Enhancing and directing light emission in semiconductor nanowires through leaky/guided modes

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Abstract

In the present work, photoluminescence from finite semiconductor nanowires is theoretically[1] and experimentally[2] investigated, exploring and predicting their antenna-like properties for light emission in a variety of configurations of interest in Nanophotonics. The theoretical analysis is based on the leaky/guided mode dispersion relation for infinite nanowires, which governs the local density of available electromagnetic states. Light emission from finite nanowires is then numerically investigated in various scenarios with regard to its enhancement and directionality. A simple analytical model based on currents flowing in a cavity is derived that, upon tuning leaky/guided mode coupling through dipole position/orientation and nanowire geometry (radius and length), allows us to predict their antenna-like behavior and thus to tailor photoluminescence at will, with regard to both enhancement/inhibition of the total radiated power and associated radiation patterns, as shown in Figure1.

On top of the theoretical results, direct experimental evidence of this so-called nanoantenna effect in vertically standing single Indium Phosphide (InP) nanowires (see Figure 2) will be presented. The experimental setup, based on Fourier microscopy[2], allows one to study the angular photoluminescence pattern from isolated nanowires, as shown in Figure 2, thus providing means to directly test predictions from theory.

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References

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Figures

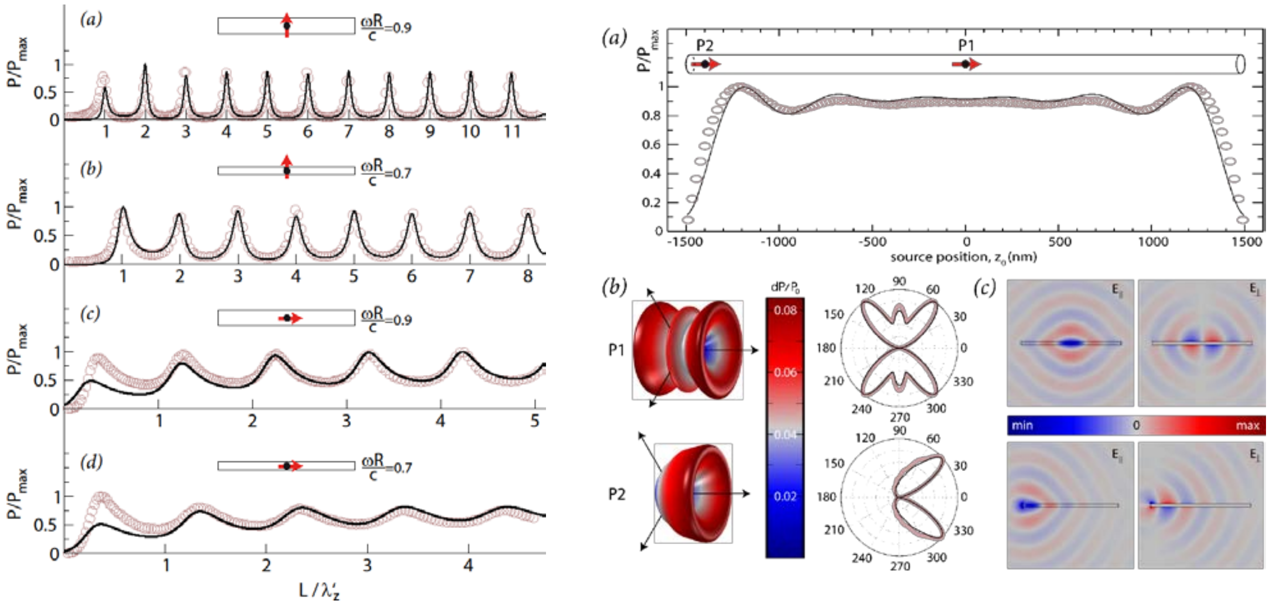

Figure 1. (left) Full numerical simulations (hollow symbols) and model predictions (solid lines) of the normalized total radiated power P/P_{max} as a function of the NW length L, rescaled by the corresponding guided mode wavelength $\lambda'z=2\pi/kz'$: HE_{11} for the perpendicular dipoles, (a) and (b), and TM_{01} for parallel dipoles, (c) and (d). (right) (a) Normalized radiated power (hollow symbols) as a function of (parallel) dipole position z at the NW axis for a finite (L=3 μm, R=50 nm) InP NW at λ=880 nm (at which only the TM_{01} leaky mode is excited). Model predictions are also shown (solid curve). (b) Far-field intensities of the light emitted by two dipoles, located at either the NW center (P1) or close to the NW edge (P2, at a distance d=100 nm), together with model predictions. (c) The corresponding emission snapshots in the near-field map.

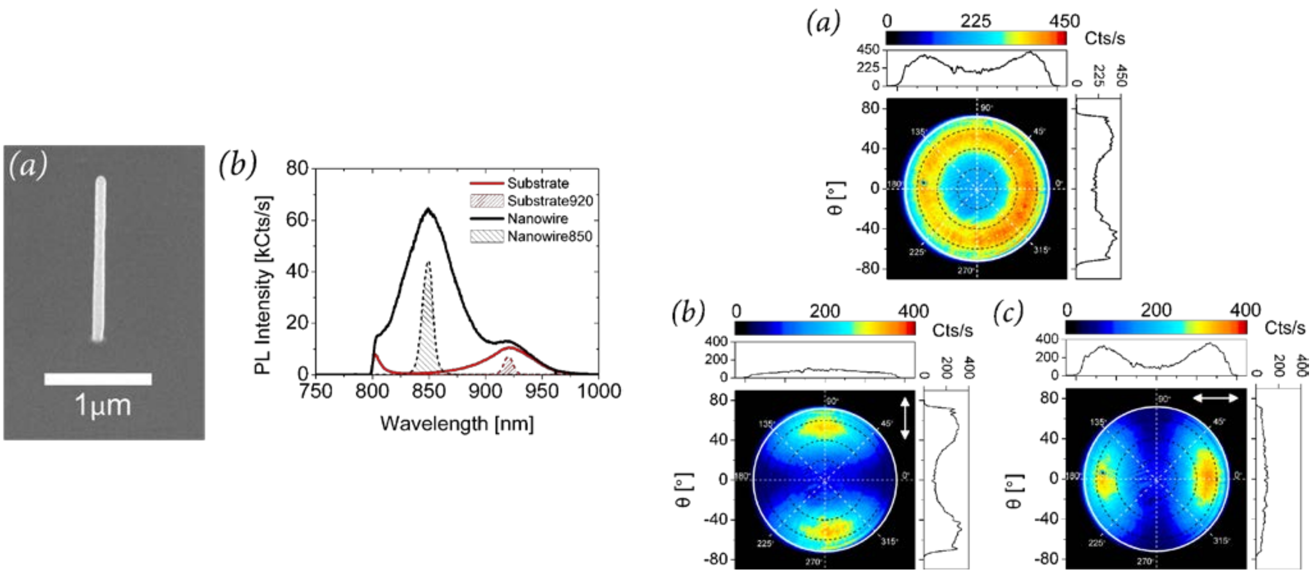

Figure 2. (left) (a) SEM image of the isolated InP nanowire studied and (b) its photoluminescence spectrum. (right) Experimental Fourier images of the emission from InP nanowires at λ =850 nm. Fourier images of the unpolarized (a) emission and with a polarizer with the transmission axis along the vertical (b) and horizontal (c) directions.