Evaluation of the light response performance of 2D-BIB Ge detector on a Si/Ge heterojunction structure

(Si/Geヘテロ構造の二次元平面展開BIB型Ge検出器の光応答性能の評価)

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科研費
KAKENHI

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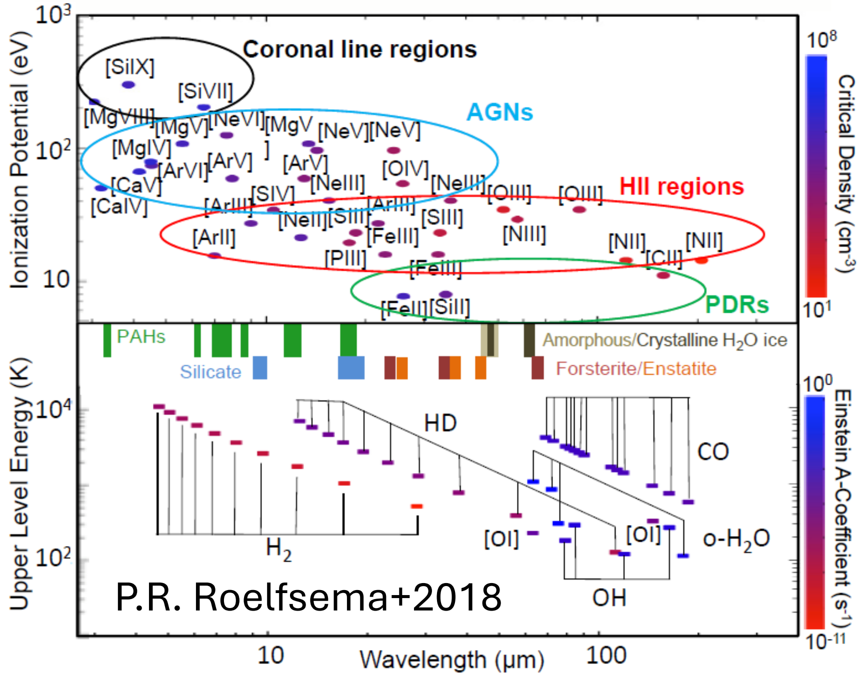
The significance of mid-to-far Infrared observation and detector development

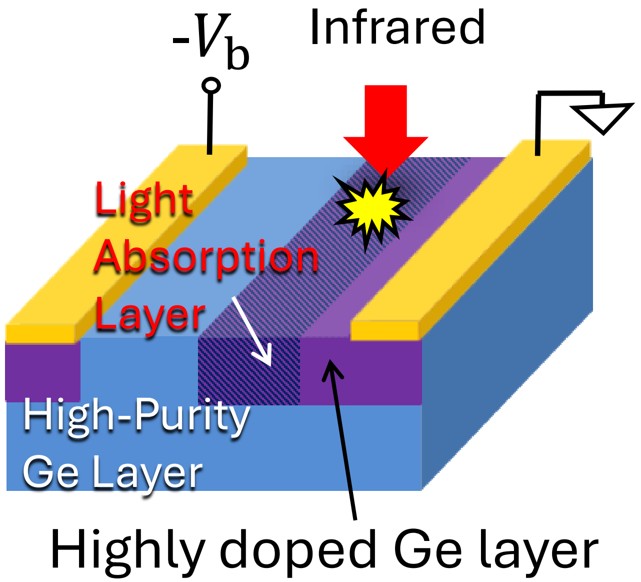


P.R. Roelfsema+2018

- Band radiation: solid materials
- Emission lines: atomic/molecular gas

Diagnosis of physical and chemical states

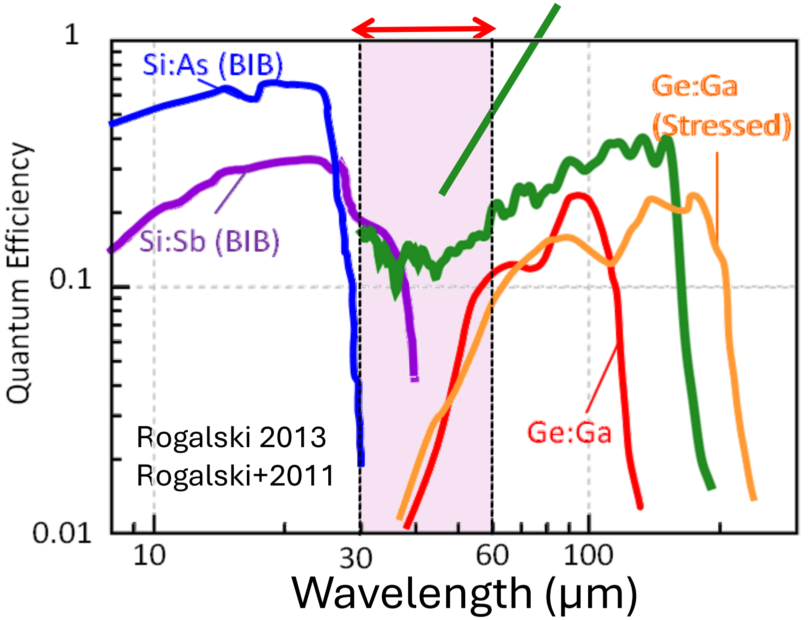
(Example) H_2O ice (43,62 μm band)
Tracking thermal history



Unexplored wavelength band

2D-BIB

Saito・Fujiwara master thesis(2020)



Rogalski 2013
Rogalski+2011

Demonstration of light sensitivity in the 30–200 μm wavelength band

- **Two-dimensional deployed BIB (2D-BIB) Ge Detector**

Directly irradiation infrared light to the light absorption layer
Reduction of lattice absorption

Adoption of a highly sensitive 2D-BIB Ge detector in the mid-to far-infrared wavelength range

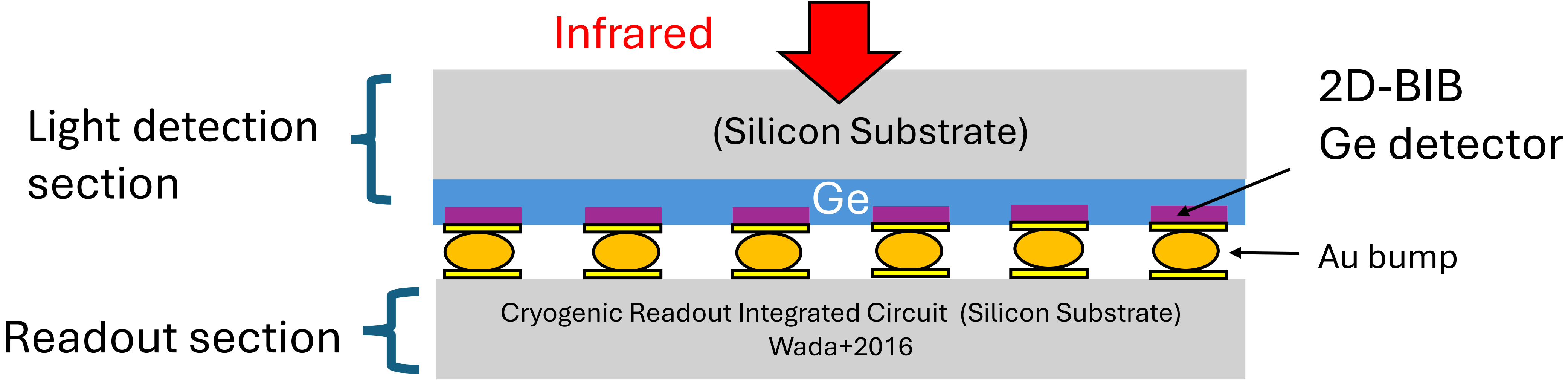
Development policy of mid-to-far-infrared detector

High Sensitivity: 2D-BIB Ge detector as the Light detection section
High Resolution: Cryogenic Readout Integrated Circuit (Silicon)

Problem：Electrical connection failure due to thermal expansion coefficient difference during cooling

$$\int_{2K}^{300K} [\alpha_{Ge}(T) - \alpha_{Si}(T)]dT \sim 8 \times 10^{-4}$$

Solution：Bring the mechanical properties of the light detection section closer to those of silicon.



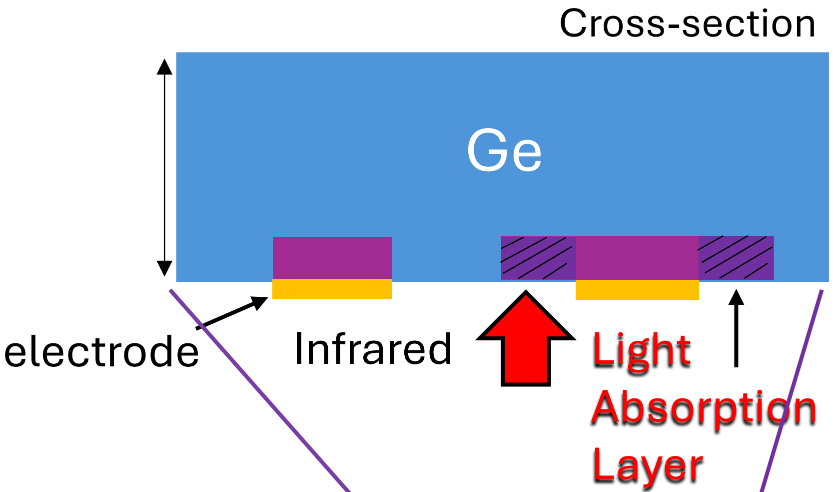
Wada+2016

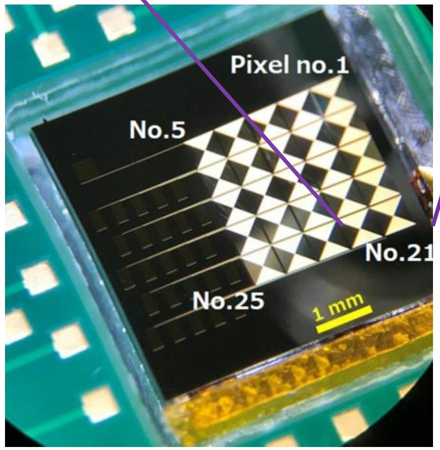
Assignment：Detector forming on a Si/Ge heterojunction and operating demonstration has yet to be achieved.

Verification of the effect of Si/Ge heterojunction light response performance

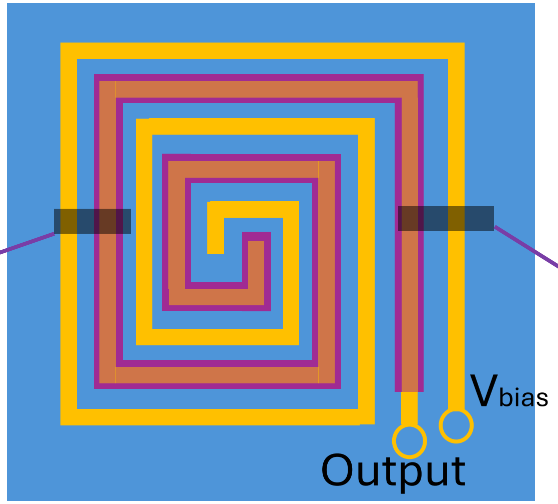
Prototype of 2D-BIB-type detector on a Si/Ge heterojunction

Conventional



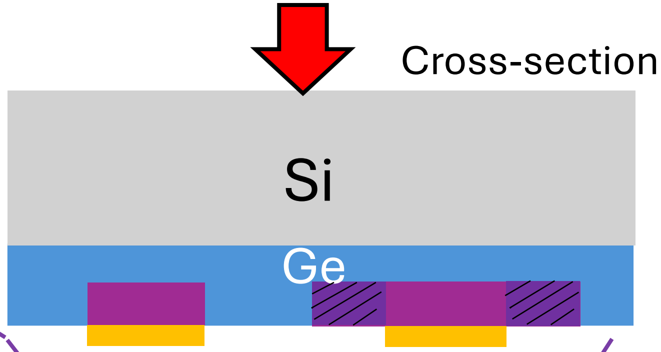


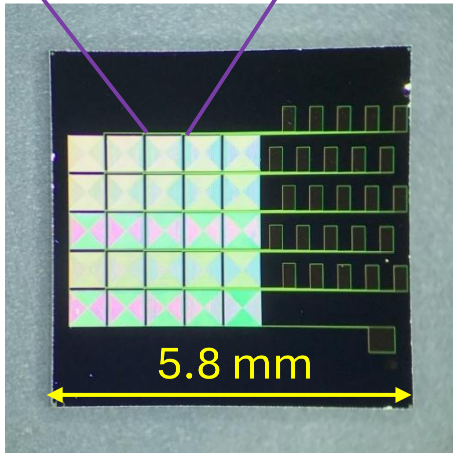
Saito・Fujiwara
master thesis (2020)



View from the electrode

This research

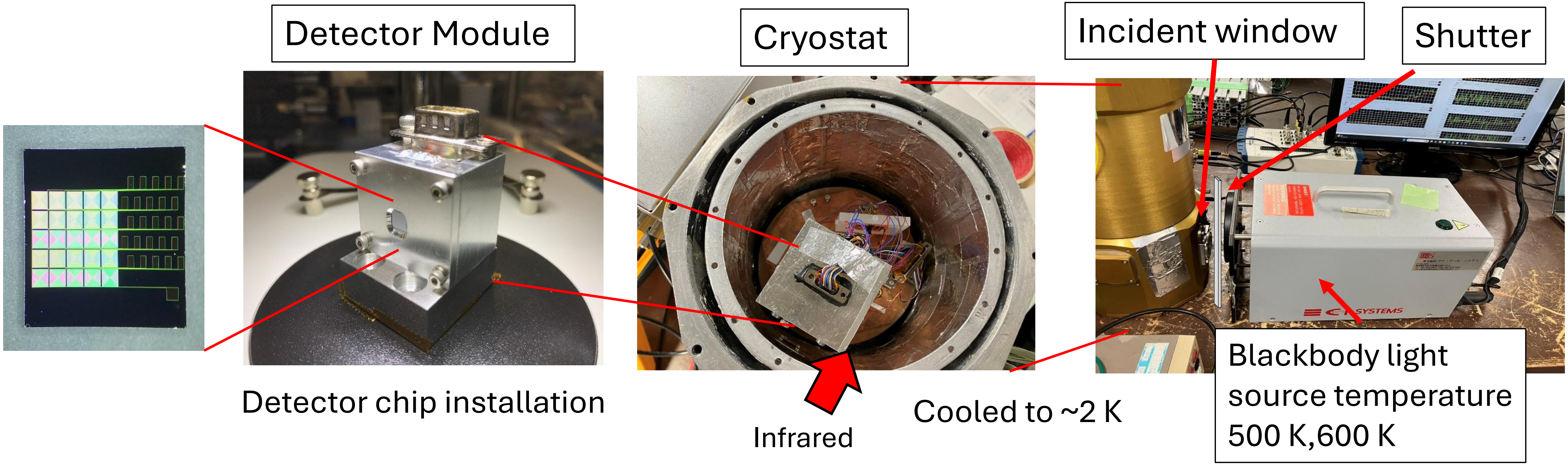




The detector structure is the same
The infrared incident direction differs

Successful prototype
development of the detector

Measurement of current and voltage characteristics



Detector Module

Cryostat

Incident window

Shutter

Detector chip installation

Infrared

Cooled to ~2 K

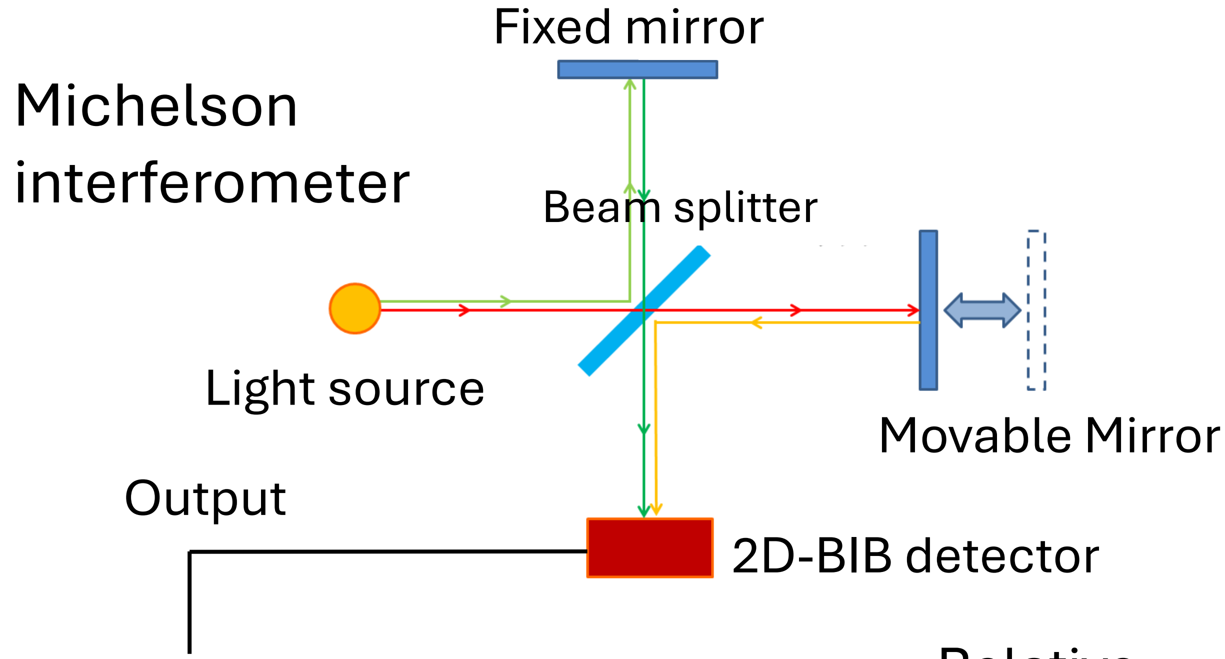
Blackbody light source temperature 500 K,600 K

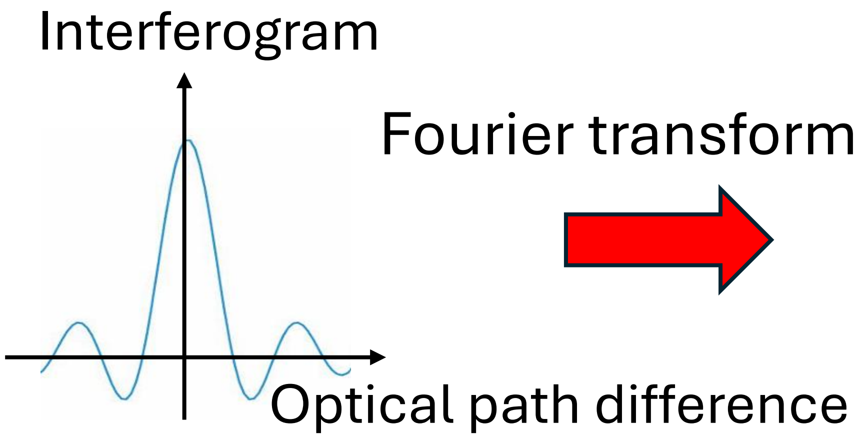
① Irradiate with blackbody radiation and measure changes in the current flowing through the detector by opening and closing the shutter

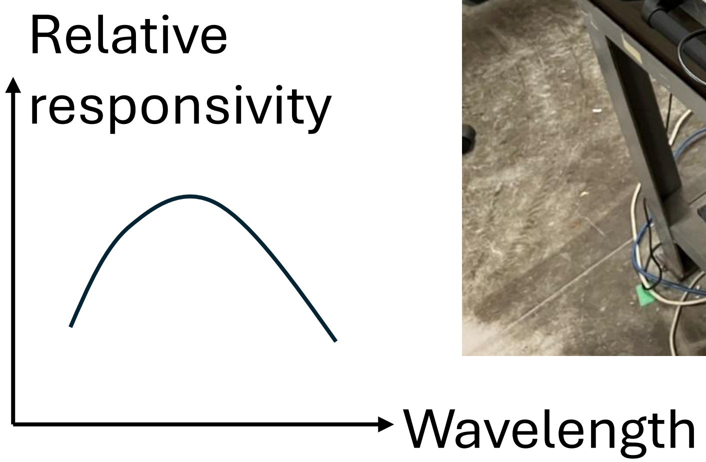
② Irradiate with blackbody radiation at two temperatures and measure the relationship between the detector bias voltage and current

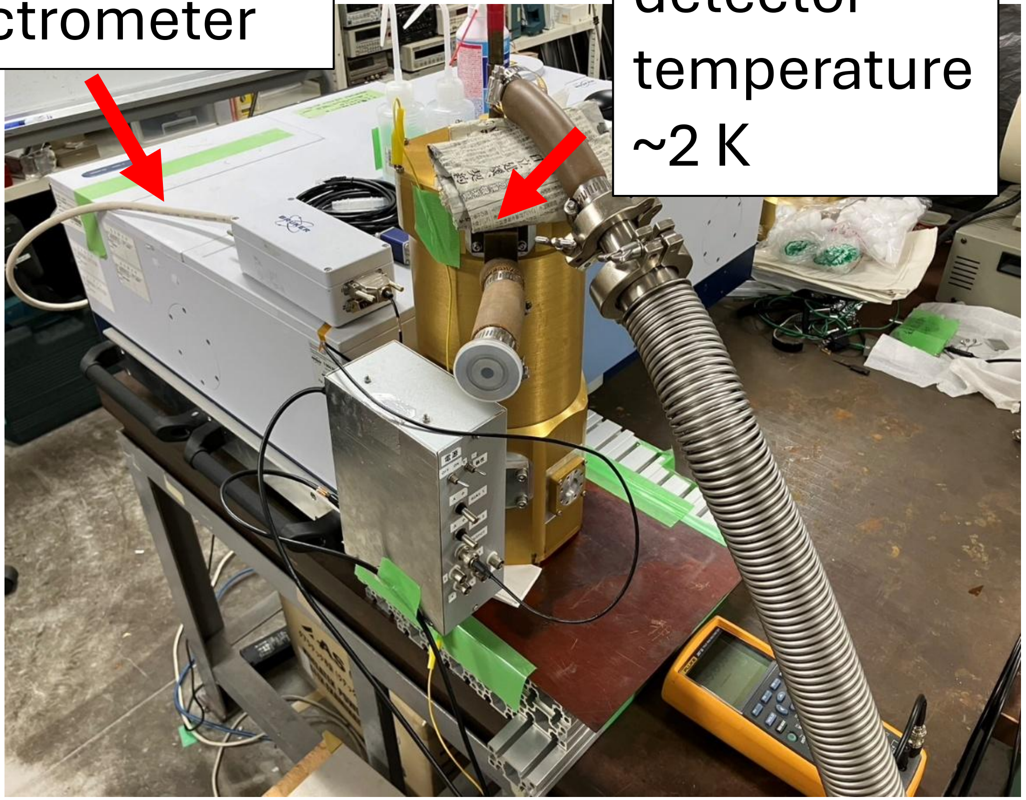
Verification of detector soundness, evaluation of absolute sensitivity

Measurement of relative responsivity wavelength characteristics



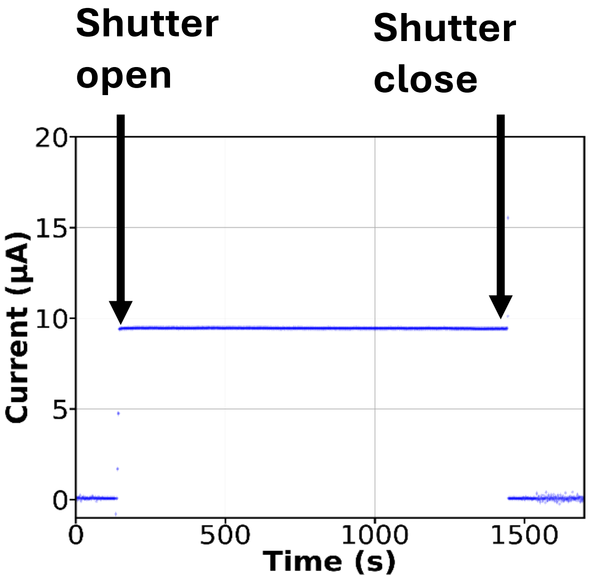


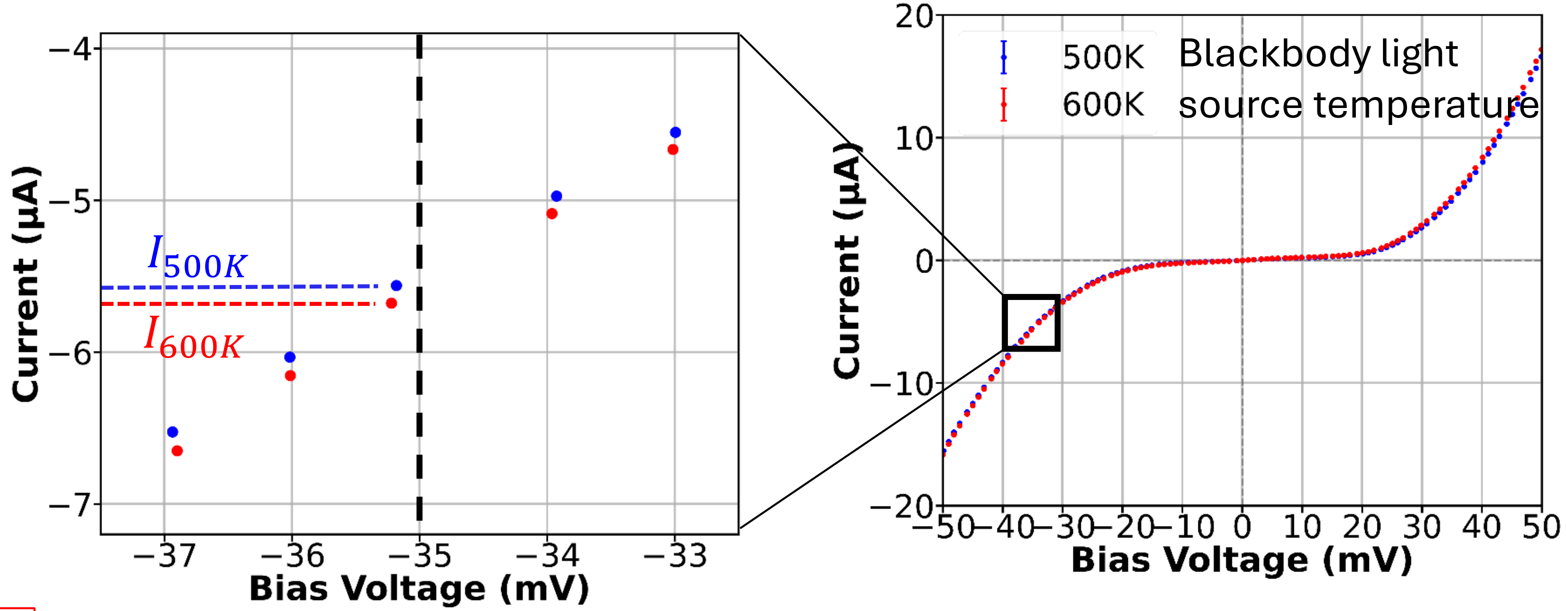




Evaluate the relative responsivity of the detector for each wavelength by FTIR

Measurement results of current and voltage characteristics





- Confirmed to be sensitive to infrared

Absolute responsivity

$$R = \frac{I_{600K} - I_{500K}}{P_{600K} - P_{500K}}$$

$$P = P_{bg} + S\Omega \int T_F(\lambda) B_\lambda(T,\lambda) d\lambda$$

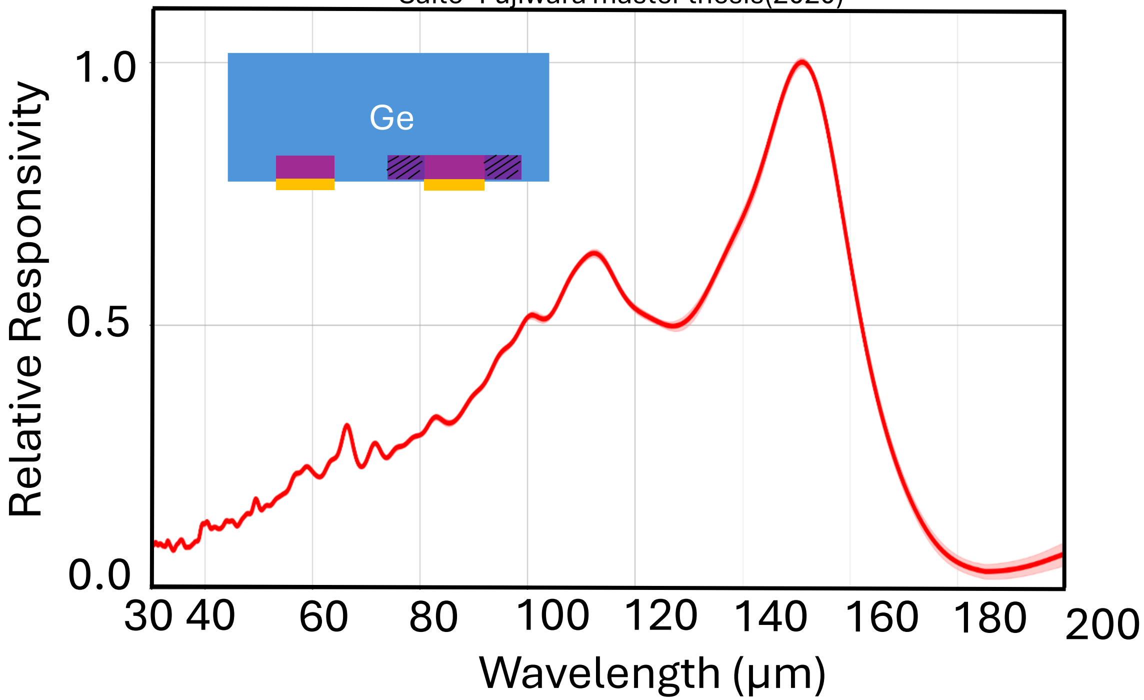
P_{bg}: Background light intensity
S: Element area
Ω: Solid angle subtended by the element
$B_\lambda(T,\lambda)$: Planck function
$T_F(\lambda)$: Optical window transmittance

Absolute responsivity
@V_{bias}~-35 mV

Conventional	This research
3.2 A/W	5.1 A/W

This research(1.6 times)>Conventional

Measurement results of relative responsivity wavelength characteristics



Conventional

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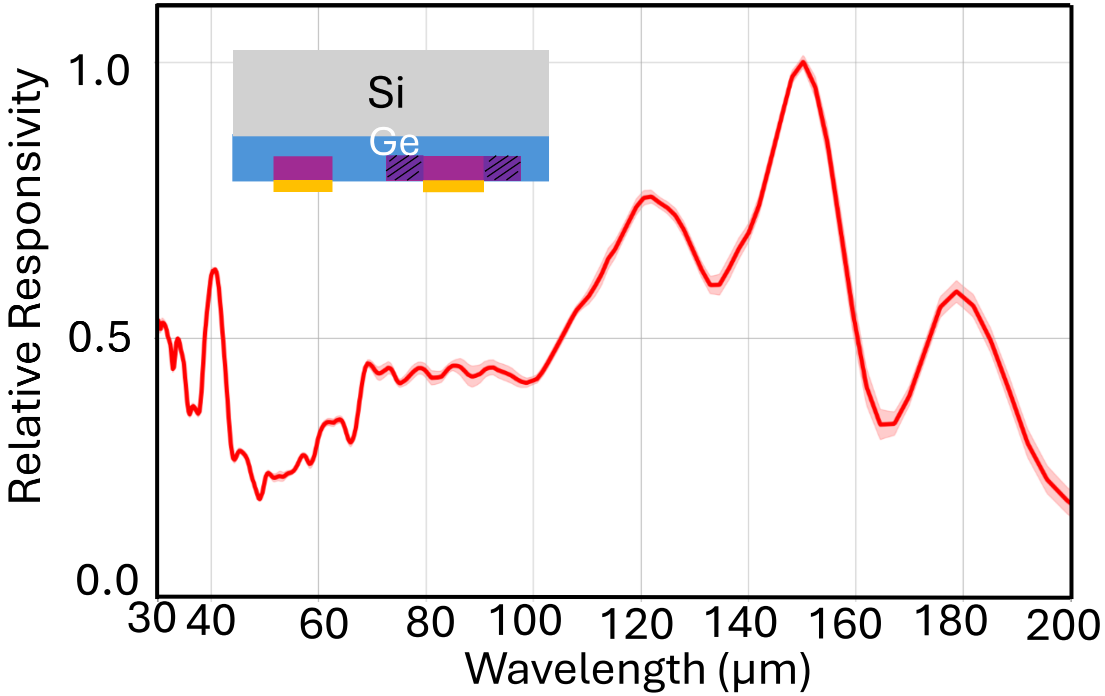

This research

- This research exhibits light sensitivity over a broader wavelength range than conventional elements.
  - Multiple local peaks observed
  - Improved relative sensitivity at short wavelengths

The wavelength of the local peak differs compared to conventional

Summary

【Background･Purpose】

- Developing a high-sensitivity, high-resolution mid-to-far-infrared detector for the 30–200 µm wavelength band.
- As a component development, fabricated a 2D-BIB-type Ge detector on a Si/Ge heterojunction.
- **Evaluating the impact of the Si/Ge heterojunction on the light response performance of the detector.**

【Method】

- Formed a detector structure identical to conventional detector on the Ge layer of the Si/Ge heterojunction.
- Cooled the detector to 2 K and obtained its IV characteristics and relative sensitivity wavelength characteristics.

【Result】

- IV Characteristics: Absolute responsivity is 1.6 times higher compared to conventional detector.
- Relative responsivity wavelength characteristics: Covers a broader wavelength range compared to conventional, with different local peak wavelengths.

【Conclusion】

- The formation of detector on a Si/Ge heterojunction confirmed an improvement in light response performance.