L.12: Photonic nanojet for enhancement of transmission through nano apertures

The nanoscale aperture probes used for near-field imaging and spectroscopy applications have very poor throughputs. Among the conventional near field probes the best throughput is provided by hollow pyramid shaped tips and this is typically of the order of ~10^{-5}-10^{-6} for an aperture of diameter 100 nm. Further, the power that can be injected into these nano aperture probes is also limited by the photo-thermal damage to either the probe itself or the sample in close contact with the probe that gets heated. Development of approaches for enhancing the throughput of the near field probes is therefore being actively researched. Most of the approaches investigated for this purpose use plasmon mediated confinement of light which require sophisticated fabrication process and elaborate schemes for efficient coupling of light to the plasmonic mode. Further, the enhancement can be obtained only over a limited spectral range. At Laser Biomedical Applications & Instrumentation Division, we have shown that highly localized beam of light generated by dielectric microsphere often termed as photonic nanojet (PNJ) can also be used to improve the throughput of nano apertures by an order of magnitude. For this a silica microsphere of diameter 5µm was inserted in the hollow cantilever probe by maneuvering a single microsphere placed in the base of near field probe. Figure L.12.1 shows the SEM image of the top view of probe (tip apex 100 nm) with a microsphere insert and the PNJ generated by the microsphere in free space.

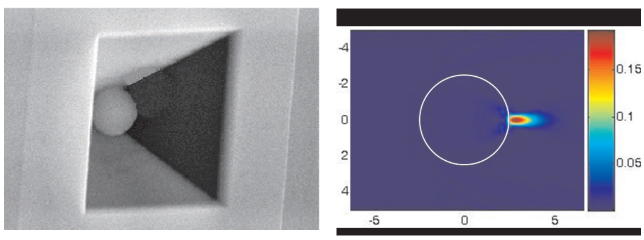

Fig. L.12.1: SEM image of the probe with a 5 µm silica microsphere insert (left) and the photonic nanojet generated by the microsphere under plane wave illumination (λ= 850nm) in free space (right).

Since the length and transverse dimensions of the photonic nanojet depends on the size of the microsphere and input beam parameters, first detailed simulations were carried out to determine the values for these parameters that would optimize transmission through a pyramidal shaped probe having a tip aperture ~ 100nm. The results showed that a silica microsphere having~ 5µm diameter would be a good choice. Simulated field distribution for a probe with a 5 µm diameter silica microsphere insert is shown in Fig. L.12.2.

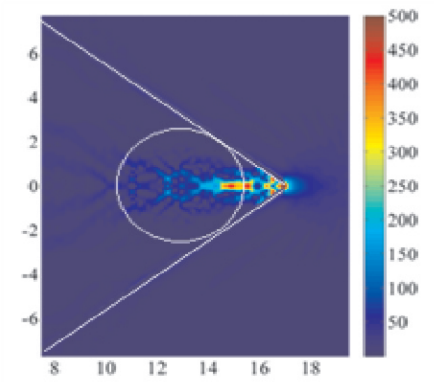

Fig. L.12.2: Simulated field distribution for a probe with 5µm silica microsphere. The source for excitation was TM polarized Gaussian beam focused at 8.25 µm inside the tip.

The experimentally measured transmission spectra of the hollow cantilever aperture probe and the near field image of the nanowires acquired before and after inserting the 5µm silica microsphere in probe are shown in Fig. L.12.3. It can be seen from the figure that transmitted intensity of the probe is enhanced by more than an order of magnitude after insertion of the microsphere. The enhanced transmission also leads to improved contrast in the near field image of the sample.

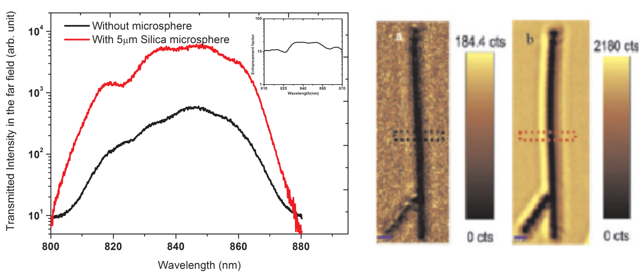

Fig. L.12.3: Left panel: Transmission spectra recorded from hollow pyramid shaped probe (black line) and from the probe with 5 µm silica microsphere inserted. Inset shows the enhancement factor. Right panel:Image of nanowires acquired with regular probe (a) and probe with microsphere (b). Input power to probe: ~150 µW.

The modified probe not only shows enhanced transmission but coupling of light into nano aperture also gets considerably simplified as the transmission though such tip is relatively less sensitive to the axial and lateral offset between the beam waist and symmetry axis of the probe tip. Further, since the formation of photonic nanojet is a non-resonant phenomena the enhancement observed is independent of wavelength. For more details please refer to *H. S. Patel et al., J. Optics 17 (2015), 055005.*

Reported by:
H.S. Patel (harish@rrcat.gov.in)