

Optical Science and Engineering

Participating Departments:

Department of Physics and Optical Science (lead)
Department of Mechanical Engineering
Department of Electrical Engineering

Team Leads:

Glenn Boreman, Professor and Chair, Department of Physics and Optical Science
Tom Suleski, Professor, Department of Physics and Optical Science
Tino Hofmann, Assistant Professor, Department of Physics and Optical Science

Participants:

Ishwar Aggarwal	Research Professor	Physics & Optical Science
Angela D. Allen	Professor	Physics & Optical Science
Vasily Astratov	Professor	Physics & Optical Science
Glenn Boreman	Professor and Chair	Physics & Optical Science
Matt Davies	Professor	Mechanical Engineering
Shunji Egusa	Assistant Professor	Physics & Optical Science
Kosta Falaggis	Assistant Professor	Mechanical Engineering
Mike Fiddy	Professor (phased retirement)	Physics & Optical Science
Nate Fried	Professor	Physics & Optical Science
Greg Gbur	Professor	Physics & Optical Science
Tsing-Hua Her	Associate Professor	Physics & Optical Science
Tino Hofmann	Assistant Professor	Physics & Optical Science
Thomas Hutchens	Postdoctoral Fellow	Physics & Optical Science
Rosario Porrás-Aguilar	Assistant Professor	Physics & Optical Science
Menelaos Poutous	Associate Professor	Physics & Optical Science
Yasin Raja	Professor	Physics & Optical Science
Tom Suleski	Professor	Physics & Optical Science
Susan Trammell	Professor	Physics & Optical Science
Yong Zhang	Bissell Distinguished Professor	Electrical Engineering

Keywords:

Optics, photonics, sensing, metamaterials, freeform

Target Category:

Existing and Emerging Excellence

1. Executive Summary

Optics, the science of light, is a key interface technology which impacts diverse applications such as bridge-health monitoring, laser surgery, sensors for self-driving cars, medical diagnostics, identifying sources of heat loss in buildings, additive manufacturing, defense sensing, astronomical telescopes, fiber-optic communications, cell-phone cameras, and virtual reality. Optics has been a signature strength of UNC Charlotte even before the founding of the Center for Optoelectronics and Optical Communications (“Opto Center”) more than 20 years ago. We have significant faculty expertise in optics within the Department of Physics and Optical Science (Aggarwal, Astratov, Allen, Boreman, Egusa, Fried, Fiddy, Gbur, Her, Hofmann, Porras, Poutous, Raja, Suleski, and Trammell) and ongoing research collaborations with UNCC faculty in the departments of Biology, Chemistry, Electrical Engineering, Mechanical Engineering, and Math.

We have extensive experimental facilities related to optics research which includes 12,000 square feet of individual faculty research space and an additional 9,000 square feet dedicated to shared-use research activity. This shared-use facility is administered and maintained by the Opto Center, which operates as a recharge unit that serves both university clients and external industry clients. Within the past 12 months, the Opto Center has served UNCC students and faculty from the departments of Biology, Chemistry, Electrical Engineering, Mechanical Engineering, and Nanoscale Science; along with 13 industry clients, including a number of small businesses in the greater Charlotte region: Eminess Technologies (Monroe), FLIR Systems (Charlotte), Goulston Technologies (Monroe), Keselowski Manufacturing (Statesville), Moore Nanotechnology (Concord), NuSpot Technologies (Charlotte), Paragon Polymer (Mooresville), United Protective Technologies (Locust), and US Conec (Hickory). Industry clients from outside the region include: BAE Systems (Nashua, NH), Nanohmics (Austin, TX), Phoebus Optoelectronics (Potsdam, NY), and Plasmonics (Orlando, FL).

Our department administers interdisciplinary MS and PhD programs in Optical Science and Engineering (OSE), with typical enrollments of 10 in the MS program and 50 in the PhD program. Our typical student cohort in the PhD program is one third female and is about half domestic and half overseas students. Since 2006, the OSE program has graduated 70 MS and 80 PhD students. Optics research is of central importance to two Industry/University Collaborative Research Centers (I/UCRCs) in the department – the Center for Freeform Optics (“CeFO,” directed by Suleski, with Falaggis from Mechanical Engineering as Associate Site Director), and the Center for Metamaterials (“CfM,” with Aggarwal as Director and Hofmann as Associate Director). These I/UCRCs are financially supported by the National Science Foundation (NSF) and by 22 industrial and Government-laboratory partners. These entities pool their contributions (about \$45,000 annually) to support projects proposed by the faculty and voted on by the partners. This arrangement benefits the graduate students supported as research assistants on these projects, and those students are often hired by the sponsoring organizations when they complete their degree programs. Optics faculty also closely collaborate on research projects with the Center for Precision Metrology (“CPM” which is administered by the Department of Mechanical Engineering.

The external research funding awarded to PIs in the Department of Physics and Optical Science in the past five years is \$12,463,909. The most recent Stanford University list of the top 2% of the world’s most-cited researchers included seven members of our optics faculty (Aggarwal, Astratov, Boreman, Fried, Gbur, Her, Tyson), more than any other department on campus.

2. Evidence of Strength and Excellence

The optics faculty within the Department of Physics and Optical Science and allied departments (Electrical Engineering and Mechanical Engineering) have research interests in four main concentration areas: 1) Bio-Optics (Egusa, Fried, Porras, Trammell); 2) Micro-Optics (Aggarwal, Astratov, Boreman, Fiddy, Her, Hofmann, Porras, Poutous, Suleski); 3) Optical Fabrication and Testing (Allen, Davies, Falaggis, Suleski); and 4) Optical Communications (Gbur, Raja, Zhang). Within these four research areas our faculty teams collaborate with one another and with colleagues across the UNCC campus. Drawing on data from our recent departmental annual reports, typically 50% of the publications from our faculty are co-authored with UNCC collaborators. Our collective scholarly activity has resulted in \$12,463,909 of sponsored research over the past five years (PIs in the Department of Physics and Optical Science). This funding is primarily used to support graduate students on research assistantships. Our department administers the interdisciplinary MS and PhD programs in Optical Science and Engineering (OSE). Since 2006, the OSE program has graduated 70 MS and 80 PhD students. The research reputation of our faculty members brings significant prestige to UNCC. The most recent Stanford University list of the top 2% of the world's most-cited researchers included seven members of our optics faculty (Aggarwal, Astratov, Boreman, Fried, Gbur, Her, Tyson) – more than any other department on campus.

Central to our shared success in experimental research is UNCC's strategic investment in support personnel and facilities and our longstanding departmental culture of willingness to share experimental resources. We have 12,000 square feet of individual faculty research space and 9,000 square feet of shared-use facilities. These are administered and maintained by our Center for Optoelectronics and Optical Communications ("Opto Center"), which operates as a fee-for-service recharge unit available to university clients and external business partners. Resources of the Opto Center include the Grigg Hall cleanroom of 2850 square feet (shown below), with extensive facilities for optical and electron-beam lithography, deposition (thermal, e-beam, and atomic-layer), plasma-assisted etching, optical and electron-beam microscopy, and material characterization (profilometer- and ellipsometer-based). Other Opto Center facilities include an x-ray diffraction instrument, staff machine shop, laser cutters, 3D printing capabilities for fabrication of custom experimental apparatus, various interferometers for characterization of optical-surface profiles, and a suite of scattered-light metrology instruments useful for measuring the residual roughness of optical surfaces fabricated by diamond-machining techniques. These resources are available on a modest fee-for-use basis. This arrangement is advantageous, especially for startup companies, because initial investigations and prototype device development can be done without the need to immediately capitalize expensive equipment.



Most of the cleanroom tools were purchased in 2005 with \$10,000,000 of Federal funding; several of them are increasingly difficult to maintain in reliable operating condition. Five team members (Astratov, Boreman, Hofmann, Poutous, Suleski,) recently submitted a proposal for

\$600,000 to the DoD Research and Education Program for Historically Black Colleges and Universities and Minority-Serving Institutions to replace two of the heavily used etching tools.

Our department administers two Industry/University Collaborative Research Centers (I/UCRCs) – the Center for Freeform Optics directed by Suleski, with Falaggis from Mechanical Engineering as Associate Site Director, and the Center for Metamaterials (“CfM,” with Aggarwal as Director and Hofmann as Associate Director). These I/UCRCs are financially supported by the National Science Foundation (NSF) and by 22 industrial and Government-laboratory partners. These entities pool their contributions (about \$45,000 annually) to support projects proposed by the faculty and voted on by the partners. This arrangement benefits the graduate students supported as research assistants on these projects. Often, the sponsors hire the students when they graduate, because the firms have had an opportunity to observe the students’ work over an extended period.

Optics faculty also closely collaborate on research projects with the Center for Precision Metrology (“CPM”) which is administered by the Department of Mechanical Engineering. All three of these Centers facilitate faculty collaboration through the typical practice of sharing PI responsibilities on projects and by our collective response to the needs and interests of the industry partners. Faculty with current Center grants include: CfM/Metamaterials (Astratov, Bejger (Chem), Egusa, Her, Hofmann, Mencagli (EE), Willis (EE)); CeFO/Freeform (Allen, Davies (ME), Falaggis (ME), Porrás, Suleski); and CPM/Metrology (Allen, Falaggis, Her, Porrás, Suleski). An example of the tangible results of the collaboration between CeFO and CPM is the recent award of \$946,716 from AFOSR to the Davies/Suleski team for the purchase of a state-of-the-art diamond machining tool for fabrication of ultrasMOOTH optical surfaces. Another notable collaborative funding success is “Development of an in-situ controlled atomic layer deposition tool,” which was awarded \$440,546 from NSF to a team of eight investigators (Aggarwal, Egusa, Her, Poutous, Raja, Suleski, Zhang) led by Hofmann.

Additional resources, as available, could be usefully invested in replacing equipment and upgrading our shared research facilities. This investment is especially critical for our 16-year-old cleanroom micro-fabrication tools. These instruments have been the most problematic to maintain because their high-voltage and high-vacuum interconnects tend to degrade with time and because of the inherently complex electronic-control systems. Over the past few years, our PIs have experienced a number of delays on their funded-research activities because of equipment downtime. When they write proposals, faculty need to know that the experimental facilities that they depend on are solid and reliable. In the current competitive funding landscape, we must be aggressive and confident in our proposed statements of work. To maintain and extend our competitive advantage on proposals in micro-optics and metamaterials, having fabrication tools that we can count on is of critical importance. Faculty research productivity would benefit from more common use of postdocs. Postdocs increase both the size and creativity of research groups. Some initial funding for those positions would be helpful, allowing faculty to manage larger programs, and to eventually absorb the costs of postdocs as normal operating expenses. It would also be useful to augment the stipend amounts for graduate students. The recruiting landscape is extremely competitive, especially for under-represented minorities and domestic students. Several of our legacy graduate-assistant lines are funded at levels well below the uniform pay scale currently required. Finally, additional faculty lines as cluster hires in optics would enable us to grow our research portfolio and to offer an undergraduate degree program specializing in optics. A degree program in the intersection area of optics and precision mechanics would be unique on a national level, giving UNCC an advantage in both student recruitment and research funding.

3. Alignment with Regional and National Priorities

Optics is an enabling technology for a surprisingly wide range of applications critical to US competitiveness and national security – from advanced manufacturing, displays, communications and information technology, defense and national security, energy, to health and medicine. Optics is a national priority as evidenced by the National Photonics Initiative (lightourfuture.org) and the American Institute for Manufacturing Integrated Photonics initiative (aimphotonics.com). Optics is always strongly represented in Department of Defense solicitations, consistent with guidance given in the National Defense Strategy: dod.defense.gov/Portals/1/Documents/pubs/2018-National-Defense-Strategy-Summary.pdf.

Undergraduate- and graduate-level optics training is only available at a few institutions nationally. The largest players in this arena are the Universities of Arizona, Rochester, and Central Florida. These programs cannot supply all of the personnel needed by industry and Government labs. Our graduates at MS or PhD levels are highly sought after, with placements of graduates over the past five years at the US Air Force Research Laboratory, US Army Aberdeen Proving Ground, National Geospatial Intelligence Agency, Naval Surface Warfare Center, Duke University, Pennsylvania State University, Wageningen University, University of Chicago, University of Rochester, Alcon, ANSYS, Aperture Optical Sciences, Apple, Cytek Biosciences, Intel, L3Harris, Lasertel, Magic Leap, Micron, Nikon, Nutronics, Optis, Opto-Alignment, OptoFidelity, Optoniks, Precision Pharmacotherapy, Sensory Analytics, Senstar, Synrad, and UES. We often place students at summer internships in industry or in Government labs to gain practical experience. We are presently in discussions with Naval Surface Warfare Center (Dahlgren, VA) and the Air Force Test Center (Edwards AFB, CA) to expand graduate training opportunities in optics at UNCC for their civilian employees.

Our optics program at UNCC has some unique niches – our I/UCRCs in metamaterials and freeform optics are good illustrations. Additionally, the overlap between mechanical engineering and optics is an area of significant employer interest, given our emphasis on design, fabrication, and testing of prototypes using the shared toolsets in the Opto Center, the Freeform Center and the Metrology Center. The connections between machining and metrology are strong at UNCC, and the Metrology Center is key to the success of many of the Freeform Optics programs. This synergy resulted in the decision of a key industry partner to relocate a research and development center nearby. Quoting from www.globenewswire.com/news-release/2020/09/22/2097108/0/en/Moore-Nanotechnology-Opens-Process-Development-Center-in-Concord-North-Carolina.html: “Moore Nanotechnology (Nanotech), a leading global supplier of ultra-precision machining systems, announces the grand opening of their Ultra-Precision Machining Process Development Center in Concord, NC. Nanotech has seen significant growth around the world as demand for high-performance optical systems continues to expand. Nanotech made a purposeful decision to have this facility near the UNCC campus to form a more collaborative relationship with Matt Davies in diamond-turning research and Chris Evans with precision metrology.”

The range of industry and Government partners in our two I/UCRCs is further evidence of our relevance to National needs. The Freeform Center has as members: Air Force Research Lab, Aperture Optical Sciences, Ball Aerospace, Collins Aerospace, Facebook, LightPath Technologies, Lockheed-Martin, Microsoft, Nanohmics, Nikon, OptiPro, Poco Graphite, SA Photonics, Synopsys, Thales, and Zeiss. The Metamaterial Center has as members: Air Force Research Lab, L3Harris, NASA, Phoebus Optoelectronics, US Conec, and J.A. Woollam.