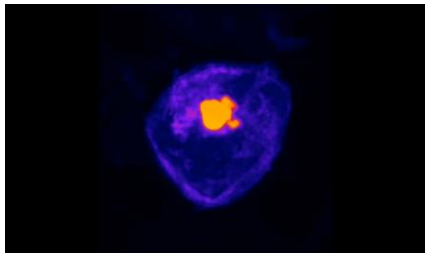


Multi-photon Microscope



Objective: to develop in Thailand state-of-the-art multi-photon and single-molecule fluorescence microscopes.





Human Embryonic Kidney Cell (HEK)
samples courtesy of Dr. Praopim Limsakul

The first modular two-photon microscope set-up in Thailand

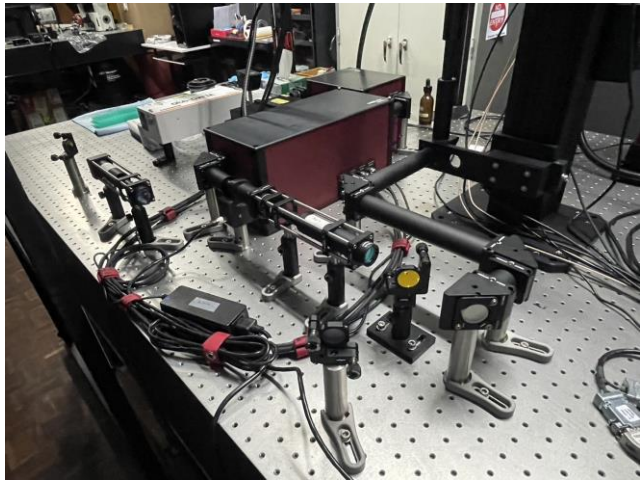
2022:
- Upright two-photon fluorescence microscope setup (M1).
- Study Human Embryonic Kidney Cell (HEK) samples

2023:
- M1 upgrade (930 nm femtosecond laser)
- M1 upgrade (two-photon polymerization)
- Study mouse pancreatic tissues for diabetes medication research.
- Study HEK samples for cancer research.
- Imaging chloroplasts (teaching)

2024:
- Single molecule fluorescence microscope (Msm)
- M1 upgrade (EMCCD installation)

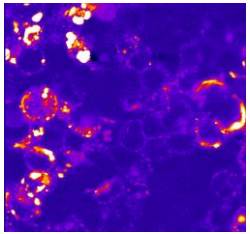
2025:
- Inverted two-photon fluorescence microscope for better live cell imaging

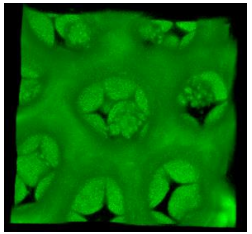
Multi-photon Microscope

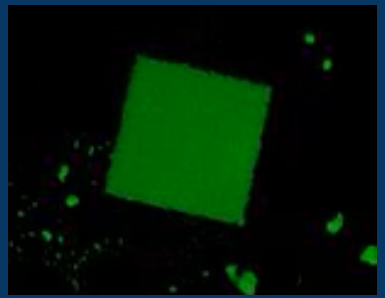


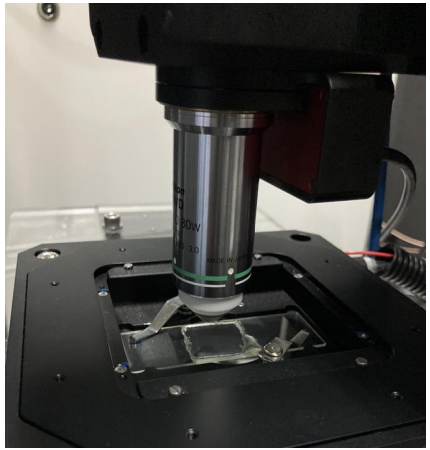
Two-photon polymerization:
Micro-scale 3D printing

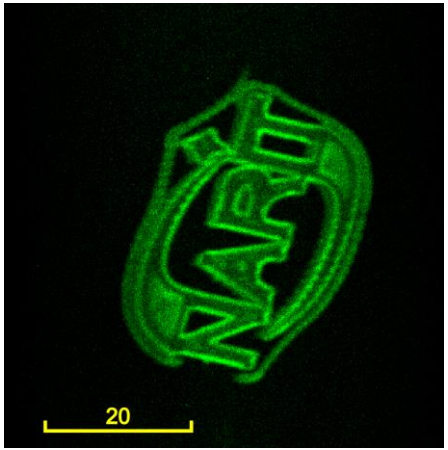
Potential applications:
- Miniaturized optical bio- and chemical sensors
- Microfluidics
- Lab-on-chip



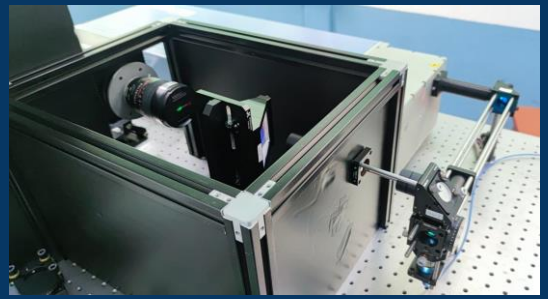






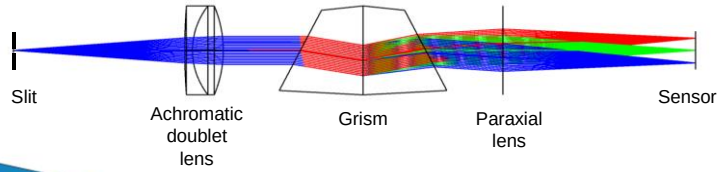


Time-resolved Raman spectroscopy system

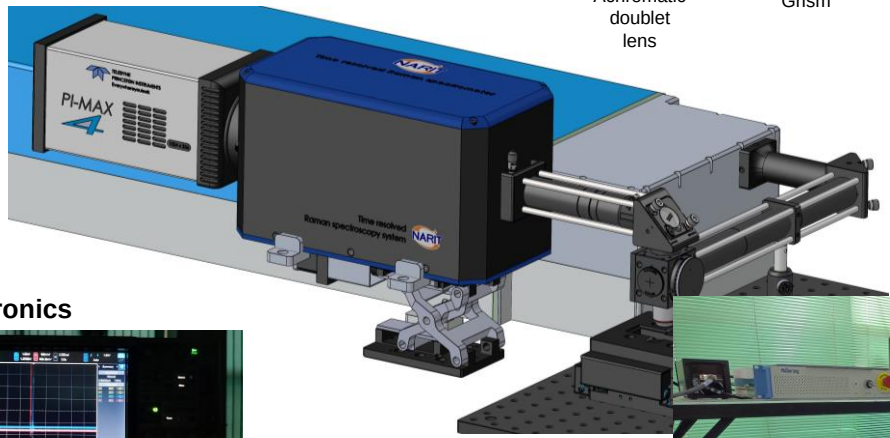


Objective: to develop in Thailand state-of-art Raman spectroscopy system

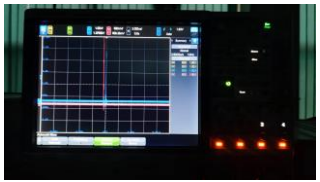
Optical Design

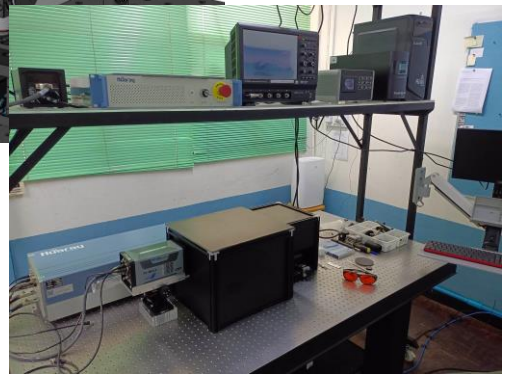


Opto-mechanical Design

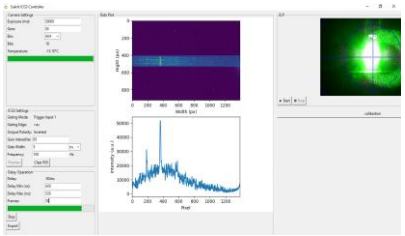


Electronics





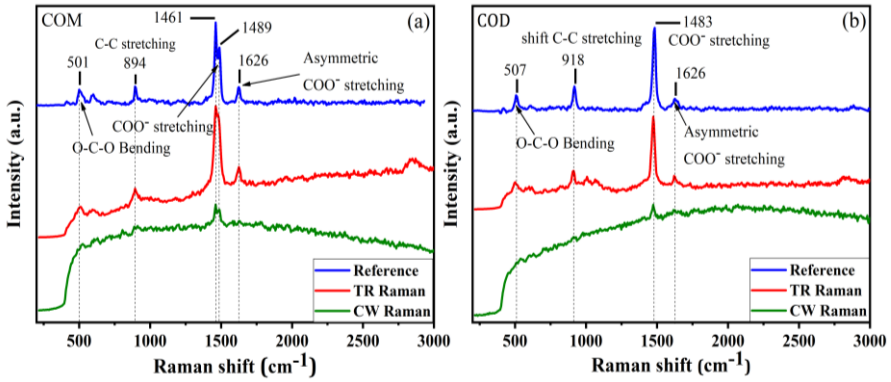
Software & Data processing

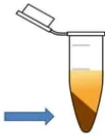


- ✓ Fluorescence background suppression
- ✓ Enhance sensitivity
- ✓ Time-resolved or distance-resolved Raman spectrum acquisition

Time-resolved Raman spectroscopy system

Kidney stone early detection:
Fluorescence-suppressed Raman spectroscopy enables quick and sensitive detection of urinary stone composition, e.g. COM (a) and COD, directly from urinary sediment

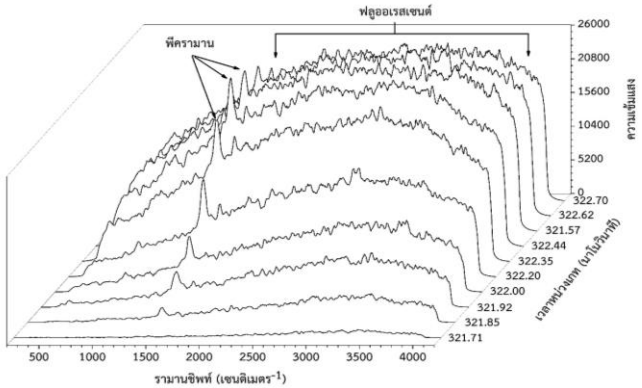


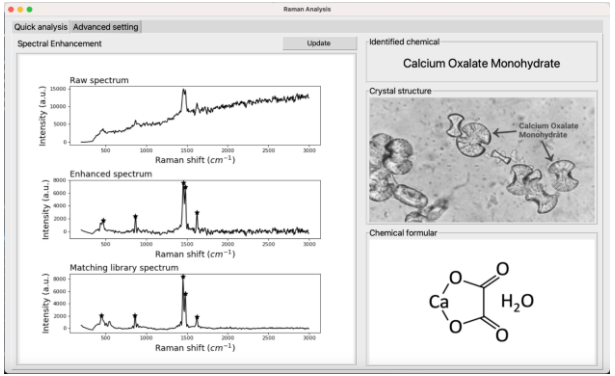


Urinary sediment

COM (calcium oxalate monohydrate)

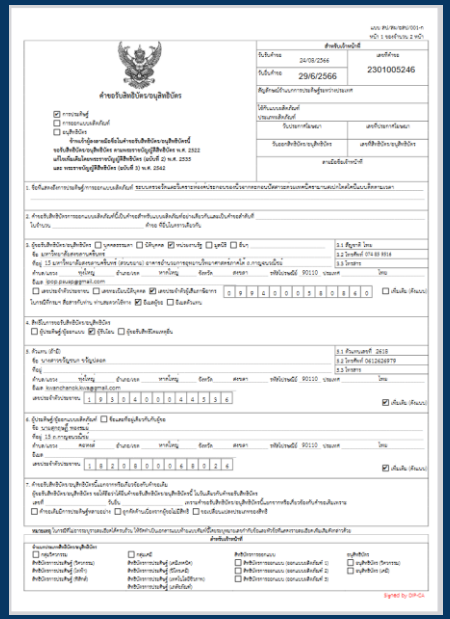
COD (calcium oxalate dihydrate)

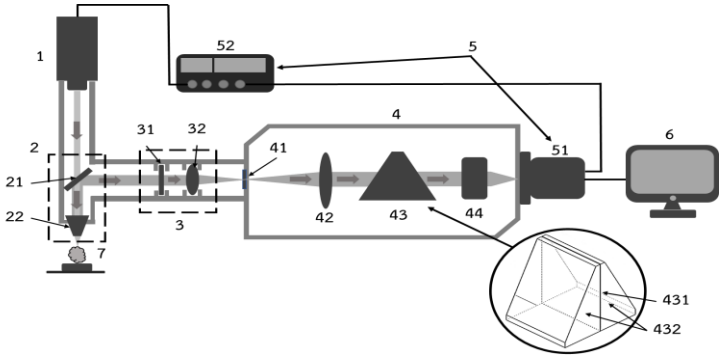


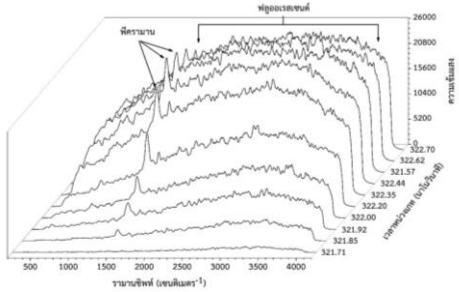


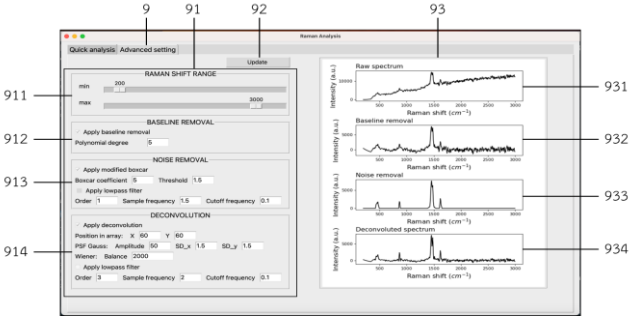
Time-resolved Raman spectroscopy system

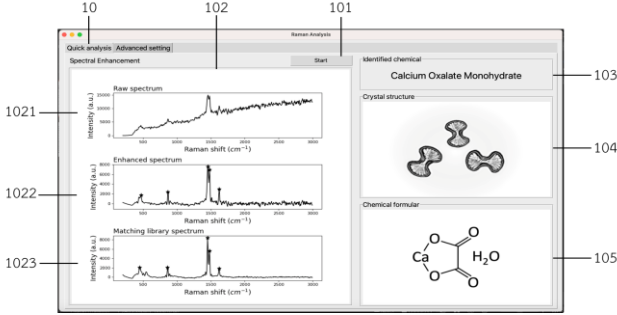
ระบบตรวจวัดและวิเคราะห์องค์ประกอบของนิ่วจากตะกอนปัสสาวะด้วยเทคนิครามานสเปกโตสโคปีแบบติดตามเวลา



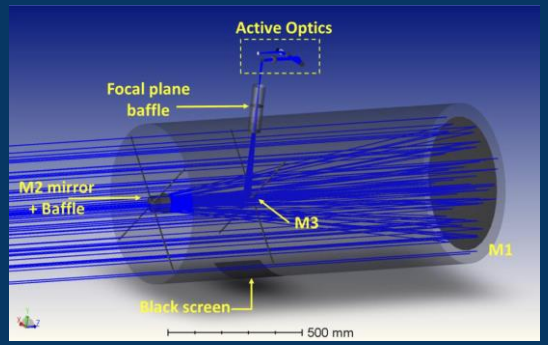






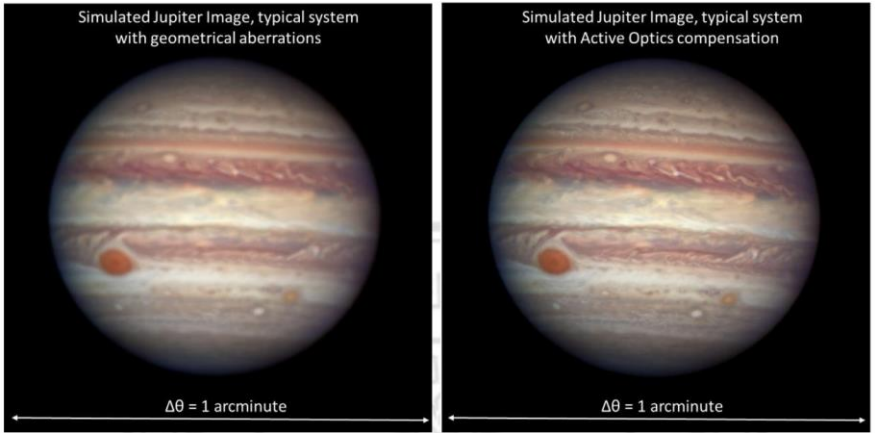


Telescope Development

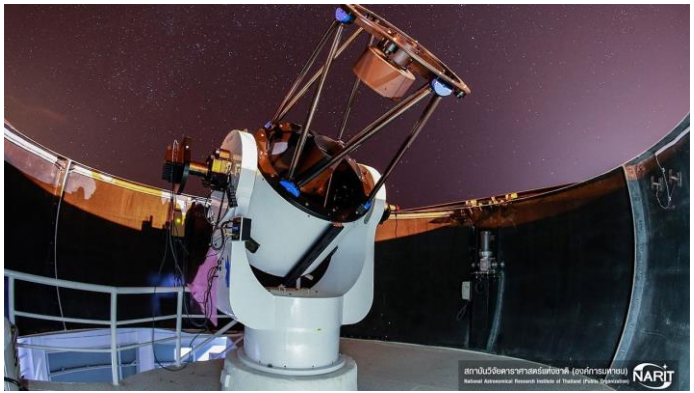


Objective: To build up NARIT staff capabilities in telescope optical design and mechanical design and to be able to assemble telescopes

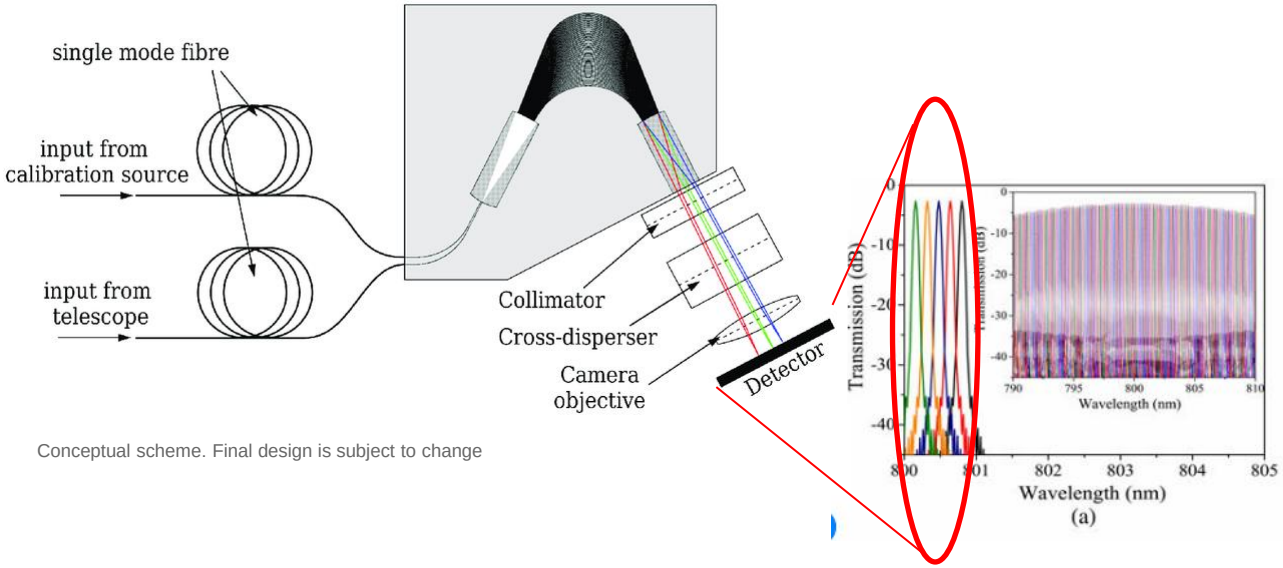
0.5 m Planetary Imaging Telescope



0.8 m Telescope for Regional Observatories



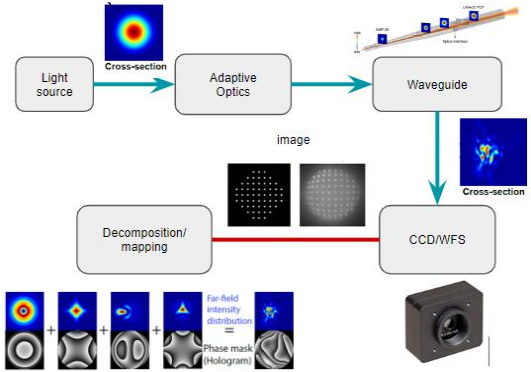
Photonics chip and Fiber optics



Conceptual scheme. Final design is subject to change

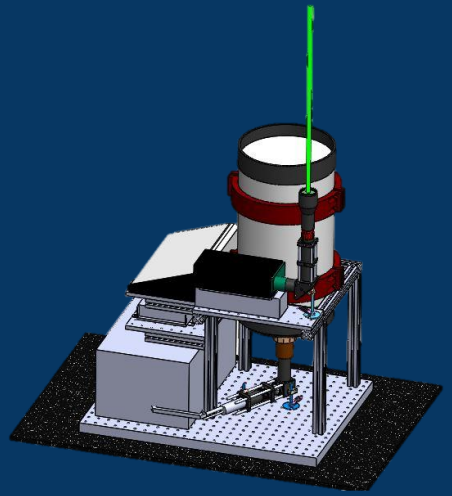
Overall objectives:

- Create optical apparatus for photonic chip and fiber optics operation at NARIT, especially for the spectroscopy application
- Create optical apparatus for characterization of distorted wavefront when photons pass through waveguide
- Create a build-in-house tapered fiber machine and fabrication of taper for research purposes
- Create a proper environment and efficient pipeline for in-house chip design and outsourcing fabrication



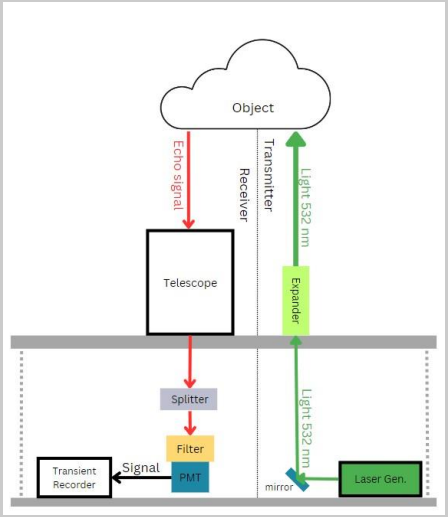
Objective: Develop the operation and characterization apparatus for spectroscopy on photonic chip

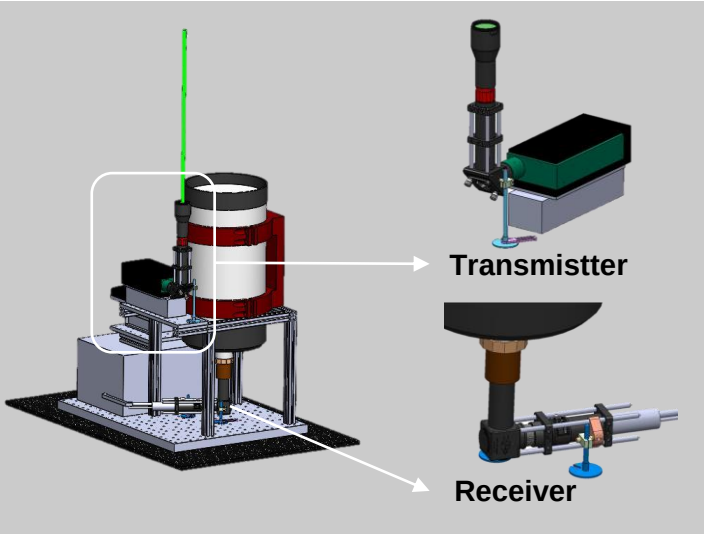
Atmospheric LiDAR

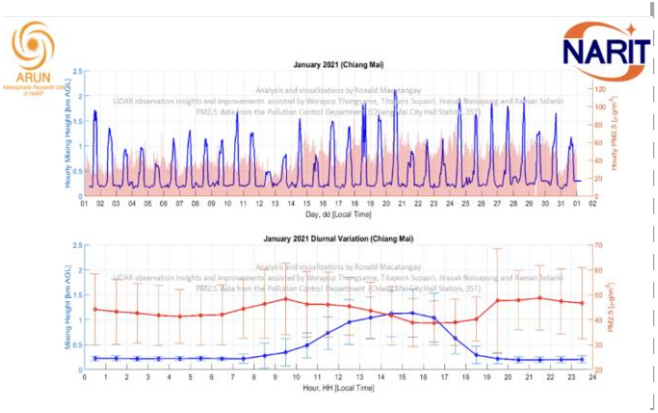


Objective: To investigate and develop a MIE scattering LiDAR system for atmospheric application

Atmospheric LiDAR Design





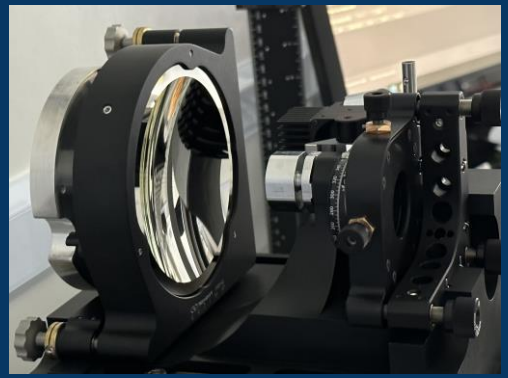


Expectation output

Phase I (March-September 2023):
- Single wavelength (532 nm)
- Unpolarized
- 10 km (night-time)

Phase II (October 2023-September 2024):
- Prototype development
- 10 km (night-time)/ 5 km (day-time)
- Data processing (Polarization)

Hyperspectral Imager

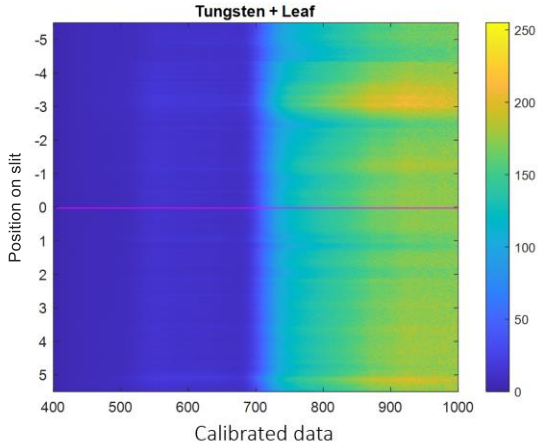


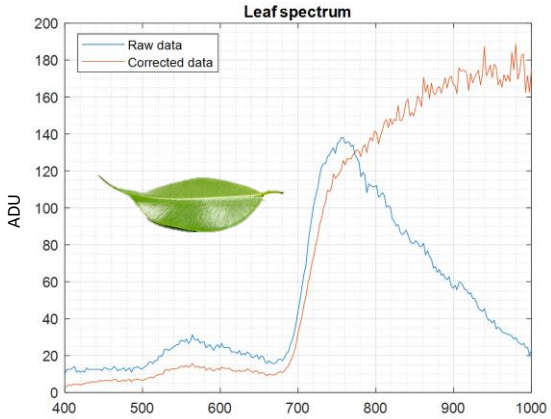
Objective: To develop the spectrometer prototype for the TSC-1 hyperspectral imager

Satellite TSC-1

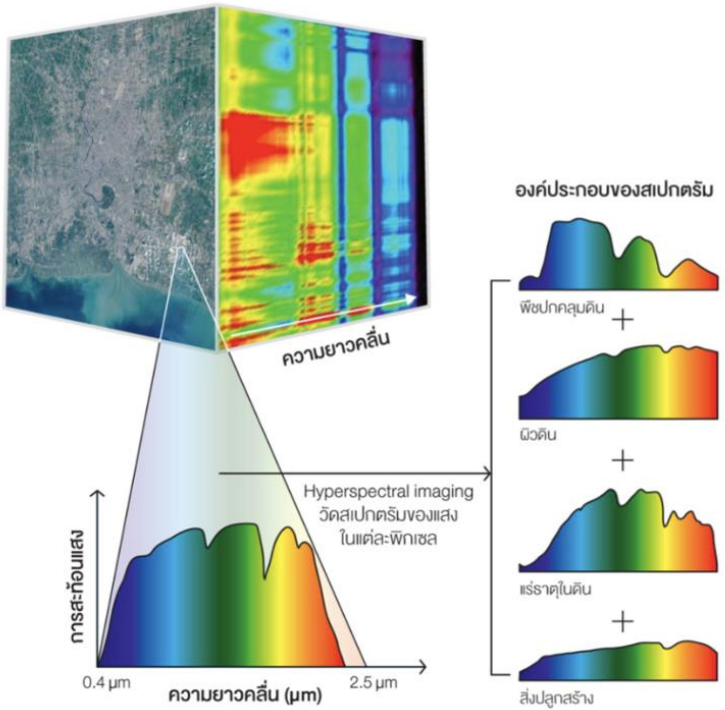
- **Microsatellite Mass**:~100 Kg.
- **Main Payload equipment**: Hyperspectral Imaging Camera 15 ~30 m GSD

Preliminary calibrated data

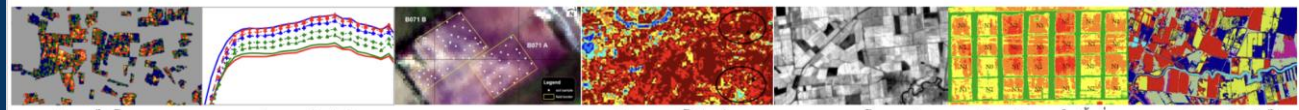




Hyperspectral Imager



Hyperspectral Drone



ปริมาณไนโตรเจน ในไร่อ้อย | การจำแนกชนิดวัชพืช โดยอัตโนมัติในไร่ข้าวโพด | ลักษณะดิน | ปริมาณคลอโรฟิลล์และ ไนโตรเจนในต้นข้าว | การตรวจหาโรคราสนิม ในไร่อ้อยก่อนลูกลาม | ปริมาณชีวมวลในพื้นที่ เพาะปลูก | การจำแนกชนิดพืชไร่ และวัชพืชโดยอัตโนมัติ

Pedagogical project

Objective: To promote optical instrument design education in Thailand

PI: Dr. Chanisa kanjnasakul
Team: Mr. Weerapot Wanajaroen

Advanced physics laboratory course:
• Introduction to Optics design, Aberrations
• Single lens, Doublet and Telescope design class using CODE V software
• Optical design class 9 hr (on-line) for SUT students
• Optical design class 15 hr at CMU
• Total student: 30 students
(22 CMU students, 2 SUT students, 5 NARIT engineers, 1 CMU lecturers)

THANK YOU