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Direct writing of planar lightwave devices using ultrafast lasers

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ABSTRACT — **Ultrafast laser direct write micro-fabrication has emerged as a significant enabling technology creating new opportunities in microphotonics. The talk will present recent results of the performance of laser written microphotonic componentry in bulk glasses.**

I. Introduction

The tightly focused output beam of ultrafast lasers can be used to induce refractive index modification in most types of glass. The mechanism by which the refractive index is modified is still the source of much debate among researchers. The commonly accepted explanation is that energy deposition into the matrix via non-linear or multiphoton absorption leads to melting. It has been proposed that densification results when the molten material resolidifies [1]. Densification has also been associated with refractive index change in fibre Bragg gratings upon exposure to UV light although the mechanisms producing this are very different.

Because the femtosecond writing process uses multiphoton and non-linear absorption to generate refractive index changes it is not reliant on photosensitized target substrates. Glasses that have been processed with this technique include silica, fused silica, borosilicate, doped silicates, phosphate, doped phosphate and chalcogenide glasses. Positive refractive index changes ranging from 10^{-3} to 10^{-2}, depending on the type of host glass, have been reported. Refractive index changes of this scale are sufficient for generating lightwave components.

In this talk we will discuss the development of this fabrication technique and review advances leading to the generation of embedded waveguides in bulk glasses that exhibit low loss and low birefringence. The performance of photonic components including splitters, waveguide arrays, amplifiers and gratings, and opportunities for 3D fabrication will also be highlighted.

II. Experiment

The laser used in this work was a commercial, ultra-fast femtosecond laser (Spectra Physics Hurricane). The laser produced up to 1mJ of pulse energy with pulse width <120 fs at a wavelength of 800 nm. The laser was focused inside glass samples using a 20x microscope objective (Olympus UMPlanFL, NA 0.46). A simple beam shaping technique was used to produce circularly symmetric waveguides [2]. The glass samples were translated in three dimensions, through the fixed focal spot of the laser, using high precision translation stages (Aerotech linear bearing stage FA-130 coupled to an air bearing stage ABL2000).

III. Results and Discussion

To date our research program has focused on the development of processing methodologies enabling the fabrication of the key building blocks of photonic circuitry, namely, waveguides, splitters, gratings and amplifiers. Figure 1 shows a phase contrast image of a planar array of waveguides and 50:50 splitters written with laser direct-write techniques. The working distance of the focusing objectives

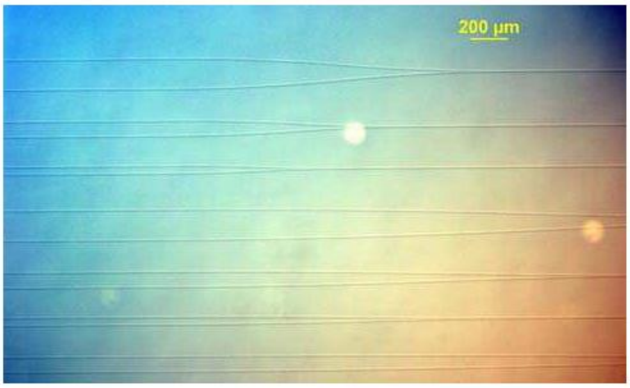

Fig.1: Difference Interference Contrast micrograph of an array of embedded 50:50 waveguide splitters written inside bulk silica.

used in this system enable the inscription of guided wave devices at depths ranging from 100μm below the surface to 2mm deep. As a result, this fabrication method can readily produce 3D devices such as 1x 4 splitters (see Fig. 2) and 3D waveguide arrays. Writing methodologies have also been developed enabling full control over the period, phase offset, frequency and amplitude of laser direct-written Bragg gratings. As a result, Bragg gratings of any arbitrary design can be fabricated. Demonstrations of this capability thus far include multiple, chirped and sampled gratings. We have also demonstrated gain of 2 dB/cm in waveguides written inside Er-Yb doped phosphate glass.

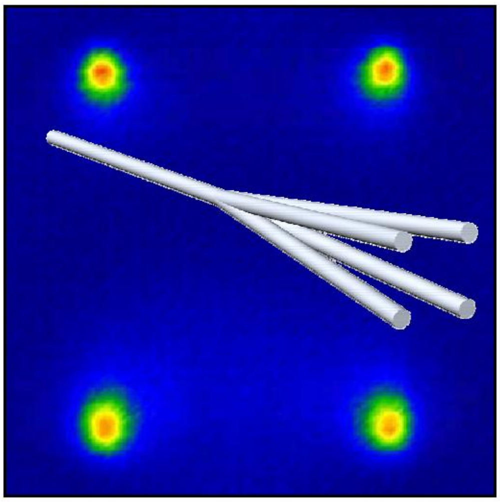

Fig.2: Schematic of a 3-dimensional 1 x 4 splitter and an optical image of the output of that device.

The current thrust of this research program is directed towards optimization and integration of these photonic components onto a monolithic optical chip. Recent results include demonstrations of high gain Er-doped waveguide amplifiers (EDWAs) and narrow linewidth waveguide Bragg gratings (WBGs) [3].

V. SUMMARY

The development of a new fabrication platform enabling both 2D and 3D writing of refractive index guided photonic components in a range of glasses will be reviewed. Demonstrations of low loss waveguides, splitters, simple and complex Bragg gratings will also be shown. Finally, the performance of working photonic devices such as EDWAs and WBGs, and the future implications for this technology will be discussed.

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