CREOL: Founded in 1987 as Center for Research & Education in Optics & Lasers. Became a college in 2004. First in US.

Faculty: world renowned, award winning, Fellows & leaders of professional societies, editors of key journals, . .

Scholarship & Inventions
26 Books
4000 journal papers, ~100,000 citations.
300 patents, 27 spinoffs
2016 external funding: $17M

Students:
~ Total 300 PhD degrees awarded
~ Total 400 MS degrees awarded
Alumni employed in prestigious research labs and in industry
Current enrollment: 120 Graduate, 115 undergraduate

Facilities: Excellent facilities for lasers, optical fibers, LEDs, LCDs, integrated photonics, optical materials, . .

Industrial Affiliates program: 62 companies
5 incubated startups

Outreach: Home of the Florida Science Olympiad

Partnership:
Florida Photonics Cluster

Florida Photonics Cluster
Research

Basic Science, Technologies & Applications

- Lasers
- Imaging, Sensing, & Display
- Optoelectronics & Integrated Photonics
- Fiber Optics
- Nonlinear & Quantum Optics

- Industry & Manufacturing
- Biology & Medicine
- Communications & Computing
- Defense & Security
- Light & Energy
Biophotonics should be a national priority. *National Academies Report*
Lasers
Directed energy, spatially concentrated power, temporally concentrated power (ultrashort pulses), narrow spectrum (spectral reference), tunable wavelength (penetration through various material), controllable polarization (probes anisotropy), . . .
Interacts with matter in many ways: reflection, refraction, absorption, scattering, fluorescence, dispersion, ionization, breakdown, optical force/torque, sensitive to the spectral signature of matter, senses motion (Doppler), . . . . .

Optical Fibers
Flexible conduit of light, collects and directs light, sensitive to environment (good sensor), can be made in glass, polymers, multimaterials, microstructured, . . .
Optoelectronic & Integrated Photonic Devices
Micro- & nano-devices emitting, detecting, or processing light on a chip. Can be integrated with silicon, multimaterials (semiconductors, organic semiconductors, thin film glass, polymers, metamaterials, plasmonic . . .). Great sensors (chemical, biological, . . ).

Sensing & Imaging Technologies
Contactless near and remote sensing and imaging. Spectral imaging. Scanning microscopy, interferometry, nonlinear imaging
Active Apps: Therapy and surgery
Focused energy alters matter
ophthalmology (lasik and laser photocoagulation), angioplasty, cancer treatment, dermatology, lithotripsy, liposuction, prostatectomy, repairing damaged DNA, etc.
Optical force: Moves and reshapes specimens
optical scalpels and tweezers.

Passive Apps: Imaging and diagnostics.
Imaging of biological material at the molecular, cellular, tissue, and organ levels.

At the macroscopic scale:
• endoscopy, skin and organ imaging, oximetry, mammography, . . .

At the microscopic scale:
• Fluorescence microscopy (multiphoton) using engineered fluorescent proteins
• Nanoscopy. Cellular & molecular imaging. single protein molecule in living cell
• Label-free cell analysis by Raman scattering spectroscopy,
• Optical coherence tomography (retinal imaging, . . )
• Brain imaging,
• DNA sequencing and mapping,
Combined active/passive Apps

- Image-guided surgery/therapy
- Living cells and biological systems are manipulated with optical forces while they are being imaged.
- In optogenetics, light is used to control neurons which have been genetically sensitized to light.

Imaging Science

Quantitative image analysis, visualization, and simulation and modeling are useful tools in radiology and medicine, and these rely heavily on imaging science.
All CREOL faculty can contribute to biomedical optics & photonics

Faculty with projects in biomedical optics & photonics

Senior
- Aristide Dogariu
- Konstantin Vodopyanov
- Ayman Abouraddy

Junior
- Sean Pang
- Ryan Gelfand
- Kuy Young Han

CalTech, Duke
- X-ray imaging

Northwestern, NSF Fellow Biology
- Optical biosensing,
- Single molecule control

Mac Planck Biophys H Hughes Med Inst
- Nanoscopy, Live cell imaging
- Single-molecule imaging

Search is ongoing for a senior faculty in biomedical optics/photonics
Some Existing Projects

- Monitoring of blood coagulation in ICU
- Instrumentation for breath analysis
- Controlling myelination in nerve biology
- X-ray biological imaging
- Monitoring DNA-protein interactions,
- RNA imaging in live mammalian cells
- Optical Control of Cell Motility
- Cell-separation using magnetic-fluorescent polymer particles
- Nanoparticles for cancer treatment
- Spectroscopy of single protein molecule
- Biosensors using optical traps
- . .
Photonics Technology for Blood Rheology

Why blood rheology?
Pathological conditions change the viscoelasticity of blood in a measurable fashion.

Why optical sensors?
Current measurement technologies are slow, require blood removal and chemical activation.

Applications

Intensive Care (ICU) and Bedside Hemorrhage Management
Venous Thromboembolism and Pulmonary Embolism require continuous monitor of anticoagulant and thrombolytic therapy.

Hemodialysis
More than 300,000 patients in US undergoing ~3 procedures/wk, estimated number of procedures ~50M/year; equipment & supplies market ~$14.3B in 2012
Typical procedures last ~4 hrs, during which antithrombotic treatment is mandatory to prevent blood clotting in the extracorporeal circuit;
Need: Real-time, continuous monitor to manage the therapy

Trauma management
Hemorrhage is the major cause of death in potentially salvageable combat casualties; overall prevalence of early coagulopathy in transfused combat casualties is 38%; Coagulation labs are logistically prohibitive
Need: ruggedized, miniature devices that can detect acute coagulation system dysfunctions in real-time.

Optical technology operating in ICU environment

Optical fiber mounted inside the OTW lumen

Probe integration allows unprecedented in-vivo measurements at desired locations within the circulation system
Using optical torques, it was demonstrated that actively guiding the morphology & dynamic actions of a large group of cells is possible. The technique is noninvasive and does not cause phototoxicity.

Fluorescence image of fixed SH-SY5 cells not subjected to illumination (a) and after being illuminated with light polarized as indicated (b).

SH-Sy5 cells position after exposure to polarized light. Systematic tests verified the cells vitality after irradiation.

Regenerative medicine
Cell therapies

Photonic “scaffolds” for tissue repair and engineering

Cell migration and motility assays

CREOL
The College of Optics & Photonics
Fabrication of magnetic-fluorescent polymer particles via an in-fiber fluid instability

**Cyclic olefin polymer (COP)**

**Iron-oxide core**

**Coated with transferrin**, a compound that allows for binding to prostate cancer cells, as the cancer cells have transferrin receptors on their surface.
Cell-binding, particle uptake, and sorting

Microparticles: external adhesion

Nanoparticles: internalization

Particles undergo endocytosis & are taken up into cell.

Cells may then be moved in a magnetic field

Flow-through and separated cells

Cell-separation using magnetic-fluorescent polymer particles

Flow Through

% of Cells Collected

No NPs
Uncoated
PLL
BSA
Non-Mag Tf
Tf-488

Particle Coating
Structure of SOD1 protein and how its misfolding contributes to amyotrophic lateral sclerosis (ALS) disease.

R. Gelfand (CREOL) & E. Bossy-Wetzell (BSBS)

The vibrational spectrum of a single, free solution protein is measured using two-photon beat spectroscopy (Raman Extraordinaire).

Method eliminates averaging & inhomogeneous broadening effects, also single protein assays require less material than conventional assays, saving costs and time.

Technique is used to study structure of SOD1 protein & how its misfolding contributes to amyotrophic lateral sclerosis (ALS) disease. Will help with diagnose of ALS and other neurodegenerative proteopathic (misfolded protein) diseases such as Alzheimer’s.

Single protein spectroscopy of 3 different proteins, showing 3 unique spectra in the microwave regime. These spectra provide structural information and a means of identification.

(i) Cyclooxygenase-2, (ii) Carbonic Anhydrase, (iii) Aprotinin
Visualization of macromolecular complexes and cellular structures with sub-diffraction resolution (< 30-40 nm)

Super-resolution bio-imaging  Stimulated emission depletion microscopy

STED: Kuy Young Han 2014
Optical dissection of underlying disease mechanisms in single proteins

Ultrasensitive detection and quantitative analysis of proteins in Parkinson’s and Alzheimer’s disease from human brains

NIH NeuroBioBank

Magnetic bead

Cell sorting

Cell lysates

(+) α-SYN

(-) α-SYN

Opto-Neuroscience
Frequency comb mid-IR spectroscopic system with unprecedented spectral coverage (2.6-7 µm, no gaps) was demonstrated, capable of massively parallel and ultrasensitive molecular detection for medical breath analysis.

A portable frequency comb system is now being built at Vodopyanov Lab.
Patients wearing a pacemaker have difficulties during MRI since RF magnetic field heats up pacemaker leads causing thermal damage to tissues.

- Reducing MRI-induced heating by tailoring electromagnetic properties at the surface of the material using laser surface modification.
Biophotonics is a key area of growth for CREOL

Strong collaboration with COM, hospitals, medical research centers, and industry is expected.
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