Organic Light Sources for Polymeric Singlemode and Multimode Waveguides

Marko Čehovski*, Sebastian Döring*, Torsten Rabe*, Reinhard Caspary*, Wolfgang Kowalsky*
*Institut für Hochfrequenztechnik, Technische Universität Braunschweig, 38106 Braunschweig, Germany
mailto:marko.cehovski@ihf.tu-bs.de

Thin film devices like organic light emitting diodes (OLED) and organic photovoltaics or organic photodiodes (OPV or OPD) are more and more commercially used. Moreover, new fields of applications are signal sources and sinks in integrated flexible polymeric waveguide (PW) and sensor systems. Additionally, coherent light sources, such as organic thin film laser (OLAS), become more and more important in the field of sensor technology. Therefore, special optical requirements are placed on the integration of these elements into such systems.
In this paper we want to discuss the fundamental integration concepts of coherent and non-coherent signal sources into polymeric multimode and singlemode waveguides. By varying the layer thickness of each functional OLED layer forming a microcavity, light coupling efficiencies η_{PW} from the OLED into the PW of up to 50 % could be measured. We also demonstrate the OLAS integration via distributed feedback (DFB) Bragg gratings and also a Fabry-Pérot resonator concepts leading to laser thresholds of about $\approx 10\,\mu\text{J/cm}^2$. These results outline the OLED and OLAS integration into polymeric waveguides and emphasize the necessity of further investigations.

1 Introduction

Organic light sources like the OLED and OLAS offer the opportunity to integrate ultra thin and flexible optical devices into transparent polymeric waveguide systems like in Lab-on-Chip or Lab-on-Foil applications [1]. Figure 1 shows the first integration of OLEDs and OPDs (organic photodetector) onto a flexible polymeric waveguide foil.

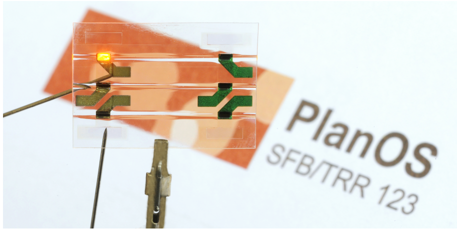

Fig. 1 *Integration of OLEDs and OPDs onto a waveguide foil towards Lab-on-Foil applications.*

For this purpose, an efficient light coupling between the organic light source and the waveguide is important (see Fig. 2).

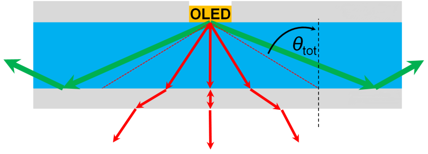

Fig. 2 *Schematic illustration of the OLED integration onto a waveguide maximizing the optical power in the waveguide (green arrows).*

In case of the OLED, this can be achieved with additional coupling elements like diffraction gratings. An alternative approach is to adjust the OLED radiation pattern. Concerning the OLAS, typically DFB Bragg gratings are used.

2 OLED integration

As the OLED is a plane emitter and follows the Lambert's cosine law a direct integration onto a multimode waveguide would lead to an inefficient light coupling into the waveguide. Therefore, adjusting the OLED radiation pattern towards an increased emission to higher exit angles leads to an increased light coupling to waveguide modes (cf. Fig. 2 and 3).

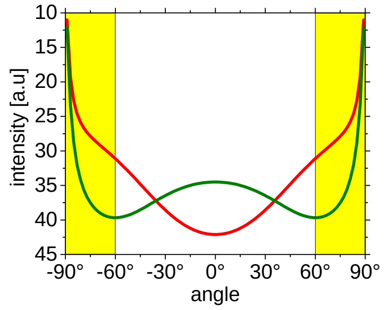

Fig. 3 *OLED radiation pattern; normal (red) and adjusted (green) for an increased light coupling into waveguide modes.*

This radiation pattern can be achieved by varying the thicknesses of the OLED layers forming a microcavity [2]. Thus, the angle of total reflection can be overcome and the amount of light which is coupled into a polymer waveguide increases. To verify this characteristic six OLED-Stacks have been

DGaO Proceedings 2016 - http://www.dgao-proceedings.de - ISSN: 1614-8436 - urn:nbn:de:0287-2016-A019-0
submitted: 15.Jul.2016 - published: 5.Aug.2016

defined and processed onto a glass substrate and onto a polymeric film waveguide. The optical output power of these devices was then measured in an integrating sphere. Figure 4 shows the result of these measurements. The light coupling efficiency of the OLEDs into the waveguide can be estimated up to 50% in case of the OLED with stack 2. This is a remarkable result regarding that substrate modes in conventional OLED on glass substrates amount 20 - 30% [3]. Therefore, forming a microcavity and adjusting die OLED radiation pattern (see Fig. 3) is an easy and efficient way to increase light coupling into a polymer waveguide.

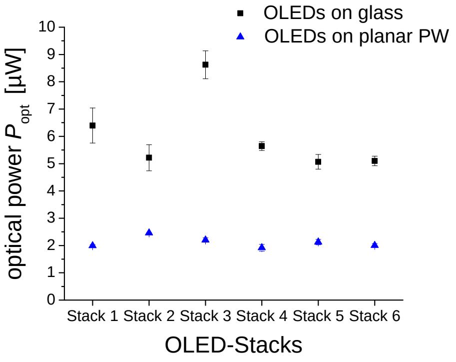

Fig. 4 *Optical power out of the OLEDs onto glass and onto a polymeric film waveguide.*

But we also have to note, that every change in an OLED stack leads to a different OLED performance, respectively there is a discrepancy between electrical and optical optimum in an OLED.

3 OLAS integration

Organic lasers, as well as all other lasers, need three essential elements: a pump source, an active gain material and a resonator. However, the resonator appears to be the key elements concerning OLAS integration into polymeric waveguides (see Fig. 5). In this context first integration concepts have been done to verify the possibility of OLAS integration.

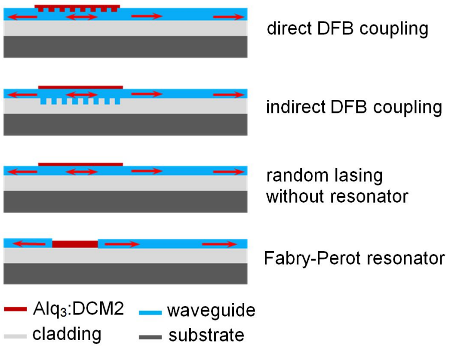

Fig. 5 *Possible OLAS integration into polymeric waveguide.*

Figure 6 depicts the laser threshold and the spectra of the OLAS with DFB Bragg gratings in the cladding material. The used active material was a guest-host system consisting of Tris-(8-hydroxyquinoline)aluminum as the host and 4-(Dicyanomethylene)-2-methyl-6-julolidyl-9-enyl-4H-pyran as the guest material (Alq_3:DCM2, 5%). This material system is very suitable for lasing applications because of its high optical gain [4]. The laser threshold is about 30 µJ/cm^2. This relatively high excitation density can be addressed to the DFB coupling in the cladding with the evanescent field of the laser. Active organic gain material applied directly on DFB Bragg gratings show laser thresholds around 3 µJ/cm^2.

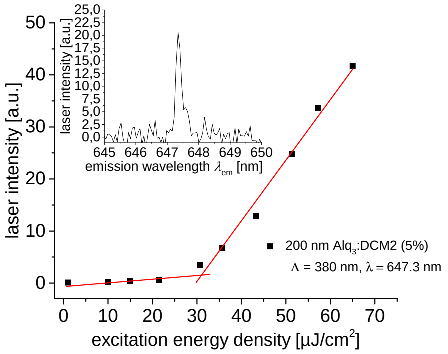

Fig. 6 *Laser threshold of the OLAS integrated in PW with DFB gratings in the cladding material (indirect coupling).*

Moreover, a Fabry-Pérot resonator system can be build up by using the waveguide facets and the active organic material in between. Thereby, the stability of the resonator as well as the quality of the laser are part of further investigation. This system is currently under development and will be presented on the next DGaO conference.

4 Acknowledgments

The authors thank the German Research Foundation DFG for funding this work within the SFB/TRR 123 PlanOS project.

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