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High order Bragg grating microfluidic dye laser

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Abstract: We demonstrate a single mode distributed feedback liquid dye laser, based on a short 133'rd order Bragg grating defined in a single polymer layer between two glass substrates.

OCIS codes: (140.2050) Dye Lasers; (140.3410) Laser Resonators

Integration of optical transducers is considered an important issue for future lab-on-a-chip microsystems [1]. One approach is based on miniaturization of liquid dye lasers formed by embedding a laser cavity inside a microfluidic channel by using lithographic techniques [2]. Using standard laser dyes, this type of device will be able to operate in a wide continuous range of wavelengths. Our current laser is based on an ethanolic solution of the laser dye Rhodamine 6G in a polymer structure, and pumped optically with a pulsed frequency doubled Nd:YAG laser at 532 nm (5 ns pulses at 10 Hz). Our device is easily integrated with waveguides and fluidic components for lab-on-a-chip purposes [3].

The laser resonator is a distributed feedback structure, defined by a 133'rd order Bragg grating with a central $\pi/2$ phaseshift. This structure is embedded in a microfluidic channel, as outlined in Fig. 1. The grating is formed by an array of channels interleaved by sections (bars) of polymer (SU-8 from Microtech). The channels carry the dye solution, and the structure exhibits a refractive index modulation perpendicular to the channels due to the difference in refractive index of the polymer (n=1.59) and the ethanolic dye solution (n=1.33). In our design we have formed this array in a 10 µm high SU-8 layer by making 23 channels 21.5 µm wide, interleaved by 22.43 µm of polymer. The grating forms an optical resonator with a modespacing of 2.5 nm, which is large enough to achieve single mode lasing with Rhodamine 6G with the achieved finesse.

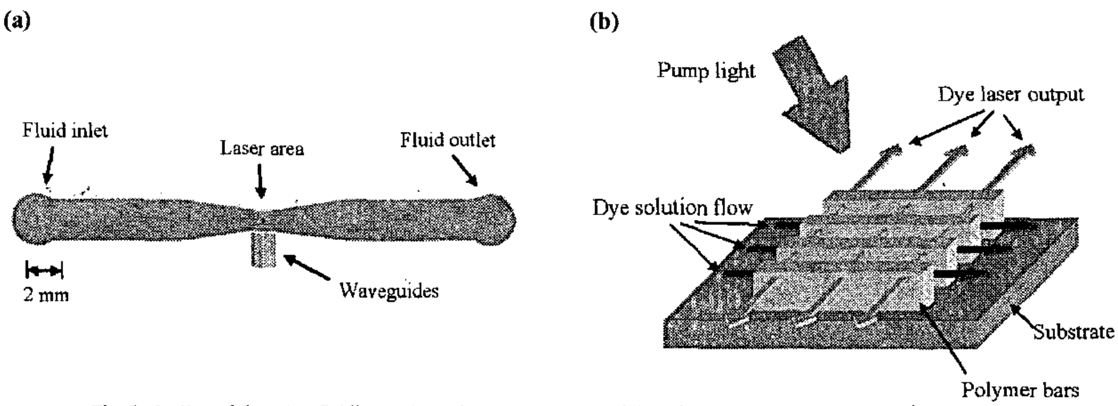

Fig. 1. Outline of the microfluidic dye laser design. (a) Layout of the microfluidic channel and waveguide structures defined in the 10 µm thick SU-8 polymer film. (b) Schematic of the laser cavity. The polymer bars and the channels for the dye solution compose a Bragg grating due to the differences in refractive index. The laser dye is pumped from above by a frequency doubled Nd:YAG laser and the dye laser light is emitted parallel to the substrate

In fabrication, the laser structure is lithographically defined in a 10 µm thick SU-8 polymer layer on top of a Borofloat glass substrate and the channels in the polymer are sealed by another glass substrate using polymethylmethacrylate (PMMA) mediated bonding [4]. Fluidic connections are facilitated by holes drilled through the glass. In order to ease measurements on the laser, the emitted laser light is coupled directly into 50 µm wide SU-8 waveguides [5], and directed to the edge of the chip.

The emission from the dye laser was measured using a spectrometer with a 0.5 nm FWHM response. Figure 2 shows a spectrum taken with a Nd:YAG pump power density of 26 kW/mm^2. The laser line at 572.9 nm has a linewidth below the resolution limit of the spectrometer. The pump residue from the Nd:YAG laser (not shown in figure) coupled into the waveguides has an intensity less than 4% of the dye laser light. The lasing threshold is determined to be at less than 0.5 kW/mm^2 pump intensity, and the efficiency of the laser is app. 1%.

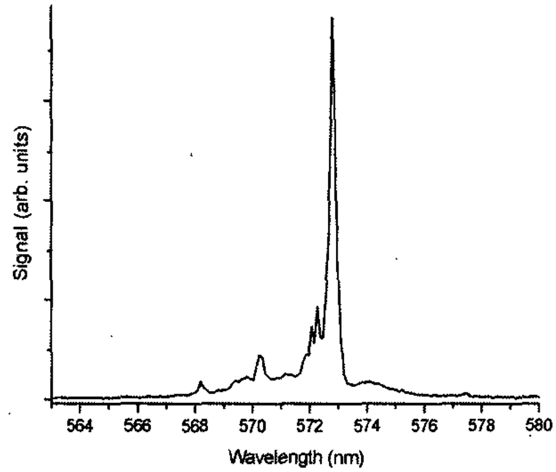

Fig. 2. Emission spectrum from the dye laser pumped with 5 ns pulses at an intensity of 26 kW/mm^2. The linewidth reflects the limited resolution of the spectrometer (0.5 nm).

In conclusion we have demonstrated a new type of liquid dye laser displaying single mode operation from a very high order Bragg grating based distributed feedback resonator. Due to the fabrication method, the laser is easily integrated with waveguides and fluidic components for lab-on-a-chip purposes.

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