MODERN TRENDS IN SUBWAVELENGTH MICROSCOPY: CONFOCAL AND TIP ENHANCED RAMAN AND FLUORESCENCE MICROSCOPY, 3D IMAGING, LIGHT TRANSPORT IN NANOSTRUCTURES, COMBINATION WITH AFM

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Optical microscopy and spectroscopy are remaining to be one of the most common and comprehensive sample characterization techniques. They do not only allow one to “see” the sample directly or by using various contrasting techniques, but provides information about sample composition and chemical structure (e.g. in Raman studies), its molecular energy states (in fluorescence), electronic band structure and many other diverse properties – depending on the object of interest. Resolution of common optical techniques is naturally limited by the wavelength of light and rarely goes below a few hundred of nanometers. On the other hand, Scanning Probe Microscopy (or Atomic Force Microscopy - AFM) has proven itself to be a very flexible and powerful tool for sample *physical* characterization with the nanometer spatial resolution. Surface topography as well as electrical, magnetic and even mechanical properties of the sample can be studied by a wide range of scanning probe techniques (Scanning Kelvin Microscopy, Electrostatic Force Microscopy, Atomic Force Acoustic Microscopy and many others) based of different types of interaction between AFM probe and surface.

In this report, we demonstrate the power of integration of the above techniques in one experimental setup. NT-MDT Ntegra Spectra instrument integrates Atomic Force Microscope, SNOM, optical microscope and confocal Raman/fluorescence microscope into one measurement platform controlled by a single piece of software [1]. It becomes possible to perform all optical and all AFM measurements on the *same* place of the sample or on the *same* object – even if this object is of a nanometer scale. Thus, physical characterization properties of AFM merge with chemical resolution of confocal Raman microscope and general capabilities of optical microscope. Physical and chemical properties of various objects are characterized: carbon nanotubes, cells, silicon structures etc.

We also study waveguiding properties of semiconductor and polymer nanofibers of different sizes and materials [2]. Light of different wavelengths is injected into an individual nanofiber either by a SNOM fiber tip or by a diffraction limited (~400 nm) spot of a high aperture objective. The point of light injection is chosen to be either nanofiber end, body or defect. A portion of light transmitted through nanofiber is collected from its end by a high aperture objective, and analyzed by a spectrometer. We study spectra of transmitted light with respect to the injected light wavelength. We also estimate light transmission efficiency for nanofibers of different diameters and materials paying attention on the role of defects on the transmission coefficient.

The ultimate goal of integrating AFM with optics is to bring resolution of optical methods (mainly, Raman and fluorescence) down to resolution of AFM (a few nm). There exists a number of ways how to use light interaction with the apex of AFM cantilever to produce an optical signal originated from a substantially *subwavelength* sample area ($<100\text{x}100$ nm^2) located *right below* apex of AFM probe [3-5]. By scanning the AFM probe along the sample, getting 2D maps of Raman or fluorescence signals with subwavelength resolution (down to a few dozens of nm) is possible. In this report, we will mainly concentrate on Tip Enhanced Raman Scattering experiments – where Raman signal from narrow sample area below the metallized AFM tip is resonantly enhanced due to interaction with plasmons localized at the tip apex [3,4].

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