One Nanometer Resolution With An Optocal Microscope! Impossible You Say?

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When physicists of the last century were studying the nature of light and its application to the newly-refined microscopes, they devised certain laws relating to physical limitations to resolution. These laws had something to do with the wavelength of light being proportional to the limit of resolution. Lately these laws haven't just been broken, they've been shattered! But in all fairness to our predecessors, light is being used now in a manner that they could not have imagined. The scanning interferometric apertureless microscope (SIAM) recently refined by a team led by H. Kumar Wickramasinghe with colleagues Frederic Zenhausern and Yves Martin is a prime example.[2] Using this ingenious instrument, they have achieved resolution of one nanometer, and theory predicts even better resolution, down to the atomic level!

The basic "trick" is not to use the entire wavelength of the laser light, but rather just a small fraction of the wavelength. The information is contained within an interference pattern. An incident laser beam is focused on the back of a transparent substrate that holds the sample. A vibrating tip is positioned within one or two nanometers over the sample surface, using an attractive-force atomic force microscope (AFM). The tip vibrates (250 kHz) in the z direction with an amplitude of 6 to 10 nm. (Tip diameter about 5 nm; spring constant of 20 N/m) The return laser beam is composed of the reflection from the substrate plus the tip-sample scattering. This beam was combined with a reference beam and detected with an interferometer. The signal put out by the interferometer is indicative of either the reflection from the substrate plus the tip-sample scattering, or the phase difference with the reference beam. The latter signal represents the contrast mechanisms.

A theory based on dipole-dipole coupling was proposed to explain the contrast mechanism in SIAM. Because the optical dipole interaction varies with the cube of the radius of the tip-feature spacing, the measured signal primarily is derived from the tip end. Wickramasinghe et al. offered mathematical evidence of how manipulation of the tip geometry and other factors could theoretically yield information on an atomic scale. As if that weren't enough, they also pointed out that scattered electric fields could be detected with SIAM. This new technology has applicability to imaging and spectroscopic examination of biologic specimens on a subnanometer scale.

Wickramasinghe's team published micrographs that were simultaneously recorded with an attractive-force AFM and their SIAM. Astonishingly, more detail is visible in the optical images! Abbé, von Helmholtz, Rayleigh, Zeiss, and those guys would have been amazed to see their "laws" broken by several orders of magnitude. ■

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2 Zenhausern, F., Y. Martin, and H.K. Wickramasinghe, Scanning interferometric apertureless microscopy: Optical imaging at 10 Angstrom resolution, *Science* 269:1083-1085, 1995.

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