Superimposed multiple Bragg gratings

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The authors demonstrate the inscription of seven Bragg gratings at the same location on a photosensitive fibre. These superimposed Bragg gratings were written over a 60nm span in the region of 1530nm with reflectivities better than 45%. Effects due to the inscription of multiple gratings within the same location on the fibre such as wavelength shifting and linewidth narrowing are studied.

Introduction: Since the first demonstration of interferometrically written Bragg gratings in germania doped silica optical fibres [1], there has been a great deal of interest in these devices, mainly due to their potential applications in the fields of telecommunications and optical fibre sensors [2]. An area of Bragg grating research that has not been thoroughly investigated is the inscription of more than one grating at the same location on an optical fibre. This is of interest from both a fundamental and practical point of view. A device of this type can be very useful in fibre based communications, laser, and sensor systems. Because multiple Bragg gratings at the same location basically perform a comb function, this device is ideally suited for multiplexing and demultiplexing signals. The beauty of this novel device is that it does not require much space because all the gratings are written at the same location on the fibre. This lends itself well to optical integrated technology, where the issue of size is always a concern. This type of device can also be used for material detection where the multiple Bragg lines can be designed to match the signature frequencies of a given material. In this Letter, we report the writing of several Bragg gratings on the same location of a fibre that was first hydrogen loaded to enhance its photosensitivity. To our knowledge, this is the first demonstration of the fabrication of superimposed multiple Bragg gratings.

Experiment: A KrF excimer laser (Lumonics 600) was modified with intracavity air gap etalons to narrow its linewidth to ~0.4cm^{-1} [3]. The lasing wavelength as well as the linewidth were controlled by tilting the intracavity etalons with motor driven micrometers. An external etalon and a linear diode array provided continuous feedback for stabilisation of the linewidth and laser wavelength. This laser produced 12ns 30mJ pulses and has a rectangular beam shape of 10 x 0.6mm^2. The beam from the laser was directed into a interferometer where it was split into two equal-intensity beams and then recombined to produce an interference pattern along the fibre core. The interferometer was set for writing gratings at ~1550nm. In this experiment, an AT&T Accutether fibre was used. This fibre was first hydrogen loaded to enhance its photosensitivity. The fibre was placed in a fibre holder and remained in the same position throughout the experiment to ensure that all the gratings were written at the same location on the fibre. Care was taken to ensure that the intersecting beams from the interferometer formed the fringe pattern at exactly the same location on the fibre each time a grating was written. A light emitting diode (LED), a 2 x 2 coupler, and an optical spectrum analyser were used to monitor the formation of the Bragg grating in reflection. We limited the number of inscribed gratings to seven over a span of 60 nm only because our interrogating LED source had a limited bandwidth.

Results and discussion: Fig. 1 shows the reflectivity for seven Bragg gratings superimposed on the same area of the photosensitive fibre. The first grating was written at 1550.05nm and reached a reflectivity of 100% within 15s of UV exposure and had a linewidth of 0.25nm. After adjusting the interferometer to write at a different Bragg wavelength, the second grating was written at 1542.6nm with approximately the same characteristics. Each time a new grating was inscribed, the reflectivity of the existing gratings was reduced. Fig. 2 shows the Bragg grating reflectivities against the number of gratings written at the same location. As shown, even after superimposing five gratings, their reflectivities were higher than 60%. After superimposing seven gratings, all of the Bragg gratings maintained a reflectivity higher than 45%.

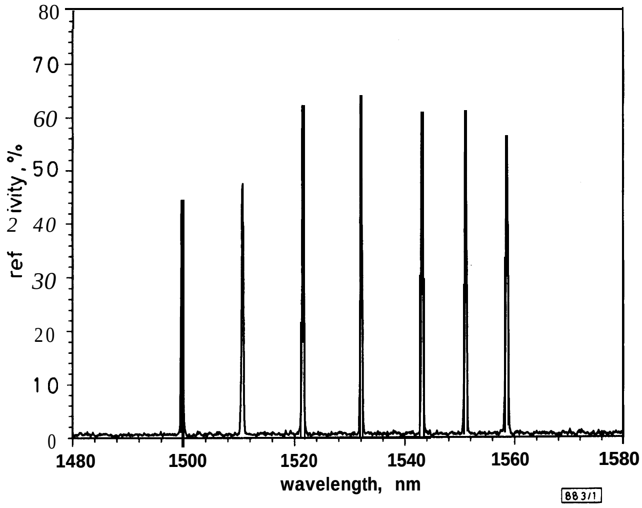

*Fig. 1 Superimposed multiple **Bragg** gratings at same location on photosensitive optical fibre*

Another interesting observation is that the centre wavelength of the existing Bragg gratings shifted to longer wavelengths each time a new grating was inscribed. For example the first grating started with a centre wavelength at 1550.05nm and shifted to 1550.975 nm by the time the last grating was inscribed (see Fig. 3). Considering the Bragg condition $\lambda_b = 2n_{eff}\Lambda$ (λ_b is the Bragg wavelength, A is the periodic grating spacing, and n_{eff} is the effective refractive index) which determines the reflected Bragg centre wavelength, it is clear that a change in the effective index of refraction is responsible for the wavelength shift. The shift in wavelength of the first grating after writing all seven gratings corresponds to an effective index of refraction increase of 0.86 x 10^{-3}.

Each time a new grating is superimposed onto the already existing gratings, the linewidths of the existing Bragg gratings are reduced. This effect is due to a change in the modulation depth of the refractive index perturbation of the grating, Δn. A general expression for the approximate full width half maximum bandwidth, $\Delta\lambda$, of a grating is given by [4]

$$\Delta\lambda = \lambda_b s \sqrt{\left(\frac{\Delta n}{2n_{eff}}\right)^2 + \left(\frac{1}{N}\right)^2} \quad (1)$$

where $s \simeq 1$ for strong gratings (near 100% reflection) and $s \simeq 5$ for weak gratings, and N is the number of grating planes. As shown in eqn. 1, a change in An and n_{eff} will result in a change of the linewidth. Because the change in the effective refractive index

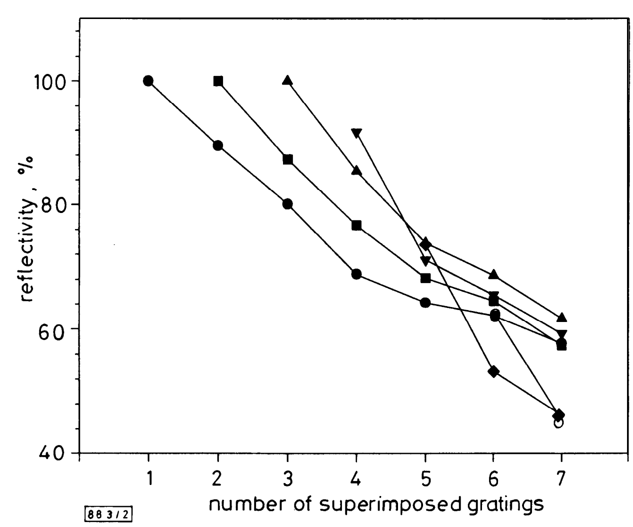

*Fig. 2 **Reflectivities** for each of Bragg gratings as function of number of gratings superimposed on same location*

The lines through the symbols are only guides to track the reflectivity changes

Bragg grating number

—●— 1 —▼— 4
—■— 2 —◆— 5
- A - 3 —O— 6

is small, the main contribution to the linewidth reduction is attributed to the change in the modulation depth of the refractive index perturbation. The calculated linewidth change can be obtained from a simple differentiation of the above equation with respect to An. For the first grating, a reflectivity reduction from -100% when it was first inscribed to -58% after the last grating was superimposed, corresponds to a change in modulation depth of refractive index, $d(\Delta n)$, of 0.2 x 10^{-3}. This gave a calculated linewidth reduction of 0.057nm which agrees with the observed linewidth reduction of 0.06nm as shown in Fig. 3.

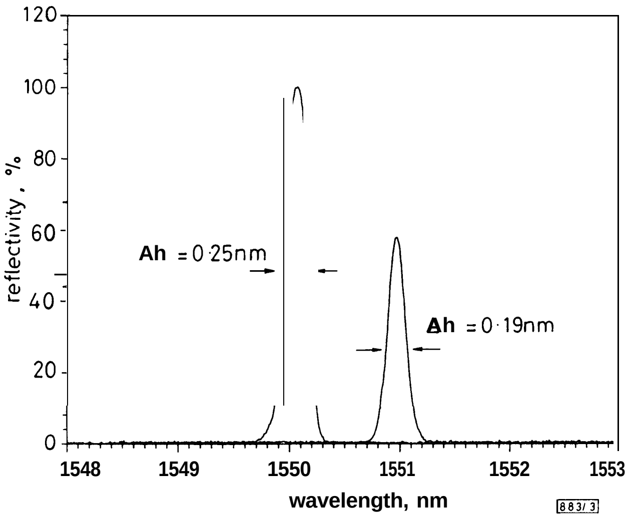

Fig. 3 *Reflection spectrum of first Bragg grating inscribed*

The first peak shows the spectrum of the grating as it was first formed (-100% reflection) and the second peak shows the same grating after all seven gratings were superimposed (-58% reflectivity). This figure clearly illustrates the changes in reflectivity, Bragg centre wavelength, and linewidth.

Conclusions: We have demonstrated the writing of several Bragg gratings superimposed at the same location of a photosensitive fibre. Each time a new grating is introduced, the already existing gratings shift to longer wavelengths and their reflectivities and linewidths are reduced. These effects are attributed to changes in the mode effective index of refraction and the modulation depth of refractive index perturbation.

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