Liquid crystals are evolving to be the world’s dominant mode of information display for work and play, rapidly replacing other display media, and clearly established as one of the top few industrial technologies of the 21st century. Looking to the future, the diversification of liquid crystal applications, spearheaded by a variety of entrepreneurial ventures, promises an important role for scientists and engineers trained in this exciting technology. Despite its importance, there are very few comprehensive, interdisciplinary educational programs targeting this new and rapidly growing industry. The Graduate Program in Liquid Crystal Science and Technology involves Chemistry and Biochemistry, Physics, and Chemical and Biological Engineering in an interdisciplinary program including both research and education. This PhD program trains students to be scientists and engineers at the leading edge of liquid crystal technology.

**Program Highlights**

- Interdisciplinary training leading to a PhD in one of the following fields:
  - Chemistry and Biochemistry
  - Physics
  - Chemical and Biological Engineering
- Extensive coursework and research experience in liquid crystal science and technology
- Affiliation with the NSF-funded Liquid Crystal Materials Research Center (LC MRC)
- Multidisciplinary research projects including rotations in multiple Center laboratories
- Interactions with local, national and international liquid crystal industry through internships, short courses, and research projects
- Program support provided primarily by the US Department of Education
Graduate Program in Liquid Crystal Science and Technology

The Graduate Program in Liquid Crystal Science and Technology is offered by the Liquid Crystal Materials Research Center (LC MRC), one of the world’s leading liquid crystal research centers, and a principal source in the US of PhDs with training in liquid crystal science.

The development of new liquid crystal (LC) technologies, primarily for information display, requires innovative scientists with a broad background in chemistry, physics, and engineering. Recognizing that few of us can hope to be simultaneously at the cutting edge of every discipline, the Center strongly encourages collaboration - a philosophy that has led directly to the Center’s international reputation for quality research - and maintains extensive shared research facilities. Experimental techniques commonly employed include optical microscopy and laser light scattering, visible and IR spectroscopy, x-ray diffraction, scanning probe microscopy, and calorimetry. The Center has state-of-the-art wet-benches for chemical synthesis, extensive analytic facilities, a clean room, and a high performance array of Unix workstations for computational studies. While each graduate student must satisfy the core course requirements of his/her home department, this program specifically fosters a broad education in all aspects of liquid crystal science. Oral skills are honed in seminars and informal research presentations, and students in the program are expected to teach in their first year. Each student spends one semester in rotations among various Center laboratories, and gains industrial experience through a three-month internship facilitated by the Center.

Interdisciplinary Training for Careers in Liquid Crystal Science and Engineering

Liquid crystal science, as practiced by the members of the LC MRC, is highly interdisciplinary, and at the cutting edge of the new field growing from the merging of condensed matter physics and organic photonic materials chemistry and engineering. Students with an academic career in mind will find that their training in the Center prepares them well for the new interdisciplinary academic research model required for breakthroughs in cross-disciplinary fields.

As is true for much of the best materials research, however, industrial applications are remarkably close to the research labs in the LC field. It is now abundantly clear that organic materials have a key role to play in displays and in the emerging photonics technologies. While industrial activity around LC applications is strongly centered in Asia, companies in the US are finally exploiting breakthroughs coming from US laboratories. This nascent US liquid crystal industry is burgeoning largely by virtue of the activities of a host of small entrepreneurial ventures, several of which are located in Boulder County, having spun out of University research labs. This commercial activity has created a strong and increasing demand for people trained in LC science and engineering. Students and postdoctoral research associates involved in the LC MRC are not only working at a frontier of science, but are also creating the technological underpinnings of the US display and photonics industries. Currently, 23 of the Center’s PhD graduates (60%) are working in liquid crystal-related industrial positions within the US.
Center students, due to the fundamental nature of their research, are taught to work as part of a team and to think broadly about research problems. Center faculty make an explicit effort to teach problem-solving skills and foster a broad knowledge base. Weekly Center group meetings, an active seminar program, and interdisciplinary course offerings supplement traditional individual group meetings, divisional seminars and graduate courses. Many of the Center’s faculty have strong ties to the LC industry, and the Center’s approach to teaching has been developed in response to the needs of this industry. Building upon the current tradition, graduates of the Center should be well-positioned to help continue the creation of a world-leading US liquid crystal industry.

Research at the Forefront of Liquid Crystal Science and Engineering

*Design, Synthesis, and Characterization of New Liquid Crystal Materials*
- Novel chiral liquid crystals
- Liquid crystals for nonlinear optic applications
- Hydrogen bonded dimer liquid crystals

*Liquid Crystal Composite Materials*
- Creation of polymer/liquid crystal composite materials by photopolymerization
- Liquid crystal/colloidal crystal composite materials as a basis for electro-optic photonic bandgap structures

*Liquid Crystal Structures and Phases*
- Ferroelectric liquid crystals via spontaneous polar ordering
- Twist grain boundary phases
- Chiral liquid crystal phases from achiral bow-shaped molecules
- Design and synthesis of new ferroelectric and antiferroelectric liquid crystals

*Computer Simulation and Modeling of Liquid Crystals*
- $^{13}$C nuclear magnetic resonance and infrared dichroism study of molecular conformation
- Atomistic simulation of molecular organization in liquid crystal phases
- Development and simulation of liquid crystal model systems
- Mean-field modeling of polarization and optical properties of liquid crystals

*Liquid Crystal Surfaces and Interfaces*
- Sum frequency generation nonlinear optical study of liquid crystal surface orientation
- Interaction of liquid crystals with self-assembled monolayers
- Scanning tunneling and atomic force microscopy of two dimensional liquid crystal structures
- Total internal reflection ellipsometry of liquid crystal surface orientation

*Liquid Crystal Engineering and Technology*
- Analog electro-optic effects
- Photoaddressed spatial light modulators
- Liquid crystal alignment technology
Degrees Offered
PhD with Certificate in Liquid Crystal Science and Technology

Financial Support
Annual stipend, plus full tuition support and health insurance

Minority and Women Applicants
The LCSAT program seeks to establish and maintain a student profile representative of the 21st century high-technology workplace. To help meet this goal, we are seeking minority and women students who wish to participate in this exciting program.

Note for Faculty Advisors
Please consider recommending the Liquid Crystal Science and Technology Program to students who might be interested in graduate training, and particularly point out this opportunity to women and minority students.

Boulder, Colorado
The University of Colorado campus is situated in Boulder, a city of 96,000 located about 20 miles northwest of Denver along the foothills of the Rocky Mountains. The city is surrounded by over 30,000 acres of parks and open space and is renowned for its year-round high quality of life.

How To Apply
Entrance Requirements
Entrance requirements are those of the participating academic departments. Students who wish to be considered for LCSAT must also write a short (less than one page) description of how a program in liquid crystal science and technology fits into their overall career objectives. Successful applicants to the individual departments will then be considered for LCSAT based on their overall academic records, GRE scores, letters of recommendation, and description of career objectives.

Application Procedure
Students who wish to participate in LCSAT must apply through, and be accepted to, the PhD program in the University of Colorado’s Department of Chemistry and Biochemistry, Department of Chemical and Biological Engineering, or Department of Physics. Application packets for these departments may be obtained from the LCSAT program office at the address below.

Important Note
To be considered for the LCSAT program, students must notify the LCSAT office at the time they submit their applications to one of the participating University departments, or shortly thereafter. The address is listed below.

For Correspondence or More Information
Information about the LCSAT program is available from:

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