Outsmarting light

October 13 2005

A team of scientists headed by Dr. Christoph Lienau of the Max Born Institute for Nonlinear Optics and Short Pulse Spectroscopy (MBI) in Berlin develops and utilizes novel nanoptical techniques for imaging structures that are many times smaller than the wavelength of light.

The research is based on a special Scanning Near-Field Optical Microscope (SNOM), patented by MBI, providing extremely high optical resolution and flexible combination with different spectroscopic techniques. A microscope based on this patent was now built for the Research Centre Jülich (Forschungszentrum Jülich), where scientists will use it to examine optical absorption in thin nanostructured layers of silicon. These studies at the Jülich facility are aimed at increasing the efficiency of silicon-based thin-film solar cells.

“We need to know the local optical properties of the silicon structures”, says Jülich scientist Dr. Reinhard Carius. It is not sufficient to only know the morphology of the surface. Therefore, neither atomic-force microscopes nor other electron microscopes can help, because these yield information on the surface structure but only limited knowledge about their electro-magnetic properties. “The SNOM built by the colleagues at MBI allows us to investigate how light propagates in the silicon thin films”, says Carius. What’s more, the near-field microscope is highly versatile. Carius adds: “I know of no other place to get such a machine, that is why we asked the MBI to build a duplicate for us.”

So, what is it that makes scanning near-field optical microscopy so special? “We outsmart light with it”, says Dr. Christoph Lienau of the

Max Born Institute. He and his colleagues have constructed the SNOM and got it patented. Lienau explains: “Normally, with visible light, one cannot image structures that are smaller than its wavelenght.” However, light can be regarded not only as a wave phenomenon but as a stream of particles as well. And these particles, called photons, go through seemingly impenetrable barriers. In quantum physics this is known as a tunneling process. “Photons are tunneling through tiny holes smaller than the wavelength of light”, explains Lienau, “and we count the photons and measure their properties.”

The tiny aperture through which the photons are tunneling is located at the very tip of a thin, metal-coated optical fiber. The scientists create these apertures in a controlled way by slightly moving the tip of the fibre into the sample that is to be examined. Then they send light through the fibre and measure how much light is emitted through the hole. Thus, they determine the size of the hole – in the current set-up of the microscope, the hole measures less than 50 nanometers (nm). 1 nm equals the billionth part of a meter. Depending on the colour, visible light has a wavelength of 400 to 800 nm. “We achieve a spatial resolution of 50 nm with our optical near-field microscope”, says Lienau, “that is up to fifteen times smaller than the wavelength of light.”

However, the images generated by SNOM do not directly resemble images obtained by conventional optical microscopy or photography. This is due to the fact that the SNOM-technique belongs to the family of scanning probe methods. In a way, it is similar to Scanning Tunneling Microscopy (STM) or Atomic Force Microscopy (AFM). The tip of the optical fiber scans the sample point by point. If you compare the different methods, you could say that STM or AFM yield information in the same way as a blind person gets information by tactile sensitivity. Touching an object tells you about the surface geometry, and about properties like temperature or maybe electric charge, but it gives no information on colour or transparency. The SNOM-technique overcomes this problem.

The machine built by MBI works in the temperature range between 10 and 300 Kelvin. That equals minus 260 degrees Celsius up to room temperature. Only the sample is cooled by liquid helium. The sensitive scanning module and the tip, however, are located in a vacuum chamber at room temperature, greatly increasing the ease of operation.

The Scanning Near-Field Optical Microscope is roughly the size of a washing machine. It is easily integrable and is easily integrable into convential optical setups, providing, e.g., spectral and/or temporal resultion. Before receiving the order from Jülich, the MBI scientists already built two similar SNOMs for other research groups. The scientists tested the machine in advance and will deliver it to Jülich on October 17. The tests ended highly successful, says Dr. Lienau. Adds Dr. Reinhard Carius: "My colleagues and I at the Research Centre in Jülich are very pleased about the excellent collaboration with the Max Born Institute. We are glad that we have found such reliable partners."

Source: Forschungsverbund Berlin e.V. (FVB)