

Direct 213 nm UV written Bragg gratings and waveguides in planar silica without hydrogen loading

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Abstract: We report the first demonstration of integrated waveguides and Bragg gratings direct UV written into planar silica using a fifth harmonic 213 nm laser without hydrogen loading. We observe 0.44 ± 0.26 dB cm⁻¹ propagation loss. © 2020 The Author(s)

1. Introduction

Direct UV Writing (DUW) is an established technique for defining low-loss channel waveguides, Bragg gratings, directional couplers, and polarisers in photosensitive planar silica. The technique relies on photosensitivity of the core layer which is achieved by doping silica with germanium and boron. DUW uses a continuous-wave frequency-doubled argon-ion laser beam operating at 244 nm wavelength and average power up to 100 mW [1]. The doped silica layers require hydrogen loading to ensure sufficient refractive index change during 244 nm UV writing. Hydrogen loading is a time consuming process, which requires leaving the samples at high pressures (≈ 120 bar) in a hydrogen cell for several days. Furthermore, outgassing of hydrogen during writing results in a time-dependent variation of final written structures and makes it more challenging to define more complex planar circuitry. Recently, fifth harmonic solid-state Nd:YVO₄ lasers operating at 213 nm wavelength have become commercially available, which provide nanosecond pulses with a high peak power. Compared with a typical argon-ion laser this source can be compact and cost-effective in terms of footprint and power consumption. In the past this new laser source has been used to produce strong Bragg gratings within the core of hydrogen-free SMF-28 fibre using a phase mask technique [2] and single-mode waveguides in hydrogen-loaded planar silica [3].

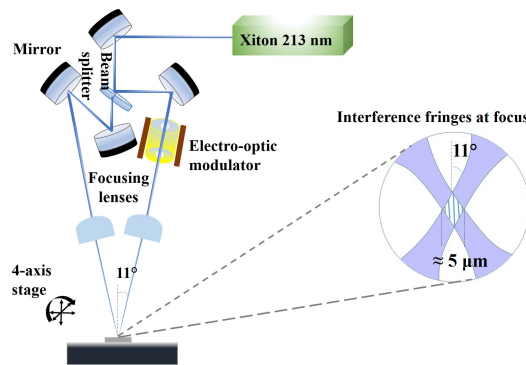


Fig. 1. Schematic of the 213 nm direct UV writing setup for defining channel waveguides and Bragg gratings simultaneously in planar silica layers.

Here we report the first successful fabrication of integrated waveguides and Bragg gratings by 213 nm direct UV writing in both hydrogen loaded and hydrogen-free planar silica samples. We characterise various properties of the waveguides including fluence dependence and propagation loss [4].

2. Method

Flame Hydrolysis Deposition (FHD) was used to deposit a 4.3 μm thick core layer of germanium and boron doped-silica onto a silicon wafer with a 15 μm thick thermal oxide. The core layer was capped with boron and phosphorus-doped 15 μm thick silica cladding layer. The core and cladding layers were fabricated to have similar refractive indices. 20 mm long individual chips were diced from this wafer, and several were hydrogen loaded

in a pressure cell for several days. A 213 nm laser was used to simultaneously write waveguides and Bragg gratings within the photosensitive core layer through the small spot direct UV grating writing technique [1] as shown in Fig. 1. An average power of 12 mW and a Gaussian spot size of 5 μm , determined through knife edge measurements was used to write the hydrogen-loaded chip. Writing fluence for each waveguide was controlled by the stage translation speed, and a fluence range of 0.5 kJ cm^{-2} to 1.1 kJ cm^{-2} was used. Each written waveguide contained ten 1 mm-long Bragg gratings with a Gaussian apodisation profile. The periods of gratings were changed to produce a spectral response between 1520 and 1590 nm. The hydrogen-free sample was similarly inscribed with waveguides integrated with ten 1.5 mm-long gratings with a fluence range of 20 kJ cm^{-2} to 100 kJ cm^{-2} . Higher fluences were required to achieve a sufficient change in the refractive index. In order to avoid the damage threshold of FHD glass, the average power of the laser was reduced to 4 mW. The total writing time for five waveguides was about 17 hours. For characterisation, an Er-doped ASE broadband source was launched into the UV written waveguides through a fibre V-groove assembly. The reflected grating spectra were collected on an optical spectrum analyser.

3. Results

Fig. 2(a) shows a photograph of hydrogen-free fabricated chip. It shows the diffraction of the white light illumination source from the Gaussian apodised gratings. Fig. 2(b) shows an example reflection spectra observed from opposite ends of the waveguide. Maximum peak reflectivity of the gratings was observed ($\approx 20\%$) at a fluence of 60 kJ cm^{-2} . Propagation loss was obtained using the Bragg grating reflectivity technique [4]. The measured loss was $0.44 \pm 0.26 \text{ dB cm}^{-1}$ for 213 nm written hydrogen-free silica and $0.28 \pm 0.13 \text{ dB cm}^{-1}$ in hydrogen loaded silica.

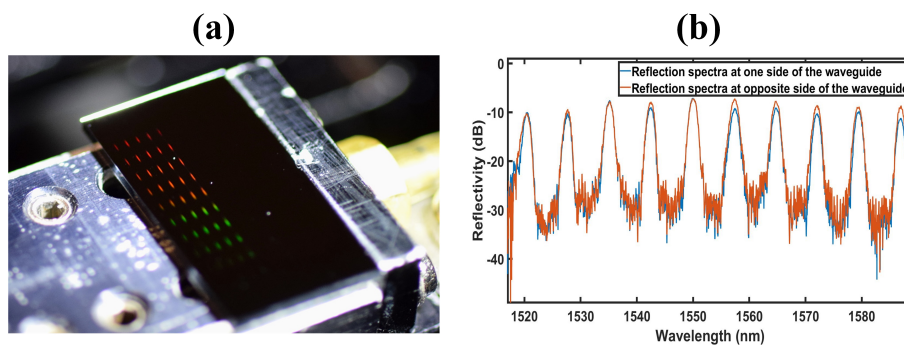


Fig. 2. (a) Photograph of a fabricated chip taken during characterisation, which shows a colorful scattering of white light from the Gaussian apodised gratings.(b) Reflection spectra obtained from launching lights from both end facets of the chip.

4. Conclusion

We have shown for the first time the successful fabrication of integrated waveguides and Bragg gratings in silica-on-silicon chips (with and without hydrogen loading) by 213 nm DUV writing. A Bragg grating based technique was utilised to measure the propagation loss of 213 nm written waveguides. The lowest propagation loss observed was $0.44 \pm 0.26 \text{ dB cm}^{-1}$ in hydrogen free and $0.28 \pm 0.13 \text{ dB cm}^{-1}$ in hydrogen loaded silica. We will present an in-depth comparison between hydrogen loaded and hydrogen free chips written with 213 nm laser, including the trend in propagation loss as a function of fluence, birefringence measurements and modal properties.

References

1. C. Sima, J. C. Gates, H. L. Rogers, P. L. Mennea, C. Holmes, M. N. Zervas, and P. G. R. Smith, "Ultra-wide detuning planar Bragg grating fabrication technique based on direct UV grating writing with electro-optic phase modulation," *Opt. Express* **21**, 15747–15754 (2013).
2. M. Gagné and R. Kashyap, "New nanosecond Q-switched Nd: VO₄ laser fifth harmonic for fast hydrogen-free Fiber Bragg Gratings fabrication," *Opt. Commun.* **283**, 5028–5032 (2010).
3. P. C. Gow, R. H. S. Bannerman, P. L. Mennea, C. Holmes, J. C. Gates, and P. G. R. Smith, "Direct UV written integrated planar waveguides using a 213 nm laser," *Opt. Express* **27**, 29133–29138 (2019).
4. H. L. Rogers, S. Ambran, C. Holmes, P. G. R. Smith, and J. C. Gates, "In situ loss measurement of direct UV-written waveguides using integrated Bragg gratings," *Opt. Lett.* **35**, 2849–2851 (2010).