

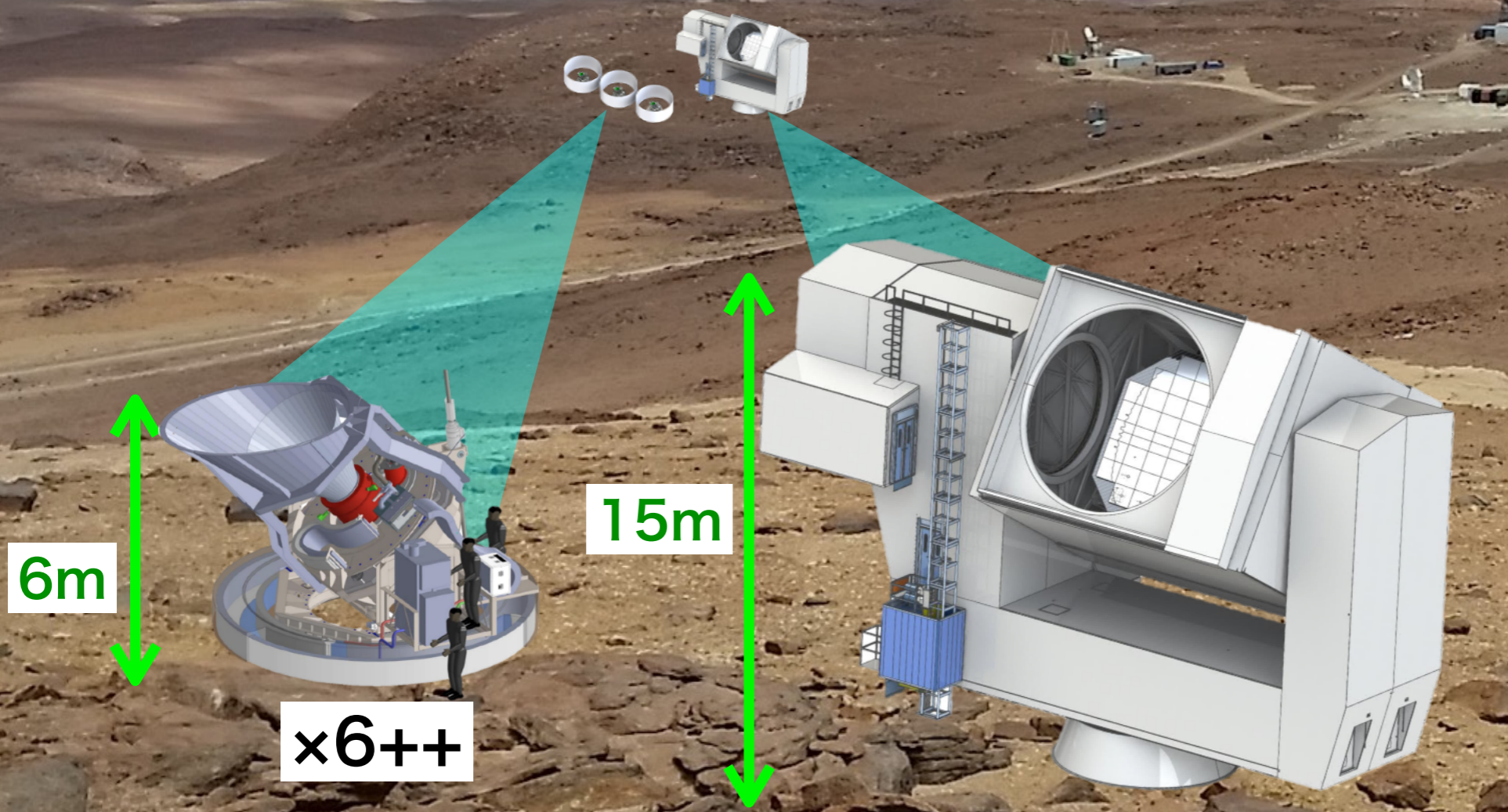
Fast modulated thermal radiator “Stimulator” for gain & time-constant calibration in SO

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Princeton University¹, Kyoto University²

Simons Observatory

@Chile, 5200m



- CMB observation
- $\sim 10^5$ TES
(Superconducting detector, Transition Edge Sensor)
- Six bands
(27~270GHz)
- 0.02° resolution
at 150GHz

Small aperture telescope

Large Aperture Telescope

LAT

Specialized for good angular resolution!

Simons Observatory

@Chile, 5200m

Telescope for this talk

- CMB observation
- $\sim 10^5$ TES
(Superconducting detector, Transition Edge Sensor)
- Six bands
(27~270GHz)
- 0.02° resolution
at 150GHz

6m

x6++

Small aperture telescope

15m

Large Aperture Telescope

LAT

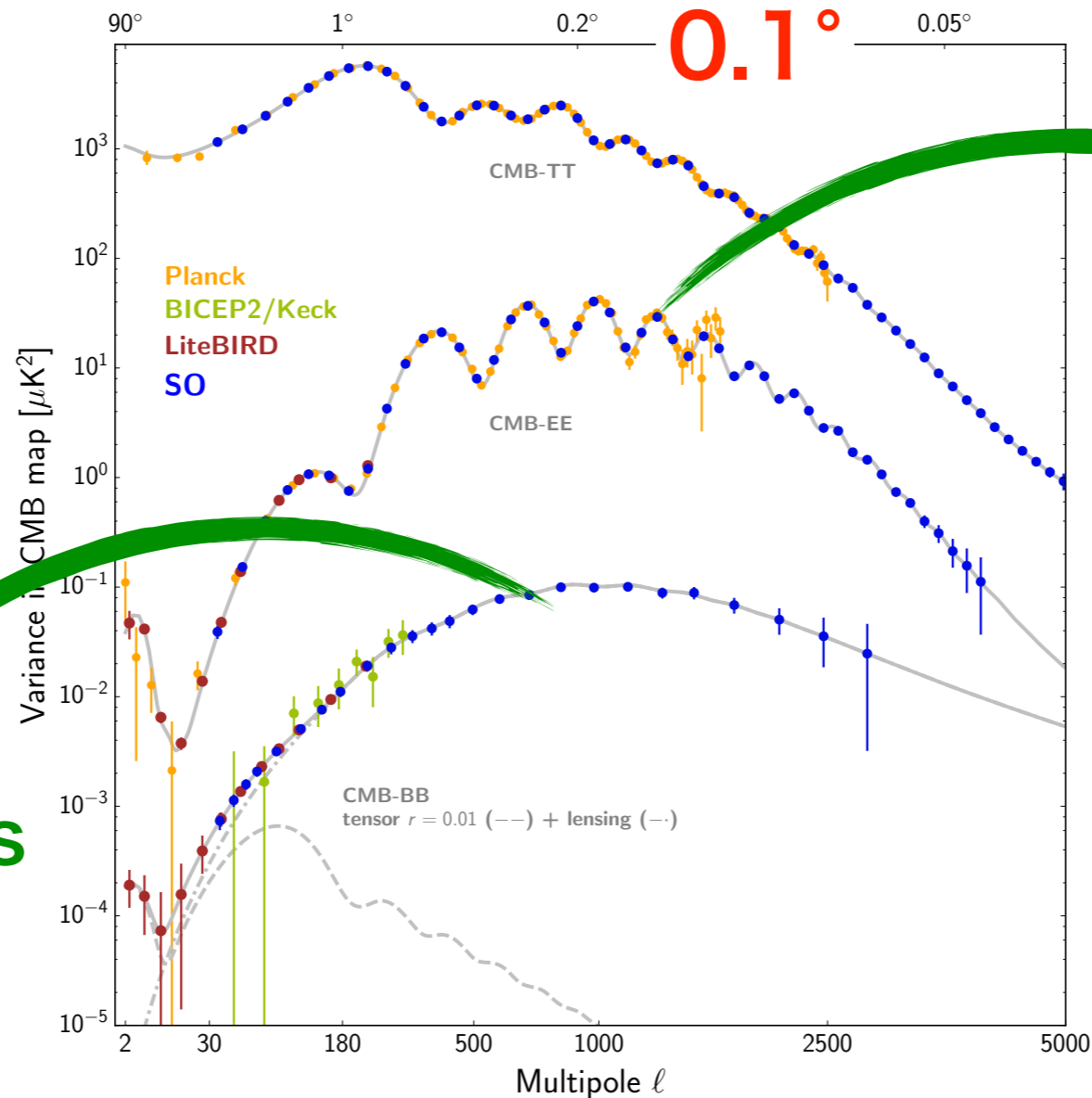
Specialized for good angular resolution!

Small angular scale physics

CMB in small angular scale has various physics information.

Good angular sensitivity is important!

CMB spectrum

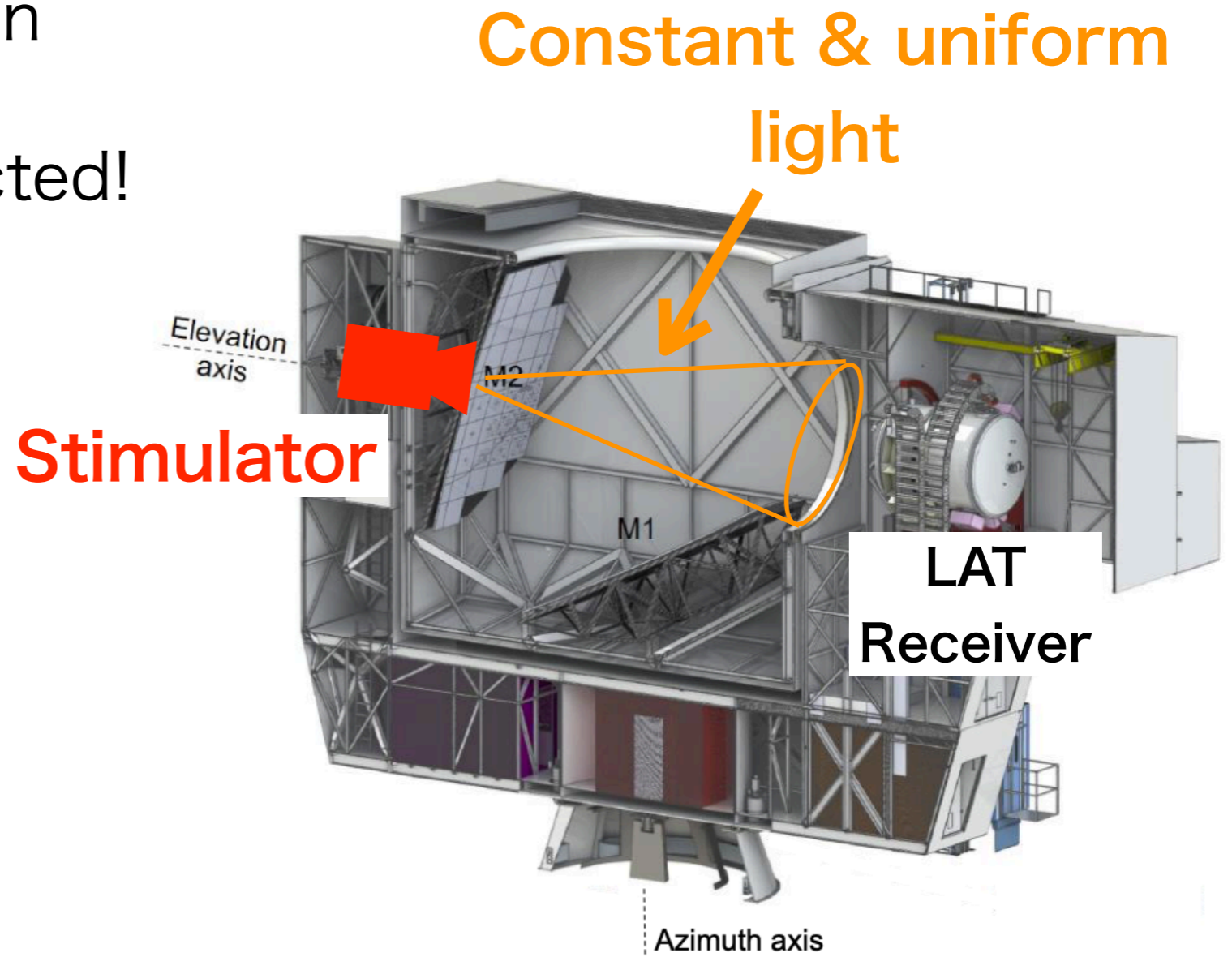


Sum of neutrino mass

Neff

Calibrator for good angular sensitivity

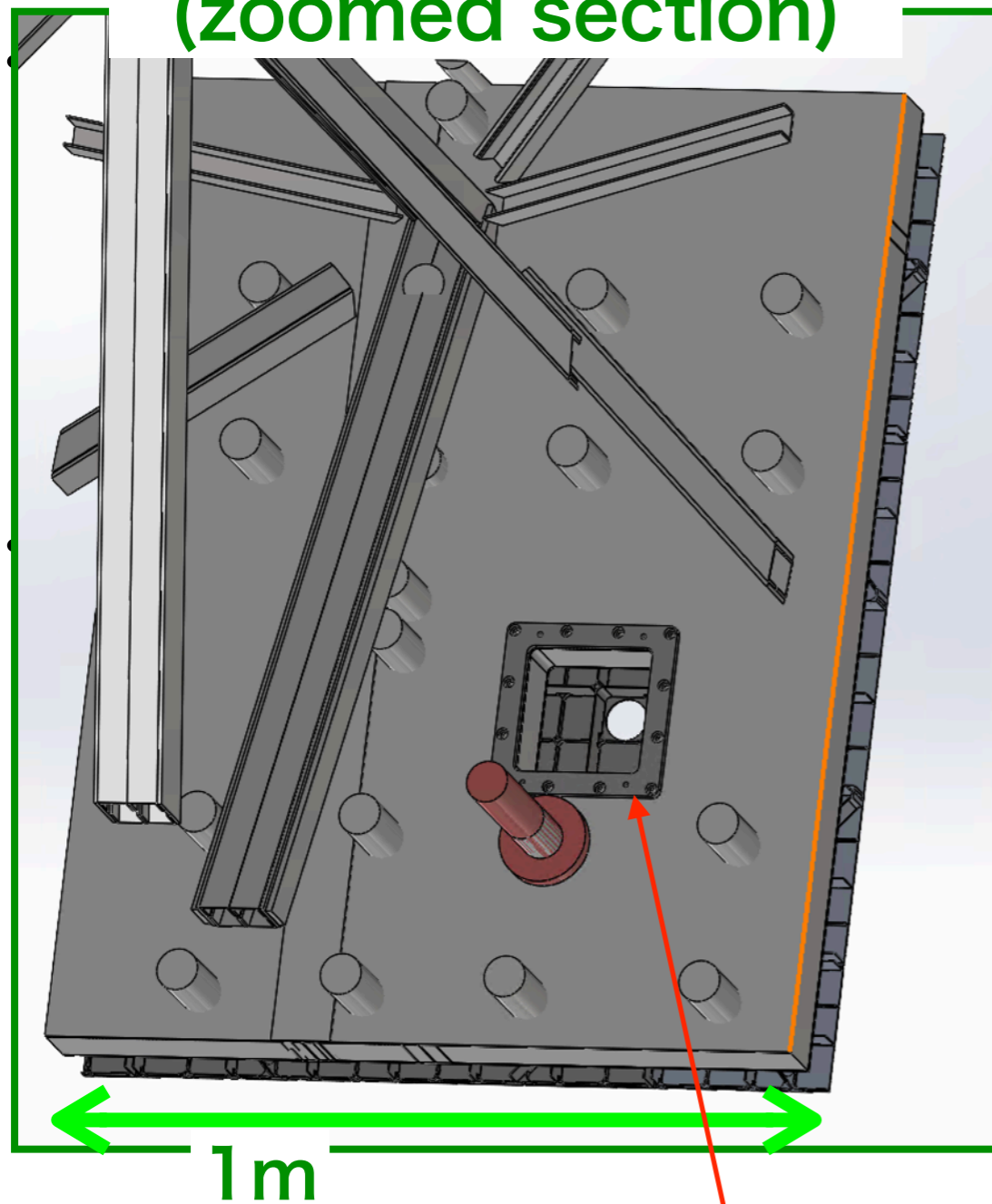
- SO requires accurate calibration
 - Relative gain: 1%
 - Time constant: 10%
 - ~hourly calibration
- Light source is expected!
→ Stimulator



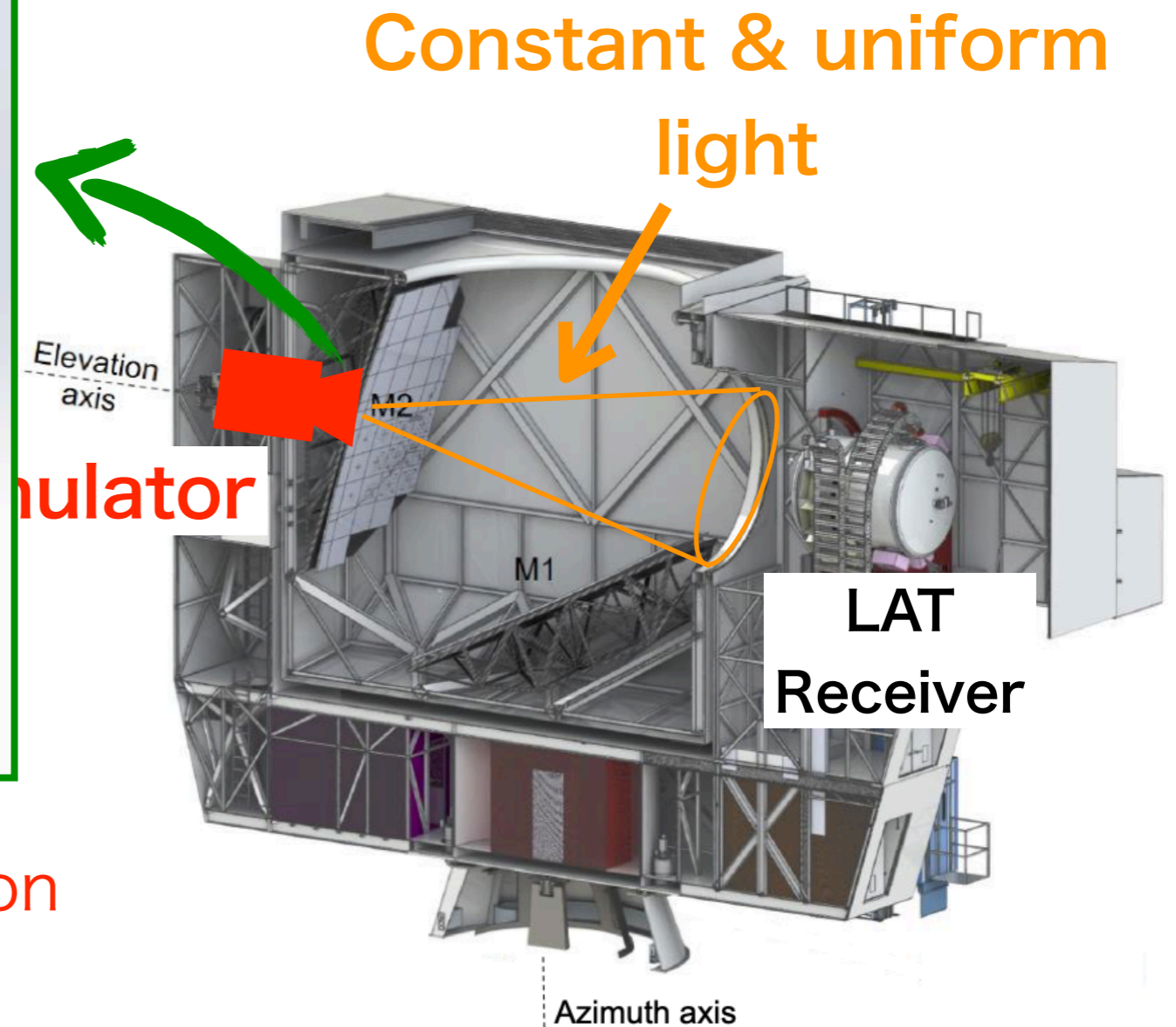
Calibrator for good angular sensitivity

Back view of mirror

(zoomed section)



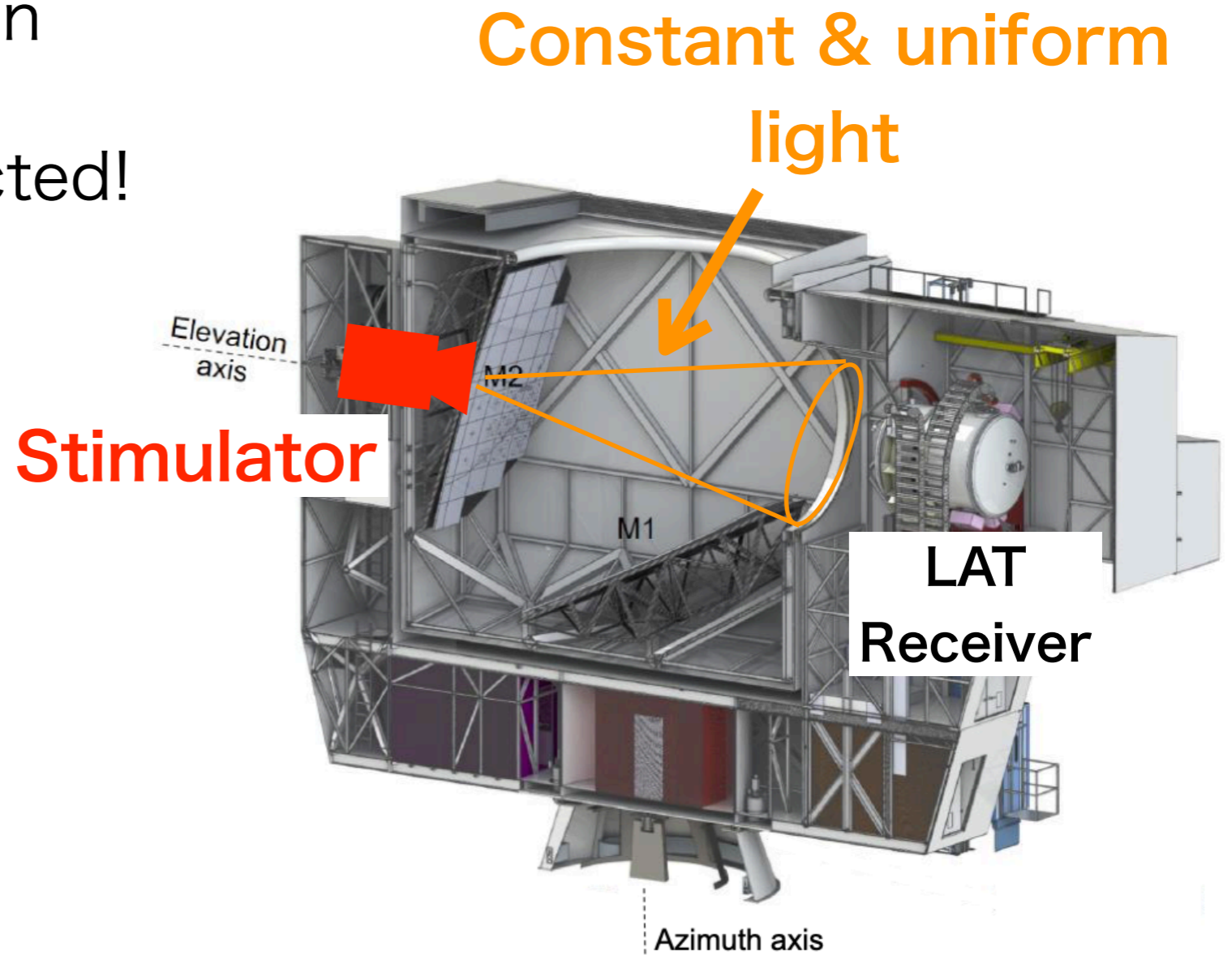
rotation



Stimulator position

Calibrator for good angular sensitivity

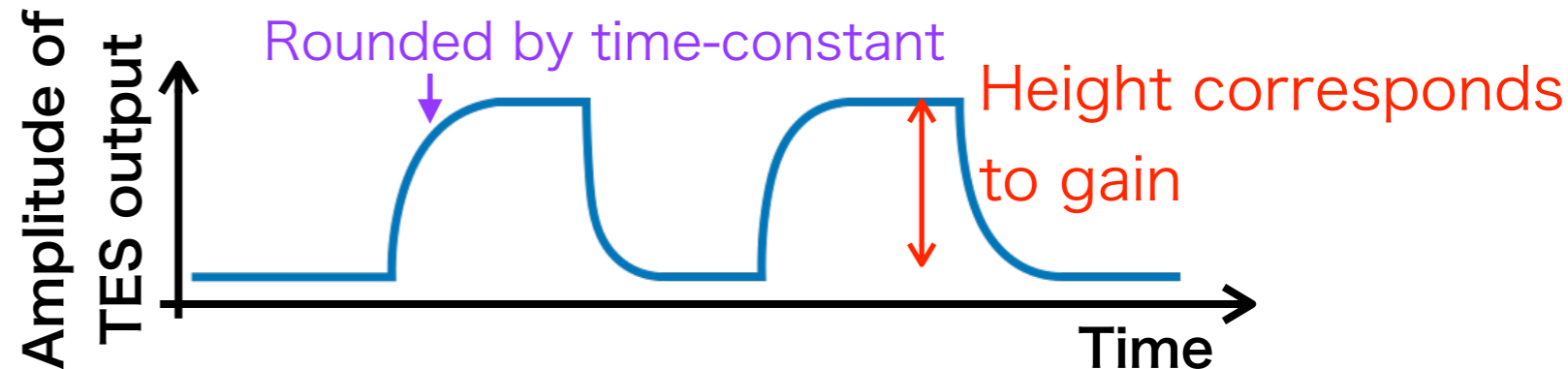
- SO requires accurate calibration
 - Relative gain: 1%
 - Time constant: 10%
 - ~hourly calibration
- Light source is expected!
→ **Stimulator**
- Requirements are
 - Intensity: >9mK
 - Uncertainty: <1%
 - Compact: ~20cm



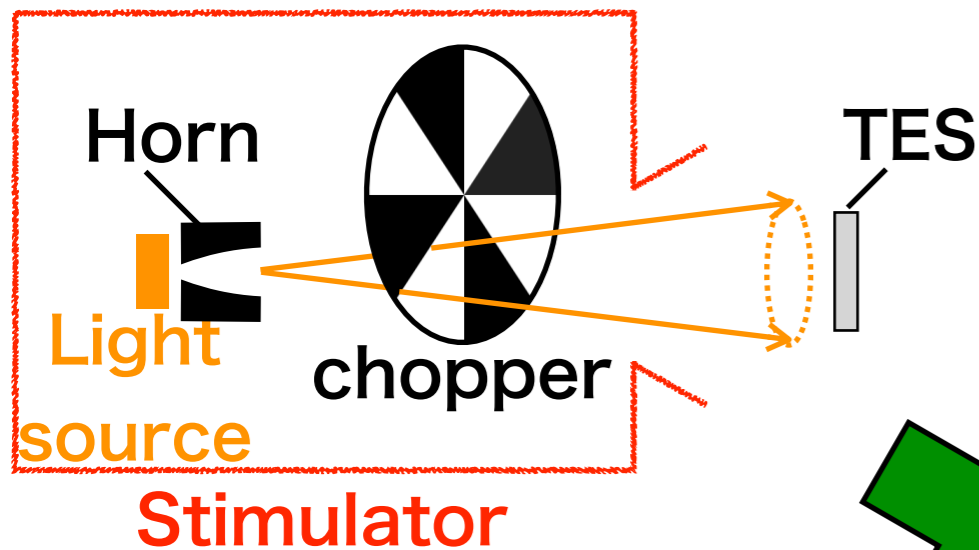
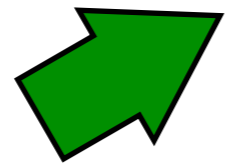
Calibration strategy

Gain calib

: Take TES data with slow frequency

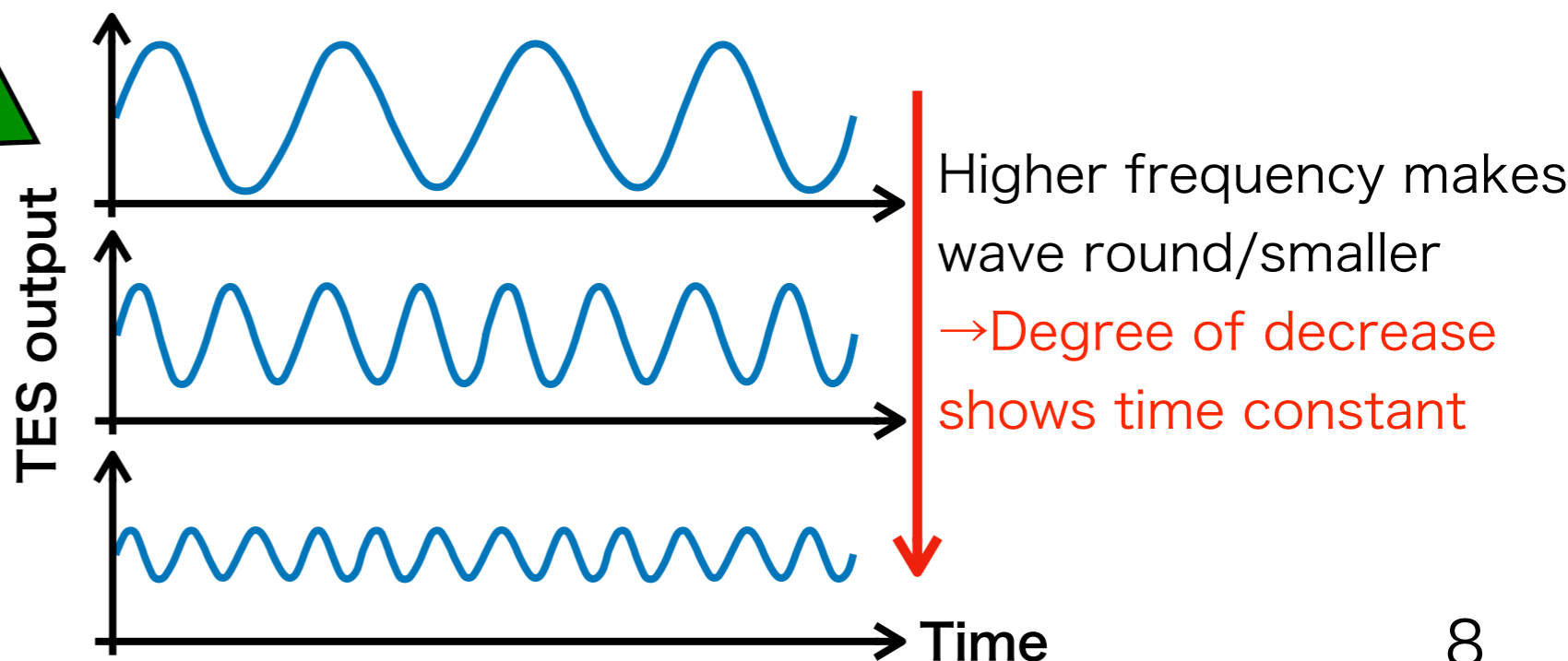


Illuminate TES
& rotate chopper



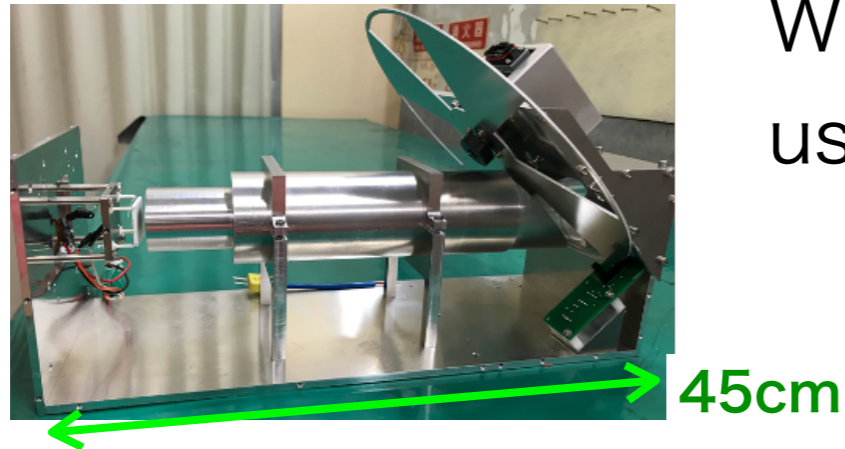
Time-constant calib

: Take TES data with some frequency



Strategy test w prototype stimulator

Proto stimulator

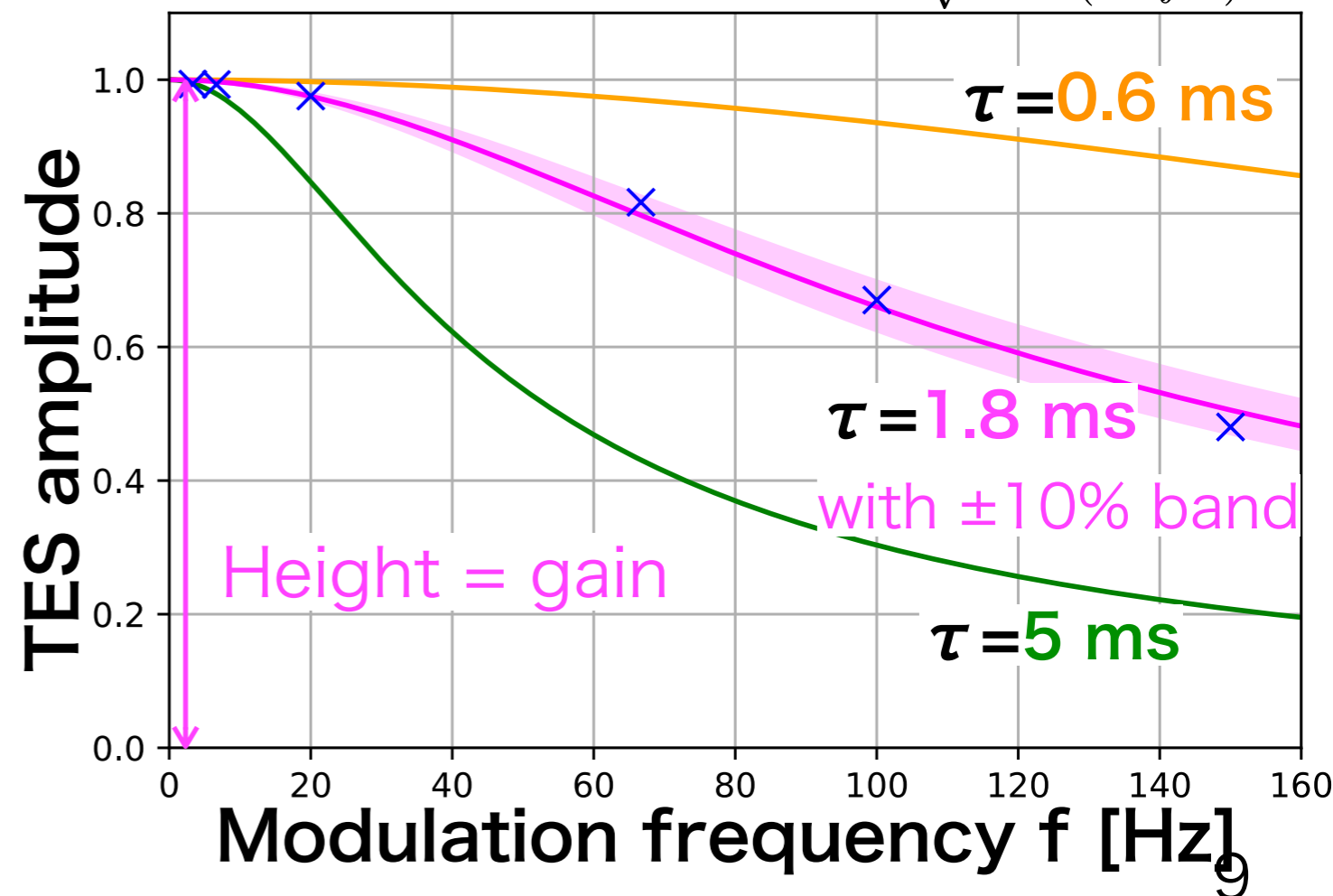
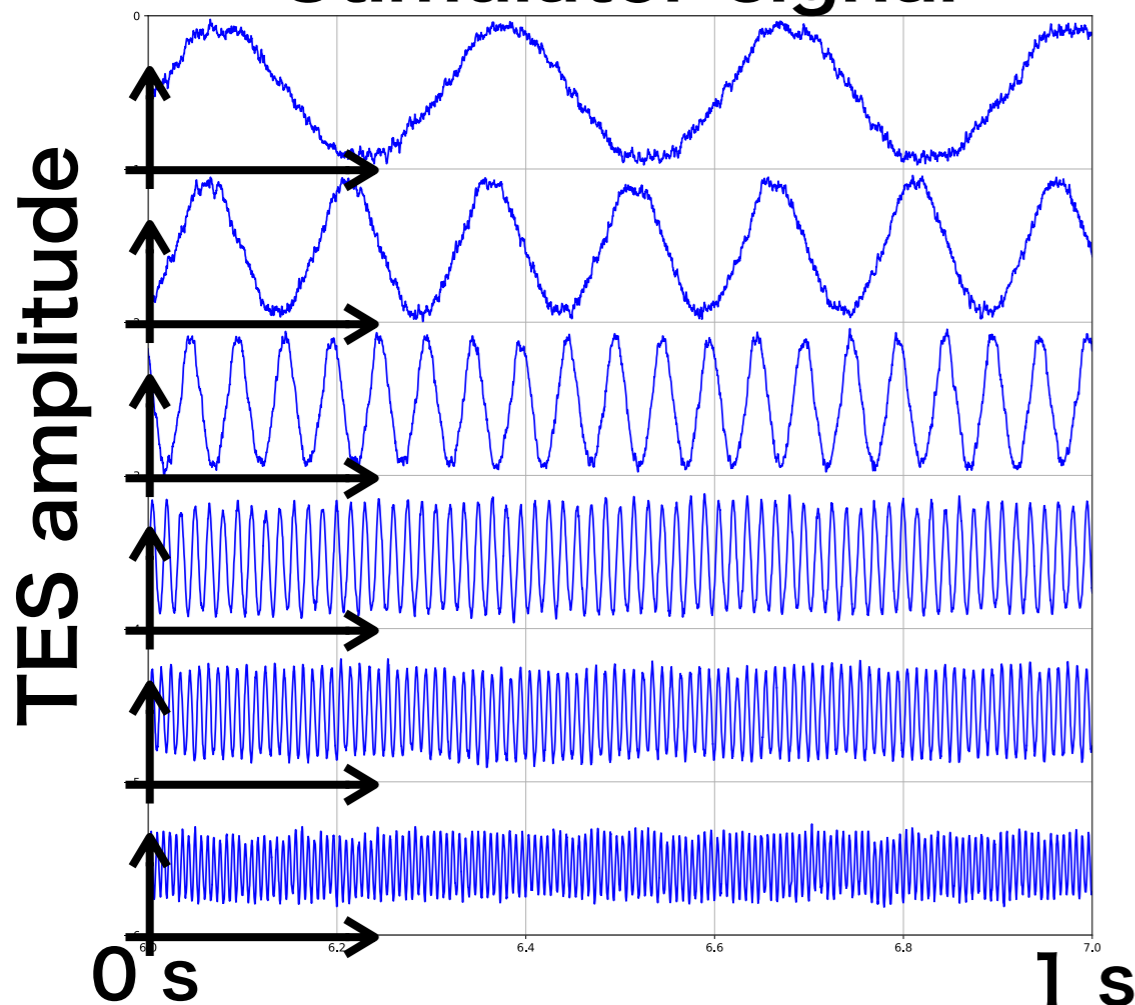


We tested strategy using proto stimulator & SO proto detector.

Response function

$$A = \frac{1}{\sqrt{1 + (2\pi f\tau)^2}}$$

Stimulator signal



Strategy test w prototype stimulator

Proto stimulator



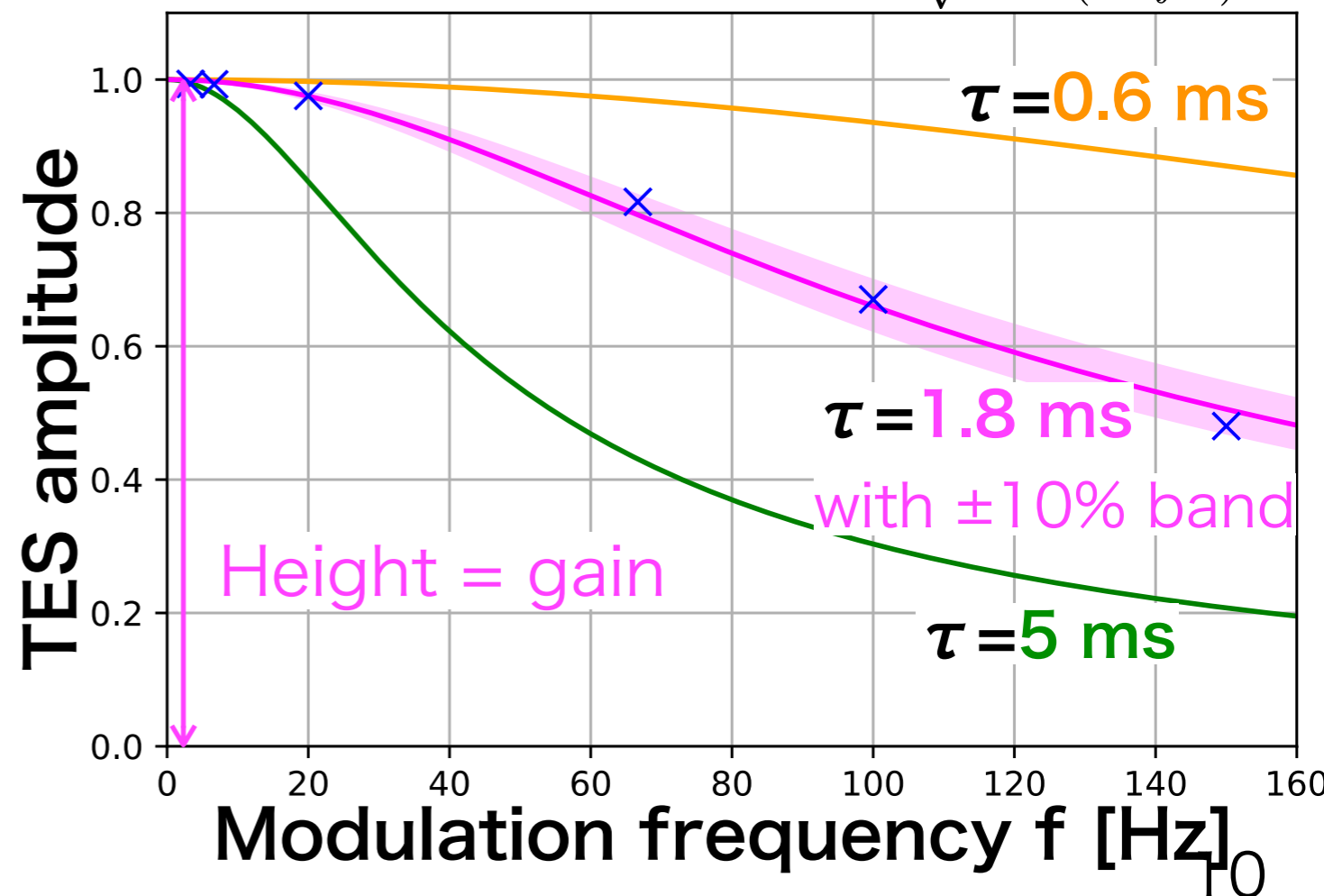
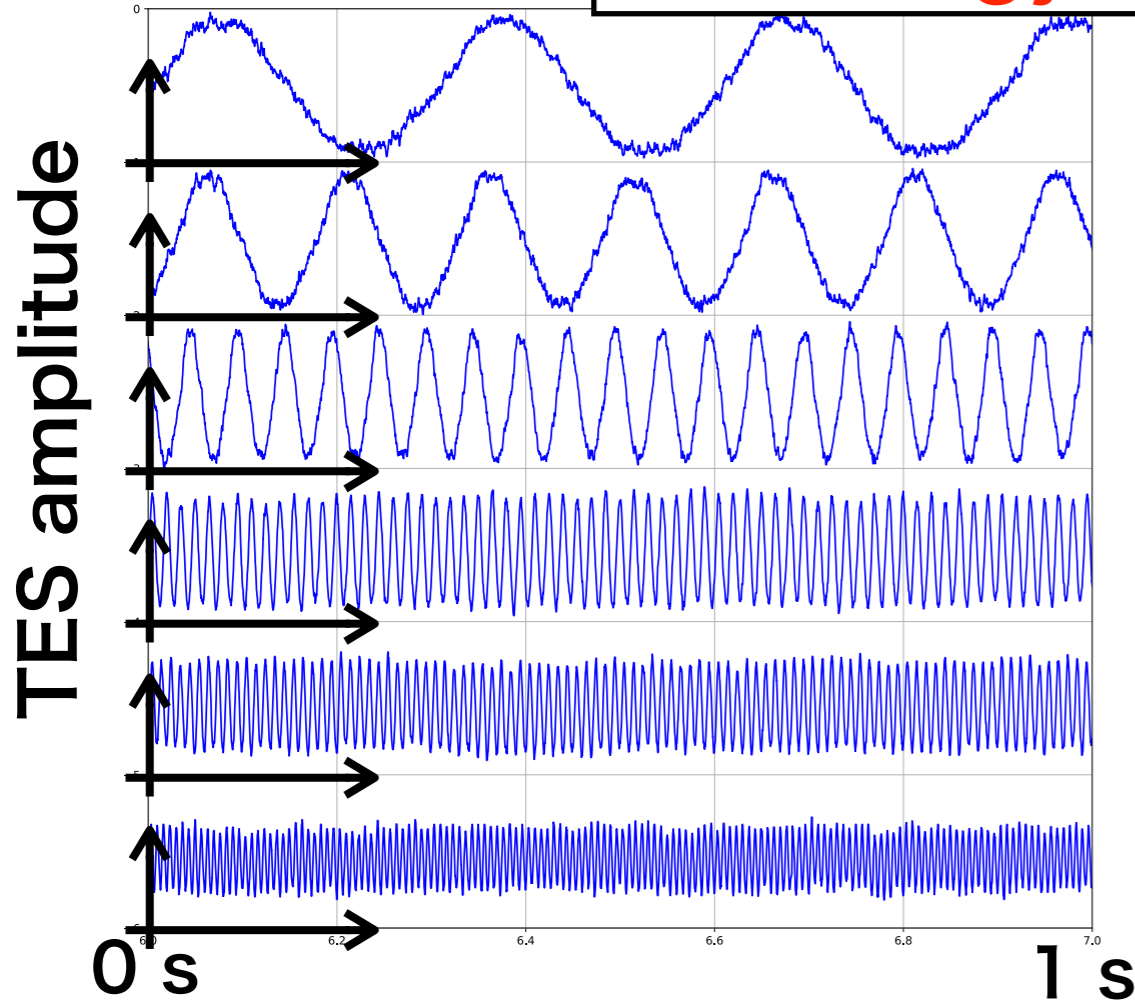
We tested strategy using proto stimulator & SO proto detector.

✓ Gain σ (1%), Time-constant σ (3%)
by least square fit

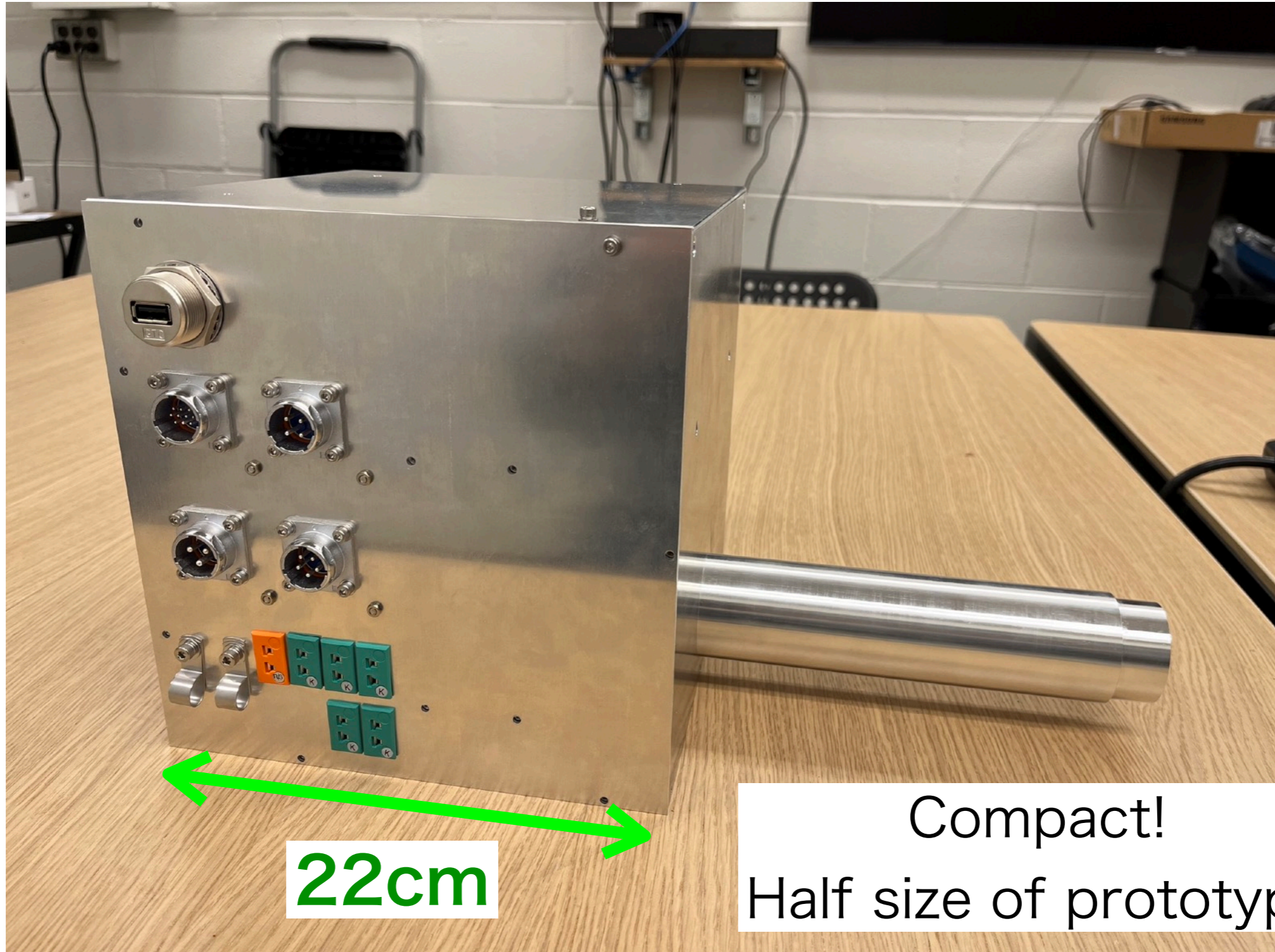
Stimula

✓ Strategy was confirmed!

$$\text{response function} = \frac{1}{\sqrt{1 + (2\pi f\tau)^2}}$$



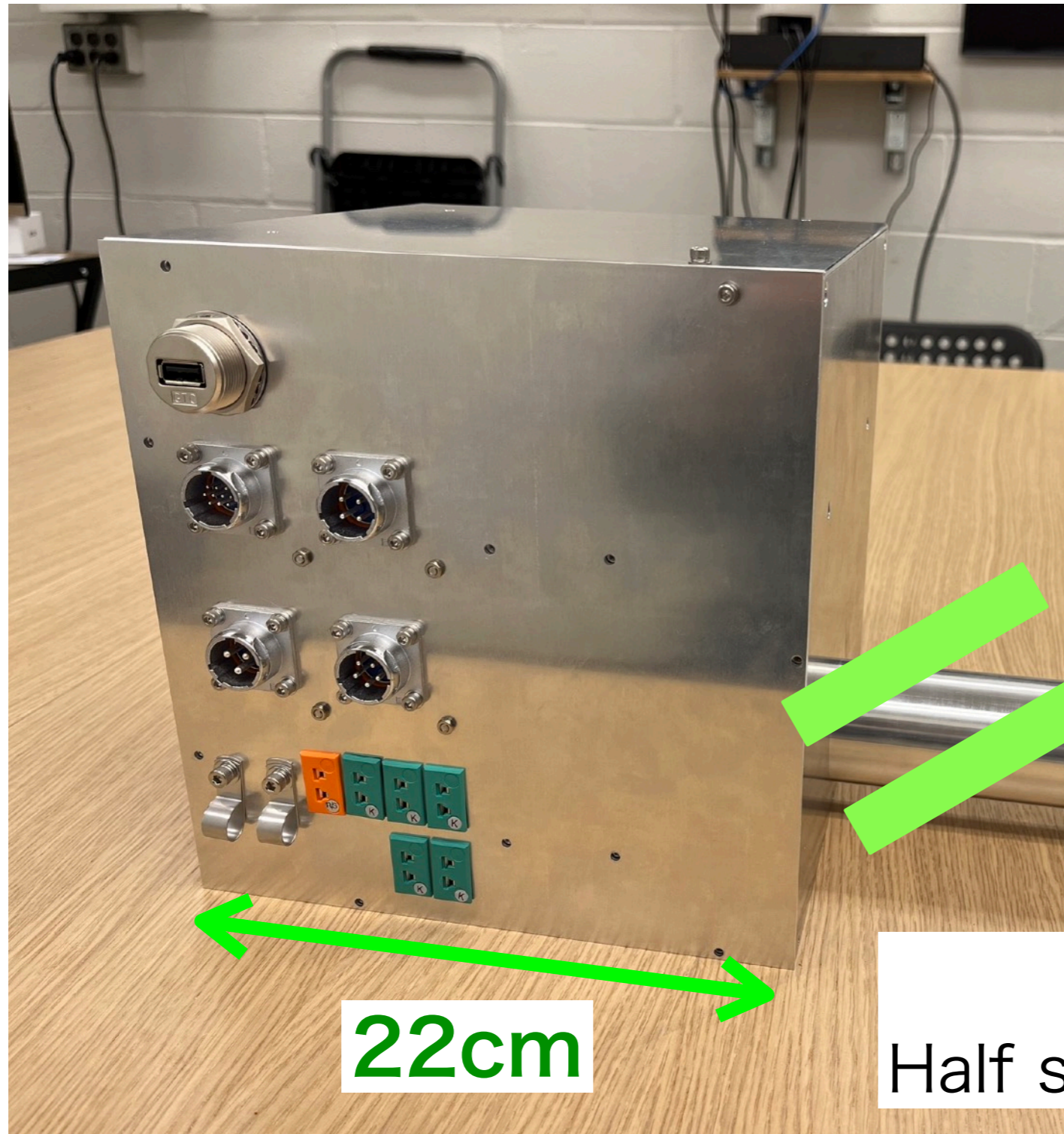
We made stimulator!



22cm

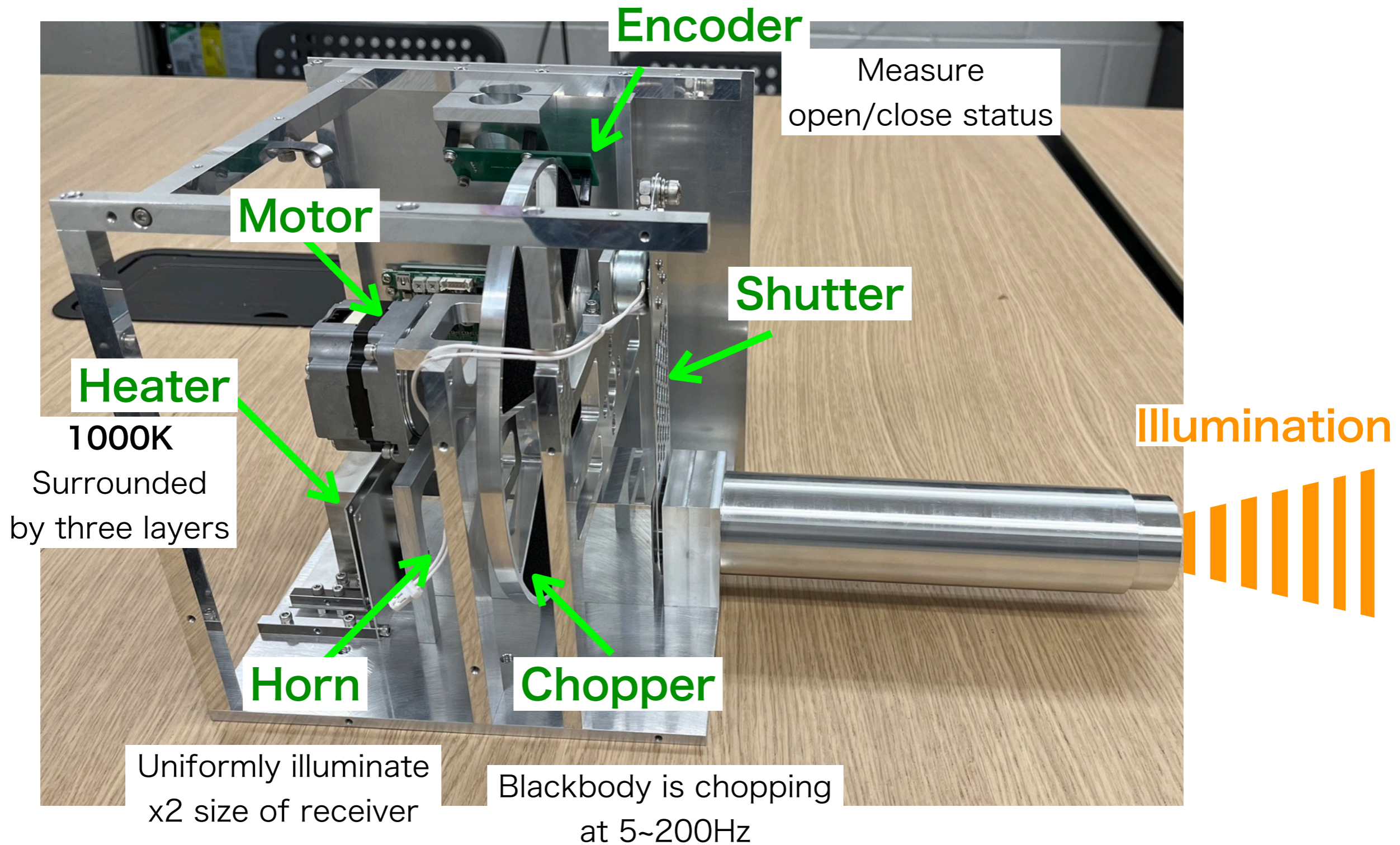
Compact!
Half size of prototype

We made stimu 5 months baby, Akito

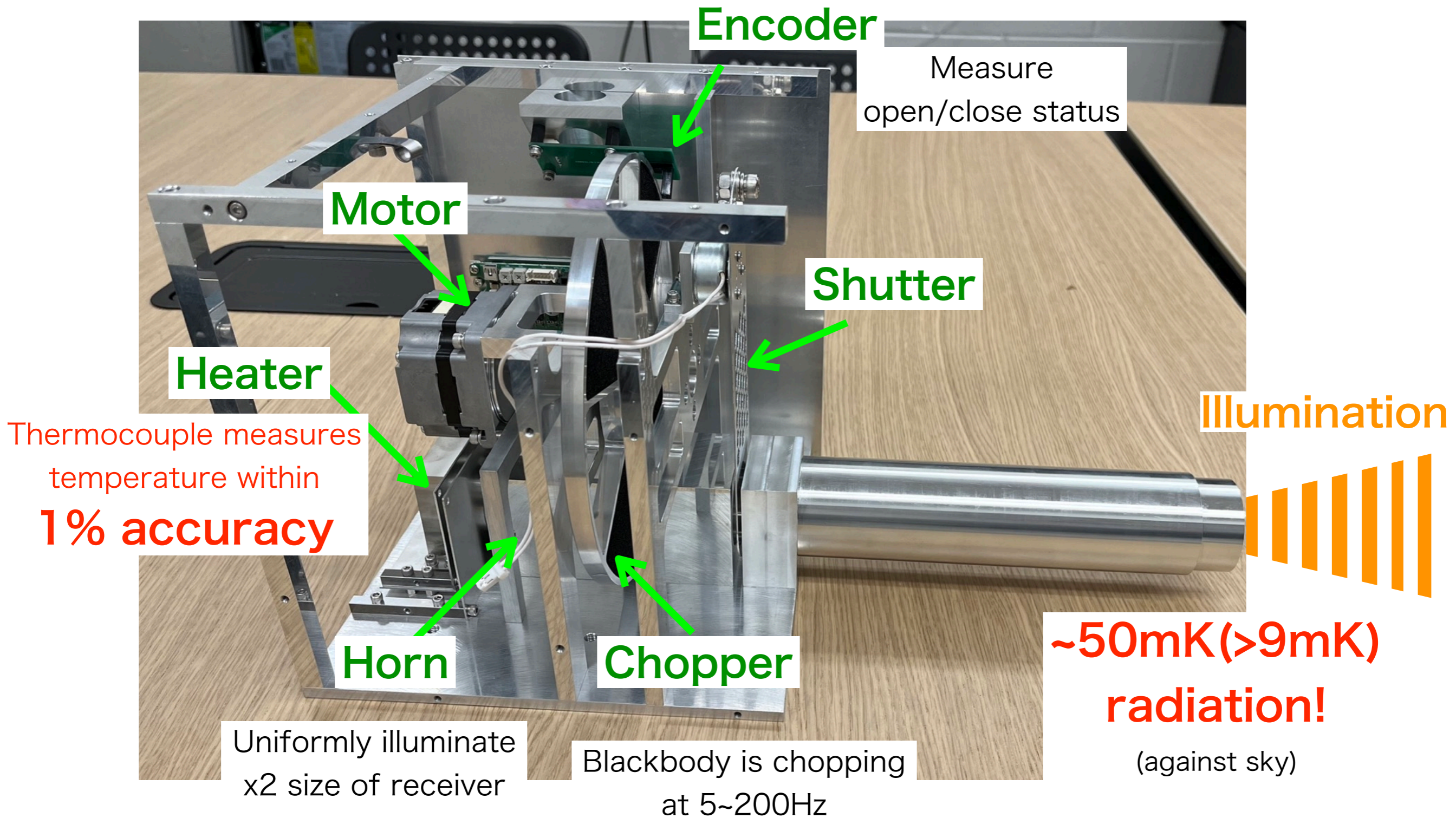


Compact!
Half size of prototype

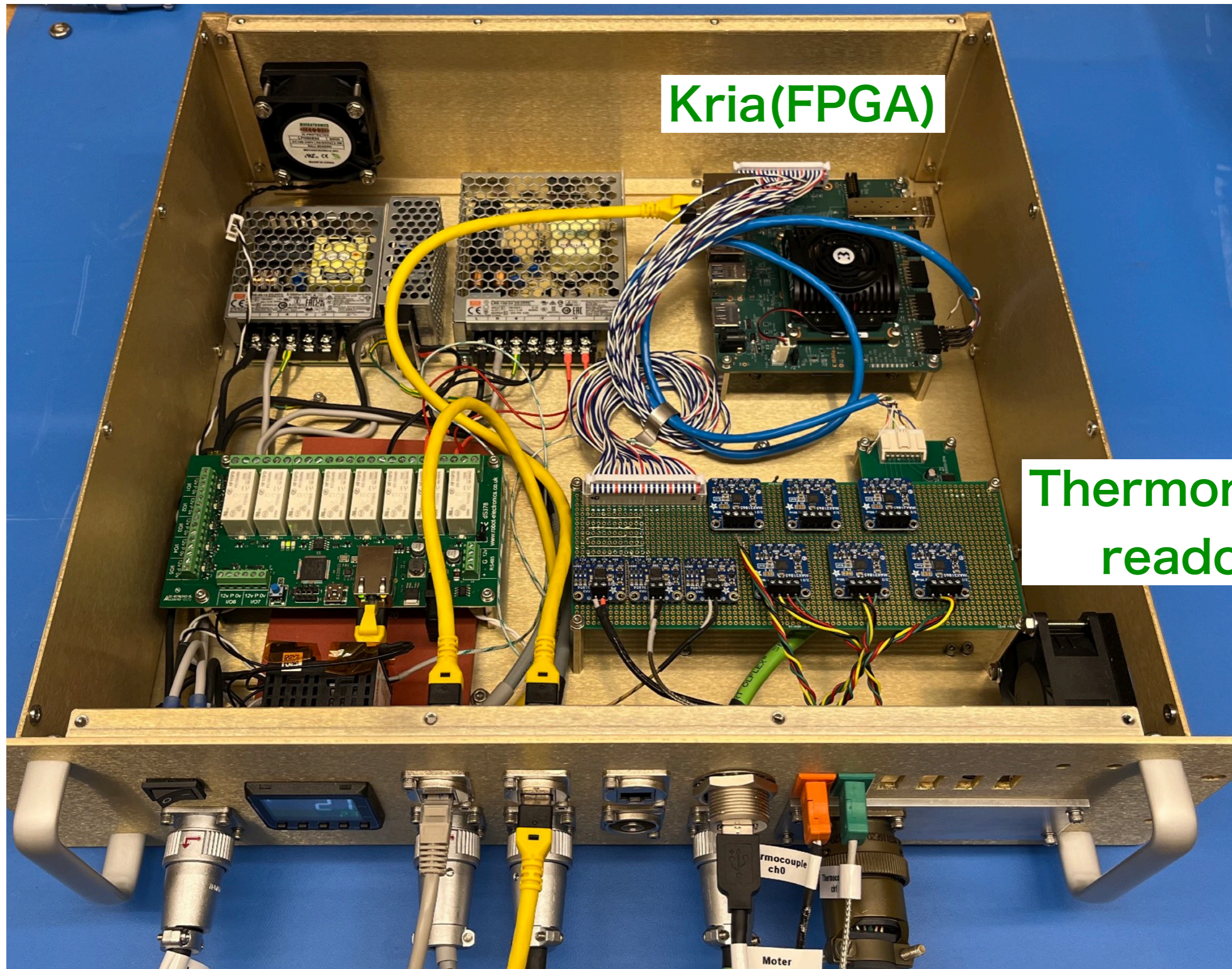
Stimulator inside



Stimulator inside



Electronics is also completed!



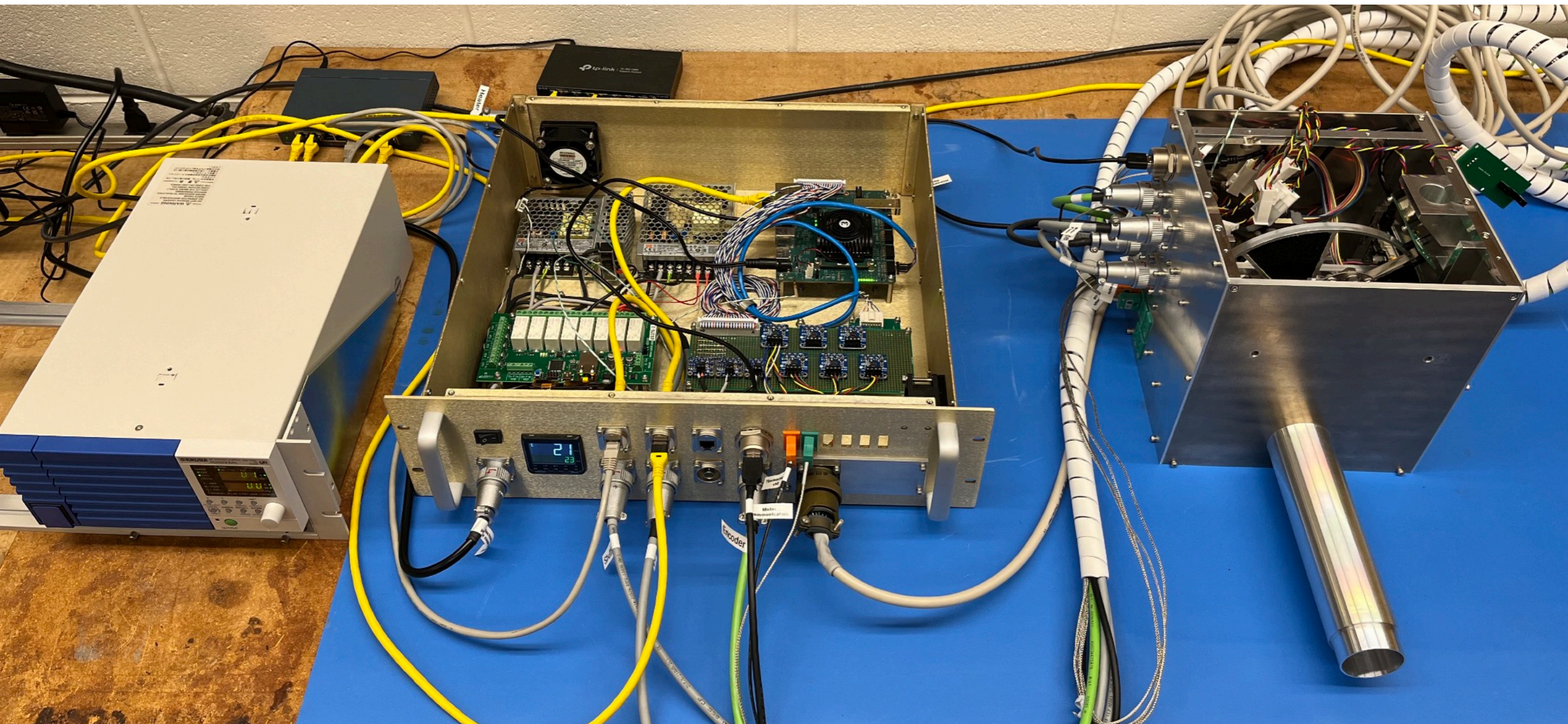
Kria(FPGA)

Thermometer
readout

Operation test

Operation tests were done at lab!

- ✓ Mechanical test
- ✓ Remote control software test



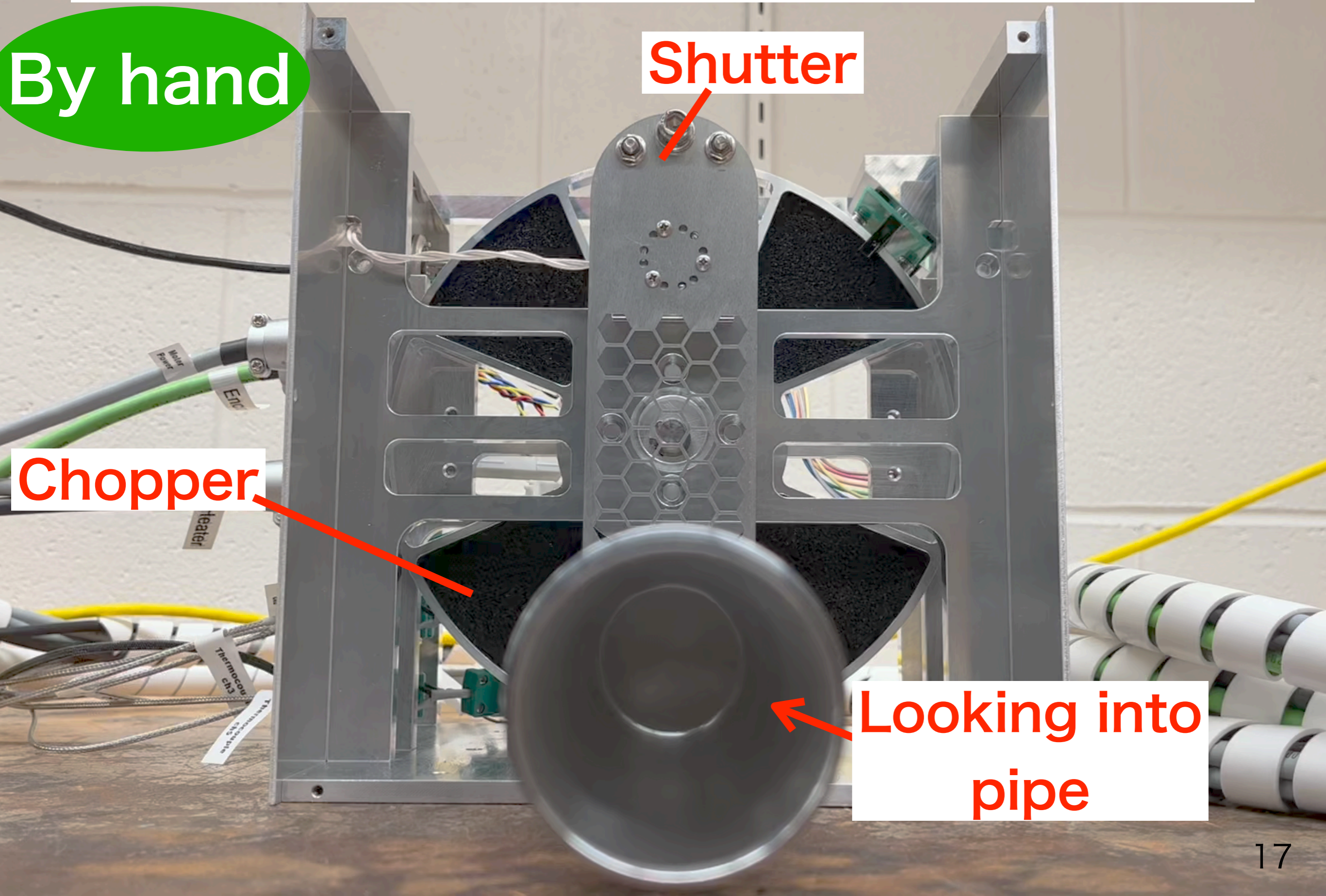
Test by hand

By hand

Shutter

Chopper

Looking into pipe



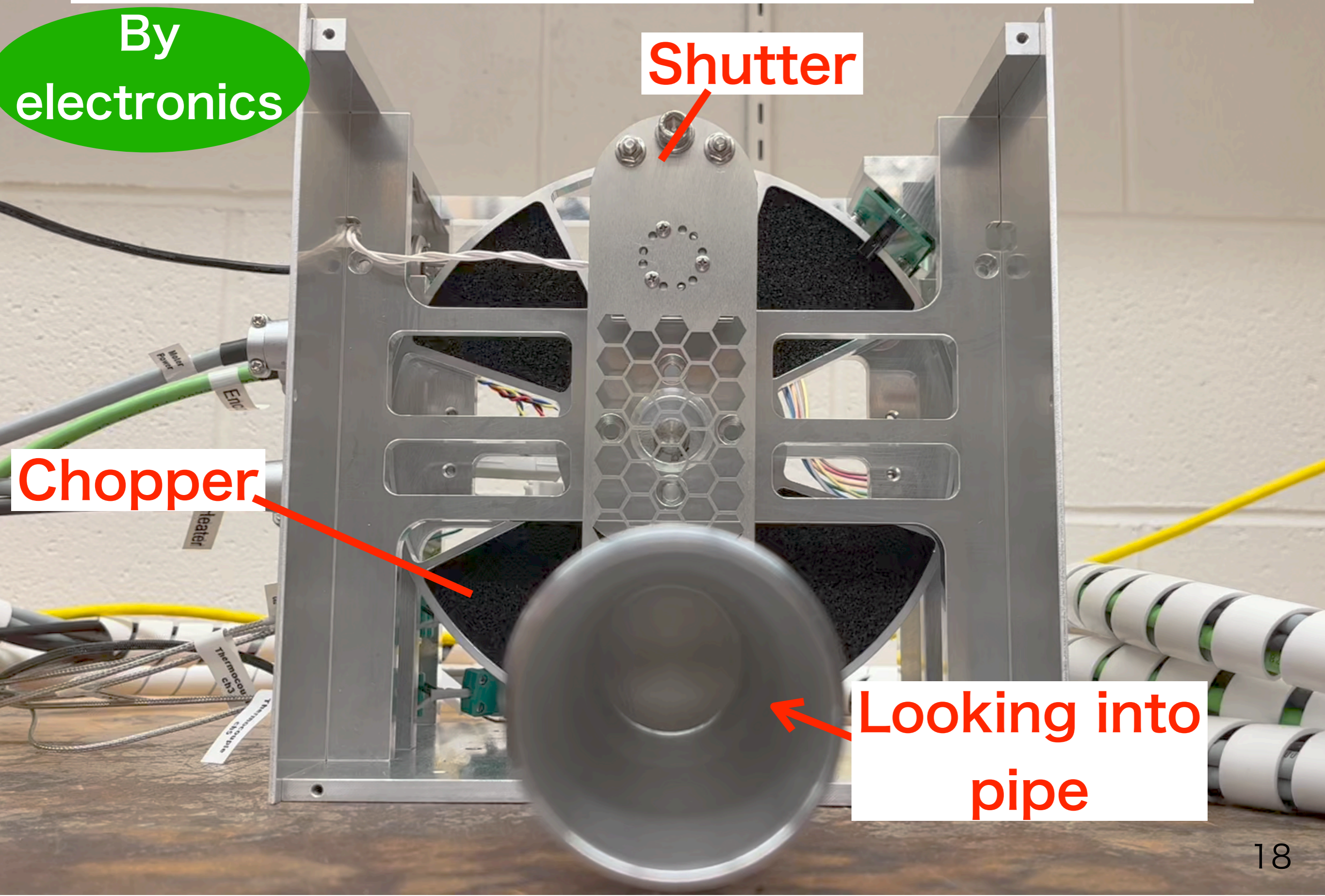
Operation with electronics

By electronics

Shutter

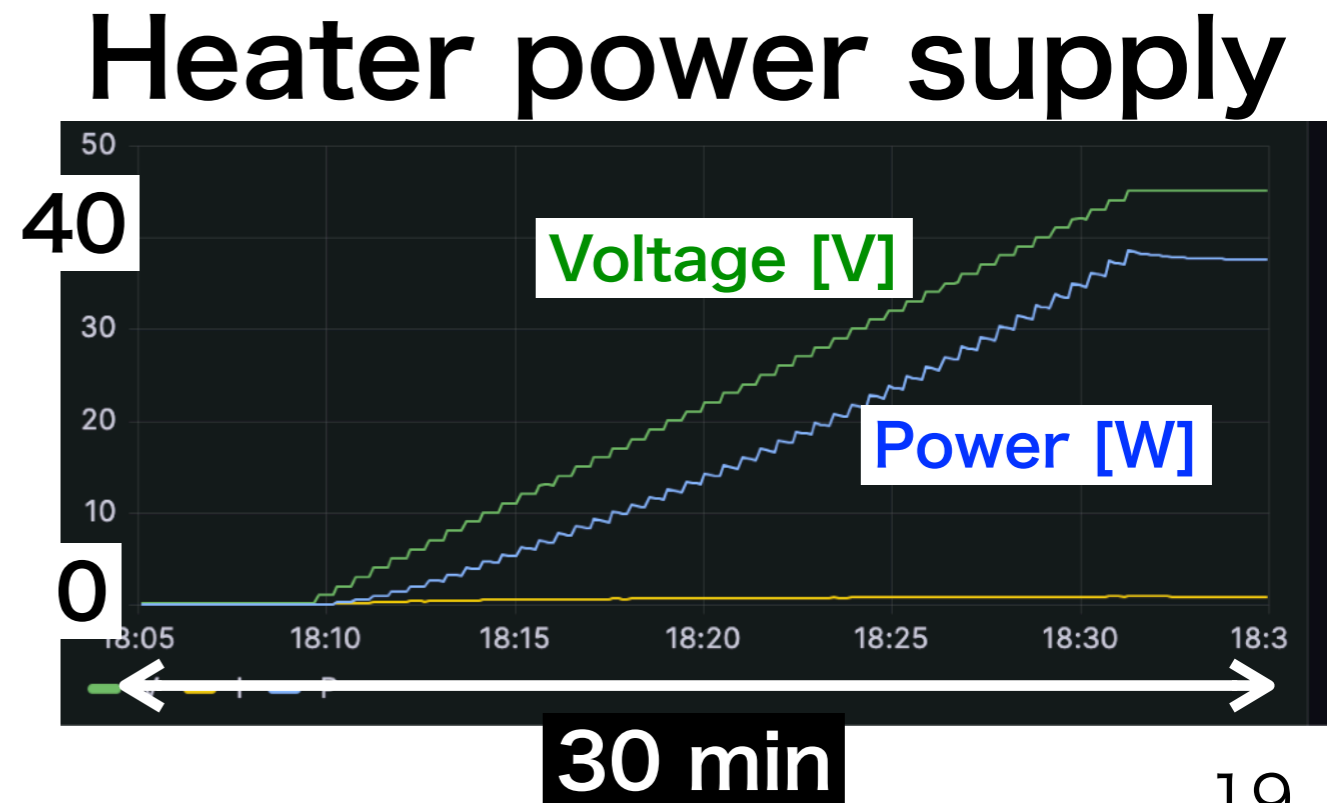
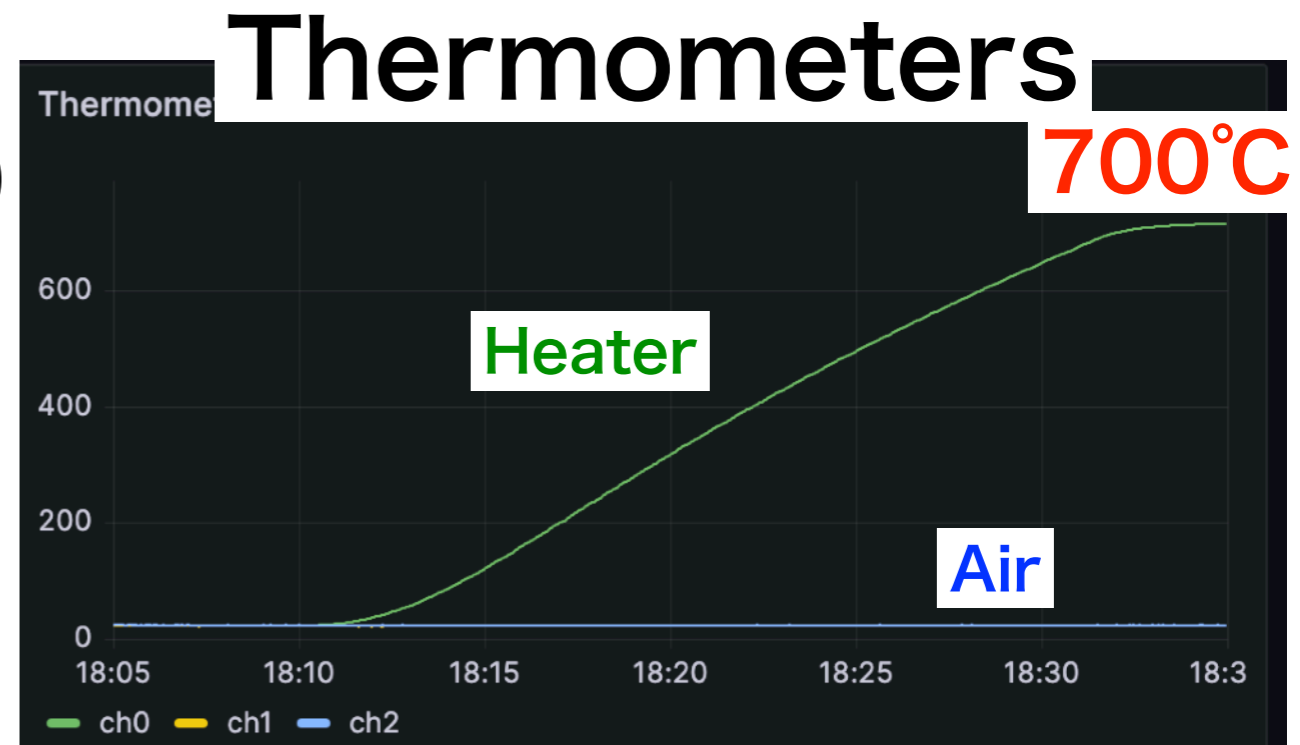
Chopper

Looking into pipe



Software test (demonstration)

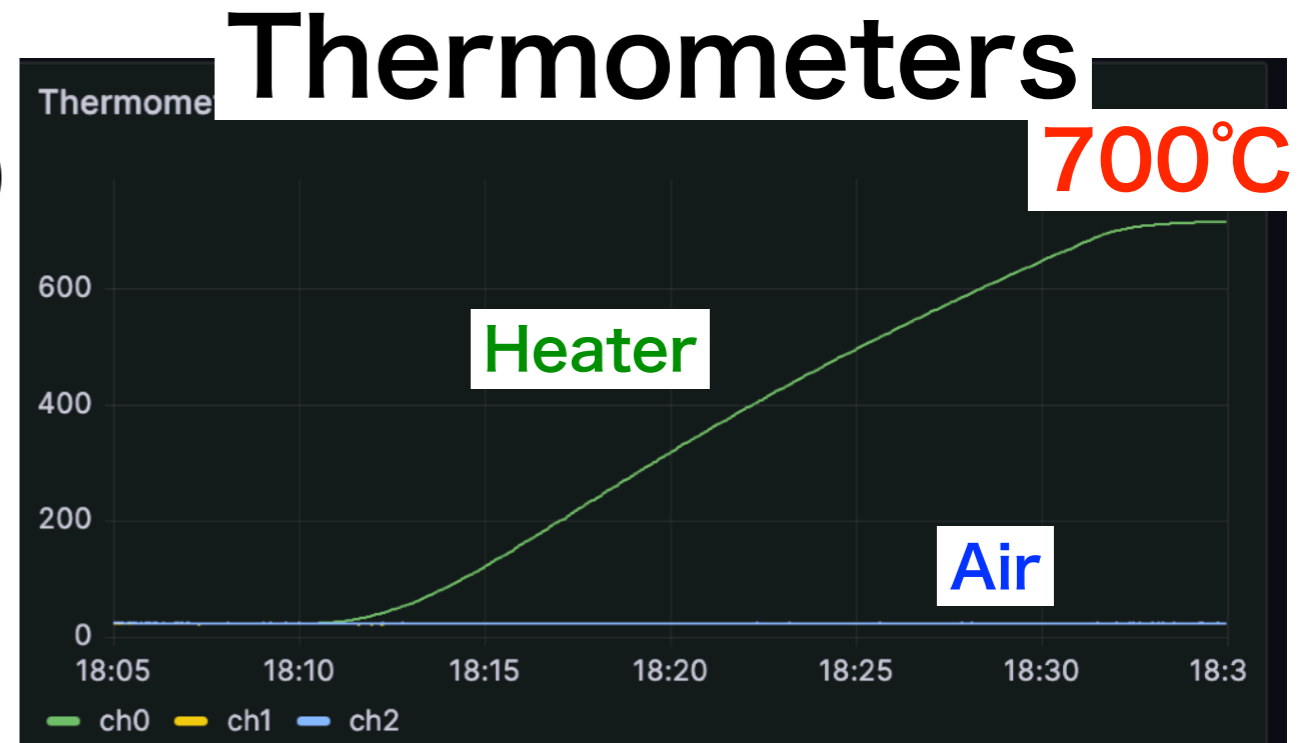
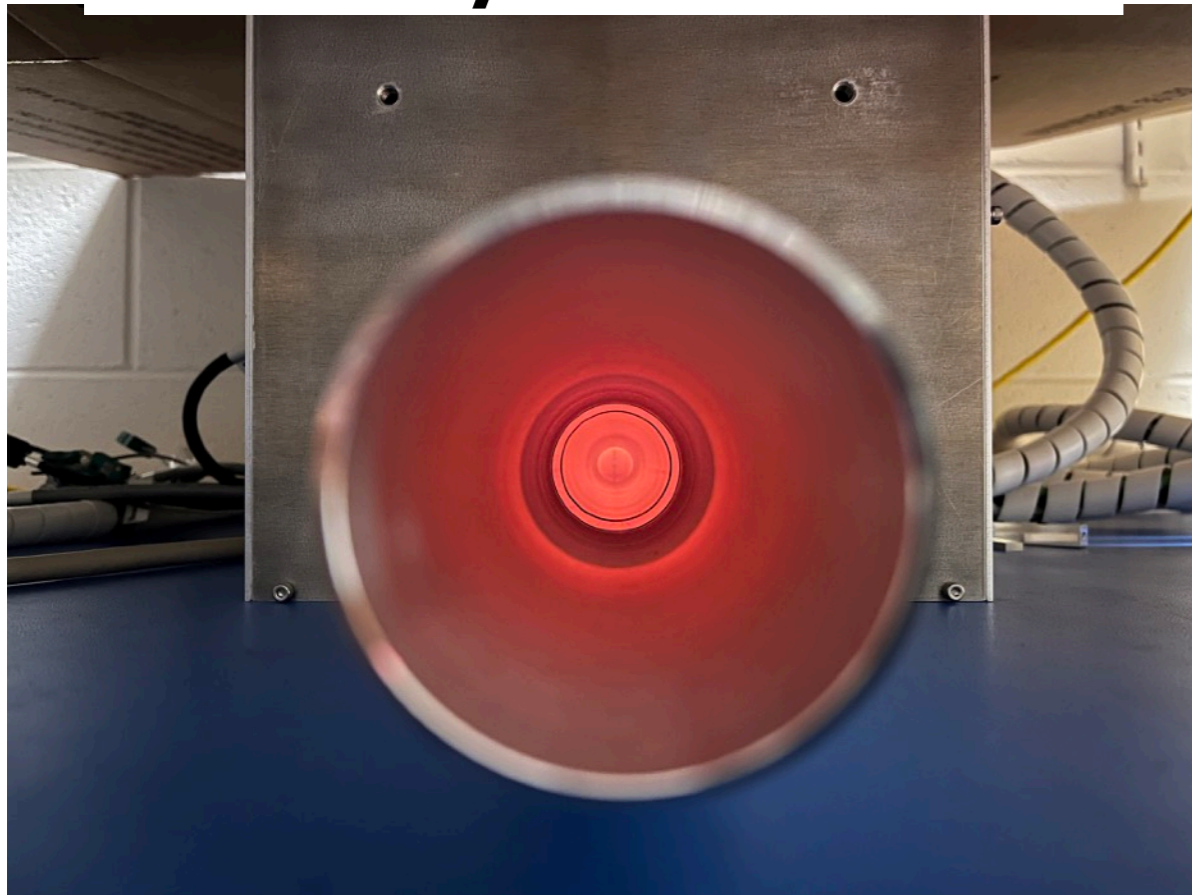
- ✓ Voltage applied appropriately.
- ✓ Heater reached target temp(700°C)



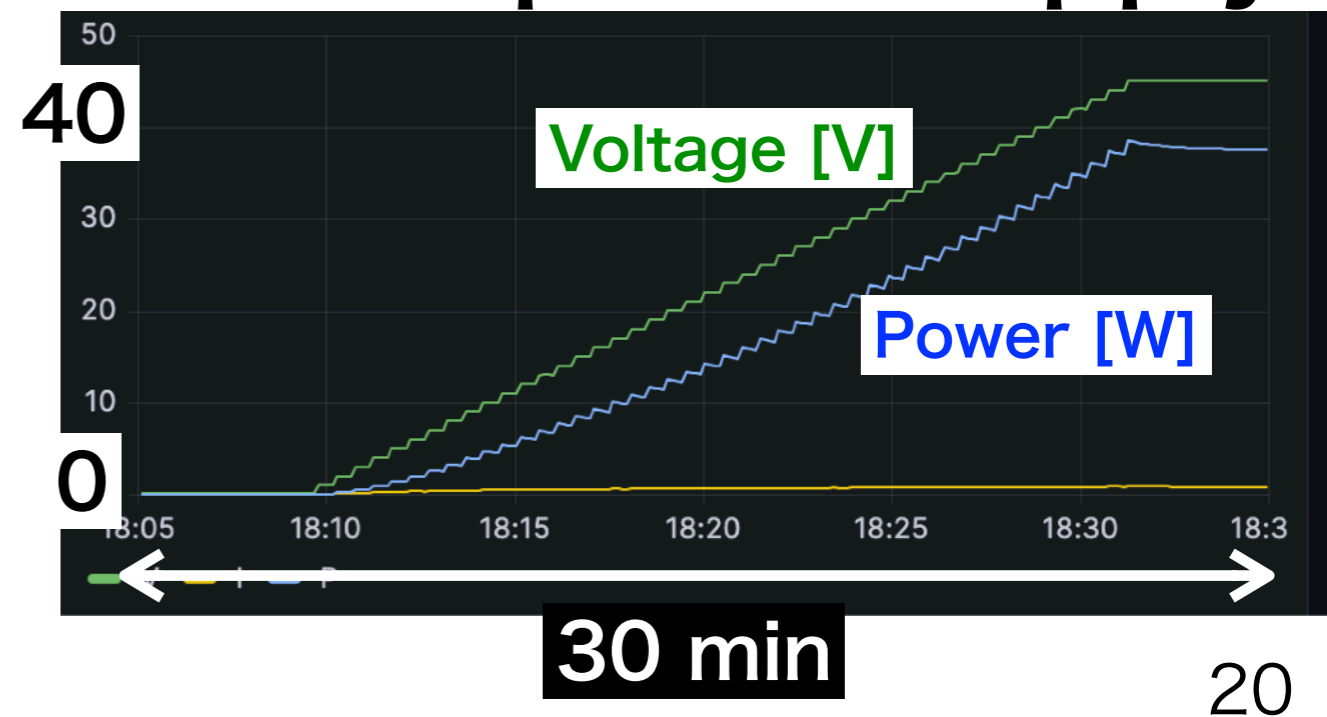
Software test (demonstration)

- ✓ Voltage applied appropriately.
- ✓ Heater reached target temp(700°C)

Front view of heater/stimulator



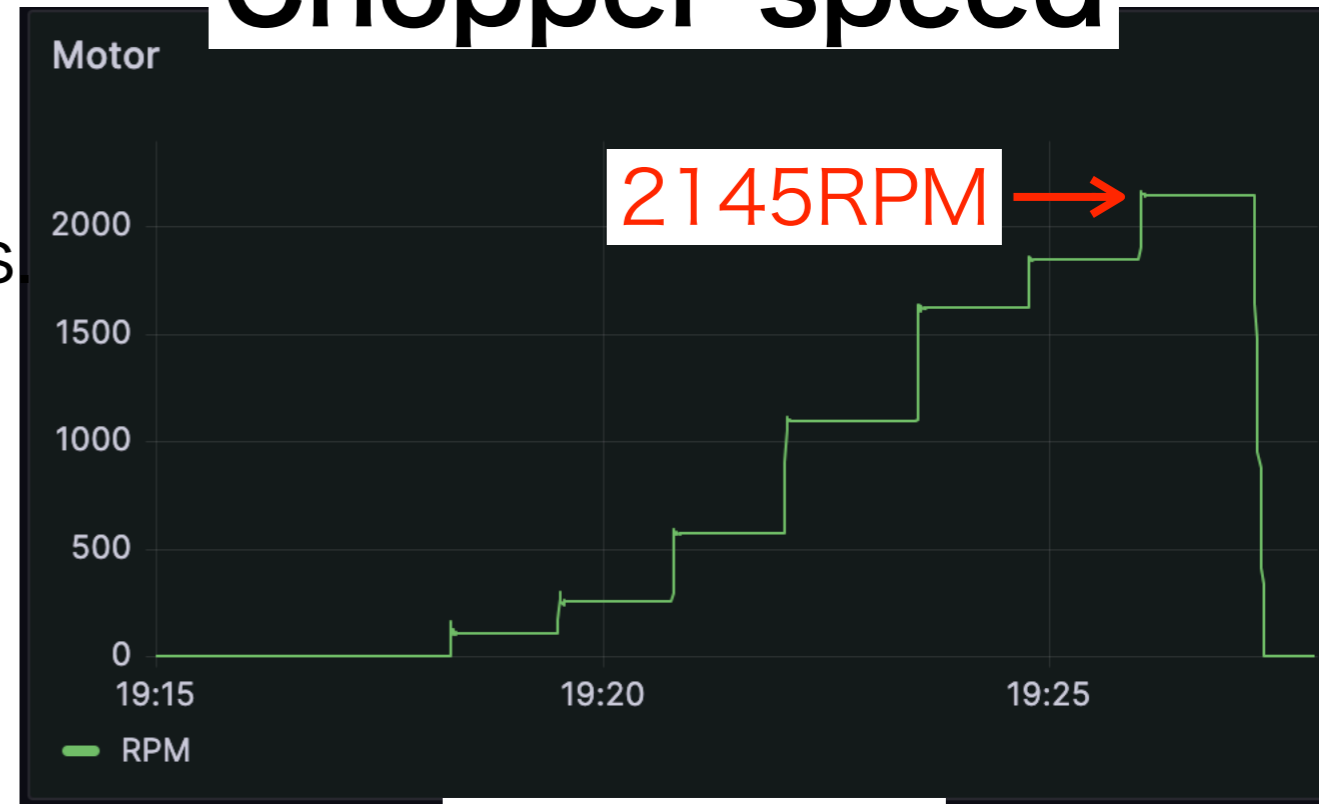
Heater power supply



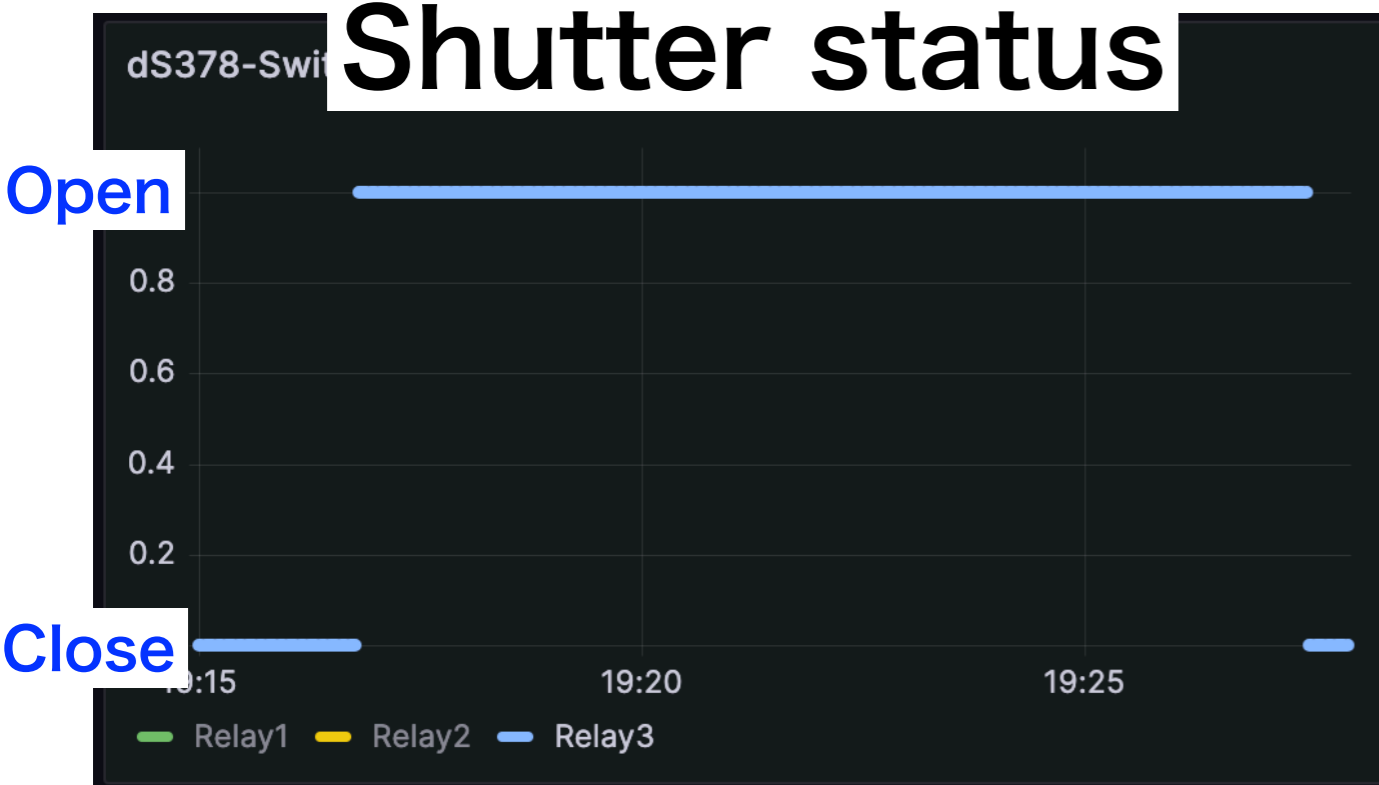
Software test (demonstration)

- ✓ Shutter opened/closed.
- ✓ Chopper rotated with several freqs
- ✓ Encoder measured chopper open/close status.

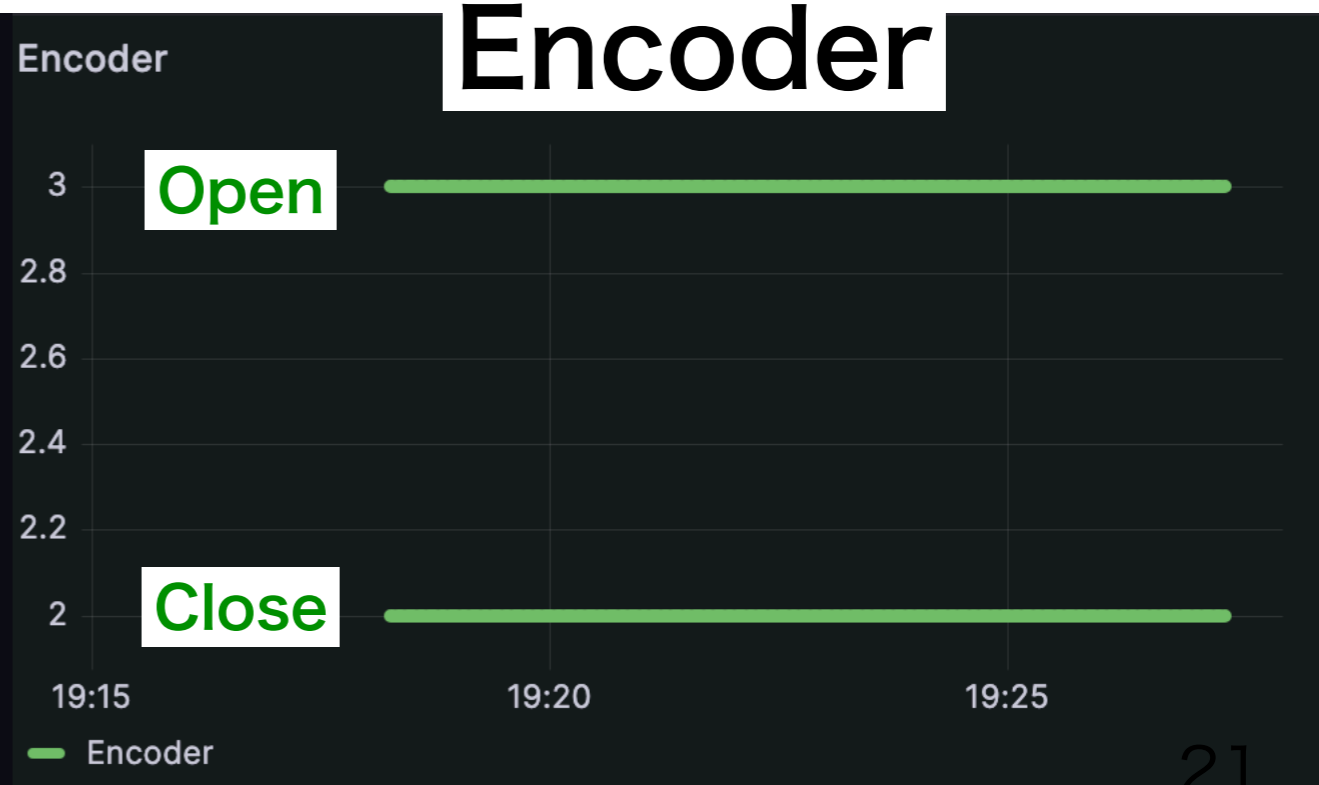
Chopper speed



Shutter status



Encoder



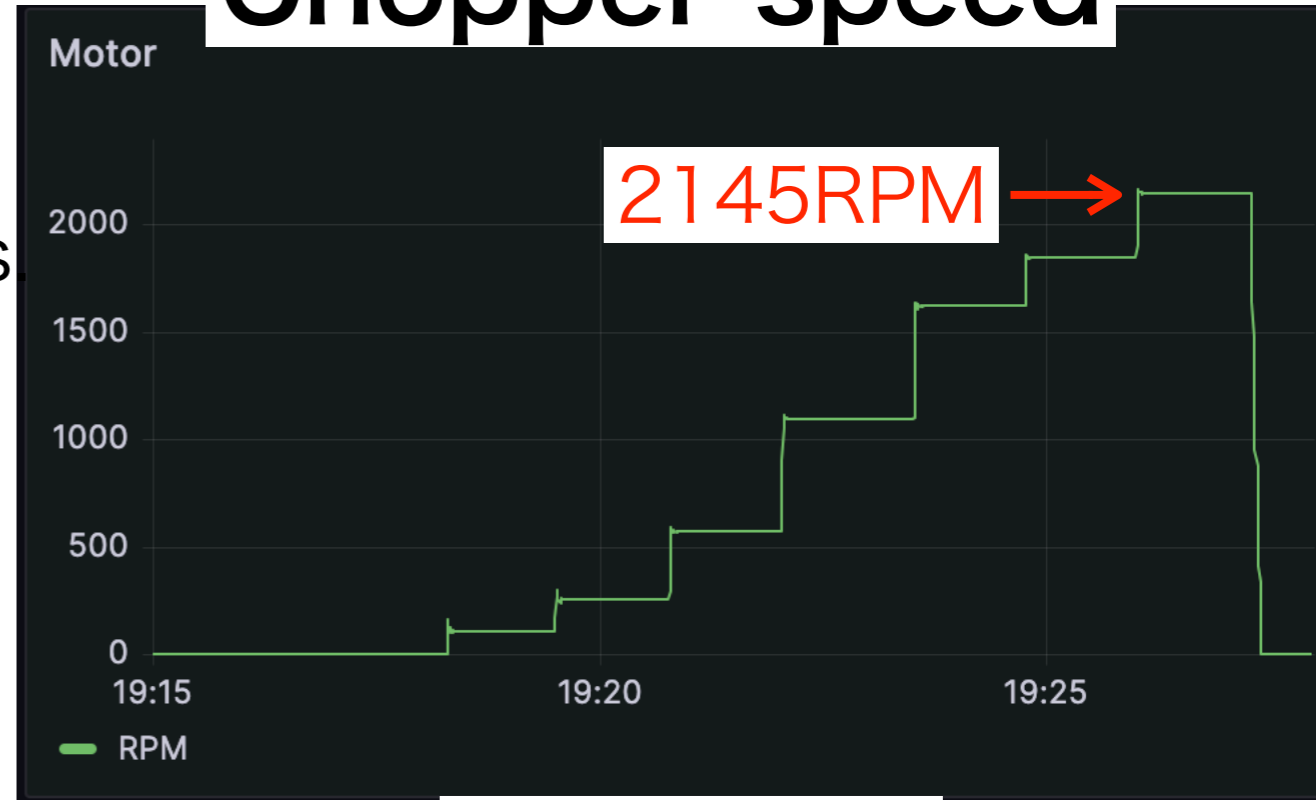
Software test (demonstration)

✓ Shutter opened/closed.

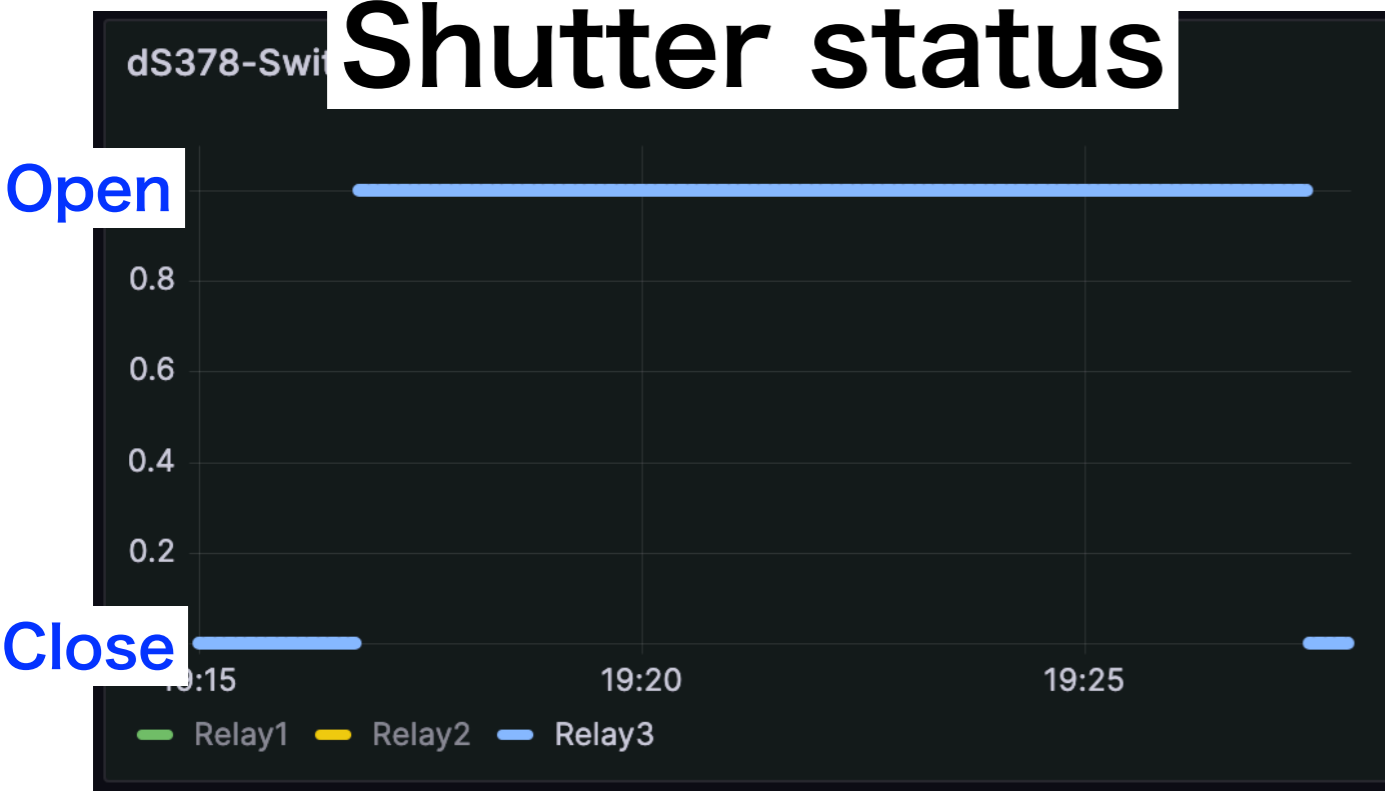
✓ Chopper speed controlled with feedback

✓ Encoder worked as expected!

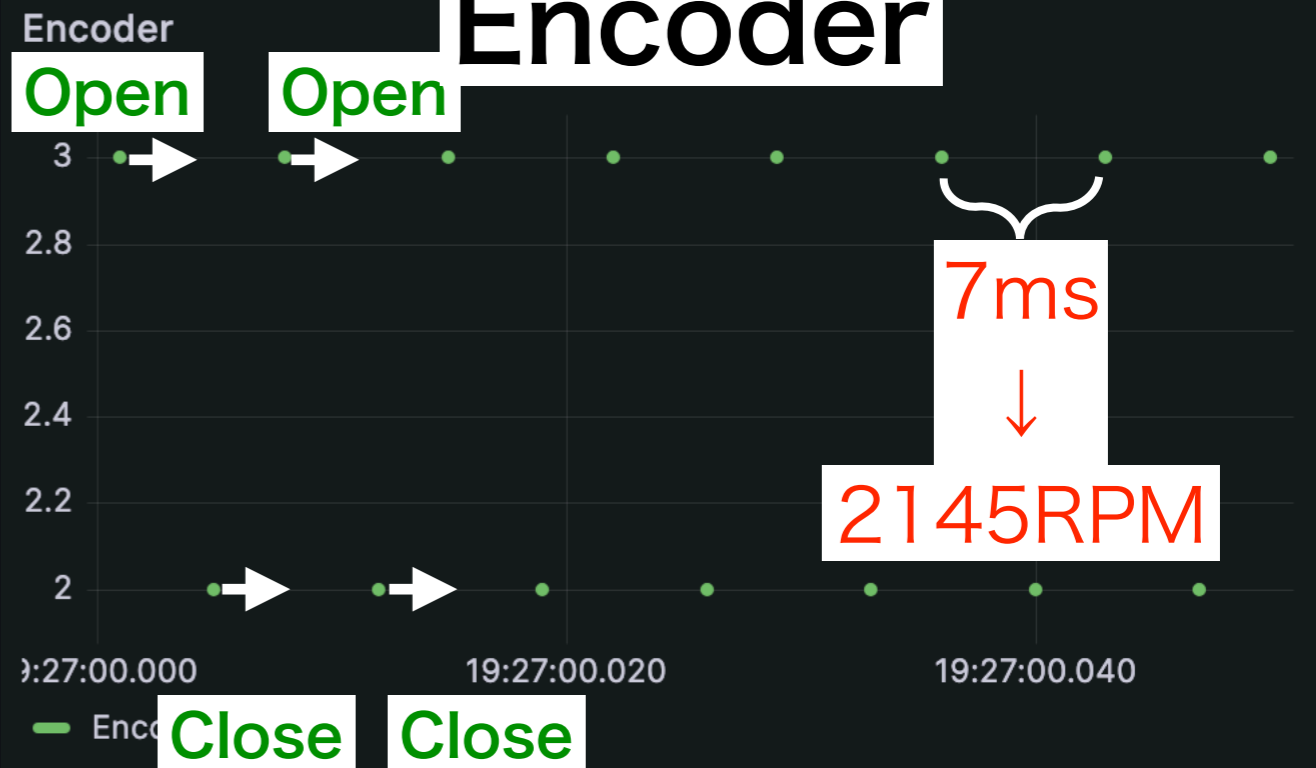
Chopper speed



Shutter status

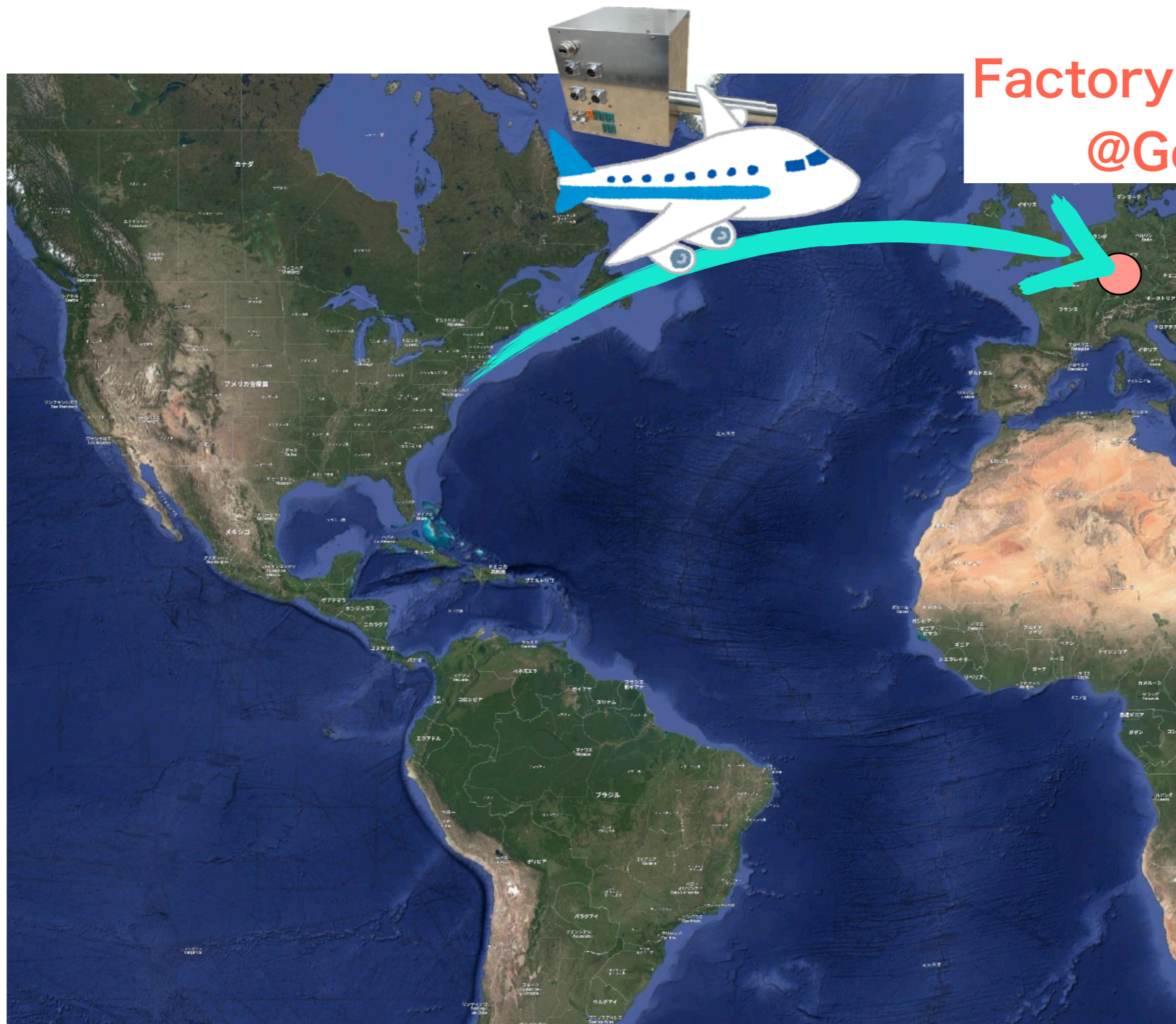


Encoder



Stimulator is on the way to site!

- Before go to site, we did fit test with telescope's mirrors.



Fit test with mirror

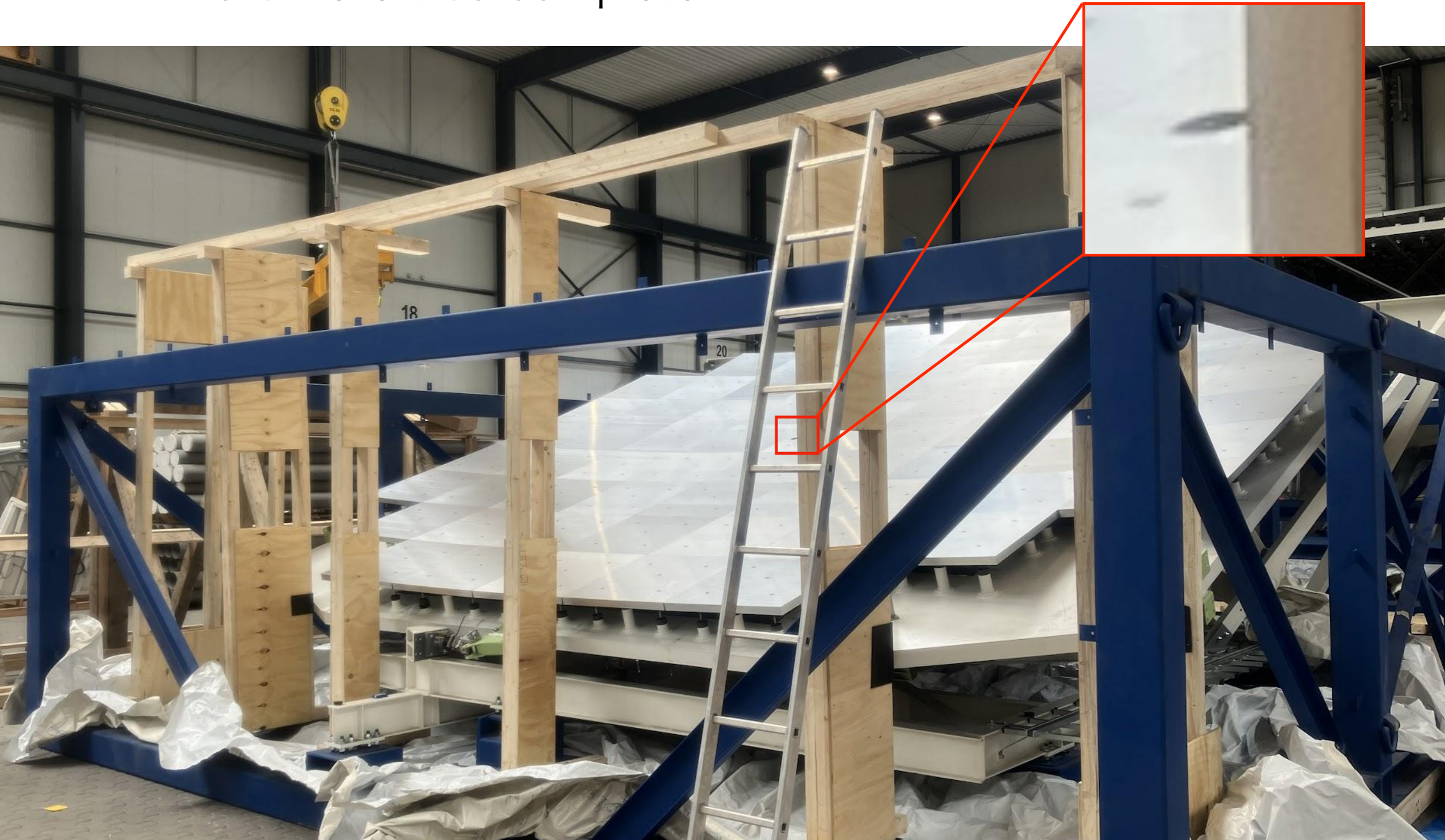
- Successfully fit with mirror! Operated with no problem.



Mirrors

- Mirrors were also completed!

Hole for stimulator



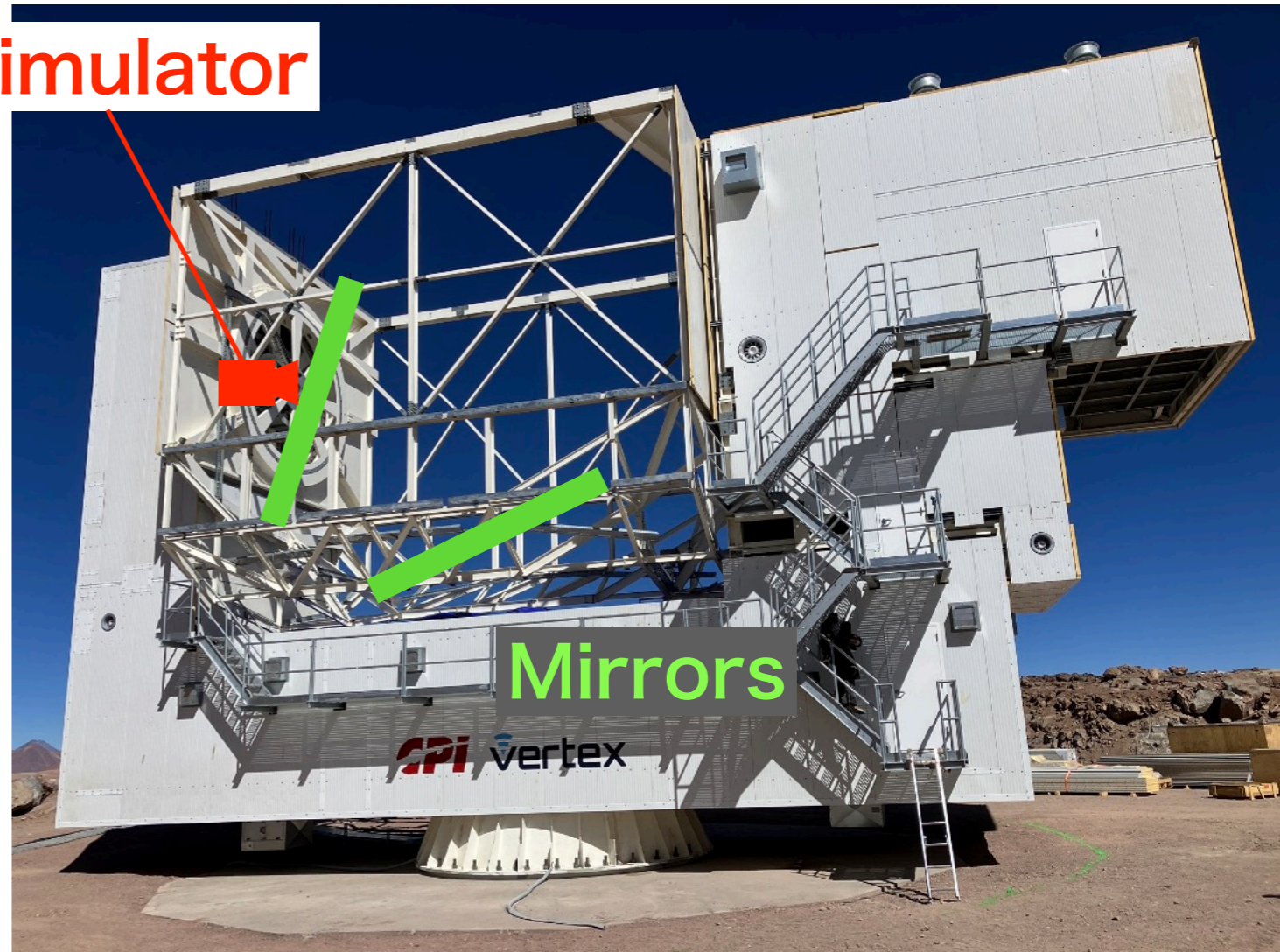
Stimulator&Mirrors are on the way to site now!



Future plan

- **Dec:**
Arrive at site!
- **Early 2025:**
Mirror installation
-> Stimulator installation
- **After installation:**
Deploy, commissioning
to evaluate systematics

Stimulator



Summary

- Stimulator calibrates SO detector's.
- Will be operated for ~hourly calibration to achieve 1% relative-gain and 10% time-constant accuracy.
- Successfully developed.
Installation will happen early next year!!!

and, thank you for supporting us!



UK Research and Innovation

