Statement of research

Progress in modern science and technology strongly depends on available research instruments and techniques. Dramatic technological changes took place in the field of biomedicine during last decades. Researches in this area cover a wide range of interdisciplinary problems. Biophotonics is a good example of cooperation between medicine and optics. Optics allows realizing non invasive and high-accuracy measurements of different processes and is very perspective in biology and medicine. My research activity is focused on investigation of light-tissue interaction, new optical and imaging techniques development and their biomedical applications.

Interaction of coherent light with tissue is accompanied by scattering and speckle pattern rises. First speckle was reported as noise, but later it was shown that speckle carries useful information. Recently I studied properties of scattered coherent light [29, 31, 32, 41, 46, and 47][1].

Dynamics of speckle pattern depends on velocity of scattering particles and this fact was used to develop technique and device to measure blood microcirculation [9, 18, 19, and 20]. This technique is promising for detecting of the cancerous and pre-cancerous changes in tissues.

Analyzing scattered light one can obtain much more information than that of blood microcirculation. In particular I showed that movement of muscle fibers during contraction create temporal fluctuations of intensity that can be distinguished from fluctuations created by blood cells. This fact was used to investigate muscle contraction velocity and to develop a novel optical myography technique [11, 18, 26, and 30].

Medical imaging involves image analysis as part of diagnostic systems. My interests focus on development of automated measuring techniques utilizing analysis of images. The main point is image understanding of objects having complex morphology like cross-sections of fibres, cells, and particles [1,6,7,8,10]. Modern imaging methods provide an increasing number of continuously improving three-dimensional images. Advanced imaging like holographic interferometry, differential, polarized, and confocal microscopy were successfully applied in my research projects to investigate blood fluxes, mass transport in neurons, and nerve fiber structure and cell morphology.

Some more details about accomplished projects and full list of articles can be found on my site http://markoff5.tripod.com

Currently I am working to develop newest low coherence speckle techniques, which are part of domain of low coherence tomography intensively investigated last years for internal vision in tissues. Recent studies show that these techniques can be used to distinguish between different tissues (live or necrotic, healthy or malignant), to investigate dynamics of different processes, and to control treat tumors. One of my projects involves quantification of skin parameters. There are some evidences that there exist important modifications of skin that could consistently differentiate a malignant skin tumor from a benign one and can be used to control a medical treatment. The main idea of proposed technique is to use low coherent light and measure speckle contrast. The technique promises to be simple, fast, and inexpensive.

This job is planned to be done in cooperation with BC Cancer Research Agency.

[1] Full list of articles can be found on my site http://markoff5.tripod.com/publications.html .

Optical speckle technique for in-vivo measurement of skin roughness

Plan of research

1. Survey of existing profilometric skin techniques. Survey of speckle roughness measurements. Purpose: to study previous results and experience, to choose a technique to be realized.
2. Computer modeling of skin surface. Goal: to develop program that can generate two dimensional set of data simulated surface of skin
3. Simulation of monochromatic and polychromatic speckle pattern created by skin surface model. Comparison of different light sources.
4. Creation of experimental set-up prototype.
5. Development of data processing program.
6. Experiments to measure standard roughness samples to verify chosen method
7. Obtaining of malignant and benign tumor replica. Experiments to measure replicas roughness. Verification of results (comparison with independent measurements).
8. Modification of set up for measurement of skin roughness.
9. Experiments to measure skin roughness in vivo
10. Documentation and plan of future work.

TEACHING PHILOSOPHY

My teaching philosophy is to tell about contemporary biophysics using an easy understandable language, modern practical examples, and newest learning technologies.

Contemporary physics and biophysics become more and more complicated. If yesterday to explain the phenomena of interference we discussed two-slits screen, Young fringes, and simple sinus law, today to explain speckle we need to discuss stochastic interference from many holes, phase screens and autocorrelation functions. Teaching is an opportunity for me to share my knowledge with students. I show them how to see simple physical pattern through complex mathematical description. Preparing carefully prior to introducing material to students I use the most current information available. I start every theme from basic physical models and finish with practical applications of considering phenomena.

Practical applications and examples from everyday life are very important for students, because they feel that physics is a live science, it is used in our day-to-day environment.

To simplify explanation I actively use modern learning technologies [2-4, 12, 13, 14, 15, 23, 24][2]: computer illustration, animation, and simulation. Preparing lecture I try to improve illustration and material analyzing student feedback. They usually say that visualization of physical phenomena helps them to understand process better

[2] Full list of articles can be found on my site http://markoff5.tripod.com/publications.html. To see some descriptions of educational programs please visit page http://markoff_1.tripod.com/programming.html

and faster. My strong computer skills help me a lot. I encourage students to take part in computer simulation. I am planning to adopt some developed educational programs for the students training.

I also try to interact directly with students in my classes by moderating discussions and encouraging independent research. I believe that learning is driven most effectively by self-interest. Accordingly, I concentrate on the latest scientific research and breakthroughs. I typically teach physics and instrumental optics courses; I would like to train two newest advanced courses such as Biophotonics and Stochastic Optics for graduate students. Biophotonics course outline is given in application.

APPLICATION: BIOPHOTONICS COURSE OUTLINE

1. Introduction

1.1. Light-tissue interaction 1
- Absorption
- Elastic Scattering
- Inelastic (Raman) Scattering
- Fluorescence

1.2. Light-tissue interaction 2
- Photothermal
- Photomechanical
- Photochemical

2. Radiative Transport Theory

2.1. Optical transport parameters - μa, μs, g

2.2. Propagation of light in tissue
- Transport equation
- Diffusion Theory

2.3. Optical properties of tissue
- Methodology of measurements
- Tissue chromophores – melanin, hemoglobin, bilirubin
- Transport parameters of biological tissues

2.4. Monte Carlo Simulation
- Light distribution in tissue/Reflectance measurements
- Fluorescence measurements/Raman measurements

3. Tissue Spectroscopy

3.1. Instrumentation
- Optical fibers
- Light sources
- Spectrograph/monochromators
- Detectors (1D & 2D)

3.2. Reflectance spectroscopy
3.3. Fluorescence spectroscopy
3.4. Raman spectroscopy

4. Optical Imaging of Tissue

4.1. Reflectance and polarizing imaging
4.2. Fluorescence imaging
4.3. Time resolved imaging (time domain & frequency domain)
4.4. In vivo confocal imaging/2-photon excitation fluorescence imaging
4.5. Optical coherence tomography (OCT)
4.6. Lab demonstration of tissue imaging and spectroscopy

5. Clinical Applications

5.1. Dermatology
5.2. Ophthalmology
5.3. Endoscopy
5.4. Selective photothermolysis
5.5. Photodynamic therapy (PDT)