Ultrafast Far-Infrared Detectors

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Outline

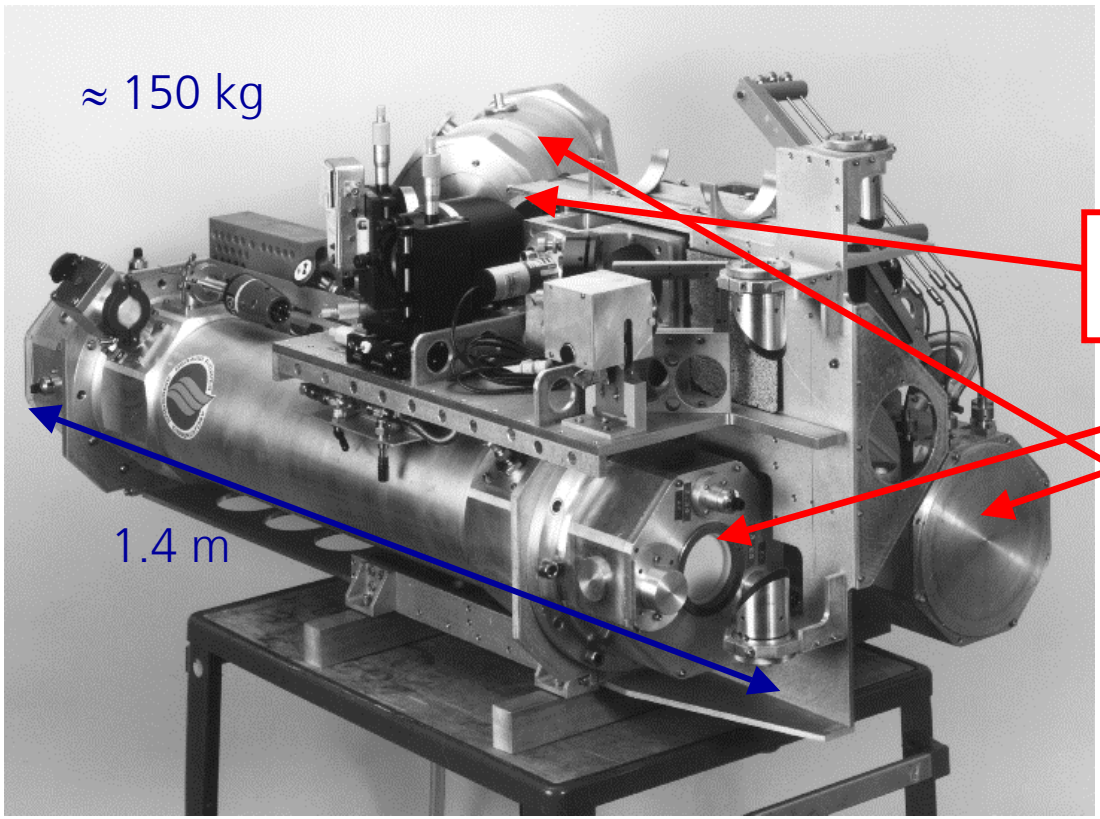
1. Background

2. InSb detector

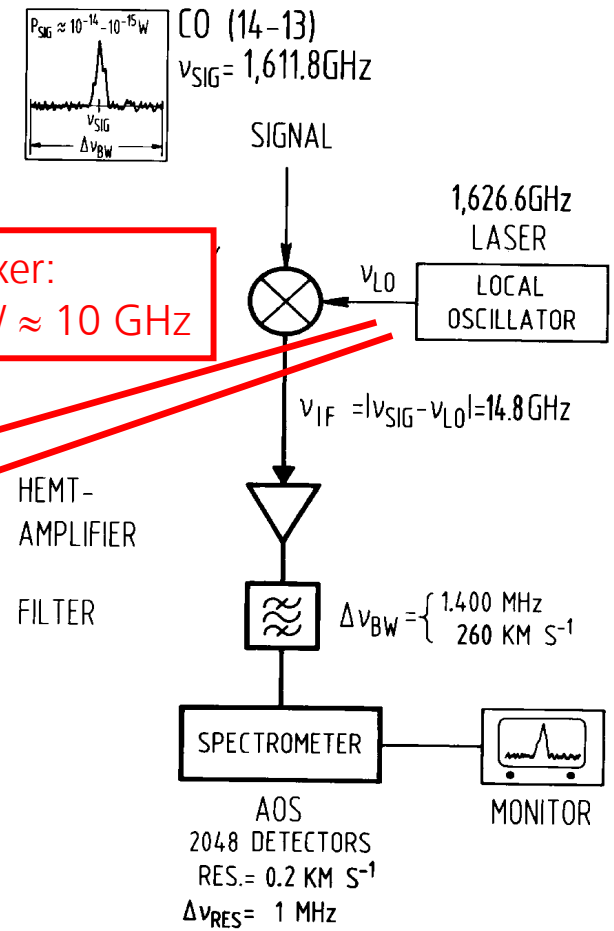
3. Superconducting hot electron bolometer
   - Basics
   - Design
   - Results

4. Summary

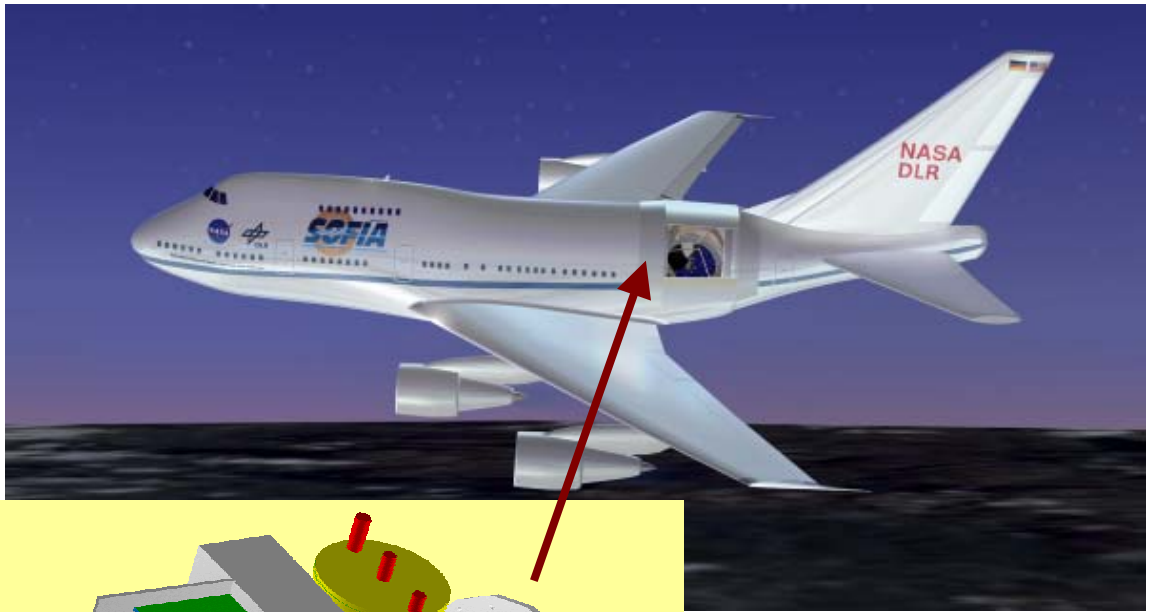
Airborne Heterodyne Receiver for FIR-Astronomy

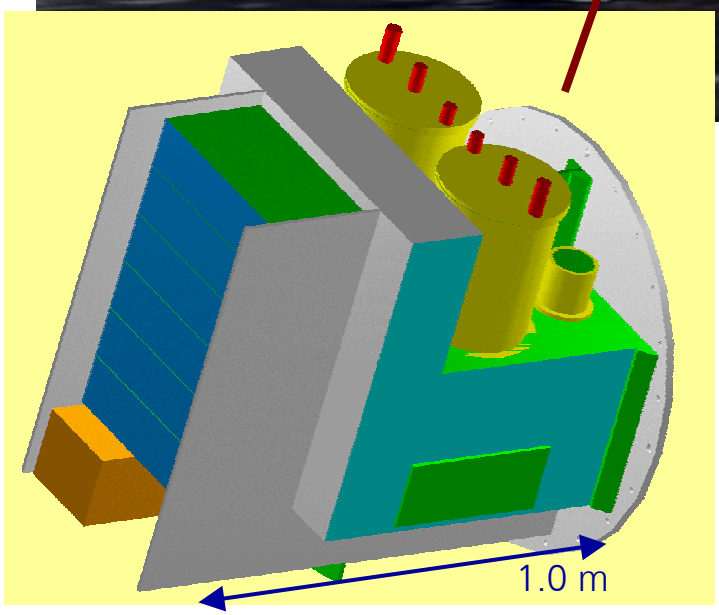


Mixer:
BW ≈ 10 GHz

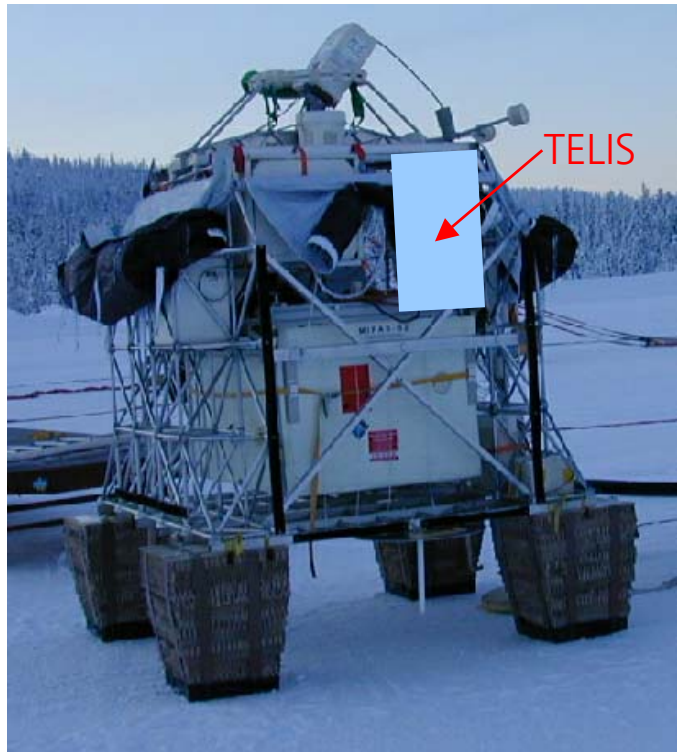


Current Projects: GREAT and TELIS



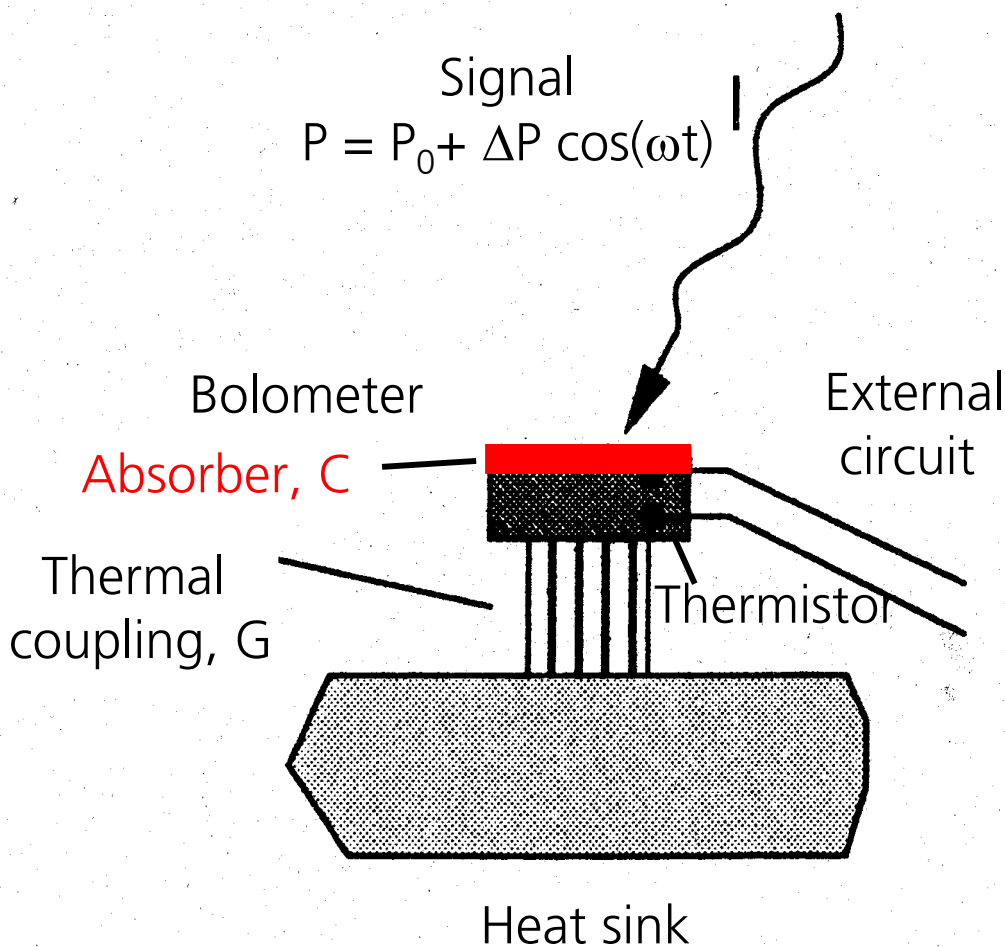


GREAT
German Receiver for Astronomy at THz Frequencies



TELIS
THz Limb Sounder

Bolometer



Heat transfer:

$$C \frac{dT}{dt} = P(t) - G\,(T - T_0)$$

C: heat capacity
G: heat conductivity

Temperature modulation:

$$\Delta T = \frac{\Delta P}{G\sqrt{1+\omega^2 (C/G)^2}}$$

Responsivity:

$$R(\omega) = \frac{\Delta V}{\Delta P} \propto \frac{1}{G\sqrt{1+\omega^2 (C/G)^2}}$$

$$\omega \ll 1/\tau : \quad R(\omega) \propto \frac{1}{G}$$

$$\omega \gg 1/\tau : \quad R(\omega) \propto \frac{1}{\omega C}$$

$\tau = C/G$: bolometer time constant

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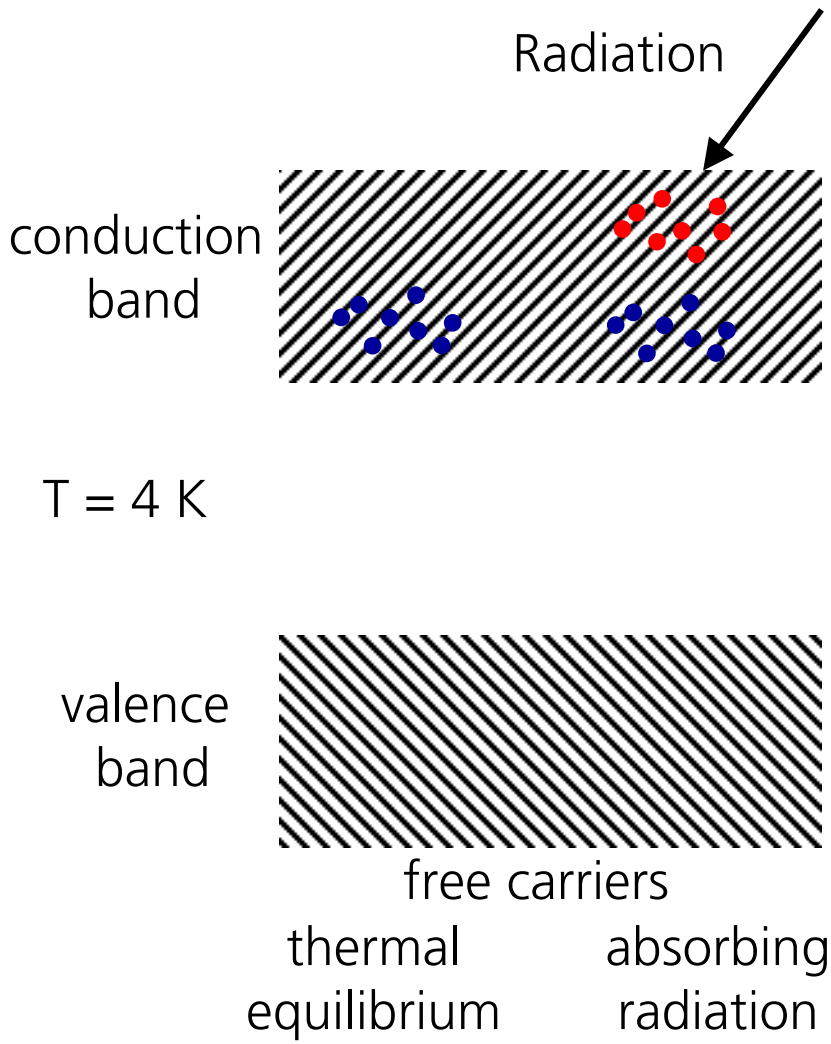
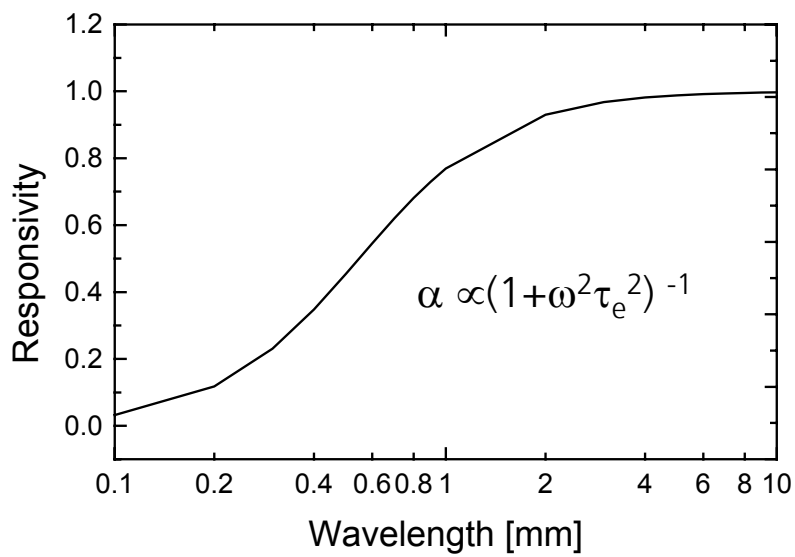
InSb-Detector: Basics



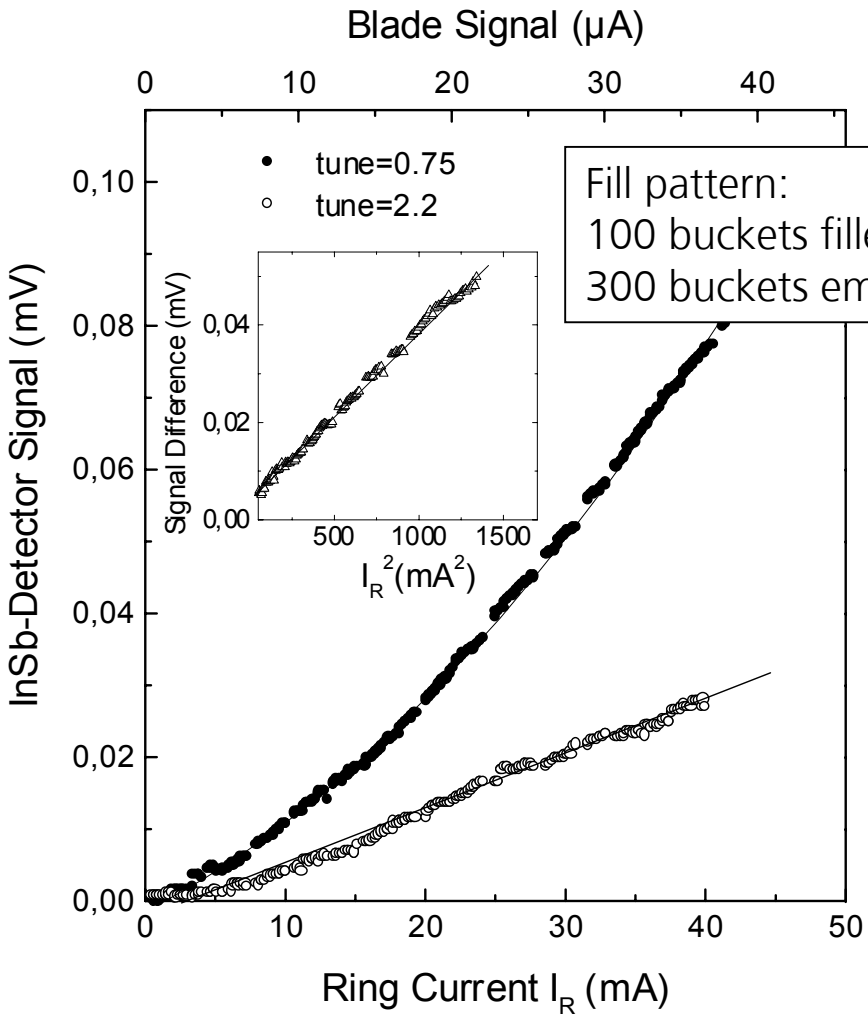
Detection mechanism:

Absorption of radiation by free electrons

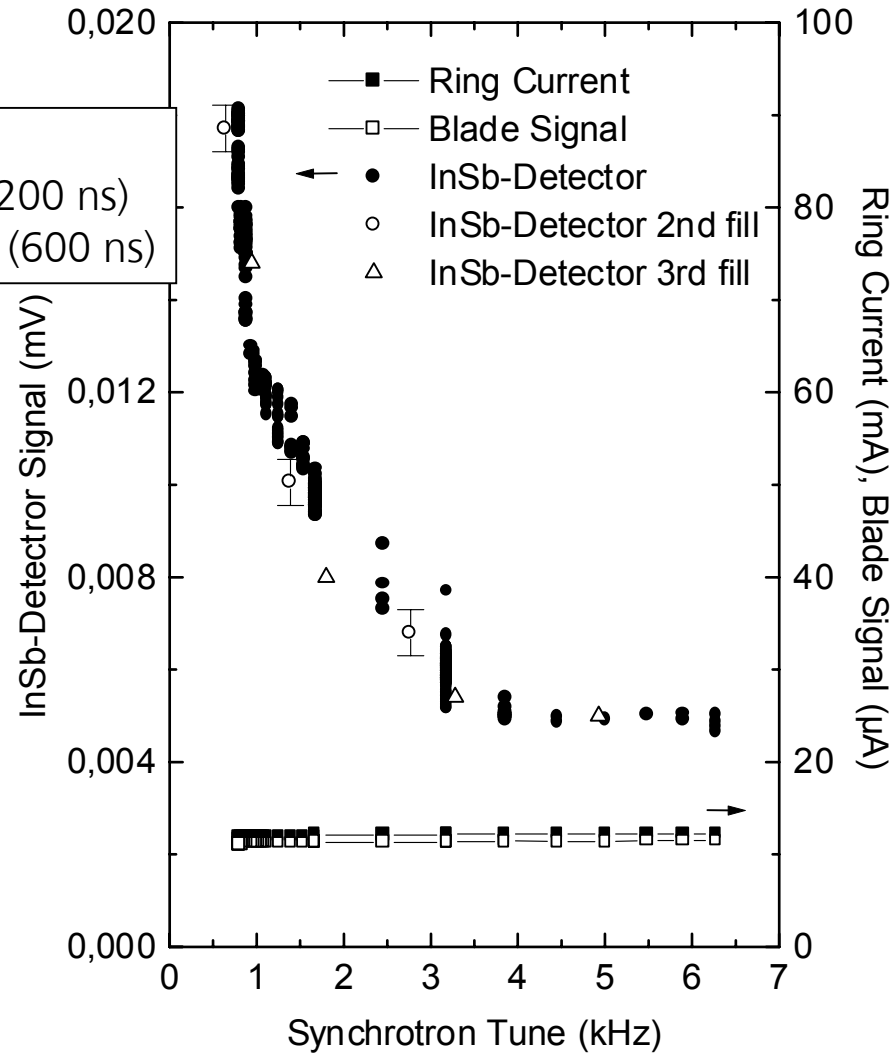


Response time: ≈ 200 nsec (≈ 1.5 MHz)

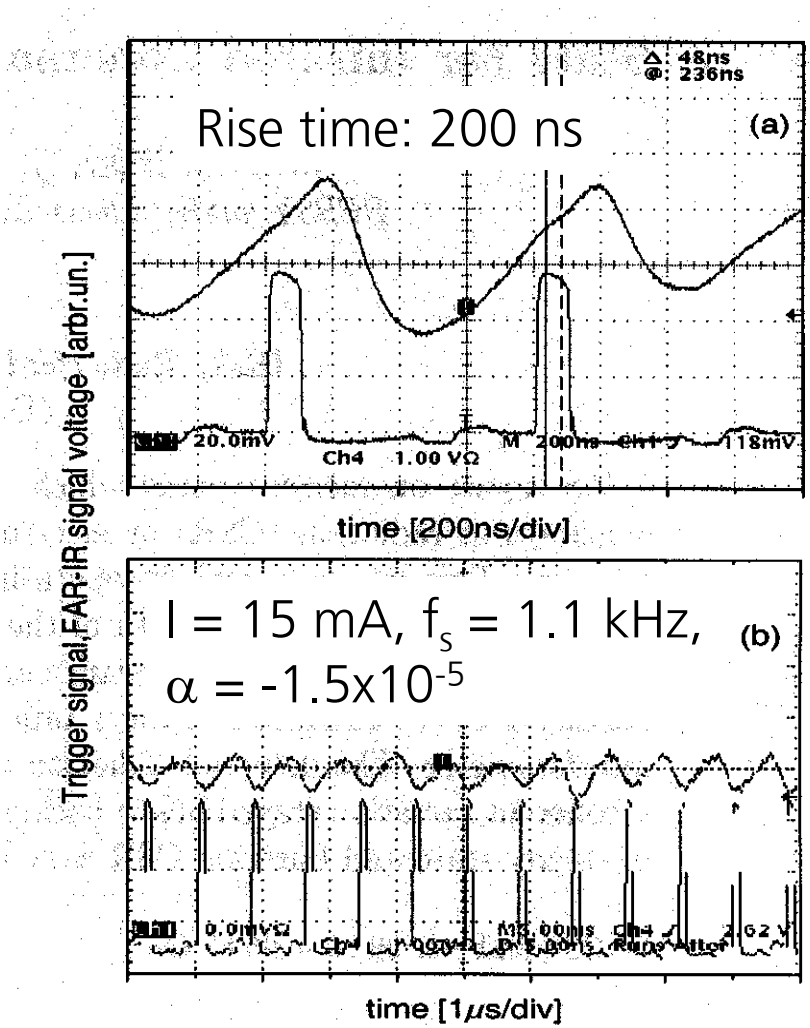
InSb-Detector: Results



Fill pattern:
100 buckets filled (200 ns)
300 buckets empty (600 ns)



InSb-Detector: Time Domain



Rise time: ≈200 nsec

Decay time: > 400 nsec

Resolution of single bunches within a train of bunches is not possible.

Fill Pattern:
100 buckets filled (200 ns)
300 buckets empty (600 ns)

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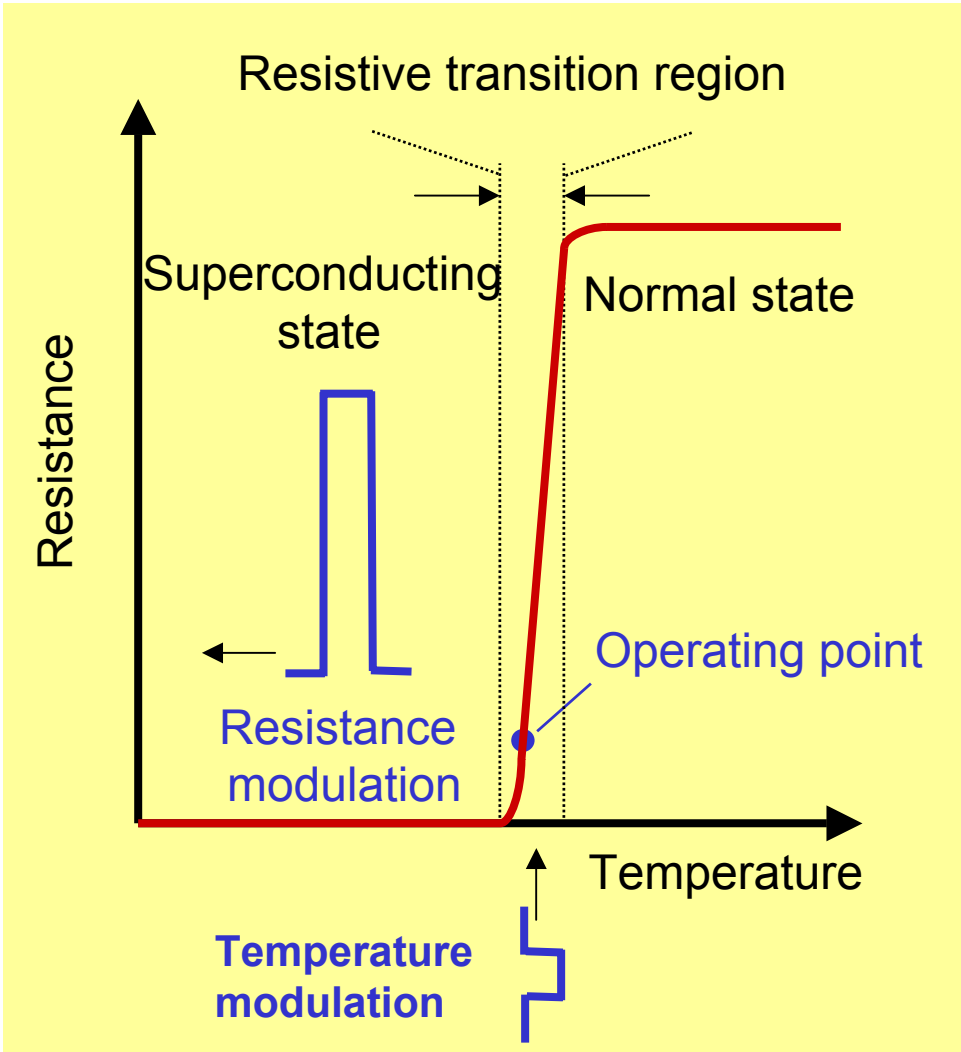
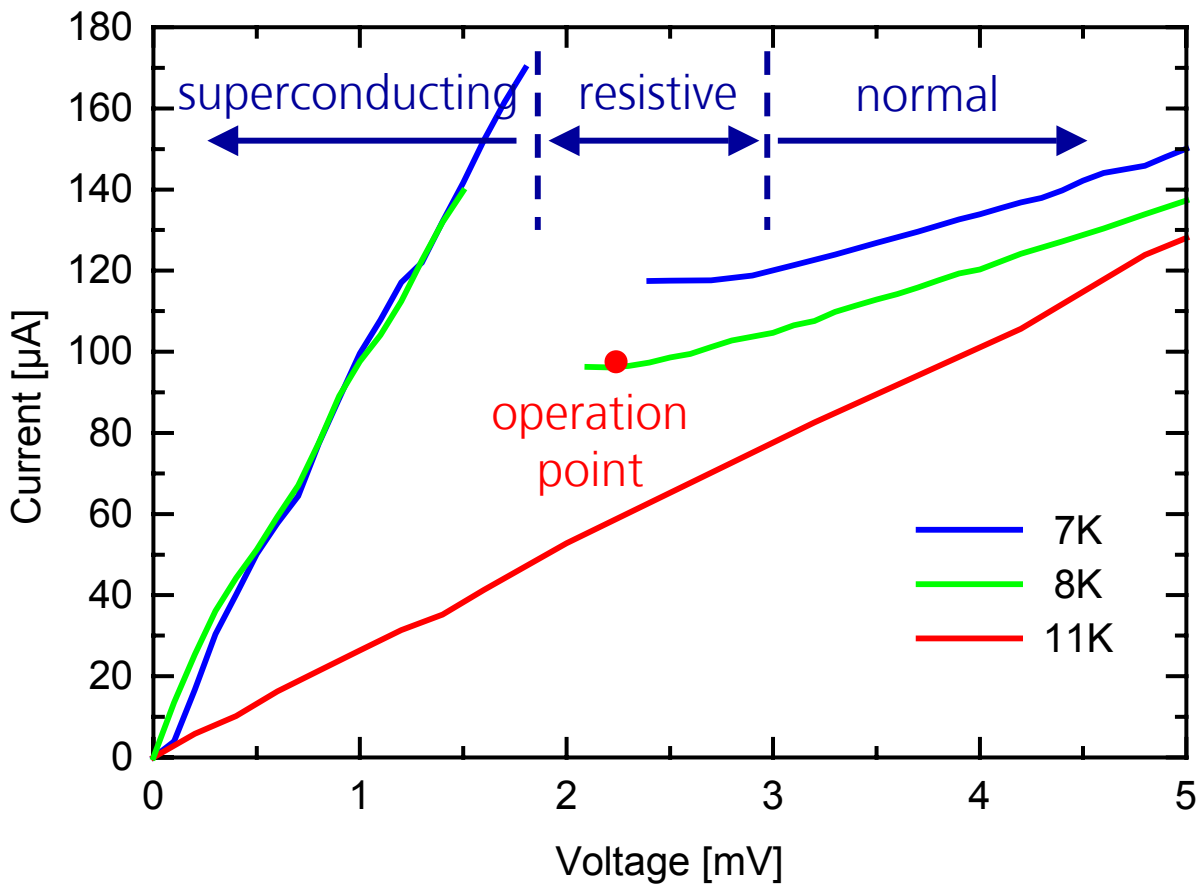
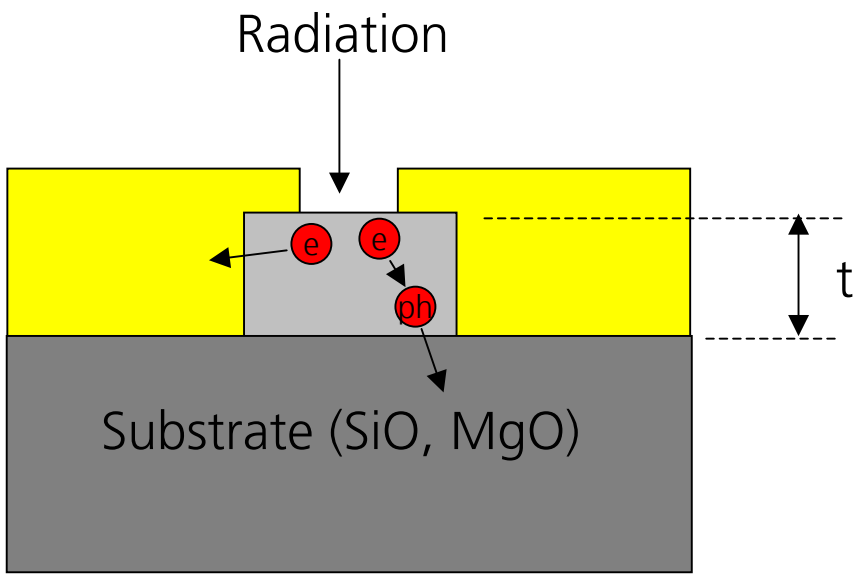
HEB-Detector: R-T Curve

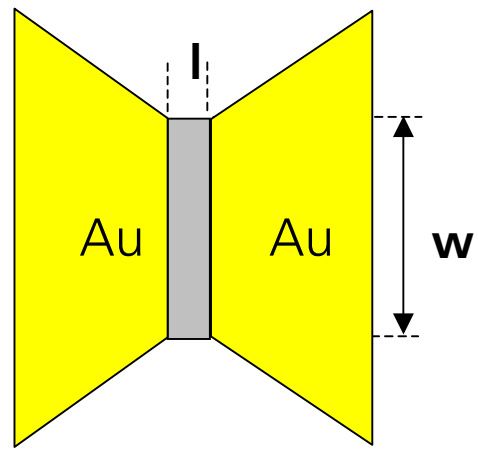


HEB-Detector: I-V Curve



HEB Mixer: Basics





Time scales (NbN):

$\tau_{e\text{-}e} \approx 2$ ps

$\tau_{e\text{-}ph} \approx 15$ ps

$\tau_{esc} \approx 25\text{-}50$ ps (3.5 nm film)

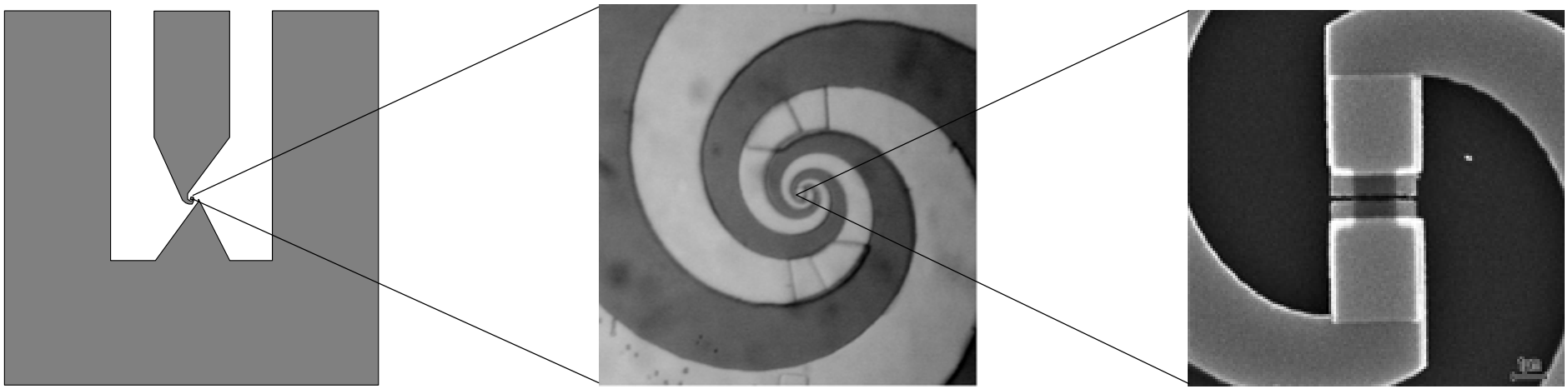
Dimensions:

l: 0.2 - 1.0 µm

w: 1 - 4 µm

t: 3.5 nm

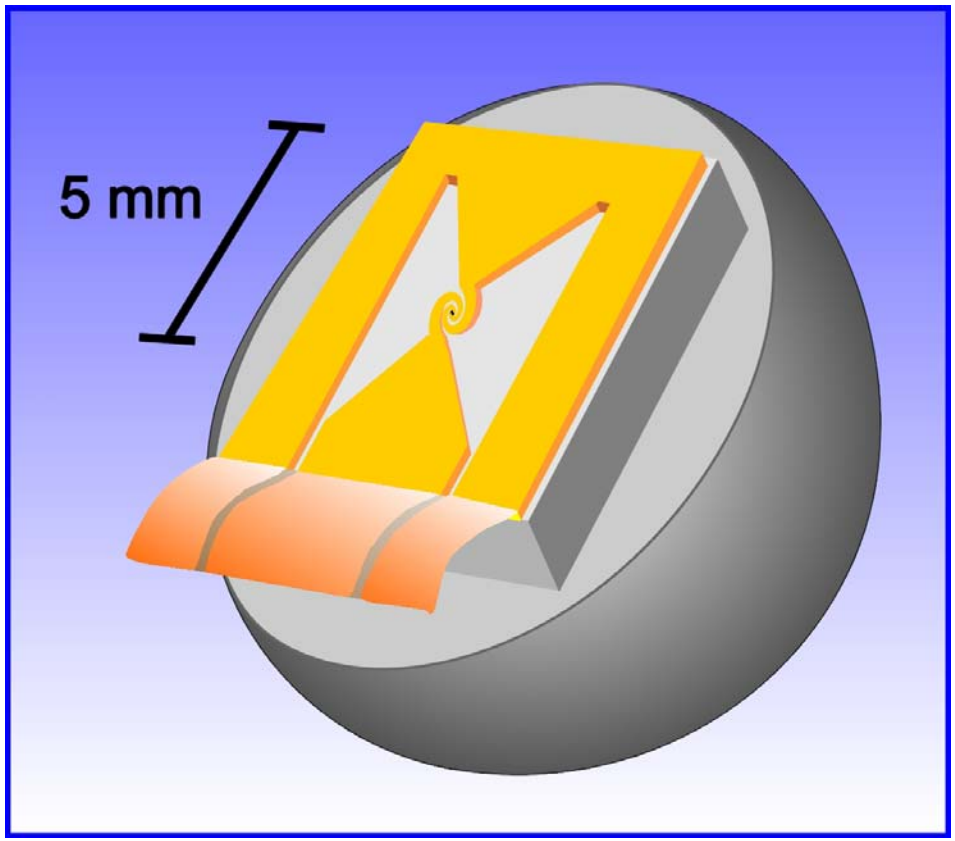
HEB Mixer Design I

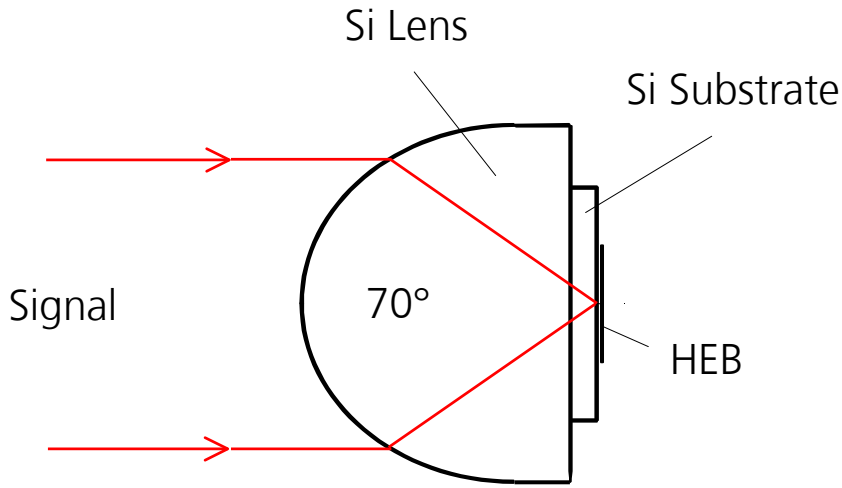


- NbN film: 3.5 nm thick (dc reactive magnetron sputtering)
- Transition temperature: 9 K, width: ≈ 0.5 K
- Si substrate: > 10 kΩ cm
- Two arm log-spiral antenna terminated by 50 Ω coplanar line

(in cooperation with G. Gol`tsman, MSPU)

HEB Mixer Design II



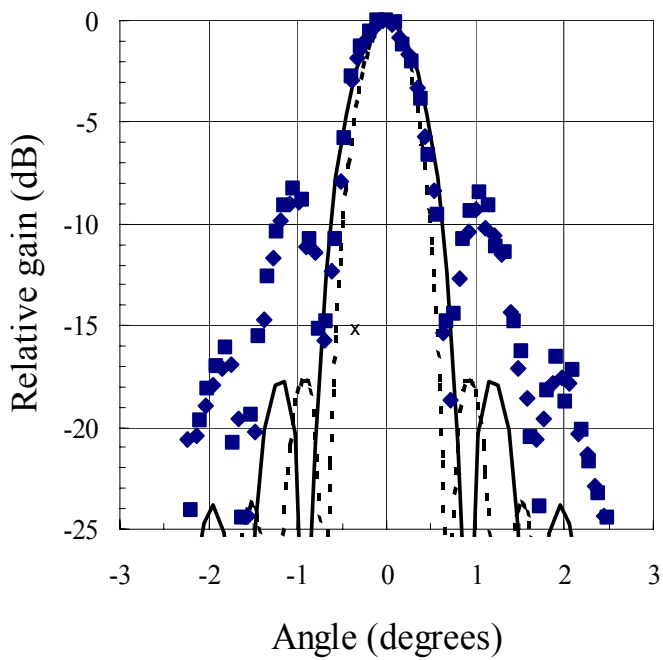


12 mm extended hemispherical Si lens

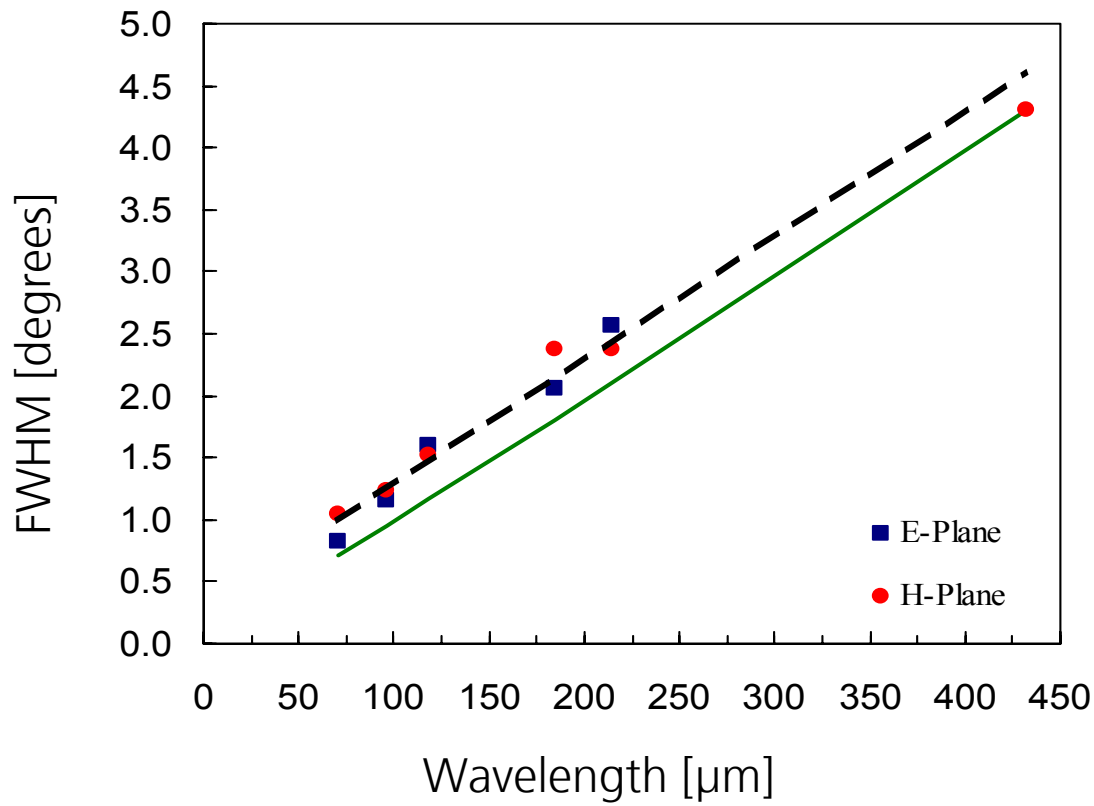
with Parylene AR coating

HEB: Antenna Pattern

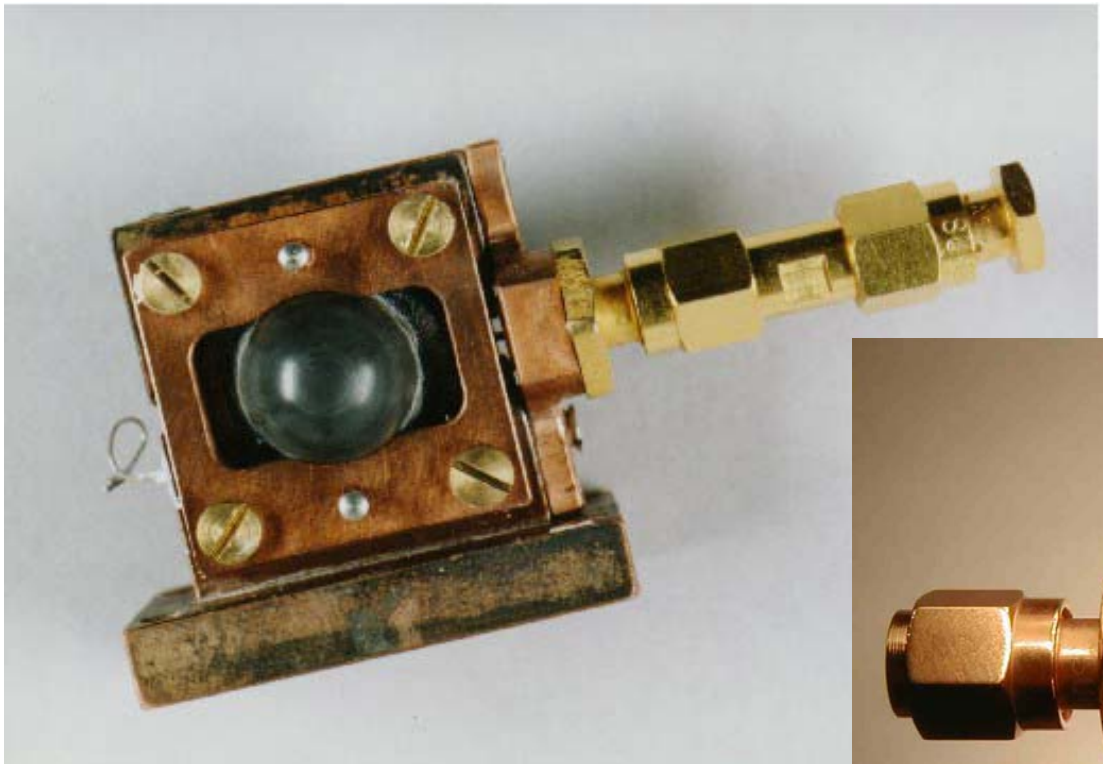
12 mm lens (λ = 118.8 µm)

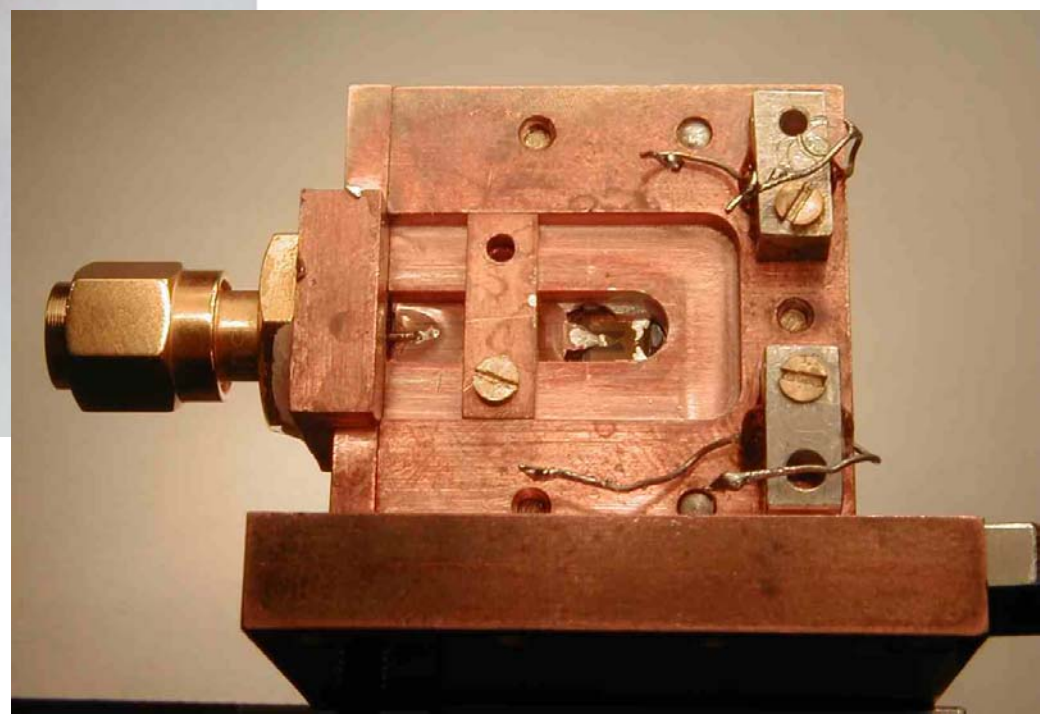


FWHM: 0.75°

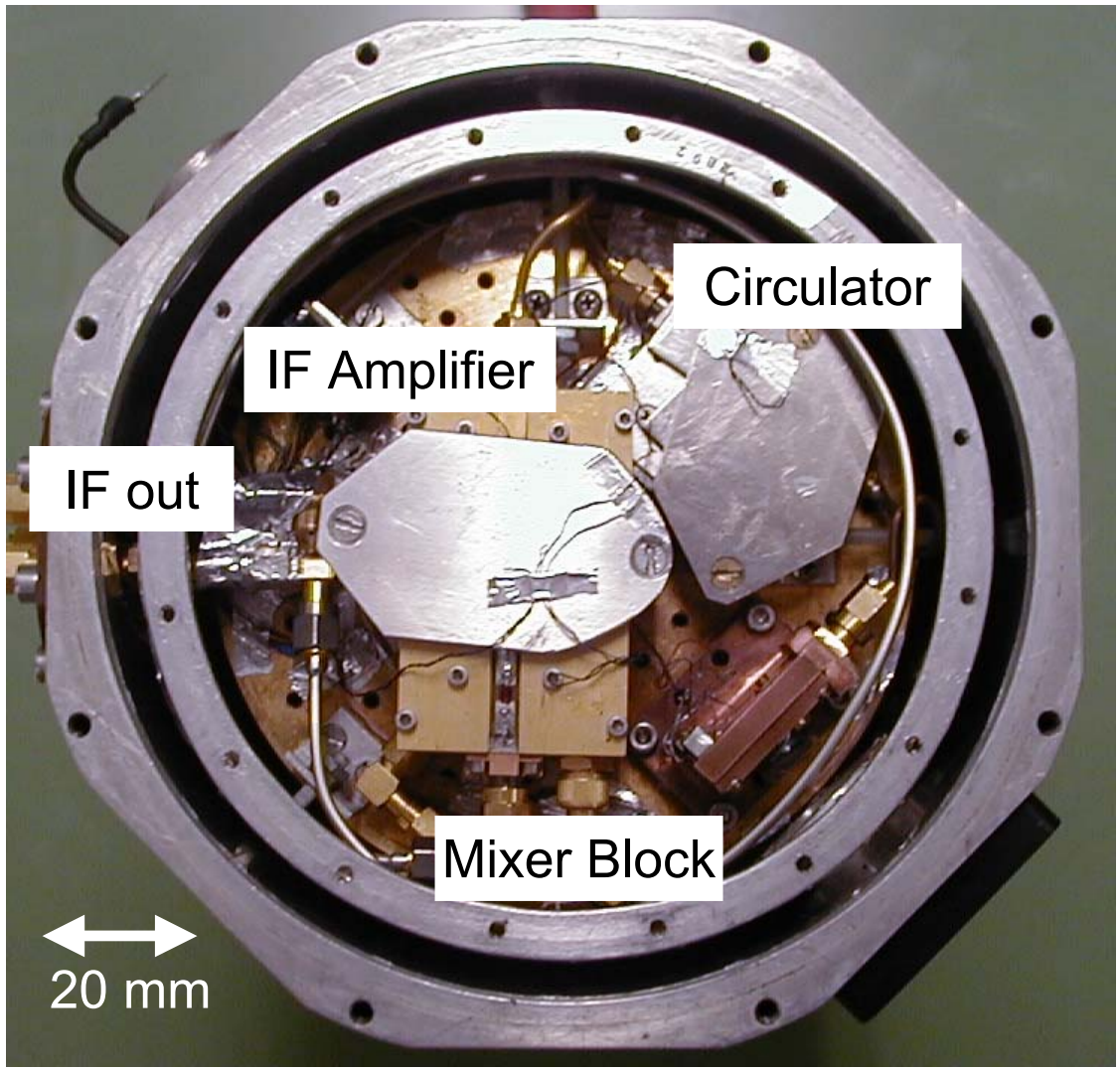


Mixer Block

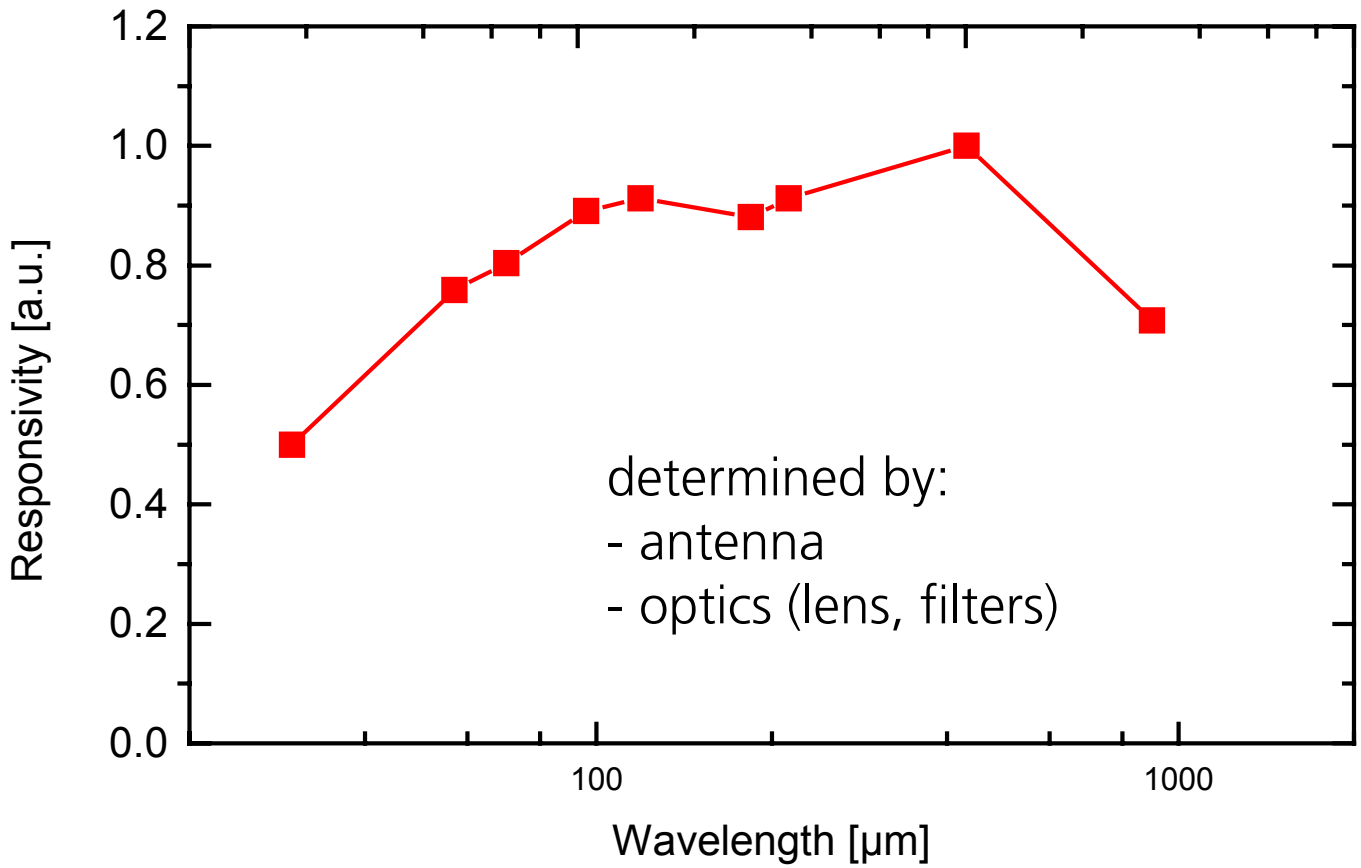




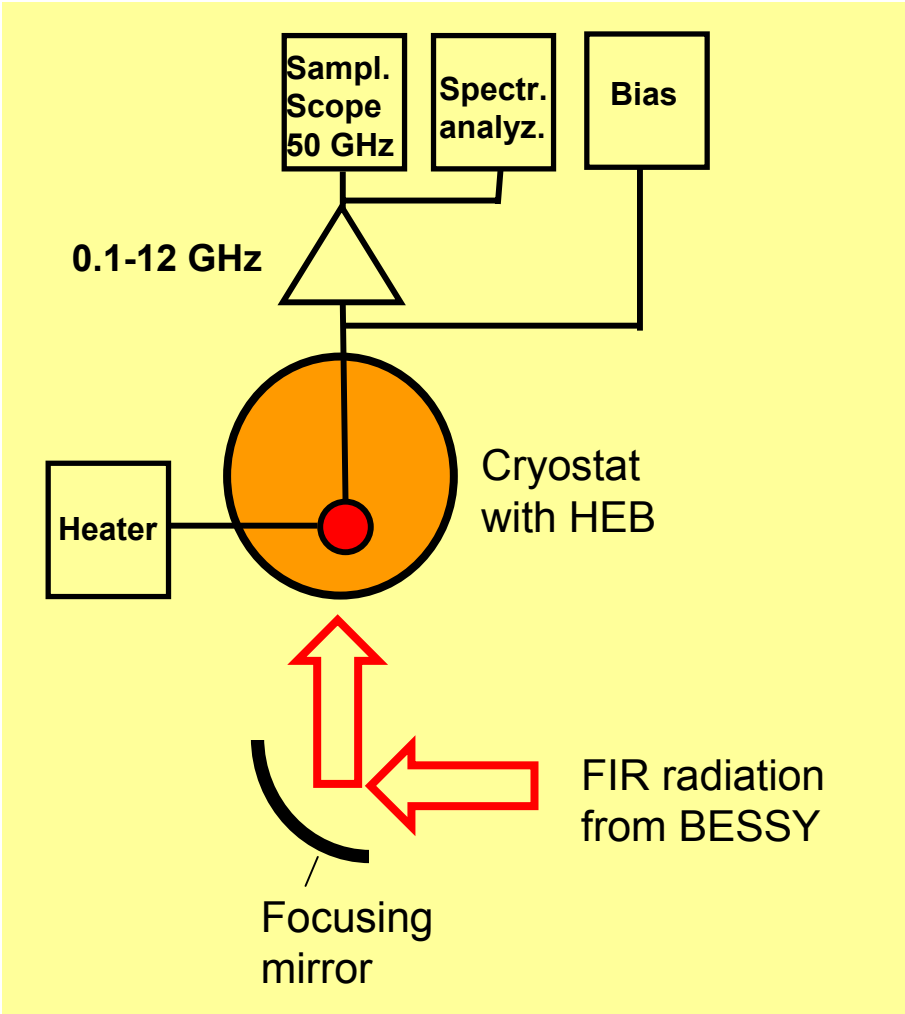
HEB-Detector in Cryostat



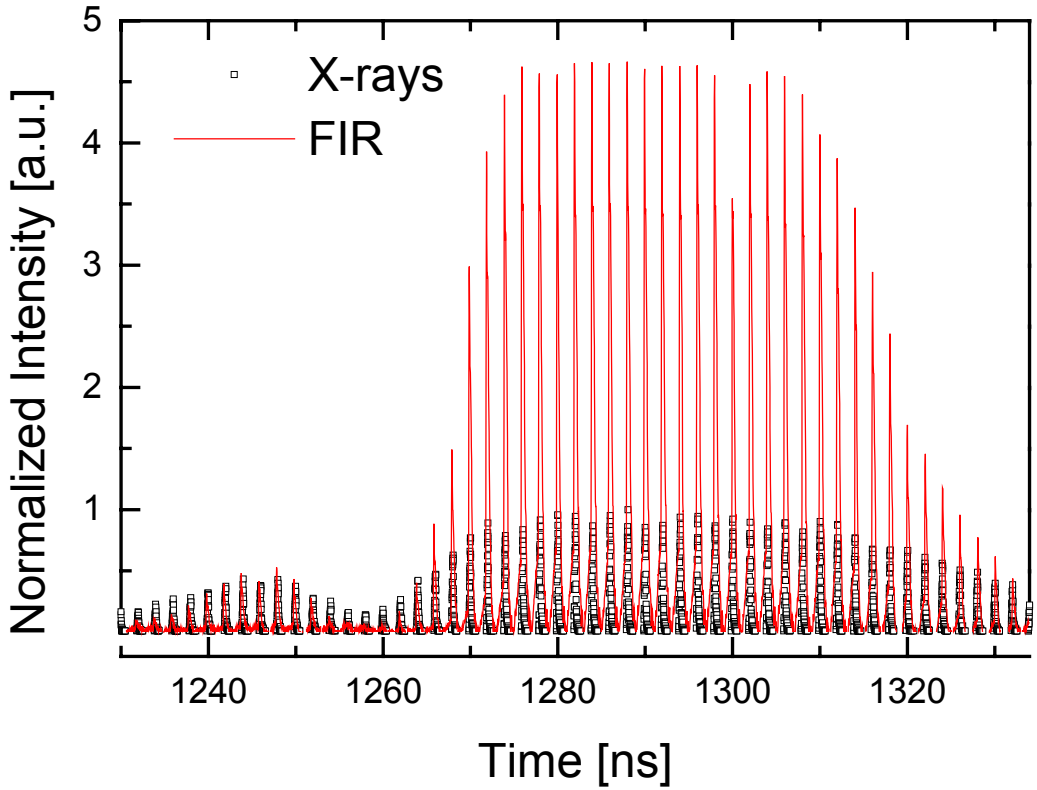
Responsivity vs. Wavelength

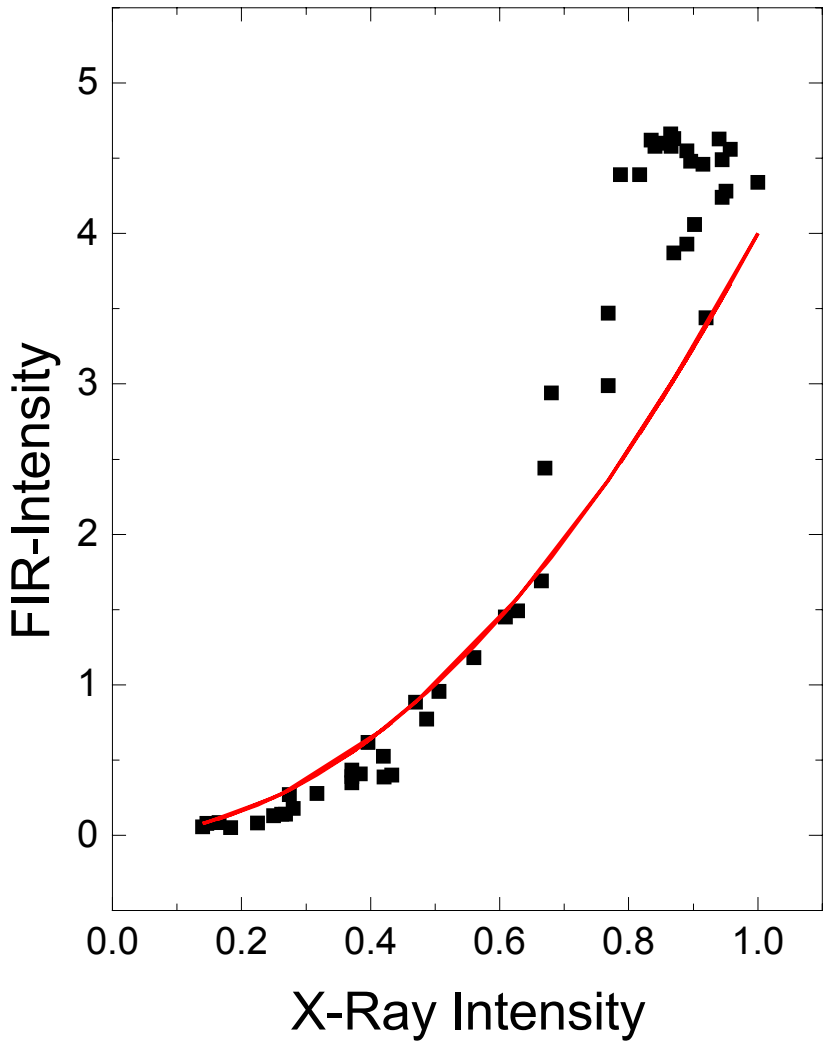


Experimental Setup

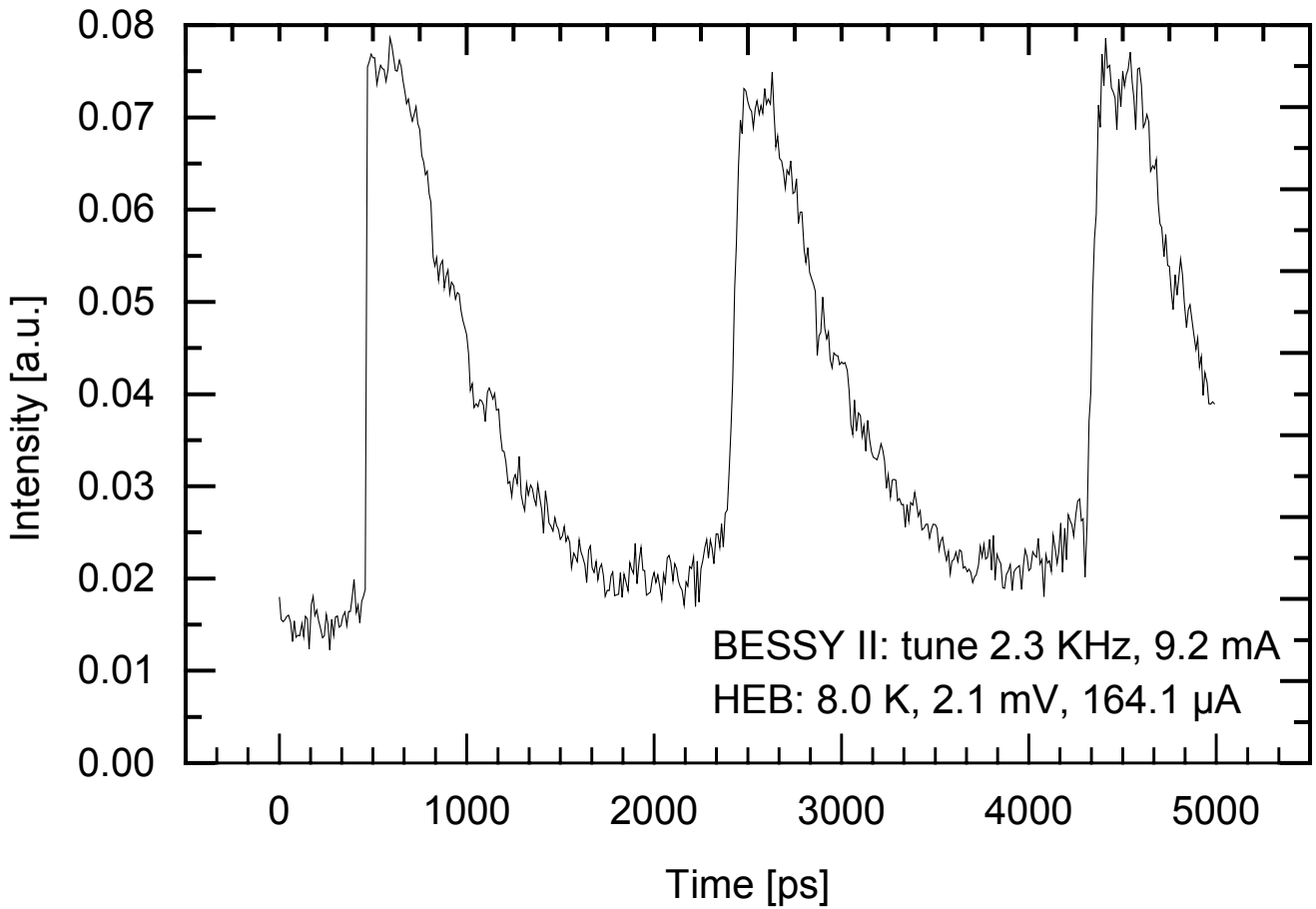


Fill Pattern

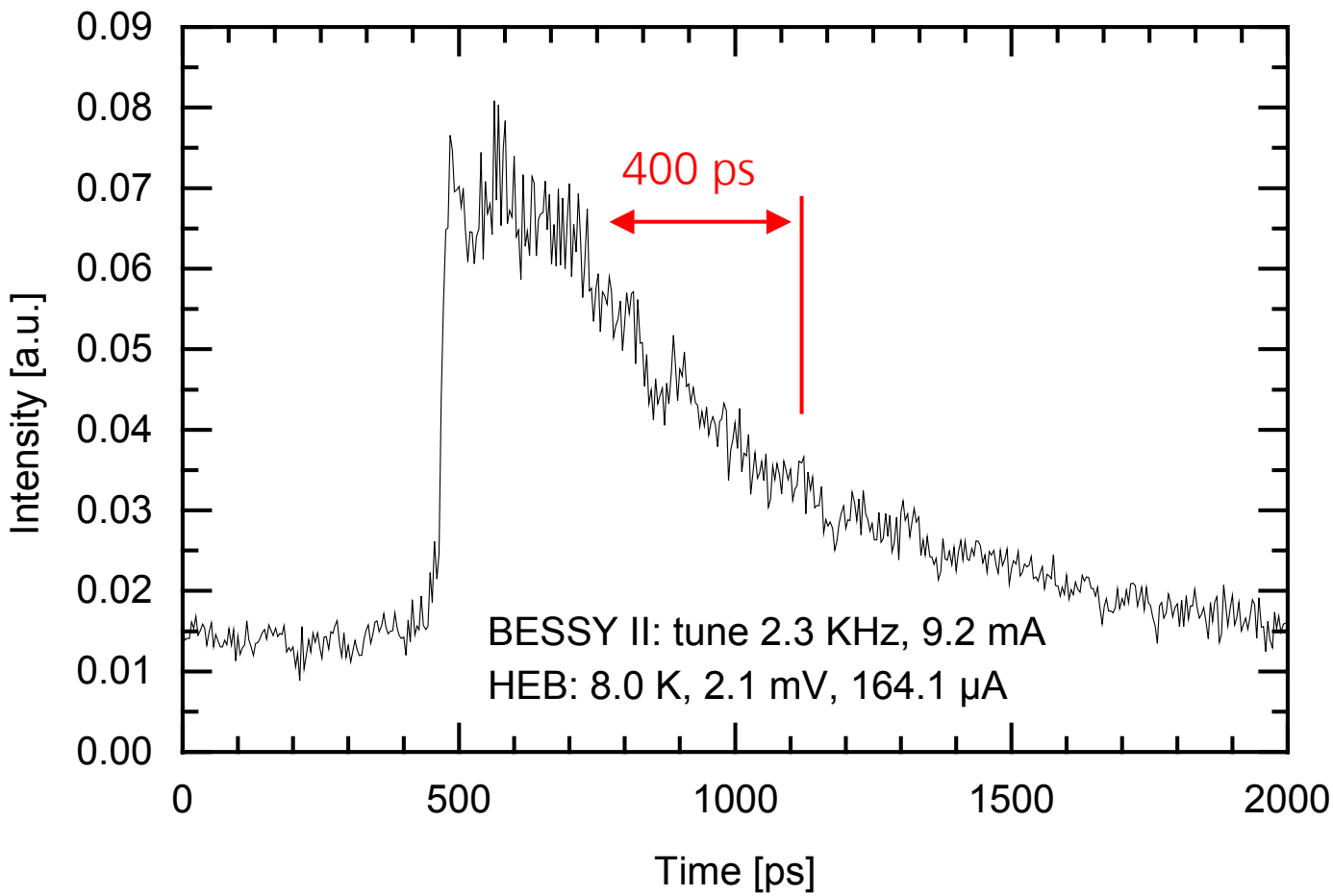




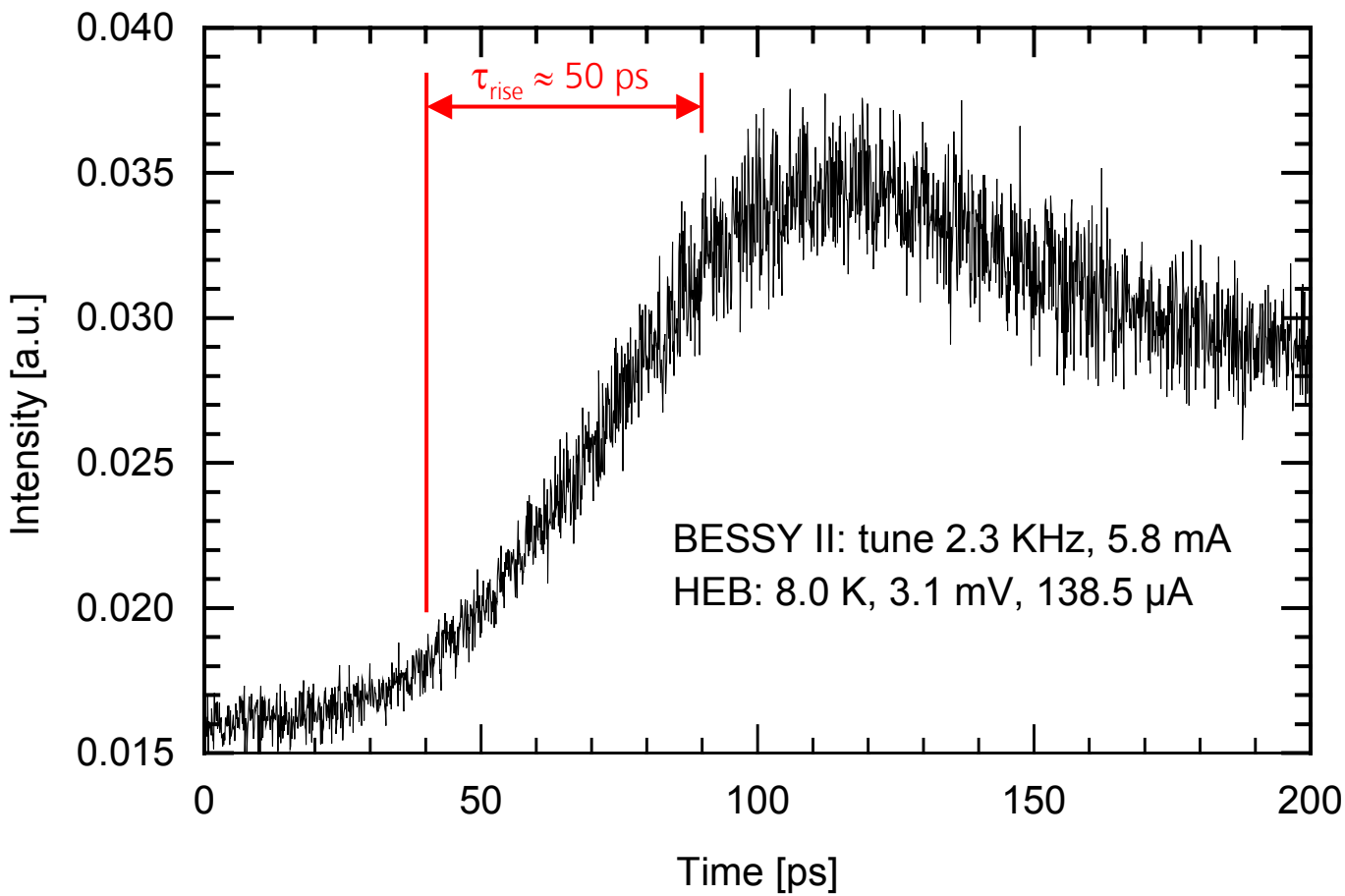
Single Pulses



Single Pulse: Decay



Single Pulse: Rise



Measurement:

$\tau_{rise} \approx 50$ ps

Detector:

$\tau_{e\text{-}e} \approx 2$ ps

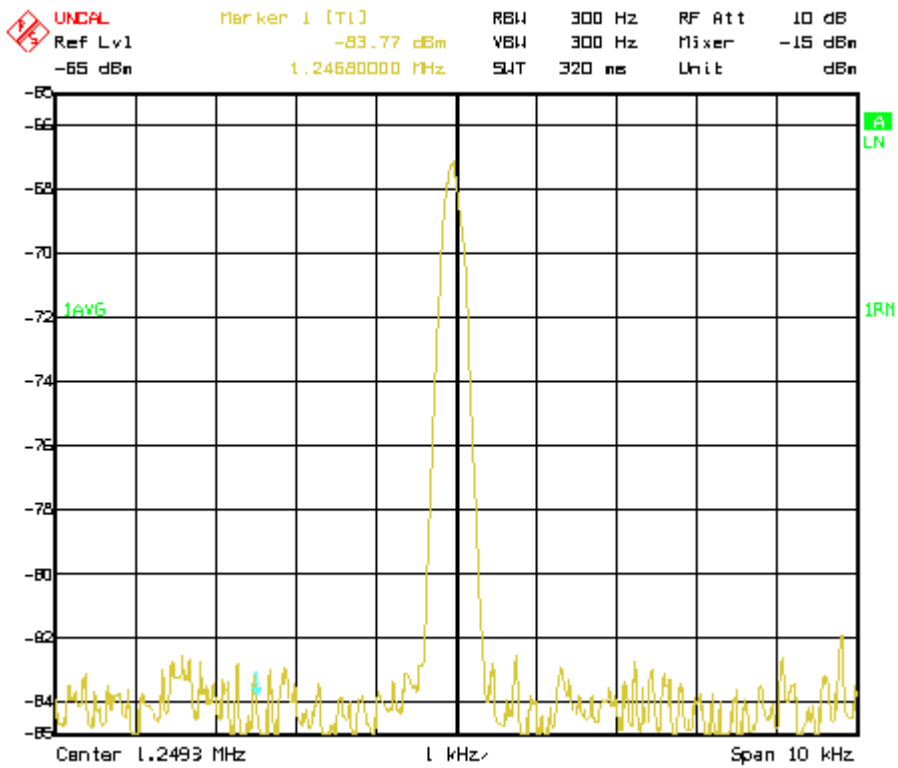
$\tau_{e\text{-}ph} \approx 25$ ps

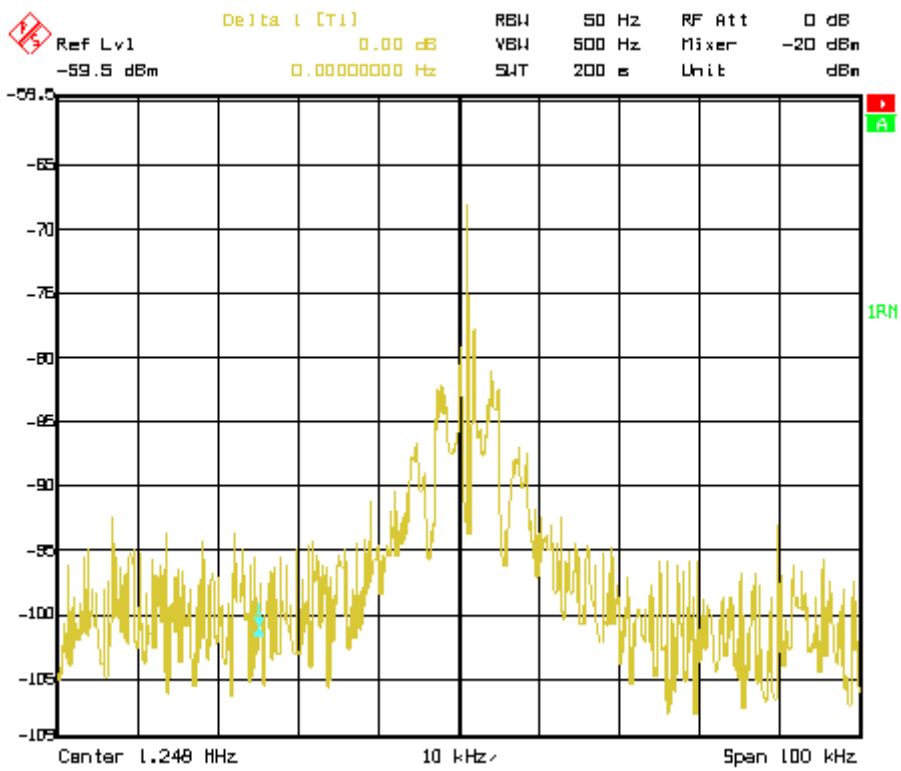
$\tau_{electr} \approx 35$ ps

Electron bunch:

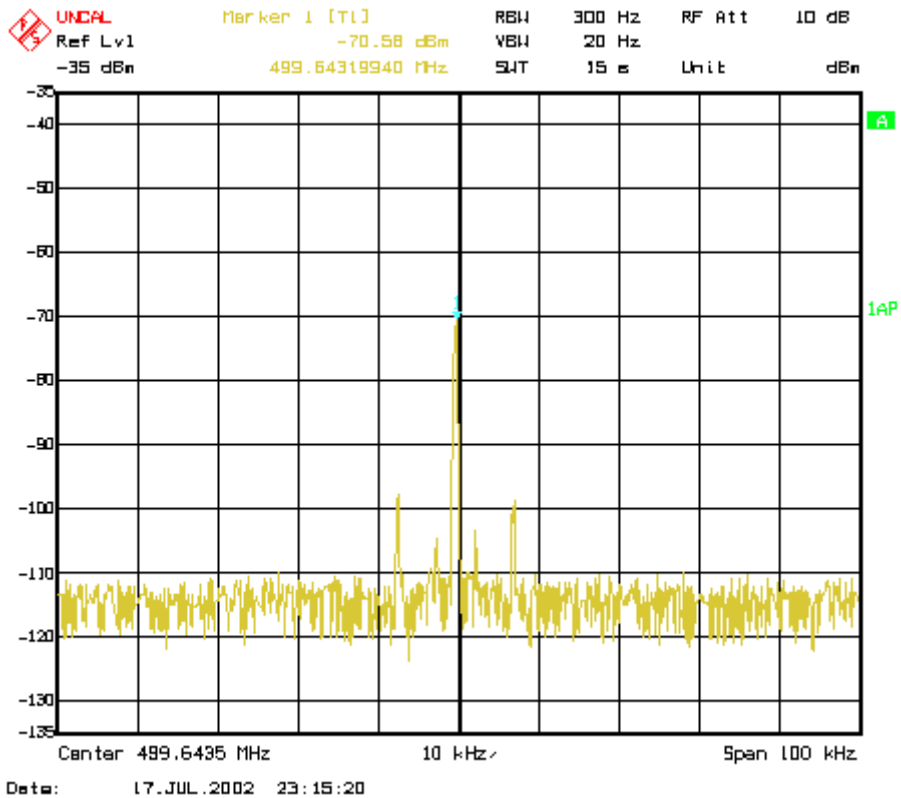
$\tau_{FWHW} \approx 10$ ps

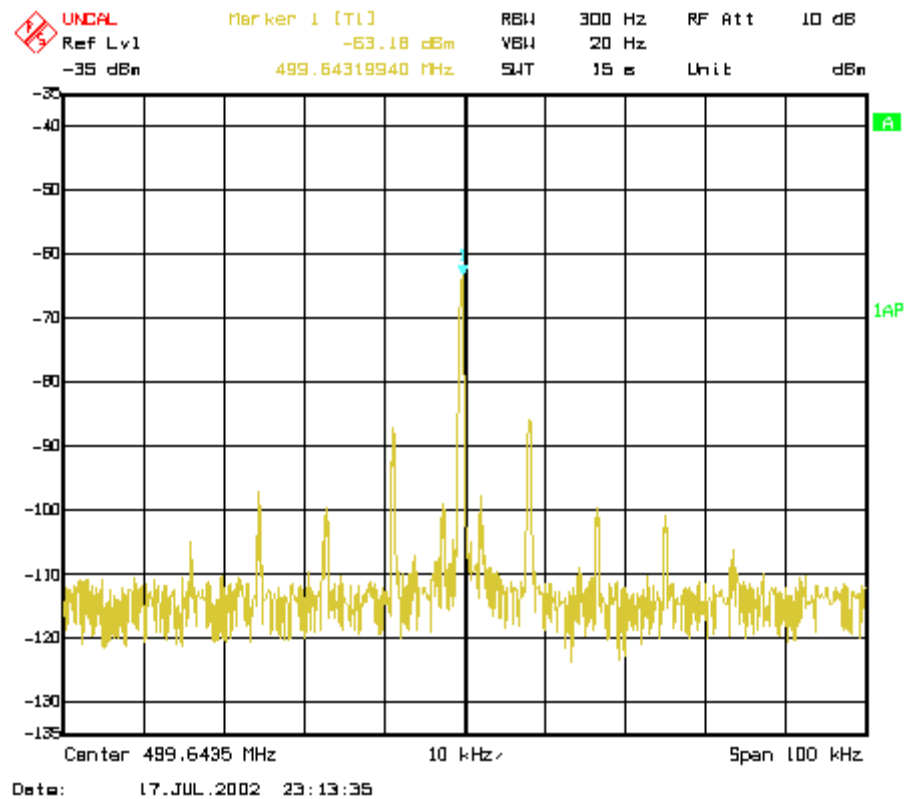
Frequency Domain @ 1.25 MHz





Frequency Domain @ 500 MHz





Conclusion

- Fast FIR detectors are useful for the analysis of CSR;

- High sensitivity across a wide range of wavelengths;

- Time resolution of the superconducting HEB is sufficient to resolve the fill pattern;