



High Resolution Measurements of the Displacement of Thin Piezoelectric Films

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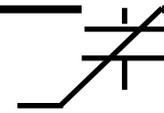
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Radiant Technologies, Inc.

*2020 International Workshop on Piezoelectric Materials and
Applications in Actuators and Devices*

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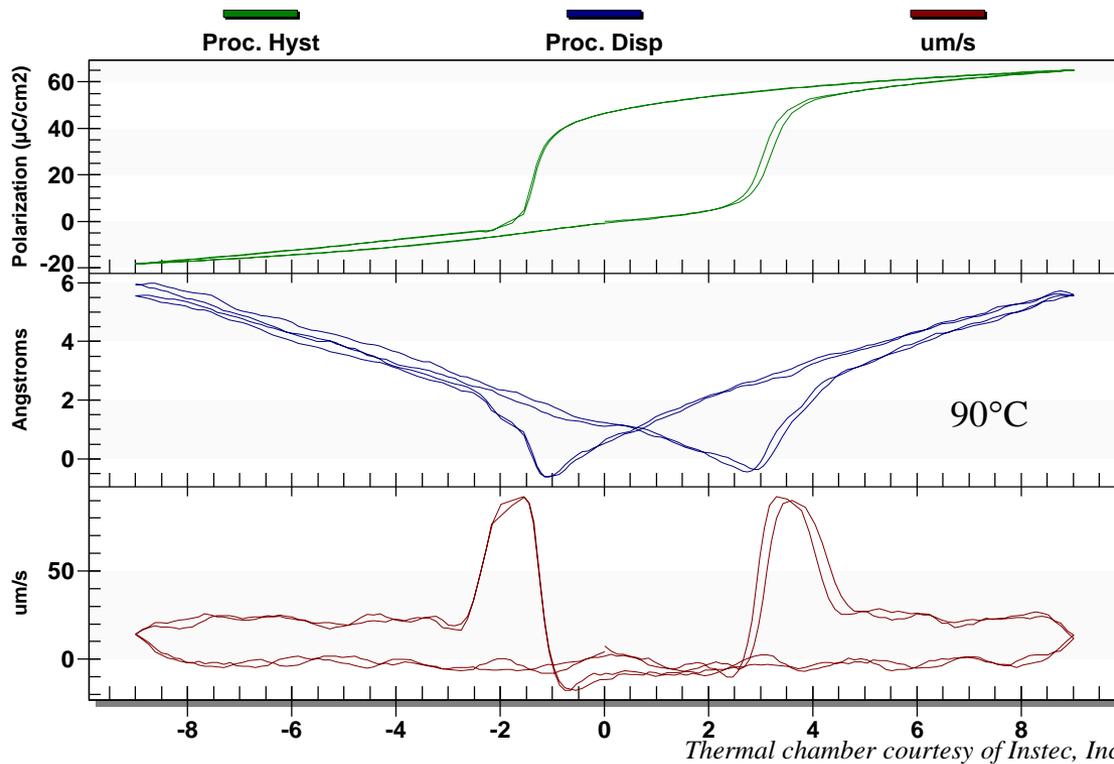
Introduction



Radiant has verified that the Polytec NLV Laser Doppler Vibrometer has the resolution to capture butterfly loops of the surface motion of a piezoelectric film clamped by the substrate down to 6 Ångstroms at multiple temperatures.

Polarization, Butterfly, and Surface Velocity

[In Instec DHC612G-PM]

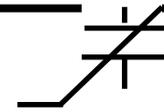


The test profile consists of two continuous cycles so two traces appear in each parameter. All three parameters were captured synchronously.

This presentation will describe the instrumentation and measurements.

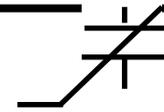
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Outline

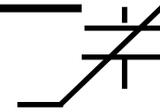


- Performance of the Polytec NLV
- Description of the sample
- Temperature chambers
- Integrated test fixture for displacements at temperature
- Test results
- Alternate fixture for piezoMEMS structural motions

Polytec NLV LDV

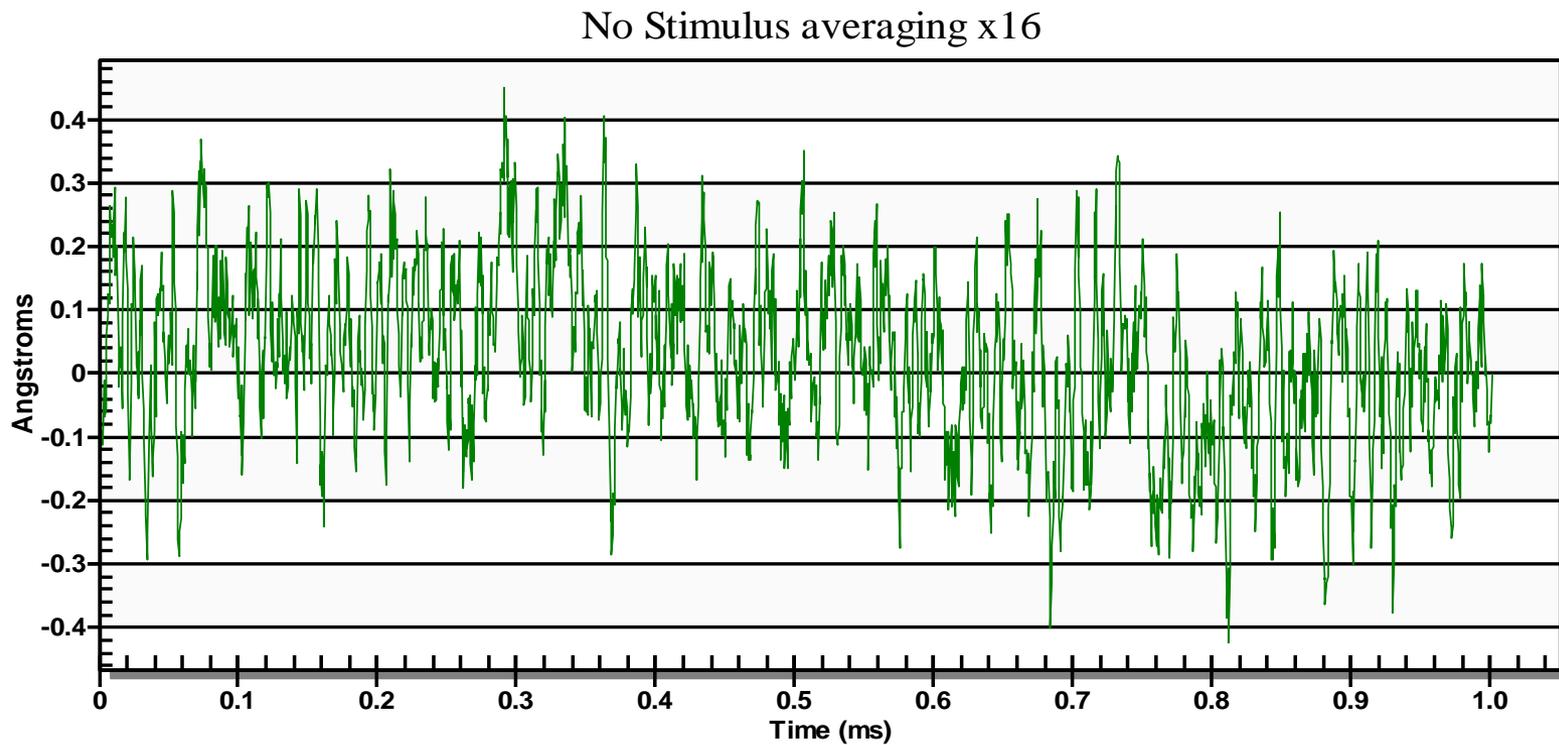


- For this evaluation Radiant used the **Polytec NLV** laser which captures displacement at a single point on the sample surface and outputs a real time voltage proportional to the movement of the sample surface.
 - Polytec has since replaced the NLV with the newer *VibroOne* system which operates in the same manner.
- The Polytec NLV and VibroOne have a minimum resolution specified to 0.3 Ångstroms at 500 Ångstroms per volt.
- The Radiant 18-bit testers (Premier II, Multiferroic II, and pMEMS) have a 300μV single-pass noise floor with a minimum voltage resolution of 76.3μV that can be reached using averaging.

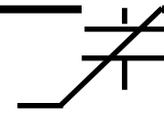


Noise Floor

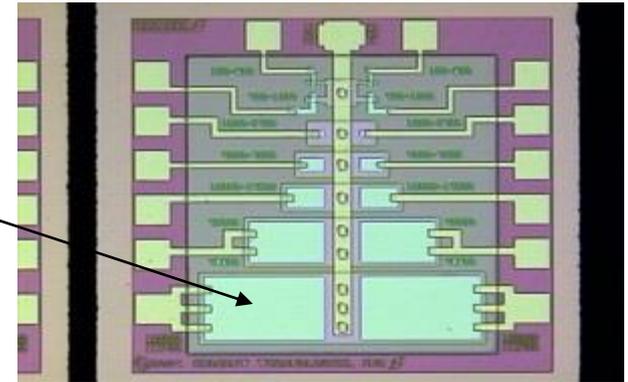
- Averaging 16 measurements with no stimulus yields a minimum real-world resolution of 0.3 Ångstroms.



Sample

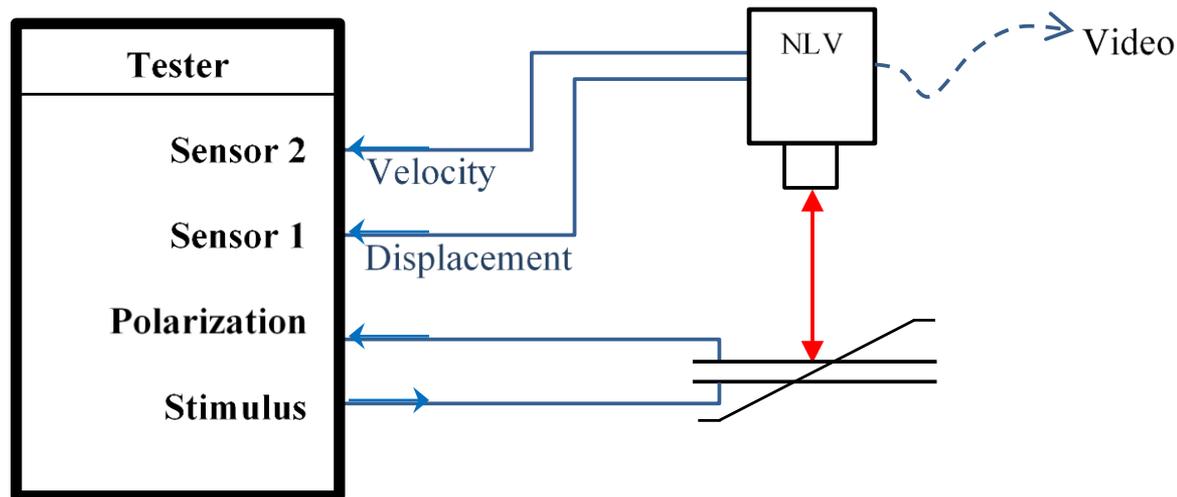


- The capacitor under test had the following physical properties:
 - 4% niobium-doped 20/80 PZT
 - **Thickness = 0.25 μ m**
 - Dimensions = 400 μ m x 250 μ m
 - Platinum top and bottom electrodes
 - Full integration with glass passivation above the capacitor
 - Chrome/Gold probe pads and traces



Test Configuration

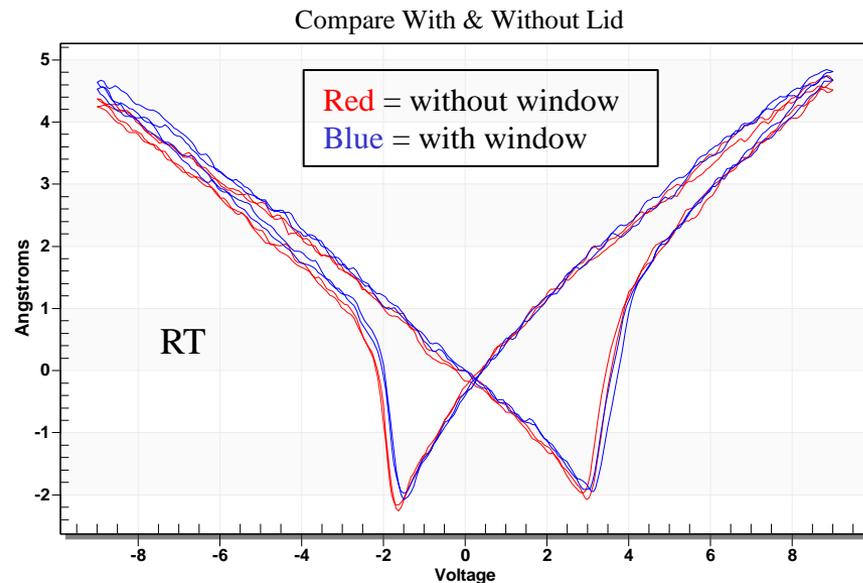
- Each Radiant tester has four measurement channels that captures the voltage across the sample, the polarization generated by the sample, the vertical “piston” displacement of the sample surface (clamped d_{33}), and the surface velocity.



Thermal Test Configuration

- The Linkam HFS600E-P, Linkam LTS420E-P and the Instec HCP612PG fit beneath the NLV on its MSA-500 fixture.
 - For cryogenic measurements, the HFS600E-P and LTS420E-P are rated to -195°C while the Instec HCP612PG is rated to -190°C .
 - For high temperatures, the Linkam HFS600E-P and Instec HCP612PG are rated to 600°C while the Linkam LTS420E-P reaches 420°C .
 - All three have built-in micropositioners connected to external BNC connectors.
 - The chambers were mounted on an X:Y:Tip:Tilt table on the base of the laser.

The sapphire optical windows in the chambers do not seem to affect measurement accuracy.

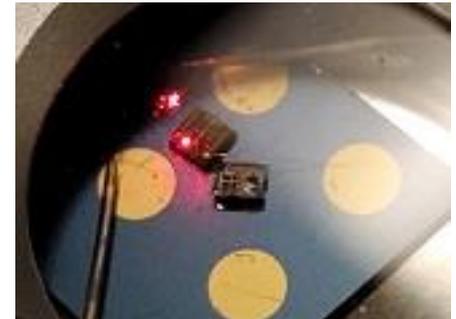
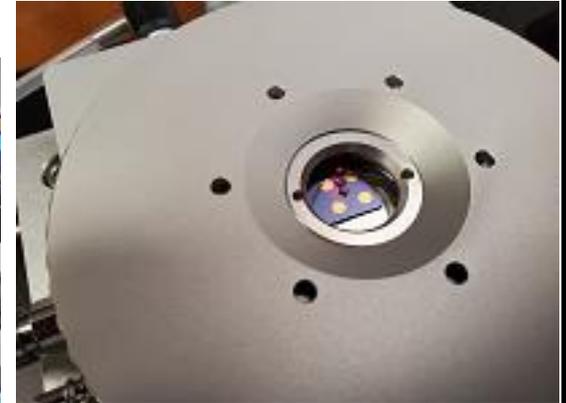


Integrated Test Station

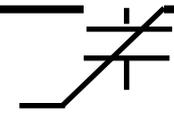


Thermal chamber courtesy of Linkam Scientific Instruments

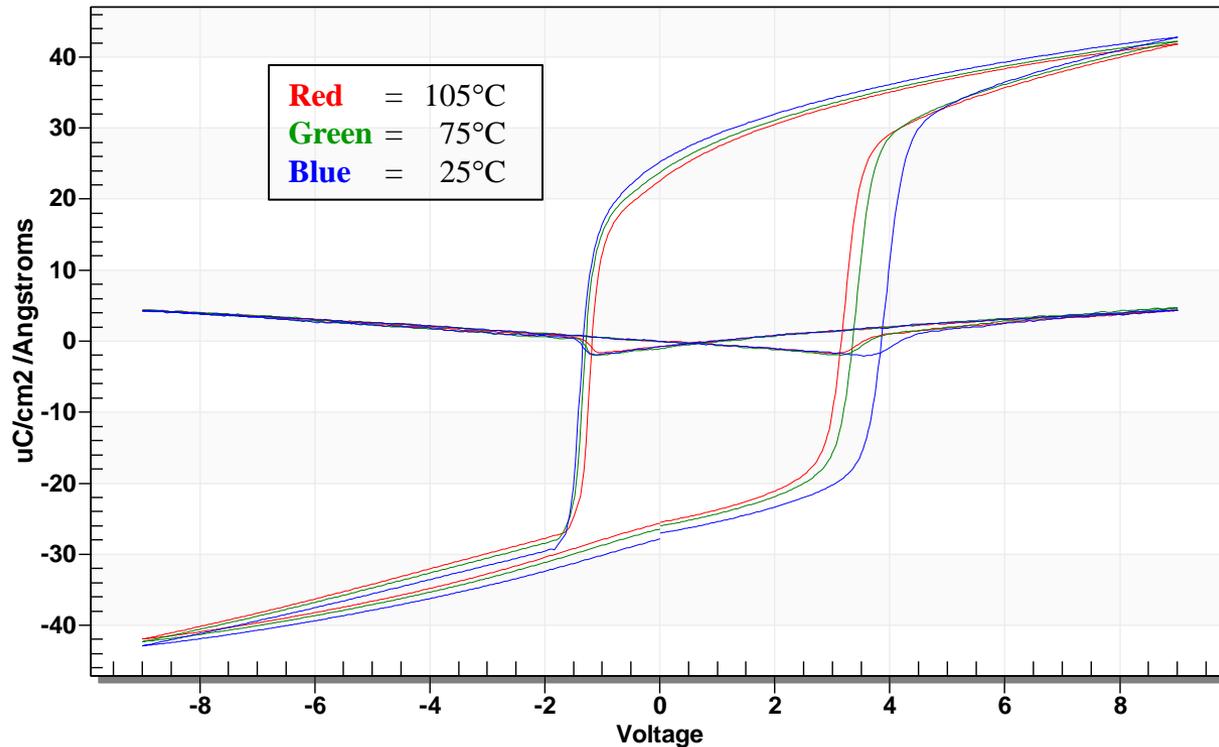
Measurements were taken as shown above with no vibration isolation or turbulence barriers though both are recommended.



Results vs Temperature



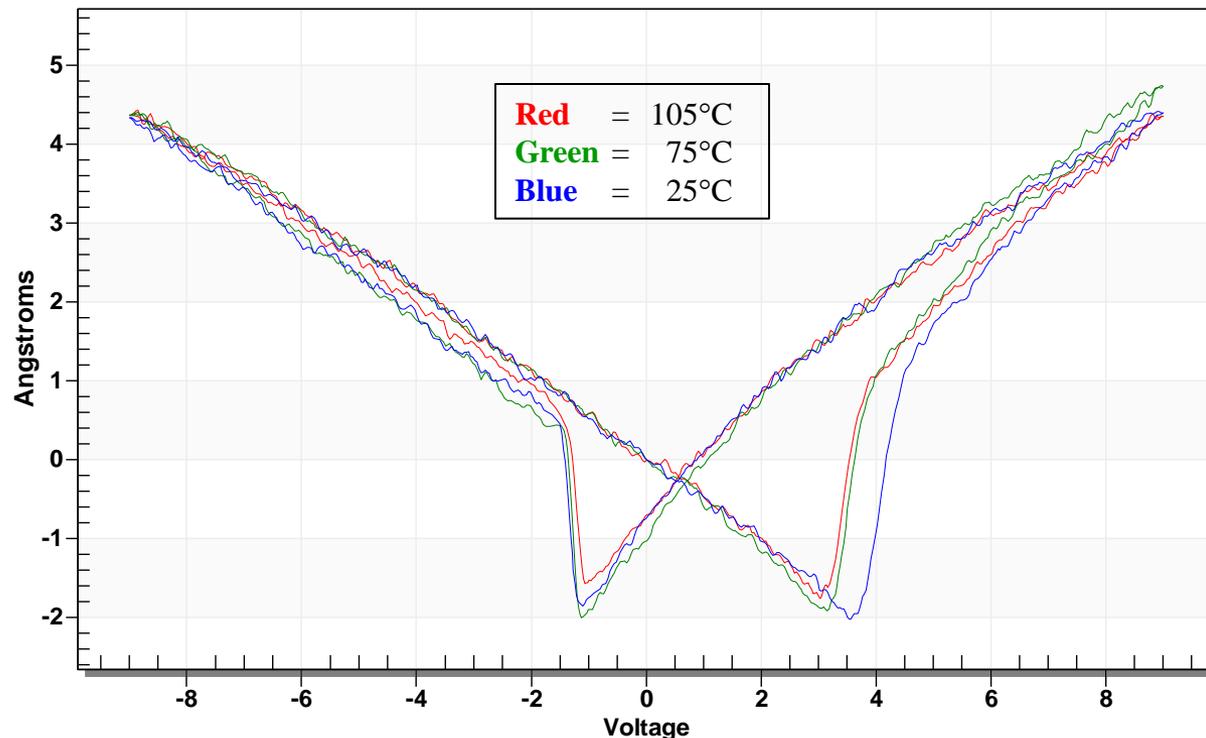
Piezo vs Temperature
[Radiant Type AC BLUE in Linkam Chamber]



Measurement frequency 5kHz in sealed temperature chamber. Notice the change in coercive voltages with temperature for both polarization and piezoelectric butterfly loops.

Butterfly vs Temperature

Piezo vs Temperature
[Radiant Type AC BLUE in Linkam Chamber]

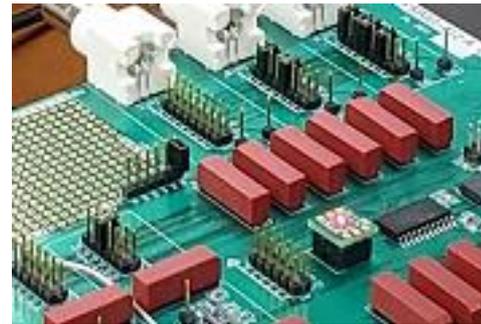
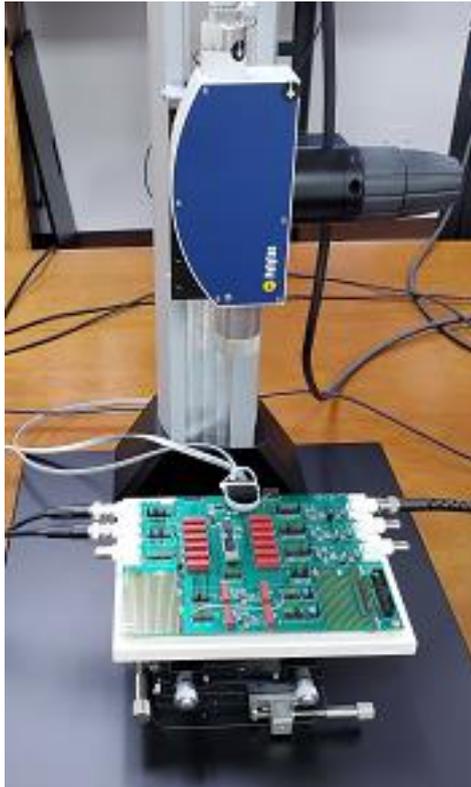


*The tips of the wings do not change much if at all with temperature but the bottom half of the wings which respond to remanent polarization switching do change with temperature
See the reduction in the coercive voltages of the three loops at the higher temperatures.*

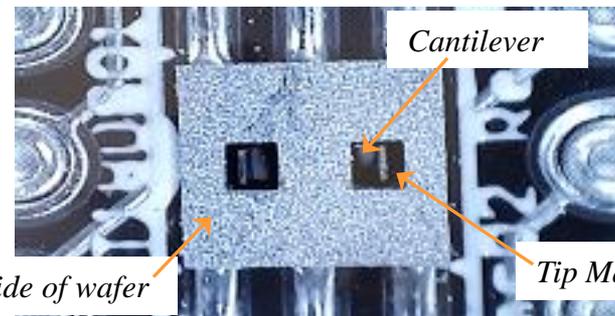
pMEMS Test Configuration

- Other fixtures may be mounted on the X:Y:Tip:Tilt table beneath the laser in place of a thermal chamber.
- Below, a pMEMS die with two wings having tip masses are mounted below the laser on a Radiant's Matrix PCB. Relays route signals during testing.

LDV courtesy of Polytec GmbH



Displacement @ 9V ~ 6 μ m



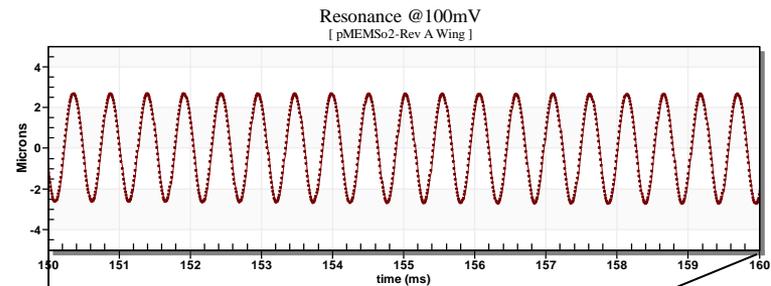
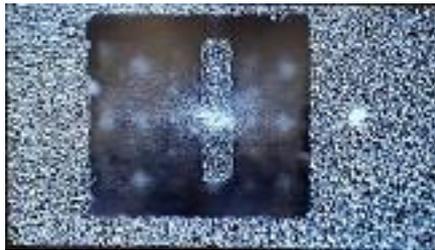
Unpolished backside of wafer

Tip Mass

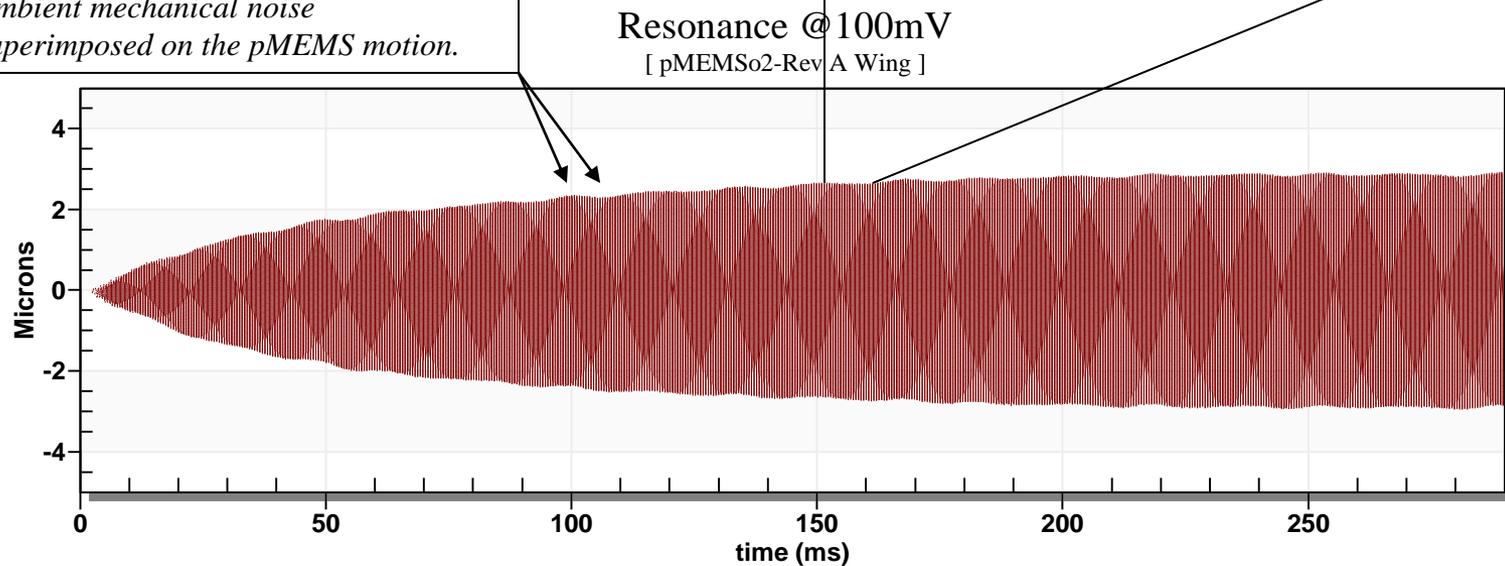
Resonator characterization

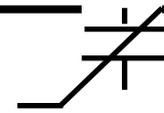
- The NLV has a bandwidth of 2 MHz so it can be used to find mechanical resonances.

Image of coaxial video camera of NLV



*Ambient mechanical noise
superimposed on the pMEMS motion.*





Conclusion

- piezoMEMS technology has progressed such that precise measurements are needed for capturing Ångstrom-level displacements of the surface of clamped thin piezoelectric film capacitors.
- Reproducible measurements of butterfly loops down to 6.5 Ångstroms have been demonstrated.
- Measurements are compatible with commercially available thermal chambers capable of reaching down to cryogenic temperatures and up to 600°C in a single test profile.
- LDVs will also work integrate with other custom sample fixtures that allow measurement of the dynamics of pMEMS structures.

Acknowledgements



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(<https://www.linkam.co.uk/>)

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