Exceptional service in the national interest

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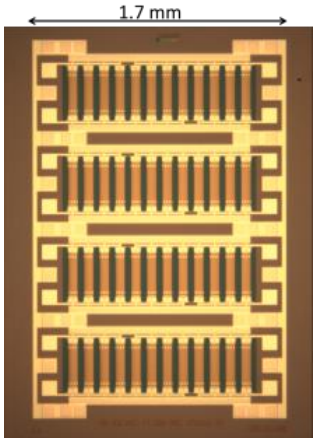

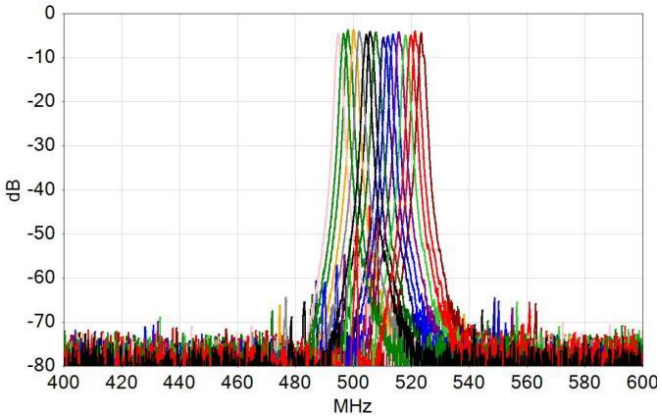

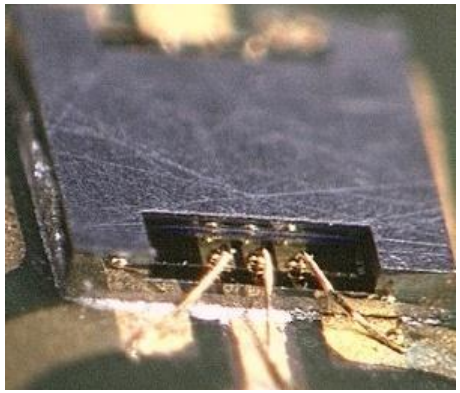

Microresonators for Advanced RF Devices

Roy H. Olsson III, Ken Wojciechowski and Chris Nordquist

SAND Number: 2013-7164 W

U.S. DEPARTMENT OF ENERGY

NNSA National Nuclear Security Administration

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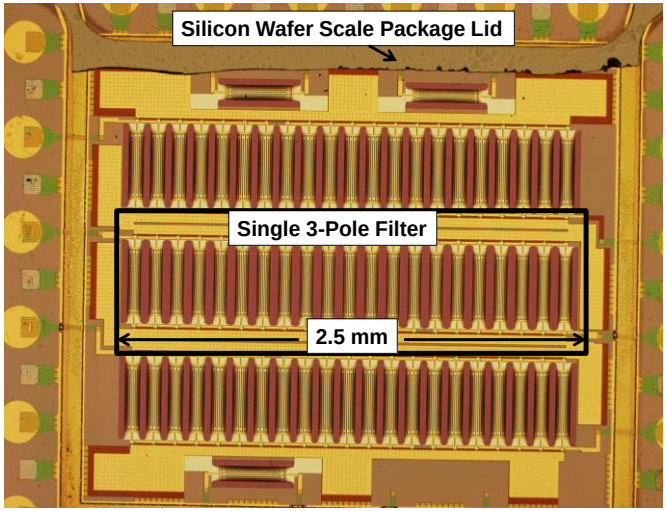
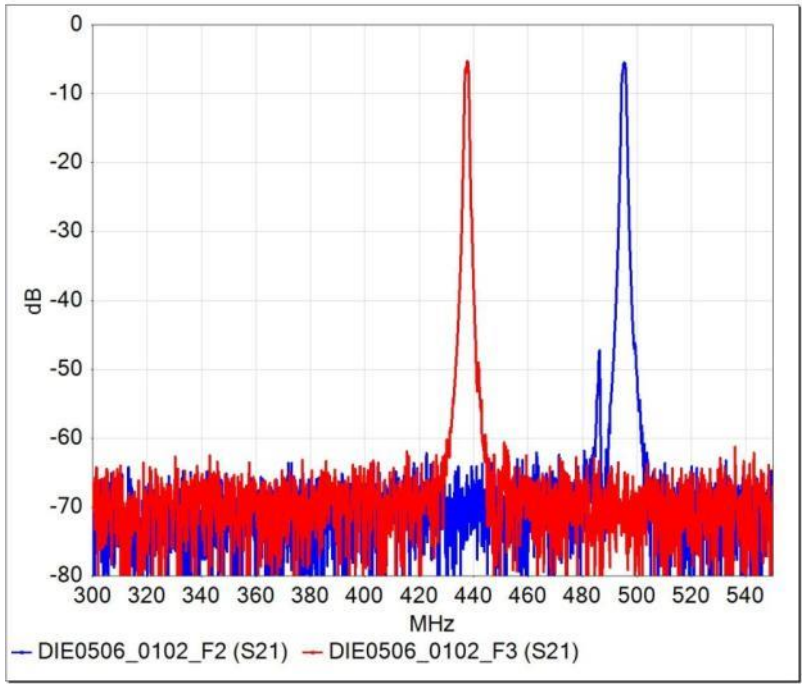
Microresonator Technology

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*

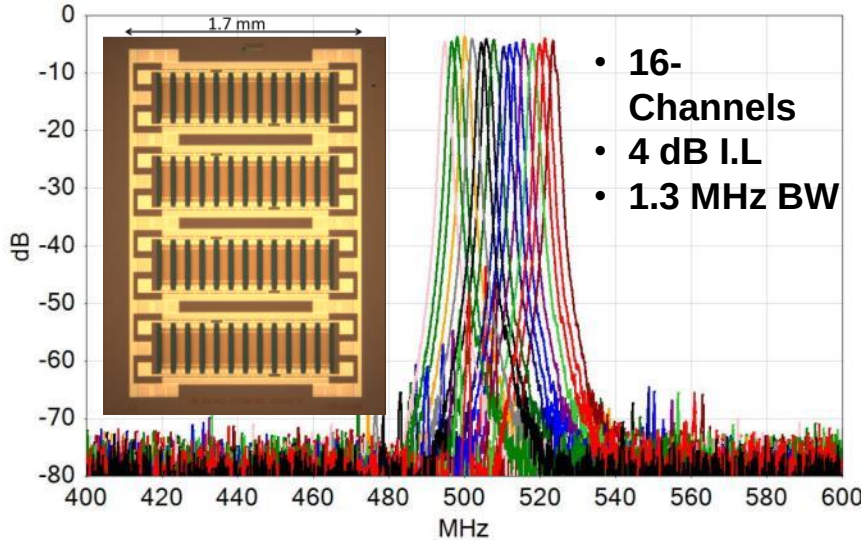




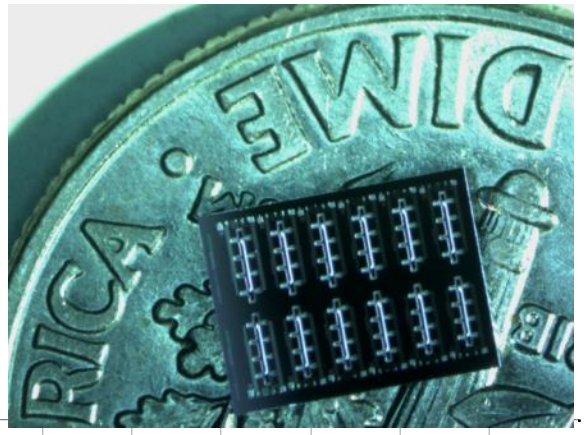
1.7 MHz 3 dB Bandwidth AlN Filters in a Wafer Level Package

Microresonator Filter Arrays

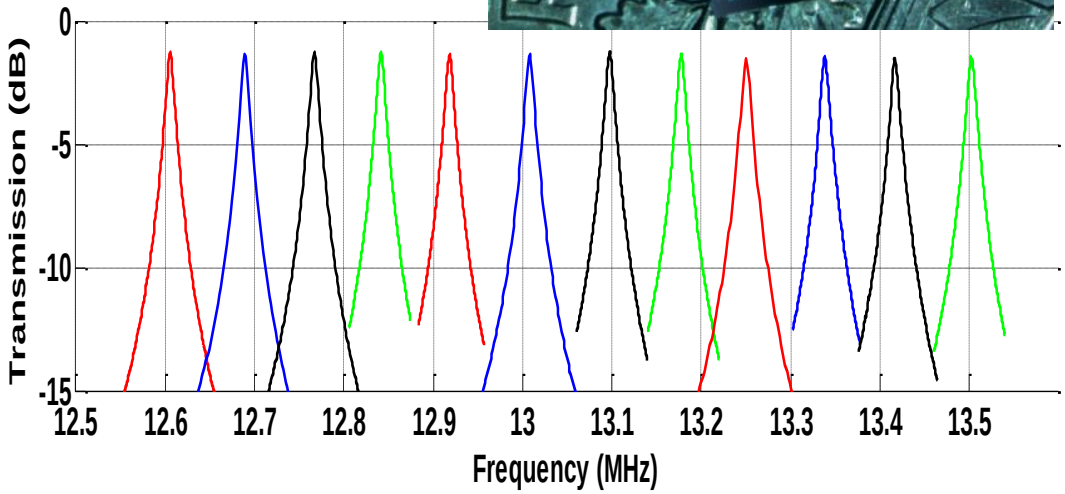
- Filter Banks for Cognitive and Multi-Band Radios
- Anti-Jam and Secure Adaptive RF Front-Ends
- Filter Arrays for Fast Spectrum Analysis
- Ultra Small Footprint
- HF to X Band!

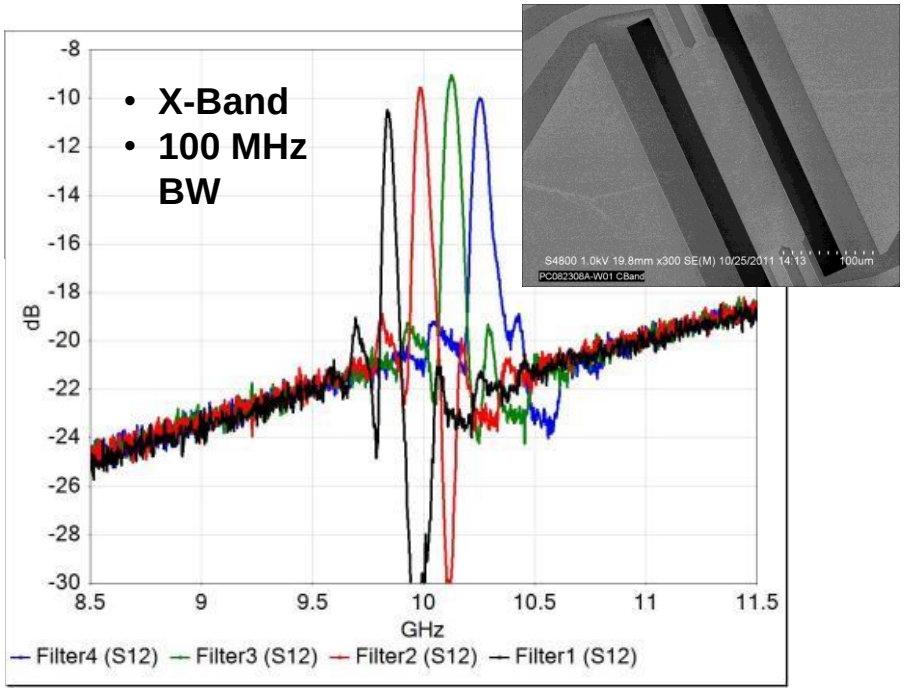


- **16-Channels**
- **4 dB I.L**
- **1.3 MHz BW**



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

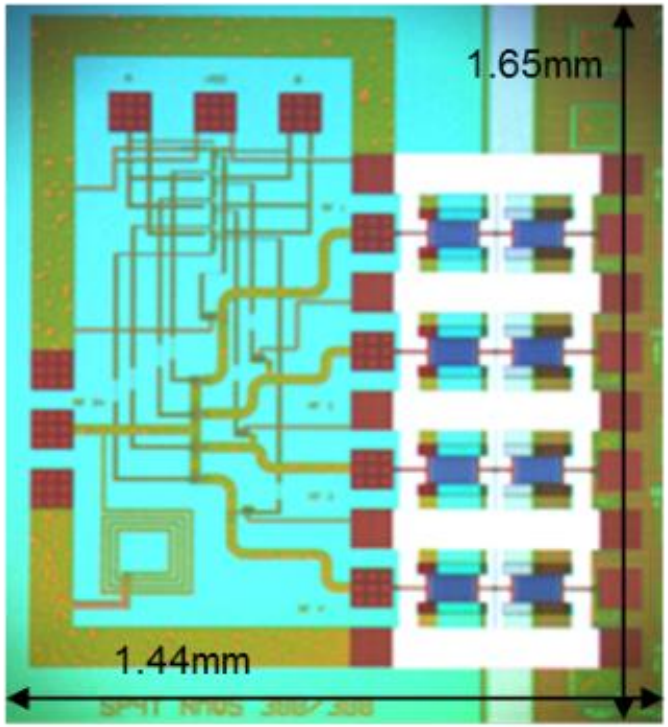


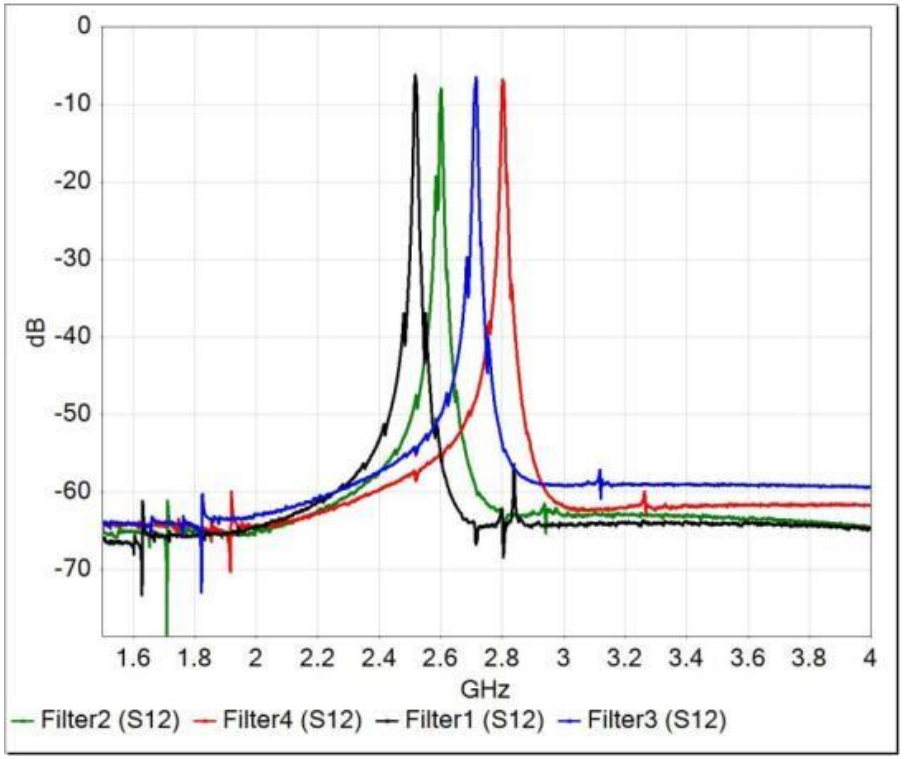


- **X-Band**
- **100 MHz BW**

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



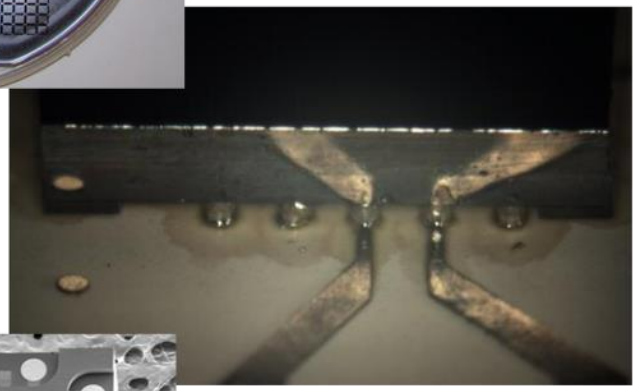


S-Band 4-Channel
Switched Filter Array

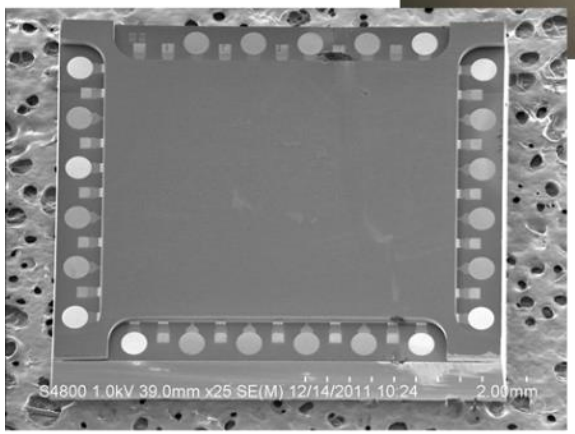
Wafer Level Packaging

- *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*

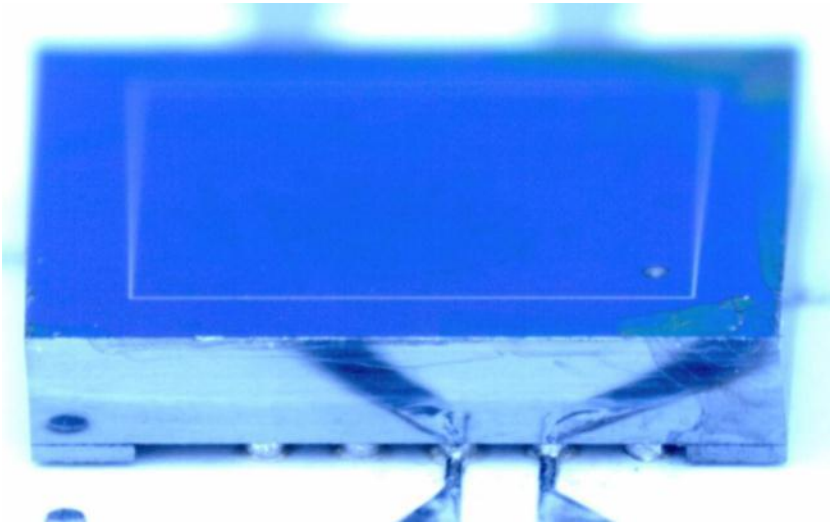
Wafer of Packaged AlN MEMS Devices



Packaged Surface Mount AlN Filter on a PCB

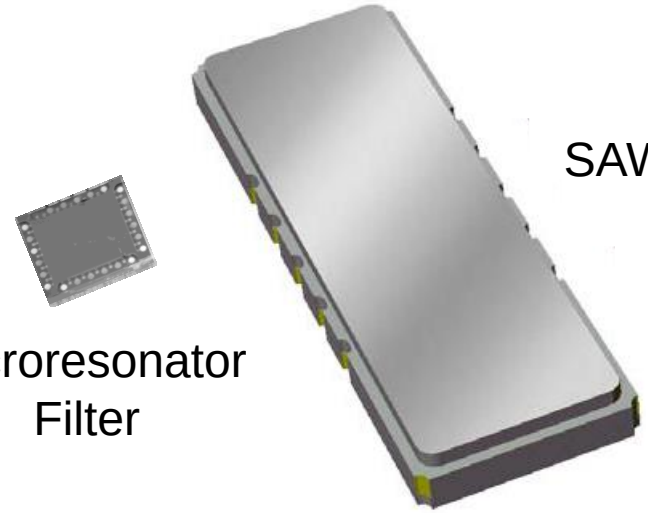


Chip and Wire AlN MEMS Die



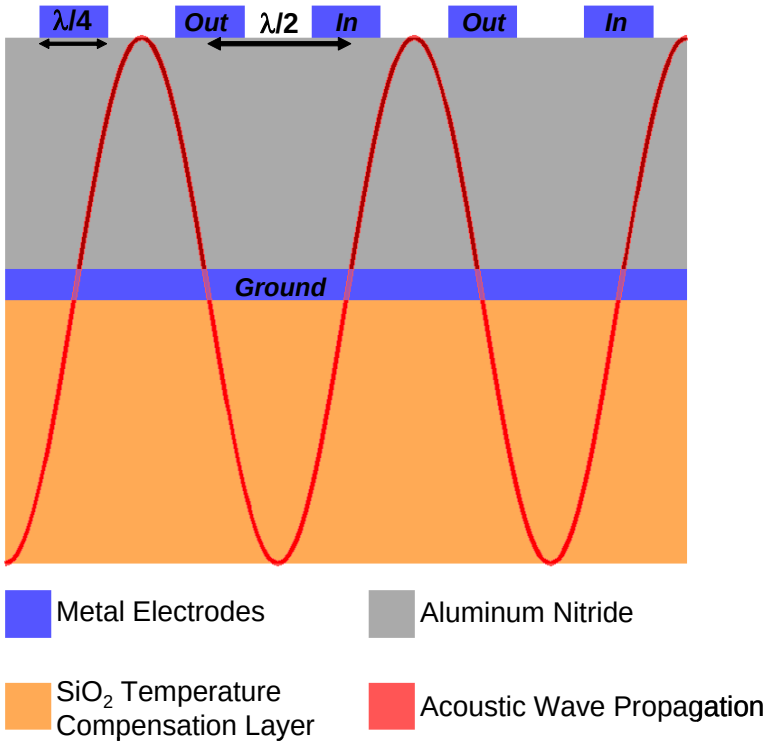
VHF/UHF Filters

- Size of Surface and Bulk Acoustic Wave Filters ~ 1/Frequency^2
- Size of Microresonator Filters ~ 1/Frequency
- Below 500 MHz Microresonator Filters are Much Smaller Than the Incumbent Technologies



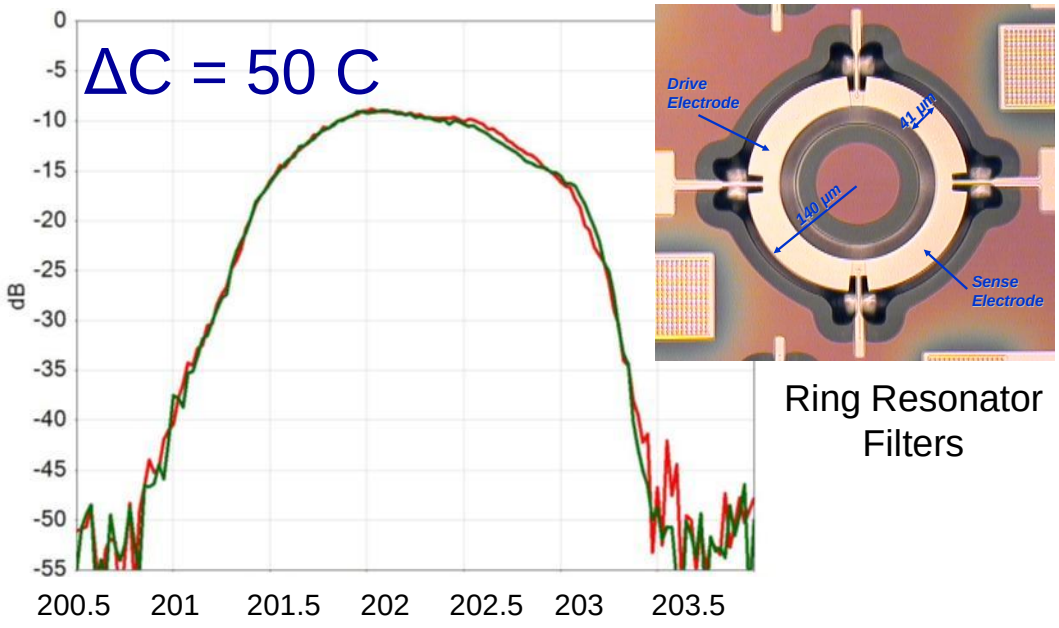
Size to Scale of ~200 MHz Microresonator and SAW Filters

Temperature Compensation

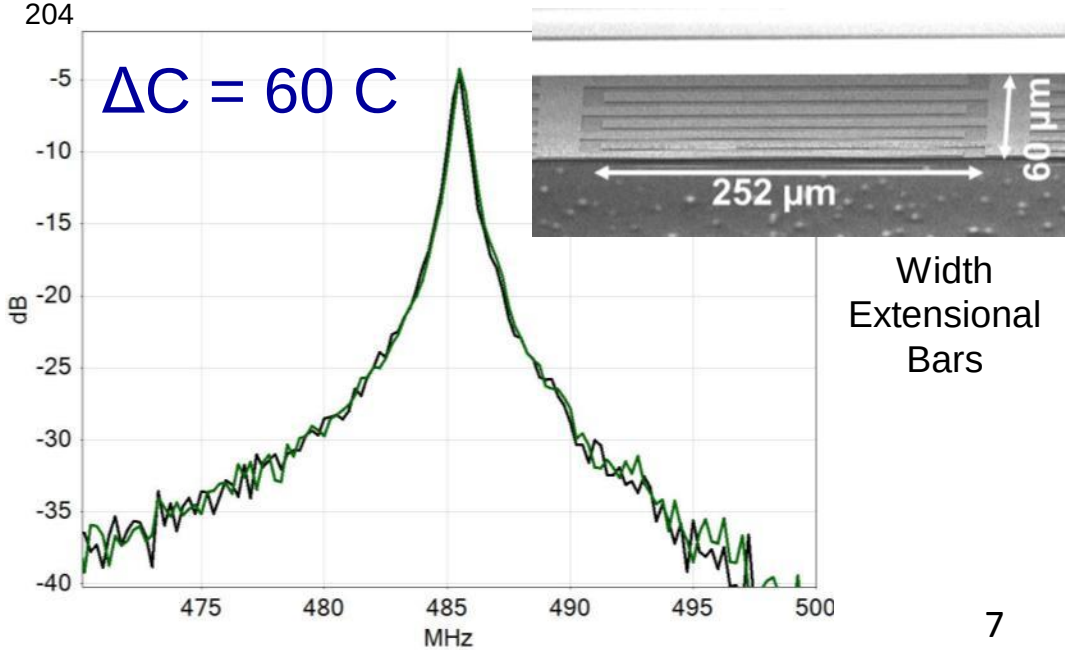


Resonator Cross-Section

- Filter Drift of < 1 ppm/C is Achievable



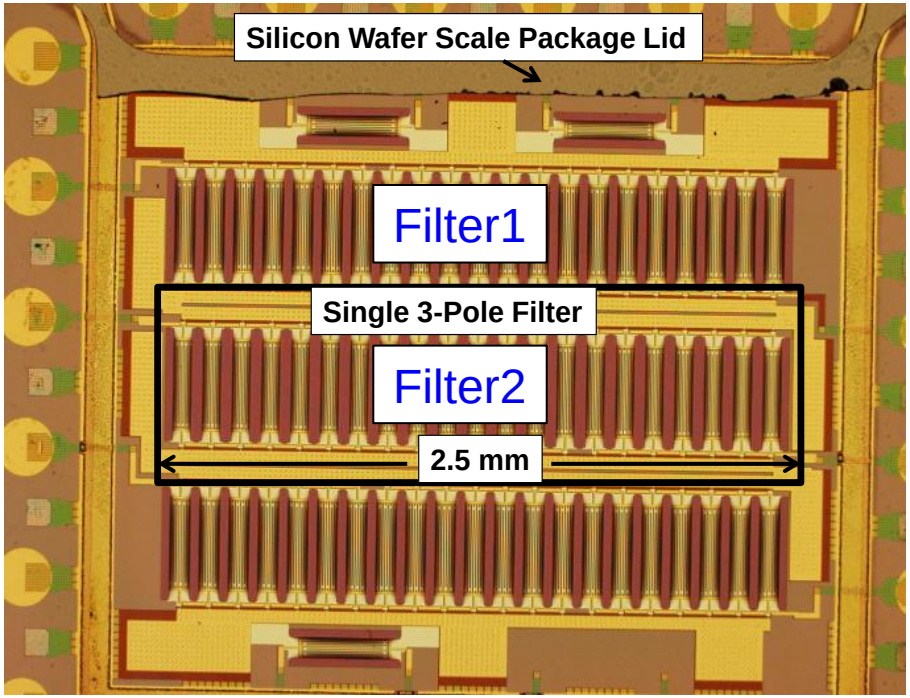
Ring Resonator Filters

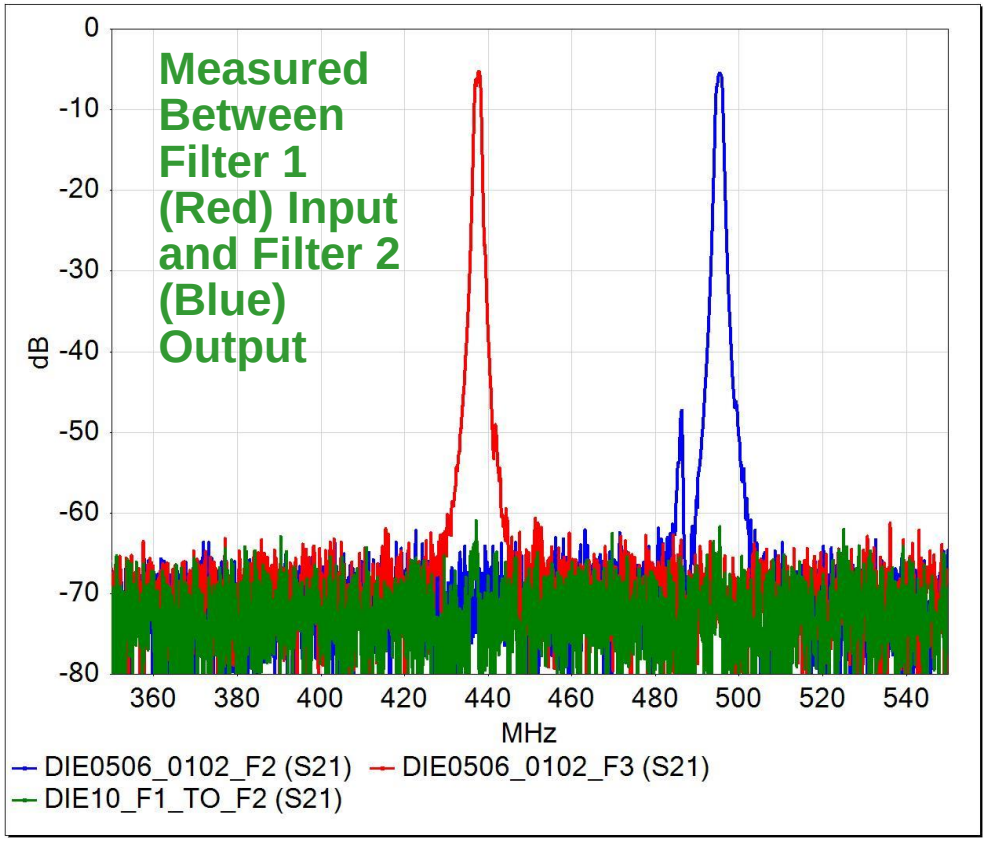


Width Extensional Bars

Filter Cross-Talk

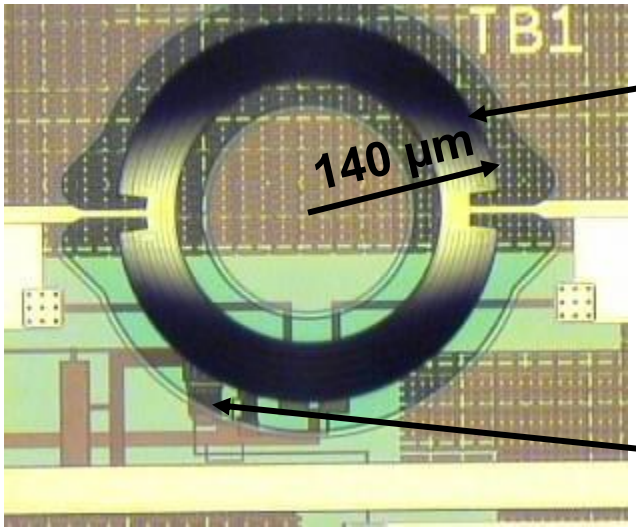
- Cross-Talk Between Filters in the Same Wafer Level Package Less Than 0.5 mm Apart is > 55 dB

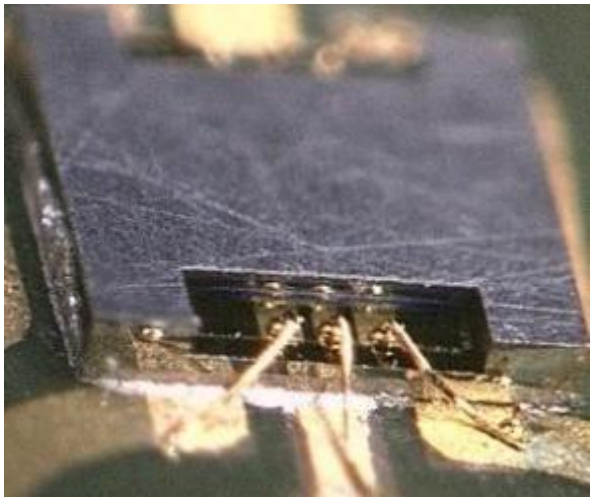




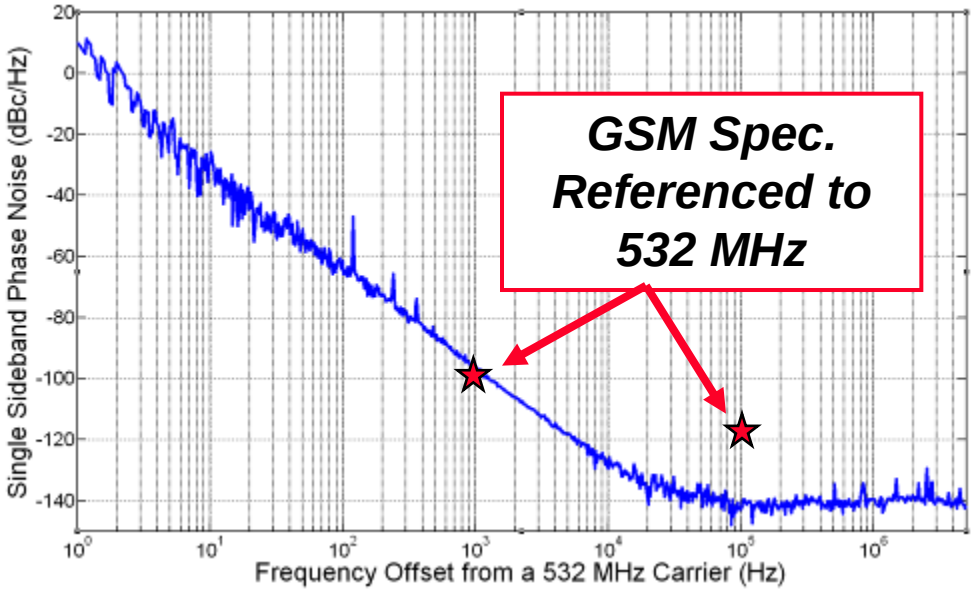
Thin Clocks and Oscillators

- High-Q Factor Resonators in Wafer Level Packages with Thicknesses < 200 µm
- 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

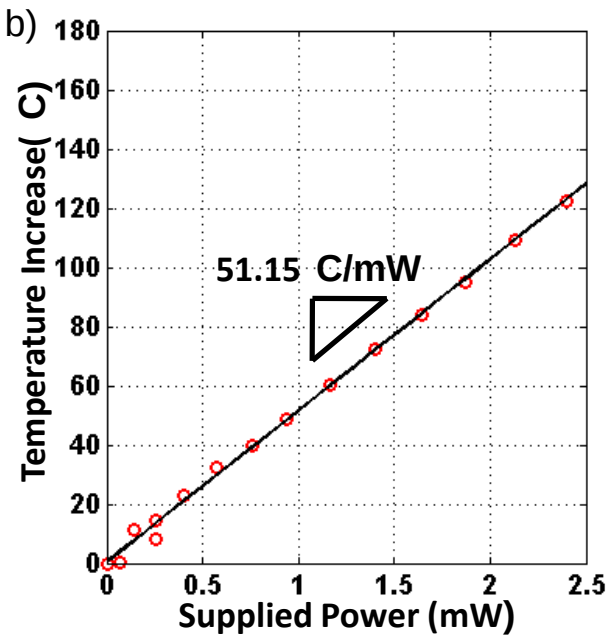


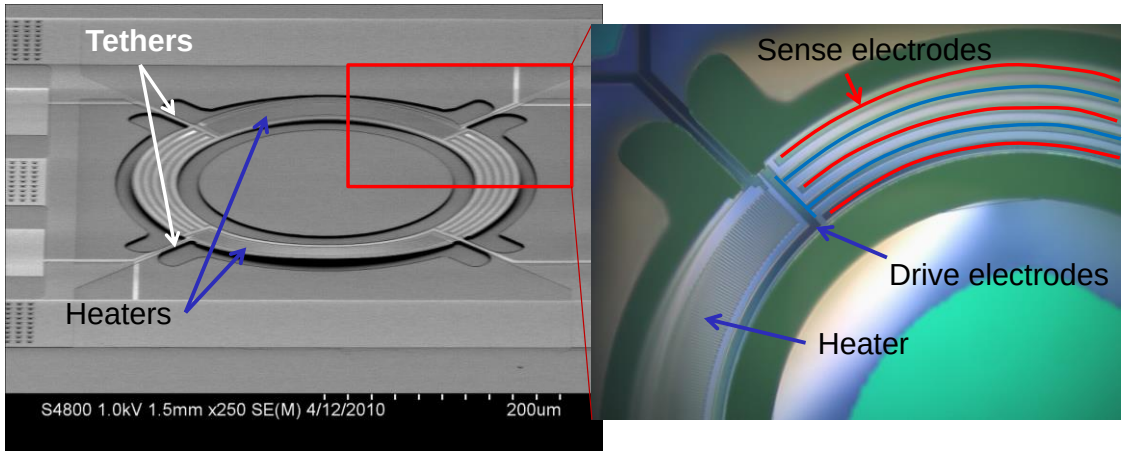
Picture and Phase Noise of a 532 MHz AlN Oscillator Integrated Directly Over CMOS

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