Device Fabrication: The ITO glass with the resistance ≤ 15 Ω per square was cleaned by ultrasonication using detergent, water, acetone and isopropyl alcohol respectively (30 min each) and then dried in oven at 70 °C overnight. The cleaned ITO glass was treated with UV-O₃ for 15 min. Then, the ZnO precursor solution with a concentration of 0.23 M (zinc acetate dissolving in 2-methoxyethanol mixing with ethanolamine for sufficient stirring) was spin-coated onto the ITO glass at 3000 rpm for 60 s in a N₂-filled glovebox. The ZnO coated substrates were baked in air at 110 °C for 10 minutes and then annealed at 200 °C for 1 hour. For the comparison, the PEDOT:PSS (purchased from Baytron PAI 4083) was also spin-coated onto the ITO glass at 5000 rpm for 40 s. Then, the PEDOT:PSS coated substrates were baked in air at 120 °C for 10 minute. All the coated substrates were moved into the N₂-filled glovebox. P3HT (purchased from J&K Scientific Ltd.) and O-IDTBR (purchased from Derthon Optoelectronic Materials Science Technology Co. Ltd.) with a weight ratio of 100:1 was dissolved in 1,2-dichlorobenzene (o-DCB) to prepare a blended solution with a
concentration of 40 mg/mL. The thick active layers (~255 nm) were formed by spin-coating the active layer solution onto the ZnO- or PEDOT:PSS-coated substrates at 600 rpm for 25 s. Then, the active layers were dried naturally or annealed at 80 °C (20 s or 40 s) immediately. Finally, aluminum electrode (80 nm) was thermally deposited under $10^{-5}$ Pa. The active layer of all OPDs was 4 mm$^2$.

**Fig. S1** Transient response characteristics of the OPD under the 525 nm light illumination: under biases of -15 V (a) and 15 V (b). The section circled with red dashed-line shows the gradually shortened rise time of the OPD with increasing light intensity.

**Fig. S2** Normalized absorption spectrum of the active layer annealed at 80 °C for 20 s.
**Fig. S3** Normalized absorption spectrum of the ZnO interfacial layer (~40 nm).

**Fig. S4** EQE spectra of the optimized OPD based on ZnO or PEDOT:PSS under -15 V bias (a); Dashed lines in (a) show the clear variation of EQE spectral shapes, especially in the short wavelength range; *J*-*V* characteristics of the OPD based on ZnO or PEDOT:PSS under dark and light illumination at 1.5 mW/cm², respectively (b); The insert in (b) shows the corresponding *J*₀-*V* characteristics.

**References**
