Fibre Bragg gratings written through the coating

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Abstract

Fibre gratings can be written through the primary fibre coating using conventional UV exposure techniques. This leads to superior strength and yield and improved ease of manufacturing.

Introduction

Fibre Bragg gratings are widely used in the fields of optical fibre communication and fibre sensor systems. In the normal process of fibre grating fabrication, all coatings must be stripped off and the fibre cleaned thoroughly before the grating can be written and, in order to preserve the mechanical strength of the fibre, it must be re-coated soon after the grating is manufactured. This procedure is both time consuming and may reduce the fibre strength due to exposure of the bare fibre to air. Ideally, it would be possible to write the grating through the coating without having to remove it first.

To solve this problem, a number of solutions have been proposed. In [1], a fibre was coated with a UV-transparent polymer coating and gratings were written without removing this coating. Ideally, this would be the preferred solution, however the polymers which have been developed to date suffer from relatively high absorption at the shorter wavelengths where grating inscription is more efficient, limiting the quality of gratings which can be obtained [2]. To get round this problem, gratings have been written through the coating with 330nm light instead of at the more conventional wavelengths of 193/244/248nm [3]. A specially developed phase mask was required to work at this non-standard wavelength, together with an increased exposure time due to the reduced UV absorption of the fibre core. In addition, it was necessary to limit the laser fluence in order to minimise the risk of damage to the coating.

An alternative method involves in-line writing of the grating as the fibre is being drawn [4]. This technique is useful for the fabrication of large arrays or mass production of gratings, however a short pulse laser must be used in order to 'freeze' the motion of the fibre during the exposure, and the desired grating must be capable of being written with only a single laser pulse.

It is also possible to use a thermally strippable coating which can be removed locally prior to writing the grating, then reapplied immediately after inscription, possibly as part of an automated production line [5]. This method has the disadvantage of briefly exposing the fibre to atmosphere, while also requiring a coating which may not be sufficiently robust for certain sensor applications.

Silicone rubber may also be used to coat the fibre, and it is possible to find commercial varieties of this material which have high transparency at wavelengths above 220nm. This enables the use of KrF excimer (248nm) and frequency-doubled Ar^+-ion lasers (244nm) to write the gratings [6]. Silicone rubber has the additional advantage of being usable over a far wider temperature range than most conventional polymer coatings. However, it has the disadvantage that the refractive index is less than that of silica, so cladding modes are not stripped efficiently. As a demonstration, a boron co-doped silica/germania photosensitive fibre was coated with General Electric RTV615, a commercially available thermally curable silicone rubber which has been used to coat fibre in the past. This material has a high transmission of 92% at a wavelength of 248nm for a coating thickness of 150µm, however the fibre coating in this case had an average thickness of only 60µm. Grating inscription was initially carried out using a 248nm excimer laser and a 1540nm phase mask optimised for 248nm operation. A 1cm long grating was produced by scanning a 3mm wide beam over a section of the coated fibre, each individual part of the fibre receiving an exposure of 3 minutes at 20Hz. The individual pulse fluence was set at $64mJ/cm^2$. A grating with a reflectivity of 92% was obtained (see figure 1 – solid line), limited by the resolution of the optical spectrum analyser (approximately 0.1nm), which corresponds to an index change of 2.4×10^{-4}. For comparison, the coating was stripped off and the fibre exposed under identical conditions, and this grating is also shown in figure 1 (dotted line). The almost identical result suggests that the effect of writing through the coating is almost negligible.

In order to test for possible coating-induced thermal effects on grating uniformity, a 25mm long Blackmann apodised grating was written through the coating at 244nm using a frequency-doubled Ar^+-ion laser in a D_2-loaded sample of the same fibre, and the reflection characteristic of this result is shown in figure 2. The intensity in this case was 2.2kW/cm^2 with a total fluence of 1kJ/cm^2. It can be seen that most of the reflected light outside of the central peak is >30dB down on the peak reflectivity, indicating excellent grating uniformity and a grating quality well suited for wavelength-multiplexed sensor purposes. The index change obtained was 1.0×10^{-4}.

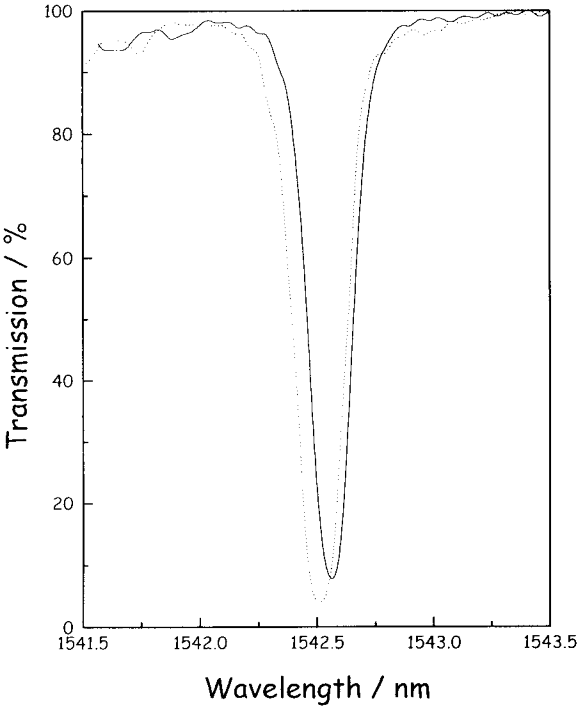

Figure 2: Transmission spectra of grating in Ge/B fibre, coated (solid) and un-coated (dotted)

To verify the heat resistance of the coating, a fibre with the silicone rubber coating together with a fibre coated with UV curable polymer was placed on a hot plate at a temperature of 300°C for 3 minutes. A visible darkening of the polymer was observed, however the effect on the silicone rubber coated fibre was negligible.

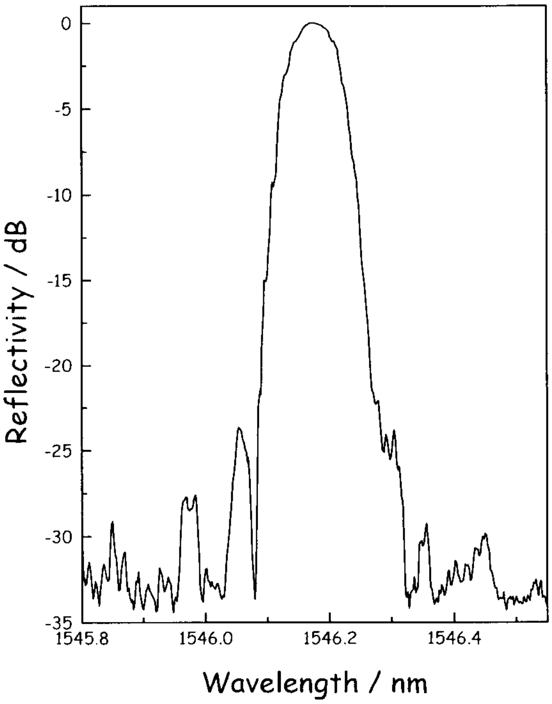

Figure 1: Reflection spectrum of Blackmann apodised grating written in coated fibre

Conclusions

Several techniques are available which can be used to produce more robust fibre gratings than was previously possible. These techniques have the additional benefits of allowing for automated mass production of fibre gratings and the fabrication of long arrays at lower cost. This will hasten the acceptance of fibre gratings in the sensor and telecomms sectors.

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