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Near infra-red liquid crystal lasers

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1. Introduction

The self-organising photonic band gap structure of dye-doped chiral nematics gives rise to highly efficient optically pumped liquid crystal (LC) laser devices, with mirror-free cavities only a few microns across. Furthermore, their simple construction makes the concept of cheap, versatile (and possibly disposable) tunable laser devices a genuine possibility.

So far, due to the relative abundance of commercially available laser dyes and their ease of dissolving in LC hosts, research has focussed upon LC lasers emitting in only the visible part of the spectrum [1, 2]. Whilst these systems have great potential in many fields, there are also many other applications that require simple, compact, tunable lasers operating in the near infra-red region. The successful demonstration of such a device would facilitate the application of LC lasers to areas such as optical telecommunications, non-invasive medical treatments, and sub-dermal imaging techniques such as Optical Coherence Tomography.

In this paper a wide range of commercially available organic infra-red dyes are canvassed, including indoles, benzoxazoles, benzothiazoles and rhodamines. Their solubility, absorbance and fluorescence properties are determined, and their suitability for band-edge LC lasing assessed.

2. Absorbance and fluorescence of dye-doped nematic mixtures

Eleven different commercially available dyes (Exciton) were tested. By using a technique of thermally assisted sonication, seven of these were found to be soluble in the nematic LC BL093 (Merck). The remaining four (ionic) dyes were found to be insoluble in the (non-ionic) LC, even with additional solvent assistance, and were thus considered unsuitable for LC lasing applications in their current form.

A discussion of the solubility of the dyes in LC is presented, considering chemical structure and including also calculations of the dyes' dipole moments. Conclusions of this theoretical analysis support the experimental results to solubility.

Absorbance measurements of all the soluble dye/nematic LC mixtures were, enabling optimal wavelengths for optical pumping to be identified. Polarisation dependency of the absorbance data determined that all soluble samples had a positive order parameter, indicating that chiral versions of these would have a preference for lasing at the long band-edge of their photonic band gap.

Fluorescence measurements identified the possible range of lasing wavelengths for each dye. By adding an appropriate quantity of the chiral dopant BDH1305 (Merck), the pitch of the resulting dye-doped chiral nematic could be tailored to match the fluorescence maximum of each dye.

3. Lasing of dye-doped chiral nematic mixtures

Three of the LC/dye mixtures (HITC perchlorate, DOTC perchlorate and Rhodamine 800) successfully achieved lasing when pumped at a suitable wavelength from a tunable pulsed laser source. Emission wavelengths were arbitrarily selectable (with choice of dye and chiral dopant concentration) over the range of 800 to 850 nm.

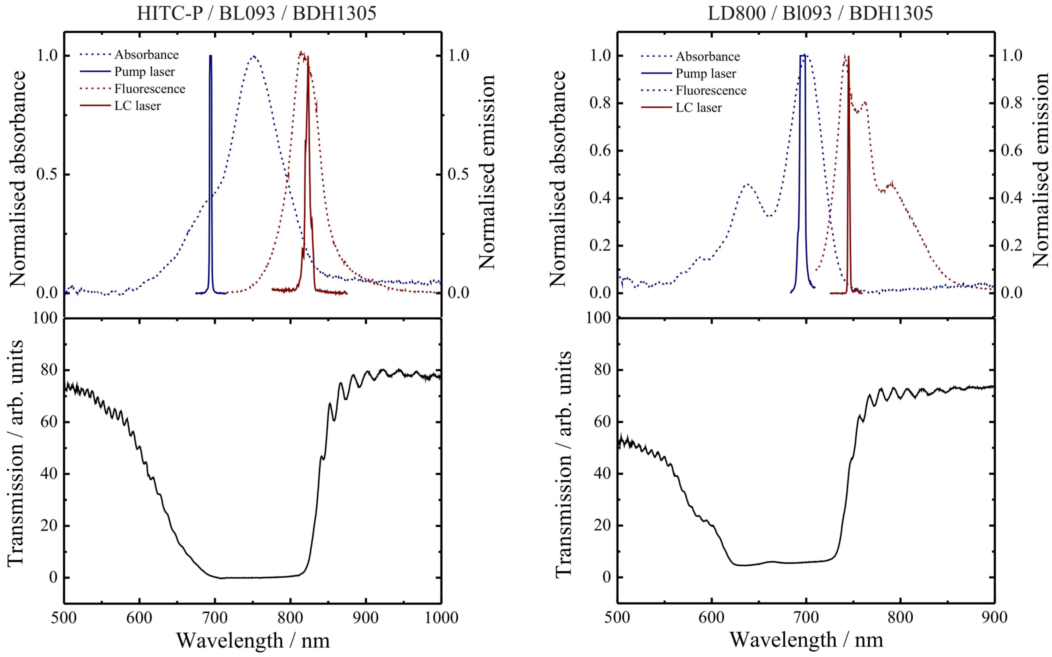

Fig. 1. Absorbance and flourescence data with corresponding examples of pump and LC laser wavelengths in BL093 nematic host (top), and the photonic band gap in a chiral host (bottom), for two different dyes: HITC-perchlorate (left), Rhodamine 800 (right).

Slope efficiencies of the systems were calculated and ranged between 1.4 and 4.1 % (± 0.2 %). Although not optimised for maximum efficiency, it compares very favourably to more conventional and optimised DCM dye-doped samples in the same LC host (3.0 %) measured using the same apparatus. A basic theoretical model of LC lasing is presented, which supports the conclusion that infra-red lasing is more efficient than visible lasing, despite the fact that infra-red dyes have generally lower quantum efficiencies than their visible counterparts.

Lasing in the near infra-red has been successfully demonstrated. Further improvements are anticipated with the development of new dyes with improved solubility in LC hosts and with higher Stoke's shifts. These results show great promise for the application of LC lasers to near infra-red applications.

4. References

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