TERAHERTZ IMAGING SYSTEM BASED ON SUPERCONDUCTING INTEGRATED RECEIVER

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MSPU

SCoNTel
Super Conducting NanoTechnology

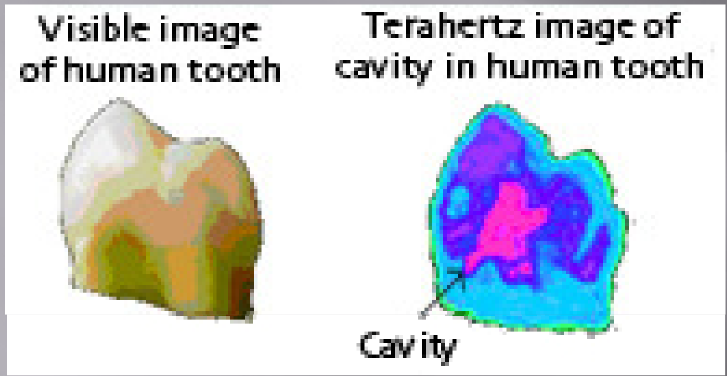
Terahertz Imaging System based on Superconducting Integrated Receiver.

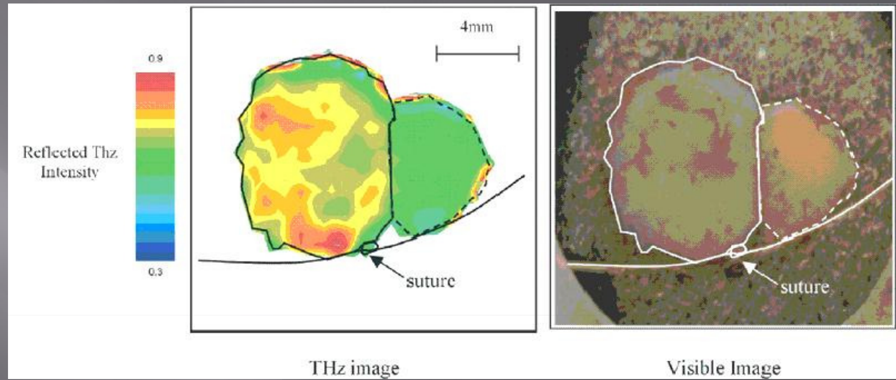
Outline

- Introduction and motivation: overview of several applications of terahertz imaging
- Superconducting Integrated Receiver
- NETD of SIR and applying of terahertz image.
- Conclusions

Possible Application of Terahertz Radiovision

Biological & Medical Applications





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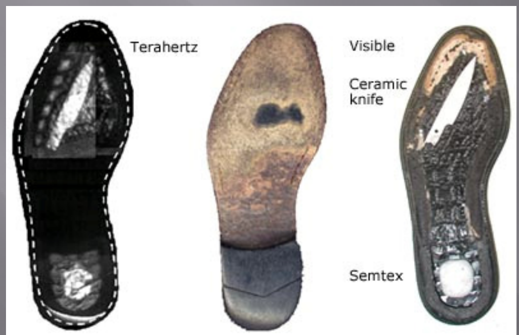
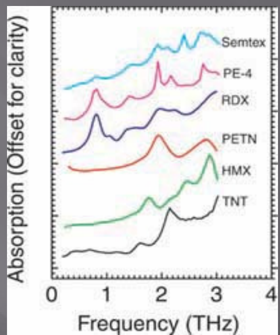
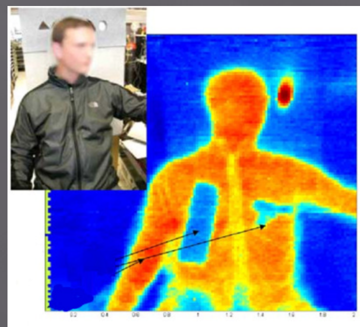
Security Applications







A. Luukanen, et al. An ultra-low noise superconducting antenna-coupled microbolometer with a room-temperature read-out. IEEE Microware and wireless components letters, V.16, No.8

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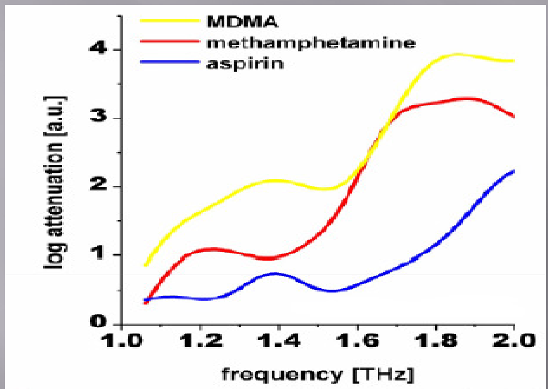
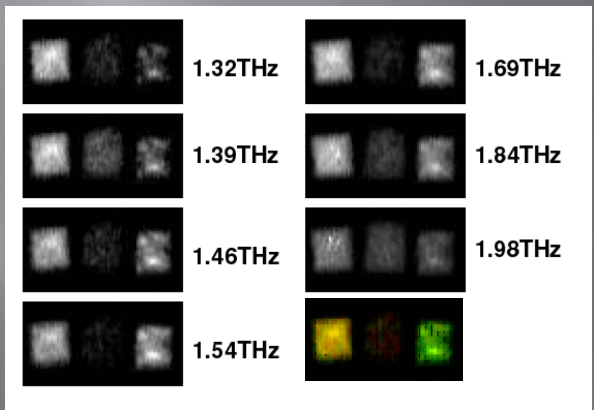
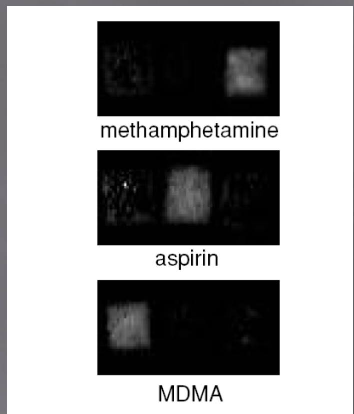
Possible Application of Terahertz Radiovision

Drag Inspection



Terahertz parametric sources and imaging applications. Kodo Kawase, Yuichi Ogawa, Hiroaki Minamide and Hiromasa Ito. Semicond. Sci. Technol. **20** (2005) S258–S265





$$[I] = [S][P]$$

$$[P] = ([S]^{t}[S])^{-1}[S]^{t}[I]$$

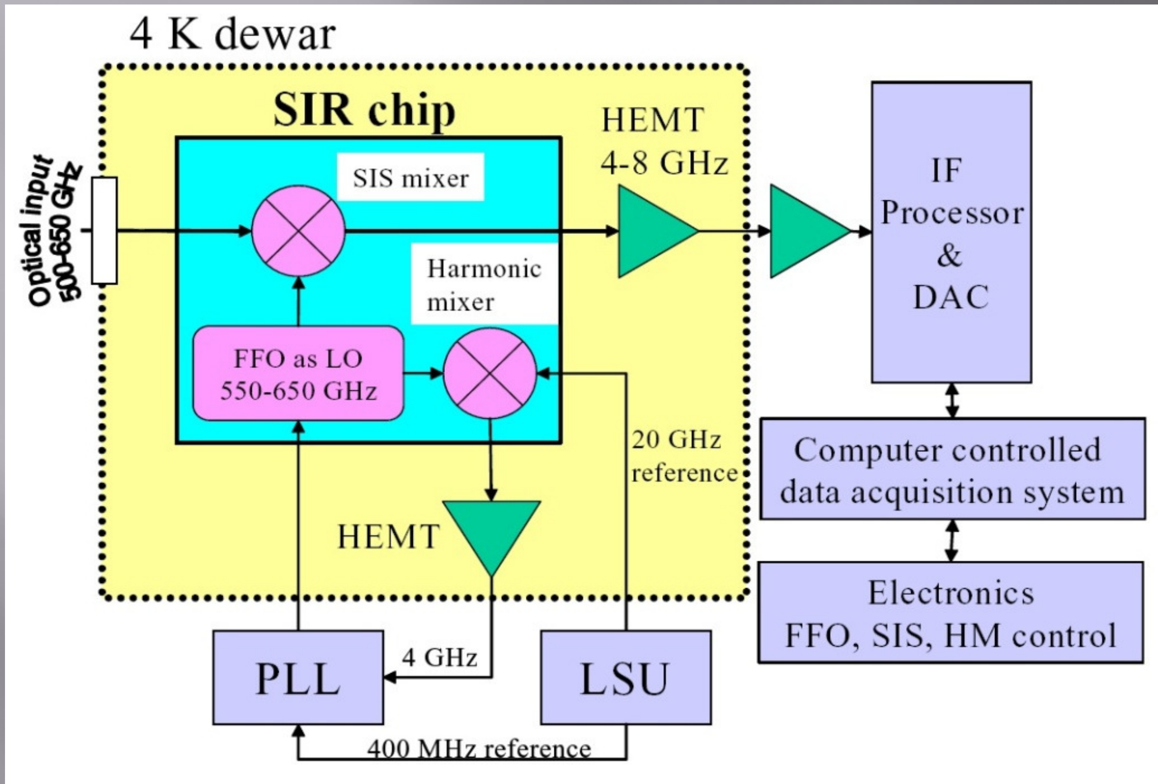
Basic Methods of THz Imaging

- Active THz imaging systems
  - Time domain terahertz pulse system.
  - Active THz imaging system with direct detection or heterodyne receivers.
- Passive THz imaging system
  - Direct detector
  - Heterodyne receiver.

Main advantages of passive imaging system based on heterodyne receiver.

- high temperature resolution, comparable to the best results for incoherent receivers;
- high spectral resolution allowing spectral analysis of various substances;
- the local oscillator frequency can be varied to obtain images at different frequencies, effectively providing "color" images;
- since a heterodyne receiver preserves the phase of the radiation, it is possible to construct 3D images.

Superconducting Integrated Receiver

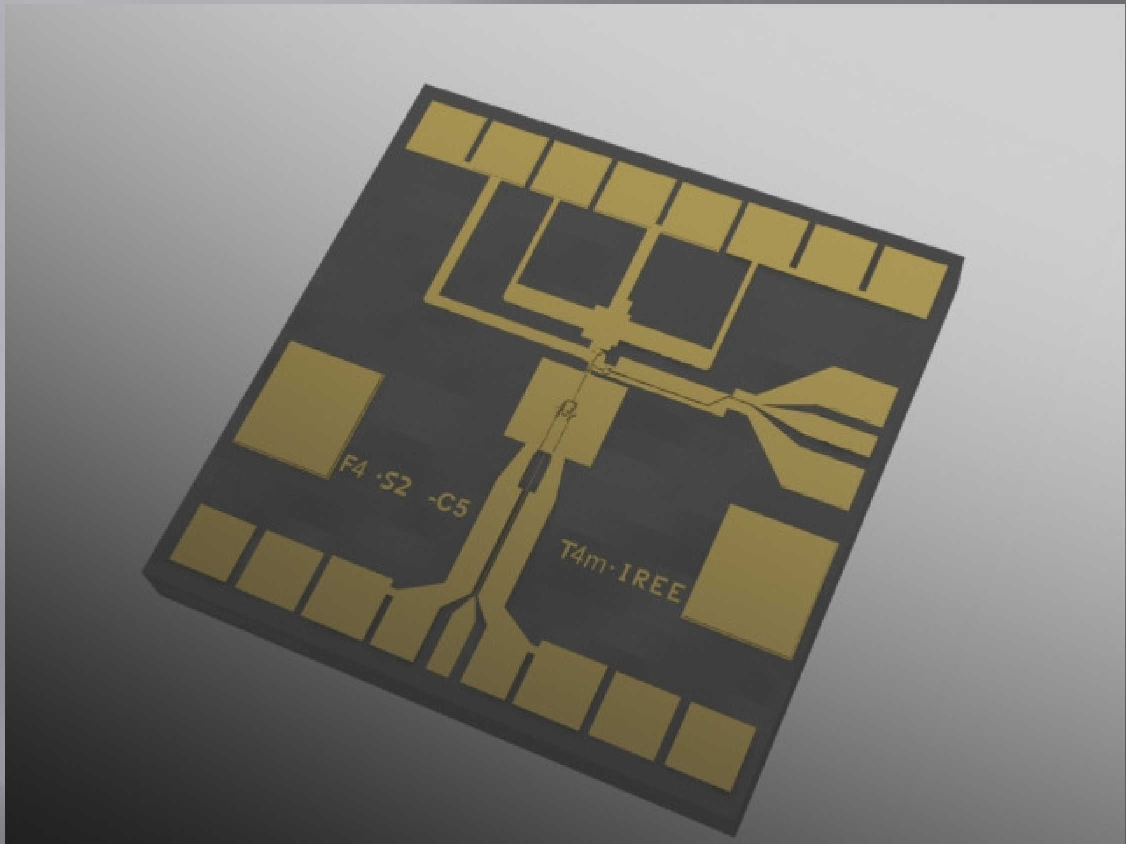


TELIS – TeraHertz Limb Sounder

Koshelets V.P., Shitov S. V., Filippenko L. V., et al. // Appl. Phys. Lett. 1996. V. 68. 9. P. 1273.

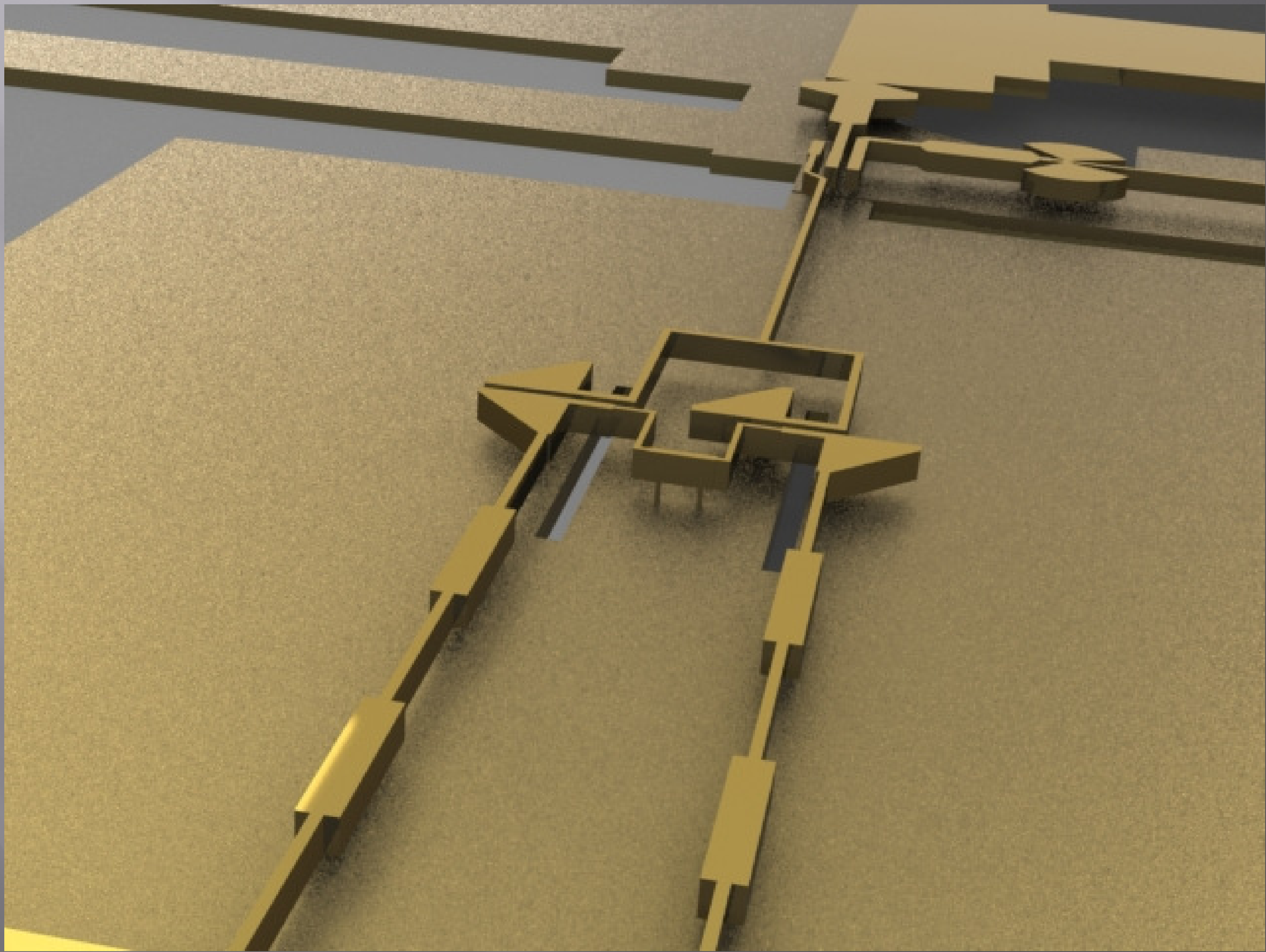
Gert de Lange, et al. “Development and Characterization of the Superconducting Integrated Receiver Channel of the TELIS Atmospheric Sounder”, Supercond. Sci. Technol. vol. 23, 045016 (8pp), (2010).

Superconducting Integrated Receiver

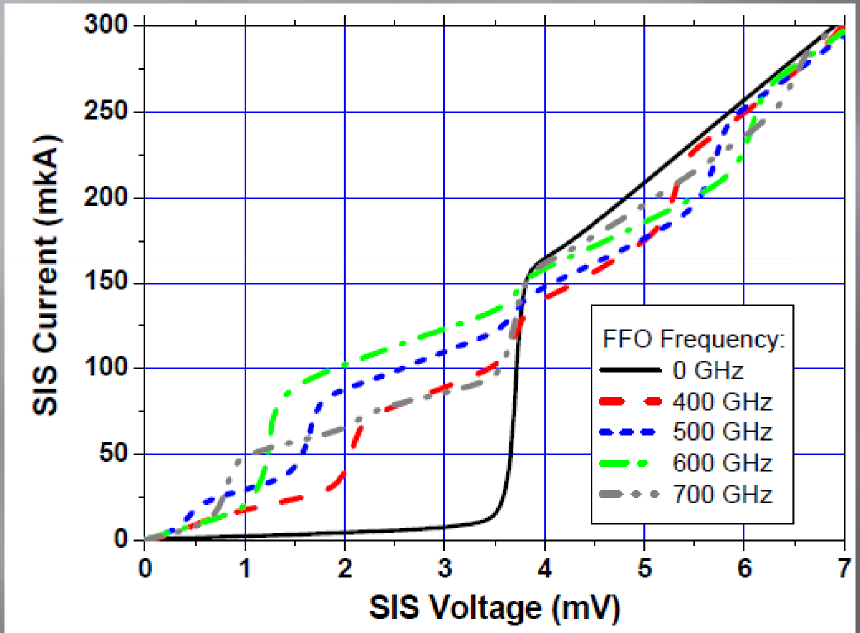


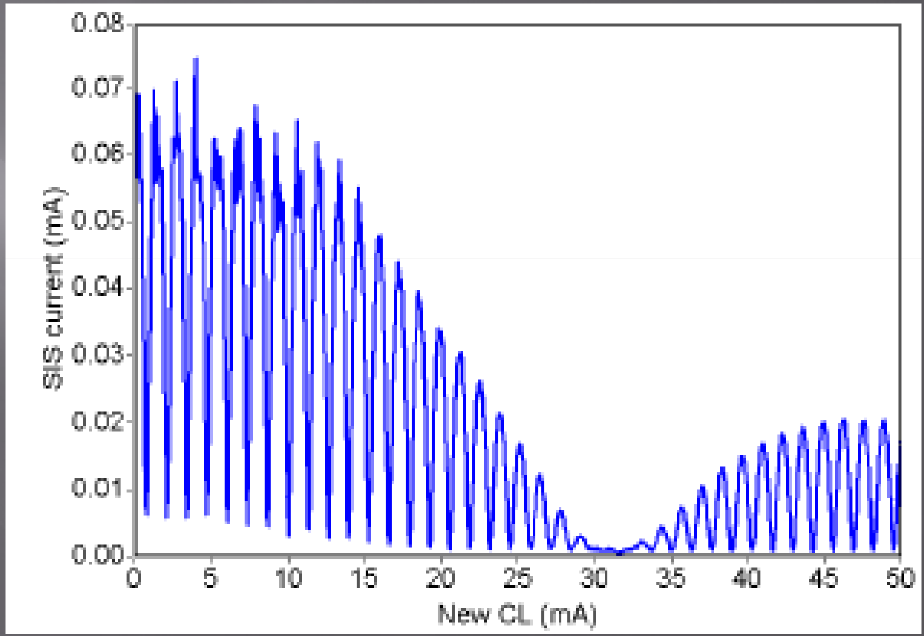
Tehnology:
nanostructure Nb–AlOx–Nb
or Nb-AlN-NbN
on Si substrate.
Critical current density:
Jc = 3 – 8 кA/sm^2;
Tunnel barrier thikness :
~ 1 nm;
SIS junction square:
S_{SIS} ~ 1 µm2
Microchip size: 4x4x0.5 mm^3

SIS-mixer

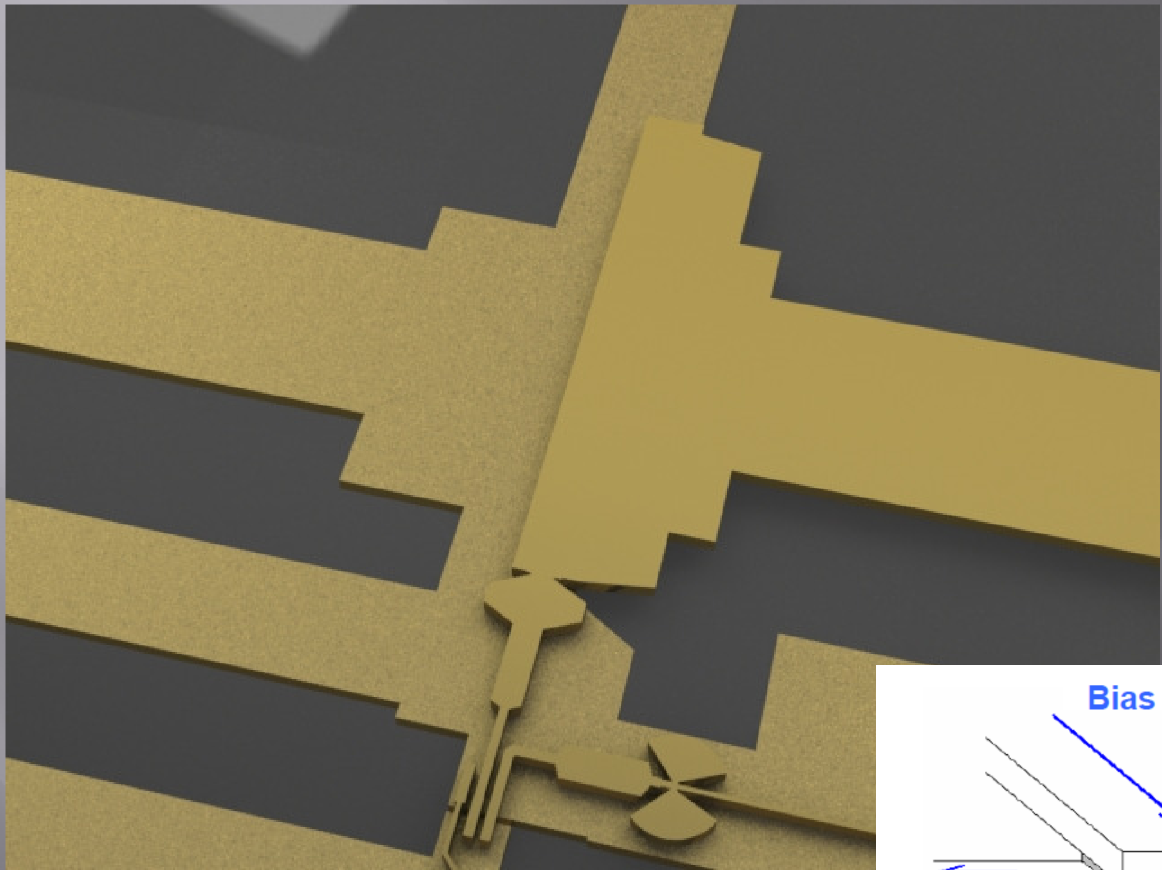


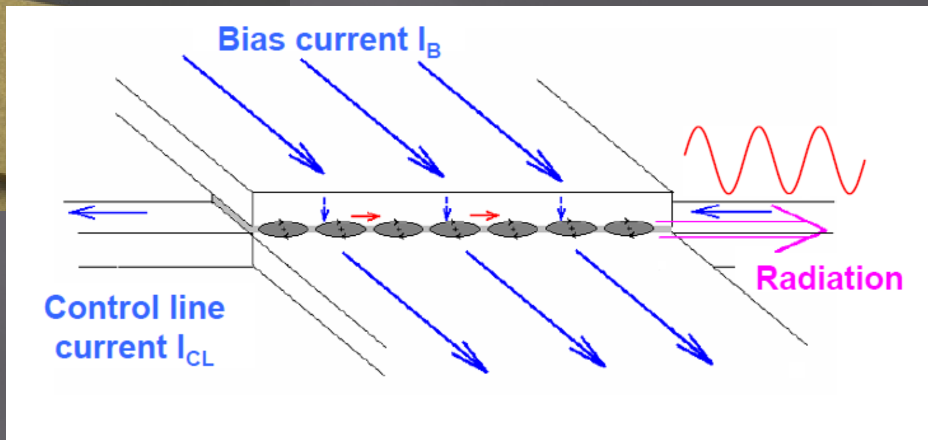
Basic characteristics of SIS mixer



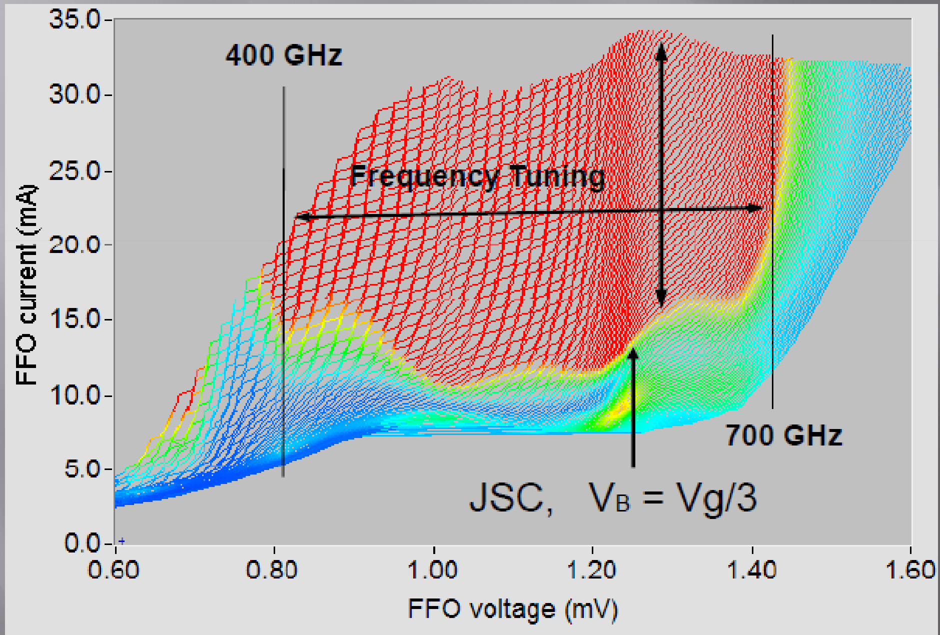


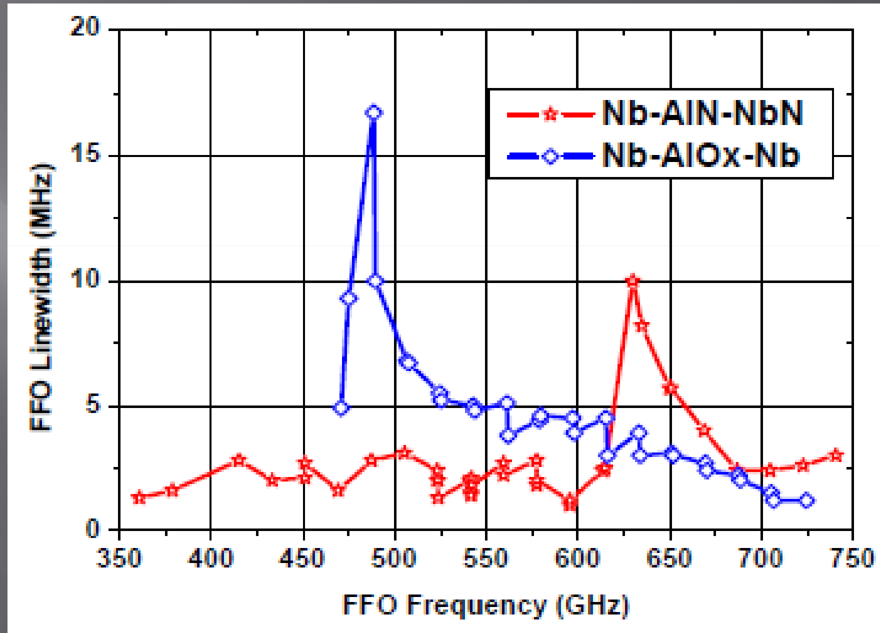
Flux Flow Oscillator as Local Oscillator to pump SIS mixer





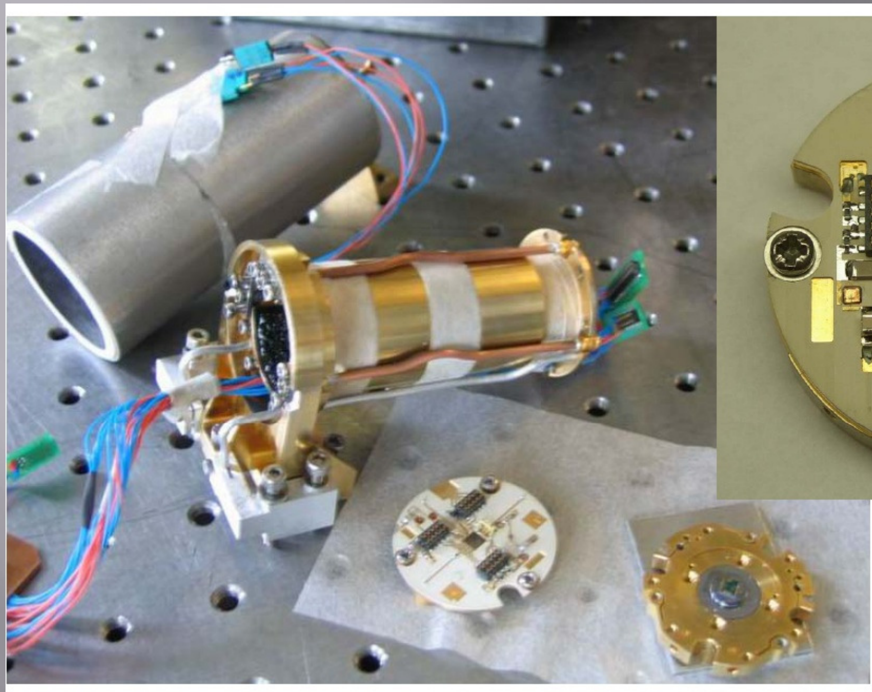
Basic characteristics of FFO

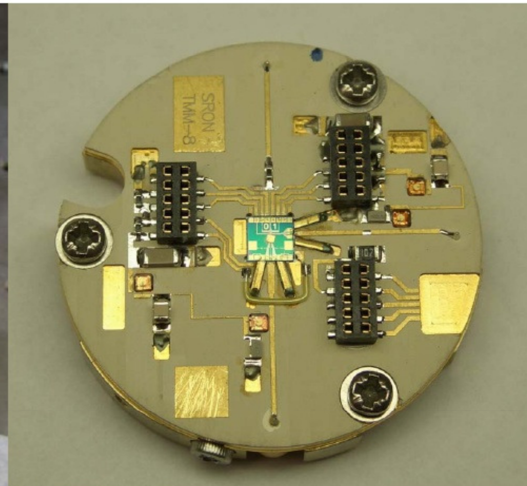


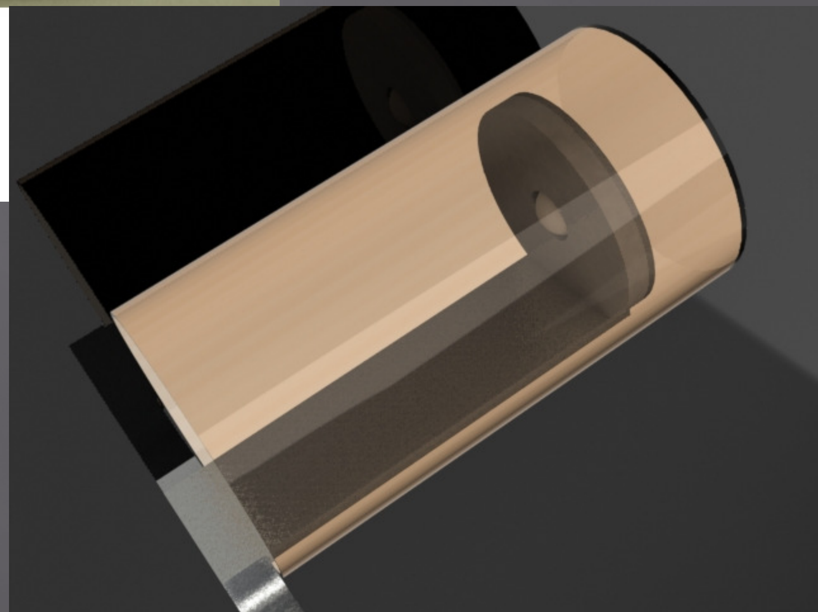


V.P. Koshelets, et al, Phys. Rev. B, vol. **56, pp 5572-5577, (1997)**

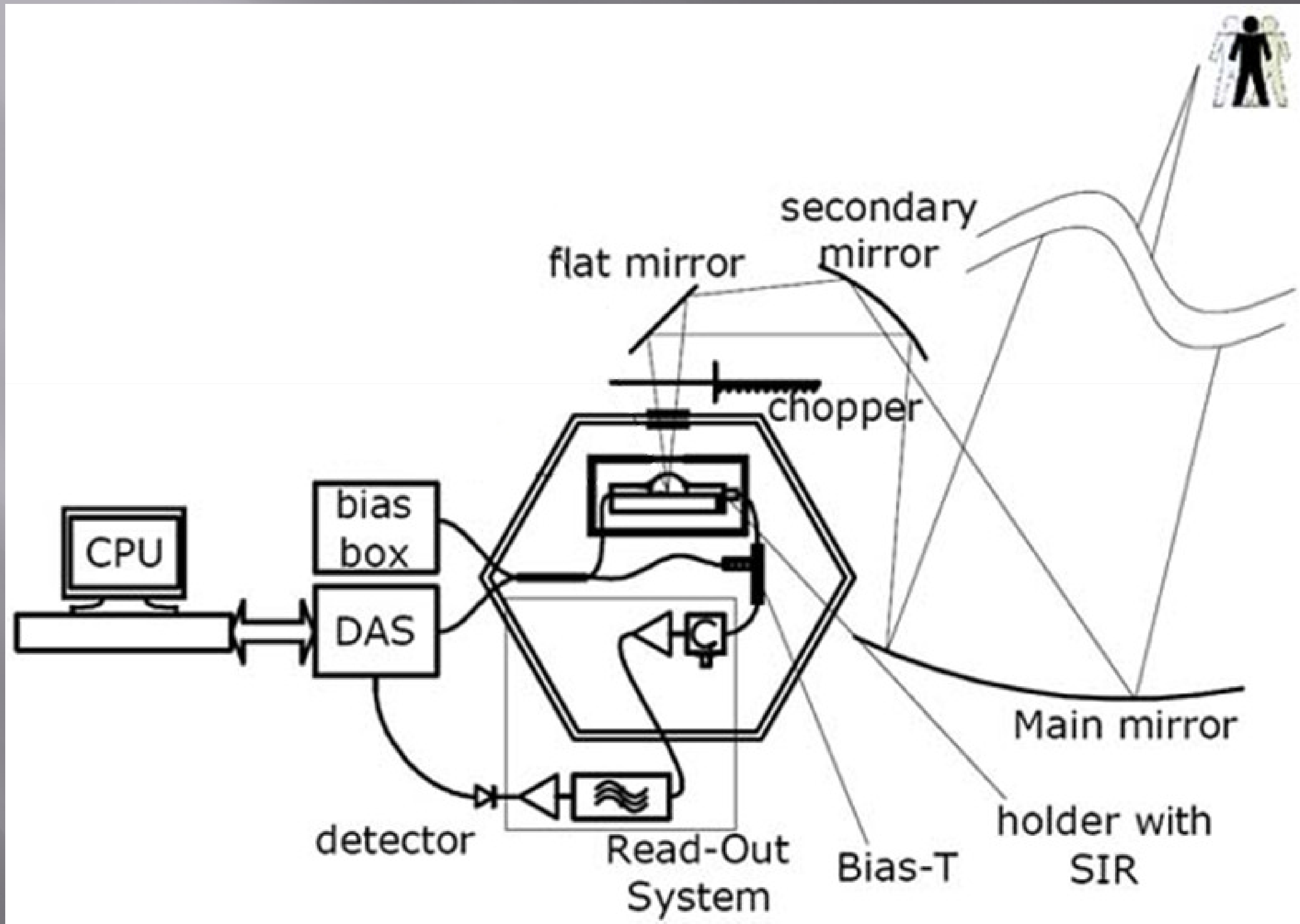
Chip holder



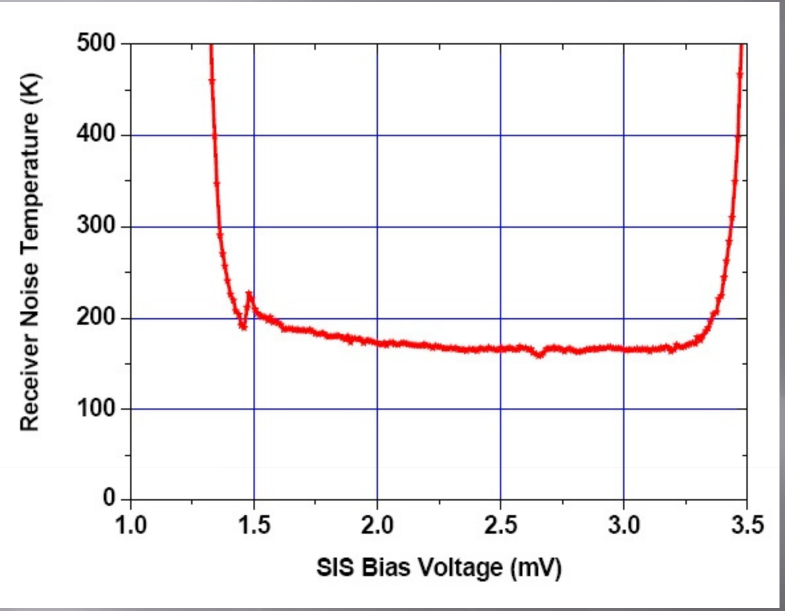


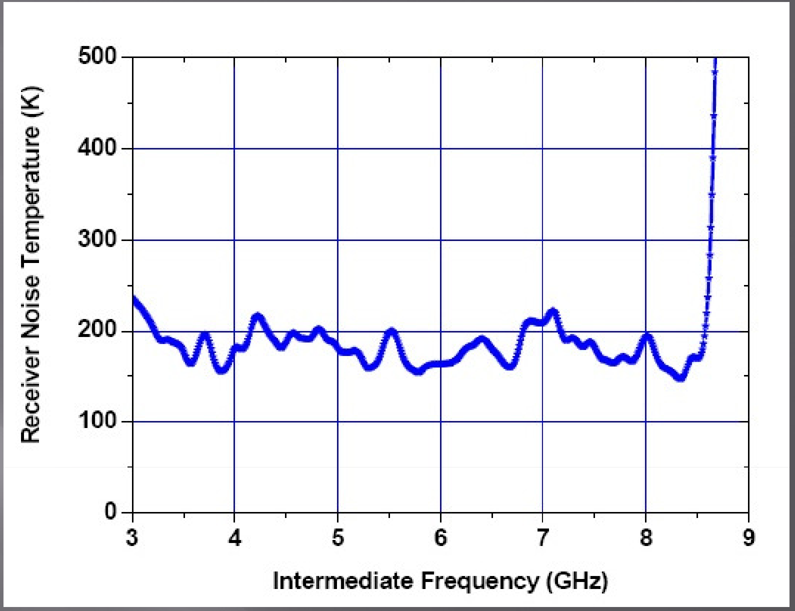


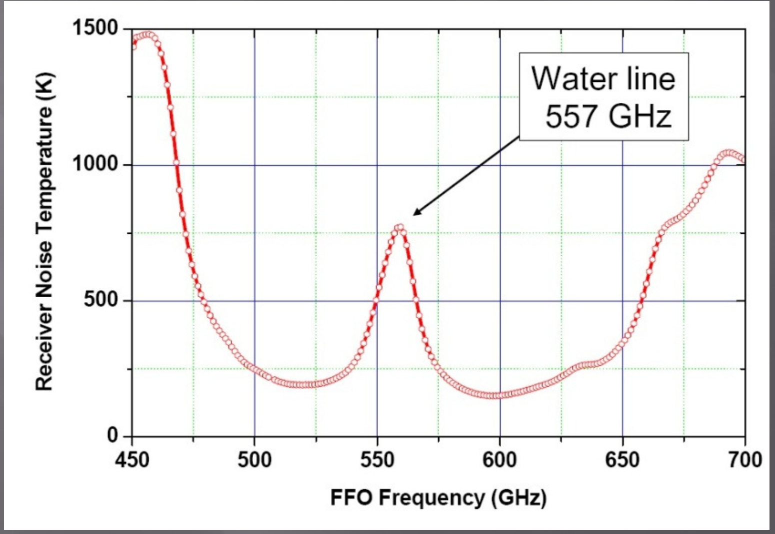
Laboratory setup



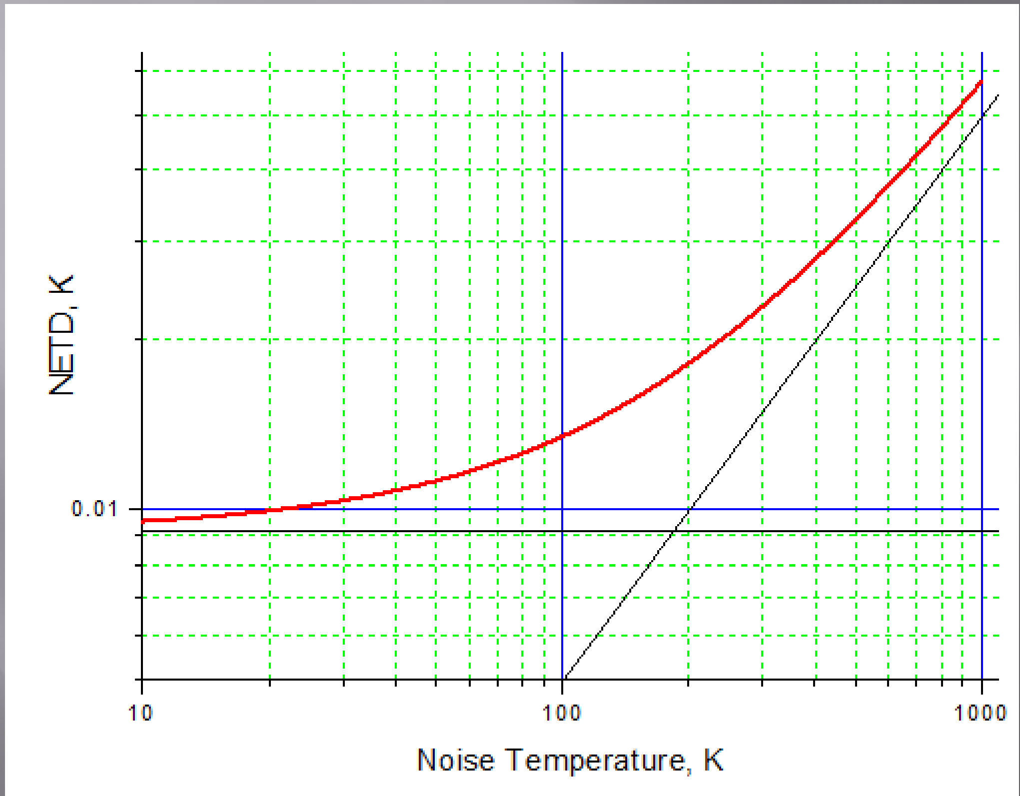
Noise performance of SIR







Noise equivalent temperatures difference versus noise temperatures



$$\Delta T_H = \alpha T_N \sqrt{1 + \frac{3}{8}\left(\frac{T_S}{T_N}\right)^2 + \frac{T_S}{T_N}} \frac{1}{\sqrt{B_H \Delta t}}$$

$$T_N >> T_S \qquad \Delta T_H = \alpha T_N \frac{1}{\sqrt{B_H \Delta t}}$$

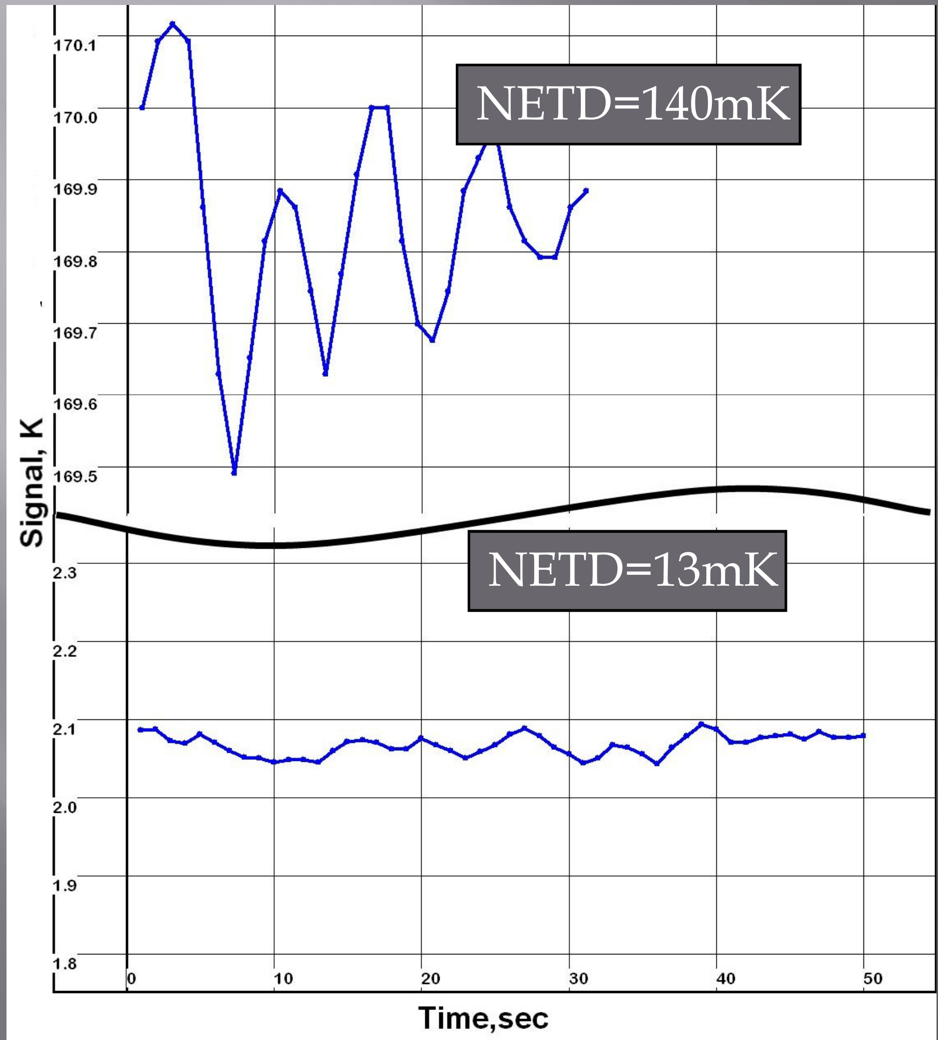
$$T_N << T_S \qquad \Delta T_H = 0.612 \alpha T_S \frac{1}{\sqrt{B_H \Delta t}}$$

$$\alpha = \pi \qquad T_S = 300K$$

$$(B_H = 4GHz, \ \Delta t = 1sec)$$

Esepkina N. A., Korol'kov D. V., Pariyskiy Yu. N. Radiotelescopes and radiometers.1973. //in Russian.

NETD of SIR



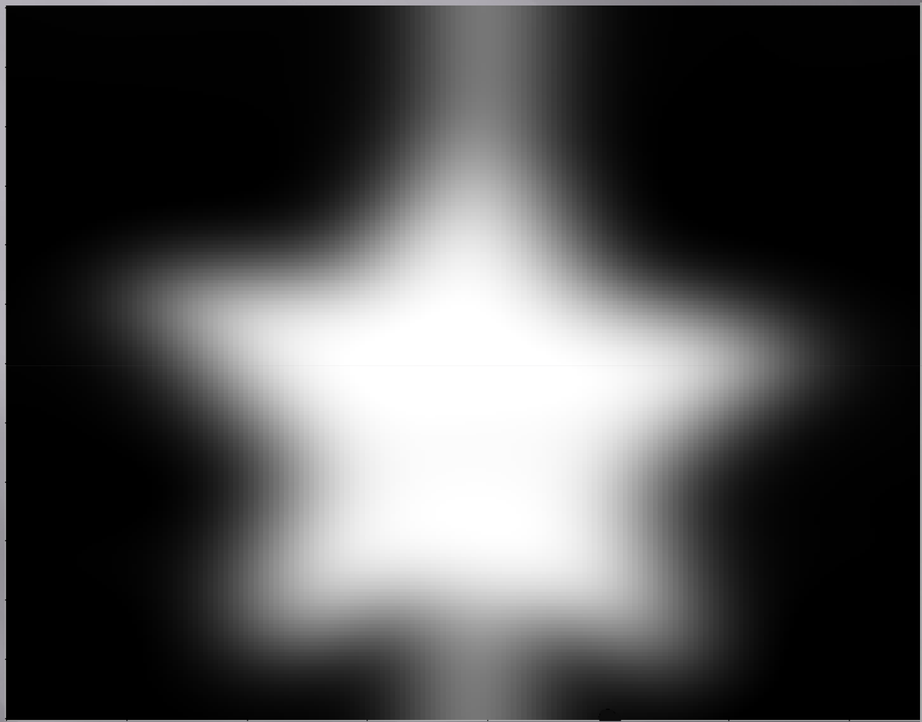
$$\Delta T = \sqrt{\overline{\Delta T_n^2} + \overline{\Delta T_a^2}}$$

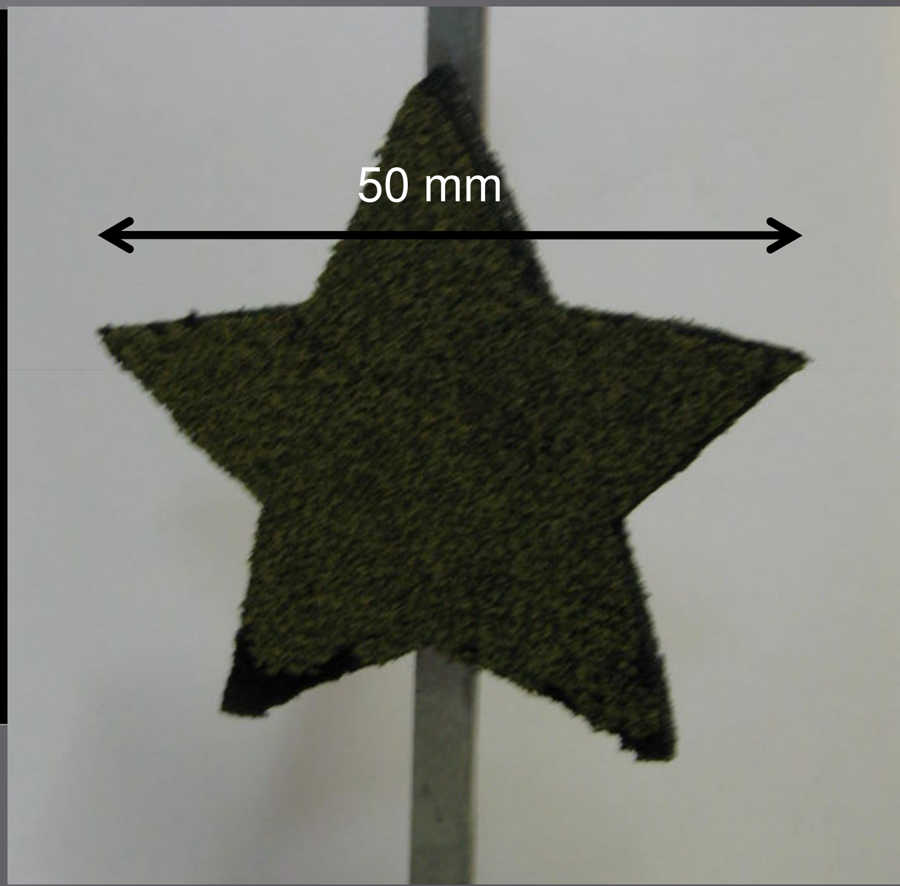
$$\Delta T_a = \sqrt{\overline{\Delta T_1^2} + \overline{\Delta T_2^2}}$$

$$\overline{\Delta T_1}^2 \propto T_N \int_{F-\Delta F}^{F+\Delta F} S_G df$$

$$\overline{\Delta T_3}^2 \propto (T_M - T_S)^2 \int_0^{\Delta F} S_G df$$

Example of Image applying with one pixel SIR and mechanical scanning





Objects temperature	300 K
Background temperature	284 K
Spatial resolution	2 mm
Diameter of optics	100 mm

Conclusions

- In present time we have one pixel receiver with mechanical scanning.

  NETD ~ 13 mK. Spatial resolution ~ 2 mm.
- Next step: array of SIRs. Decreasing shot time and optics simplification .