Simulations and measurements to optimize the optical coupling of LEKIDs

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NIKA (NEEL-IRAM-KIDs-Array)

Lumped Element KID Array

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Institut de Radioastronomie millimétrique Grenoble, France	M. Rösch, K.F. Schuster S. Leclercq
Università di Roma la Sapienza, FBK Trento	A. Cruciani, C. Giordano

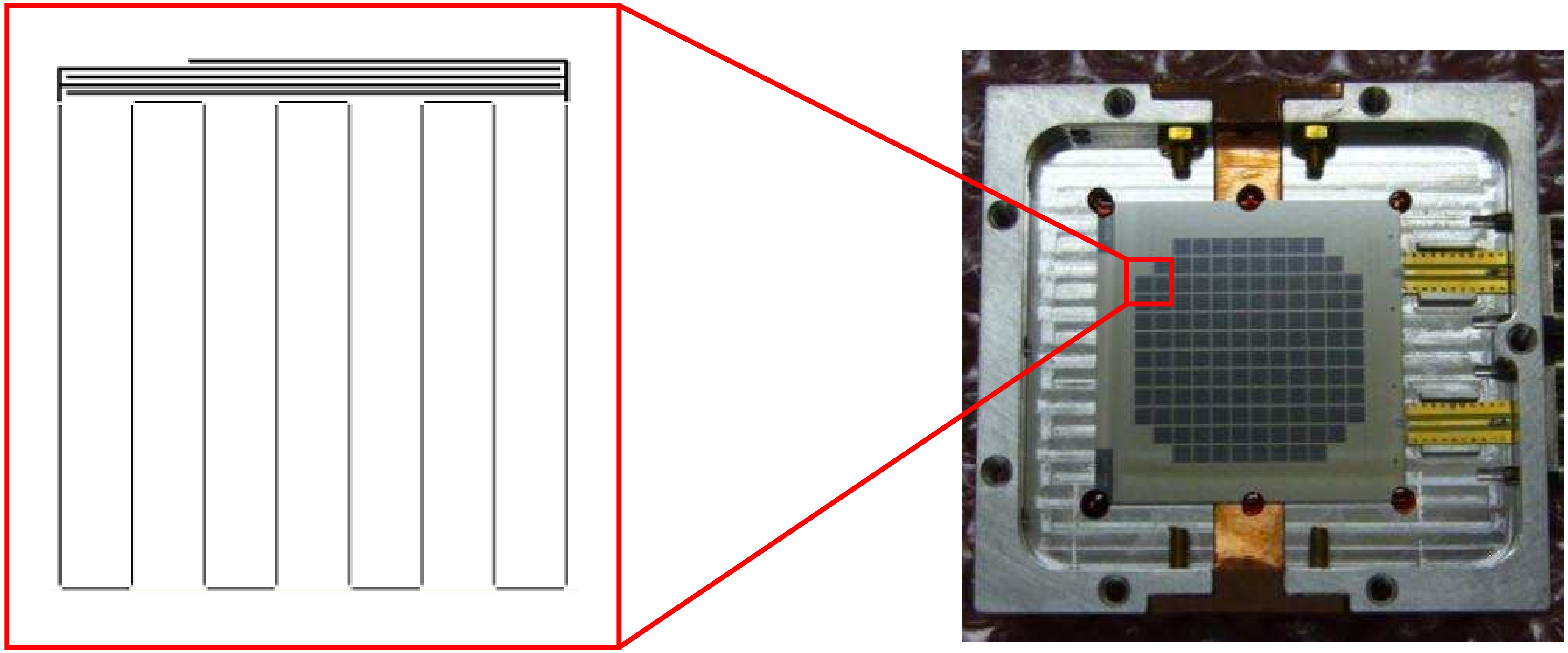
Antenna coupled KID Array

SRON Netherlands Institute for Space research Groningen, Utrecht, Netherlands	J. Baselmans, S. Yates, A. Barychev, J-J. Lankwarden, L. Ferrari
Delft University of Technology Delft, Netherlands	A. Endo

The NIKA 2-mm LEKID array

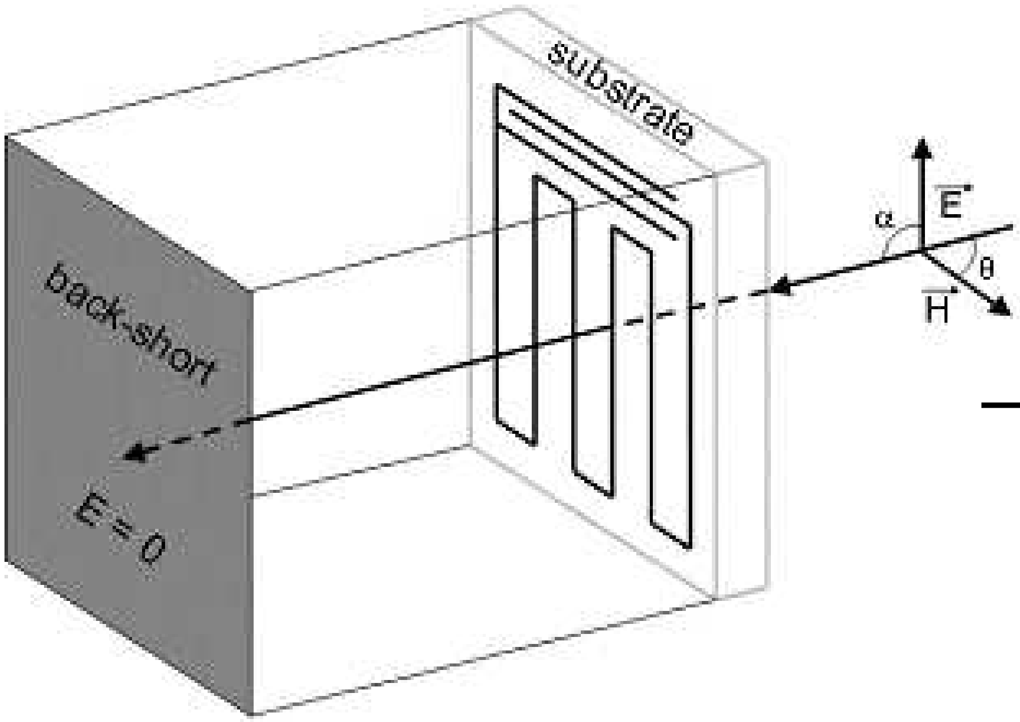
Material: aluminum
Thickness: 20 nm
Substrate: high resistive silicon

number of pixels: 132
sample holder: aluminum
not visible: back-short



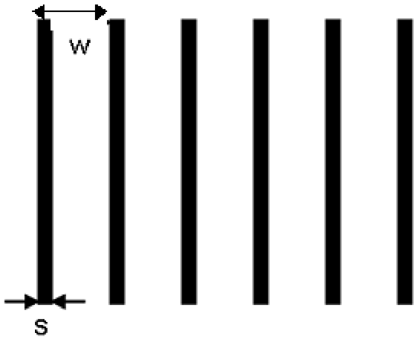
More details about NIKA will be presented by Alessandro Monfardini

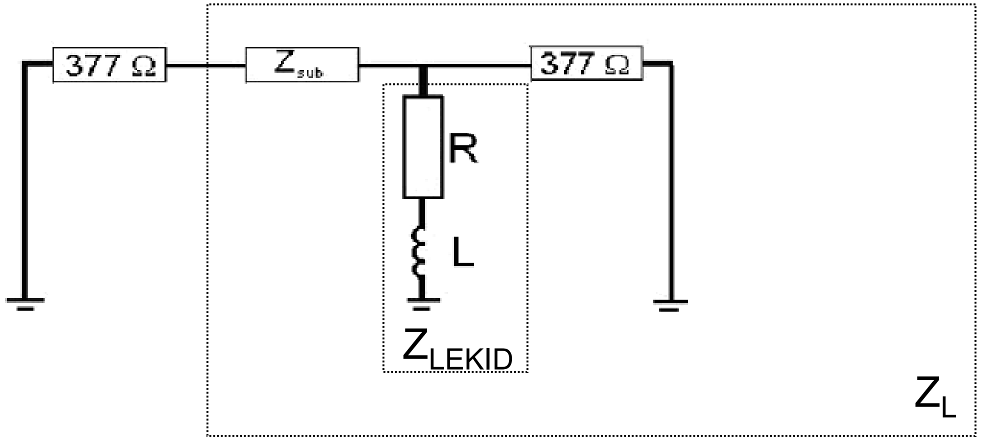
Optical coupling



Model with lumped elements

Transmission line model





$$Z_{substrate} = \frac{Z_{FS}}{\sqrt{\varepsilon_r}} = \frac{120\pi}{\sqrt{\varepsilon_r}}$$

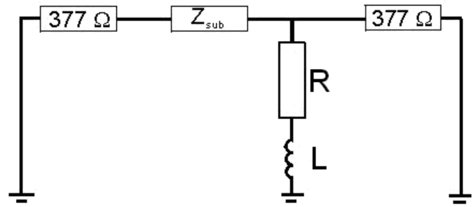
$$Z_{LEKID} = R + j\omega L = \frac{R_{sheet}}{s/w} + j\frac{w}{\lambda}\ln\csc\left(\frac{2w}{\pi s}\right)Z_0$$

Ulrich, Infrared physics, vol. 7, pp. 37-57, 1967
Marcuvitz, Microwave Handbook

$$\left|\underline{S}\right|_{11} = \frac{\left|Z_L - Z_0\right|}{\left|Z_L + Z_0\right|}$$

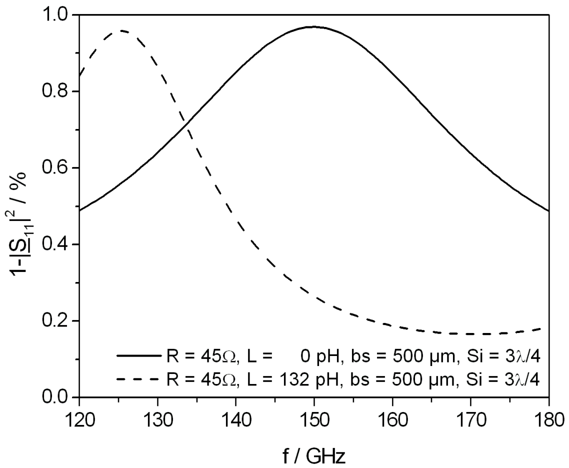
$$absorption = 1 - \left|\underline{S}_{11}\right|^2$$

Transmission line model

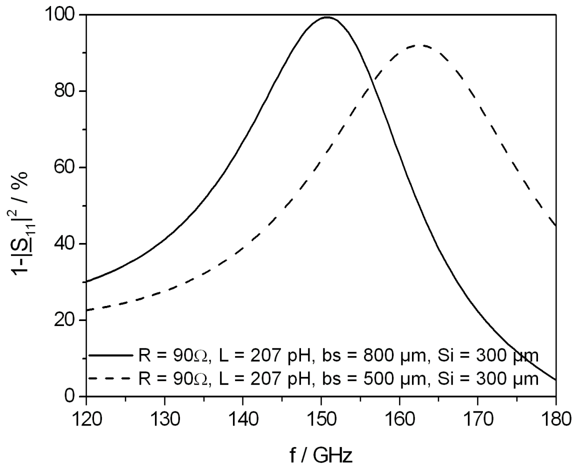


Optical coupling depends on:

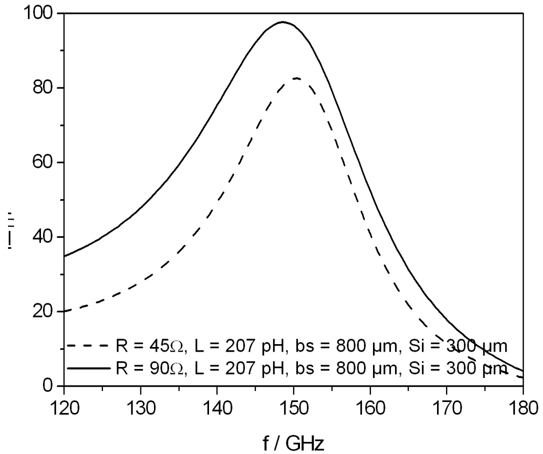
Inductance L of Z_{LEKID}



Back-short and substrate



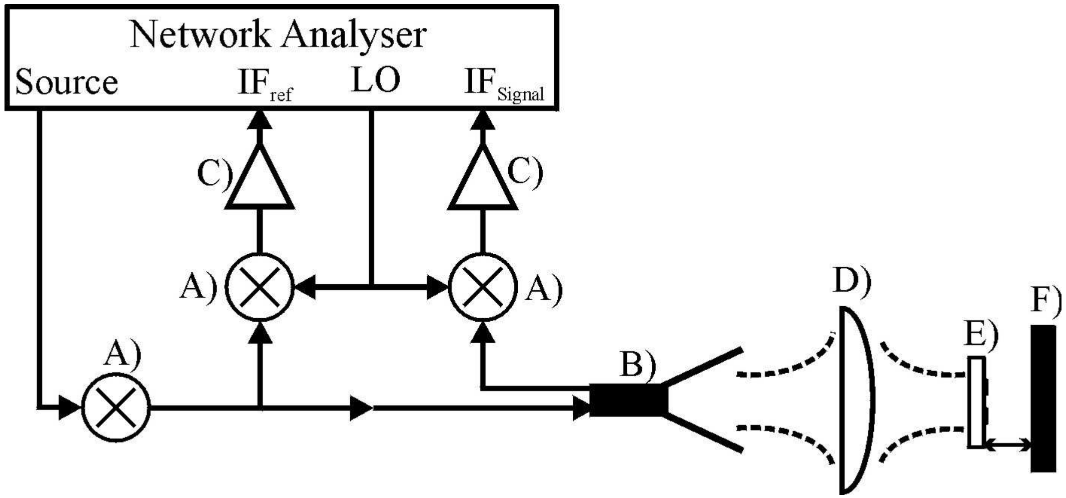
Resistance R of Z_{LEKID}



Cryogenic measurements to optimize these parameters are very time consuming

Reflection measurements at room temperature

Assumptions:
- detection = absorption
- el. properties are comparable to cryogenic case (150 GHz > 90 GHz gap frequency of aluminum)
- resistivity can be adapted by RRR factor

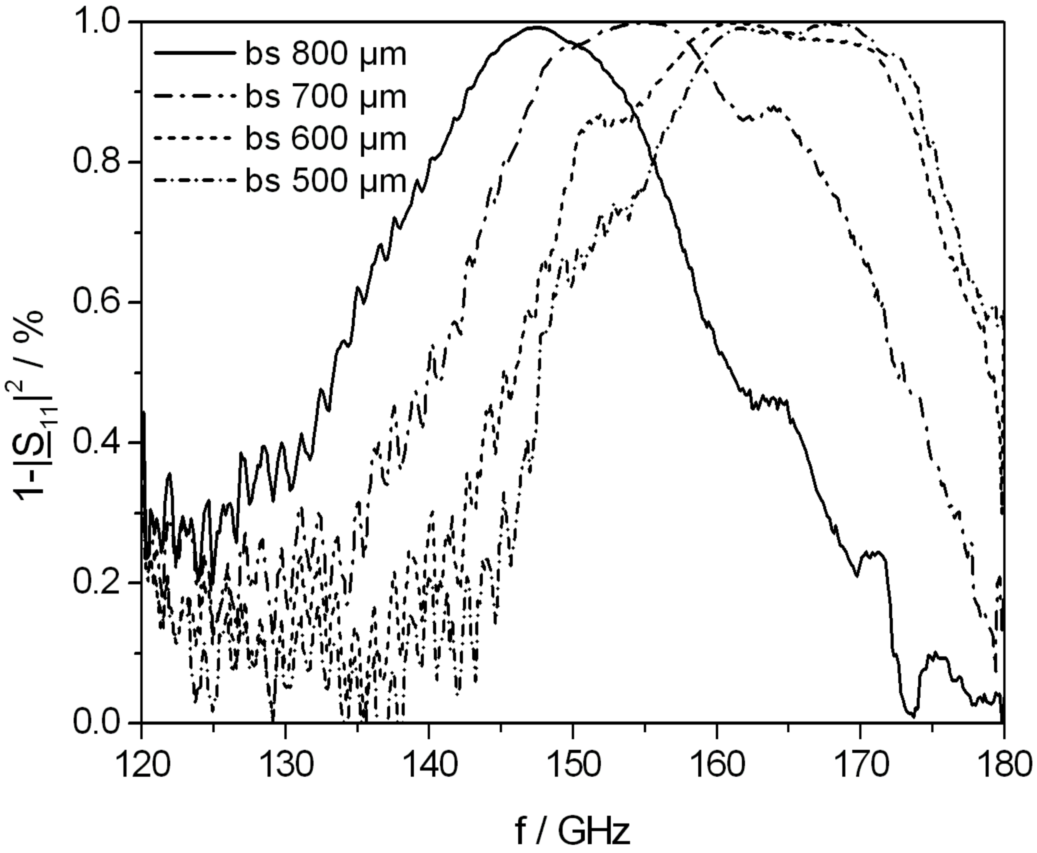


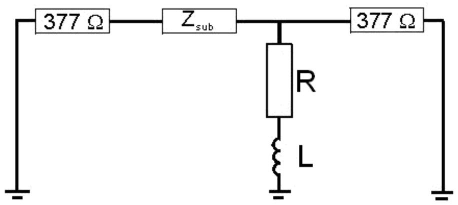
- frequency band: 120 – 180 GHz
- only one polarization measurable
- only first mode measurable
- side lobes are not considered
- Radiation in different polarizations are not considered

A) Harmonic mixer
B) Corrugated feed horn
C) Amplifier
D) Corrugated lens
E) Sample
F) Back-short

Reflection measurement results

Back-short dependence of optical coupling





- 40 nm aluminum film

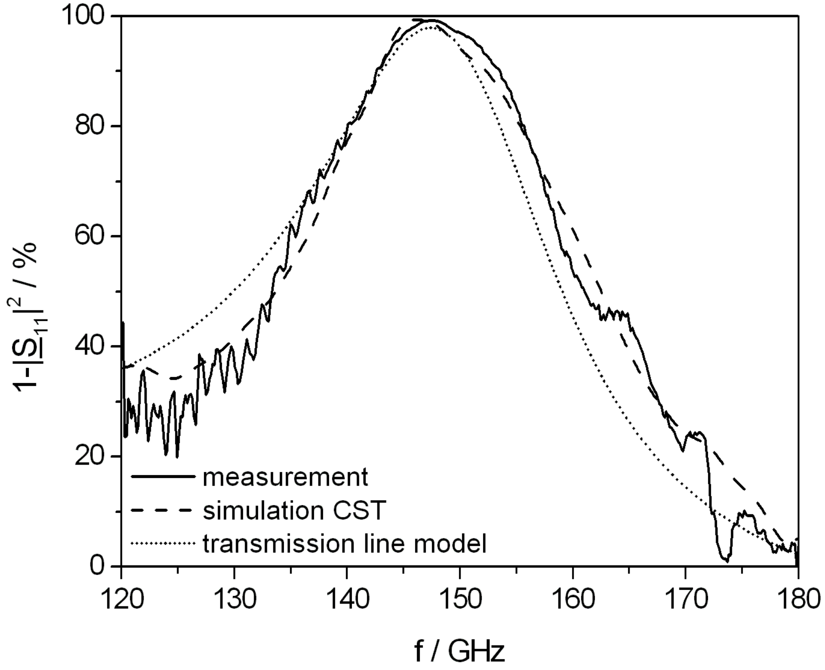
→ R_{sheet} = 1.3 ohm
→ R = 90 ohm with s/w=(69)^-1
→ L = 200 pH

This corresponds to 25 nm aluminum film at a temperature just above $T_{C,al}$ = 1.2 K

- 300 µm high resistivity substrate

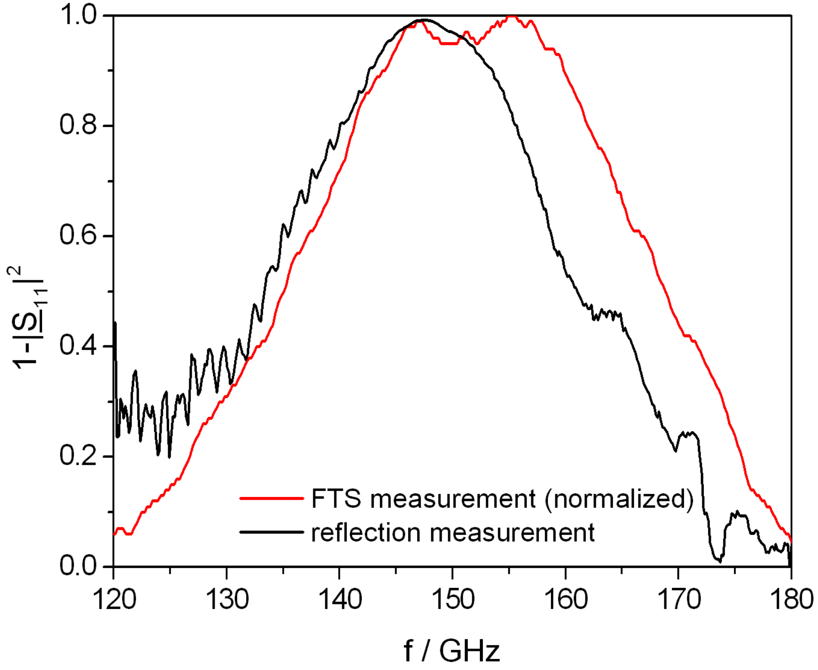
Measurement and simulation

Comparison of reflection measurement, simulation and transmission line model



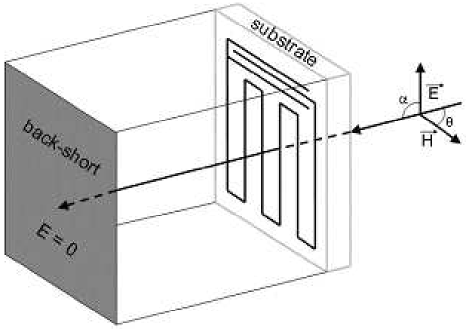
Comparison of reflection measurement and FTS measurement at 100 mK in camera

A. Bideaud, thesis, 2010
A. Monfardini et al, ApJ, 2011

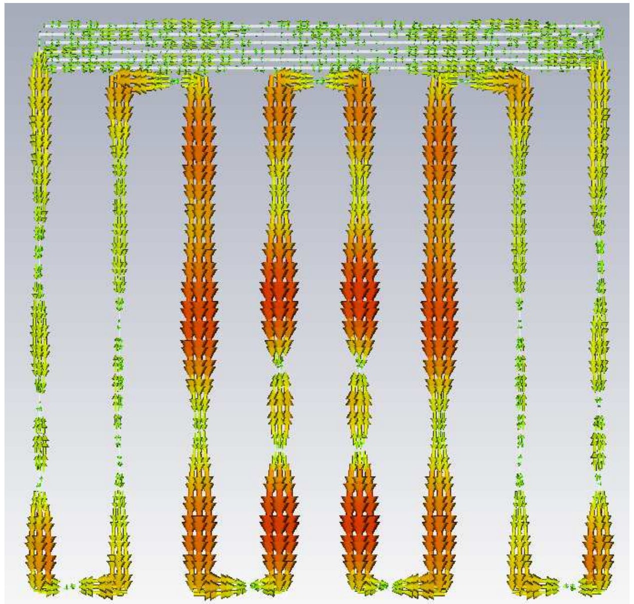


Simulation of current distribution in LEKIDs

Phase: 0 deg



Phase: 90 deg



Current distribution varies with the phase of the incoming mm-wave

Current in strips that are orthogonal to the el. field vector are small
→ Error due to radiation in different polarizations is small

Currents in strips close to the ground plane are smaller
→ filling factor is higher → lower impedance → less absorption

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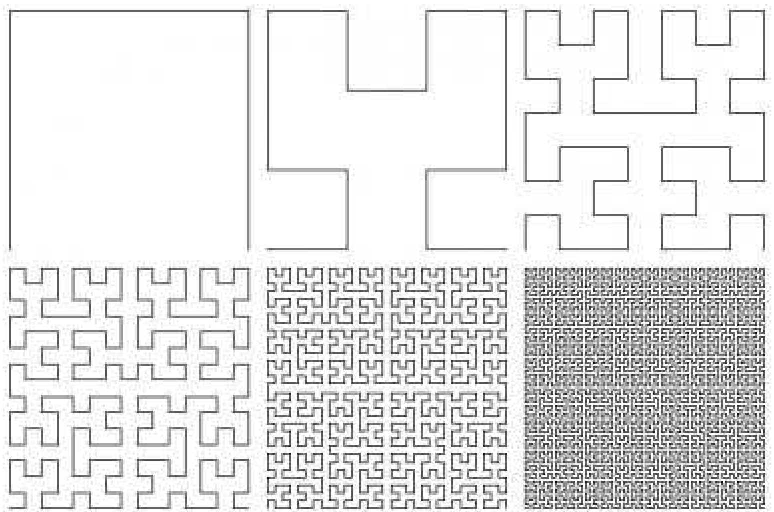
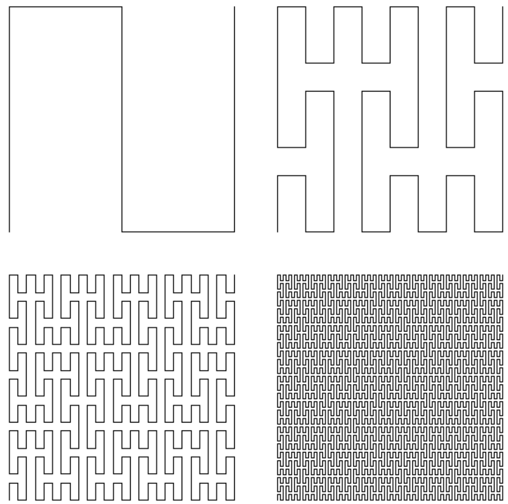
LEKID geometry for 2 polarizations

- constant filling-factor over the whole direct detection area
- reasonable filling factor for optimal optical coupling
- symmetrical geometry:
  - same optical coupling for horizontal and vertical orientation
  - symmetrical current distribution

Hilbert curve

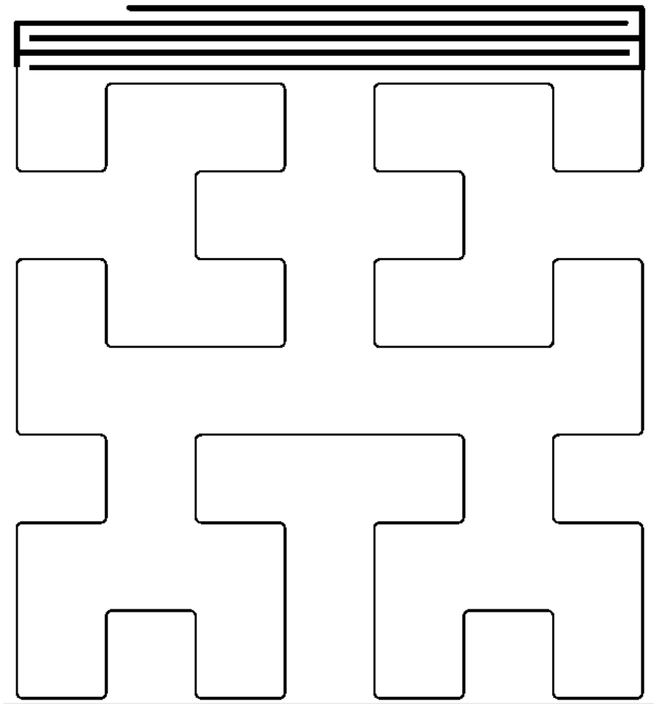


Peano curve

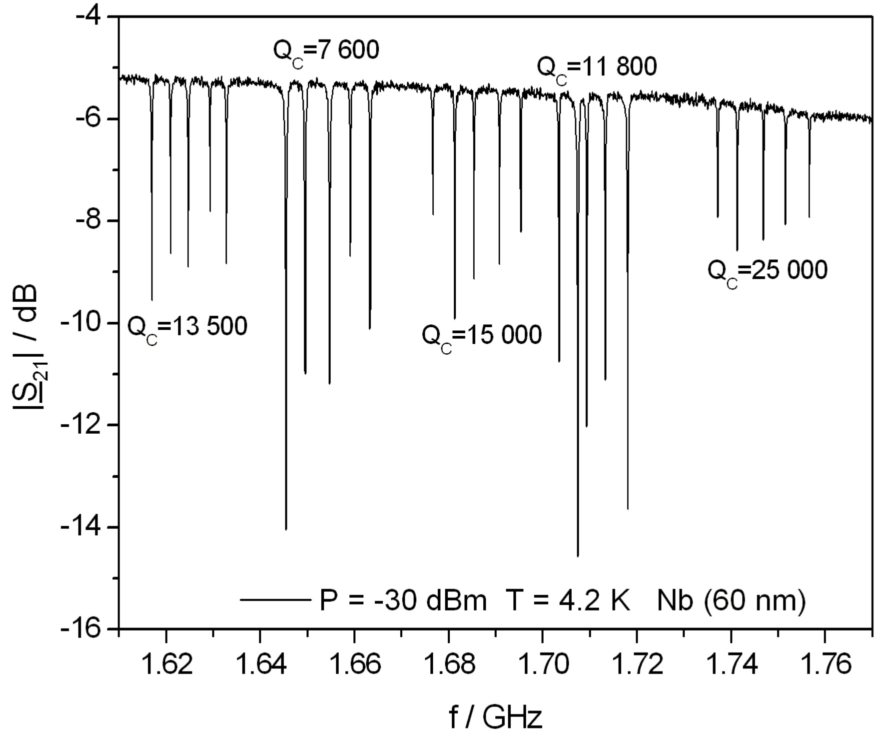


LEKID geometry for 2 polarizations

Hilbert curve 3rd order



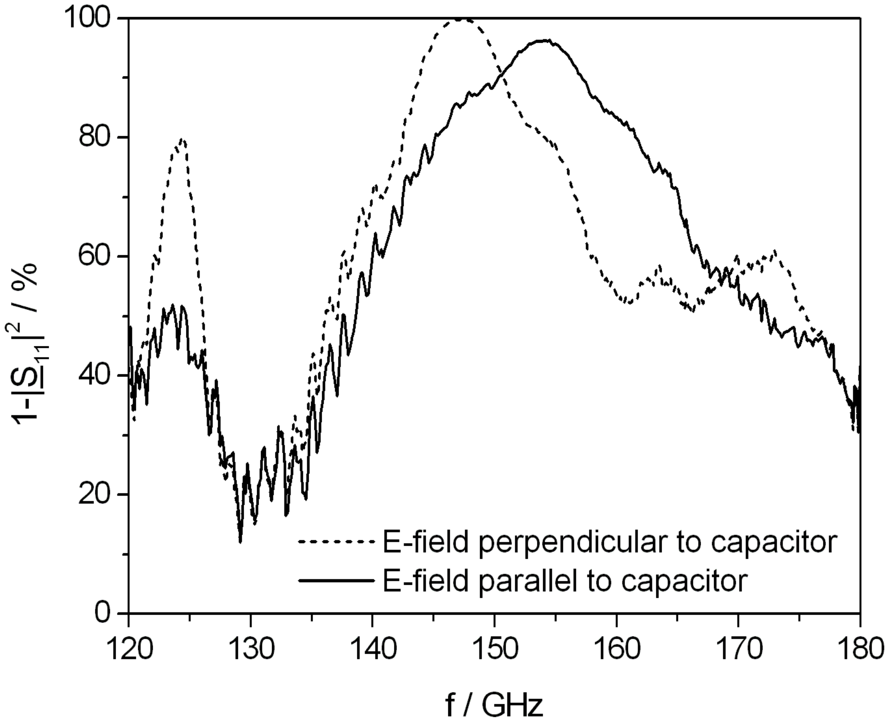
25 pix array with 5 different Q_C to feed line



- same filling-factor as meander geometry
  (assuming similar absorption in interrupted lines
- same coupling to feed line

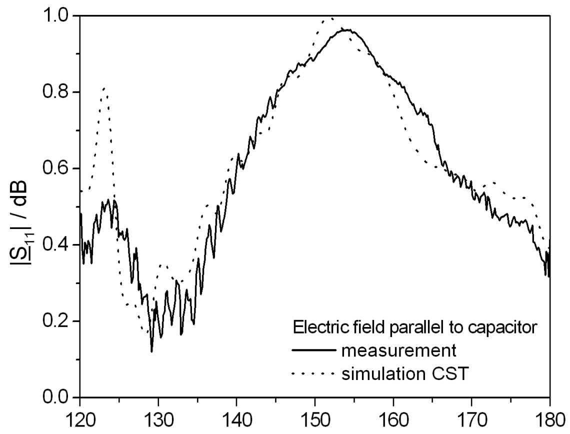
Optical absorption

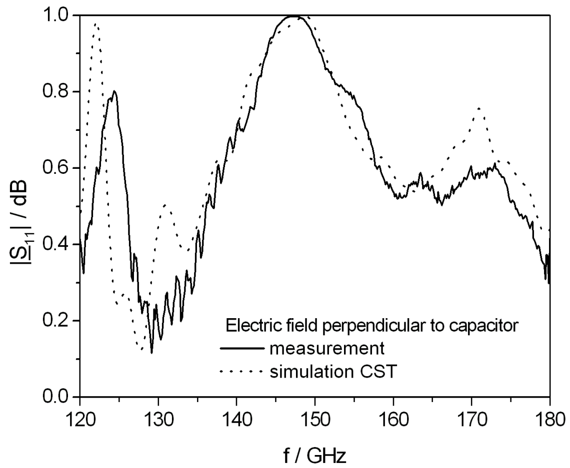
Reflection measurement of Hilbert LEKID



almost identical absorption for both polarizations

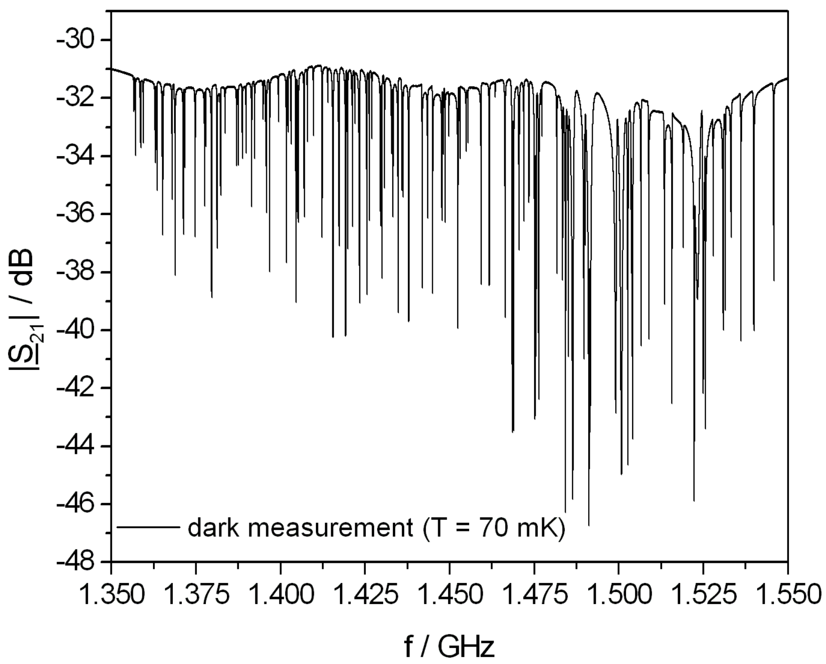
Measurement and simulation



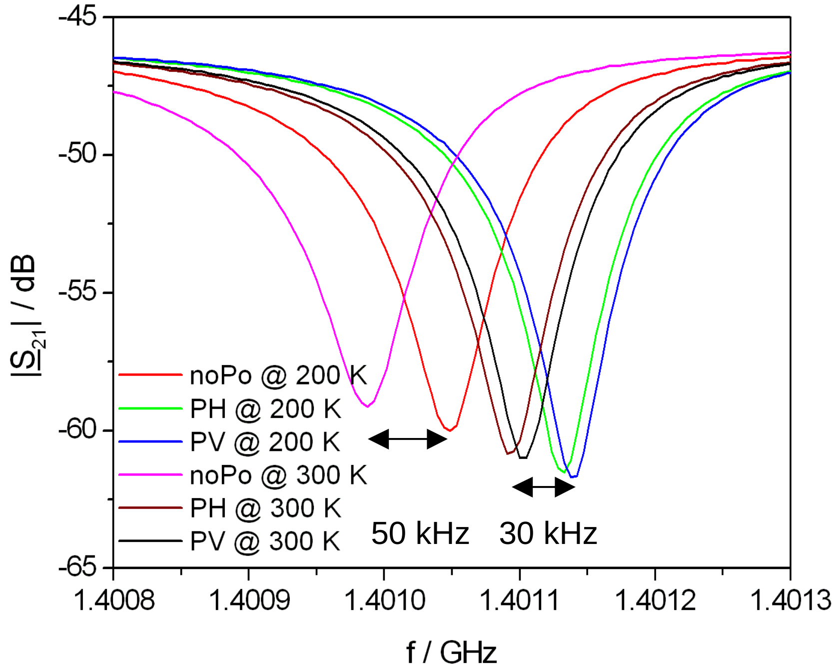


Low temperature measurements of Hilbert LEKID

VNA scan of 132 pixel array



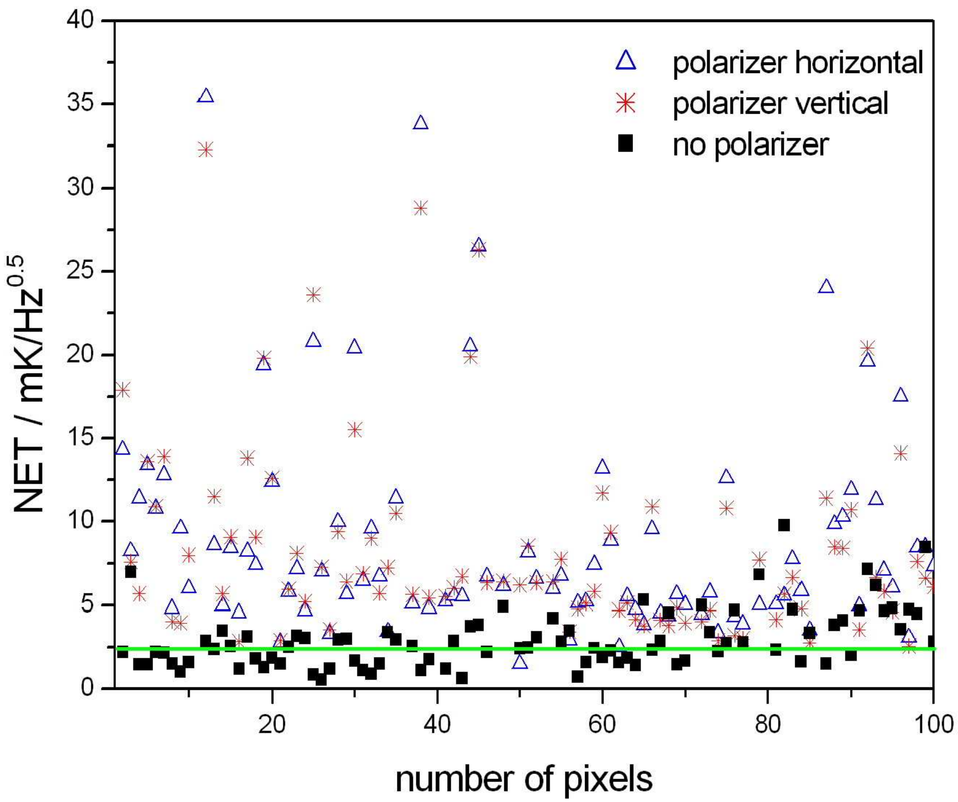
Optical response (load 200 and 300 K)
(using polarizer in front of cryostat)



Response for both polarizations identical

4th microresonator workshop
July 2011, Grenoble

Sensitivity of a 20 nm Al Hilbert LEKID array



- Average sensitivity: NET = 2.5 mK/Hz$^{0.5}$ per pix (factor 2-3 from IRAM specifications)
- Best pixels: NET = 0.8 mK/Hz$^{0.5}$ per pix

Conclusion

- Reflection measurement setup to optimize the optical coupling at room temperature as alternative to cryogenic measurements

- Good agreement between reflection measurements, transmission line model, simulation and FTS measurement

- Two polarization geometry shows promising results

- Factor gained compared to meander structure ~ 1.5

- Best pixels showed NET = 0.8 mK/Hz^0.5 → new record for LEKIDs at the 2 mm window

Outlook

- developing arrays for 1 mm
- Optimize the optical coupling by simulations and measurements for 1 mm
- cross-talk issues
- investigation in TiN LEKIDs

- 3rd telescope run foreseen in October 2011