

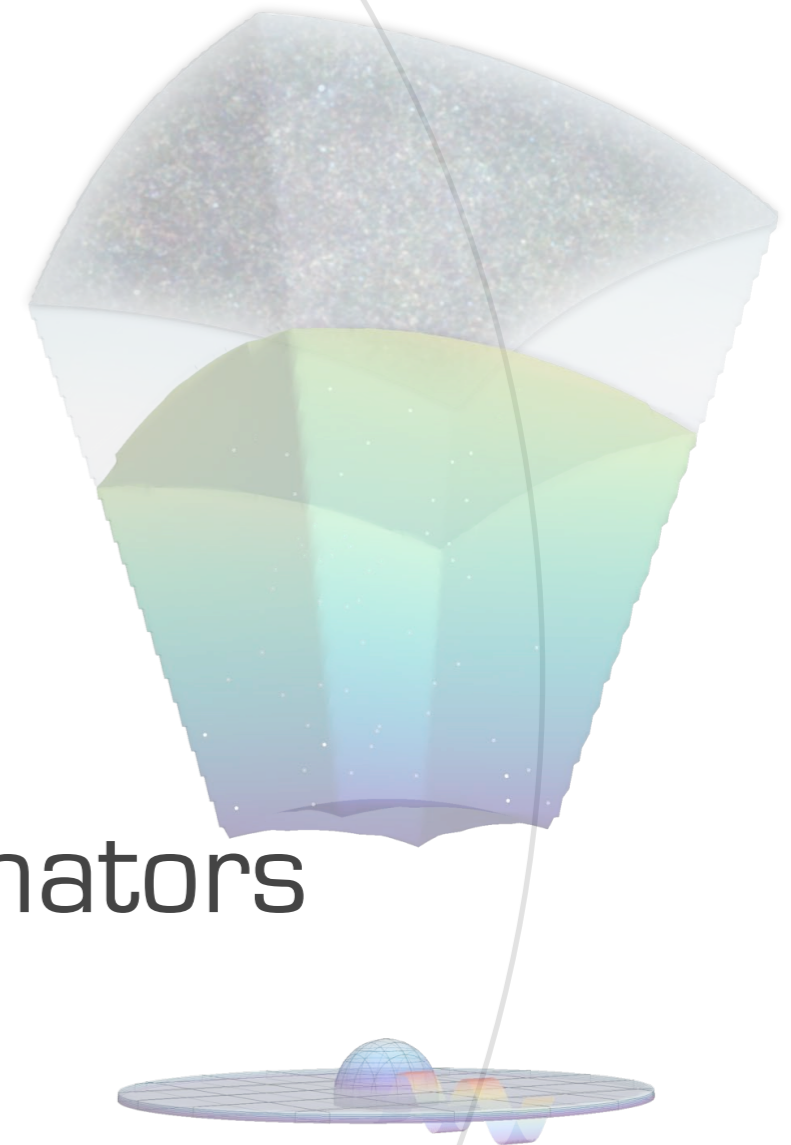
integrated filterbank for

DESHIMA

on-chip imaging spectrograph

based on superconducting resonators

arXiv:1107.3333v1 [astro-ph.IM]



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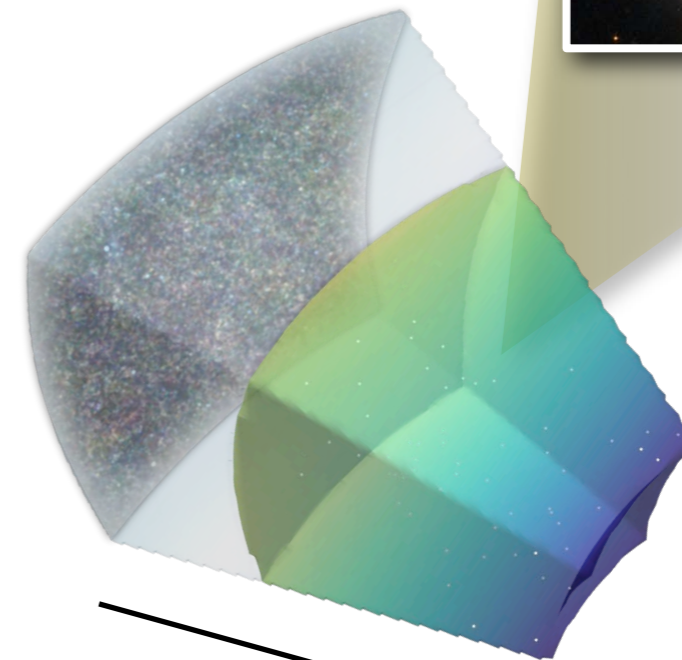
Probing the Cosmic History of Star- and Galaxy-Formation

- ▶ Imaging arrays → 2D projection
- ▶ The 3rd dimension = redshift (time)



broadband (several 100 GHz)
spectrometer = **Z-machine**

2D projection



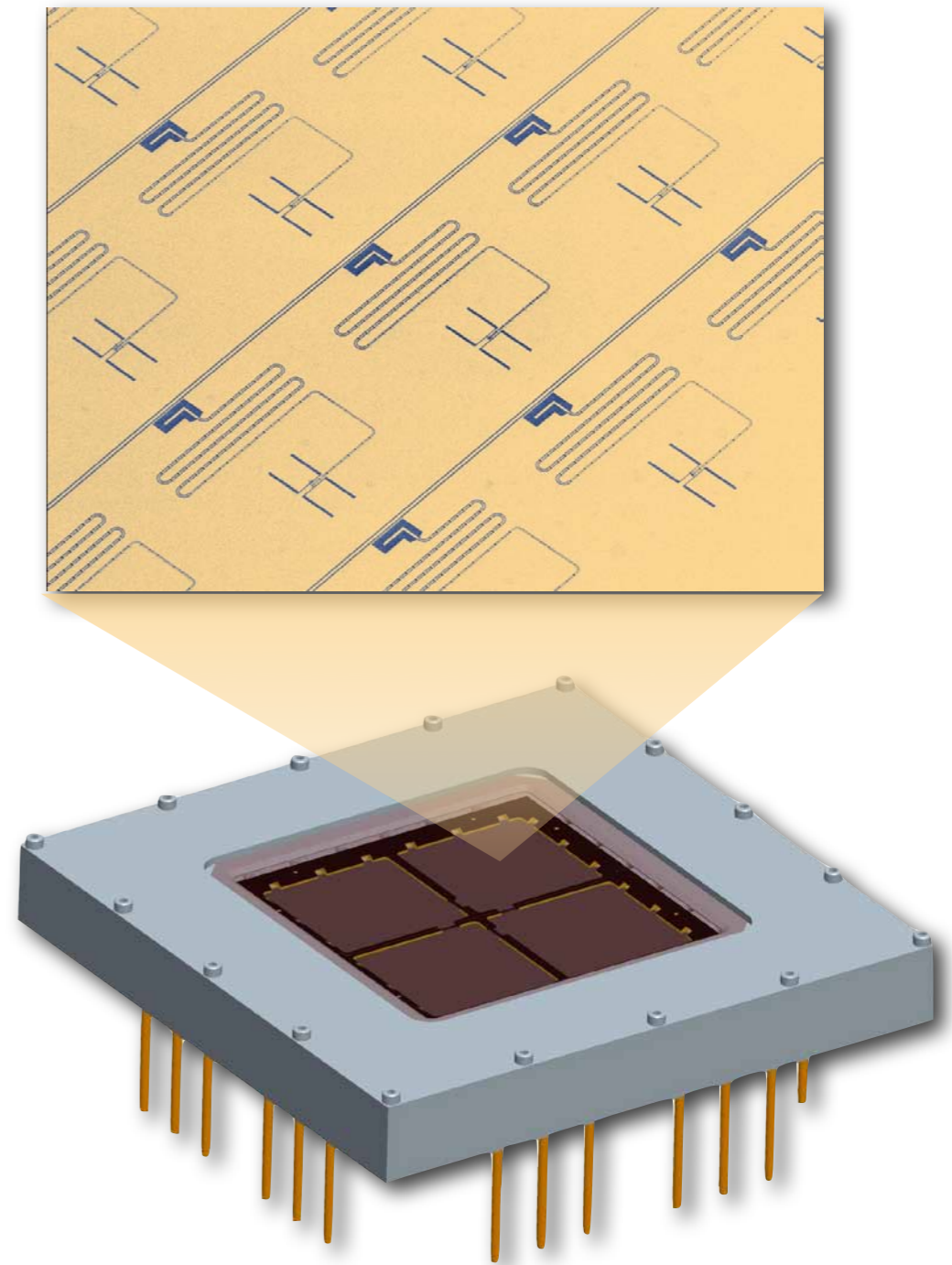
Galaxies in
3D space

Time



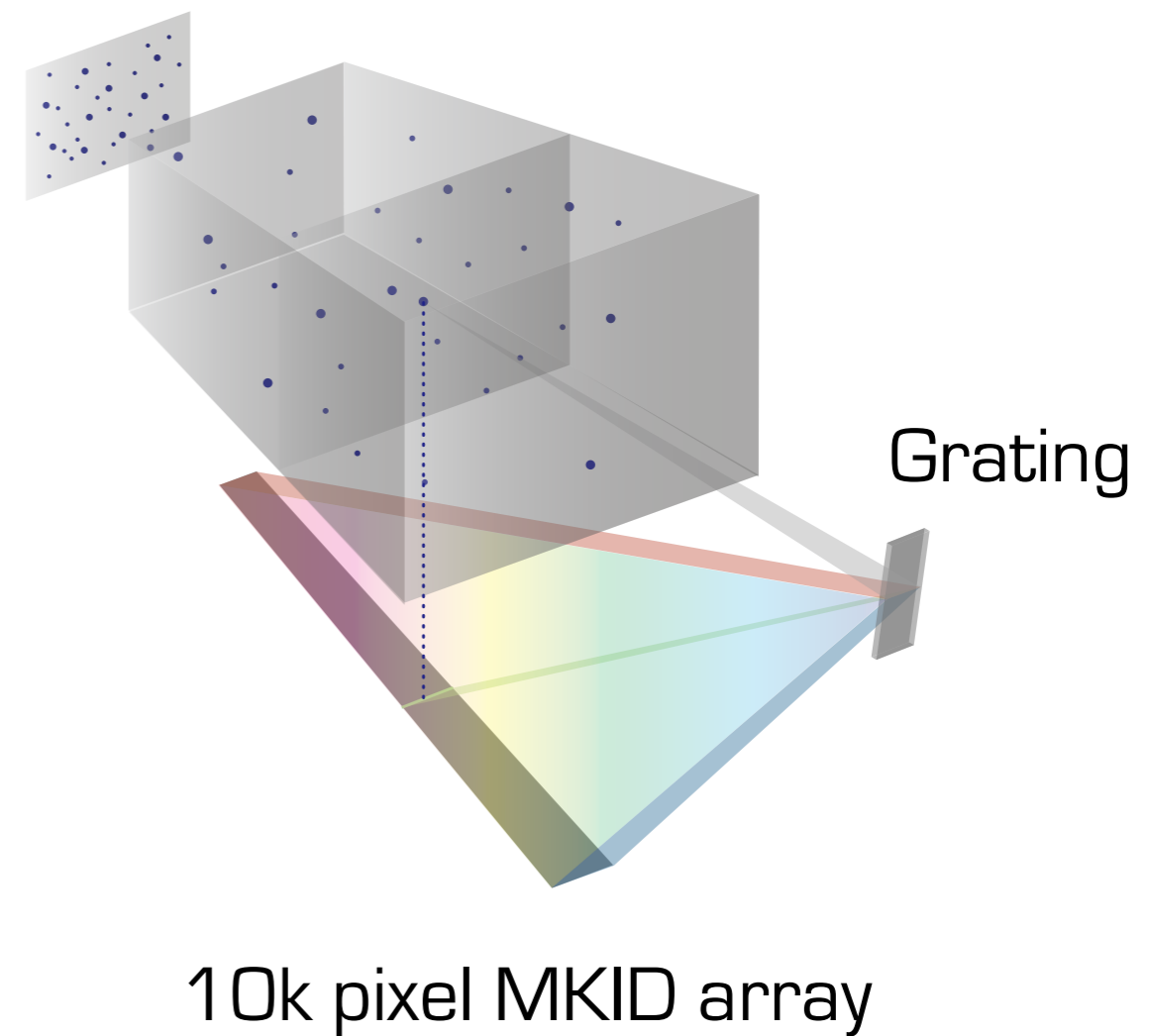
DESHIMA: Redshift (Z)-machine using MKIDs

- ▶ MKID cameras under development:
 - >10k pixels
- ▶ Enough for 10 pixels x 1000 colors
 - instantaneously cover 300-950 GHz with a frequency resolution of $f/df = 1000$
 - e.g., C⁺ 1.9 THz line at redshift 1-5



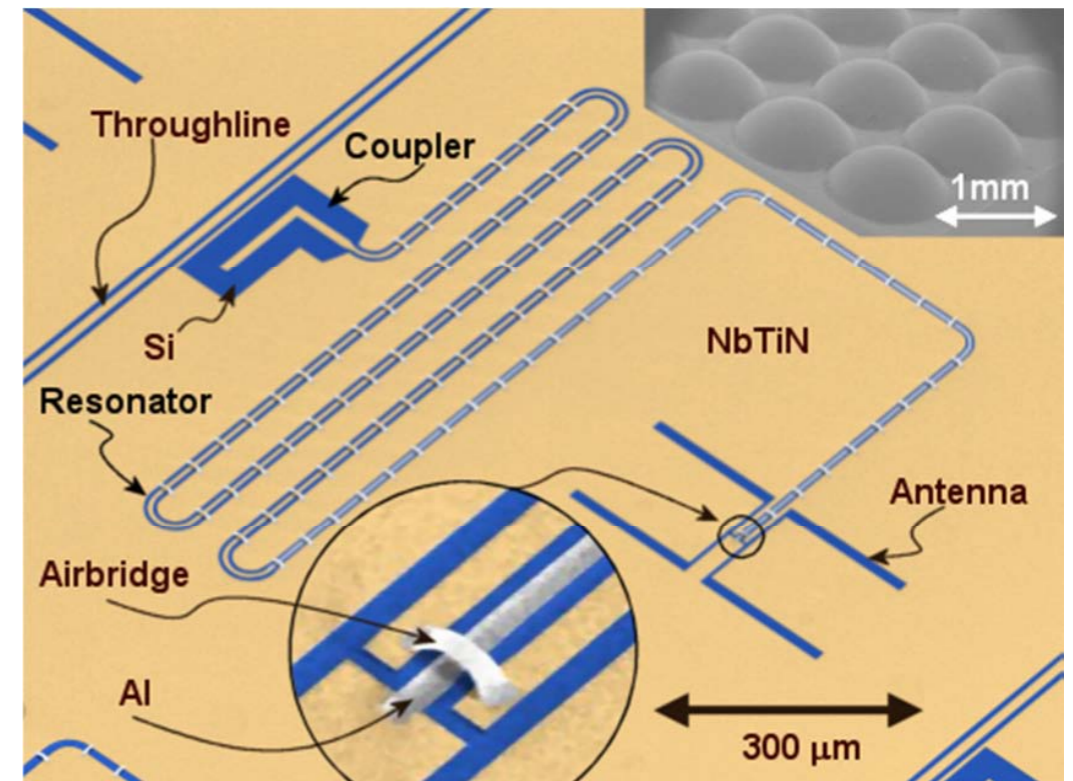
Grating Type Z-machine with MKIDs ?

- ▶ 1st generation grating z-machines with 100-1000 detectors have been successful (Z-spec, ZEUS)
- Technology:
big leap from a plain imaging camera
- Flexibility:
spatial sampling over a 2D space?



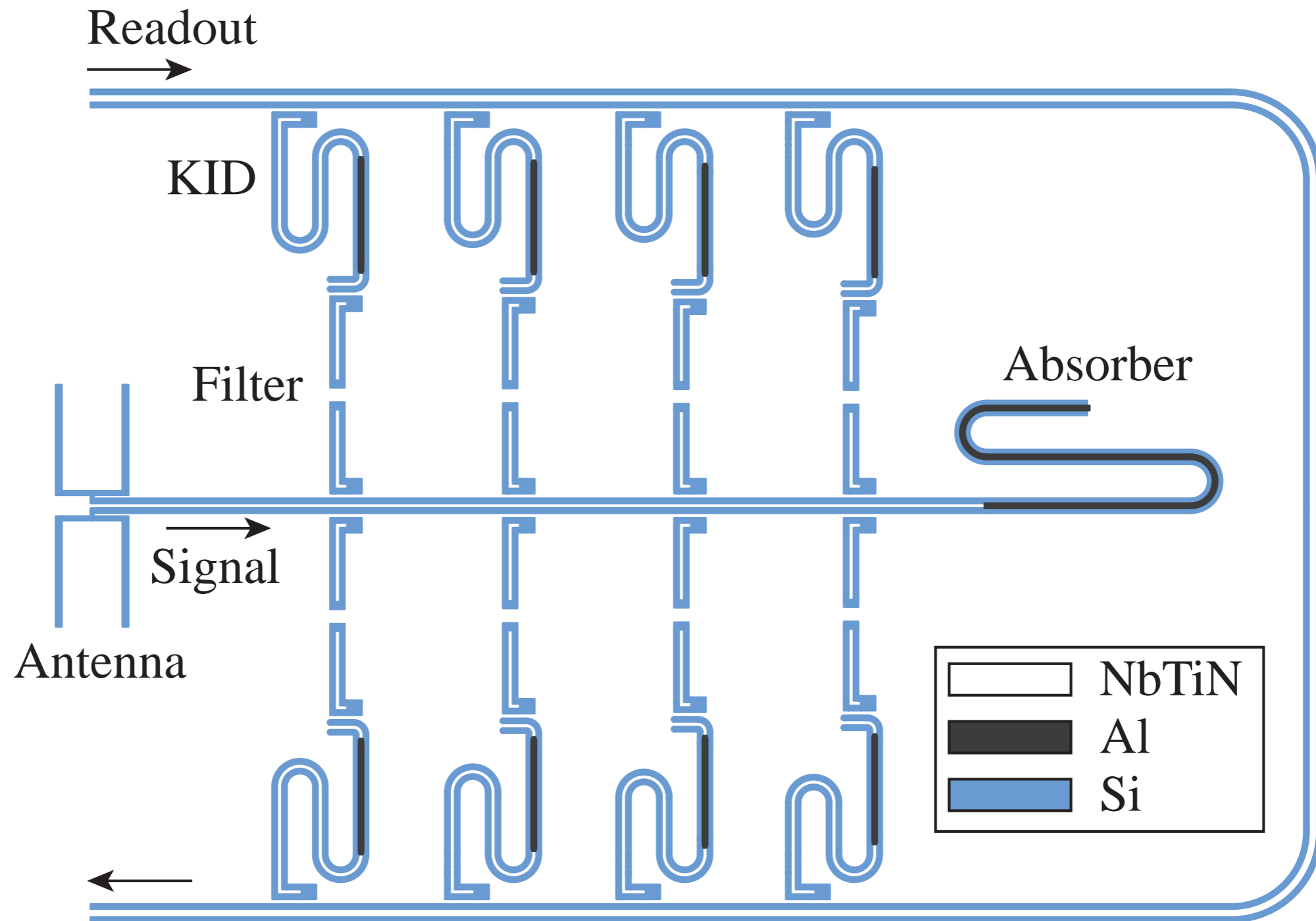
Our Home Ground Technology: Lens-antenna Coupled NbTiN/Al MKIDs

- ▶ Photon-noise limited NEP down to loading powers of 100 fW
(Yates et al., APL, arXiv:1107.4330v1)
- ▶ NbTiN transmission lines lossless up to 1.1 THz
- ▶ Coherent radiation coupling (efficiency > 80%)



Yates et al. APL (2011)

Integrated Filterbank (IFB): Idea



“That has been done 20 years ago!”

Yes, but at a frequency 1/1000 lower..

A low-cost filterbank spectrometer for submm observations in radio astronomy

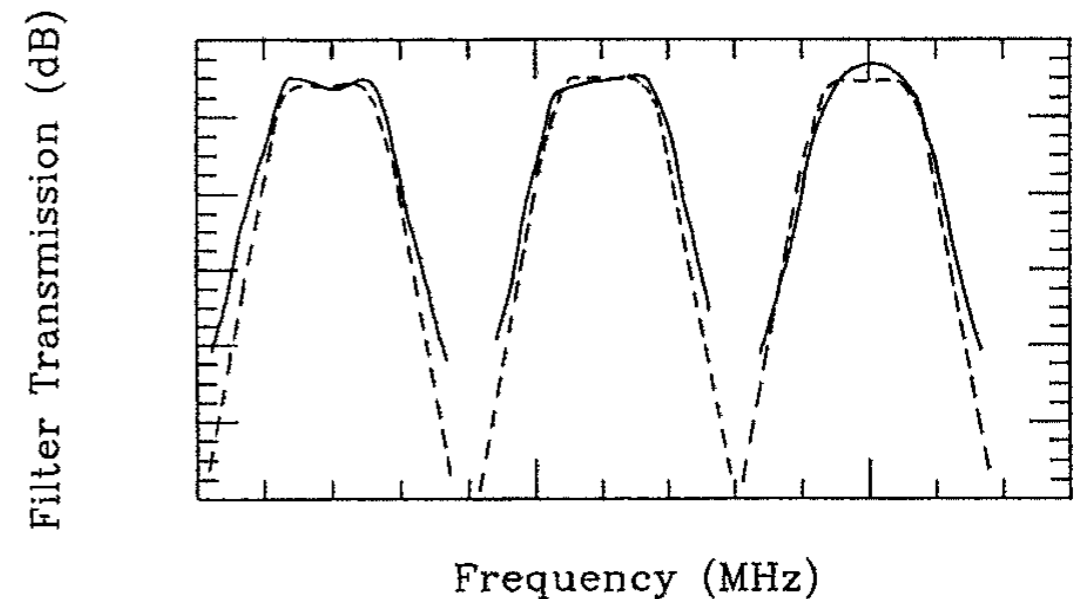
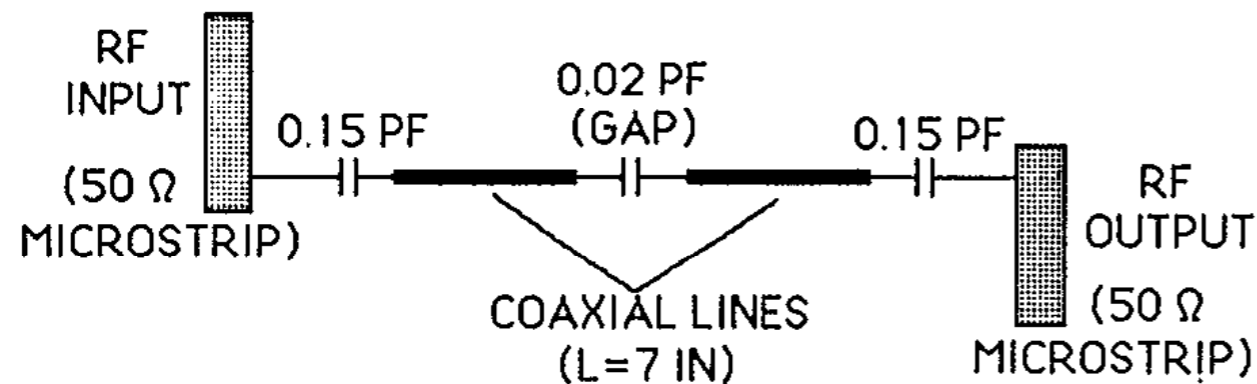
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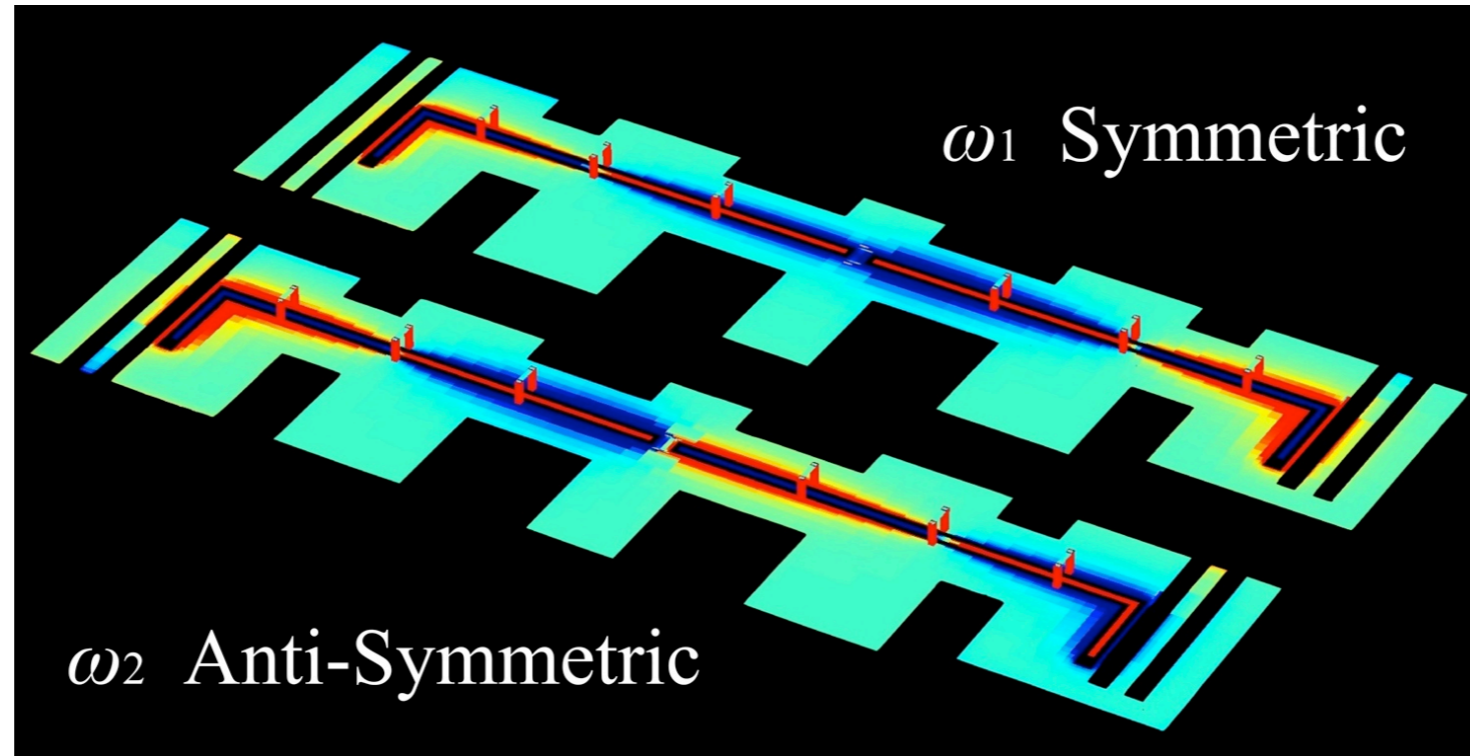
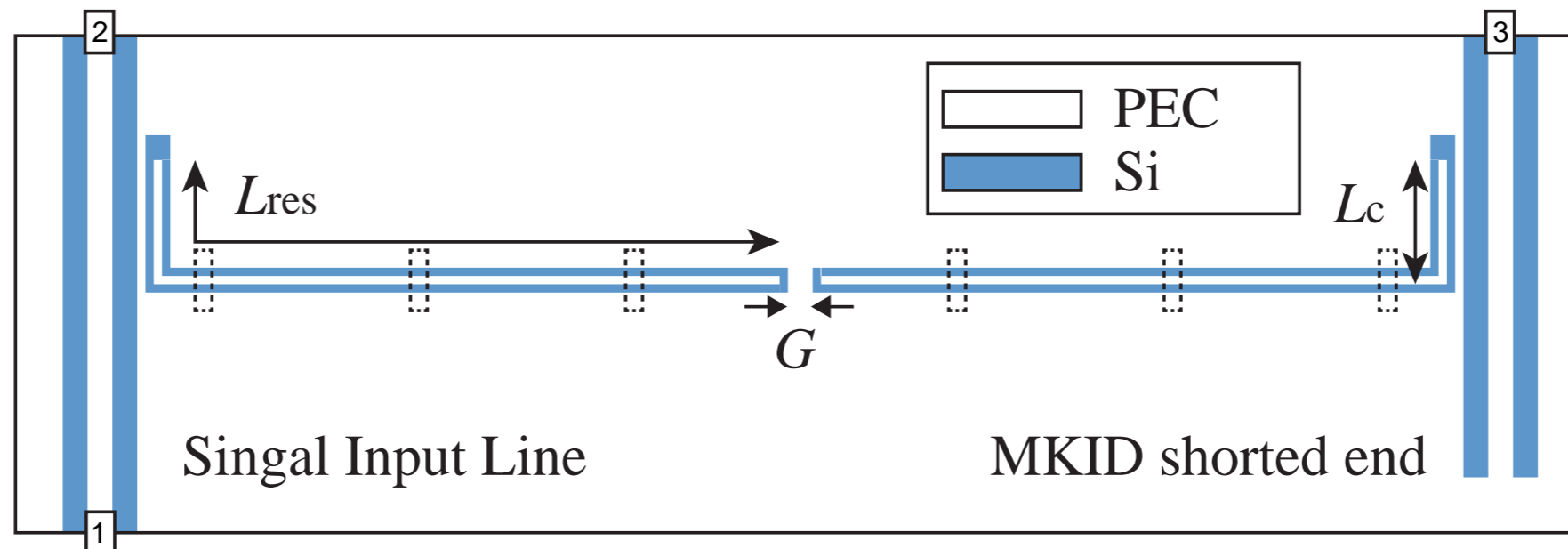
(Received 10 December 1990; accepted for publication 22 January 1991)



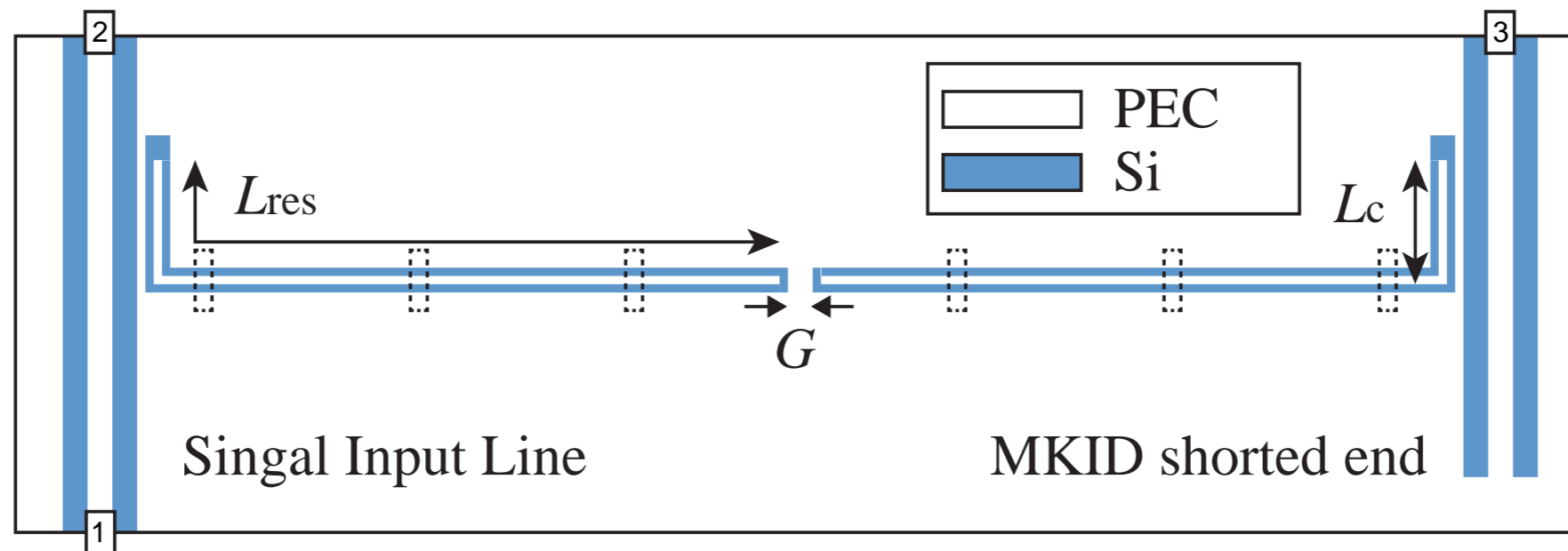
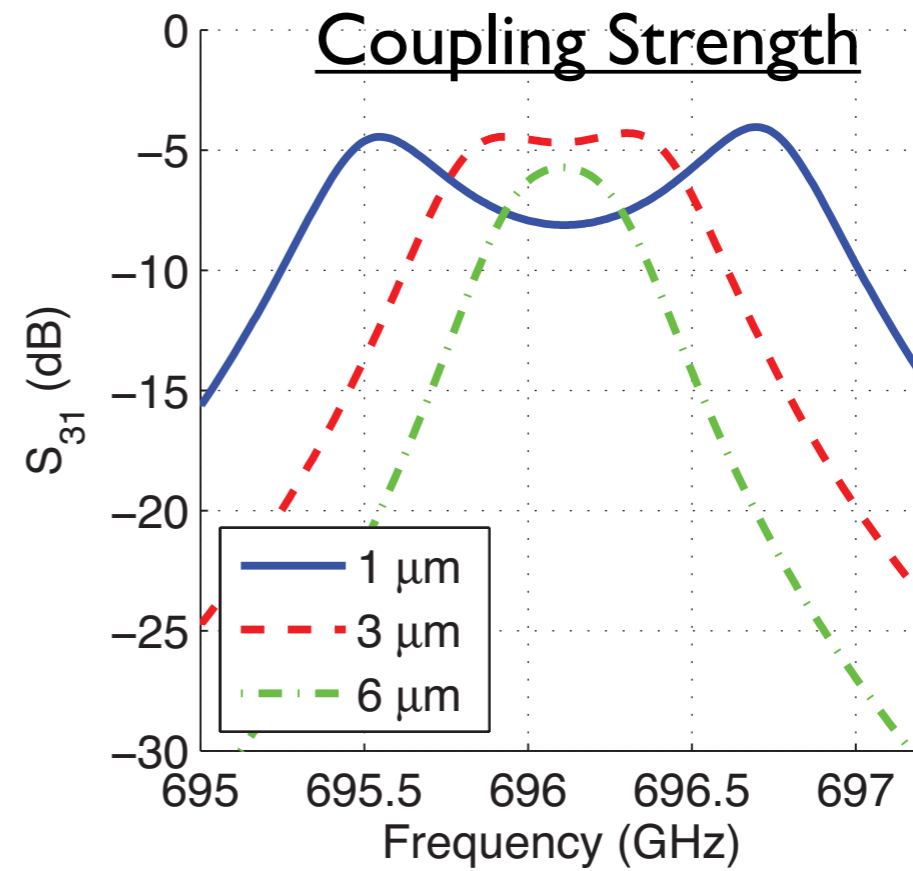
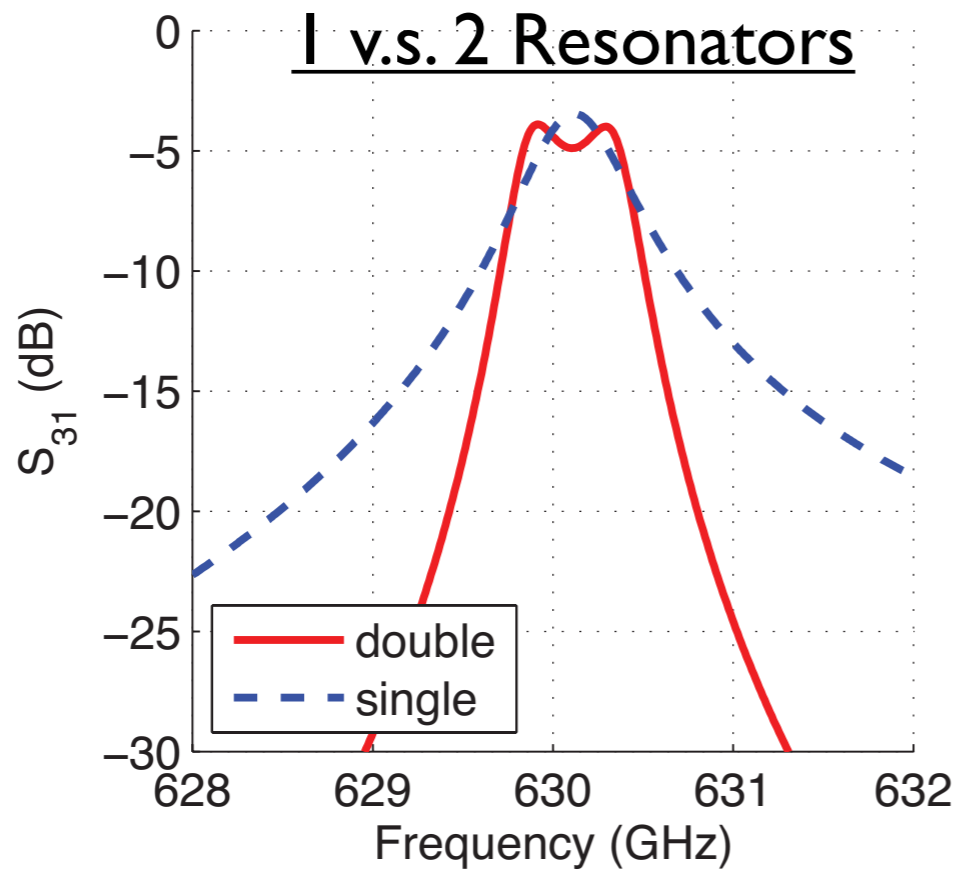
► Key points

- Convenient resolution: $f/df = 1000$
- Coupled resonators provide a flat-top transmission profile

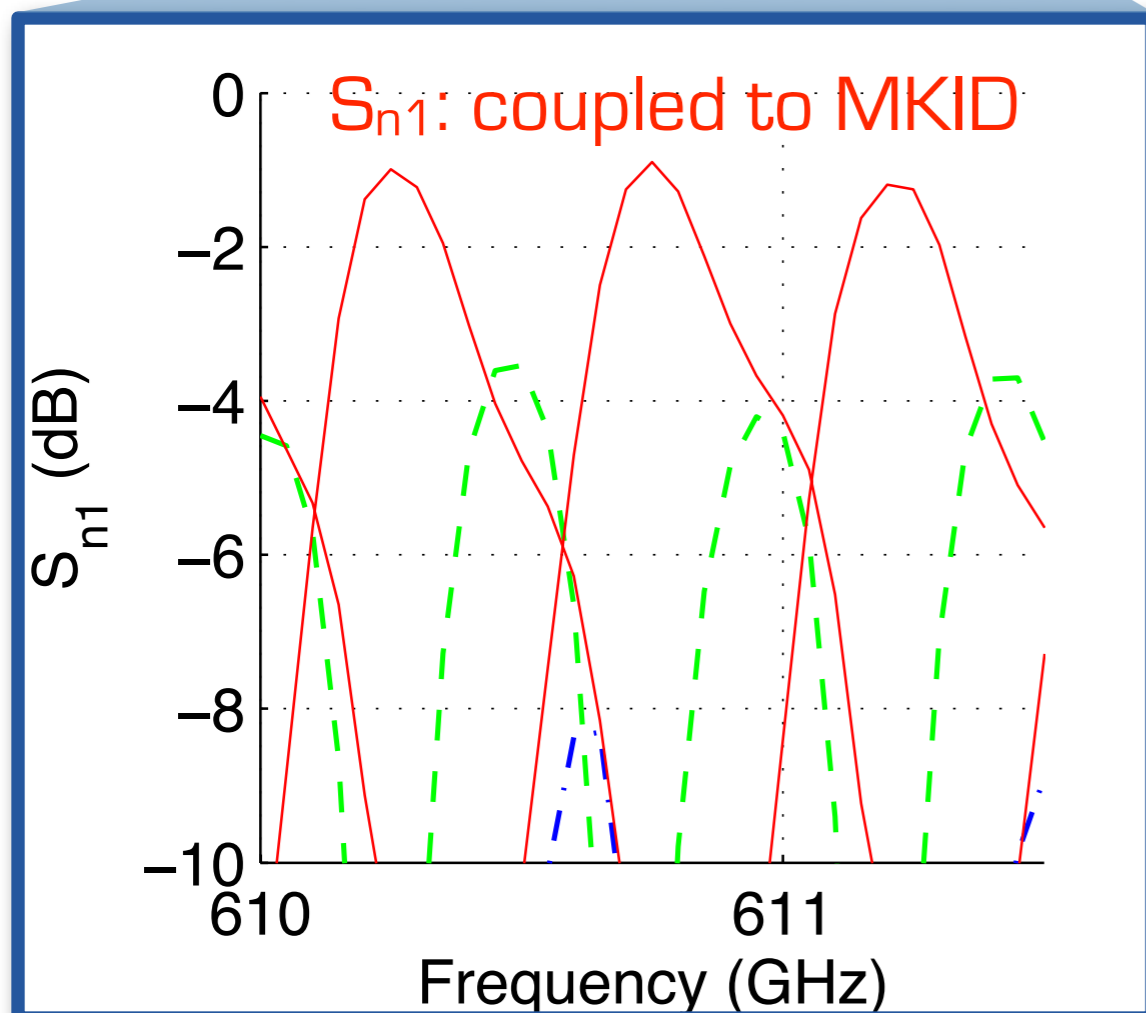
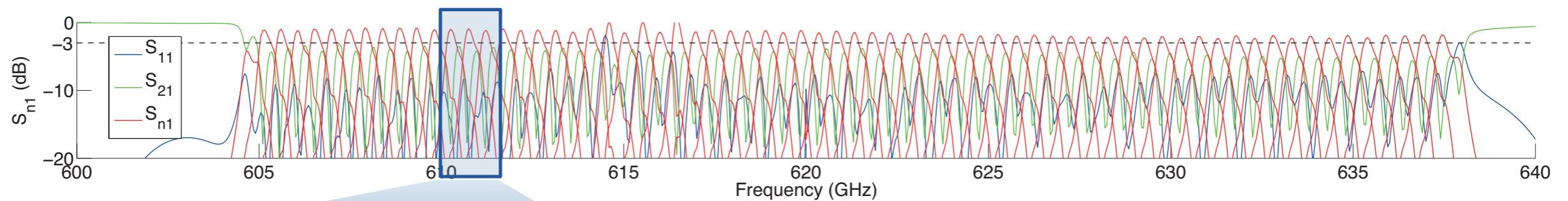
Replacing Coax filters with CPWs



Simulated Transmission (by Sonnet)

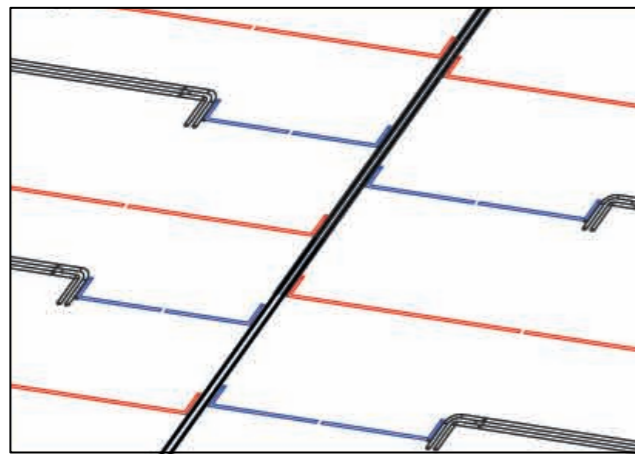
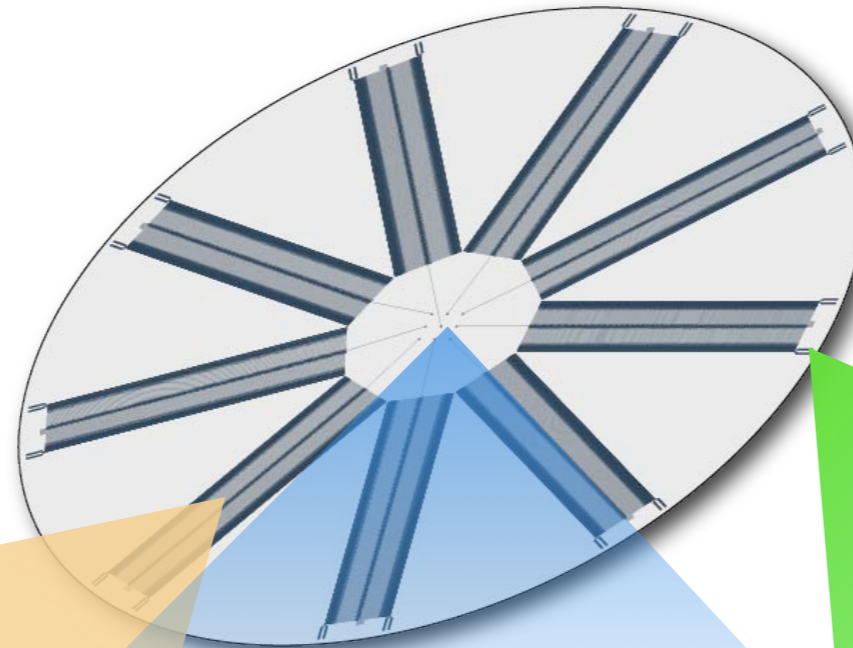


Network Model of 68 Filters

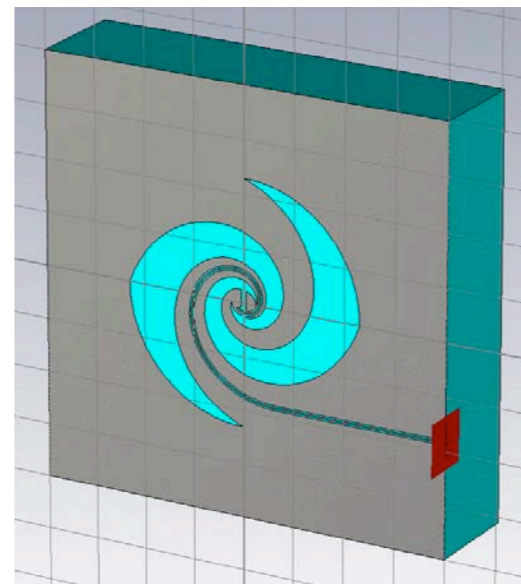


- ▶ Coupling efficiency η stays constant over the entire bandwidth
- ▶ $\eta > -3$ dB
- Stronger than for a single isolated filter:
 $\eta_{\text{peak}} = -4$ dB

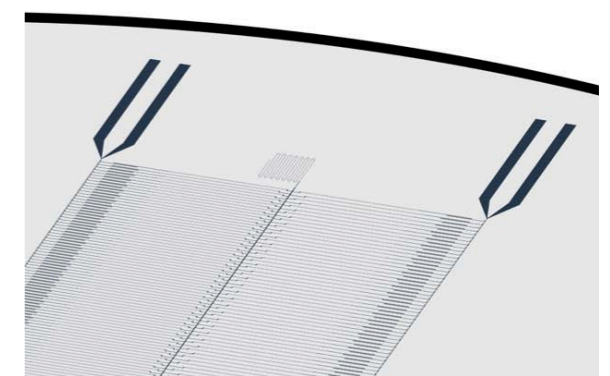
DESHIMA on a 4-inch Si Wafer



920 color filterbanks
(320-475 and 600-950 GHz)



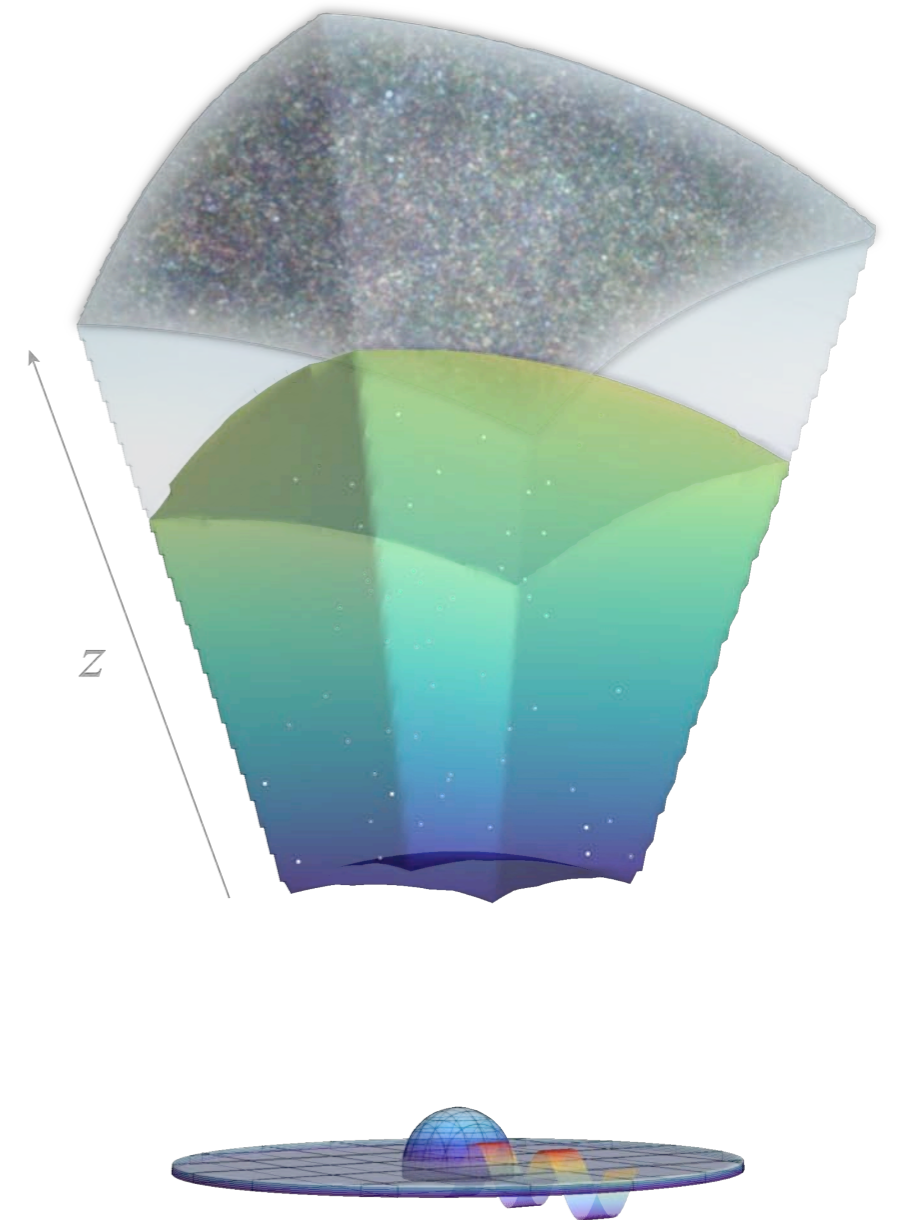
antenna x 9



readout ports

Advantages of the IFB Approach

- ▶ **Compact**
- ▶ **Interchangeable with imaging arrays**
- ▶ **Flexible**
 - 2D spatial sampling
 - Arbitrary sampling in an extremely broad frequency space
 - Many applications other than Z-machines



Variety of New Astronomical Observing Modes that the IFB Could Offer

▶ **1000 colors × 10 pixels (DESHIMA)**

— Broadband multi-pixel Z-machine

▶ **100 colors × 100 pixels (DESHMA-II)**

— Blind survey of high-redshift, low-metallicity objects

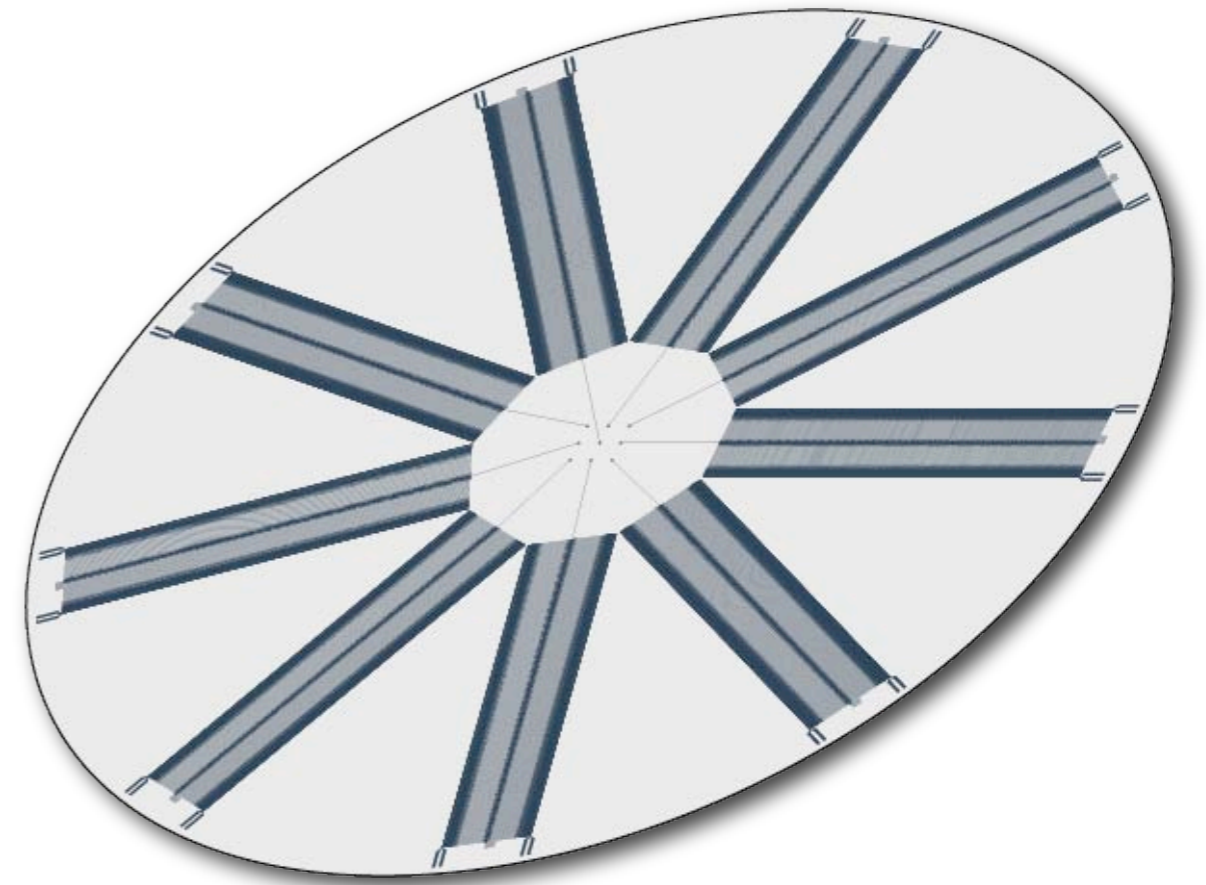
▶ **(A+B+C) colors × ~50 pixels (DESHIMA-III, -IV, etc.)**

— Simultaneous mapping of local objects in multiple emission lines



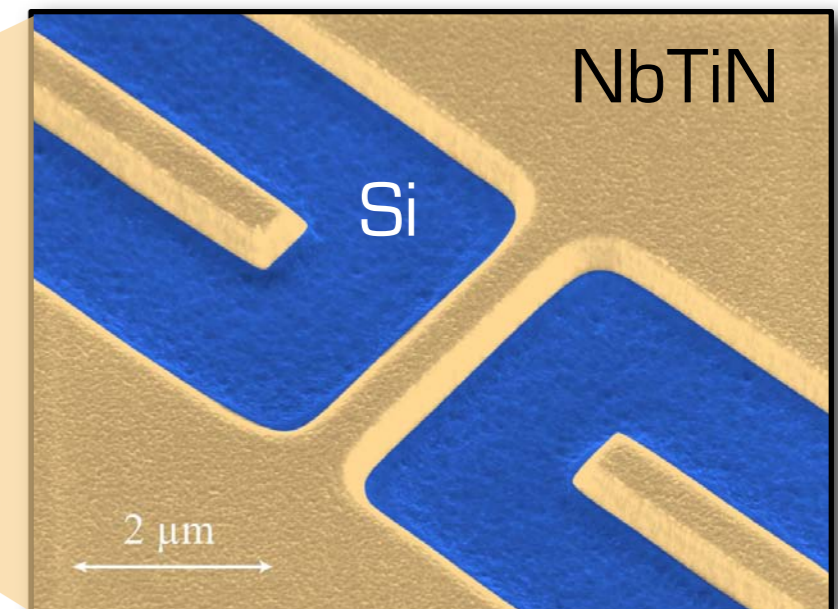
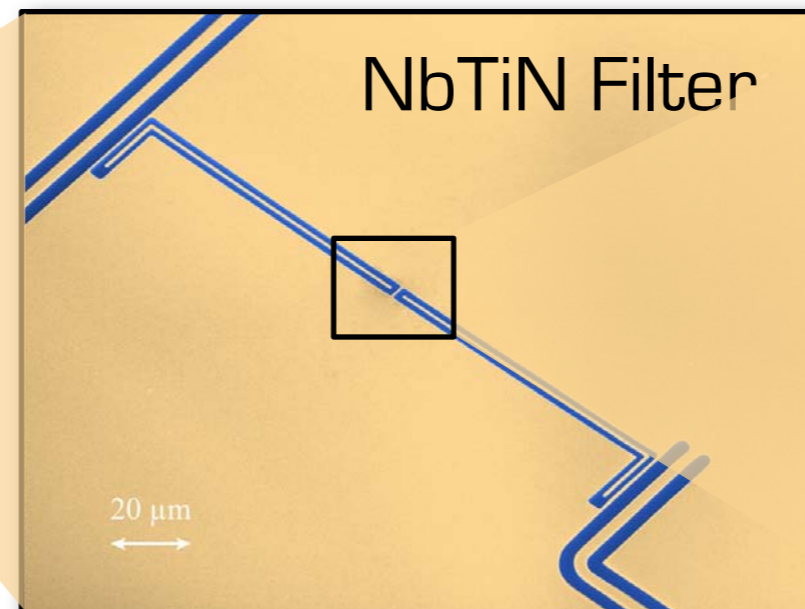
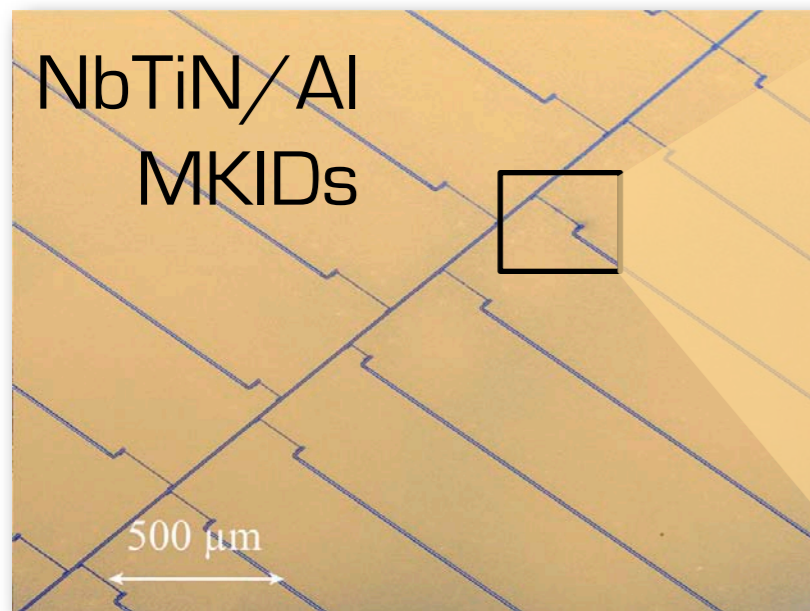
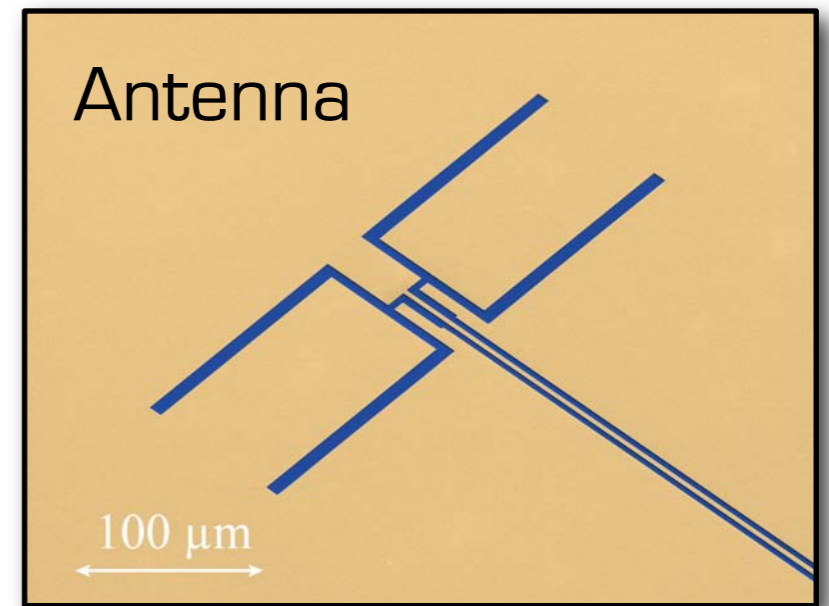
Boundary Conditions and Potential Difficulties

- ▶ inter-channel crosstalk
 - ▶ Signal line length = 50 mm
 - ▶ Length step: 50 nm
 - ▶ ~20k channels on a 4-inch diameter wafer
- diameter wafer



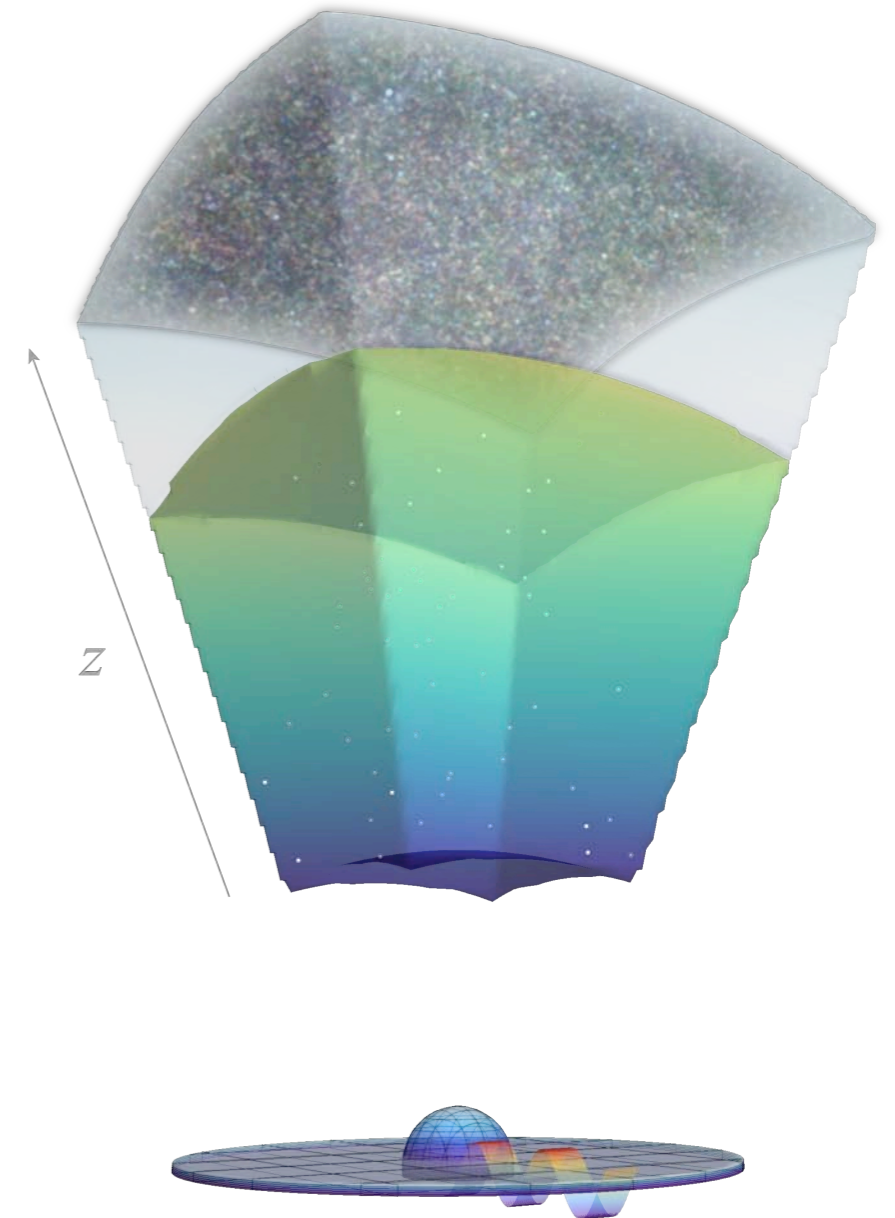
First Chip for Lab Demonstration

- ▶ Designed for the 650 GHz band
- ▶ Fabrication uses the same technology as MKID imaging arrays
- ▶ Electron beam lithography and dry etching for the filters



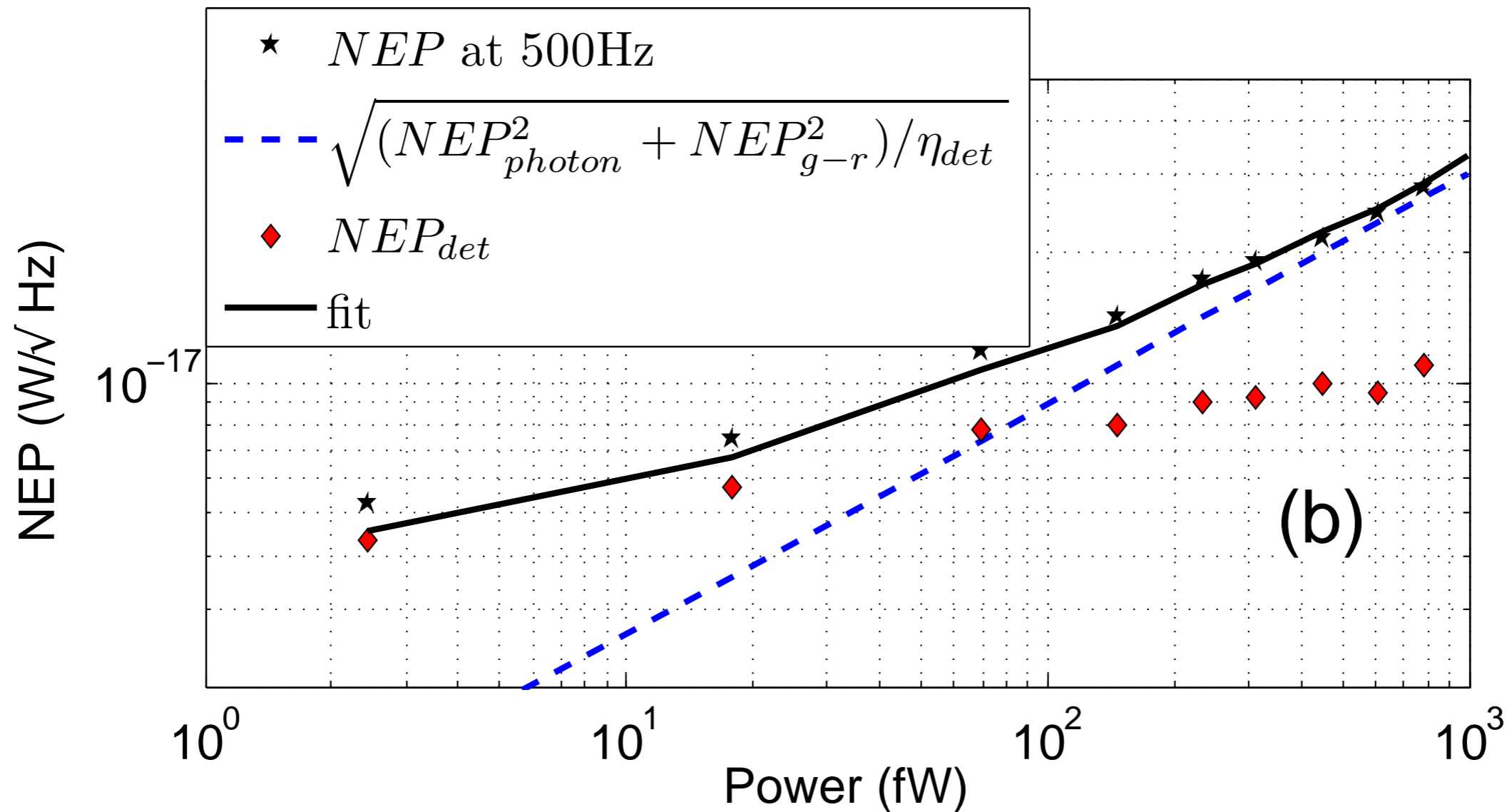
Conclusion

- ▶ **DESHIMA** is a z-machine using MKIDs
- ▶ Advantages of the IFB solution
 - Reduced size and complexity
 - Interchangeable with imaging arrays
 - 2D spatial sampling
 - Broad and flexible frequency sampling
- ▶ Experimental demonstration is under preparation



For details: [arXiv:1107.3333v1](https://arxiv.org/abs/1107.3333v1) [astro-ph.IM]

Photon-noise Limited NEP at 100 fW



Yates et al. APL (2011)