Electronic Supplementary Material (ESI) for Materials Horizons.

Supporting Information

Near Infrared to Visible Light Organic Up-conversion Devices with Photon-to-photon Conversion Efficiency Approaching 30%

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When the up-conversion device is exposed to the near infrared (NIR) light, the NIR light is absorbed in the photosensitive layer (PSL) with an efficiency of η_A. The PSL convert to photocurrent with an efficiency of η_{PSL}. The generated photocurrent will flow into emitting layer (EML) and generate visible light in EML with an efficiency of η_{EML}. The generated visible light will partly absorb by PSL with a ratio of α and partly output to forward direction with an out-coupling efficiency of η_o. The visible light absorbed in the PSL will generate photocurrent with the same efficiency as that of the NIR light. The generated photocurrent will flow into EML and generate visible light again. The loop will go on. The detailed working processes are shown in FigureS1. The photon-to-photon efficiency $\eta_{p\text{-}p}$ should be the sum of each visible light output to forward direction, which can be calculated as the following equation,

$$\eta_{p-p} = \eta_A\eta_{PSL}\eta_{EML}(1-\alpha)\eta_o + \eta_A\eta_{PSL}\eta_{EML}\alpha\eta_{PSL}\eta_{EML}(1-\alpha)\eta_o$$
$$+\eta_A\eta_{PSL}\eta_{EML}[\alpha\eta_{PSL}\eta_{EML}]^2(1-\alpha)\eta_o + \text{L}$$
$$= \frac{(1-\alpha)\eta_A\eta_{PSL}\eta_{EML}\eta_o}{1-\alpha\eta_{EML}\eta_{PSL}}$$

The photon-to-electron efficiency $\eta_{p\text{-}e}$ should be the sum of the photocurrent efficiency generated by each light, which can be calculated as the following equation,

$$\eta_{p\text{-}e} = \eta_A\eta_{PSL} + \eta_A\eta_{PSL}\alpha\eta_{EML}\eta_{PSL} + \eta_A\eta_{PSL}[\alpha\eta_{EML}\eta_{PSL}]^2$$
$$= \frac{\eta_A\eta_{PSL}}{1-\alpha\eta_{EML}\eta_{PSL}}$$

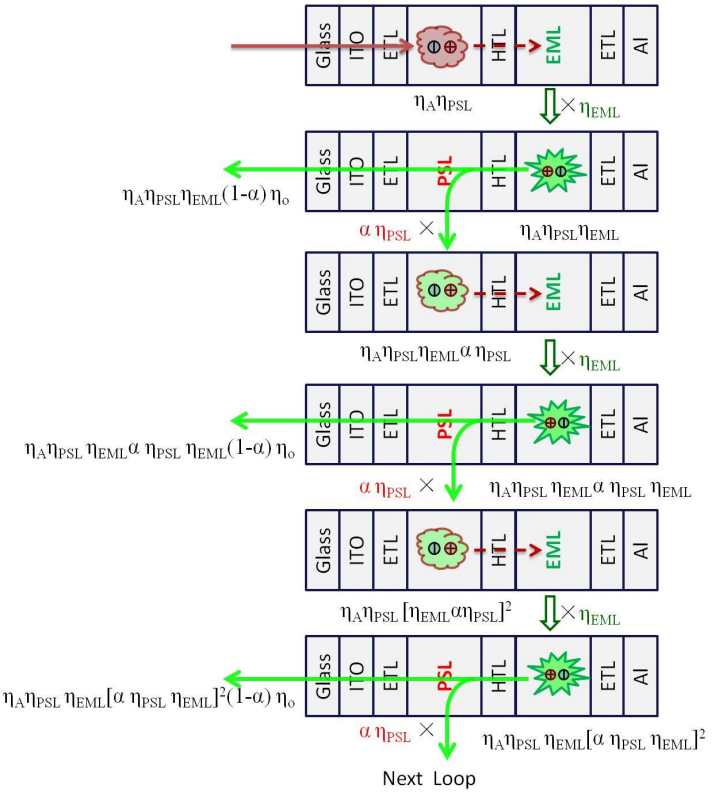

Figure S1. Working processes of the reuse of the visible light absorbed by the PSL.

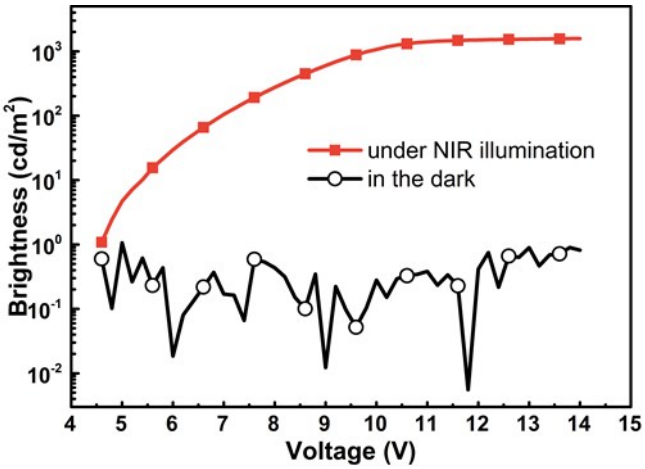

Figure S2. Voltage-brightness characteristics of T-UCD in dark and under NIR illumination.

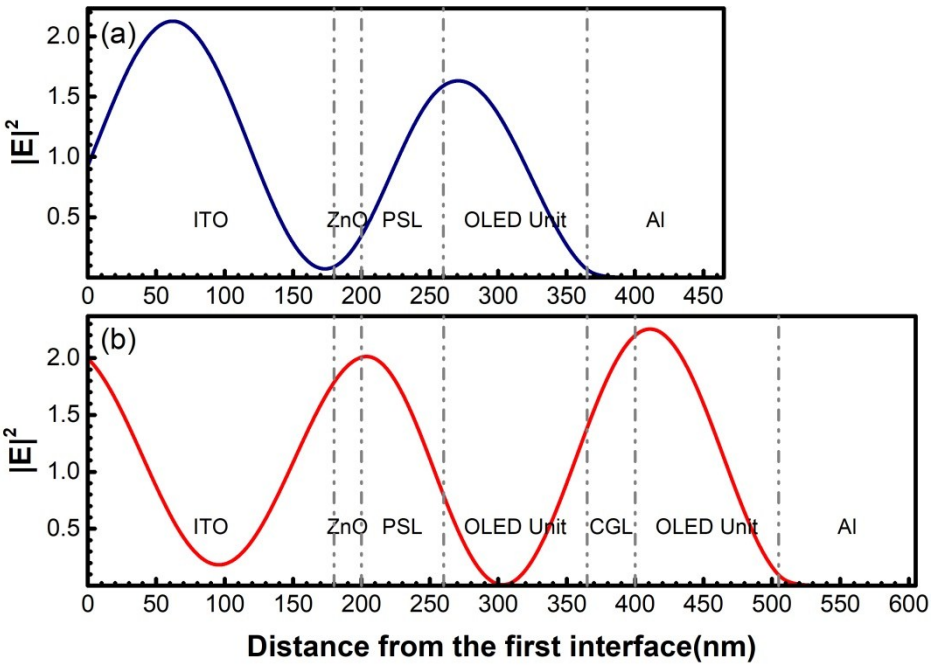

Figure S3. Calculated distribution of the normalized modulus square of optical electric field $|E|^2$ inside (a) Device B with blue solid line and (b) Device A1 with red solid line at the excitation wavelength of 800 nm. The photosensitive layer refers to PDPP3T:PCBM (60 nm). The OLED unit is the structure of TAPC(40 nm)/$Be(pp)_2$:$Ir(ppy)_2(acac)$ (10 nm, 8wt%)/$Be(pp)_2$ (55 nm)/Li_2CO_3(1 nm)/Al(1 nm). The charge generation layer (CGL) is TAPC(20 nm)/ HAT-CN(15 nm).

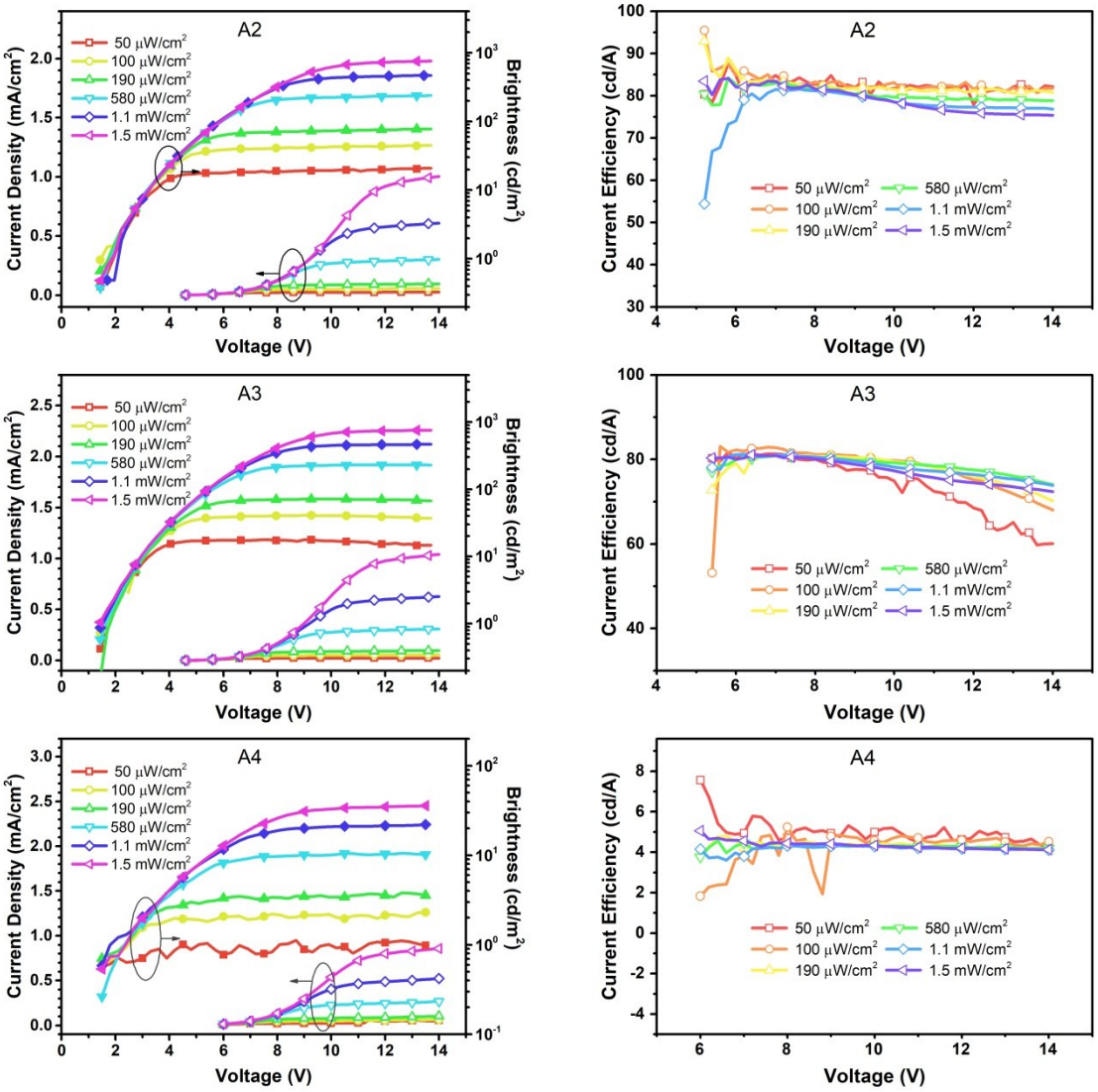

Figure S4. Current density-brightness-voltage (left) and current efficiency-voltage (right) characteristics of Device A2, A3 and A4.