Research Group
Nanooptics

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DNA Assisted Directional Plasmonic Nanoantenna

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Introduction

Directional plasmonic nanoantennas have been used in various areas from sensing, spectroscopy to directional photon sources and wireless communication in optical nano-circuits. To obtain desired directionality the morphology and spatial arrangement of nanosized antenna elements must be precisely controlled and optical-frequency quantum emitters need to be accurately attached to provide local driving power. Small distortion of the antenna structure leads to change of the emission pattern.

Goals

1. Realization of photoluminescence-driven directional nanoantennas.
2. Driving the directional nanoantenna with single fluorescent molecules.
3. Manipulation of orientation of nanoantenna to create directional meta-surfaces.

1. Photoluminescence-driven directionality

Nanometre scale positioning accuracy of DNA origami is used to deterministically arrange gold nanoparticles (AuNPs) in a trimer structure to tailor the photoluminescence (PL) of gold in specific directions at specific frequencies. AuNPs are arranged in two different configurations: Type-A for bigger; Type-B for smaller AuNPs to obtain the same inter-particle distance (IPD).

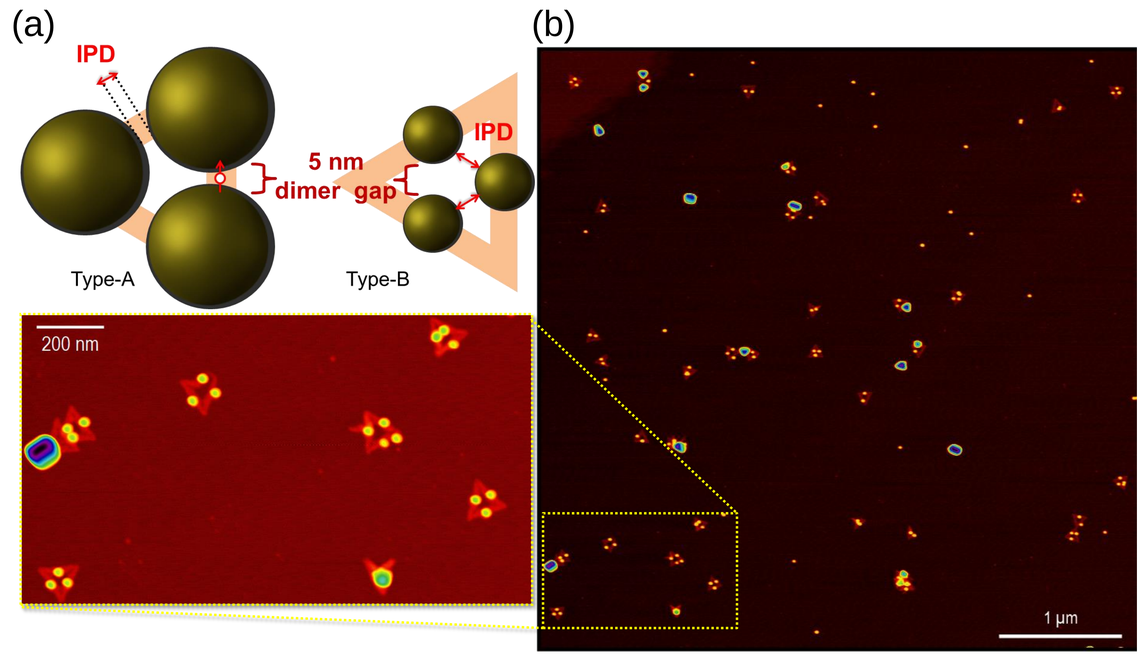

Figure 1: Directional nanoantenna design. (a) AuNPs can be arranged in two configurations depending on their size. (b) Scanning probe microscope image of triangular DNA origami assisted nanoantennas in Type-B arrangement. AuNPs are 15 nm in size.

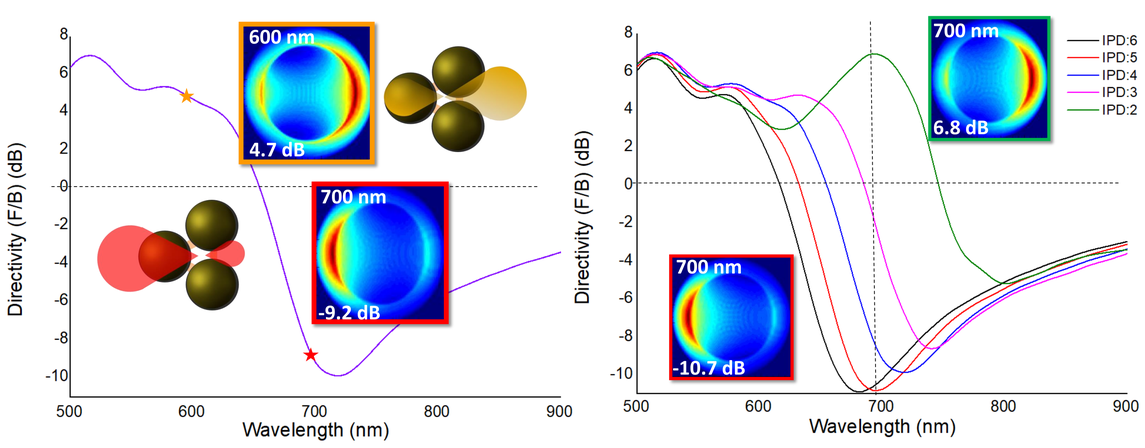

Figure 2: Directivity as a function of wavelength. Diameter of simulated AuNPs are 120 nm. The gap between the dimers is fixed to 5 nm. (a) Emission at different wavelengths are sorted into different directions. IPD:4 nm. (b) When IPD:2 nm the emission is in forward direction, whereas when IPD:5 nm it is in the backward direction at 700 nm.

2. Incorporation of a single quantum emitter

A single quantum emitter will be put in the gap shown in Fig.1(a) in Type-A configuration as the red arrow to drive the nanoantenna. In Fig. 3(a) the antenna is excited with a plane wave and the hotspots are shown on the right. When ATTO655, a dye molecule with its absorption maximum at 655 nm, is put in the hotspot and excited with 655 nm laser it couples to antenna and radiates at 680 nm. The back-focal-plane image of radiation exhibits 5.7 dB directionality.

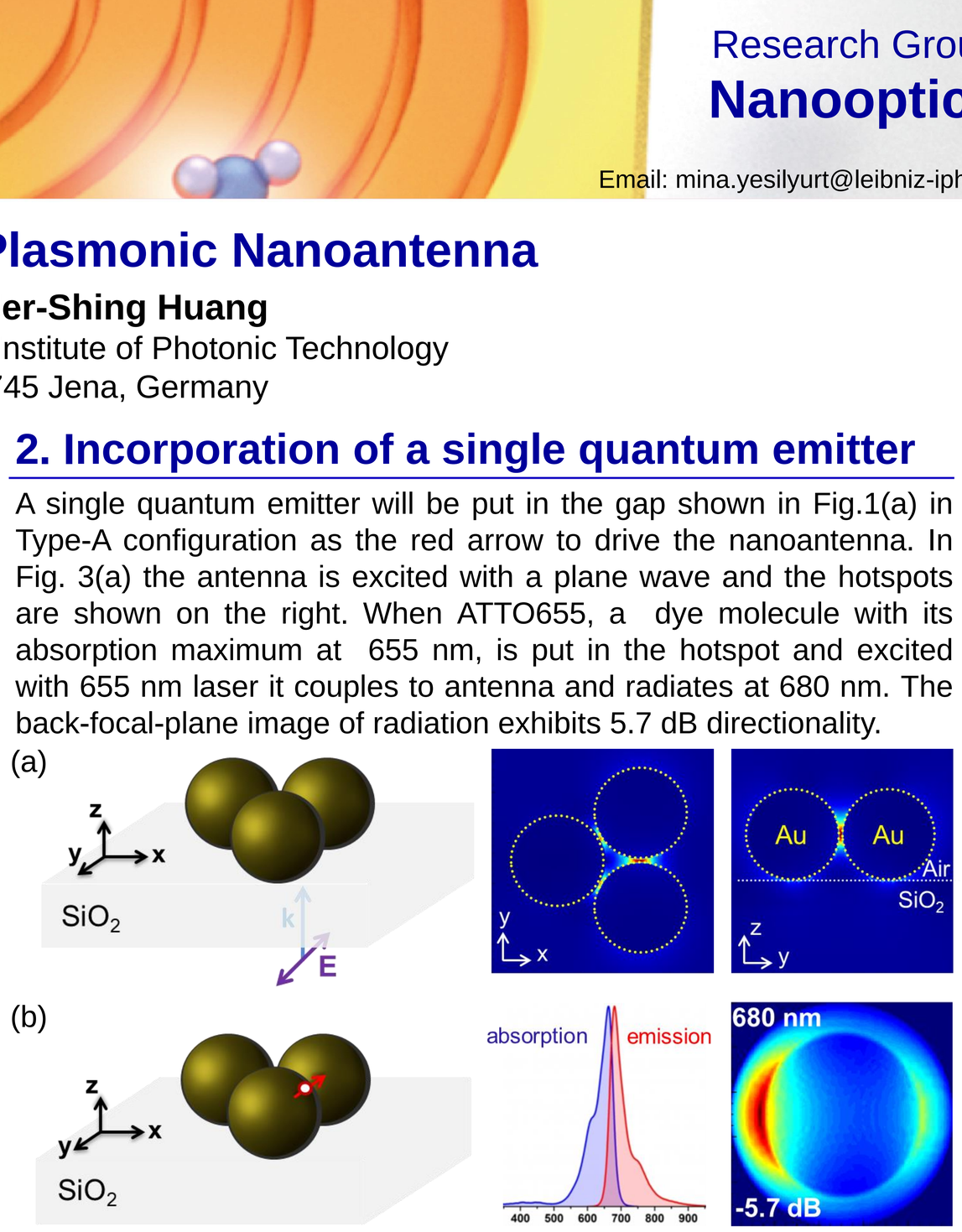

Figure 3: (a) Trimer excited with a plane wave excitation from below. Top and side view of the hotspot between the dimers, where the dye molecule will be placed. (b) Dye molecule represented as the red arrow is oriented along y-axis. ATTO655 absorption/emission spectra and back-focal-plane image of antenna radiation at ATTO655's emission peak.

3. Creation of meta-surfaces

Single directional nanoantennas will be placed on planar substrates to create meta-surfaces that emit/absorb light into/from specific direction. The substrate surface will be patterned with electron beam lithography and origamis with AuNPs will be immobilized on it.

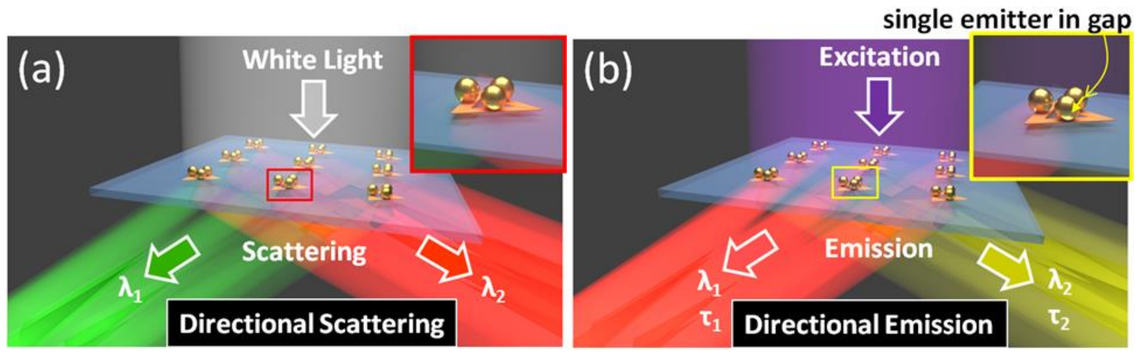

Figure 4: DNA assisted directional nanoantennas oriented and aligned on a planar substrate. (a) PL of AuNPs from each nanoantenna is collectively sorted into different directions. (b) Depending on the excitation wavelength emission of quantum emitters from each antenna can be steered into different directions.

Outlook: Active Tuning of Directionality

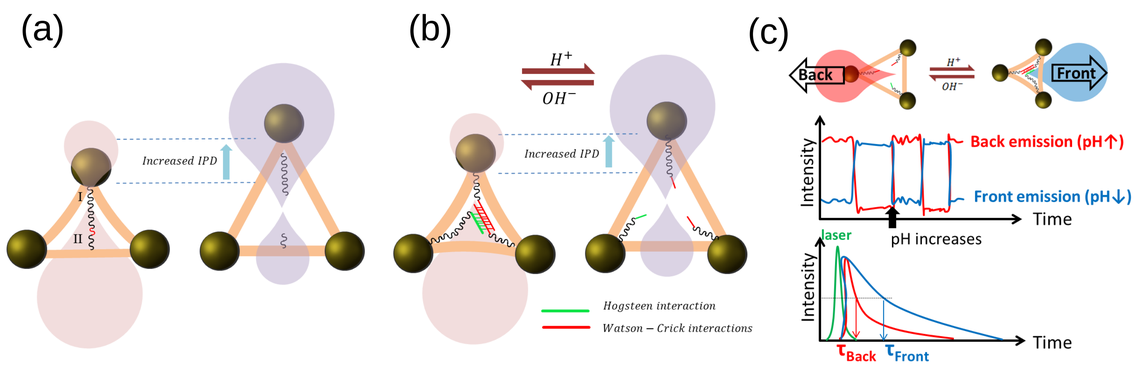

Figure 5: (a) High concentration of target analyte cleaves the disulfide bond connecting the tip and the opposite edge. Once the tip is released radiation direction changes. (b) When the environment becomes acidic, triple bond via Watson-Crick and Hogsteen interactions breaks and AuNPs are separated from each other. Eventually, the radiation changes direction. (c) Presence of external stimuli recognition by usage of photon statistics.