Development of Waveguide and Quasi-Optical Devices for Multi-pixel Astronomical Instruments

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RadioNet 2nd Engineering Forum Workshop – Multi-Pixel Camera Receivers

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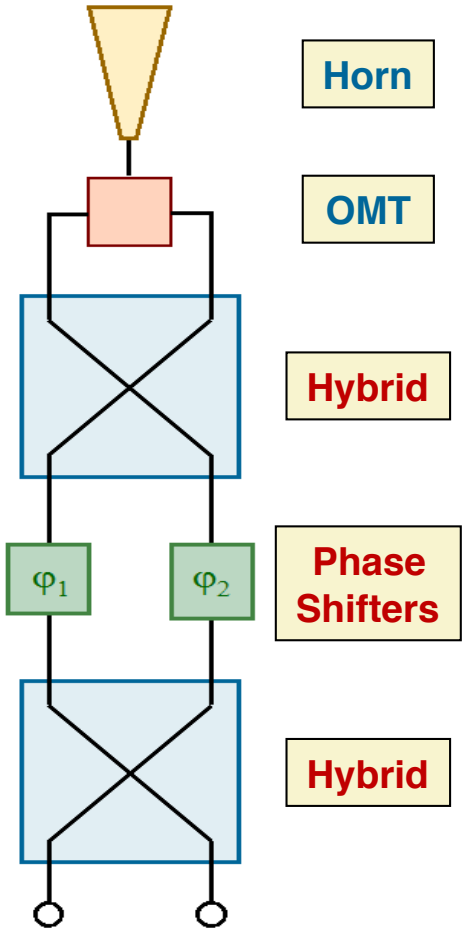
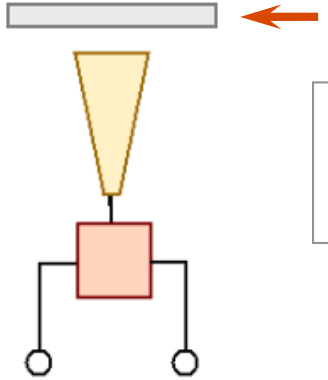
Focal plane optics: Polarimeter options

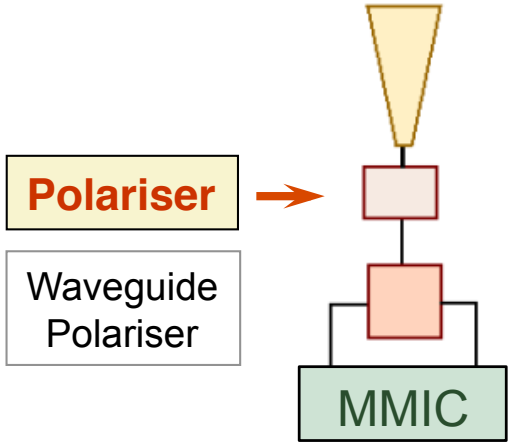
Pseudo-Correlator



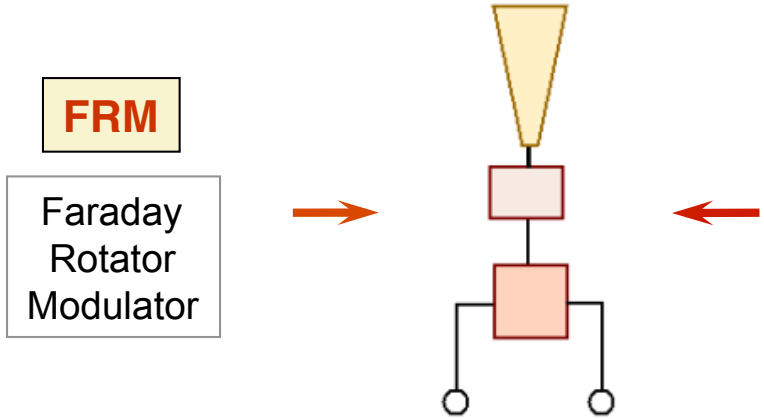
Quasi-optical pol. modulation



Left-Right wg modulation



Waveguide polarisation modulation

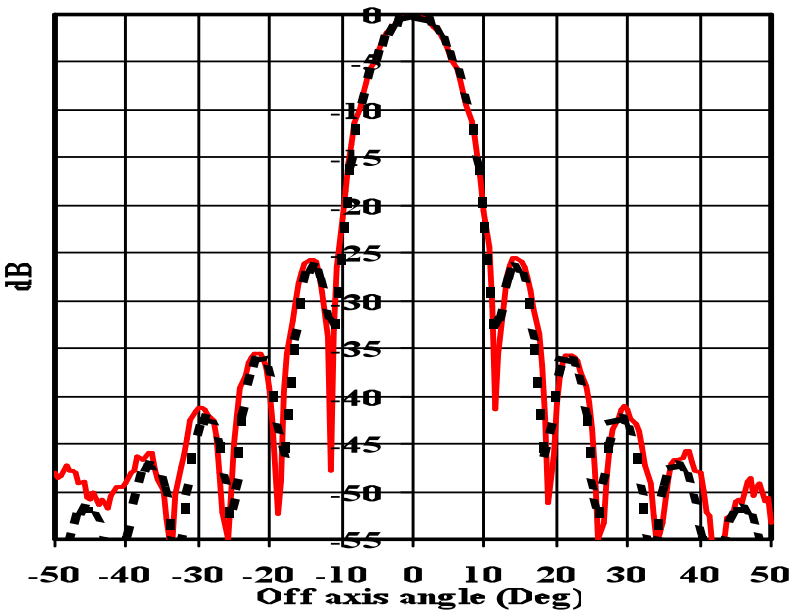


Horn & OMT Common to all the Options

Passive components development

- Waveguide components
  - Corrugated Horns
  - Orthomode transducers
  - Phase shifters
  - Polarisation modulators
- Quasi-optical components
- Single pixels
- Focal Plane Arrays

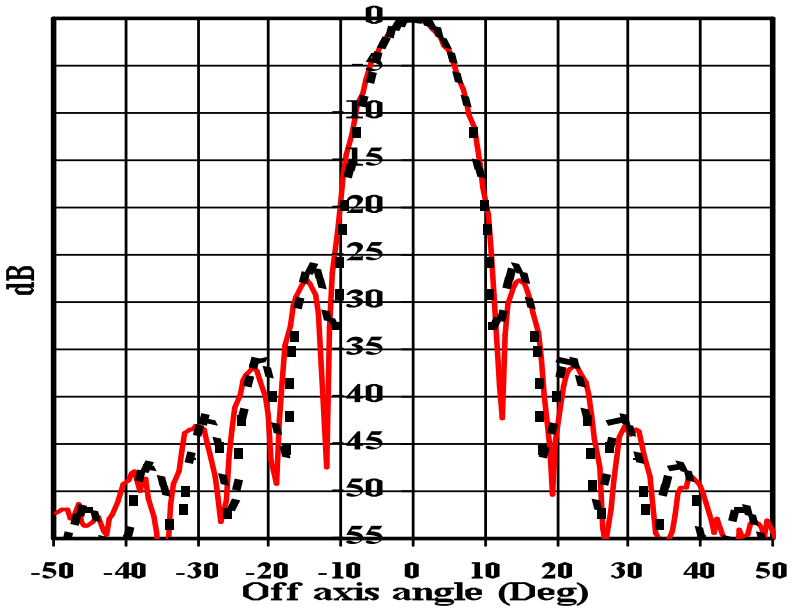
Corrugated Horns: Development & Tests

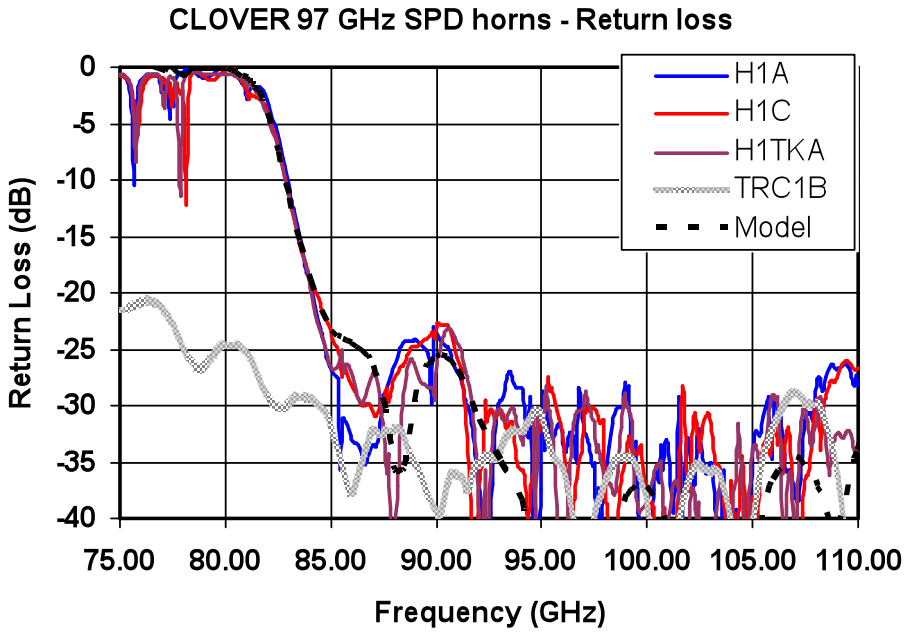


Clover Horn prototype

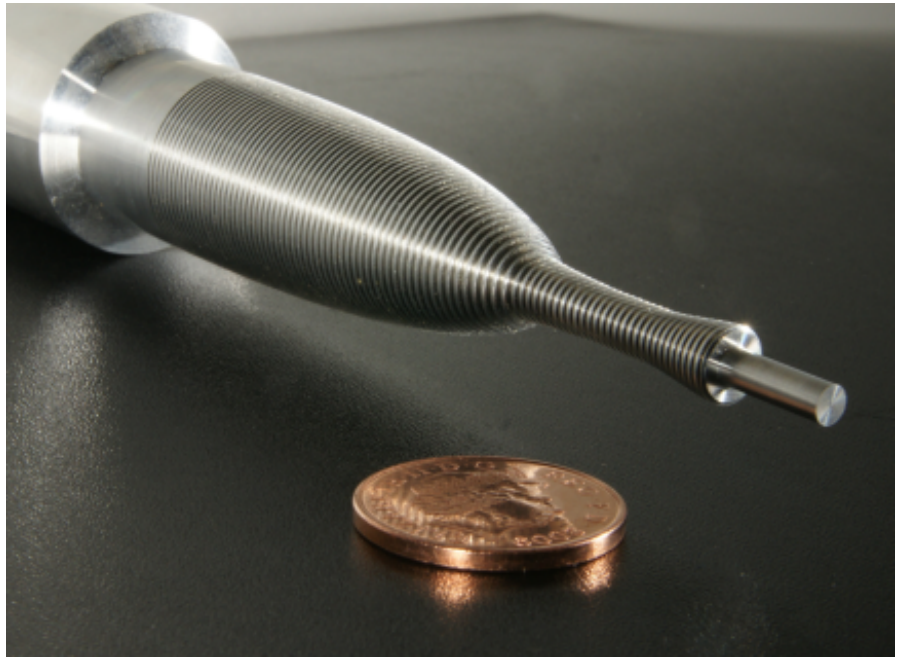
X-Pol < -40dB

E and H cuts: Model and data



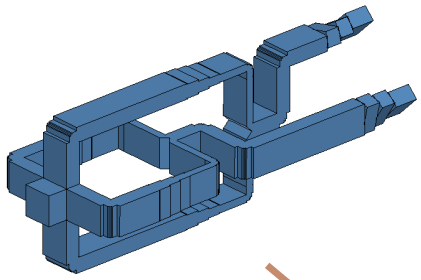


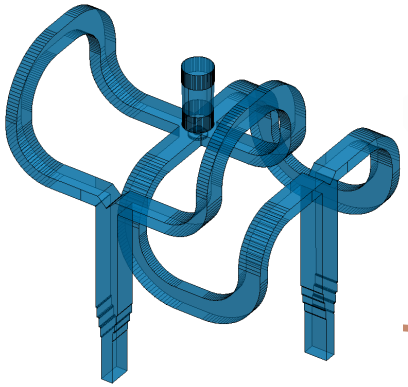
Corrugated Horns: Development

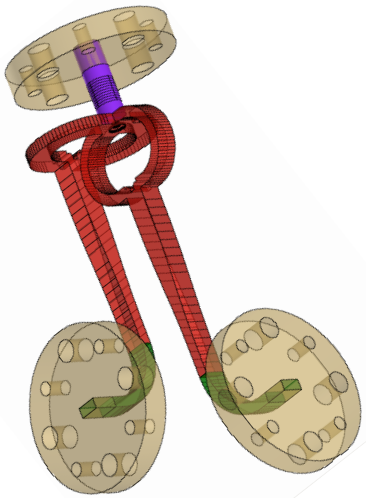


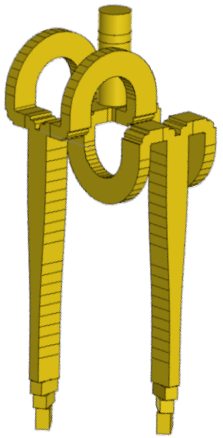
100 GHz Horns

97 GHz Orthomode Transducers development





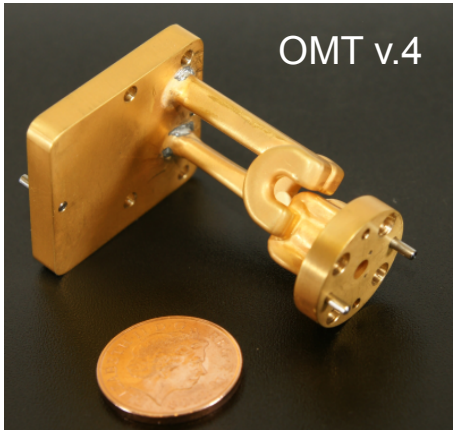




Equi-phase

Equi-phase

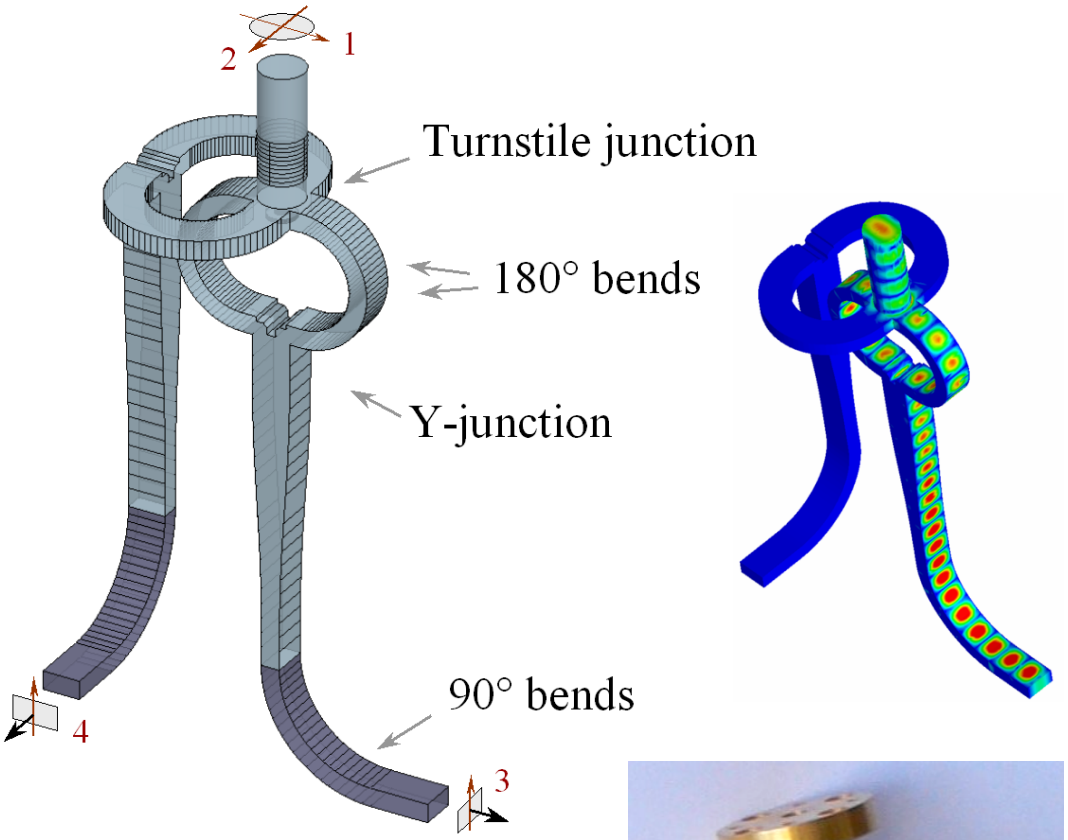
Non Equi-phase

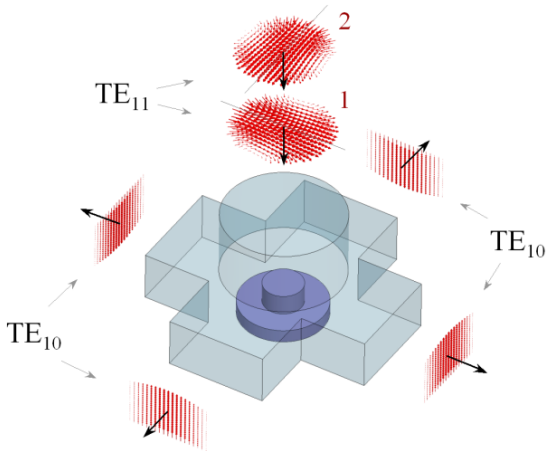


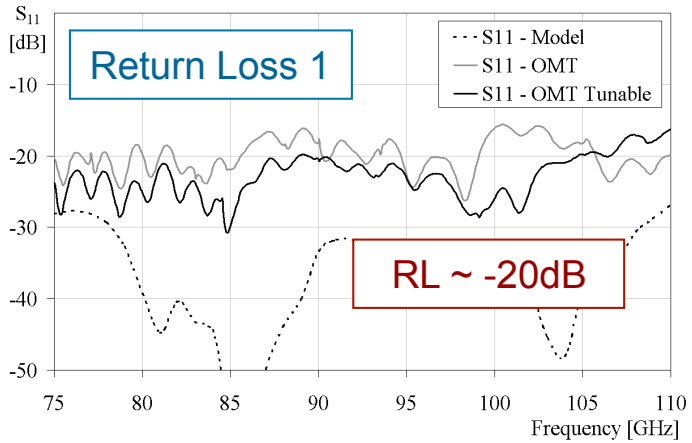
Equi-phase

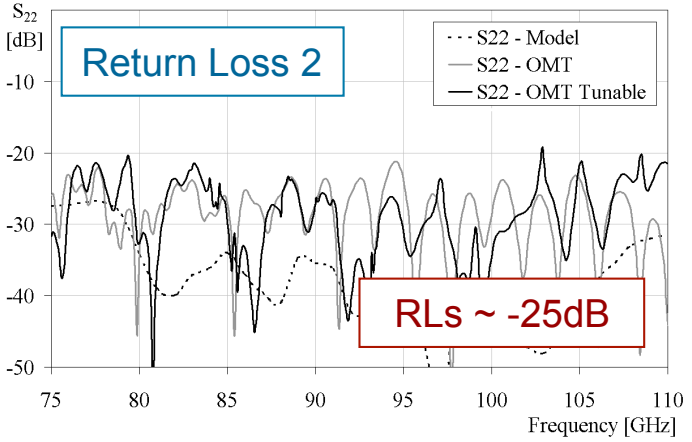
97 GHz Orthomode Transducer v.3: Design and Tests

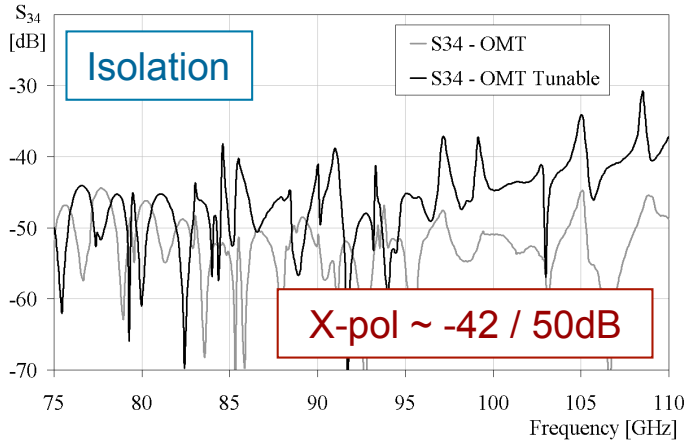
Pisano et al. - IEEE Micr.Wir.Comp.Lett. (4/2007)





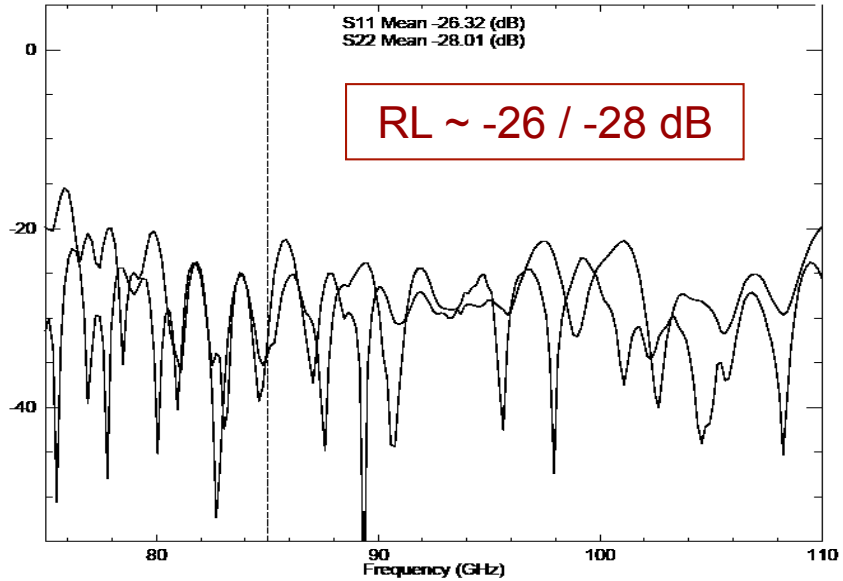




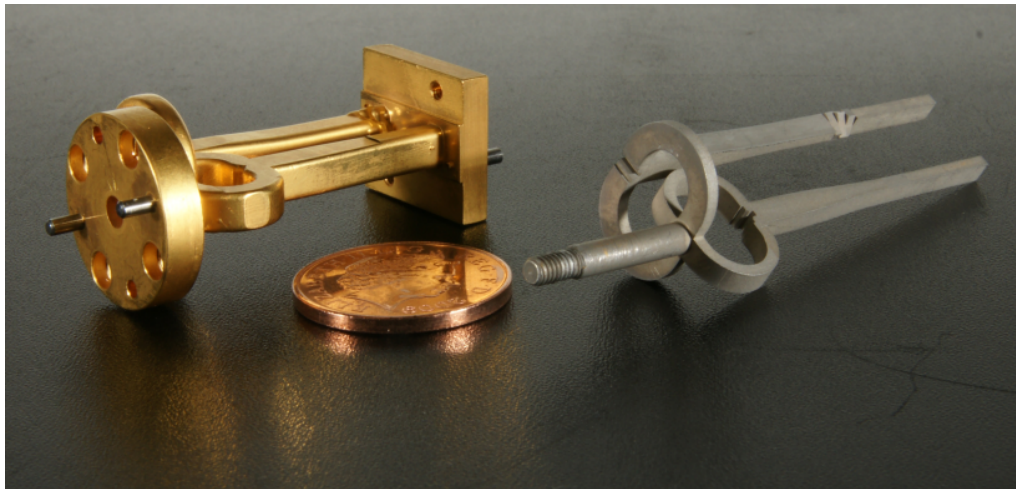


97 GHz Orthomode Transducer v.3: Design and Tests

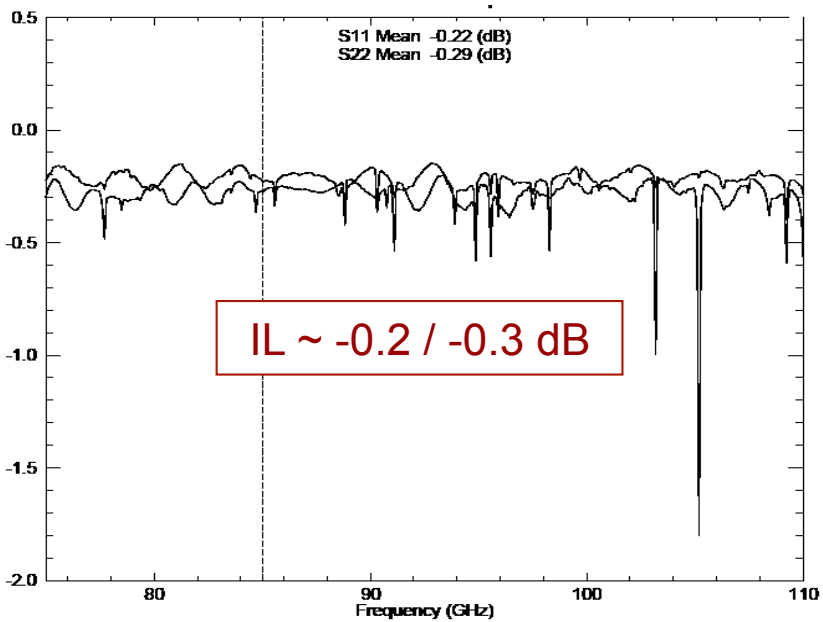
Return Loss



Clover Horn prototype



Insertion Loss

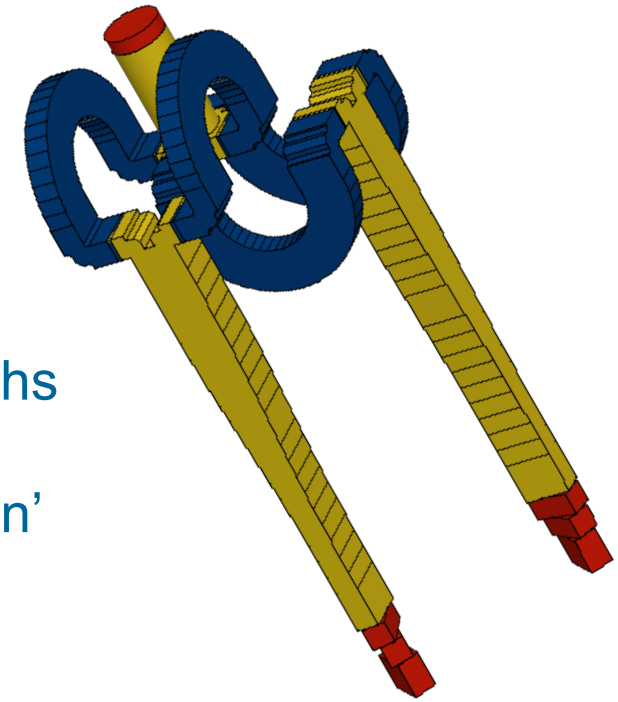


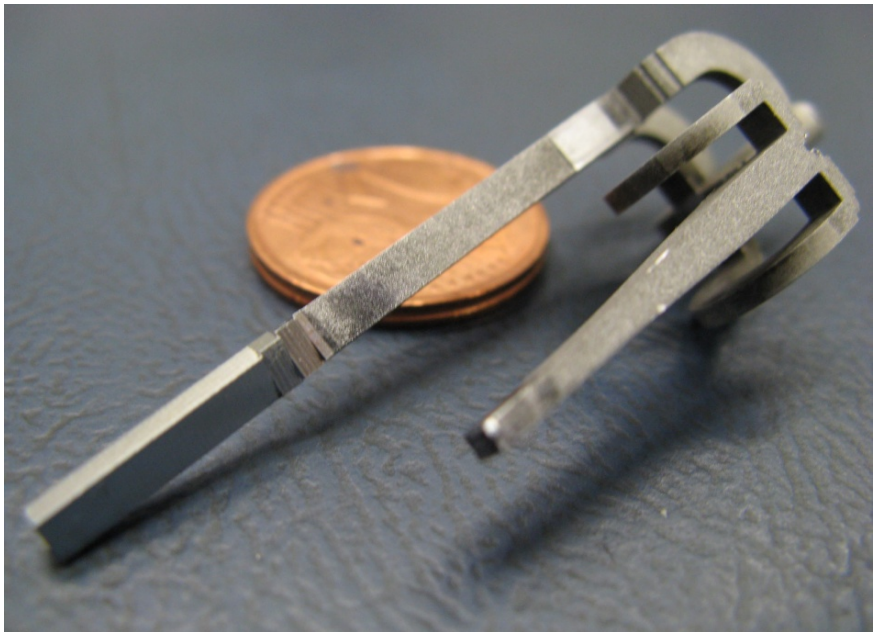
W-Band Equi-Phase OMT: Design

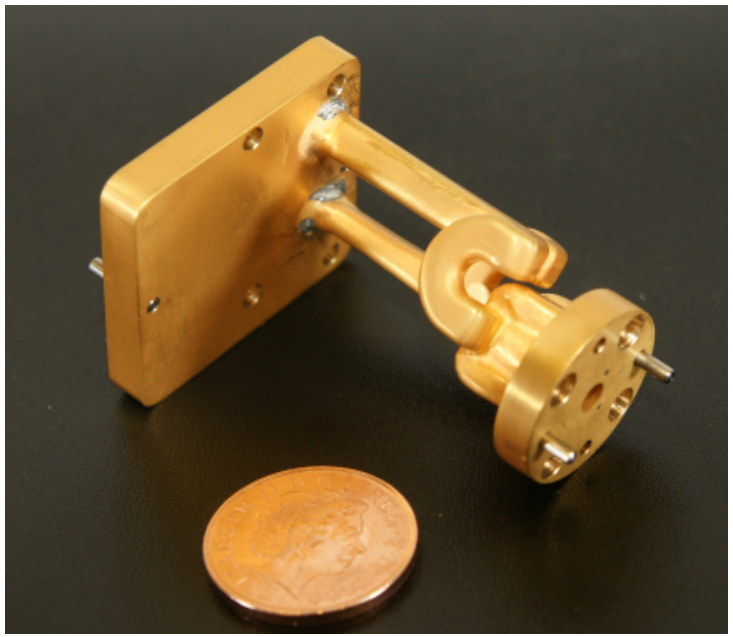
- Single electroformed component

- Polarisations identical electrical paths

- Based on ‘Turnstile junction’

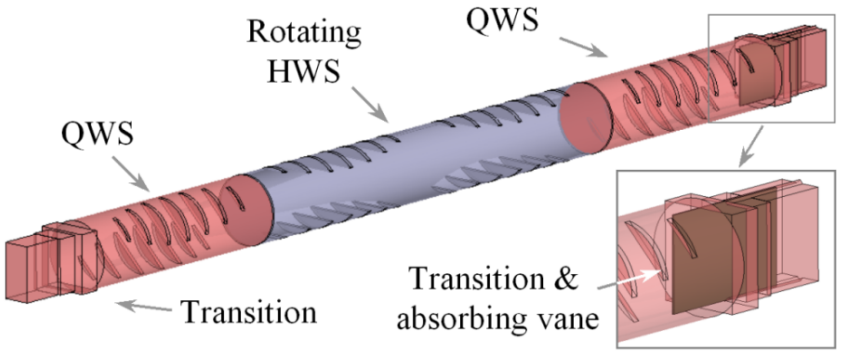


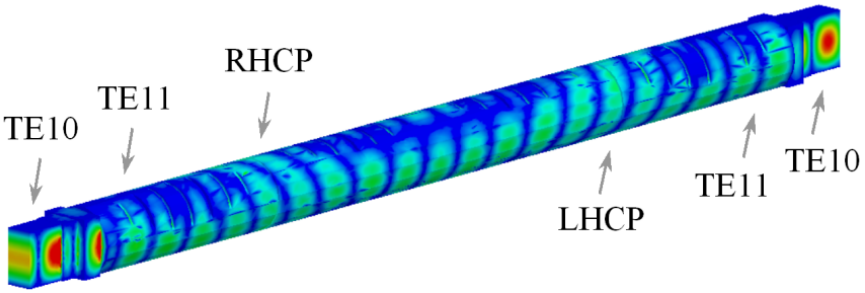


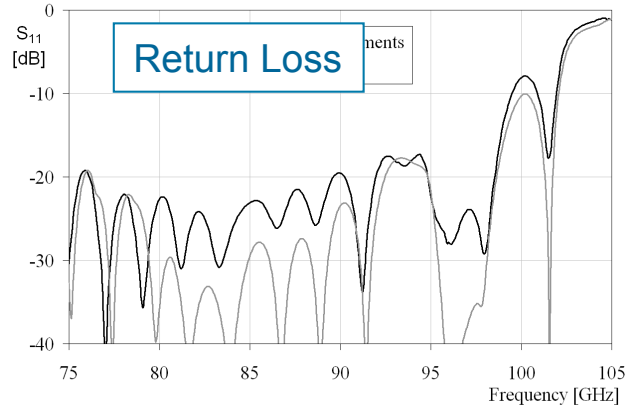


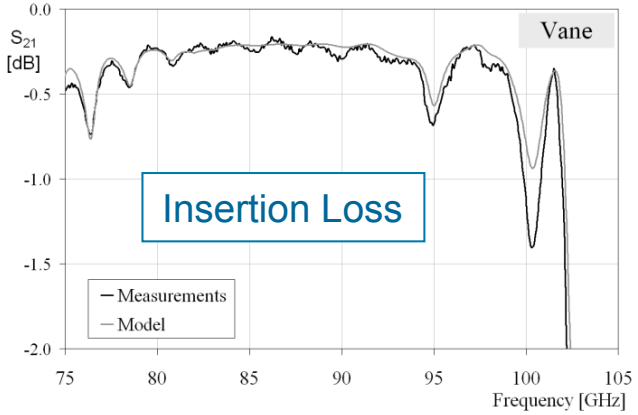
90 GHz Mechanical Phase-Shifter: Design and Tests

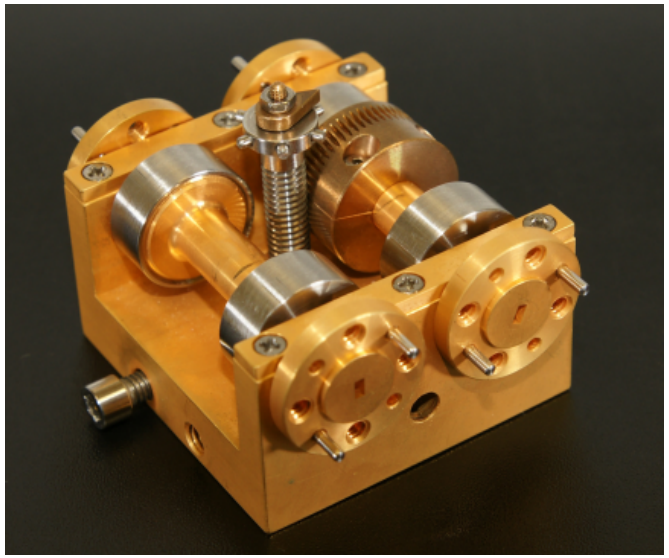
Pisano et al. – IEEE Micr.Wir.Comp.Lett.- (3/2007)





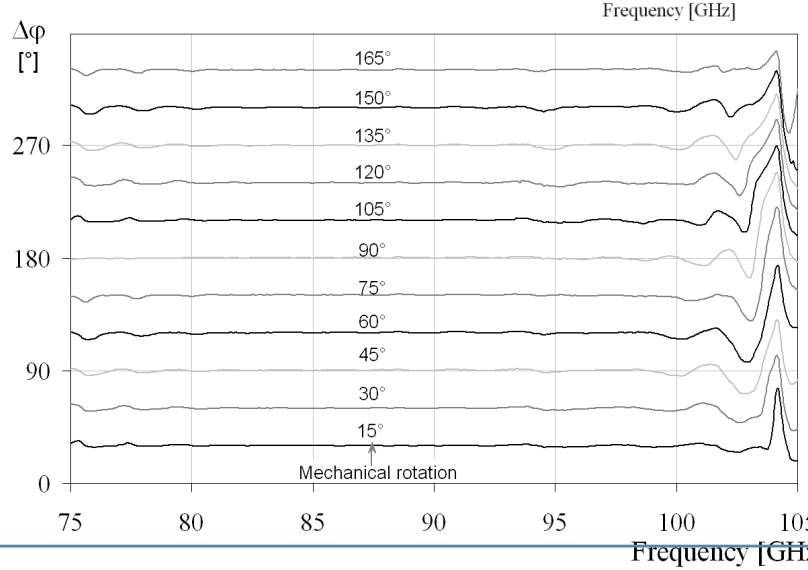




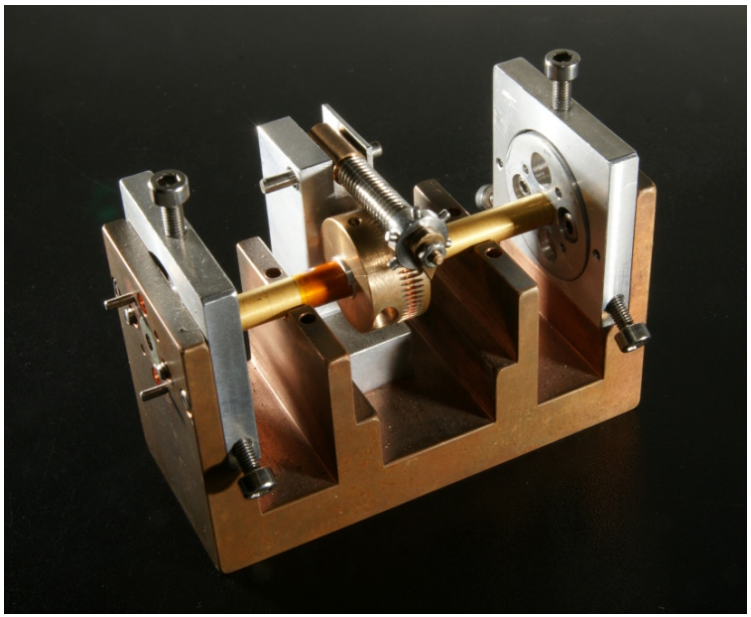


Phase-Shift

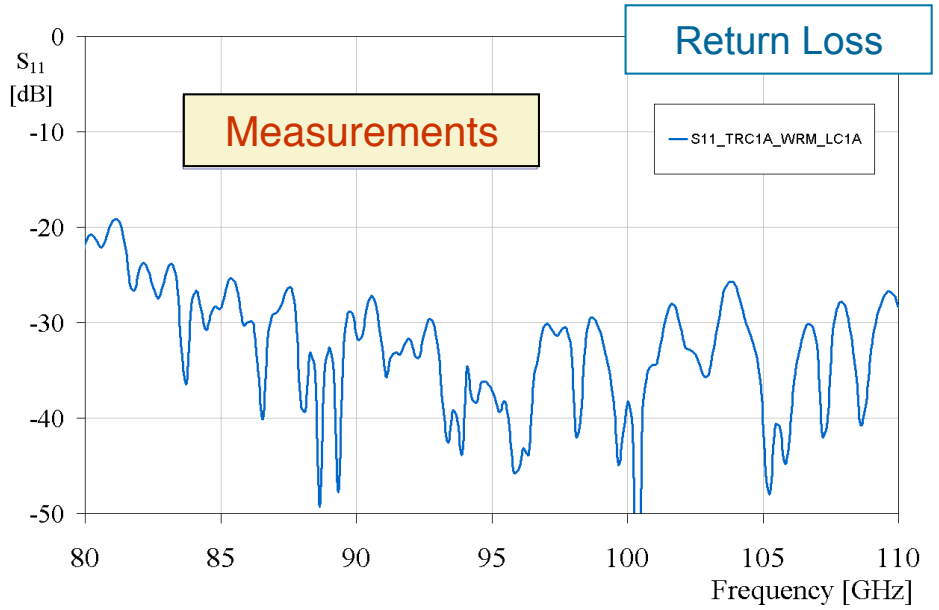
$\Delta\Phi < 1$ deg

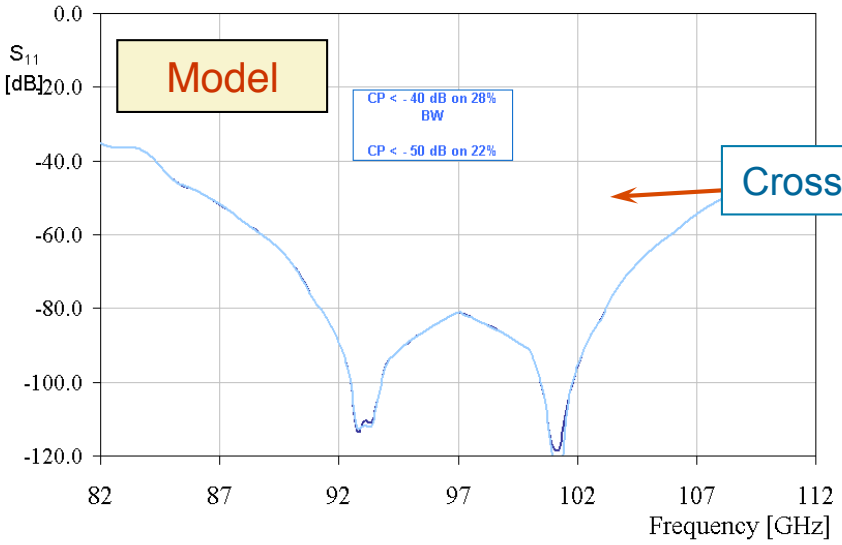


Waveguide Polarisation Modulator: Design and Test

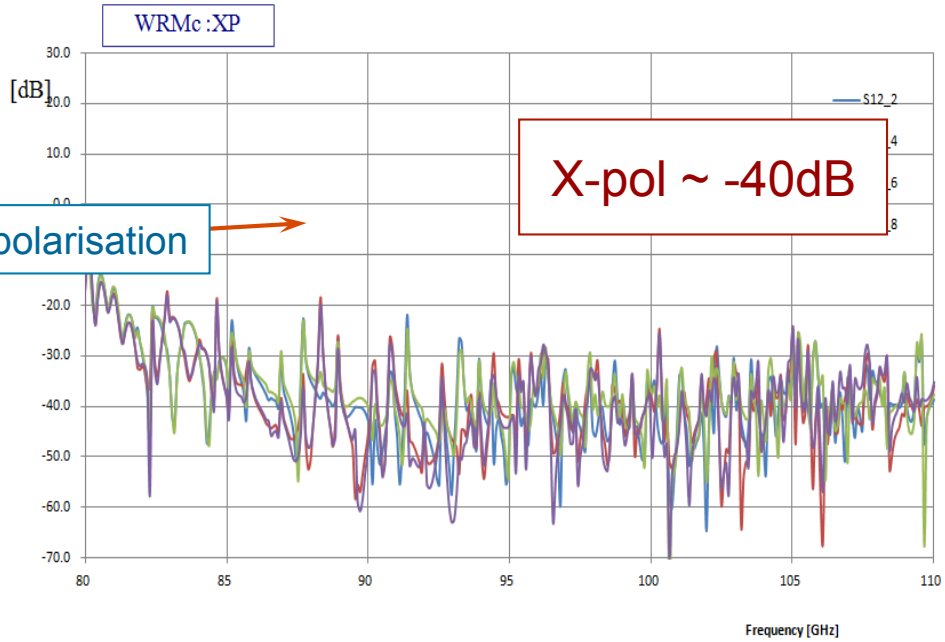


Pisano – Patent submitted



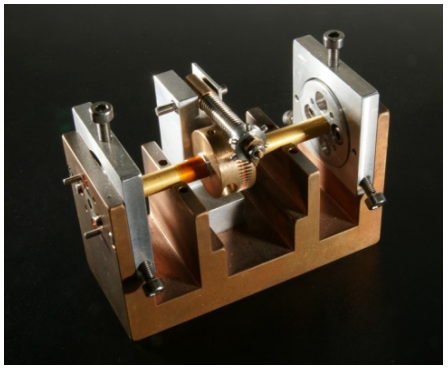


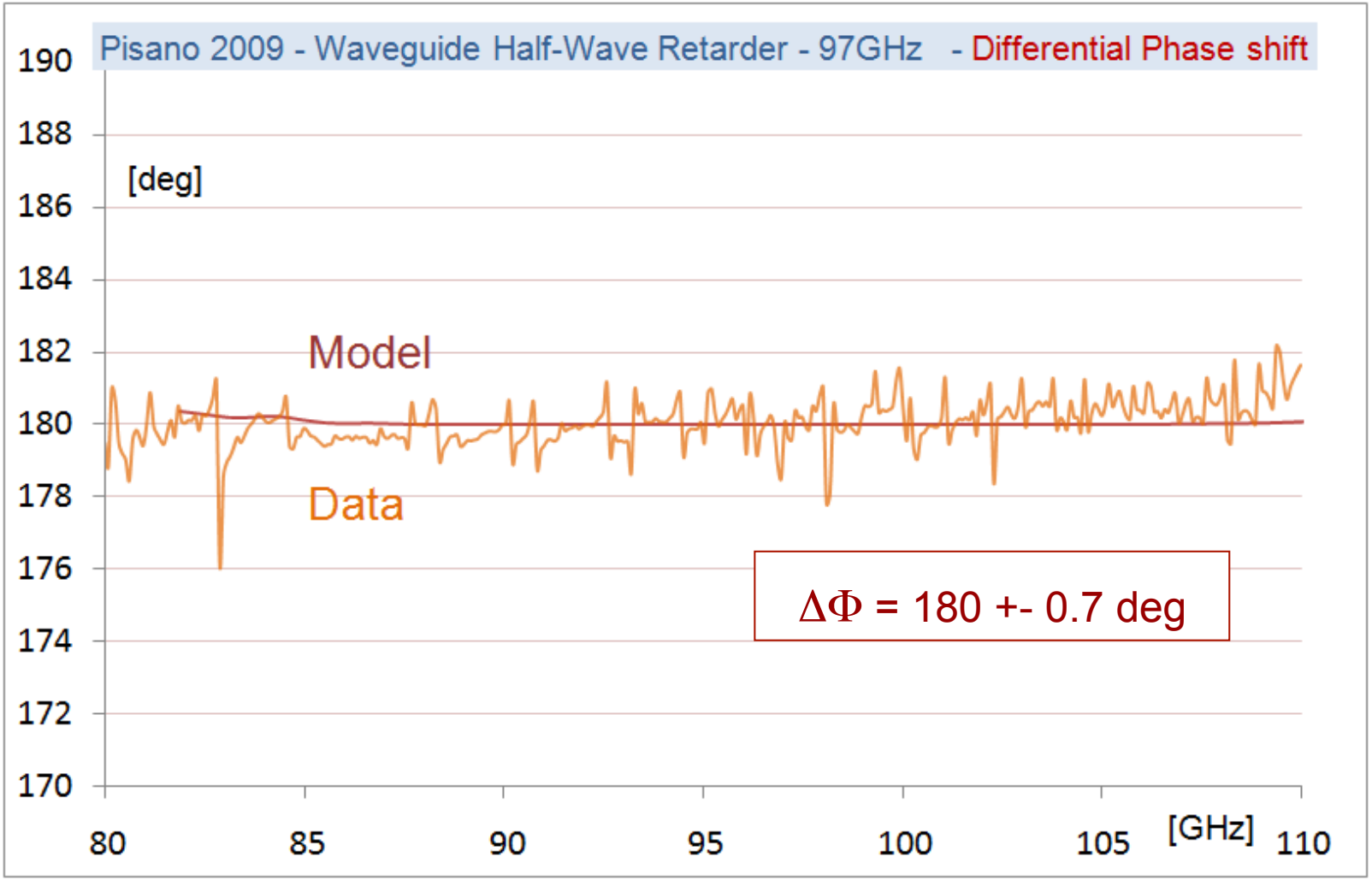
Cross-polarisation



Waveguide Polarisation Modulator: Tests

- Half-wave retarder → 180 deg expected





Passive components development

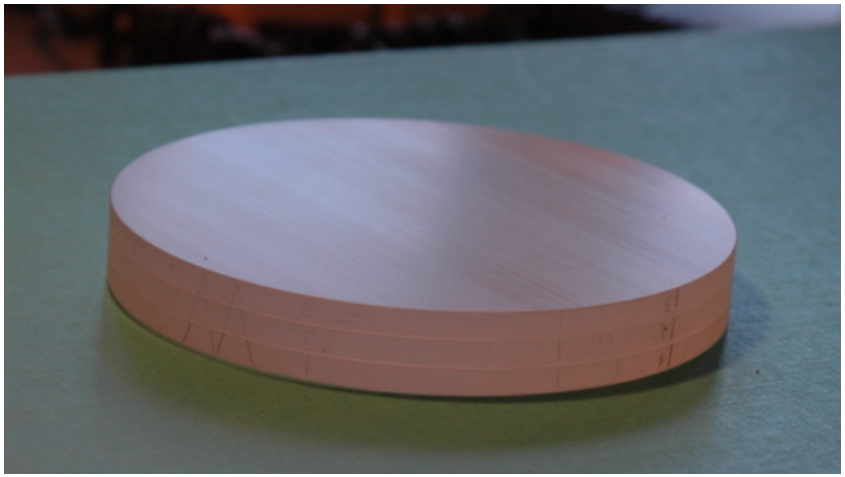
- Waveguide components
- Quasi-optical components
    - Half-Wave Plates
    - Mesh filters
    - Mesh-HWPs
- Single pixels
- Focal Plane Arrays

Sapphire Achromatic HWPs: Modelling & Tests

G. Pisano et al., *Applied Optics v45, n26 (2006)*
G. Savini et al., *Applied Optics v45, n35 (2006)*

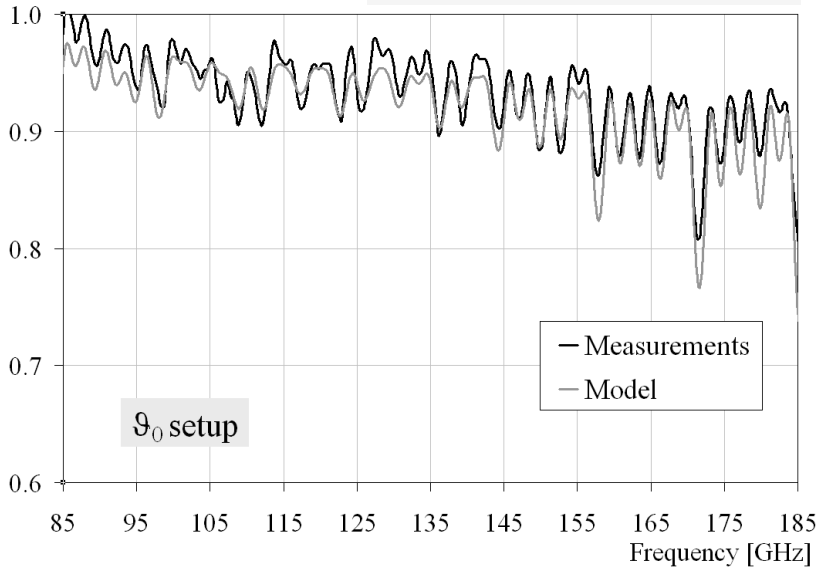
Model

Size/costs problems



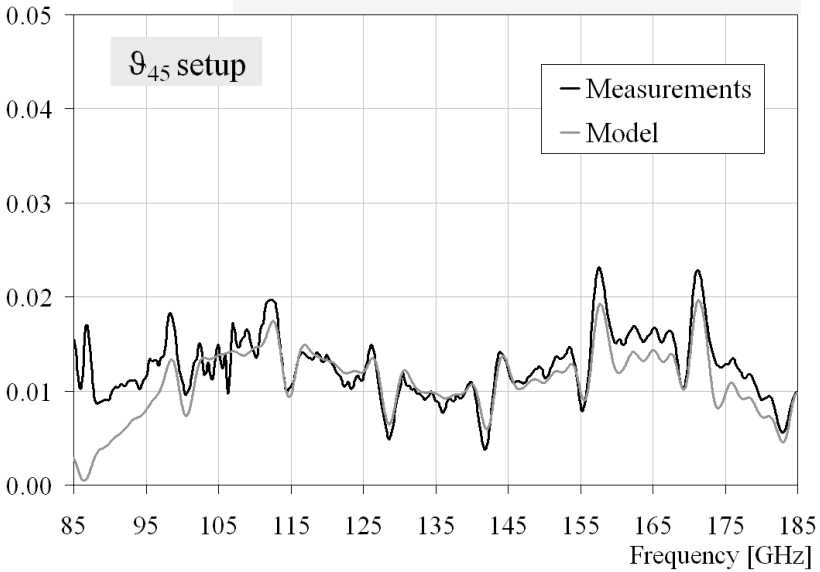
Results

Fast axis Transmission

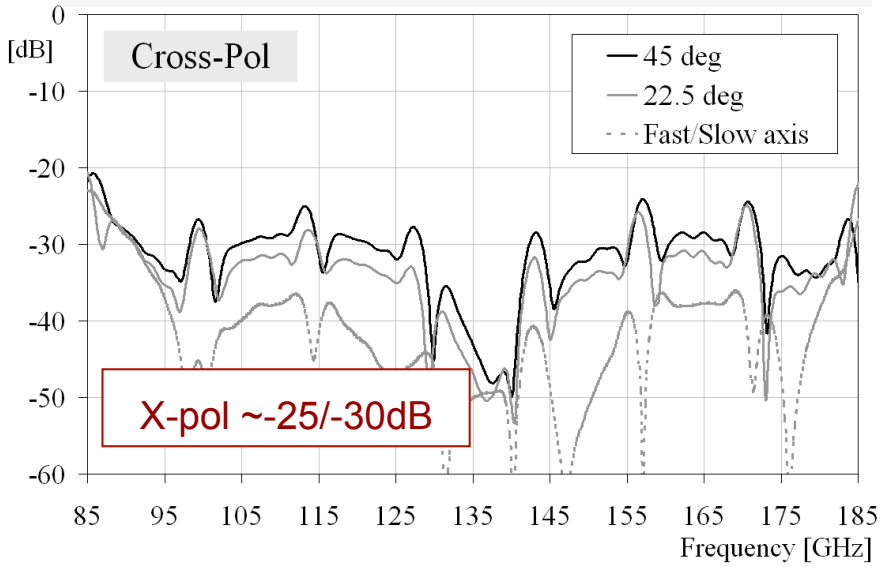


Results

Measured Cross-Polarisation



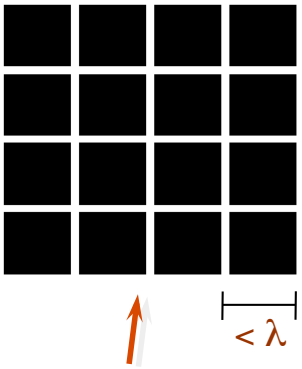
Extrapolated Minumum Cross Polarisation



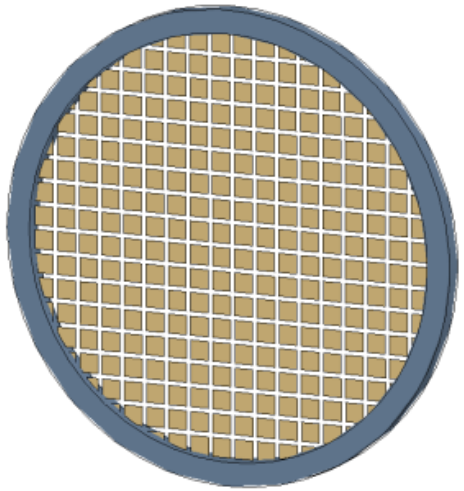
Metal mesh filters: Modelling, manufacture & tests

G. Pisano, et al., *Infr.Phys.Tech. v.48, p49 (2006)*

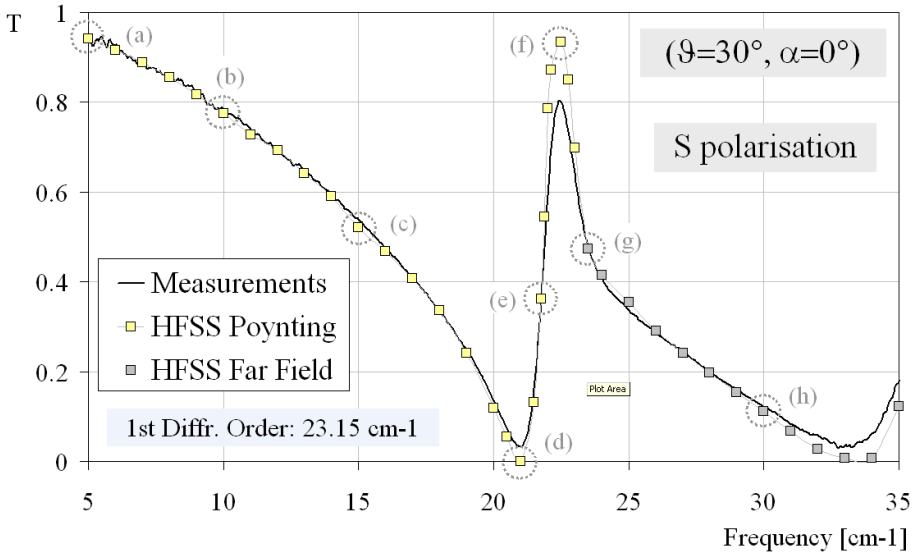
Capacitive Low-Pass filter



Sub-wavelenght
Periodic structures



Off-axis *"S"* polarisation model & tests

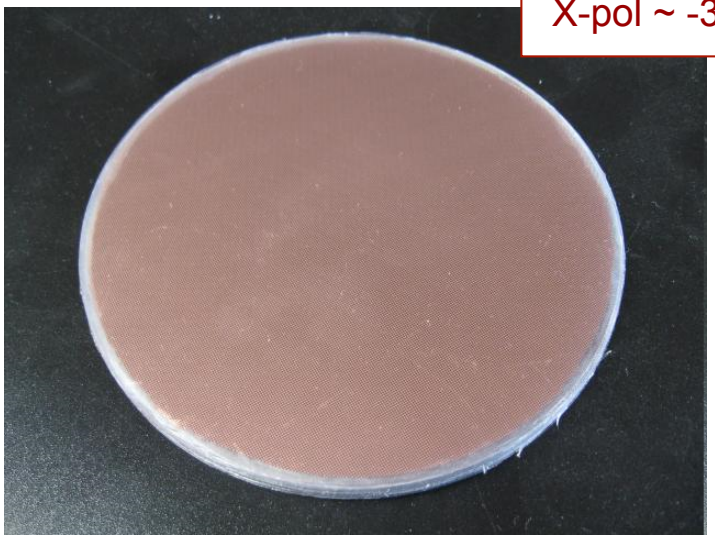


Devices

X-pol variable

Single Metal Mesh on dielectric substrate

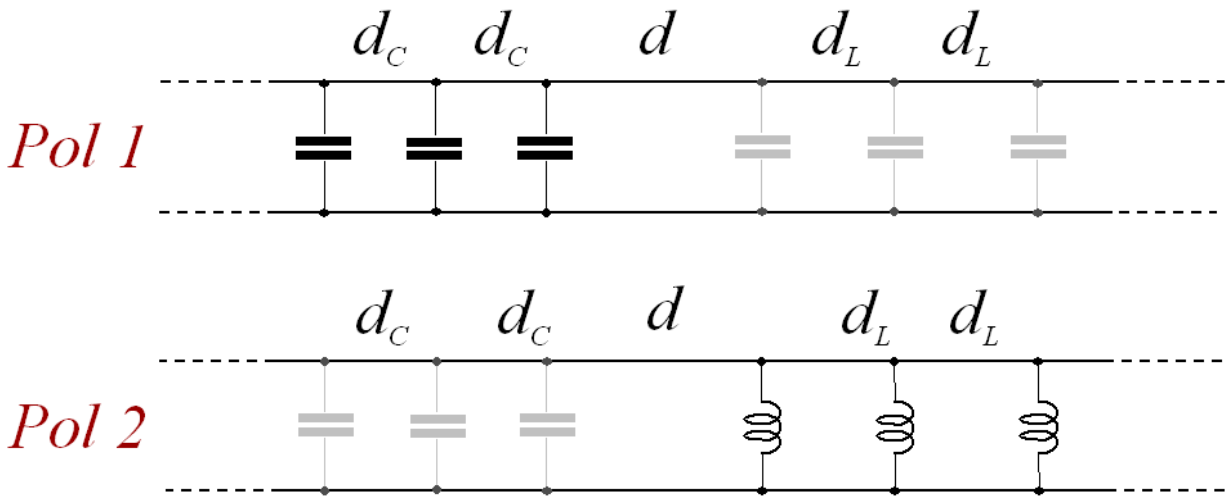
X-pol ~ -30/-40dB

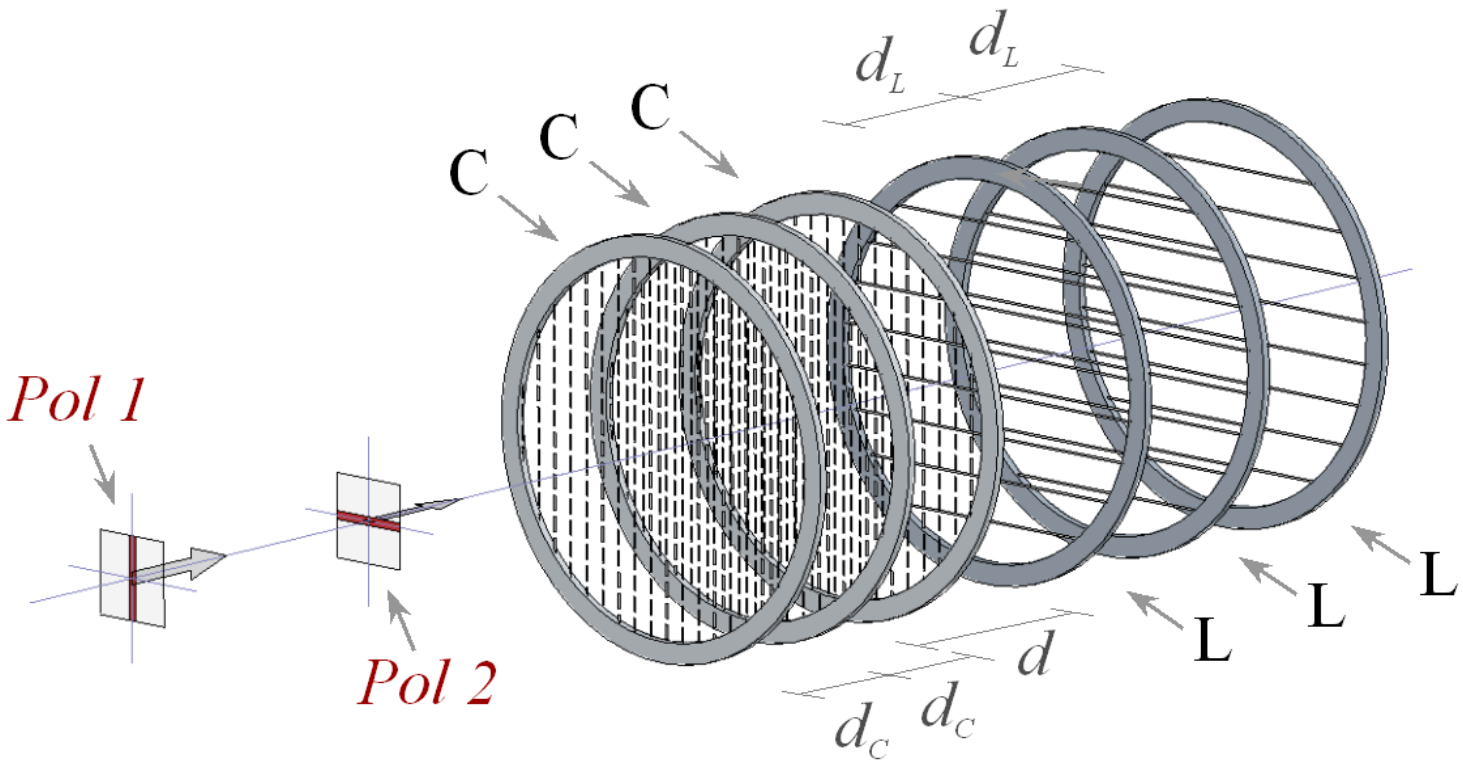


Dielectrically embedded multi-mesh filter

Mesh Half-Wave Plate: Air-gap design

G. Pisano et al., *Applied Optics v47, n33 (2008)*

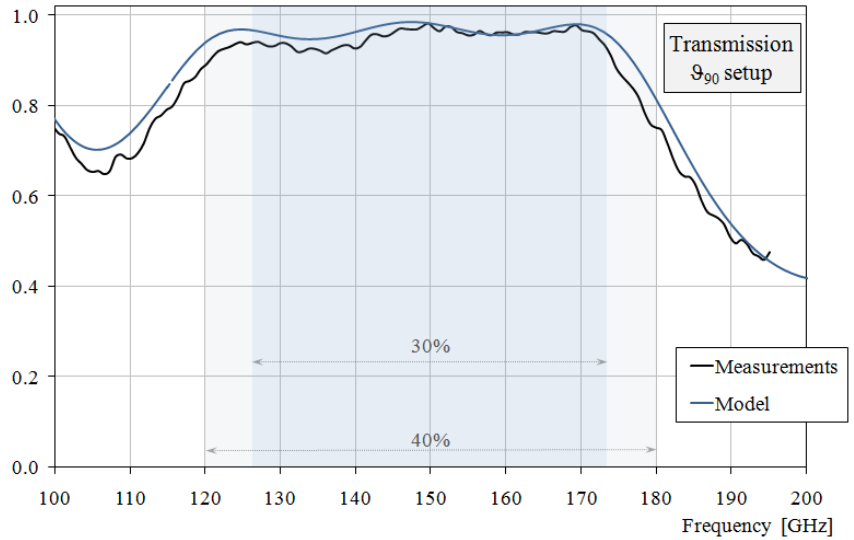




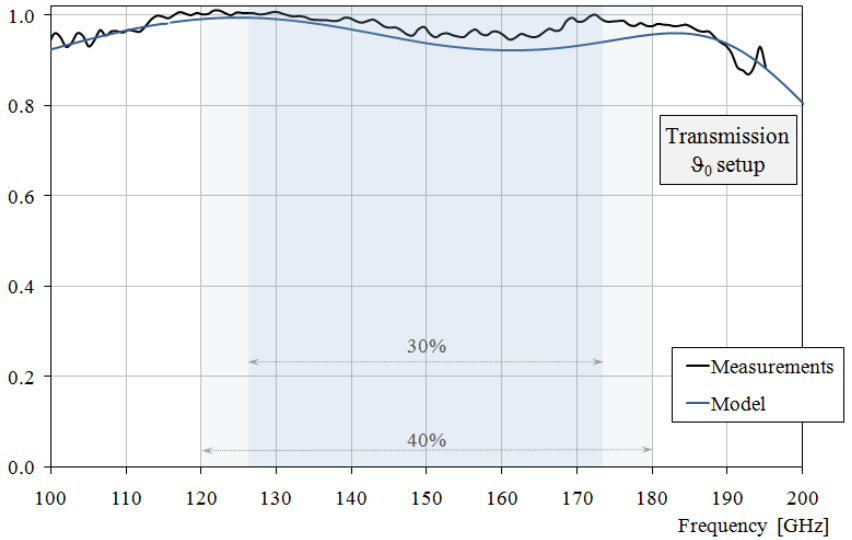
Mesh HWP : Air-gap design results

G. Pisano et al., *Applied Optics v47, n33 (2008)*

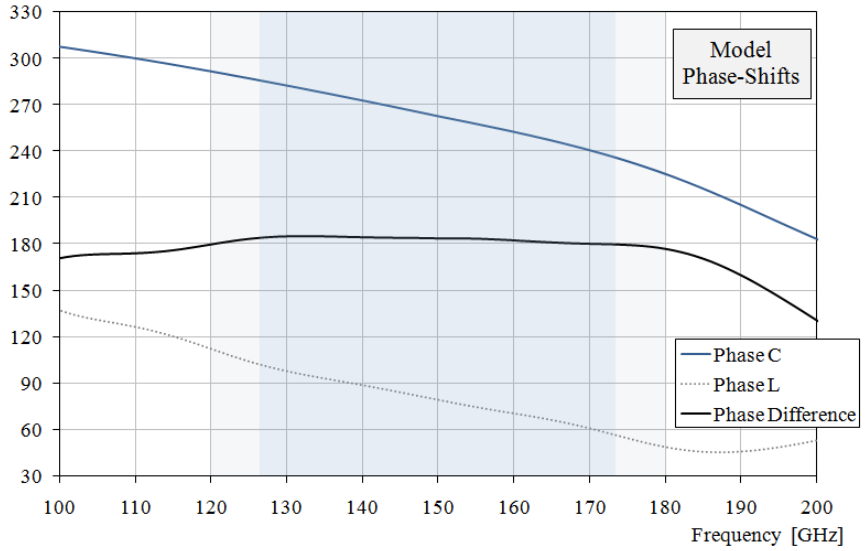
Fast Axis Transmission



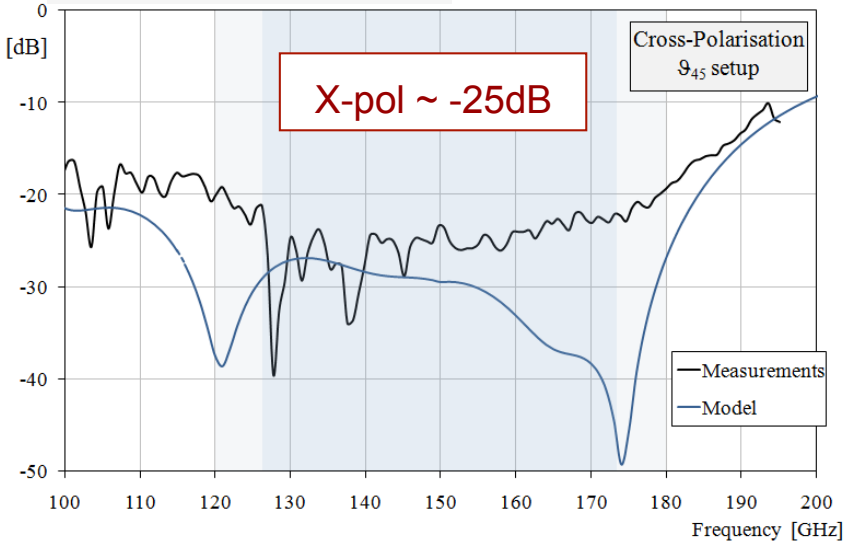
Slow Axis Transmission



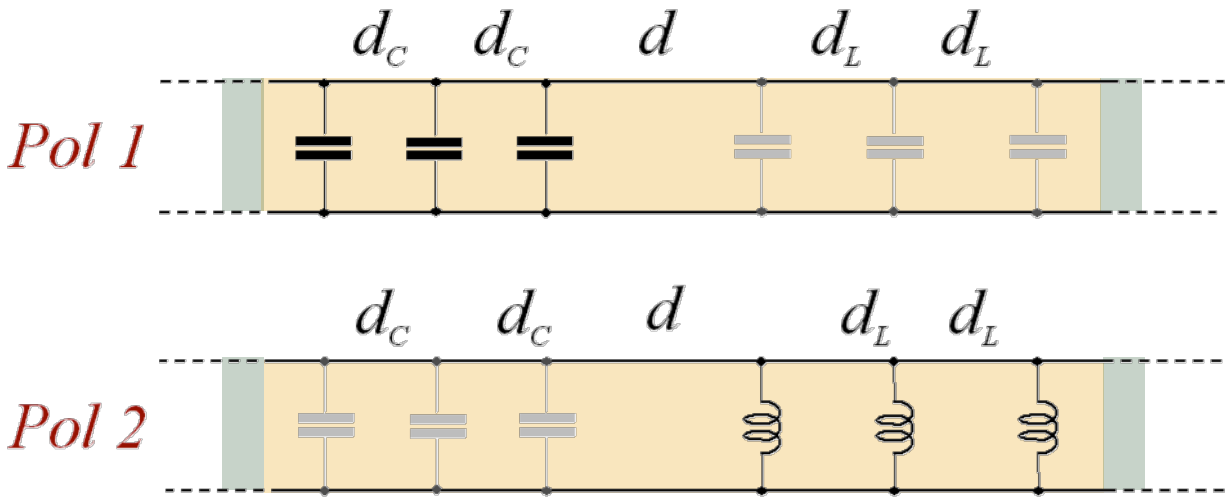
Differential Phase-Shift

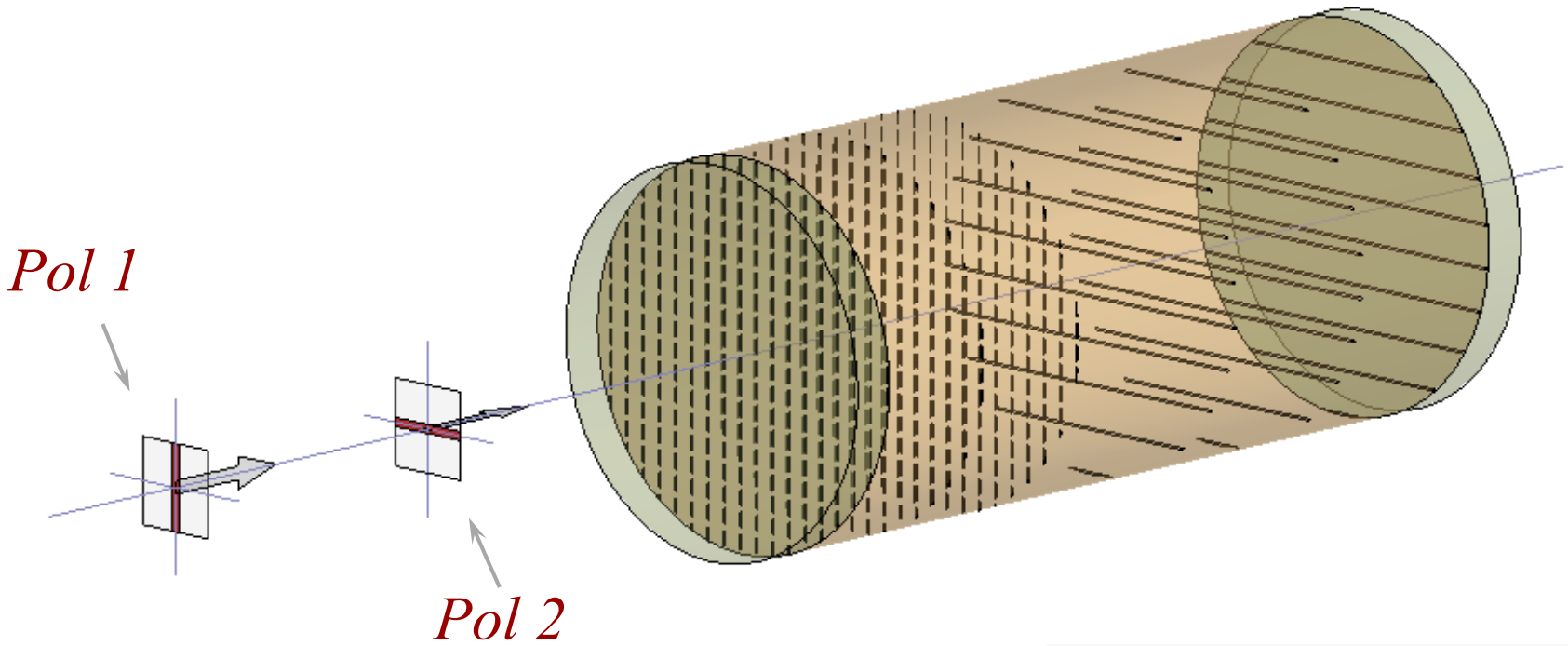


Cross-Polarisation



Mesh Half-Wave Plate: Dielectrically embedded design



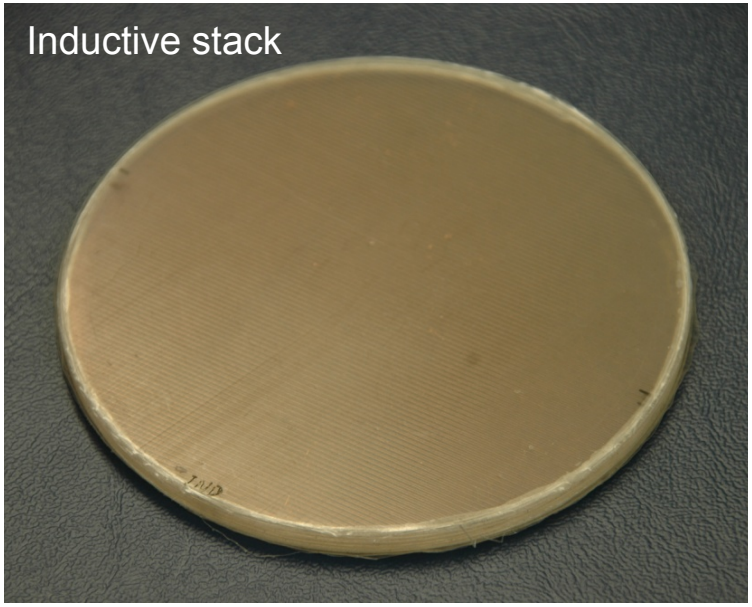


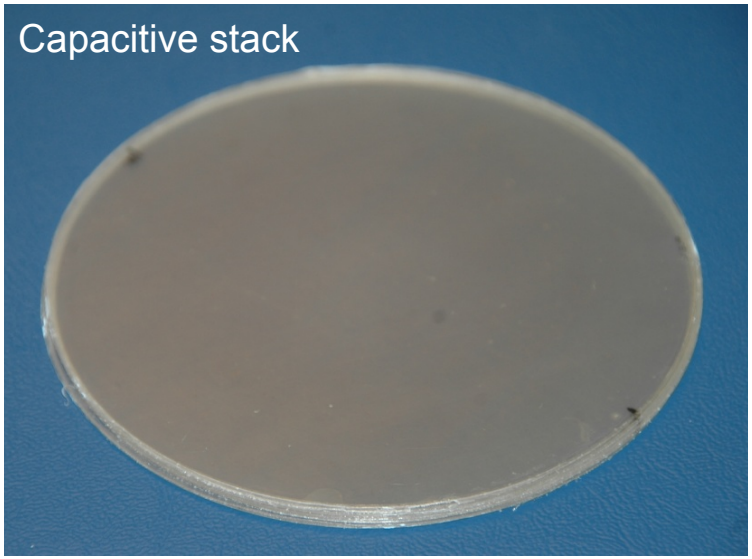
G. Pisano et al., to be submitted to *Appl. Optics*

Mesh HWP : Dielectrically embedded design results

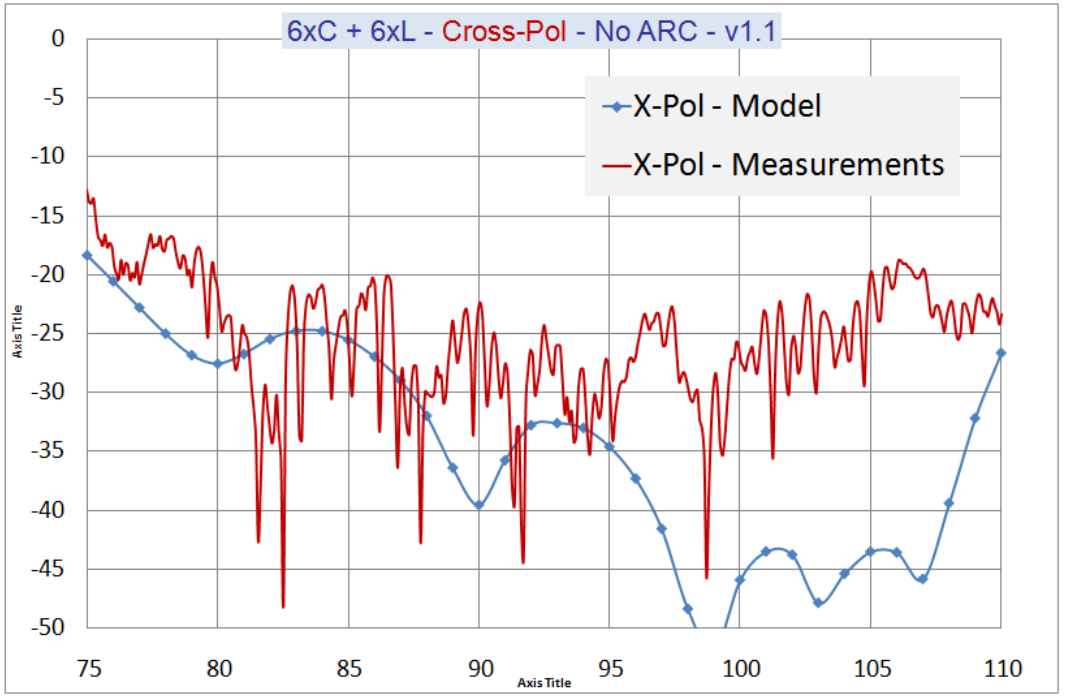
G. Pisano et al., to be submitted to *Appl. Optics*

Prototype





Cross-Polarisation Measurements



X-pol ~ -25dB

(No ARC added yet)

← Very robust device

Passive components development

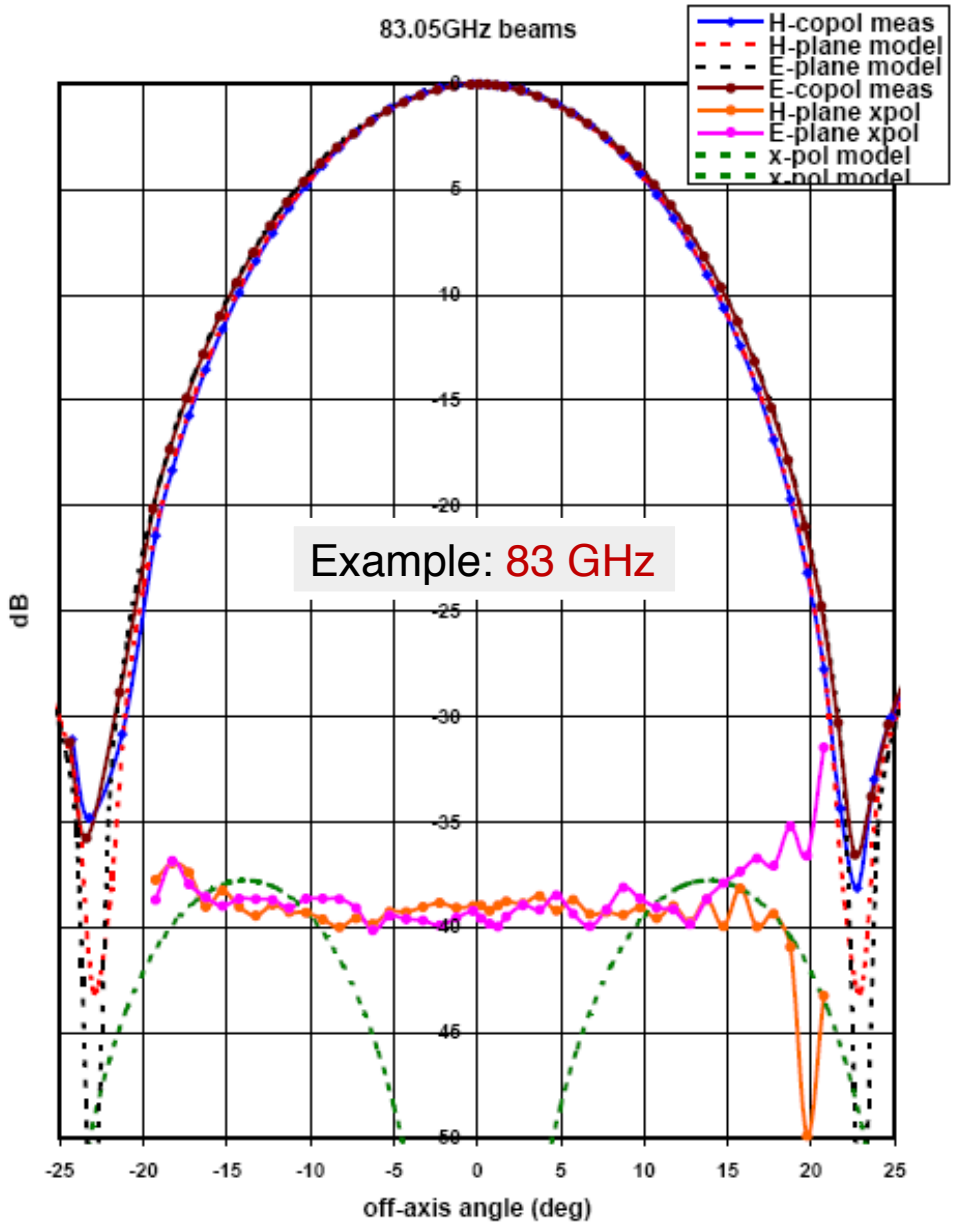
- Waveguide components
- Quasi-optical components
- Single pixels
    - Horn + OMT
    - Horn + WRM + OMT
    - Q.O. HWP + Horn + OMT
- Focal Plane Arrays

Pixel tests: Horn + OMT

Horn-OMT Pixel

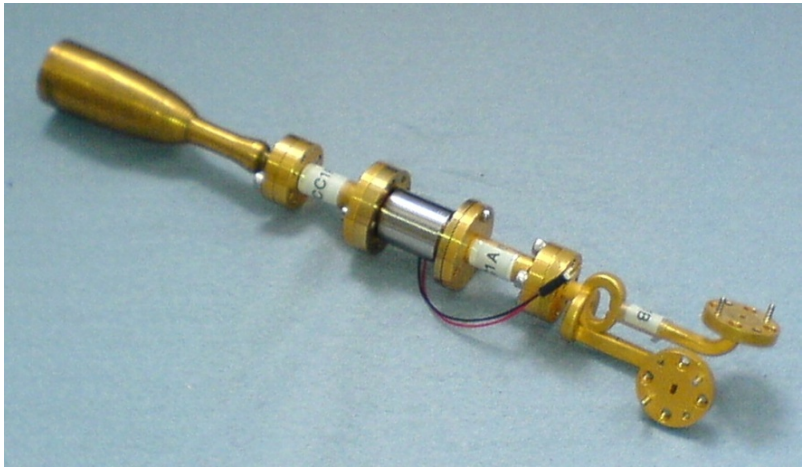
Measured Cross-Pol: -40dB

Co-Pol & Cross-Pol Beams



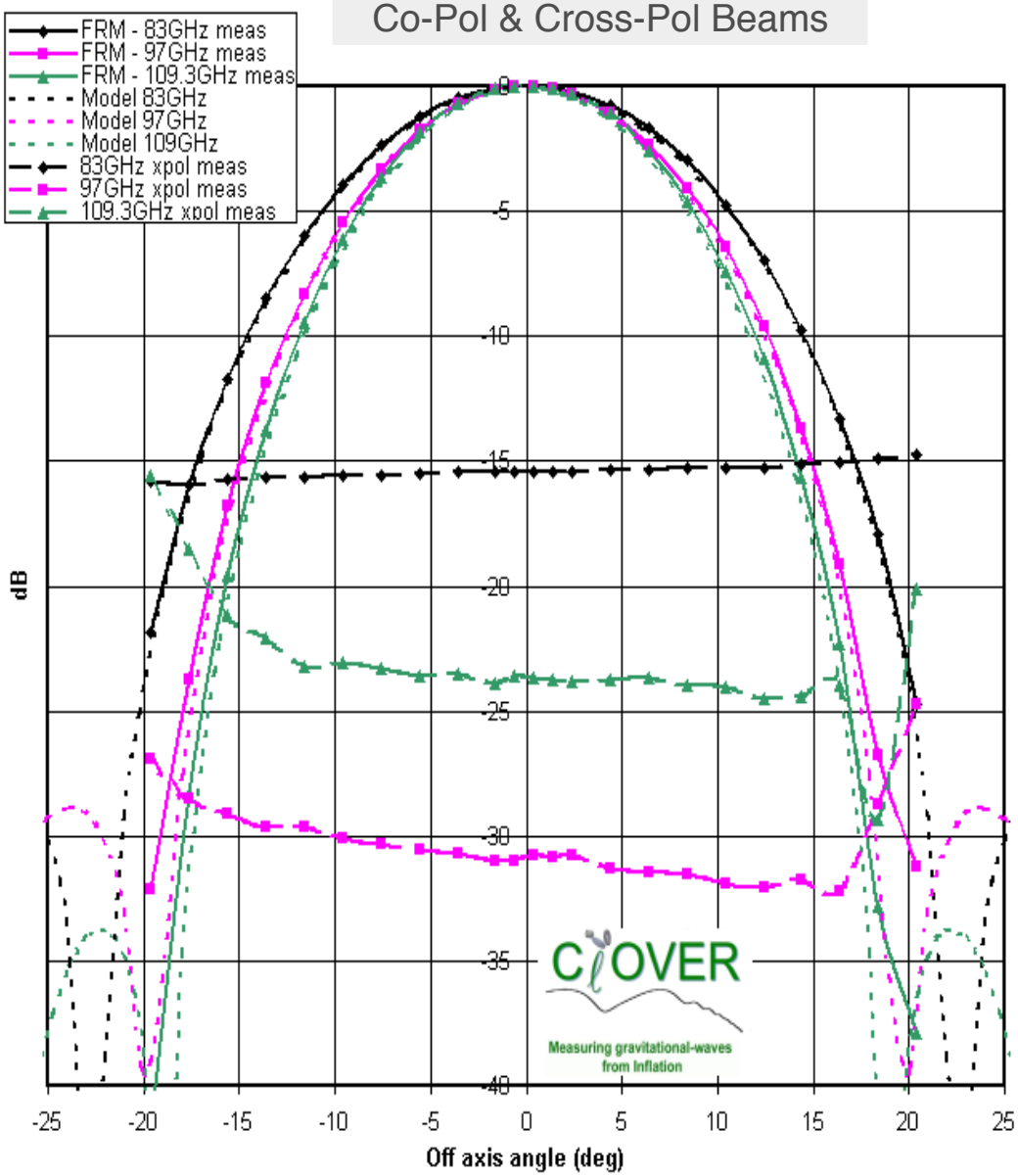
Pixel tests: Horn + FRM + OMT

FRM pixel



Averaged Cross-Pol: -24dB

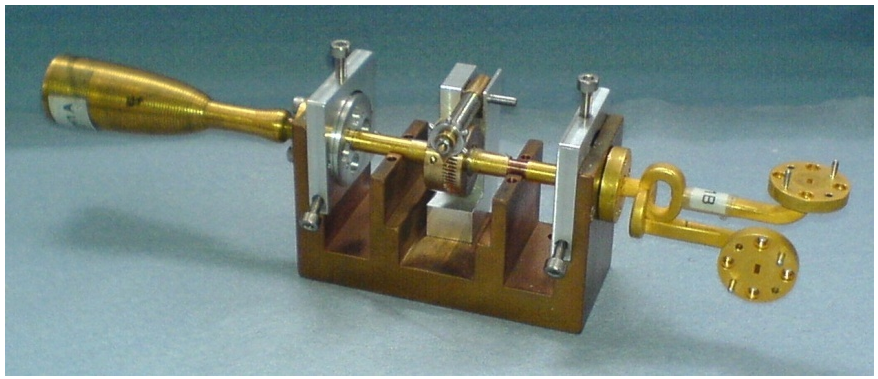
Co-Pol & Cross-Pol Beams



Note that it has not been optimised for Clover

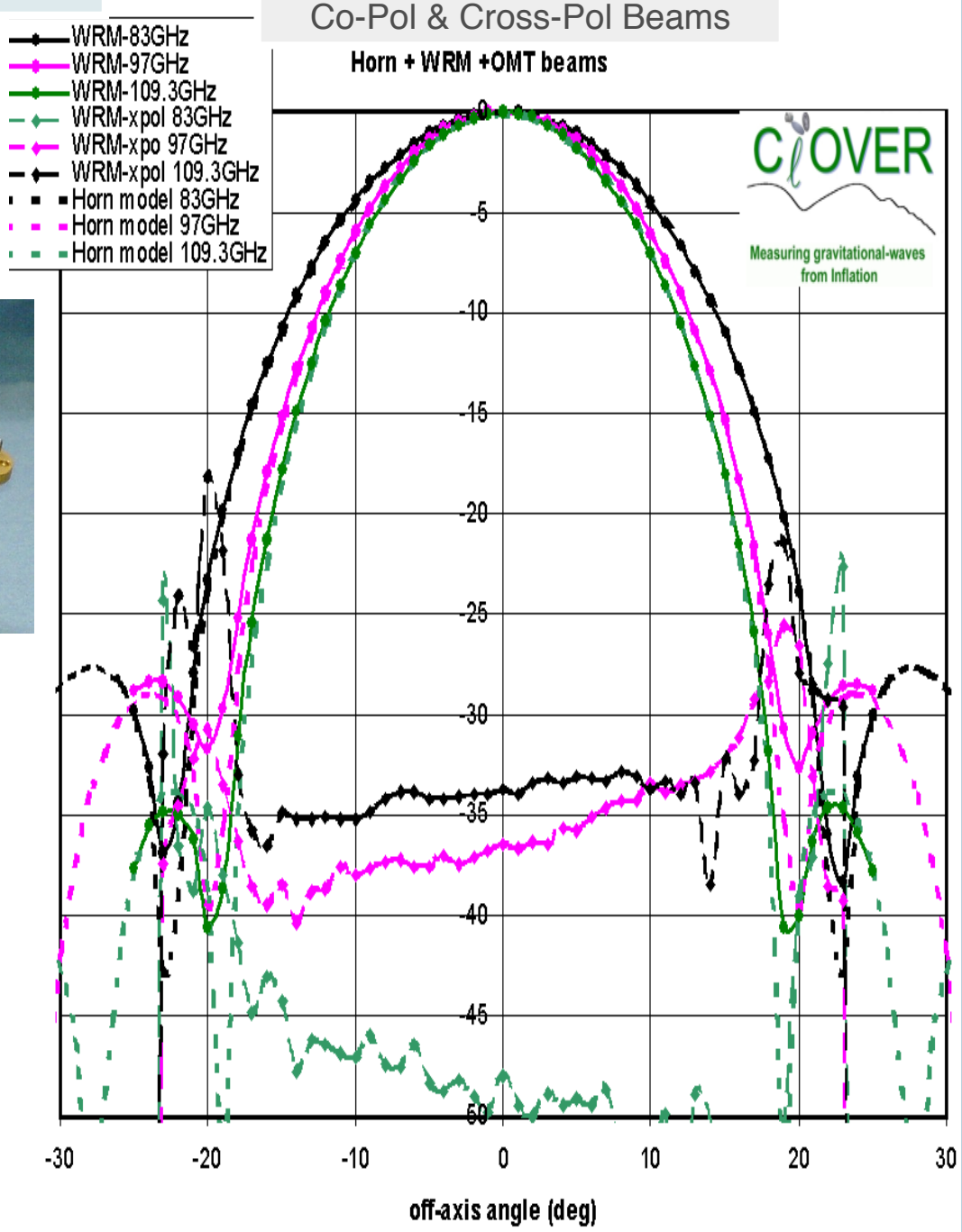
Pixel tests: Horn + Pol-Modulator + OMT

Modulator Polarimeter Pixel



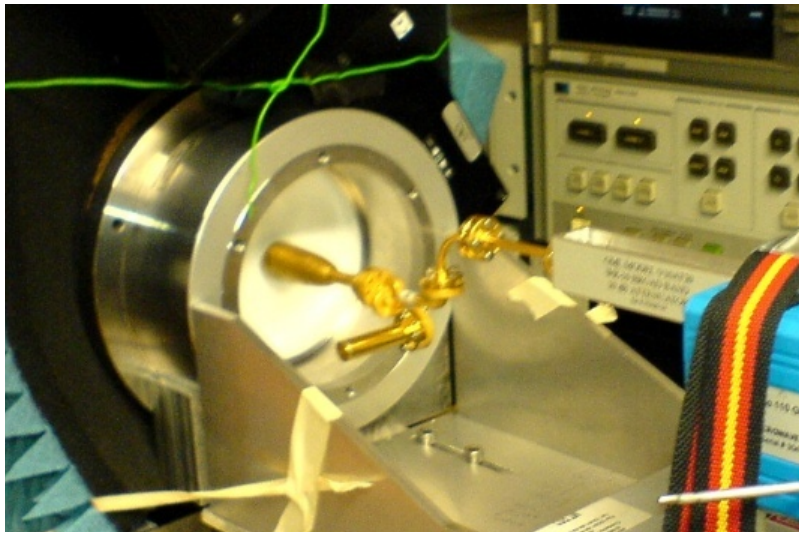
Measured Cross-Pol: -35dB

Co-Pol & Cross-Pol Beams



Pixel tests: HWP + Horn + OMT

Horn-OMT pixel + HWP



Averaged Cross-Pol: -29dB

Co-Pol & Cross-Pol Beams

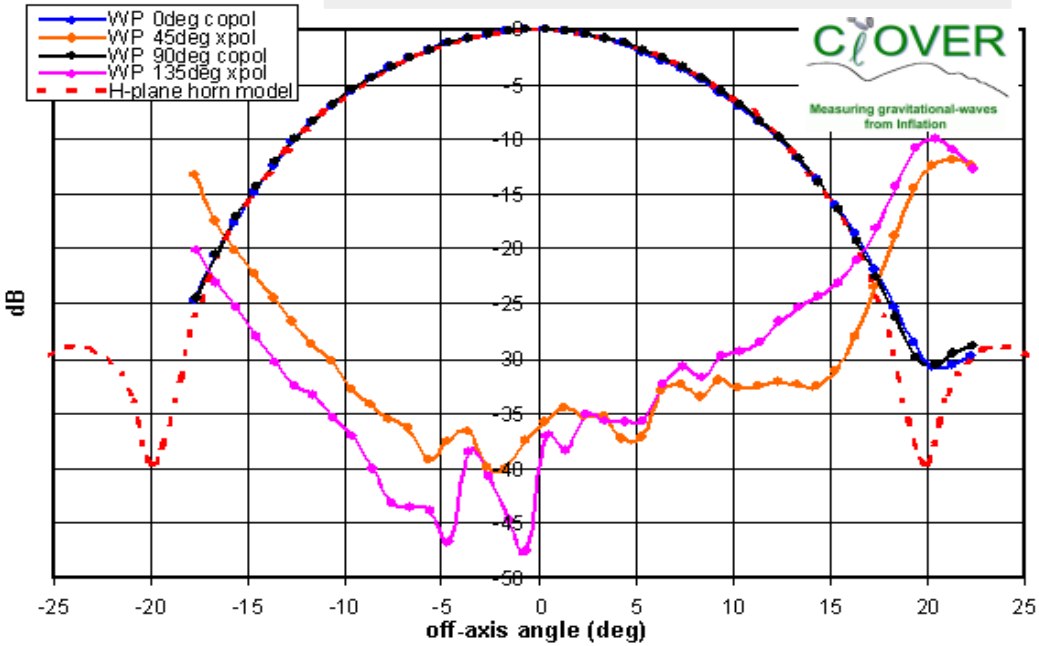
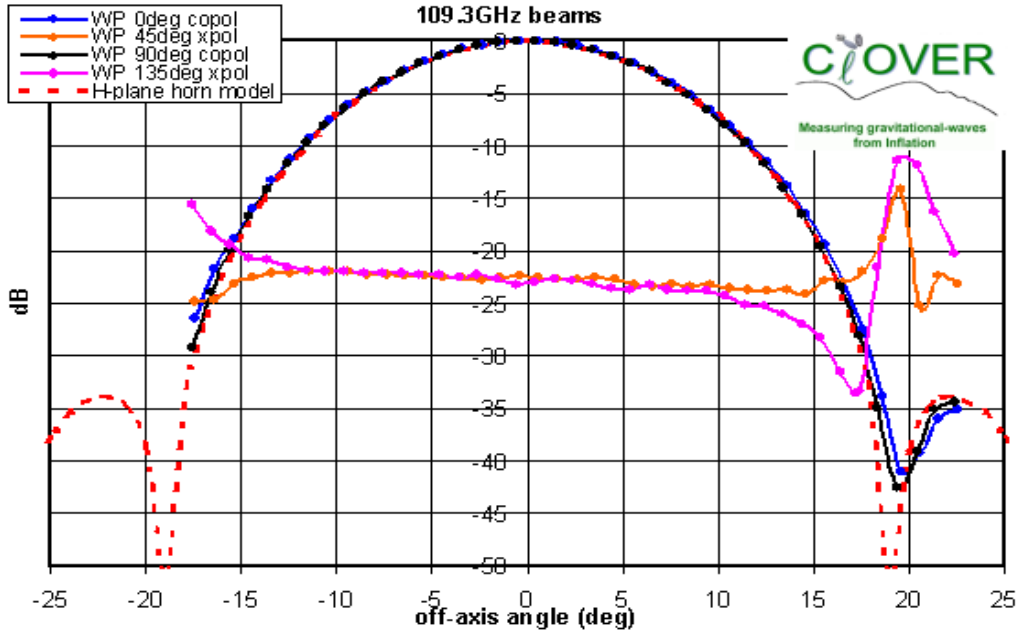


Figure 5: HWP+horn+OMT beams at 97GHz – co and cross polarisation



Single Pixel Beam Tests Performances

→ Integrating across the 82-110 GHz band and over the beam:

Polarimeter	Components	Cross-Pol
No modulation	Horn + OMT	-40dB
FRM	Horn + FRM + OMT	-24dB
WRM	Horn + WRM + OMT	-31dB -35dB
HWP	HWP + Horn + OMT	-29dB

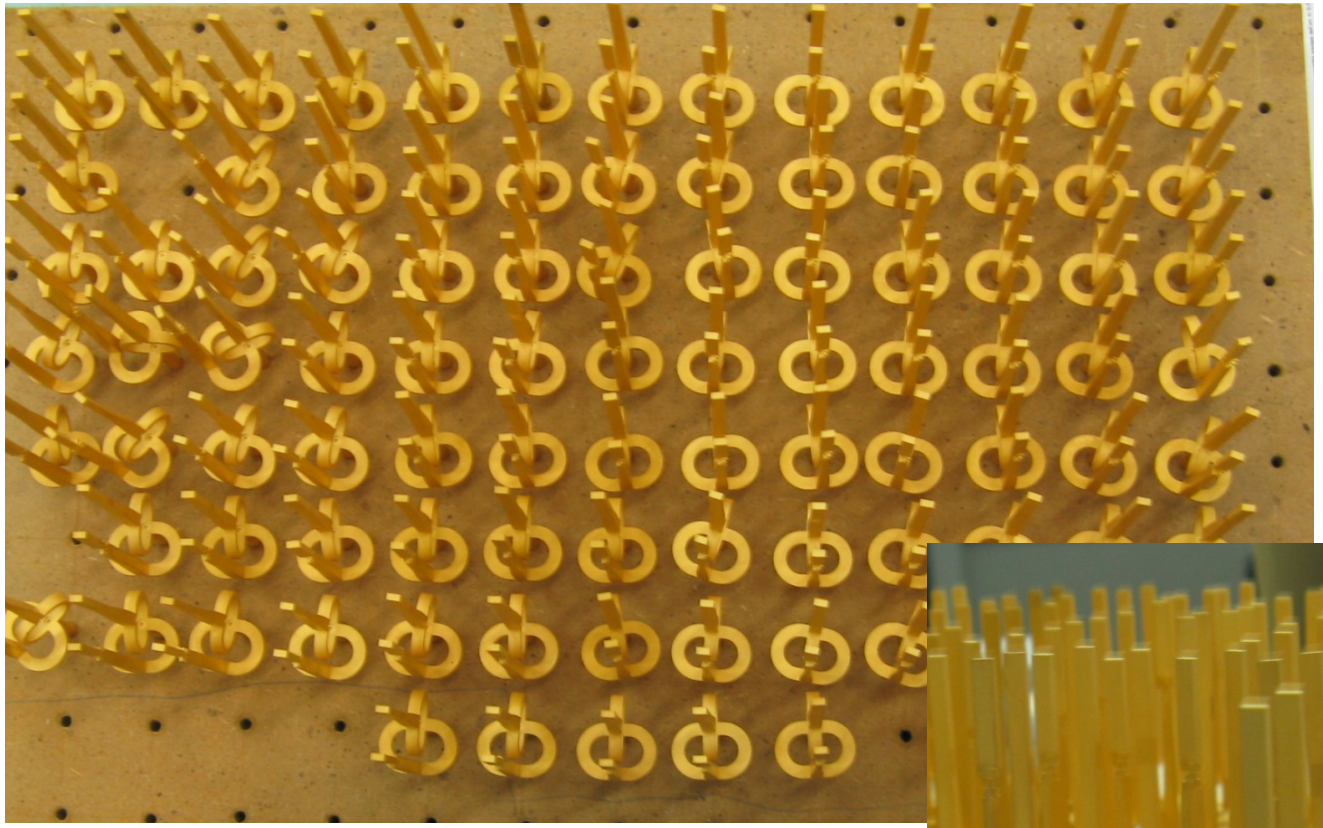
Table 2 – Polarimeter pixel measured performance

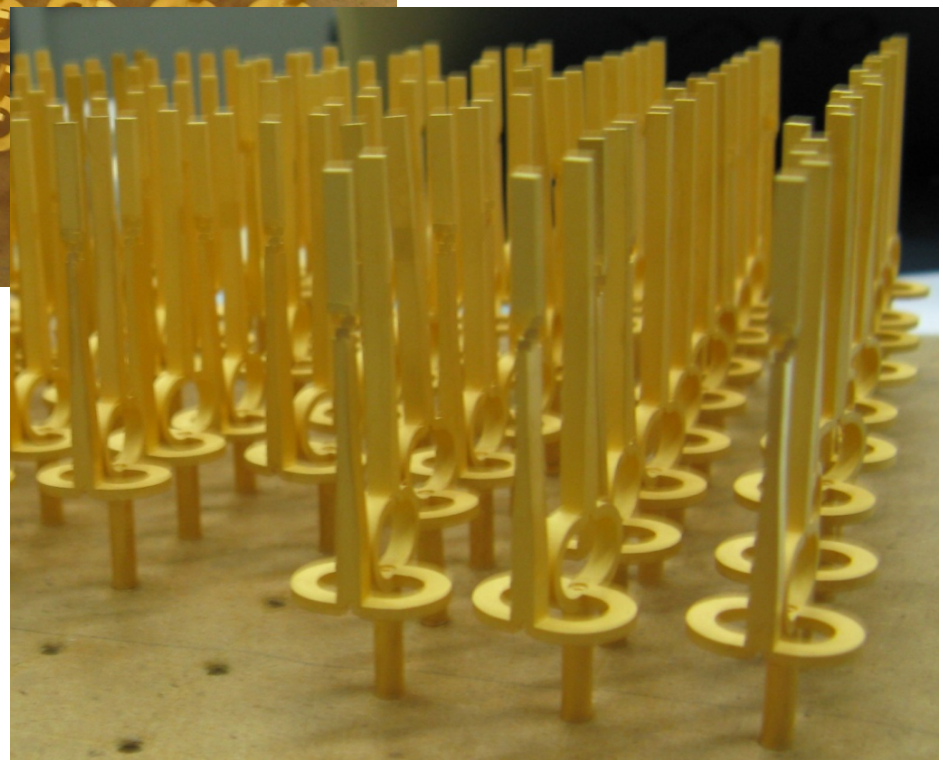
Passive components development

- Waveguide components
- Quasi-optical components
- Single pixels
- Focal Plane Arrays
    - Clover 97GHz

Clover 97GHz Focal Plane Array: Horn production

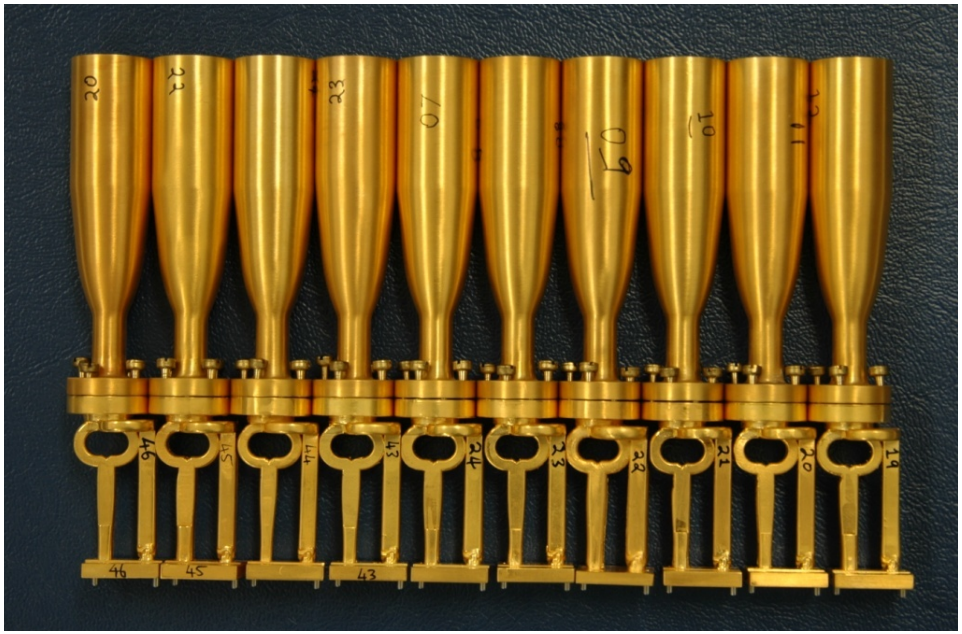
Clover 97GHz Focal Plane Array: OMT production

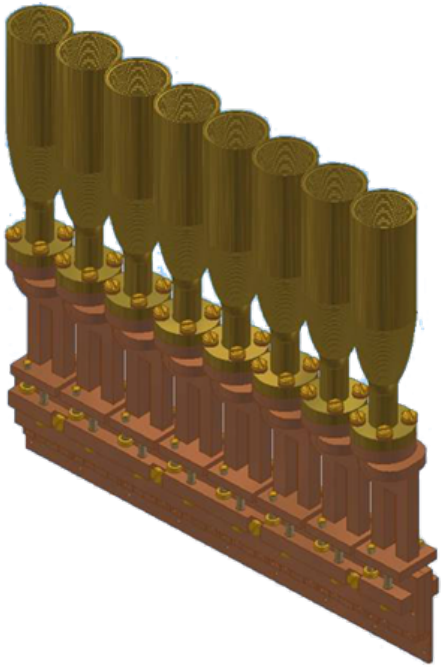




Gold-plated aluminium mandrels
before electro-forming

Clover 97GHz: Focal Plane Array Design & Assembly





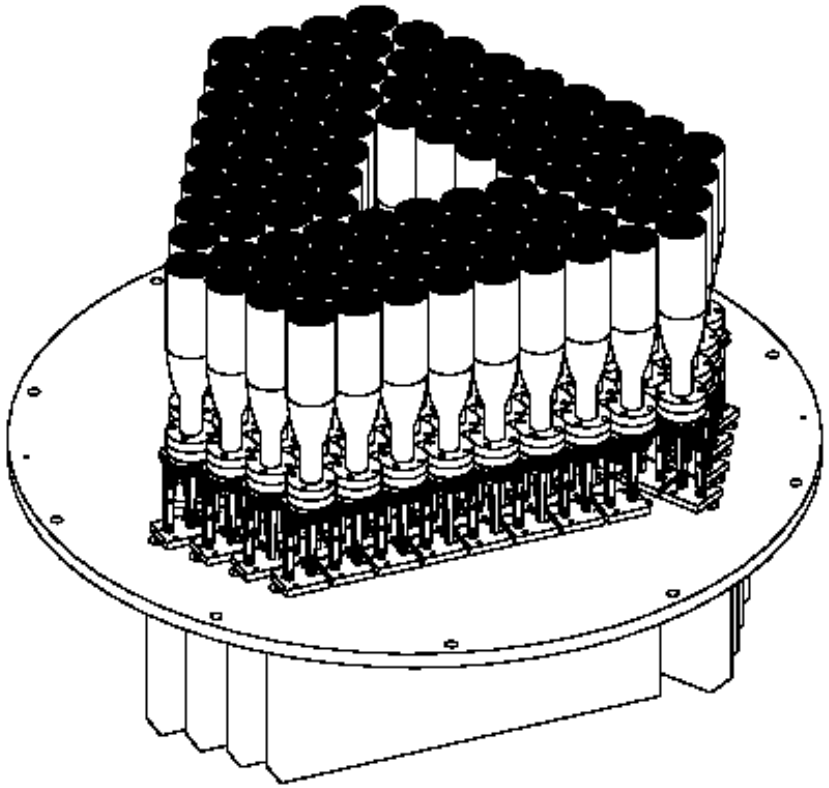
Corrugated Horns

Waveguide OMT

Finline Detector Block

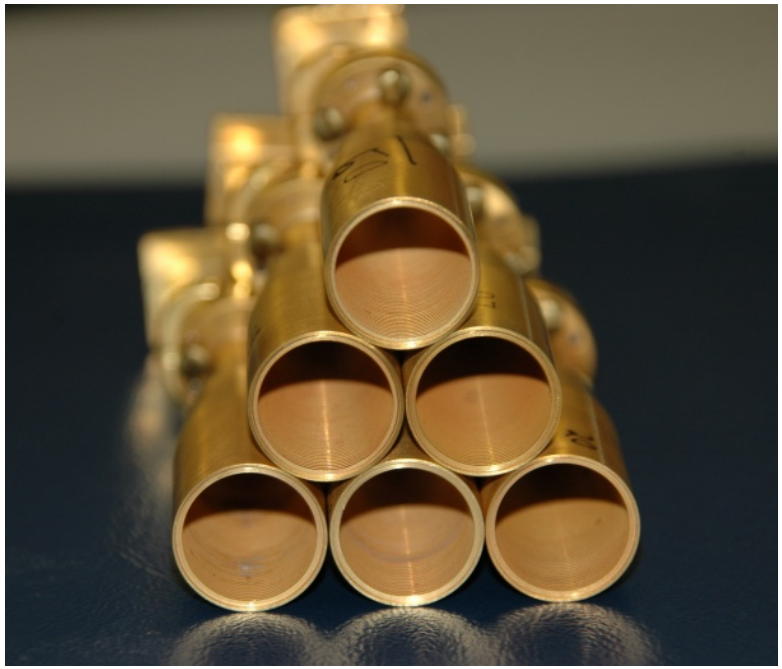
Clover Collaboration:

- Cambridge
- Cardiff
- Oxford
- Manchester



– 8x1 blocks of detector pairs
– 96 pixels (192 detectors)
– 230 mm diameter

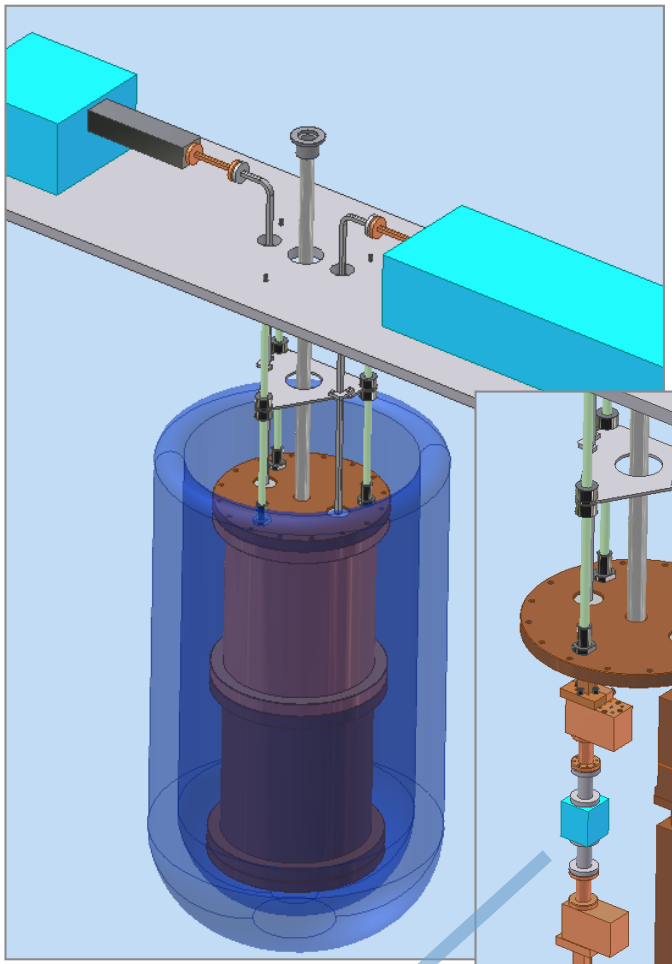
Clover 97GHz: Focal Plane Sub-Array

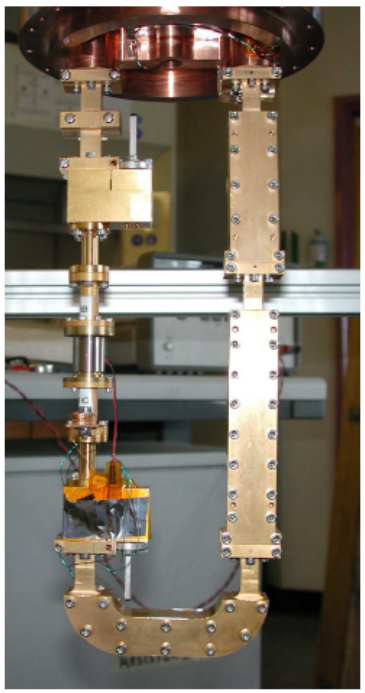


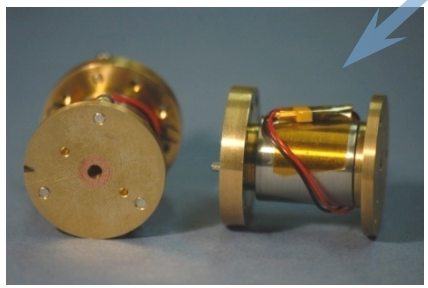
The End

Testing: VNA cold tests setup

Cryogenic test bed (4K)







Faraday Rotator Modulator Setup