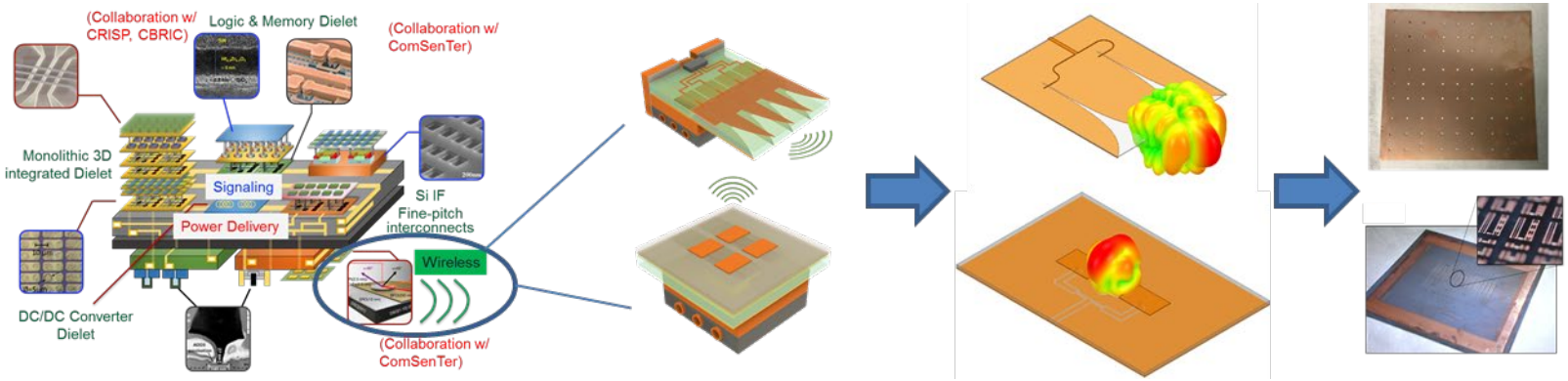
Session III Poster Title:
mm-Wave and sub-Terahertz Antennas for 5G and 6G Applications

Students: Kai-Qi Huang, Serhat Erdoğan, and Muhammad Ali
Faculty: Dr. Madhavan Swaminathan and Dr. Fuhan Liu

- Objective:
  - Design, fabricate, and prototype miniaturised wide-band high-gain high-efficiency antennas at mm-wave to sub-terahertz frequency bands
- Technical Approach:
  - Design and modelling of antenna structures
  - Materials and fabrication process for antennas
- Latest Results:
  - Test structures fabricated on Astra substrate for 5G
  - Antenna design based on glass FOPLP at 140 GHz for 6G



This work was supported in part by ASCENT, one of six centers in JUMP, a Semiconductor Research Corporation (SRC) program sponsored by DARPA.

Session-III: Substrate Integrated Waveguides for Sub-THz Region

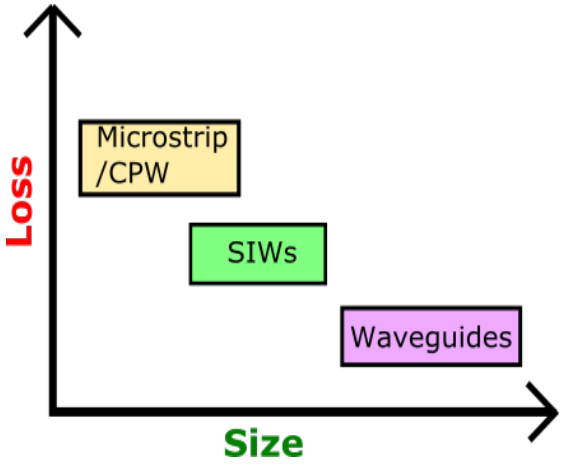
Student: Mutee ur Rehman Faculty :Madhavan Swaminathan

Objective

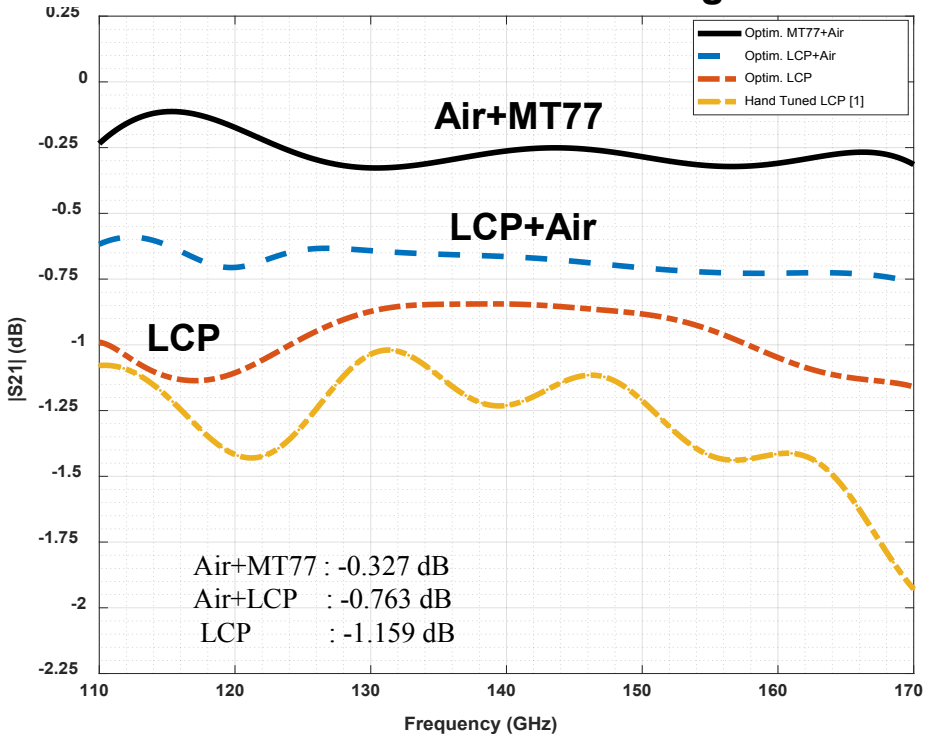
- High performance passives and interconnects for sub-THz
- MS and CPW lines → bandwidth and cross talk
- Traditional waveguides→ bulky

Technical Approach:

- Substrate Integrated Waveguides
- Reduce Dielectric Losses



Insertion loss of 2mm long SIWs



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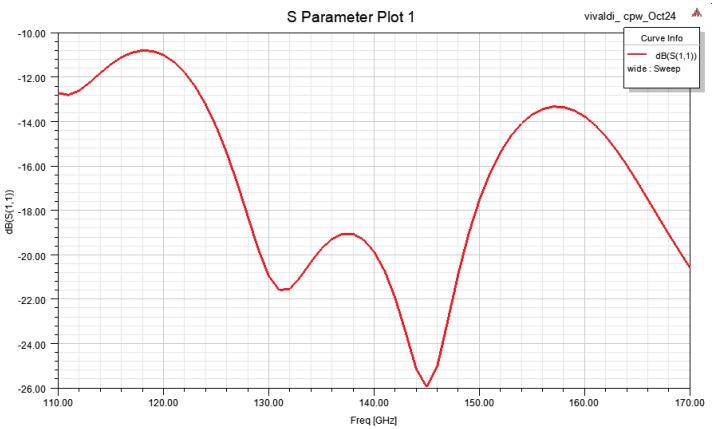
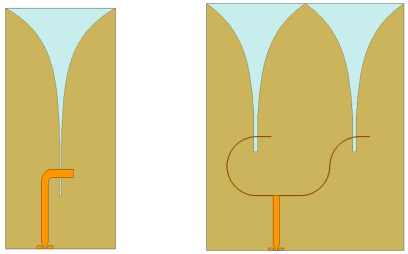
Session III - Design of D-Band Glass-based Vivaldi Antennas for 6G Applications

Student(s): Serhat Erdogan Faculty: Madhavan Swaminathan

- Objective:
  - Design and implement end-fire antennas on D-band for 6G applications
- Technical Approach:
  - Vivaldi antennas on different Glass-based stack-ups are being investigated for best performance
- Latest Results:
  - An initial design of 2.86mm x 2 mm on 100um glass stack-up with 7.5 dBi gain and a 1x2 array of 10 dBi gain have been manufactured. Measurements will be performed.





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Session-III: Design and Demonstration of Integrated Passive Components Test Vehicle for 5G and mm-Wave Applications

Students: Muhammad Ali, Atom Watanabe, Tong-Hong Lin
Faculty: Prof. Raj Pulugurtha, Prof. Manos Tentzeris, Prof. Rao Tummala, Prof. Madhavan Swaminathan
Industry Partners: Samsung, Qualcomm, AGC, Ajinomoto, Taiyo, Corning

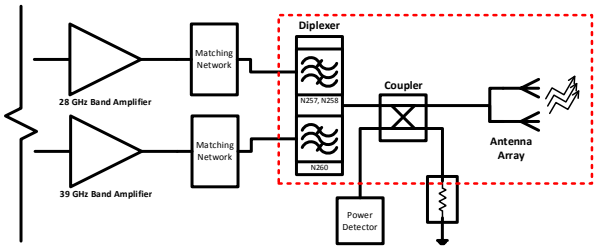
❑ Objectives:

Model, design, fabricate and characterize high-performance, miniaturized and integrated passive components for 5G and mm-wave applications (28 and 39 GHz bands) with next generation of package substrates such as laminated glass

- Filters and Power Dividers
- **Diplexers and Couplers**

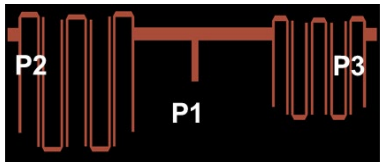
❑ Technical Approach:

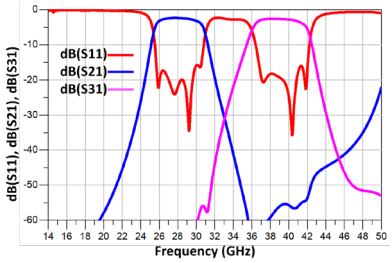
- Integrate filters, power dividers, diplexers and couplers in an ultra-thin glass stackup to emulate a front-end module



❑ Latest Results:

- Low-loss and high selectivity filters for 5G NR bands
- Low-loss, high selectivity and high isolation diplexers
- Couplers
- Integrated couplers and diplexers

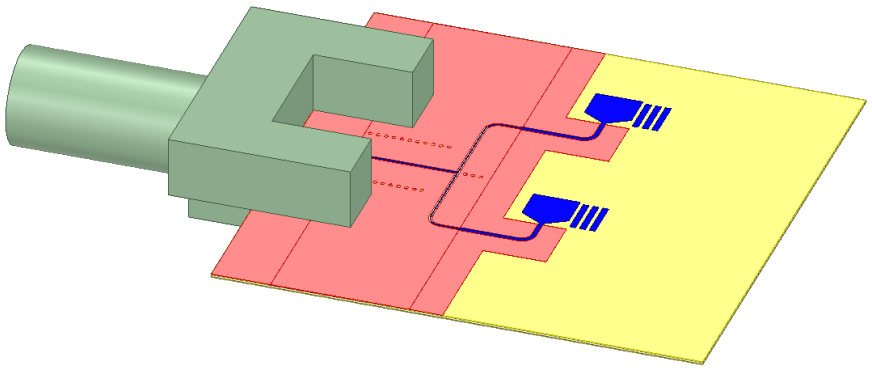




Session III
UWB 5G Package-Integrated Antenna Array Design

Student: Tong-Hong Lin
Faculty: Prof. Manos Tentzeris, Prof. Madhavan Swaminathan

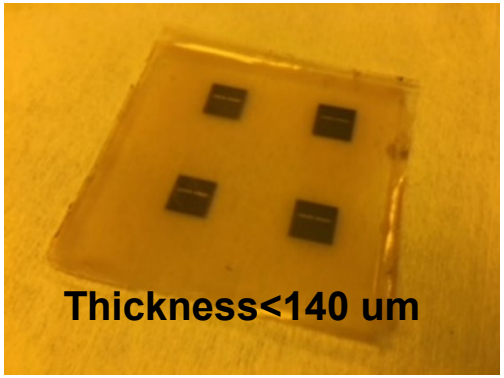
- Objective:
  - Designed UWB and miniaturized antenna array to solve the challenges of new 5G NR communication
  - Utilized the designed antenna array to form a fully functional 5G SoP application
- Technical Approach:
  - Monopole Yagi design to enhance the bandwidth and reduced the side
  - Ultra-thin glass stack with low loss JSR polymer
- Latest Results:
  - Optimized element and 2x1 array designs meet all requirements
  - Taken the possible thickness variation end launch connector into consideration

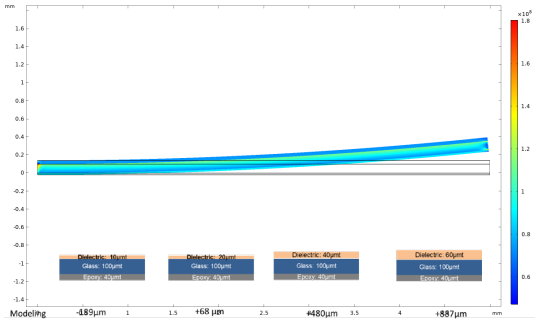


Session III Poster Title: Design and Demonstration of Ultra-thin Glass Panel Embedding Packages for RADAR Applications

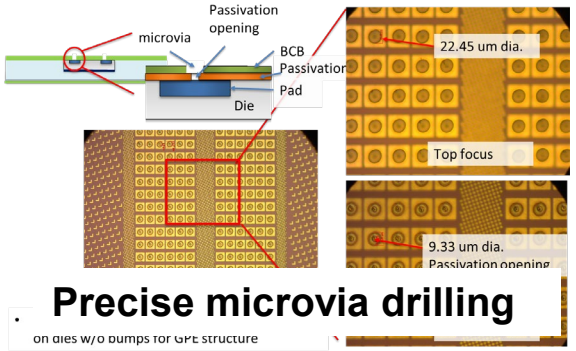
Student(s): Tailong Shi Faculty: Dr. Mohan, Nobuo Ogura

- Objective:
  - **Design and Demonstration of Ultra-thin, High-performance Glass Panel Embedding (GPE) Packages for RADAR Applications**
- Technical Approach:
  - Embedded chips for ultra-thin packages and short signal length
  - Low loss enabled by low-loss dielectrics and via in line interconnects
- Latest Results:
  - Demonstration of ultra-thin GPE packages below 140 um thick
  - Modeling and process optimization for warpage reduction
  - Demonstration of precise microvia drilling for low-loss interconnects





Modeling for warpage



Precise microvia drilling

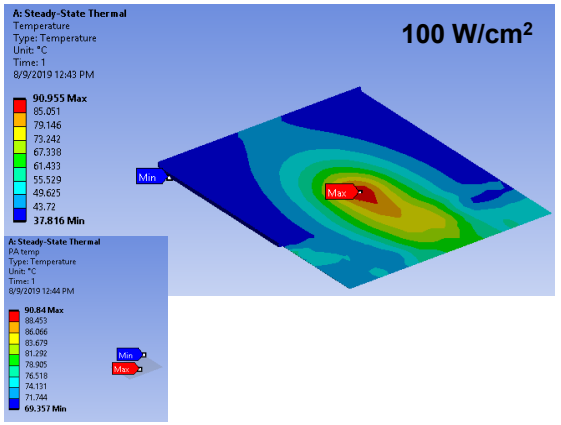
Session III

Poster Title: Thermal Management for 6G Module Using Vapor Chamber

Students: Nahid Aslani Amoli and Madeline Parnall

Faculty: Prof. Madhavan Swaminathan and Prof. Yogendra Joshi

- Objective:
  - Investigating the effectiveness of the vapor chamber (VC) as a thermal management solution for 6G module
- Technical Approach:
  - Using the conduction-based model of VC
  - Modeling thermal conductivity of VC with orthotropic approach
  - Conducting parametric analysis of VC dimensions to control the junction temperature of PA arrays in ANSYS Workbench
- Latest Results:
  - Right sizing of VC along with the liquid convection by the cold plate can lead to an efficient thermal management of 6G module



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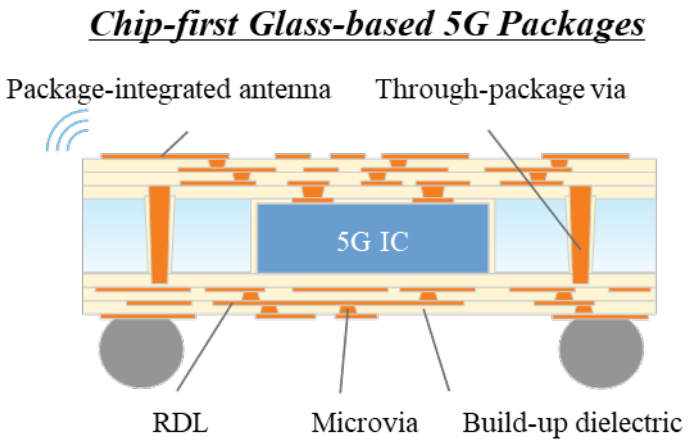
Session-III: Design and Demonstration of High-Performance and Ultra-Thin Antenna-Integrated 3D Glass-based mm-wave Packages

Student(s): Atom Watanabe, Muhammad Ali, Tong-Hong Lin
Faculty: Prof. Raj Pulugurtha, Prof. Rao Tummala, Madhavan Swaminathan

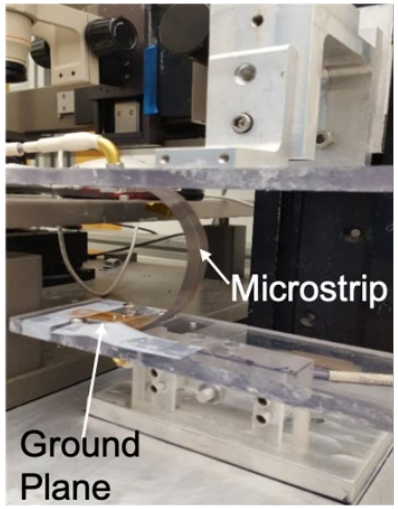
- Objective:
  - Model, design, and demonstrate high-performance ultra-thin antenna-integrated 3D glass-based mm-wave modules on 100-200 µm thick glass substrates for 5G packages.
- Technical Approach:
  - Chip-first GPE 3D mm-wave modules with miniaturized filters integrated.
  - Dual-pol antenna integration into 200 µm glass substrates.
- Latest Results:
  - Modeling and design of packaging architectures with dual-pol antenna and filters integrated
  - Glass-panel embedding – Chip-first process for ultra-short interconnects and low insertion loss from chip to antenna



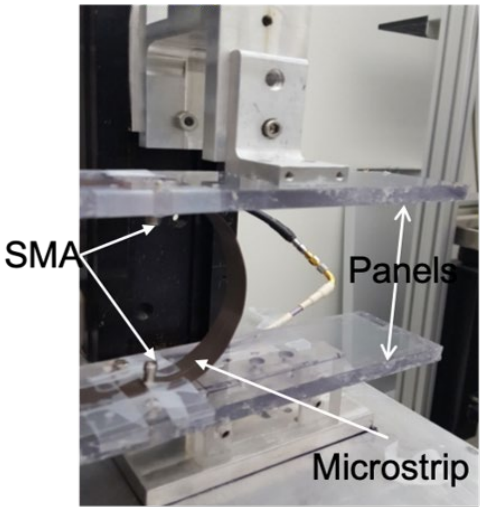
Session III Poster Title: Model Development for Flexible Hybrid Electronics Process Design Kit (FHE-PDK)

Student(s): Sridhar Sivapurapu, Nahid Aslani Amoli
Faculty: Dr. Sitaraman, Dr. Swaminathan

- Objective:
  - Populate FHE PDK with several components with frequency dependence
  - Include flexibility (bending) as a parameter for these components (if necessary)
- Technical Approach:
  - Use electrical and mechanical simulation tools to determine the impact of bending components on electrical performance
  - From electrical models, create a P-cell (parametric cell) using machine learning techniques to populate the PDK
- Latest Results:
  - PDK 1.0 has been released
  - Models for Coplanar Waveguide, Microstrip Tranmission Line, Patch Antenna, and Power Inductor are now included in the PDK



Tensile



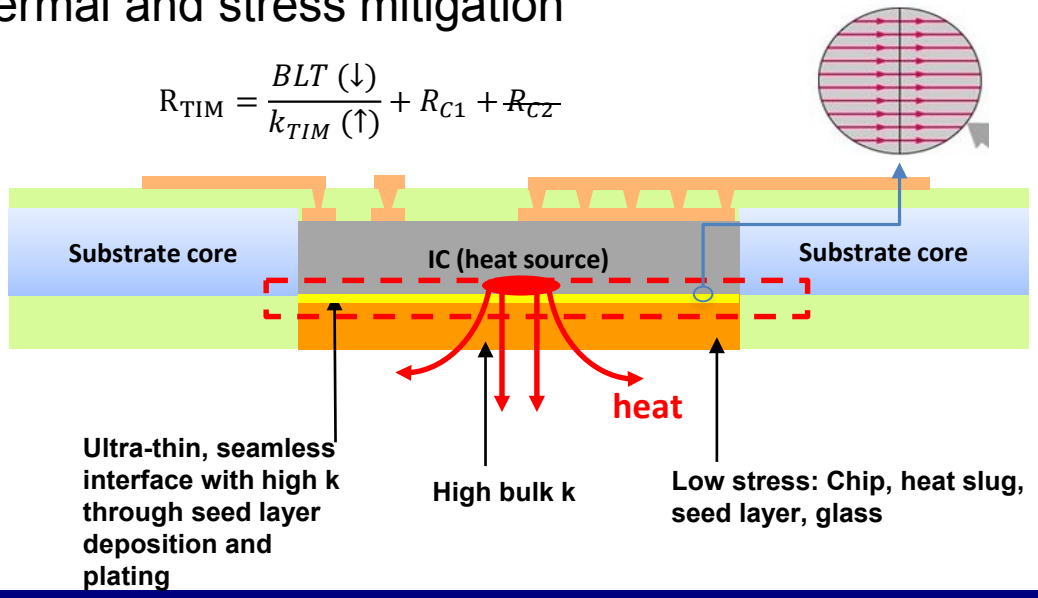
Compressive

Session III: Thermal/Thermomechanical Analysis of GPE Packages: Integrated Heat Spreader Design for High Heat Flux Densities and Reliability

Student(s): Nithin Nedumthakady Faculty: Dr. Smet, Prof. Tummala, Prof. Swaminathan

- Objective:
  - Modeling, design, fabrication, and demonstration of low stress, high thermal conductivity, low thermal resistance interfaces between device and heat spreader in glass embedded packages
- Technical Approach:
  - Near-zero thermal interface resistance between chip and heat spreader by sputtering of ultra-thin film, conductive seed layer
  - Modeling and design of aligned Cu-G composite interface material properties and geometry for thermal and stress mitigation
- Latest Results:
  - Thermal and thermomechanical modeling and analysis of GPE package
  - Design plan for reduced stress, high thermal conductivity material

$$R_{TIM} = \frac{BLT\ (\downarrow)}{k_{TIM}\ (\uparrow)} + R_{C1} + \cancel{R_{C2}}$$



Session-III: Bandpass Filters for D-band Application

Students: Xiaofan Jia, Muhammad Ali
Faculty: Madhavan Swaminathan

This work was supported in part by ASCENT, one of six centers in JUMP, a Semiconductor Research Corporation (SRC) program sponsored by DARPA.

- Objective:
  - Design and Measure microstrip structures on glass stack up at D-band
  - Demonstrate the performance of microstrip bandpass filters at D-band
- Technical Approach:
  - Ultra thin Glass core and Taiyo Zaristo Dielectric layer
  - High precision Semiadditive patterning (SAP) process
- Latest Results:
  - Simulated result of classic Coupled Line Microstrip Bandpass Filter with center frequency of 140GHz and 10% bandwidth.