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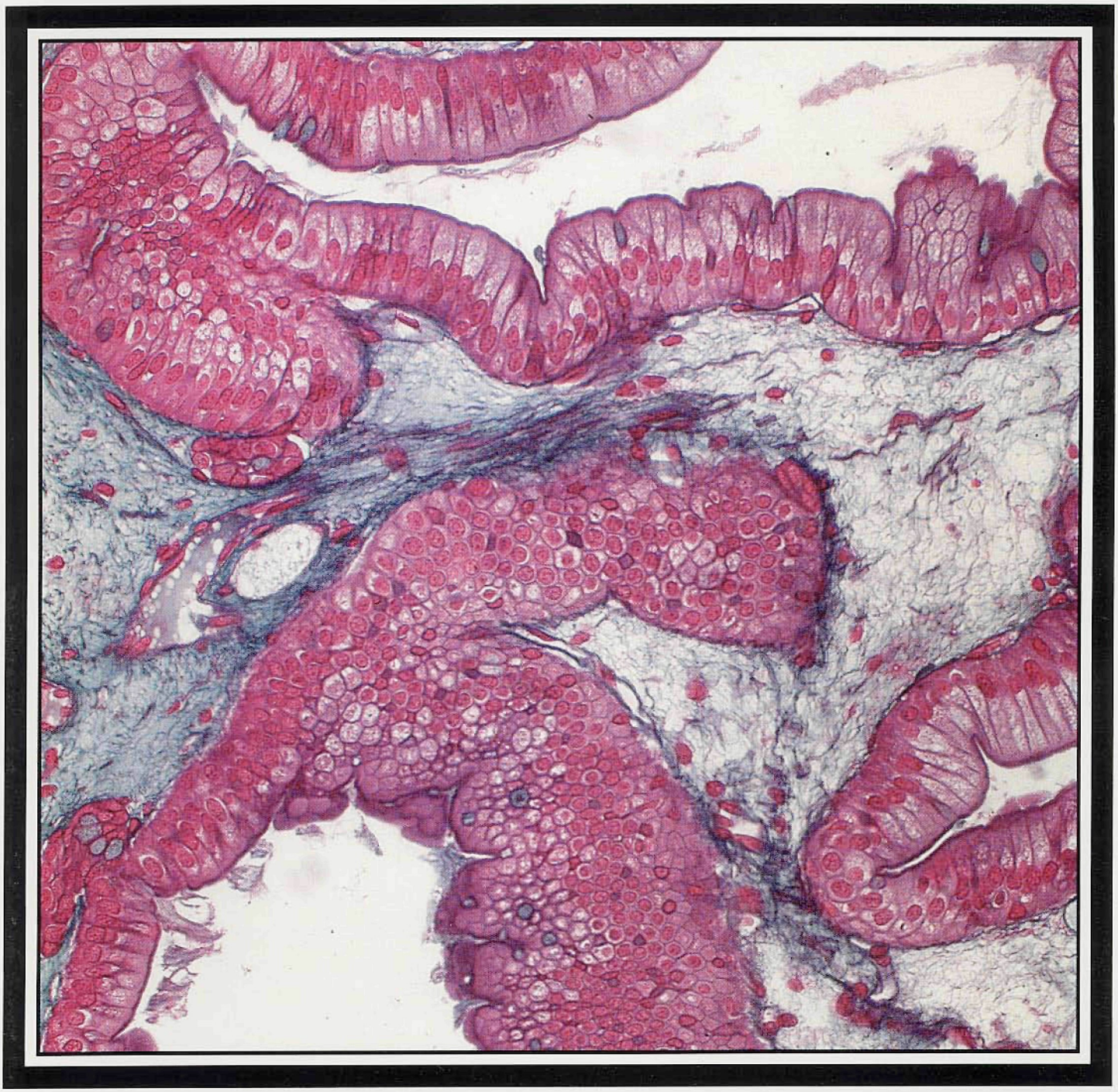

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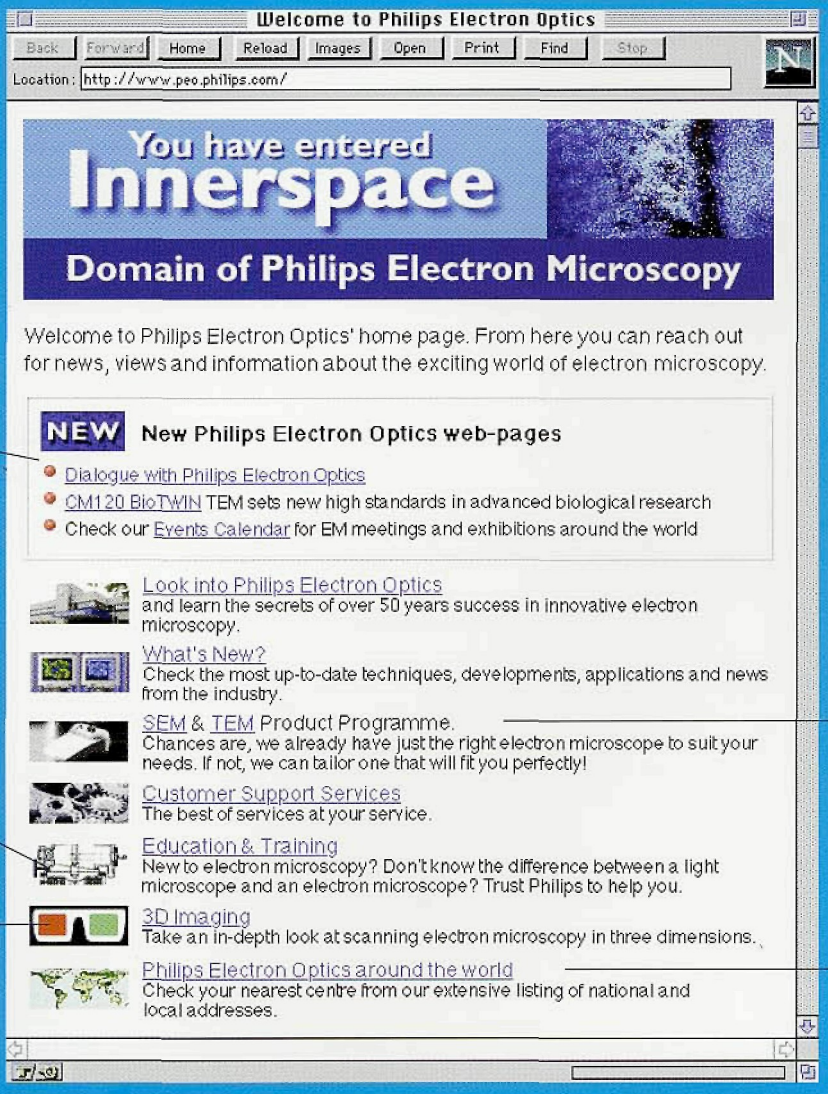

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Near-Field Plasmon-Resonance Scanning Microscopy

Sheldon Schultz, University of California, San Diego

In the past few years the field of near-field scanning optical microscopy (NSOM) has developed rapidly with applications spanning all the physical sciences.[1] A key goal of this form of microscopy is to obtain resolution at levels well beyond those possible with the usual far-field optics. In contrast to far-field optics, which is bounded by the well known limits imposed by diffraction, near-field optics has no "in principle" fundamental lower limit in lateral size, at least down to atomic dimensions, although in practice, signal-to-noise considerations may restrict the application of NSOM to a few nanometers.

The simplest form of NSOM to visualize is based on the principle of a sub-wavelength aperture (with $D/\lambda << 1$) in an opaque plane. Light impinging on this aperture may only be transmitted through the diameter D, and, indeed, were it observed in the far-field, would be spread out over the entire half space due to diffraction. However, if the sample to be studied is placed in the near-field of the aperture, say within a distance D away, the region illuminated will also be restricted to a lateral dimension very close to D. The light impinging on the sample may result in all the usual consequences of transmission, reflection, excitation, absorption, etc., with subsequent optical observations of elastic scanning, fluorescence, etc., all made in the far-field. When the sample is then scanned past the aperture, resulting data images constitute the NSOM technique. The practical realization of such an aperture was developed by E. Betzig, et al., who showed that heating and pulling a commercial optical fiber down to ~50 nm diameter, followed by evaporative coating of the tapered walls with aluminum, produced tips with enough throughput for effective NSOM imaging and spectroscopy.[2]

The essence of NSOM is to have an optical element which produces extremely spatially limited optical fields, i.e., via the rapid attenuation of the near-fields. One also wishes to have a bright source, and the ability to perform the scanning while holding the dimensional variations to nm tolerances. We have developed an alternative form of NSOM based on the defining optical element being an individual Ag spherical particle, ~40 nm in diameter, that is excited at the peak of its surface plasmon resonance. Techniques for making, mounting, characterizing, and scanning such a particle past a reflective thin film sample have been developed. The primary excitation of such a plasmon resonance by an incident plane wave is the dipole mode, whose fields decay as $1/r^3$, providing the requisite rapid attenuation. We find that such a configuration also permits retention of plane polarization of the light, and have reported on the application of the Ag plasmon ball resonator to observe the magnetic Kerr rotation in sub-micron written bits in perpendicular magneto-optic thin films.[3]

Having demonstrated the practical application of plasmon based NSOM for Kerr imaging, we have undertaken a theoretical and experimental investigation of the ultimate resolution of such a system for diverse applications, including fluorescence, Raman, as well as Kerr microscopy.[4] ■

1. D.W. Pohl nd D. Courjon, Eds. *Near-field Optics*, NATO ASI series: *Applied Sciences*, 242. (1993) Kluwer Academic Publishers. Also note that the most recent near-field conference was held in Brno Czech Republic, May, 1995.
2. E. Betzig, et al., 'Breaking the diffraction barrier: optical microscopy on a nanometric scale', *Science*, 251, (1991) 1468.
3. T.J. Silva, et al., 'Scanning near-field optical microscope for the imaging of magnetic domains in optically opaque materials', *Appl. Phys. Lett.*, 65 (1994) 658.
4. The author is pleased to acknowledge the collaboration of Dr. T.J. Silva, whose thesis project was the development of the Kerr plasmon based NSOM microscope. Support for the studies to be reported is by National Science Foundation grants DMR-93-02913 and DMR-94-00439.

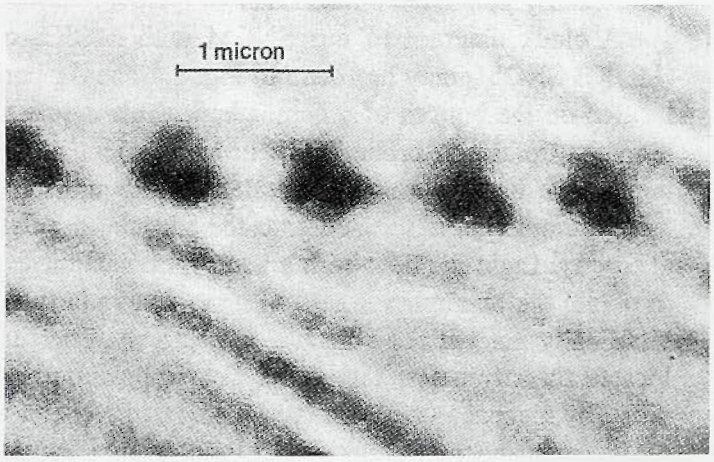

FIG. 1. - A magneto-optic NSOM image of five individual 0.5 μm-diameter magnetic domains in the Co/Pt multilayer film. The diagonal banding is due to the surface texturing of the disk. The irregular features for any given image are reproducible. The width of the domain walls in the image suggests a current resolution in excess of 100 nm.

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Front Page Image
Intestine Cross Section as Viewed Through a Digital Microscope (Brightfield)

Image directly acquired as a digital file using the KODAK DCS 460 Digital Camera at 3060 x 2036 pixels of resolution. Image acquisition time: 1/60 second.

Note: Image provided as an uncompressed TIFF file on Kodak Writable CD - and directly converted to film for printing plate production.

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Don Grimes, Editor