The status of the development for Simons Array experiment

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ON BEHALF OF POLARBEAR COLLABORATION

Why does the Universe accelerate? – Exhaustive study and challenge for the future. 2018/02/11, Tohoku University.

Status of CMB experiments

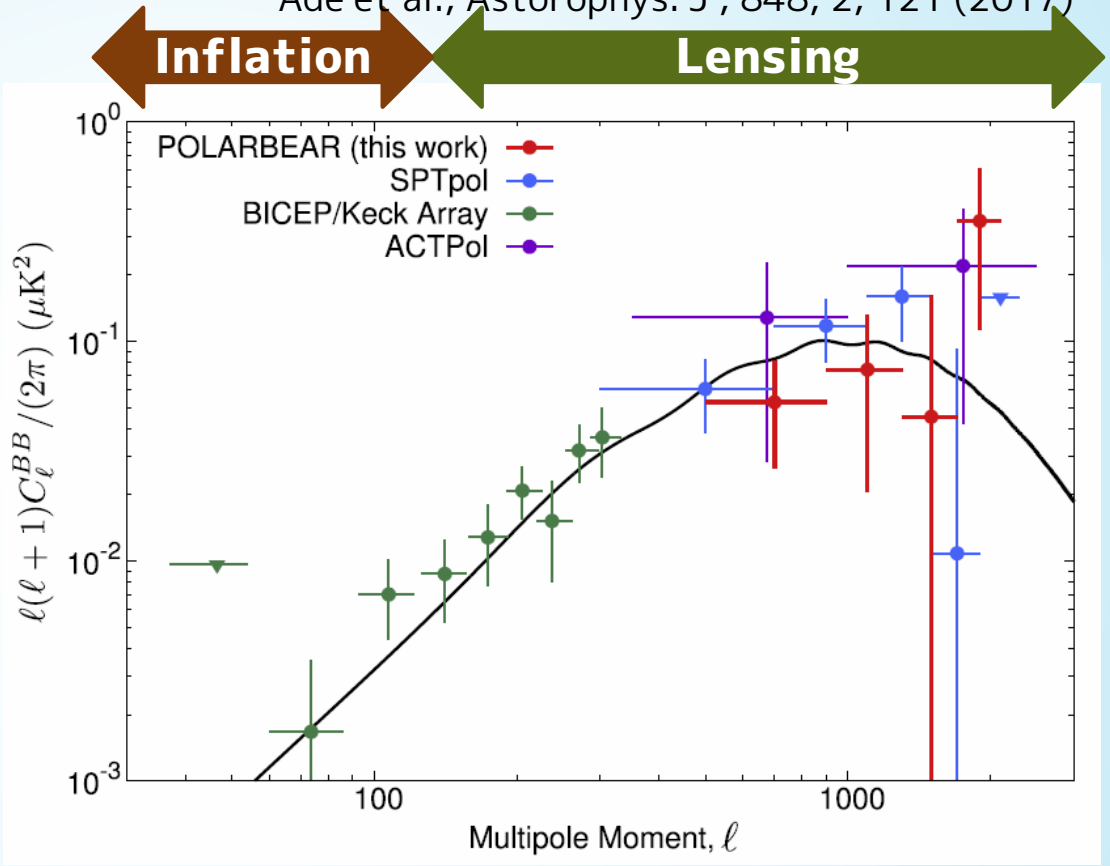
In recent years,

Many ground experiments succeeded to observe B-mode polarization of **gravitational lensing**.

But, B-mode of **primordial gravitational wave from inflation** has not been discovered yet.

Competing experiments are moving from stage-2 to stage-3 experiments.

Ade et al., Astorophys. J , 848, 2, 121 (2017)



POLARBEAR and Simons Array Project
(PB) (SA)

Site

- Chile, Atacama
  - ~5200 m altitude
  - Very low humidity

Telescope

- Huan Tran Telescope (HTT)
  - 2.5 m primary mirror
  - 3.5′ resolution (150GHz)
  - Off-axis Gregorian system

Collaboration

~100 researchers
from institutes
in 8 countries

Australia, Canada,
Chile, France,
Italy, Japan,
UK, USA

Sponsored by

SIMONS FOUNDATION

MEXT

JAPAN SOCIETY FOR THE PROMOTION OF SCIENCE · FOUNDED 1932 ·

CONICYT
Ministerio de Educación
Gobierno de Chile

NSF

NASA

Project history

POLARBEAR history

2011 : Construction finished
2012 : Start observation
2014,15: Publish first results
- Lensing B-mode was found

2017- : Publish second results

Upgrade to Simons Array

- Observation with 3 telescopes
- Upgraded receiver of larger focal plane 6 times more sensors
  1274 → 7588
- Observation of 95/150 GHz for better foreground removal
  (3rd unit : 220/270 GHz)

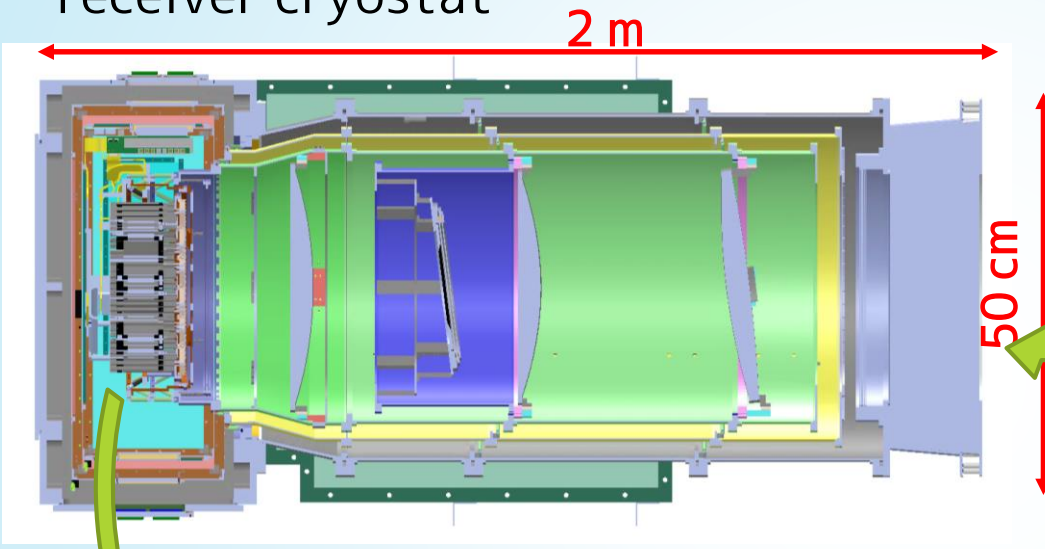
Papers

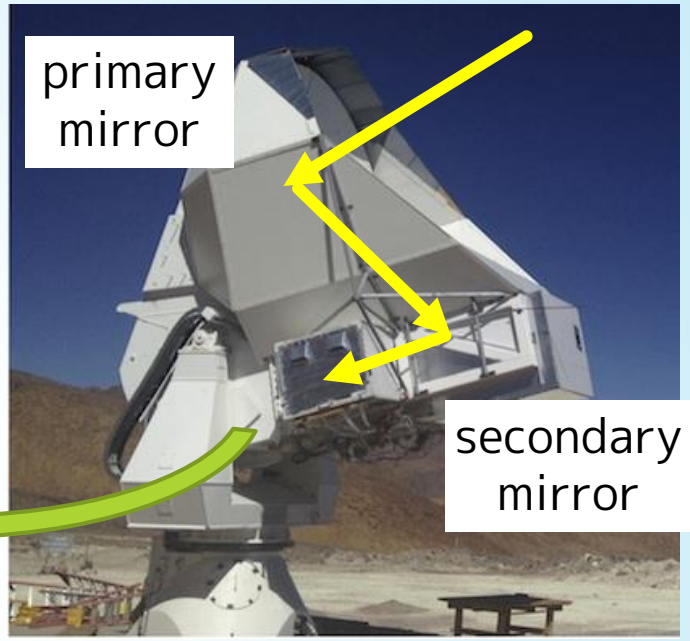
Phys.Rev.Lett., 112, 1302 (2014)
Astorophys.J., 794, 2, 171 (2014)
Phys.Rev.Lett.,113, 1301 (2014)
Astorophys.J., 809, 1, 63 (2015)
Phys.Rev.D, 92, 123509, (2015)

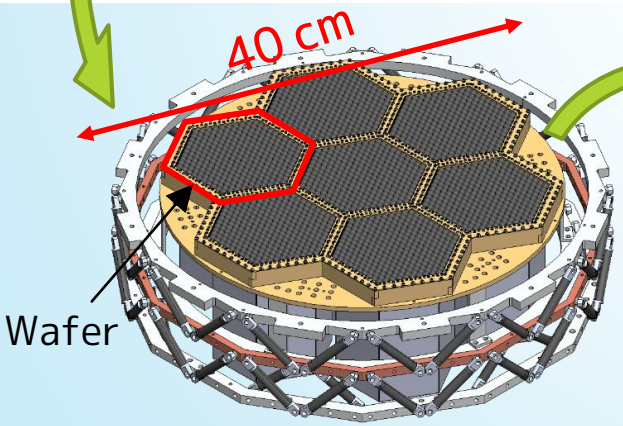
Astorophys.J., 848, 2, 121 (2017)

POLARBEAR-2 receiver

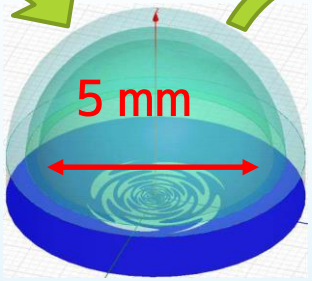
Cross-section of POLARBEAR-2 receiver cryostat



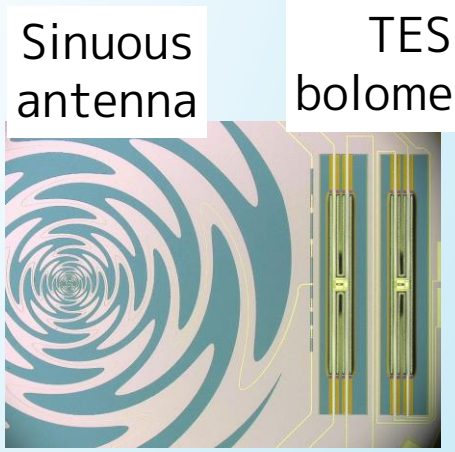




Focal Plane Detector



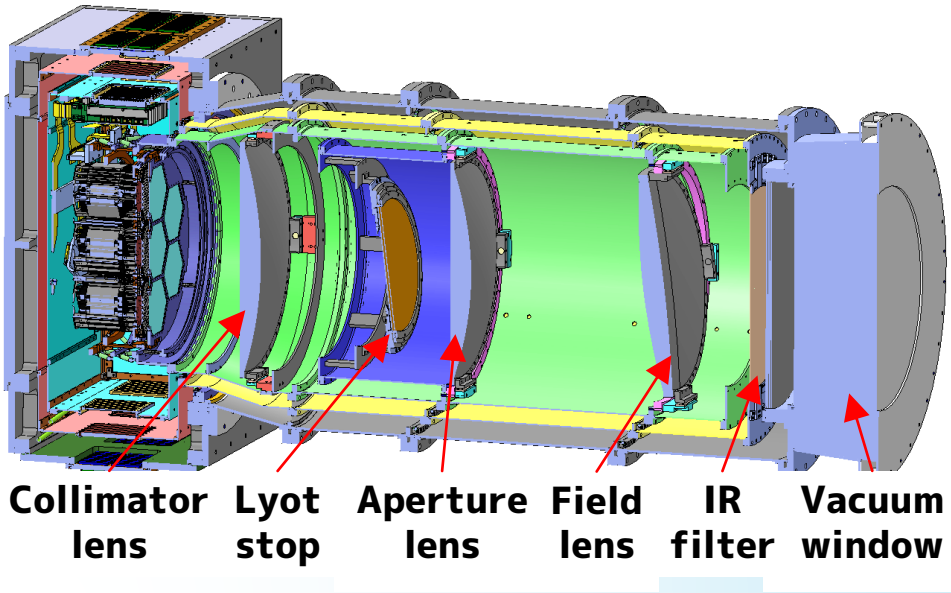
Lenslet and sensor

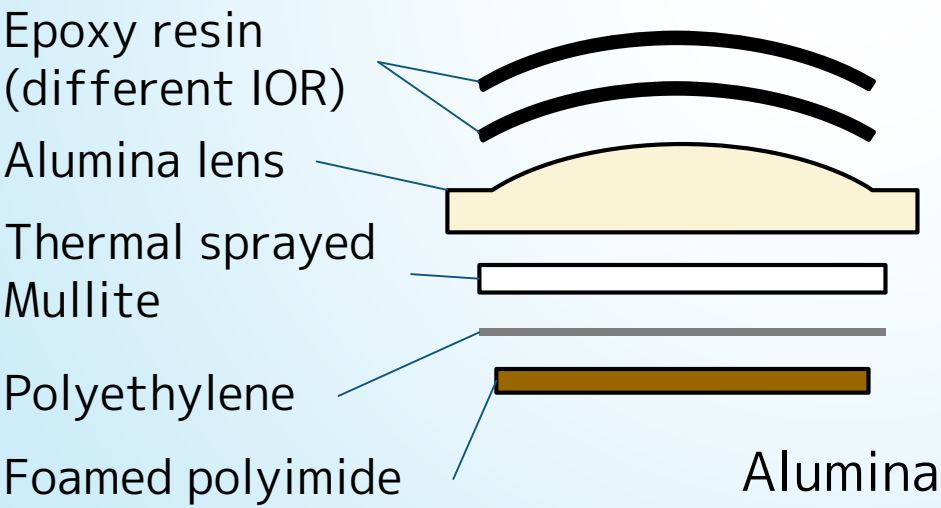


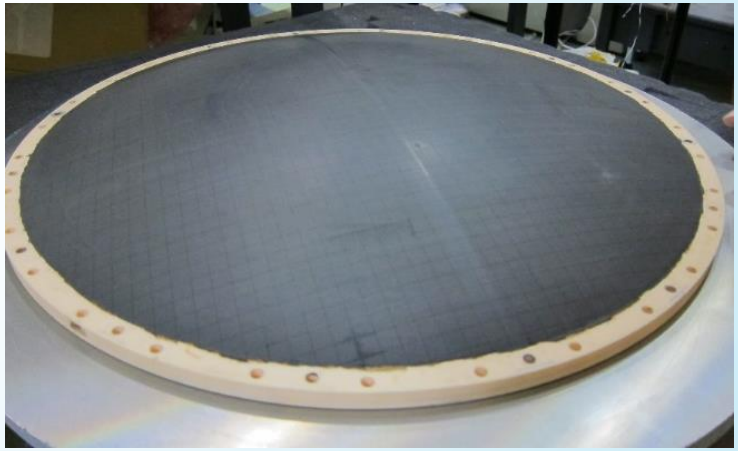
Close-up to sensor

Optics system

- **Re-focus image at Gregorian focus on to detector plane**
- **Main components are at 4K, by pulse tube refrigerator**
- **Three alumina lenses which have high thermal conductivity and low loss**



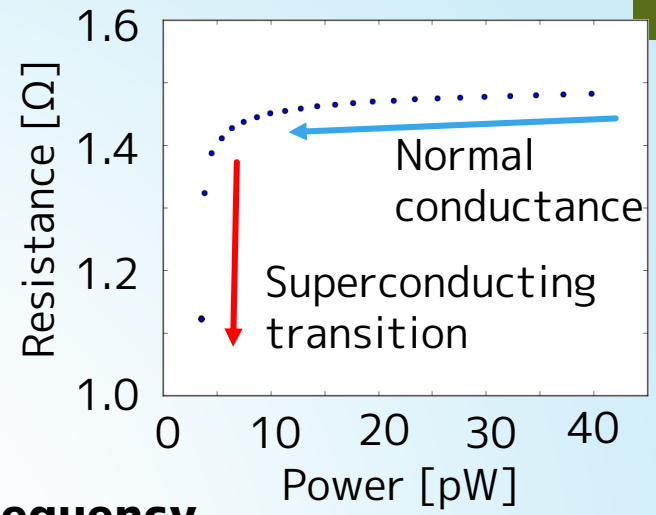


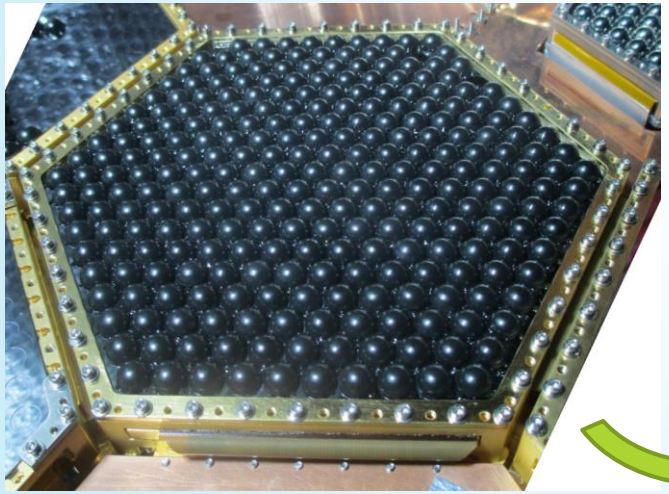


Alumina lens has two-layered Anti-Reflection coating (Alumina IOR= 3.1)

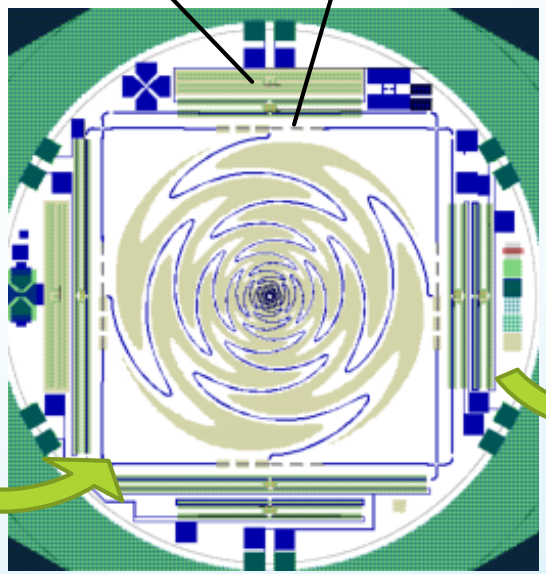
TES bolometer detector

- **SA experiment is designed to make photon noise limited detection with Transition Edge Sensor bolometer**
- **Detector plane is cooled by He sorption refrigerator to 270mK**

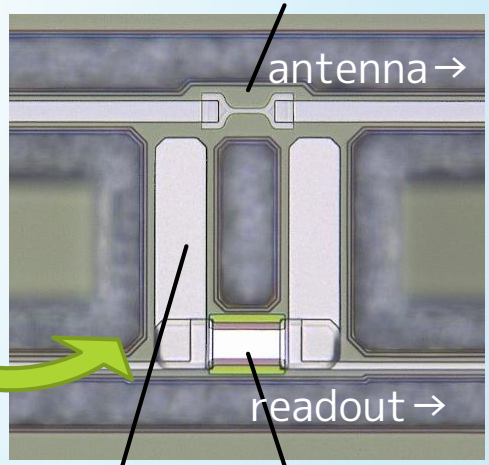




Detector wafer close-up

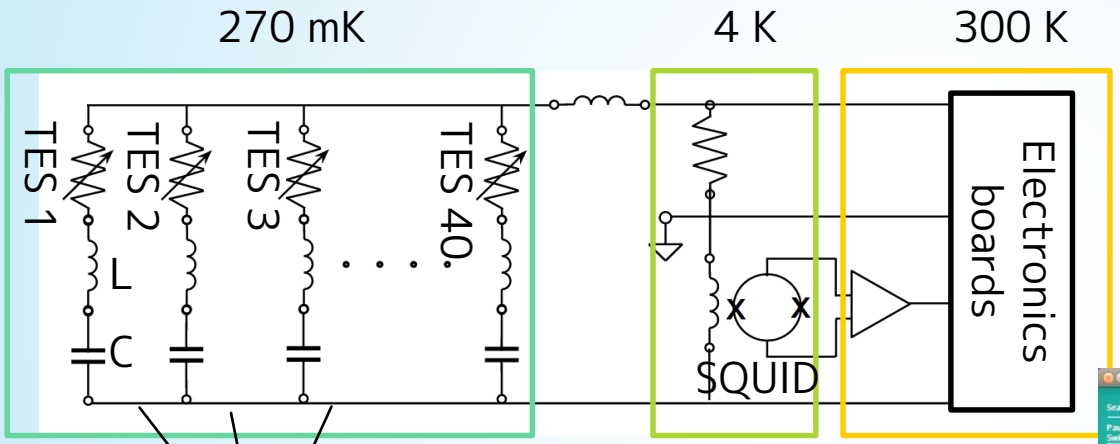


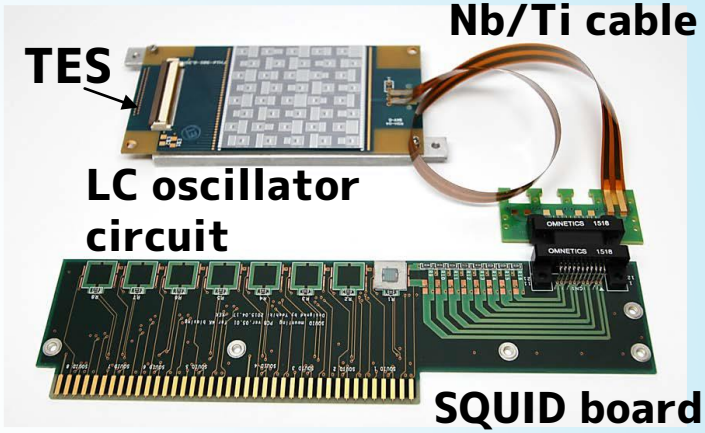
Sinuous antenna and TES bolometer

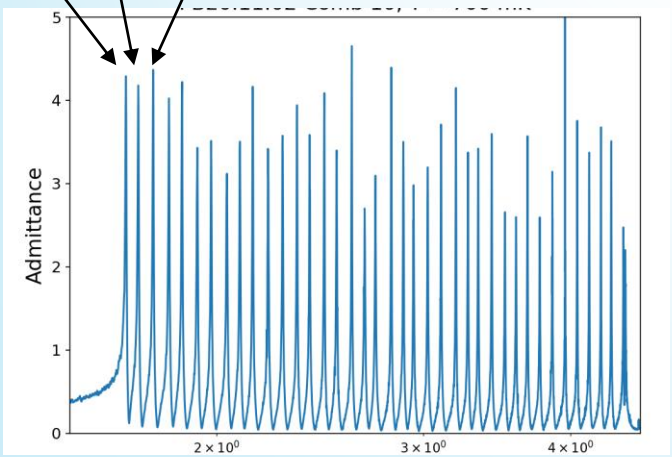


Read-out system

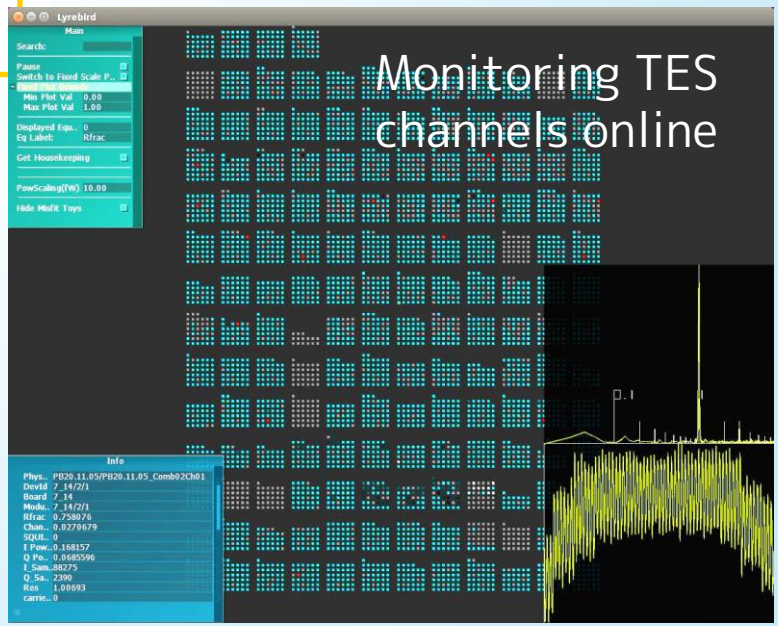
- **Digital Frequency-Division Multiplexing (DfMUX) method with 40 multiplexing factor**
- **Low noise amplification with SQUID**







frequency (1-5 MHz)



Test items in laboratory

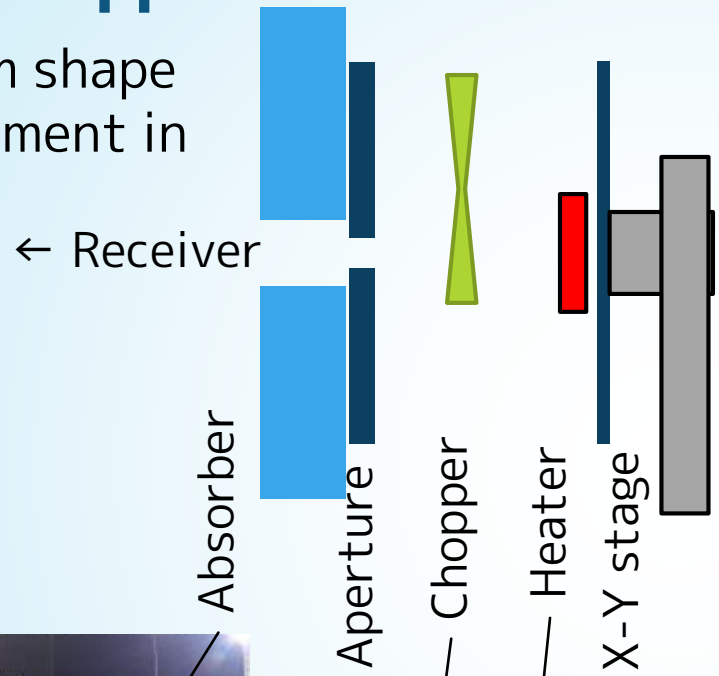
- **Cryogenic**
  - Achieved temperature
  - Hold time
- **Readout**
  - Yield
  - Noise level
  - Stability
- **Optical**
  - Detection efficiency
  - Beam shape
  - Spectroscopy
  - Polarization
- **Environmental**
  - Magnetic field
  - Vibration
  - Temperature
  - RF noise

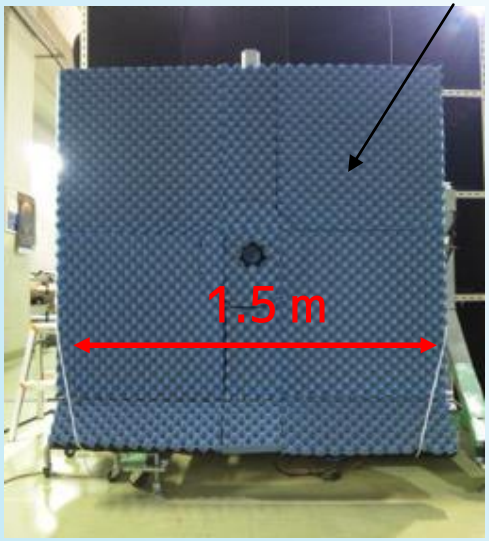
Red colored items has not confirmed or not achieved to designed value.

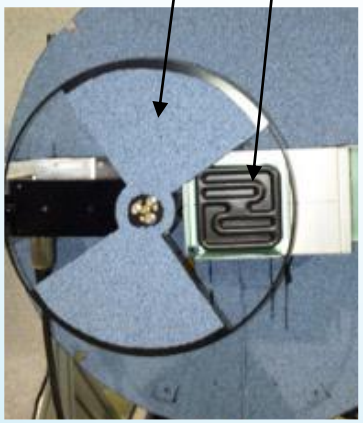
Calibrators (example)

Beam mapper

for beam shape measurement in lab.

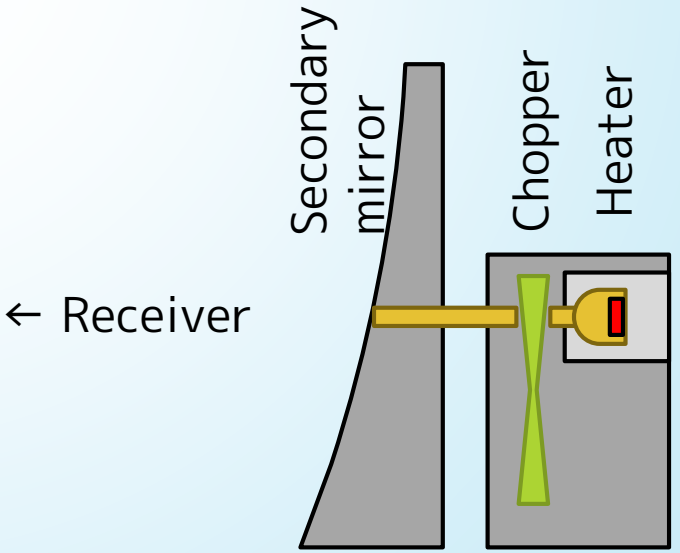






Stimulator

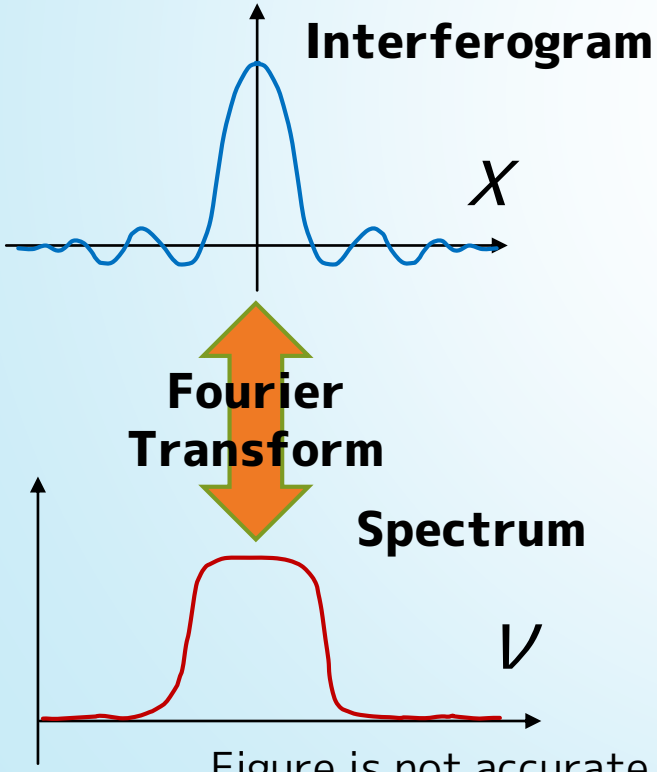
Constant, non-polarized mm-wave source.
In physics run, it is used between scans for gain calibration.

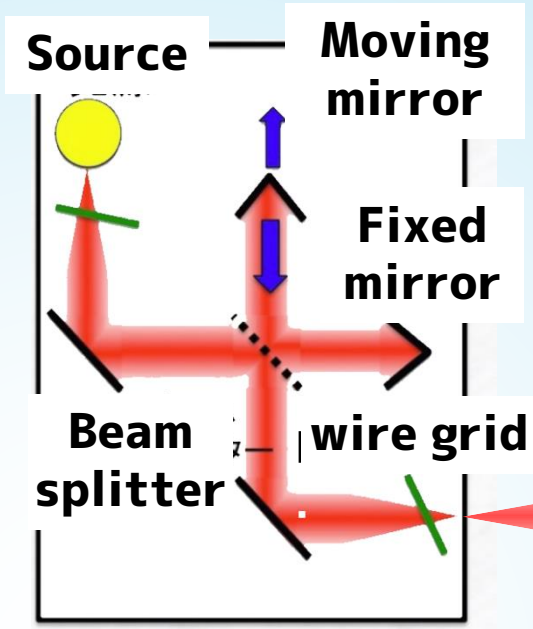


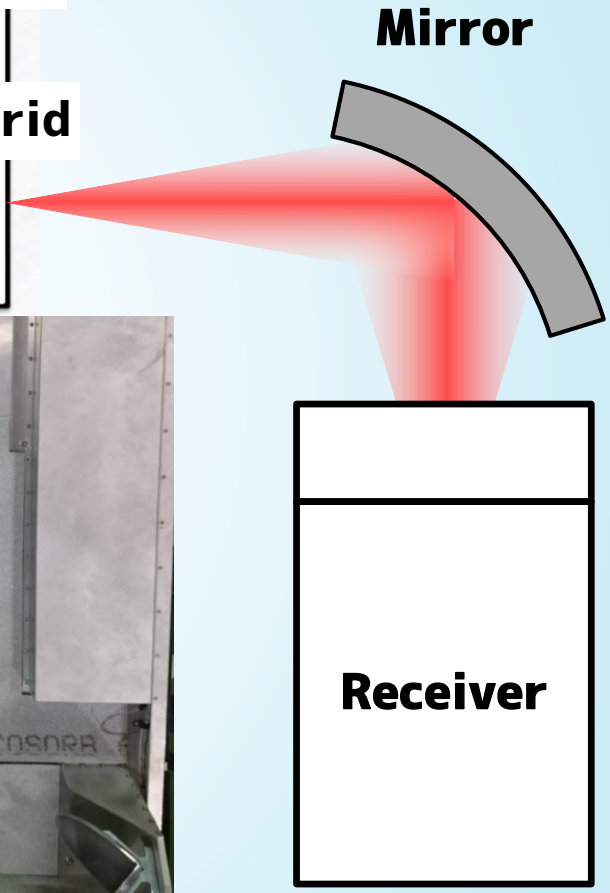
Calibrator (FTS)

Fourier Transform Spectrometer

Measuring interferogram, by moving mirror to obtain spectrum.

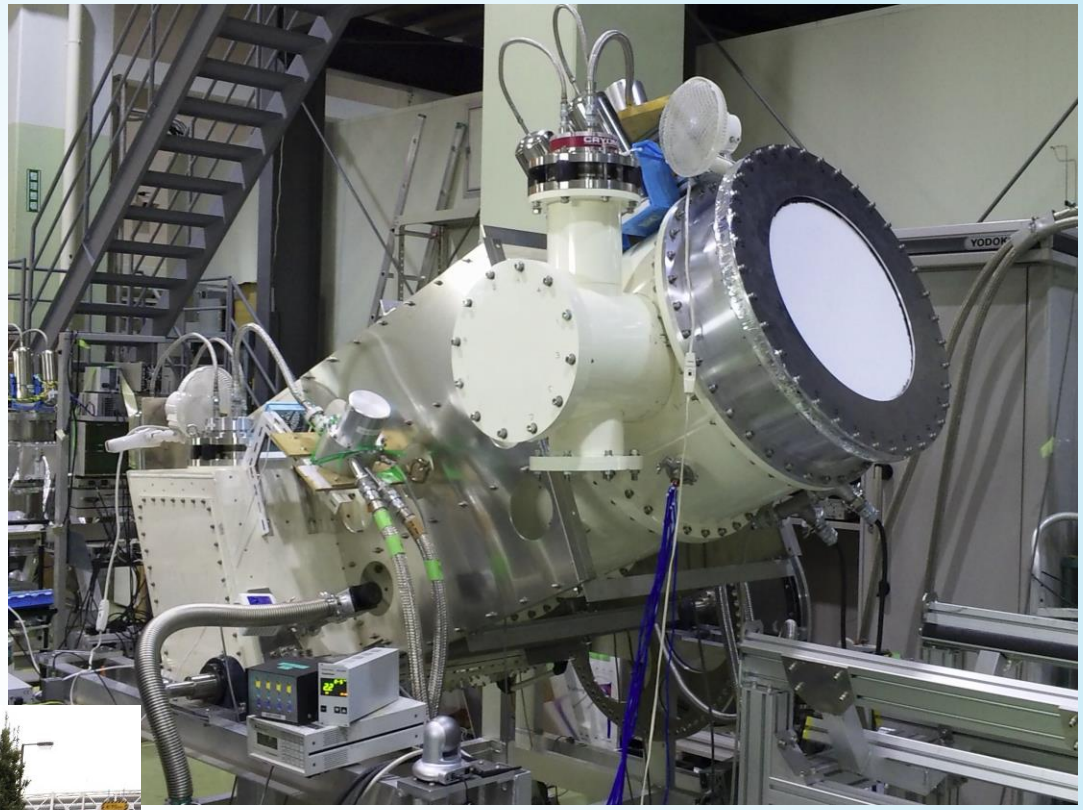






Status of the First unit

- **Now at final performance tests in laboratory**
- **Some tests have already cleared, but some need to be checked in next cooling period.**
- **Transportation to Chile is also prepared**



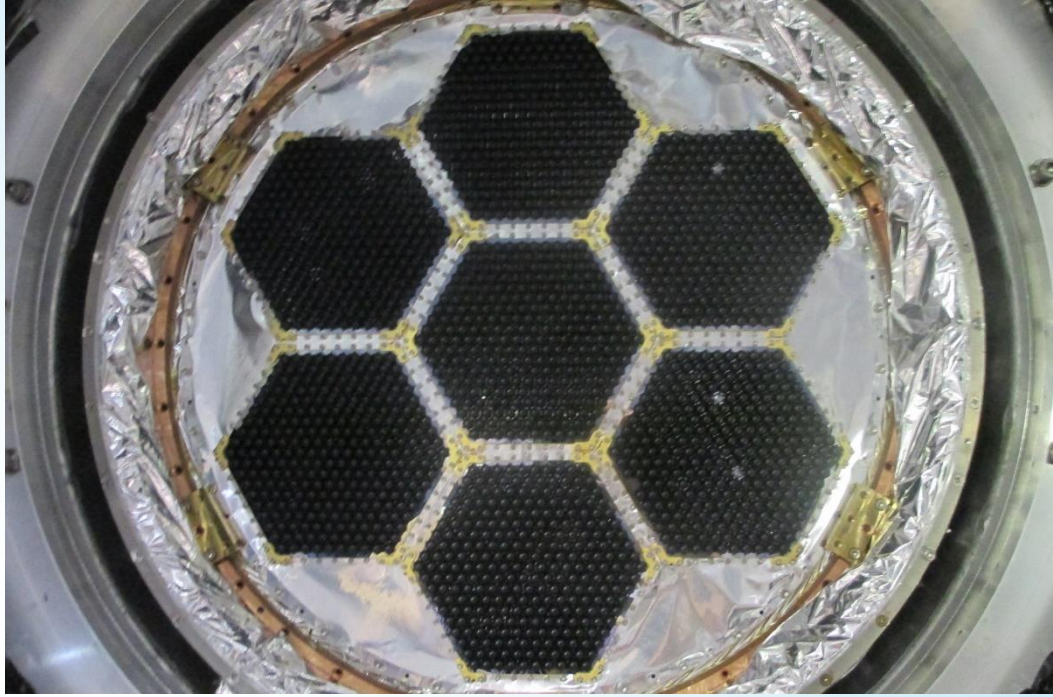
↑ PB-2 receiver in lab.

←Transportation
inside of the lab building

Test status

Last cooling test was performed with full 7 wafers assembled from Oct to Dec.

Now, next (hopefully final) test is being prepared.

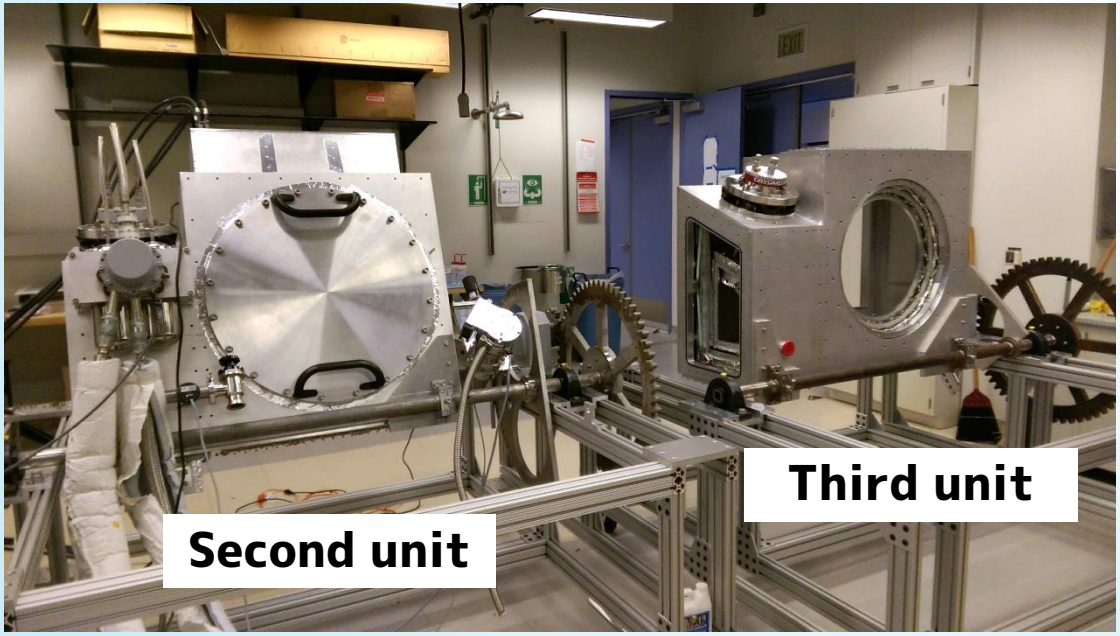


Preliminary results

Preliminary

Status of Second, Third receiver

- Second unit is mechanically assembled
- Some cooling and readout tests have been conducted with test wafers and electronics
- Third unit is under construction, now focal-plane structure is being assembled
- Validation test of refrigerator is underway

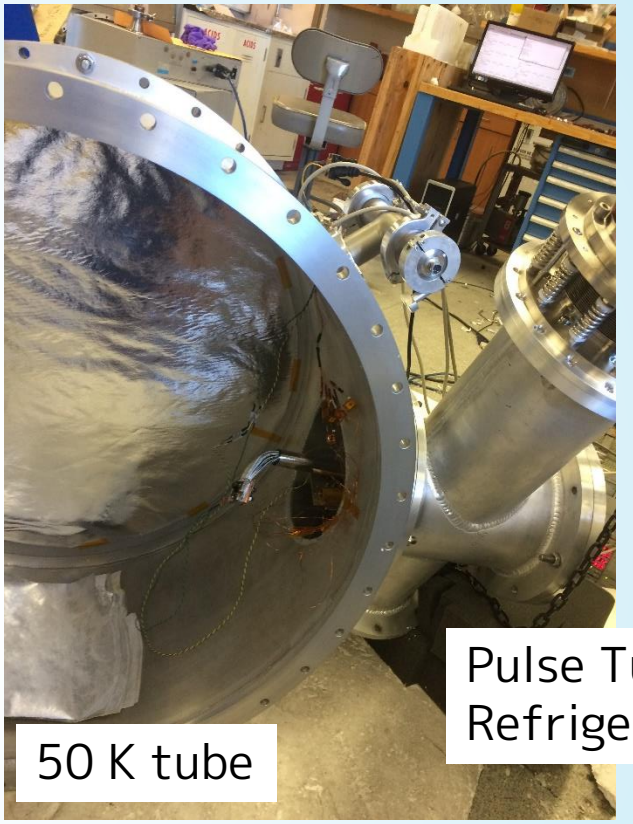


Second, Third Optics system

- **Second optics tube is partially assembled, and is on refrigerator validation**
- **Testing anti-reflection for lenses**

Wafers

- **Final version for first and second unit was assembled**
- **Fabrication of wafer for third unit starts soon**

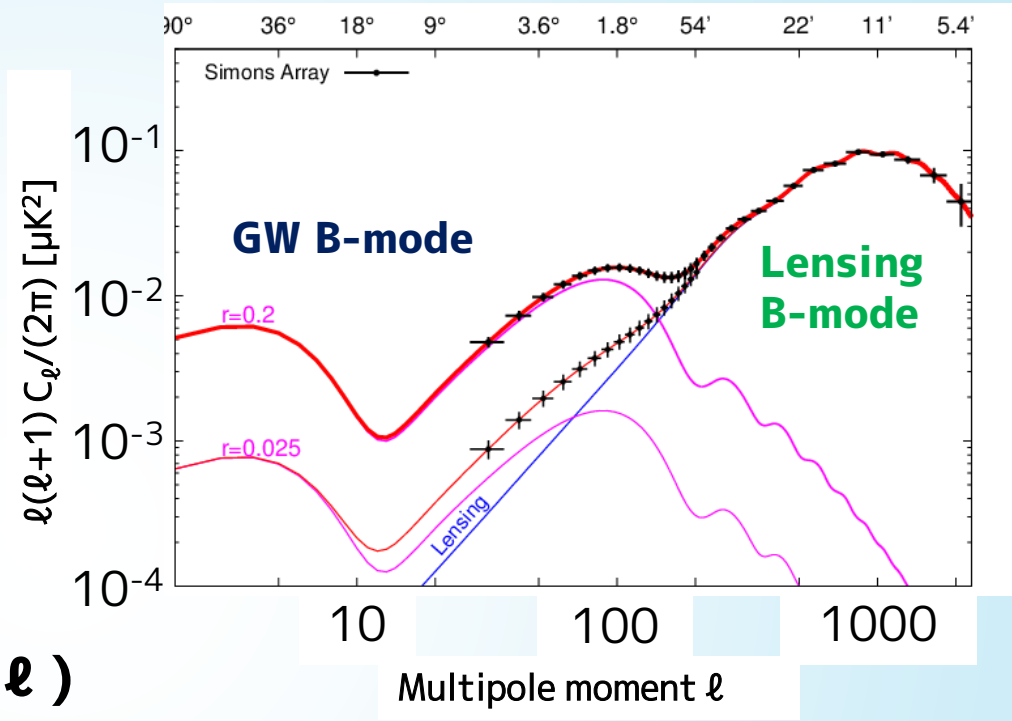


Status of Atacama site

- Second and third telescopes were build
- First POLARBEAR-2 receiver will be deployed in 2018
- Second and Third will arrive soon after first PB-2

Expected science

After 3 years observation with 3 receivers.



- **From GW B-mode (low-ℓ)**
  - **tensor-to-scaler ratio "r"**
  - $\sigma(r)|_{r=0.1} = 0.006$
- **From Lensing B-mode (high-ℓ)**
  - **Sum of neutrino masses**
  - $\sigma(\Sigma m_\nu) = 40\ [\mathrm{meV}]$

    (combined with DESI BAO result)

Summary

- Discovery of B-mode polarization of CMB from primordial GW is waited for long.
- Simons Array experiment is upgraded experiment of POLARBEAR at Atacama, and development is in the final stage.
- After 3 years of observation with 3 POLARBEAR-2 receiver, B-mode from inflation down to r~0.01 would be found.