COLLEGE OF OPTICAL SCIENCES

50 YEARS

of Optical Sciences at the University of Arizona

THE UNIVERSITY OF ARIZONA

50 Years

1964 - 2014

COLLEGE OF OPTICAL SCIENCES

50 YEARS OF OPTICAL SCIENCES AT THE UNIVERSITY OF ARIZONA

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North face of Meinel Building, with clouds. (Photo by R. Dawson Baker)

I

MESSAGE FROM DEAN THOMAS L. KOCH


Dean Thomas L. Koch

Welcome to the College of Optical Sciences at the University of Arizona. In this 50th anniversary year, it is rewarding to reflect on the growth and tremendous impact the college has had on education and research in the field of optics.

On behalf of the faculty, I am thrilled that we can bring so many opportunities to students as they enter such a dynamic and exciting field. From its inception as the Optical Sciences Center with a focus on graduate education, the college has now produced over 2,400 professionals in the field of optics and photonics. This includes nearly 700 Ph.D.; 1,200 M.S.; and now 500 B.S. students from our undergraduate program that produced its first graduates just some 20 years ago. Comprising a significant fraction of today's professional talent in the field, our students have benefited from an unparalleled breadth of courses now numbering over one hundred, and many have enjoyed unusual opportunities to gain experience in real, deployed optical systems. In our engineering areas, many of our faculty have substantial industry experience and are able to convey the essential tradeoffs and integration of design, materials and fabrication. In the fundamental science areas, we pursue high-risk, provocative new ideas, and we are proud to count three Nobel Prize winners among our faculty. Many of our faculty have been recognized in the national academies and professional societies both with awards for their accomplishments and in leadership roles.

From the very beginning, by attracting the nation's top talent in optics to our faculty, OSC's initial focus on optical design and engineering quickly blossomed to include exceptional research programs in the most fundamental of optical physics, image science and the rapidly growing technologies of photonics and fiber optics. Today our students and faculty are making research advances that enable breakthroughs in science, ranging from astronomy and exoplanet research to quantum information and control. Their research programs and collaborations are improving the world around us every day, enabling exciting and often lucrative new applications of optics and photonics in fields ranging from medicine to optical communications, and from critical defense technologies to entertainment.

This booklet provides a glimpse into the history and profile of the College of Optical Sciences for our prospective students, our industry partners and the optics community at large and also includes highlights of some of our current research endeavors. Enjoy!

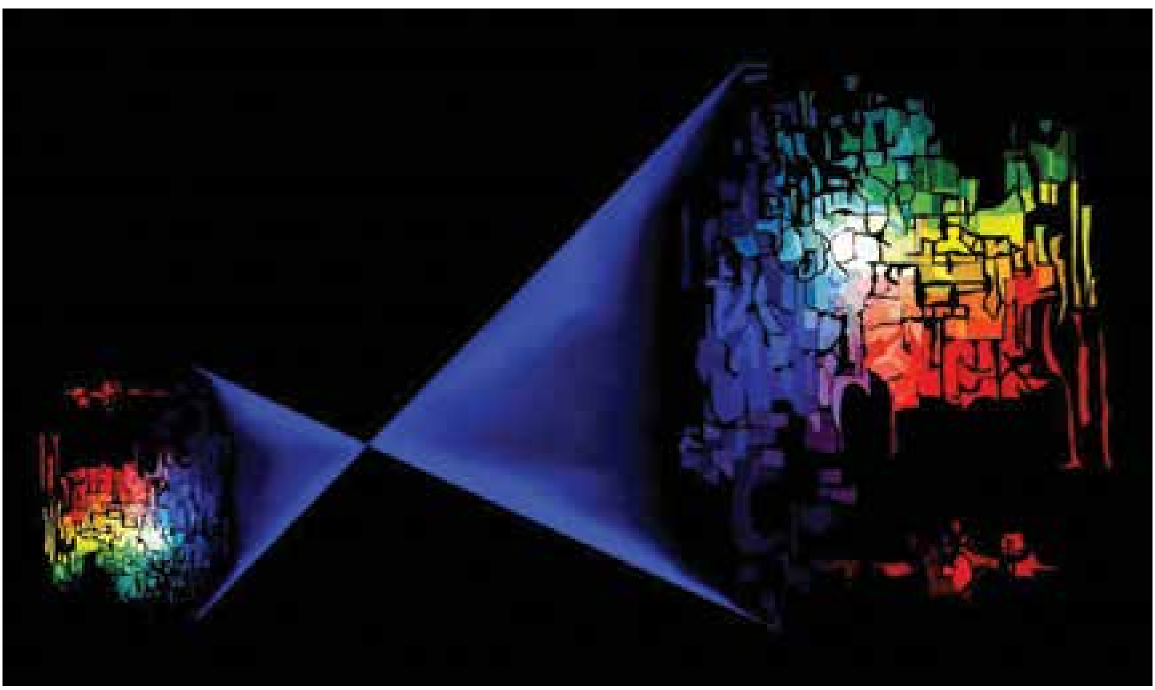
Meinel Building at night. (Photo by Chris Summitt)

II

THE UNIVERSITY OF ARIZONA COLLEGE OF OPTICAL SCIENCES

The College of Optical Sciences, founded as the University of Arizona Optical Sciences Center, has been shaping the future since 1964 by offering highest-quality graduate and undergraduate educations, cutting-edge research programs and a solid commitment to the economic development of the optics industry.

Throughout its 50-year history, OSC has stood on the forefront of the field; today, it educates more students in optics than any institution in the U.S., provides the world's most comprehensive educational program in optics and maintains a worldwide reputation as a premier institution for optical sciences and engineering.



Imaging as envisioned by muralist Don Cowen, 1967. (Photo by Margy Green PhotoDesign)

"Desert Flower": Glass sculpture by artist Christopher Ries, donated by SCHOTT North America Inc. and located in the lobby of the Meinel Building. (Photo by Chris Summitt)

III

MISSION STATEMENT AND VISION

MISSION STATEMENT

The mission of the University of Arizona College of Optical Sciences is to provide the state of Arizona and the nation with an internationally pre-eminent program in education, research and outreach in all aspects of the science and application of light.

VISION

The College of Optical Sciences at the University of Arizona will cultivate the development of optics education and advance society with cutting-edge optical sciences research, which promises to revolutionize medicine, energy efficiency, defense and manufacturing and to push the frontiers of science.

To maintain and improve its leadership position in optical sciences, the college will excel at:

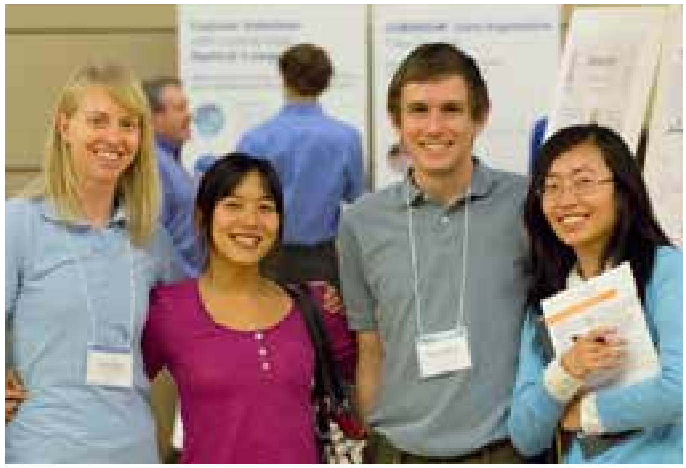
Offering comprehensive undergraduate and graduate educational programs with robust distance learning options that cover the foundations and new concepts in all areas of optical sciences and engineering.

Providing a strong outreach program to educate the public about the importance of optics and to encourage grade school and high school students to consider careers in optics.

Conducting state-of-the-art research and development that expands the fundamental knowledge of optics and optical engineering and extends the application of optical technology to help solve critical problems facing society in such fields as health care, environmental monitoring, information technology, industrial competition and defense technology conversion.

Interacting closely with companies that benefit from optics, especially those located in the Optics Valley of southern Arizona, to ensure that new technology is transferred from the laboratory to the marketplace.






a laser to these atomic transitions to
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ransition

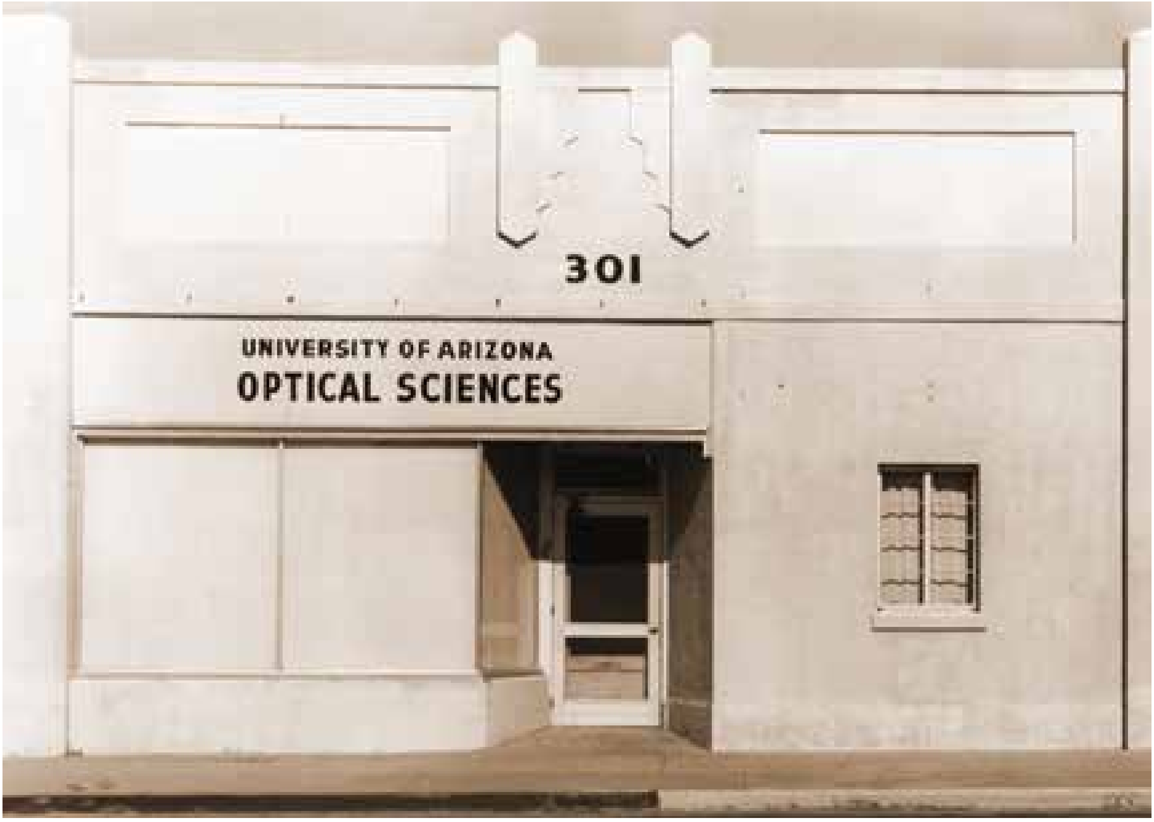

IV
STUDENTS

Students come to the College of Optical Sciences from a variety of academic, cultural and national backgrounds. Upon acceptance, they embark on enlightening journeys that pave the way for a multitude of professional opportunities. Some enrich their studies by taking on teaching or research assistantships. Thanks to a number of generous donors, OSC is also able to support many matriculants with scholarships.

The diverse research performed at the college provides students with a broad range of subjects to explore. Its faculty members are internationally recognized in their specialties, offering students unique opportunities to be taught and mentored by indisputable experts. The college's courses also impart the knowledge and hands-on experience that any optical scientist or engineer needs to succeed in the real world.

The OSC community works to build a stimulating and creative environment. In addition to their academic and research activities, students participate in professional societies and conferences, field trips, volunteer work, and sporting leagues.

The field of optics has been, is and will continue to be a crucial enabler of technology. While some graduates of the College of Optical Sciences continue to expand the discipline's depth in academia, others pursue key business and governmental positions. The college's Industrial Affiliates program, in its more than 30 years of existence, has created a strong connection between OSC and the profession of optics and currently provides numerous networking opportunities (see Section IX for more information). OSC's students look forward to rewarding and fully satisfying careers in optical sciences.



First location of optics shop in downtown Tucson, circa 1967.

Initial construction on Optical Sciences Center building, 1968.

V

HISTORY

The College of Optical Sciences, formerly known as the Optical Sciences Center, was established in Tucson, Arizona, in 1964 to fulfill a national need for more highly trained engineers and scientists in the field of optics. OSC's history reflects its commitment to generating and disseminating knowledge critical to developments in nearly every field of science and technology.

Aden B. Meinel:
Founding Director, 1964-1973.

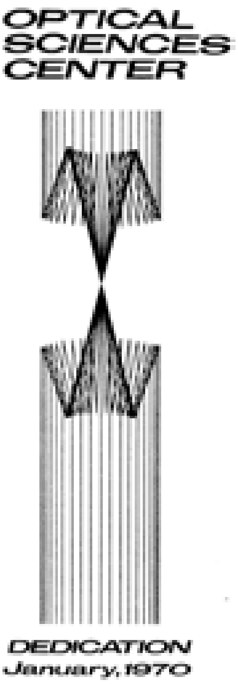
The concept for the Optical Sciences Center originated in the early 1960s when very few people were being educated in optics, and the shortage of trained optical scientists was judged to be a national crisis. In response to this great need, the Air Force Institute of Technology, together with the Needs in Optics Committee of the Optical Society of America and Aden B. Meinel, director of the University of Arizona Steward Observatory, drafted a proposal to set up a center for research and education in the optical sciences.

In 1964, with financial support from the University of Arizona Foundation and the promise of research contracts from the U.S. Air Force, Meinel rented temporary quarters on the UA campus, brought faculty members on board and opened the doors to OSC's first students.

Through visionary negotiations and excellent logistical assistance from University of Arizona President Richard Harvill and the UA Foundation, Meinel, who had been named director of the new center, was able to obtain partial support from the Air Force for seven years as well as funding to construct a new building. The 80,000-square-foot facility was completed by Blanton and Cole Architects and Engineers in 1969 and dedicated in January of the next year.

However, setting the foundation for a robust faculty was even more important than setting up walls. Robert H. Noble from Perkin-Elmer readily joined in 1964. He was immediately followed by Roland V. Shack, who had just returned to Perkin-Elmer from Imperial College in London; Shack was followed in turn by Stephen F. Jacobs, late of TRG (Technical Research Group) and Perkin-Elmer, in 1965.

Completed Optical Sciences Center building, 1970.



Optical Sciences Center logo used in dedication ceremony, 1970.

It is because of Noble and Shack's appointments that 1964 is recognized as OSC's founding year. Their hires, and Steve Jacobs', were made possible by the inclusion of the new optical sciences program in a Science Development Program grant given to the University by the National Science Foundation.

From the outset, Aden Meinel realized the importance of a faculty with diverse backgrounds and a broad range of expertise. He hired glass specialist Clarence L. Babcock from Owens-Illinois and B. Roy Frieden, a recent University of Rochester graduate, in 1966. James A. Eyer, who had been teaching at Rochester's Institute of Optics, and Orestes N. Stavroudis from the National Bureau of Standards arrived in 1967. Peter H. Bartels from Ernst Leitz Optical Co., Philip N. Slater from UA's Steward Observatory, William Swindell from the University of Sheffield in the United Kingdom and recent Stanford graduate Jack D. Gaskill all came in 1968. Arvind S. Marathay from Technical Operations Research, Murray Sargent III from Bell Telephone Laboratories, Robert R. Shannon from Itek Corp. and William L. Wolfe Jr. from Honeywell joined in 1969. With the encouragement of Steve Jacobs, Meinel was also able to attract Marlan O. Scully, a powerhouse in quantum optics, from MIT in 1969. (Scully would be key in drawing other top quantum optics specialists to the center — including, in 1974, Nobel laureate Willis E. Lamb Jr.) In 1970, Bernhard O. Seraphin arrived from the Michelson Laboratory at the China Lake Naval Weapons Center. In 1971, Meinel recruited Arthur Francis Turner from Bausch and Lomb. Finally, in 1972, Richard L. Shoemaker from IBM Research Laboratories came aboard.

Three universities provided 10 of these early faculty hires. Frieden, Eyer and Shannon were all graduates of the Institute of Optics at the University of Rochester. Scully, Sargent and Fred A. Hopf, a 1970 arrival, came from Yale, and Marathay, Shack, Slater and Stavroudis were all alumni of Imperial College.

OSC programs involved personnel from other academic departments from the beginning, thanks to Meinel's belief in interdisciplinary research, including Richard H. Cromwell from astronomy, Hans Roehrig and Sol Nudelman from radiology, Ralph M. Richard and Allan J. Malvick from civil engineering, and Lawrence Wheeler from psychology.

In 1966, Aden Meinel had the good fortune to entice Don Loomis, a master optician with whom he had worked at Kitt Peak, to join the group. Theirs had been, and would continue to be, a very productive partnership. Loomis initially set up his optics fabrication shop in an annex off campus. He then played a key role in designing the new building's test tower and large optics shop. The large optics shop became essential to many of the largest telescope mirror projects, and indeed, OSC's entire optical engineering program.

As contract support developed, Meinel formed a steering committee comprising Jim Eyer as associate director, Bob Noble as director of academic affairs and Phil Slater as assistant director.

In the midst of these strong scholastic and scientific hires, Meinel also stayed mindful of the arts. He brought aboard Australian painter Don Cowen, who created technical illustrations and produced superb decorative pieces, including a colorful mural that graced the center's lobby, the beautiful Pyrex sculpture that currently adorns the college's north entrance and Meinel's very own official portrait.

Night view of Pyrex glass sculpture by artist Don Cowen, installed in the original building's lobby, circa 1970.

First graduate Jim Mayo with director of academic affairs Bob Noble, 1968.

The center began accepting students in 1967. Its first graduate was U.S. Air Force officer James W. Mayo, who received an M.S. in 1968. (He described his experiences as an early Optical Sciences Center student in a recent article available in the history section of the college's website.) In fact, 12 of the center's first 42 graduates were Air Force officers. The Air Force needed an abundance of optics personnel, and OSC was more than willing to train them.

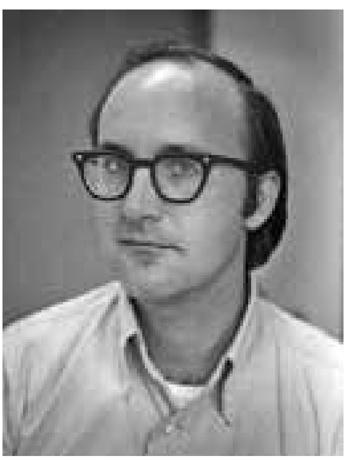
Dean B. McKenney, who was advised by thin films pioneer Arthur Francis Turner, received the center's first Ph.D. in 1969. He was then promptly named to the faculty as assistant professor.

In 1973, Aden Meinel, eager to pursue new research, chose to turn over the Optical Sciences Center to fresh management. Peter A. Franken, an expert in nonlinear optics from the University of Michigan, was selected as OSC's second director.

Peter A. Franken:
Director, 1974-1983.

Franken held substantial leadership experience, a talent for bringing out the best in people — and a sparkling sense of humor. He hired Floyd Lance as business manager and retired Air Force Colonel Don Hillman as program manager. Phil Slater was promoted from assistant to associate director, a title he kept until 1975, when he became chair of the University's interdisciplinary graduate program in remote sensing and spatial analysis.

Faculty brought aboard during Franken's time included Harrison H. Barrett, Willis Lamb Jr. and James C. Wyant in 1974; Eustace L. Dereniak and H. Angus Macleod in 1978; Hyatt M. Gibbs, Dror Sarid and George I. Stegeman in 1980; Chris L. Koliopoulos in 1981; and James J. Burke and Charles M. Falco in 1982. Among the joint professors Franken welcomed were George A. Atkinson of chemistry, Robin N. Strickland from electrical and computer engineering and William H. Wing of the department of physics.



Harrison H. Barrett:
Interim Director, 1983.

Franken quickly realized that Jack Gaskill was the perfect person to direct and foster the center's then-emerging academic programs. Indeed, Gaskill established a strong tradition of student support, satisfaction, selection and retention in the 20 years he spent managing academic ventures, most notably launching OSC's Industrial Affiliates and bachelor's degree programs.

Peter Franken stepped down as director in 1983. Harry Barrett served as interim director during the search for his replacement, and in 1984 Bob Shannon became the new director. Shannon had spent 10 years at Itek Corp. managing optical design projects and developing optical systems for photoreconnaissance satellites before joining the Optical Sciences Center faculty.

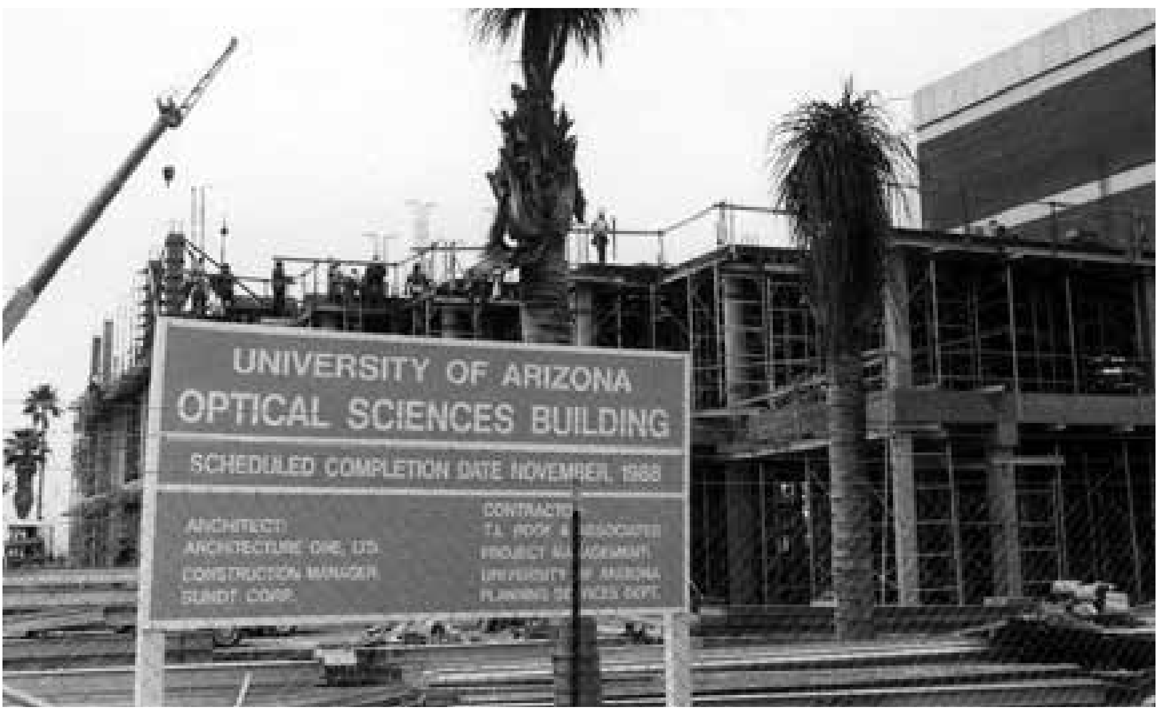
Faculty hires under Shannon's directorship included Nasser Peyghambarian in 1985, Masud Mansuripur in 1988, Tom D. Milster in 1989, Ewan M. Wright in 1990, John E. Greivenkamp in 1991 and Galina Khitrova in 1992. He also provided, among others, Robert A. Schowengerdt from electrical and computer engineering and arid land studies, Kenneth A. Jackson from materials science and engineering, and John A. Reagan from electrical and computer engineering with joint appointments.

Robert R. Shannon:
Director, 1984-1992.

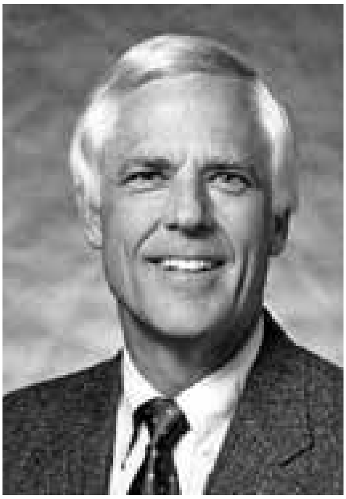
Under the guidance of Shannon, Jack Gaskill and research professor James M. Palmer, UA's undergraduate optics program began in 1988. Although the industry had been keen to hire B.S. graduates, the Optical Sciences Center, as a center and not a full-fledged department, had only been able to offer M.S. and Ph.D. degrees. However, OSC and the electrical engineering department collaborated on a joint bachelor's degree in optical sciences and engineering, to be awarded by the College of Engineering.

OSC had grown a lot since 1969, the year Shannon was hired and the original optical sciences building had been completed. With some persuasion, the University constructed a 30,000-square-foot addition, designed by Architecture One Ltd., on the east side of the original building. It was dedicated in 1989.

In 1992, Bob Shannon retired as director.



Construction of east wing, 1987.



Richard C. Powell: Director, 1993-1999.

The University performed a national search for the next director. Richard C. Powell, who had been running the Center for Laser Research at Oklahoma State University, was chosen.

The Optical Sciences Center experienced some rocky economic straits during Powell's time as director, but he was able to finesse a financial agreement with the University that would become perhaps the most important in OSC's history, with the exception of the one resulting in its founding. Powell solicited more state support for the center, but none was available. So instead, he worked out an arrangement with UA in which OSC received additional overhead return from outside grants and contracts. Unlike state funding, this was not "guaranteed" funding, but the faculty responded well to the challenge and the financial situation improved. It was also under Powell's leadership that OSC's facility was officially named the Meinel Optical Sciences Building.

Powell made many excellent faculty hires, including Poul Jessen in 1993, Rolf Binder and Kurtis J. Thome in 1994, Mahmoud Fallahi and José Sasián in 1995, Glenn T. Sincerbox in 1996, and Michael Descour and Jim H. Burge in 1997. Rick Shoemaker, who had been a faculty member since 1972, became associate director of academic programs.

At the end of 1998, the University appointed Dick Powell vice president of research.

James C. Wyant: Director and Founding Dean, 1999-2012. (Photo by Margy Green PhotoDesign)

After a very short search, James C. Wyant became the center's director in January 1999. Wyant had served on the faculty since 1974, though he had been on a part-time schedule for several years while running optical metrology company WYKO.

The next 13 years saw good growth for the Optical Sciences Center. While state funds were reduced nearly every year, for a total cut of more than one-third, contracts and grants grew several times over. OSC was able to increase its faculty and nearly triple its number of students.

The distance learning program greatly expanded as well. Two new classrooms were built to record classes to be streamed online, empowering industry workers around the world to take the same high-quality classes as local students and obtain graduate certificates or master's degrees with limited residency. OSC's undergraduate partnership was opened from just the electrical engineering department to the entire College of Engineering, allowing for specialized tracks in optoelectronics, optomechanics and optical materials. In 2002, it also earned one of the first ABET accreditations in optics.

More faculty and more students necessitated more space, so OSC put forth a bold notion: If additional research facilities became available, the overhead income from associated grants and contracts would pay for construction. Few outside the Meinel Building were confident in the proposal, but the University administration was ultimately convinced to build a 47,000-square-foot addition. This "west wing," designed by Phoenix firm Richärd & Bauer and constructed by Lloyd Construction Co., received national architectural awards. The results of OSC's ambitious plan, both in funding and in production, far exceeded expectations.

And soon, visitors to the new wing were able to enjoy not only its architectural appeal, but also a growing collection of antique optical instruments and glass sculptures curated by professor John E. Greivenkamp. While art in optics and optics in art are themes often explored by OSC students and faculty, they are displayed with clarity in the Museum of Optics.

By 2005, the Optical Sciences Center had increased sufficiently in size and stature to be named the University of Arizona College of Optical Sciences, and Jim Wyant became its first dean.

Faculty hired under Wyant's leadership included another Nobel laureate, "father of nonlinear optics" Nicolaas Bloembergen. He, Brian P. Anderson and Grover Swartzlander arrived in 2001. Russell A. Chipman, Franko Kueppers, Matthew A. Kupinski and Miroslav Kolesik came in 2002, Hong Hua in 2004, Stanley Pau in 2005, J. Scott Tyo in 2006, R. Jason Jones in 2007, Robert A. Norwood and Leilei Peng in 2009, Jim Schwiegerling in 2010, and finally Yuzuru Takashima, Milorad Cvijetic, Rongguang Liang and Amit Ashok in 2011. Michael Nofziger, a 1995 alumnus of the Ph.D. program who had been coordinating OSC's outreach program and teaching the University's introductory optics courses for several years, was also promoted to full professor in 2011.

College of Optical Sciences Meinel Building complex, 2010.

Thomas L. Koch: Dean, 2012-present.

Upon Rick Shoemaker's retirement in 2007, alumnus Carl F. Maes, who had received his Ph.D. in 2003 and then taught at the Air Force Academy and the UA physics department, became the new associate dean for academic programs.

In 2010, Jim Wyant decided to step down from the college's administration. However, he remained in his position until 2012, when optoelectronics expert Thomas L. Koch, a graduate of Princeton and the California Institute of Technology, was hired. Koch came aboard with rich industrial and academic credentials, having worked at Bell Labs, SDL Inc., Lucent Technologies and Agere Systems, and served as professor and director of the Center for Optical Technologies at Lehigh University.

Koch currently oversees numerous adjunct appointments, including the college's third affiliated Nobel laureate, Roy J. Glauber of Harvard University, and National Medal of Technology and Innovation awardee Gholam A. Peyman. In addition, many joint professors advise and mentor OSC students closely. Notable joint appointments include Regents' Professors J. Roger P. Angel, Neal R. Armstrong, Michael W. Marcellin, Pierre Meystre and Farhang Shadman, as well as recent MacArthur Foundation fellow Olivier Guyon.

And in the brief time since his arrival, Koch has also hired Khanh Kieu to the faculty and selected R. John Koshel as associate dean for academic programs. He continues the strong leadership that has shaped OSC into a premier institution.

The significant accomplishments of its tenured and tenure-track faculty, among others, have truly set OSC apart over the last 50 years. Those professors include the following:

Brian P. Anderson
Amit Ashok
Clarence L. Babcock
Harrison H. Barrett
Peter H. Bartels
Rolf Binder
Nicolaas Bloembergen
Jim H. Burge
James J. Burke
Russell A. Chipman
Katherine Creath
Milorad Cvijetic
Eustace L. Dereniak
Michael Descour
James A. Eyer
Charles M. Falco
Mahmoud Fallahi
B. Roy Frieden
Jack D. Gaskill
Hyatt M. Gibbs
John E. Greivenkamp
Hong Hua
Stephen F. Jacobs
Poul Jessen
R. Jason Jones
Galina Khitrova
Khanh Kieu
Miroslav Kolesik
Chris L. Koliopoulos
R. John Koshel
Franko Kueppers
Matthew A. Kupinski
Willis E. Lamb Jr.
George N. Lawrence
Rongguang Liang
H. Angus Macleod
Masud Mansuripur
Arvind S. Marathay
Dean B. McKenney
Tom D. Milster
Robert H. Noble
Robert A. Norwood
Stanley Pau
Leilei Peng
Nasser Peyghambarian
Murray Sargent III
Dror Sarid
José Sasián
Jim Schwiegerling
Marlan O. Scully
Bernhard O. Seraphin
Roland V. Shack
Robert R. Shannon
Richard L. Shoemaker
Glenn T. Sincerbox
Philip N. Slater
Orestes N. Stavroudis
George I. Stegeman
Grover Swartzlander
William Swindell
Yuzuru Takashima
Kurtis J. Thome
J. Scott Tyo
William L. Wolfe Jr.
Ewan M. Wright
James C. Wyant

VI

WORDS FROM PAST DIRECTORS

Aden B. Meinel

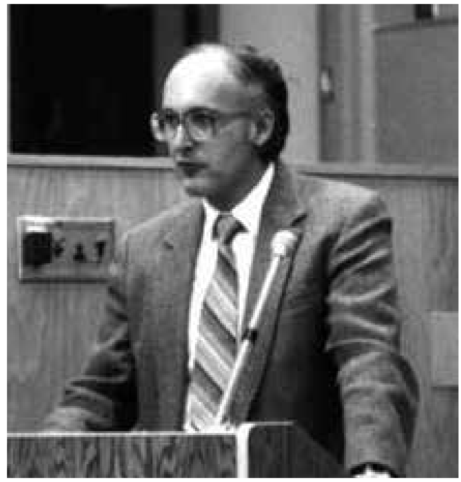
Aden B. Meinel portrait by artist Don Cowen, 1970.

"Would we ... be able to meet the expectations for the center? Would we become what was envisaged ... by the OSA? Would we become a major contributor to applied optics fields envisaged by the [U.S. Air Force]? Four years later, having retired as the first director of the center, with the contract renewal signed that assured the final lease payment for the center and with the new director in sight, I felt all had been well established. I am certain that the second decade of the Optical Sciences Center will be even greater than the first. The friends of the center who made the center possible join me in this prediction."

Peter A. Franken

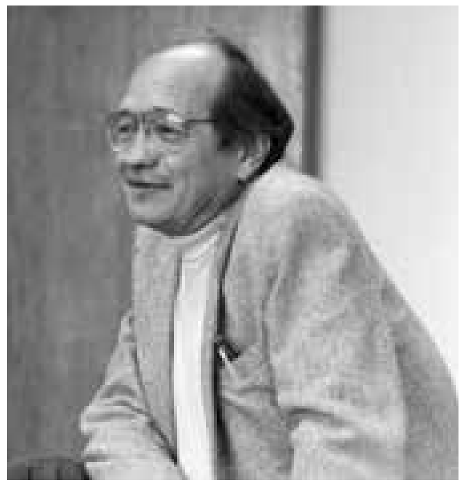
"The quality and the quantity of our graduate degree recipients, together with the published research accomplishments of the center, are the most impressive testimonial we can muster for our assertion that this federal investment has permitted the University of Arizona to develop a truly outstanding capability for research and graduate training in the optical sciences."

Harrison H. Barrett



"In 40 years of teaching and research at this great university in the desert, I have frequently been able to witness the power and beauty of imaging. Scarcely a week goes by that a student does not come into my office and say, 'Hey, do you want to see my latest images?' I always say yes, no matter what I am doing. Sometimes the images are simulations, and sometimes they are from real data. Sometimes they are puzzling, and sometimes they are informative. Sometimes they tell us something about the object being imaged, sometimes about the imaging system, sometimes about the science of imaging."

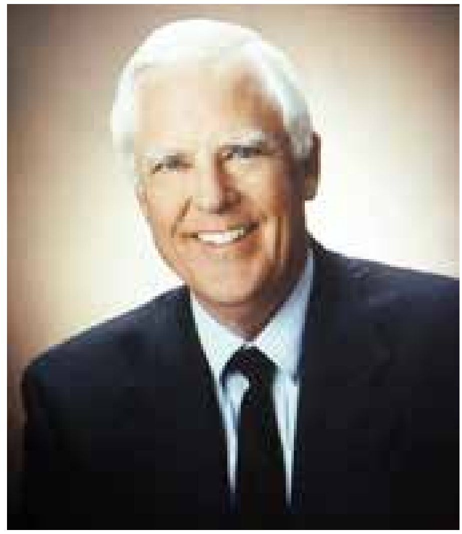
Robert R. Shannon



"The past year has been significant. ... In December 1988, we finally achieved a major expansion in building space when we occupied a new 36,000-square-foot addition to the center. The operations of the center continue to increase, with a total cash flow of almost thirteen million dollars in 1988. Our academic program continues to thrive, with 163 graduate students active in the department. The future continues to look bright, with many new research programs thriving, and strong support from the government and industry foreseen for the future."

"Earthrise" mixed media art by Peter Franken.

Richard C. Powell



"I had the privilege of serving as director of the Optical Science Center from 1992 to 1998. The biggest challenge we had during those years was replacing some of the superstar faculty members who had reached retirement age. This resulted in major budget and personnel issues that were solved by hiring several outstanding young faculty members.

"In my opinion what makes the UA College of Optics such a special organization is the technical breadth of the program ranging from basic optical science to optical systems engineering with a broad scope of applications such as astronomy, medicine, communications, military, solar energy, etc. This provides our students with a unique educational experience and gives us the capability of supporting the Arizona optical industry."

James C. Wyant

"I have been very fortunate to be associated with [OSC] for 40 years, first as a professor and then as director and dean. While [it] has great facilities, the best thing about [it] is the people. The faculty has a broad range of optics expertise ranging from basic quantum optics to applied areas of optics to optical engineering. They are all world leaders in their specialty. Many of them have worked in industry and several have started companies. They care about both their teaching and their research and they are always willing to help one another and the students. An excellent staff supports them. It is an enjoyable place to work.

"What I have enjoyed most about [OSC] is working with the students. Optics is a wonderful career where you can be a physicist or an engineer or a businessperson or a combination of the three. It is so much fun giving the students the opportunity to have a career in optics and enjoy optics as much as I have. Following their careers after they leave [the College of] Optical Sciences is extremely enjoyable and knowing that in some way I have helped them gives me great pleasure and satisfaction."

A poster hanging outside the Academic Programs office showcases all 2,407 OSC graduates and their respective degrees.

VII
ACADEMIC PROGRAMS

The College of Optical Sciences boasts one of the best educational programs in the field, teaching more students in optics than any other U.S. institution. As of 2014, more than 2,407 degrees (694 Ph.D.; 1,187 M.S.; 500 B.S.; 70 certificate; and three specialist) have been awarded.

Since its founding, OSC has grown and evolved in response to changing national needs and now includes a world-class faculty, an international student body, an undergraduate optical sciences and engineering degree program, and distance learning classes that provide graduate certificates and master's degrees. In response to strong industrial demand, the academic program has expanded to include more than one hundred graduate- and undergraduate-level courses. The college's graduates are in great demand and work for national and international governments, businesses and universities, and some have started successful companies.

The faculty includes Nobel laureates and members of the American Academy of Arts and Sciences, the National Academy of Engineering and the National Academy of Sciences. Many have taken leadership roles in the field's professional societies, including serving as presidents of the Optical Society (OSA) and SPIE.

The Academic Programs office is supported by excellent staff who carefully and conscientiously steer students throughout their studies.

UNDERGRADUATE DEGREES

Bachelor of Science in Optical Sciences and Engineering

The B.S. in OSE program, jointly administered with the UA College of Engineering, gives its graduates more-than-sufficient skills to succeed in the modern optics workforce. The curriculum is ABET-accredited and actively reviewed and includes an interdisciplinary senior capstone project. The B.S. in OSE includes optics, optoelectronics, optical materials and optomechanics tracks so students can specialize in preferred subjects.

Optics Minor

Interested undergraduates can supplement their major with a specified number of required upper-division classes. The optics minor prepares graduates for careers that require the material of other disciplines foremost but feature elements in optics. It also encourages them to pursue graduate study in optics.

GRADUATE DEGREES

Professional Graduate Certificate in Optical Sciences

The Graduate Certificate provides postbaccalaureate professionals with the opportunity to supplement working knowledge with formal coursework. Active members of the workforce who have bachelor's, master's or even doctoral degrees make perfect candidates for this program. While a fitting choice for those pursuing distance learning, it is also available to students on campus.

Professional Graduate Certificate in Photonic Communications Engineering

Like the Professional Graduate Certificate in Optical Sciences, this certificate suits those currently working in the communications industry. OSC administers this degree along with the National Science Foundation Engineering Research Center for Integrated Access Networks. The program includes a curriculum in entrepreneurship and marketing.

Master of Science in Optical Sciences

The M.S. in Optical Sciences degree equips its graduates for fulfilling careers in industry or for continued academic study. It is offered both on campus and online through distance learning. The curriculum is flexible, allowing students to choose among thesis, nonthesis with final report and nonthesis with comprehensive course evaluation options. Graduates seek careers in industry, go onto doctoral studies or work in research centers such as government labs.

M.S. in Optical Sciences and MBA Dual Degree

This one-of-a-kind program offers students an opportunity to gain two prestigious degrees — one from OSC and one from the UA Eller College of Management — concurrently, preparing them with a powerful advantage for entrepreneurial success. At the conclusion of their studies, students present their optics master's report and their MBA summer project.

Master of Science in Photonic Communications Engineering

The M.S. in PCE, presented in conjunction with the College of Engineering and CIAN, educates engineers for modern photonic engineering challenges with an emphasis on industrial relevance. It can be done both on campus and online, with thesis and nonthesis options.

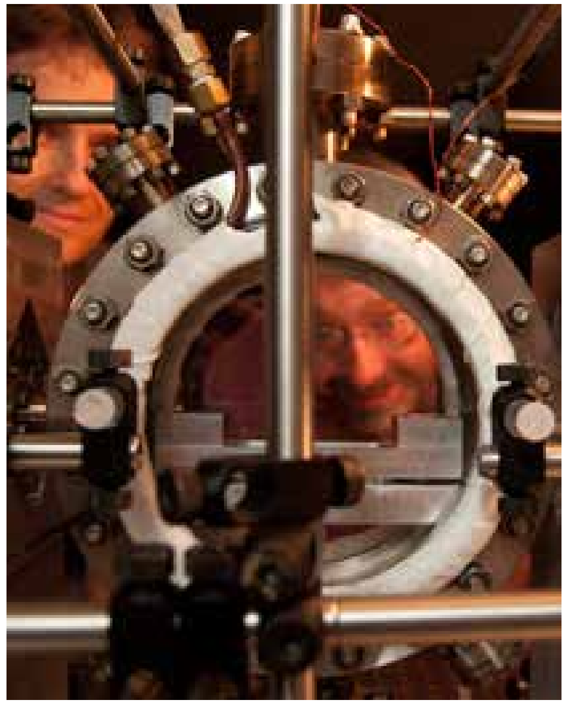
Doctor of Philosophy in Optical Sciences

The Ph.D. in Optical Sciences opens windows to extraordinary careers, be they in academia, research or industry. Core courses grant students a firm foundation in math and physics, statistics, electromagnetic waves, geometrical optics, quantum optics and solid-state optics, but the curriculum is also flexible enough that they can tailor their studies to their interests. Comprehensive exams, both written and oral, test students' knowledge early in their doctoral studies, while the dissertation proposal and final defense ensure they can conduct independent research. Students work on state-of-the-art research, with the college providing opportunities in all aspects of optical science and engineering, as enumerated in Section VIII.

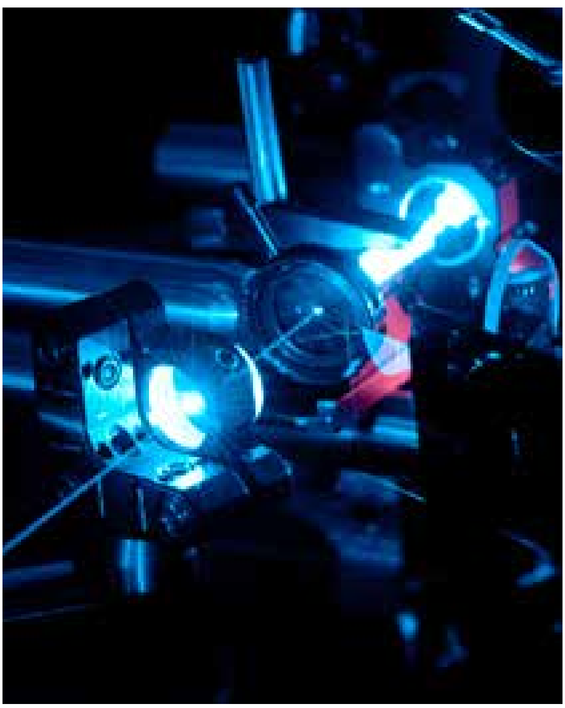
Optics Minor

Graduate students in other departments can also supplement their knowledge of optics with courses from the College of Optical Sciences.

OPTICAL ENGINEERING
3-D glasses. (Photo by Jacob Chinn)



OPTICAL PHYSICS
Research laboratory for ultracold atoms.



PHOTONICS
Laser for detecting explosives. (Photo by Jacob Chinn)

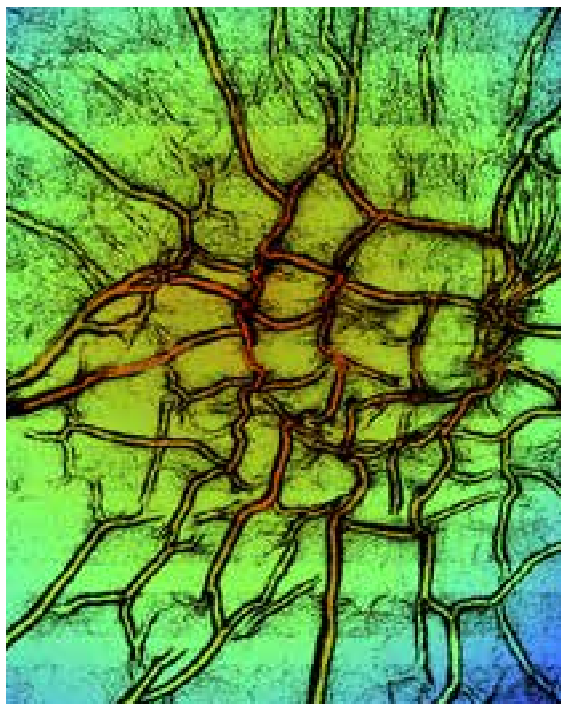


IMAGE SCIENCE
False color retina. (Image courtesy of Sean McCafferty)

VIII
RESEARCH SPECIALTIES

The research programs at OSC span the breadth of the optical sciences, from the big — polishing the telescope mirrors that explore the stars — to the small — applying optical nanotechnologies in agriculture, energy generation, medicine and more. From the hot — fine-tuning the images that diagnose cancer — to the very cold — stopping single atoms with laser beams — the college strives for excellence in the study of all aspects of the engineering and physics of light.

Research plays an incomparable role in OSC's renown. It serves a critical part in shaping students' experiences, sets the college in a realistic context with respect to industrial and societal needs, and invites government, commercial and interdisciplinary collaboration. There are often more than one hundred research projects ongoing at OSC at once, keeping its atmosphere vibrant and exciting.

Research falls into four major specialties at OSC: optical engineering, optical physics, photonics and image science. Projects are led by world-leading faculty, including research, joint and adjunct professors, and are supported by excellent technical and administrative personnel. Current initiatives are described throughout this section.

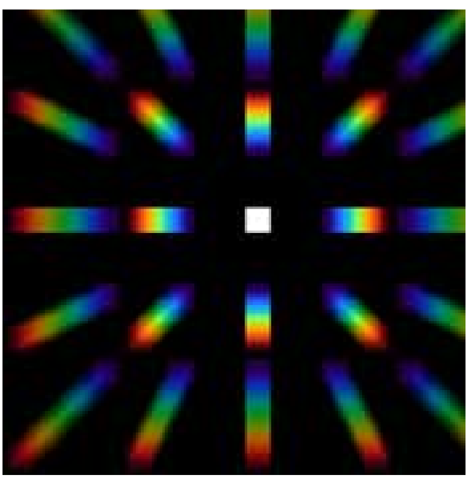
OPTICAL ENGINEERING

Optical engineering uses classical optics techniques to create novel devices and instrumentation, and the College of Optical Sciences leads the field in designing and fabricating highly specialized optics. OSC maintains state-of-the-art facilities and a superb technical staff for grinding, polishing, measuring and aligning the world's most challenging mirrors — including those for astronomical telescopes. Students work side-by-side with experienced professionals on extensive, distinctive projects like the Giant Magellan Telescope, the Large Synoptic Survey Telescope and OSIRIS-REx, an unmanned space probe that will launch in 2016, land on an asteroid and return to Earth with a material sample.

The Large Optics Fabrication and Testing Group, led by Jim H. Burge, develops advanced technologies for testing and fabricating large-scale optical components and systems. LOFT research is closely tied to hardware projects at both the College of Optical Sciences and the University of Arizona Steward Observatory Mirror Lab, allowing them to build new classes of optical components and systems.

Recently completed large computer-controlled polishing machine being used to make the 4-m diameter primary mirror for Daniel K. Inouye Solar Telescope. (Photo by Frank S. Gacon)

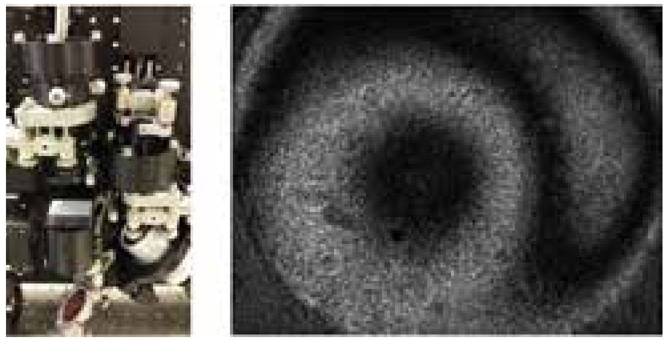
LOFT students and faculty make significant contributions to astronomical telescopes and advanced instrumentation.



Dispersed image recorded on focal plane of camera. (Image courtesy of Dereniak lab)

Eustace L. Dereniak's Optical Detection Laboratory specializes in measuring optical radiation in spectral regions from the visible to the long-wavelength infrared. The most recent emphasis has been in the area of two-dimensional infrared detector arrays in the development of imaging spectrometers and polarimeters. These instruments are uniquely capable of obtaining spatial and spectral information simultaneously, in "snapshot mode." They gather the data cube (x, y, l) in each integration time of the camera or focal plane array, recording images like that shown left.

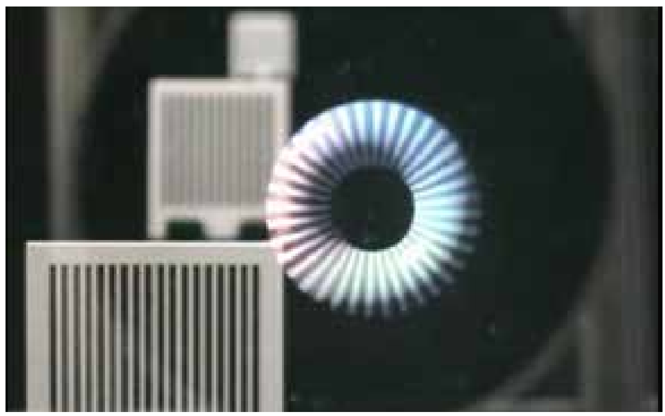
The Aspheric Metrology Laboratory headed by John E. Greivenkamp designs and builds advanced interferometric systems for metrology and optical testing. Research interests include ophthalmic and visual optics, ophthalmic instrumentation and measurements, interferometry and optical testing of aspheric and freeform surfaces, optical fabrication, optical system design, optical metrology systems, distance measurement systems, sampled imaging theory, and optics of electronic imaging systems.



Left: Partial view of instrument for acquiring corneal topography.

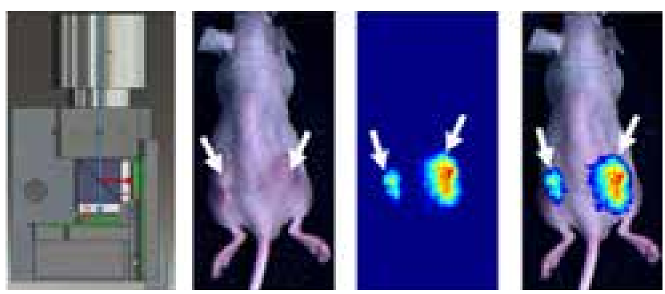
Right: Interferogram of a test sample. (Images courtesy of Greivenkamp lab)

Hong Hua's 3-D Visualization and Imaging Systems Laboratory specializes in a wide variety of optical technologies enabling advanced 3-D displays, 3-D visualization systems and collaborative immersive virtual and augmented environments, and novel imaging systems for medicine and surveillance applications. The 3DVIS Lab also uses 3-D displays to better understand human visual perception and visual artifacts and investigates design principles for effective human-computer interface in augmented environments.



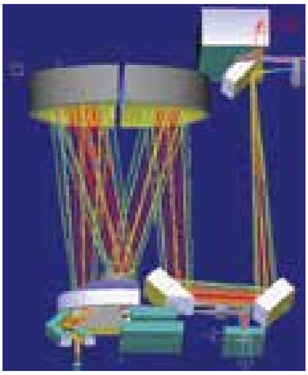
Demonstration of realistic cues for 3-D displays.
(Image courtesy of Hua lab)

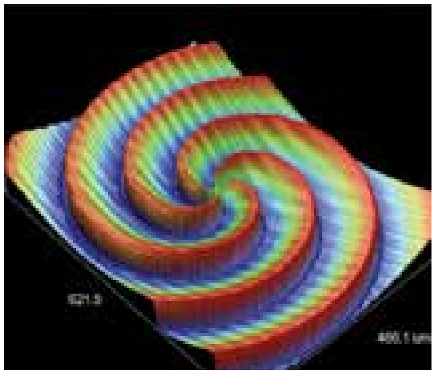
The Applied Optics Laboratory led by Rongguang Liang focuses on biomedical optical imaging and optical engineering. The lab develops bio-instrumentation, such as array imaging systems, endoscopes and image-guided surgical systems, for research and clinical applications. Other interests include 3-D measurement, imaging systems, display technology, illumination, space optics, optical design, and the design, fabrication and testing of freeform optics.



Far left: Image-guided surgical system.

Right: Images of subcutaneous breast cancer mouse model. (Images courtesy of Liang lab)

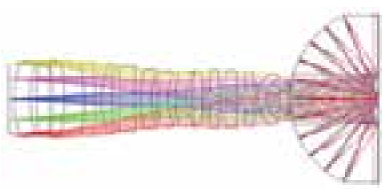




Left: Lithography tool.

Right: Measurement of micro-optical structure fabricated by Milster lab. (Images courtesy of Milster lab)

Tom D. Milster's research aims to "push the boundaries of optical science and engineering to produce the maximum amount of information from a given volume of space and time." His group designs, simulates and fabricates custom computer-generated holograms, Diffractive Optical Elements, phase structures and amplitude masks. They investigate hyper-numerical-aperture linear and nonlinear microscopy, where the NA is greater than 1.5 and evanescent waves provide resolution well beyond conventional microscope limits. They are also interested in the development of "freeform" holography, with DOEs adding function and utility to 3-D structures. Unique instruments in the lab include a vacuum-ultraviolet microscope at the 121.6-nanometer wavelength and a high-resolution infrared microscope for determining subcellular metabolism. Research applications include industrial inspection, graphene characterization, metamaterial testing, data storage, lithography, and bio-film and subcellular imaging.

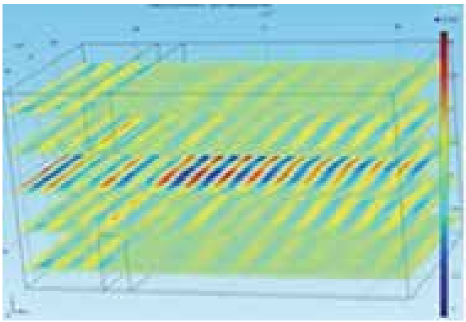


Lens design of wide-field and hyper-high-numerical-aperture projection system. (Image courtesy of Sasián lab)

José Sasián's Optical Design Laboratory conducts research in optical design, including imaging and nonimaging systems; optical aberration theory and novel methods for aberration correction; illumination optics; aspheric surfaces; optical testing methods and modeling; optomechanics; optics for lithography; microscope design; optics for visual systems; light in gemstones; and modeling light propagation in optical systems.

Specialized screen for visual assessment. (Image courtesy of Schwiegerling lab)

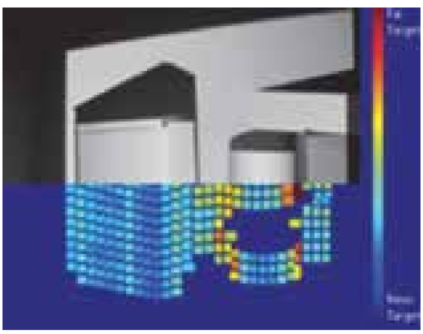
The Ophthalmic and Visual Optics Laboratory led by Jim Schwiegerling designs and fabricates instrumentation for assessing various properties of the human eye. These devices include wavefront sensors for measuring aberrations of the eye and topographers for measuring the three-dimensional geometry of the corneal surface. The lab has developed novel retinal imaging techniques incorporating both polarimetric and spectroscopic measurement of the retinal tissue. Schwiegerling's group is also expanding usage of these core technologies to address needs in the fields of optical design and testing, biometric identification and computational photography.

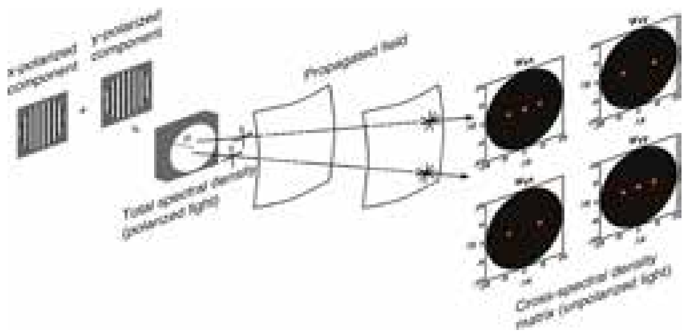


Left: Full electric-and-magnetic modeling of nanophotonic device with enhanced transmission.

Right: Scanning electron microscope picture of CMOS-compatible vertical optical coupler for photonic interconnect. (Images courtesy of Takashima lab)

Yuzuru Takashima's laboratory constructs innovative optical devices through a wide spectrum of optical science and engineering techniques. Research topics include the design and fabrication of nanophotonic devices, micro-optics, network-based optical input-output devices, and optical and holographic information storage. Among additional areas of interest are X-ray phase contrast imaging, ultrawide field-of-view imaging, micromirror fabrication, CMOS-compatible packaging for silicon photonics and heads-up displays for mobile applications.





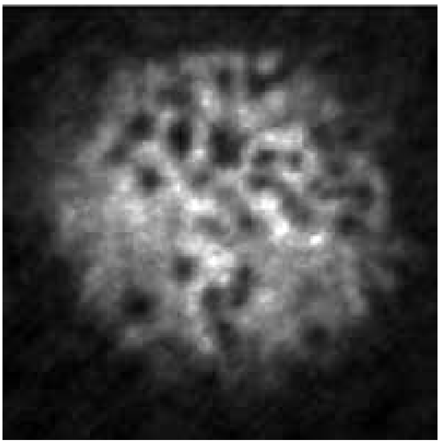
Left: Concept for 3-D depth-sensing camera.

Right: Fundamental research in light polarization states. (Images courtesy of Tyo lab)

The Advanced Sensing Laboratory headed by J. Scott Tyo focuses on nonconventional electromagnetic sensing methods, such as polarimetry, spectral imagery, coherence imaging and terahertz imaging, with a special interest in the physics-based exploitation of image data that capitalizes on knowledge of the wave-target-sensor interaction to maximize performance in sensing applications. Other research subjects include polarimetric display, modulated polarimeter theory and operation, long-wavelength infrared imaging polarimetry, high-power microwave sources, and compact antennas for high-power microwaves.

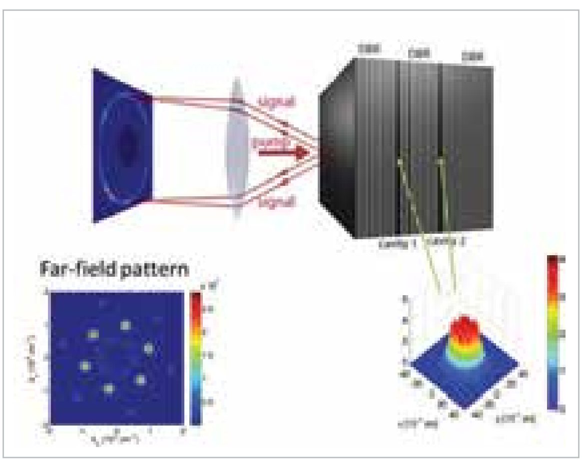
OPTICAL PHYSICS

Optical physics studies the interactions of light with atoms, molecules and semiconductor systems in different contexts. At the College of Optical Sciences, nine different research groups pursue projects in quantum gases, quantum information, theoretical and computational optical physics, experimental and theoretical semiconductor quantum optics, and ultrafast lasers, with impacts to the theory and applications of high-harmonic generation, laser cooling and trapping, quantum control, and much more.



Vortices showing quantum turbulence in a BEC. (Image courtesy of Anderson lab)

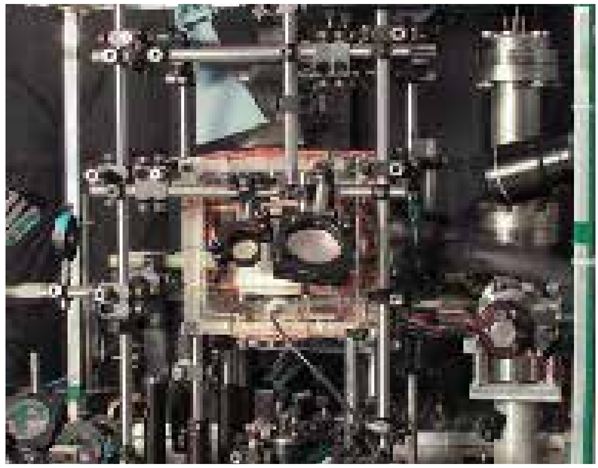
Brian P. Anderson's Quantum Gases Group uses laser light to cool gases of rubidium atoms to a few billionths of a degree above absolute zero. These atomic fluid droplets, called Bose-Einstein condensates, follow the laws of quantum physics and serve as valuable tools for exploring fundamental physics topics such as quantum turbulence, the primary concern of the Anderson group. BEC turbulence is indicated by the motion of vortices, microscopic holes that identify fluid circulation like the eyes of tiny hurricanes. New regimes of quantum fluid dynamics and quantum turbulence can be discovered by watching how these vortices move and interact.



Optically pumped semiconductor microcavities exhibiting near-field and far-field patterns in the polariton quantum fluid. (Images courtesy of Binder lab)

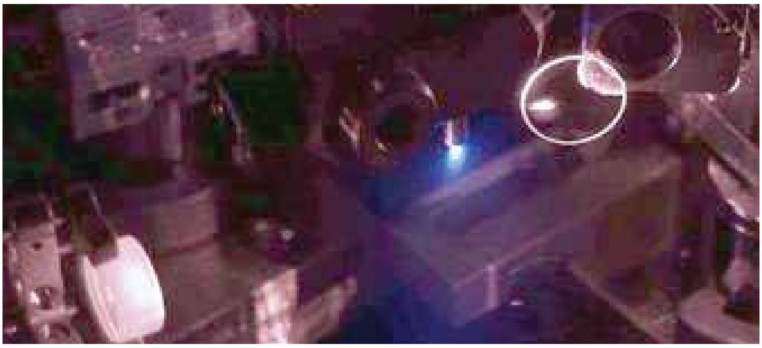
The Theoretical Solid-State Optics Group led by Rolf Binder focuses on the optical properties of semiconductor structures. Using microscopic quantum-mechanical many-body theories, including nonequilibrium Green's functions, the group pursues projects ranging from basic physical studies to application-oriented simulations. Recent and ongoing examples include slow- and fast-light effects in bulk semiconductors and semiconductor heterostructures, optical refrigeration of semiconductors, optical and elastic properties of semiconductor nanomembranes, optical properties of graphene, and pattern formation and control in quantum fluids realized by exciton polaritons in semiconductor microcavities.

Poul Jessen's Quantum Information and Control Group investigates fundamental problems in quantum information science using ultracold atoms. One project uses Zeeman sublevels in the electronic ground state of atomic cesium to explore computer-optimized quantum control, quantum tomography and quantum chaos. A second project creates many-atom spin-squeezed states through quantum measurement back-action, with the long-term goal of improving quantum-limited atomic clocks and sensors. A third project traps atoms in the evanescent field around an optical nanofiber, with the aim of developing an atom-light quantum interface.



Experiment for production and quantum control of ultracold atoms. (Image courtesy of Jessen lab)

The QuIC group is a founding member of the National Science Foundation Center for Quantum Information and Control and works closely with its quantum information theorists at the University of New Mexico.



Ionization of xenon during intracavity high-harmonic generation. (Image courtesy of Jones lab)

The Ultrafast Lasers Group headed by R. Jason Jones employs novel light sources, such as the femtosecond frequency comb generated by a phase-stabilized train of ultrashort pulses, for experimental ultrafast optical science and precision laser spectroscopy. Such sources have enabled studies of temporal dynamics in light-matter interactions ranging from attosecond to several-second time scales, leading to the development of new atomic clocks and subfemtosecond timing.

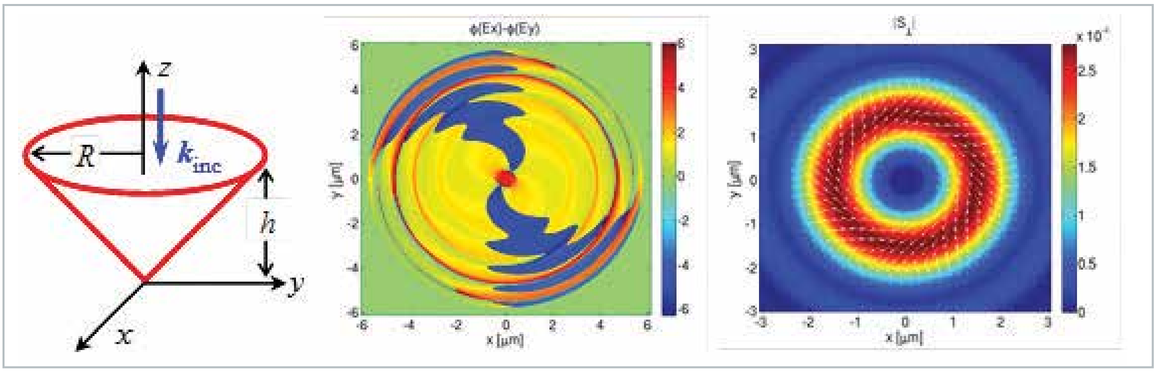
Current activities include precision spectroscopy of laser-cooled mercury and the development of frequency comb sources in the extreme-ultraviolet based on intracavity high-harmonic generation.

Model of silver dipole antenna coupled to near-surface indium-gallium-arsenide quantum well. (Image courtesy of Khitrova lab)

Galina Khitrova's Quantum Nano-Optics of Semiconductors Group conducts experimental studies of the light-matter interaction of semiconductor heterostructures (quantum wells and dots) coupled to nanoscale optical cavities. Recently, this has led to the investigation of metallic cavities that allow light to be confined to regions one thousand times smaller than typical dielectric cavities, which creates a large vacuum electromagnetic field that greatly alters the dynamics of the c oupled quantum emitter. Among the group's goals is to use these nanocavities to demonstrate Purcell enhancement of spontaneous emission and cooperative emission from semiconductor quantum dots.

The Theoretical and Computational Optical Physics Group led by Miroslav Kolesik explores the intersection of modern nonlinear optics, atomic and molecular physics, and strong-field phenomena. Research interests span statistical mechanics, Monte Carlo simulation, critical phenomena, nonequilibrium and driven systems, semiconductor laser simulation and optics; current activity concentrates on computational optics, particularly ultrashort optical pulse interactions.

Recent work includes first-principle methods to describe light-matter interactions in regimes that defy the tools and notions of traditional nonlinear optics and that scale from the quantum through the optical to the macroscopic. The challenge is in the integration of the microscopic medium description into space- and time-resolved, realistic simulations of experiments. Substantial research is being done in close collaboration with teams in the U.S. and Europe.



Light reflected from a hollow cone undergoing changes in spin and orbital angular momentum, as shown by the variation of the Poynting vector and phase in transverse plane. (Images courtesy of Mansuripur lab)

Masud Mansuripur's Optical Physics Group researches optical-magnetic-macromolecular data storage, light-matter interaction, magneto-optical effects and the mechanical effects of light involving the exchange of linear and angular momenta between electromagnetic fields and material media.

As an example of the latter effects, the figure above shows a hollow metallic cone with an apex angle of 90 degrees, illuminated by a circularly polarized light beam. Upon reflection from the cone, the spin angular momentum of the beam is reversed. However, no angular momentum is transferred to the cone, because the reflected beam picks up an orbital angular momentum twice as large but opposite in direction to that of its spin. The figure also shows profiles of the phase and the Poynting vector in the cross-sectional plane of the reflected beam.

The Theoretical-Computational Optical Physics and Applied Mathematics Group led by Jerome V. Moloney studies ultrashort laser pulse interaction with gases and condensed media under extreme conditions. Extreme intensities acting over tens to hundreds of femtoseconds strip and accelerate electrons from an atom, creating anisotropic distributions of electrons and ions that eventually equilibrate to form a plasma channel. This channel acts like an extended conducting wire and can direct high-voltage charges and, potentially, lightning strikes. Accompanying this explosive event is the creation of a white light super-continuum source that can be used to perform remote spectroscopy and detect atmospheric molecules and pollutants at multikilometer ranges.

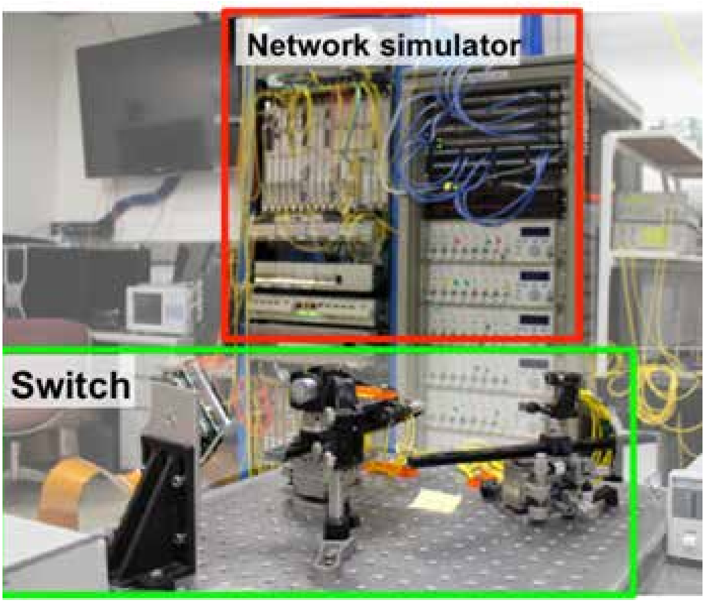
In another activity, Moloney's team is designing new classes of high-power ultrashort-pulsed semiconductor disk lasers using first principles quantum many-body theory, processing these into laser devices and demonstrating them in the laboratory.

The Theoretical Optical Physics Group headed by Ewan M. Wright conducts research across a broad area including nonlinear optics, the physics of ultracold gases and the exploration of novel laser beams. Key theoretical contributions include the elucidation of the physics underlying light string propagation in media such as air, the early treatment of the field of nonlinear atom optics and the optical binding of nanoparticles.

PHOTONICS

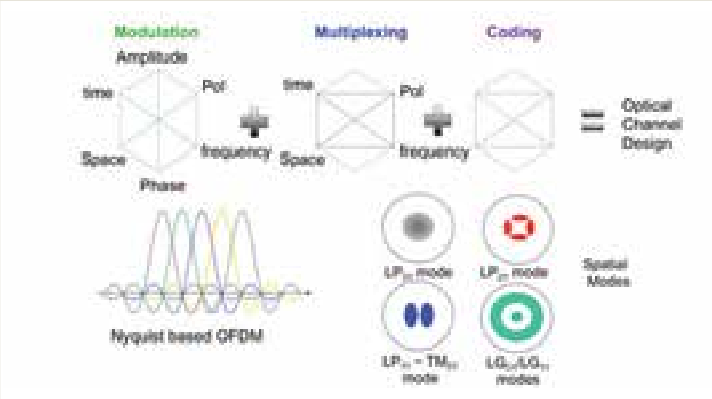
Photonics is the science and technology of generating, controlling and detecting particles of light. As such, photonics impacts a broad range of fields, including communications, defense, health and medicine, and manufacturing. The College of Optical Sciences has a rich history of key contributions in photonics, with seminal research in electro-optic polymer modulators, fiber lasers, magneto-optic materials and devices for optical storage, photorefractive polymers, semiconductor devices, solar energy and 3-D displays.

Current research ranges in scope from fundamentally new tools, such as small-footprint, high-throughput multiphoton microscopes, through exceptionally high-power semiconductor lasers, to components and systems for next-generation optical networks for both the Internet and data centers, and into consumer equipment. New areas are constantly explored by the nine faculty in the specialty as photonics becomes more pervasive in modern lives.



Holographic optical switch based on digital micromirror devices is evaluated in CIAN's TOAN test bed. (Image courtesy of Peyghambarian lab)

The flagship of the college's photonics program is the $40-million, 10-year National Science Foundation Engineering Research Center for Integrated Access Networks, one of only 15 NSF ERCs in the country. CIAN's director, Nasser Peyghambarian, has led it through six years of research highlights thus far, together with eight partner universities: the University of California, San Diego; the University of Southern California; the University of California, Los Angeles; the California Institute of Techology; the University of California, Berkeley; Columbia University; Norfolk State University and Tuskegee University. CIAN's two working groups organize system, subsystem and component research around two primary themes: agile networking and data center photonics. Highly sophisticated test beds with state-of-the-art equipment enable CIAN to stay at the forefront of optical networking.



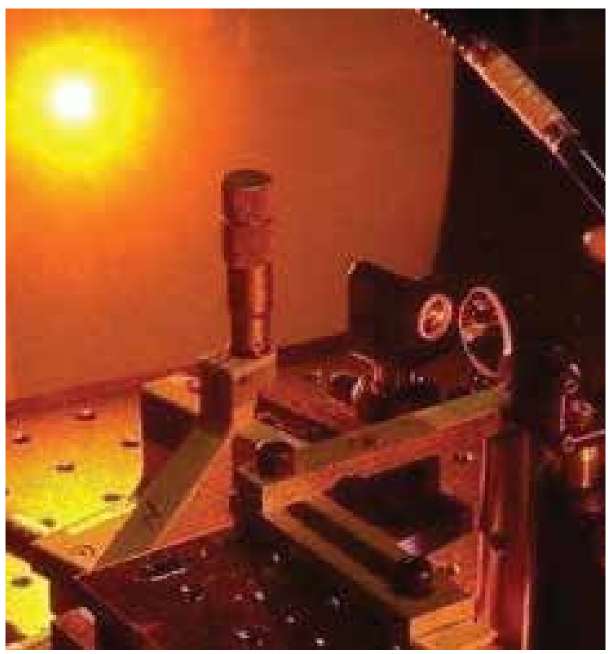
A wide variety of modulation and multiplexing methods are now used to increase the capacity of the Internet. (Images courtesy of Cvijetic lab)

Milorad Cvijetic researches new formats for optical communications, pioneering the area of spectral-spatial mode multiplexing, which considers the use of optical modes to put additional information over the optical fiber that fuels the increasingly crowded Internet.

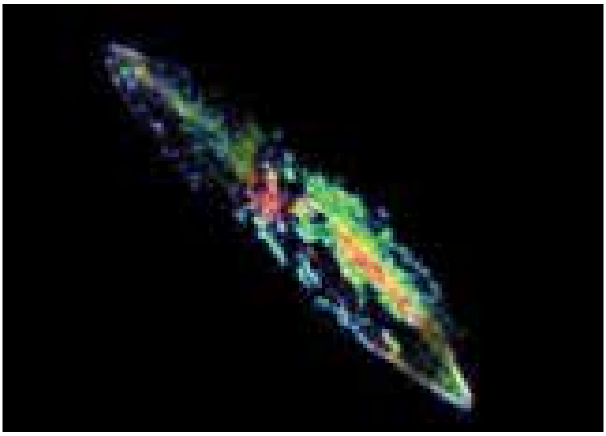
Charles M. Falco has used thin film photonics to analyze and verify the authenticity of works of art. He is acclaimed worldwide for these abilities and can be found in far-flung locales discussing his techniques and findings. Falco is currently working with Masud Mansuripur to develop new optical materials technologies, most notably new transparent conductors to replace current-generation transparent conducting oxides like indium tin oxide. These materials will find applications in areas as diverse as solar energy and interactive touch-screen displays.

Semiconductor lasers have, in the last few years, gone from the relatively low-power examples found in DVD players to the high-power equipment that is now replacing more conventional lasers in many applications. Mahmoud Fallahi has built on the highly successful VCSEL technology to develop vertical-external-cavity surface-emitting lasers to create a new generation of compact, high-power light sources.

When coupled with nonlinear optical crystals, VESCEL-based semiconductor lasers like those shown at right can generate desirable wavelengths, such as the 589-nanometer wavelength useful for dermatology. These lasers have myriad uses, from medicine to manufacturing to metrology.



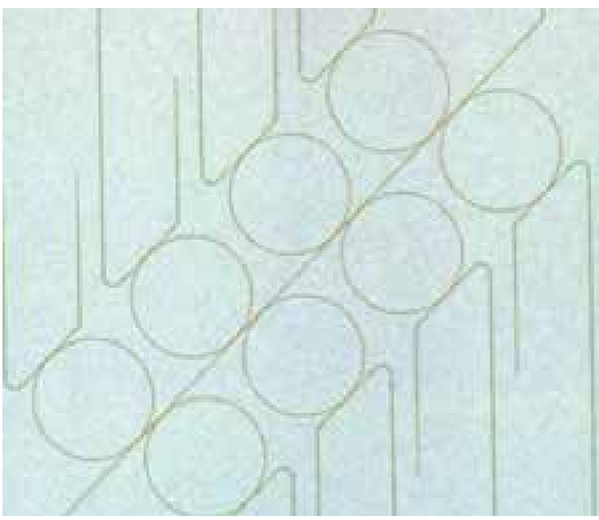
Yellow light source enabled by high-power VECSELs. (Image courtesy of Fallahi lab)



Multiphoton microscope image of marine diatom. (Image courtesy of Kieu lab)

Khanh Kieu recently developed a multiphoton microscope that is based on a turn-key, handheld 150-femtosecond laser that he created during graduate studies at OSC. This microscope uses a fundamental wavelength of 1,550 nanometers to study samples that include thin film materials such as graphene, biological samples such as diatoms and nanophotonic devices such as electro-optic polymer-silicon hybrid modulators.

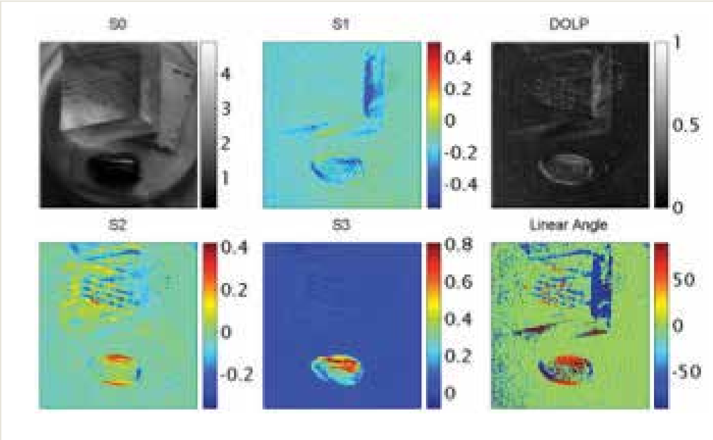
The picture at left shows the multiphoton imaging of a diatom, a species of plankton. The red region indicates second-harmonic light at 775 nanometers, while the green regions correspond to third-harmonic generation at 517 nanometers. The image reveals the microstructure of the diatom, assisting researchers in better understanding photosynthesis and other processes in these pervasive organisms. This work points toward using multiphoton microscopy to interrogate a wide range of biological specimens, as well as micro- and nanophotonics circuits.



Silicon photonic microring resonators for ultracompact high-speed optical switching. (Image courtesy of Norwood lab)

In the silicon age, the seemingly inexorable progress of Moore's Law touches more and more of life. The remarkable success of silicon in manufacturing processes has driven intensive research into its use for photonics, culminating in the commercialization over the last five years of optical communications based on Si photonics components. Robert A. Norwood is working to add new capabilities to the Si photonics platform, namely the means to rapidly switch and route light of various wavelengths.

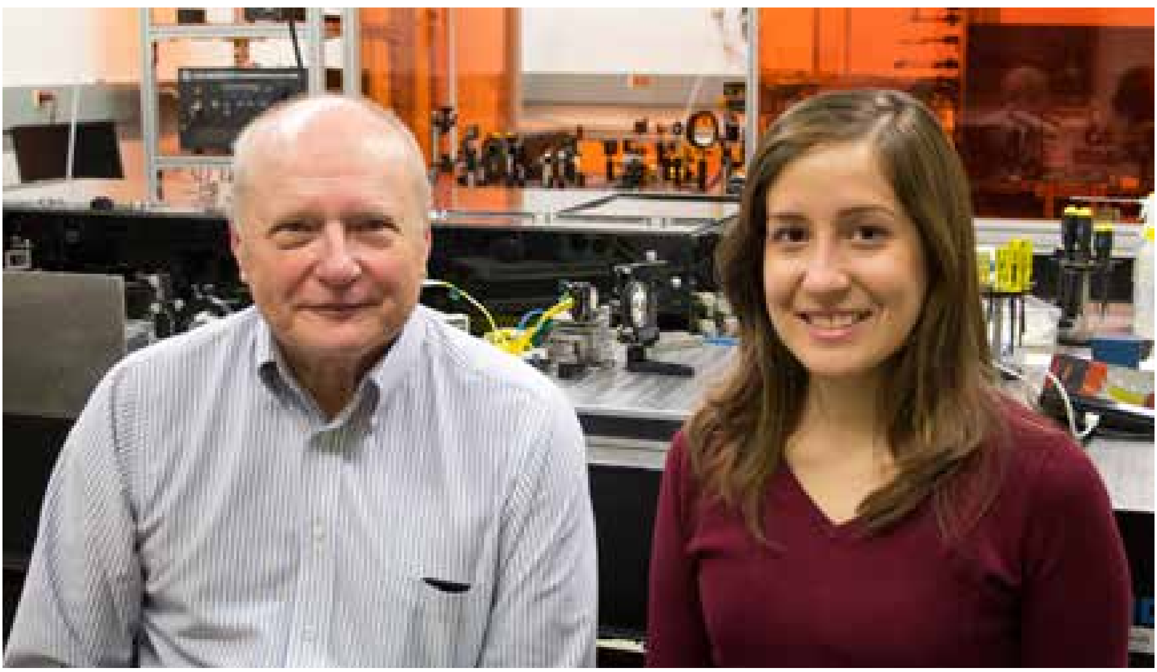
Seen at left is a portion of a wavelength-switching device based on silicon microring resonators. Each resonator pictured is about 50 microns in diameter; the rings are made of silicon and the underlying material is silicon dioxide. Coating such silicon waveguides with newly developed materials called electro-optic polymers can make switches of exceptional speed, more than one hundred gigabits per second. This work is among the numerous breakthrough technologies emerging from CIAN.



Polarimetric imaging enabled by novel micropolarizers and waveplates based on liquid crystal polymer. (Images courtesy of Pau lab)

The polarization of light is not readily apparent to human eyes, but it becomes obvious when observed through sunglasses or from the reflection off a glass surface. Indeed, watching how an object interacts with polarized light can give a far more complete picture than is possible with a simple photograph.

Polarimetric cameras render images for various light polarizations to make use of this fact. While these cameras are ordinarily bulky and cumbersome, Stanley Pau has recently created micropolarizer and waveplate films based on liquid crystal polymers that enable compact polarimetric imaging such as that shown above, making this technique more useful and versatile in fields from microscopy to surveillance.

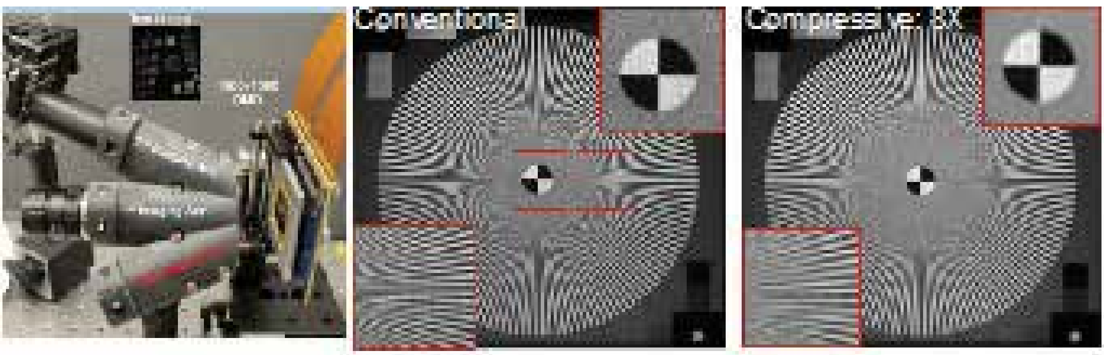


Jim Wyant, left, with Maria del Carmen Ruiz, 2013-2014 recipient of the Louise A. Wyant Memorial Graduate Student Endowed Scholarship in Optical Sciences.

IMAGE SCIENCE

Image science investigates the ways that image quality can be defined, measured and optimized; it touches and improves the visualization of everything from healthy bones to unstable atmospheres to millennia-old geological formations. This interdisciplinary field studies the physics of photon generation, the propagation of light through optical systems, signal generation in detectors and more, and considers the statistics of random processes and how they affect the information contained within images.

The faculty in image science at the College of Optical Sciences show particular strength in designing new technology for medical imaging, homeland security, earth sciences and other applications, and in developing new methods for assessing image quality by quantifying how accurately imaging systems can accomplish certain analytical tasks.

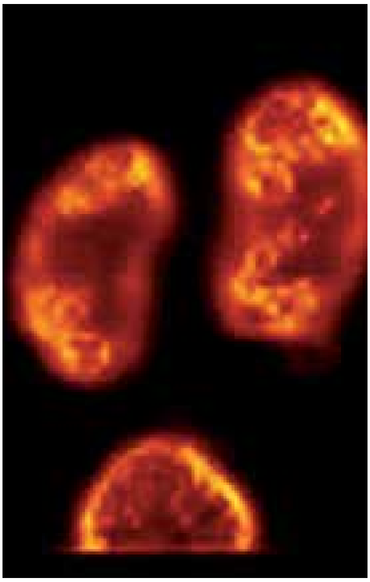


Left: Compressive imager prototype.

Right: Images from traditional imager and prototype at eight times compression. (Images courtesy of Ashok lab)

As imaging devices — from smartphones to military drones to security cameras to cars — become ubiquitous, rising data volume and processing demands become problematic. Compression is routinely employed to reduce image file sizes for convenient storage and transmission. However, the success of image compression techniques suggests that traditional imaging systems can be highly inefficient, collecting redundant data that could be compressed without significant degradation. The field of compressive imaging addresses this shortcoming by acquiring a “compressed image” directly in the optical domain.

One direct benefit of such optical compression is that it employs energy-efficient low-resolution sensors, rather than the power-hungry high-resolution image sensors typically found in traditional high-quality cameras (e.g., digital single-lens reflex cameras). The prototype shown above, developed by Amit Ashok’s Intelligent Imaging and Sensing Laboratory under U.S. Army and Defense Advanced Research Projects Agency programs, is capable of forming high-resolution images using a low-resolution sensor and a programmable spatial light modulator. Compressive imaging has the potential to make significant impacts in spectral bands (e.g., infrared, terahertz), where sensor costs and complexity dominate camera design.

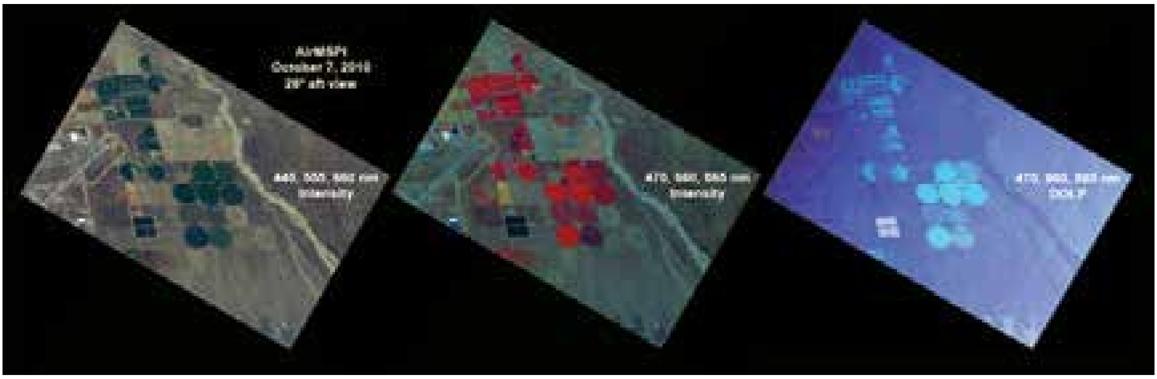


Left: High-resolution mouse kidney and bladder SPECT image acquired with cadmium-zinc-telluride gamma-ray pixel detectors.

Right: Coregistered mouse SPECT/CT image acquired with FastSPECT II and FaCT (adaptive X-ray computed tomography) systems. (Images courtesy of the CGRI)

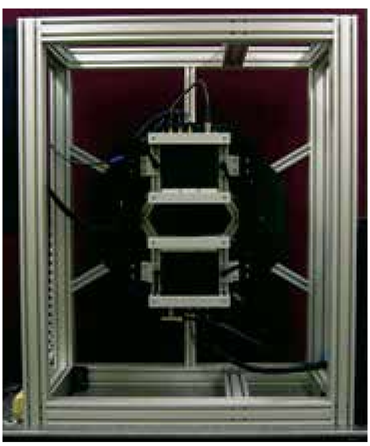
Nuclear imaging modalities, such as positron emission tomography and single-photon emission computed tomography, form an important element of modern medical diagnostics. The University of Arizona Center for Gamma-Ray Imaging, led by Harrison H. Barrett in cooperation with Lars R. Furenlid, Matthew A. Kupinski and Eric W. Clarkson, focuses on advancing the state of the art in radionuclide imaging (e.g., PET and SPECT). The CGRI uniquely combines rigorous theory, inventive computational tools, advanced detectors and electronics, innovative imaging systems, novel radiotracers and cutting-edge clinical and preclinical applications. This work is done within the context of gamma-ray imaging, but it is important to other forms of medical imaging and image science in general.

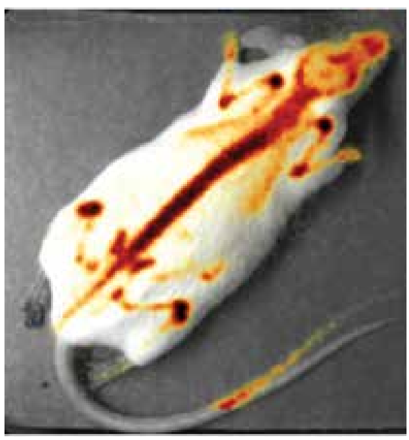
The collaborative research supported by the CGRI applies these new imaging tools to basic research in functional genomics, cardiovascular disease and cognitive neuroscience, and to research in breast cancer and surgical tumor detection. An exciting direction of research in the center is examining multimodal and adaptive imaging systems. A multimodal imaging system becomes adaptive when the information from one system is used to modify a second system before data is taken with it. For example, the first system (MRI or computerized tomography) may be used to locate regions of abnormalities, and then the second system (SPECT or PET) can be modified to focus on these regions for functional imaging.



AirMSPI image showing surface features that show up preferentially in the degree of linear polarization image. (Image courtesy of Chipman lab)

The polarization of scattered or reflected light from an object carries information about its material characteristics. Russell A. Chipman's Polarization Laboratory specializes in developing precision polarimeters that measure from the ultraviolet to the short-wave infrared. When configured as imaging devices, these polarimeters can produce research-grade spatial and angular resolution for sample characterization. With polarimetric accuracy of 0.1 percent, the instruments are ideal for precise optical characterization, such as measuring the concentration and distribution of aerosols in the atmosphere.

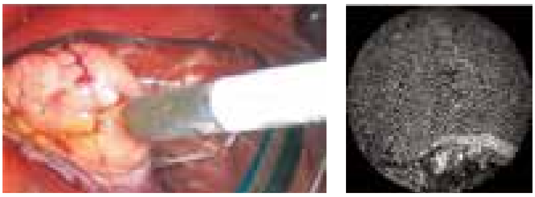




Left: ModPET system.

Right: Maximum intensity projection of mouse bone scan overlaid on optical image. (Images courtesy of the CGRI)

Lars R. Furenlid and his team at the Center for Gamma-Ray Imaging specialize in developing and applying advanced X-ray and gamma-ray detectors and commissioned SPECT, PET and X-ray CT imaging systems. They study the physics of scintillation and solid-state detectors and the design of pulse-processing electronics, digital data-acquisition systems, and data inversion and reconstruction with a variety of computational methods.



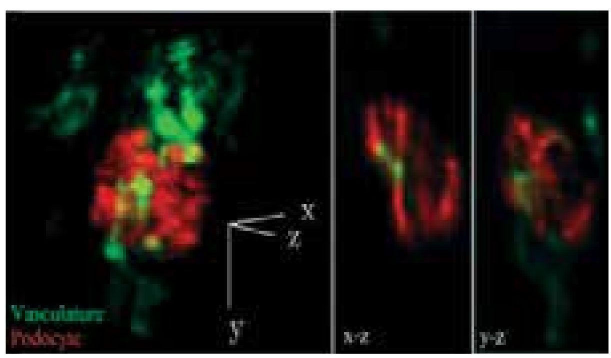
Left: Confocal microendoscope imaging probe in contact with an ovary surface during a laparoscopic procedure.

Right: Fluorescence image obtained from the probe showing individual nuclei of cells on the epithelial ovary surface. (Images courtesy of Gmitro lab)

Optical imaging techniques are now frequently employed for medical diagnosis. A familiar example is biopsy, where a pathologist observes an excised tissue sample under an optical microscope to diagnose a disease. The discipline of optical biopsy takes an optical instrument (e.g., a confocal microscope) in a miniaturized endoscopic form directly to the tissue in need of evaluation. Optical biopsy allows real-time in situ analysis with greater ease and, potentially, increased accuracy. Arthur Gmitro's research group has pioneered the development of fiber-bundle-based fluorescence confocal microendoscopy, building systems to image a variety of endoscopically and/or laparoscopically accessible organ sites. The instrument shown in the figure at above left is being clinically evaluated for its ability to identify early-stage ovarian and fallopian tube cancers.

Matthew A. Kupinski's Image Science Laboratory explores concepts in objective image quality assessment and applies them to diverse areas, including diffuse-optical imaging, clinical CT imaging and national security arenas. His team has developed novel models of imaging systems that make the most efficient use of scattered light, combining task-based imaging with radiative-transport models of light propagation to allow all acquired data to be used when performing a scientifically relevant task. In addition, the Image Science Lab has applied task-based measures of image quality to homeland security imaging, wherein large-scale imaging devices search for sources of radiation in urban environments. These promising techniques have led to collaboration with Sandia National Laboratories and the U.S. Department of Energy on the development of imaging systems for confirming nuclear-treaty disarmament. In addition, Kupinski's group has worked with a number of commercial system manufacturers to bring image-science concepts out of the university environment and into the commercial realm.

Fluorescence imaging is a powerful and versatile tool in fundamental and applied biology and biomedical research. Leilei Peng's Biomedical Spectroscopy and Interferometry Laboratory develops innovative optical microscopy methods for quantitative, functional, three-dimensional fluorescence imaging of live cells and animals. Her group has created a scanning laser-sheet microscope system that employs a two-photon Bessel beam to allow fast 3-D imaging of the deep internal organs of live zebra fish embryos with high spatial resolution, as shown in the figure on the right.



Dual-color two-photon image of zebra fish kidney. (Images courtesy of Peng lab)

Faculty, staff, students and OSC affiliates gather during an Industrial Affiliates workshop.

Affiliates attend a presentation during the 2014 Spring Industrial Affiliates Workshop.

Casual lunches and student poster sessions allow discussions about real-world experiences.

The biannual workshops give the affiliates a chance to interact with the OSC community, offering insight into the student body's exceptional talents.

IX

INDUSTRIAL AFFILIATES PROGRAM

Created in 1980 by associate director Jack Gaskill, the Industrial Affiliates program has engaged optics and photonics companies in shaping and supporting academic affairs at OSC for more than 30 years. Members meet and recruit students, partner with professors on research projects, and help guide the college's course structure and curriculum.

Nearly 50 organizations presently participate, from small local startups to some of the largest multinational names in the field.

Representatives from many companies attend OSC's biannual workshops, which are held each fall and spring on the University of Arizona campus. These gatherings give them the chance to interact closely with the College of Optical Sciences community, offering insight into the student body's exceptional talents and the faculty's diverse strengths. Undergraduates talk about their multidisciplinary senior capstones; graduate students detail their latest breakthroughs. Short faculty presentations spark opportunities for collaboration or technology transfer, and less formal lunch breaks lead to discussions about real-world work experiences. Some affiliates also use these visits to conduct on-site interviews with job seekers.

Program dues provide other concrete impacts to OSC student life, including travel funds for conference trips, journal subscriptions for the college's library and 24 teaching assistantships each year.

A plaque on the third floor of the Meinel Building lists current members, and more information is available on the OSC website.

The college appreciates the significant benefits that the Industrial Affiliates program contributes to its student activities and thanks its industrial sponsors.

Donor wall in the lobby of the Meinel Building.

Above: Principals of Opticks scholarship endowment society lapel pin.

Right: Those who support the college through scholarships are recognized in the staircase leading from the Meinel Building's third-floor lobby.

X

"A DISTINGUISHED GROUP OF INDIVIDUALS ..."

Found in the Meinel Building's main lobby are special dedications to "a distinguished group of individuals whose generosity demonstrates a commitment to the traditions of our past and the success of our future" through philanthropic support of the College of Optical Sciences.

As the 21st century ushers in unprecedented scientific and societal challenges, it is paramount that OSC prepares its graduates to become innovators and trailblazers. As of its 50th year, the college indeed educates more students in the critical applications of optical sciences and engineering than any other institution in the United States.

OSC has been extremely fortunate in the support provided by alumni, friends and industry partners since its earliest days, and it is enormously grateful for the commitment that each donor has made in helping to change and shape the college.

One such group is the prestigious Principals of Opticks, a scholarship endowment society that celebrates those intrepid spirits who have offered $75,000 or more toward scholarship endowments at the college. Nineteen inaugural members were inducted into this society in February 2014, and the college looks forward to honoring the altruism of many more.

As state appropriations for public education erode, private assistance allows OSC to keep focus on its mission. Such consideration illustrates an unprecedented commitment to the field that has brought these benefactors so much fulfillment. Because of their contributions, the College of Optical Sciences can continue to seek answers, inspire scholars, change lives and strive for further success.

This landmark 50th anniversary lends countless reasons to look back on the remarkable leadership, vast partnerships and incredible technological breakthroughs that have been associated with OSC since 1964 — and it also gives myriad motivations to look forward.

We applaud our distinguished donors and their generosity!

Sine wave sculpture by Stephen F. Jacobs, located on the eighth-floor patio.

“Sphere” sculpture in Meinel Building lobby, 2014. (Photo by José Sasián)

2014 College of Optical Sciences group portrait. (Photo by Robert Walker)

Looking west down the Mall, with the Tucson Mountains in the background. (Photo by Jeff Smith)

THE UNIVERSITY OF ARIZONA

COLLEGE OF OPTICAL SCIENCES
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