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OPTICS
COMMUNICATIONS

Optics Communications 127 (1996) 200-204

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Received 27 November 1995; accepted *24 January* 19%

ELSEVIER

15 June 1996

OPTICS
COMMUNICATIONS

ELSEVIER

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Abstract

Fibre Bragg gratings have been post-fabrication processed using localised heat treatment, with significant changes to their transmission and reflection characteristics being observed. Experimental results of the spectral changes, together with an explanation of their origin, are provided in this article.

Keywords: Fibre Bragg gratings; Phase shifted gratings; Optical fibres; Optical communications

1. Introduction

Irma-core fiber optic Bragg gratings continue to be of significant importance to the fibre optic communications and sensors community. These versatile devices have been demonstrated in such varied applications as discrete sensors [1] for strain and temperature measurements; as narrowband wavelength selective elements for doped fibre lasers [2] and hybrid semiconductor lasers [3]; and as dispersion compensators for optical fibre communication links [4].

In this article the authors report some findings from experiments which have recently been undertaken in order to investigate the effect of localised heat treatment (LHT) on the wavelength reflection (and optical wavelength transmission) characteristics of Bragg gratings. Such post-fabrication processing by LHT yields significant changes in the optical characteristics of the gratings. Experimental observations on such processed gratings, together with an explanation of the origin of the observed effects, are reported.

2. Experimental details

Bragg gratings for our experiments were formed in photosensitive optical fibres which had been previously subjected to high pressure hydrogen loading at 1500 p.s.i with the loading chamber at room temperature. The hydrogen loading is known to enhance the photosensitivity of the fibre. Bragg gratings were also formed in nonhydrogenated photosensitive fibre. All gratings used in the experiments were fabricated by the transverse holographic technique using an amplified, spectrally narrowed excimer laser producing 12 ns duration pulses with 50 mJ/pulse energy and a pulse repetition rate of 30 Hz. Gratings thus formed were determined to be around 8 mm in length.

Localised heat treatment (LHT) was applied to the gratings by means of a laboratory fusion splicer. Using this equipment, it is convenient to locally apply high temperatures to optical fibres in a region of around 1 mm length along the fibre. The grating region in the fibre was positioned between the elec-

PII S0030-4018(96)00059-4

trodes of the splicer (Power Technology Model PFS330) for heat treatment. Other apparatus was set up to observe the characteristics of the gratings. The light source used in this work was a broadband LED centred at 1550 nm with a FWHM bandwidth of 70 nm, whilst all reflection and transmission spectra were recorded using a HP Model 71450A optical spectrum analyser.

Prior to the main work with the fibre gratings, the localised heat treatment was applied to several samples of the same type of photosensitive fibre in which the gratings were fabricated. This was done in order to determine the settings of the fusion splicer (namely arc current and arc duration) which could produce an electric arc that would locally heat, but not permanently distort, the fibre. From these initial studies the arc current and arc duration required to meet the above criterion were established to be 7 mA and 6 s for the fibre samples. With these settings of the fusion splicer now established, the gratings were subjected to the LHT.

3. Results

Fig. 1 shows the wavelength transmission spectrum of the Bragg grating, from which it can be deduced that the peak reflected intensity occurs at 1550.68 nm, whilst the FWHM was measured to be 0.23 nm. The reflectivity of the grating was measured to be 59.8%. When this grating was subject to LHT at its centre the spectrum shown in Fig. 2 was obtained. This shows both the reflection and transmission spectra from which it can be seen that the peaks in the reflection spectrum correspond in wavelength to the troughs in the transmission spectrum.

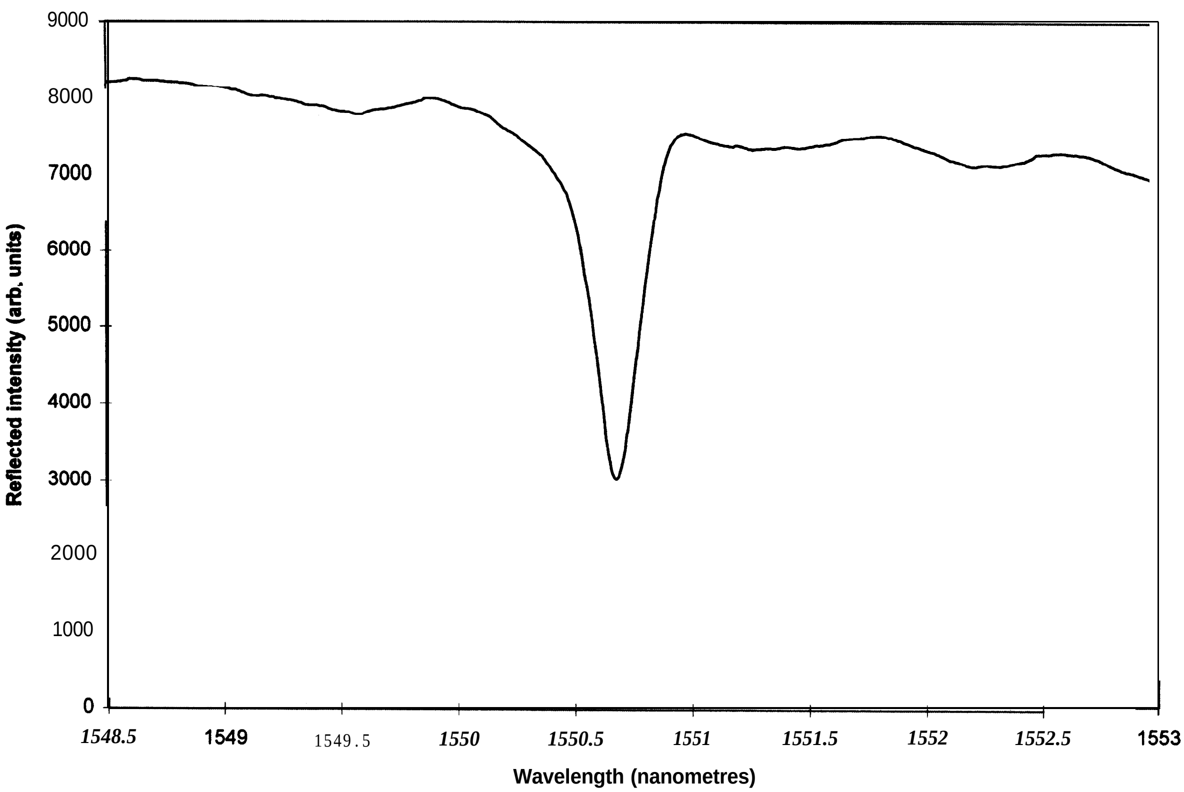

Fig. 1. Reflection spectrum of original grating used for LHT at its centre.

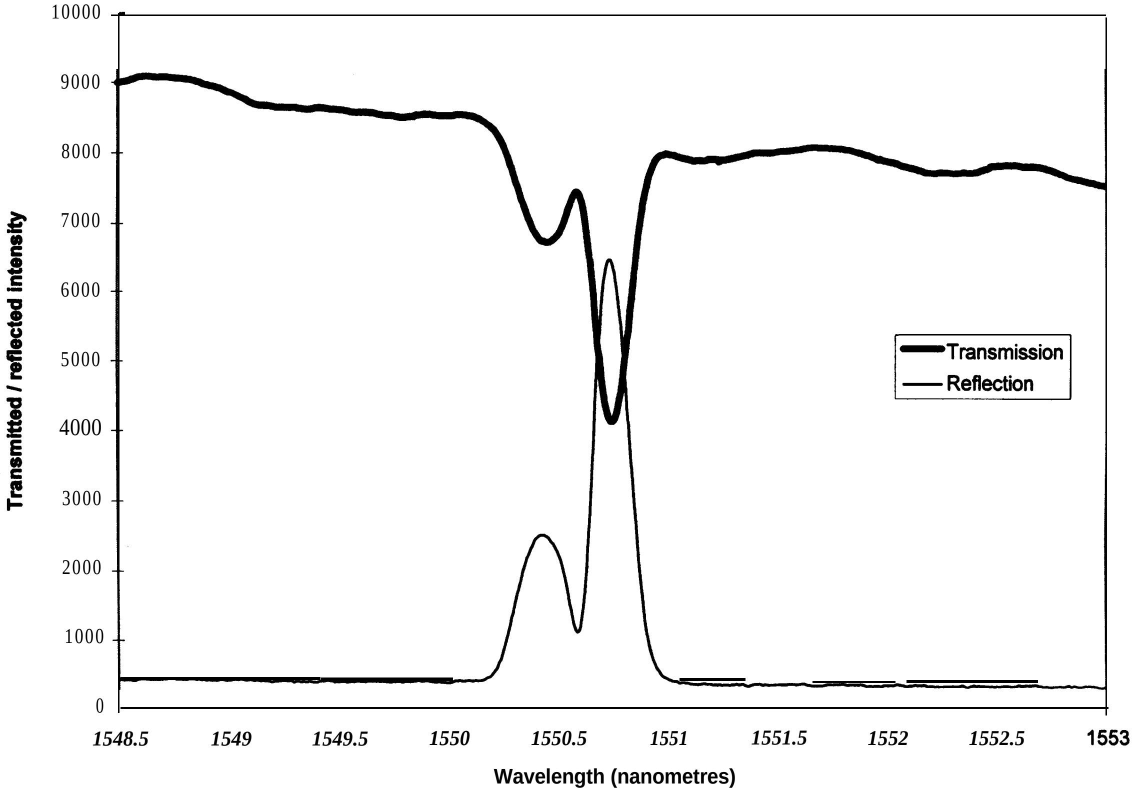

Fig. 2. Transmission and reflection spectrum of Bragg grating of Fig. 1 after LHT at its centre.

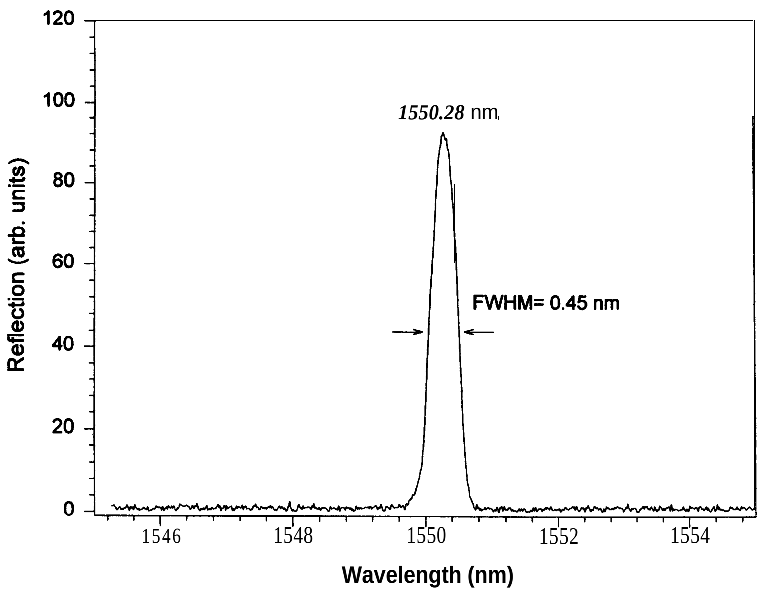

Fig. 3. Reflection spectrum of original grating used for LHT at two points.

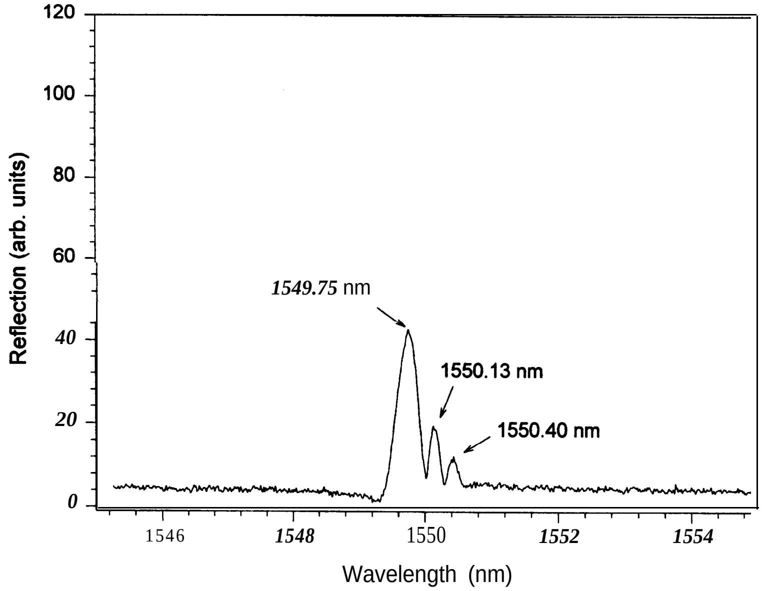

Fig. 4. Reflection spectrum of Bragg grating after LHT at two points along its length.

The peak at the left of the figure has a centre wavelength of 1550.43 nm (0.26 nm FWHM) whilst the peak at the right has a centre wavelength of 1550.74 nm (0.18 nm FWHM). Also, the values of the two reflectivities are, respectively, 20.9% and 48.1% which can be compared to the reflectivity of 59.8% of the grating before LHT.

A similar experiment was repeated, this time by applying the LHT to two points along a different fibre grating, roughly at positions one third and two thirds along its length. The untreated grating had a single reflection peak at 1550.28 nm (0.45 nm FWHM), as shown in Fig. 3. Fig. 4 shows the changes which occur after the treatment. The peaks in Fig. 4 occur at the wavelengths of 1549,75 nm, 1550.13 nm and 1550.40 nm (0.37 nm, 0.20 and 0.17 nm FWHM respectively). The results presented here are just some typical examples obtained from LHT of many Bragg gratings, and were observed in gratings made from both hydrogenated and non-hydrogenated photosensitive fibre.

4. Discussion

The significant change in the spectra of fibre gratings subjected to LHT is due to the creation of a phase shift region within the grating. This arises by the localised erasure of the grating [5] which occurs when the grating is subject to short bursts of high temperature produced by the electrical discharge at the fusion splicer electrodes between which the fibre is placed. We have not directly measured the temperature which the fibre locally attains (this being a difficult task), but it only needs to be recalled that the localised temperatures attainable are sufficiently high to soften the optical fibre for fusion splicing. The erasure of a short region of the grating in effect creates a Fabry-Perot structure with two wavelength selective reflectors separated by a short waveguide region which contributes a phase shift between the reflectors. Wavelength selectivity then simply follows in this Fabry-Perot configuration. A theoretical analysis of Bragg gratings incorporating phase shift regions has been reported in Ref. [6], and the experimental results of the work described here broadly match the results of Ref. [6]. The non-uniformity in the wavelength spectrum of Figs. 2 and 4 implies that the phase shift region produced by erasing the gratings is not positioned symmetrically along the original grating length. Also, the spectra were recorded using radiation from an LED source rather than the preferred approach which would have involved use of a tunable laser and would have yielded more accurate spectra. However, through this article we have demonstrated that post-processing of a fibre grating to modify its optical characteristics is possible using a relatively simple approach.

In practice, better control would need to be exercised before LHT could be routinely applied to provide a desired phase shift on a grating. In particular a laboratory fusion splicer does not represent the best arrangement for this task, although its use is sufficient to demonstrate what can be achieved. Apparatus of the type used for producing fused single mode fibre directional couplers, where a narrow high temperature flame is precisely applied to optical fibres, presents a better prospect for achieving LHT to a fibre grating with better control.

Phase masks, in which phase-shift regions have been written into the mask design, are now routinely used to fabricate such phase-shifted gratings as described in Ref. [7]. Post-processing of a grating by exposure of the grating region to pulses of UV laser radiation has been described in Ref. [8]. The results of both Refs. [7] and [8] are similar to results presented here except that the recorded spectra in both mentioned works used a tunable laser, whilst our spectra were recorded using an LED.

5. Conclusion

Phase-shifted Bragg gratings are routinely formed using a suitably designed phase mask incorporating a phase shift region. UV post-fabrication processing of a grating has also been applied to accomplish the same effect. The work described in this communication is similar in principle to the latter formation technique showing that LHT, in our case applied by use of a laboratory fusion splicer, yields the same type of result. Further research including the construction of purpose built apparatus for LHT will be necessary before our initial results can be translated to a more controlled process.

Acknowledgements

One of the authors (DU) would like to thank the Nuffield Foundation for the award of a Science Travel Grant aimed at developing this work.

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