SINGLE PULSE BRAGG GRATINGS WRITTEN DURING FIBRE DRAWING

L. Dong, J.-L. Archambault, L. Reekie,
P. St. J. Russell and D. N. Payne

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For the first time the production of Bragg fibre gratings written by single excimer laser pulses as the fibre is being drawn is demonstrated. Reflectivities approaching 100% have been obtained, demonstrating the feasibility of online mass production.

Since the first demonstration of tranversely written photorefractive Bragg gratings in germania-doped silica optical fibres by Meltz *et al.* [1], much interest has been shown in these devices due to their numerous applications in the fields of fibre sensors, communications and lasers. Recently, there have been several advances in the field. Photoinduced refractive index changes of $\sim 10^{-3}$ have been demonstrated in standard telecommunications fibre [2]. Various techniques such as flame brushing [3], boron codoping [4] and hydrogenation of fibres [5] have been introduced to increase fibre photosensitivity, and index changes in excess of 10^{-2} have been observed [6]. Fibre gratings have also been written using only a single excimer laser pulse [7–9]. However, all of these techniques suffer from a severe drawback, namely that a section of fibre must be stripped of its UV-absorbing polymer coating in order for the grating to be exposed. This drastically weakens the fibre at the site of the grating due to surface contamination, even if the fibre is subsequently recoated. It is also not possible to mass produce fibre gratings in the same piece of fibre within a reasonable time scale, for example for use in a long quasidistributed fibre sensor. We demonstrate that it is possible to overcome both of these problems by writing the gratings during the fibre drawing process, just before the fibre is coated.

A line-narrowed KrF excimer laser (Lambda Physik EMG 150 MSC) with a beam size of $20 \times 5\ \text{mm}^2$ and pulse width of ~ 20 ns was used. This laser was situated in a different laboratory from the fibre drawing tower, so the UV beam was piped under the floor via eight mirrors along a 20 m beam path to the fibre (Fig. 1). Beam divergence over this path length was negligible. An interferometer similar to that described previously [8] was mounted directly on the fibre drawing tower between the fibre diameter monitor and the coating cup. The coating fluid, being a few centimetres below the point of writing, served to damp out lateral vibrations in the fibre. The beam was focused to a line $7 \times 0{\cdot}5\ \text{mm}^2$ using a single cylindrical lens. The position of the fibre did not alter visibly during the writing process. The drawing capstan was modified in order that the free end of the fibre could be spliced into the diagnostics, which consisted of a 1·55 μm pigtailed ELED, a 50 : 50 fibre coupler and an HP 71450A optical spectrum analyser. This allowed the grating production to be monitored online. The fibre was drawn at speeds ranging from 3 to 23 m/min to a diameter of 110 μm, resulting in an axial displacement of only 1 nm (at 3 m/min) during the 20 ns pulse duration. The fibre chosen for this experient had an NA of 0·3 and cutoff wavelength of 1100 nm.

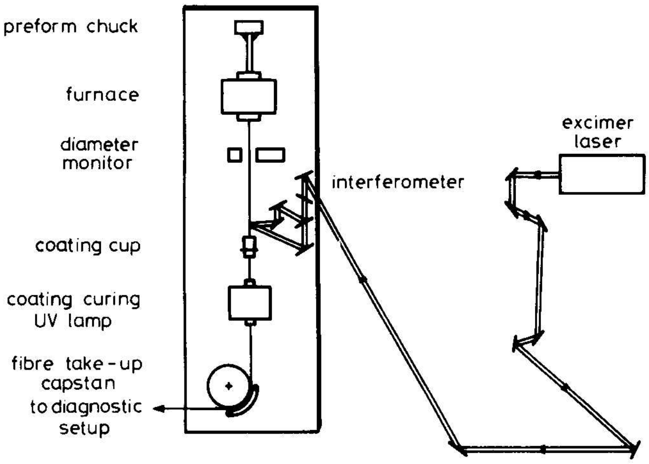

Fig. 1 *Layout of experiment, showing interferometer on drawing tower and path of beam from excimer laser*

Previously [9], we have reported the production of a new class of fibre grating, referred to as type II, which consists of a periodically modified core/cladding interface and can be formed using only a single high peak power optical pulse. Both these, and the conventional type I photorefractive gratings were written into the fibre as it was being drawn. The reflection spectra from three consecutively written type I gratings (pulse energy ~ 10 mJ) are shown in Fig. 2*a*. A reflectivity of $\sim 2\%$ was obtained, limited by the refractive index change which could be induced by a single excimer laser pulse. The centre wavelengths of the gratings vary by 0·2–0·3 nm, probably due to fluctuations in the pulling tension and/or core temperature. A temperature variation of only 30°C would account for the observed wavelength shift. It was possible to move the peaks apart, thus removing the wavelength degeneracy, by applying strain to the gratings offline; this is shown in Fig. 2*b*. There is a small variation in the amplitude of the pulses due to pulse-to-pulse energy fluctuations. It is worth noting that straining of the fibre could be carried out online by using a fibre proof tester after the drawing capstan, allowing the gratings to be individually monitored.

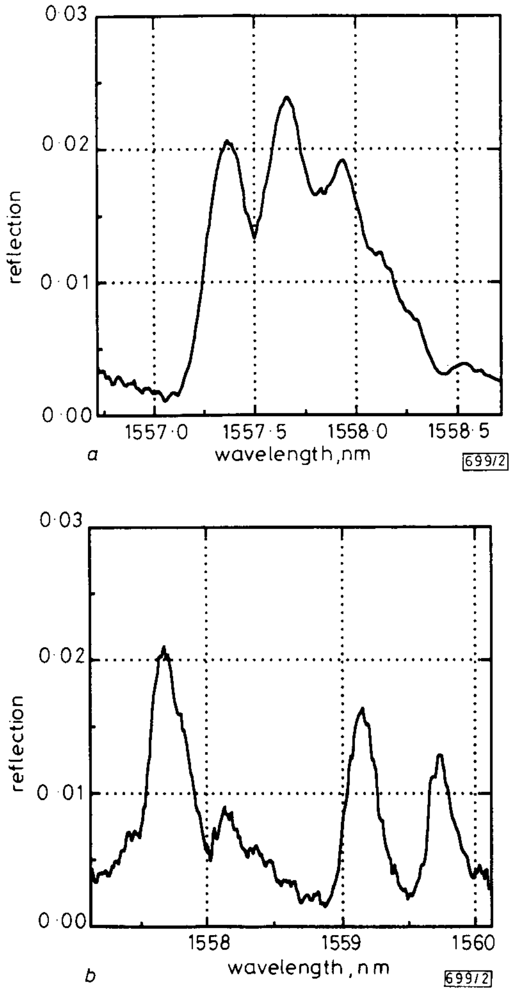

Fig. 2 *Reflection spectra of three consecutively written type I gratings, and spectra of gratings with strain applied*

a Reflection spectra: unstrained
b Reflection spectra: strain applied to each grating

By increasing the pulse energy to 40 mJ, it was possible to write type II gratings in the fibre, and the transmission spectrum of one such grating is shown in Fig. 3. The irregularities which were observed are due to the poor beam profile of the excimer laser, due in part to the long optical path length required in our setup. Transmission at the peak of the grating spectrum was measured to be <0·2%, limited by the noise floor of our diagnostics, and all of the type II gratings produced online had characteristics similar to those described in Reference 8. The induced background loss was measured to be ~0·5 dB at $\lambda = 1\cdot6\ \mu m$.

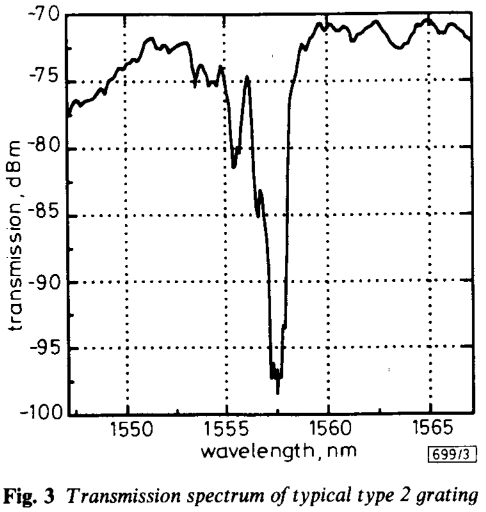

Fig. 3 *Transmission spectrum of typical type 2 grating*
Transmission at grating peak <0·2%

In conclusion, we have demonstrated that it is possible to write Bragg gratings into an optical fibre as it is being drawn from the preform and before it is coated. This overcomes the problem of having to strip the polymer coating from the fibre before writing the grating, thus weakening the fibre. Using this technique, it becomes feasible to write many type I gratings into long (~km) lengths of optical fibre for use in quasi-distributed fibre sensors. Reliable production of both type I and II gratings has been carried out. It should be possible to enhance the quality of the gratings by improving the beam profile of the writing laser.

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L. Dong, J.-L. Archambault, L. Reekie, P. St. J. Russell and D. N. Payne (*Optoelectronics Research Centre, University of Southampton, Southampton SO9 5NH, United Kingdom*)

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