Core Faculty Profile

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Research Interests

Broad Research Interests

Analytic and experimental analysis of the interaction of laser radiation with tissue, Development of diagnostic and therapeutic applications of lasers.

Optical Stimulation of Nervous Tissue

The goal of this project is to improve the spatial resolution of neural stimulation. Electrical stimulation of nerves has long existed. One example is the stimulation of the inner ear (the cochlea) using electrodes. Cochlear implants have allowed many deaf patients to again understand speech and participate more broadly in life. These implants, however, are limited to stimulation of but a few frequency bands. The limitation is due to the spread of electrical current from one electrode to the stimulation region of neighboring electrodes.

We have shown that infrared radiation can induce action potentials in irradiated nervous tissue. The physics of light propagation predicts that the stimulation can be more spatially selective than electrical stimulation. Further, the irradiation can be done without the introduction of external agents (i.e., without the use of external chromophores) - thus removing one of the limitations of other optical stimulation techniques.

This project is funded by NIH- National Institute of Deafness and Other Communication Disorders under Contract No. HHSN260-2006-00006-C / NIH No. N01-DC-6-0006, NIH-STTR: 1R41DC008515-01, NIH-SBIR: 2R44NS051926-02.

Representative Publications:

Izzo AD, **Walsh JT**, Jansen ED, Webb J, Ralph H, and Richter C-P. *Optical parameter variability in laser nerve stimulation: a study of pulse duration, repetition rate, and wavelength.* IEEE Trans Biomed Eng 54:1108-14, 2007.

Izzo AD, Suh E, Pathria J, Whitlon DS, **Walsh JT**, and Richter C-P. *Selectivity of neural stimulation in the auditory system: a comparison of optic and electric stimuli*, J Biomed Opt 12(2), March/April 2007.

Recent press:

http://www.nidcd.nih.gov/news/releases/07/01_04_06.htm

http://www.medschool.northwestern.edu/newsworthy/2007K-February/cochlear.html

Collaborators:

Claus-Peter Richter, Otolaryngology

Agnella Izzo, Otolaryngology

Duco Jansen, Vanderbilt

Anita Mahadevan-Jansen, Vanderbilt

Polarization Based Imaging

Traditional optical imaging of tissue generally ignores the affects that tissue structures have on polarized light. The polarization state of light is altered as it passed thru various structures. Most prominently, collagen is known for its birefringent properties, but other proteins alter the polarization properties of light.

We have shown that illumination of tissue with incident linearly or circularly polarized light and then measurement of the polarization state of the remitted light provide a means by which various tissue structures can be differentiated. In one set of experiments in which a rat tail was embedded within a turbid gelatin such that there was a variable depth of medium above it, we showed that by varying the incident polarization angle, IPA, of the illuminating linearly polarized light, the geometry, and the orientation angle of the tissue, a series of 2-D degree of linear polarization image maps could be created using our Stokes polarimetry imaging technique. Whereas images taken with non-polarized white light photography show no details of the tail structure (indeed the presence of the tail is just visible), the image maps taken with polarized light show locations of the polarization sensitive structures in the rat tail, including soft tissue, intervertebral disks, and tendons. The observed morphologies in the image maps indicate locations where the depolarization of light differs according to the tissue type and underlying layers. The data indicate the importance of varying the IPA, and that tissue dichroism and birefringence affect the degree of linear polarization image maps. Diagnostic information regarding subsurface tissue structures is obtained.

We have designed, constructed, documented, and tested a Stokes Polarization Imaging system that can be used with commercial camera lenses, thus allowing imaging in a manner similar to classical photography (e.g. as used in dermatology). The system is also capable of imaging via commercial laparoscopes, thus allowing the imaging of structures during minimally invasive surgery. Via clinical trials we expect polarization-based images will improve the differentiation of normal structures from pathologic lesions.

This work is supported by the National Institutes of Medicine - National Institute of Child Health and Human Development (R01 HD044015).

Representative papers:

Wu PJ, **Walsh JT**: *Stokes polarimetry imaging of rat-tail tissue in a turbid medium using incident circularly polarized light.* Lasers Surg Med 37(5):395-406, 2005.

Wu PJ, **Walsh JT**: *Stokes polarimetry imaging of rat tail tissue in a turbid medium: degree of linear polarization image maps using incident linearly polarized light*. J. Biomed. Opt. **11** 014031-10, 2006.

Collaborators:

Magdy Milad, OB/GYN

William Johnson. Urology

Mary Martini, Dermatology

Surface-Enhanced Raman Spectroscopy (SERS) for quantification of analytes

We have developed a new class of biosensor based on Surface Enhanced Raman Spectroscopy (SERS) that shows great promise for sensing glucose and other metabolic analytes in biological fluids. The overall goal of this project is to understand the spectroscopic, materials, surface chemistry, biochemical, and physiological factors that control the sensitivity, selectivity, and long-term stability of in vivo SERS-based biosensors. We expect that a SERS glucose sensor approach will improve upon currently available continuous glucose measurement devices (e.g., limited sensitivity and accuracy in sensing hypoglycemia). We are working to develop a minimally-invasive SERS based sensor that will give sensitive, direct, and accurate glucose measurements.

This project is funded by NIH- National Institute of Diabetes and Digestive and Kidney Diseases under grant R33 DK066990.

Representative Publications:

Stuart D. A., Yuen J. M., Shah N. C., Lyandres O., Yonzon C. R., Glucksberg M. R., **Walsh J. T**., Van Duyne R. P. : *In Vivo Glucose Measurement by Surface-Enhanced Raman Spectroscopy*, Anal. Chem., 78, 7211-7215, 2006.

Lyandres, O., Shah, N.C., Ranjit-Yonzon, C., **Walsh, J.T.**, Glucksberg, M.R., Van Duyne, R.P.: *Real-Time Glucose Sensing by Surface-Enhanced Raman Spectroscopy in Bovine Plasma Facilitated by a Mixed Decanethiol/Mercaptohexanol Partition Layer*. Anal. Chem 77: 6134-6139, 2005.

Collaborators:

Matthew Glucksberg, Biomedical Engineering

Richard van Duyne, Chemistry

Link to Professor Walsh's "4-page CV" (pdf)

Link to Professor Walsh's "Full Academic CV" (pdf)

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