High Field Magneto-Optical Studies of Liquid Crystals and Complex Fluids

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Introduction

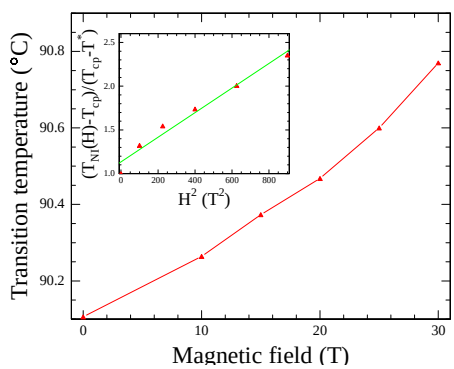
New categories of liquid crystals bring exciting opportunities for both new technological applications and fundamental science. High magnetic fields enable exploration of otherwise inaccessible regions of the phase diagram, and so are an important tool in furthering our understanding of what mesogenic states of matter are possible. Our initial project studied a class of liquid crystals having bent-core or boomerang shape; we have since transitioned into a greater study of biologically compatible materials known as lyotropic chromonic liquid crystals. The key question here, which can only be answered using ultra-high magnetic fields is whether or not the molecules have formed supermolecular aggregates which are capable of adopting liquid crystalline order.

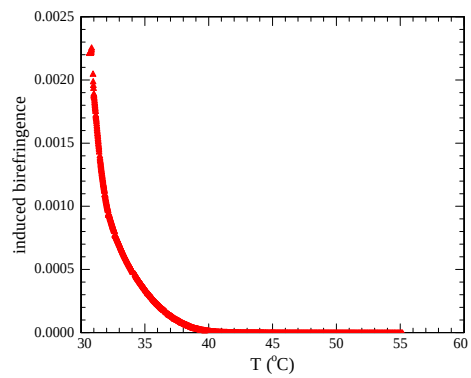
Experimental

The principal tool for studying liquid crystal material science has always been optics using polarized light. Deploying this tool in NHMFL resistive solenoid magnets is a technical challenge. In 2008, during two weeks of magnet time we measured magnetic field induce optical birefringence, optical rotation and circular dichroism in a variety of different liquid crystal formulations. The latter two measurement techniques have not been previously employed on these materials. We were joined by two new collaborators on this project. Dr. Y. Nastishin of the Institute of Physical Optics, Lviv, Ukraine, and Prof. P.J. Collings of Swarthmore College.

Results and Discussion

Our most important results in 2008 were: i) confirmation of a magnetic-field induced first order phase transition in a bent-core liquid crystal,[1] and ii) first-ever observation of the loss of field-induced optical birefringence in a lyotropic chromonic liquid crystal. The former is an effect which has long been known to be possible but had not been previously observed for two reasons: first, strong enough magnets were not available and second, previously known liquid crystal materials have too strong a first-order character to make this observable. An example of the shift in transition temperature is shown at left.





2008 saw our first investigation into chromonics, and the initial results are tantalizing. Unlike traditional liquid crystals, the structure which can possess orientational order in chromonics is a supermolecular aggregate, so in addition to the cooperative effects between aggregates, we must also consider the characteristics of the aggregates themselves. High magnetic field studies at temperatures above where the solution spontaneously exhibits liquid crystalline behavior reveal that at a finite temperature, the birefringence abruptly disappears, indicating the absence of aggregates. This is shown at right: the induced birefringence vs temperature at 25T magnetic field.

Acknowledgements
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[1] T. Ostapenko, et al, *Physical Review Letters*, **101**, 247801-1—247801-4, (2008).