Putting Plasmonic Probes in Perspective: The Case for the Campanile Tip

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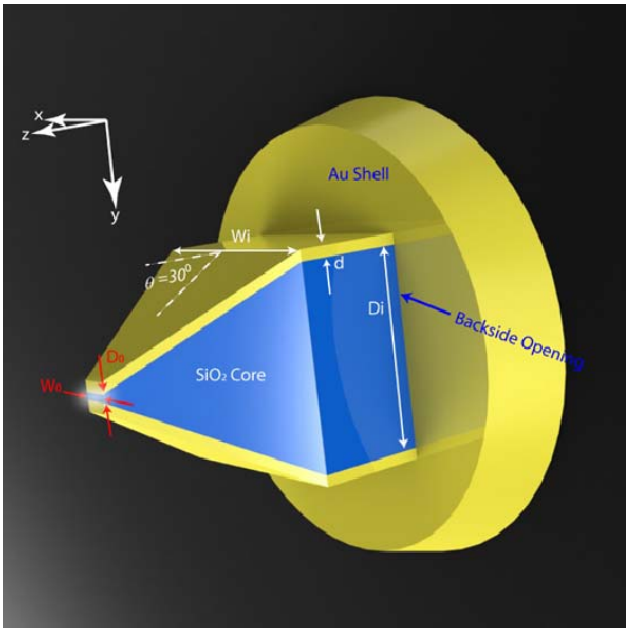
Efficiently converting photonic to nano-plasmonic modes for localizing and enhancing optical near fields is of high interest for applications ranging from nano-optical imaging and sensing to computing. Based on extensive simulations of various "optical transformer" geometries, we propose a novel photonic-plasmonic hybrid Scanning Near-field Optical Microscopy (SNOM) probe called the "campanile" tip. These campanile tips couple the photonic to the plasmonic mode, then adiabatically compress the plasmon mode, over a broad bandwidth, which is crucial for many optical spectroscopy techniques. The confinement of the optical near field is determined by the gap size between the two antenna arms, which can be well below 10nm given the appropriate resolution of the dielectric deposition method. Based on excitation through the back of the tip similar to traditional aperture-based NSOM tips, these campanile tips are an excellent candidate for background-free nanoscale imaging and spectroscopy applications on dielectric, non-transparent substrates. We used FEM to simulate conventional aperture-based probes, the coaxial plasmonic probes, traditional apertureless SNOM tips and the state-of-the-art adiabatic-compression-type probes, and compared them all with the campanile tip geometry. The understanding of relative strengths and weaknesses of each SNOM probe geometry served as the guideline for the design of the campanile tips, resulting in their superior field coupling, enhancement and resolution capabilities.



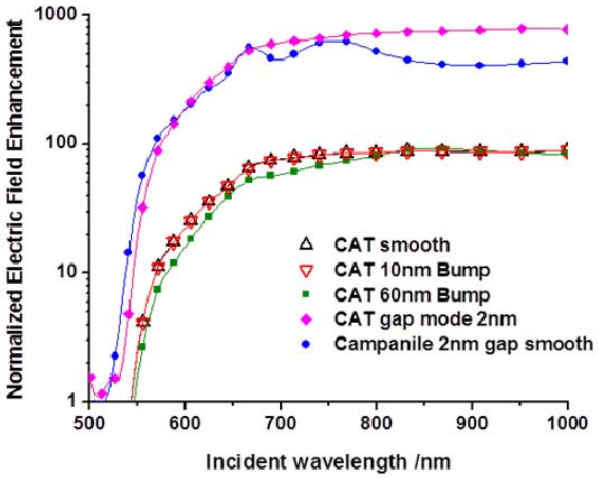


Fig. 1. (Top) Schematic of a "campanile" tip, showing the tree-dimensional adiabatic tapering of a metal-insulator-metal plasmonic waveguide. (Bottom) Plot of electric field enhancement vs. wavelength for both the campanile tip and a conical adiabatically tapered (CAT) tip in operating in tip-substrate gap mode. Both tips have similarly large enhancements, and both demonstrate broadband behavior, but only the campanile tip achieves these while avoiding the tip-substrate gap mode.