ALCOM Update

Vol. 10, No. 4 December 2000

Milestone anniversaries highlighted at recent ALCOM symposium

The year 2000 marked three important anniversaries involving the ALCOM Center. The National Science Foundation celebrated the 50th anniversary of its inception with events scheduled throughout the year. The Liquid Crystal Institute marked the 35th year of its founding by Professor Glenn H. Brown in 1965 and the ALCOM Center completed its 10th year of research as an NSF Science and Technology Center.

To celebrate, the ALCOM Center sponsored a two-day symposium to acknowledge NSF support for years of liquid crystal and polymer research and to highlight future technologies. The symposium, *Liquid Crystals and Polymers: Past, Present and Future*, was held October 30-31, 2000 at the Sheraton Suites, Cuyahoga Falls, Ohio.

Distinguished scientists from around the world spoke on their research areas. Invited speakers were Dirk J. Broer (Philips Research Labs, The Netherlands), Noel A. Clark (University of Colorado), Heino Finkelmann (University of Freiburg, Germany), John W. Goodby (University of Hull, U.K.), Tomiki Ikeda (Tokyo Institute of Technology), Tom C. Lubensky (University of Pennsylvania) and Robert B. Meyer (Brandeis University). Additionally, ten ALCOM principal investigators gave oral presentations on their research.

Nearly 175 people from universities, business and industry, military, state and federal governments representing the U.S. and eight other countries attended the meeting.

A session on Monday consisting of 38 posters provided an opportunity for participants to talk one-on-one with scientists and graduate students about their current ALCOM research.

A poster honoring the 50th anniversary of the National Science Foundation was presented. The poster included a letter of congratulations from LCI and ALCOM director, John L. West, a list of more than 60 NSF grants provided to the Liquid Crystal Institute and ALCOM Center for individual research, education outreach, and scientific collaborations. Also shown were ALCOM success stories including the polymer liquid crystal tutorial, modeling software, electronic document viewer, negative birefringence retardation films, experiment-at-a-distance, liquid crystal student symposia and liquid crystal start-up companies.

ALCOM principal investigators Peter Palffy-Muhoray (left) and Chuck Gartland (center) talk with invited speaker, John Goodby, during a symposium break.

Over 165 attend the banquet Monday evening where honored guests addressed the audience. Dr. Carol A. Cartwright (President, Kent State University), The Honorable Thomas C. Sawyer (U.S. House of Representatives) and

Anniversary, *continued on page 7*

Taylor receives NSF and PRF research grants

Alcom Principal Investigator, Philip L. Taylor, recently received an NSF grant from the Materials Theory Program, Division of Materials Research. The three-year $174,000 grant entitled, "Liquid Crystal Anchoring at a Polymer Surface," will continue research previously supported through the NSF ALCOM Center.

Professor Taylor also received a grant from the Donors of the Petroleum Research Fund administered by the American Chemical Society. The two-year $60,000 grant entitled, "Theory and Simulation of Liquid Crystal Anchoring," will also continue ALCOM research.

Dr. Taylor is the Perkins Professor of Physics at Case Western Reserve University, Cleveland, Ohio.

From the Director

John L. West

This year has flown by. As I look back I realize how much we have done in 2000. The establishment and growth of local liquid crystal companies accelerated over the last twelve months, directly demonstrating the economic impact of ALCOM. Our Optical Beam Steering symposium held in June and co-sponsored by Wright Patterson AFB points to new research directions for ALCOM and extends our collaborations.

ALCOM was well represented at the 18th ILCC in Sendai in July and as always was a powerful presence at SID and related display industry meetings.

Appropriately, we ended the year celebrating the anniversaries of NSF, LCI and ALCOM. I was particularly pleased by the broad attendance at the symposium by the leading world scientists who accepted our invitation to speak.

I look forward to the new year and the opportunities and challenges that lie ahead. We'll work together to continue and expand our collaborations. I wish you Happy Holidays and success in the New Year.

Chien serves on SPIE committee

Professor Liang-Chy Chien from Kent State University has been named a program committee member for *Organic Photonic Materials and Devices III* in the upcoming SPIE International Symposium, *Optoelectronics 2001*. The meeting will take place January 24-25, 2001, in San Jose, California.

This SPIE conference is comprised of seven sessions and will address the progress on photonic technologies based on organic materials. Conference information is available on the web at www.spie.org/info/pw.

Gartland is new ILCS Treasurer

ALCOM Principal Investigator, Eugene C. Gartland, Jr., has accepted the position of Treasurer for the International Liquid Crystal Society. He will serve a minimum of two years. Gartland is a professor in the Department of Mathematics and Computer Science at Kent State University.

Our condolences to the family of Professor Sukant Tripathy, who recently passed away. He was a valued colleague, world-class scientist and friend. ALCOM is in his debt for the excellent guidance and support which he provided as a member of the Advisory Board. We will miss him.

ALCOM

NSF Science and Technology Center
for Advanced Liquid Crystalline Optical Materials
Consortium of three Northeast Ohio universities:
Kent State, Case Western Reserve and Akron

Director **- J.L. West**
Associate Director **- J.L. Koenig**

ALCOM Principal Investigators

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D.W. Allender, L. M. Bartolo, P.J. Bos, L.-C. Chien, D. Finotello, J.E. Fulghum, E.C. Gartland, A. Jákli, J.R. Kelly, S. Kumar, O.D. Lavrentovich, M.E. Neubert, P. Palffy-Muhoray, S. Sprunt, R.J. Twieg, J.L. West, D.K. Yang

University of Akron
S.Z.D. Cheng, F.W. Harris, T. Kyu

Case Western Reserve University
W.L. Gordon, S.D. Hudson, A.M. Jamieson, J.L. Koenig, J.B. Lando, J.A. Mann, R.G. Petschek, C. Rosenblatt, D.E. Schuele, K.D. Singer, P.L. Taylor

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Ameritech Electronic Classroom students visit the ALCOM Center

Alkarockets?

You just never know what you will discover when visiting the ALCOM Center.

Students from Grill Elementary School in Norton, Ohio, visited the Liquid Crystal Institute in November and learned to make Alka-Seltzer rockets and drinking straw kazoos. It is all part of the Ameritech Electronic University School Classroom in the College of Education at Kent State University.

The Ameritech Classroom, under the direction of Professor Dale L. Cook, studies how current technology impacts teaching and learning. Results of the study will provide teachers with the tools needed to instruct students in tomorrow's technology-rich classrooms.

For six weeks Grill Elementary School students spent one-half of their daily classes on the Kent State campus in a classroom fully equipped with the latest technology. In conjunction with the instruction they received from their regular classroom teacher, the center staff arranged in-depth learning utilizing various campus resources such as the fashion museum, greenhouse and LCI. Lessons were designed around the essential question, "How do patterns affect your daily life?" and included the study of patterns in music, nature, fashion design, poetry, physics and mathematics.

Dr. Godfrey talks to the students while they wait for their "Alkarockets" to take off.

Dr. Max Godfrey, ALCOM Education Outreach Project Coordinator, works with K-12 students in Northeast Ohio by providing demonstrations and hands-on experiments on the physics and chemistry of liquid crystals.

"My goal is to get the kids in there doing science, not just showing it to them or telling them to read about it," Dr. Godfrey said. "The ALCOM Center collaborates with several Kent State programs such as Upward Bound, Creative Connections and the Ameritech Classroom. These programs provide the opportunity for us to expose students to hands-on science," he added.

Students examine table salt with a magnifying glass to examine the crystalline structure.

To learn about chemical reactions students took a plastic film canister, filled it with water and one-fourth of an Alka-Seltzer tablet. They made a paper cone on top to give it a "rocket look" and then waited in anticipation of the launch. Students were delighted as, one by one, the rockets lifted off.

Students also learned that items they use every day, such as salt, can be seen through a magnifying glass to have crystalline properties and how an ordinary drinking straw can be used to create sound vibrations.

Dr. Godfrey correlated the hands-on experiments with the students' study of patterns by taking a crystal and cleaving it with a hammer. The smallest of crystals had the same pattern as the large one had before breaking.

Mrs. Pat Mazzer, a retired teacher from Brown Middle School in Ravenna, Ohio, is Instructional Specialist for the Ameritech Classroom. She schedules school activities and supports teachers while at the Center. Mrs. Mazzer also assists the teachers in writing grants to obtain funding for technology in their own classrooms.

Mrs. Mazzer has been involved with the Liquid Crystal Institute and ALCOM Education Outreach program since 1994 when she was a participant in the *Science and Math on the Net* program.

"For me the integration of technology into the curriculum all began with the SamNet program at LCI," according to Mrs. Mazzer. "It was there that I began to see the possibilities and eventually led to my role in the Ameritech Classroom. I still get excited when I visit the ALCOM website and see our experiment with lizards."

The Ameritech Classroom is almost three years old and to date more than 50 teachers and 600 students have participated in the program. Information on the Ameritech Class

Alkarockets, *continued on page 6*

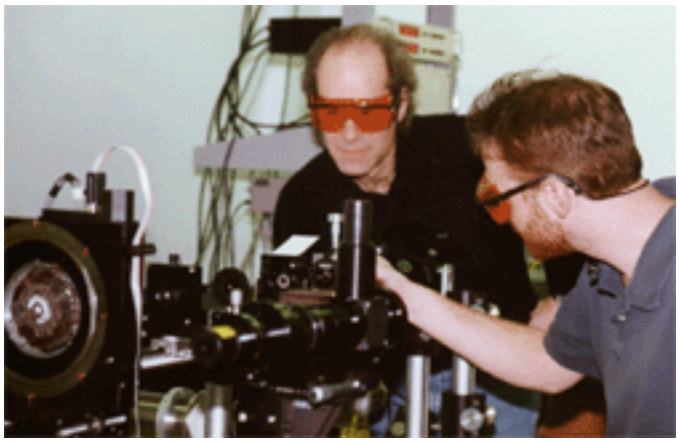
Principal Investigators

Sprunt develops instrument to aid liquid crystal research

In his Kent State laboratory, ALCOM principal investigator, Samuel N. Sprunt researches dynamic light scattering of chiral smectic liquid crystals including ferro-, antiferro-, and ferri-electric phases, twist grain boundary (TGB) phases of liquid crystals, and various modulated phases. To aid in his research, Sprunt and Dr. Alan Baldwin, Research Engineer in the Physics department, are developing an ultra high-speed digital correlator for dynamic light scattering.

Currently in the testing phase, the electronic instrument will be capable of measuring dynamic fluctuations in soft matter systems down to time scales of 500 picoseconds. The instrument will cover dynamics over 12 decades with high resolution. It uses advanced DSP (digital signal processing) technology.

"With DSP boards and time digitizers getting faster, this instrument has the potential to stay on the cutting edge of making fast time correlation measurements and could provide new insight into dynamical properties of chiral smectics, as well as other liquid crystal phases" Sprunt said.



Dr. Sprunt and Physics graduate student, Tony Adorjan, make final adjustments for light scattering experiments on a ferroelectric liquid crystal.

In addition to dynamic light scattering, Sprunt collaborates with ALCOM principal investigator, L.C. Chien, to research polymer stabilized liquid crystals and, in particular, polymer stabilized cholesterics with a view toward applications in electrically switchable diffraction gratings. He also has begun work with ALCOM principal investigator, Antal Jakli, to study achiral ferroelectrics (banana phases) in liquid crystals.

Prof. Sprunt sees an area of future research in biological and biophysical systems. Experimental techniques and theoretical modeling in liquid crystals are applicable to biological systems.

Sprunt, *continued on page 6*

Publications

"Lasing in Cholesteric Liquid Crystals," P. Palffy-Muhoray, A. Munoz, B. Taheri, R. Twieg, *SID 00 Digest*, 1170-1173 (2000).

"Analytical Solution of Maxwell's Equations in Lossy and Optically Active Crystals," H. Yuan, W. E, P. Palffy-Muhoray, *Phys. Rev. E* **61**, 3264-3266 (2000).

"Phase Structures, Transition Behavior, and Surface Alignment in Polymers Containing Rigid-Rod Backbones with Flexible Side Chains. 4. Solid-State ^{13}C NMR Studies of Molecular Motions in PEFBPs(n) (n-10 and 11)," J.J. Ge, M. Guo, Z. Zhang, P.S. Honigfort, I.K. Mann, S.-Y. Wang, F.W. Harris, S.Z.D. Cheng, *Macromol.* **33**, 3983-3992 (2000).

"Phase Identification in a Series of Liquid Crystalline TPP Polyethers and Copolyethers Having Highly Ordered Mesophase Structures. 8. Phase and Structural Evolution in a Series of Copolyethers Containing Odd-Numbered Methylene Units in Both Comonomers," R.-Q. Zheng, E.-Q. Chen, S.Z.D. Cheng, F. Xie, D. Yan, T. He, V. Percec, P. Chu, G. Ungar, *Macromol.* **33**, 5159-5168 (2000).

"Computer Simulation Evidence of the Transient Planar State during the Homeotropic to Focal Conic Transition in Cholesteric Liquid Crystals," J.E. Anderson, P. Watson, T. Ernst, P.J. Bos, *Phys. Rev. E* **61**, 3951-3960 (2000).

"Rheological Behavior of Dilute Solutions of a Side-Chain Liquid Crystalline Polysiloxane in 4,4'-n-octylcyanobiphenyl," N. Yao, A.M. Jamieson, *Rheol. Acta* **39**, 338-345 (2000).

"Deuteron NMR Study of Monolayer Thick Films of Nematogenic Molecules," B. Zalar, S. Zumer, D. Finotello, *Phys. Rev. Lett.* **84**, 4866-4869 (2000).

"Electrorheological Determination of the Leslie Viscosity Coefficient (α_2) of a Main-Chain Liquid Crystal Polymer in a Nematic Solvent," Y.-C. Chiang, A.M. Jamieson, *Rheol. Acta* **38**, 268-273 (2000).

"Polydiacetylene Fiber Optic Pressure Sensors," M. Tabib-Azar, S. Angkaew, J.B. Lando, *Ann. Tech. Conf. Soc. Plast. Eng.* **46**, 1453-1457 (2000).

"User-Defined Access to a Polymer Liquid Crystal Thesaurus," A. Trimble, L.M. Bartolo, *Proc. Intnl. Soc. Knowledge Org. 2000*, 1643 (2000).

"Fine Structure of Defects in Radial Nematic Droplets," S. Mkaddem, E.C. Gartland, Jr., *Phys. Rev. E*, **62**, 6694-6705 (2000).

"Waveguide Based Cholesteric Liquid Crystal Displays," H. Yuan, P. Palffy-Muhoray, *SID 00 Digest*, 814-817 (2000).

Publications, *continued on page 6*

ALCOM holds ninth short course on liquid crystal materials and displays

The ALCOM Center held its ninth annual short course, "Liquid Crystals: Materials and Display Devices," November 14-17, 2000, at the Liquid Crystal Institute.

The 3 ½ day lecture and laboratory course covered a broad range of technical and practical topics. Beginning with the basics such as liquid crystal structures, chemistry and physical properties, the course progressed to electro-optic behavior of devices, computer modeling methods, and the design of liquid crystal displays.

Attendees were a mixture of scientific, technical, and managerial personnel from companies in the United States, New Zealand, Japan, Canada, and the Netherlands. Their backgrounds included chemistry, physics, material sciences, business, mechanical, electrical, and chemical engineering.

The morning lecture topics included basic concepts, liquid crystal materials, polymer liquid crystals, nematic devices, smectic liquid crystals, polymer/liquid crystal dispersions and devices, computer modeling, bistable nematic and ferroelectric devices, cholesteric liquid crystals, and photonic applications of liquid crystals.

The first day of afternoon labs included a tour of the LCI characterization facilities and the Liquid Crystal Display Resource Facility. Attendees suited up in full clean room protective wear and were given a complete tour of the clean room. While in the clean room, they fabricated substrates that were later used to make devices.

The second and third days of labs included one lab each for fabricating cholesteric and polymer dispersed liquid crystal devices. Two other labs were devoted to constructing and characterizing three nematic devices – ECB, TN and STN cells.

New this year to the short course was a lecture on device drive electronics. Building on the nematic labs and lectures, the presentation covered multiplexing schemes and included a demonstration of a commercially available display evaluation kit. The demonstration illustrated the ease with which liquid crystal displays can be incorporated into instruments and equipment.

Students work in small groups to characterize cells which they made during the Nematic Devices construction lab.

Dr. Michael Fisch gives an introduction to device drive electronics during the Nematics lab.

While students watch, Dr. Vassa Sergan (seated) glues together substrates which students assembled during the Nematic Devices construction laboratory.

Though occasionally described as drinking from a fire hose, the short course was well received. One participant commented that the classes were all very technical and detailed but yet were understandable to the lay person.

Preliminary plans are underway for the 2001 short course. As in years past, 36 is the maximum number of students. If you would like to be added to the mailing list to receive information on the 2001 course, send e-mail to brenda@ lci.kent.edu.

The short course web site, www.lci.kent.edu/shortcourse.html, will be updated with information as it becomes available.

ALCOM researchers create displays from banana-shaped liquid crystals

The first displays using banana-shaped liquid crystals were invented at the Liquid Crystal Institute in the laboratory of Antal Jakli. The invention is a result of collaborative work between ALCOM principal investigators, Jakli and L-C. Chien, and scientists D. Krüerke, H. Sawade and G. Heppke from the Technical University of Berlin, Germany.

Liquid crystal films containing banana-shaped molecules in a tilted smectic phase can switch optically with electric fields without the need of polarizers or any external back-lighting. The display is similar in appearance to polymer dispersed liquid crystals (PDLC) and polymer network stabilized liquid crystals (PNLCs) but with crucial differences. In PDLCs and PNLCs the scattering is due to the coexistence of solid and liquid crystal phases with different optical properties. In the present case there are only liquid crystals of banana-shaped molecules. Light scattering in banana-shaped liquid crystals is due to defect walls separating into differently tilted domains (in the OFF state of a racemic structure and the ON state of a chiral phase).

In PDLCs and PNLCs the switching times are well over one millisecond, whereas for banana-shaped molecules the switching time is typically less than 100-ms (about two orders of magnitude faster). This is due to the polar nature of the phases which provides first order interactions between field and polarization. In addition, the viewing angle and the transmittance of the clear state are much better.

In "banana materials" there are two distinct states, "racemic" and "chiral," which work in opposite fashion. The racemic state is scattering at the OFF state and optically clear under electric fields. The chiral state is transparent at zero fields and scattering at fields of about *8V/mm*. Most importantly, these two states may be reversibly interchanged. This implies their use in devices that do not consume any energy, except during switching from one state to other. Such technology has applications in information products such as electronic books and signs.

The switching in the chiral state of banana-shaped liquid crystals is shown in the figure below.

OFF ON

Illustration of the capability of the "B2 banana phase" for use as an electrically switchable light shutter. 10-mm sample with 1cm^2 active area at room temperature. A sheet of paper showing the acrynom, "ALCOM" is placed behind the cell. At zero fields the film is transparent and the text is visible. At fields E>8V/mm the film is opaque and the text is not visible.

Sprunt, *from page 4*

"A lot of what we have learned in solving problems and conducting research in the field of liquid crystals is proving to be applicable in biological science in some very interesting ways," according to Sprunt.

Real biological systems are very complex and a critical issue is defining a manageable problem and optimizing the techniques carried over from the study of liquid crystals. Sprunt sees biomedical engineers as a particularly important group with whom to collaborate, as these scientists have particular expertise in producing model systems that are simpler than natural systems but still incorporate some important functionality. Sprunt and a scientist at Scripps are discussing research in the area of fast fluctuations in DNA and unfolded proteins using fluorescence correlation. The new, high speed correlator may find an interesting application in this area.

Sprunt is Associate Professor of Physics at Kent State. He joined the Physics faculty in Fall, 1995 in the area of condensed matter physics. Information on Prof. Sprunt's research is on the web at http://cnr2.kent.edu/Physics/Sprunt.html. He is also developing a laboratory web page with experimental interface which will soon be available.

Publications, *from page 4*

"Helical Filamentary Growth in Liquid Crystals Consisting of Banana-Shaped Molecules," A. Jakli, Ch. Lischka, W. Weissflog, G. Pelzl, A. Saupe, *Liq. Cryst.* **27**, 1405-1409 (2000).

"Measurements of the Hyperpolarizability Tensor by Means of Hyper-Rayleigh Scattering," V. Ostroverkhov, R.G. Petschek, K.D. Singer, L. Sukhomlinova, R.J. Twieg, S.-X. Wang, L.C. Chien, *J. Opt. Soc. Am. B* **17**, 1531-1542 (2000).

Alkarockets, *from page 3*

room can be found on the *Research Center for Educational Technology* web site, www.rcet.org, under the Ameritech Classroom link.

Through programs such as ALCOM Education Outreach and the Ameritech Classroom, more students will learn to launch rockets at the LCI -- and maybe someday at Cape Canaveral.

Anniversary symposium, *from page 1*

Dr. W. Lance Haworth (Executive Officer, National Science Foundation) spoke about the impact that the ALCOM Center has made in Ohio and the nation. Dr. J. William Doane, Director Emeritus of the Liquid Crystal Institute, gave the keynote address highlighting the history of the Liquid Crystal Institute and ALCOM.

The symposium concluded on Tuesday with a presentation by John West on the past accomplishments and future direction of the ALCOM Center.

The meeting was the 13th symposium sponsored by the ALCOM Center since its inception in 1991. The agenda and a complete list of previous symposia can be found on the web at www.lci.kent.edu/ALCOM/symposia.html.

In celebration of its anniversary, the National Science Foundation created a web page devoted to the year-long activities (www.nsf.gov/od/lpa/nsf50/start.htm). A link on the ALCOM web site (www.lci.kent.edu/alcom/alcom.html) was created to salute the NSF 50th anniversary. The ALCOM site includes links to NSF web sites.

Professor Bill Glenn from Florida Atlantic University (left) converses with ALCOM principal investigator, Phil Bos, during a break in the symposium talks.

Bin Wang (second from left), Chemical Physics doctoral student at Kent State, explains his research during the poster session.

Degrees, Awards and Recognition

Kent State student receives SPIE scholarship

Kent State University doctoral student, Dmitry Voloschenko has been awarded a 2000 SPIE Educational Scholarship in Optical Science and Engineering. Mr. Voloschenko is a doctoral student in the Chemical Physics Interdisciplinary Program under the direction of Professor Oleg D. Lavrentovich. He is currently finishing his doctoral thesis while exploring physical properties of liquid crystals and developing new liquid crystalline devices at Motorola.

Kent State student receives Medal

Kent State University doctoral student, Tod L. Schneider received the Silver Medal during the Awards Ceremony at the MRS Fall meeting in Boston, November 26-December 1, 2000. MRS graduate student awards are given to "honor and encourage graduate students whose academic achievements and current materials research display a high order of excellence and distinction." Mr. Schneider made a presentation to a panel of judges on "Oriented Monolayer Stacks of Lyotropic Chromonic Liquid Crystals." His doctoral advisor is Prof. Oleg D. Lavrentovich.

Graduate degrees awarded

Case Western Reserve University

Travis Ribar, Masters Degree, January 2001, "FT-IR Imaging of the Dissolution of Poly(α-methylstyrene) in Solvent Mixtures and Spectroscopic Analysis of Vapor Diffusion through an Aniline Oligomer Chemical Sensor," J.B. Lando, advisor.

Kent State University

James Anderson, Ph.D., Chemical Physics, December 16, 2000, "Transitions from the Homeotropic State in Cholesteric Liquid Crystals," P.J. Bos, advisor. Currently at Hana Microdisplay Technologies.

George F. Barrick, Ph.D. in Applied Mathematics, December 16, 2000, "Analysis of Numerical Methods for 1-D Liquid Crystal Display Optics," E.C. Gartland, Jr., advisor.

Dmitri Konovalov, Ph.D., Physics, December 16, 2000, "A Dynamic Light Scattering Study of Ferrielectric Phases of Chiral Smectic Liquid Crystals," S.N. Sprunt, advisor. Postdoctoral Fellow, Brandeis University.

Xiang-Dong Mi, Ph.D., Chemical Physics, December 16, 2000, "Dynamics of the Transitions Among Cholesteric Liquid Crystal Textures," D.K. Yang, advisor. Research Scientist, Eastman Kodak.

Degrees, *continued on page 8*

Degrees, Awards and Recognition, *from page 7*

Anlun Tang, Ph.D., Physics, December 16, 2000, "Dynamics of Chiral Smectic-A and Twist Grain Boundary Phases of Liquid Crystals," S.N. Sprunt, advisor. KLA-Tencor, California.

Charles Titus, Ph.D. in Chemical Physics, December 16, 2000, "Refractive and Diffractive Liquid Crystal Beam Steering Devices," P.J. Bos, advisor. Postdoctoral Fellow, Liquid Crystal Institute, Kent State University.

Haijun Yuan, Ph.D., Chemical Physics, December 16, 2000, "Light Propagation in Complex Liquid Crystal Structure," P. Palffy-Muhoray, advisor. Manager of Liquid Crystal Technologies, LambdaFlex, Inc.

Calendar

Optoelectronics 2001
Jan. 20-26, 2001, San Jose, CA

2001 European Conference on Liquid Crystals
March 29-30, 2001, Halle, Germany

ANTEC, Society of Plastics Engineers
May, 2000, Orlando, Florida

SID '01, Society for Information Display
June 3-8, 2001, San Jose, CA

2001 Gordon Research Conference
June 24-29, 2001, New London, NH

Web Sites

ALCOM Home Page
http://www.lci.kent.edu/alcom/alcom.html

Liquid Crystal Institute, KSU
http://www.lci.kent.edu

Dept. Macromolecular Science, CWRU
http://k2.scl.cwru.edu/cse/emac/

Department of Physics, CWRU
http://erebus.phys.cwru.edu/phys/physdept.html

Polymer Science, University of Akron
http://www.polymer.uakron.edu/

ALCOM Education Home Page
http://olbers.kent.edu/alcomed/k12.html

ALCOM Update newsletters with color photos
www.lci.kent.edu/newsletters.html

Heterogeneous Structures Project Database
http://hsp.kent.edu

KSU Office of Technology Transfer
http://www. techtrans.kent.edu

On-Line Polymer Liquid Crystal Tutorial
http://plc.cwru.edu

Experiment at a Distance
http://olbers.kent.edu/alcomed/Experiment/eo.html

Optics of Cholesteric Liquid Crystals
http://alcom.kent.edu/~tik/choles.html

Edison Polymer Innovation Corp.
http://www.epicpoly.org