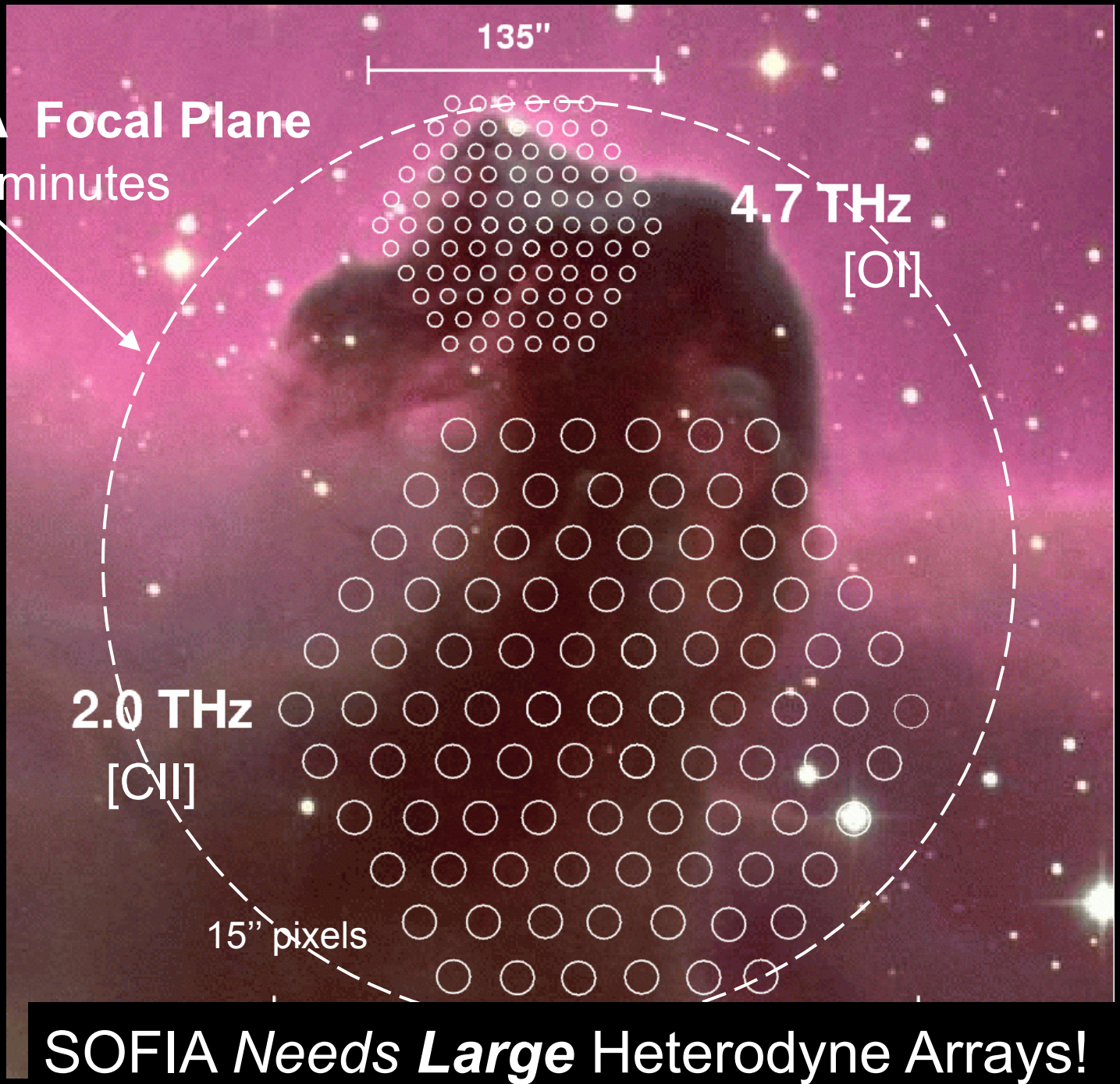
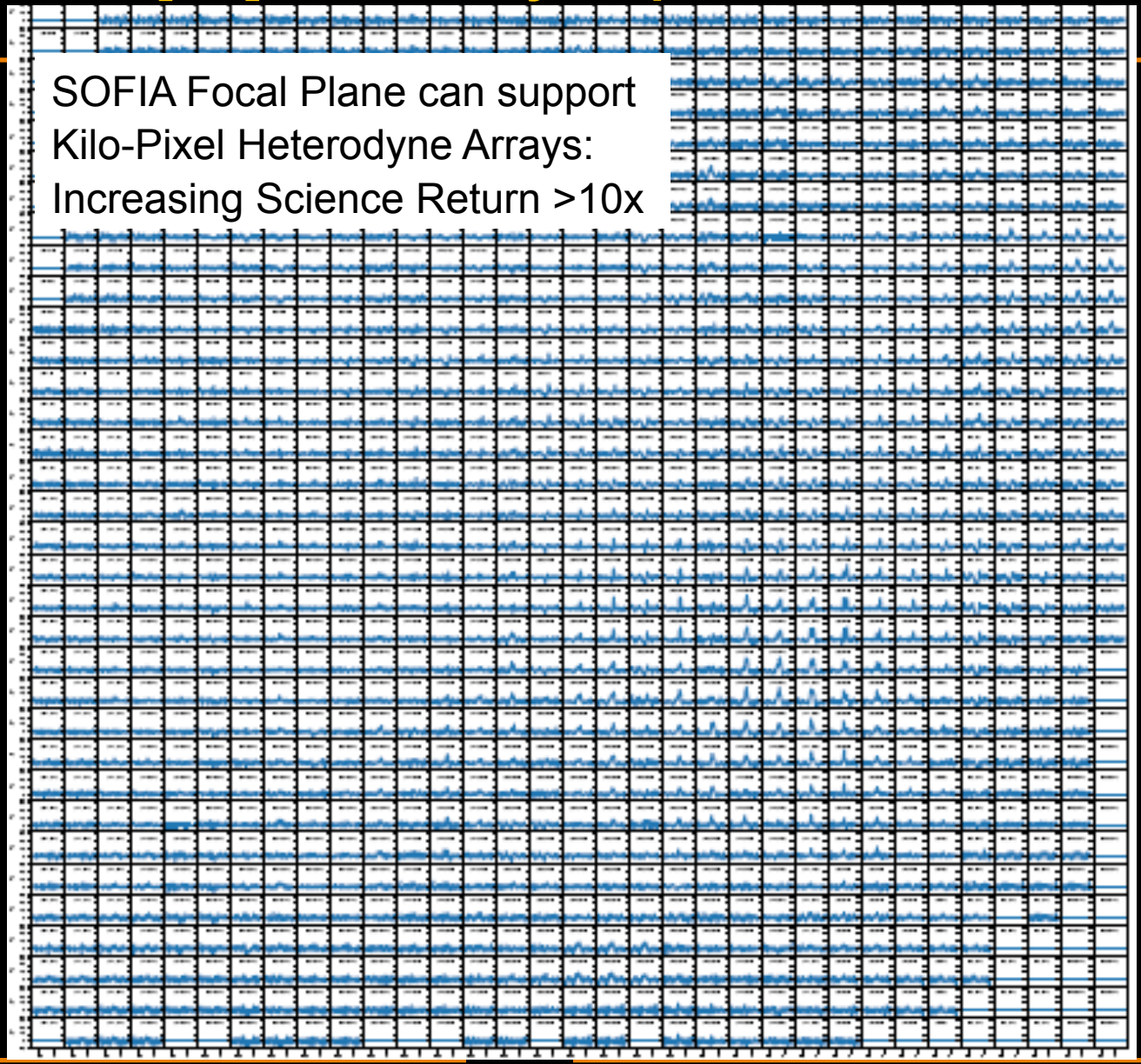
Large TeraHertz Arrays for SOFIA

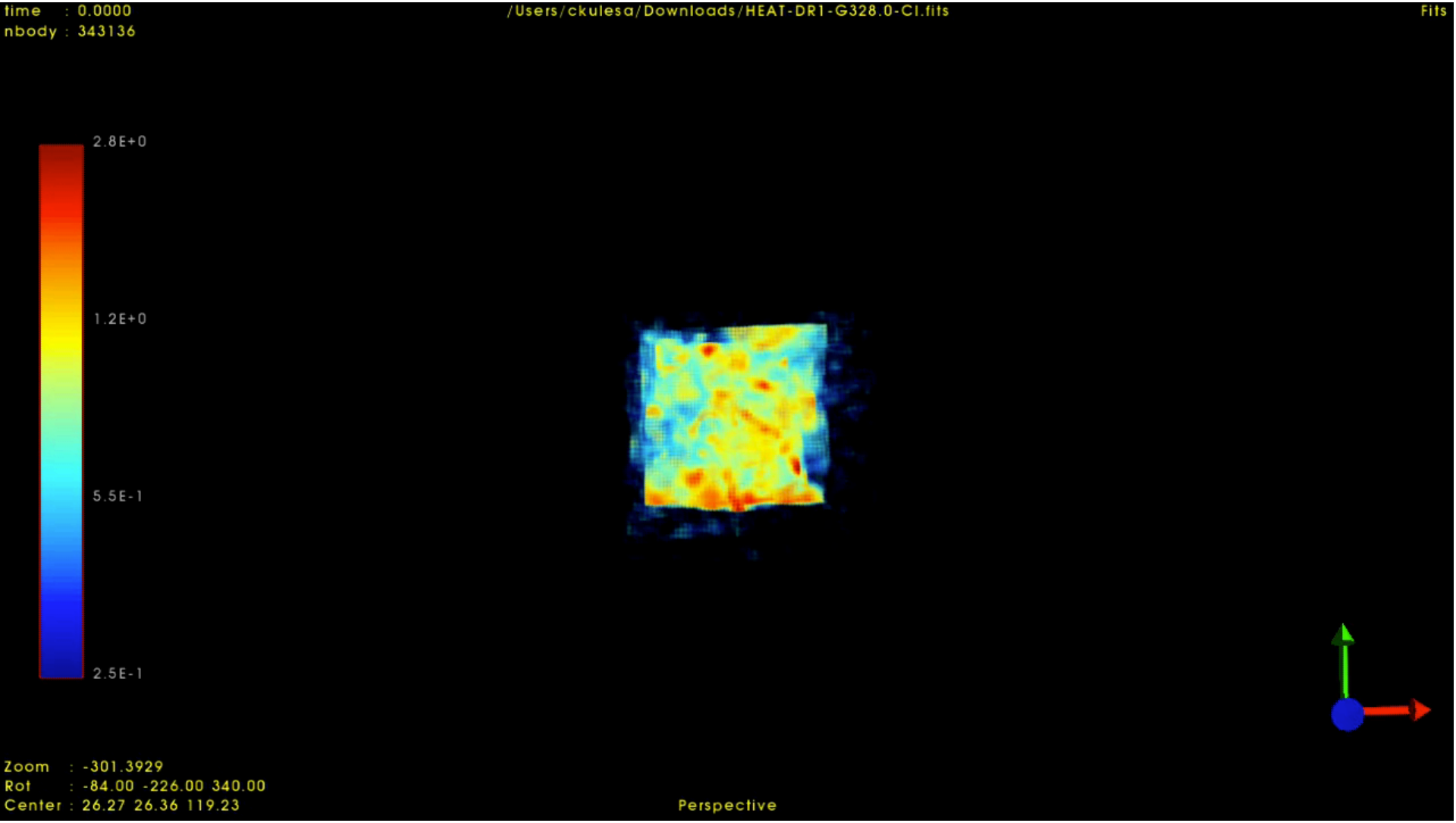


SOFIA *Needs* ***Large*** Heterodyne Arrays!

STO-2 [CII] On-the-Fly Map of Carina Nebula



Spectral Resolution is Key to Disentangling Complex Lines of Sight

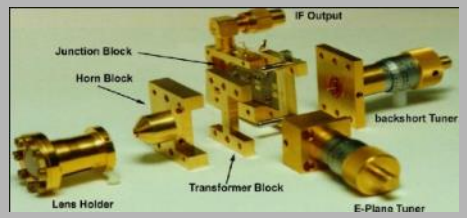


THz Arrays: Why Now?
A Confluence of Technologies:

- Mixer technology
- LO technology
- Microfabrication
- IF amplifiers
- Digital signal processing

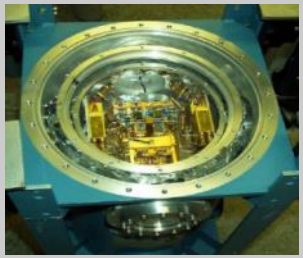
THz Mixer Evolution

(from 2010 SOFIA Asilomar)



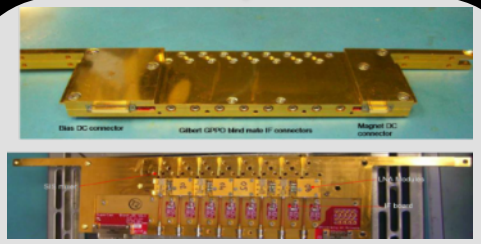
CSO Mixer @ 492GHz

ca. 1990



4 pixel AST/RO array @ 810GHz

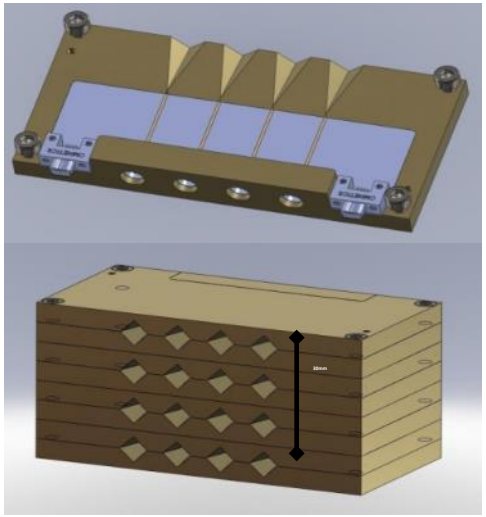
ca. 2000



SuperCam 8x8 Array

@ 350 GHz

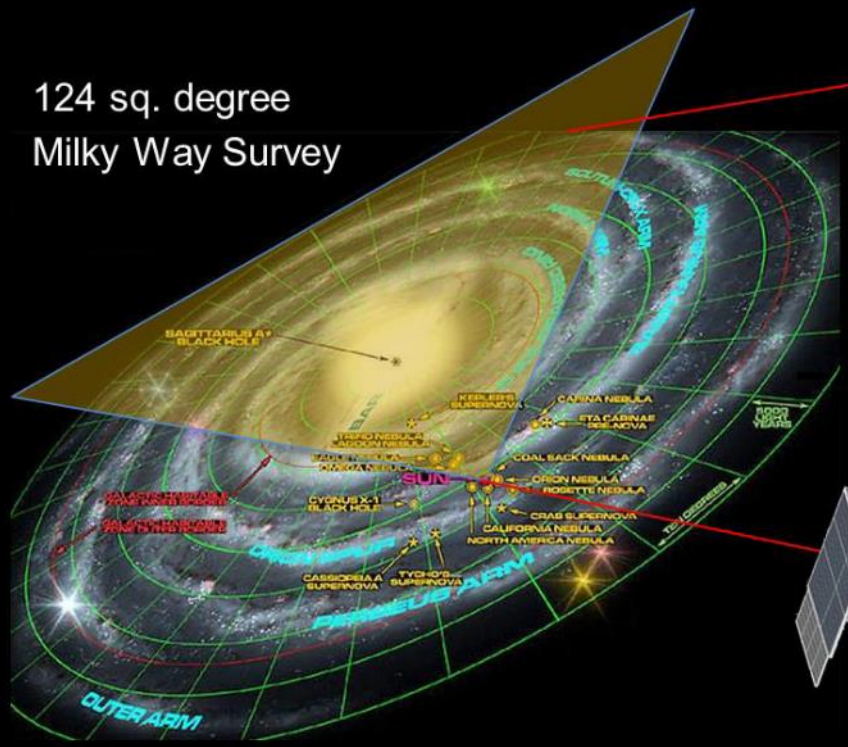
ca. 2010

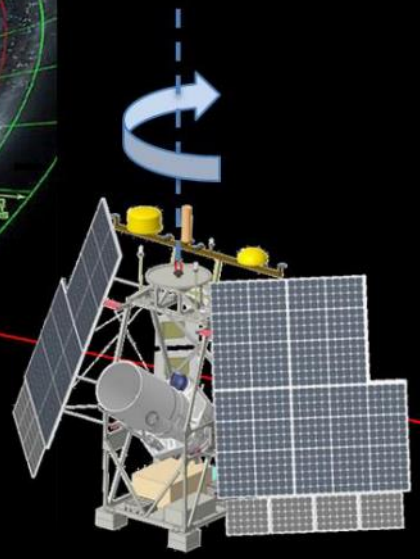


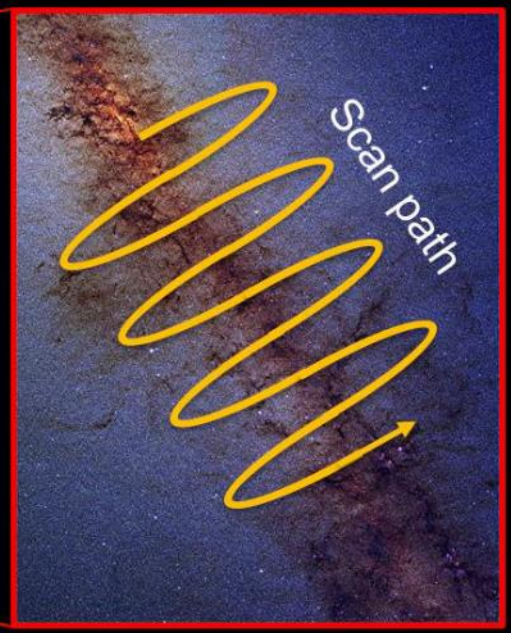
Prototype: 2 THz Stacked Linear Arrays

GUSTO Observational Objectives: [CII], [OI], & [NII] Surveys of MW and LMC

124 sq. degree
Milky Way Survey

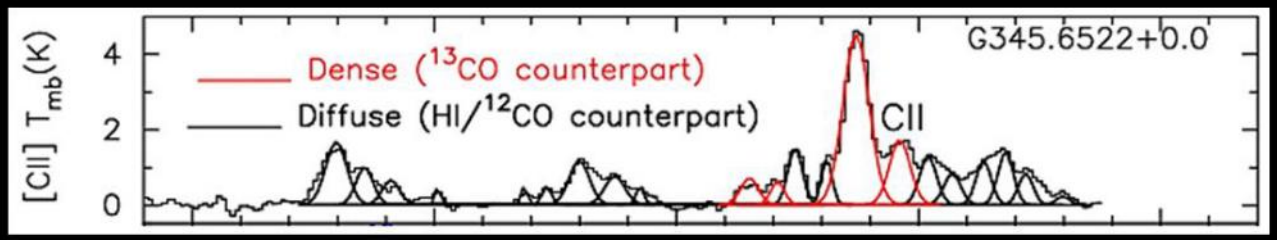


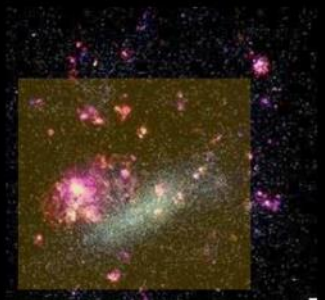




On-the-Fly Mapping

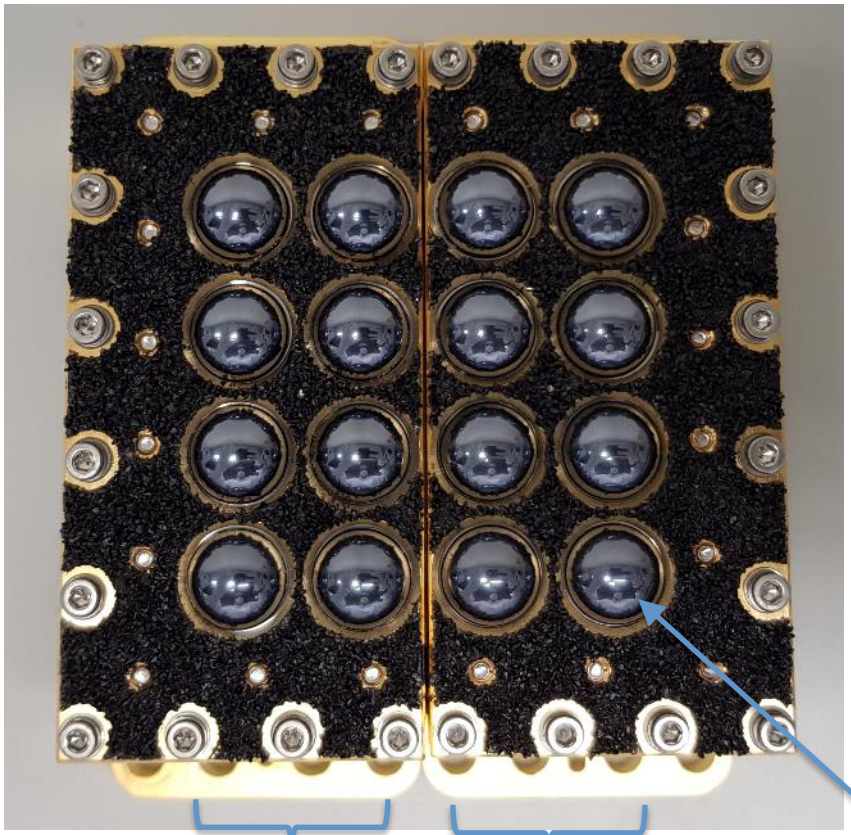
Herschel CII line of sight (LOS): GUSTO will observe 540,000 LOS's

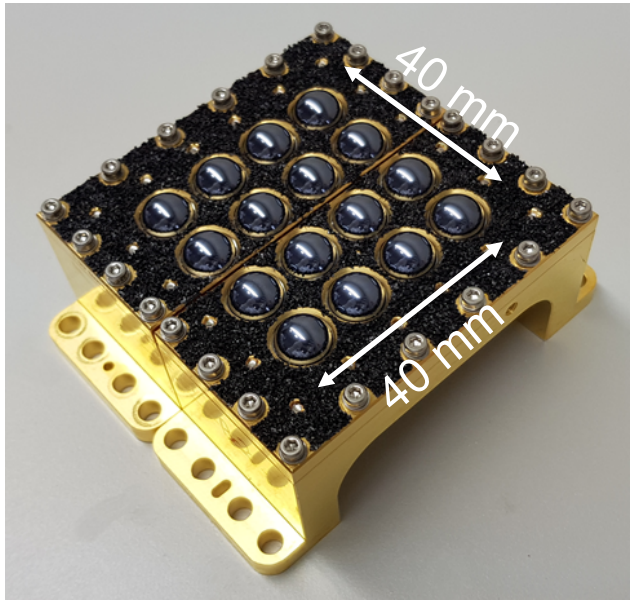




25 sq. degree
LMC Survey

GUSTO Quasioptical Mixer Arrays





Silicon Lenses

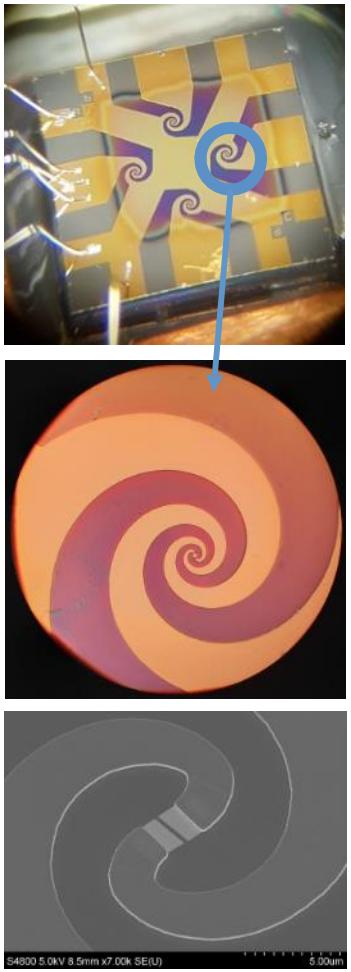
2x4 [NII]
1.46 THz

2x4 [CII]
1.9 THz

2x4 [OI] HEB Array Assembly at SRON 4.7 THz

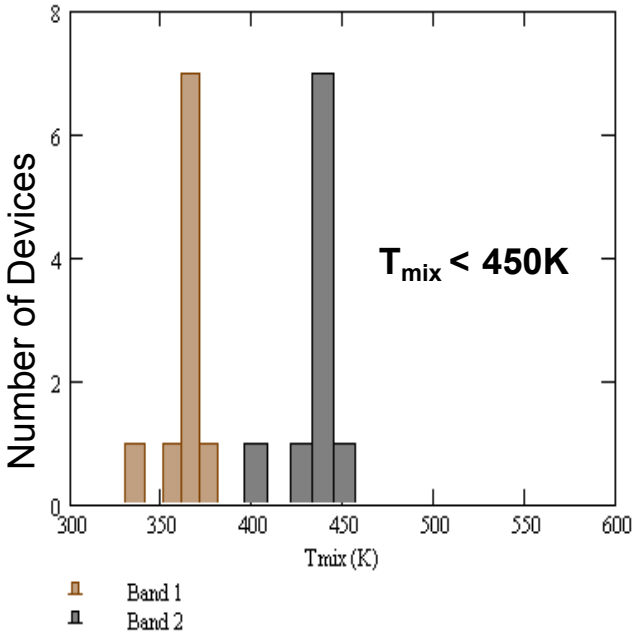
Back of Array

SRON-TU Delft HEB detector array

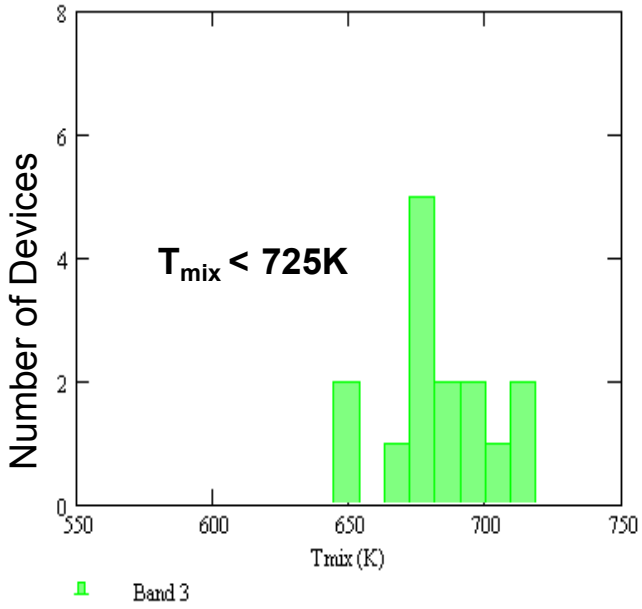


- **NbN HEBs on 2x2 mm Si chip fabricated at TU-Delft.**
- **SiO_2 passivation layer to prevent oxidation.**
- **Spiral Antenna**
  - **Same mixer works from 1 to 6 THz!**

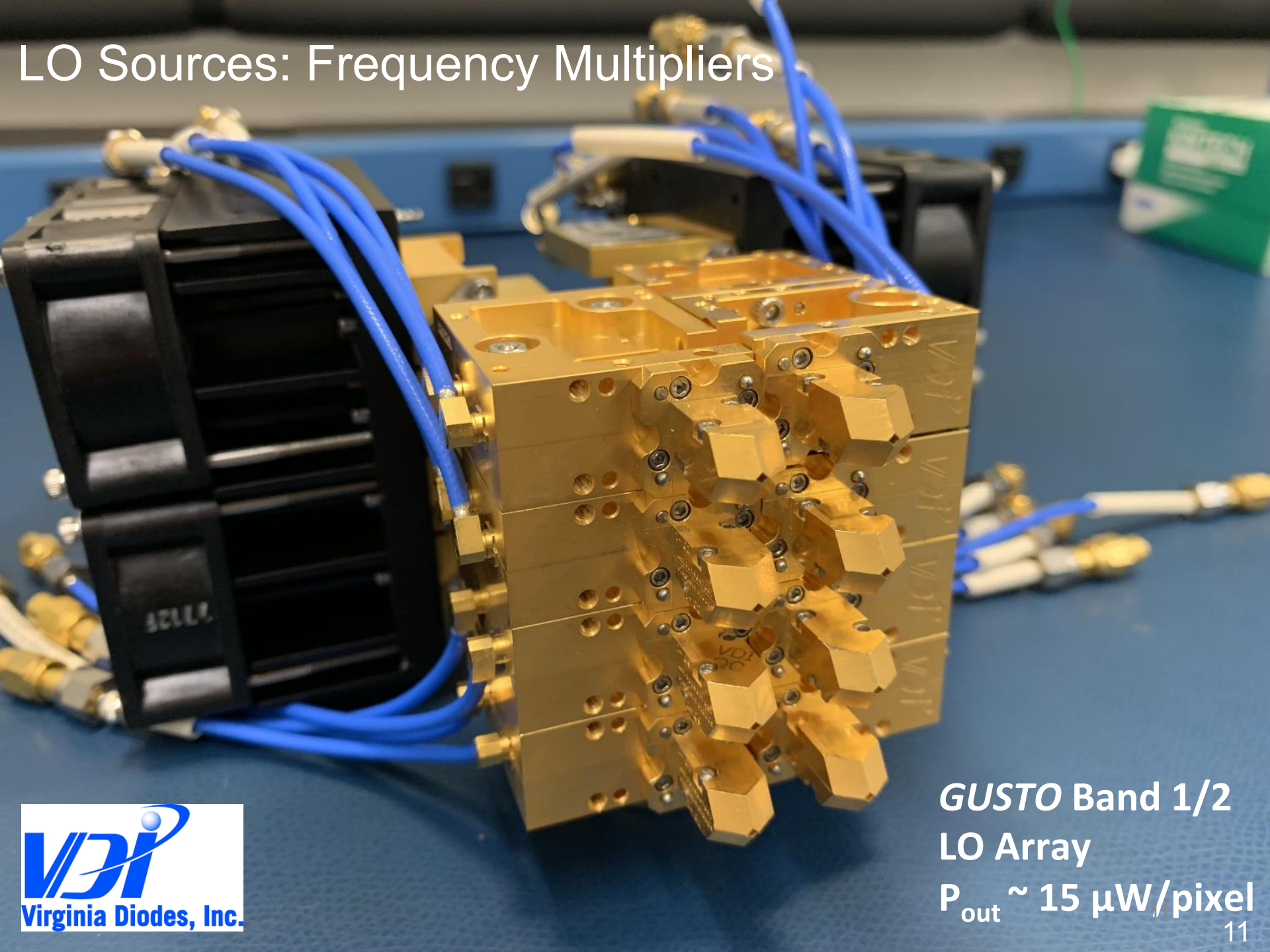
2 THz Performance



4.7 THz Performance



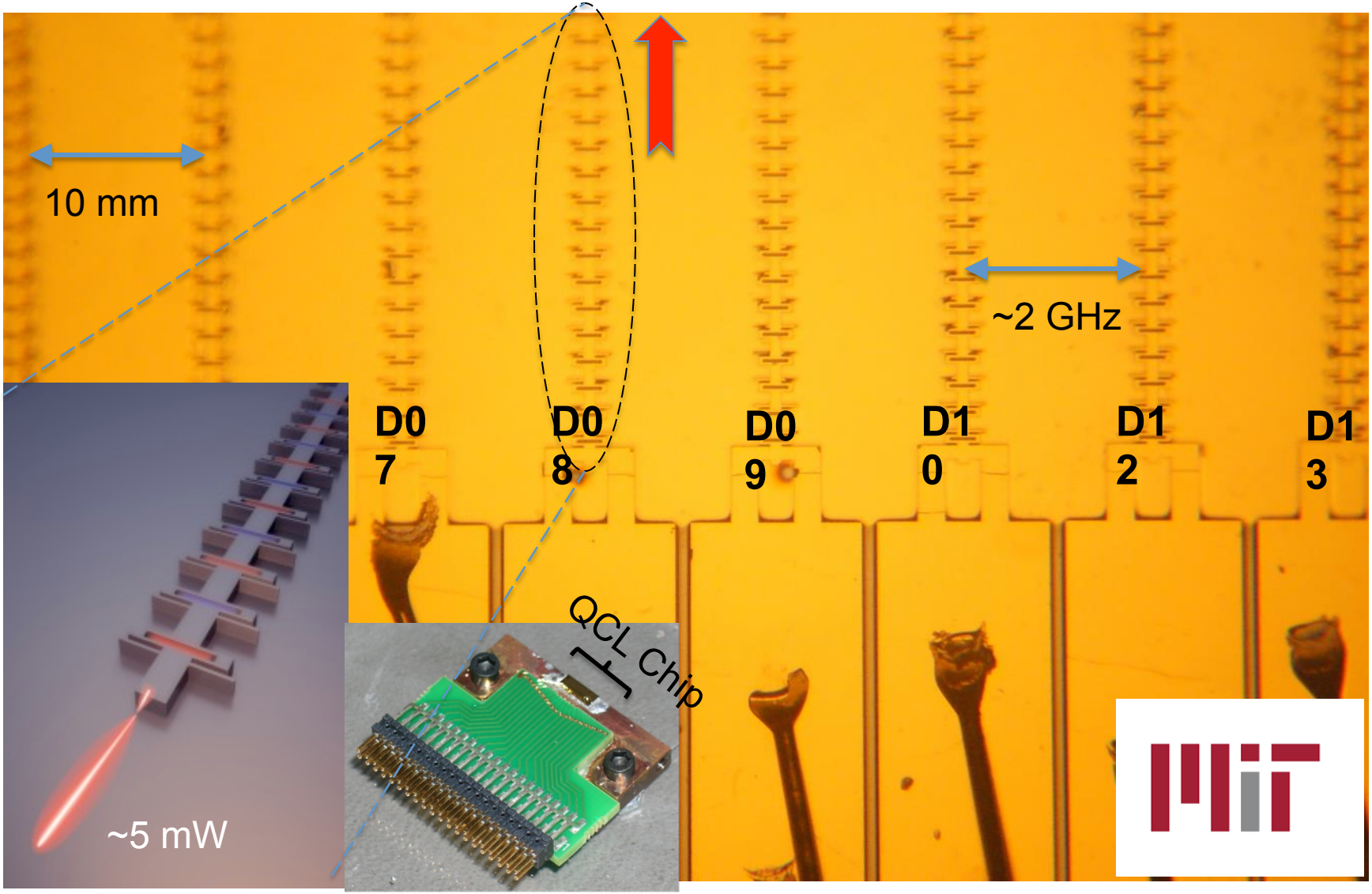
LO Sources: Frequency Multipliers



***GUSTO* Band 1/2**
LO Array
P_{out} ~ 15 µW/pixel

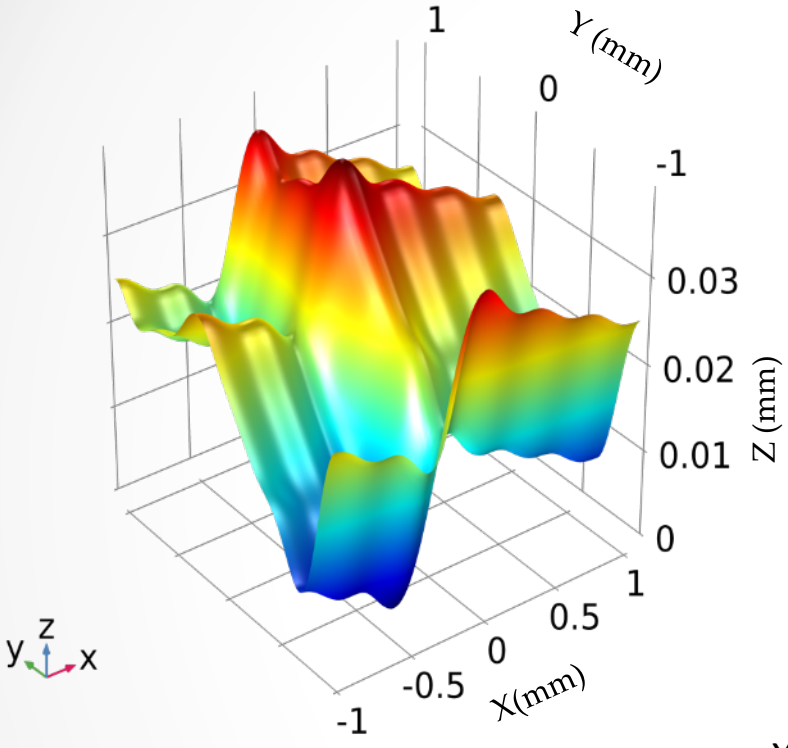
Virginia Diodes, Inc.

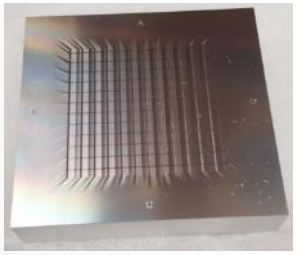
LO Sources: 4.7 THz Quantum Cascade Laser

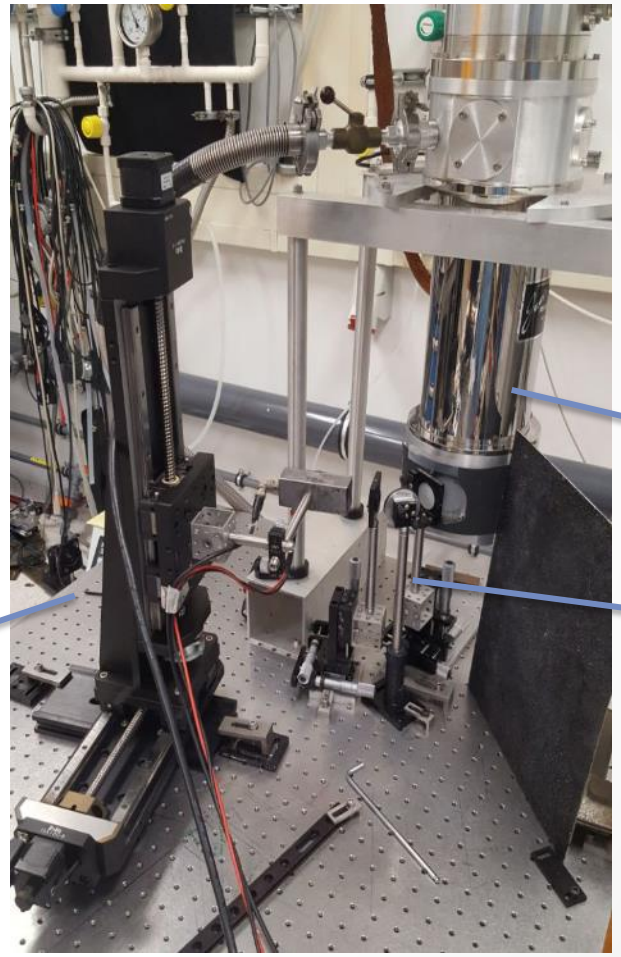


Phase Grating for GUSTO

Designed, Modelled and Tested-Verified in TUDelft

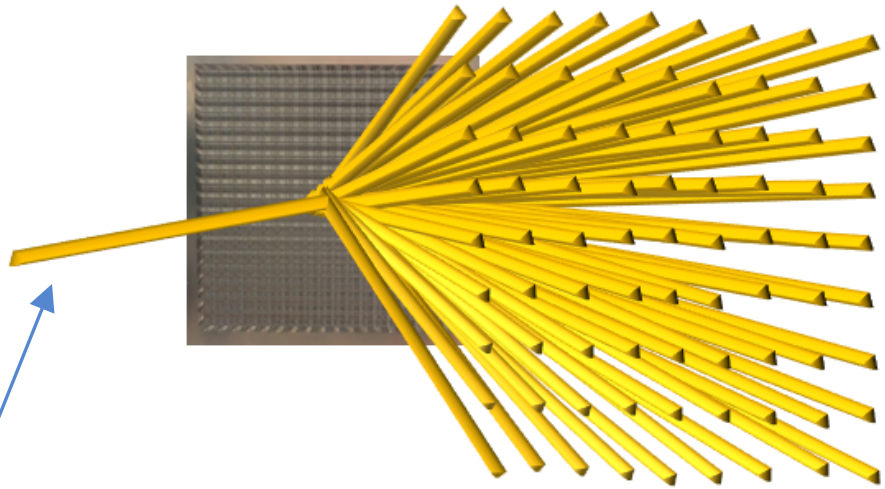






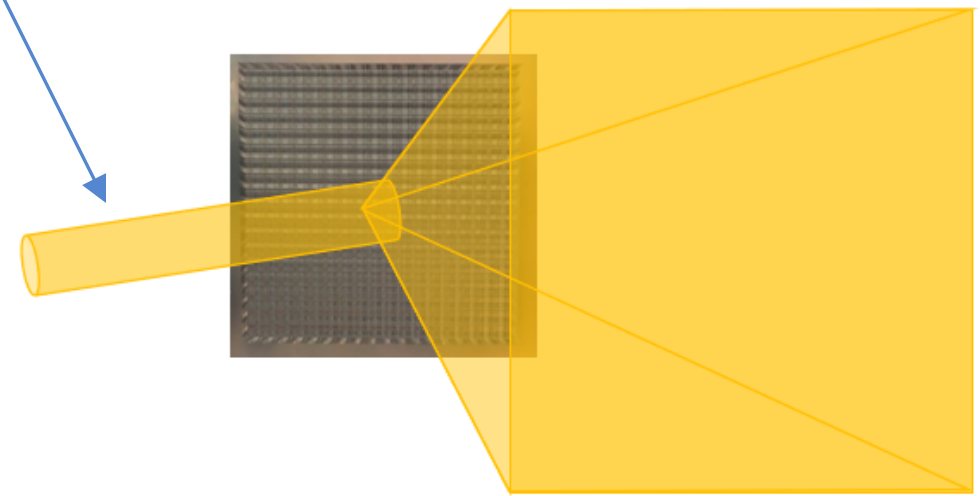
Manufactured by Arizona State University

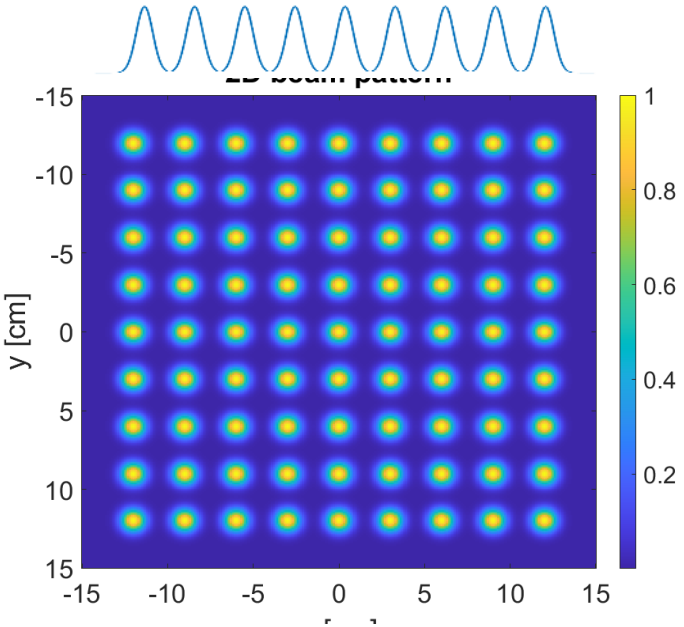
Phase grating to produce uniform square flat beam LO illumination for 32x32 pixels

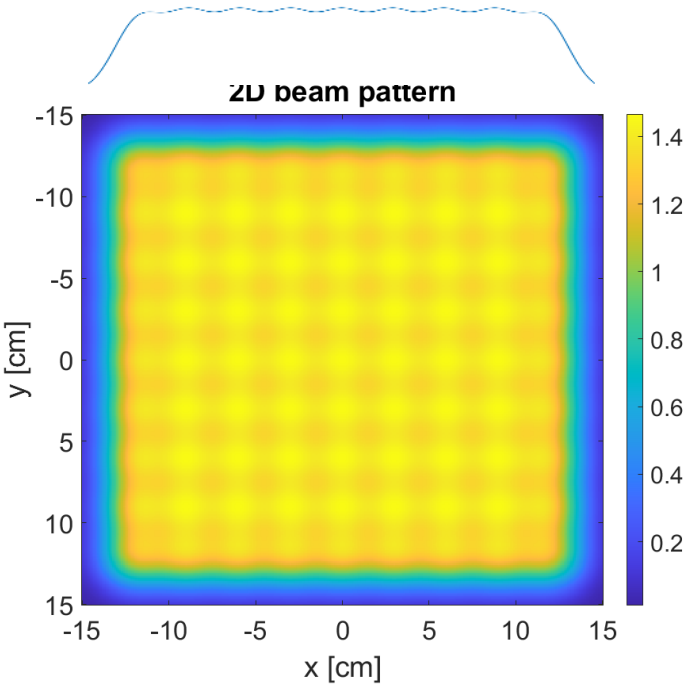


QCL Beam

Y. Gan, B. Mirzaei, et al., Opt. Express, 2019

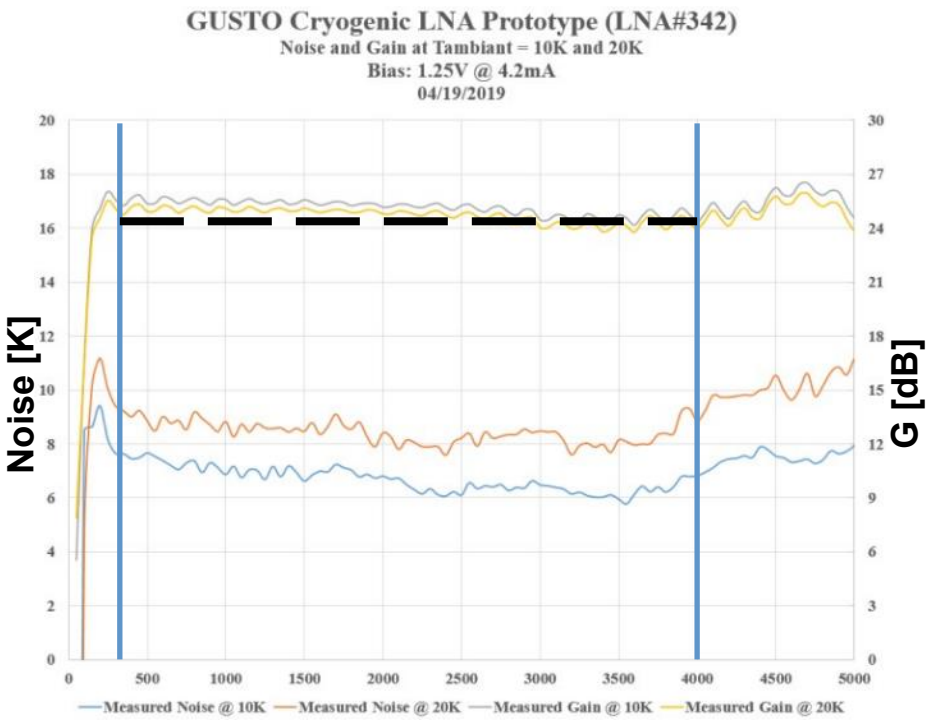


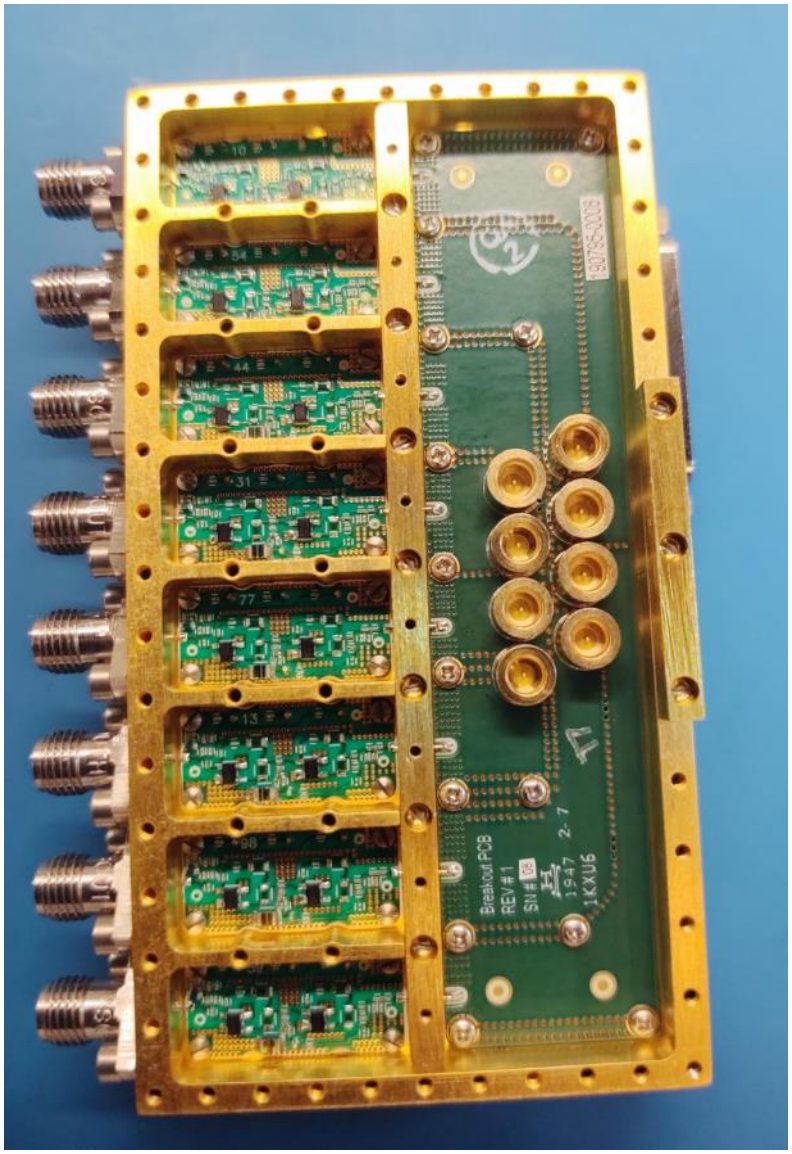




GUSTO 1x8 Cryogenic LNA block

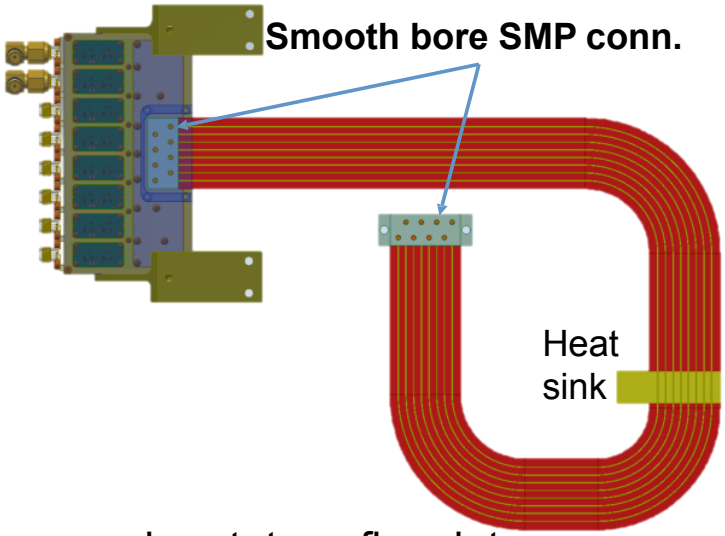
Noise @ constant Bias
@ different temperatures



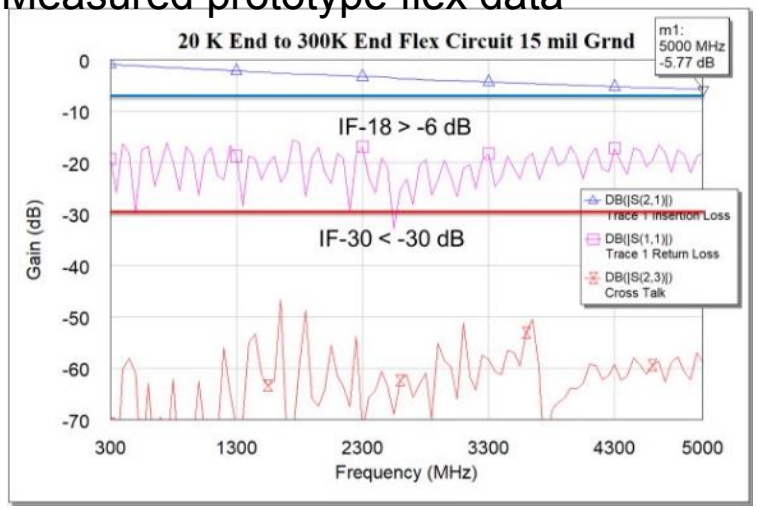


Arizona State University

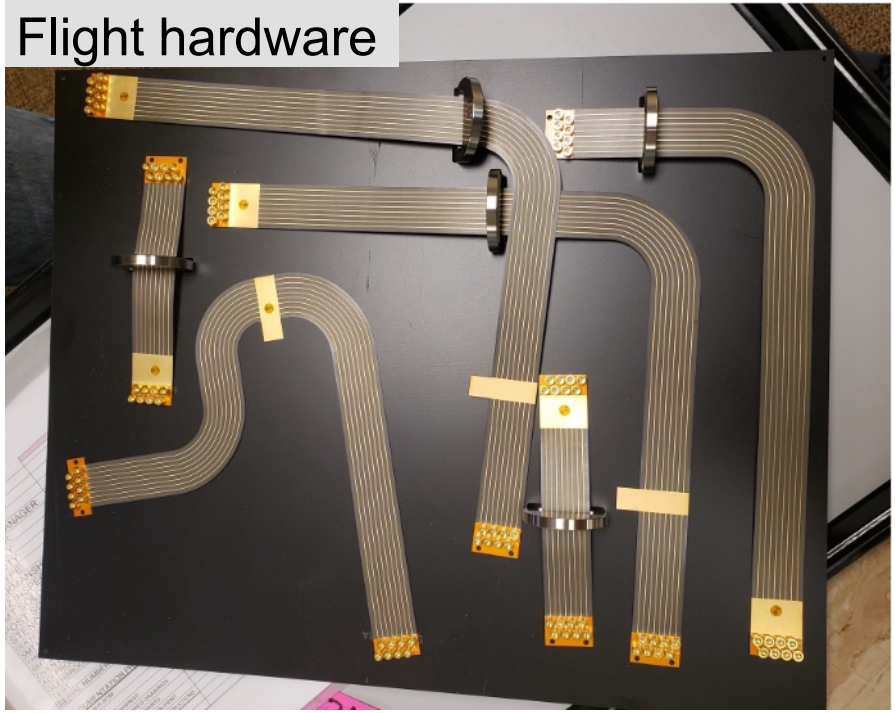
Flexible 0.3-4 GHz RF line: No more Cryo Coax!



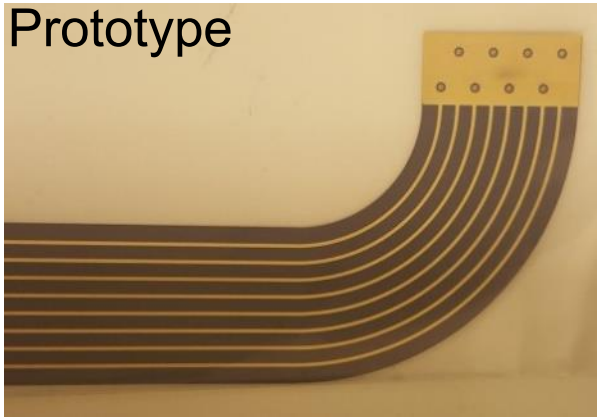
Measured prototype flex data



Flight hardware



Prototype

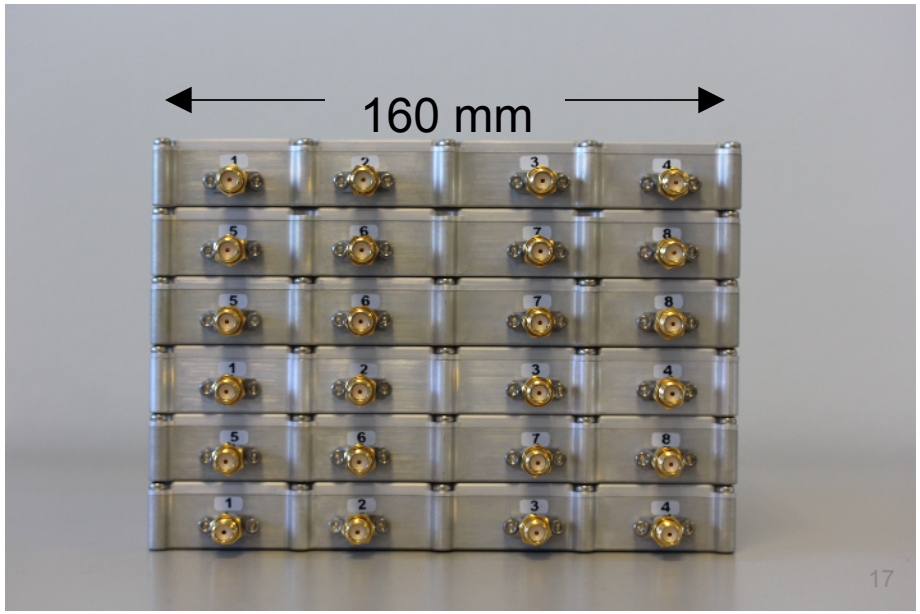


8 IF Lines

Arizona State University

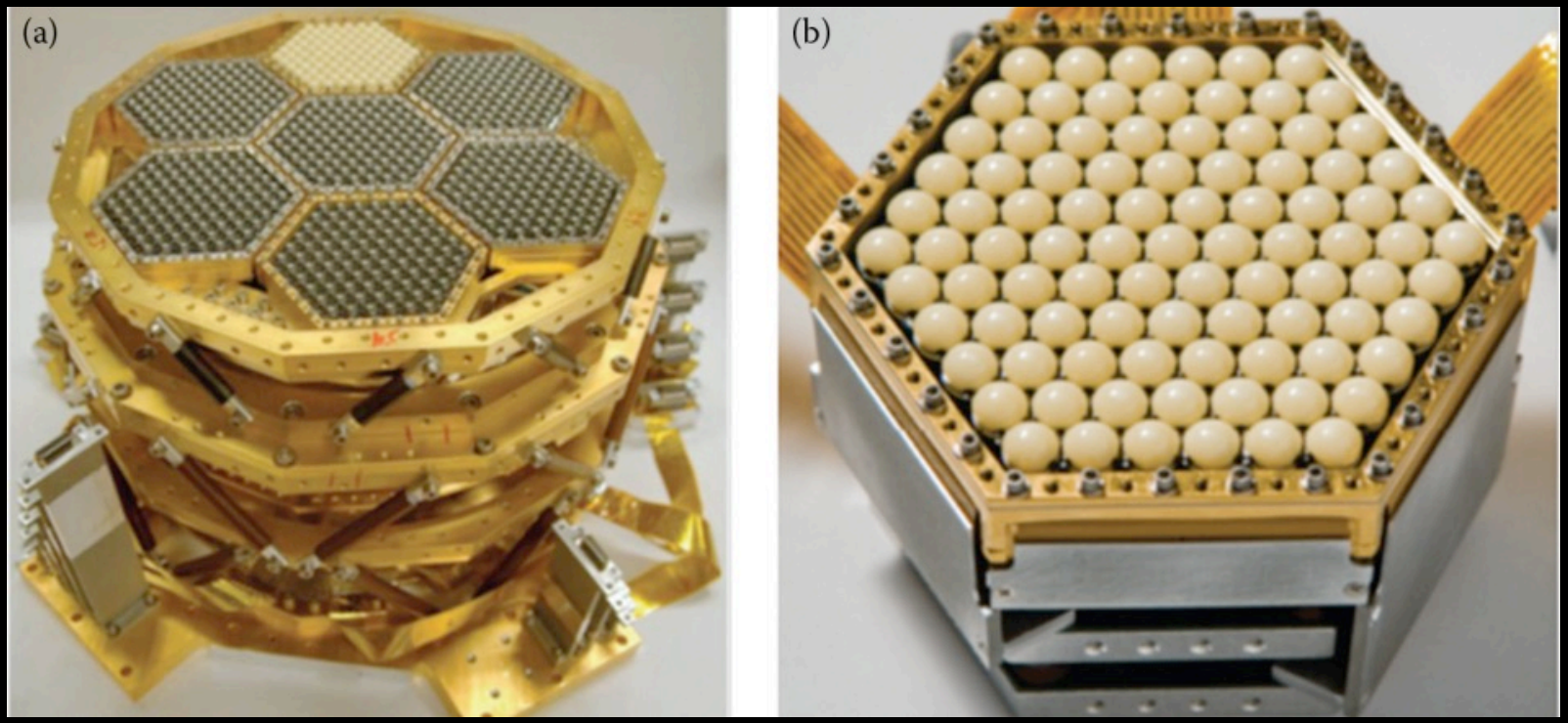
GUSTO Autocorrelator System

- 24 X 5 GHz
  (Total 120 GHz)
- 24,576 Channels
- 75 W
- 2.5 kg
- 160 x 160 x 160 mm



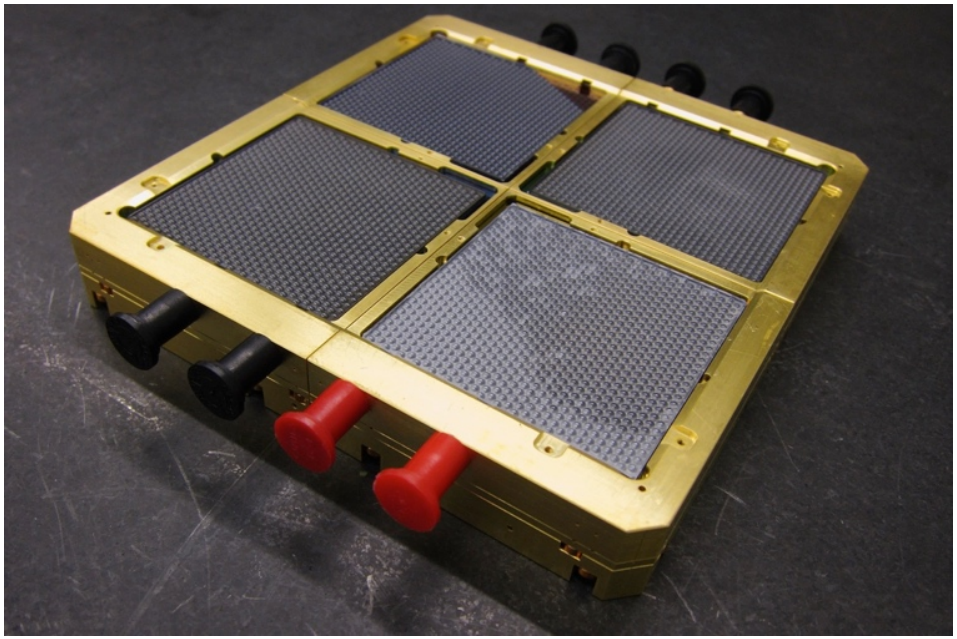
Realizing a 1024 Heterodyne Array with GUSTO Technology

Incoherent Quasioptical Approach

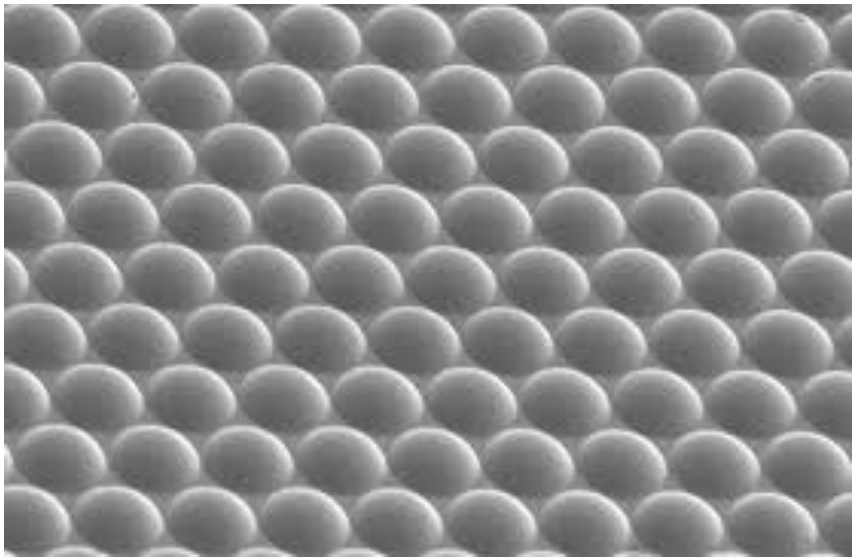


“POLARBEAR” focal plane array composed of antenna coupled bolometers Arnold, et al. 2012.

Microlens array technology is well developed



AMKID (KID) detector arrays (APEX)



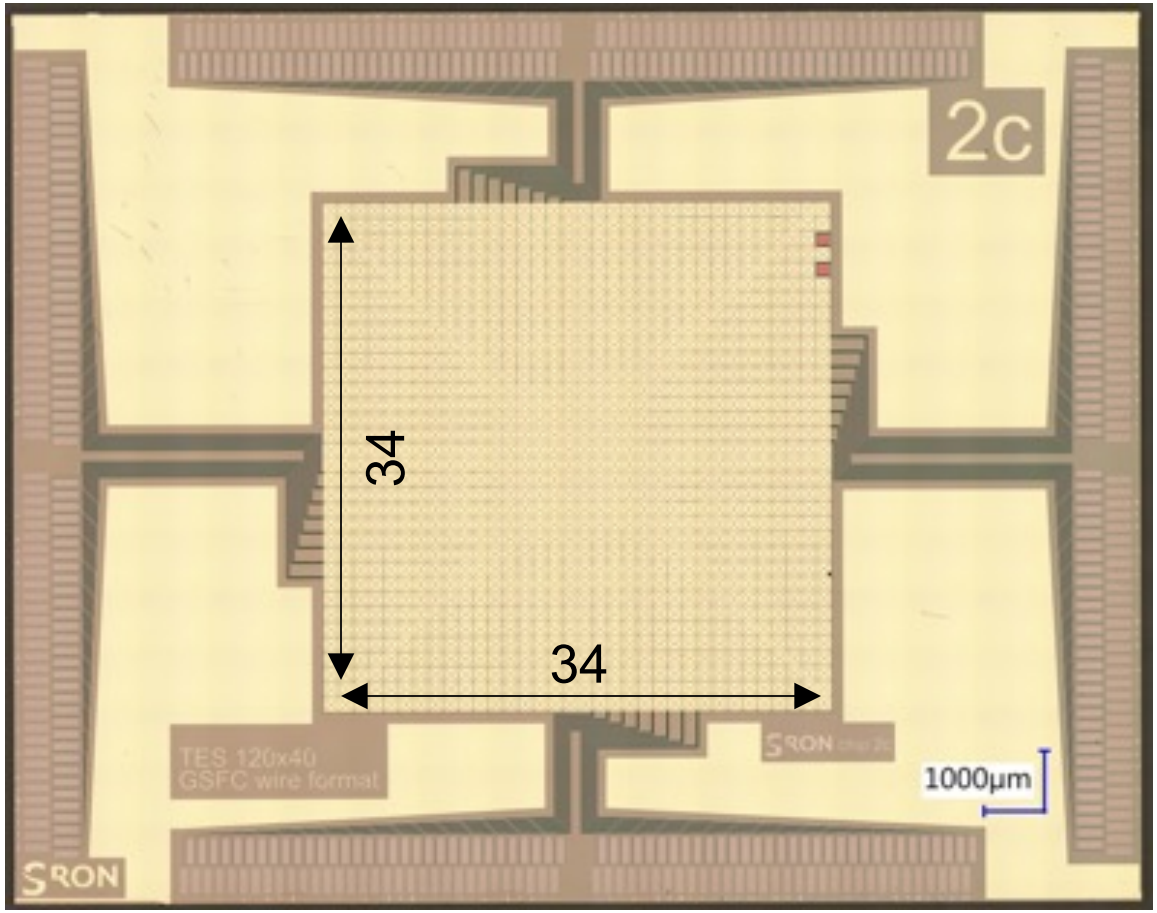
MicroLens array

SRON Netherlands Institute for Space Research

TU Delft

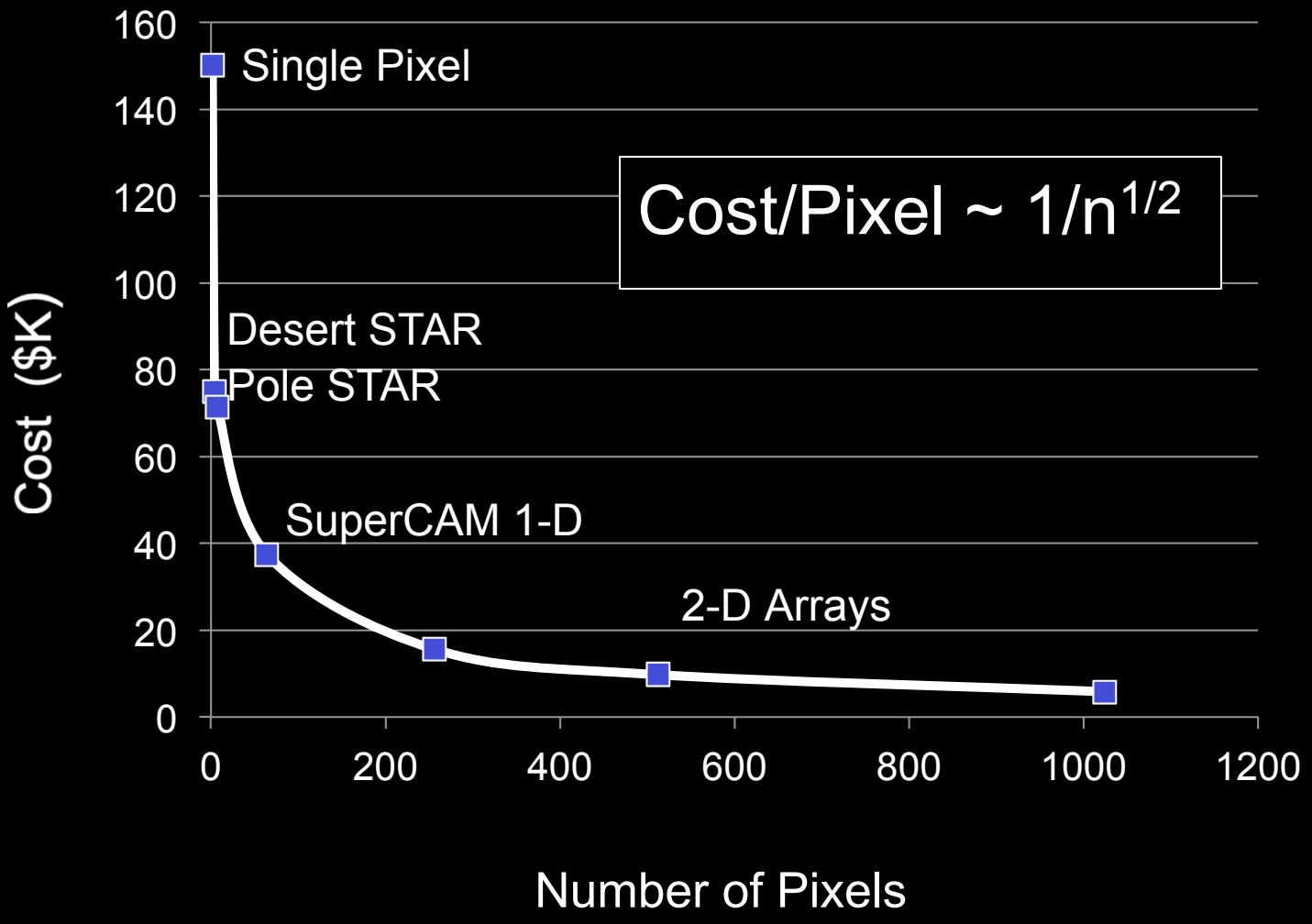
Max-Planck-Institut für Radioastronomie

Microstrip wiring for IF and DC wiring



Kilo-pixel TES for XIFU-Athena developed @ SRON using microstrip wiring structures for k-pixles

Cost/Pixel vs. Size



Walker et al. 2008

SOFIA Kilopixel Coherent Camera (KCAM)

Strawman Budget

Mixers	5M
LO's	5M
LNAs	1M
IF Boxes	1M
Spectrometer	5M
Cryo	1M
Mechanical	1M
Labor	4M
TOTAL COST	$23M

Time Line

Detailed Design	0.5 yr
Component Fabrication	3 yr
I&T	1 yr
TOTAL TIME	~4.5 yrs

⇐ Leverages off GUSTO/STO NRE

Summary

- Technological advancements now make it possible to construct a Kilopixel Heterodyne Camera capable of operation from ~1 to 6 THz.
- Such a camera would increase the science return of SOFIA by ***more than an order of magnitude per flight and could be constructed within 5 years.***