

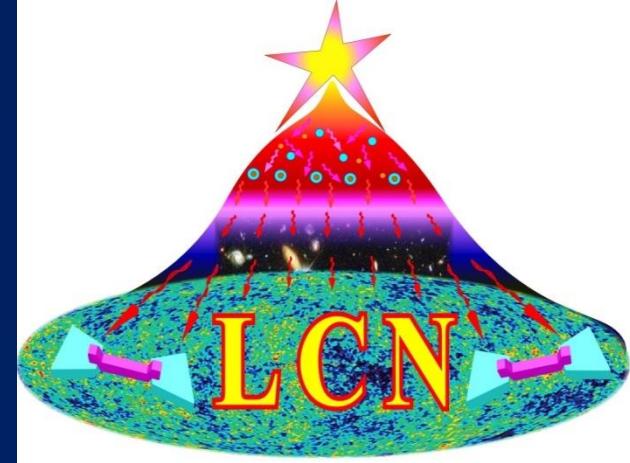


Chalmers University,
MC2

Per aspera ad astra

Через тернии к звездам!

CEB for CMB



Nizhniy Novgorod State Technical University
Laboratory of Cryogenic Nanoelectronics

Realization of the Resonant Cold-Electron Bolometer with a Kinetic Inductance Nanofilter for Multichroic Pixels

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In collaboration with:

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ESA consortium on Multichroic Systems,**

Outline

- **ESA-COrE, Multichroic Systems.**
- **Resonant Cold-Electron Bolometer (RCEB)**
- **Cross-Slot Antenna with RCEBs**
- **Seashell Antenna with RCEBs**
- **Conclusions**

Next Generation Sub-millimetre Wave Focal Plane Array Coupling Concepts.

Multifrequency Systems for COrE

**APC Paris Laboratoire de Astroparticule et Cosmology
Cardiff University, UK**

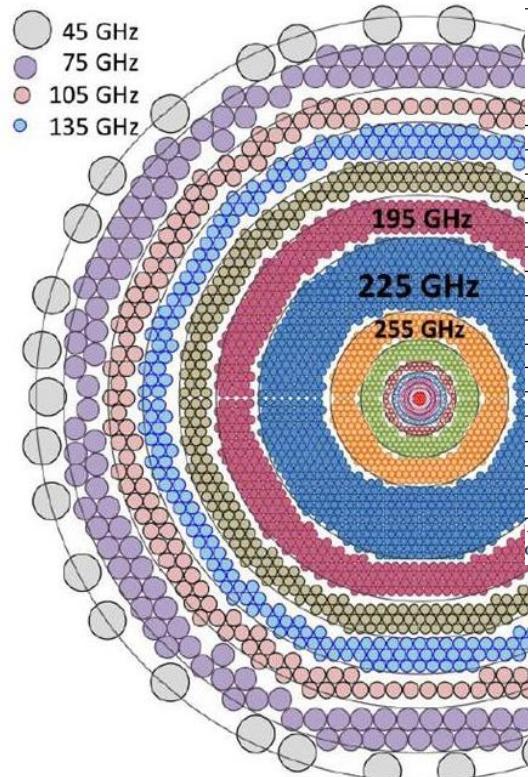
**Chalmers Technical University, Göteborg
La Sapienza, Rome**

**Manchester University, UK
NUI Maynooth, Ireland**



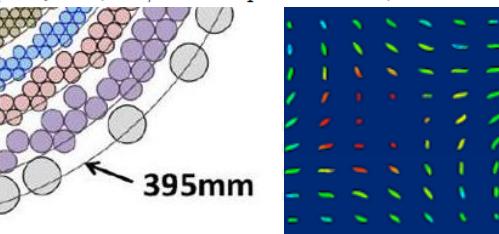
Disadvantage of current technologies: The focal plane of Planck

The focal plane of COrE

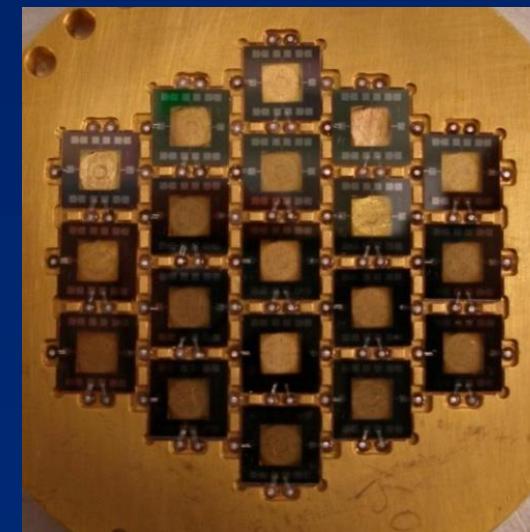


Central Frequency (GHz)	Bandwidth (GHz)	Angular Resolution (arcmin)	Q&U Sensitivity ($\mu\text{K}\cdot\text{arcmin}$)	Out of band Rejection (above 1THz)	Beam Ellipticity (% @-3dB)	Cross-polarisation (dB)
45	15	23.3	9.0	> 120 dB	< 1%	< -30 dB
75	15	14	4.7	> 120 dB	< 1%	< -30 dB
105	15	10	4.6	> 120 dB	< 1%	< -30 dB
135	15	7.8	4.5	> 120 dB	< 1%	< -30 dB
165	15	6.4	4.6	> 120 dB	< 1%	< -30 dB
195	15	5.4	4.5	> 120 dB	< 1%	< -30 dB
225	15	4.7	4.5	> 120 dB	< 1%	< -30 dB
255	15	4.1	10.4	> 120 dB	< 1%	< -30 dB
285	15	3.7	17	> 120 dB	< 1%	< -30 dB
315	15	3.3	46	> 120 dB	< 1%	< -30 dB
375	15	2.8	117	> 120 dB	< 1%	< -30 dB
435	15	2.4	255	> 120 dB	< 1%	< -30 dB
555	195	1.9	589	> 120 dB	< 1%	< -30 dB
675	195	1.6	3420	> 120 dB	< 1%	< -30 dB
795	195	1.3	20881	> 120 dB	< 1%	< -30 dB

The total optical efficiency shall be larger than 50% (TBC). This includes any (quasi-optical) filter, lens/reflector spillover loss etc, and include the (bolometer) coupling.



COrE
Cosmic Origins Explorer



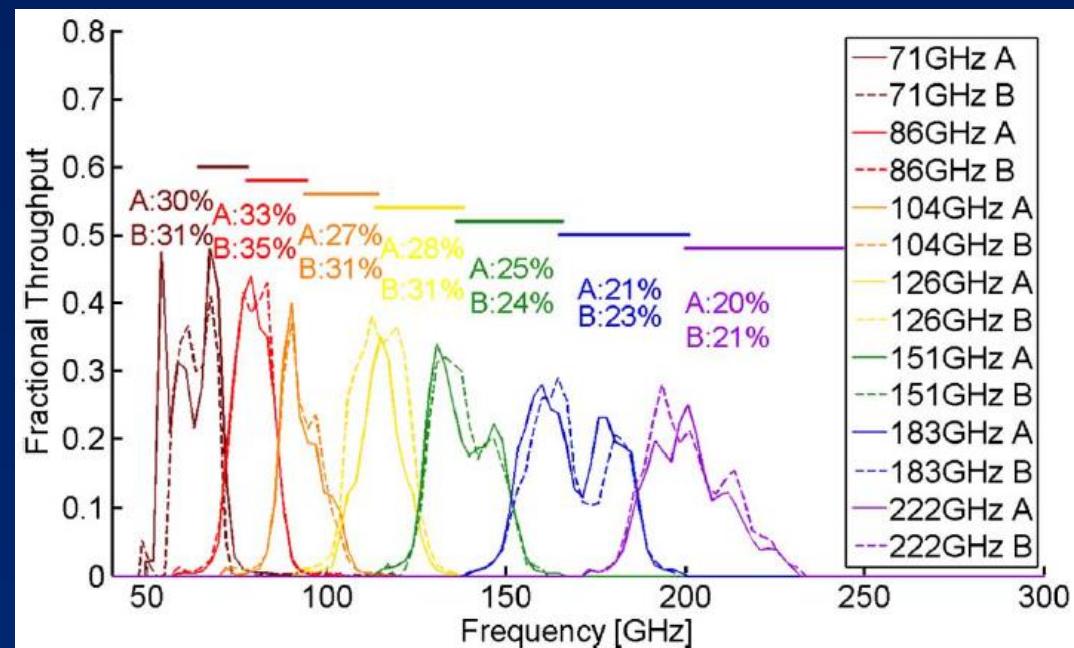
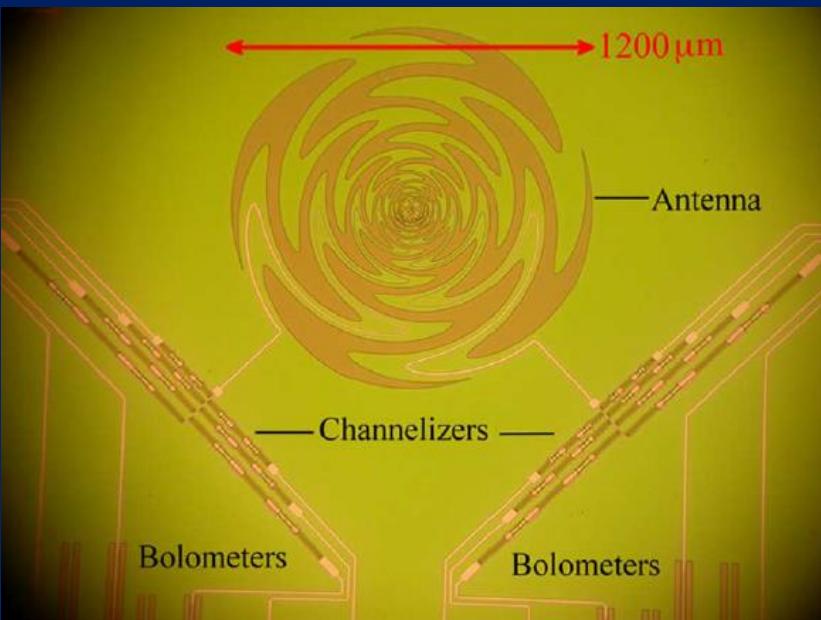
Optical Criteria for 75 and 105 GHz channels

Parameter	Value	Comments
Beam ellipticity	<5 %	$\text{Ell 1} = (A-B)/(A+B)$ $\text{Ell 2} = A/B; \text{ Ell 2}=1+2*\text{Ell 1}$
Beam FWHM	~20deg	Depending on exact optical configuration
Cross polarisation	< -30 dB	Ludwig III polar convention defined as $E_{\text{cross}}^2/E_{\text{co}}^2$
Bandwidth, at 3 dB	>20% or 15GHz	
In band transmission (filtering)	80%	
In band transmission (overall)	60%	All optical components
Out of band rejection (near)	10^{-3}	As obtained for Planck
Out of band rejection (far)	10^{-15}	As obtained for Planck
Return loss	< -20 dB	Limited in-band reflection to reduce standing waves
Sidelobes	< -20 dB	

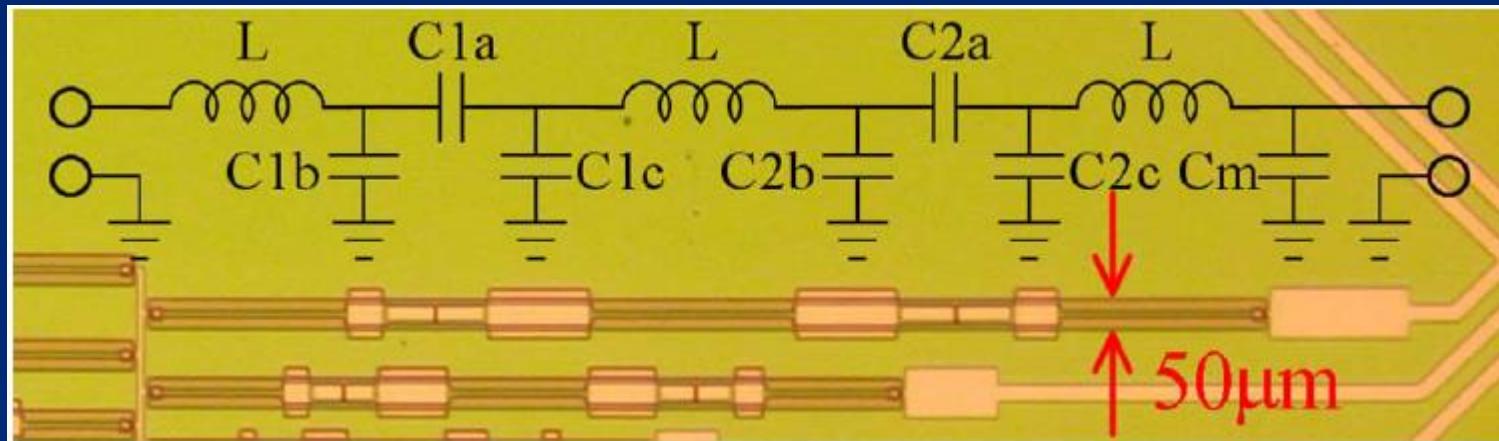
15 Ohm < ReZ < 30 Ohm for matching with MSL and CEB

Sinuous Antenna

R. O'Brian et al., IEEE Appl. Sc. (2011)

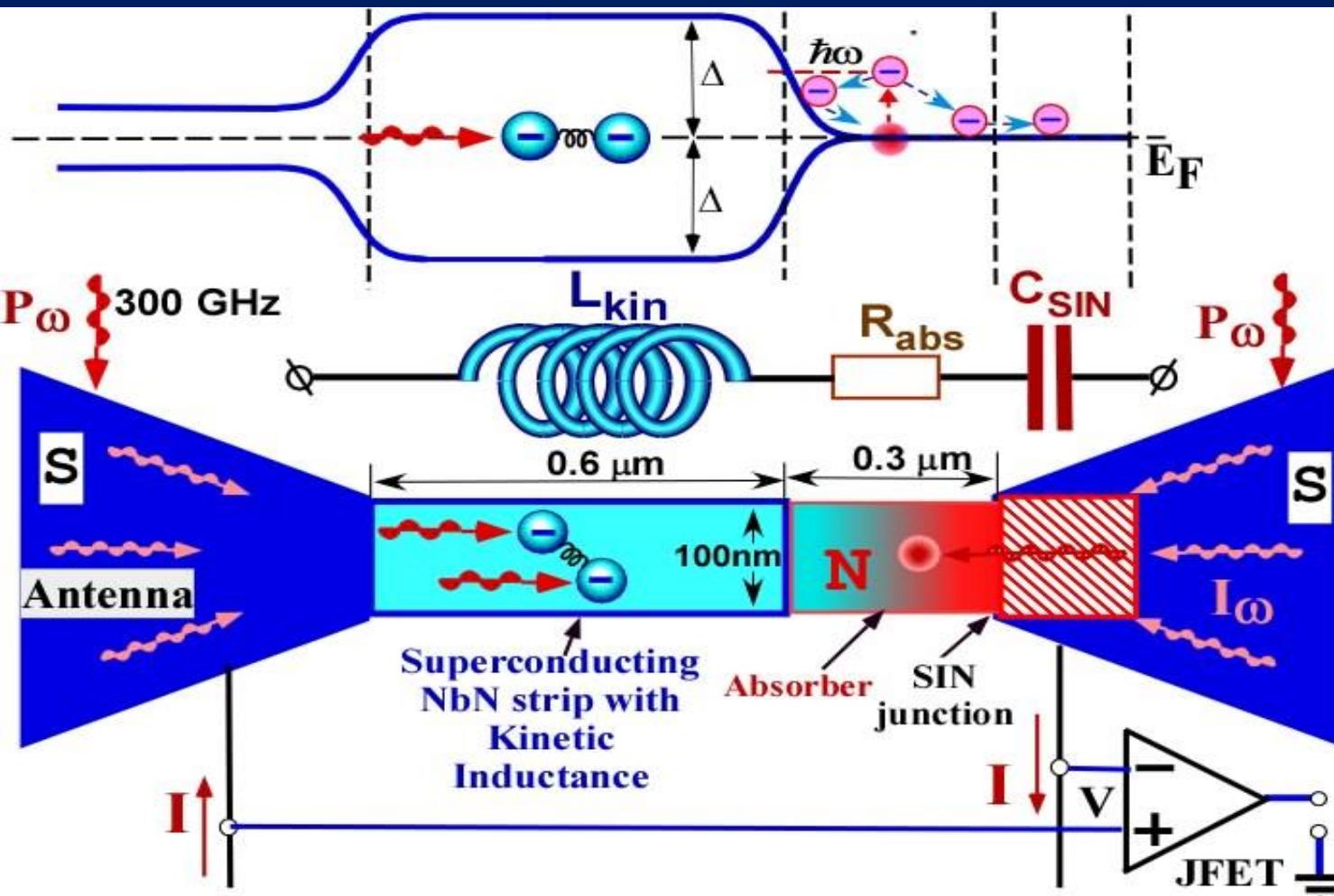


Length of Microstrip lines is 7 mm!



Resonance Cold-Electron Bolometer (RCEB) with Nanofilter by a Kinetic Inductance of the NbN strip and a Capacitance of the SIN Tunnel Junctions

L. Kuzmin, ISSTT, 2013; IEEE TST, 2014

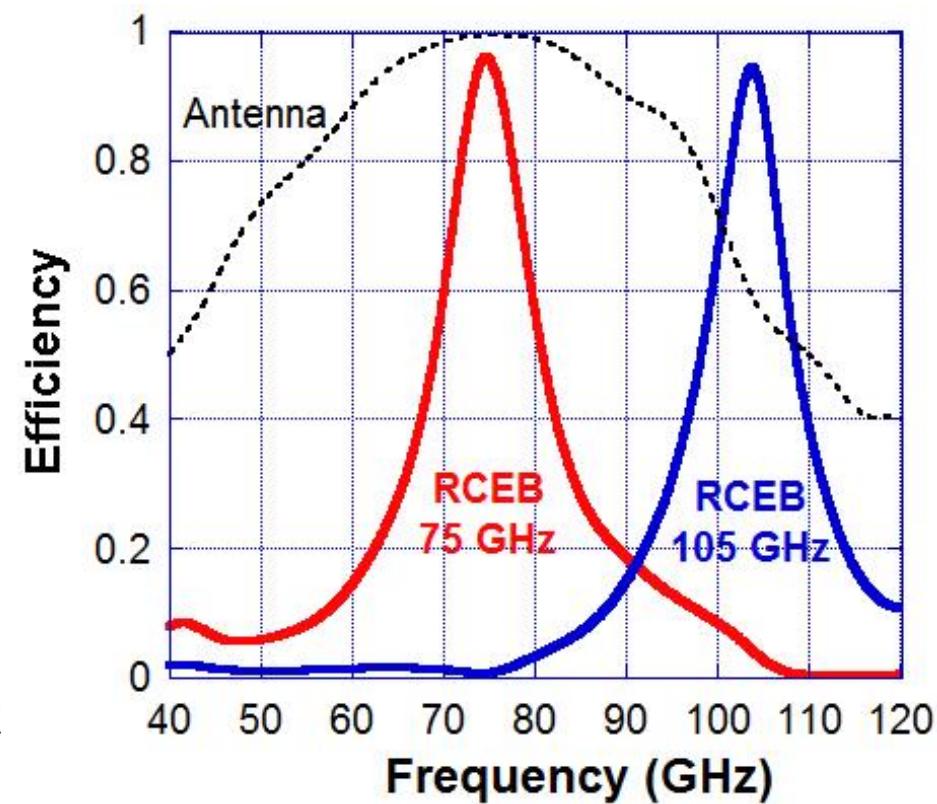
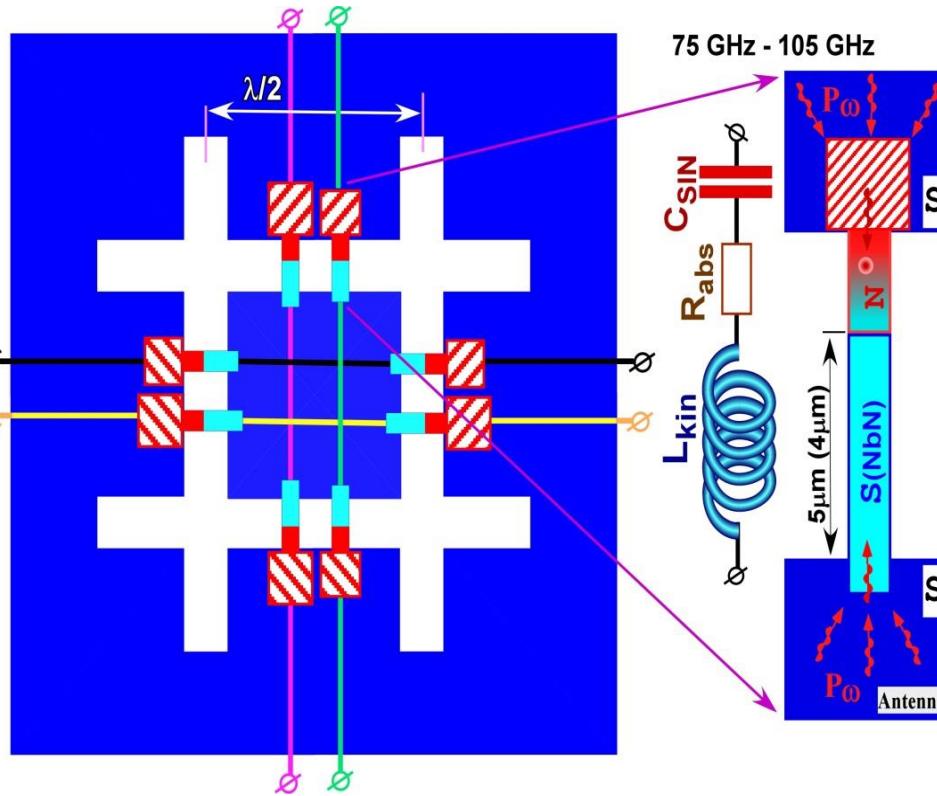


$$L_k = \frac{\mu_0 l}{w} \left[\frac{\lambda^2}{b} \right]$$

NbN: $\lambda=400 \text{ nm}$, $b=10 \text{ nm}$, $L_{kin}=140 \text{ pH}$ for $l=0.6 \mu\text{m}$

$Q=10$, $R_{abs}=15 \text{ Ohm}$, $\omega L_{kin}=300 \text{ Ohm}$ @ 350 GHz, SIN: $S=0.04 \mu\text{m}^2$

Cross-Slot Antenna with RCEB for 75 and 105 GHz

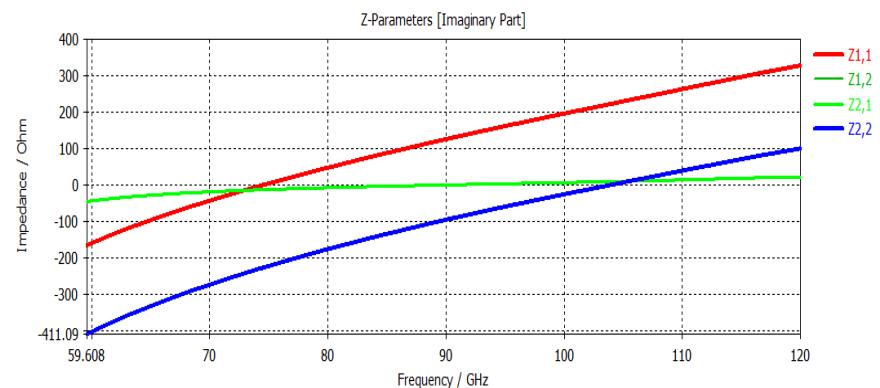
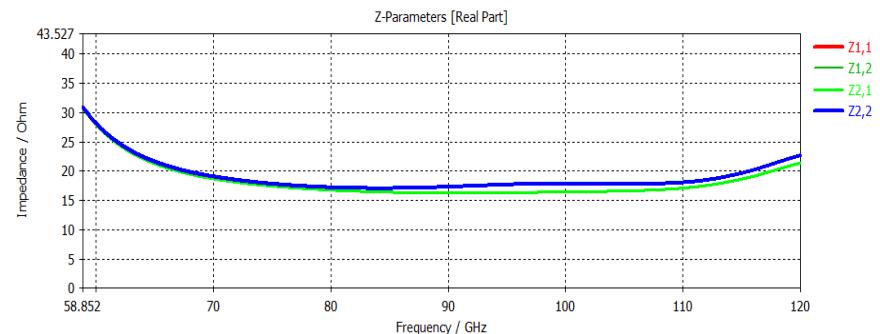
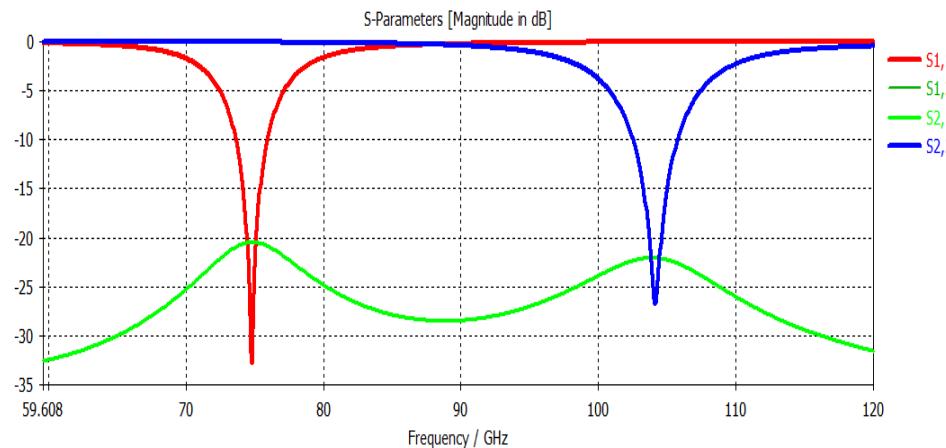
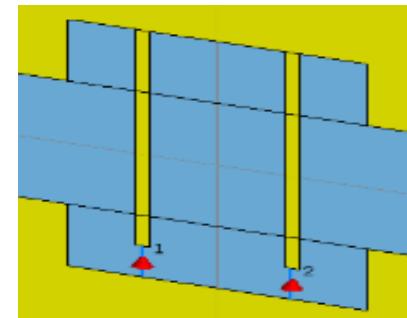
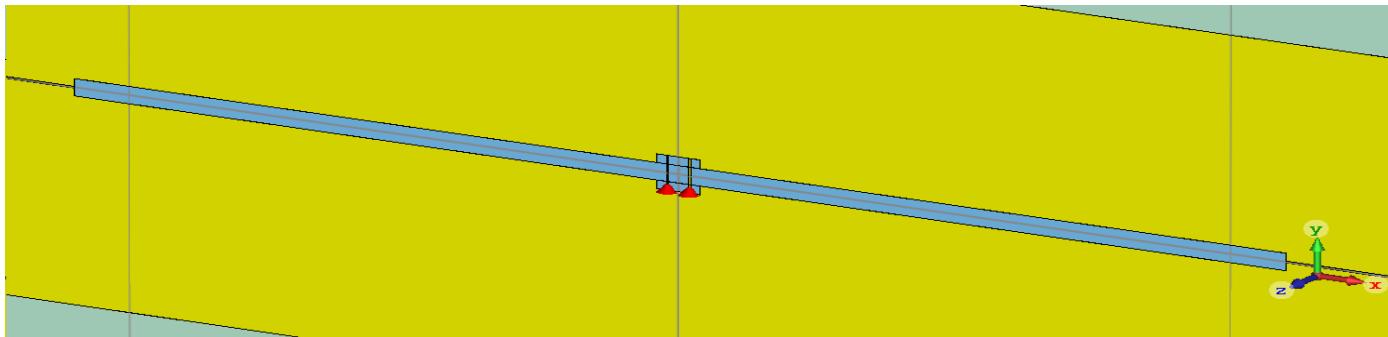


Cross-Slot Antenna - J. Zmuidzinas et al,

Preliminary frequency selection in each pixel is done by the antenna and the final selection is done by RCEB.

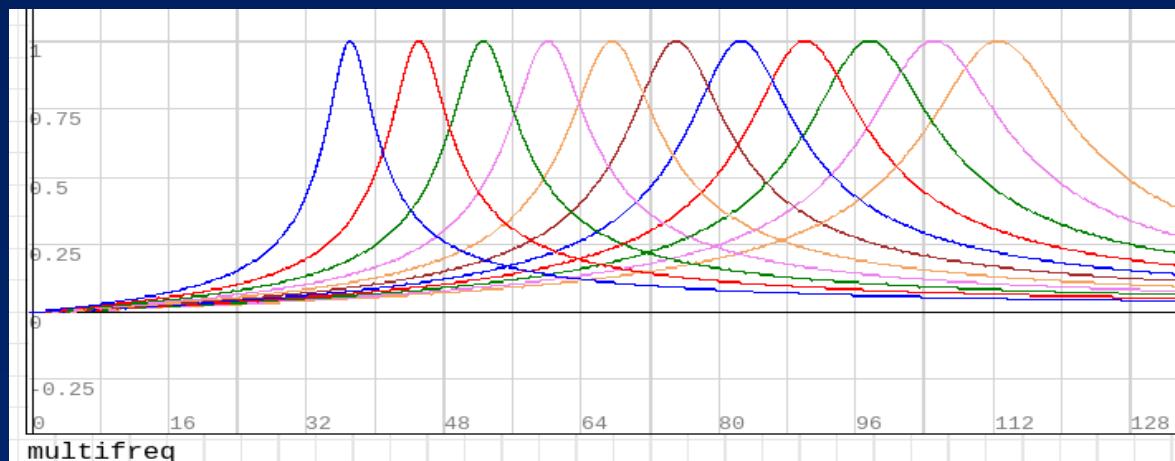
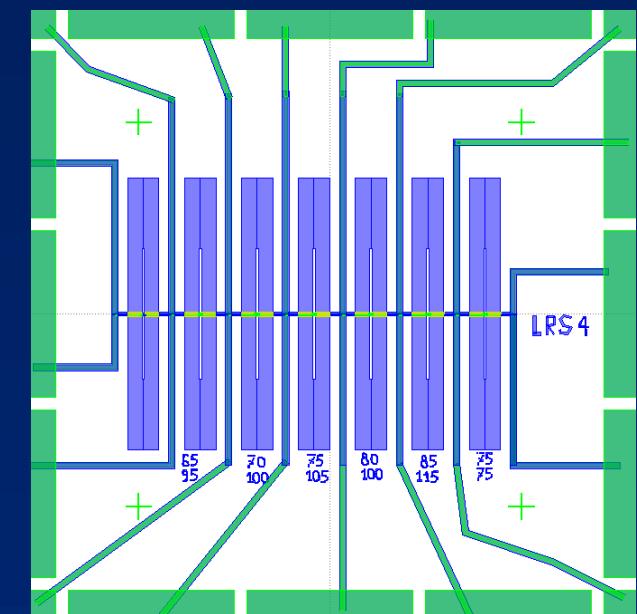
$L_{kin}/s_{sq} = 4\pi\lambda^2/b / H$ NbN: $\lambda=300 \text{ nm}$, $b=10 \text{ nm}$, $L_{kin}/s_{sq}=20 \text{ pH/sq}$, $L_{kin}=400 \text{ pH}$, $l=2 \mu\text{m}$, $Q=10$, $\rho=20 \text{ Ohm}$, $R_{abs}=20 \text{ Ohm}$, SIN: $S=0.2 \mu\text{m}^2$, $C_1=11\text{fF}$,

S, Z -parameters of a slot antenna with RCEB

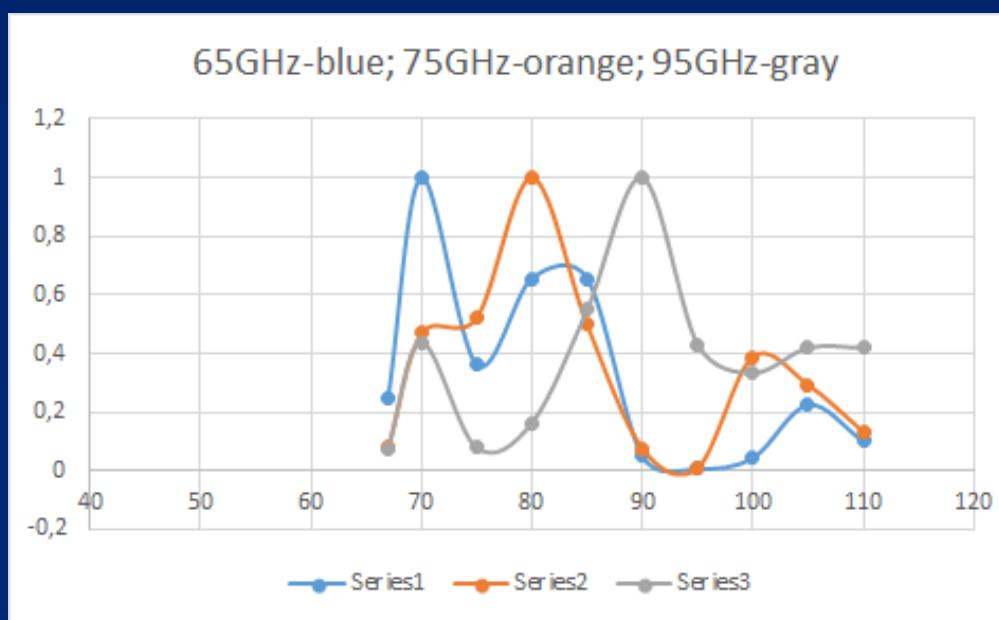
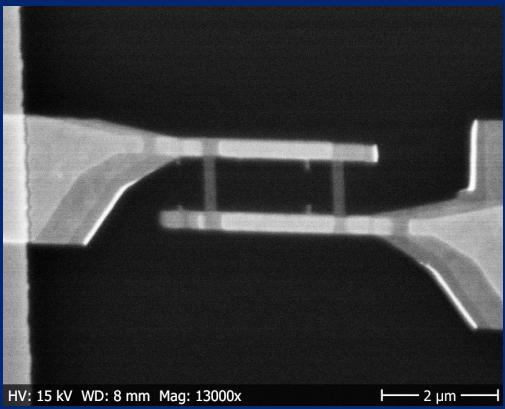
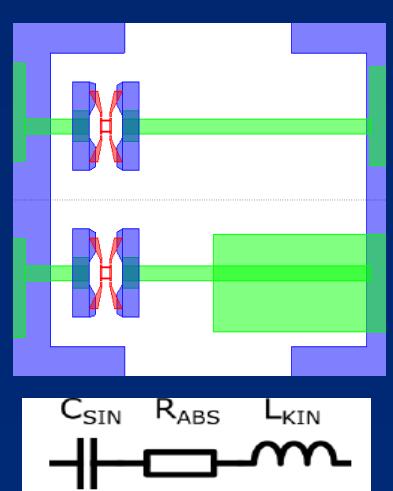


Multichroic Lambda slots with 2 RCEBs for 75 and 105 GHz for cross-slot antenna

A. Mukhin, A. Chekushkin, M. Tarasov, L. Kuzmin,
P. de Bernardis,

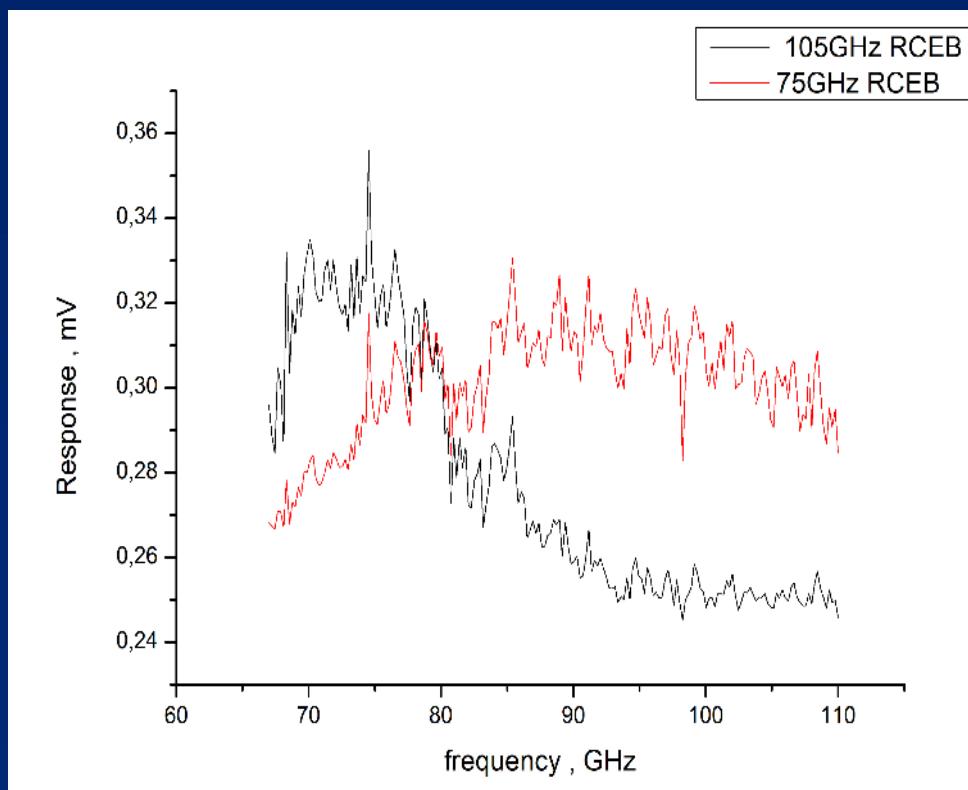
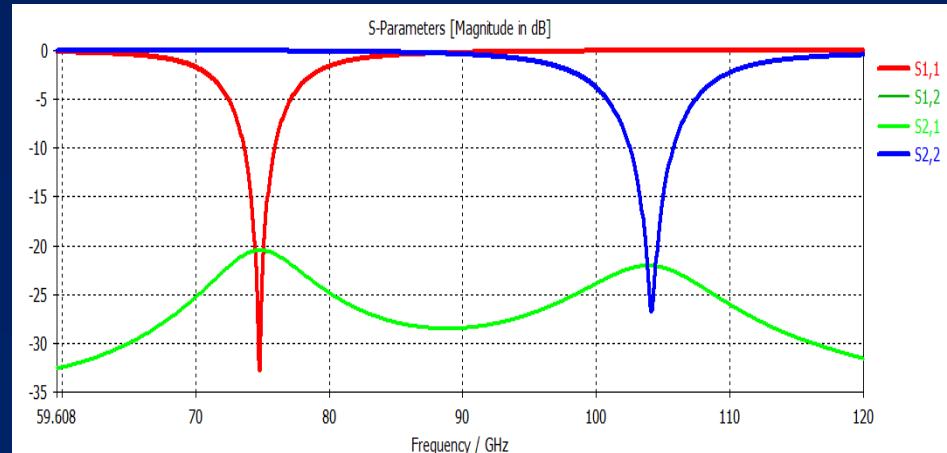


Series of resonances of RCEBs inside Lambda slots



Response of 65, 75 and 95 GHz bolometers to signal from 65 to 110 GHz

Spectral response of two RCEBs in the same slot antenna

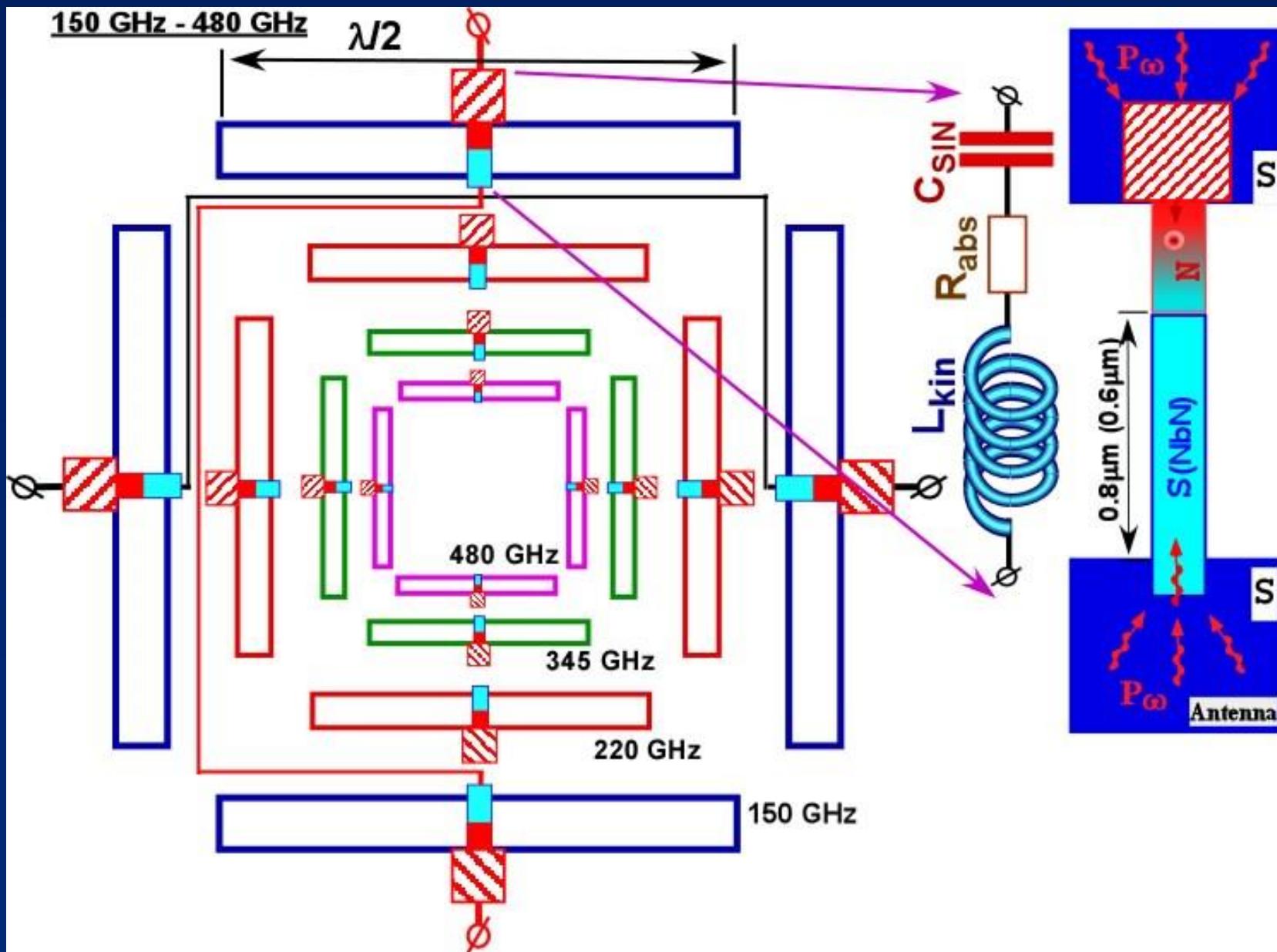


“Seashell” Slot Antenna with RCEBs

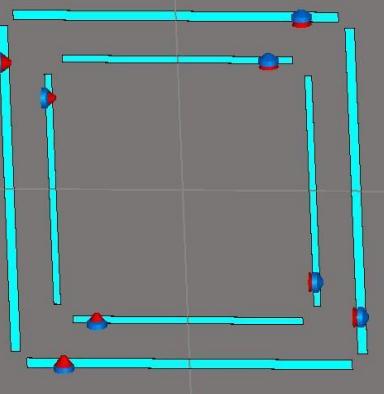
Leonid Kuzmin , Rome, 21 Sept 2013

Stimulative discussions with Paolo de Bernardis are acknowledged

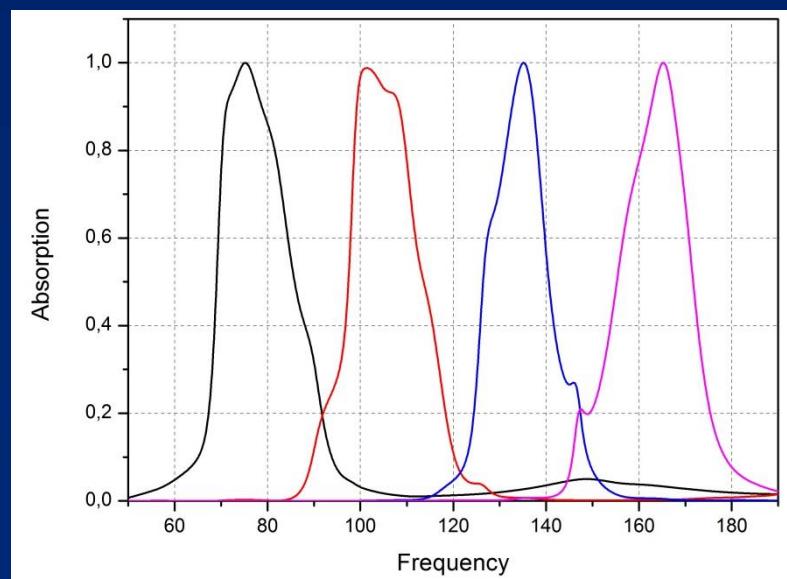
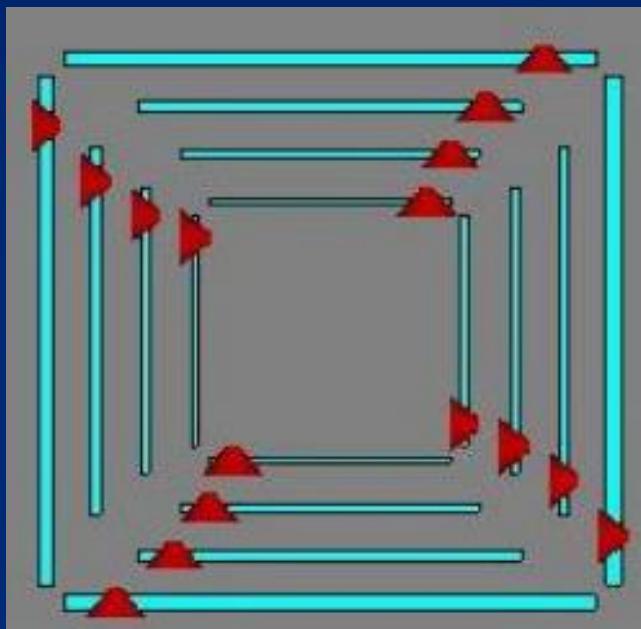
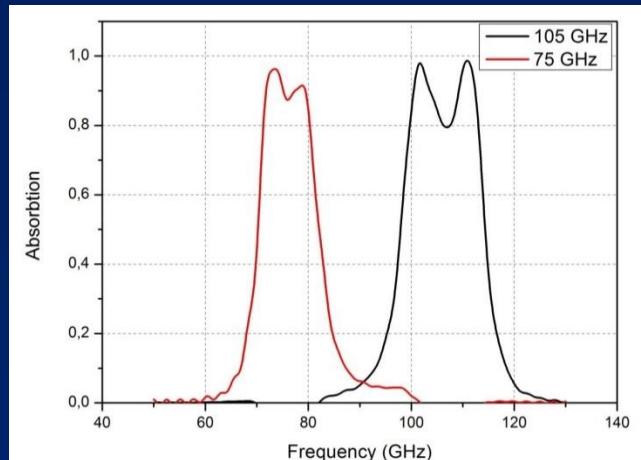
For OLIMPO



"Seashell" Antenna with $\lambda/2$ Slots and RCEBs



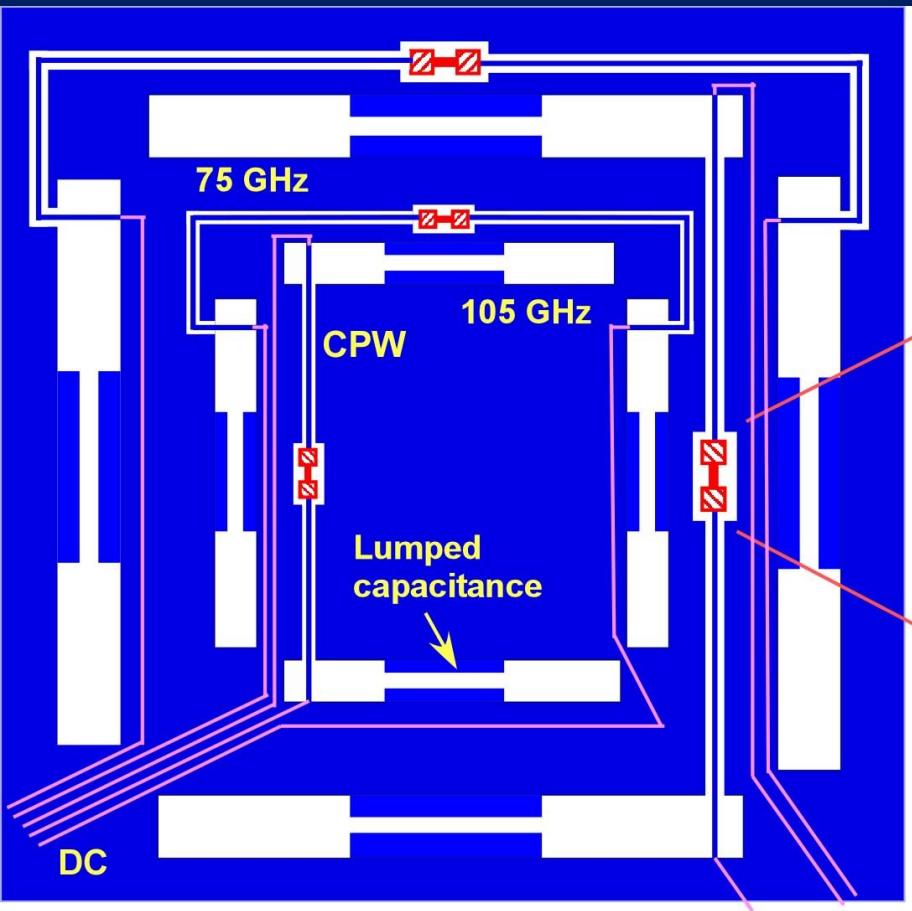
Beam ellipticity 4.9% at 75 GHz
8% at 105 GHz



Absorption in 4-Frequency Seashell Slot Antenna
with RCEBs designed for 75, 105, 135, and 165 GHz

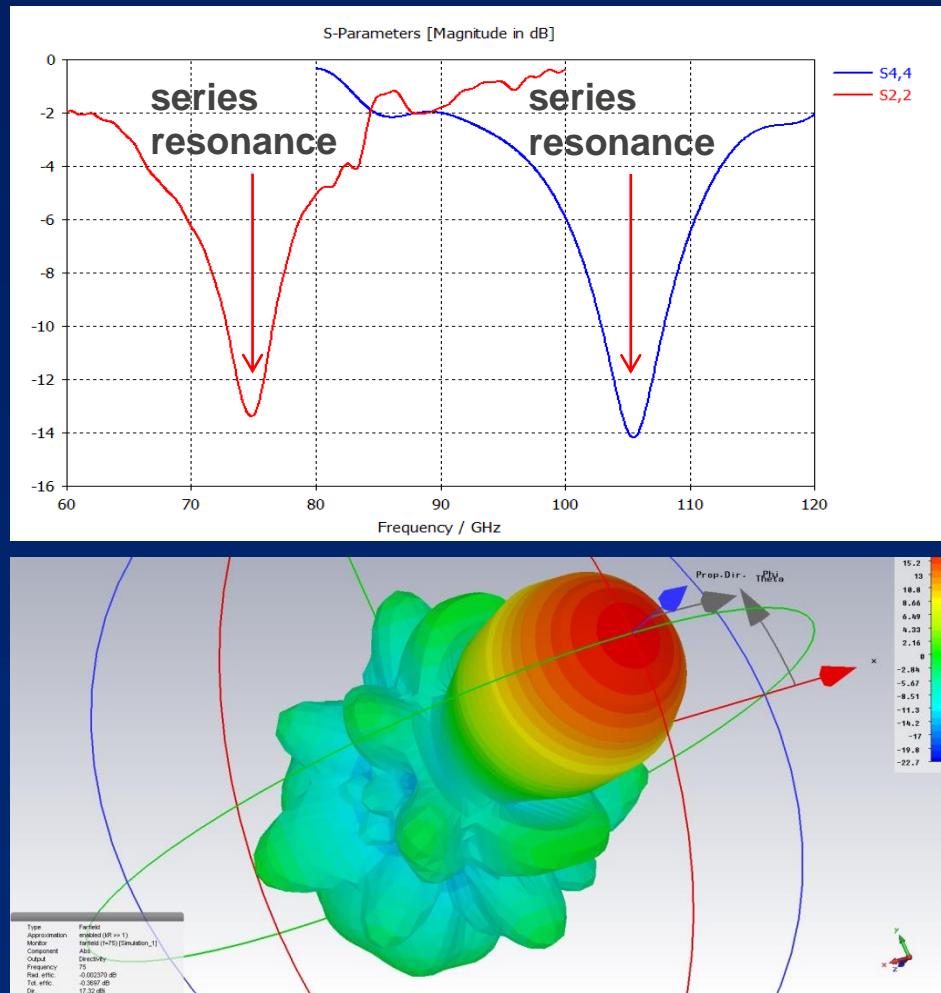
Seashell Antenna with CPW and RCEB for 75/105 GHz

L. Kuzmin, A. Chiginev, E. Matrozova, and A. Sobolev. IEEE Trans. on Applied Superconductivity, (2016);
L. Kuzmin, A. Chiginev, Proc. SPIE (2016)



CPW: 1 RF layer (4 layer technology):

1. DC wires (30 nm Au)
2. SiO₂ insulation, 50 nm
3. Ground plane (Au or Nb, 150 nm)
4. CEB (FeAl/oxid./Al)



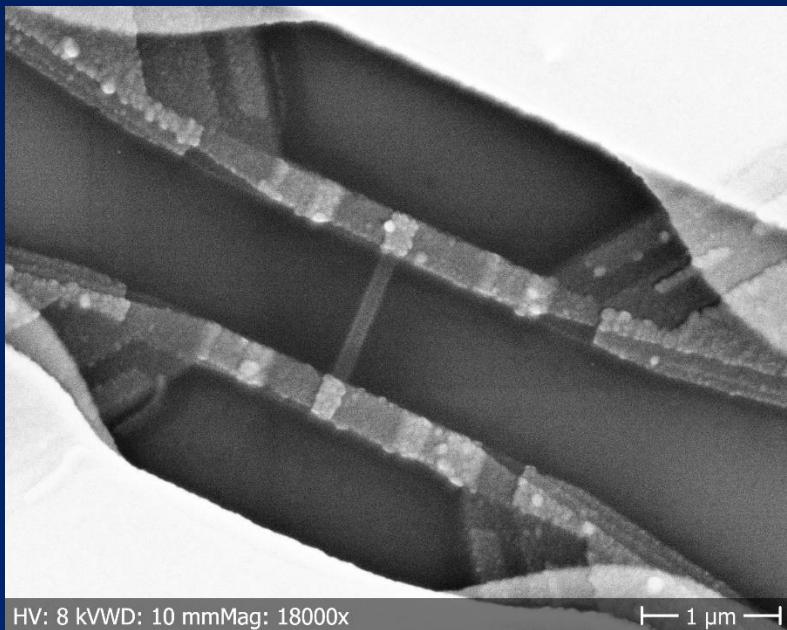
Ellipticity: 2% – 4% !

ReZ = 13 Ohm

Bandwidth: > 20%

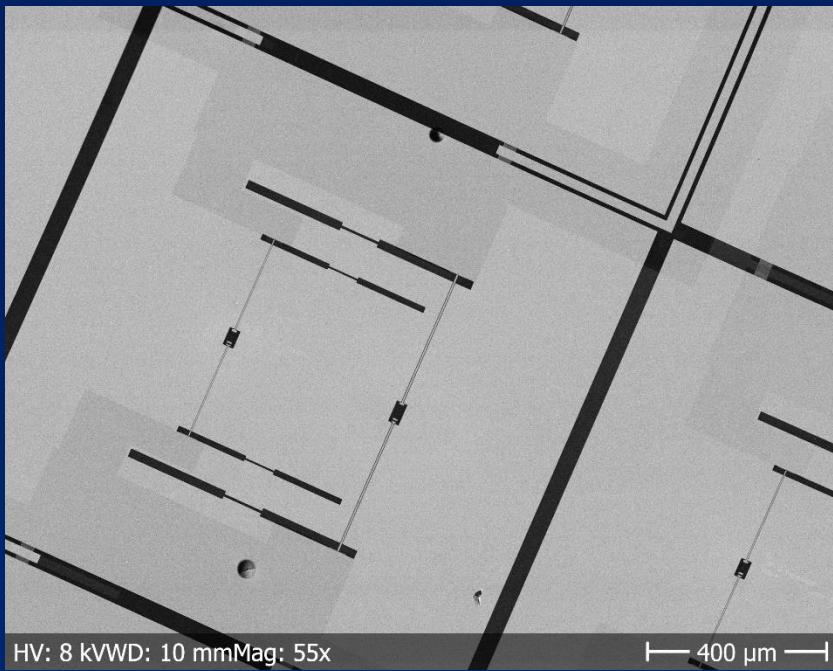
Crosspol: 15-20 %

One polarization Seashell antenna with 2 RCEBs



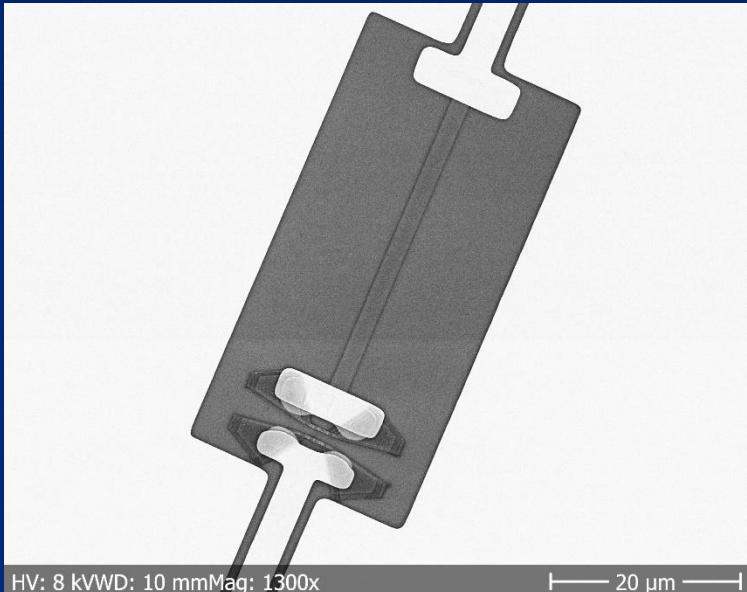
HV: 8 kVWD: 10 mmMag: 18000x

1 μm



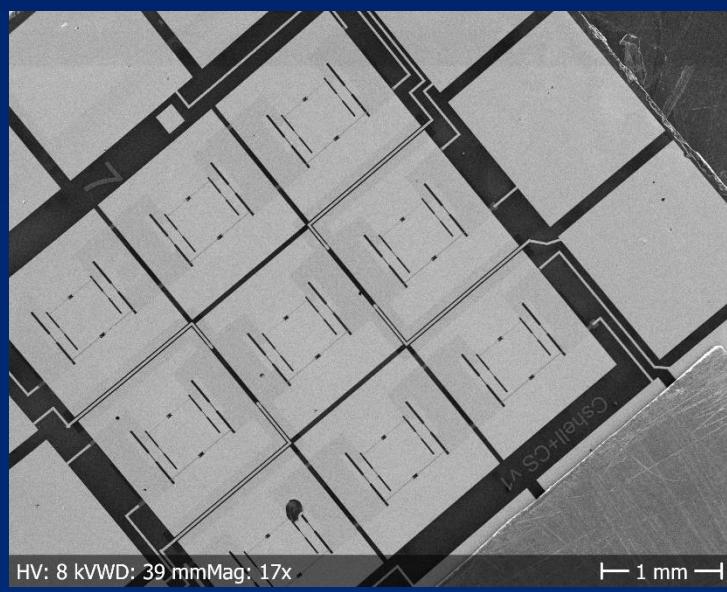
HV: 8 kVWD: 10 mmMag: 55x

400 μm



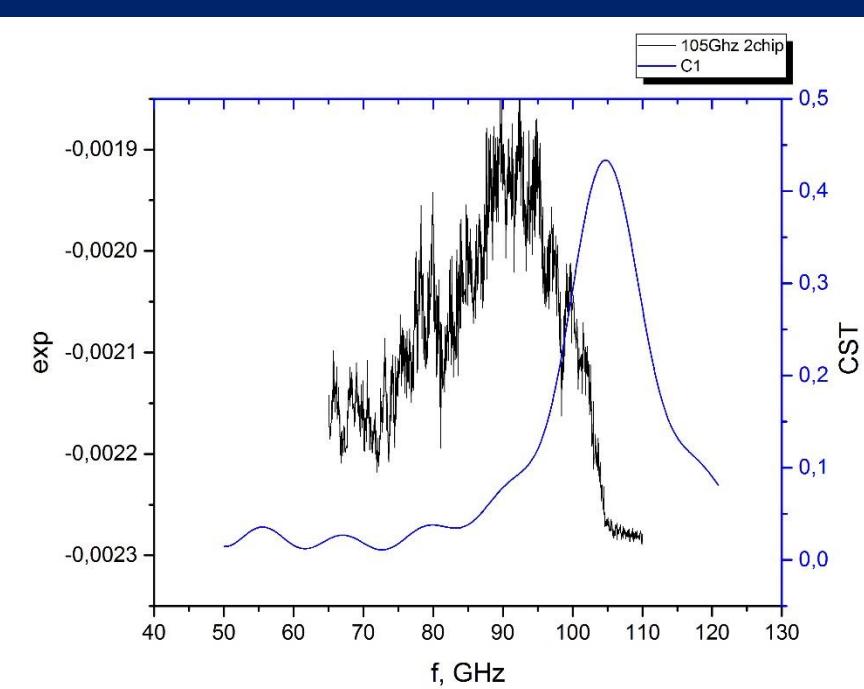
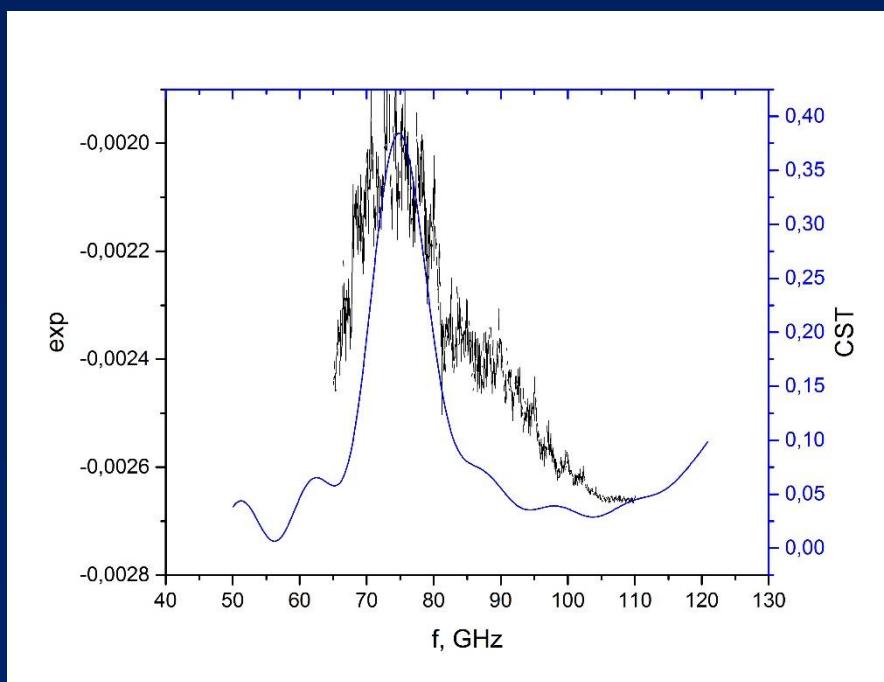
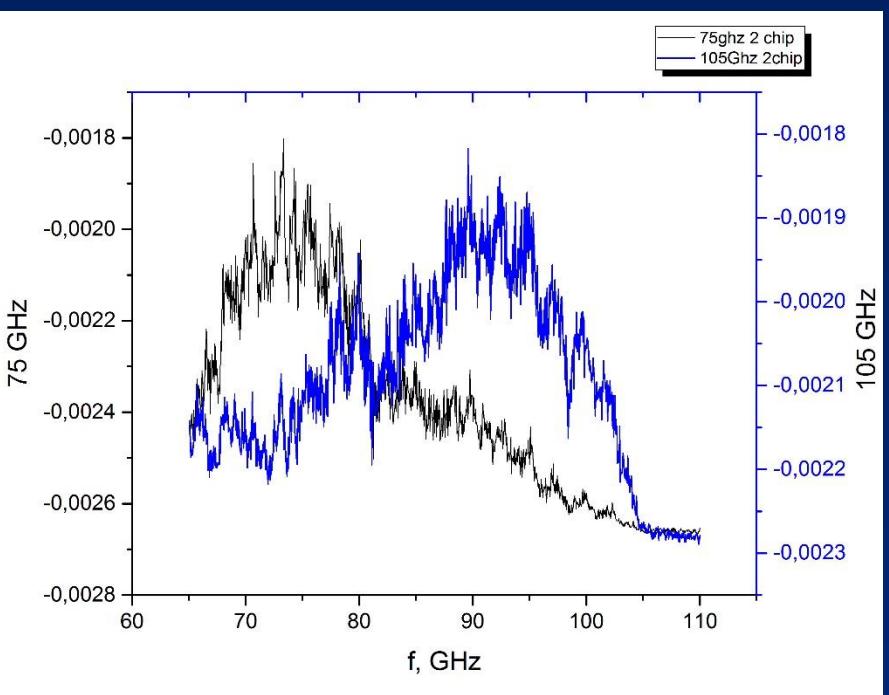
HV: 8 kVWD: 10 mmMag: 1300x

20 μm



HV: 8 kVWD: 39 mmMag: 17x

1 mm



Conclusions

- Next Generation of Multichroic Systems is needed for the space mission COrE
- Resonant Cold-Electron Bolometer (RCEB) - unique concept with internal filter for multichroic pixels
- Cross-Slot antenna with 2 RCEBs – simple decision for 2 frequencies
- Seashell Antenna: - promising concept with independent tuning of slots with RCEBs!