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Nano-optics Beyond the Diffraction Limit

The development of an optical microscope capable to show a color image of molecules in nanometer scale has been a dream of scientists. An individual molecule responds to the photon at a frequency corresponding to the vibration of molecule. By choosing a frequency (wavelength) of light in visible or infrared region, we can see an image of selected molecule. However, due to the diffraction of light that is wave nature of light, photons cannot be focused within a space smaller than the half wavelength of light. This limitation prevents the photon technology to serve for advanced nanoscience and nanotechnology.

In this presentation, I will explain two breakthrough ideas to overcome this classical limit inherent in optical technology. In the first idea, we bring a metal nano particle in the near field of sample surface. A metal nano particle (or probe) generates a photon spot much smaller than the wavelength of the light, but as small as the probe diameter. By scanning such a metallic probe on the sample surface, we can obtain an image of the sample in the resolution given by the diameter of probe apex. This idea is called as near-field scanning optical microscope (NSOM). I will show our new results of Raman spectra and Raman images of nano-crystals, carbon nano-tubes and DNA networks using a metal-probe NSOM. Three distinct features of near field optics are seen in the results: field enhancement as a electromagnetic effect due to the resonance of plasmon polariton, spectral shift and enhancement due to charge transfer from molecule to metal atom as a chemical effect, and spectral shift due to the force exertion onto the metal-molecule complex as a mechanical effect.

Nonlinear effects also bring optical technology to the nano world beyond the diffraction limit of light. Femto-second laser technology plays an important role for generating nonlinear effects. Two-photon photo-polymerization for three-dimensional micro-fabrication, two-photon photo-isomerization for multi-layer data storage, two-photon laser stimulation to cell organelle, and other interesting results of three-dimensional manipulation in the resolution beyond the diffraction limit will be also shown.

Publications

1. S. Kawata, ed. "Near Field Optics and Surface Plasmon Porlariton", Springer Verlag, 2001.
2. S. Kawata et.al. ed, "Nano Optics", Springer-Verlag, 2002.
3. H. Watanabe et.al. Phys. Rev. B 69, 155418 (2004).
4. T. Ichimura, et.al., Phys. Rev. Lett. (in press)..
5. S. Kawata, et.al. Nature, 412, 697, 2001.