Giant flexoelectricity of bent-core nematic liquid crystals

J. Harden[1], B. Mbanga[1], N. Éber[2], K. Fodor-Csorba[2], S. Sprunt[3], J.T. Gleeson[3] and A. Jákli[1]

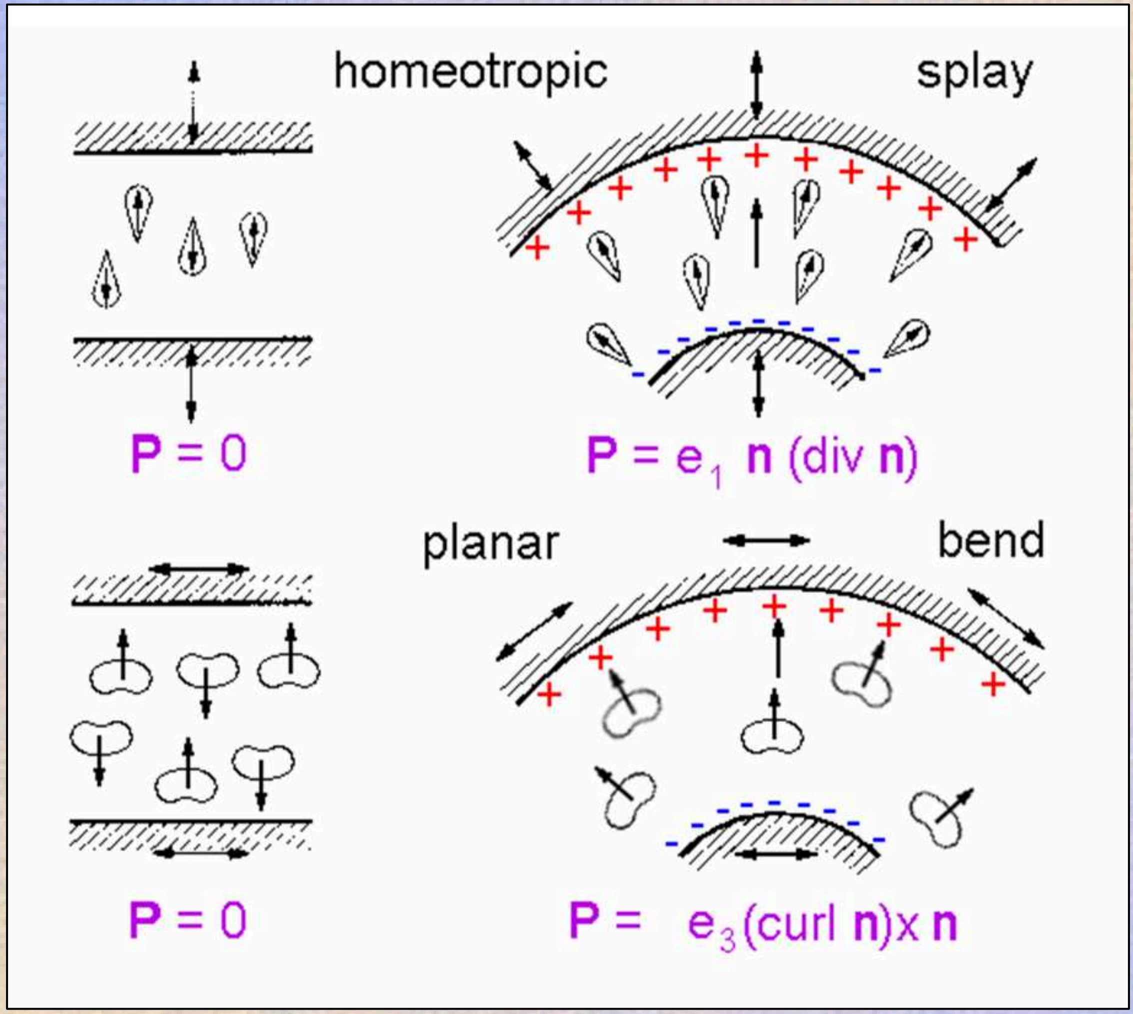
[1]Chemical Physics Interdisciplinary Program and Liquid Crystal Institute, Kent State University, Kent, Ohio 44242, USA

[2] Research Institute for Solid State Physics and Optics, P. O. Box 49, H-1525 Budapest, Hungary

[3] Department of Physics, Kent State University, Kent, Ohio, 44242, USA

The work has been supported by NSF DMR

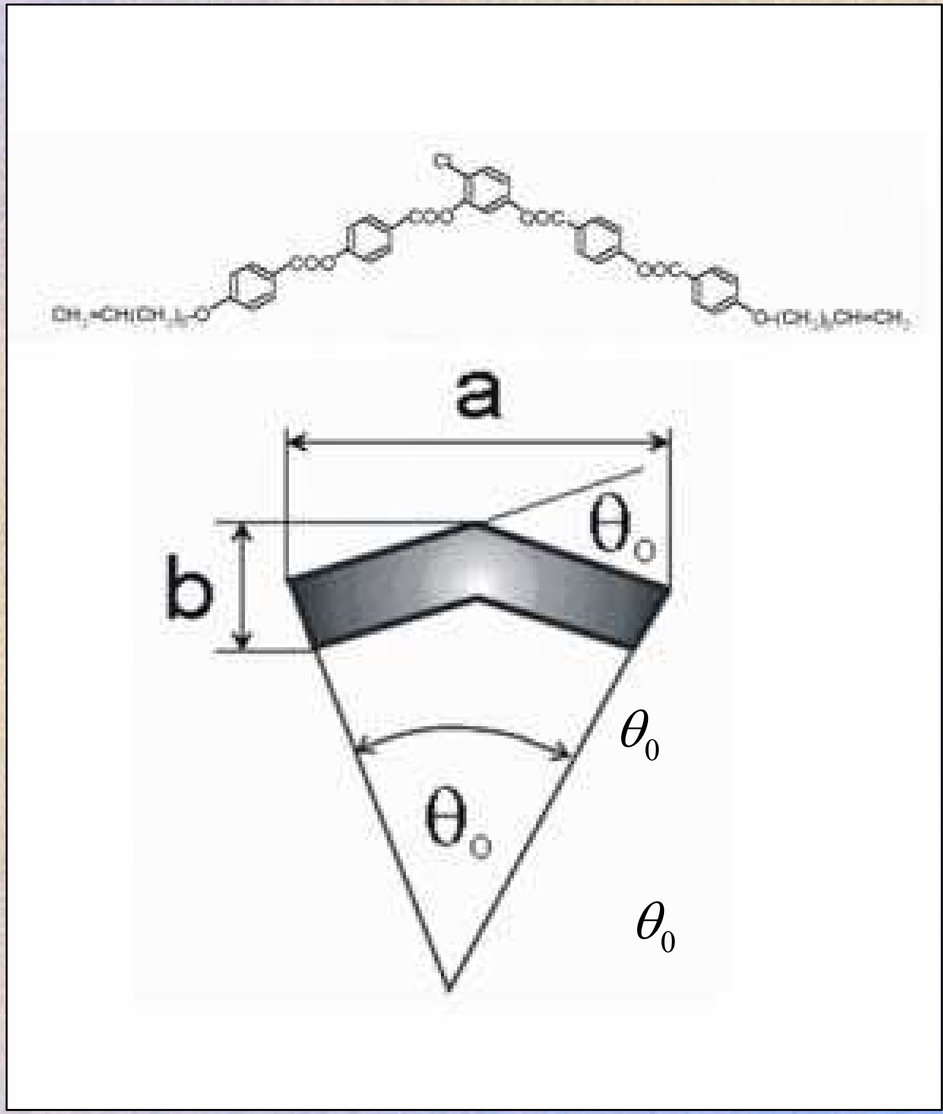
Flexoelectricity



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

Robert B. Meyer, Physical Review Letters, 22, 918-921 (1969)

Helfrich[1] and Derzhanski - Petrov[2] Model



$$e_3 = \frac{\mu_\perp K_{33}}{2k_B T}\theta_o \left(\frac{b}{a}\right)^{2/3} N^{1/3}$$

For rod shaped molecules θ_o <1°, e_1 and e_3 typically 1- 10 pC/m

For bent-core molecules θ_o ~60°, expect e_3 below nC/m order of magnitude.

[1]W. Helfrich, *Phys. Lett., 35A*, **393 (1971);** *Z. Naturforsch,* **26a, 833 (1971)**

[2] A. Derzhanski, A.G. Petrov, *Phys. Lett.,* **36A, 483 (1971)**

KENT STATE UNIVERSITY

Measuring the Coefficients Optically

•Requires previous knowledge of many material parameters elastic, dielectric constants, birefringence, anchoring energies etc.

▪Published data vary considerably depending on technique.

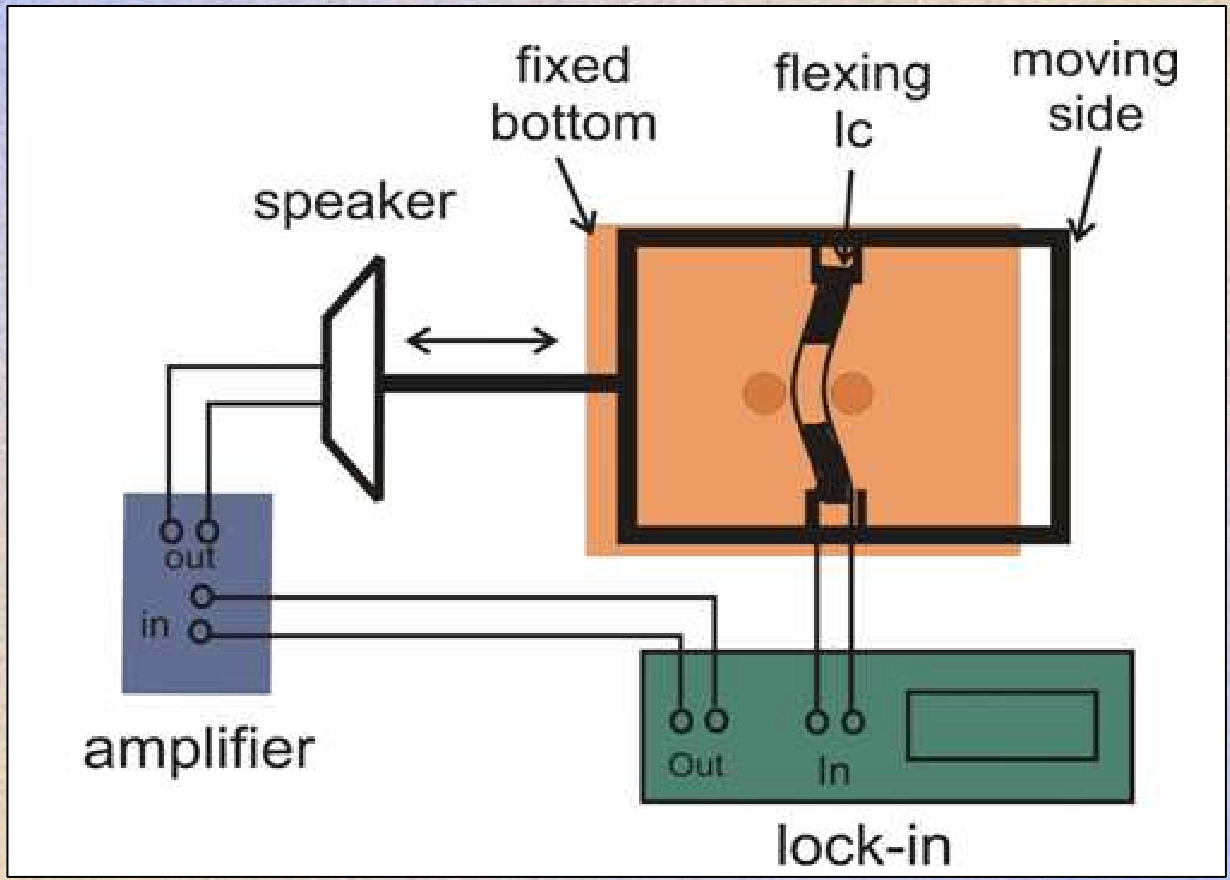
▪Coefficients e_1 and e_3 can not be measured independently.

▪Requires hybrid alignment, but bent-core molecules align planar in hybrid substrates.

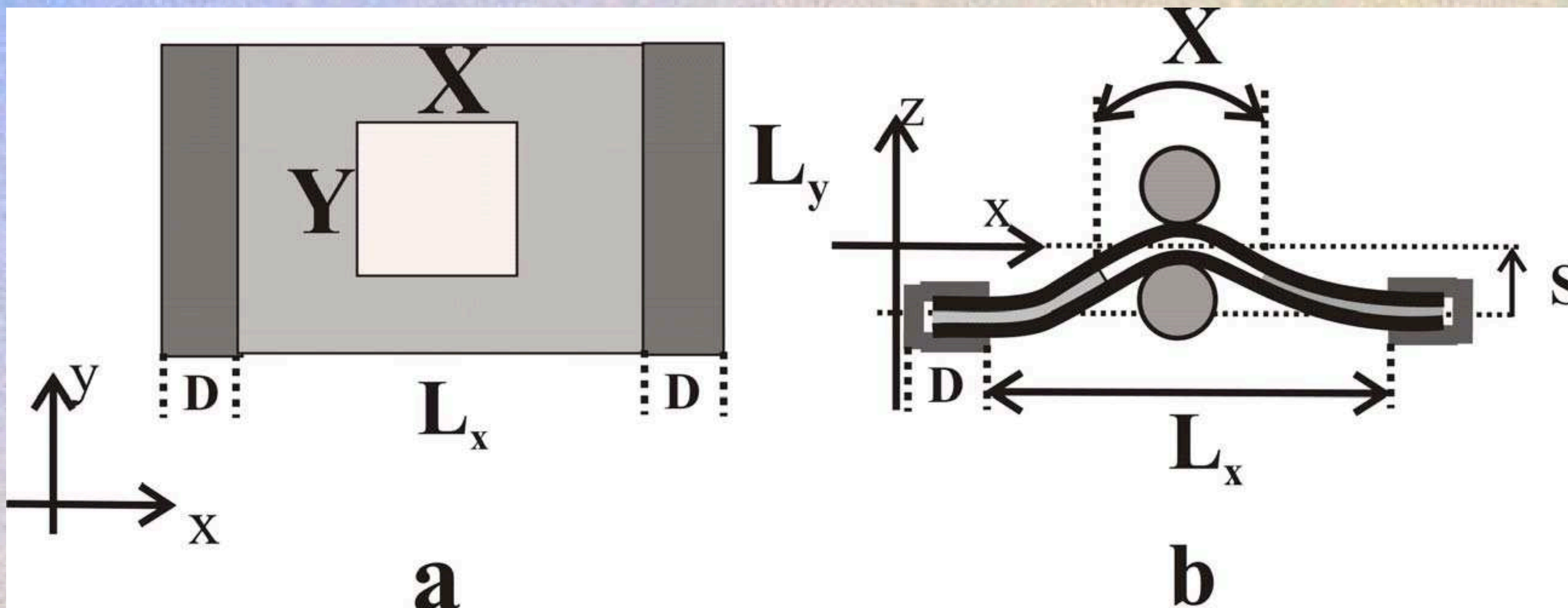
Direct Flexing Technique

- Bent-core molecules can be measured.
- Coefficients e_1 and e_3 can be measured independently
- No previous knowledge of material parameters is required.

Experimental Setup



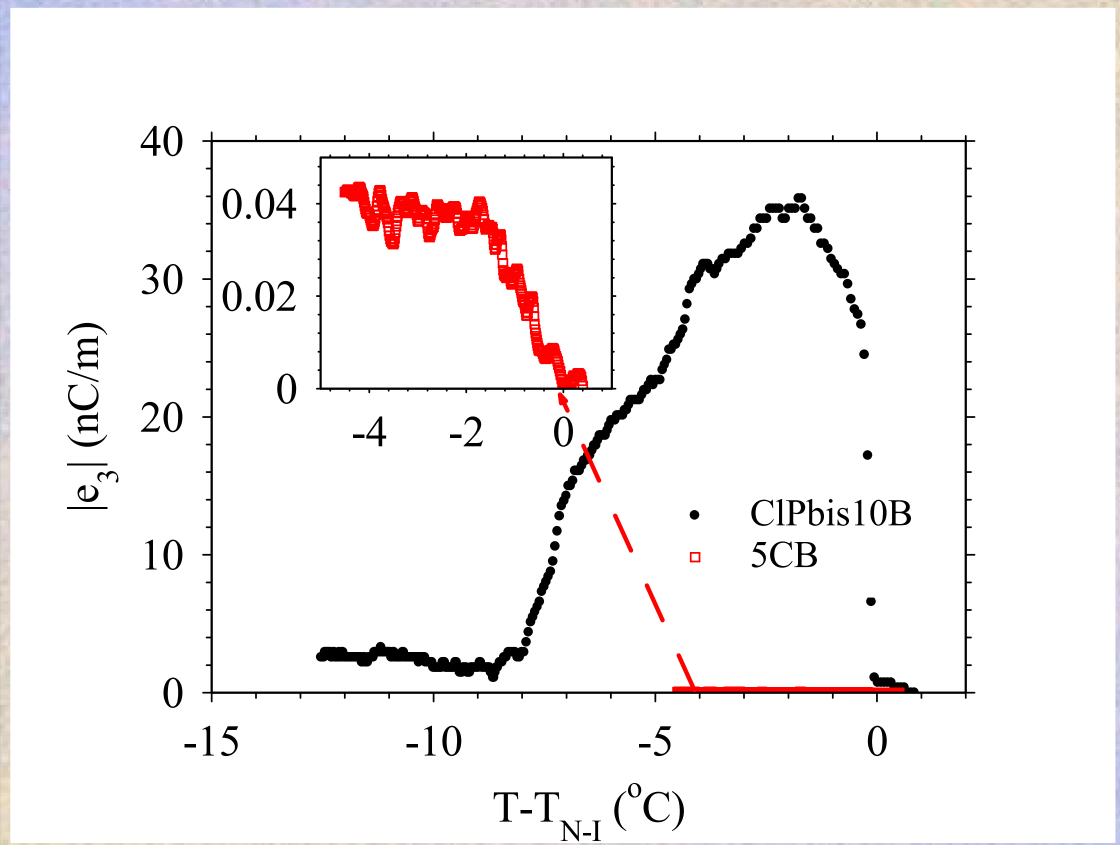
Determining e_3



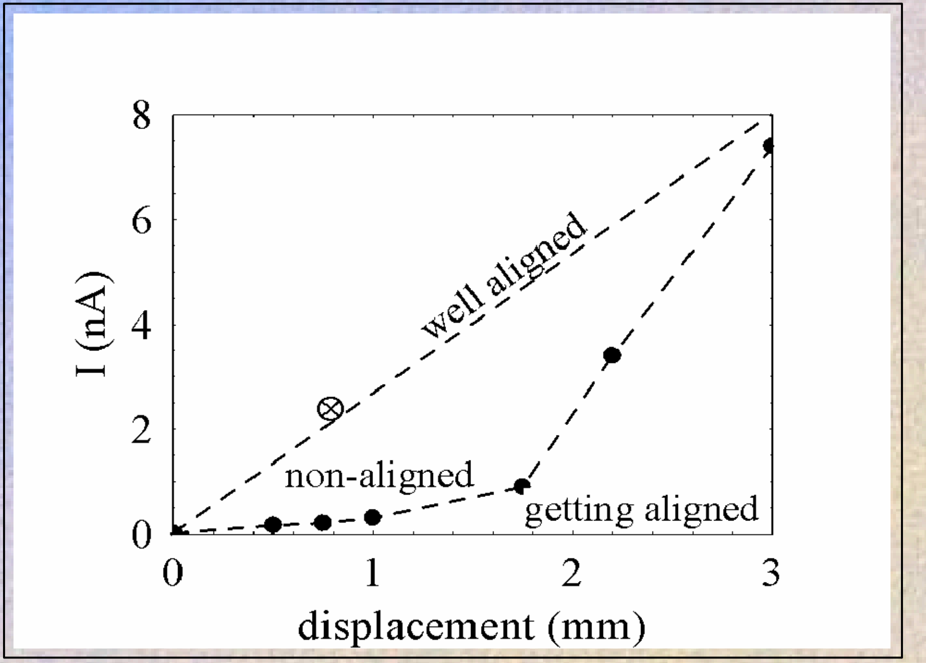
$$|e_3| = \sqrt{2}\, I_{rms} \frac{L}{4\pi f \beta Z S_0} \quad \text{where} \quad \beta = 6\left\{2\left(\frac{2X}{L_x}\right)^2 - \left(\frac{2X}{L_x}\right)^3\right\}$$

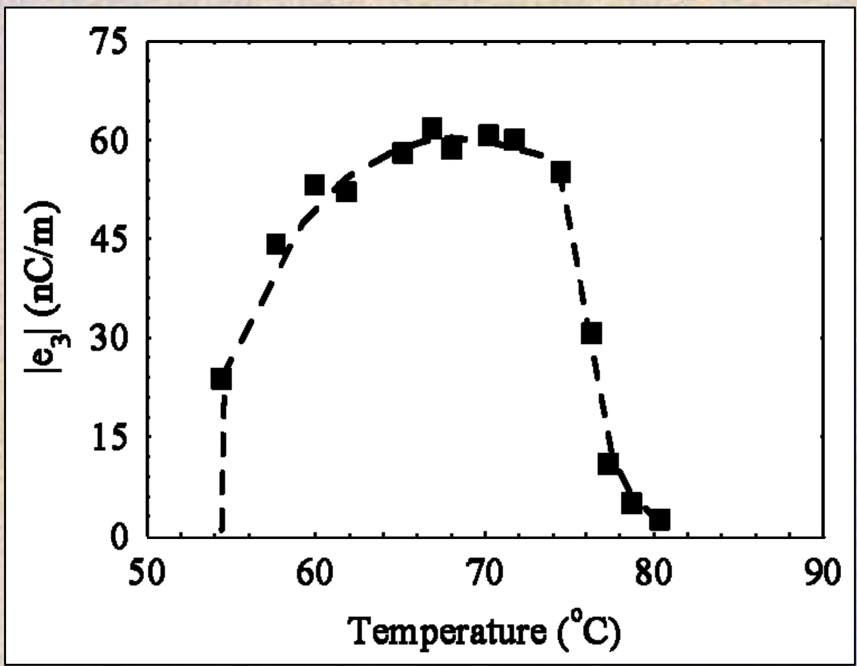
Harden J, Mbanga B, Eber N, et al. PHYSICAL REVIEW LETTERS 97 (15): Art. No. 157802 OCT 13 2006

Measurements in Brass Cell with No Alignment Layer



Variation of the flexoelectric coefficient on a relative temperature scale T-TN-I for the bent-core liquid crystal ClPbis10BB as well as for the calamitic liquid crystal 5CB measured in cells of A=1cm2 active areas. The inset shows part of the figure (|e3| of 5CB) at a magnified scale.





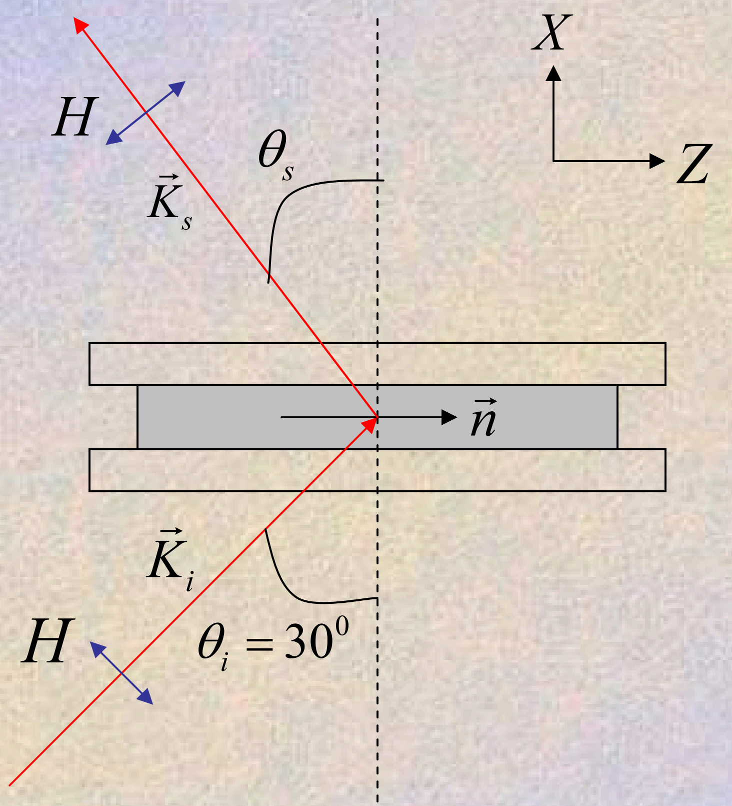
Displacement dependence of flexoelectric current (in rms values) of ClPbis10BB at 74°C; (b) the temperature dependence of |e3| of a well aligned cell measured at 5Hz in 15mm x 15 mm active area plastic cells

Dynamic Light Scattering Results

M. Majumdar, K. Neupane, S. Sprunt

$T = T_{NI} - 2^0 C$

$\vec{q} = \vec{K}_s - \vec{K}_i$



In our experiment :

$\theta_s = 29^o \rightarrow 31^o \approx \theta_i \quad and \quad q_x \ll q_z$

2 modes detected:

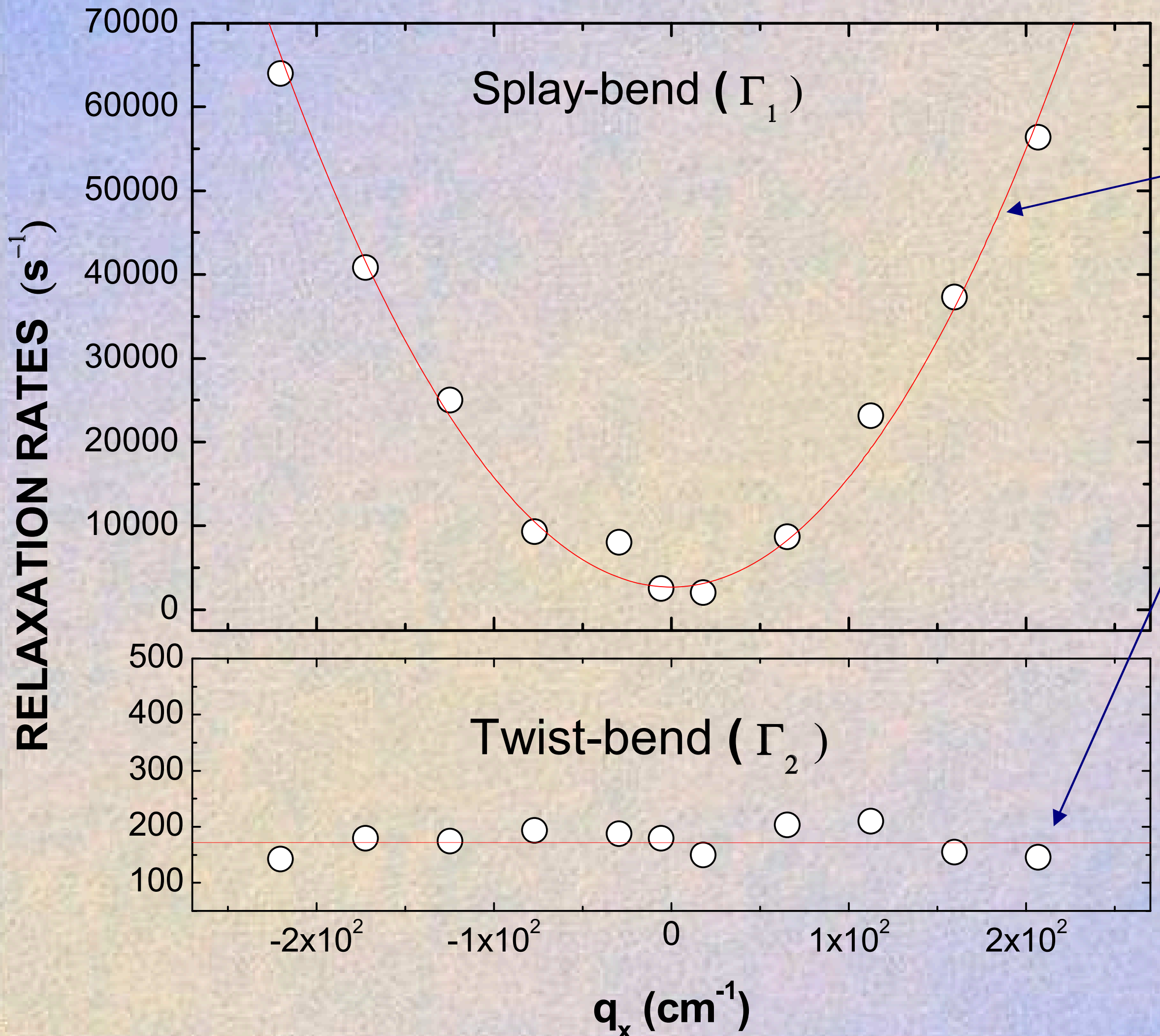
- Splay-bend, strongly selected by scattering geometry
- Twist-bend, weakly coupled to light due to alignment defects, etc.

10ClPbisBBs (saturated version of the other material)

Preliminary Experimental results:

Relaxation rates vs. scattering vector q_x

[For theory of effect of flexoelectricity on director modes, see de Gennes and Prost, *The Physics of Liquid Crystals* (Clarendon , Oxford, 1993), Chapter 3]



For $q_x \ll q_z = 9.9\times10^4\,cm^{-1}$:

$$\Gamma_1 = \frac{K_3 q_z^{\ 2} + 4\pi e^2 \varepsilon_{\|}^{-1} q_x^{\ 2}}{\eta_b}$$

$$\Gamma_2 = \frac{K_3 q_z^{\ 2}}{\eta_b}$$

From fits:

$$\frac{4\pi e^2}{\varepsilon_{\|} K_3 q_z^{\ 2}} = 0.0076\,cm^2$$

Using known $\varepsilon_{\|}, K_3, q_Z$,

$$e = e_1 + e_3 = 90\,nC/m$$