Strong fibre Bragg-gratings written in highly photosensitive Sn-doped fibres without H_2-loading using KrF excimer and UV copper vapour lasers

G. Brambilla[1], H.J. Booth[2], E.K. Illy[2], L. Reekie[3], H. Rutt[1] and L. Dong[4]

[1] *Optoelectronics Research Centre, Southampton University, Southampton, UK.*
Tel: +44 (0) 2380 593954, Fax: +44 (0) 2380 593149, E-mail: gb2@orc.soton.ac.uk
[2] *Oxford Lasers Ltd, Abingdon, UK*
Tel: +44 (0)1235 554211, Fax: +44 (0)1235 554311, E-mail: heather.booth@oxfordlasers.com
[3] *JDS Uniphase 4 Byfield Street, North Ryde, NSW 2113, Australia.*
Tel: +61 (0)2 8875 2914, Fax: +61 (0)2 8875 2901, E-mail: ***laurence.reekie@au.jdsuniphase.com.***
[4] *Corvis Canada, 520 Mc Caffrey, St Laurent, QC H4T 1N1 Canada.*
Tel: +1 514 736 5440, Fax: +1 514 736 5446 E-mail: LDong@Corvis.com

Abstract: Sn-doped silica optical fibres are temperature resistant, have high photosensitivity and low loss at 1.55 μm, properties which make them desirable for use in telecom components and sensors. Results of the fabrication of Bragg gratings in Sn-doped fibres using KrF excimer and UV copper vapour lasers will be presented.

1. Introduction

Since the first observation in 1978 by Hill and co-workers [1], photosensitivity has launched many new fields in telecom and fibre optic based devices. In the last decade many papers have been published showing enormous progress both in grating writing techniques and fibre fabrication. New materials have been studied to increase the photosensitivity of telecom optical fibres that would otherwise be insufficient for many applications. SnO_2-doping was proposed as a convenient co-dopant [2,3,4,5] because of its low-absorption in the third telecom window at 1.55 μm and high photosensitivity when exposed to 248 KrF excimer laser (KEL) radiation.

Recently it was demonstrated that the reflectivity of gratings written with frequency-doubled copper vapour laser (CVL) is similar to the reflectivity of the gratings written with the frequency-doubled argon ion laser [6]. Moreover, the CVL can be used to write simultaneous multiple gratings with identical reflectivity [6,7].

In this work we study the photosensitivity of tin-doped fibres with the CVL and compare it to the photosensitivity achieved with the KEL.

2. Experimental results

Three fibre compositions were studied: tin-silicate (SS), tin-phosphosilicate (SPS) and tin-germanosilicate (SGS) fibres. All the fibres were produced by modified chemical vapour deposition (MCVD) at the University of Southampton. Their properties are shown in table 1.

Fibre	NA	λ_c (nm)	$[SnO_2]$ (mole %)	Reference
SS	0.1	1.38	~0.2	[2]
SPS	0.23	1.32	~1	[3]
SGS	0.3	1.40	~1	[4]

Table 1. Fibre physical features. NA, λ_c and $[SnO_2]$ represent the numerical aperture, the cut-off wavelength and the tin molar concentration respectively.

Gratings were written using phase masks and two UV lasers: a KEL (Lambda-Physik EMG150) working at 248 nm and a CVL (Oxford Laser) working at 255 nm. Pulse duration and repetition rate were 20 ns and 20 Hz for the KEL, 20 ns and 6 kHz for the CVL. Pulse fluence was estimated to be ~0.1 J/cm^2 for gratings written in the SS fibre, ~0.2 J/cm^2 for the others. While the KEL beam was rectangular, the CVL beam was circular. The CVL beam was focused with a 30 mm cylindrical lens that reduced the beam dimensions to approximately 1 mm x 30 μm. The grating reflectivity was measured by launching light from a white light source and monitoring the transmitted signal with an optical spectrum analyser. For uniform gratings (as in the case of the KEL), the refractive index modulation (Δn_{mod}) was evaluated from the maximum reflectivity R at the Bragg wavelength λ_B using the formula:

$\Delta n_{mod} = \frac{\lambda_B}{\pi L} \tanh^{-1} \sqrt{R}$ (L is the grating length). In the case of apodised gratings (as was the case for the focused CVL), Δn_{mod} was evaluated using the transfer matrix method.

Table 2 summarizes the results achieved from the gratings written in the three fibres.

Fibre	KEL		CVL		R
	Δn_{mod} (x10^{-4})	Exposure time (s)	Δn_{mod} (x10^{-4})	Exposure time (s)	
SS	2.7	13300	1.4	150	1.9
SGS	14 [2]	1800	5	10	2.8
SPS	10	1800	2.3	150	4.3

Table 2. Comparison between the strength of gratings written using the KEL and the frequency-doubled CVL. SS, SPS and SGS represent the tin-silicate, tin-phosphosilicate and tin-germanosilicate fibres, respectively. $R = \frac{\Delta n_{KEL}}{\Delta n_{CVL}}$ is the ratio between the Δn_{mod} obtained with the KEL and the CVL.

While the SS and SGS fibres gratings exhibit a similar Δn_{mod} (R=1.5-2), in the SPS fibre the Δn_{mod} obtained using the KEL is ~4 times bigger that the Δn_{mod} achieved with the CVL, even when the fluence experienced by the fibre exposed to the CVL is 25 times bigger than that experienced by the fibre exposed to the KEL. A possible explanation is the different coupling efficiency of the different materials. In fact, while SS and SGS glasses show absorption peaks at ~252 nm [2,4], SPS exhibits a nearly-exponential decrease of the absorption in the whole range 230-300 nm [3]. As a consequence, the radiation-to-network coupling efficiencies at 248 nm and 255 nm are comparable in SS and SGS fibres. On the contrary, a factor of two exists in the case of SPS. In addition, photosensitivity in SPS fibres is extremely sensitive to the intensity of the incident radiation [3], indicating that the laser radiation at short wavelengths (i.e. high photon-energy) might be more effective in modifying the glass structure to induce a refractive index change.

Finally, from table 2 it is possible to note that the high repetition rate of the CVL allows the grating to be written in very short time in the tin-doped fibres. In fact, under these exposure conditions gratings appeared to saturate after 90-120 seconds both in the SS and the SPS fibres.

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4. References

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