Millimeter-Wave Substrate-Integrated Circuits on Photo-imageable Substrate and LTCC

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OUTLINE

Photoimageable thick film technology

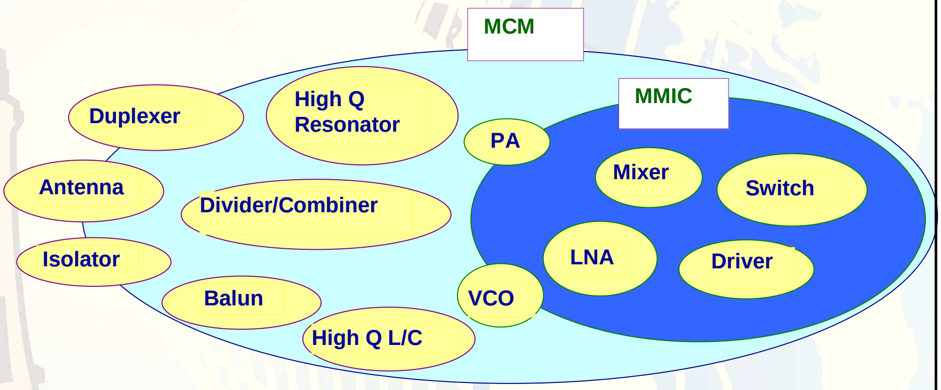
“Rapid Prototyping” LTCC Technology using LPKF Laser

Laser Machining of Microvias and Trenches

Future Work:-

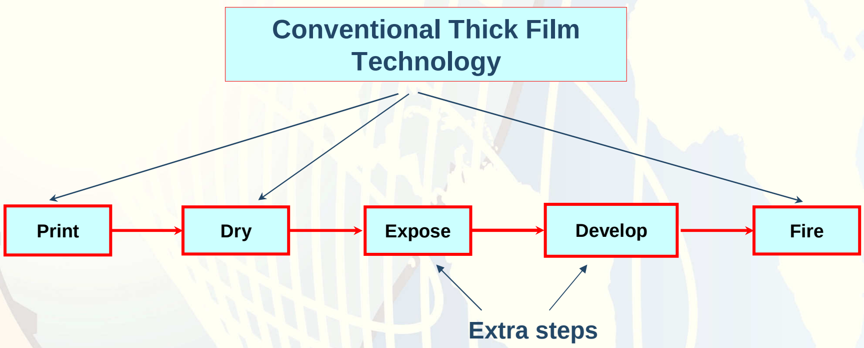
- Novel filter topologies
- SIWs & Antennas
- Systems integration

MOTIVATION



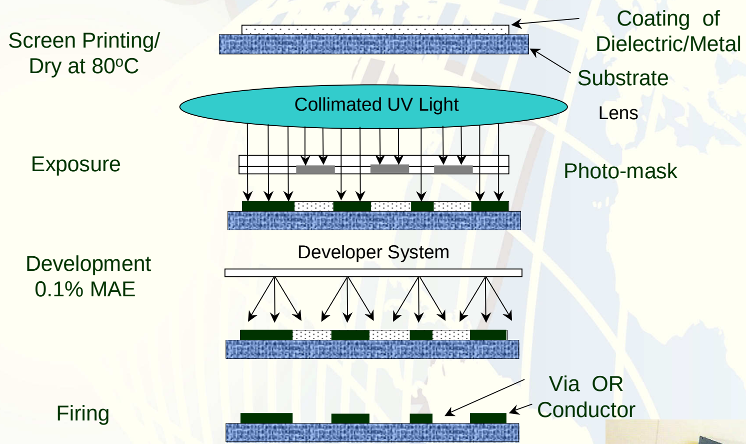
THICK-FILM TECHNOLOGY PURSUED FOR LOW COST FABRICATION OF LARGE AREA SYSTEM-ON-SUBSTRATE APPLICATION

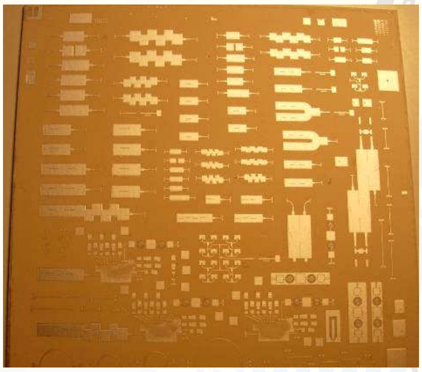
MULTILAYER PHOTOIMAGEABLE THICK FILM PROCESS

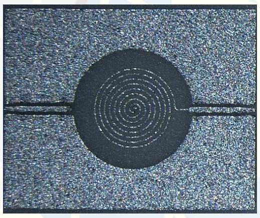


MULTILAYER PHOTOIMAGEABLE THICK FILM PROCESS

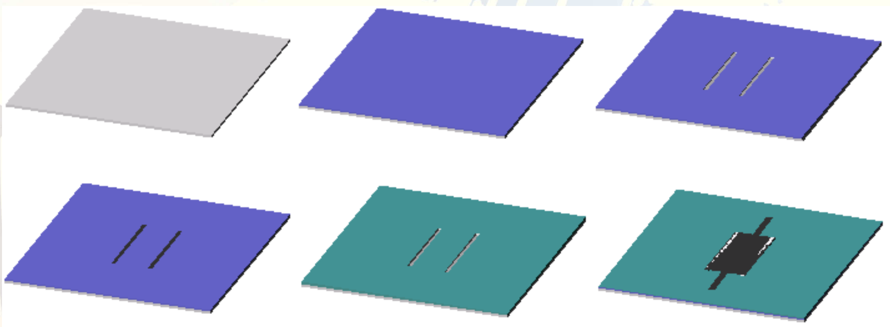
- Special type of photosensitive thick film material
- Features are defined by exposure of dry paste to UV light
- Gold, silver and dielectric pastes available
- Rheology of paste can be optimised for smooth finish
- Fine width/gap, easy to fabricate, low cost





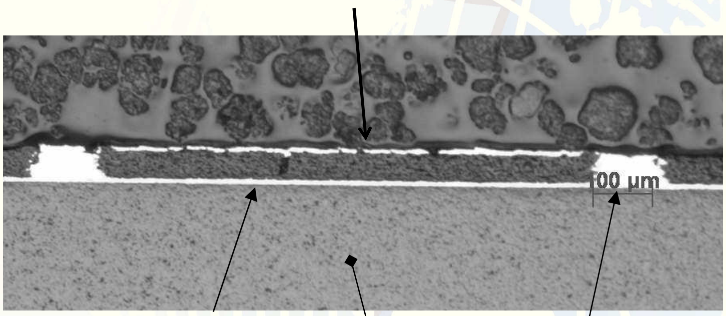


SIW Fabrication

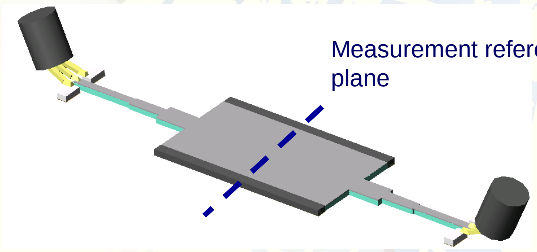


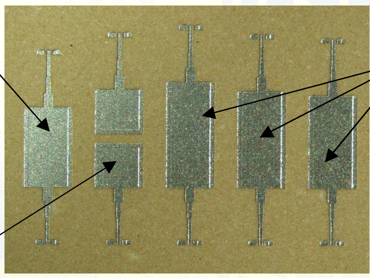
- Conductor print defines ground plane
- Dielectric layer exposed & developed to create vias for sidewalls
- Conductor print forms guide sidewalls
- Repeat dielectric prints to build guide height
- Final conductor print forms upper broadwall

Fabricated waveguide

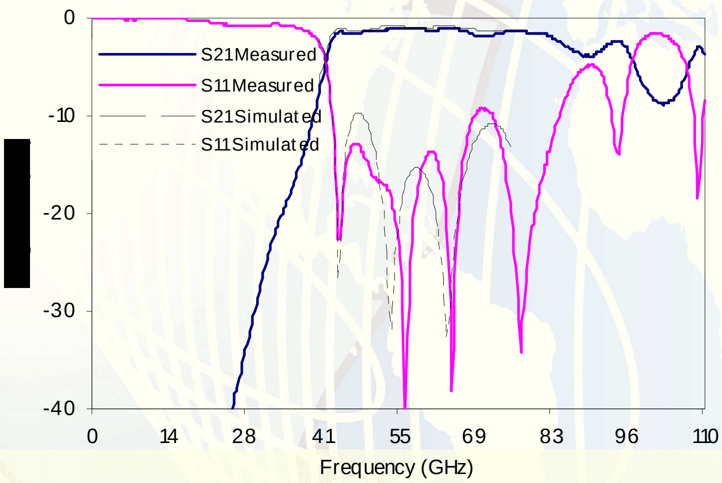


TRL calibration

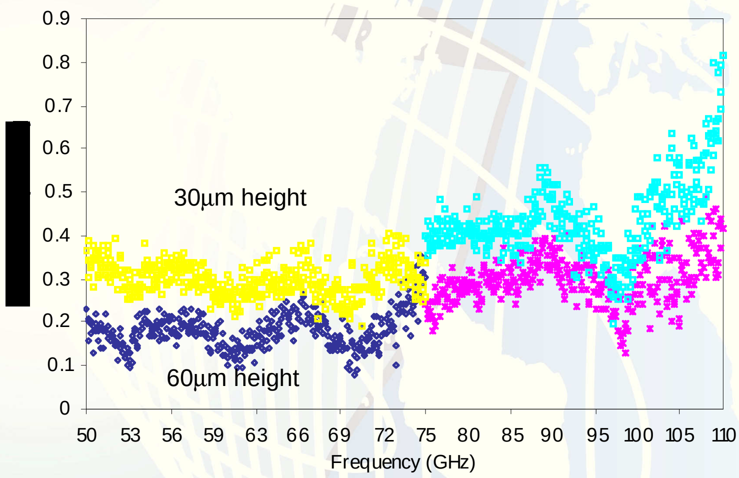




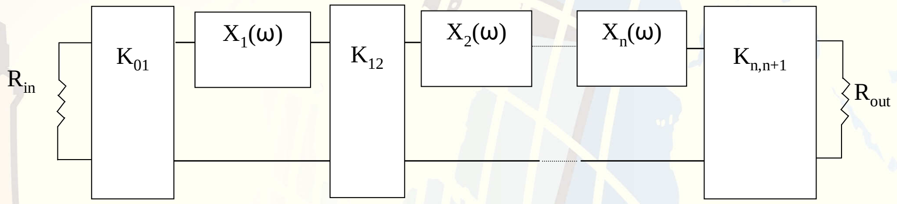
V band waveguide back-to-back transition measurements



Measured attenuation (dB/mm) for V and W-band waveguides.

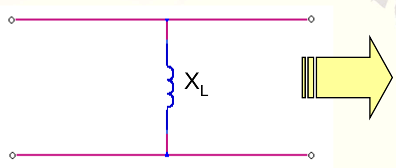


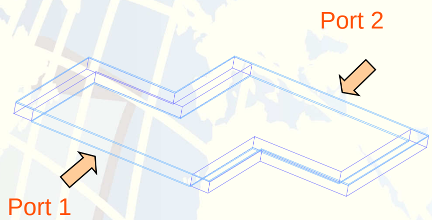
Inverter-coupled filter



- K_{ij} impedance inverters and $X_n(\omega)$ resonator sections are series connected

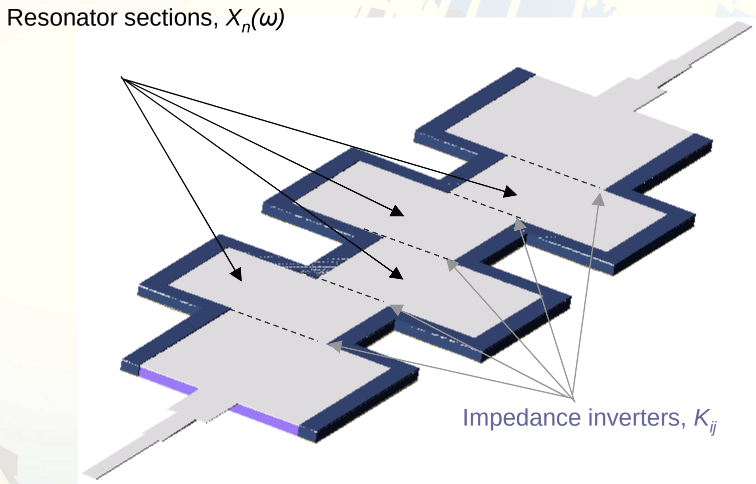
Inverter





- Inductive reactance readily realized by a H-plane offset
- Displaced junction characterized in HFSS

SIW filter synthesized



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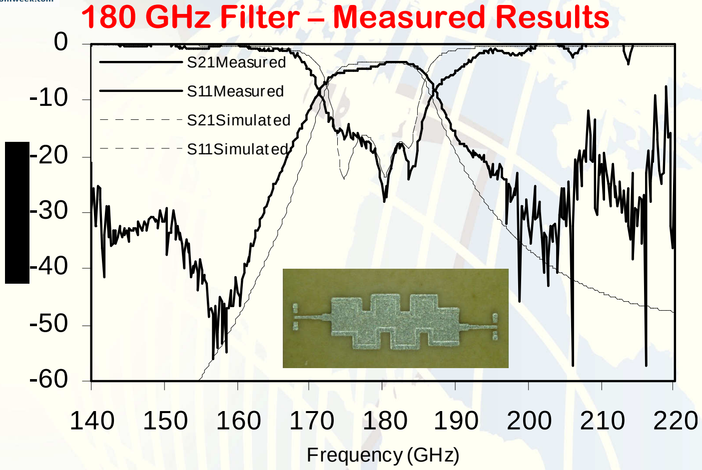
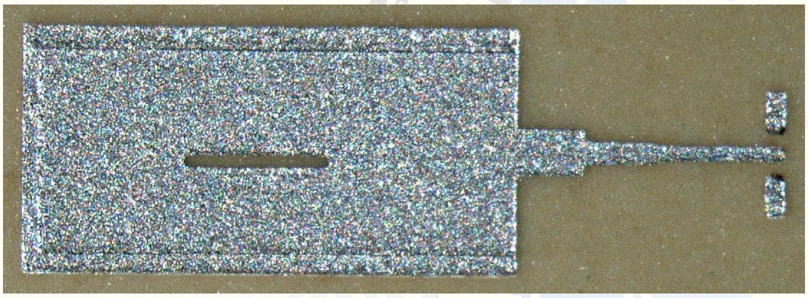
180 GHz Filter – Measured Results



Stephens, D.; Young, P.R.; Robertson, I.D., **"Design and characterization of 180 GHz filters in photoimageable thick-film technology"** IEEE MTT-S IMS, 2005, vol. 1, pp. 451-454

W-band Antenna



Stephens, D.; Young, P.R.; Robertson, I.D. (2005) **W-band substrate integrated waveguide slot antenna.** Electronics Letters, 41(4), pp.165-167.

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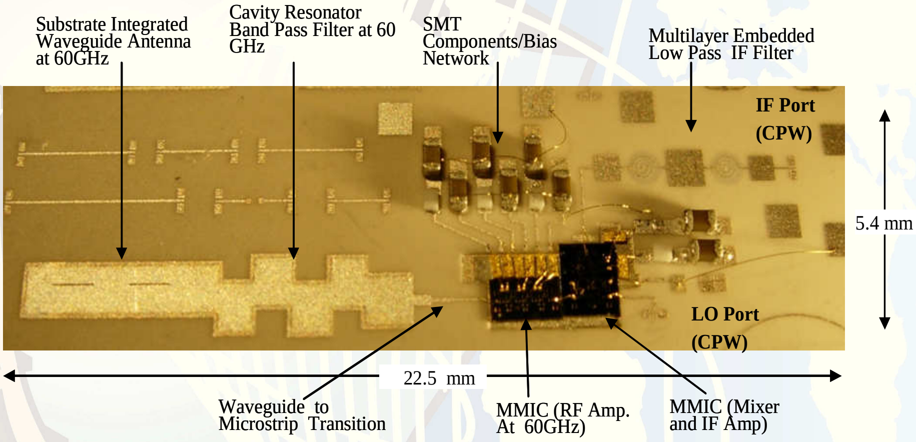
Complete SIW/MMIC 60GHz Receiver



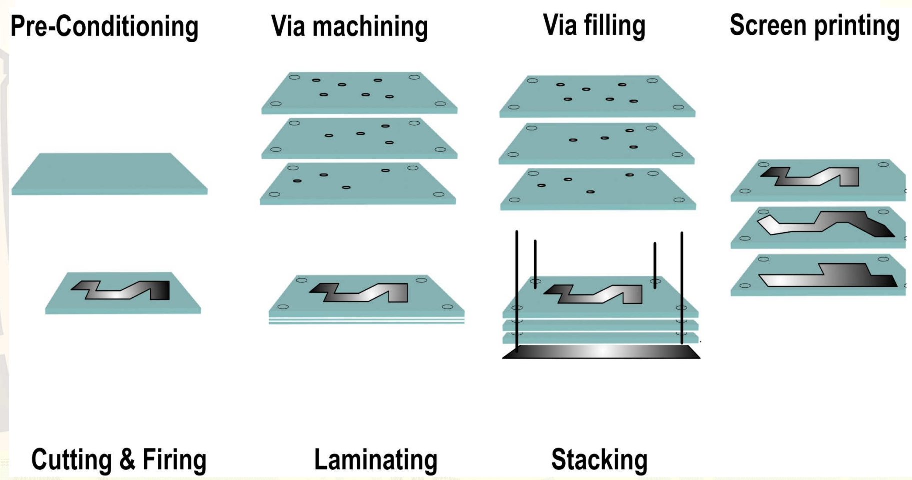
Major drawback of thick film photoimageable approach for SIWs

Waveguide height!

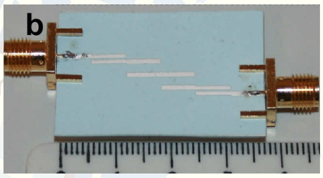
Even achieving 100 microns height requires many print-expose-fire cycles

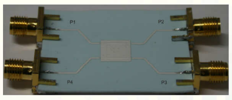
Alignment becomes challenging

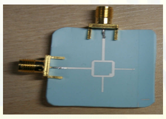
LTCC Process



LTCC prototyping using LPKF laser system







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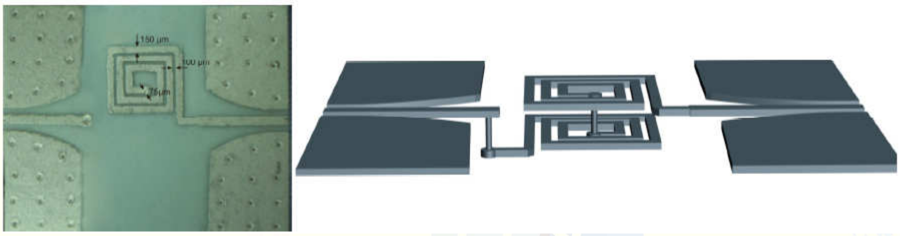
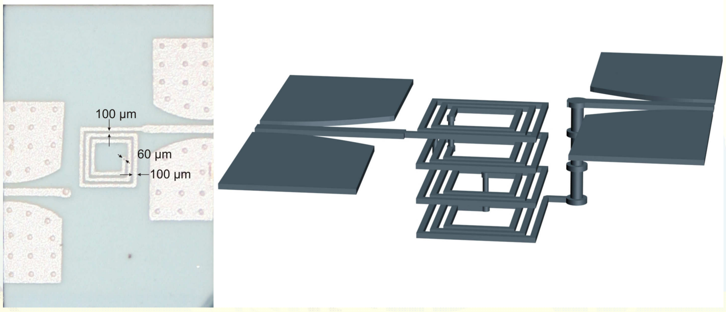
Equipment and Material

- Protolaser 200 Nd:Yag Laser etching machine from LPKF
- 943PX, 254 µm green tape from DuPont
- HF612 silver paste from DuPont
- HF600 via filling paste from DuPont

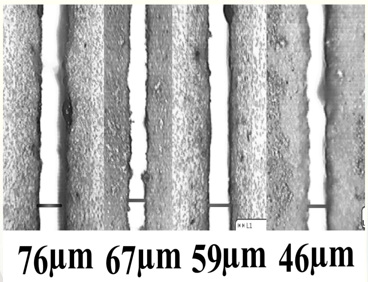


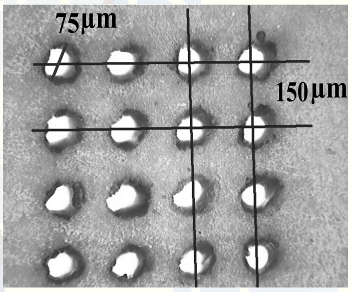


Via machining

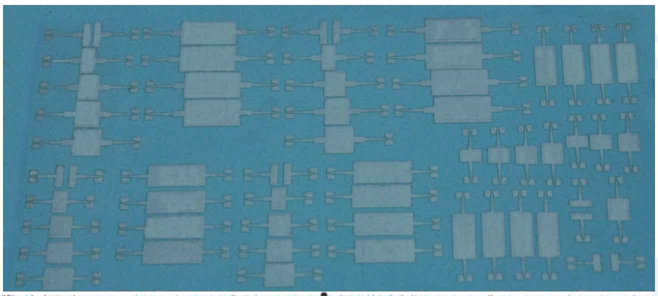
Mechanical drill and punches	Laser machining
Low capital cost	High capital cost
Single use	Multipurpose
Low punching rate	High punching rate
Clean and precise diameter	Not very clean, precision suffers
Holes only	Arbitrary shape possible
No optimization required	Hard to optimize
Direct contact with the material	No direct contact with material
Short tool life	Long life

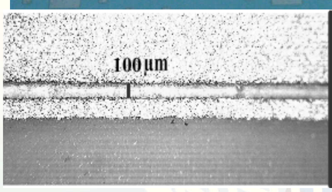
Minimum dimensions

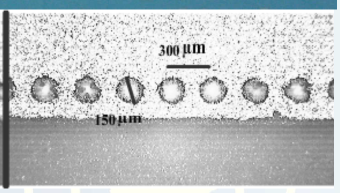




SIW with solid wall and via posts







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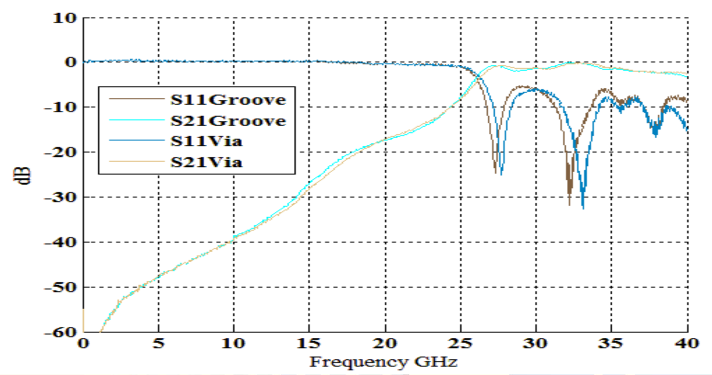

- Both solid walled (groove based) and via post SIW can achieve similar performance

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Further Developments

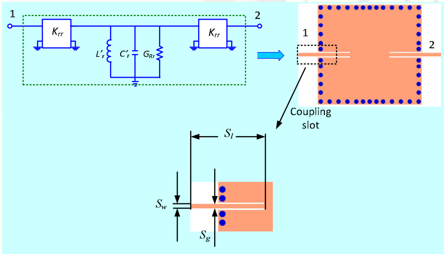
Novel filter topologies

SIW / Antenna integration

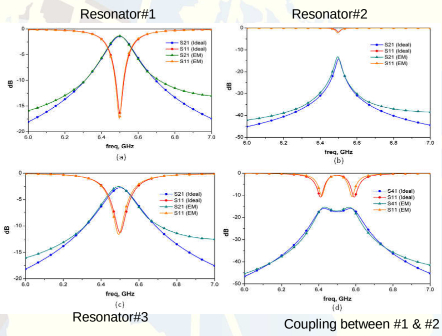
Higher frequencies

Novel reconfigurable systems

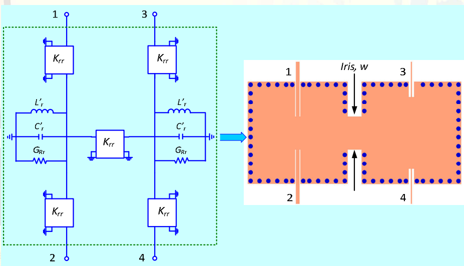
SIW Resonator

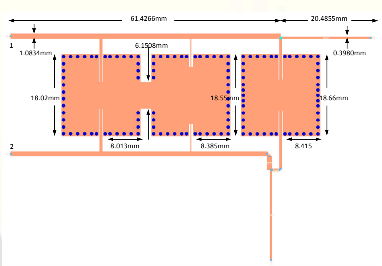


Ideal vs EM

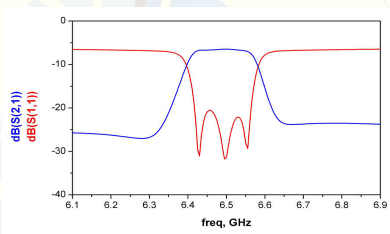


Inter-Resonator Coupling



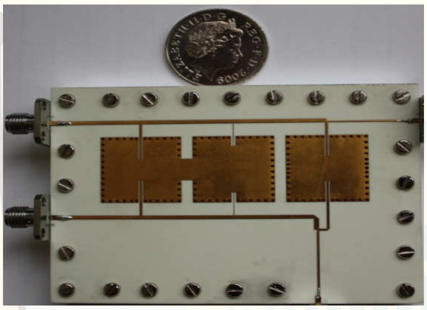


Layout

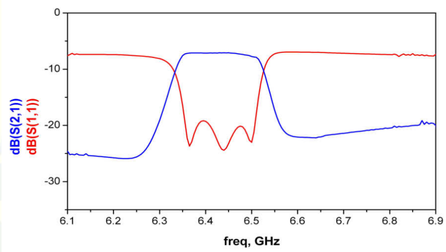


Simulated response

Results

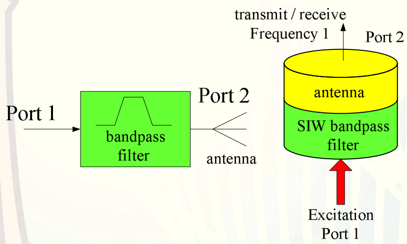


Photograph of the fabricated filter

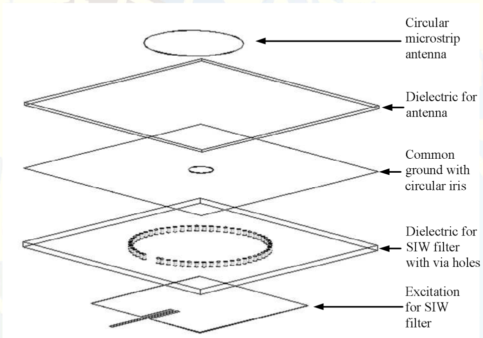


Measured response

INTEGRATED MICROWAVE FILTER AND ANTENNA



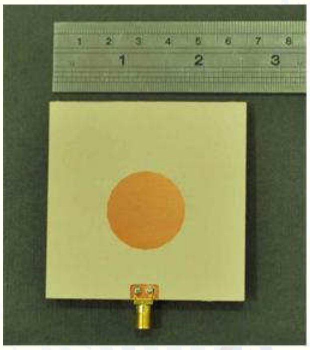
Block diagram



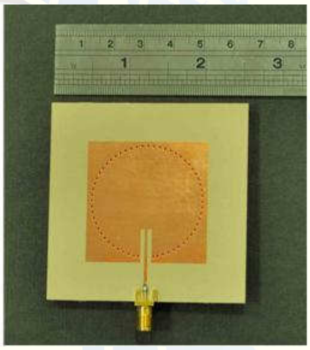
Exploded view

PHOTOGRAPH OF FABRICATED INTEGRATED SIW FILTER AND MICROSTRIP ANTENNA

Fabricated on Rogers Duroid 6010 of ε_r=10.2

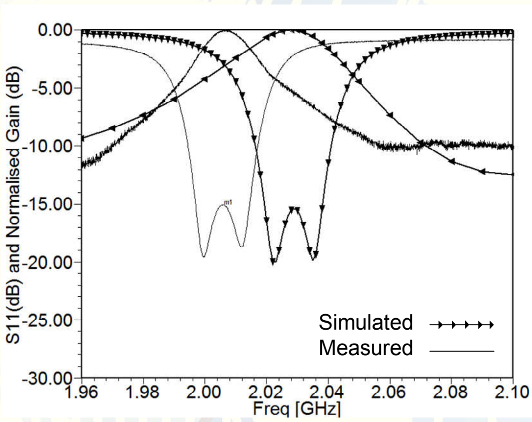


Top View



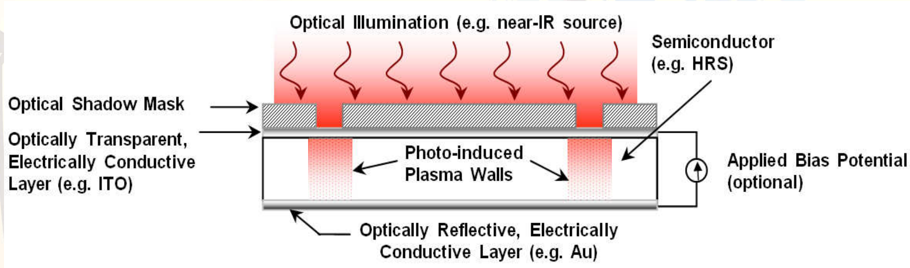
Side View

SIMULATED AND MEASURED RESULTS



The RETINA concept

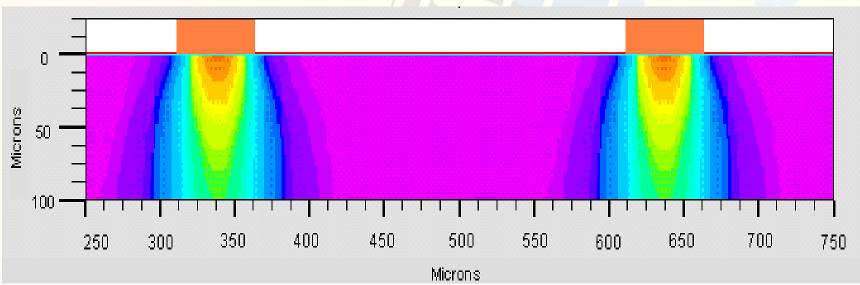
REconfigurable Terahertz INtegrated Architecture (RETINA)



Basic RETINA concept is based on creating virtual side walls using optical illumination and the photoconductivity effect

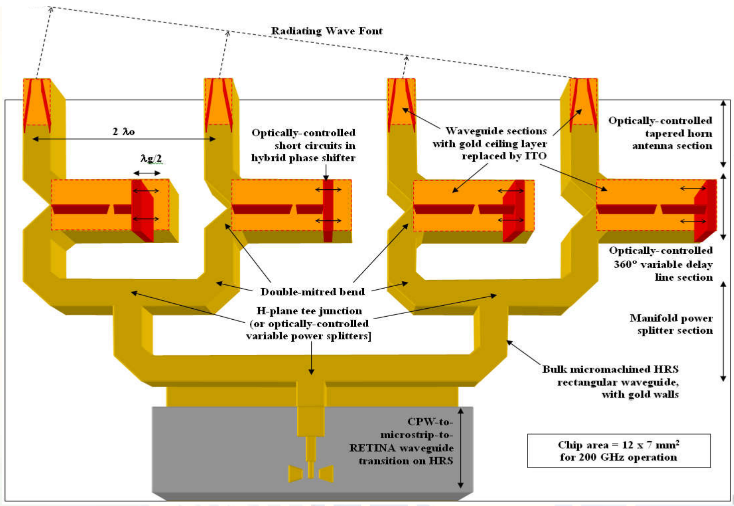
Y. Zhou and S. Lucyszyn, "Modelling of reconfigurable terahertz integrated architecture (RETINA) SIW structures", EM Academy's PIER Journal, vol. 105, pp. 71-92, Jun. 2010

Silvaco™ TCAD simulations: 2D Luminous



Beam Width = 50 µm
Wafer Thickness = 100 µm
Optical Incident Power Range: 10-100 W/cm²

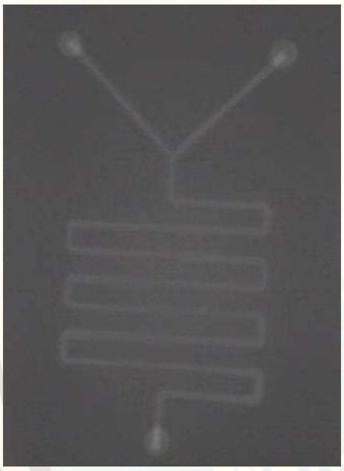
Scanning phased Array Antenna Concept at 200 GHz

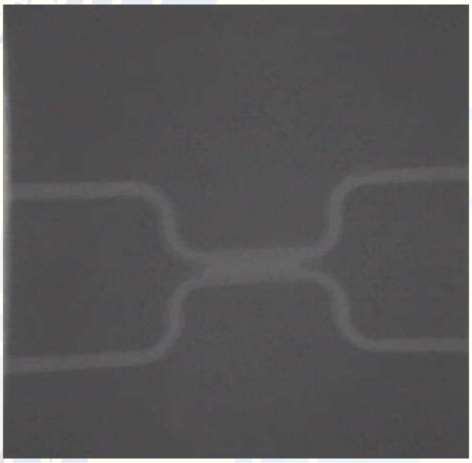


Loss Comparison with Various SIW Technologies

Technology	Frequency (GHz)	Insertion loss (dB/mm)	Conductor loss scaling to 300 GHz (dB/mm)
Alumina SIW	50	0.03	0.07
Ceramic (HT1000) SIW	60	0.20	0.45
Ceramic (QM44F) SIW	74	0.70	1.41
Polyimide (Kapton HN) SIW	79	0.17	0.33
Photoimageable Dielectric HD1000-filled MPRWG	83	1.2	2.3
Air-filled MPRWG	100	0.01	0.017
Polyimide-filled MPRWG	105	8.98	15.18
Air-filled MPRWG	400	0.086	0.074
RETINA (simulated)	300	3.88	3.88

LTCC Microfluidic Channels





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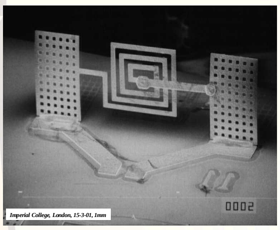
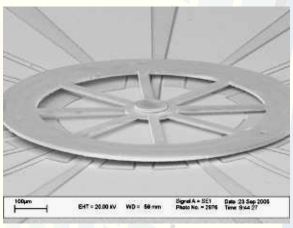
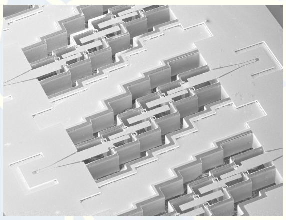
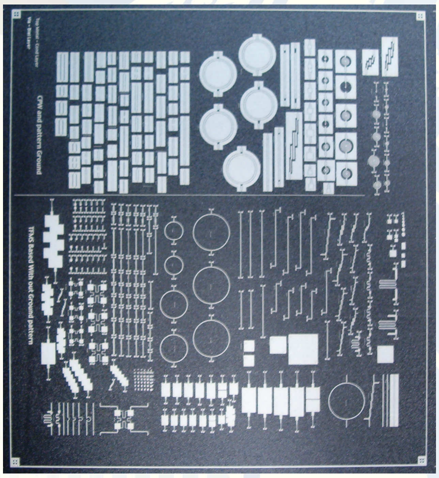
Previous Imperial-Leeds collaboration in RF MEMS & Micromachined Components









Collaboration with Mechanical Engineering on Large Area Screen Printing

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Conclusions

Ceramic technologies are highly suited to the realisation of SIW filters and circuits

To go significantly beyond 100 GHz requires research into improved materials and fabrication techniques

In LTCC, a wide range of microfluidic and mechanical components can be integrated to form a truly multifunctional system-on-substrate

A major challenge for the next few years is to study the feasibility of realising screen-printed RF MEMS integrated with SIWs to make tuneable filters

Addressing these challenges can lead to highly novel large-area SIW-based systems

Acknowledgments

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