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Variable Capacitance and Pull-in Voltage Analysis of Electrically Actuated Meander-Suspended Superconducting MEMS

Nouha ALCHEIKH

Pascal XAVIER

Jean Marc DUCHAMP

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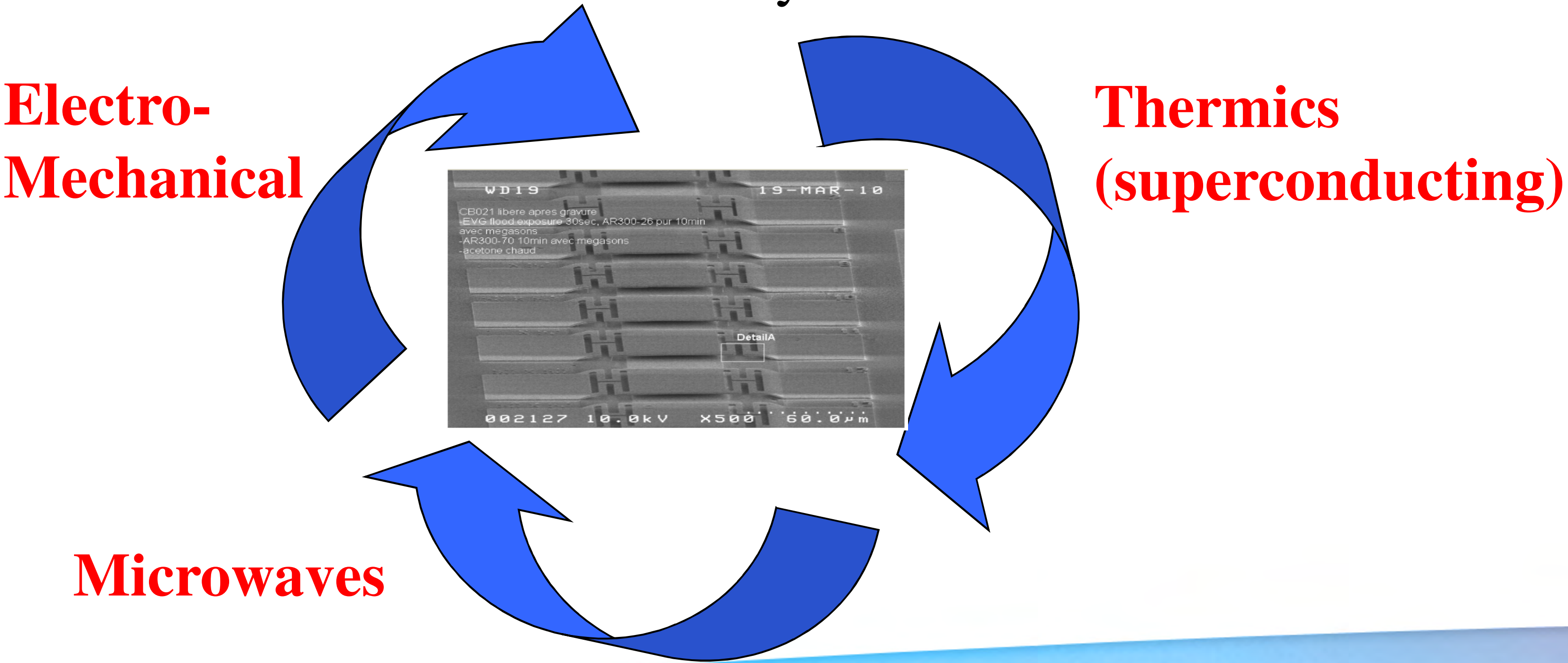
Context

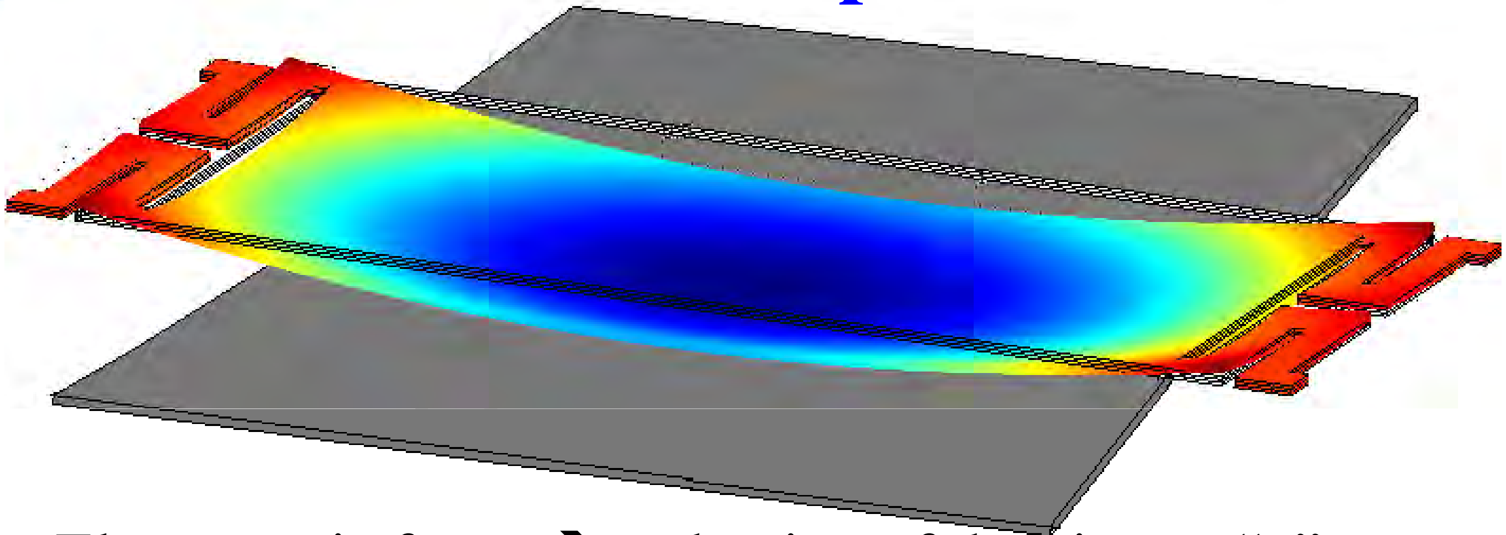
- Use of superconducting MEMS for tuneable RF devices
- Behavioral multi physic model of a MEMS:
    - IRAM process : Niobium on quartz
    - Influence of the sacrificial layer



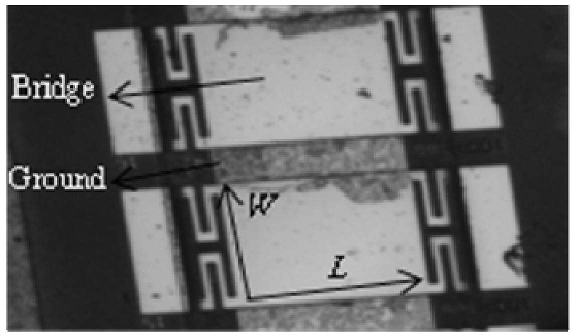
Outline

- ❖ Presentation of suspended-meander MEMS
- ❖ Experimental characterization
- ❖ Multiphysics simulation
    - ❖ Mechanical simulation
    - ❖ Coupled Simulation without electrostatic force
    - ❖ Coupled Simulation with electrostatic force
- ❖ Conclusions & Perspectives

Presentation of suspended-meander MEMS



- Electrostatic force ➔ reduction of the air gap "g"
- Variation of the capacitance : $C = \frac{\varepsilon_0 \times b \times L}{g} \rightarrow C$
- Deformation of the meanders
- *C*(*V*) depends on the meanders
- Optimal ΔC/C



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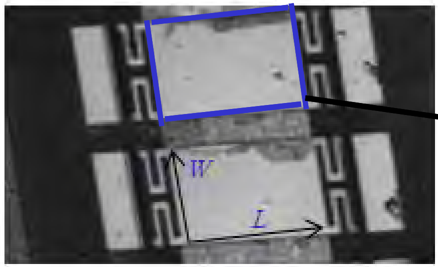
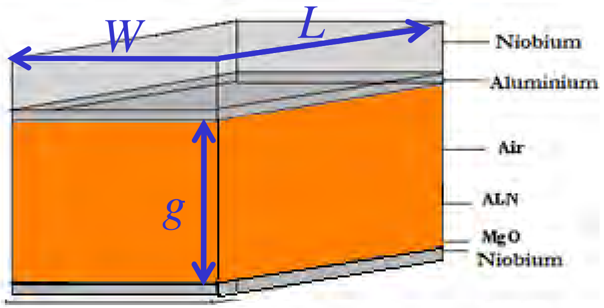
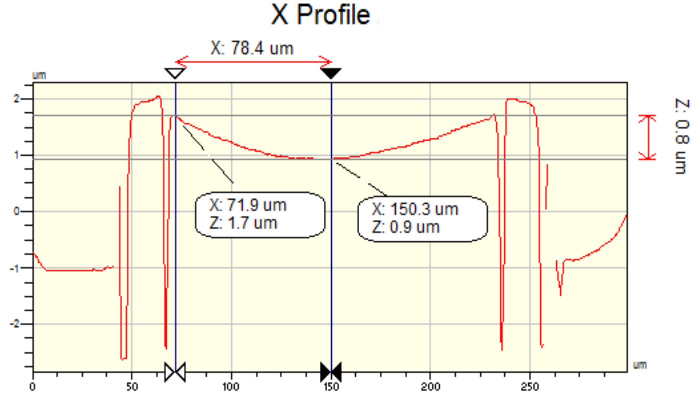
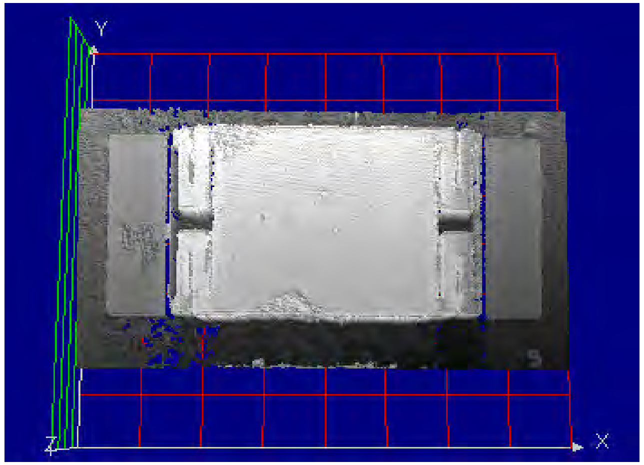
Experimental characterization





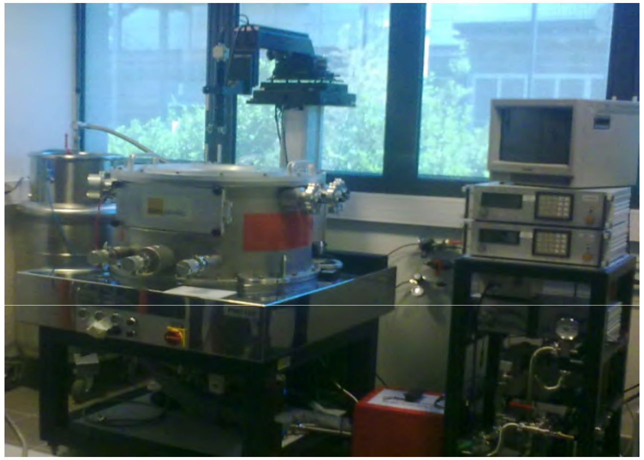
- L=160µm , W=100µm, g=2.6µm

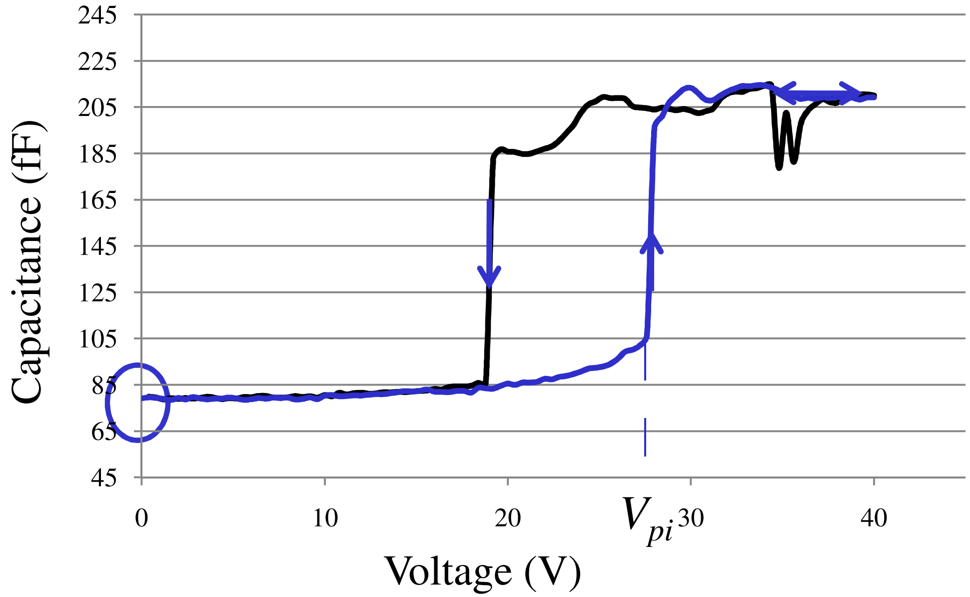




- Q1 : Interferometric measurements shows that the MEMS bridge is initially slightly deflected.

Experimental characterization





V_{pi} =27.6 V and $\Delta C(V)/C(0)$ is 33%.

Q2 : $C(0)_{measure}$ =79fF & $C(0)_{Calculated}$ =67fF

Can COMSOL help us to answer these questions ?

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COMSOL multiphysic simulation

Objectives

- Mechanical simulation to explain the deflection of the bridge

- Coupled simulation to find extra capacitance origin.

- Multiphysics electromechanical simulation to describe C(V) measured for suspended –meanders MEMS

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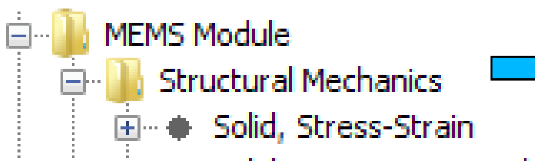
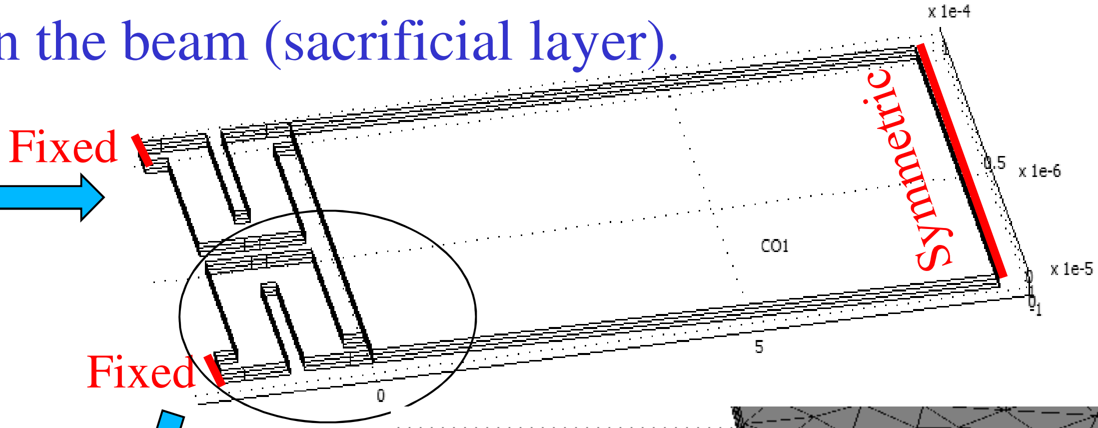
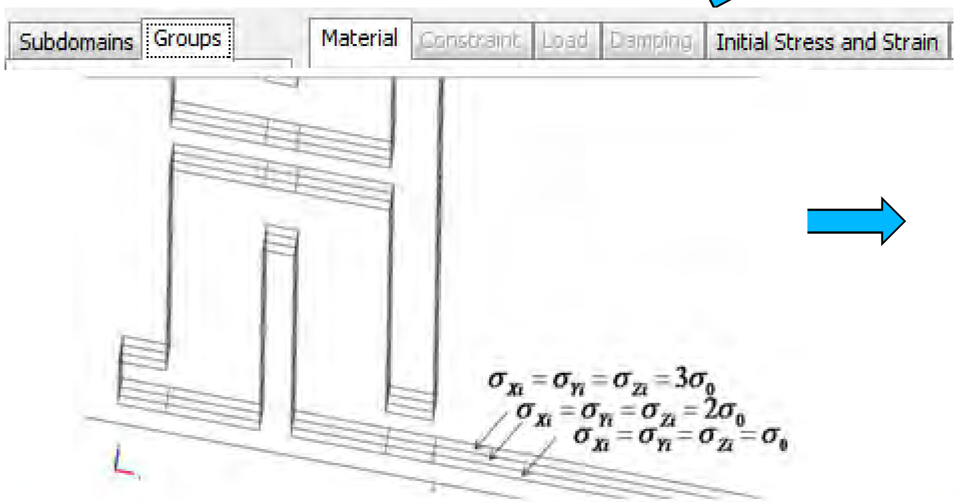
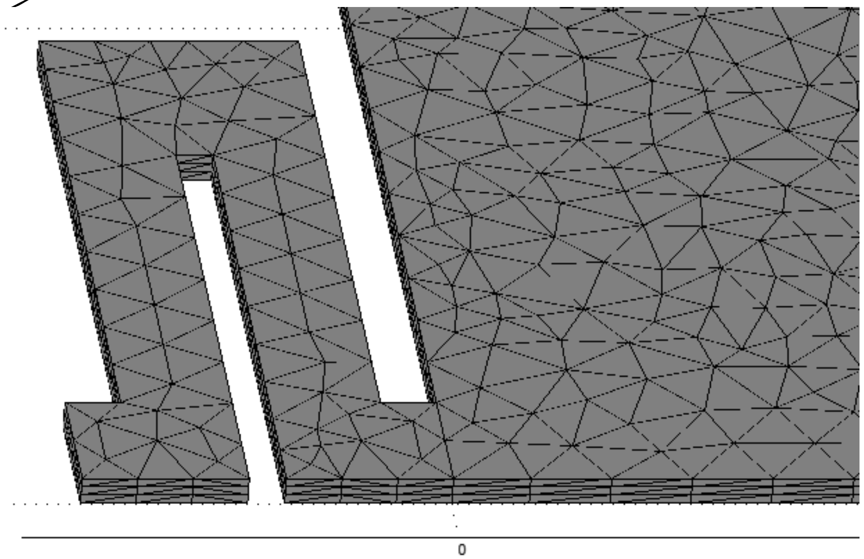
Mechanical simulation

- Assumption: Observed deflection result from intrinsic stress gradient in the beam (sacrificial layer).

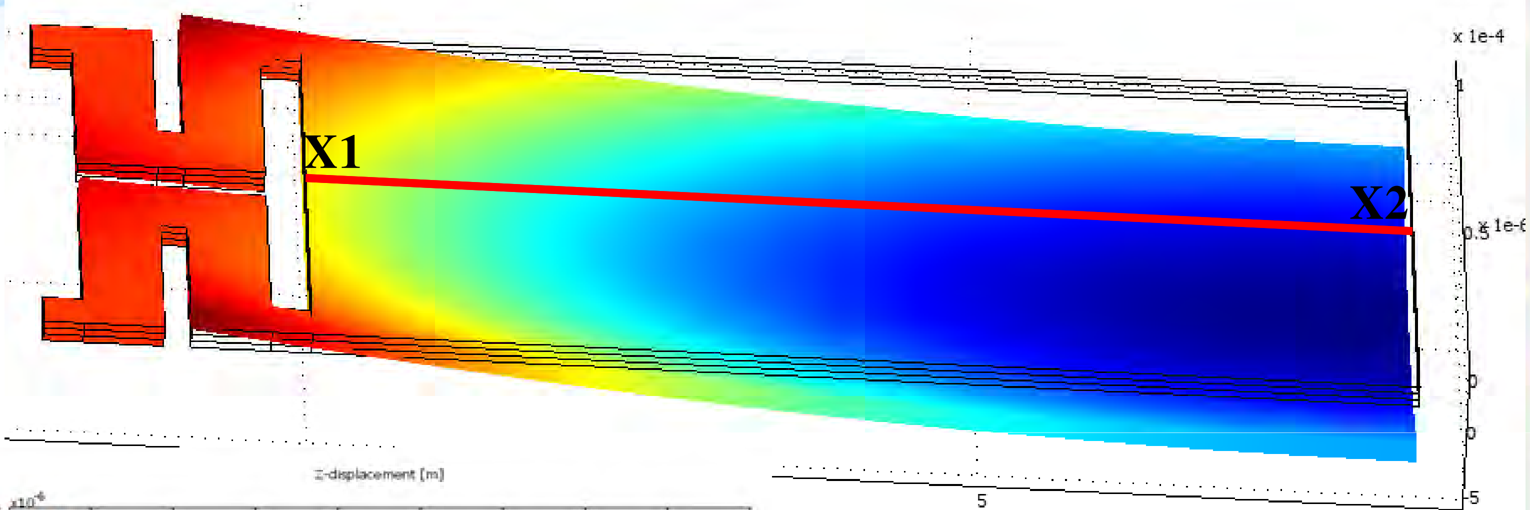


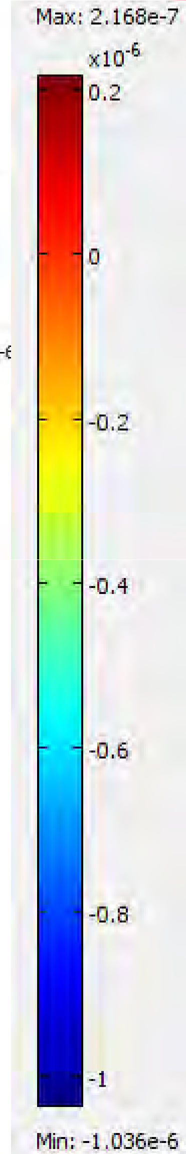


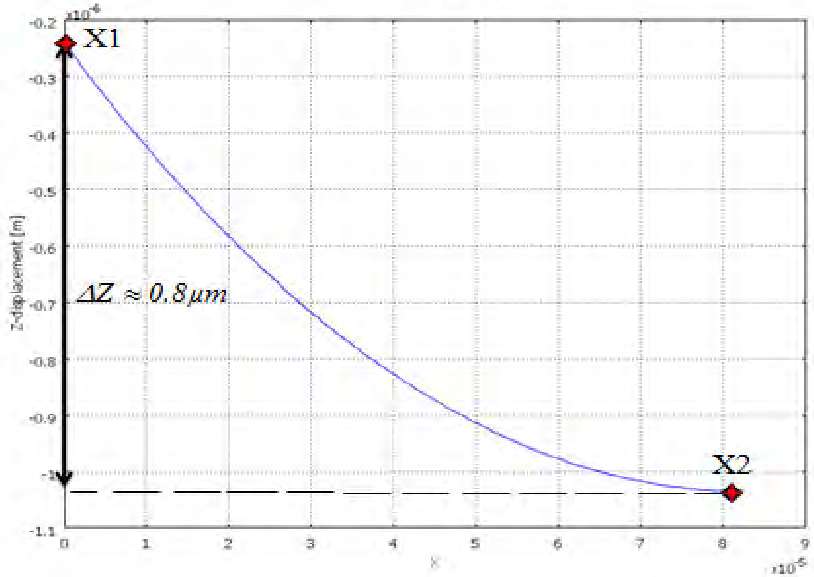




Mechanical simulation







Measure deflection ≈simulated deflection

For $\sigma 0$ =85 Mpa

Should be confirmed by X ray measurement

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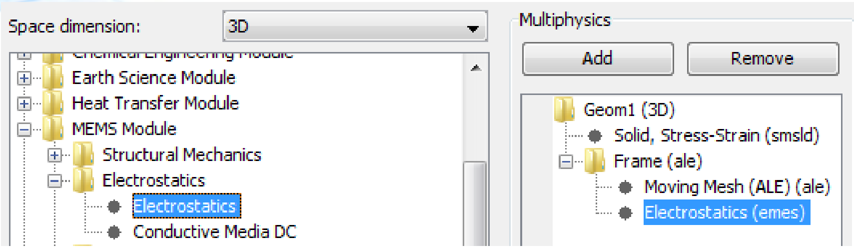
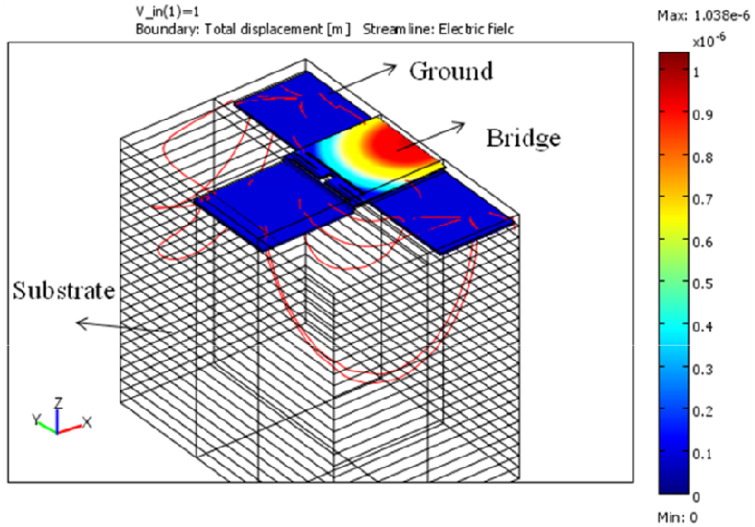
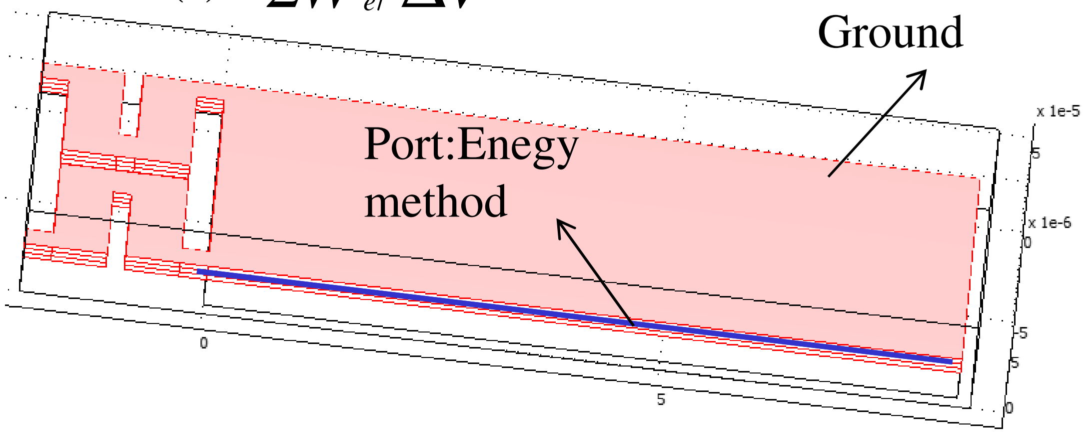
Coupled simulation without electrostatic force





The value of the capacitance is

$$C(0) = 2W_e / \Delta V^2$$



C(0)=70 fF with air substrat

C(0)=81.6 fF with quartz

Extra capacitance : 11.6 fF as shown on measure

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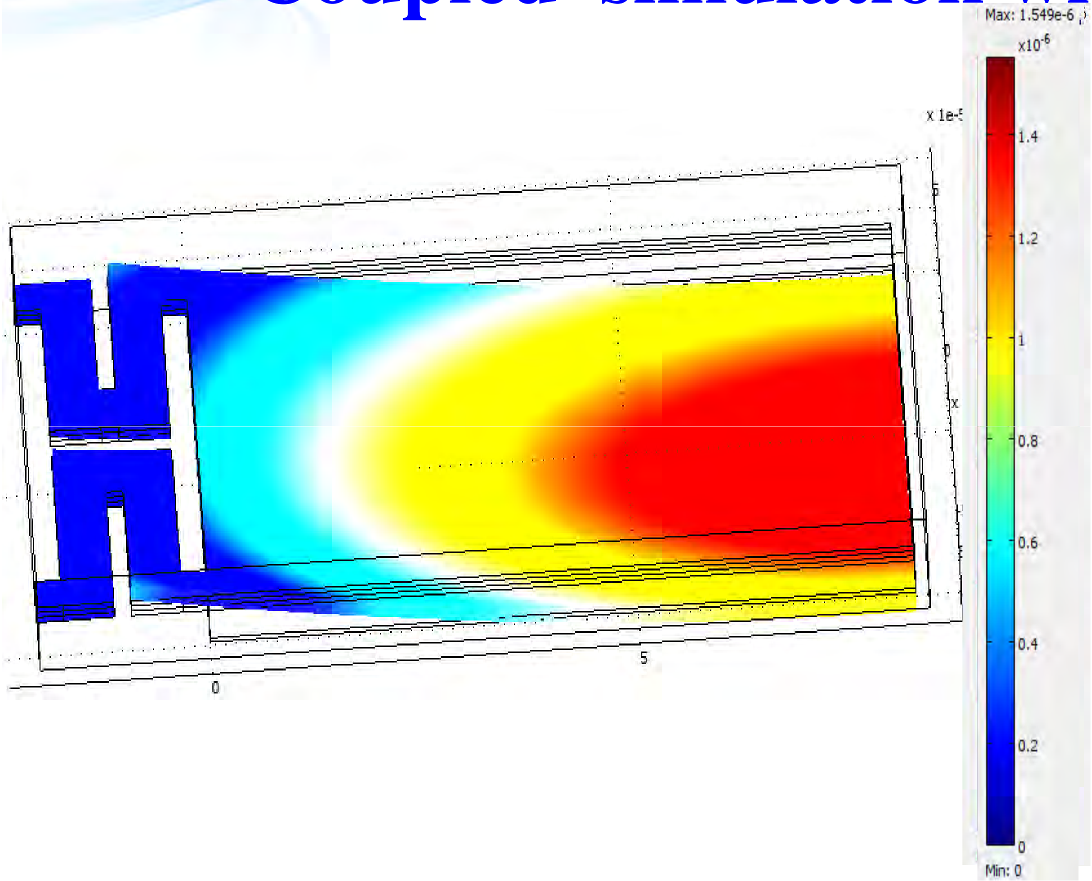
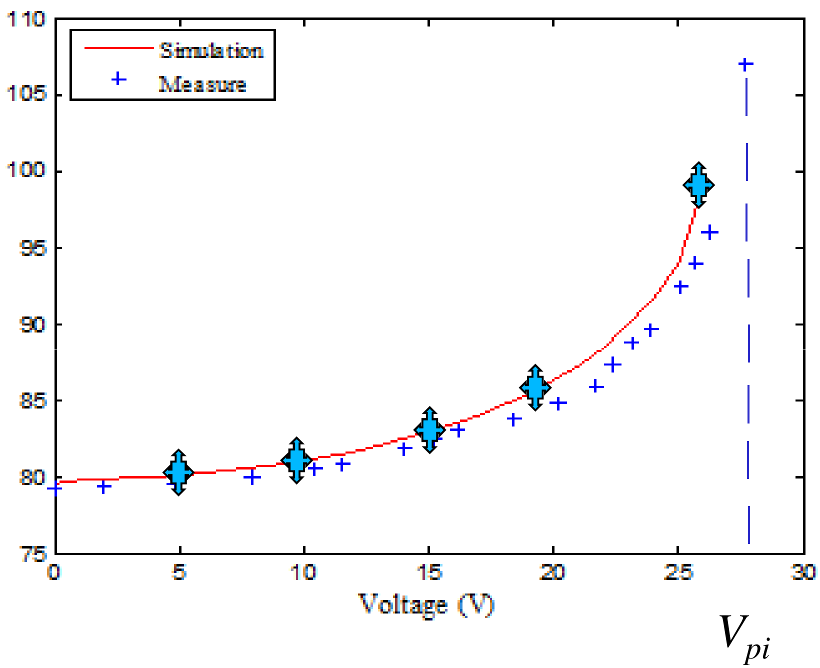
Coupled simulation with electrostatic force





$C(V)$ measure ≈ $C(V)$ simulation

Conclusions &Perspectives

- C(V) is validated by an Electromechanical 3D simulation and predict the pull-in voltage
- The deflection of the bridges can be explained by an intrinsic stress gradient in the beam
- Extra capacitance is due to the quartz substrate
- Explain the effect of hysteresis by a simple simulation using COMSOL
- Superconducting modeling

THANK YOU