DYNAMIC ANALYSIS OF CMUTs IN DIFFERENT REGIMES OF OPERATION

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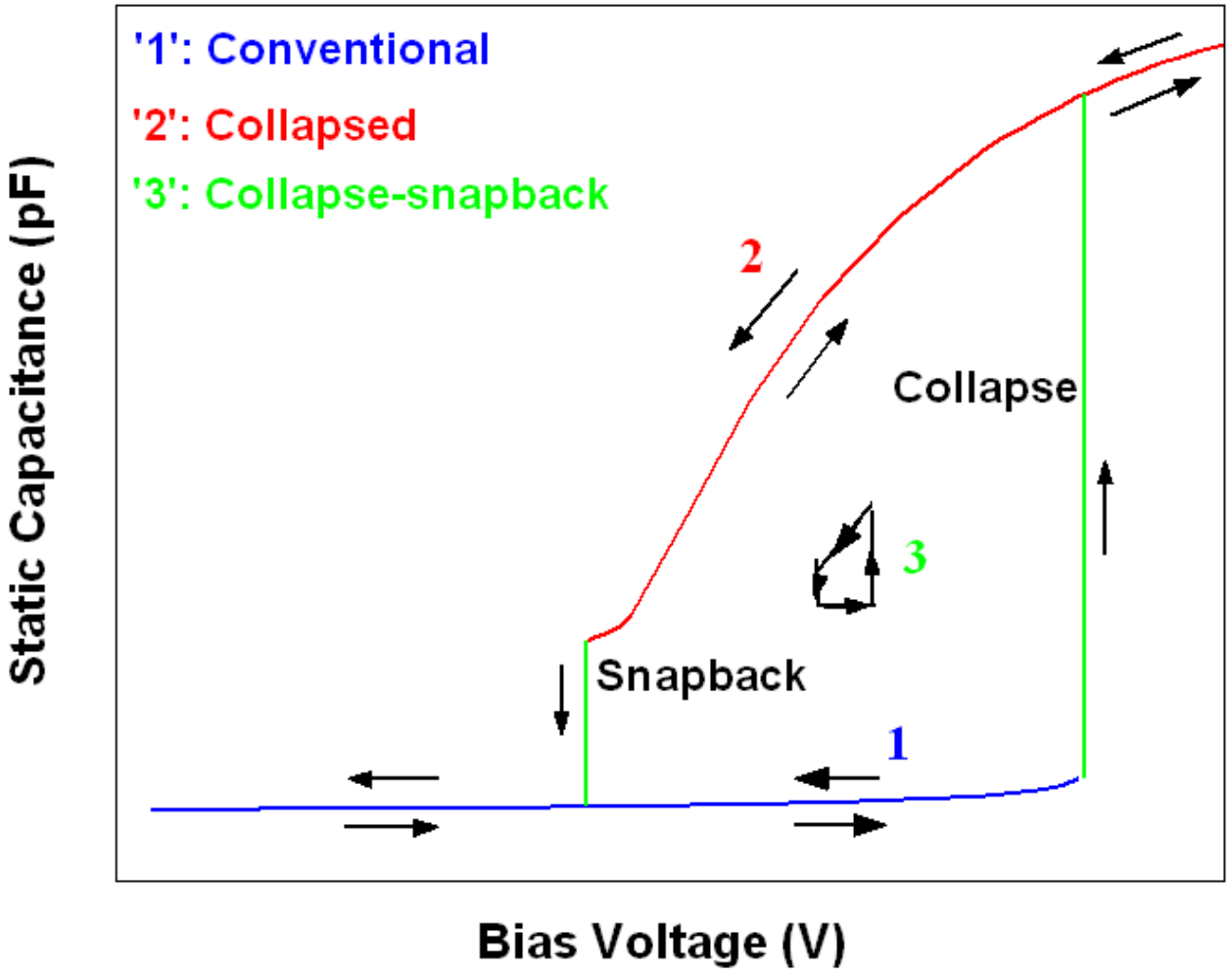
Outline

- Motivation
- FEM model of a single CMUT cell
- Dynamic FEM analysis
- Results
- Conclusion

Motivation

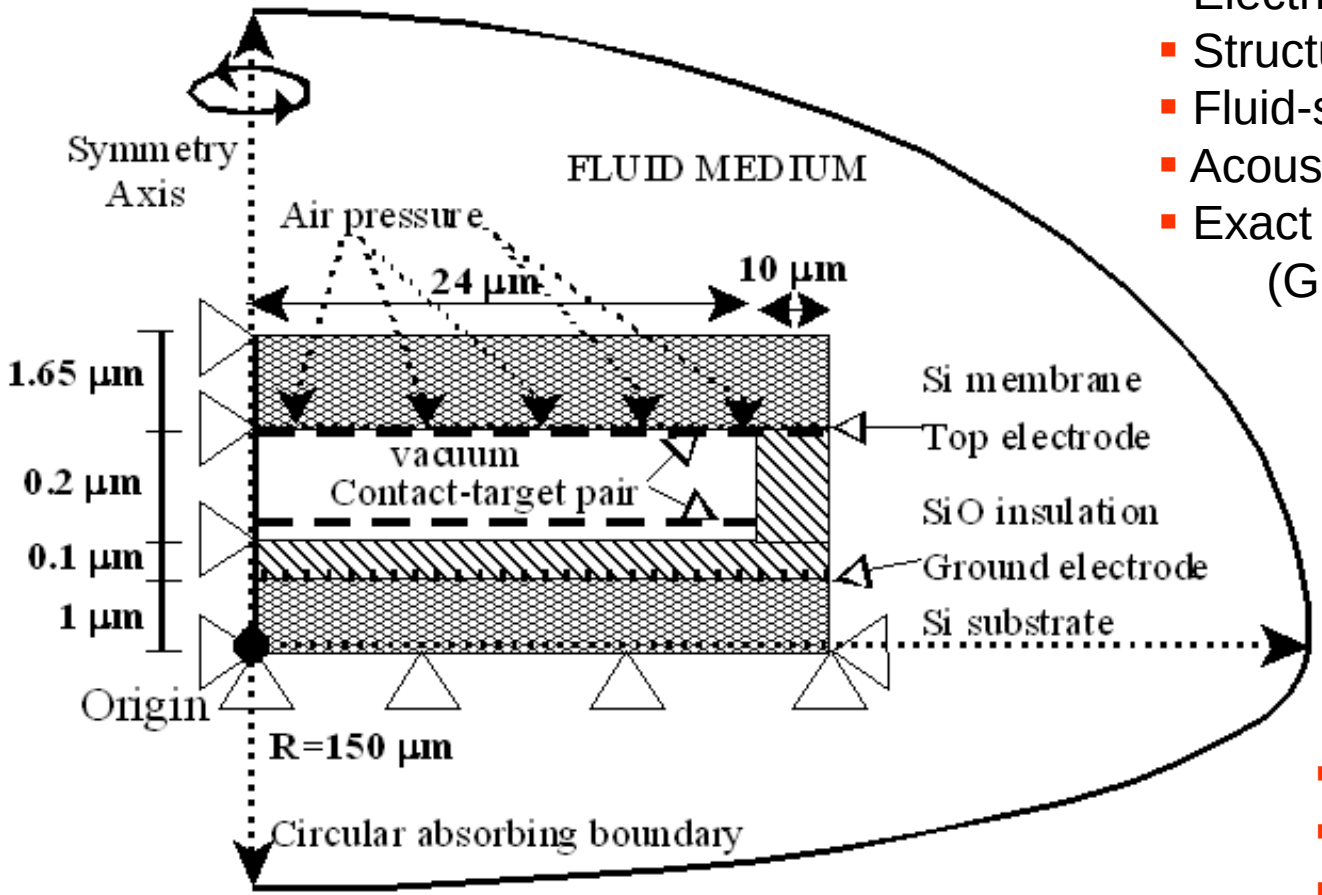
- Goal: Low voltage, high frequency CMUTs with more output power & less nonlinearity
- Method: Investigate different operation regimes for CMUTs:
  - Conventional (no contact)
  - Collapsed (always in contact)
  - Collapse-snapback (intermittent contact)

Different Operation Regimes



FEM model of a single CMUT cell

- Axisymmetric 2-D model
- Electrical Properties
- Structural Properties
- Fluid-structure Interface
- Acoustic Wave Equation
- Exact Absorbing Boundary (Grote *et al*)



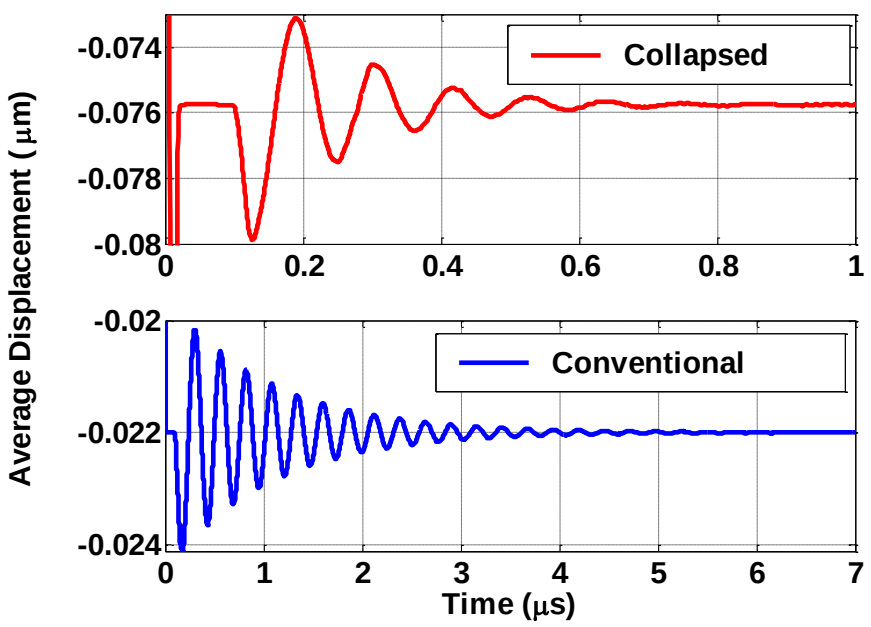
Basic Properties

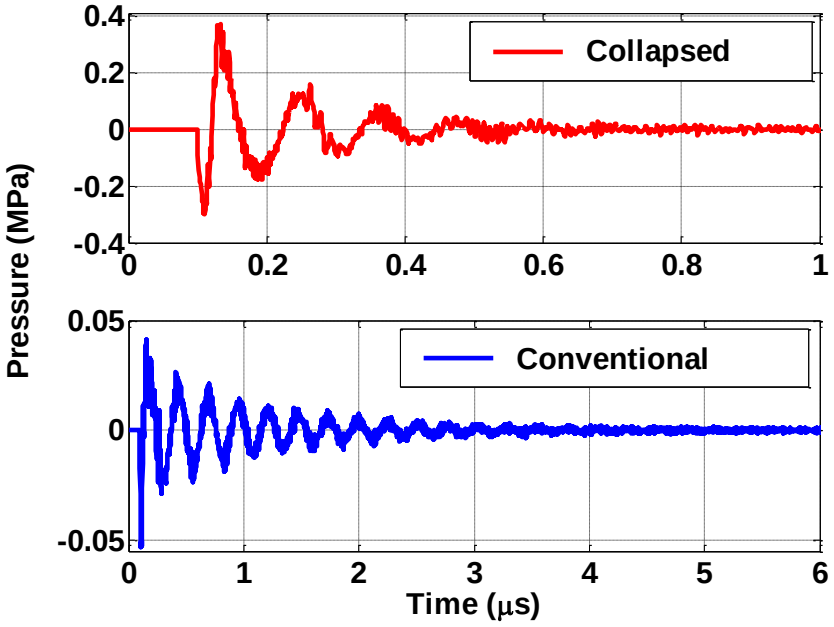
- Collapse: 80 V
- Snapback: 50 V
- Resonance: 5 MHz

Dynamic FEM Analysis

- Commercially available software (ANSYS 7.1)
- Transient Analysis
  - Coupled electrical & structural analysis
  - Fluid medium
  - Contact capability
  - Exact absorbing boundary (Grote *et al*)
- Large Signal Characterization
  - Pulse and sinusoidal (AC) excitation
  - Displacement and pressure output
  - Nonlinear distortion: 2^{nd} harmonic

Results: Pulse Excitation

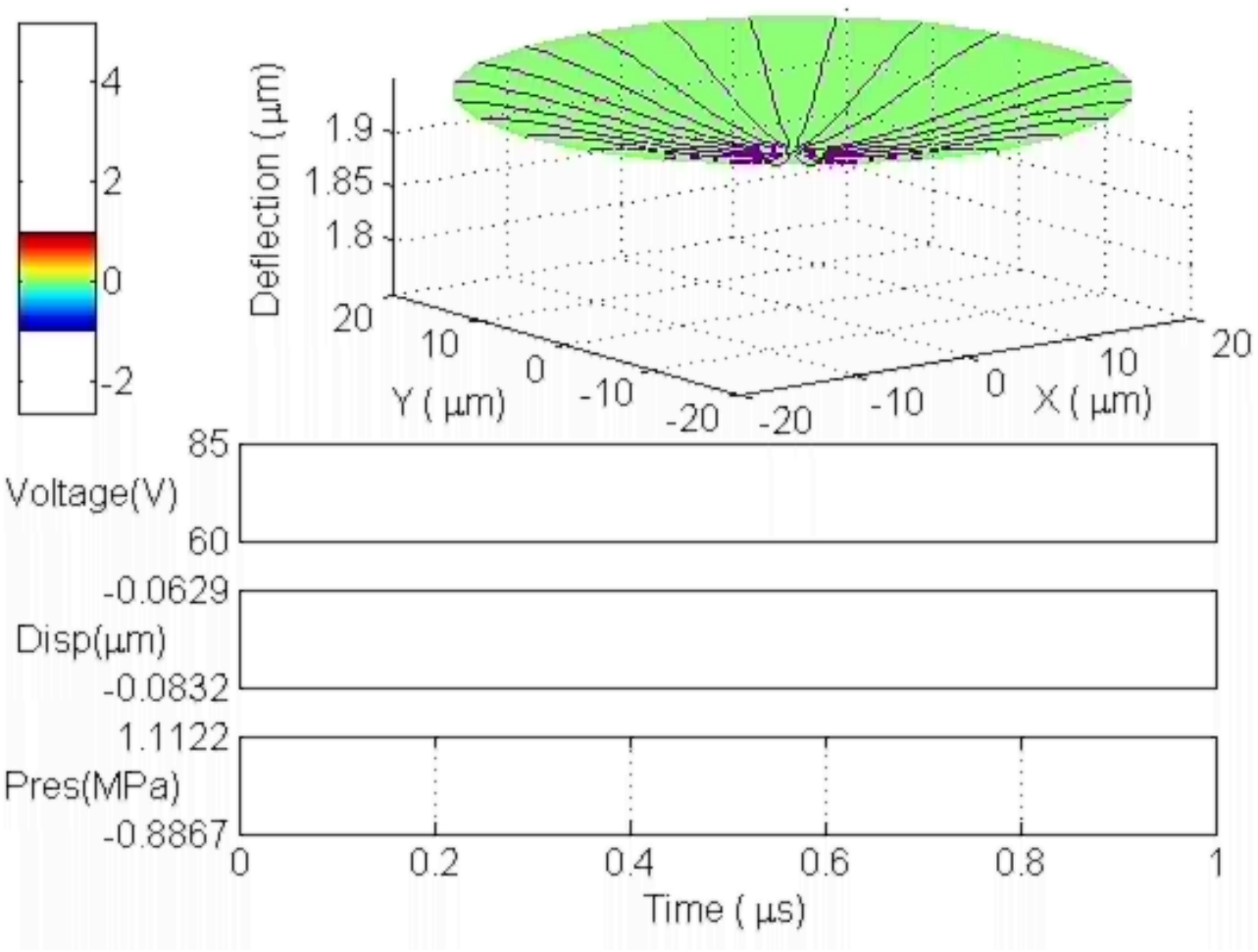




V_{BIAS}=70V, V_{PULSE}=+5V, t_{PULSE}=20ns

	Conventional	Collapsed
Displacement (p-p) (Å)	39	**70**
Resonance freq. (MHz)	3.84	8.75

Results: Pulse Excitation



Collapsed operation

V_{BIAS}=65 V

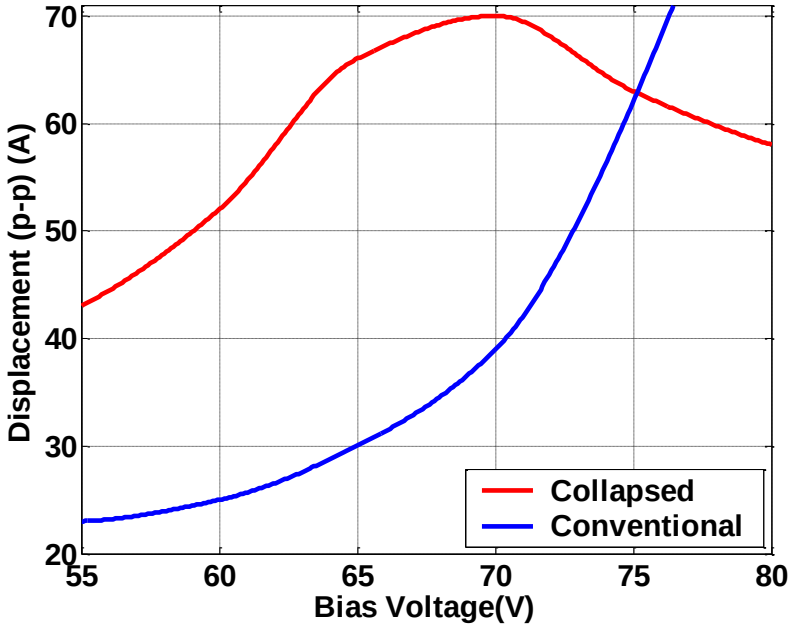
Pulse excitation:

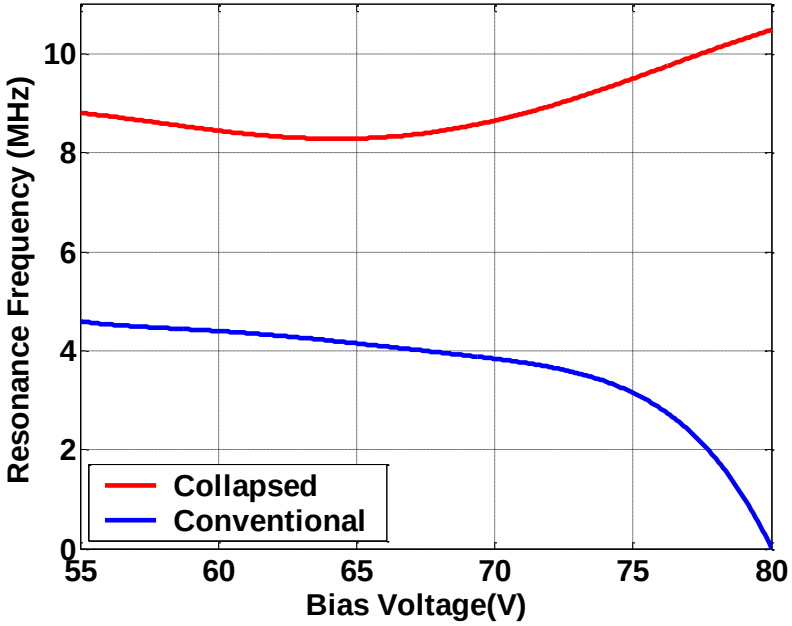
V_{PULSE}=15V

t_{PULSE}=20ns

- Displacement (p-p): **200 Å, 13 Å/V**
- Pressure (p-p): **2000 kPa, 133 kPa/V**

Results: Bias Voltage

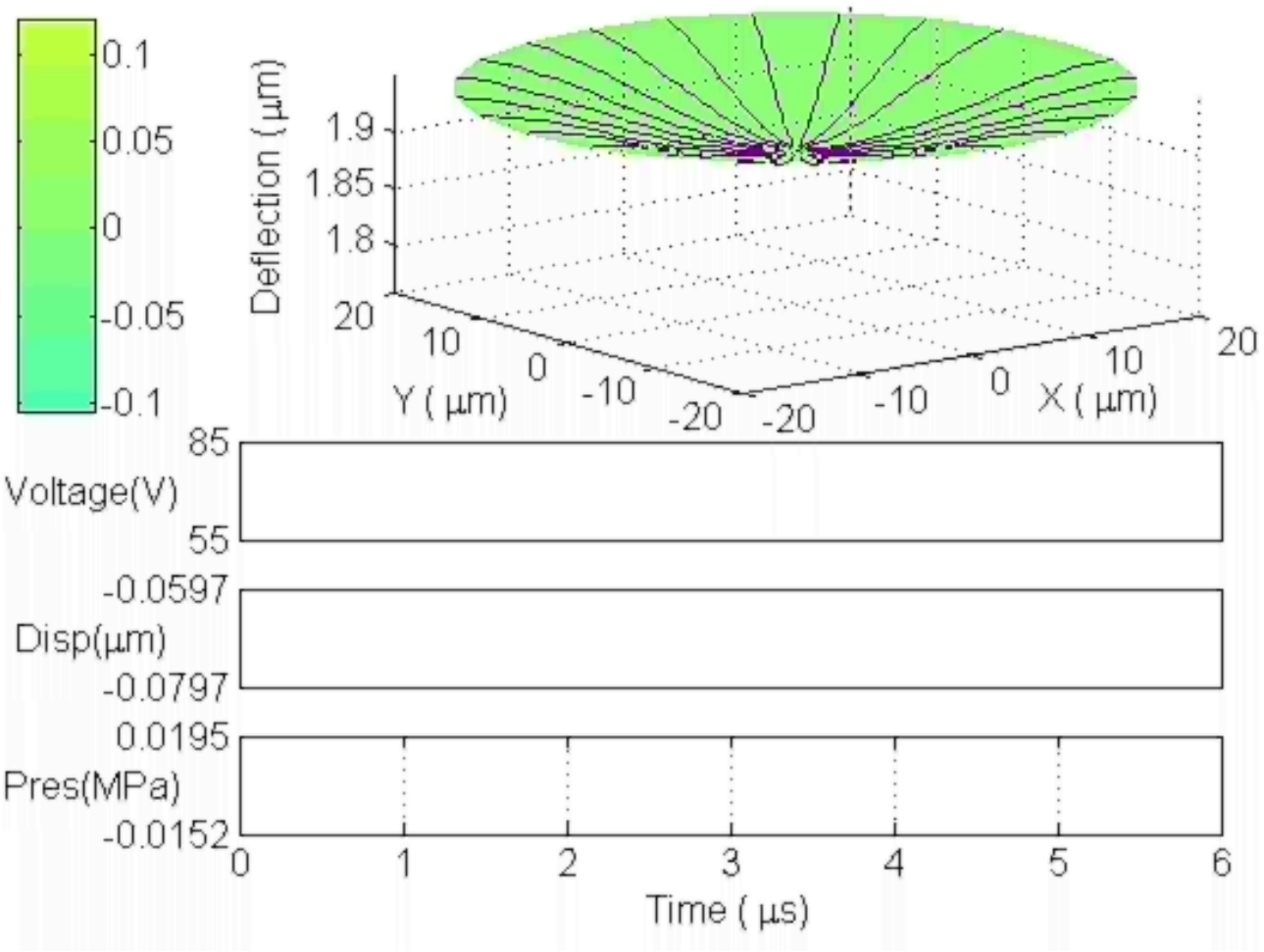




V_{PULSE}=+5V, t_{PULSE}=20ns

- Collapsed operation:
  - Higher resonance frequency : contact radius effect
  - Larger displacement & output pressure

Results: AC Excitation



Collapsed operation

V_{BIAS}=70 V

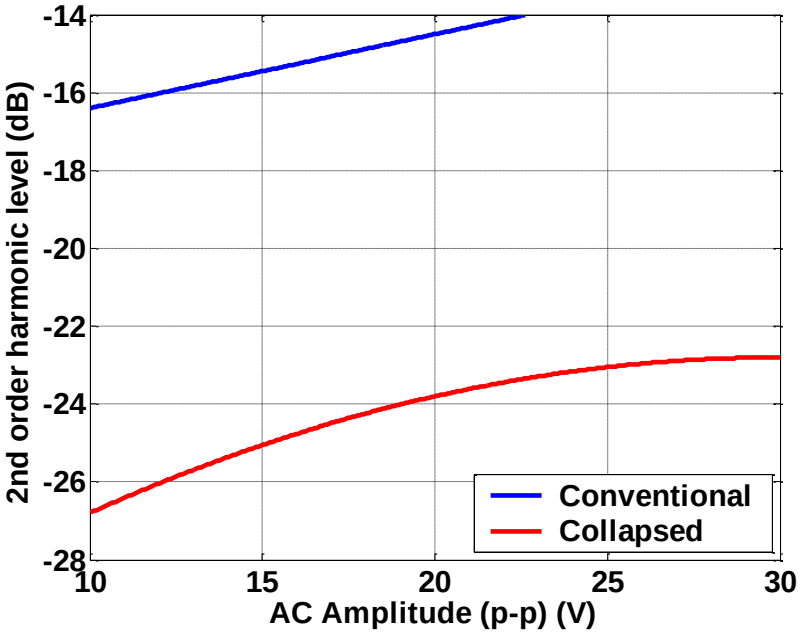
AC excitation:

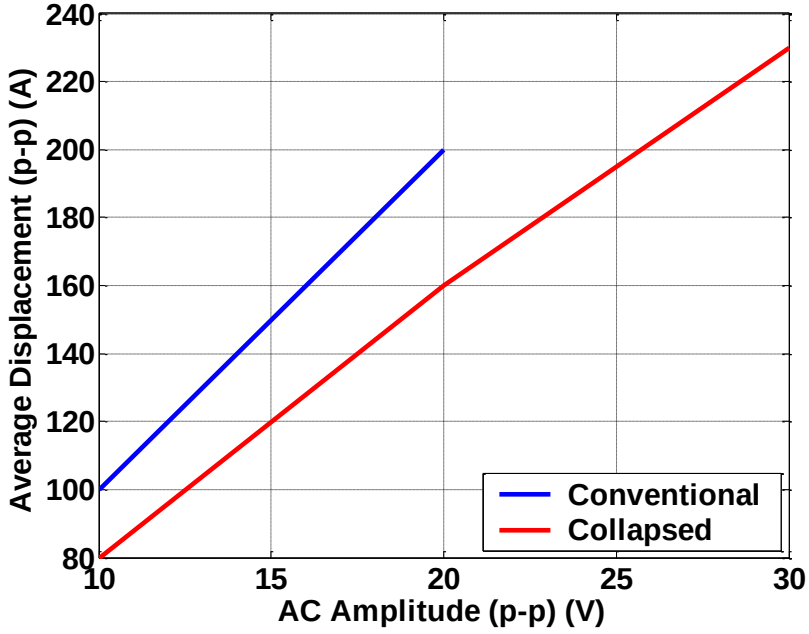
f_{EXC}=1 MHz

V_{P-P}=30V

- 2nd harmonic: **-23 dB**
- Displacement (p-p): **200 Å, 7 Å/V**
- Pressure (p-p): **36 kPa, 1.2 kPa/V**

Results: AC Amplitude

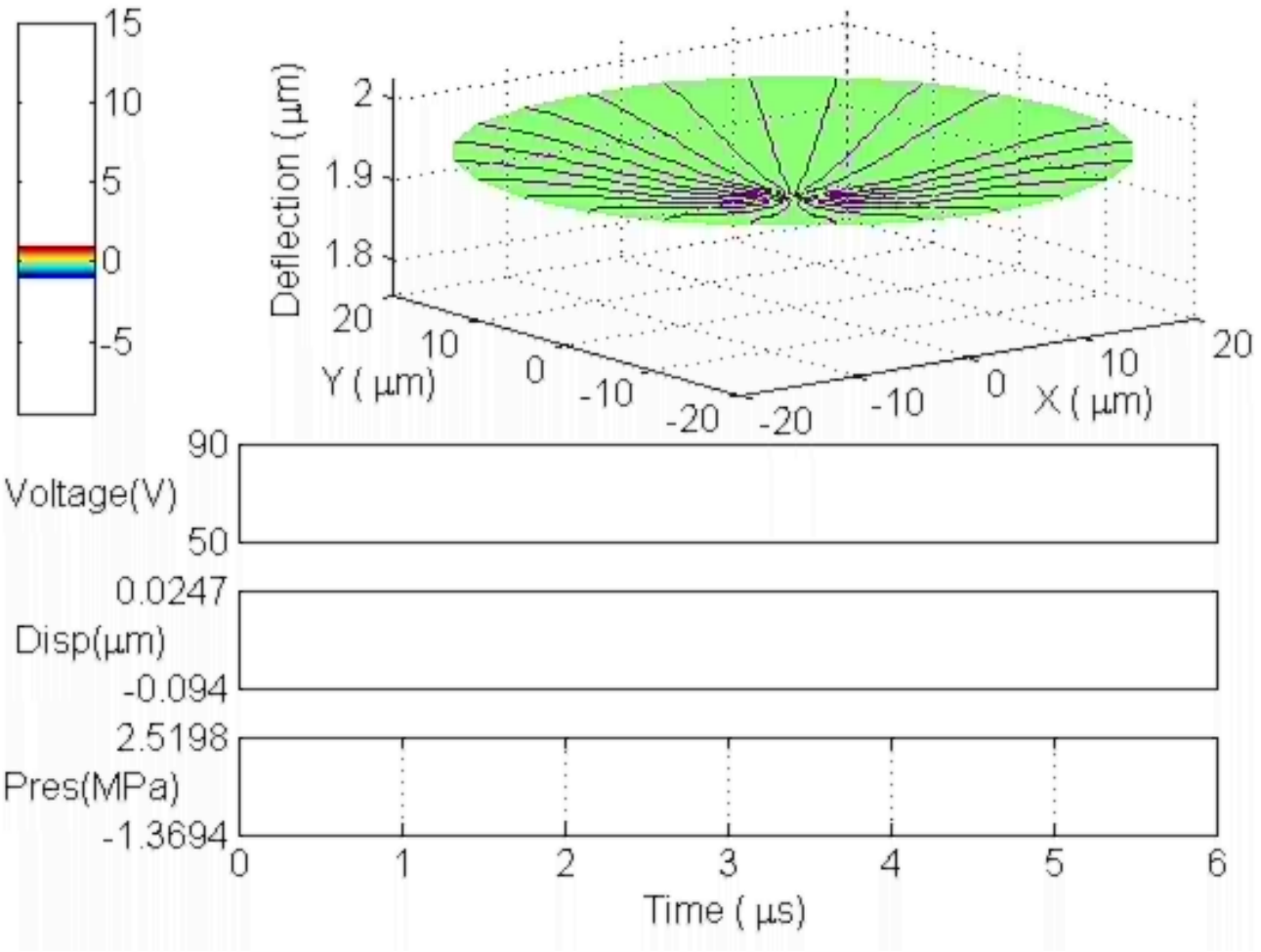




V_{BIAS}=65 V, f_{EXC}=1 MHz

Collapsed operation: MORE LINEAR RESPONSE

Results: Collapse-snapback



Collapse-snapback operation

V_{BIAS}=70 V

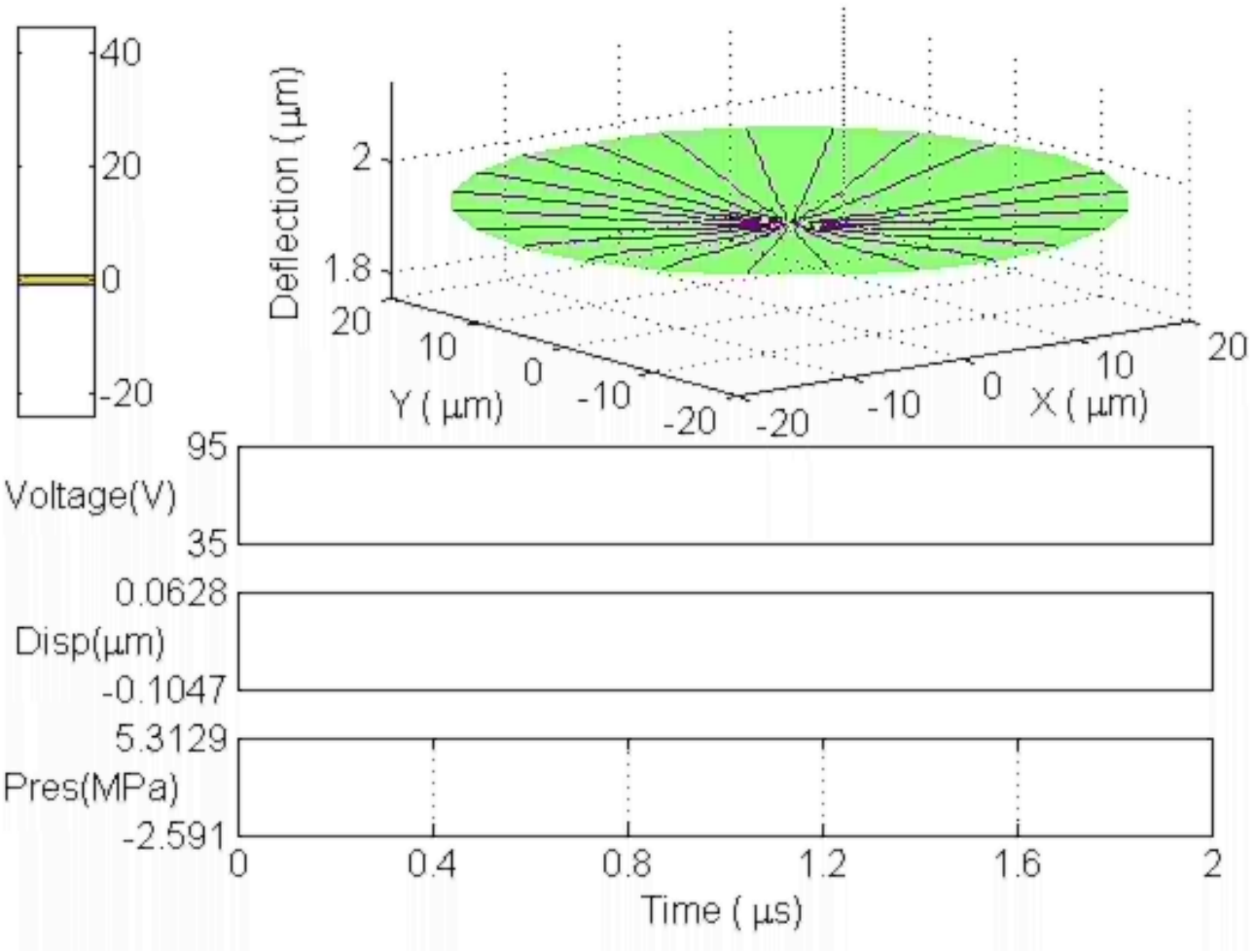
AC excitation:

f_{EXC}=1 MHz

V_{P-P}=40 V

- 2nd harmonic: **-18 dB**
- 3rd harmonic: **-10 dB**
- Displacement (p-p): **1200 Å, 30 Å/V**
- Pressure (p-p): **3600 kPa, 90 kPa/V**

Results: Collapse-snapback



Collapse-snapback operation

V_{BIAS}=65 V

AC excitation:

f_{EXC}=5 MHz

V_{P-P}=60 V

- Displacement (p-p): **1600 Å, 26 Å/V**
- Pressure (p-p): **9500 kPa, 158 kPa/V**

Comparison of Operation Regimes

Performance	**Conventional**	**Collapsed**	**Collapse-Snapback**
V_{BIAS}	High	Low	Low
V_{TOTAL}	$<V_{COLLAPSE}$	$>V_{SNAPBACK}$	$>V_{COLLAPSE}$ $<V_{SNAPBACK}$
Output Power	Low	Medium	High
Linearity	Good	Better	Worse

Conclusion

- **Investigated different regimes of operation using transient analysis in FEM**
  - **Collapsed operation:**
    - More linear
    - Low voltage bias
    - Higher frequency
  - **Collapse-snapback operation:**
    - Higher output pressure
- **Future work: 3D analysis of CMUT arrays**