Large Mirror Actuators of the 21st Century

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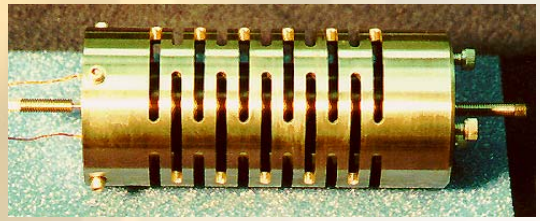
Whether Force or Displacement Actuators

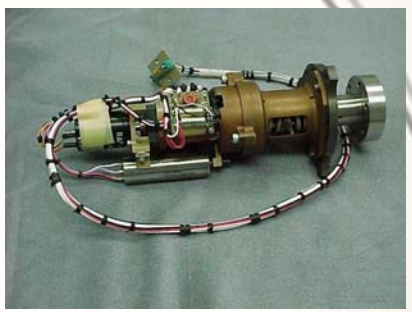
… An Evolution from Ceramics Back To Crystals

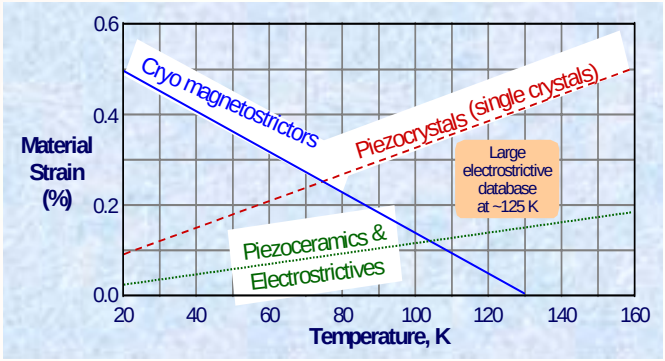
Magnetostrictive Actuator:
TeFe + Superconducting Coil



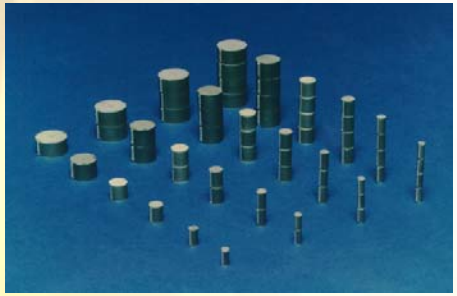
Piezoceramic Inchworm:
Mechanism + Multilayer Stack

Composite Electromagnetic:
Stepper Motor Coarse + Ceramic Fine



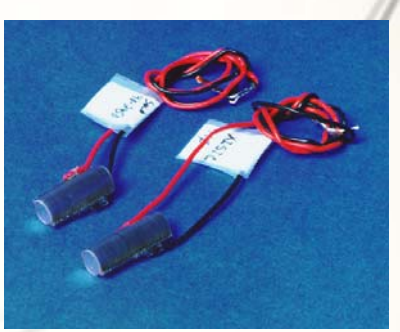


Electroceramic Actuators:
Multilayer Cofired Stacks



Piezoelectric Single Crystals:
Multilayer Bonded Stacks

Electroceramic Actuators:
Multilayer Bonded Stacks



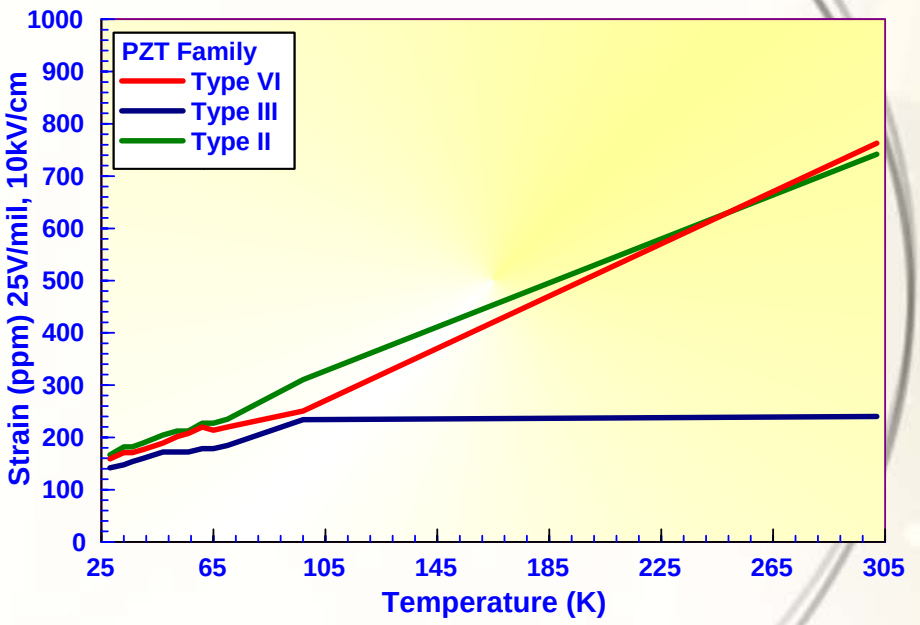
Solid State Ferroelectric Materials

Dimensionally Stable Precision Motion

Hard and Soft Piezoelectric Actuators

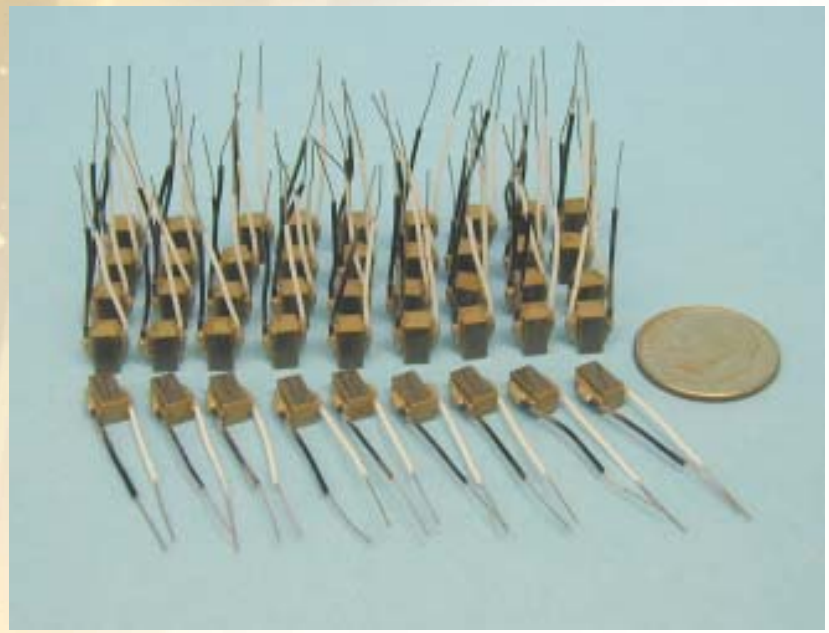
… Poled Ceramics Subject to Creep, Aging, Hysteresis

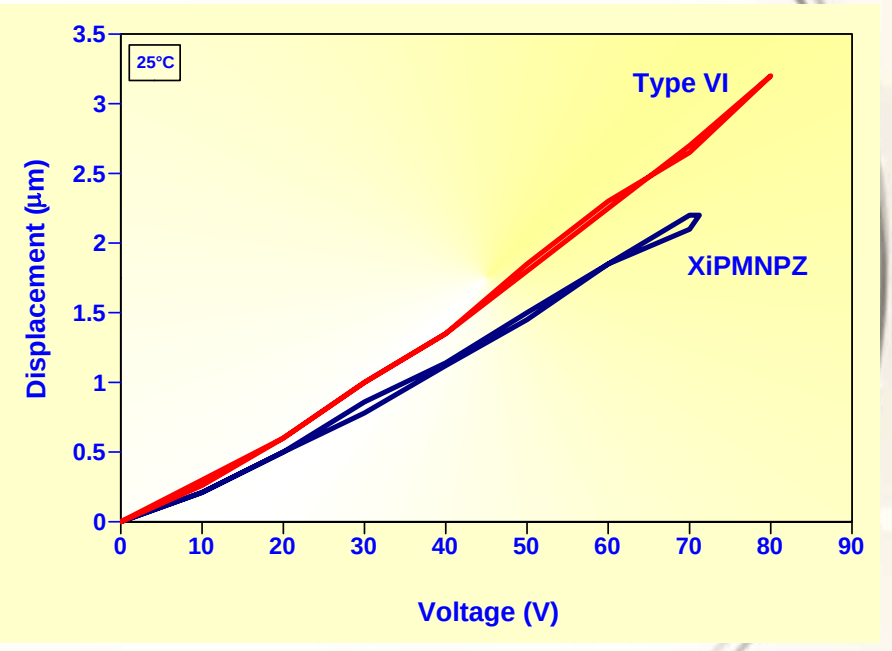
- Lead-Zirconate-Titanate (PZT) Based Materials
- High Curie Temperature between 130 to 300C
- Induced Strain via Polarization Orientation
- Broad Temperature Response
- Hard Ferroelectric Lower Strain with Reduced Hysteresis
- Soft Ferroelectric Higher Strain with Increased Creep and Hysteresis



Cofired Piezoelectric Actuators

$Pb(Zr,Ti)O_3$ and $Pb(Mg_{1/3}Nb_{2/3})O_3$-$PbTiO_3$

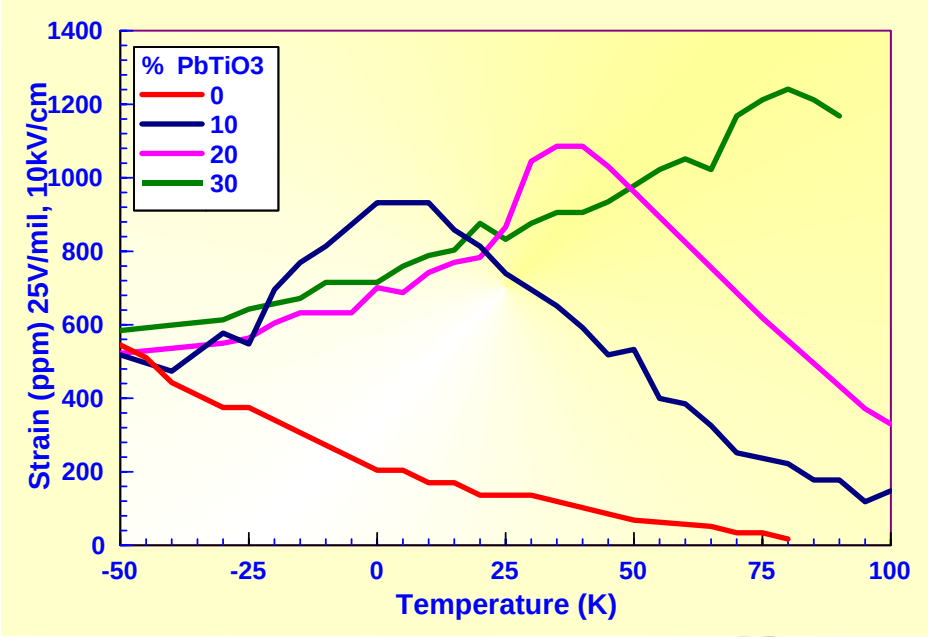




Relaxor Ferroelectrics Tunable Response

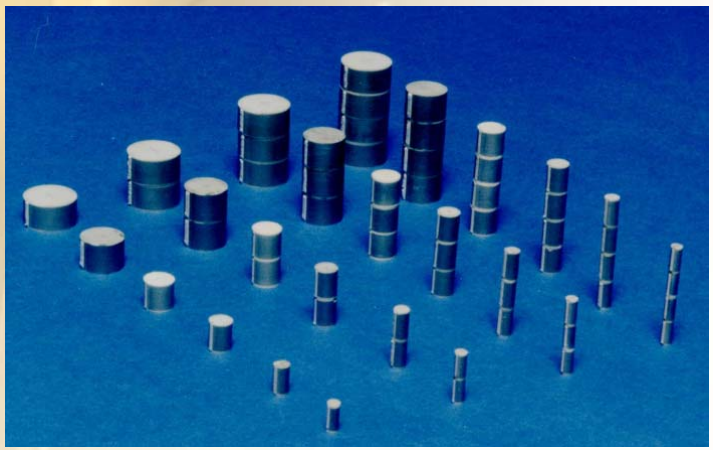
… Phase Change Response Strongly Reciprocal

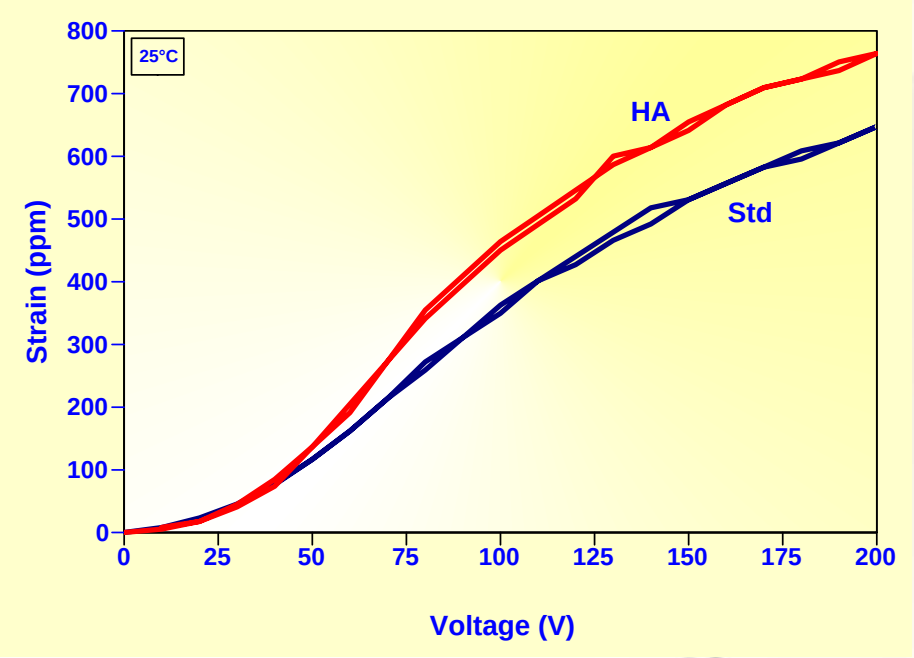
- Lead-Magnesium-Niobate (PMN) Based Materials
- Lower Curie Temperature between 0 to 130C
- Induced Strain via Unit Cell Change
- High Elastic Modulus and Minimal Dielectric Loss
- Dimensionally Stable with Minimal Hysteresis and Creep
- Lead Titanate Dopant Shifts Curie Temperature
- Enables Tuned Response Specific to Application



Xinξtics Cofired Multilayer Actuator Lines

… *Electrostrictive* $Pb(Mg_{1/3}Nb_{2/3})O_3$ *– based*



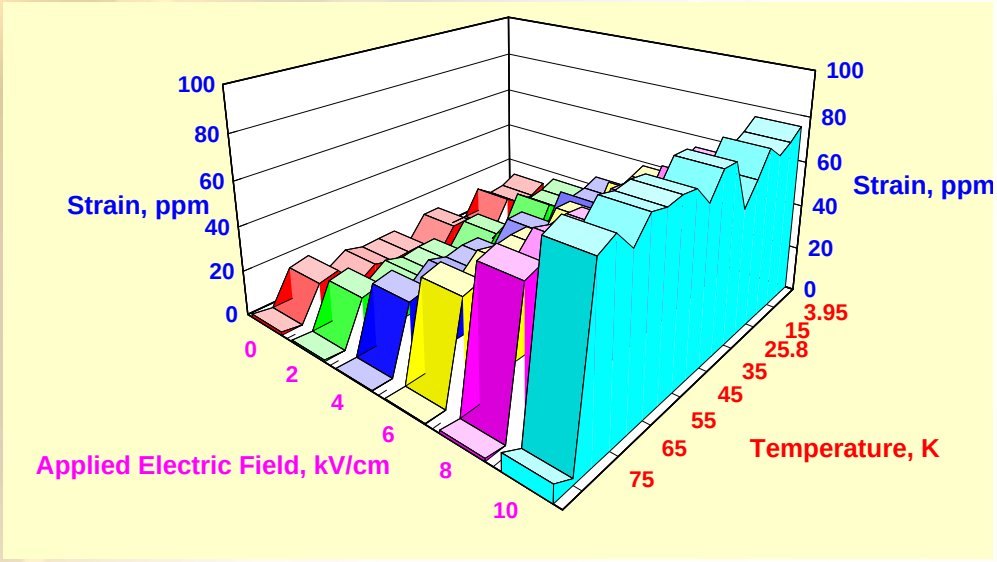


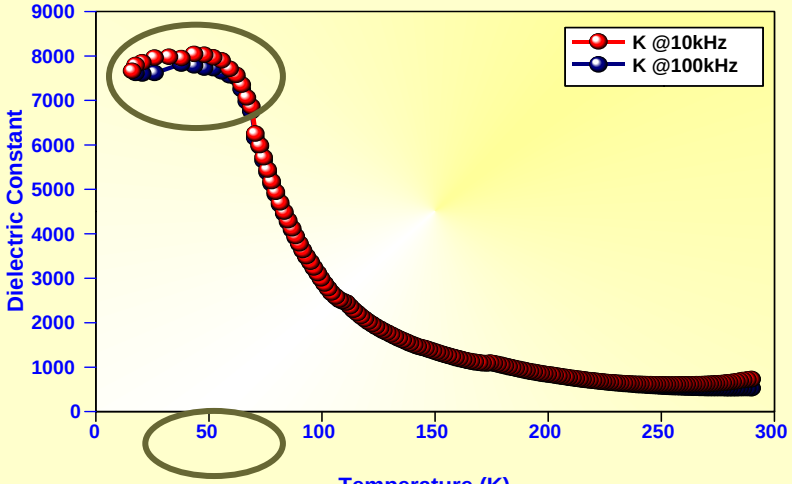
Cryoceramic Ferroelectric Materials

Engineered Materials for Extreme Conditions

Stroke Proportional to Dielectric Constant

… Enables Fast Track Material Tailoring

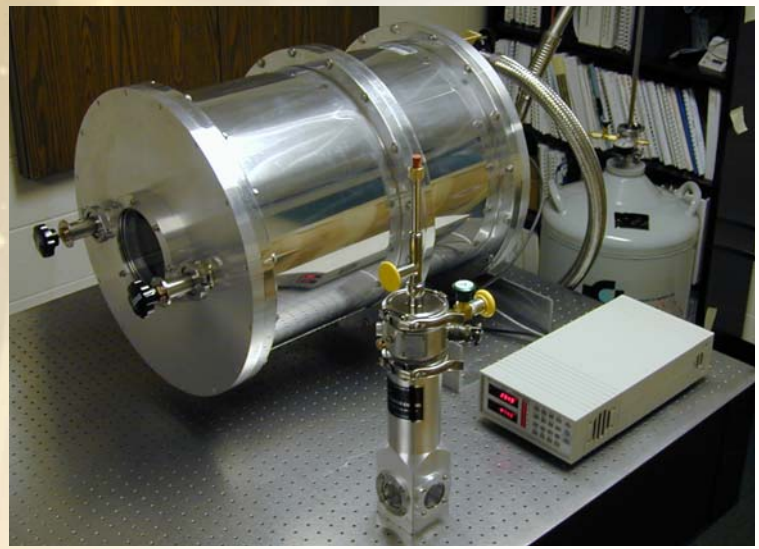


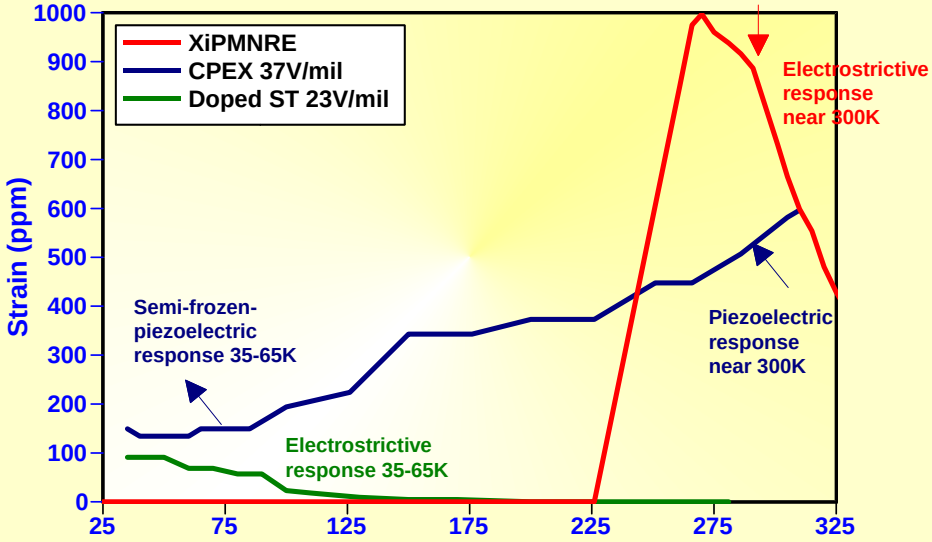


* Near Linear Dielectric Constant and Strain Observed between 25-65 K

Material Formulated for Ambient and Cryo

… High Dielectric Constant Correlates to Strain Response

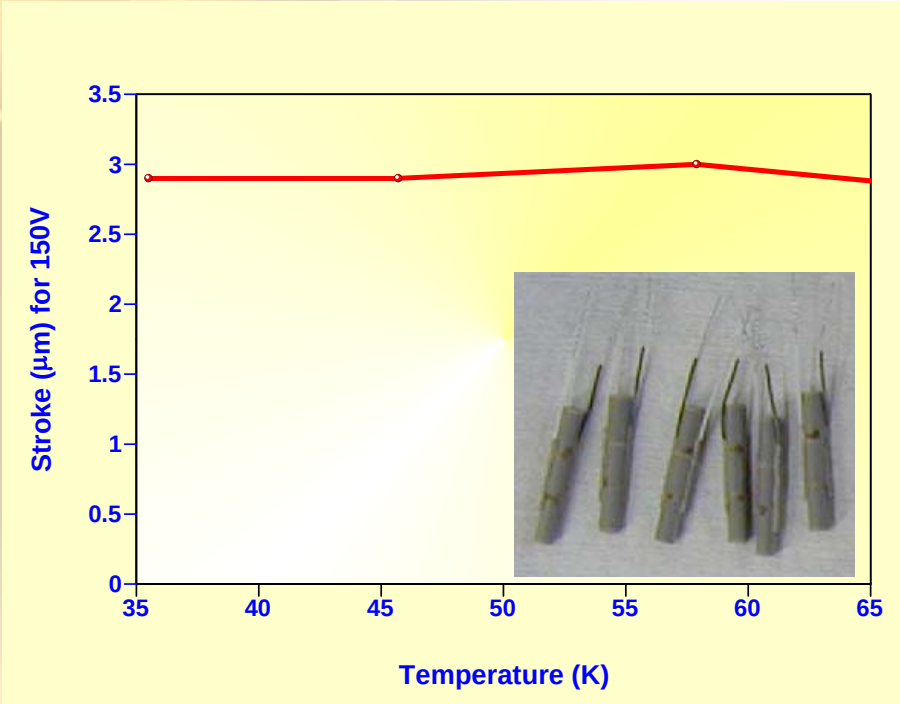




* Cryo Test Facility Build In-House to Test both Actuators and DM

JWST Cryogenic Actuator Evolution

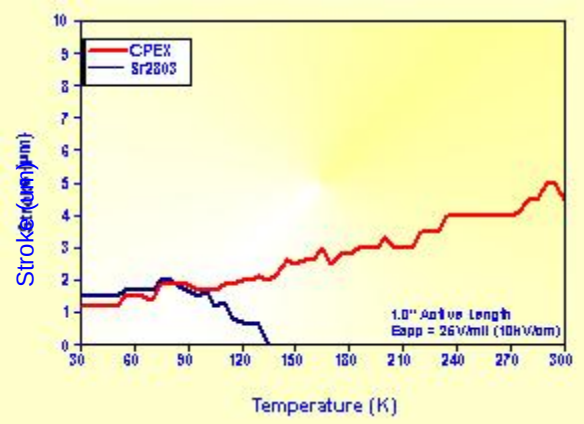
… Cofired Process Developed in Two Years



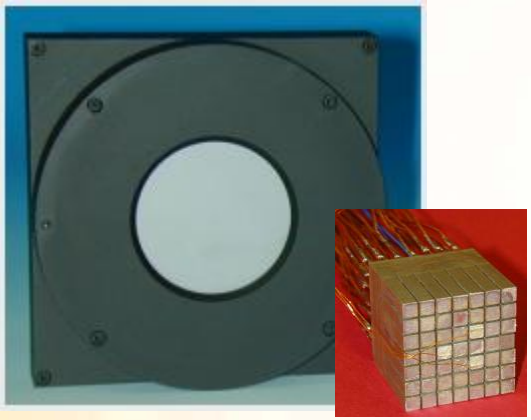
- Xinetics Cryogenic Cofired Actuators Electrically Cycled between 35 & 65K over 10x
- Free Strain Very Linear from 35 to 65K
- Broad Temperature Response with Dimensionally Stable Behaviour
- Transfer Function Shown for JWST 349-Ch Cryogenic DM

JWST Cryogenic Deformable Mirror

… Cryogenic Deformable Mirrors with Cofired Actuators

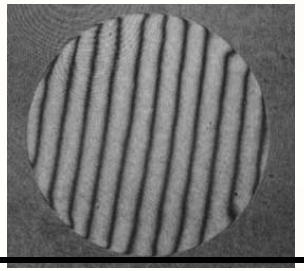


Cryoceramic Materials



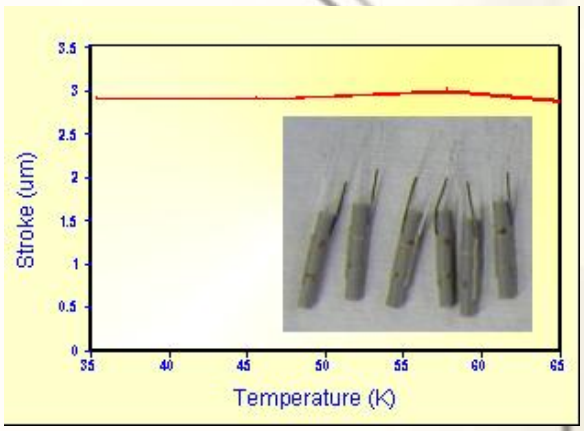
349-Ch Cryogenic Modular DM
Weighs 3 lbs

349-Ch Cryogenic
Discrete Actuator DM



After Polishing Stats

- **λ/5 p-v**
- **≤20 Å rms**
- **≤ 60/40**



Discrete, Cofired Actuator Set

XiMUX Set and Forget Electronics

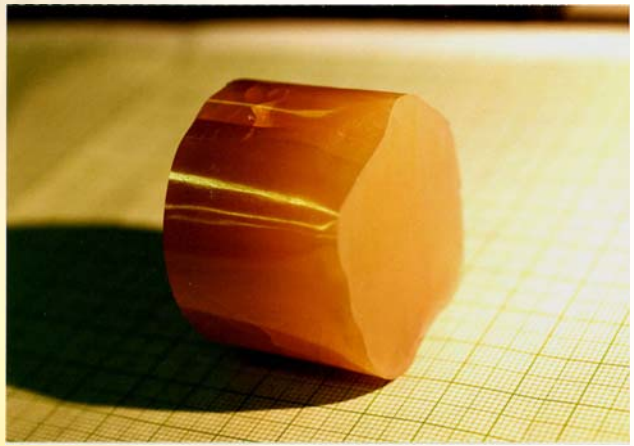
Single Crystal Ferroelectric Materials

High Strain Broad Temperature Response

Single Crystals Enable High Authority

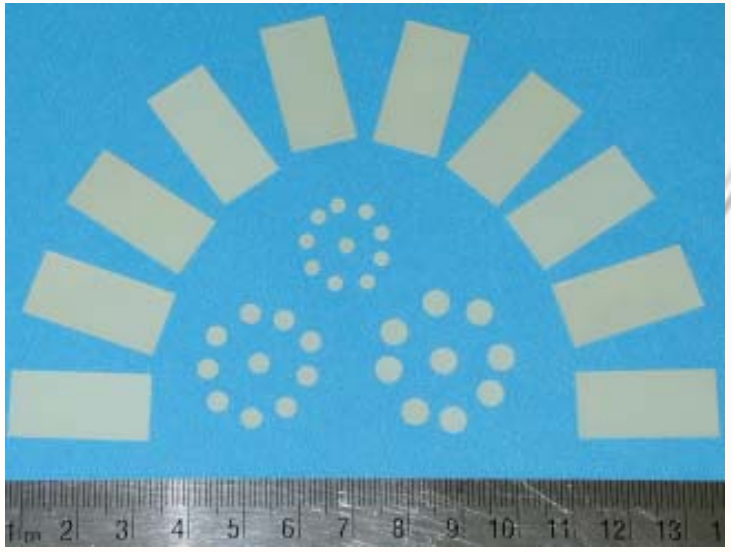
… Crystal Processing Scaled to Large Formats

1.5-Kg Single Crystal Boule



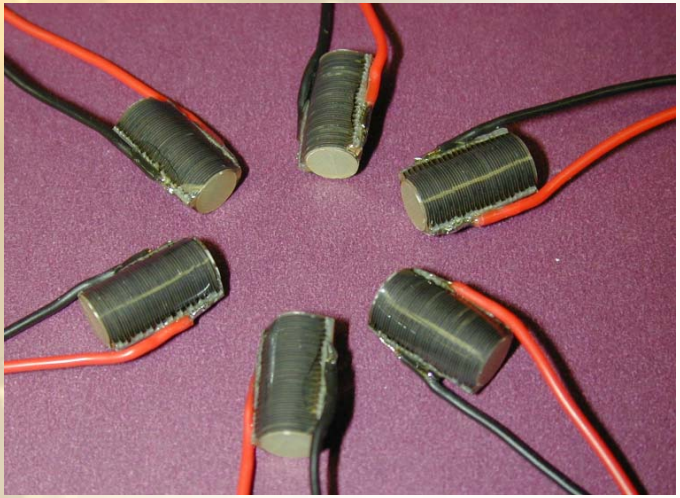
500-g Single Crystal Boule

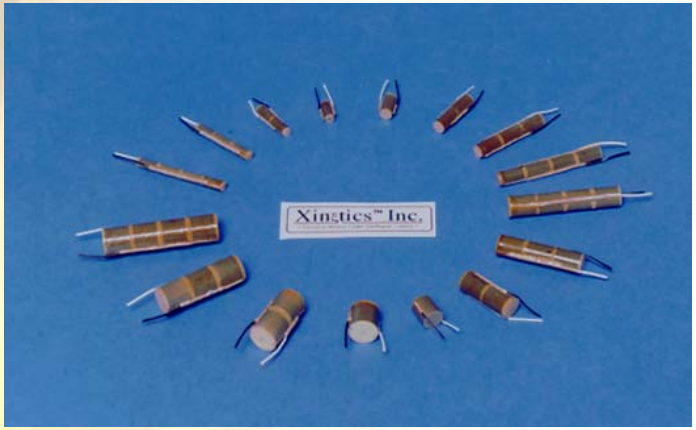
Various Shape for New Device Development

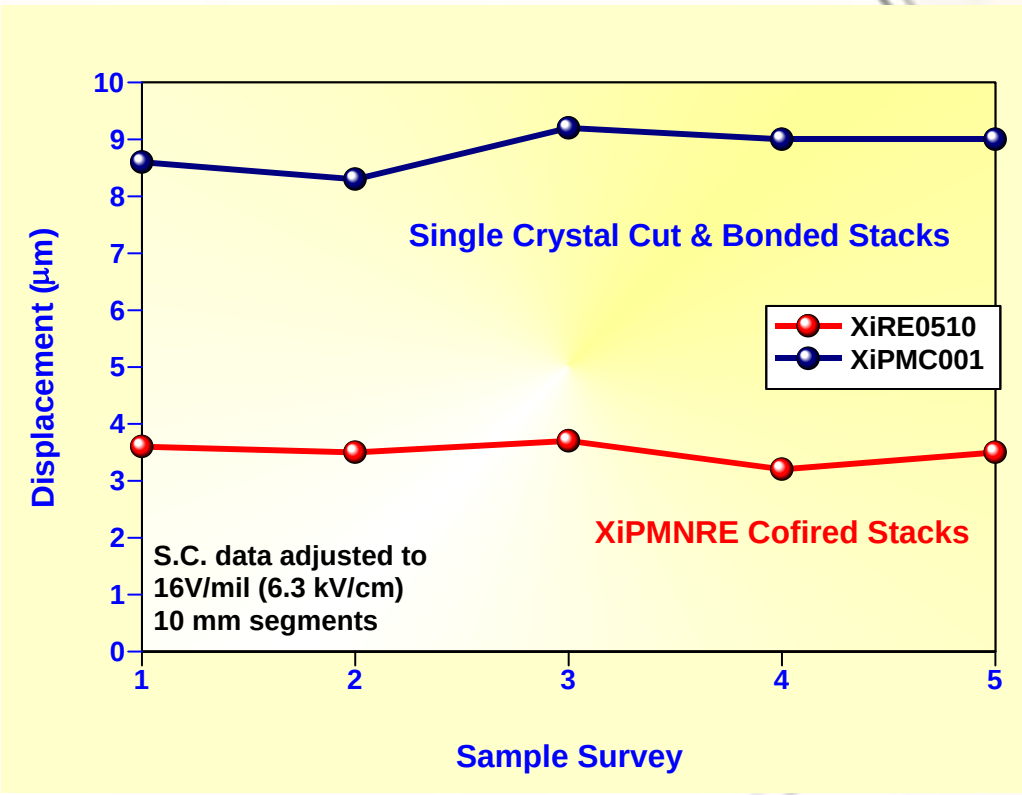


Single Crystal Stacks Provide 2x Increase

… Epoxy Bonded Multilayer with BeCu Mesh Electrodes

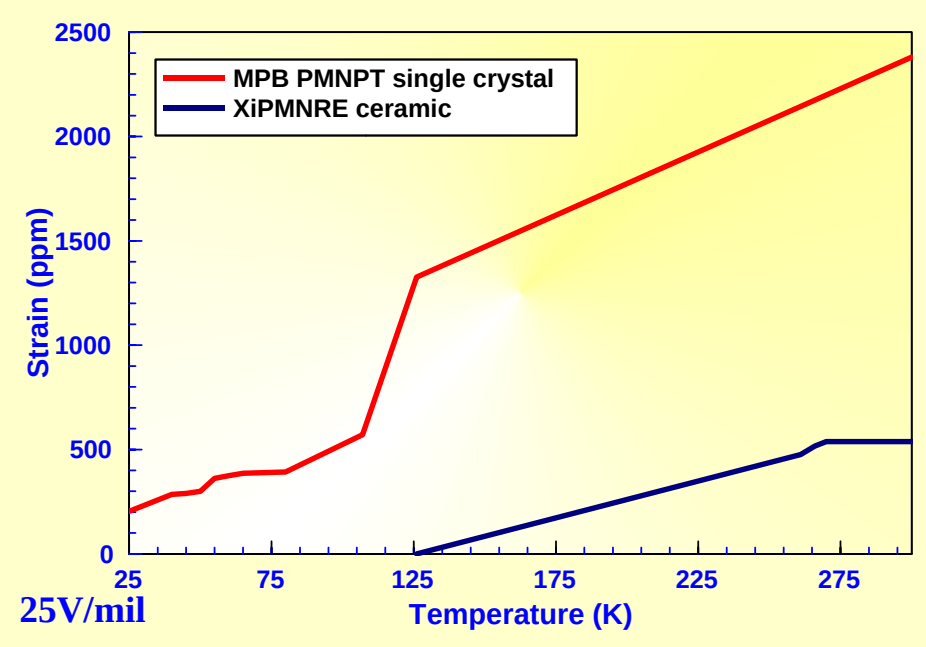


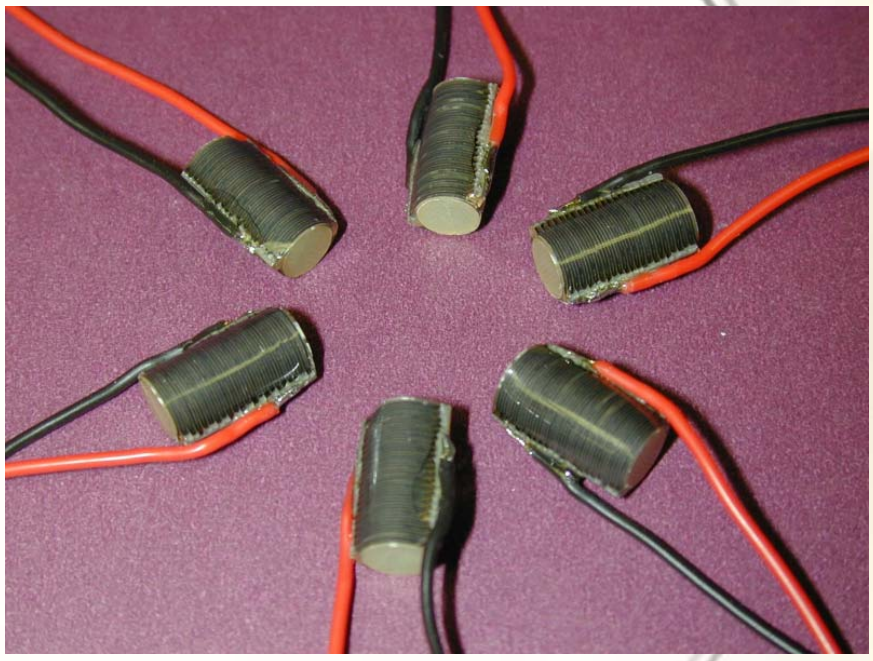




Single Crystal Stacks 300 to 25 K Performance

Cryo-S.C. strain comparable to ceramic 300 K strain





Xinetics has built many single crystal stack demonstrating reproducible strain performance.