Quilt Packaging® Microchip Interconnect Technology

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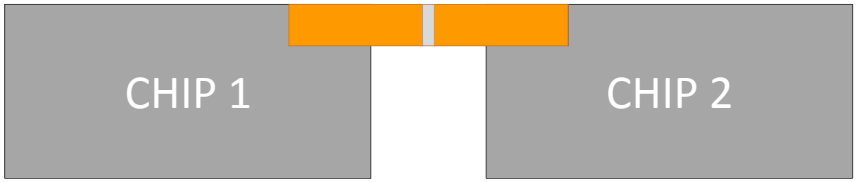
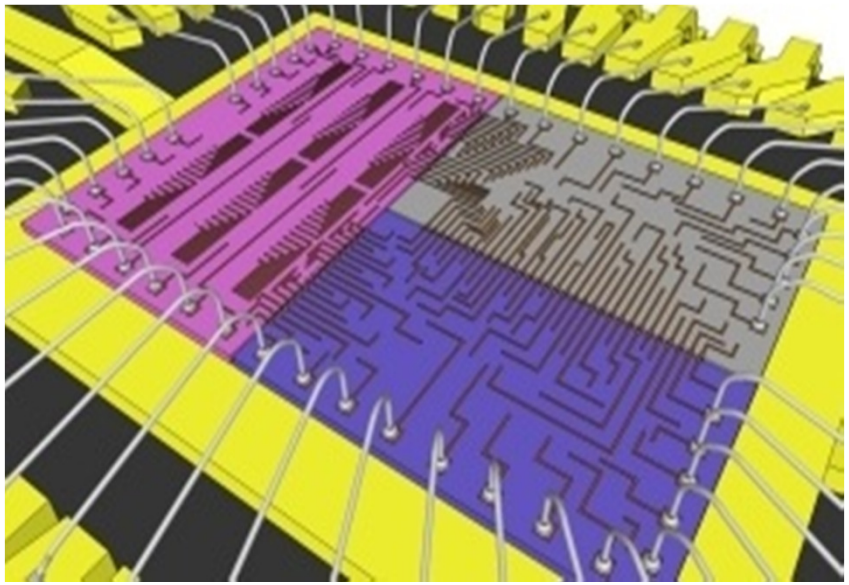
Overview

- Introduction to IIC
- Quilt Packaging (QP)
  - Concept
  - Electrical Performance
  - Fabrication
  - Advantages
- IIC as an R&D partner

Quilt Packaging (QP) Technology

- Edge-connections joined to create multi-chip “quilt,” developed at Notre Dame
- “Monolithic” assemblies from same or disparate materials & process technologies
- Enables optimization for cost and functionality
- Alternative or complementary technology
- Industry-standard tools and fabrication processes





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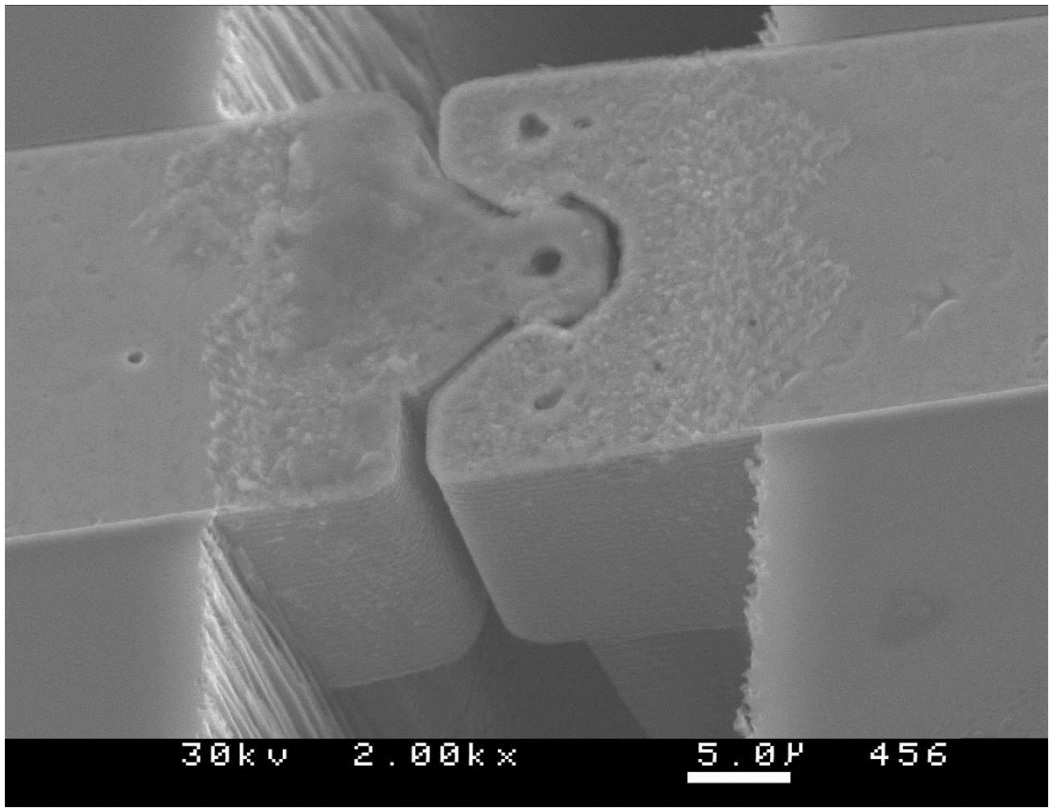
QP-Interconnect Structures

- Edge connection structures called “nodules”
- Solid metal, typically 10-200 um wide, ~ 20-50 um thick
- Customizable shapes-including interlocking-enables sub-micron chip alignment



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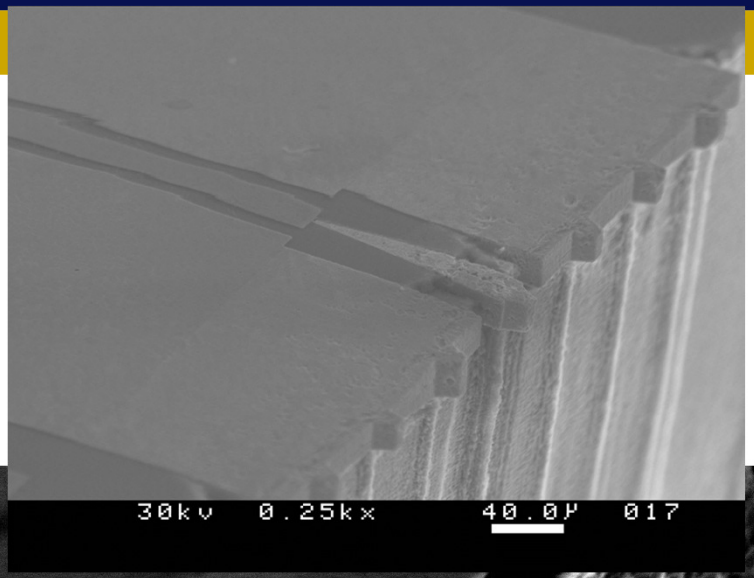
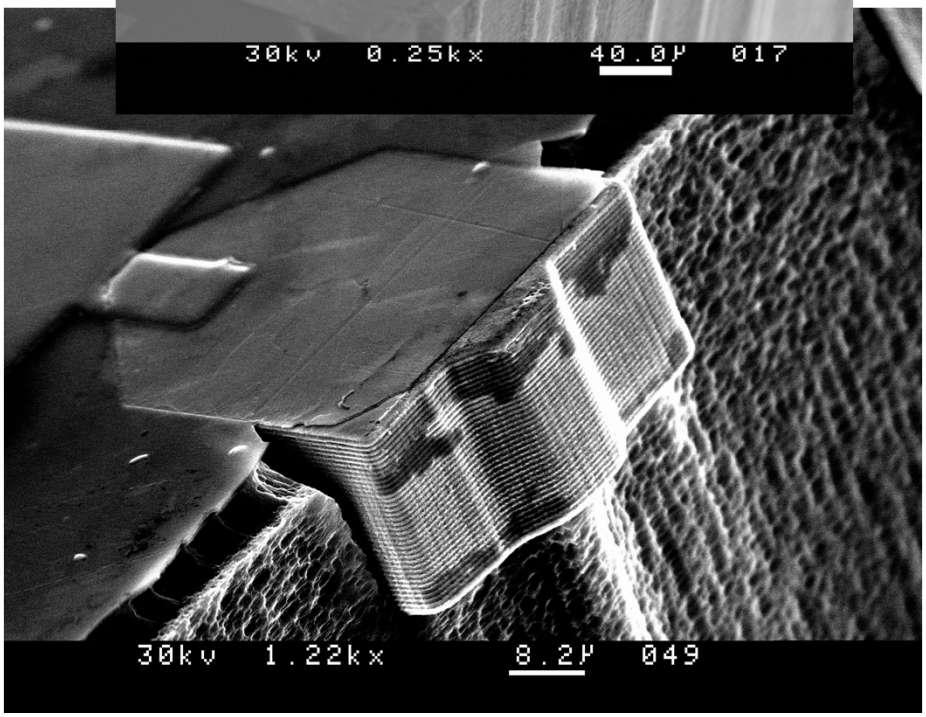
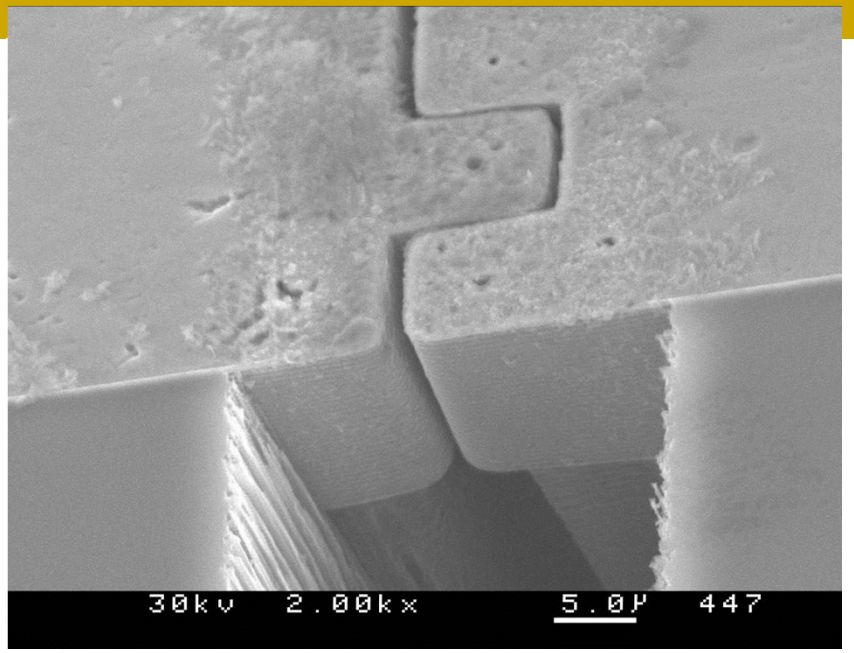
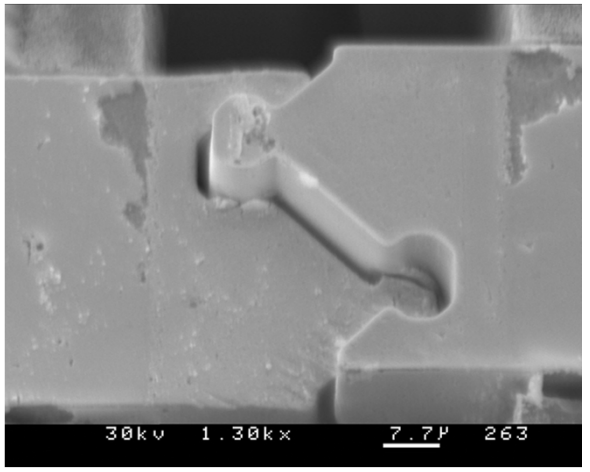
QP Customizable I/O









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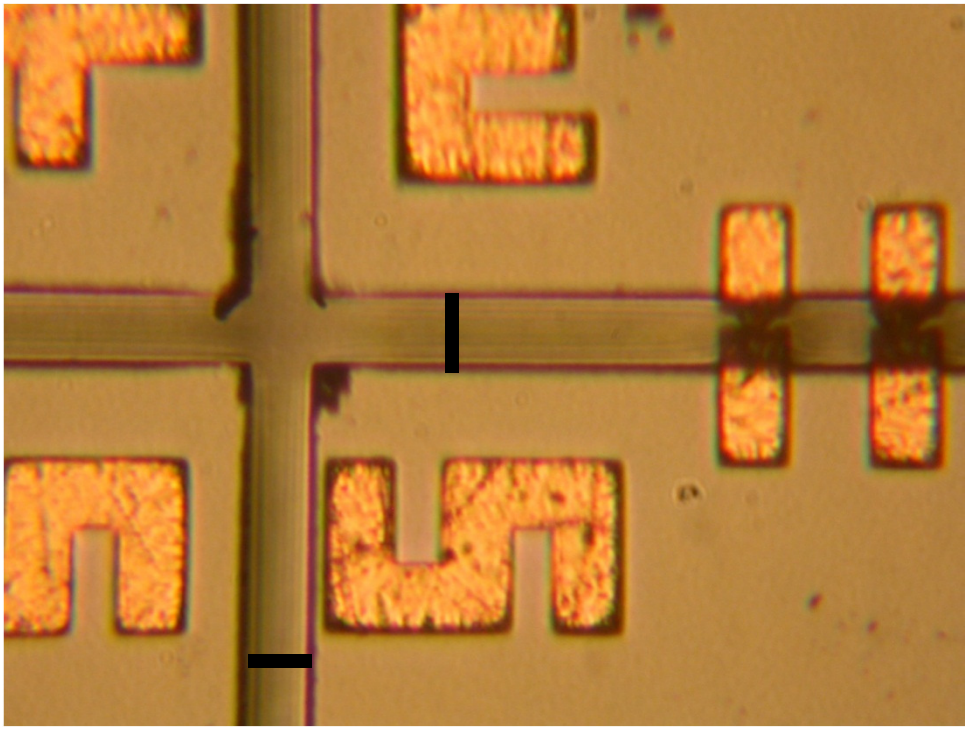
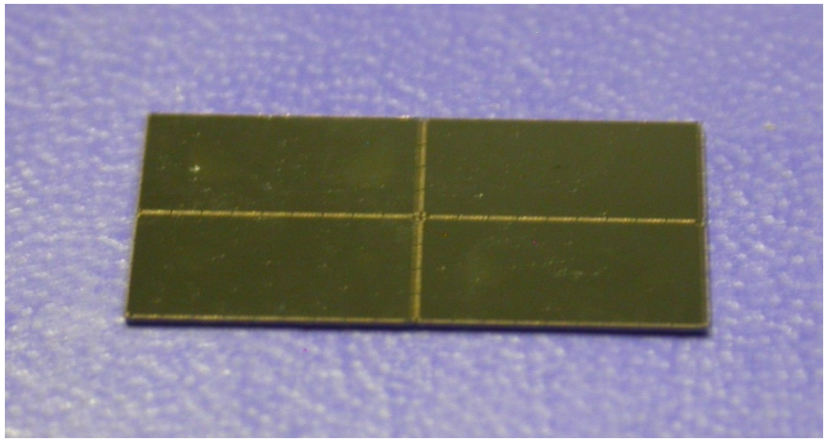
Sub-Micron Chip Alignment



= 30 micron



Interior (left) of four-chip quilt (above)

QP enable extremely accurate alignment

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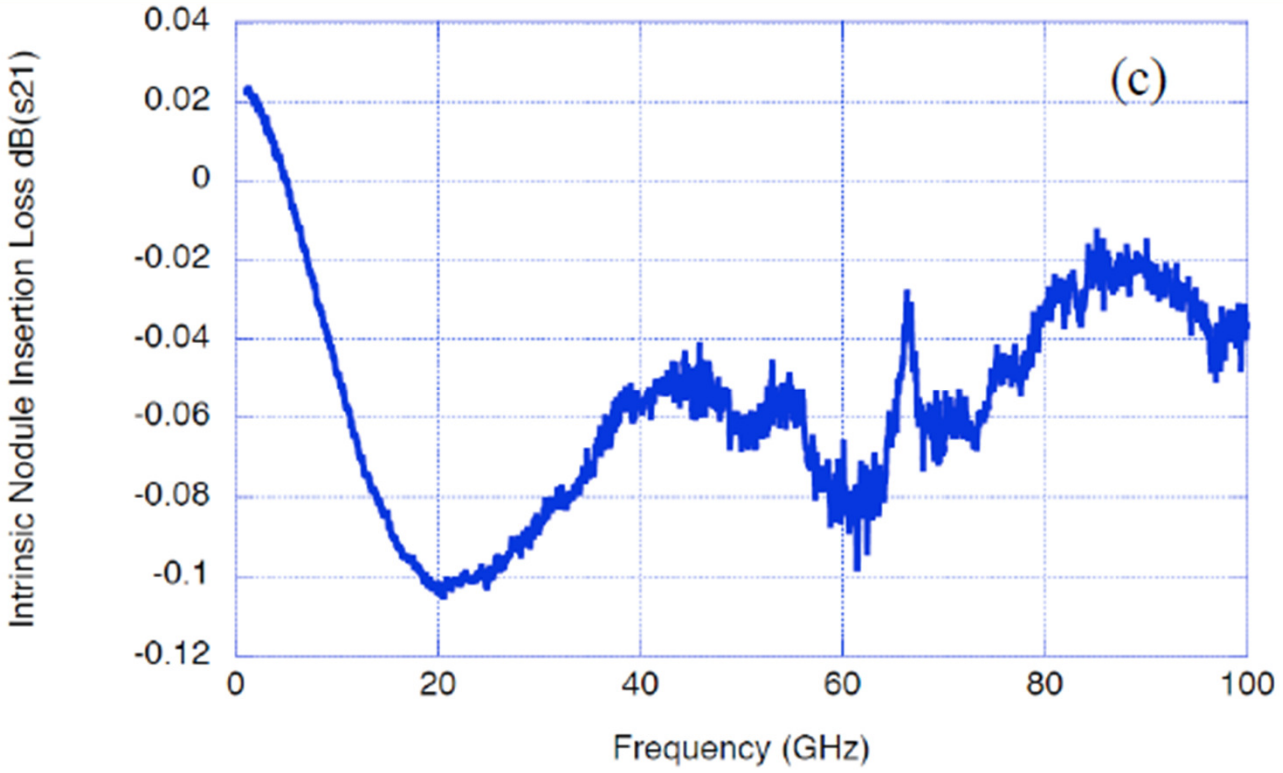
QP Microwave Performance



Less than 0.1 dB insertion loss from 50 MHz past 100 GHz, with no resonances. Recent unpublished results under 0.9 dB at 180 GHz

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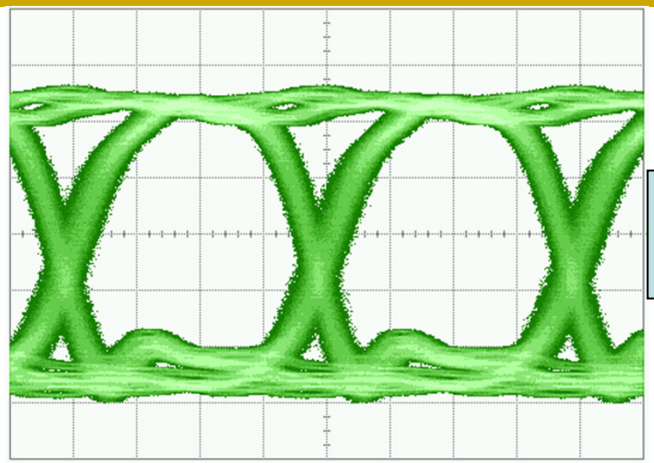
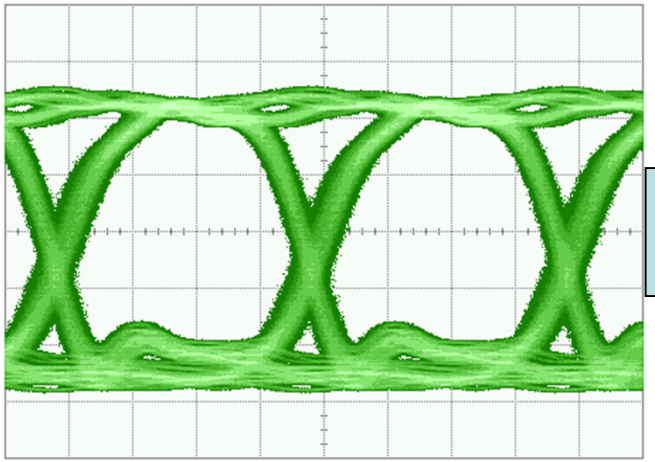
QP Eye diagrams

- Measurement of 12 Gb/s eye pattern (Anritsu MP1763B)
  - Horiz. 100 mV/div
  - Vert. 20 ps/div
- Data stream: 2^{31}-1 pseudo-random bit sequence
- Nearly ideal interconnect performance; indistinguishable from PG.
- Error-free operation
  - SNR (Q) = 12.9 for pattern generator alone, 12.4 after chip-to-chip interconnect



Raw pattern generator



50 µm GSG eye

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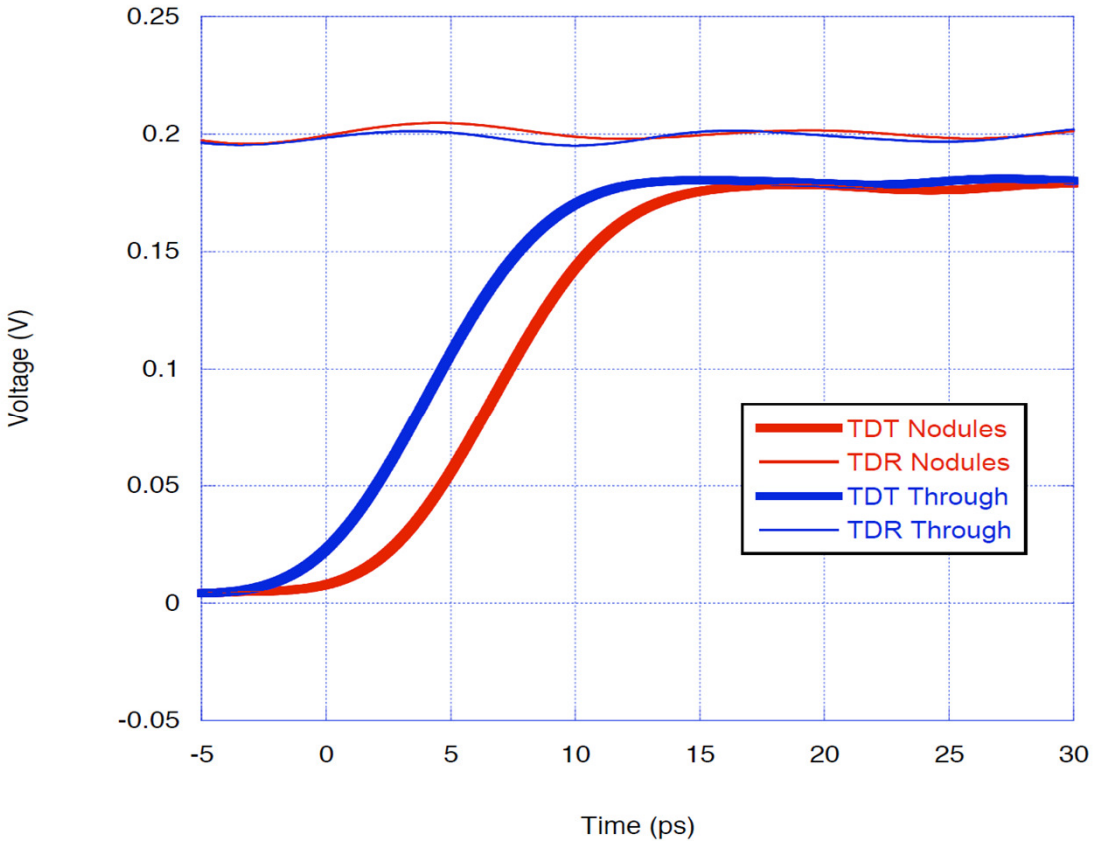
QP Time-Domain Performance

- Single-ended GSG CPW configuration
- Picosecond Pulse Labs 4022 TDR pulse enhancement module: < 9 ps risetime
- Total delay including probe pads, launcher: 7 ps (820 µm length)
- Delay due to QP nodules: 2.7 ps



100 µm nodule compared with pads/launcher, GSG

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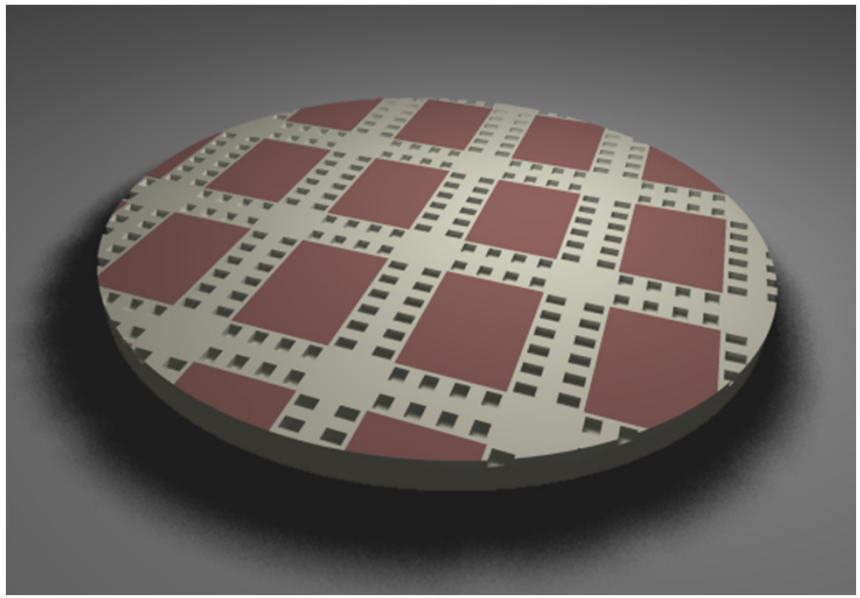
Advantages of Quilt Packaging

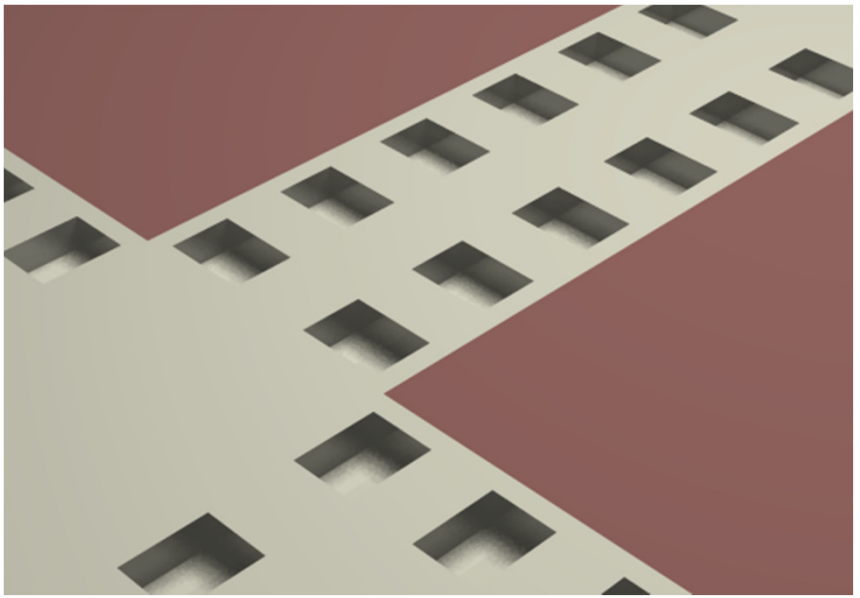
- Optimized integration of disparate materials and process technologies (Si, GaAs, GaN, AlN, more)
- Chip partitioning for optimal yield/functionality
- Increased cross-sectional area vs. WBs, bumps
- Better thermal management & failure modes compared to WB
- Reduced design time due to applicability of current 2-D tools, design re-use
- IP flexibility, security

QP Process Flow Overview

- Very similar to “via-middle” TSV process
- Utilizes industry-standard tools & processes
- At least 2 additional mask steps
  - Nodule definition
  - Separation
- Most unique feature is dry etch step for singulation
- After assembly, handle as if “normal” chip

QP Fabrication-Nodule Definition





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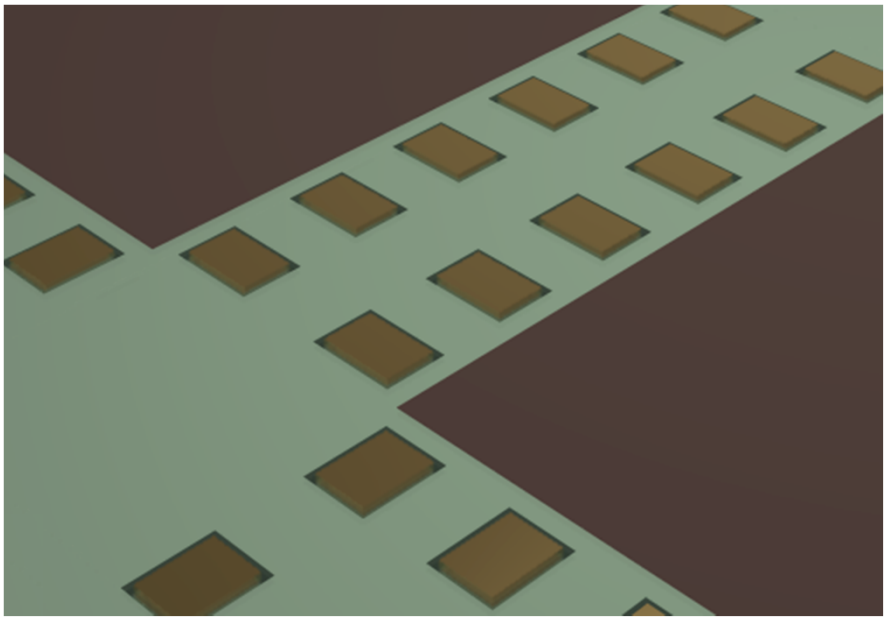
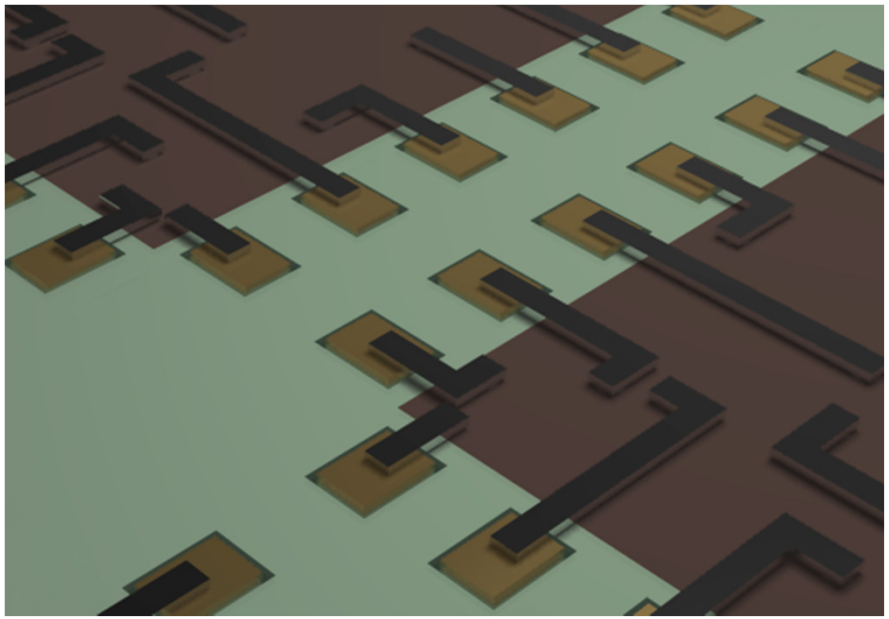
QP Fabrication- Nodule Metallization





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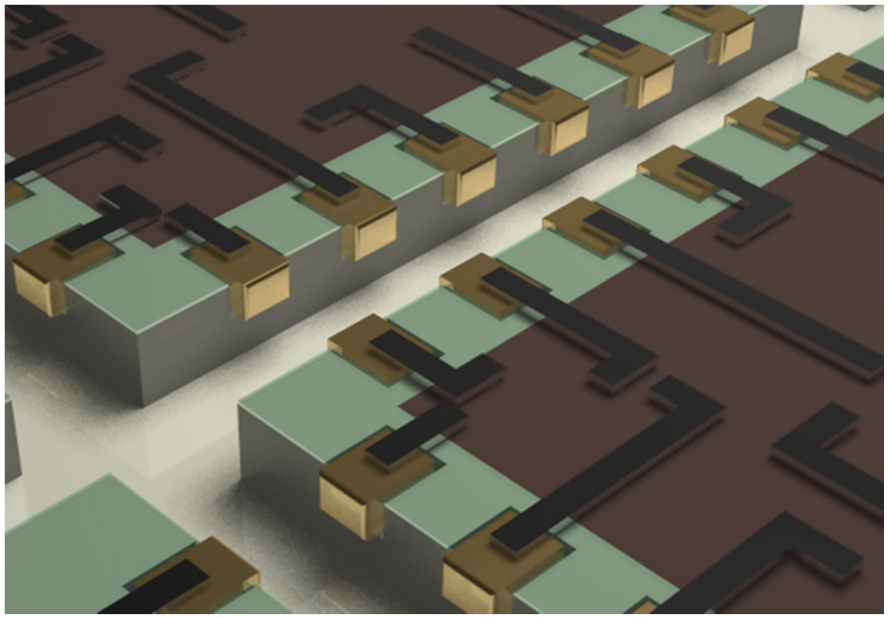
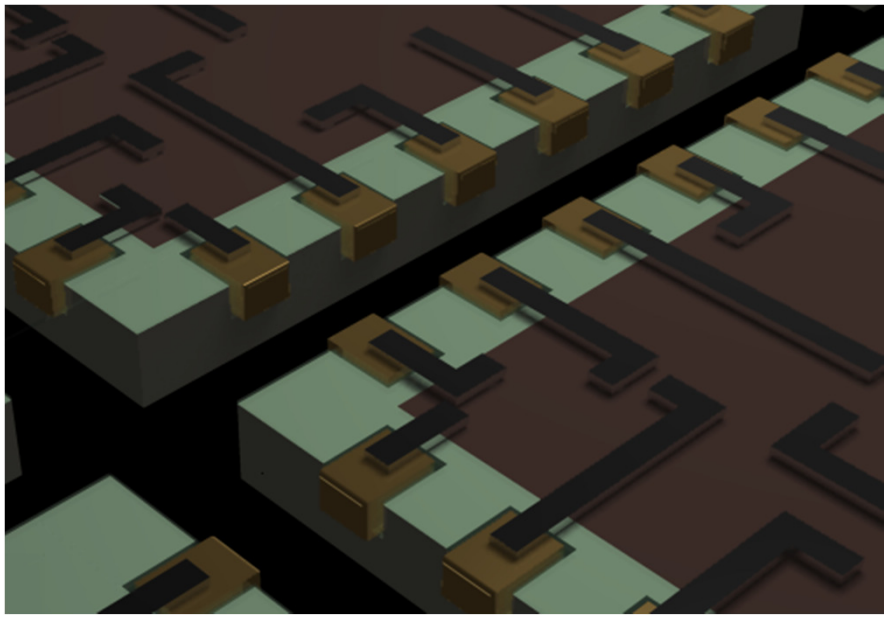
QP Fabrication-Die Singulation





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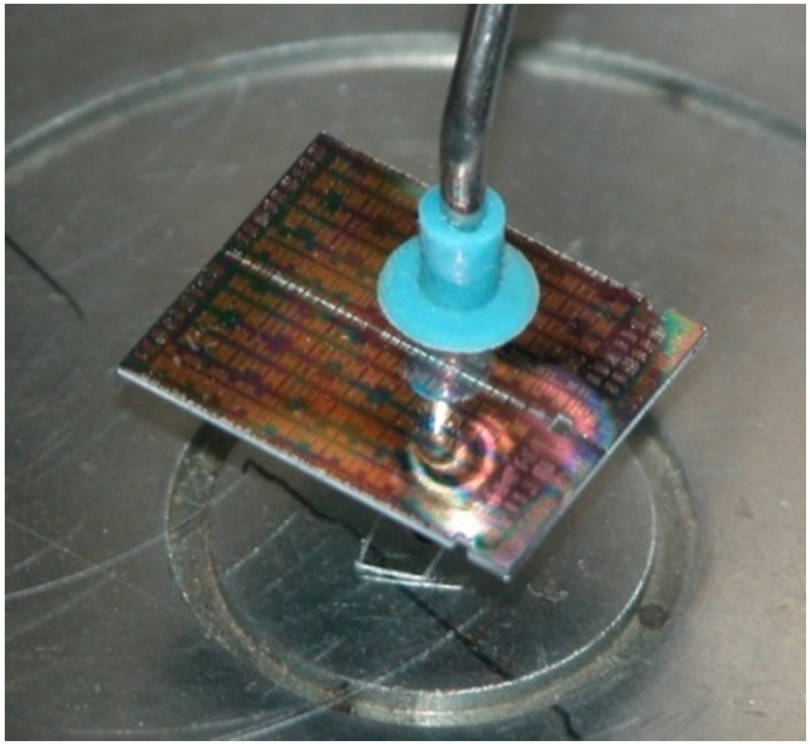
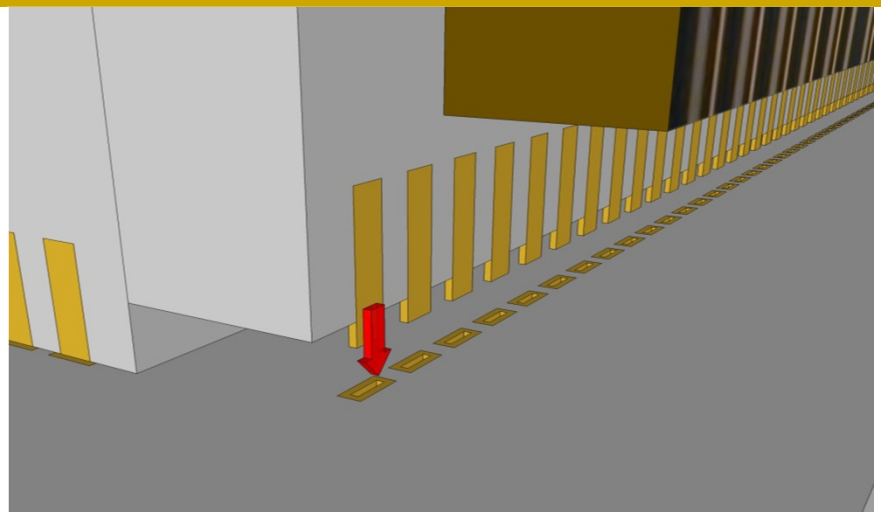
QP Assembly

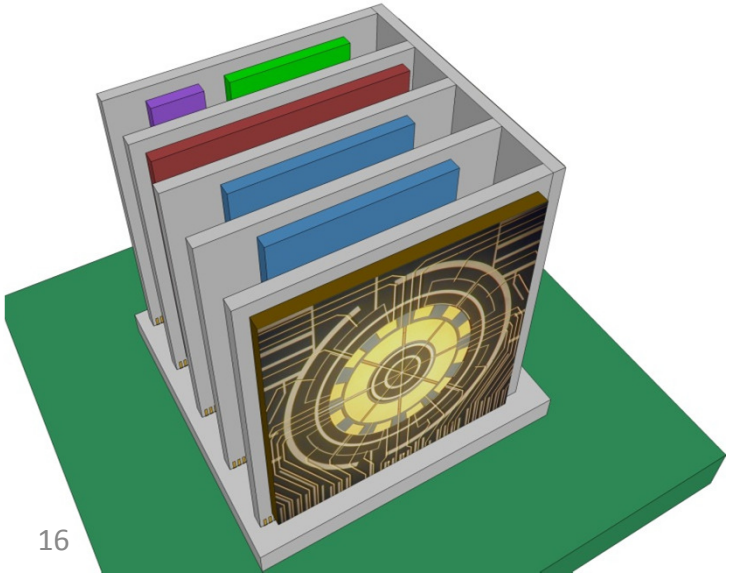
- Multiple approaches to connecting die
  - Solder, solder paste, and reflow
  - Laser welding
  - Solder-free (gold coating, epoxy in place)
- Can be automated with modifications to pick & place tools
  - Sub-micron chip-to-chip alignment



“3D-QP” and “Interposers”

- QP can enable multiple 3D configurations
- 3D-QP retains many advantages of 2D-QP
- “Quilting” interposers can decrease form-factor
- Systems benefit from QP without having to redesign chips





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IIC Fabrication Services

Contract R&D Experience:

- Materials Deposition
- E-Beam Lithography
- Specialty Plating
- DRIE & ICP etching
- IC & MEMs prototyping
- Magnetics/nanomagnetic fabrication & testing
- SEM, AFM, EDX, FIB analysis
- CMP & wafer grinding

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Additional Material

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- Bernstein, et al. "Quilt Packaging: High-Density, High-Speed Interchip Communications," *IEEE Transactions on Advanced Packaging*, Vol. No. 4, Nov. 2007, pp. 731-740.
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- Shenai, et. al. "Efficient Integrated DC-DC Power Converters—Advanced Technologies and New Challenges," IEEE Energytech, Cleveland, OH, May 2011
- E. Brookner, "Never Ending Saga of Phased Array Breakthroughs", *IEEE Microwaves Journal*, (2008).

Thank You!

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