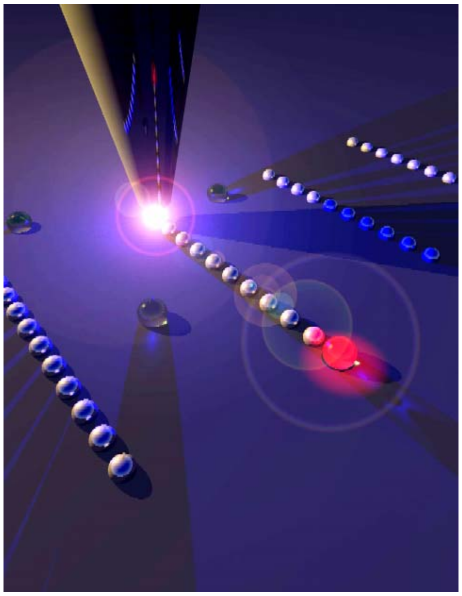
# NANOPHOTONICS AND NEAR-FIELD OPTICS - PIETER G. KIK

The field of optics is entering an exciting new phase due to the rapid development of near-field optical techniques, such as Near-field Scanning Optical Microscopy. It is becoming clear that the local electromagnetic fields that exist around dielectric and metallic nanostructures can be used to *circumvent the diffraction limit*. The diffraction limit is currently one of the main bottlenecks in further development of optical microscopy, optical projection lithography, integrated optics, and optical data storage.

Because of the economical importance of new high-resolution optical techniques, near-field optics and nanophotonics research is booming. Researchers around the world are discovering surprising new effects. Some examples of new developments include:



Energy transport in nanoscale waveguides

- optical imaging of single macromolecules
- energy transport in nanoscale optical waveguides
- extraordinary transmission through nano-apertures in metal films
- focusing in the near-field using ultrathin metal films
- nanoscale optical data storage on DVDs using near-fields

## Research in the Kik group

Work in the Nanophotonics and Near-Field Optics group concentrates on intelligent design of metallic and dielectric nanostructures, the fabrication of these structures using the Leica 5000+ e-beam lithography system in our new cleanroom, and analyzing these nanophotonic structures and circuits with near-field microscopy and spectroscopic techniques. The work is broadly divided into two main directions: *metal nanophotonics* and *semiconductor nanophotonics*.

## Metal nanophotonics

Due to the high concentration of free charges, metals exhibit unusual optical properties that allow us to construct new miniature optical devices. One example is the fabrication of *plasmon waveguides*. It has been shown that a metal nanowire or an assembly of metal nanoparticles (size <100 nm) can be used to transport light with an optical mode confinement smaller that the wavelength of light. The energy is transported in the form of collective electron oscillations, or *plasmons*. The Kik group is involved in the design, fabrication, and analysis of such plasmon based structures.

## Semiconductor nanophotonics

Many materials are found to have modified optical properties when they are reduced in size to length scales on the order of a several nanometers. This is the result of a phenomenon known as *quantum confinement*, related to the wave-like nature of matter. Thanks to quantum confinement we can tune the optical properties of semiconductors by modifying their size and shape at the nanoscale. For example, silicon nanoparticles with a diameter of a few nanometers can emit bright light in the visible range, while bulk silicon emits only very faint emission in the near-infrared range. Quantum confinement also allows for the tuning of the interaction between semiconductors and optical dopants such as the rare-earth ions. This allows us to build new types of optical waveguide amplifiers

Nanophotonic scientist at ease

# NANOPHOTONICS CHARACTERIZATION LAB - PIETER G. KIK

## Experimental techniques

The experimental analysis of nanophotonic structures requires an array of dedicated equipment. The central instrument in our NanoPhotonics Characterization Lab is the combined Near-field Scanning Optical Microscope (NSOM), Atomic Force Microscope (AFM), and Confocal Microscope. All three imaging techniques are indispensable in the investigation of nanophotonic structures.

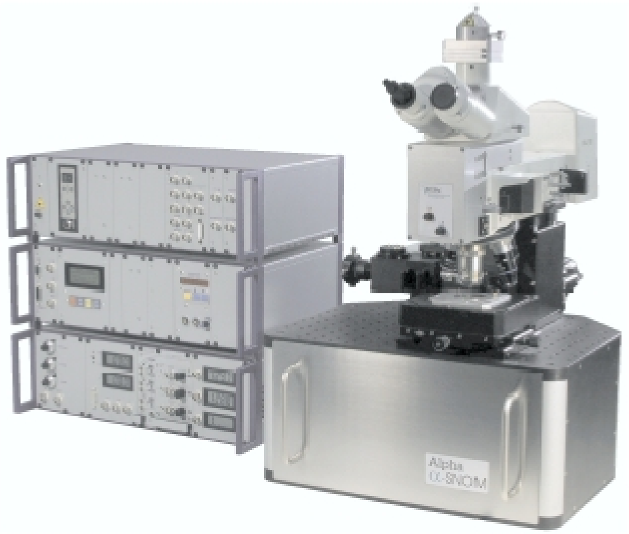
- The **AFM** mode allows us to map out the topography of a sample with near-atomic resolution, enabling the visualization of the nanostructures that make up a nanophotonic integrated circuit.
- Optical mapping or **NSOM scans** can be performed during AFM scanning, providing information about the optical properties of a sample with sub-diffraction limit resolution (50-100 nm). The near-field optical probes also allow us to illuminate samples in a <100 nm spot, which is necessary to enable the local excitation of surface plasmons.
- Finally, **confocal microscopy** can be used to collect light from a diffraction limited *three-dimensional volume*, while rejecting light emitted or scattered outside that volume. For us this represents an indispensable way to improve the optical contrast in our near-field experiments.

To learn more about our nanophotonics research, visit http://kik.creol.ucf.edu.

## Contact information

Pieter G. Kik,
Assistant Professor of Optics and Physics

Office: Room 270 / Lab 247
phone 407-823 4622
email kik@creol.ucf.edu
web http://kik.creol.ucf.edu



The AlphaSNOM Near-field Scanning Optical Microscope