PUMP SIZE DEPENDENCE OF ORGANIC SECOND-ORDER DISTRIBUTED FEEDBACK LASERS

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Abstract

Organic solid-state lasers (OSLs) have been widely investigated due to the advantages of easy processability, chemical versatility, wavelength tuneability and low cost offered by organic materials [1,2]. Among the various types of OSLs reported in the literature, distributed feedback (DFB) lasers have been particularly successful [1,2], since they present several advantages, such as easy deposition of the organic film, low thresholds, single mode emission and no need of mirrors. So, today they are being used to developed applications in the fields of telecommunications [2], biosensing and chemical sensing [3,4]. Among the methods generally used for grating engraving, nanoimprint lithography (NIL) [5] is one of the most promising technologies, even for future industrial applications, due to its high throughput, high resolution (sub-10 nm) and low cost. From the materials point of view, a wide variety of materials has been used to fabricate the active layers of organic DFBs [1]. Among them, in the last years our group has focused in polystyrene (PS) films doped with perylenediimide derivatives (PDIs), mainly due to their excellent thermal and photostability properties, as well as their high photoluminescence quantum efficiencies. We recently reported [6] low-threshold and highly photostable (under ambient conditions) DFB lasers. In these DFB lasers, DFB gratings were fabricated by thermal-NIL on a resist, then transferred to the SiO_2 substrate and finally, the active medium was spin-coated over the gratings.

Threshold and operational lifetime of the DFB laser devices are influenced by the excitation area, so in this presentation we report on the influence of the excitation area on both the threshold and operational lifetime of 1D second-order DFB lasers based on PS films doped with the N,N'-di-(1-hexylheptyl) perylene-3,4:9,10-tetracarboxylic diimide (PDI-C6) as active material [7]. The DFB gratings with depths of 120 nm and 400 nm were fabricated by NIL as mentioned before, and a film of 600 nm thickness active medium was spin-coated over the gratings. The shape of the excitation area was elliptical (Figure 1) and its size was varied from 0.008 to 2.9 mm^2. The laser thresholds of the DFB devices were measured and expressed as energy per pulse, energy density and power density (Figure 2). Effectiveness of reducing the thresholds, when expressed in energy per pulse units, by reducing the area of the excitation beam over the sample was proved (Figure 2a). However, the functionality of data obtained with small excitation areas couldn't be properly determined from this figure. So, the threshold was expressed as energy or power density (Figure 2b). In this case, increase of threshold was observed for excitation areas below a certain area, denoted as critical area (A_{crit}) (~ 0.1 mm^2 in this work). With respect to the operational lifetime, when excitation was performed with spot areas larger than A_{crit}, similar lifetimes (around 300 min) were obtained. On the other hand, as can be seen in Figure 3, when very small areas (below A_{crit}) were used, lifetimes became drastically reduced (lifetimes of only 15 min for excitation areas of 0.08×10^{-3} cm^2).

Acknowledgements

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References

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Figures

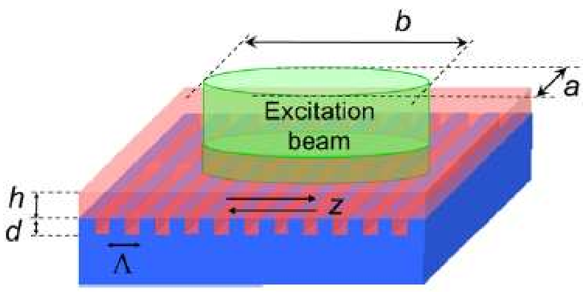

Figure 1. Sketch of the excitation geometry.

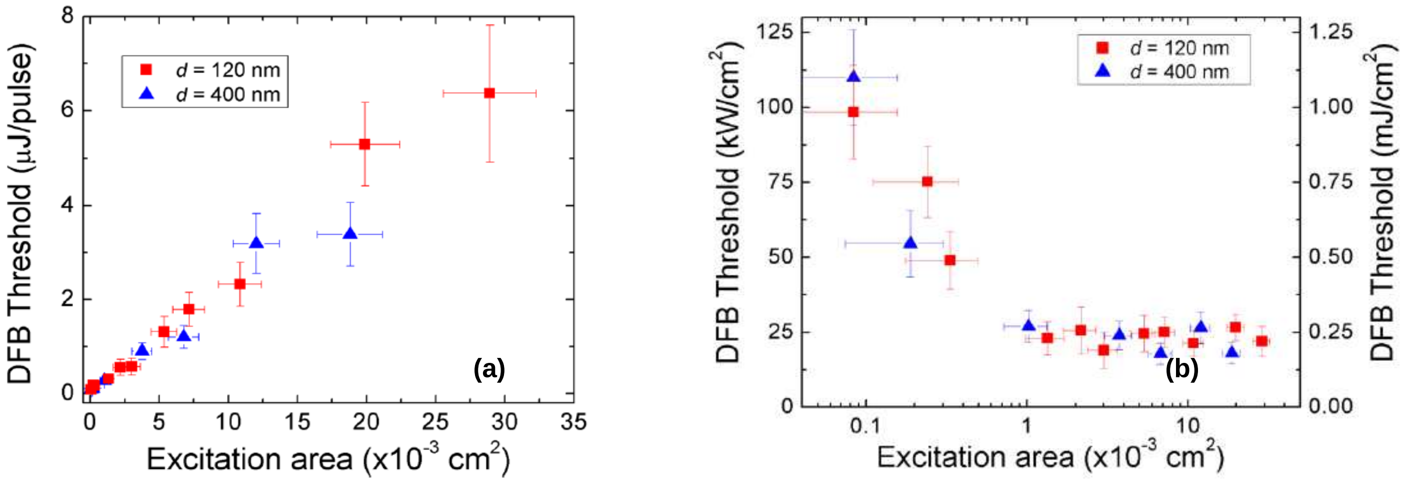

Figure 2. Laser thresholds for DFB devices with two grating depths (d = 120 nm and d = 400 nm) as a function of the excitation area over the sample expressed as a) energy per pulse, and b) energy density (right axis) and power density (left axis).

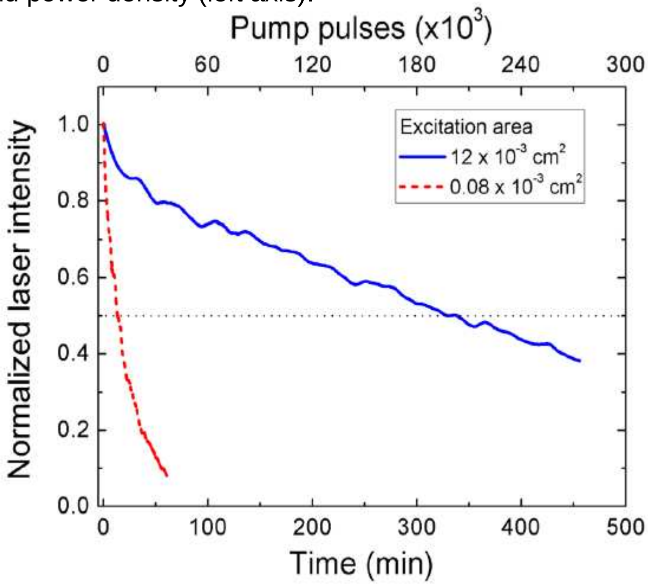

Figure 3. Normalized laser intensity versus irradiation time (bottom axis) and versus the number of pump pulses (10 ns, 10 Hz; top axis) for a DFB device with d = 400 nm, under excitation with areas below and above A_{crit} ~ 1 × 10^{-3} cm^2, at pump power densities two times above the corresponding thresholds (215 and 47 kW/cm^2, respectively).