# Sub-wavelength Structures for Organic Lasers

Basic Technology Research Programme

RESEARCH COUNCILS UK

*A 1000 micro-emitters per square millimetre*

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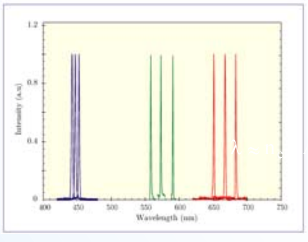
## Introduction

Since the discovery of electroluminescence from organic polymers there have been a considerable number of demonstrations of optically pumped organic lasing, with a view to developing electrically driven devices. Indeed the optical environment of these devices will play a crucial role in their operation. This presentation outlines some of the ways in which the sub-wavelength structure of devices impacts on their lasing performance.

## Polymer DFB lasers across the visible spectrum




- Optically pumped DFB lasers using 1-D gratings.
- $\Lambda$ = 250, 290, 350, 375 and 410nm, depth ~100nm, fill-factor 40-50%.

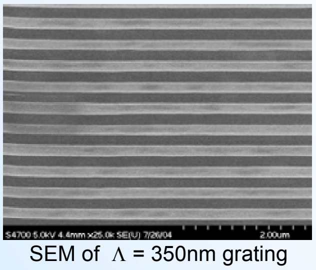
Blue $\rightarrow$ PFO, BP156

Green $\rightarrow$ F8BT

Red $\rightarrow$ Red F

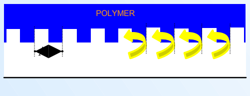
Grating parameters and/or polymer thickness provide lasing $\lambda$.

## 1D-DFB resonators for polymer emitters



SEM of $\Lambda$ = 350nm grating

- Surface Emitting 2nd Order DFB.
- Polymer indices lie between 1.6 ~ 2.
  - ↳ To span visible spectrum requires $\Lambda$ from 250 – 420nm.

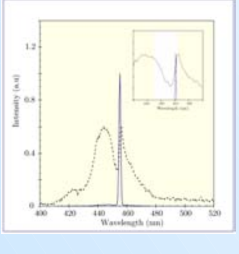


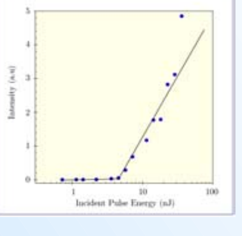

$\lambda \approx n_{eff} \Lambda$

Series of gratings

- $\Lambda$ from 250 - 420 nm
- Depth 40-120 nm
- Fill-factors 25-50%
- 1x1 mm² and 2x2 mm² size

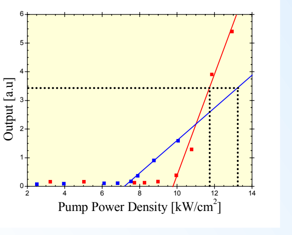
## Blue lasers: based on Polyfluorene (PFO)

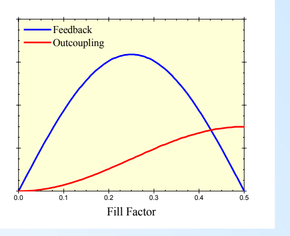


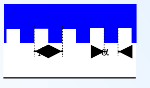

- $\Lambda$ = 290nm, polymer thickness ~100nm
- Bragg feature clearly visible, lasing near the band-edge
- $\lambda$ = 449nm $E_{th}$ = 3.9nJ/pulse (10ns) or 3$\mu$J/cm²
  slope efficiency ~ 2-3%, linewidth < 0.8nm.

## Influence of Fill Factor



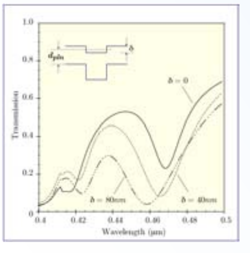



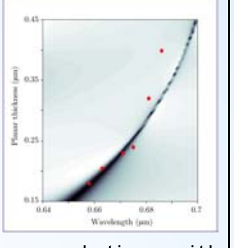

Reduce $E_{th}$ at the expense of slope efficiency when $0.25 \leq \alpha/\Lambda < 0.5$.



This is explained by the dependence of feedback and out-coupling on Fill Factor.

## Comparing Modelling with Experiment



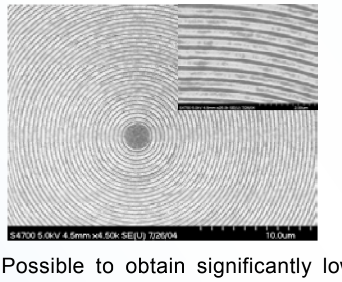



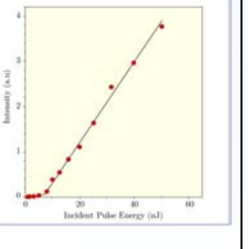

Red emitting laser structures using Red F polymer, thicknesses 180-400nm.

$\Lambda$ = 410nm, grating depth~100nm lasing over $\Delta\lambda$~30nm, $E_{th}$ ~ 20-180nJ, efficiencies ~1-3%.

Good correlation with experiment. (No attempt to fit, cf. Fixed modulation 60nm assumed for all thicknesses.)

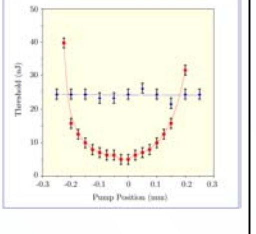
## 1D and CG-DFB Comparisons






Possible to obtain significantly lower lasing threshold (~8nJ) when using circular grating (cf. 25nJ for similar 1D grating).

- CG-DFB performance <u>is</u> dependent on the excitation position.
- Good centre pumping required for accurate performance measure




Probe the excitation position (pump spot ~50$\mu$m) and monitor threshold $\Rightarrow$

Suggestive of lasing from quasi 1-D gratings

Other studies (not shown here) include

- spatially examined polarization of laser radiation
- near field images of laser emission