Plasmon-enhanced Single-molecule Enzymology

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Single-molecule fluorescence studies of enzyme kinetics have revealed marked differences in behavior between seemingly identical molecules.1 However, the low signal-to-noise ratio (SNR) of such experiments complicates quantitation of the heterogeneity, and limits the single-molecule experiments to dilute environments.2

We show numerically that plasmonic enhancement by a single gold particle significantly improves the SNR. (Fig.1) The diffusion of a fluorophore generated by the enzyme is simulated using Brownian dynamics, whereas the optical signal is evaluated using electromagnetic simulations of the plasmon enhancement. The plasmon modifies the excitation rate and the decay rates of the fluorophore, resulting in a modified quantum yield and saturation intensity. We find a 100 fold enhancement in SNR compared to confocal excitation, where the enhancement is dependent on the size/shape of the particle, intrinsic quantum yield of the fluorescent product, and other experimental conditions such excitation intensity and signal binning.

Currently experiments are conducted for enzymes (alkaline phosphatase) conjugated to single gold particles. The improved SNR will enable the study of single molecules with high SNR in realistic but concentrated biological samples.3

Figure 1. (Left) A proposed scheme: confocal excitation of an enzyme-gold nanoparticle complex. (Right) Average SNR of single enzyme turnovers as a function of particle widths. The simulation is performed with single-enzyme-conjugated gold nanorods of varying widths and identical plasmon resonance wavelength.

References

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