CURRENT RESEARCH INTERESTS

- **Spectroelectrochemistry and Biosensing with Potential Modulated Surface Plasmon Waves**
  - Aymen H. Qatamin, Jafar H. Ghithan, Monica Moreno, Betty M. Nunn, Keenan B. Jones, Francis P. Zamborini, Robert S. Keynton, Martin G. O'Toole, and Sergio B. Mendes, *Detection of Influenza Virus by Electrochemical Surface Plasmon Resonance under Potential Modulation*, Applied Optics (2019), 58, 2839-2844.

- **Evanescent-Wave Cavity-Ring-Down Spectroscopy**
  - Shadi A. Alnaanah, Thomas J. Roussel Jr., Jafar H. Ghithan, Aymen H. Qatamin, Mohammed A. Irziqat, Hamzeh Telfah, Jinjun Liu, and Sergio B. Mendes, *Electroactive Interface for Enabling Spectroelectrochemical Investigations in Evanescent-Wave Cavity-Ring-Down Spectroscopy*, Analytical Chemistry, (2020).

- **Immunosensing with Electro-Active, Single-Mode, Integrated Optical Waveguides**

Our combination of a single-mode electro-active optical waveguide with a biological immunoassay displaying a redox probe that can be electrically controlled for optical transduction is an important innovation to the biosensing field. Due to the extremely high sensitivity of the conductive and transparent photonic device, we experimentally demonstrated a remarkable limit of detection for an avian influenza virus when using a highly selective probe that is biologically specific through the antibody/antigen binding affinity. Equally important, the transduction mechanism of the biophotonic device is also highly selective as the monitored analytical signal is optically and electrochemically locked to the probe tailored for the antigen detection. The redundancy of these selective factors is expected to minimize unwanted false signals from interferents invariably present during detection with biological specimens. Compared to the state-of-the-art (e.g., PCR, ELISA, etc.) the advances described here have the potential to create a new biosensing technology capable of offering substantially shorter detection times with simpler and more cost-effective protocols, which are critical for point-of-care applications in disease diagnostics.

- Jafar H. Ghithan, Monica Moreno, Guilherme Sombrio, Rajat Chauhan, Martin G. O'Toole, and Sergio B. Mendes, *Influenza Virus Immunosensor with an Electro-Active Optical Waveguide under Potential Modulation*, Optics Letters, (2017), 42, 1205-1208.

- Jafar H. Ghithan, Aymen H. Qatamin, Monica Moreno, B Betty M. Nunn, Robert S. Keynton, Martin G. O'Toole, and Sergio B Mendes, "Immunosensing with Electro-Active Photonic Device", book chapter in "Immunosensors – Detection Science" by the Royal Society of Chemistry, England, (2019), DOI: 10.1364/OL.42.001205.

- Detecting Influenza Virus with Electro-Active Optical Waveguides Sergio B. Mendes, Jafar H. Ghithan, Monica Moreno, Guilherme Sombrio, Rajat Chauhan and, Martin G. O'Toole, Optics and Photonics News, special issue for the year-in-review "Optics in 2017", Dec/2017, 39.

- **Optical and Electrical Impedance Spectroscopies for Electron-Transfer Kinetics of Redox Assemblies**

Several protein molecules play a crucial biological role in the energy buildup of living organisms by transferring electrons between highly-specific biological counterparts in the cellular environment. Measuring and understanding these miniscule reduction and oxidation (redox) chemical reactions are critical for elucidating many fundamental biological processes including reaction pathways, time-limiting mechanisms, and influences of the cellular environment. However, those electrochemical measurements have encountered major challenges. The cellular environment is invariably populated by large amounts of dissolved ions whose motion creates an electrical background current that far surpasses the one originated by the targeted proteins alone. An additional major hurdle has been the fact that usually only a very small number of redox-active species are present in most biomolecular assemblies of interest (e.g., species of a certain redox protein on a cellular membrane). We have found a route to overcome those difficulties by first measuring photons instead of electrons. By spectrally tuning a light beam to report exclusively when a relevant protein gives or uptakes an electron (and is essentially blind to the flow of the surrounding ions and other species) we have been able to optically follow and quantify the minute electrical signals created solely by the biological species of interest. To overcome the hurdle of a low density of the aimed species (assemblies with only a few femto-moles/cm^2) we have employed guided-wave light to enhance the optical interaction between the light beam and the targeted biomolecules. An electrically conductive and optically transparent, single-mode, integrated optical waveguide was developed to investigate electron-transfer events of redox-active species. An impedance technique based on AC-modulation of the electric potential applied to the surface of the electro-active photonic device was employed to drive electron-transfer events near the electrode surface, and those events were optically monitored by guided-wave light. The acquired optical signal (with the imprinted absorbance changes that accompany the electron-transfer process) enabled a full reconstruction of the redox electrochemical current/voltage response. A mathematical formalism was developed to determine from the experimental optical impedance data the characteristic time-scale (kinetics) of the corresponding electron-transfer process. Our novel experimental approach brings a unique and powerful route for electrochemical analysis and is expected to become an important tool in many challenging investigations of redox processes.

- Xue Han and Sergio B. Mendes, Electron-Transfer Rate in Potential-Modulated Redox Reactions with Electron-Active Optical Waveguides, Analytical Sciences, (2017), 33, 435-441, issue cover.

- Xue Han and Sergio B. Mendes, Spectroelectrochemical Properties of Ultra-Thin Indium Tin Oxide Films under Electric Potential Modulation, Thin Solid Films (2016), 603, 230-237.

- Xue Han and Sergio B. Mendes, Optical Impedance Spectroscopy with Single-Mode Electro-Active-Integrated Optical Waveguides, Analytical Chemistry (2014), 86, 1468-1477.

LAB RESOURCES:

The Photonics Research Labs is housed in approximately 1,500 sq. ft. and is well-equipped with optical, photonic, and opto-electronic instrumentations and components. In particular, we are well prepared for carrying out experiments in integrated optics, thin-films, biological and chemical assemblies, electrochemical analysis, guided-wave devices, and several optical spectroscopic techniques. Furthermore, we largely benefit from dedicated equipment and custom-made hardware developed along the years for working with planar optical waveguides and fiber optics technologies, and integration of those technologies with spectroscopic tools for studies of molecular assemblies and surface-confined phenomena.

Major resources available in the Photonics Research Labs include:

- 4 vibration-isolated optical tables (2 Newport smart tables, TMC, Melles Griot)
- optical spectrum analyzer (Ando, OSA AQ-6315A)
- CCD and ICCD cameras (Princeton, Pixis 400B and PI-MAX 3)
- spectrographs (Acton/Princeton 2156 and 2358)
- fast PMT detectors and high speed amplifiers (Hamamatsu R928, H5783-04, C5594)
- oscilloscope (Agilent, DSO8104A Infiniium, 1 GHz, 4 channels)
- gated integrators (Stanford Research Systems, SR 250, 280, 245)
- fusion splicer (Ericson, FSU 995)
- fiber cleaver (Fitel, S323)
- femtosecond tunable laser (Coherent, Chameleon Ultra, 690-1020 nm, 2.5W, 140-fs pulse width)
- He-Cd laser (Kimon, 325 and 442 nm, IK5651R-G)
- 445-nm solid state laser (Coherent, OBIS LX, 75 mW)
- 592-nm solid state laser (MPB, VFL-P 1500-592, 1.5 W)
- tunable nanosecond pulsed laser (Continuum, Panther EX OPO with doubler and Surelite SL I-20)
- super-continuum laser (Fianium, SC-400-4) with acousto-optical tunable filter (400-650 nm)
- argon-ion laser (Melles Griot, 35-LAP-321-208) multiple-lines He-Ne laser (Thorlabs, HTPS)
- single-line He-Ne laser (Thorlabs, HRP 120)
- deuterium/tungsten-halogen fiber-coupled light source (Hamamatsu L10290)
- 405-nm semiconductor laser (Nichia, 120 mW, single-mode) and current/temperature controllers
- potentiostat (Ch Instruments, CHI660D)
- optical coater
- lapping and polishing machine (Lapmaster, model 12)
- high resolution metallurgical microscope (VWR, VistaVision, T-RTP 43300-548)

- UV-Vis spectrophotometers (Varian Cary 300, SI-Photonics 430)
- prism coupler and attenuation measurement (Metricon, 2010)
- power-meters (Newport, 1830 C and 1930 C)
- power/energy meter (Newport, 842 PE)
- fast and sensitive detector heads (Newport, 818 UV/CM; NewFocus, 2051)
- lock-in amplifier (Stanford Research Systems, SR 830)
- current amplifier (Stanford Research Systems, SR 570)
- optical chopper (Stanford Research Systems, SRS 540)
- high precision 5X translation stages (Newport, Ultra-Align 561 and matching accessories)
- interferometric instrumentation for flatness measurements
- 0.001°-precision rotation stage (Danaher)
- 3 cabinets with fume hood ventilation for chemical preparation
- wet-bench for chemical preparation
- 18.2 MΩ cm de-ionized water (Millipore, Direct Q-3 with UV pump)
- ultrasonic cleaner (Branson, 2510)
- pH meter (Symphony, SB 70P)
- vacuum oven (VWR, Squaroid)
- analytical balance (Metler Toledo, AB 104-S/FACT, 0.1 mg)
- LabView and driver for computer interface
- spin processor (Laurell, WS-650Mz-23NPP)
- several personal computers
- 9 office desks for postdocs, graduate and undergraduate students