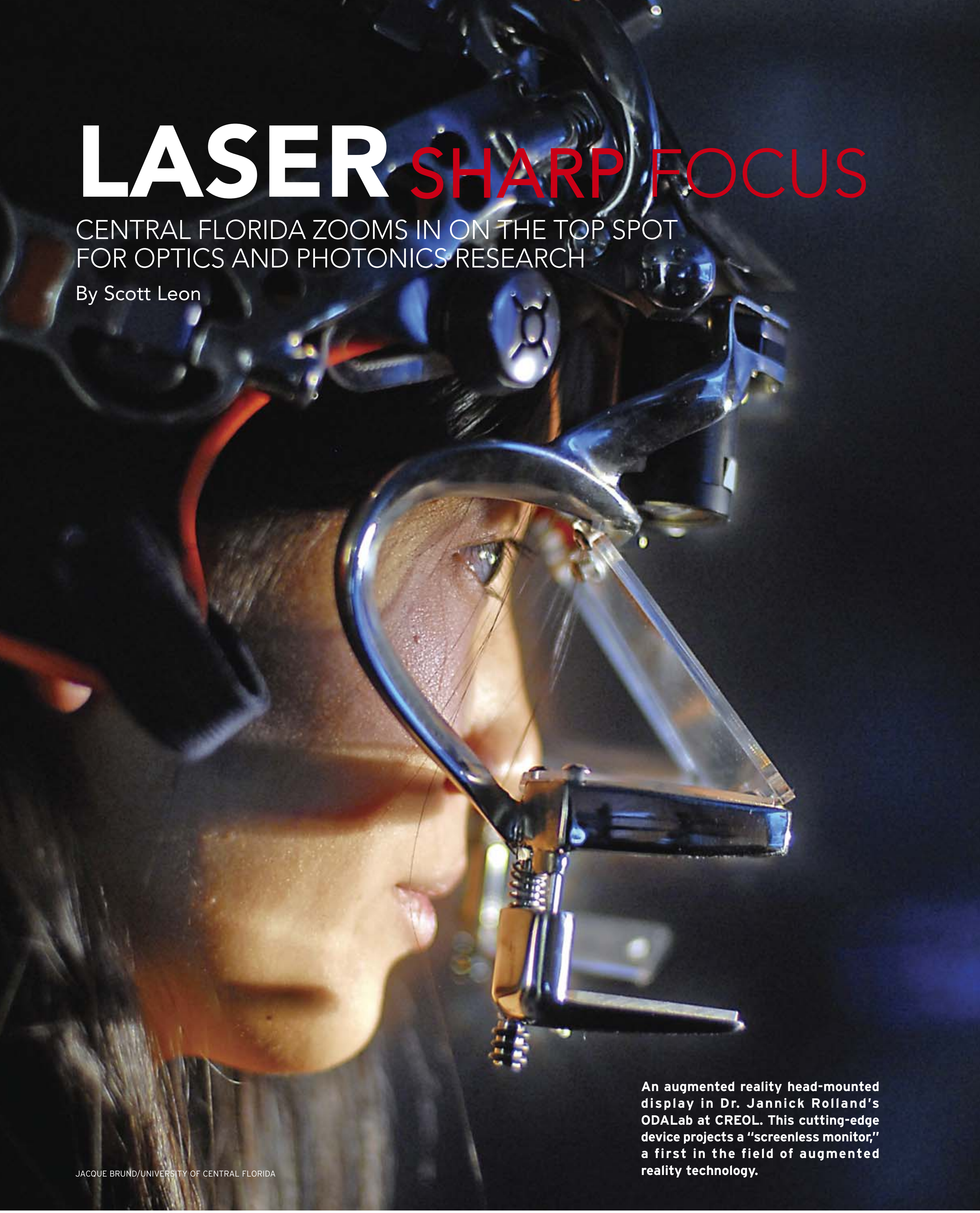
LASER SHARP FOCUS

CENTRAL FLORIDA ZOOMS IN ON THE TOP SPOT FOR OPTICS AND PHOTONICS RESEARCH

By Scott Leon



An augmented reality head-mounted display in Dr. Jannick Rolland's ODALab at CREOL. This cutting-edge device projects a "screenless monitor," a first in the field of augmented reality technology.

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If you're like most people, you owe many of the things you do on a daily basis to light, but you might not even know it. Most of us picture light as little more than the phenomenon that occurs when we flip a switch, but the reality is that "light" is far more, and its uses are nearly limitless. A vast amount of modern technology is based on the manipulation of light in terms we're not aware of — powering such everyday items as CDs, DVDs, cell phones, LCD TVs and computer monitors, and even high-efficiency light bulbs. And much of the research advancing these technologies happens right here in Central Florida.

While the 20th century was the age of electronics, the 21st century is the age of photonics. You might not realize that many household devices today use particles of light, called photons, to transmit information — something that used to be the sole responsibility of electrons and electronics, according to Dr. James Pearson, Director, Research and Administration at the University of Central Florida's Center for Research and Education in Optics and Lasers (CREOL), which is part of UCF's prestigious College of Optics and Photonics. Photonics is generally defined as the generation, manipulation and utilization of light. Light, which comes in visible and invisible forms, encompasses types used in familiar technologies like x-rays, as well as hi-tech lasers.

While not a new science, much of the research in photonics and the related field of optics — the study of the properties of light — has advanced, literally, at the speed of light over the last few decades. CREOL was at the forefront.

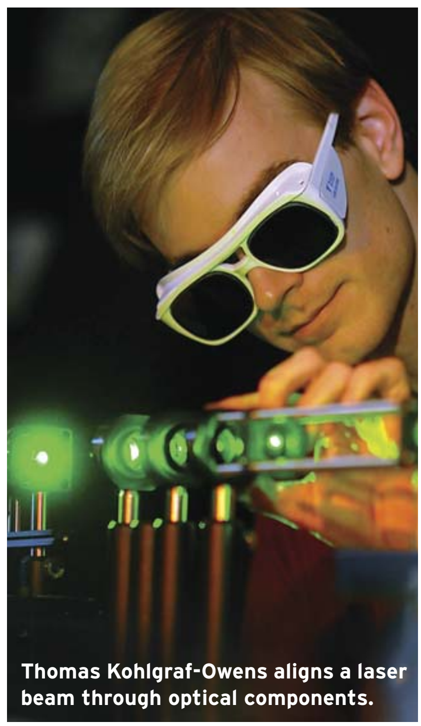
Established in 1986 to help Florida grow a budding industry, CREOL later became the first full-fledged college in optics and photonics at a university in the United States. Since then the program has spawned dozens of businesses and has generated more than 260 patent applications, with 110 patents issued. Central Florida today is home to approximately 70 photonics companies and 20,000 workers.

Currently over two dozen companies, including 13 in Florida, hold licenses for technology created at CREOL. These companies manufacture everything from lasers for industrial and military use, to technology for the medical field, to liquid crystal displays (LCDs) and even zoom lenses for cameras. In fact, Orlando currently is home to one of only a handful of educational institutions offering degrees in optical science and engineering, and is one of only a few research hubs in the U.S dedicated to this science.

WHAT IS PHOTONICS?

Photonics encompasses a large arena of subfields, but lasers are among the most well-known.

"Today we use lasers not only for cutting and welding, but also for scribing integrated circuits, transmitting information down high-bandwidth fiber-optic cables, range finding, imaging, biological material analysis, medical diagnostic and therapeutic applications, and any number of other



Thomas Kohlgraf-Owens aligns a laser beam through optical components.

JACQUE BRUND/UNIVERSITY OF CENTRAL FLORIDA civilian and military uses like night vision equipment or even land mine detection," says Pearson. "Radial Keratotomy and LASIK surgery, the latest flat panel TVs – including LCD, Plasma and DLP – high-speed Internet and even long-distance landline service owe their existence to the manipulation of light using technologies developed at CREOL or other institutes like it.

"While many companies formed around cutting-edge technology can't afford the facilities or equipment necessary to carry out the research required, we have been able to develop them at CREOL and form effective partnerships within the industry. In fact, while technology is often born here, the ideas usually end up licensed out to a company to develop and sell. Sometimes the technology can even spawn a company all unto itself," says Pearson.

AT THE SPEED OF LIGHT

Perhaps the most intriguing thing about working with light is that it's the fastest thing we know. Manipulating it to carry information by sending it in pulses means that information can be transferred at the speed of light. And that's good news for a generation that demands ever-faster and more available communication.

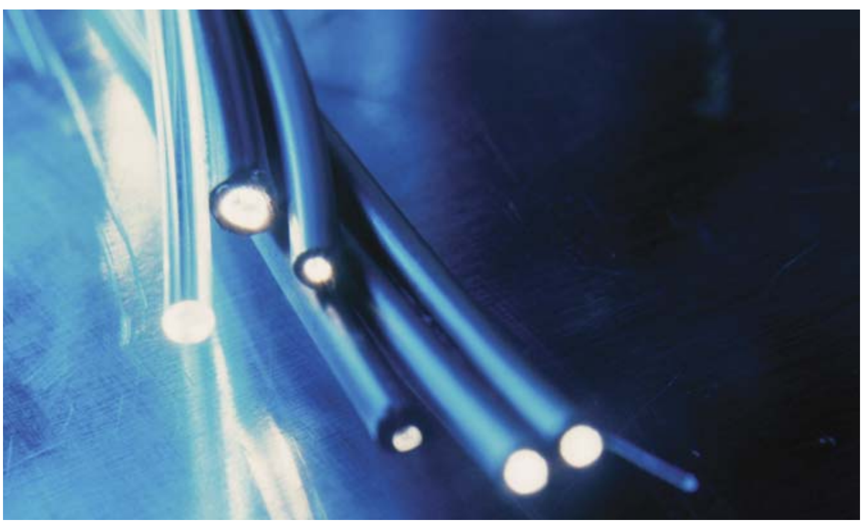
"The idea of an optical computer is nothing new. The train of light pulses becomes the digital 1s and 0s. We've been working on it for years, but there are inherent problems. Because the information travels so fast we get bottlenecks when we need to manipulate it," says Pearson. "But because laser light is very spatially confined, it's ideal for sending signals cross-country over fiber optic lines. Plus, where electrical signals can interfere with one another, photonic signals at different wavelengths remain independent, so we can send multiple signals at the same time."

"But because laser light is very spatially confined, it's ideal for sending signals cross-country over fiber optic lines" says Dr. James Pearson, at UCF CREOL.

Dr. Peter Delfyett, Trustee Chair Professor of Optics at CREOL, is a renowned pioneer in developing "ultra fast" photonics with multiple applications. One of his primary areas of research involves the development of optical clocks. Don't think of "optical" in terms of something visual. It's a clock based on timing things using the speed of light. "The difference in accuracy between optical clocks and the atomic clock that most people are familiar with is significant. Optical clocks are up to 1,000,000 times more precise," says Delfyett.

Don't worry, this isn't something designed to tell *exactly* how late you're running — it's actually used to create things that require incredible accuracy, such as Phased Array Telescopes. "Phased Array" means coordinating multiple objects to magnify their power. In this case it creates a much larger telescope area using several separate telescopes in different locations, say on two satellites, but it's only possible by precise synchronization.

Delfyett continues, "In order to achieve this, you have to know *exactly* where the telescopes are. Since we know the speed of light and we can measure the time it takes for a beam of light generated by a laser to bounce off a satellite, we can determine its position in space exactly because distance is the mathematical product of rate and time. This will eventually allow us to create telescopes that are functionally far larger than anything we could actually send into space. And if we turn that technology back on the Earth, you can imagine how accurate the images could be for military or mapping purposes."



LASER SHARP

The other area of interest for Delfyett — ultra short pulse lasers (USP) — actually spawned Orlando-based company Raydiance, Inc., which now licenses about half of his patents. These lasers stand in contrast to continuous-wave lasers, which are what typically comes to mind when we hear the word 'laser.' In addition to what its continuous-wave counterparts do, USP lasers allow for a myriad of additional applications, including, perhaps most importantly, medical uses.

Delfyett explains: "A continuous-wave laser cuts by causing the molecular bonds to heat and vibrate so violently that they ultimately break. Unfortunately, this usually damages some of the surrounding material. What we found with USP lasers was that by bombarding the molecule with very short but powerful pulses in rapid succession, we could achieve the same separation much more accurately —

and without the heat — by blasting electrons further and further away from the nucleus to the point that they no longer affect the molecule. This loss changes the polarity of the molecule and, since like charges repel each other, they separate without generating heat because it's done so fast."

Think of it as creating a hole in a wall by firing a small caliber machine gun rather than a cannon. The relative difference in precision and collateral effects is considerable. The ability to eliminate the resultant heat allows numerous additional uses, especially in medicine. USP lasers make a variety of cosmetic and laser-based eye surgeries (such as RK and LASIK) possible, and are also used to clean teeth. There have even been studies on the use of USPs in the detection of explosive devices.

One experimental area of photonic medical research is Optical Coherence Tomography (OCT) as a high-accuracy and minimally invasive diagnostic tool. Imagine inserting a small camera into the body through a blood vessel via a tiny fiber-optic cable. The camera could scan very precisely from the inside out to examine tissue. Lasers can also be used to determine what almost any material is made up of via a process called fluorescence. Put simply, this means that as the laser shines on the material, the material emits certain wavelengths of measurable light that are characteristic of that specific material. Combining these two capabilities could instantly determine the presence of cancerous cells, and allow doctors to selectively destroy those cells at the same time. It's not that far-fetched. Florida-based Ocean Optics already has developed a machine capable of detecting precancerous cells very accurately.

Until recently, one drawback with the equipment used to create and control USP lasers was its size and complexity. That's where Delfyett's technology, now at Raydiance, comes in. Based on his research and with his help, the company developed and produced the world's first compact, cost-effective and fully software-controlled USP laser system, ultimately increasing the

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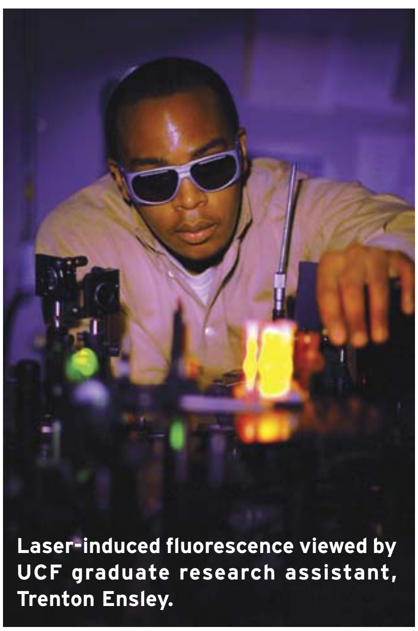
Scientists in Leon Glebov's CREOL lab use holographic optical elements. Glebov's breakthrough research in this area led to the 'spin-off' business: Optigrate. (Optigrate.com)



Laser-induced fluorescence viewed by UCF graduate research assistant, Trenton Ensley.

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accessibility of this technology for wider use, such as by local LASIK clinics. And that's just the beginning.

A LOOK AHEAD

Delfyett's research is simply one area of a large body of work being done at CREOL by 39 faculty members, 54 researchers and 160 graduate students. Research topics currently include novel camera designs; virtual reality; holographics; display technologies; new lasers; very small, "nano" optical and laser devices; and a host of theoretical topics far too complex to detail. CREOL's annual budget is approximately $20 million, with over a quarter coming from industry partners and half from the federal government. Even though it was established at UCF, CREOL began as a concerted effort on many levels. Today, funding comes through numerous channels, both national and local (including CREOL's initial $1.5 million from the State of Florida), a vibrant Industrial Affiliates Program with more than 60 members, and numerous licensing agreements. CREOL's ties to Orlando's continually growing photonics industry are fundamental.

To further bolster the growing industry in Central Florida, UCF established the Florida Photonics Center of Excellence in 2003 with a $10 million grant from the Florida Legislature to create partnerships between researchers and companies. To date, it has resulted in more than $35 million in funding, and the new Townes Laser Institute (established last year with a $4.5 million grant from Florida) is expected to create a research hub for new laser devices.

The corporate relationships fostered and built through the Affiliates Program and the UCF Technology Incubator (which was rated No. 1 in the nation in 2004) generated more than $5.5 million in the 2005-2006 fiscal year. With a rapidly growing photonics and optics industry in Metro Orlando and the surrounding area, CREOL provides a key foundation and support for the Florida Photonics Cluster (FPC), a nonprofit industry association of the state's photonic companies. Through the FPC and with the support of organizations like the Metro Orlando EDC, CREOL helps promote the interests of its members and Central Florida as a major center for photonics technology and research around the world.

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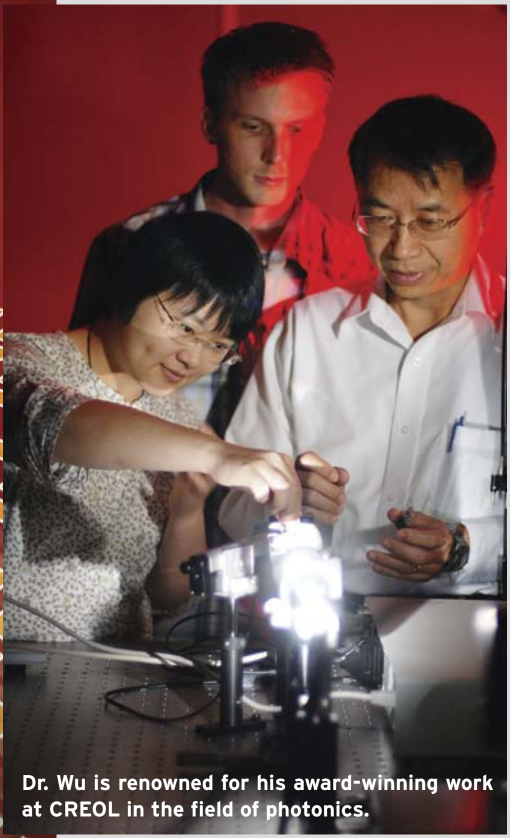
Indeed, with the addition of the College of Medicine at UCF, even more opportunity arises — advanced research into medical applications for photonics and other segments of biophotonics, which is one of the focus areas for the new Townes Laser Institute. Development of new imaging techniques, new diagnostic and treatment tools, and new surgical procedures using lasers will be possible and much more practical with the establishment of a "medical city" at Orlando's Lake Nona. Right now the groundwork for a partnership between professors and physicians is being laid, and it will allow them to work together to solve problems utilizing the resources of both worlds.

Perhaps the most impressive thing is that all of this research, happening right in Orlando's back yard, has cemented the area's position as a hub for optic and photonic research throughout the world. While the work itself may not make much sense to those of us without a Ph.D., the results certainly are illuminating. And for those of us with an LCD TV, they're kind of cool, too.



Dr. Wu is renowned for his award-winning work at CREOL in the field of photonics.

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A ZOOM WITH A VIEW

Perhaps the research at CREOL you can most relate to involves the camera on your cell phone. More than likely it has a digital zoom lens, but the inherent problem with this kind of zoom is that resolution decreases as the distance from your subject increases. Enter Drs. Shin Tson Wu and Hongwen Ren of the UCF College of Optics and Photonics, who specialize in liquid crystal (LC) lenses and liquid lenses that have zoom capabilities.

Liquid crystal displays (LCD) – used in cell phones, computer monitors and TVs – and Dr. Wu's liquid lenses are made up of a particular type of liquid sandwiched between two clear sheets of glass. Liquid crystals are liquids that exhibit crystalline properties. When these are used to create a lens, its focus can be changed by passing it through a non-uniform electric field. The advantage is that you can change the focus of the lens depending on the magnitude of the applied electric field.

"While LC lenses are a mature technology, reliable and easy to manufacture, most of the devices require a polarizer to reduce the light allowed in. They have a relatively long focal length, and are slow to focus. This led us to begin researching non-liquid crystal lenses, which focus much faster, are very reliable, have a huge dynamic range and are up to 1/10th the thickness of LC lenses. They also don't require a polarizer," says Dr. Wu.

With these lenses, a liquid is injected between two clear flexible sheets; this creates a sort of bubble. As the flexible membrane is manipulated and the bubble changes, the focus changes. Of course this technology has its limitations, too, such as problems with extreme temperatures.

Wu's group is also working on a project in biophotonics from which anyone who has ever looked at an LCD screen in the sun will benefit. Whether it's on a cell phone, a computer monitor or a depth finder on a boat, most LCD screens require two polarizers to function, and the ambient light that strikes them can affect viewablity tremendously. Anti-Reflection (AR) coatings are key to being able to use the device under a variety of light conditions. Wu and his UCF colleague, Prof. Lei Zhai, are researching this for LCDs based on a moth's eye, which has a perfect natural AR coating. x