A novel beam delivery method for femtosecond laser based direct-write waveguide fabrication

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We report results of a new beam delivery configuration for fabricating photonic waveguides and devices in phosphate glass by use of a femtosecond laser.

Recently there has been widespread international interest in femtosecond laser fabrication of a variety of photonic devices. Optical waveguides can be fabricated inside various glasses by using tightly focussed femtosecond laser pulses to induce a change in the refractive index [1]. This direct-write technique has opened new possibilities in the world of passive and active integrated optics because of its potential to generate both planar and three-dimensional photonic devices inside a wide range of materials.

Waveguides are typically fabricated by translating a sample in a direction either parallel or perpendicular to the direction of beam propagation. The perpendicular writing geometry is favoured because of its ability to write waveguides of arbitrary length. It does, however, have the disadvantage of producing waveguides with a strong core asymmetry, i.e. waveguides with elliptical cores. Focussing geometries including a high (de)magnification astigmatic cylindrical telescope have been used in the past to overcome this problem [2]. The telescope acts to reshape the beam before focussing thus allowing the waveguide cross section to be made circular and with arbitrary size. We have developed a method that is also compatible with perpendicular writing; *the spatial profiling technique*. This method involves inserting a single slit aperture of 255μm parallel to the perpendicular writing direction, before the focusing objective, instead of the astigmatic telescope arrangement. This method is simpler to implement and offers similar control to the astigmatic telescope approach. Using this technique we have fabricated single mode waveguides in phosphate glass that have roughly circular shaped cores with diameters of approximately 15μm.

Investigation of this technique shows the presence of two line focuses where the peak intensity is highest. However, detailed analysis shows that the highest average energy density, over regions comparable in size to the waveguides, lies at a point in between these regions. Most importantly we show that the effective depth of field where the energy density is highest is comparable in size to the spatial dimensions of the beam which supports direct-writing of microstructures with circular cross-sections. A review of the spatial profiling technique and its applications will be presented.

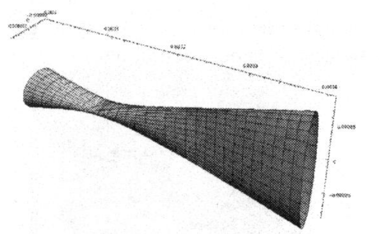

Fig 1: Evolution of the beam shape using the spatial profiling method

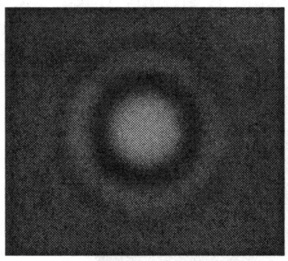

Fig 2: Far-field image of 632nm light coupled into an optical waveguide written using the spatial profiling method

References

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2. Osellame R., Taccheo S., Marangoni M. *et al.*, *Journal of Optical Society of America B* **20**, p1559, 2003