Heterodyne THz array receivers: design challenges

V. Belitsky

Group for Advanced Receiver Development
Department of Earth and Space Sciences
Chalmers University of Technology
Gothenburg, Sweden

An Unusual English Regency Enameled Metal Ear Trumpet, **circa 1820**.
10-1/2 inches long (26.7 cm). Imaged by Heritage Auctions, HA.com

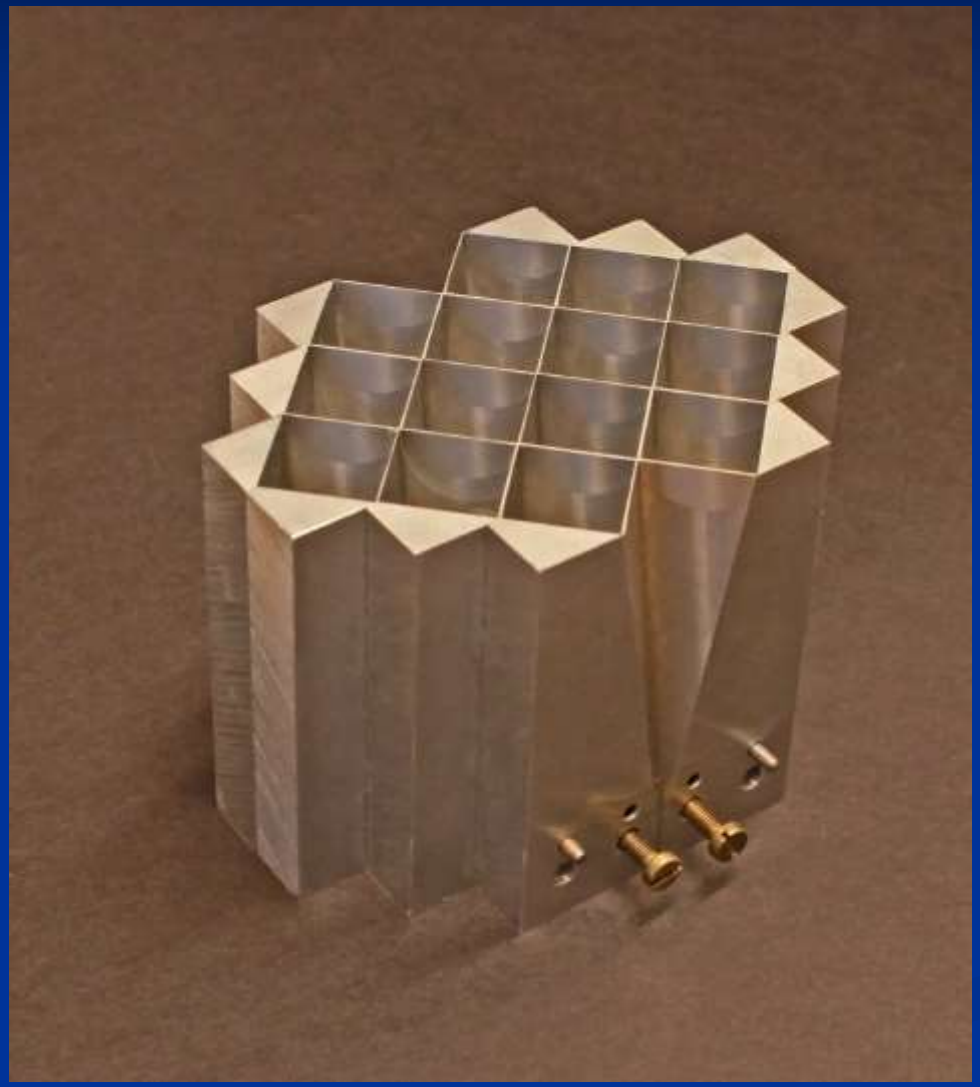
Outline

- SISYFOS project
- THz arrays: SIS vs HEB;
- THz arrays: optics;
- THz arrays: LO injection;
- THz arrays: integrated mixer design;
- Concluding remarks.

SISYFOS Project 1996

- Multi-pixel SIS receiver for Onsala 20 m antenna;
- 4x4 diagonal horn array;
- Fix-tuned SIS mixer with 0.6 GHz wide IF;
- Polarization rotation interferometer used for SSB operation;
- Gaussian-telescope partly cold optics;
- Combination of reflective optic and lens;
- LO feed system employing holographic forming of 16 beams with individual tuning of the power;
- Cooling, home-made J-T adjustable 1.5 W @4K.

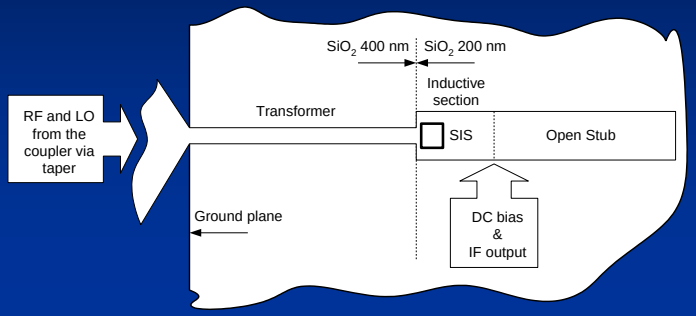
SISYFOS Project 1996

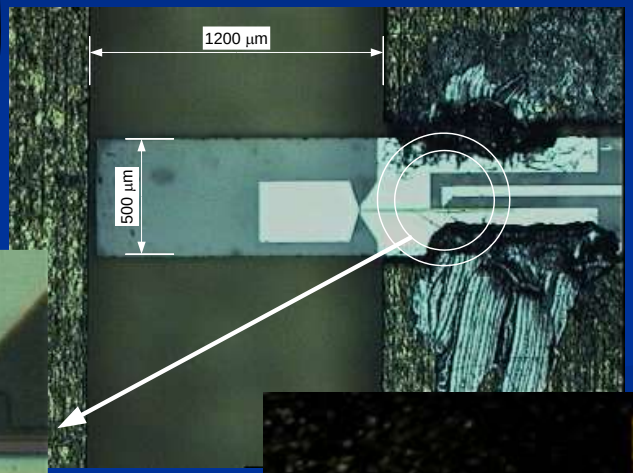


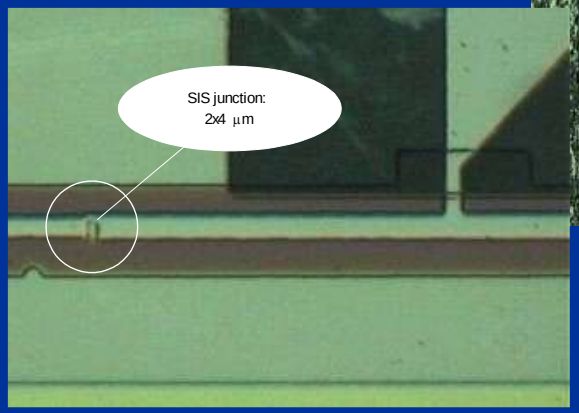
- 4x4 diagonal horn array;

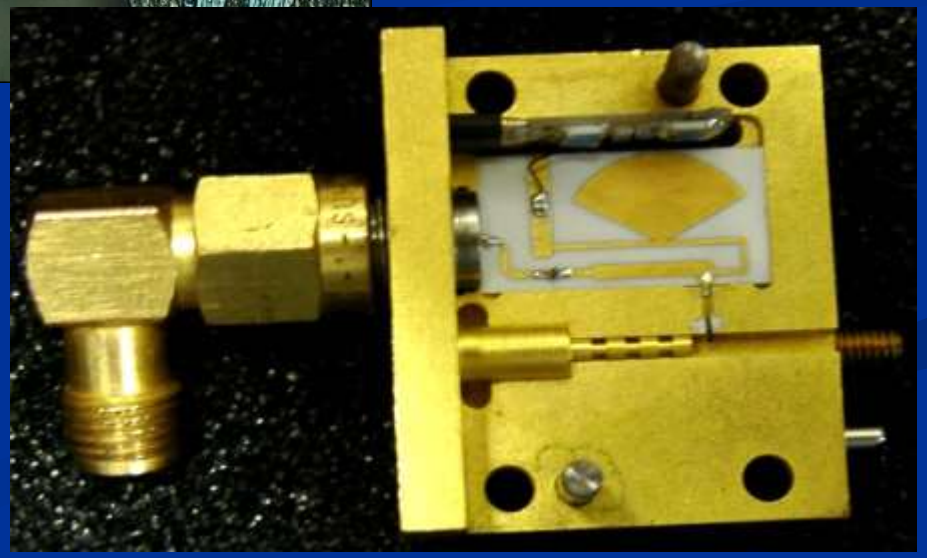
SISYFOS Project 1996

- **Fix-tuned SIS with 0.6 GHz wide IF;**



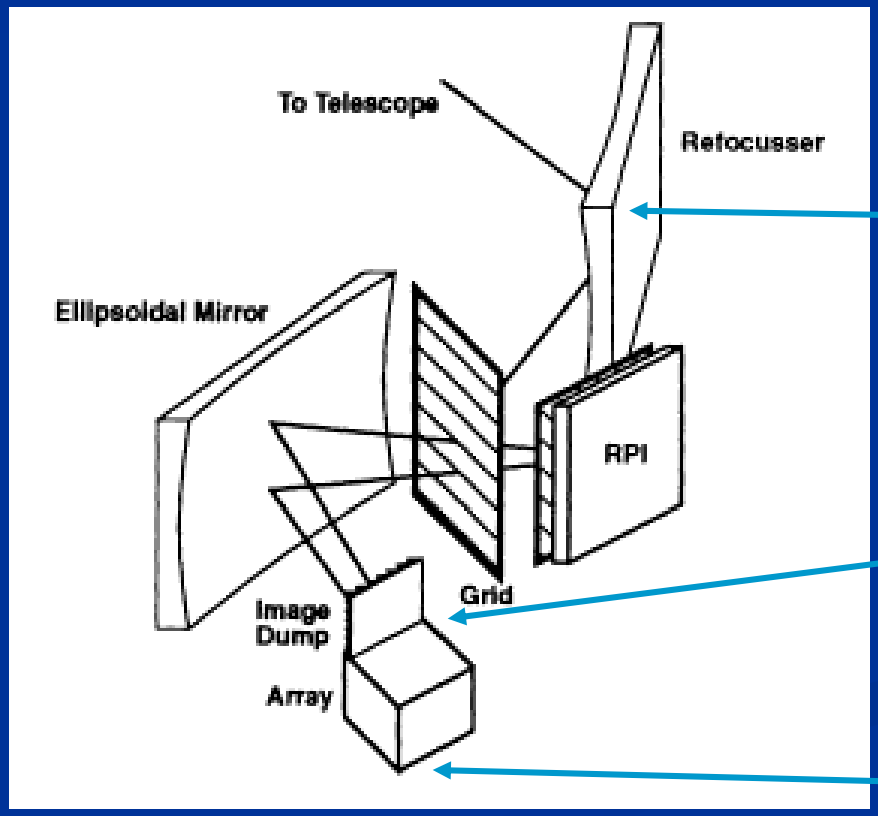






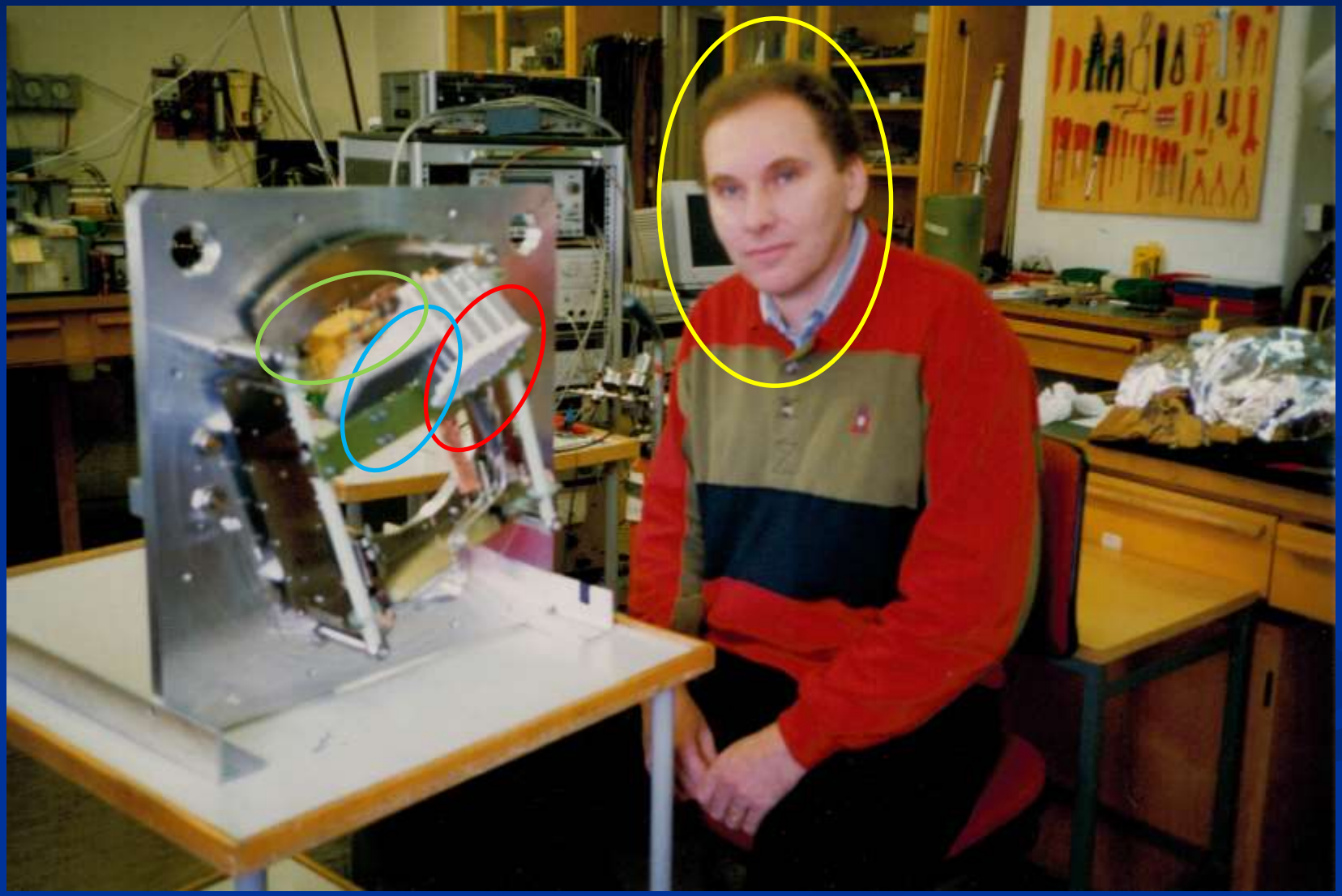
SISYFOS Project 1996

- Polarization rotation interferometer used for SSB operation;
- Gaussian-telescope partly cold optics;



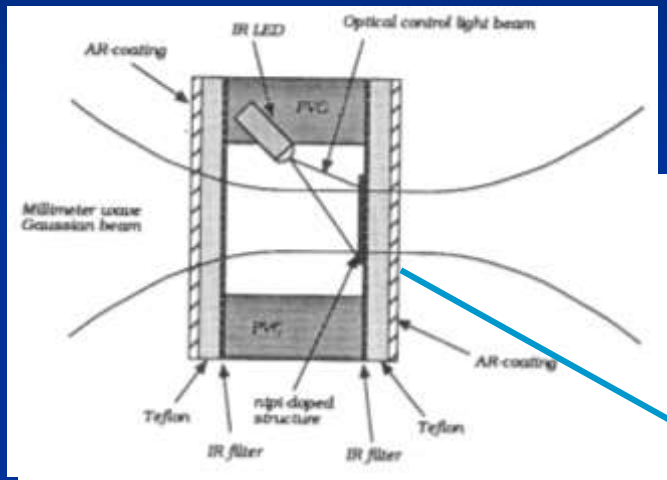
- Combination of reflective optic and lens;

SISYFOS Project 1996



SISYFOS Project 1996

- LO feed system employing holographic forming of 16 beams with individual tuning of the power;



SISYFOS Project 1996

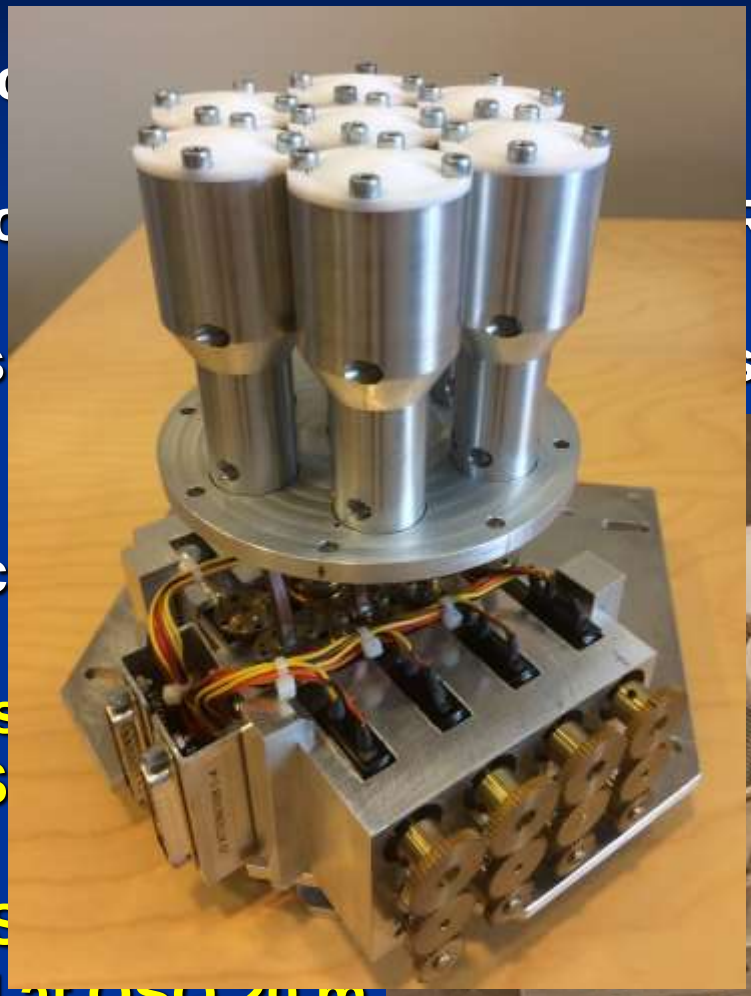
- **Cooling, home-made J-T adjustable 1.5 W @4K.**

SISYFOS Project 1996

- Issue with power dissipation of IF amplifiers;
- Issue with high cross-pol of the diagonal horns and RPI*;
- Issue with standing waves, multi-reflection and crosstalk in LO system**;
- Issue of RF losses in optics (lens);
- It does not help if several separate projects get merged into SISYFOS!
- The SIS mixer (in tunable SSB version) with new IF amp was used at OSO 20 m in single-pixel conf. for next 5 years;

SISYFOS Project 1996

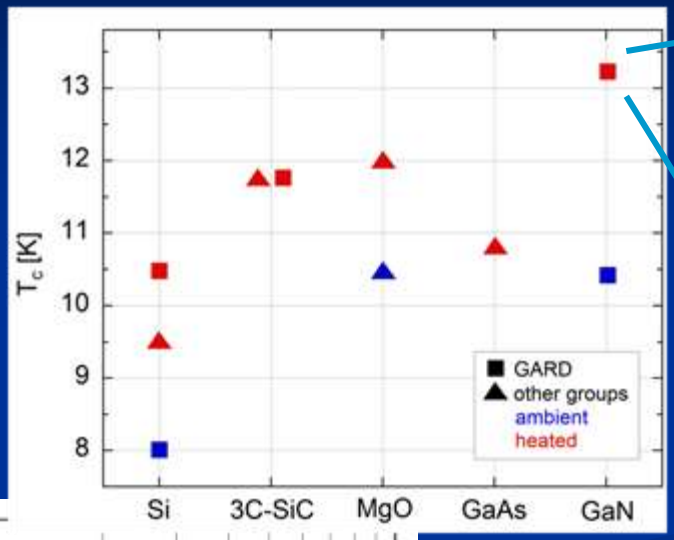
- Issue with power dissipati
- Issue with high cross-pol c RPI*;
- Issue with standing waves stalk in LO system**;
- Issue of RF losses in optic
- It does not help if several s projects get merged into S
- The SIS mixer (in tunable S with new IF amp was used at OSO 20 m in single-pixel conf. for next 5 years;

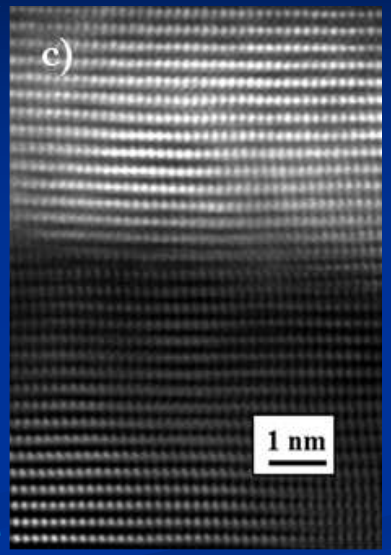


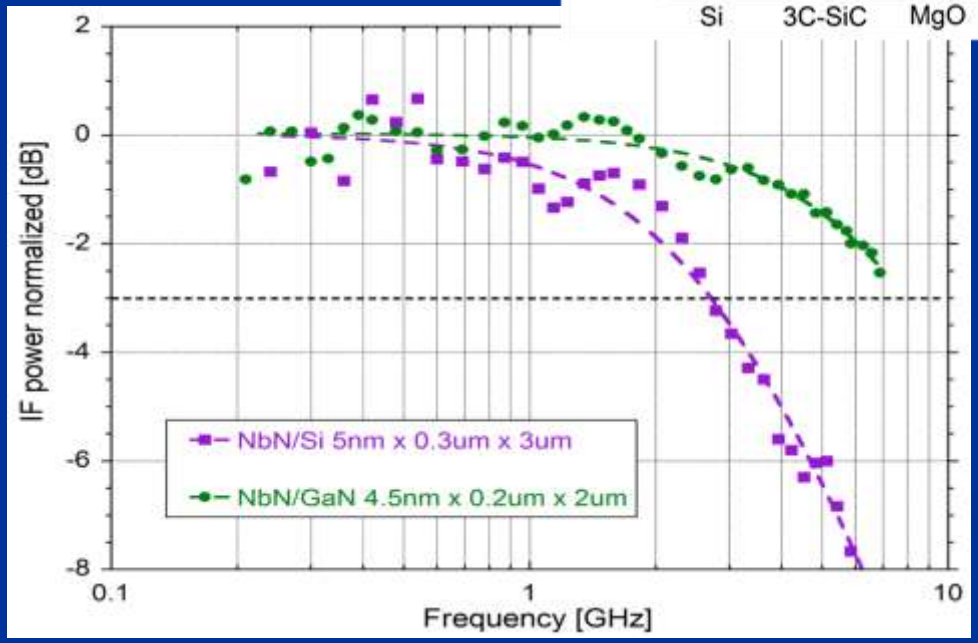
THz arrays: SIS vs. HEB

- SIS mixers are RF limited (Gap frequency and x2 Gap frequency);
- SIS mixers require tuning circuitry and higher LO power (comp. to HEB);
- SIS mixers require magnetic field to suppress Josephson current;
- Tnoise cross-over SIS / HEB around 1.2 THz ?;
- HEB mixers are IF limited (material properties);
- HEB mixers require RF pass-band control (direct bolometric effect / saturation with QO design);
- HEB stability – is it an HEB or LO issue?

Towards Wide-IF NbN HEB



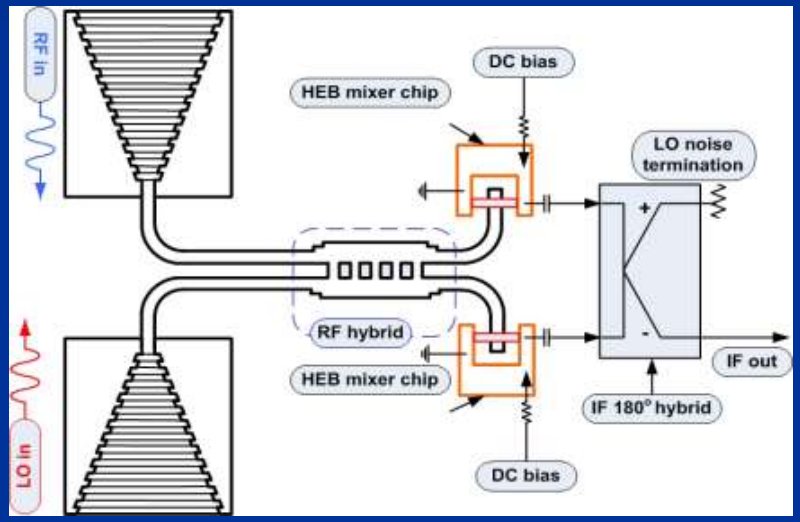




More details: poster by V. Desmaris et.al.

HEB stability: is it an HEB or LO issue

MELEDIN *et al.*: "1.3-THz BALANCED WAVEGUIDE HEB MIXER FOR APEX TELESCOPE", IEEE MTT., 2009



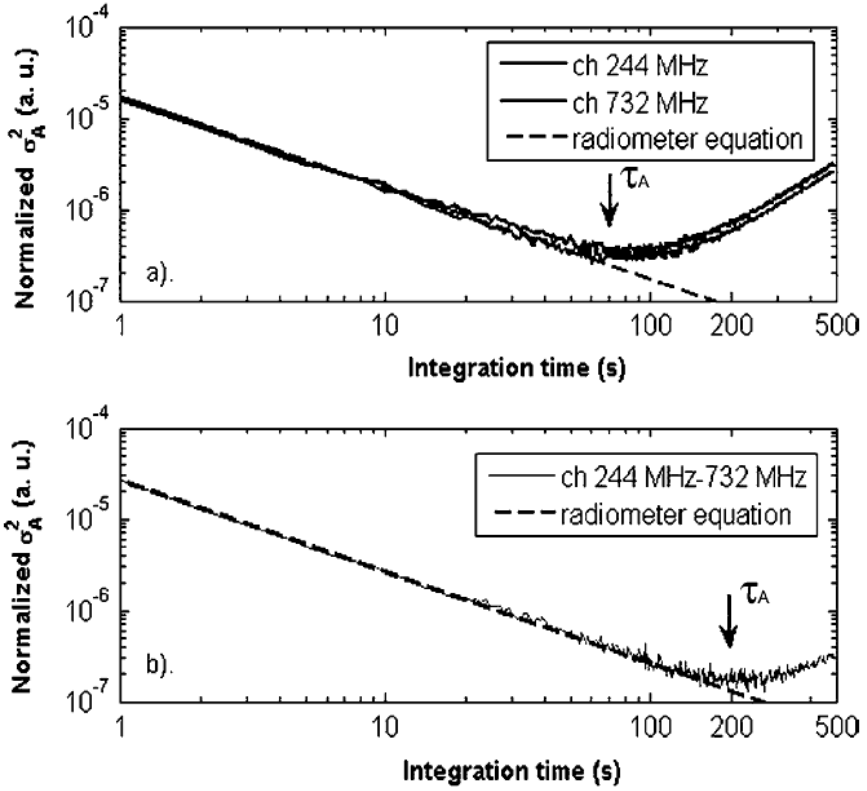
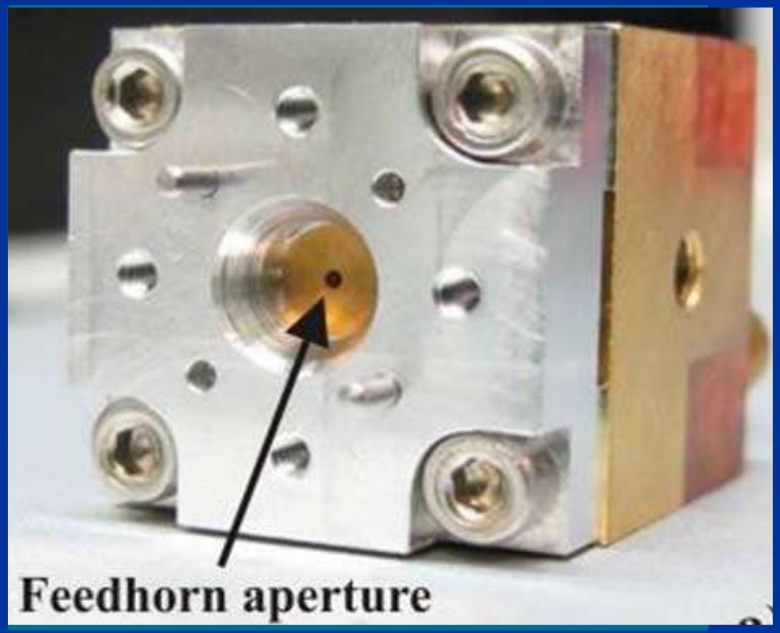


Fig. 12. (a). Normalized total power Allan variance for an LO of 1316 GHz and measured in the laboratory using the 244- and 732-MHz FTTS channels. The channel bandwidth is 61 kHz. The shape of the Allan variance shows no noticeable domination of the $1/f$ noise, in contrast to [10]. (b). Spectroscopic Allan variance measured by subtracting the channels. The dotted line shows the theoretical time dependence of Allan variance according to the radiometer equation.

More details: poster by V. Desmaris et.al.

THz arrays: optics

- Re-imaging of the array input to telescope focal plane;
- Combine RF and LO;
- Conflict between feed size, optimum pixel pitch and the mixer footprint;

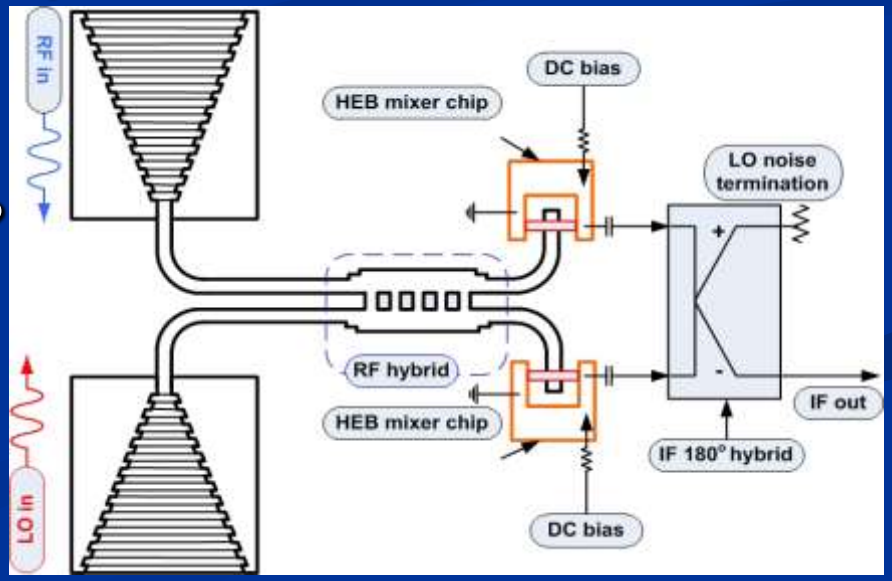


BÜCHEL *et al.*: 4.7-THZ "SUPERCONDUCTING HOT ELECTRON BOLOMETER WAVEGUIDE MIXER", IEEE Terahettz Sci.Tech., 2016

C. Risacher. et.al., "First Supra-THz Heterodyne Array Receivers for Astronomy With the SOFIA Observatory", IEEE Terahettz Sci.Tech., 2016

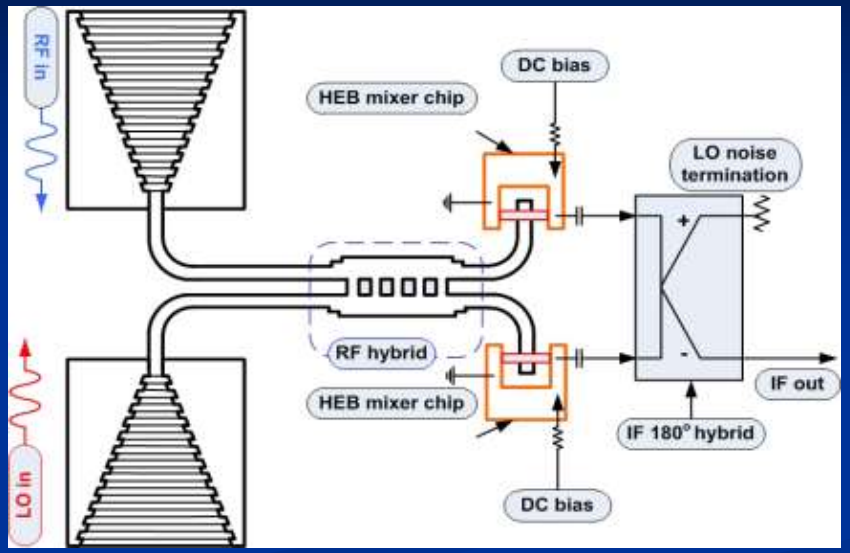
THz arrays: optics & LO

- Is the hexagonal layout optimum (central pixel?);
- Linear array with inter-leaved polarization for a tighter pitch?
- Maximum number of pixels attainable (e.g. OST calls for 16 pixels for 2-2.7THz) due to optics?
- Where to inject the LO?*;
- Options for the LO injection?

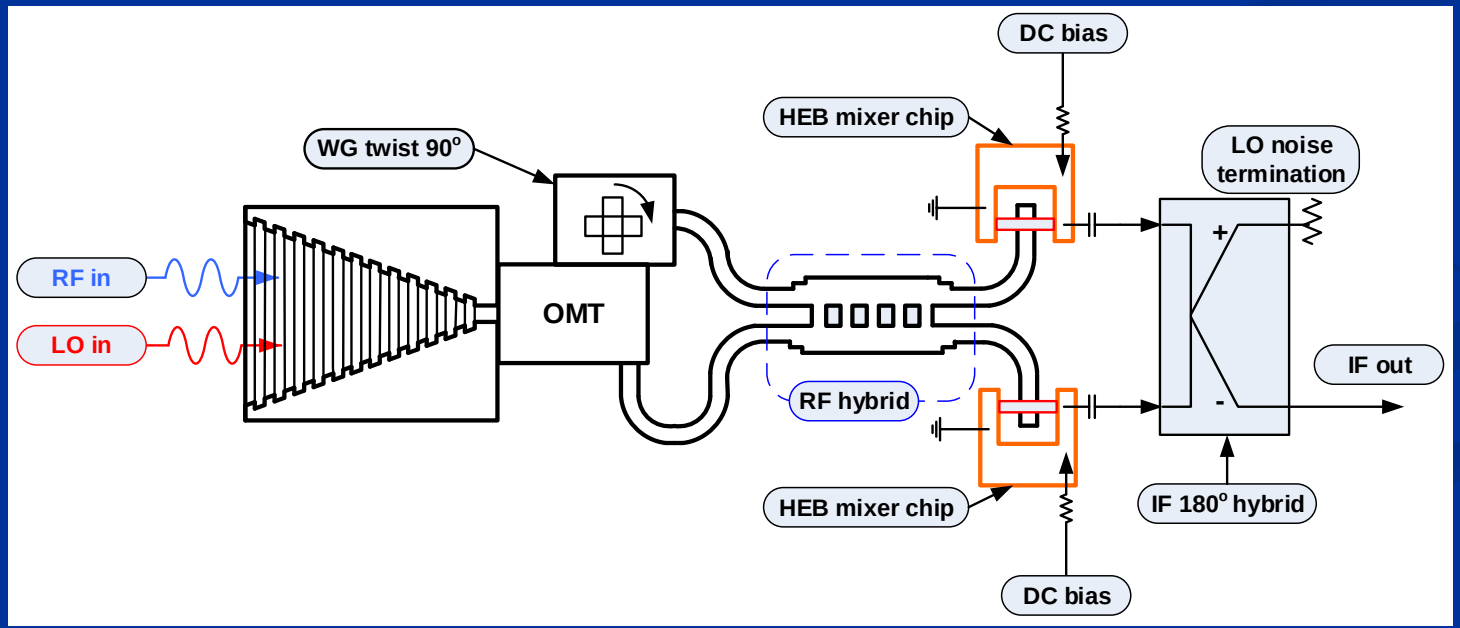


THz arrays: LO

- Options for the LO injection: beam-splitter, grid *, integrated cold multiplier?



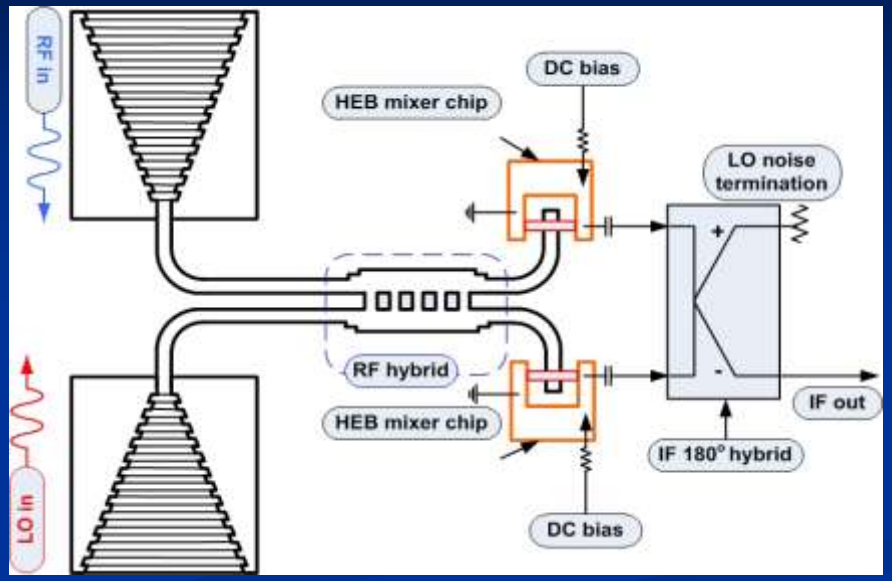
More details: poster by V. Desmaris et.al.

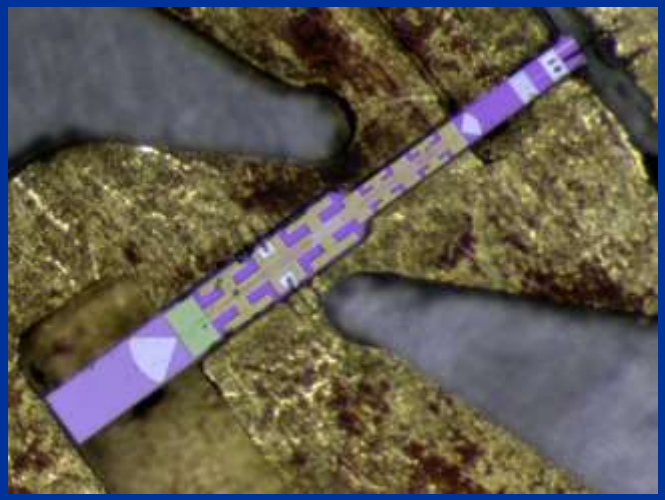


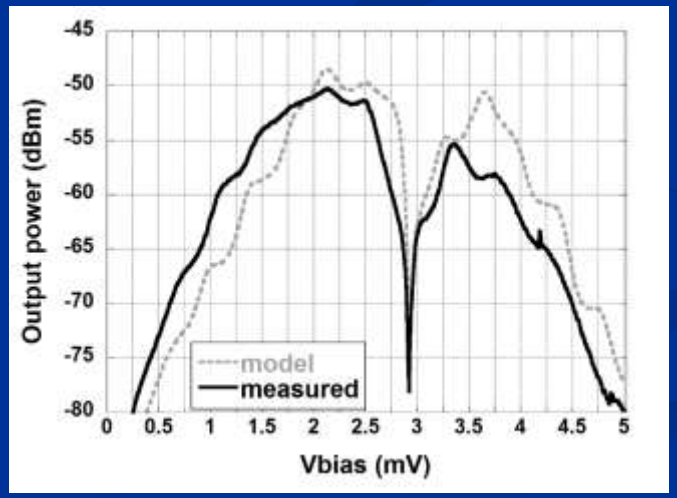
THz arrays: LO

- Options for the LO injection: beam-splitter, grid, integrated cold multiplier*?

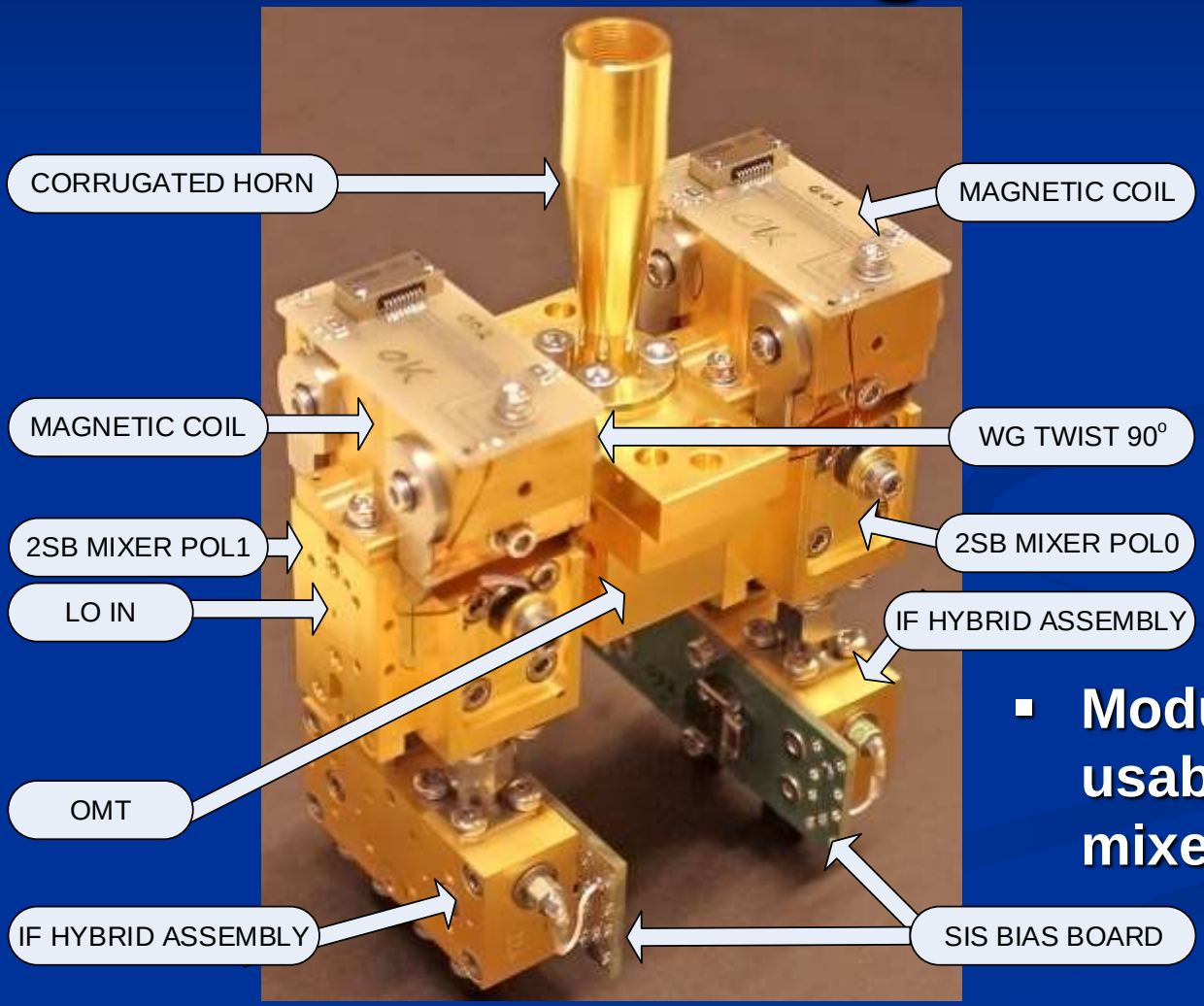
More details: poster by V. Desmaris et.al.







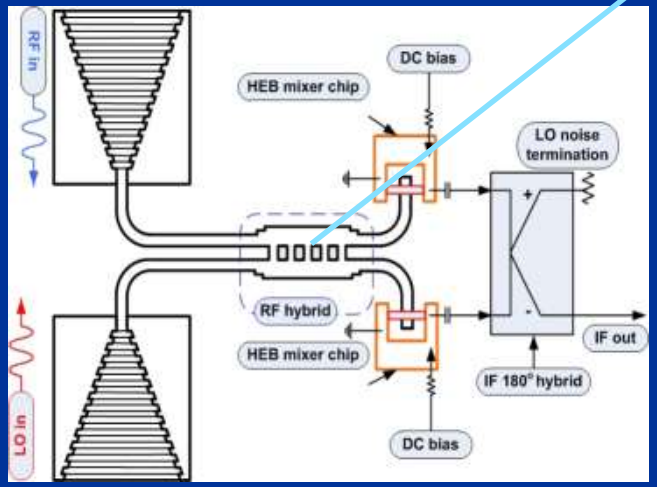
THz arrays: integrated mixer design

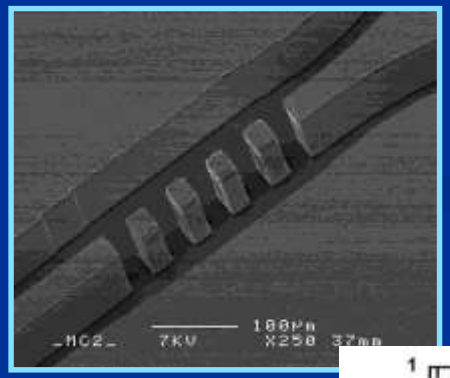


- **Modular design unlikely usable for THz arrays mixers;**

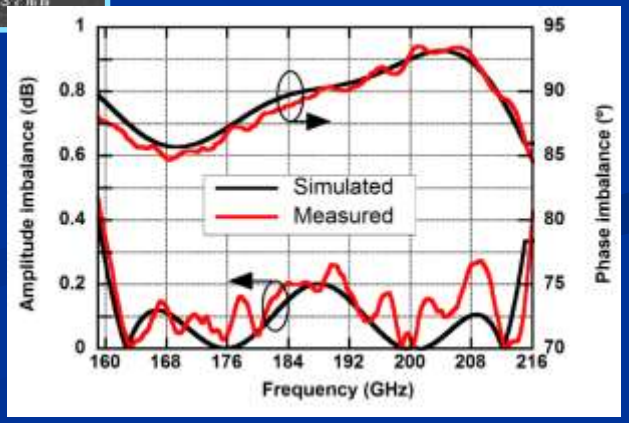
THz arrays: integrated mixer design

- Waveguide components – micromachining;
- Wide RF, e.g. 1.6-2.15 THz;



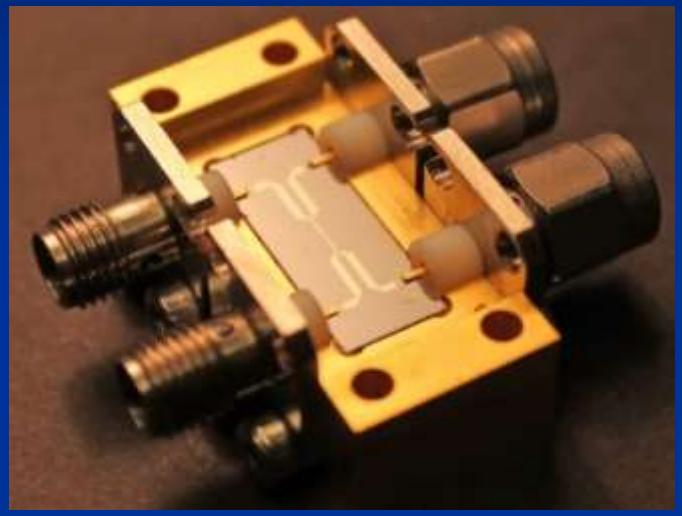


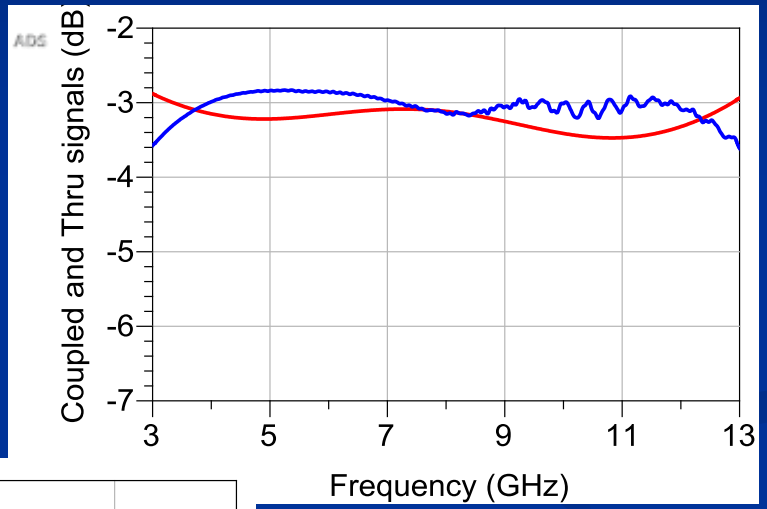
More details: poster by V. Desmaris et.al.

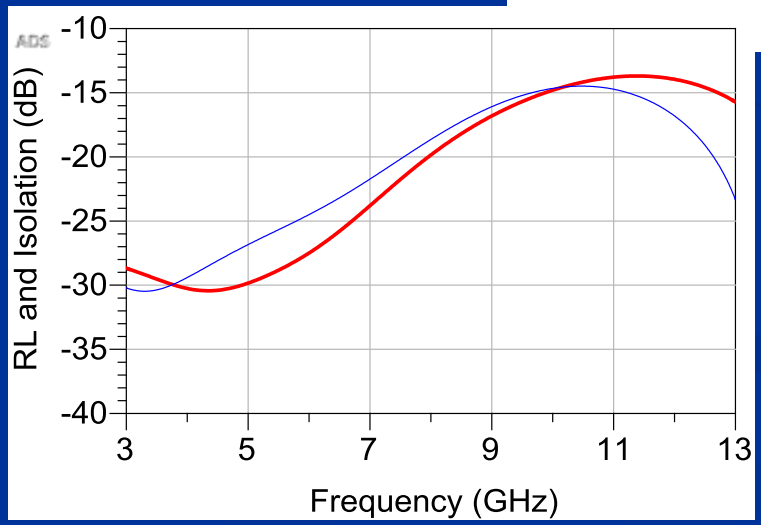


THz arrays: integrated mixer

- **Superconducting IF components to be built into mixer;**





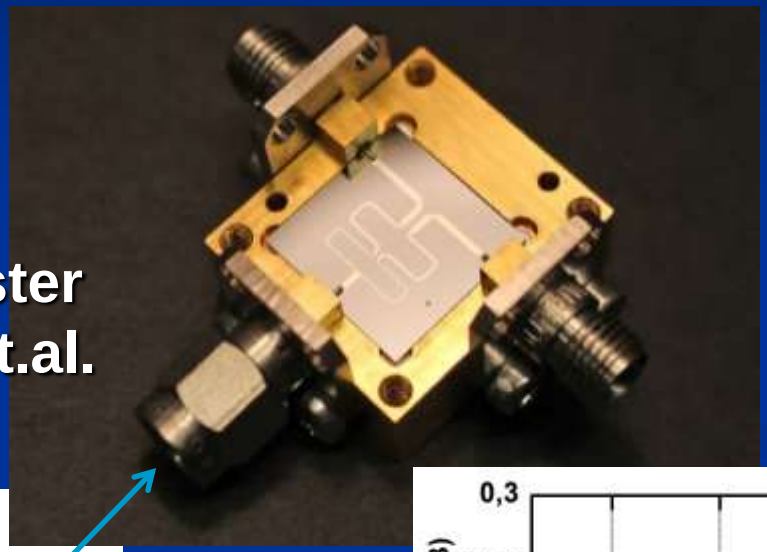


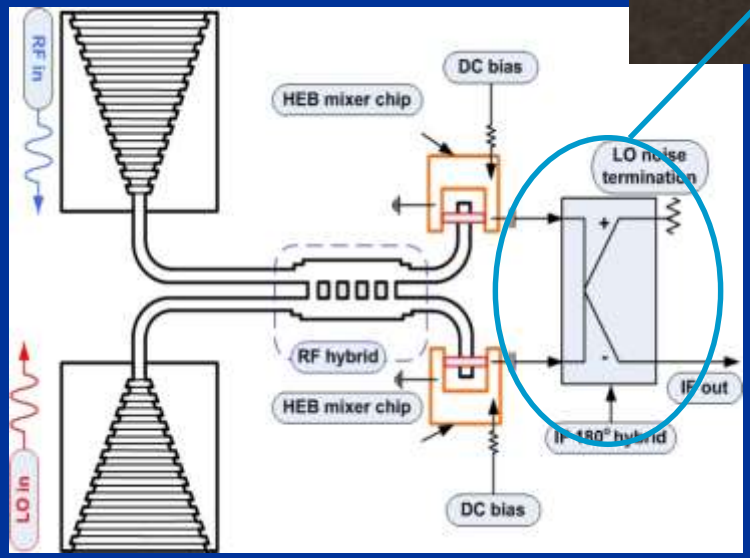
More details: poster by E. Sundin et.al., ISSTT 2017

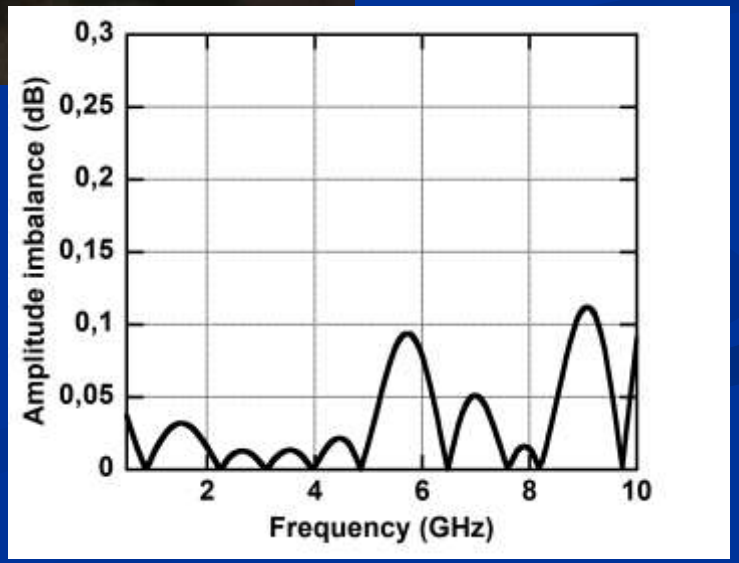
THz arrays: integrated mixer

- Superconducting IF components to be built into mixer;

More details: poster
by V. Desmaris et.al.

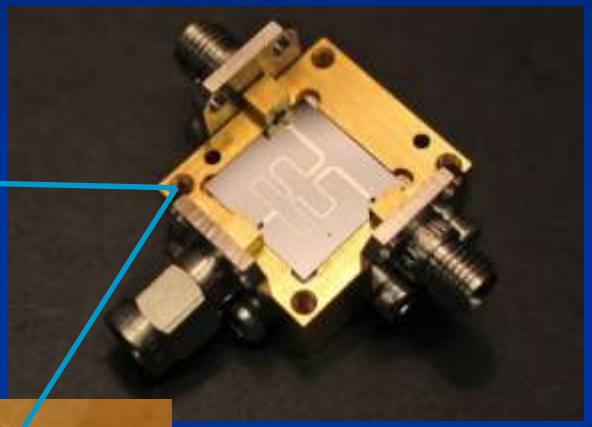


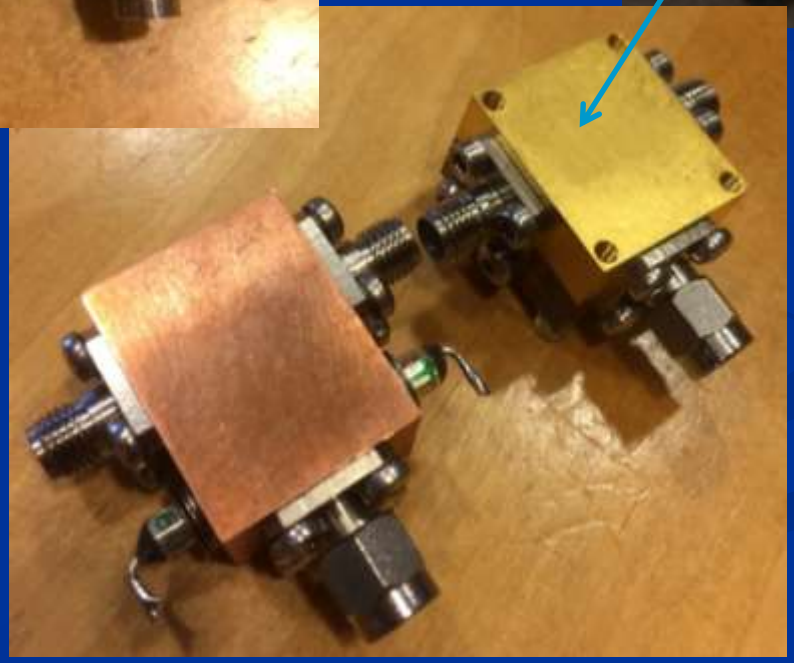




THz arrays: integrated mixer

- Superconducting IF components to be built into mixer;





Concluding remarks

- N pixels vs. complexity vs. array layout;
- LO available power vs. injection schemes vs. distribution;
- Integrated mixer design;
- Micromachining for wg up to 5 THz;
- Micromachining for HEB (SIS?) up to 5 THz;
- Integration of the IF+DC bias;
- IF amplifiers with low Pdc integrated?