Manipulating Nano-scale Light Fields with the Plasmonic Color Nanosorter

Z. Zhang[1, 2], A. Weber-Bargioni[1], S. Dhuey[1], B. Harteneck[1], P. Yang[2], S. Cabrini[1], P. J. Schuck[1]

[1]Molecular Foundry, Lawrence Berkeley National Lab, 1 Cyclotron Road, Berkeley, CA 94720; [2]Department of Chemistry, UC Berkeley, Berkeley, CA 94720

Email: zhaoyu@berkeley.edu, pjschuck@lbl.gov

A central goal of plasmonics is complete control over optical signals at deeply sub-wavelength scales. The recent invention of optical nanoantennas has led to a number of device designs that provide confinement of optical fields at nanometer length scales[1]. For photonic applications, however, the effectiveness of these structures would be *significantly improved* by the added ability to spatially sort the optical signals based on energy/color[2]. Here, we present our experimental and theoretical study of a device, termed the Plasmonic Color Nanosorter, which demonstrates both the ability to efficiently capture and strongly confine broadband optical fields, as well as to spectrally filter and steer them while maintaining nanoscale field distributions. The latter property is important because it allows for manipulation while preserving the physical match, created by the antenna, between the localized field distribution and important physical factors such as semiconductor carrier diffusion lengths and zeptoliter volumes occupied by individual nano- and quantum-objects. Because of these capabilities, color nanosorters are expected to have profound impact on a wide range of optoelectronic and plasmonic applications including ultrafast color-sensitive photodection, solar power light harvesting, and multiplexed chemical sensing.

We use an asymmetric bowtie “cross” nanoantenna to demonstrate the basic principles of a plasmonic color nanosorter. In this case, the asymmetry has been created by moving the “vertical” bowtie component of the cross left-of-center by 5 nm. The effect of this symmetry-breaking can be seen in the field distributions and the scattering spectrum shown in Figure 1. By shifting the “vertical” bowtie to the left only a few nm, the degeneracy of the nanoantenna’s primary (polarization-aligned dipole) plasmon resonance mode breaks in two, which is observed as a doublet (the two red-most peaks) in the scattering spectrum (Fig. 1b). It is straightforward to tune the spectral shift between the two modes; it is simply controlled by changing how far the vertical bowtie is translated (in the left or right direction for horizontally polarized light) from center (i.e. – by increasing the asymmetry and gap sizes between the constituent parts of the nanoantenna). We note that the device described here is a two-color nanosorter, but one can easily extend the sorting/multiplexing functionality to a greater number of wavelengths by designing the device to possess more asymmetric degrees of freedom.

1. Schuck, P. J., Fromm, D. P., Sundaramurthy, A., Kino, G. S. & Moerner, W. E. Improving the Mismatch between Light and Nanoscale Objects with Gold Bowtie Nanoantennas. Physical Review Letters 94, 017402-4 (2005).
2. Malyshev, A. V., Malyshev, V. A. & Knoester, J. Frequency-Controlled Localization of Optical Signals in Graded Plasmonic Chains. Nano Letters 8, 2369-2372 (2008).

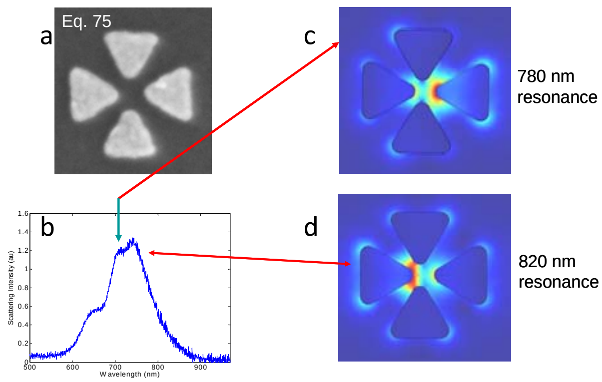

Figure 1. Photonic Color Nanosorter based on an asymmetric cross bowtie antenna as photon nanosorter. Nanosorters were fabricated using electron beam lithography (Vistec VB300 electron beam lithography system, 100 keV). It conists of equilateral triangles 75nm in length (perpendicular bisector), 20nm thick, with ~10nm radii of curvature at the tips. (a) SEM picture of a fabricated nanosorter; (b) white field scattering spectrum indicating two resonance modes; (c) and (d) simulation results of two modes