NEWS from ARO-FE (June 2002): Nano-Biophotonics

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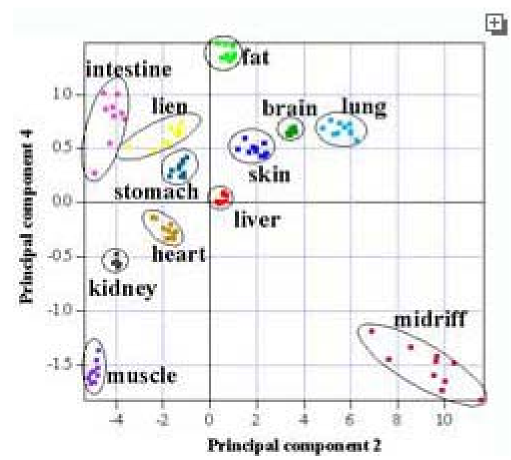
Recent advances in using light at the micro-scale wavelength have provided several scientists at Osaka University with ways of searching the world of "nano meter". In the probing of the "Nano World" the scientists are working on development of technologies for measurement, control, and fabrication in nano scale using micro-scale photons. Technologies they're using are in material control, in giga watt near infrared pulse lasers, and in photo-electronics for measuring single photons. Their efforts have lead to the development of techniques for optical data storage, optical nano fabrication, biosensors and micro machines. Recently, the Osaka researchers have started a project on "Photonic Sensing and Control for Biology and Medicine" supported by the Japan Society for the Promotion of Science. They called this new area of Research: Nano-Biophotonics. It includes Nanotechnology, Biology and Photonics.

Ultra high spatial-resolution and sensitivity for sensing biomolecules and DNA can be achieved by the use of nanotechnology with scanning probe techniques and non-linear photonics using ultra short pulsed lasers. Professor Osamu Nakamura who heads the Biophysical Dynamics and Nano-Biophotonics Group at Osaka University (nakamura@fbs.osaka-u.ac.jp) is evolving these techniques to create new biological applications, particularly, real-time measurement of the chemical reactions occurring in living cells and tissue. Up to this point, they have succeeded in: (1) nano-stimulation and nano-surgery using a femto second pulse laser; (2) real-time imaging of changes in molecular orientation and membrane potential using a second harmonic generation microscope; (3) construction of a database and characterization of near-infrared spectra of biological tissue; (4) imaging biomolecules using a near-field Raman scattering microscope. As nanotechnology and non-linear spectroscopy have not been extensively applied yet in biology, the researchers at the laboratory are very much excited by the many possibilities this field is offering. Here are examples of their work and other publications:

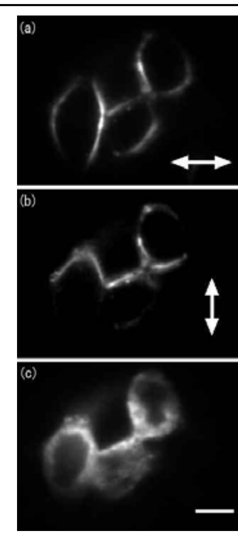
Near-infrared spectroscopy for tissue analysis

In the near-infrared region (800~2500nm wavelength), light absorption of organic molecules is dominated by the harmonic vibrational modes referred to as 'overtone' or 'combination'. The absorptions of these modes are much weaker than those of the fundamental vibrations used in mid-infrared spectroscopy. Near-infrared spectroscopy can penetrate deeper. Near-infrared spectroscopy allows the measurement of chemical information at depths of up to a few millimeters in biological tissue, while mid-infrared spectroscopy requires specimens of only a few microns thick. The Osaka researchers measure and analyze the near-infrared diffused reflectance spectra of several kinds of biological tissue, and extract the vibrational-spectroscopic information of the tissue itself. The indicated Figure classifies the near-infrared spectra of organs by principal component

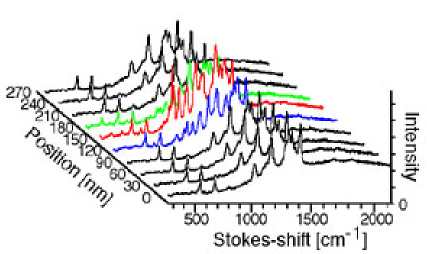


Real-time imaging of living cells using non-linear optical microscopes

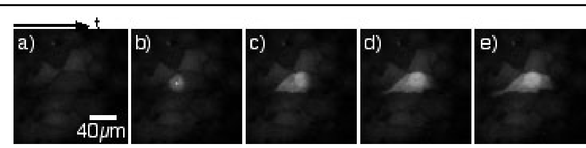
Second harmonic generation (SHG) is a non-linear optical process, where the SHG susceptibility is dependent on molecular orientation and membrane potential. The Osaka researchers have proposed that SHG should be applied in microscopy of cellular membranes. As SHG occurs only in the neighborhood of the laser focal point, a scanning SHG microscope can provide three-dimensional images of the SHG susceptibility of a living cell. This SHG susceptibility distribution directly relates to the cell's molecular orientation and membrane potential. Moreover, they have developed an SHG microscope with a multifocus scanning system for real-time imaging of cell dynamics. They are investigating the relationship between Calcium ion concentration and membrane potential in living cells such as cardiac myocytes.



Second harmonic images of a HeLa cell ((a) and (b); the arrow denotes the direction of polarization of incident light and a fluorescence image(c)



Near-field Raman spectrum of Rhodamine6G molecules with the spatial resolution of 30nm. (Hayazawa, Chem. Phys. Lett., 2001)



Ca^{2+} wave generation induced by ultra-short laser-pulse irradiation in a HeLa Cell. (Smith, Appl. Phys. Lett., 2001) (dandreag@arofe.army.mil)