Researcher improves LCDs with 3-D nanoimaging process

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Charles Rosenblatt, professor of physics and macromolecular science at Case Western Reserve University, and his research group have developed a method of 3D optical imaging of anisotropic fluids such as liquid crystals, with volumetric resolution one thousand times smaller than existing techniques. A research paper detailing the team's findings appeared in the advanced online publication of *Nature Physics*.

The molecules of these fluids, such as liquid crystals and ordered polymers, gels, and emulsion, can be oriented by magnetic or electric fields and thus can control the polarization properties of light. This is how liquid crystal displays in televisions, laptop computers, and other digital devices operate. Designing these and future devices requires a detailed knowledge of the molecular order. Until now much of the available information was based on inference from macroscopic experiments.

Using Rosenblatt's new technique, which provides detailed visual renderings of structures at the level of tens of nanometers, about 1/1000th the diameter of a human hair, we are able to create a much more detailed and nuanced picture of the structure. This will facilitate improvements to existing devices and make entirely new applications possible. Moreover, many fundamental scientific questions that deal with phase transitions or the nature of topological defects can be studied in far more detail than previously possible.

His system builds on existing techniques in near field scanning optical microscopy (NSOM) for 2D imaging. Traditionally, NSOM entails placing a very tiny optical fiber close to the specimen surface, in this case the substrate on which the anisotropic fluid resides. As the substrate is scanned back and forth below the fiber's aperture, a computer records the intensity of the light that emerges from the fiber and interacts with the surface, as well as the position of the fiber. The computer processes the information and produces a 2D optical image of the surface with resolution of several tens of nanometers. To date, NSOM has been used mainly as a surface characterization technique.

Rosenblatt's team adapted traditional NSOM technology by using polarized light, immersing the fiber into the fluid, and collecting images at a series of heights above the substrate. The result is polarized optical nanotomograpy (ONT), a system for 3D mapping of anisotropic fluid on top of a substrate.

The team chose a nematic liquid crystal, whose molecular orientation is controlled by a nanoscopic pattern scribed into the underlying polymer-coated substrate. This material was chosen because its structure can be readily calculated, giving the team an idea of what they should expect to see through the ONT imaging process.

In their ONT experiment the team immersed an optical fiber with a diameter of 60 nanometers (approximately one-tenth the diameter of the wavelength of light) into the liquid crystal to a position just above the substrate. There the fiber was scanned two-dimensionally over the surface and an image was obtained. They then retracted the fiber by approximately 25 nm and obtained a second image. In principle data from the first image could be subtracted from the second, providing information about the molecular orientation profile at 25 nm above the surface. This process was repeated out to a distance of 500 nm above the substrate. Rosenblatt's team demonstrated that the images at each height were completely consistent with the theoretical predictions, and they were able to make the first visualization and direct measurement of the 200 nanometer length over which the molecular orientation homogenizes.

The research was funded by the U.S. Department of Energy's Basic Energy Science program and the Petroleum Research Fund of the American Chemical Society.

Over the summer Rosenblatt received a three year grant from the National Science Foundation (NSF) that runs through 2011, marking 25 continuous years of NSF single-investigator funding for his research projects. The money from this grant will be used for liquid crystal interface control and phenomena on more macroscopic scales, and will be performed in collaboration with his former postdoctoral fellows who are now at the University of Calabria, Italy.

The summer of 2008 brought yet another three-year grant, this one for the study of acceleration-driven fluid interface instabilities, the type that occurs in diverse phenomena such as exploding supernovae, inertial confinement for fusion experiments used for energy production and vinegar-and-oil salad dressing. This grant was awarded jointly to Rosenblatt and his colleague Pierre Carles of the Universite Paris 6 and adjunct associate professor of physics at Case Western Reserve by the Partner University Fund administered by the French Foreign Ministry.

Source: Case Western Reserve University

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