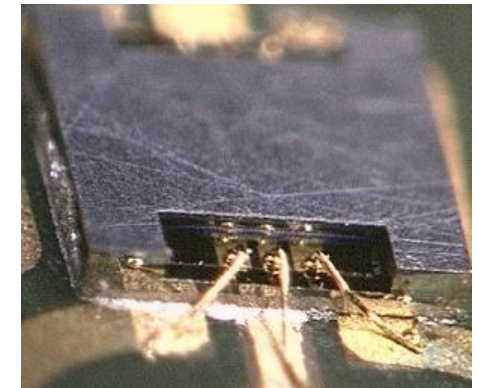
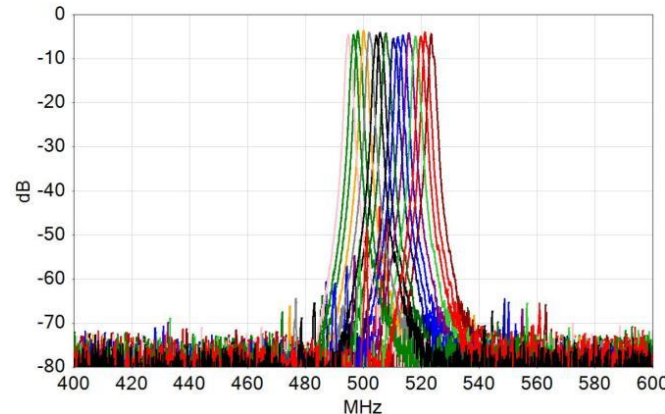
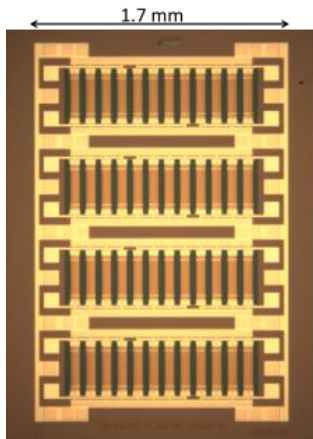


Exceptional service in the national interest



Microresonators for Advanced RF Devices

Roy H. Olsson III, Ken Wojciechowski and Chris
Nordquist

SAND Number: 2013-7164 W

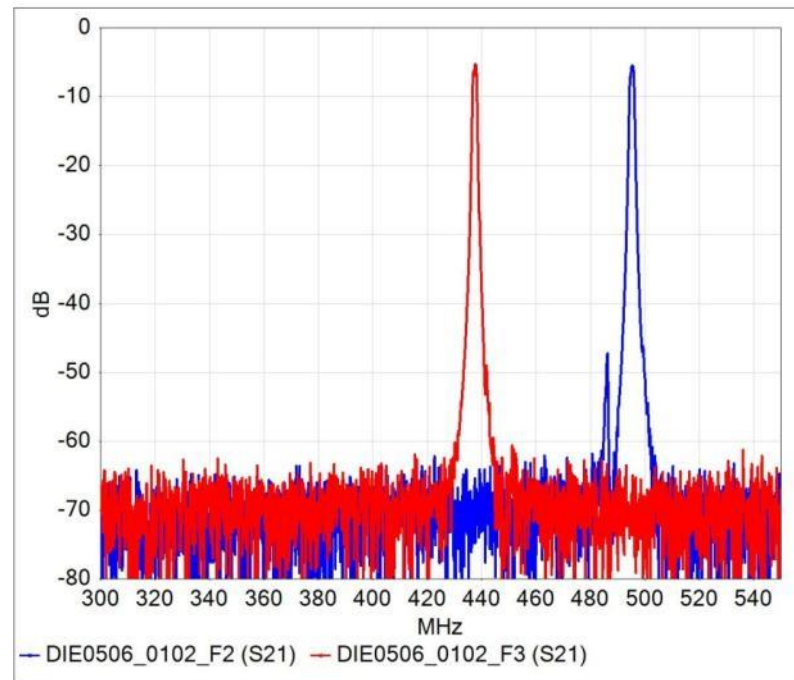
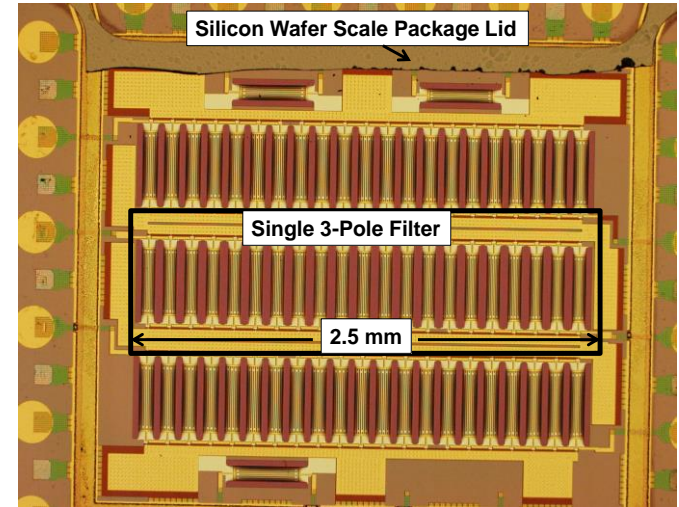


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Microresonator Technology

Microresonators are miniature, high quality factor acoustic resonators that:

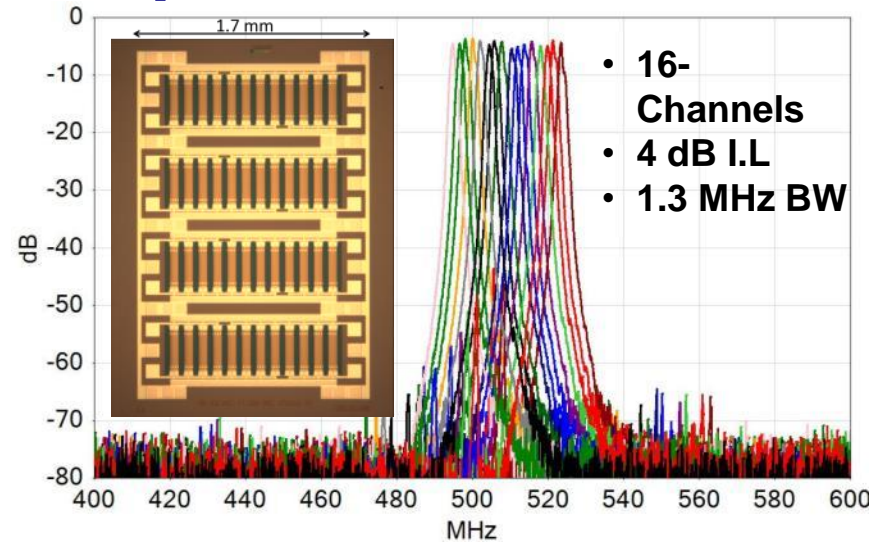
- *Are mass produced using CMOS IC fabrication techniques*
- *Are lithographically defined, allowing any resonant frequency between 32 kHz and 14 GHz on a single chip*
- *Are an enabling filter technology for multi-band and cognitive radios*
- *Can be integrated with CMOS transistors for configurability and added signal processing*
- *Can be thinned to < 200 microns*



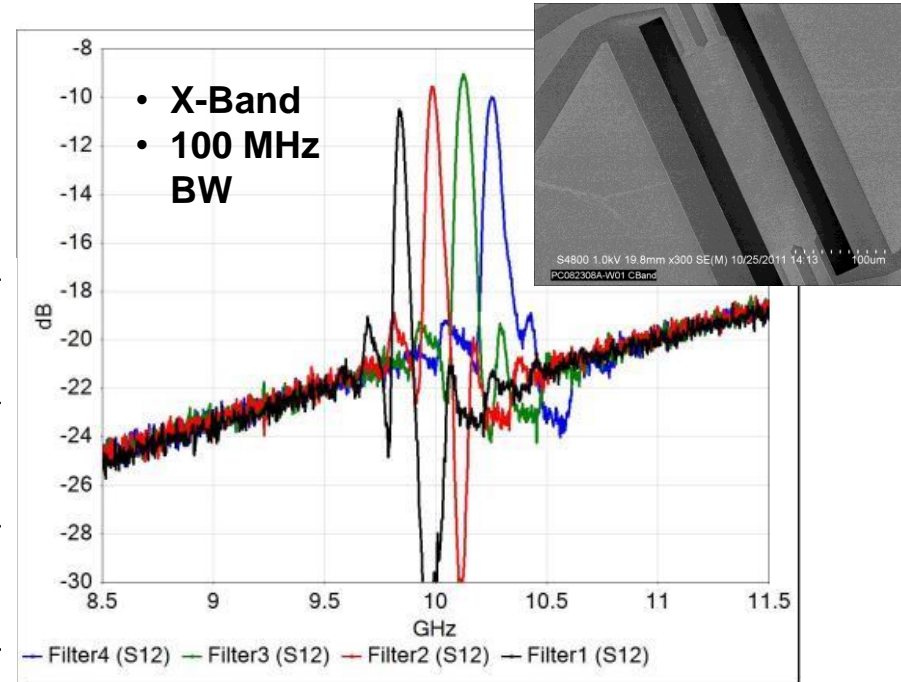
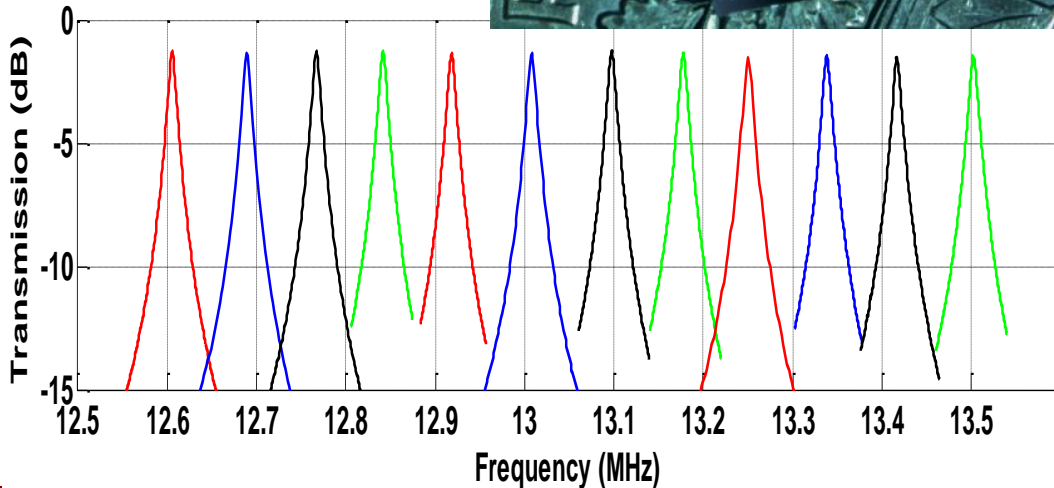
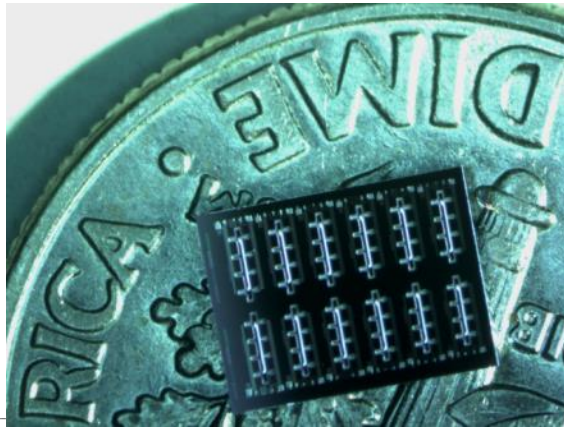
1.7 MHz
3 dB
Bandwidth
AIN Filters
in a Wafer
Level
Package

Microresonator Filter Arrays

- Filter Banks for Cognitive and Multi-Band Radios
- Anti-Jam and Secure Adaptive RF Front-Ends
- Filter Arrays for Fast Spectrum Analysis
- Ultra Small Footprint
- HF to X Band!

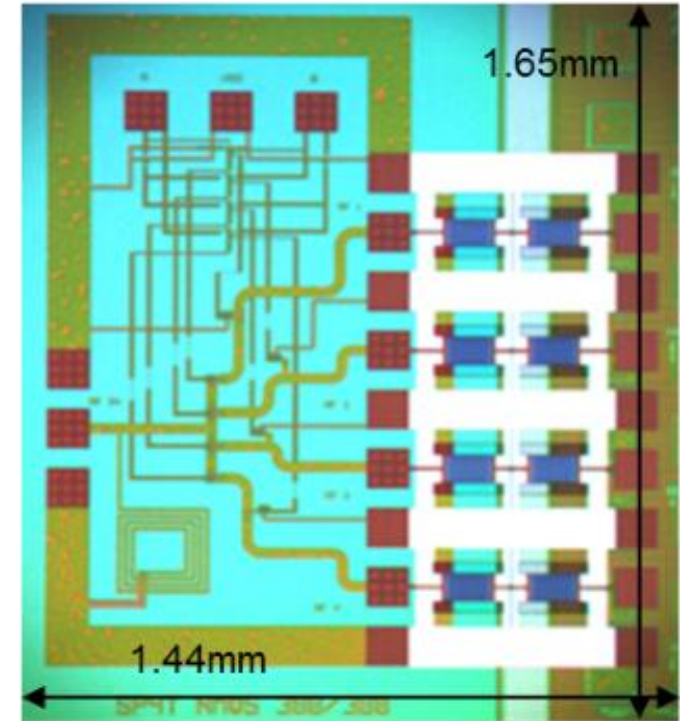
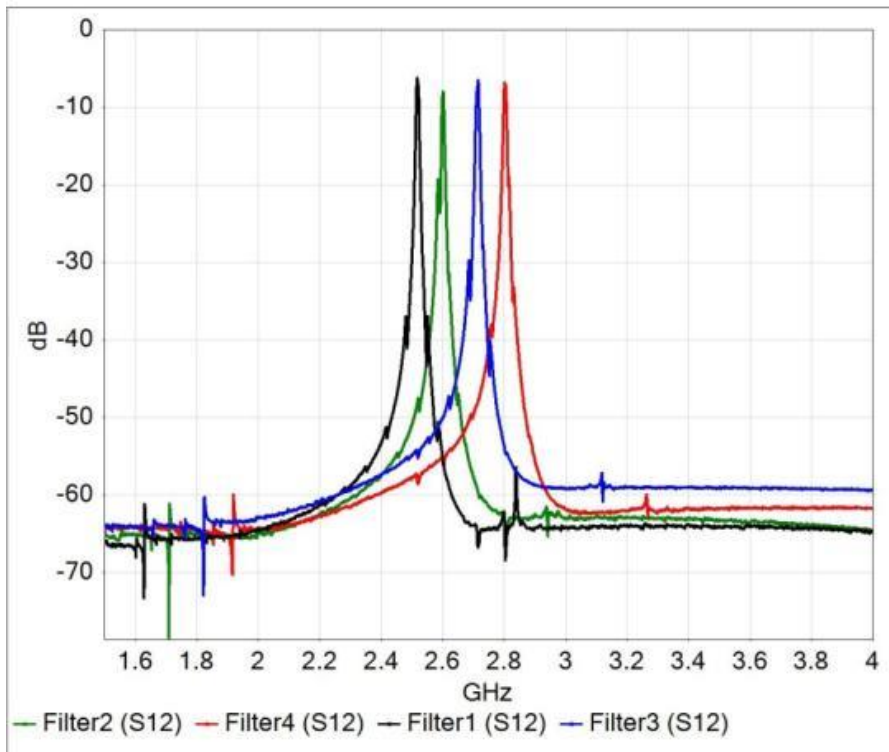


- HF-Band
- 25 kHz BW
- 12-Channels



CMOS/Filter Integration

- Integration with Electronic Switches for Reconfigurable RF Components
- Diode, Data Converter and Log Amp Integration for Power Spectrum, Phase and Waveform Analysis
- Electronics Integration Reduces Size, Power and Interconnect Parasitics, Improves Performance



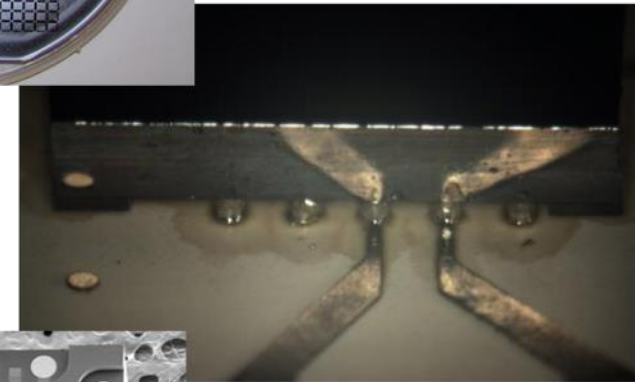
S-Band 4-Channel
Switched Filter Array

Wafer Level Packaging

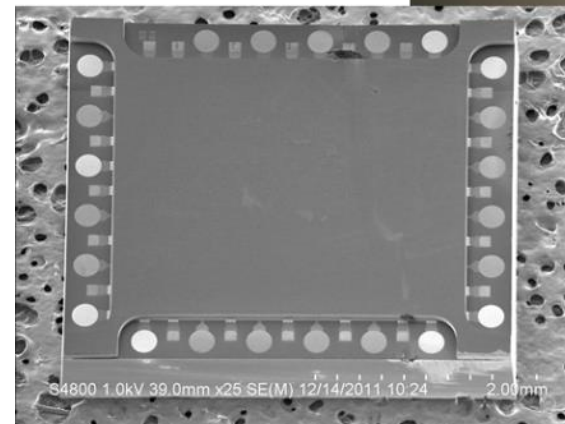
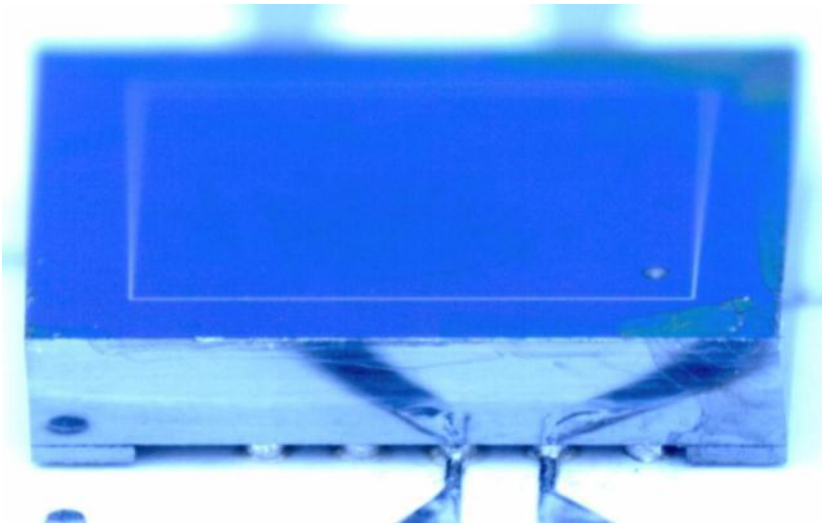
- *Maintains Small Footprint*
- *Surface Mount or Chip and Wire Assembly*
- *Enables Wafer Level Release*
- *Protects MEMS During Dicing*
- *Wafer Level Auto-Probe For Part Down Select*



Wafer of
Packaged AlN
MEMS Devices



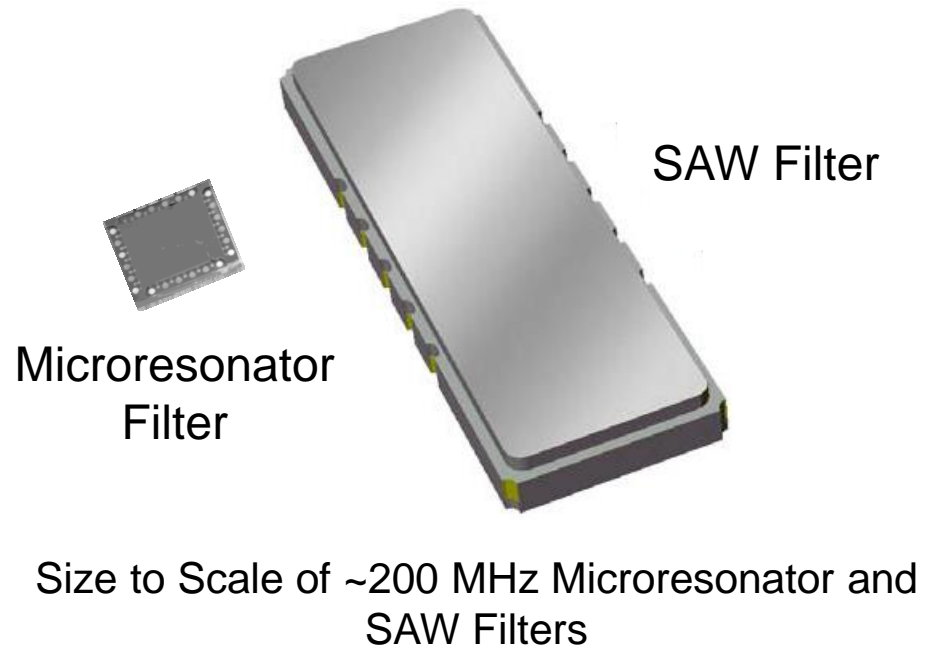
Packaged
Surface Mount
AlN Filter on a
PCB



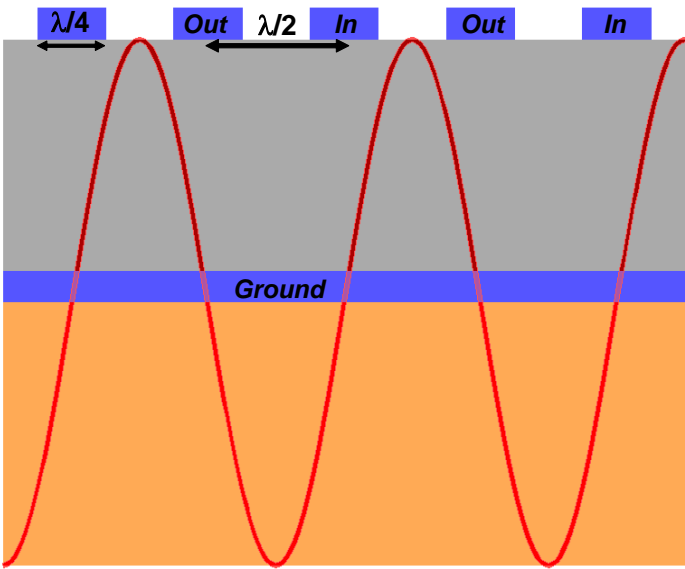
Chip and Wire
AlN MEMS Die

VHF/UHF Filters

- Size of Surface and Bulk Acoustic Wave Filters $\sim 1/\text{Frequency}^2$
- Size of Microresonator Filters $\sim 1/\text{Frequency}$
- Below 500 MHz Microresonator Filters are Much Smaller Than the Incumbent Technologies



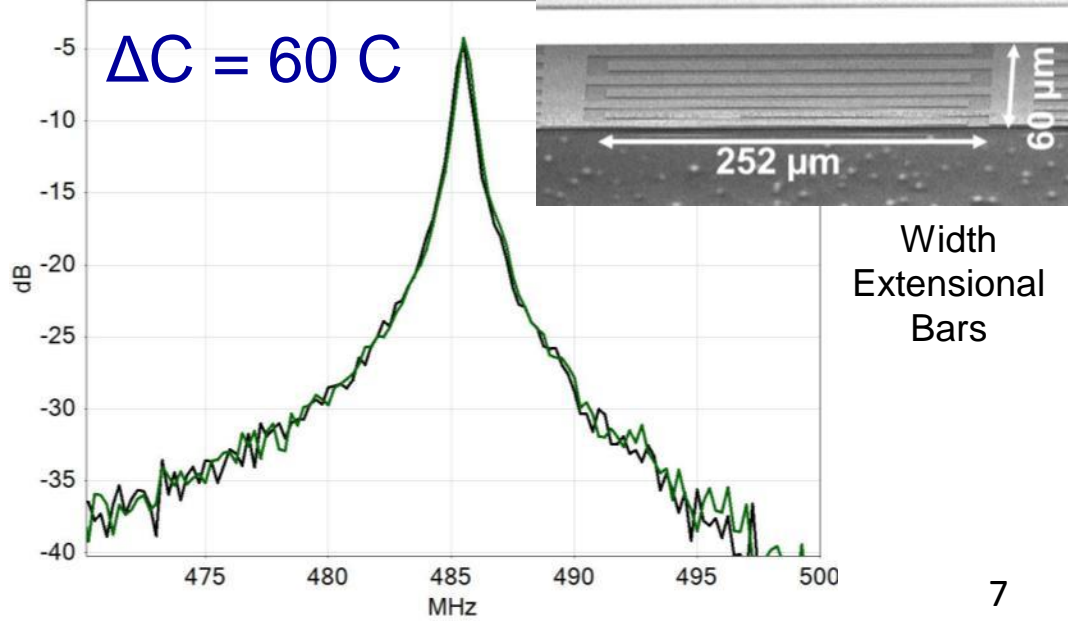
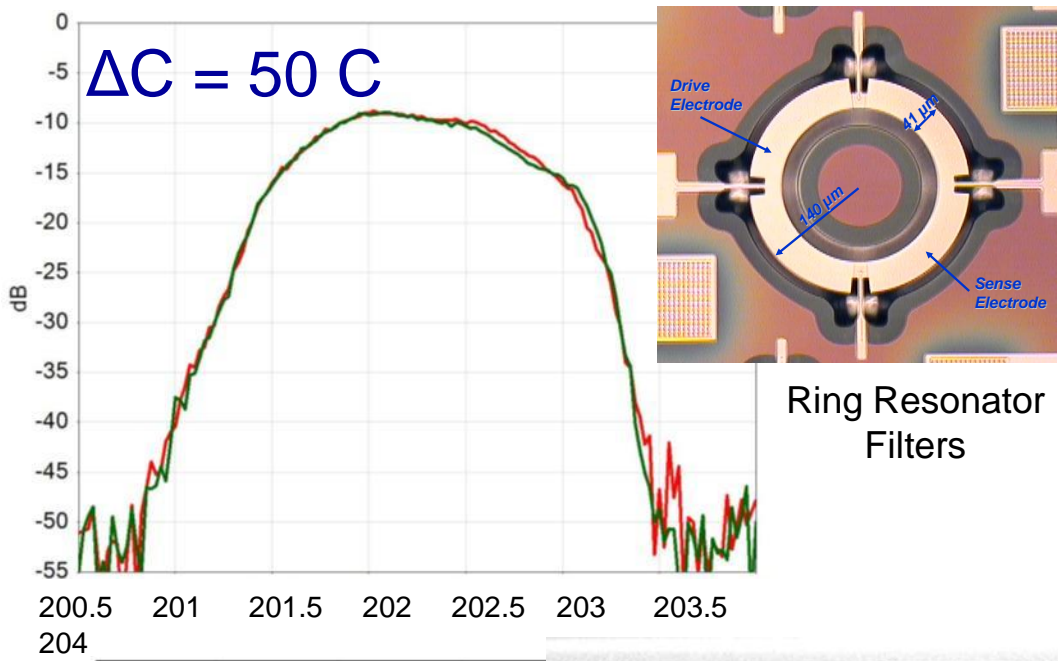
Temperature Compensation



- Metal Electrodes
- Aluminum Nitride
- SiO₂ Temperature Compensation Layer
- Acoustic Wave Propagation

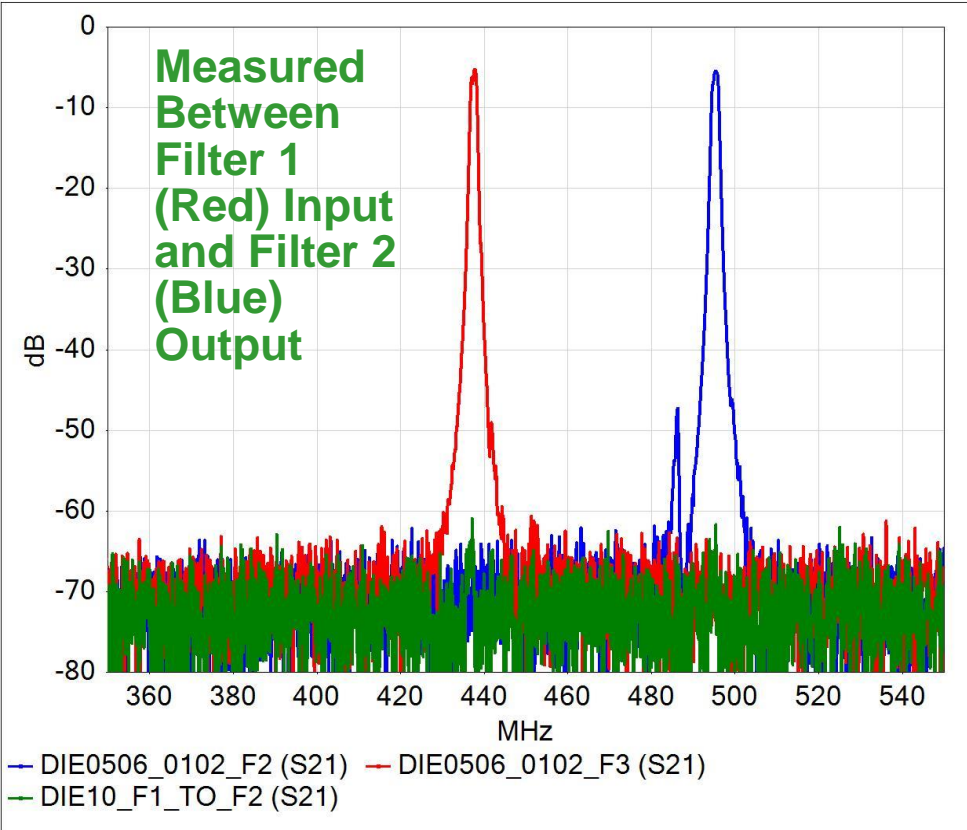
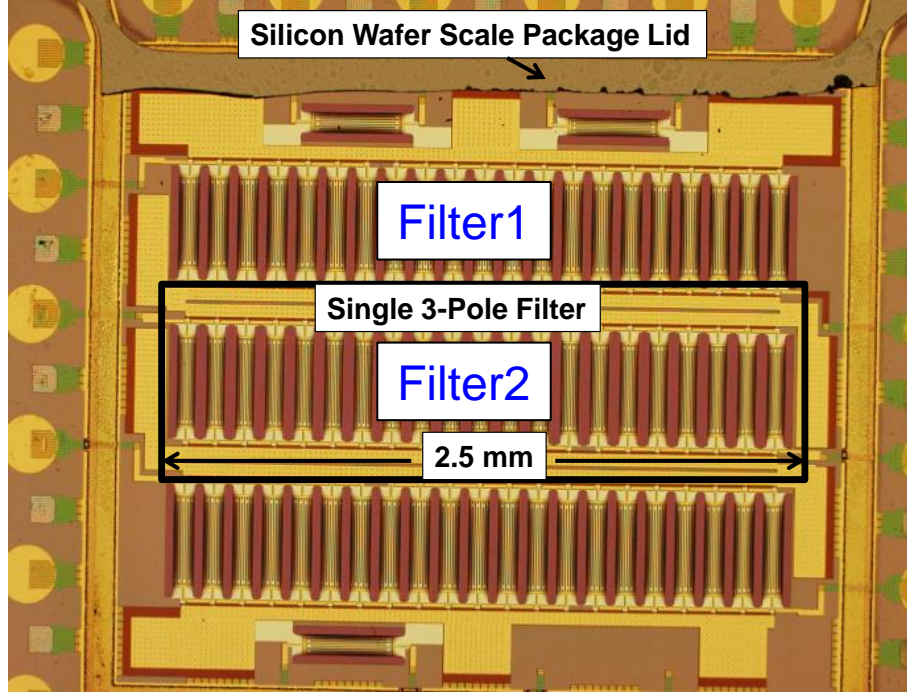
Resonator Cross-Section

- Filter Drift of < 1 ppm/C is Achievable



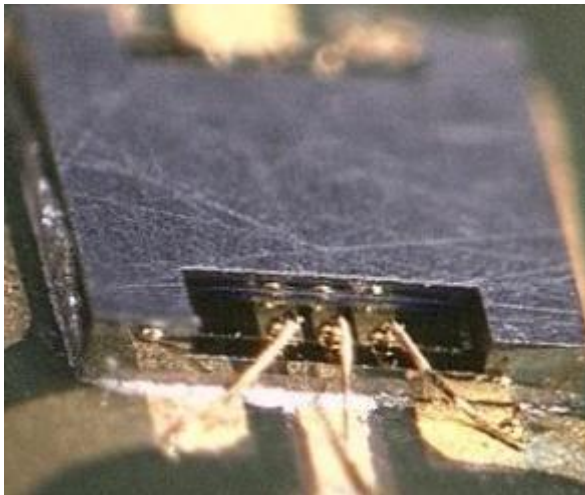
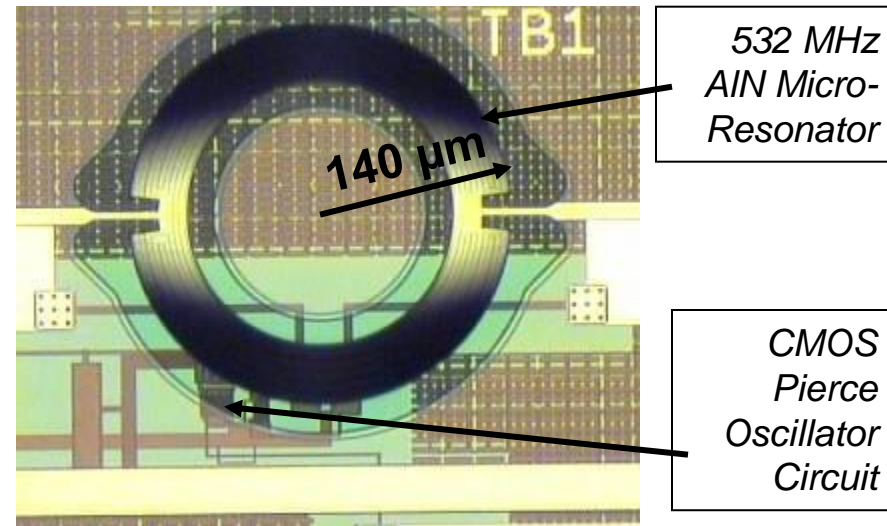
Filter Cross-Talk

- Cross-Talk Between Filters in the Same Wafer Level Package Less Than 0.5 mm Apart is > 55 dB

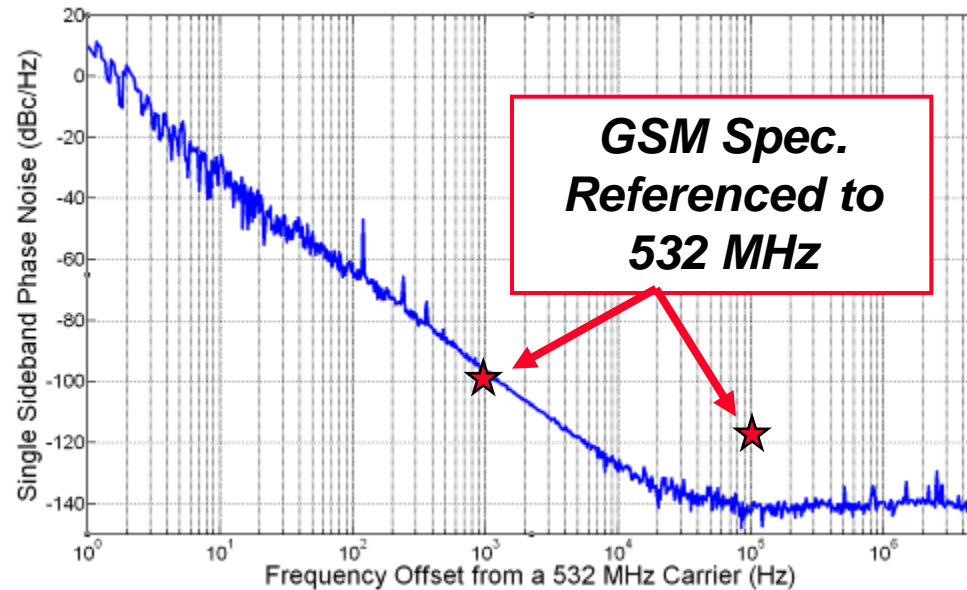


Thin Clocks and Oscillators

- High-Q Factor Resonators in Wafer Level Packages with Thicknesses $< 200 \mu\text{m}$
- Oscillator Synthesis Directly at RF for Reduced Power (No PLL) and Size
- Scaling to 32 kHz for Thin Timers



1.3 x 1.3 x 0.2 mm
Microresonator Packaging

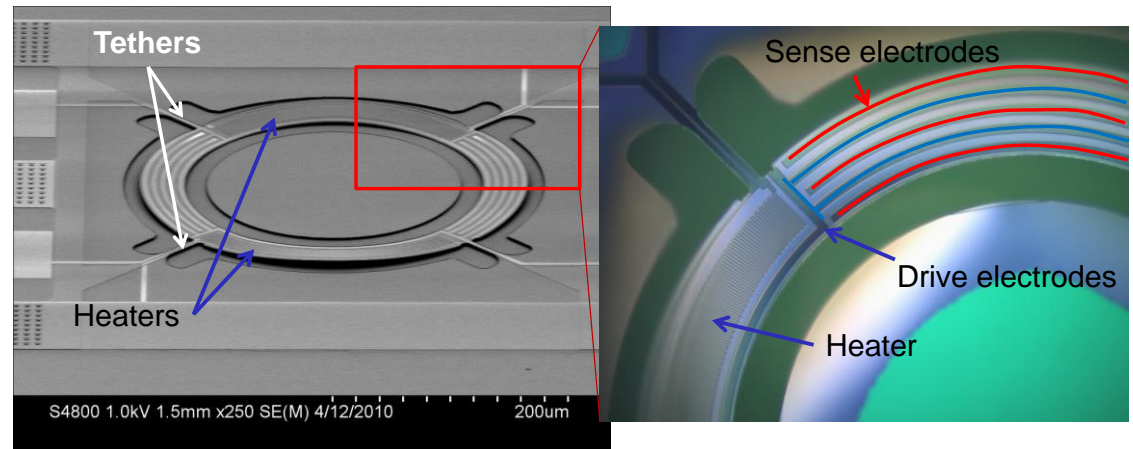
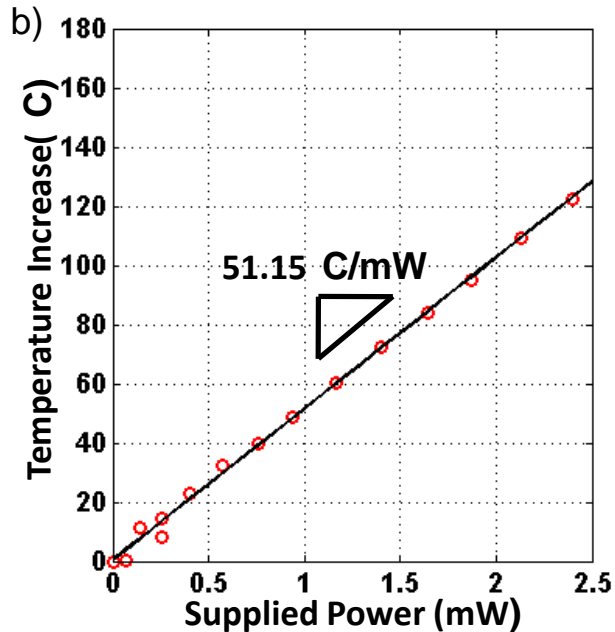


Picture and Phase Noise of a 532 MHz AIN Oscillator Integrated Directly Over CMOS

Thermal Stability

Low Power, High Stability Frequency References

- Record Low Ovenization Power of 92 C/mW
- Low Power Ovenized Oscillators with Excellent Thermal Stability
- Excellent Frequency Stability in High-G Environments
- Miniature Quartz Crystal Replacement



Measured Performance and Image of an Ovenized 627 MHz Ring Resonator