This section is referencing my paper.[1, 2]

0.1 Motivation

0.2 Theory

0.2.1 Previous Efficiency Roll-Off Models

0.2.2 Exciton Dynamics

$$\frac{dn_{ex}}{dt} = -\frac{n_{ex}}{\tau} - \frac{1}{2}k_{TT}n_{ex}^2 - k_{TP}n_{pol}n_{ex} + G_{ex} \tag{1}$$

$$G_{ex} = \frac{k_F}{4}n_{pol}^2 \tag{2}$$

0.2.3 Polaron Dynamics

$$\frac{dn_{pol}}{dt} = \frac{-k_F}{2}n_{pol}^2 - \frac{n_{pol}}{\tau_l} + G_{pol} \tag{3}$$

0.2.4 Exciton Quenching in Photoluminescence

$$V = \left[\frac{J}{e\mu N_C}d^{2l+}\left(\frac{eN_0k_BT_t}{\epsilon}\right)^l\right]^{\frac{1}{l+1}} = CJ^{\frac{1}{l+1}} \tag{4}$$

$$n_{pol} = eN_c\left(\frac{\epsilon V}{ed^2N_0kT_t}\right)^l \tag{5}$$

¡++¿

$$\frac{L(n_{pol}}{L_0} = \frac{1}{1+\tau k_{TP}n_{pol}} \tag{6}$$

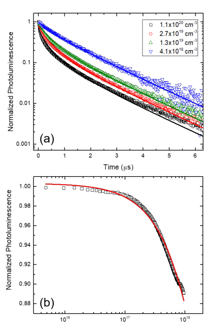

Figure 1: (a) Transient photoluminescence (PL) decays for several initial exciton densities with fits shown as solid lines using Eqn. 2. Fit parameters are discussed in SECTION. Exciton densities are calculated using measured incident power and beam size in combination iwht Beer's Law. (b) Steady-state PL quenching as a function of polaron density and the resulting fit from Eqn. 6 shown as the solid line.

0.2.5 Transient Electroluminescence

0.2.6 Efficiency Analysis

$$\eta_{EQE} = \eta_{OC}\eta_{PL}\chi\eta_{EF} \tag{7}$$

$$\eta_{EQE} = \frac{\eta_{OC}\eta_{ex}k_r}{G_{pol}/2} \tag{8}$$

$$\eta_{EF} = \frac{\frac{1}{2}k_F n_{pol}}{G_{pol}} = \frac{\frac{1}{2}k_F n_{pol}}{\frac{1}{2}k_F n_{pol} + \frac{1}{\tau_l}} \tag{9}$$

0.3 Experimental Details

0.4 Application to Devices

0.4.1 Overview of Approach

0.4.2 Initializing Parameters with Quenching Only Steady-State Model

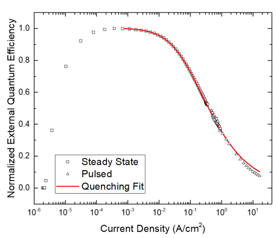

Figure 2: Normalized experimental η_{EQE} as a function of current density. Solid line is a fit to the data using Eqn. 1 and 3 in the absence of polaron loss. Pulsed η_{EQE} measurements are conducted using low duty cycle pulses to steady-state luminance to reduce Joule heating in device.

0.4.3 Transient Modeling

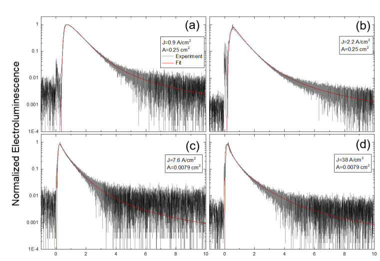

Figure 3: Transient electroluminescence (EL) for four different current densities (J) and device areas (A). (a) 0.25 cm^2 device at a current density during the pulse of J = 0.9 A/cm^2 (b) 0.25 cm2 device at J = 2.2 A/cm^2 (c) 0.0079 cm^2 device at J = 7.6 A/cm^2 (d) 0.0079 cm^2 device at J = 38 A/cm^2

Table 1: Fit parameter extracted from transient and steady-state electroluminescence. Transient EL fit parameters averaged over all measured current densities. η_{EQE} Roll-off parameters averaged over several measured devices. Triplet-triplet annihilation and triplet-polaron quenching rates are fixed to those obtained from fitting the normalized efficiency roll-off.

	Transient EL	Efficiency Roll-off
$\tau\ (s)$	$6.9 \pm 0.1 \times 10^{-7}$	6.1×10^{-7}
$k_{tt}\ (cm^3/s)$	7.1×10^{-12}	7.1×10^{-12}
$k_{tp}\ (cm^3/s)$	3.3×10^{-13}	3.3×10^{-13}
$k_F\ (cm^3/s)$	$7.7 \pm 3.5 \times 10^{-12}$	1.6×10^{-11}

0.4.4 Term Efficiency During Transient

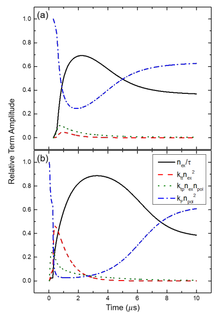

Figure 4: Term efficiency for each dynamical process influencing the exciton population for (a) 0.25 cm^2 device operated at 0.9 A/cm^2 for 500 ns and (b) 0.785 mm^2 device operated at a current density of 38 A/cm^2 for 250 ns. Relative term amplitude is calculated as the magnitude of each term in Eqn. 1 divided by the sum of absolute values of each term.

0.4.5 Extracting Exciton Formation Efficiency

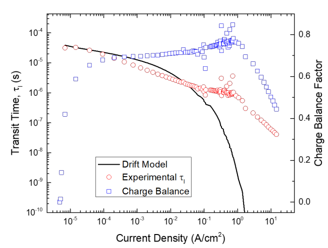

Figure 5: Transit time extracted from η_{EQE} measurements are shown as the red circles. Predictions using the drift model are calculated using Eqn. 10. The drift model assumes a uniform electric field. Good agreement between the experimental transit time and the drift model is found for a field distributed over 20 nm. The charge balance factor is shown as a function of current density in blue squares.

0.4.6 Drift Model

$$\tau_l = \frac{w}{E\mu(E)} \tag{10}$$

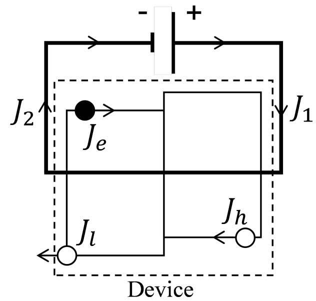

Figure 6: Current density formalism within the circuit. and are the currents measured on either side of the device. and are the electron and hole currents within the device and is the unbalanced current, assumed to be only holes, that leaks out of the opposing contact.

0.5 Understanding Assumptions of Polaron Model

References

[1] Hershey, K. W., and Holmes, R. J. Unified analysis of transient and steady-state electrophosphorescence using exciton and polaron dynamics modeling. *Journal of Applied Physics 120*, 19 (2016), 195501.

[2] Hershey, K. W., Suddard-Bangsund, J., Qian, G., and Holmes, R. J. Decoupling degradation in exciton formation and recombination during lifetime testing of organic light-emitting devices. *Applied Physics Letters 111*, 11 (2017), 113301.

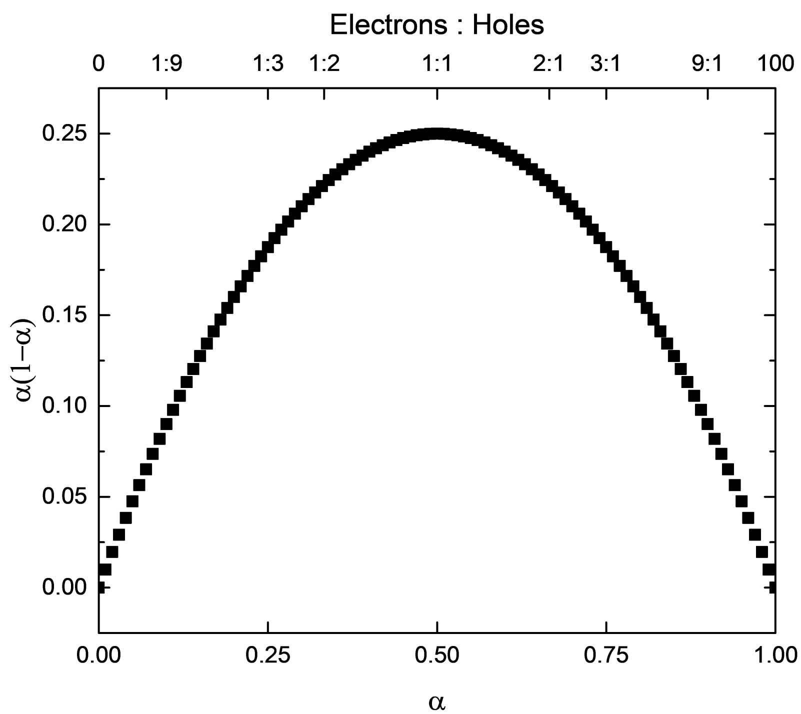

Figure 7: The quantity is plotted as a function of the polaron composition, and the electron to hole ratio.