

Novel Actuator Applications for New High Drive Piezoceramic Materials

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PiezoTechnologies

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Introduction

- Background: 2002 thru Today
- Actuator
 - Market
 - Requirements
 - Design
 - Results
 - Conclusions
- Future Work

Background

- Work on New Materials first reported @ 32nd UIA Symposia, 2002 by Liufu et al
- Brosch et al reported latest work @ ISTU, Oct. 2005 on 128 element HIFU P.A.
- Chopra, et al Sunnybrook and Women's College, 2005, Transurethral Prostate Therapy

Liufu 2002

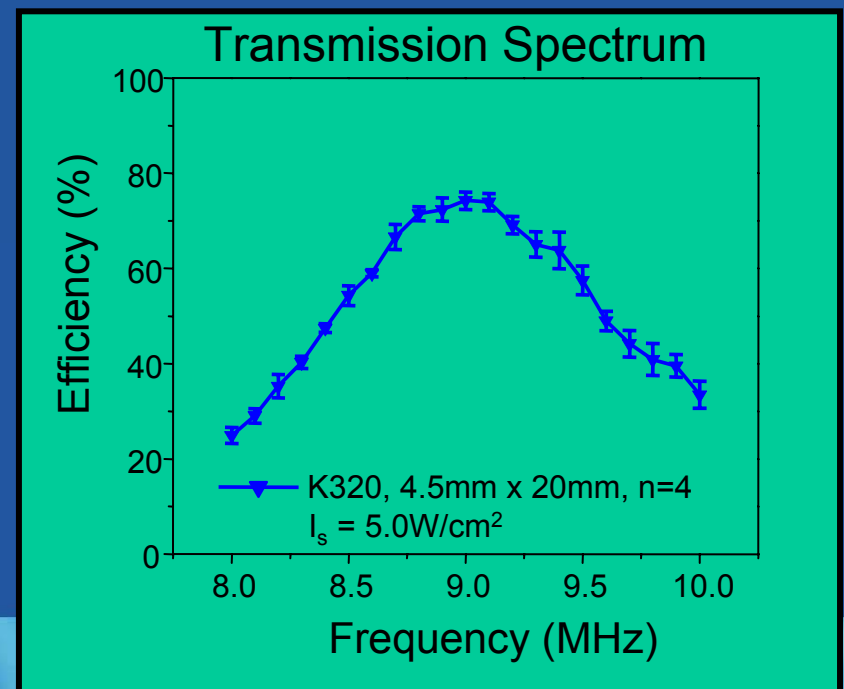
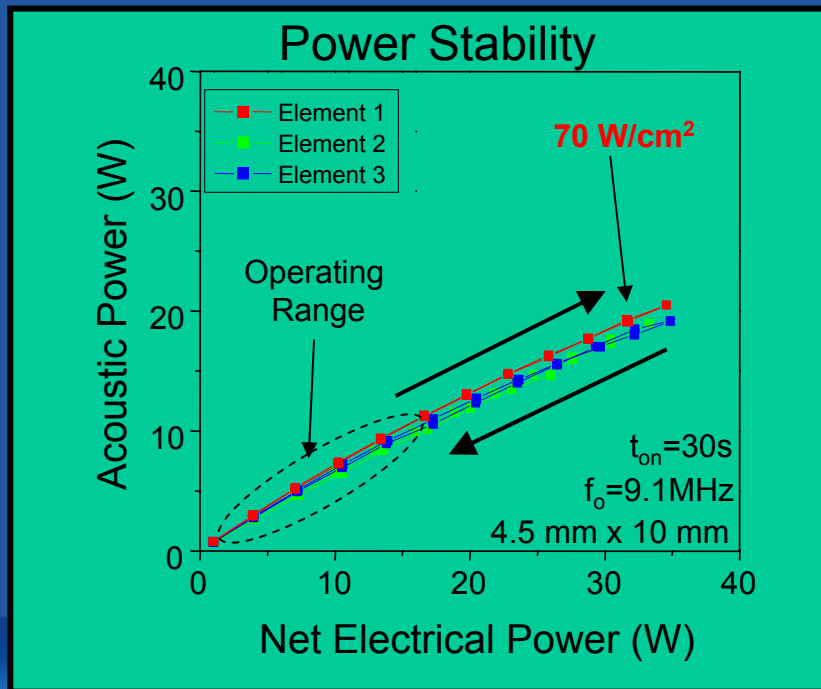
- **Conclusions**
- A new material is being developed that improves on current Navy I equivalent materials.
- The new material has equal or better performance in the tested high power transducers.
- Higher d_{33} value should allow for higher displacement at high power.
- This ceramic may be applicable for high power composites and therapeutic array work, as well as industrial high power applications.

Brosch 2005

- K320 is superior to standard high power PZT's for HIFU in terms of efficiency and power handling capability.
- K320 is easily fabricated into complicated geometries and integrated into HIFU arrays.
- The material is functional in a HIFU array in an in vitro setting

Application: Transurethral Prostate Thermal Therapy

- Multi-element transducers: small size (5mmx10mm), high power ($P_a \sim 10W$)
- Limited space for cooling
- Continuous application of power (up to 20min)
- Characterized prototype devices (K320) with radiation force measurements



Rajiv Chopra, Michael Bronskill, et al.

Sunnybrook & Women's College Health Sciences Centre, Toronto, Canada

Miniature Piezo Fan

Market Drivers

- Increased Power Requirements
- Smaller Packages: Handhelds, Portables
- Greater Heat Dissipation Needs
- Very Low Power Consumption
- Very High Annual Volumes: $>10^9$ / yr
- Target Spot Cooling Applications

Miniature Piezo Fan

General Requirements

- Low Voltage Source: 3 to 12 Vdc typ.
- Low Power Consumption: <100 mW
- Survive Reflow Process: ≤ 300 C, 90 Sec
- Very Small Footprint: < 38 mm L
x 12 mm W x 2 mm H
- Temperature: - 60 to +100 C

Miniature Piezo Fan Cooling Technologies

- PiezoFans: Single layer, Series/Parallel Bimorphs
- Heat sinks / Thermal Conductive Greases
- Heat Pumps/ Radiators
- Thermoelectric Coolers
- Axial Fans
- Evaporative Spray

Miniature Piezo Fan

Some Equations

- Series BM, $D = 1.5 * d_{31} * V * (L^2/t^2)$
- Parallel BM, $D = 3 * d_{31} * V * (L^2/t^2)$
- $C_m = (4/Y_{11}) * (L^3/(W * t^3))$
- $F_b = D/C_m$
- $M = (d_{31} * E)/Y_{11}$, $E = V/mm$

Miniature Piezo Fan

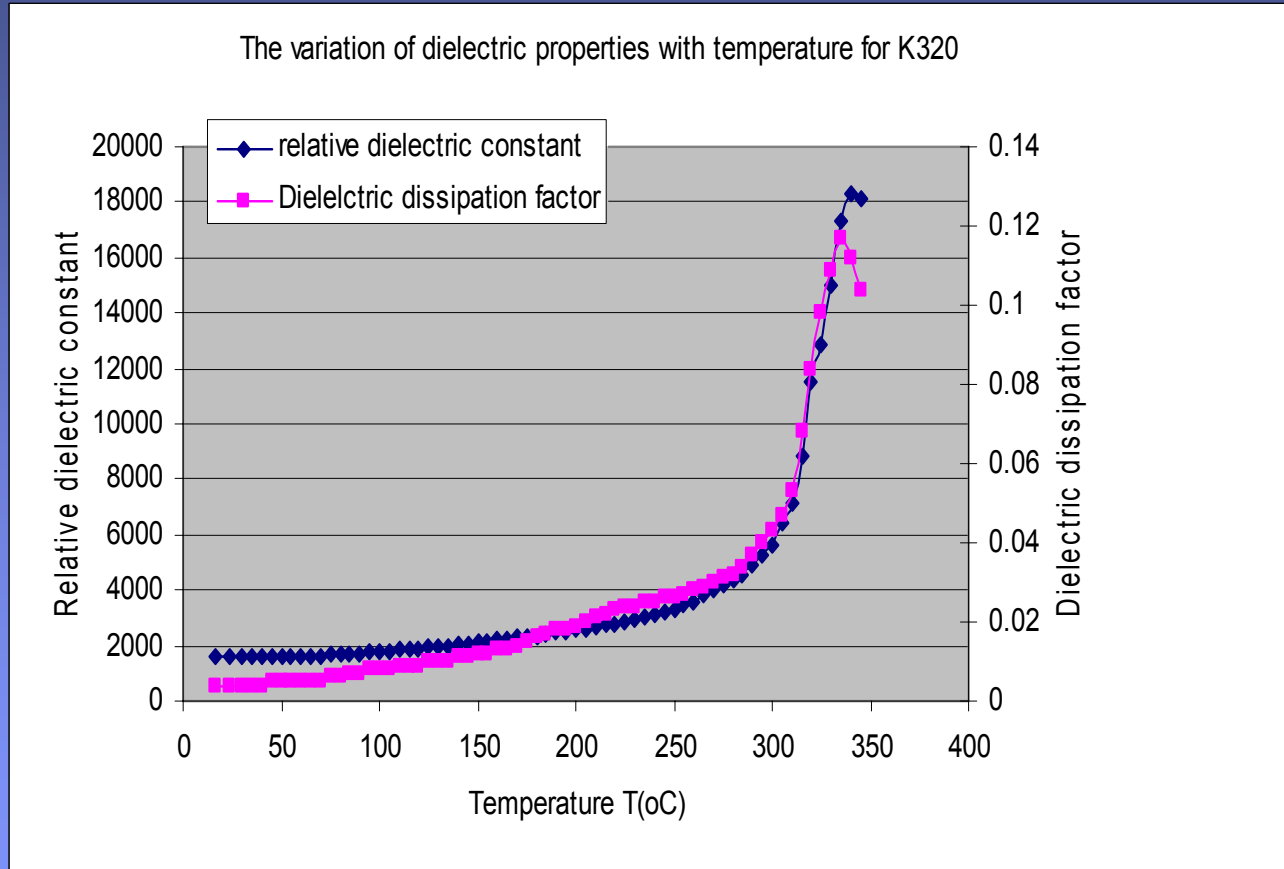
Some More Equations

- $V_{tip} = F \times D$
- $A = D \times W$
- $CFM = V_{tip} \times A / 450$

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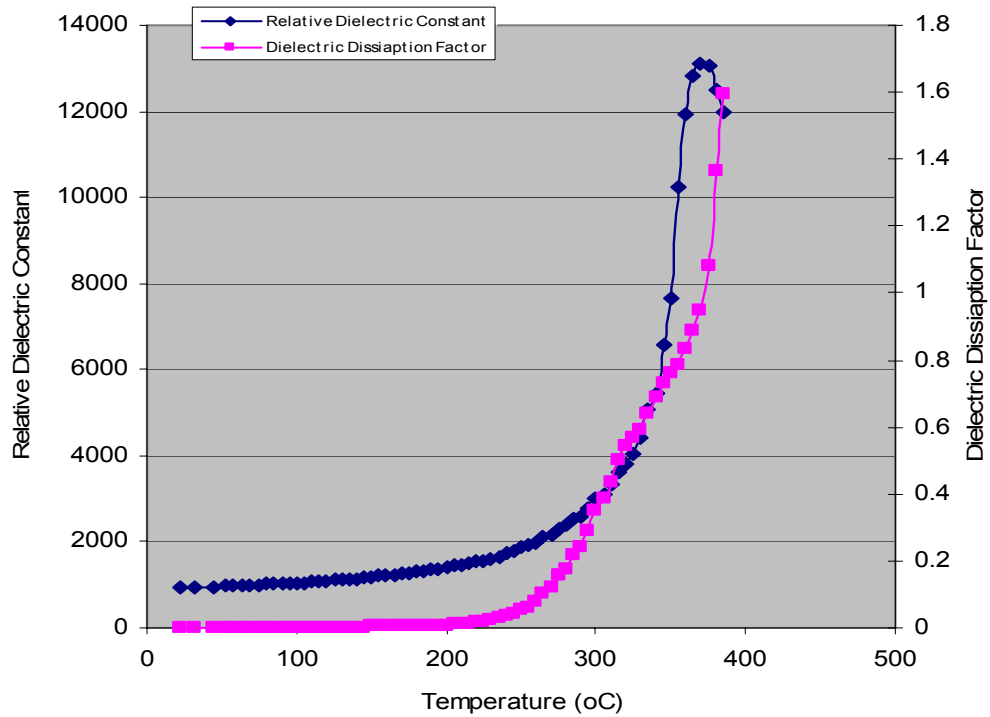
	Qm (planar)	Kp	K31	D31 (pC/N)	ϵ	Dissipation factor	Y11 10^{10} N/M ²	E (kVrms /mm)	Tc (°C)	M
K278 (Type III)	1000	0.51	0.30	-95	1000	0.004	9.9	1	300	9.6
K270 (Type I)	800	0.58	0.33	-120	1300	0.008	8.5	.4	325	5.6
*K350 (type II)	75	0.60	0.35	-170	1450	0.015	6.9	.088	350	2.2
*K320	>1500	0.58	0.27	-140	1500	0.003	9.4	1.3	335	19.4
K700 (type VII)	80	0.71	0.40	-290	4000	0.020	7.0	.08	225	6.6

Miniature Piezo Fan



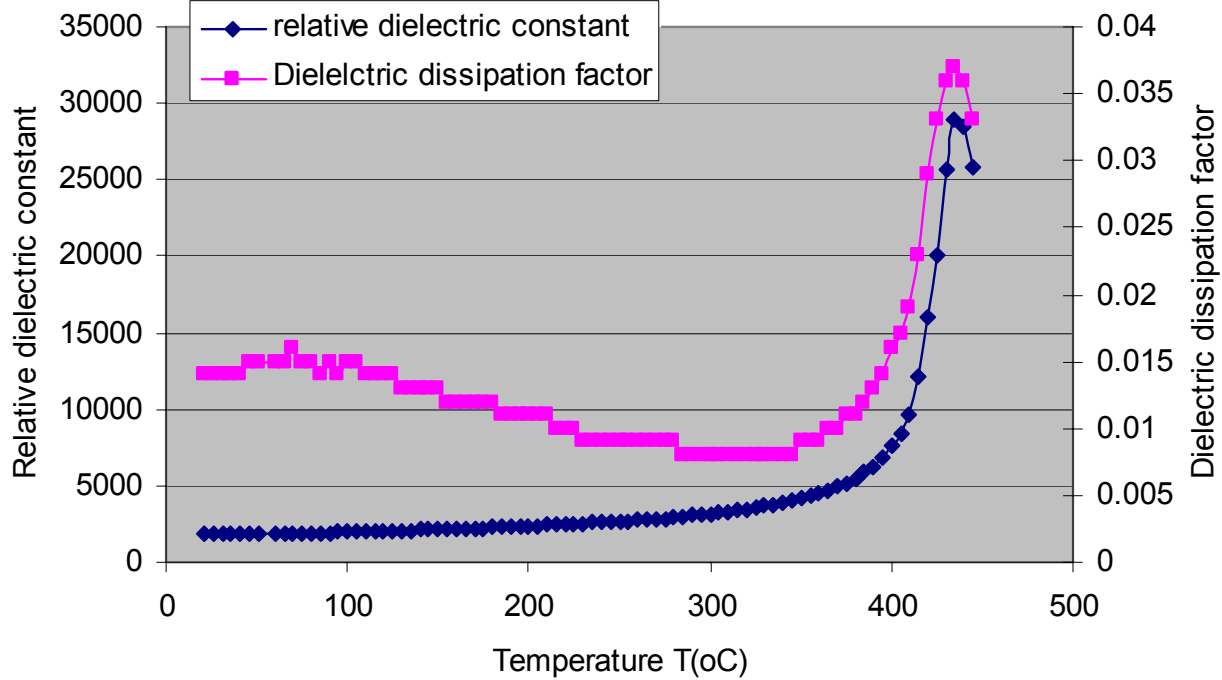
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The temperature dependence of the dielectric properties for K278



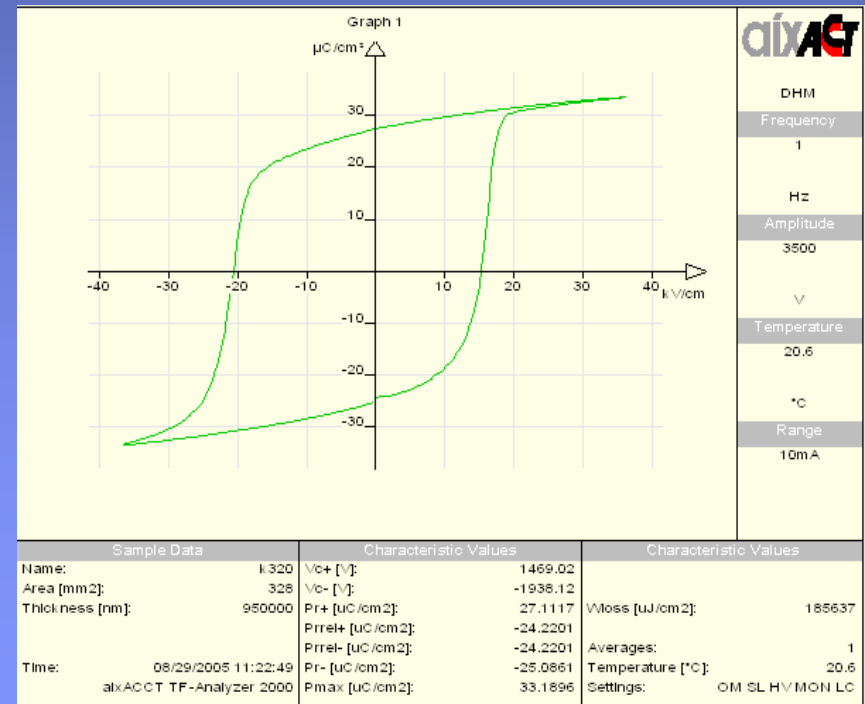
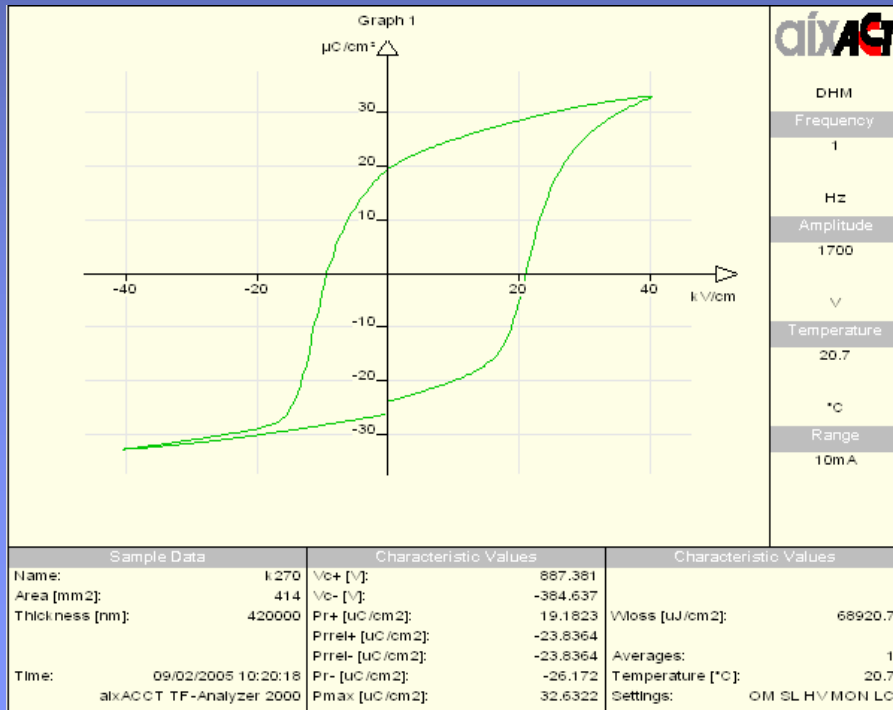
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The variation of dielectric properties with temperature for K350



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Hysteresis Loops at 1Hz show the difference in coercive fields. K320 is closer to ideal. Coercive field for PZT-4 is approximately 1.5kV/mm, K-320 is 1.8kV/mm



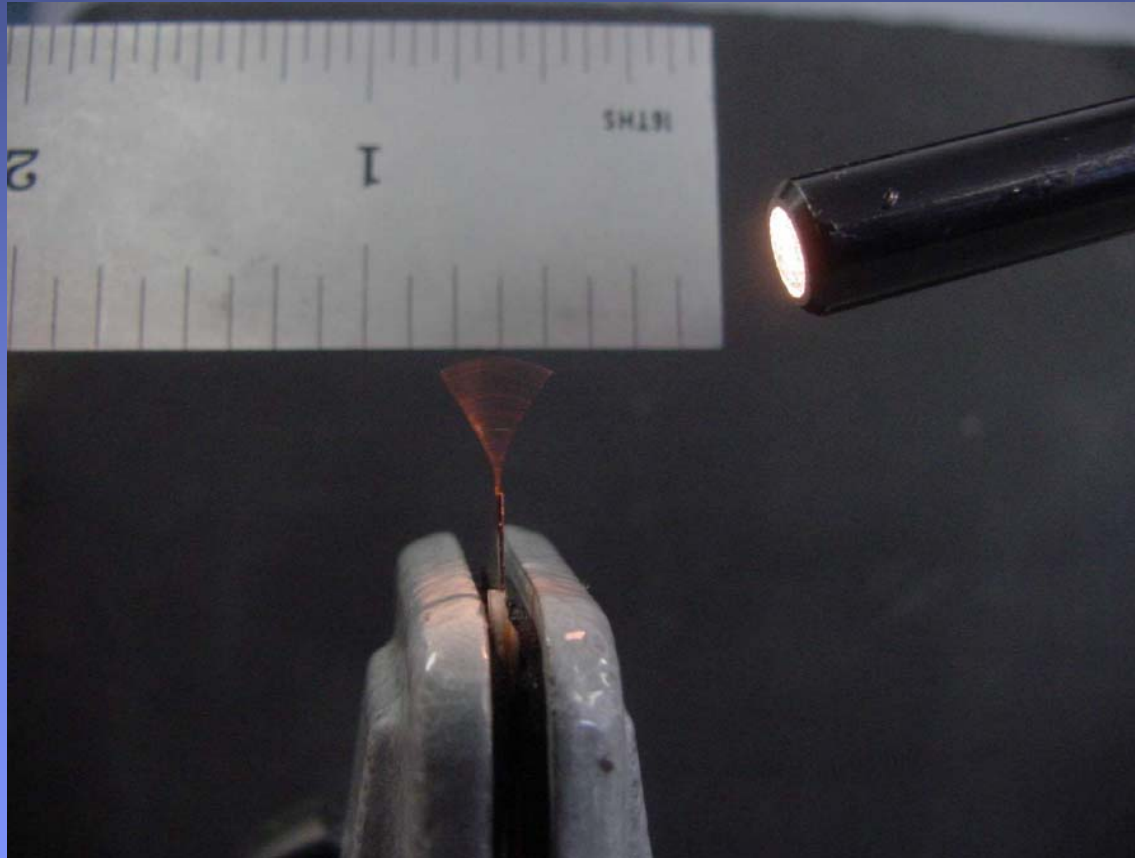
Miniature Piezo Fan

- **Fan Design Requirements**
- **1.27 cm (.50 in)L x .32 cm (.13 in)W x Max blade deflection (D)**
- **Frequency : ≤ 1 KHz**
- **Survive Reflow Temperatures, >260 C, 90 S**
- **Power Consumption: mW's**
- **High Humidity: > 90 %**
- **Operating Life: $\geq 10,000$ hrs over 3 to 20 year periods**

Miniature Piezo Fan Results

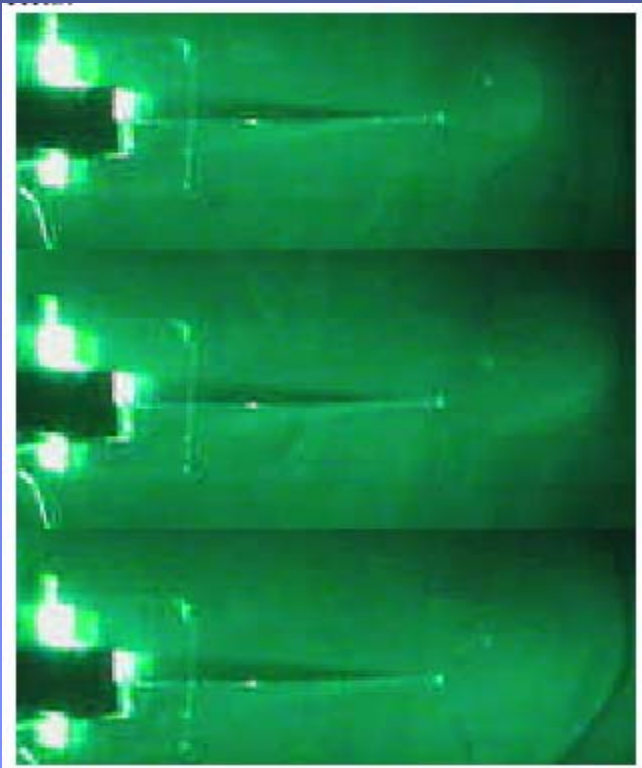
Type	F, Hz	D , mm	Vtip, mm/s	CFM	%, D/L
1.	340	5	1700	.02	39.4
2.	833	5	4160	.05	39.4
3.	202	8	1616	.18	31.5
4.	165	6.5	1070	.093	25.6

Miniature Piezo Fan



Miniature Piezo Fan

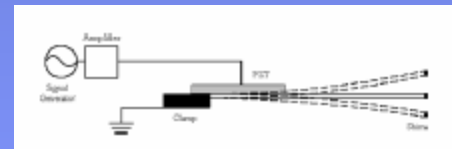
Photos courtesy CTRC, Purdue University



Edge-on view of piezoelectric fan



Fluid flow visualization from piezoelectric fan



Schematic of piezoelectric fan design

Miniature Piezo Fan Conclusions

- K320 is a viable alternative to soft piezo's for small actuator applications
- Can achieve high tip displacements and flow rates
- Can potentially reduce input power requirements to achieve this
- Can meet environmental requirements

Miniature Piezo Fan Future Work

- Design an even thinner bimorph to operate at lower voltage, yet maintain D, i.e. CFM
- Integrate with SMT connector and Drive Circuit For DC input
- Validate Operational Parameters and Survivability

Additional Work

- High Output, 260 C Use Audio Tone Generator
- 1000 W Langevin Transducer, < 40 mm AED
- < 12 mm AED, High Displacement Langevin
- HIFU Arrays and Single Element Transducers
- Several Patents applied for covering some or all of the technology being developed
- Licensing or Acquisition of IP for certain markets available

Miniature Piezo Fan

Acknowledgements

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- Dr. Suresh V. Garimella, et al , CTRC, Purdue University