

A comparative study of absorption in vertically and laterally oriented InP core-shell nanowire photovoltaic devices

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Supporting Information

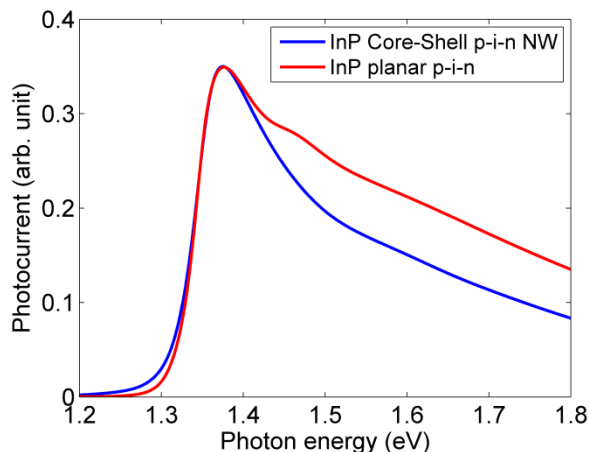


Figure S1. Spectrally resolved photocurrent recorded at room temperature from a grown nanowire (NW) core-shell p-i-n sample (blue curve) together with the corresponding measurement on a reference planar InP (zincblende) p-i-n sample (red curve).

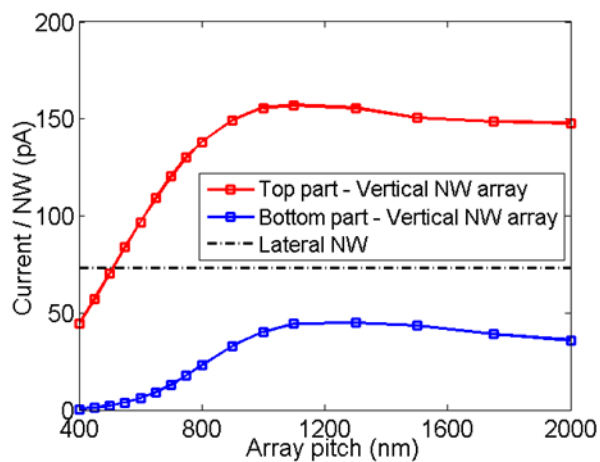


Figure S2. Short-circuit current per NW under 1 sun illumination, calculated for the top (red curve) and bottom (blue curve) segments of a NW in a vertical array versus array pitch, for our NW double-diameter geometry. The dashed line shows the calculated short-circuit current for a lateral single NW of the same geometry and under the same illumination condition.

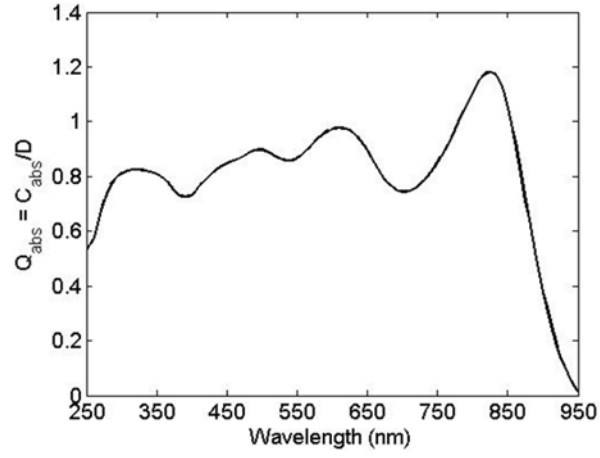


Figure S3. Modeled absorption efficiency $Q_{abs}=C_{abs}/D$ in a lateral InP NW of $D = 280$ nm in diameter. Notice that the C_{abs} is used in Eq. (1) in the main text for calculating the short-circuit current.

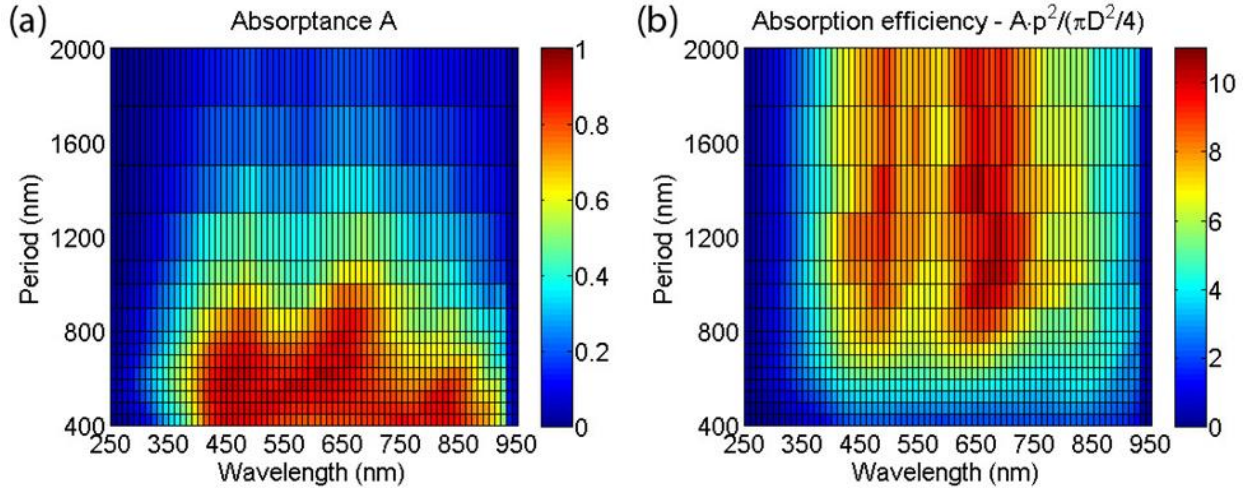


Figure S4. (a) Modeled absorptance A , which is the fraction of incident intensity absorbed, of normally incident light in the $1.1\ \mu\text{m}$ long InP core-shell segment of diameter $D = 280\ \text{nm}$. The NWs are oriented vertically and placed in a square array of period p . Each NW has a $0.9\ \mu\text{m}$ long bottom core segment of $130\ \text{nm}$ in diameter, and a $1.1\ \mu\text{m}$ long, thicker top core-shell segment with $280\ \text{nm}$ diameter, as illustrated in Figure 1 in the main text. A $75\ \text{nm}$ thick SiO_2 layer was considered to cover the bottom segments of the NWs and the InP substrate. On top of the SiO_2 layer, a $40\ \text{nm}$ thick ITO top layer was considered to cover the substrate as well as the lateral surfaces of the NWs. The ITO thickness was considered to be $150\ \text{nm}$ at the top of each NW. Experimentally determined values for refractive indices of InP¹, ITO² and SiO_2 ³ were used in the simulations. Here, we see that for $\lambda < 400\ \text{nm}$, the absorptance in the core-shell segment drops with decreasing wavelength. This drop occurs due to increased absorption in the ITO top layer and the ITO layers at the nanowire sidewall (the absorption coefficient of ITO increases rapidly with decreasing wavelength for $\lambda < 400\ \text{nm}$). (b) Same as (a) but here the absorption efficiency, defined as $A p^2 / (\pi D^2 / 4)$ is shown. Notice that this absorption efficiency denotes from how much larger area than the geometrical cross-sectional area the core-shell segment appears to absorb light. First, we notice that the absorption cross-section is not strongly dependent on the period for $p > 1000\ \text{nm}$. Thus, for $p > 1000\ \text{nm}$, neighboring NWs do not compete strongly for the absorption of incident photons. Furthermore, we identify here the absorption peaks at $\lambda \approx 650\ \text{nm}$ and $\lambda \approx 470\ \text{nm}$ to originate, respectively, from resonant absorption through the HE_{12} and the HE_{13} waveguide modes of each individual NW⁴. Considering the refractive index of InP and the diameter of $280\ \text{nm}$, we expect a resonance of the fundamental HE_{11} mode at $\lambda \approx 1300\ \text{nm}$. This wavelength is however beyond the band gap wavelength $\lambda_{bg} = 925\ \text{nm}$ of InP where the NW core-shell segment stops absorbing light. Thus, in these NWs, the HE_{11} mode does not give rise to resonant absorption.

1. Edwards, F., *Handbook of Optical Constants of Solids*, edited by ED Palik. Academic Press: New York, 1985; Vol. 1, p 547-569.
2. Wallentin, J.; Anttu, N.; Asoli, D.; Huffman, M.; Åberg, I.; Magnusson, M. H.; Siefert, G.; Fuss-Kailuweit, P.; Dimroth, F.; Witzigmann, B.; Xu, H. Q.; Samuelson, L.; Deppert, K.; Borgström, M. T. *Science* **2013**, 339, (6123), 1057-1060.
3. Philipp, H., *Handbook of Optical Constants of Solids*, edited by ED Palik. Academic Press: New York, 1985; Vol. 1, p 749-763.

4. Anttu, N.; Xu, H. *Opt. Express* **2013**, 21, (103), A558-A575.