Mixed-order distributed feed-back organic diode laser cavities: from the design to the characterization

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Keywords: Organic semiconductors, OLEDs, Organic laser diodes, Cavities, DFB, E-beam lithography

In the field of organic optoelectronics several devices have been demonstrated like organic light emitting diode (OLED), organic photovoltaic (OPV) and organic photodetector (OPD). The only device still to be demonstrated unambiguously is the organic laser diode (OLD) which would constitute a disruptive alternative to conventional laser diodes, anticipating a credible and original low-tech organic photonic platform.

The demonstration of the OLD requires the integration of a high-quality factor micro-cavity into an organic hetero-structure sandwiched between electrodes. From the literature, the cavity type offering the lowest laser threshold under optical pumping is the mixed-order distributed feed-back (DFB) [1]. This type of cavity consists of first-order gratings separated by a second-order grating; The first-order gratings act as mirrors providing the confinement of light and the second-order grating allows the coupling of the light perpendicular to the cavity. Recently, the same type of cavity has been implemented by Adachi's group that reported indication of lasing with a threshold as low as 0.5kA/cm² [2]. Several aspects of this work need to be explored further and confirmed; for example, little is said about the cavity, its quality factor, and how the precise matching of its resonance frequency with the peak of electroluminescence of the gain material is obtained despite uncertainties on the indices and on the width of the lines due to e-beam resolution.

In the current study, we present the design of the DFB micro-cavity, the fabrication process optimization procedure and the characterization under optical pumping. To design high-quality factor mixed-order DFB micro-cavities, we assimilate the quasi periodic gratings to half and quarter-wavelength multilayered system and used the matrix transfer method to calculate the reflectances and the Helmholtz equation to quantify the effective indices of the high and low indices.

The fabrication of DFB micro-cavities uses electronic lithography (E-beam), to pattern a 300nm thick HSQ resist (low-index) layer into quarter-wavelength lines separated by high-index quarter-wavelength lines later to be filled with organic semiconductors. To optimize the e-beam lithography process of the DFB cavity fabrication, we first study the impact of the charge quantity per area (dose) and the development time on the grating lines width.

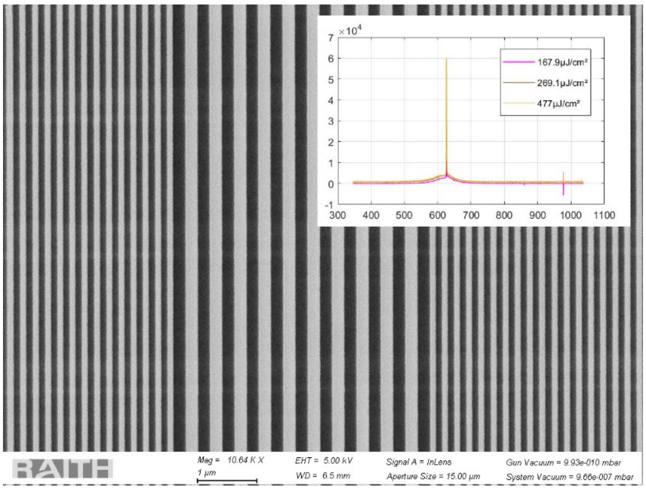

Figure 1: SEM view of a mixed order DFB microcavity. Inset shows lasing emission under optical pumping

Finally, the matching of the DFB resonance with the electroluminescence peak wavelength is validated under optical pumping before the integration of the DFB microcavity in an OLED. We fabricated a matrix of micro-cavities made from different doses and different grating periods to identify those that allow laser emission. We also present the S curve showing the light output of the device versus the pump intensity which is one of the signatures of lasing.

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