Nanotechnology Highlight

Advanced Characterization Techniques in Optics for Nanostructures (NIRT 0210752)

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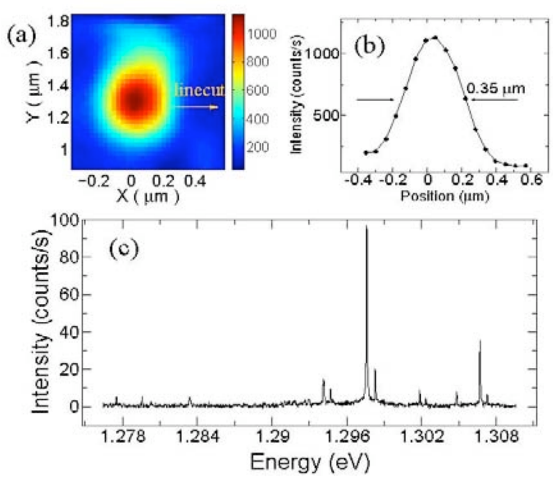
Reducing the wavelength or increasing the collected solid angle can improve the spatial resolution of surface microscopy. We have developed novel techniques based on a Numerical Aperture Increasing Lens (NAIL) to study semiconductors at very high spatial resolution. [1] The NAIL is placed on the surface of a sample and its convex surface effectively transforms the NAIL and the planar sample into an integrated solid immersion lens. An immediate impact can be expected in high-resolution imaging of semiconductor devices, defects, and quantum structures and metrology and failure analysis in the semiconductor industry. This impact will continue over the next 5 years as new semiconductor technology generations are introduced.

We demonstrated the application of a subsurface solid immersion technique to the photoluminescence spectroscopy of individual quantum dots with six times higher collection efficiency than that of a conventional confocal microscope with a high NA objective [2]. We compare the peak PL intensities of the same QD sample taken with and without NAIL (Fig. 1). Comparing the mean values of peak intensities, we find that PL measurement using NAIL technique sees an improvement of collection efficiency by a factor of six over that using conventional high NA objective.



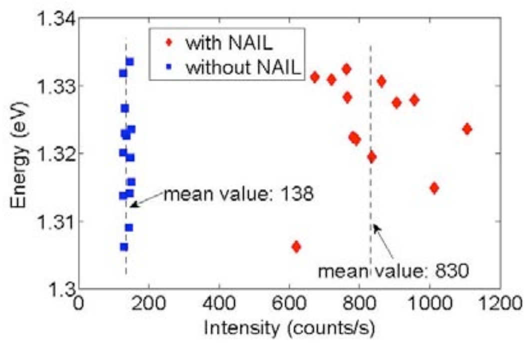


Fig. 1. (LEFT) (a) 2D spatial distribution of the intensity of a sharp QD PL line. (b) Linecut along X direction as marked by the arrow. (c) Typical PL spectrum of the QD taken with our microscope. (RIGHT) Peak intensities of the thirteen brightest QDs for each configuration.

We have also demonstrated the first application of NAIL technique to laser signal injection microscopy (also with funding from AFOSR MURI). The device under test was a 0.18 μm microprocessor unit. Figure 2 shows laser signal injection images taken at 1340 nm with an active input-output circuit bias of 0.64 V. The thermal induced voltage alteration (TIVA) signal is improved by 30%. The improved lateral spatial resolution and signal to noise ratio provided by NAIL microscopy will greatly enhance the capability of laser signal injection microscopy.

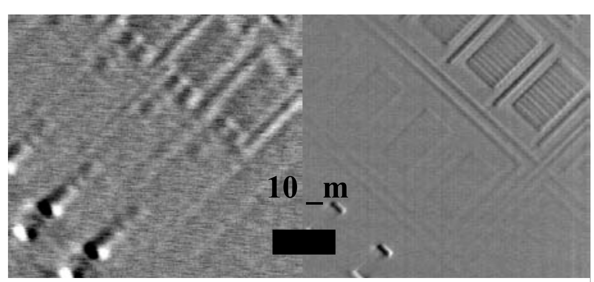


Fig. 1. (left) Conventional (with a 50X objective) and (right) NAIL+20X objective, laser signal injection images taken at 1340 nm (TIVA).

References

[1] B. B. Goldberg, et al., "Immersion Lens Microscopy of Photonic Nanostructures and Quantum Dots," IEEE J. Selected Topics in Quantum Electron., vol. 8, no. 5, pp. 1051, 2002. (invited)

[2] Z. Liu, et al., "High resolution, high collection efficiency in numerical aperture increasing lens microscopy of individual quantum dots," Applied Physics Letters, Vol. 87, August 2005, pp. 071905