# Nanophotonics with the scanning electron microscope

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Physical size and power consumption are both increasingly important issues in increasing the data throughput of future optical interconnects, switches and ultimately even optical memory elements. In this respect, phase-change memories have proven to be strong candidates, with data recording done by switching the material between amorphous and crystalline phases, much in line with today's DVD/DVR technology. However, polymorphic systems exist in which crystalline-to-crystalline transitions can provide for higher-base logics as well. In particular, by coding each distinct optical characteristic by a unique label, the different optical cross-sections of absorption and scattering of the crystalline phases of a single nanoparticle can be used as a logical element.

In our recent demonstration of a quaternary-logical (four-level) optical memory element,[1] information was encoded in the structural phase of a single 80 nm gallium nanoparticle, with its four logical states written by optical pulses of only a few pico-Joules energy. The nanoparticle was grown at the 30 nm aperture of a scanning nearfield optical microscope (SNOM) tip. This memory element is comparable in size with bits in next-generation hard disks, and radically smaller than previously suggested memories exploiting optical resonators. Furthermore, the energy required for switching the nanoparticle is one order of magnitude less than needed in DVD/DVR or hard disk technologies. This novel principle of operation equally well applies to methods for achieving plasmonic switching, in which nanoparticles can act as externally operated gates in connection to waveguides and plasmonic sources.[2]

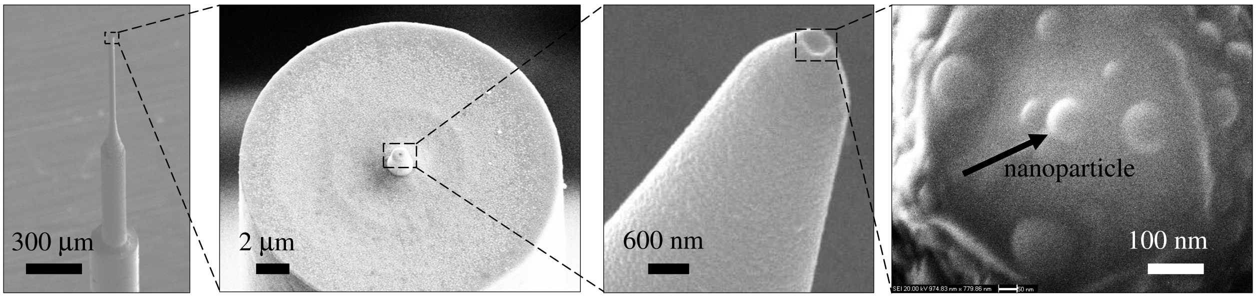

**Figure 1.** Sequence of enlargements of the gold-coated SNOM tip, finally showing the 80 nm nanoparticle grown at the center of the SNOM aperture.

In the evaluation of the nanoparticle memory element, the scanning electron microscope (SEM) provides an excellent experimental platform, as it allows for in situ monitoring of the particle growth and also maintains the vacuum for uninterrupted optical characterization at low temperatures. Via a fiber-optical feed-through into the SEM chamber, the nanoparticle can be optically probed via an external optical setup using pump-probe and broadband continuum source arrangements, across a wide temperature range. With a femtosecond laser source coupled into the fiber, the second harmonic generation (SHG) process can be used to probe the structural composition of the nanoparticles, with substantial changes in the SHG efficiency observed at phase transition points.

Equally important in this respect is the possibility of direct electronic excitation and interrogation of the nanoparticles by means of the electron beam of the SEM. By collecting the luminescence spectra emitted by ensembles of nanoparticles under electron beam excitation, we have shown on the possibility of distinguishing their different crystalline phases. Using this technique, one obtains spatial maps and important statistics of the phase distribution of particles.

[1] B. F. Soares, F. Jonsson and N. I. Zheludev (submitted); B. F. Soares, K. F. MacDonald, V. A. Fedotov, and N. I. Zheludev, Nano Lett. **5**, 2104 (2005).

[2] M. V. Bashevoy, F. Jonsson, A. V. Krasavin, N. I. Zheludev, Y. Chen, and M. I. Stockman, Nano Lett. **6**, 1113 (2006).