Supplementary Material for: "High-speed organic light-emitting diodes based on dinaphthylperylene achieving 4-Gbps Communication"

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S1-Performance of optimized bottom-emitting DNP OLEDs and comparison with BADVBi OLED

We tested a pin-OLED structure in a bottom-emitting configuration with a transparent indium tin oxide anode. The intrinsic layers consisted of 10 nm NPB as EBL, a 15 nm EML with DCJTB doped with DNP and Alq_3 as co-host, and 10 nm Alq_3 as HBL. The intrinsic layers were sandwiched with a 35-nm layer of S-TTB p-doped with F_6-TNAP at 4 vol% as the HTL and the 50-nm n-doped ETL consisted of caesium-doped BPhen. We found that this pin-OLED structure showed good OLED performance as shown in Figure S1. At 200 mA/cm^2, the external quantum efficiency (EQE) reached 5.9% with a low driving voltage at <3.6 V. Considering the high current density, the OLED showed a long operational lifetime with LT_{80} ~500 hours. We compared the operational lifetime with BDAVBi OLEDs. The device structures of the BOE-OLEDs are similar to the DNP-OLED except the emission layer and doped layer thicknesses (see Table S1 and Figure S1 for the details and performance). The OLED based on DNP showed more than 20 times longer operational lifetime than the OLEDs based on BDAVBi with, LT_{80} <24 hours.

Table S1: Details of BOE-OLED.

Type	HTL	EML	HBL	ETL
A-BOE	35 nm	15 nm-DNP	10 nm-Alq_3	50 nm
B-BOE	35 nm	15 nm-DNP	5 nm-Alq_3	50 nm
C-BOE	35 nm	15 nm-DNP	0 nm	55 nm
BDAVBi-Alq_3	30 nm	20 nm-BDAVBi	10 nm–Alq_3	30 nm
BDAVBi-BAlq	30 nm	20 nm-BDAVBi	10 nm-BAlq	30 nm

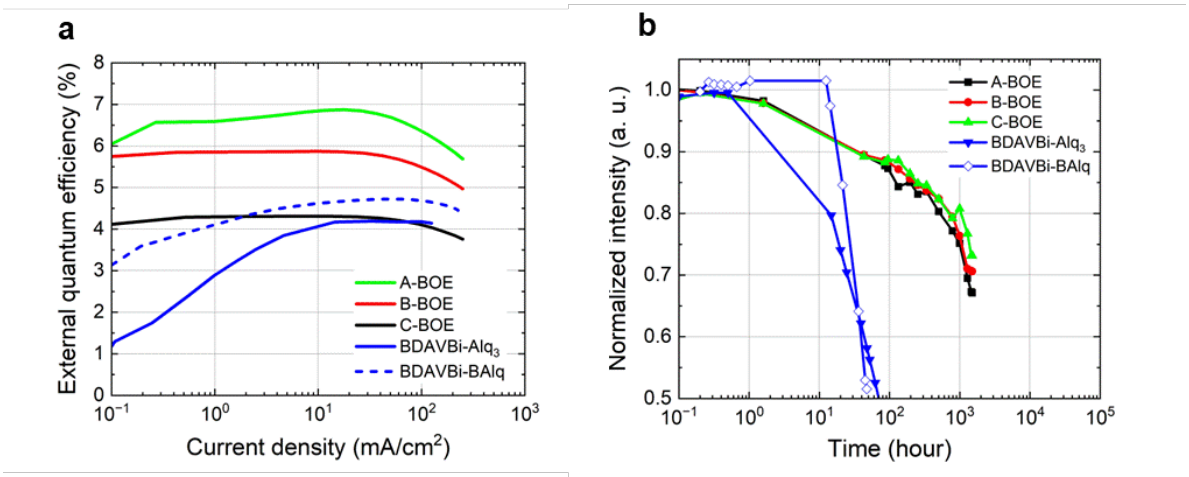

Figure S1: (a) Current density-external quantum efficiency characteristics of different bottom emitting OLEDs. (b) Evolution of EL intensity at the constant current densities of 200 mA/cm^2.

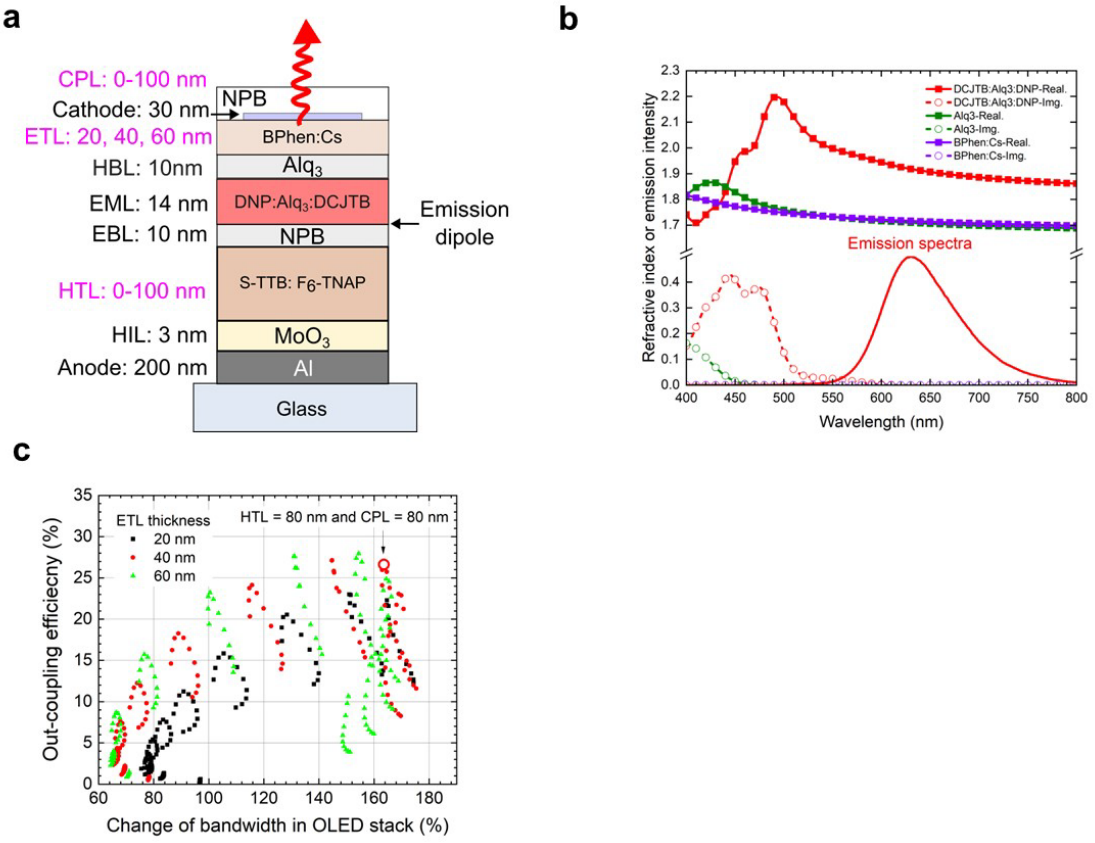

Figure S2: (a) Schematic of OLED structure used for the simulation. (b) Refractive index spectra and emission spectra of the emission layer and comparison with refractive index spectra of Alq_3 and BPhen:Cs, ETL. (c) Calculated out-coupling efficiency as a function of change of bandwidth in OLED stacks with different HTL, ETL, and CPL layer thicknesses. In part (c), an open red circle correspond to Type A-OLED.

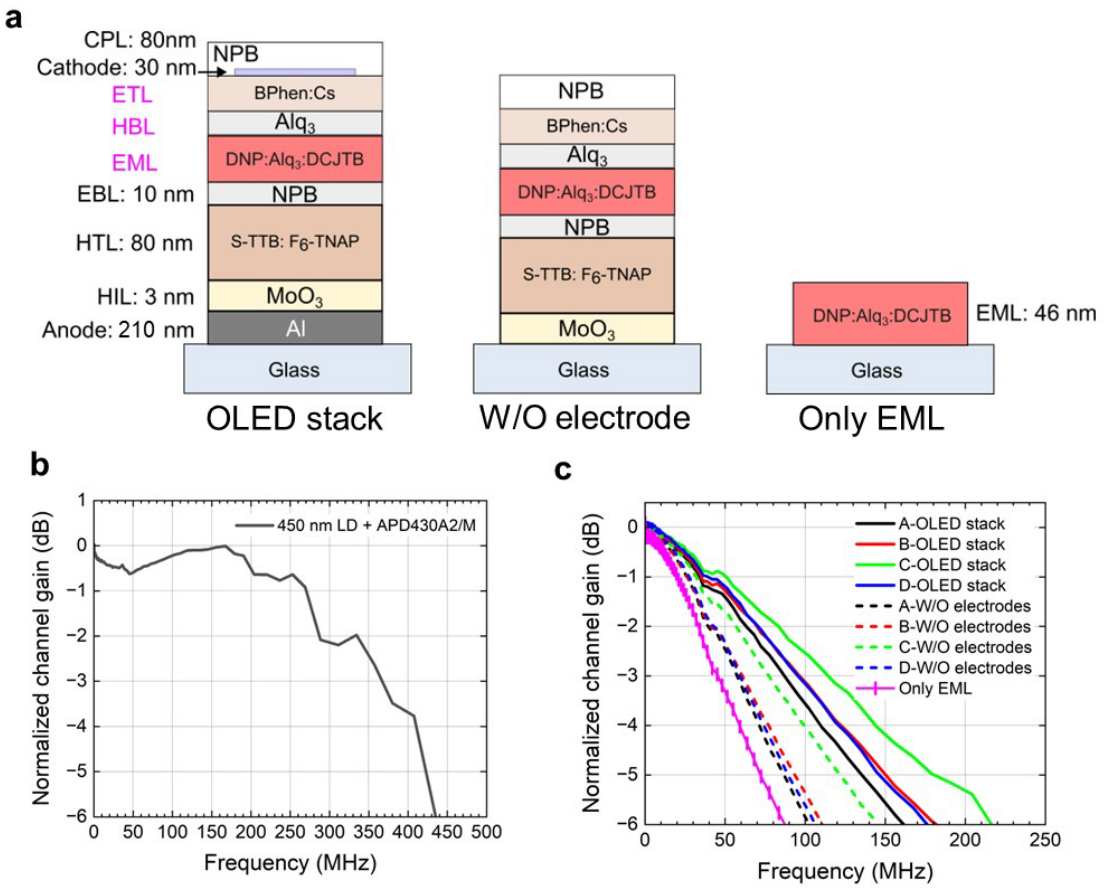

Figure S3: (a) Schematic of samples used for PL measurements. (b) Frequency response of the excitation laser. (c) Frequency response of films under optical excitation after correction for the laser frequency response.

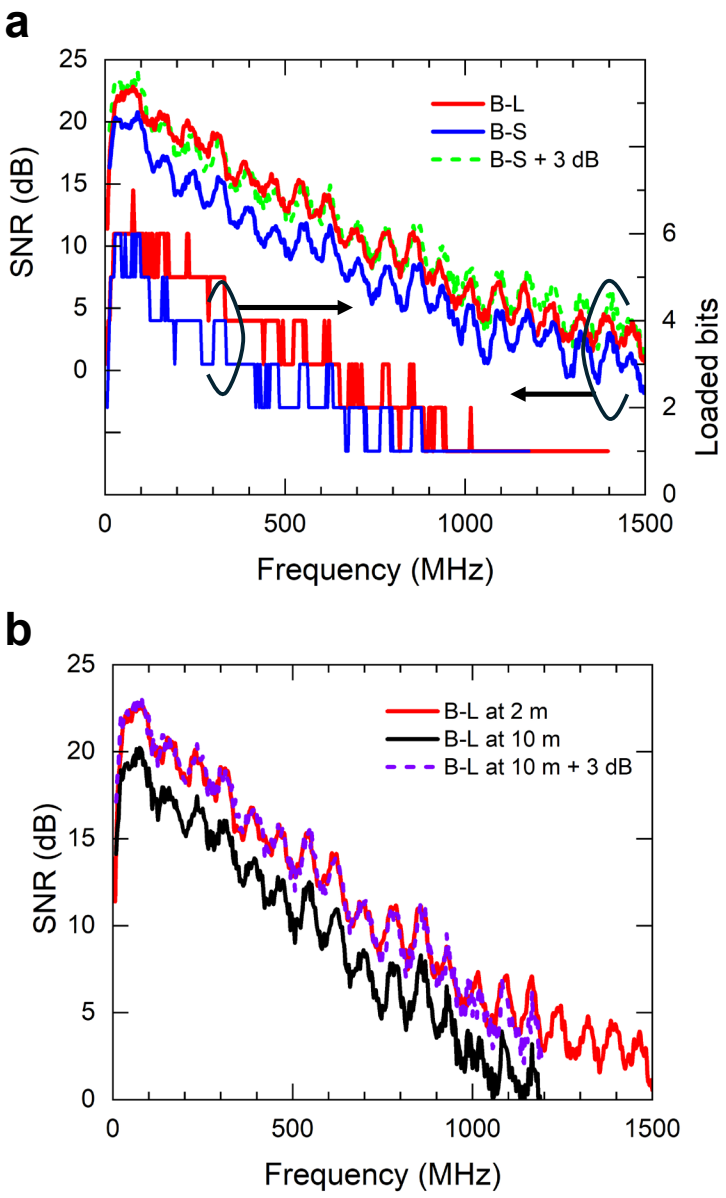

Figure S4: (a) Estimated SNR and the bit-loading with a BER of below 3.8×10^{-3} for Type-B OLEDs in a 2 m link. (b) Comparison of SNR spectra of B-L OLED at different link distances.

Table S2: Summary of data rate measurement for different samples, their averages in different data links and the peak-to-peak voltage of the OFDM signals set onto the AWG (V_{pp}). The link distance is 2 m unless noted.

Types	V_{pp}	Interpolated data rate			
		at BER of 3.8×10^{-3}		at BER of 5.54×10^{-3}	
		Each sample	Averaged	Each sample	Averaged
A-S	0.192 V	2.53 Gbps	2.6 Gbps	2.65 Gbps	2.7 Gbps
	0.192 V	2.60 Gbps		2.73 Gbps	
B-S	0.172 V	2.50 Gbps	2.6 Gbps	2.67 Gbps	2.8 Gbps
	0.172 V	2.73 Gbps		2.92 Gbps	
C-S	0.192 V	2.39 Gbps	2.4 Gbps	2.54 Gbps	2.5 Gbps
	0.192 V	2.36 Gbps		2.52 Gbps	
D-S	0.172 V	2.64 Gbps	2.7 Gbps	2.83 Gbps	2.8 Gbps
	0.172 V	2.68 Gbps		2.85 Gbps	
B-L	0.175 V	3.76 Gbps	3.8 Gbps	3.96 Gbps	4.0 Gbps
	0.172 V	3.78 Gbps		4.02 Gbps	
	0.172 V	3.86 Gbps		4.09 Gbps	
	0.172 V	3.89 Gbps		4.11 Gbps	
B-L(10 m)	0.200 V	2.79 Gbps		2.91 Gbps	
C-L	0.225 V	2.75 Gbps	3.2 Gbps	2.91 Gbps	3.4 Gbps
	0.225 V	3.14 Gbps		3.35 Gbps	
	0.175 V	3.60 Gbps		3.82 Gbps	

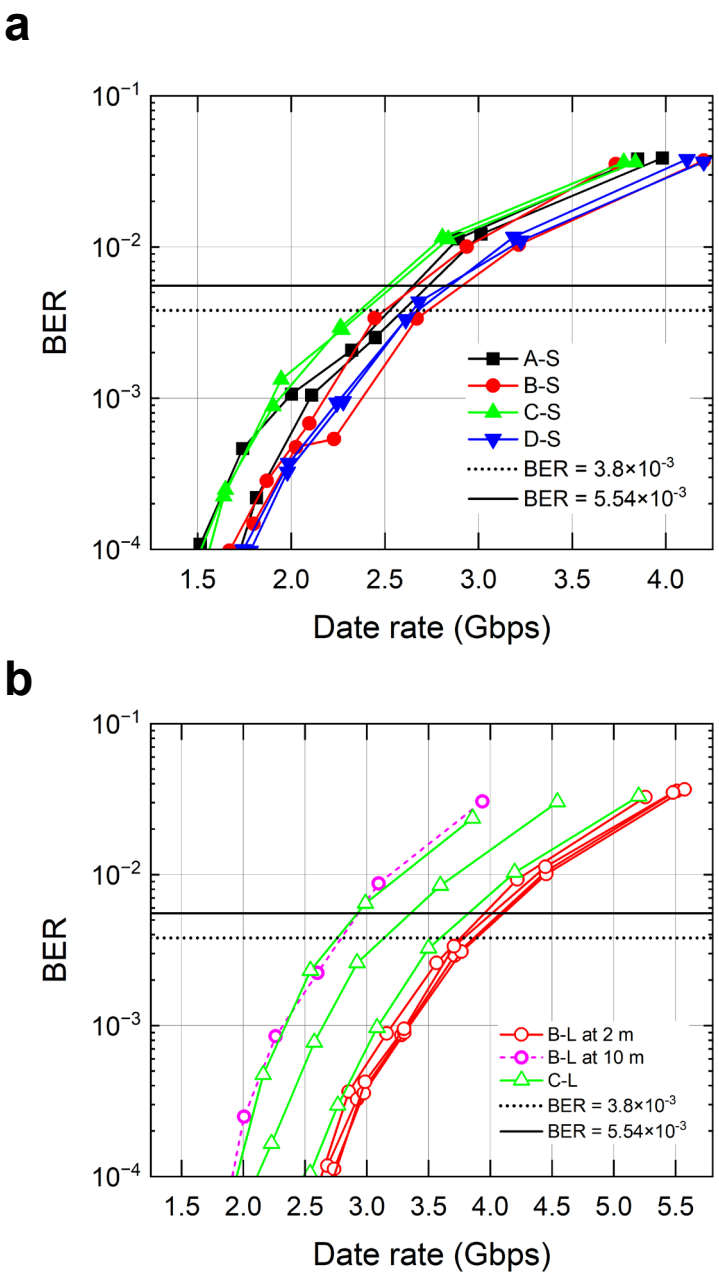

Figure S5: BER as a function of the data rate for the different types, sizes, samples, and link distances: (a) S-size and (b) L-size.

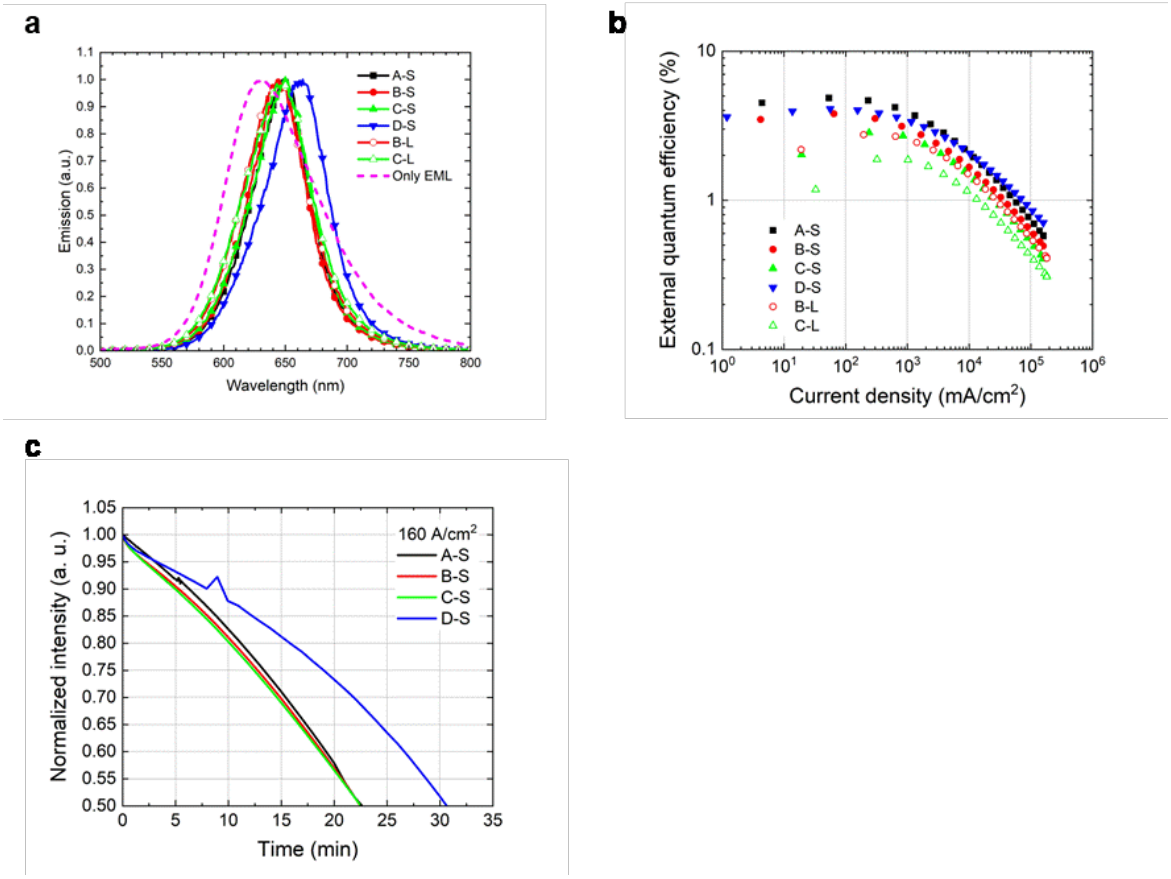

Figure S6: EL spectra. (a) EL spectra. (b) Current density-external quantum efficiency characteristics. (c) the evolution of EL intensity at the constant current densities of 160 A/cm^2.