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A simple method for measuring OLEDs efficiency

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External quantum efficiency (EQE) of organic light emitting diodes (OLEDs) is among the most important parameters for devices assessment and for comparing OLEDs performance. The EQE is the ratio of the total number of photons emitted by the OLED in all directions to the number of electrons injected.

The key point is to measure the total optical power P_{TOTAL} emitted by the OLED in the half space (i.e. waveguided light is not considered), taking into account that an LED is a polychromatic light source with a certain spatial emission pattern. To measure P_{TOTAL} a large area calibrated Si photodiode (PD) of known responsivity (W/A) placed in contact with the OLED surface can be used [1]. This requires the measurement of the PD photocurrent, together with the OLED emission spectrum to calculate the "equivalent" responsivity of the PD. The luminous efficiency (cd/A) and luminous power efficiency (lm/W) can be calculated using the photopic visibility curve and the OLED emission spectrum [2]. A calibrated Si PD is meant to be used for normal incidence of the light beam to be measured. The reflectance of the PD glass window increases for obliquely incident rays and with the PD placed in contact with the OLED surface [1] one measures an emitted optical power that is less than P_{TOTAL} but more than the power emitted by the OLED in the normal direction.

Here we present a simple geometrical modification of this method, where the PD with radius r_{PD} is placed on axis at a distance d_{PD} from the OLED with radius r_{OLED}, as shown in Fig. 1, where a radial symmetry is assumed. If $d_{PD} >> (r_{PD}\ , r_{OLED}\ )$, the PD "sees" the OLED as a point source and, taking into account the OLED spatial emission pattern I(θ), the power P_{PD} impinging on the PD area is simply related to P_{TOTAL} by:

$$f = \frac{P_{PD}}{P_{TOTAL}} = \frac{\int_0^{\theta_{PD}} I(\theta)d\theta}{\int_0^{\pi/2} I(\theta)d\theta} = \sin^2\left(arctg\,\frac{r_{PD}}{d_{PD}}\right) \tag{1}$$

where the last equality holds for a Lambertian source $I(\theta)=I_0\cos\theta$. This is a good approximation for a bilayer AlQ3 based OLED with negligible microcavity effects [3]. If the radiation pattern I(θ) is measured in advance the method can be extended to any LED source. To assess the minimum distance d_{DP} for the method validity, we measured P_{PD} vs. voltage for a 3 mm^2 AlQ3-based OLED using a calibrated Si PD (NEWPORT 808-UV with 100 mm^2 area, i.e. r_{PD} = 5.6 mm) varying d_{PD} from 6 cm to 12 cm, as shown in Fig. 2. P_{TOTAL} calculated using the correction factors f given by (1) and the corresponding luminance vs. voltage are shown in Fig. 3 including d_{DP}=0 cm i.e. the PD placed in contact with the OLED surface. Independently from d_{PD}, it can be noticed that P_{TOTAL} values are the same. As expected, with the PD placed in contact with the OLED surface the measured power is about 18% less than P_{TOTAL} above.

References

[1] S. R. Forrest et al., "Measuring the Efficiency of Organic Light-Emitting Devices", Advanced Materials, vol.15, n.13, 2003, pp. 1043-1048

[2] E. F. Zawleski, "Radiometry and photometry", Chapter 24 in Handbook of Optics vol. 2, McGraw-Hill, 1994

[3] H. J. Peng et al., "Design and Characterization of Organic Light Emitting Diodes with Microcavity Structure", SID Symposium Digest of Technical Papers, vol.34, 2003, pp. 516-519

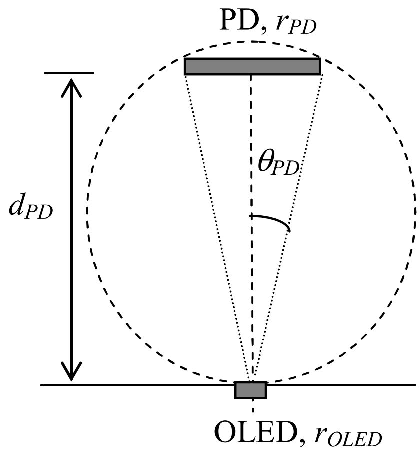

Fig. 1: Geometry of the measurement set-up.

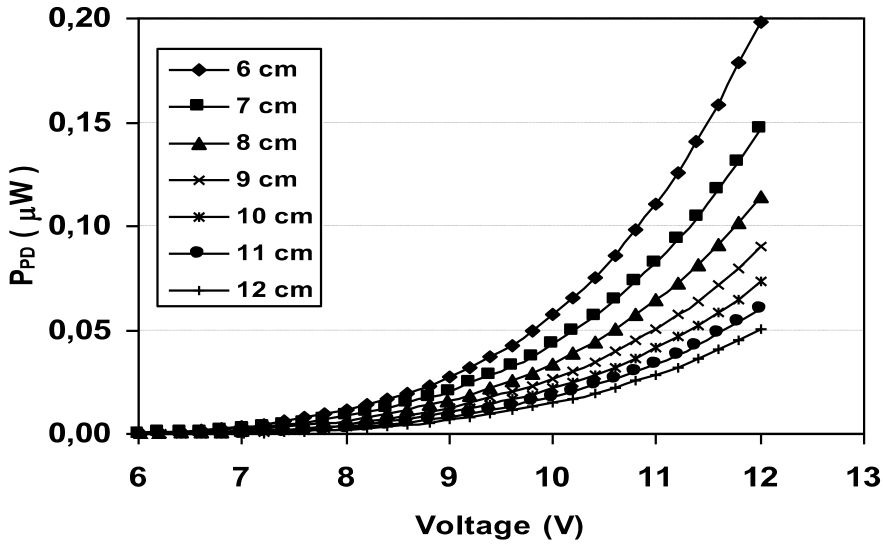

Fig. 2: P_{PD} vs. voltage with variable d_{PD}.

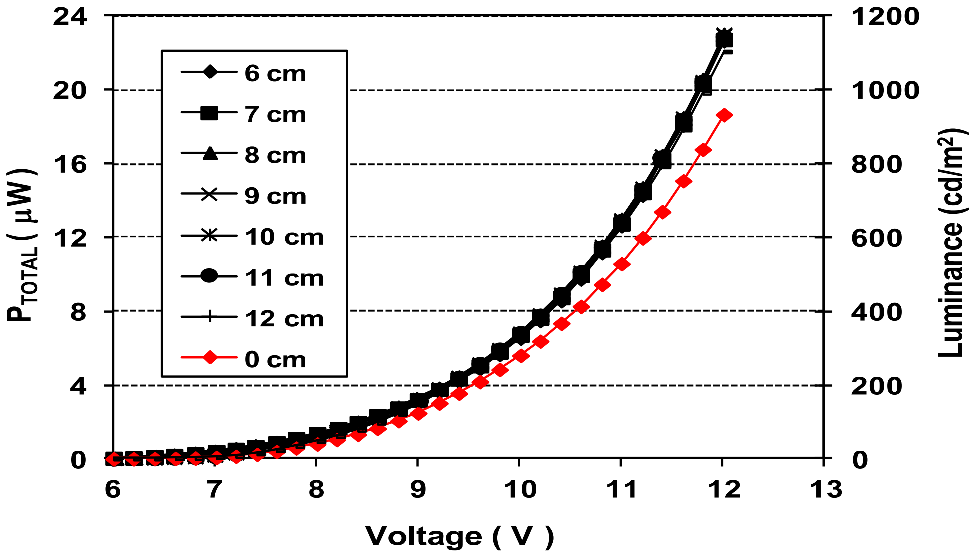

Fig. 3: P_{TOTAL}, calculated using the correction factor f, and the corresponding luminance vs. voltage with variable d_{PD}, including d_{PD}=0 cm.