First Bent-Core Nematic Liquid Crystal Elastomer: Characterization and Giant Flexoelectric Response

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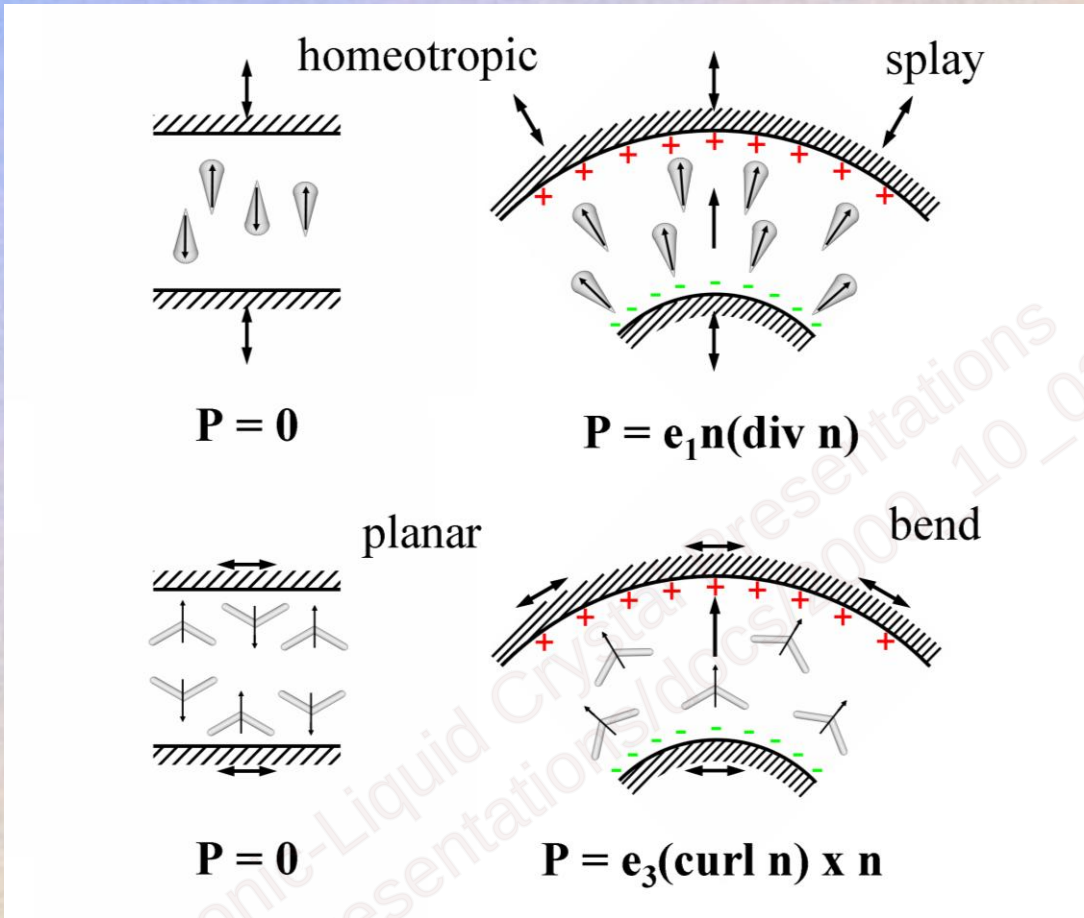
Purpose

- Synthesis and Production of Bent-Core Nematic Liquid Crystalline Elastomers (BCLCE) see Raphael Verduzco et al. talk from Thursday Bent-Core LC Elastomers and Side-Group LC Polymers Using Reactive Bent-Core Mesogens
- Study the Properties of a BCLCE Including Giant Flexoelectricity (e_3~ 30nC/m)
- Create a simple demonstration of a Giant Flexoelectric Generator



$$\vec{P}_f = e_1 \vec{n}\ \ div\,\vec{n}\ \ + e_3\ \ curl\,\vec{n}\ \ \times \vec{n}$$

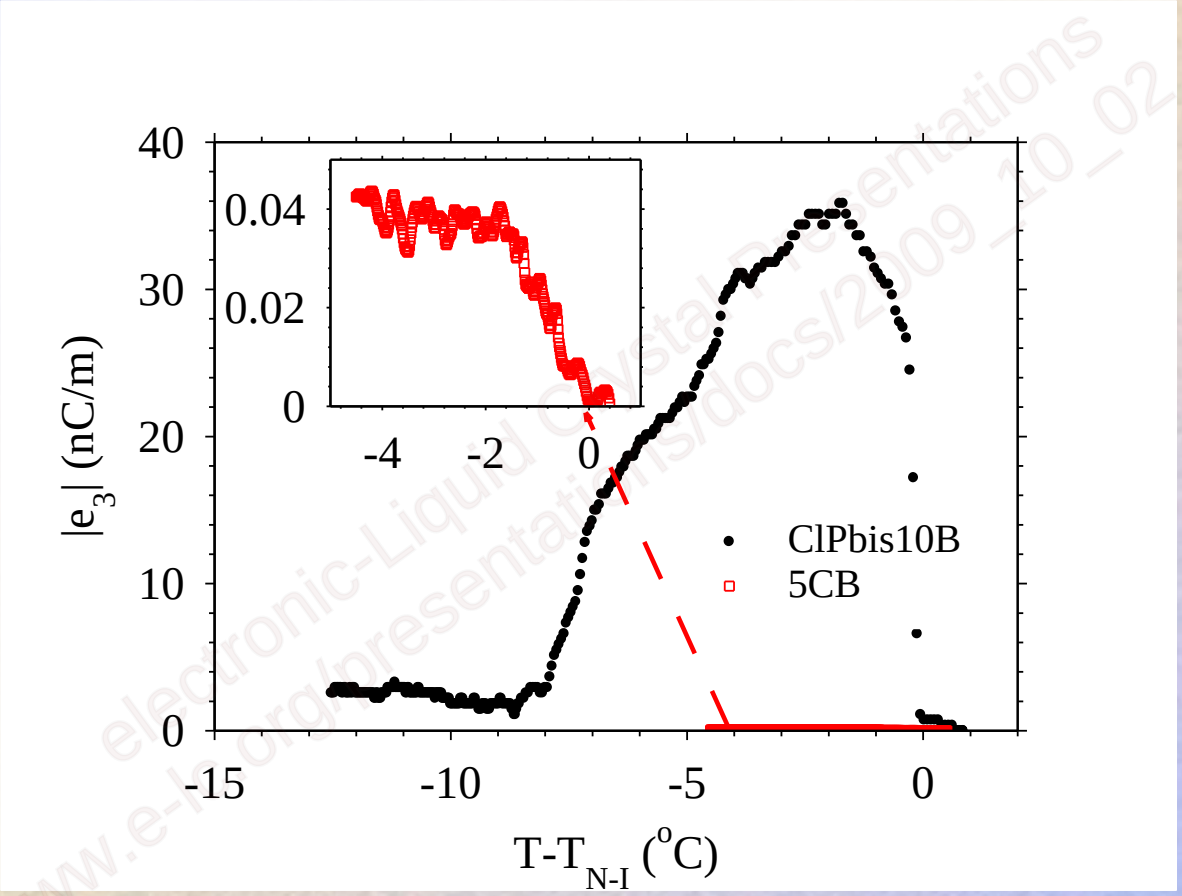
R.B. Meyer, *Phys. Rev. Lett.*, "Piezoelectric effects in liquid crystals", **22**, 918-921 (1969)

P.G. de Gennes, "The Physics of Liquid Crystals", Clarendon Press, Oxford (1975)

Macroscopic Demonstration of Alignment to a Curved Surface

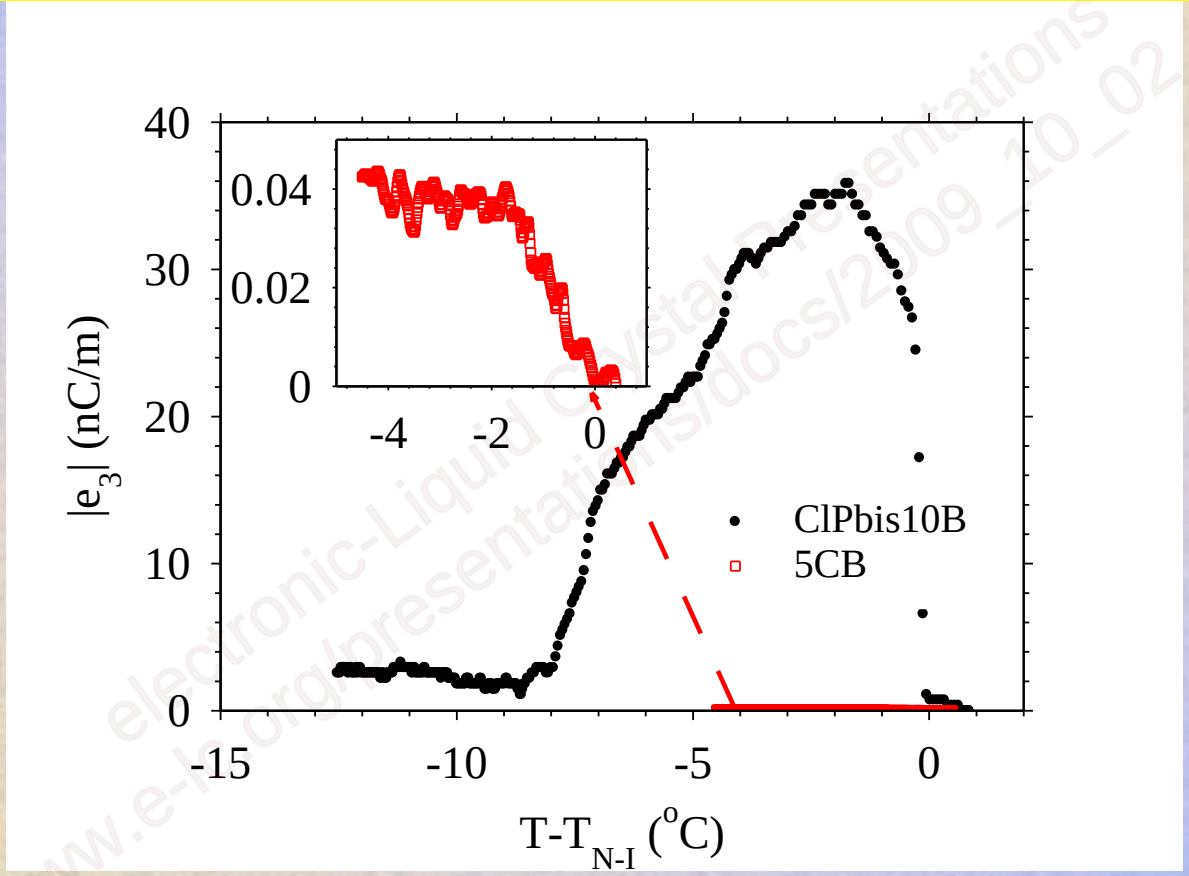
Photo by James Maxwell

Discovery of Giant Flexoelectricity in Bent-Core Nematic Liquid Crystals



Harden J, Mbanga B, Eber N, et al. PHYSICAL REVIEW LETTERS 97 (15): Art. No. 157802 OCT 13 2006

1000 Times Bigger Than Rod Like Molecules



Harden J, Mbanga B, Eber N, et al. PHYSICAL REVIEW LETTERS 97 (15): Art. No. 157802 OCT 13 2006

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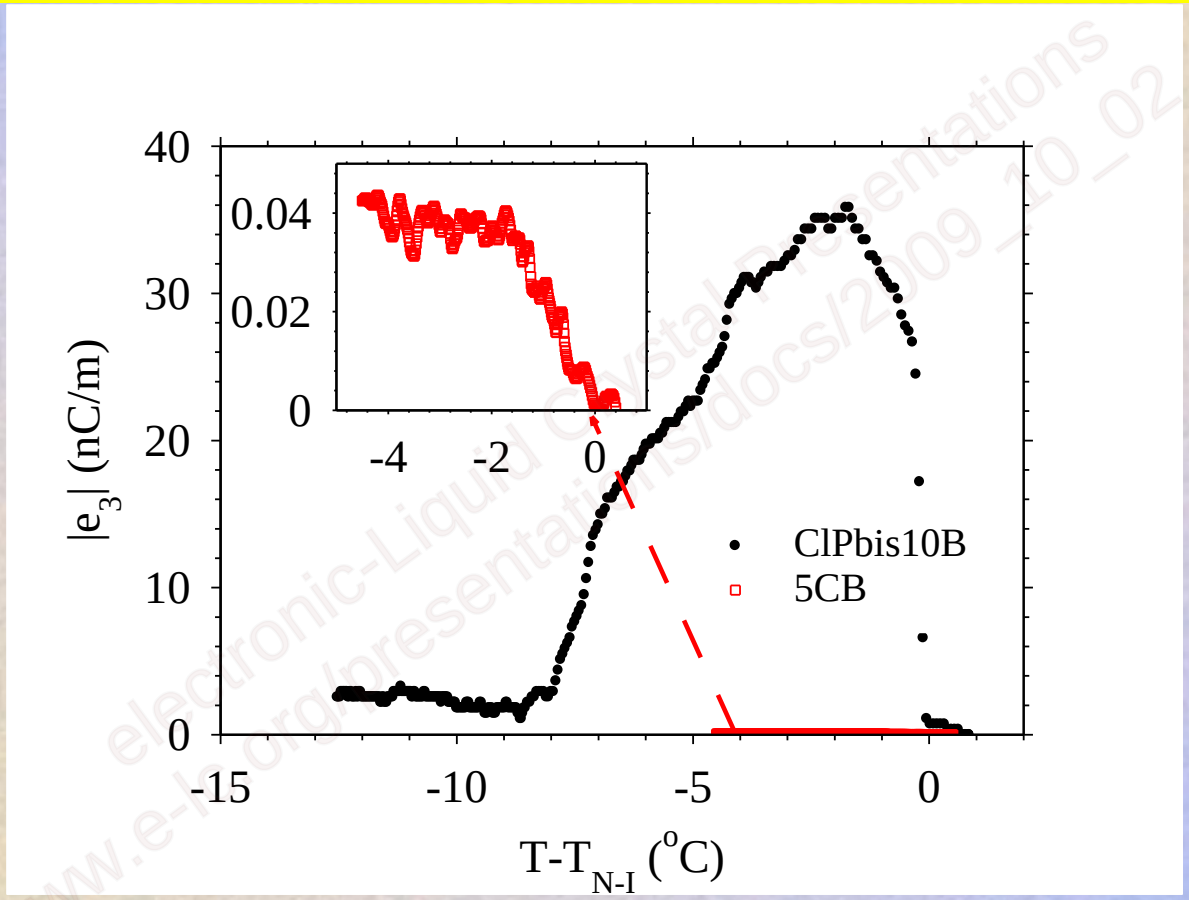
100 Times Bigger Than Predicted for Bent-Core



Harden J, Mbanga B, Eber N, et al. PHYSICAL REVIEW LETTERS 97 (15): Art. No. 157802 OCT 13 2006

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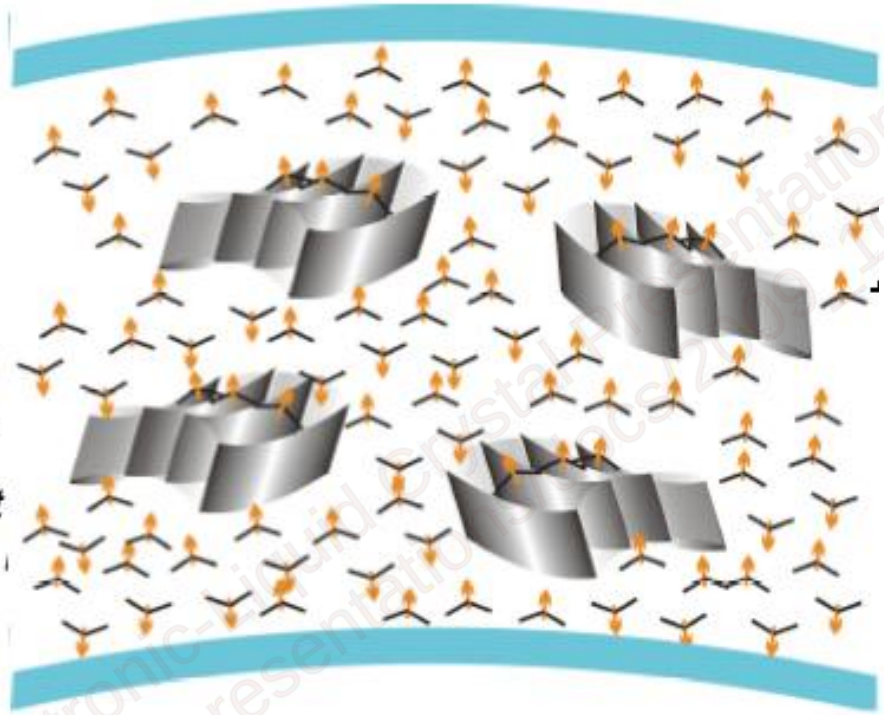
Our answer

Clusters are in B7 phase (polarization* and layer modulated) structures**



Note: this has both in layer and out of layer parts, due to SmCG structure with out of layer polarization.

Length scale:
~50nm

Clusters oriented in polarization direction according to the bend direction,
But this orientation strongly depend on bend/electric field

A. Jákli, J. Harden, J.Gleeson, S. Sprunt, 12th International Conference on Ferroelectric Liquid Crystals 2009

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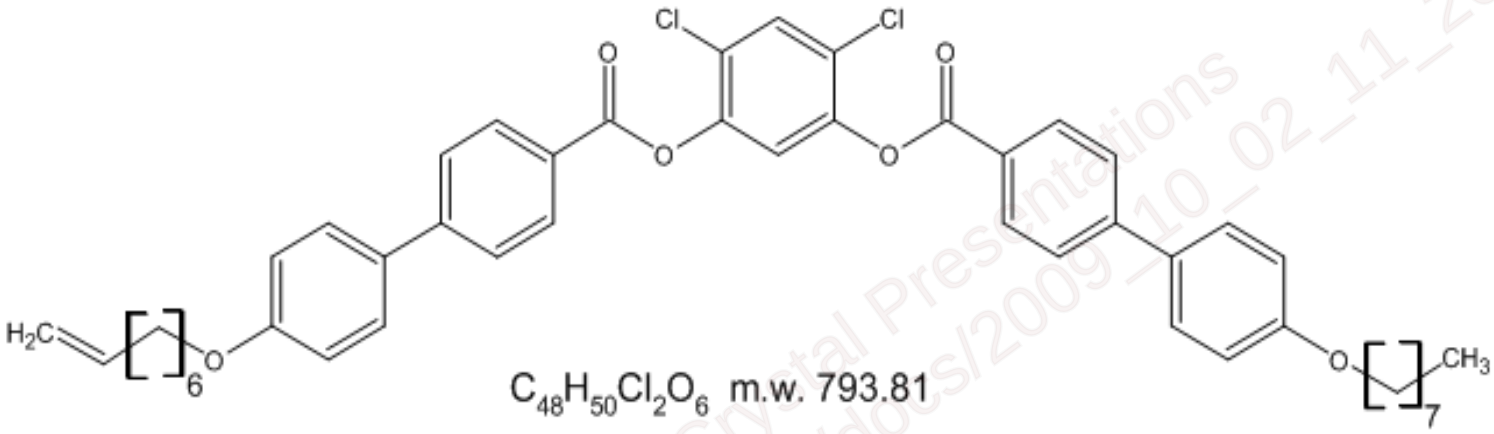
Why make a BCLCE?

- Solves the Leaking Problem (Material eventually pumps out of cell if it is fluid.)
- Solves the Shorting Out problem
- Lower and Wider Temperature Range
- We Love Bent Core Molecules!!!

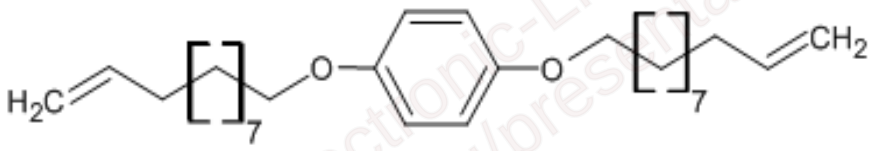
Components of the BCLCE

a



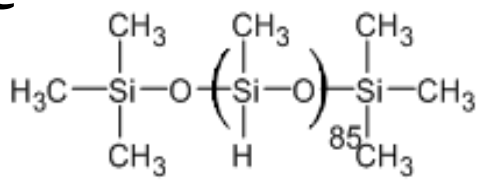
$C_{48}H_{50}Cl_2O_6$ m.w. 793.81

b



$C_{28}H_{46}O_2$ m.w. 414.66

c

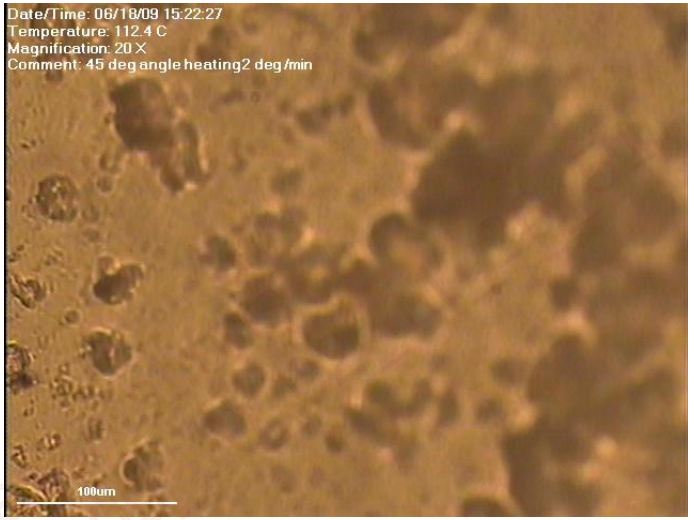


m.w. 60.124 / monomer

See R. Verduzco talk for ILCEC 2009

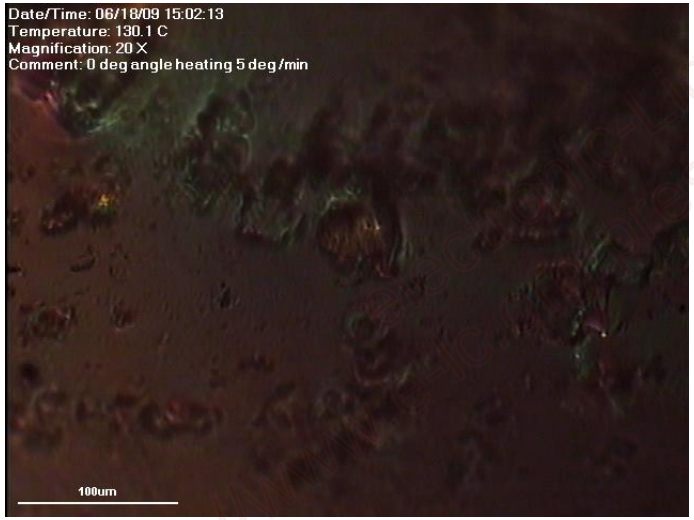
113°C

Below T_{NI}



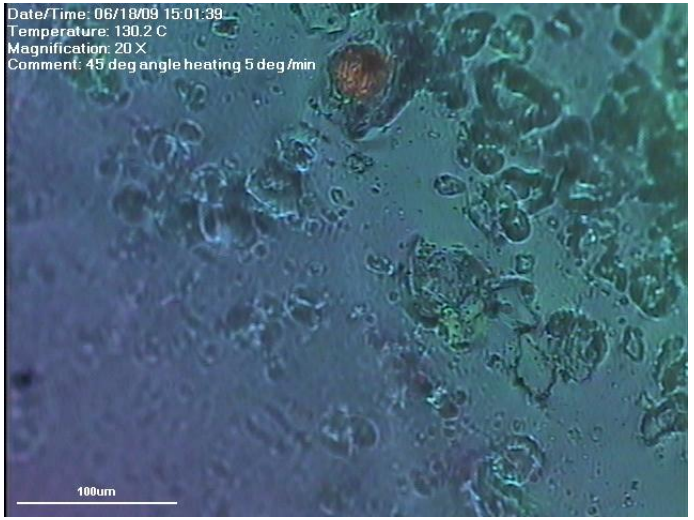
Polarizer at 0°

Polarizer at 45°



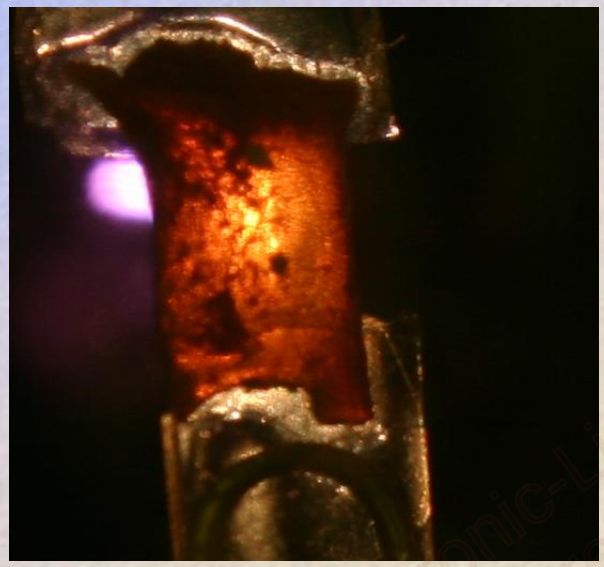
130°C

Above T_{NI}

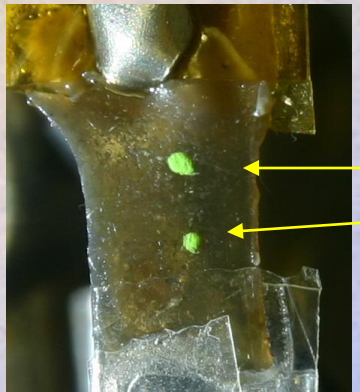


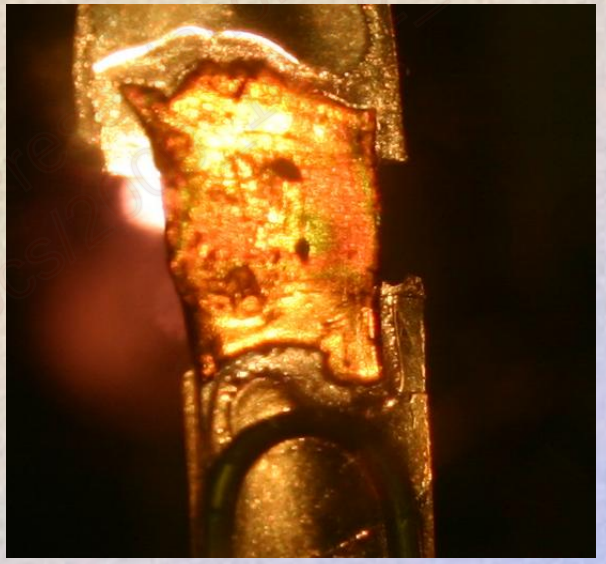
T_{NI} =120°C

Measuring Change of Length vs Temperature in Crossed Polarizers



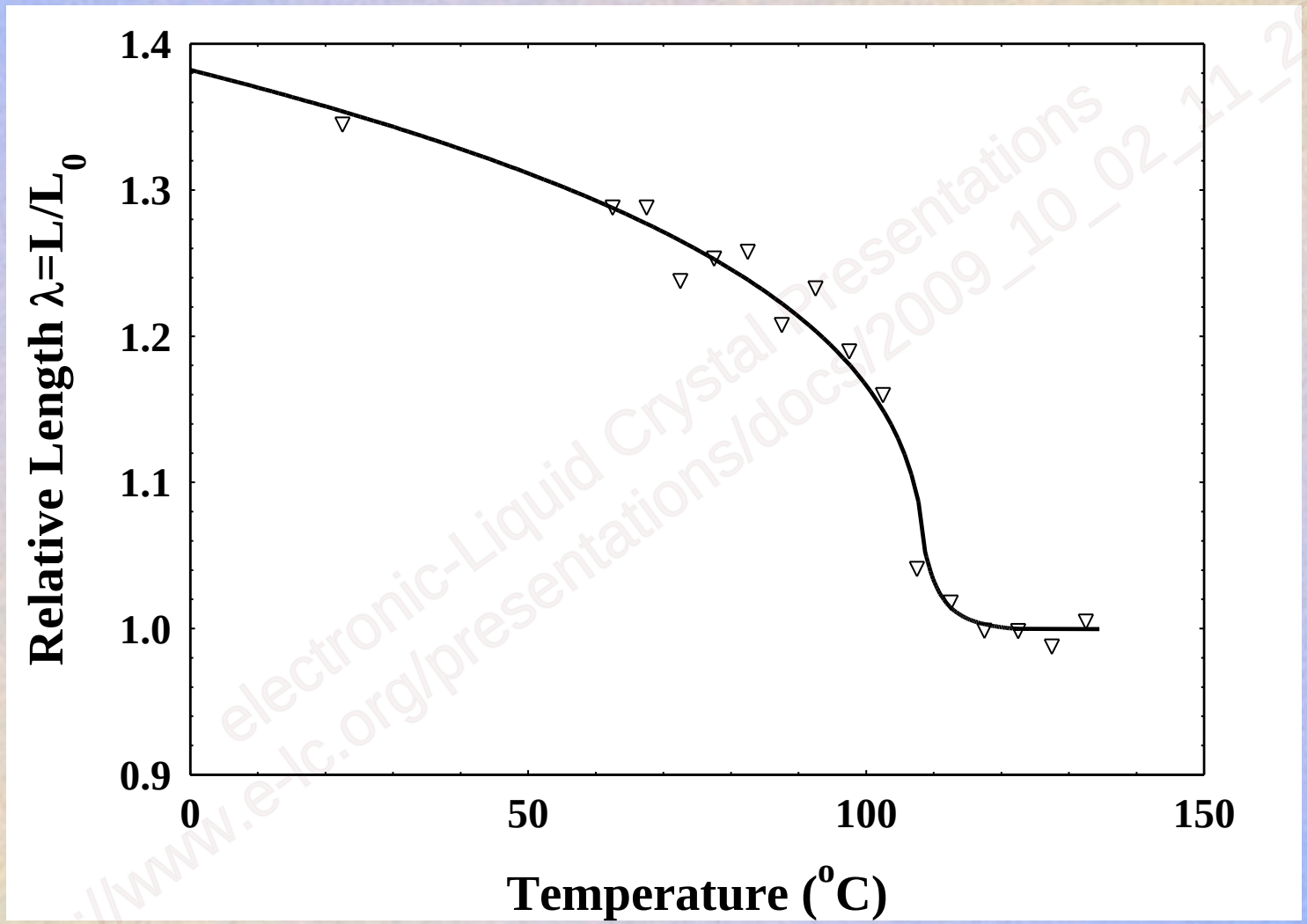
21ºC



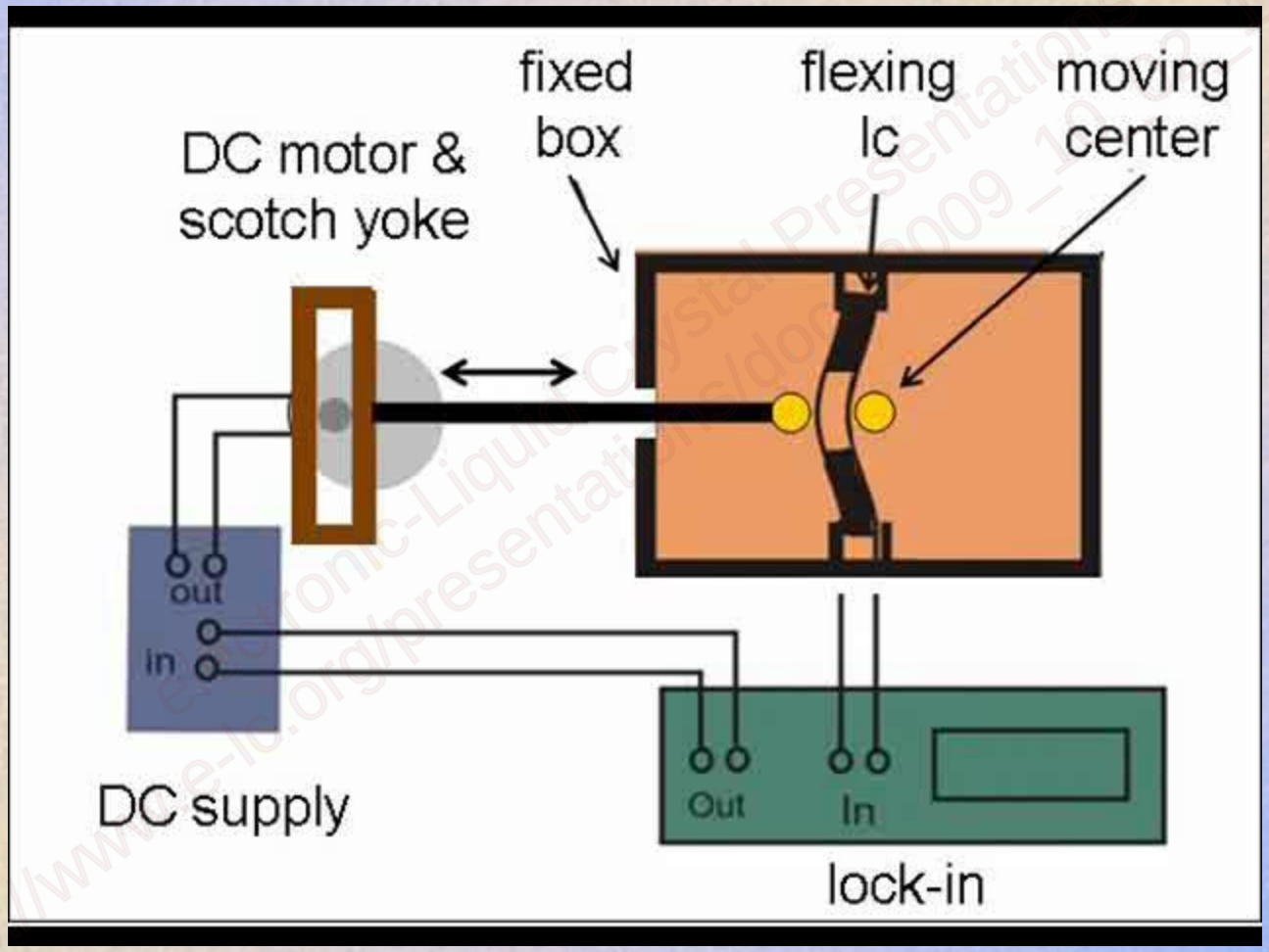


125ºC

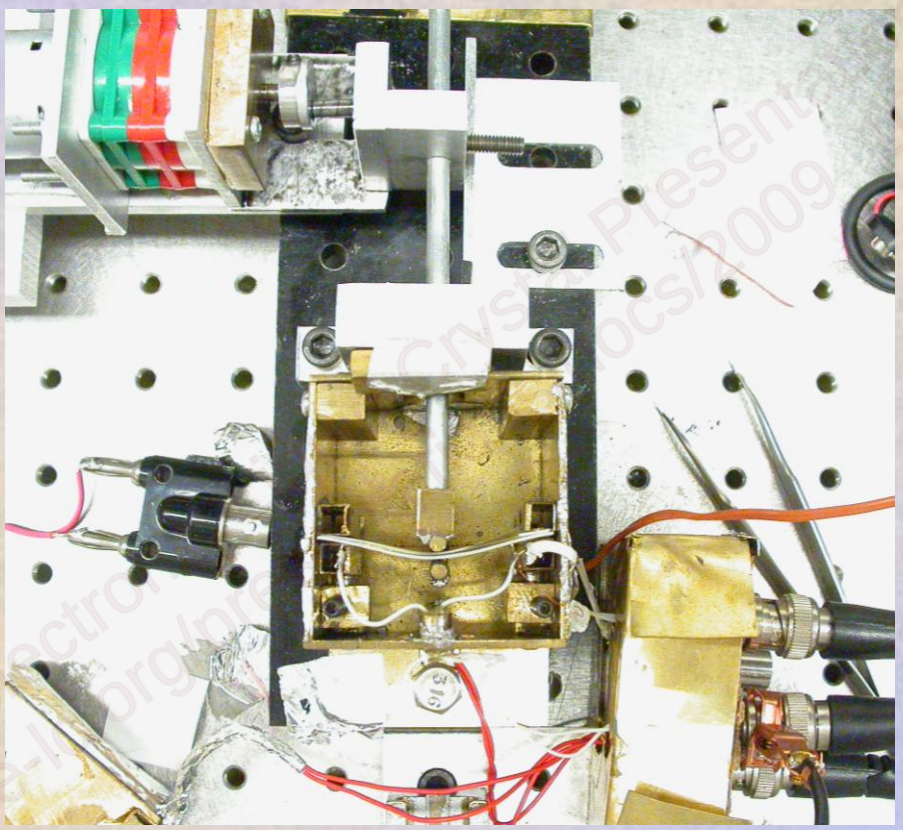
Reference Marks

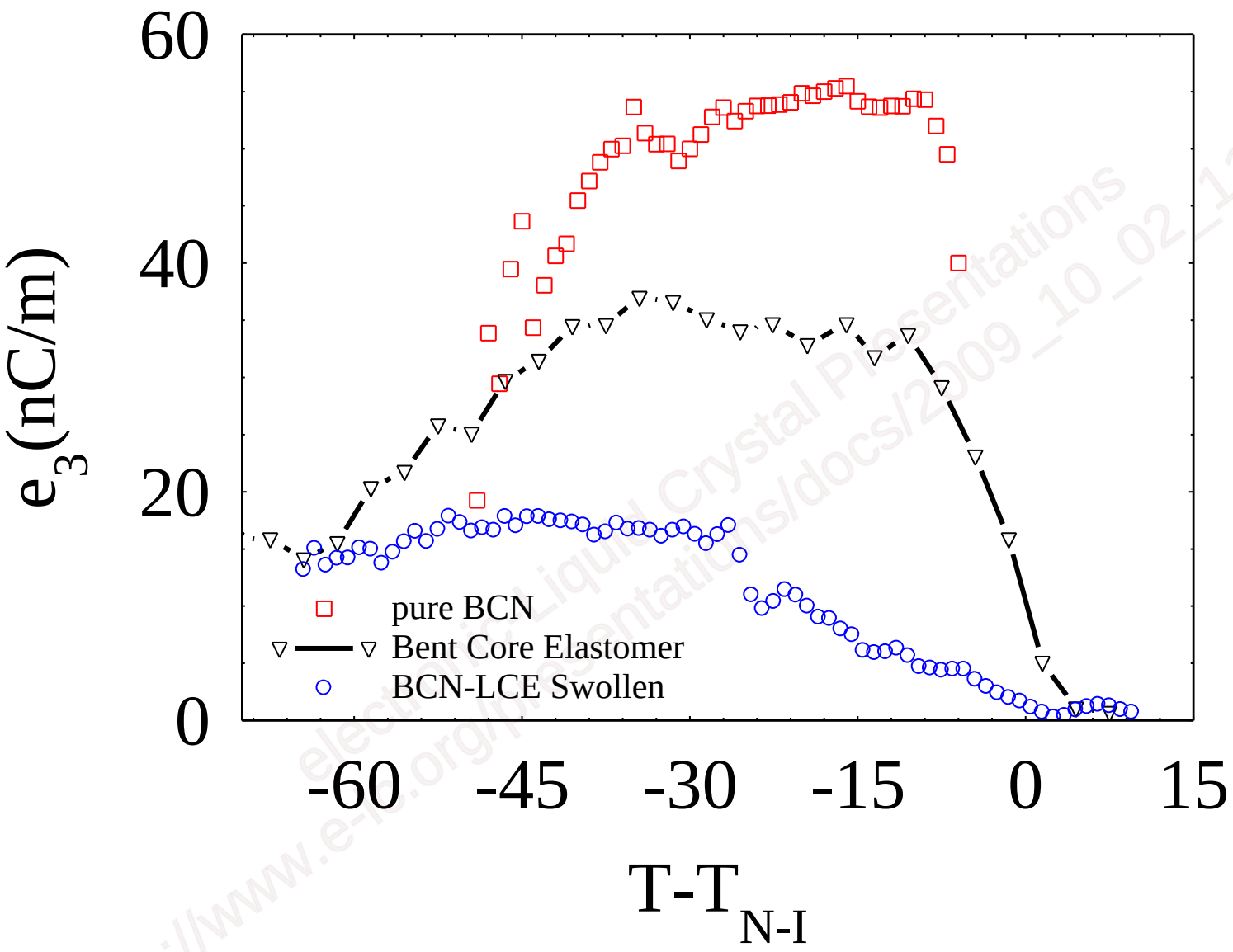


Measurement of the Flexoelectric Coefficient



Measurement of the Flexoelectric Coefficient



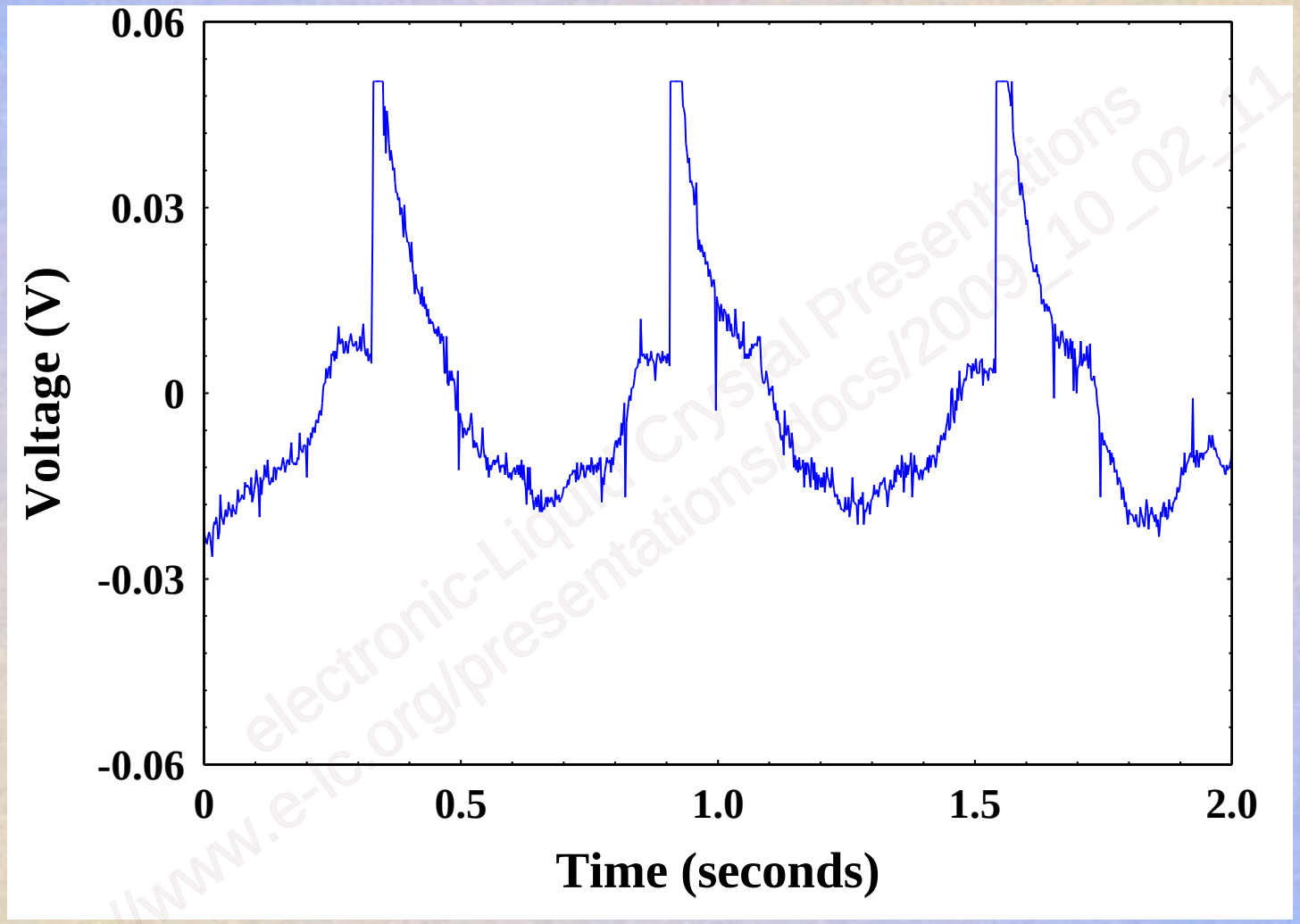


Red and Blue from M. Chambers, R. Verduzco, J.T. Gleeson, S. Sprunt, A. Jákli, J. Mater. Chem. 2009

Video of Giant Flexoelectric Effect

http://www.lci.kent.edu/PI/Jakli/gallery.html

Oscilloscope with Flexing by Hand



Summary

Giant Flexoelectric Polarization exists for BCLCE ~30nC/m
-Control Groups and Isotropic Phase show no such effect

~4mm x 4mm x 0.3mm can produce 20mV

Currently plan to work on converse effect where a field will provide a cylindrical curvature -
------see J. Harden, R. Teeling, J. T. Gleeson, S. Sprunt A. Jakli (2008). "Converse flexoelectric effect in a bent-core nematic liquid crystal." *Physical Review E* **78**(3).

Acknowledgements

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New Liquid Materials Facility , Kent State University