

268 nm Period Bragg Gratings and Integrated Circuits Produced by Direct UV writing

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We demonstrate 268nm period planar Bragg gratings and Mach-Zehnder interferometers fabricated by direct UV-writing. Grating reflectivities of ~30dB and FWHM of ~0.16nm were measured at operational wavelengths around 800nm.

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Optical fabrication technologies for integrated optical systems attract a great deal of attention based on their potential for exploiting the novel effects of quantum optoelectronics. These enjoy far-reaching applications, ranging from medicine and sensing to telecommunications and information processing by creating low cost signal processing devices using photons rather than electrons. Despite trials on many material platforms silica remains the most dominant system providing wide range of basic optical functionalities including fibre optics.

Silica-based planar waveguides offer the advantages of optical fibre compatibility, low loss and the ability to create planar lightwave circuits with integrated optical elements such as Bragg gratings, directional couplers, power splitters and Mach-Zehnder interferometers (MZI). In this report we present integrated optics elements designed to operate in the 800 nm wavelength range fabricated via direct UV writing (DUVW). Short wavelength operation offers several advantages including: good single photon detection for quantum information processing in the 800 nm wavelength region, more opportunities for sensing outside of the water absorption window, and a potential route for producing novel microcavity based light sources with selective wavelength reflectivity and filtering.

DUVW is a recently established technique for fabricating silica based planar waveguide structures. Definition of the waveguide structure is achieved via the UV radiation induced refractive index change of the photosensitive planar core layer. Relative translation of the focused UV radiation and the sample by computer controlled stages provides an accurate method of producing integrated optical elements. Exploiting a two-beam interference technique [1], one can simultaneously define the waveguide structure as well as Bragg gratings (Figure 1(a)). This technique has been extensively used in our previous studies on fabricating Bragg gratings for telecom (1550 nm) tunable filters and sensor applications.

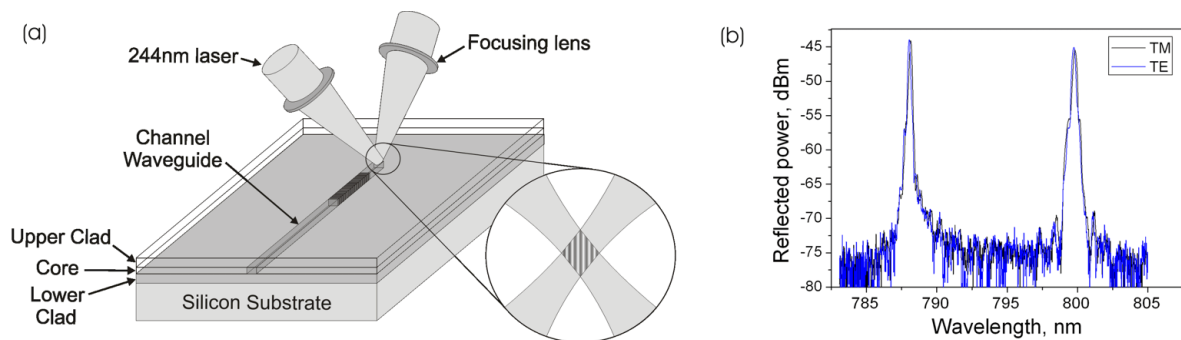


Fig. 1. Illustration of: (a) the interference pattern defined by two focused, interacting beams that forms the basis of our direct UV writing technique; and (b) grating reflectivity spectra: the left and right peaks represent uniform and sine-apodized gratings respectively.

In order to shorten the Bragg reflectivity wavelength of the UV-written gratings, one needs to reduce the period of the interference pattern obtained by the two crossed beams. This is normally achieved by increasing their crossing angle from ~26 degrees, which defines the period of 525 nm and the grating reflection wavelength of 1550 nm, up to 54° to obtain the desired Bragg grating period of 268 nm and hence to push the operation wavelength towards the near visible spectral region. However, the increase of the interaction angle encourages an enhanced sensitivity of the feature resolution accuracy arising from issues caused by sample surface non uniformity. Despite such difficulties we have successfully demonstrated a range of 1.5 mm long gratings exhibiting narrow bandwidth reflectivity of ~70% with a FWHM of 0.16nm, and birefringence of 2.2×10^{-4} (Figure 1(b)), which are comparable with the characteristics obtained in our 1550 nm planar Bragg gratings [1].

The similar high-quality Bragg grating spectra achieved at 800 nm demonstrates that the phase accuracy of our system is sufficient for reliable reproduction of the integrated devices at much shorter periods than previously demonstrated. The results look rather promising and show potential for further improvements for integrated optical systems operated at near visible wavelengths.

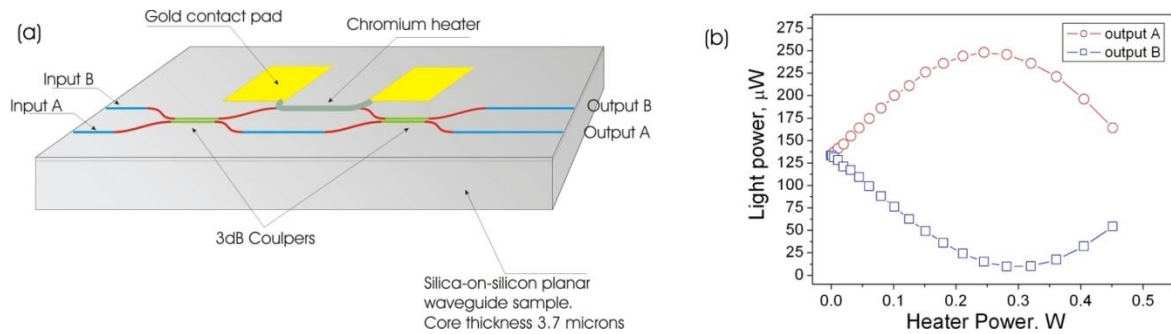


Fig.2. (a) Schematic of UV-written MZI with thermal tuning element; and (b) characterization of MZI output modulation via thermo-optical phase control.

We also present the development of MZIs based on directional couplers for operation at 800 nm wavelength (Figure 2(a)). Directional couplers employ an evanescent field coupling mechanism which provides a very flexible and reliable way of tuning the coupling ratio between the channels by simply varying the interaction length of the two closely located waveguides. An important feature of our devices is that the coupling ratio is wavelength dependent. The illustrated structure with incorporated electro-optical phase shifter provides unique control mechanism over the light output from the integrated optical circuit. In Figure 2 (b) the results of the optical output are shown as a function of electrically detuned thermo-optical modulation. These devices demonstrate excellent extinction ratios, a fast thermo-optical tuning response and long-term operational stability. However, further research into the response symmetry is required for optimisation of the fabrication process.

To conclude, we present operation of integrated elements produced by DUVW. The results offer a unique flexibility to manipulate photonic wave-packets, which can be vital for successful experimental implementation of integrated optoelectronics benefits using planar silica-on-silicon photonic chips.

[1] G. D. Emmerson, S. P. Watt, C. B. E. Gawith, V. Albanis, M. Ibsen, R. B. Williams, P. G. R. Smith, "Fabrication of directly UV-written channel waveguides with simultaneously defined integral Bragg gratings," *Elec. Lett.* **38**, 1531-1532 (2002).