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Power Handling and Intermodulation Distortion of Contour-Mode Microresonator Filters

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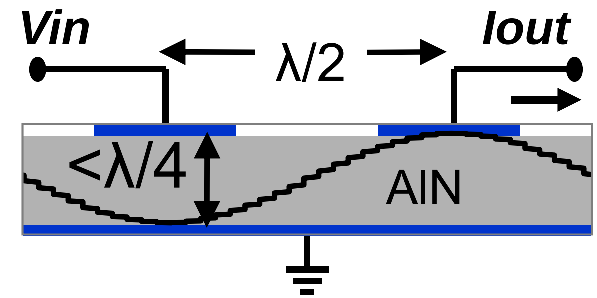
Introduction

- Contour-Mode AlN MEMS resonators offer miniature resonators covering multiple bands on a single wafer
- High power handling and low intermodulation performance is required for many insertion opportunities
- Goals of this work
  - Assess microresonator power handling performance
  - Understand scaling for increased power handling
- Overview
  - High power density in MEMS resonators generates nonlinear response at moderate powers
  - Nonlinearity must be considered when designing and using MEMS resonator filters and other devices

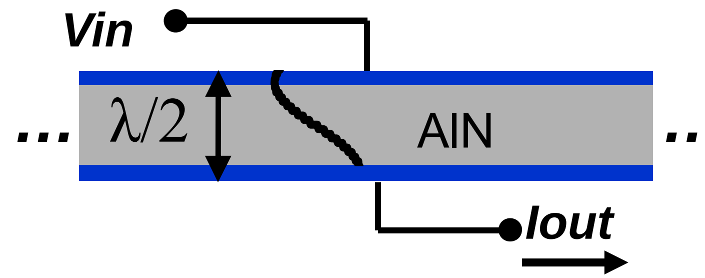
Piezoelectric Resonators

Resonator	Volume	P_{max}	IIP_3
MEMS	~5 λ^3 70 x 320 x 1 μm^3	~0 dBm	?
BAW/FBAR (Ruby, 2000) (1900 MHZ, 4 resonators) (HPMD-7905)	~1000 λ^3	>30 dBm	>60 dBm
SAW (EPCOS B5035) (200 MHz)	~1000 λ^3	>20 dBm	>40 dBm

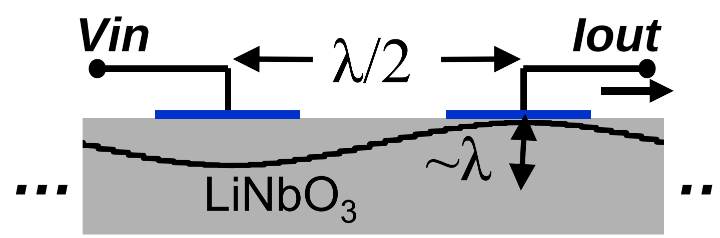
MEMS Resonator



BAW / FBAR

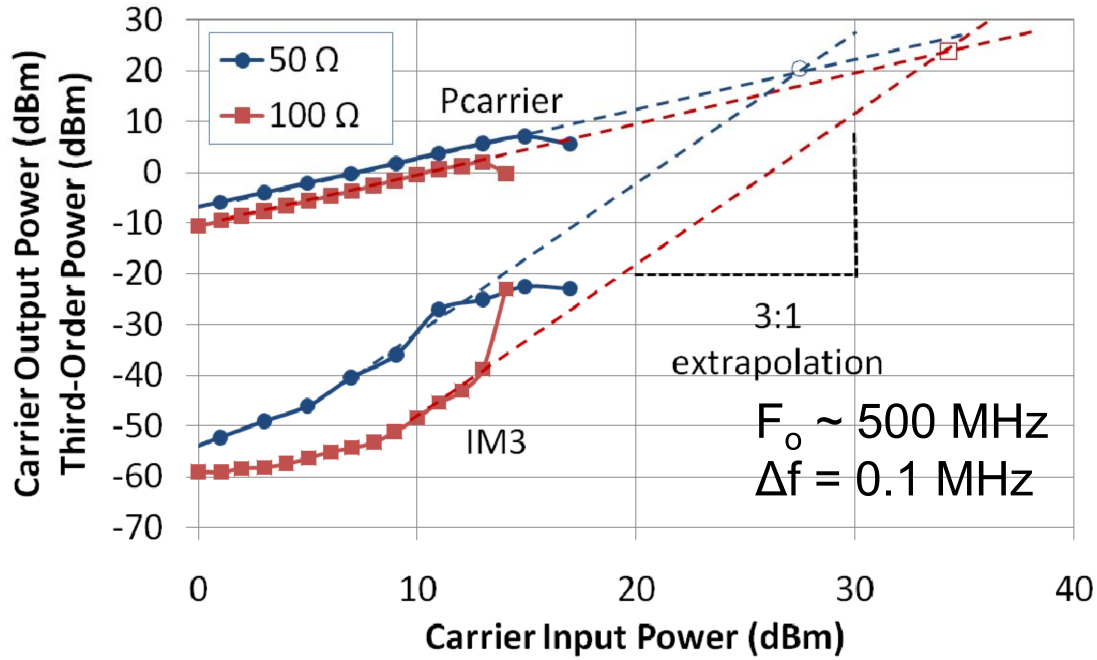


SAW



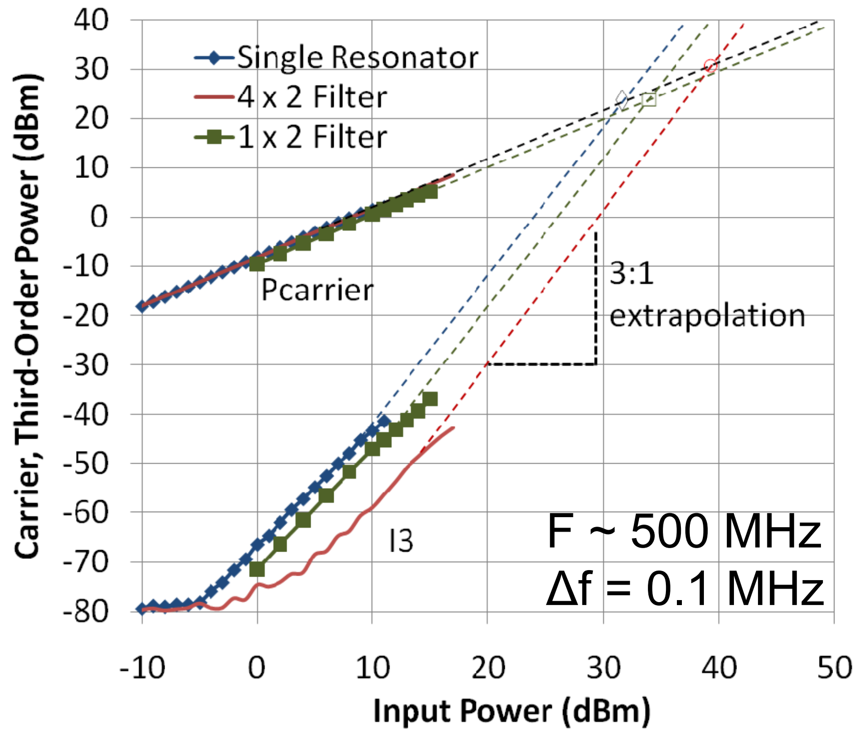
Single Resonators

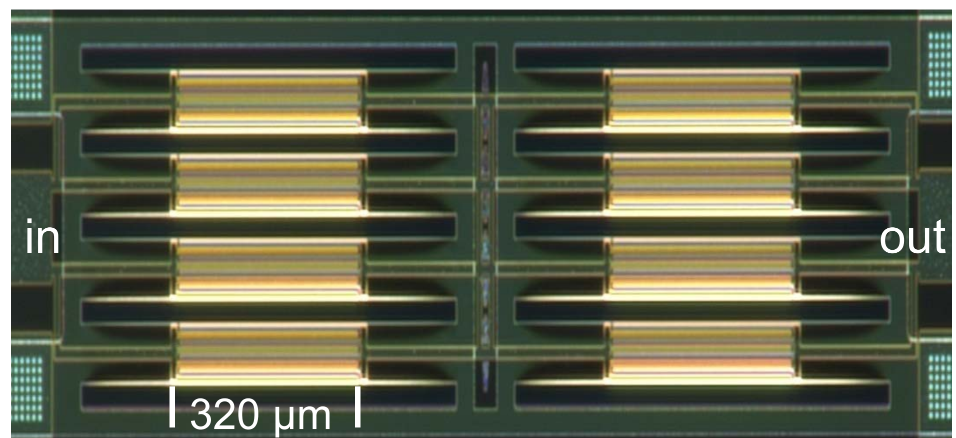
- Single devices
  - Resonator impedance determined by length of transducer fingers
  - Total length of bridge constant
  - Frequency ~ 500 MHz
  - 50 Ω & 100 Ω impedance
- Input P_{1dB} scales with A, Z^{-1}
  - Input P_{1dB} ~ 1.2 μW/ μm^3
- Output power appears to scale as Z^{-2} or A^2
  - Lower loss allows higher output power
- OIP3 ~ 20 dBm for each device



Filter Measurements

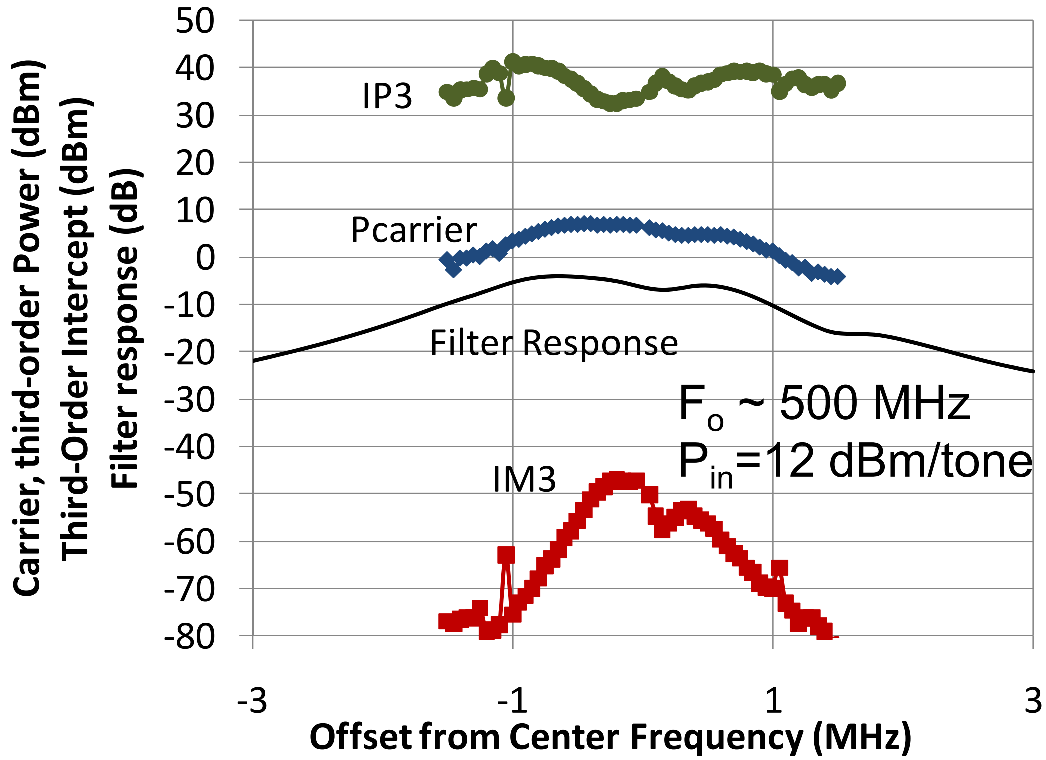
- Measurements from arrays of 60 Ω resonators
  - Single
  - 2 in series
  - Cascade of 2 sets of 4 parallel
- Input P_{1dB} scales with MxN
  - Input P_{1dB} ~ 0.3 μW/ μm^3
- Output power appears to scale as MxN but with loss penalty
  - More resonators supports more power but added loss from resonators in series reduces output power
- OIP3 ~ P_{1dB} + 18 dB





Tone Spacing

- Tone spacing swept from 0.1 MHz to 3 MHz on 4x2 filter
- Intermodulation products follow bandshape of carrier signal
    - Bandpass structure also appears in IM3
- Highest “apparent” IP3 value occurs when test tones are in-band but third-order products fall out-of-band
- IP3 begins to decrease once test tones are also attenuated



Summary

- Miniaturization of piezoelectric filters results in power handling and intermodulation limitations not apparent in larger filters
- Power handling and intermodulation improves as $(\text{area})^2$, providing guidelines for device scaling to higher power
- Series combination of resonators increases input power handling by N, but increases loss
- Parallel combination increases input power handling by M and decreases loss for the best output power per area
- The intermodulation level depends on the spacing of the test tones relative to the filter passband

Future Work

- Examine response to out-of-band signals
- Investigate higher-order intermodulation products
- Explore influence of operating frequency and Q
- Scale to higher power and frequency
- Determine mechanisms limiting power handling
- Examine role of packaging ambient
- Assess long-term reliability at power