1083

Compensation of Imperfect Phase Mask with the Moving Fibre-Scanning Beam Technique for Production of Fibre Gratings

W. H. Loh, M. J. Cole, M. N. Zervas and R. I. Laming
Optoelectronics Research Centre
University of Southampton
Southampton SO17 1BJ

Abstract

We experimentally demonstrate that the moving fibre-scanning beam technique is able to compensate for imperfections in a phase mask and thus improve the quality of the resulting fibre gratings. A 10 cm long 'uniform' phase mask which normally produces gratings with a 0.23 nm uncontrolled chirp has been corrected with our new writing technique to produce narrow band gratings with 0.10 nm bandwidth.

Introduction: The production of high quality photorefractive fibre gratings with well-controlled characteristics is of considerable importance as fibre gratings are now recognised to have numerous potential key applications in telecommunications, sensors, as well as laser systems. Currently, the two main approaches for grating fabrication are the holographic method[1] and the phase mask[2,3] technique.

The use of phase masks for producing fibre gratings is attractive because of its repeatability, while also offering considerably relaxed tolerances on the writing set-up, which is especially important in the case of writing long fibre gratings[4,5]. Balanced against these advantages, though, is that high quality phase masks, especially long masks, are expensive and difficult to fabricate. This problem is further compounded by the fact that the Bragg wavelength of the fibre gratings produced are dictated by the period of the phase mask, thus requiring different masks to be used if fibre gratings are desired over a wavelength range.

The issue of imparting wavelength flexibility into the phase mask approach has been partially addressed, with the use of a magnifying lens[6], or the recently introduced moving fibre/phase mask-scanning beam approach[7]. The purpose of this current work is to demonstrate experimentally that the latter technique is also able, for the first time, to compensate for an imperfect phase mask by removing undesired chirp during the grating writing process, thus enabling narrowband gratings to be still produced. This capability should prove highly attractive from a practical point of view, since it now relaxes the tolerance requirements on the phase mask itself, and so could open the way to using very long phase masks for making ultralong fibre gratings.

Experimental Configuration: The experimental set-up is shown in Fig. 1. The UV writing beam (244nm, 30 mW cw) is scanned at a rate of 250 μm/s across a 10 cm long zero-order nulled, 1070 nm period phase mask. The boron-codoped photosensitive fibre is mounted on a PZT stage and placed in near-contact with the mask. The PZT stage, fitted with closed loop position-feedback control, has a total travel of 20 μm with $\pm 0.5\%$ linearity. The noise equivalent motion of the PZT system was specified as 5 nm. The system is computer-controlled, enabling us to program in various fibre velocities/wavelength shifts at desired intervals during the scanning (writing) process. The reflection spectrum of the grating was monitored during the writing scan, via a 3 dB fibre coupler with an erbium-doped fibre amplifier (EDFA) as the broadband 1550 nm source, which proved very useful in identifying the portion(s) of the mask which were chirped and needed correction.

Results: Scans across the phase mask (with the fibre stationary throughout) revealed that the resulting fibre gratings had an undesired chirp, which were quite repeatable. Fig. 2 shows the transmission spectrum of the grating. The grating 3 dB bandwidth is 0.23 nm. Close examination of the reflection spectrum while the grating was being written revealed that most of the chirp came from a section of the mask 2-3 cm in length, situated near the middle, for it was during this portion of the scan that the spectrum was observed to broaden significantly by shifting to the shorter wavelength side.

To compensate for the undesirable broadening of the spectrum, a series of small wavelength shifts was programmed into the grating by moving the fibre/PZT stage at the appropriate time during the scanning process. The wavelength shifts, $\Delta\lambda$, are directly related to the fibre velocity v_f by $\Delta\lambda = \lambda v_f/v_{sc}$, where λ is the Bragg wavelength and v_{sc} the scanning beam velocity[7]. The direction of these shifts were to the longer wavelength side, to counteract the chirp from the mask. Fig. 3 shows the step-like velocity profile of the fibre along the grating length during the scan. The largest velocity used, $v_f = 22$ nm/s, corresponds to a wavelength shift of just 0.14 nm. Although such small velocities can only be approximate subject to the limitations of the equipment, it nonetheless proves to be sufficiently effective in preventing the grating from becoming excessively chirped. Fig. 4 shows the transmission spectrum of the grating produced as a result of having these small corrections imparted to it during the writing process. The bandwidth is now only 0.10 nm, which is considerably narrower than the 0.23 nm bandwidth of the uncompensated grating. In addition, it is worth noting that the peak reflectivity (90%) is now also higher, another indication that a more uniform grating, which is both stronger as well as narrower in bandwidth, has been produced by this compensating technique.

Conclusion: We have experimentally demonstrated that the moving fibre-scanning beam technique is capable of compensating for imperfections in the phase mask during the grating writing process. The approach should prove very attractive from a practical point of view, alleviating the need for very high quality phase masks. This could be especially important for the production of long gratings, where long phase masks would be required.

Acknowledgements: We would like to thank L. Dong for providing the photosensitive fibre. The Optoelectronics Research Centre is an EPSRC funded interdisciplinary research centre.

References

1. MELTZ, G., MOREY, W. W. and GLENN, W. H.: 'Formation of Bragg gratings in optical fibers by a transverse holographic method', *Opt. Lett.*, 1989, **14**, pp. 823-825.

2. HILL, K. O., MALO, B., BILODEAU, F., JOHNSON, D. C. and ALBERT, J.: 'Bragg gratings fabricated in monomode photosensitive optical fiber by UV exposure through a phase mask', *Appl. Phys. Lett.*, 1993, **62**, pp. 1035-1037.

3. ANDERSON, D. Z., MIZRAHI, V., ERDOGAN, T. and WHITE, A. E.: 'Production of in-fibre gratings using a diffractive optical element', *Electron. Lett.*, 1993, **29**, pp. 566-567.

4. MARTIN, J. and OUELLETTE, F.: 'Novel writing technique of long and highly reflective in-fibre gratings', *Electron. Lett.*, 1994, **30**, pp. 811-812.

5. ROURKE, H. N., BAKER, S. R., BYRON, K. C., BAULCOMB, R. S., OHJA, S. M. and CLEMENTS, S.: 'Fabrication and characterisation of long, narrowband fibre gratings by phase mask scanning', *Electron. Lett.*, 1994, **30**, pp. 1341-1342.

6. PROHASKA, J. D., SNITZER, E., RISHTON, S. and BOEGLI, V.: 'Magnification of mask fabricated fibre Bragg gratings', *Electron. Lett.*, 1993, **29**, pp. 1614-1615.

7. COLE, M. J., LOH, W. H., LAMING, R. I., ZERVAS, M. N. and BARCELOS, S.: 'Moving fibre/phase mask-scanning beam technique for enhanced flexibility in producing fibre gratings with a uniform phase mask', submitted to *Electron. Lett.*

Figure Captions

Fig. 1 Experimental configuration.

Fig. 2 Transmission spectrum of grating directly written from 10 cm long phase mask.

Fig. 3 Velocity profile of fibre during scan to compensate for imperfect phase mask.

Fig. 4 Transmission spectrum of grating with compensating wavelength shifts.

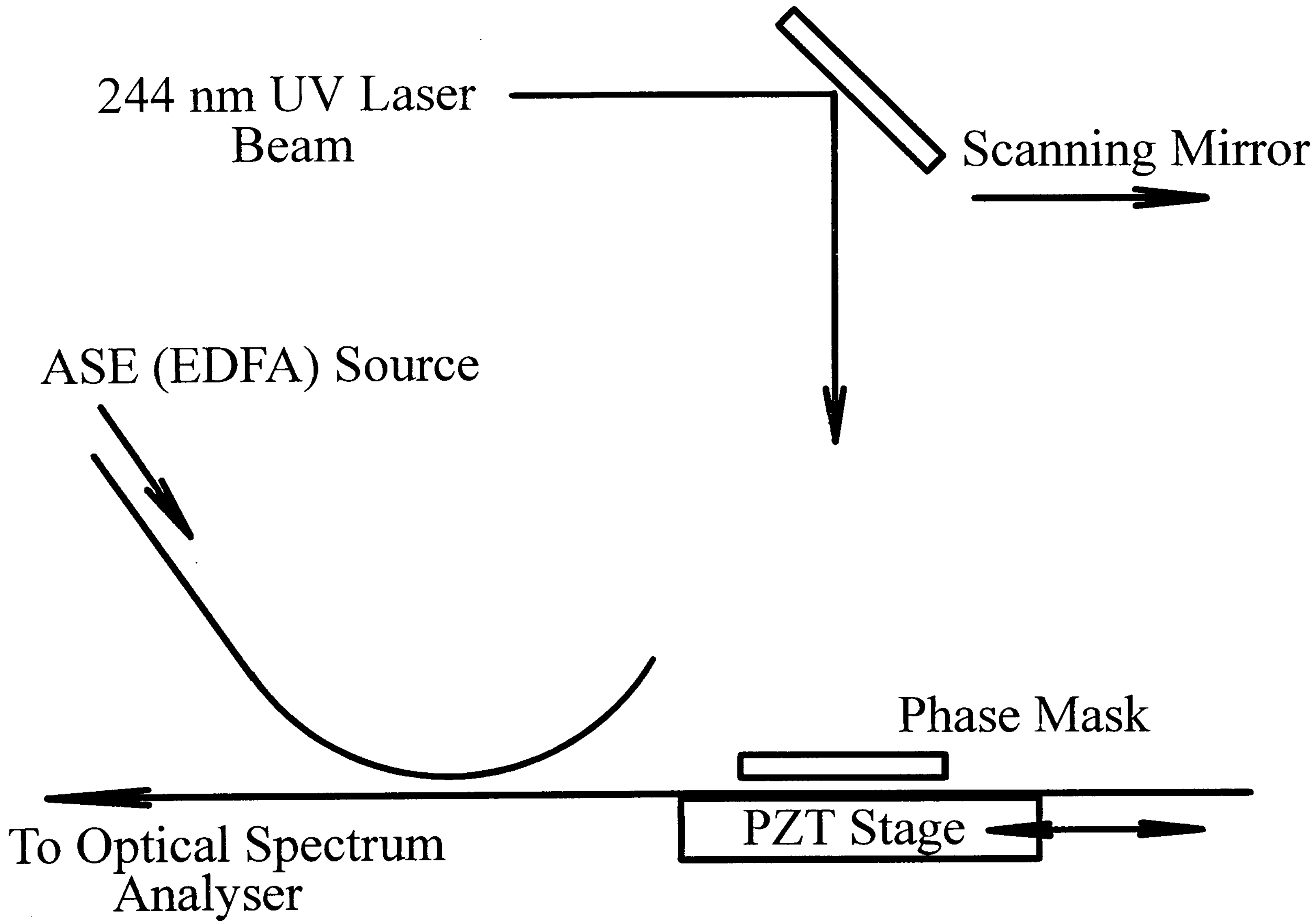
244 nm UV Laser
Beam
Scanning Mirror
ASE (EDFA) Source
Phase Mask
PZT Stage
To Optical Spectrum
Analyser

Fig. 1

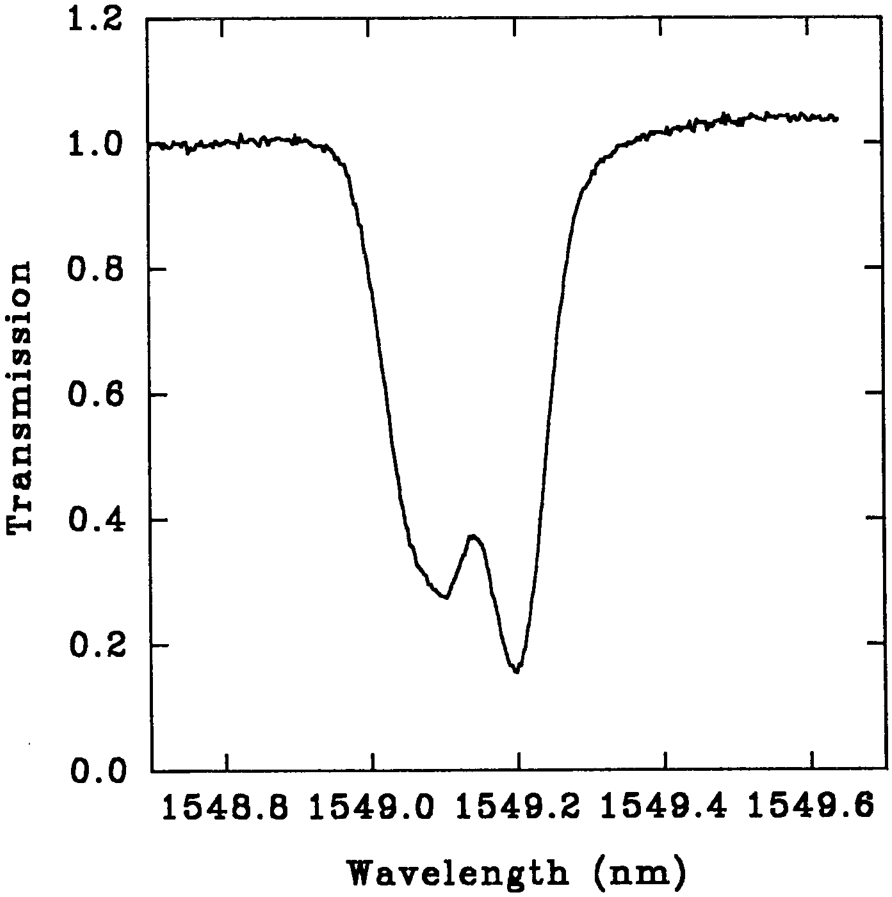
1.2
1.0
0.8
0.6
0.4
0.2
0.0
Transmission
1548.8
1549.0
1549.2
1549.4
1549.6
Wavelength (nm)

Fig 2

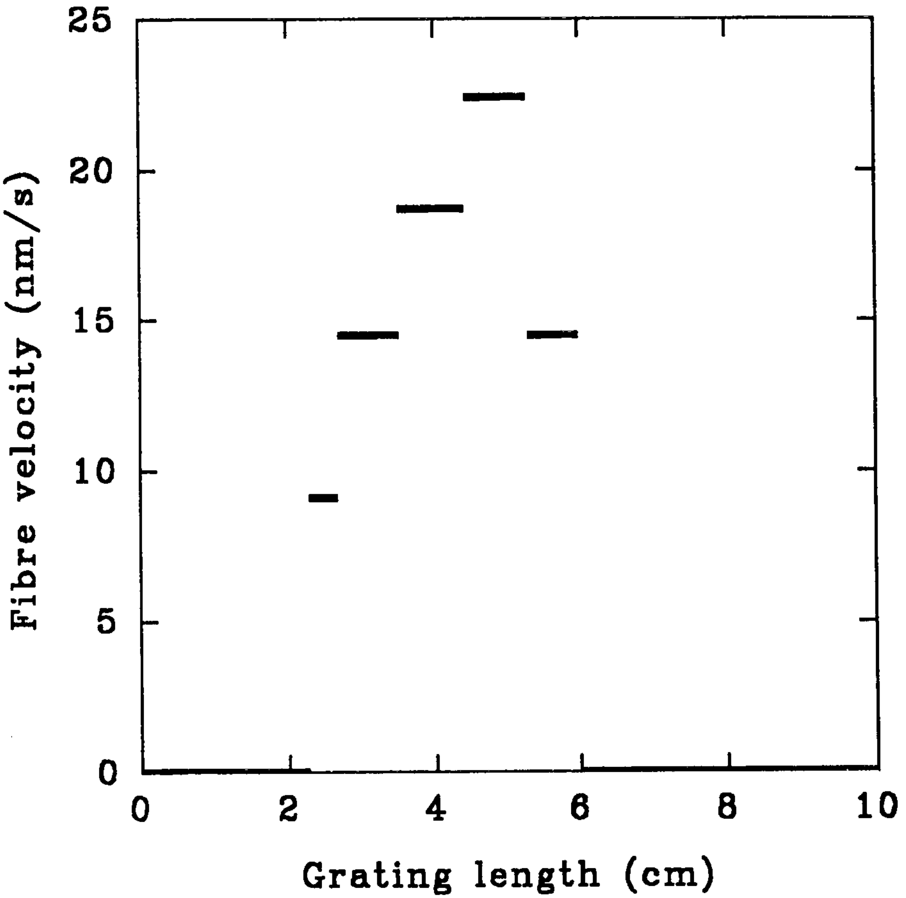

Fig. 3

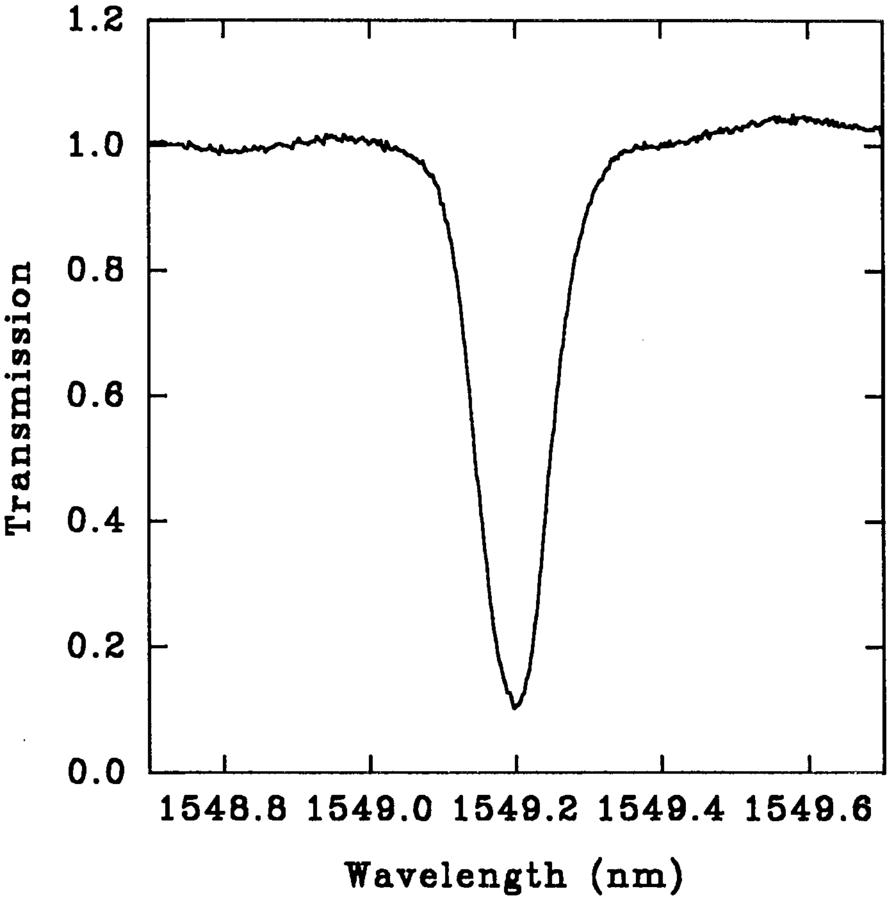
1.2
1.0
0.8
0.6
0.4
0.2
0.0
Transmission
1548.8
1549.0
1549.2
1549.4
1549.6
Wavelength (nm)

Fig 4