

# MIR high-dispersion spectrometer using a CdZnTe immersion grating

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# Need for MIR High-Res Spectroscopy from Space

**Wavelengths 10–20  $\mu\text{m}$  = “Fingerprint region”** — rich in molecular vibrational transitions

High-resolution spectroscopy will pioneer new ISM science!!

... but hardly accessible from the ground

MIR high-resolution spectroscopy **from space** is essential!

**GREX-PLUS** ( $\varnothing 1.0$  m, a candidate for JAXA’s strategic L-class)

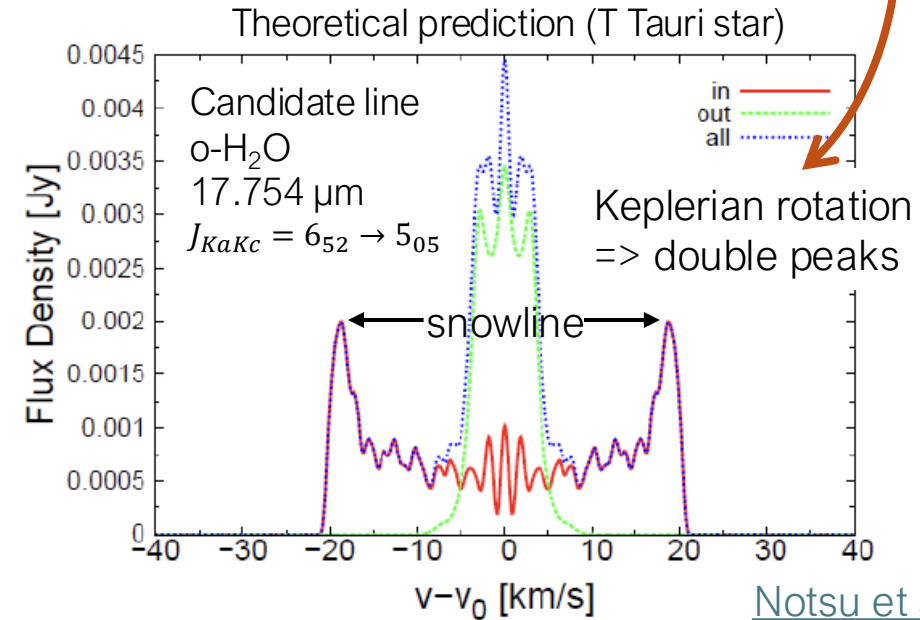
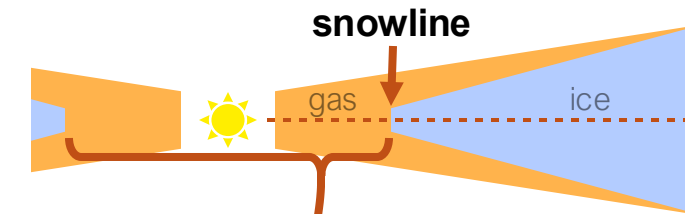
**HRS** (optional instrument; 10–18  $\mu\text{m}$ )

Main goal:

Survey of **H<sub>2</sub>O snowlines** of protoplanetary disks

Spectroscopic detection via optically thin H<sub>2</sub>O lines  
(Find the outer boundary of the gas region)

Resolution  $\mathcal{R} \equiv \lambda/\Delta\lambda \sim \mathbf{30,000}$  required  
10x higher than JWST/MIRI

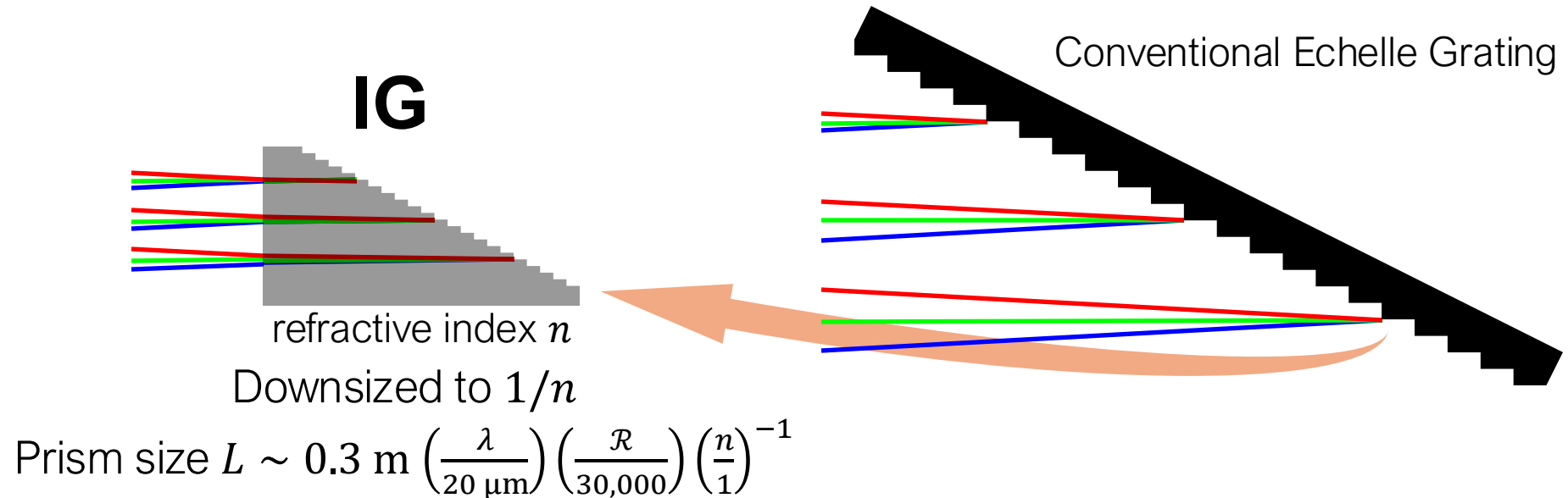


[Notsu et al. \(2016\)](#)

# CdZnTe Immersion Grating to be Established

Key technology: **immersion grating (IG)**

— Enlarged optical path difference, high- $\mathcal{R}$  with a compact layout



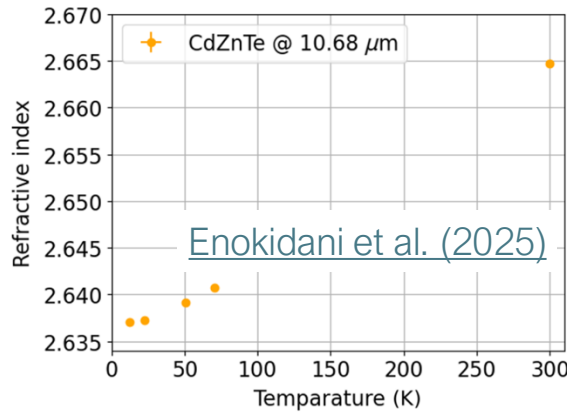
Promising material:  $\text{Cd}_{0.96}\text{Zn}_{0.04}\text{Te}$  (**CZT**;  $n \sim 2.64$ ) ([Sarugaku et al. 2012](#))

GOAL: demonstration of the fabrication of CZT-IG and its astronomical use  
by developing a ground-based spectrometer

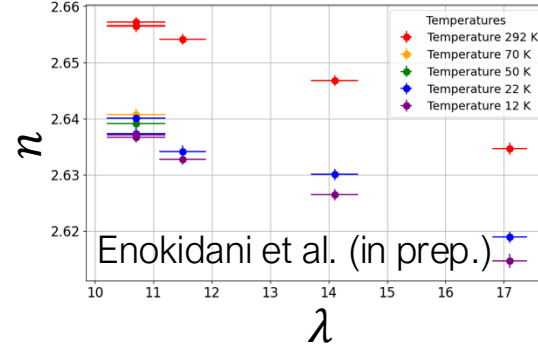
# Development Status of CZT-IG

## Refractive index

Cryogenic measurement @10.68  $\mu\text{m}$



At other wavelengths



Accurately measured ( $\Delta n \sim 10^{-3}$ )

## Absorption coefficient

Temperature (K)	Wavelength/ $\mu\text{m}$					
	10.6 $\mu\text{m}$		15 $\mu\text{m}$		19 $\mu\text{m}$	
	$\alpha/\text{cm}^{-1}$	$n$	$\alpha/\text{cm}^{-1}$	$n^a$	$\alpha/\text{cm}^{-1}$	$n^a$
12.4	0.00051 (2)	2.6367 (9)	0.00344 (5)	2.6226 (18)	0.00253 (10)	2.6069 (38)
22	0.00049 (3)	2.6373 (11)	0.00333 (5)	2.6265 (20)	0.00251 (11)	2.6106 (42)
250	0.00304 (3)	2.6571 (9)	0.00357 (2)	2.6430 (9)	0.00459 (5)	2.6263 (18)

Li et al. (2025)

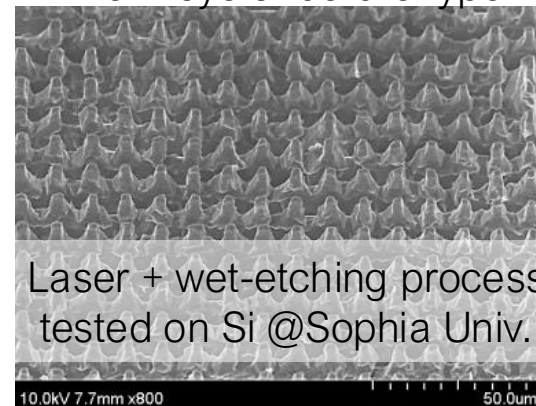
Target  $\alpha < 0.01 \text{ cm}^{-1}$  achieved with high-resistivity CZT ( $\sim 10^{10} \Omega \cdot \text{cm}$ )

## Machining

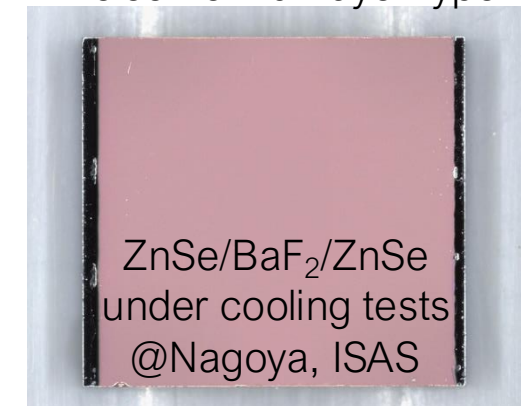


## Anti-reflection coating

Moth-eye structure type



Dielectric multilayer type



# Spectrometer Concept and Components

Coverage: N-band ( $\sim 7.5\text{--}13\ \mu\text{m}$ )

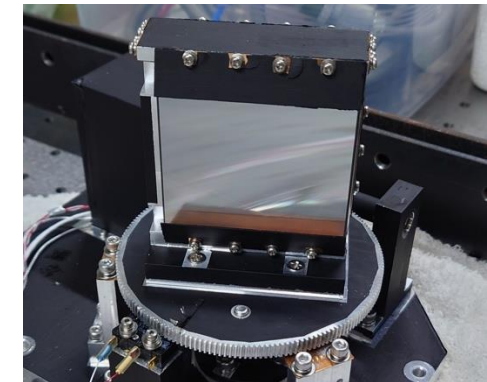
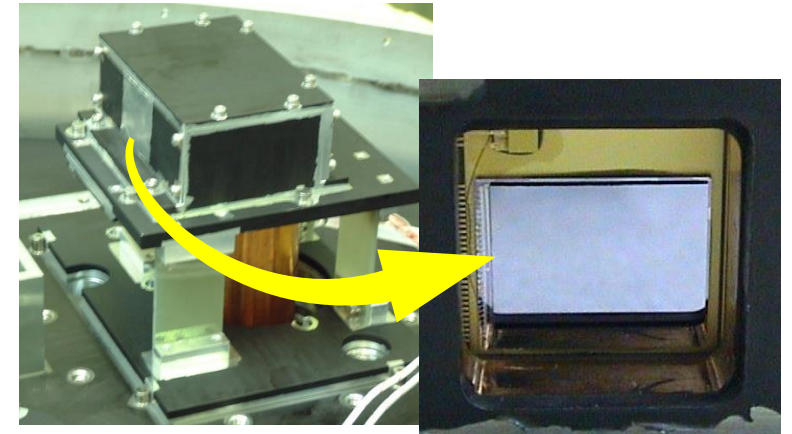
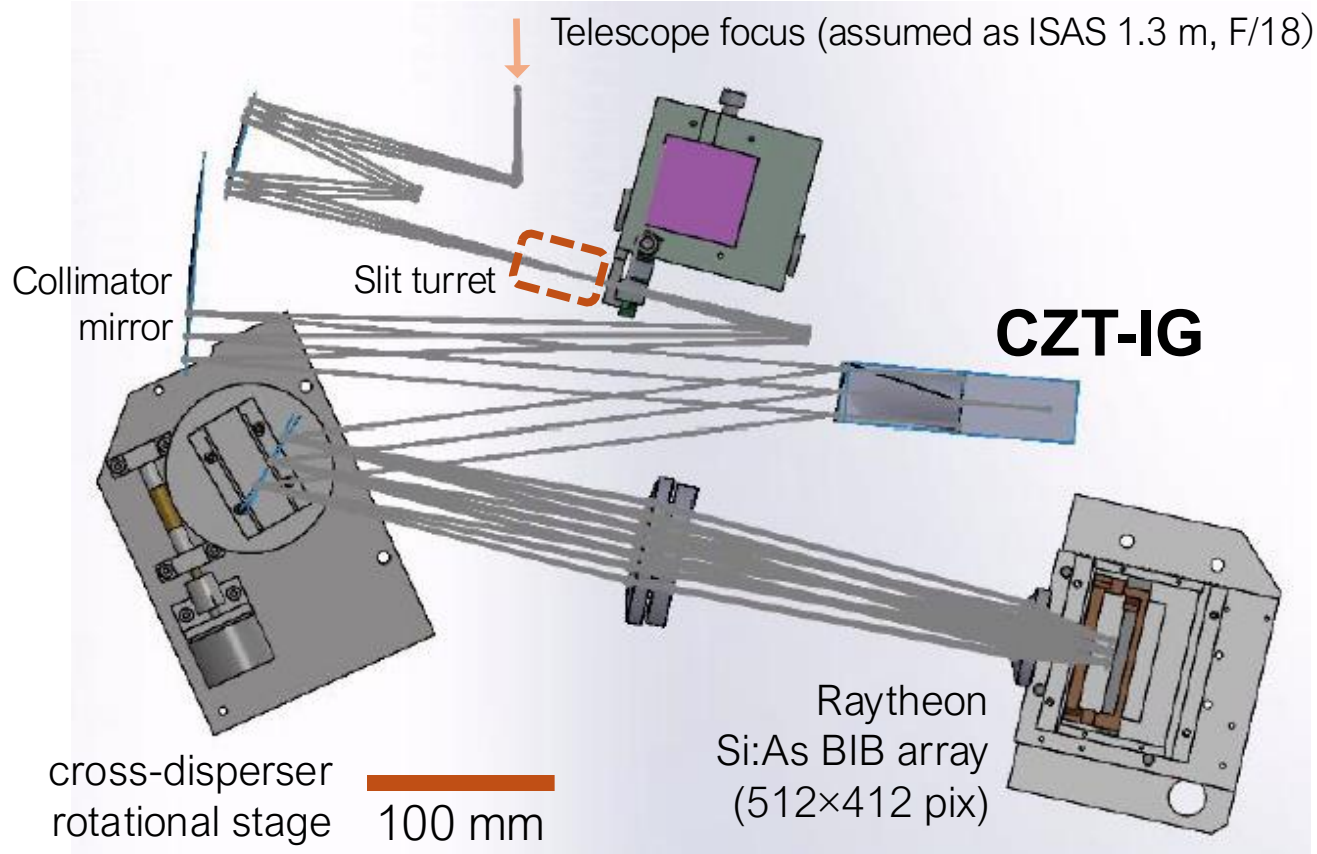
Resolution:  $\mathcal{R} \sim 30,000$  ( $\cong$  GREX-PLUS/HRS)



Narrower coverage and lower sensitivity than HRS,

... but high- $\mathcal{R}$  spectroscopy with CZT-IG can be demonstrated

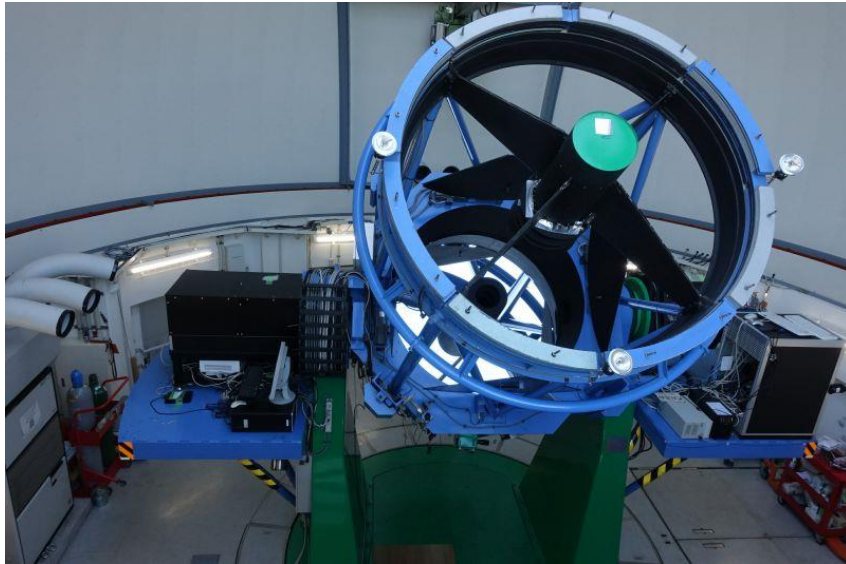
Optical layout \*\*previous ver.\*\*



The detector and the X-disperser stage will be transferred from the Ge-IG spectrometer GIGMICS ([Hirahara et al. 2012](#)).

# Plan and Design Updates

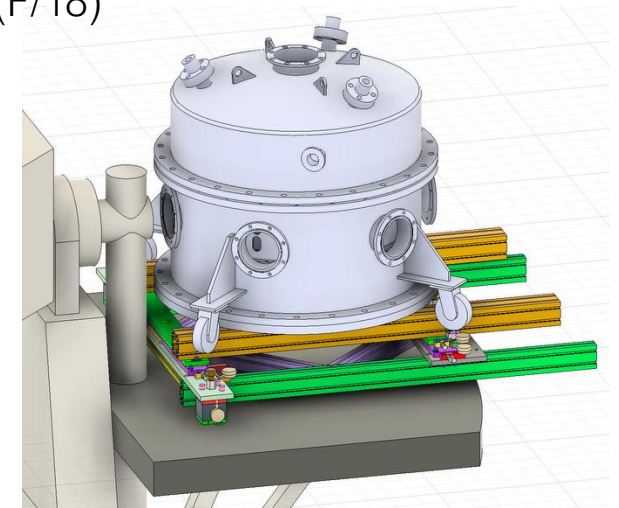
Installation to the Nasmyth focus of the **Kanata** telescope in Hiroshima (changed from the ISAS 1.3-m telescope)



- Configuration: Ritchey-Chretien
- Primary mirror: 1,500 mm (effective)
- Nasmyth foci (F/12.2) ISAS 1.3 m (F/18)
  - **Platform: 2.0×1.4 m<sup>2</sup>** ↔ 1.0×1.0 m<sup>2</sup>
  - **Max load: 1,000 kg** ↔ 200 kg

Relaxed physical constraints  
Experience of the mount of GIGMICS

→ Re-use of (a part of)  
the GIGMICS chamber



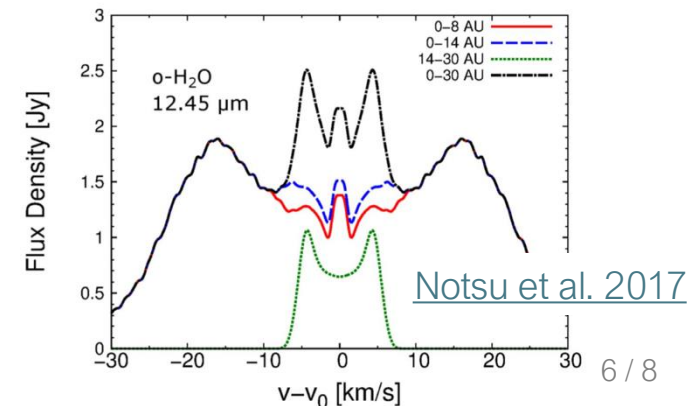
## Optical Layout under Revision

Fore-optics: Offner relay → F/# conversion (OAP relay?)

Rear-optics: Ge lens x3 → Off-axis mirrors (for extension to longer  $\lambda$ )

Sensitivity Estimate at Kanata ( $\varnothing$ 1.5 m)

Velocity profile of the H<sub>2</sub>O 12.45  $\mu$ m line from a Herbig Ae star at  $d=150$  pc  
→ **S/N~15 for 2.5 hr exposure** (w/o overheads)





# Summary

- MIR high- $\mathcal{R}$  spectroscopy in the “fingerprint region”
- CZT-IG is key for a compact space-based spectrometer
- Demonstration of CZT-IG by developing a ground-based spectrometer
- Items for CZT-IG:
  - Refractive index: Accurately measured ([Enokidani et al. 2025](#); Enokidani et al. in prep)
  - Absorption coeff.: High-resistivity CZT ( $\sim 10^{10} \Omega\cdot\text{cm}$ ) meets  $\alpha < 0.01 \text{ cm}^{-1}$  ([Li et al. 2025](#))
  - Machining: Successful diamond fly-cutting of a test piece
  - A/R coating: Moth-eye type or multilayer type, ongoing study
- Spectrometer:
  - Telescope change (ISAS 1.3 m  $\rightarrow$  Kanata 1.5 m)
  - Optical layout under revision
  - Re-use of GIGMICS components (detector, cryogenic mechanics, chamber, etc)
- Planned first light in FY2026