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High Reflectivity Fibre Gratings Written by a Single Excimer Laser Pulse

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Abstract

We report fibre Bragg gratings with up to 65% reflectivity and bandwidths as small as 6 GHz written by a single 20 ns excimer laser pulse. Our results show that ~100% reflectivity single-pulse fibre gratings should soon be produced.

Side-written fibre gratings are usually produced by exposing a fibre core to two interfering ultraviolet light beams for several minutes [1]. Recently, fibre gratings written holographically by a single 20 ns excimer laser pulse at 248 nm have been demonstrated [2]. With this extremely short exposure time, it should now be possible to write quickly and economically long sequences of Bragg reflectors in a fibre as it is being drawn from its preform. In Ref. [2], the highest grating reflectivity obtained from a single pulse was 2% and the reflection bandwidth was about 50 GHz (0.1 nm at 766 nm), corresponding to a grating length of 2 mm. As many practical applications require fibre gratings with higher reflectivity and narrower bandwidth, our effort was in writing stronger and longer single-pulse gratings. So far, we have obtained single-pulse gratings with as much as 65% reflectivity, index changes in excess of 10^{-3} and bandwidths of 6 GHz (0.05 nm at 1550 nm) for lengths of up to 15 mm.

The KrF excimer laser used in this experiment (Lambda Physik EMG-150) fires 20 ns, 0.1 J pulses and has a rectangular beam profile, 20 mm wide and 5 mm high. Our writing interferometer (Fig. 1) was used in two configurations: (a) and (b). In (a), two cylindrical lenses were placed before the beamsplitter and in (b) a single lens was used close to the fibre.

In both cases, the beams were focused onto the fibre core in one dimension only, preserving the 20 mm width. The gratings presented here were written in coating-stripped silica fibre with germanium- and boron-doped core. Gratings were also obtained in Ce^{3+}-doped fibres [3]. The gratings were characterised by coupling the output of an LED into the fibre and measuring the reflected light in an optical spectrum analyser through a 3 dB coupler.

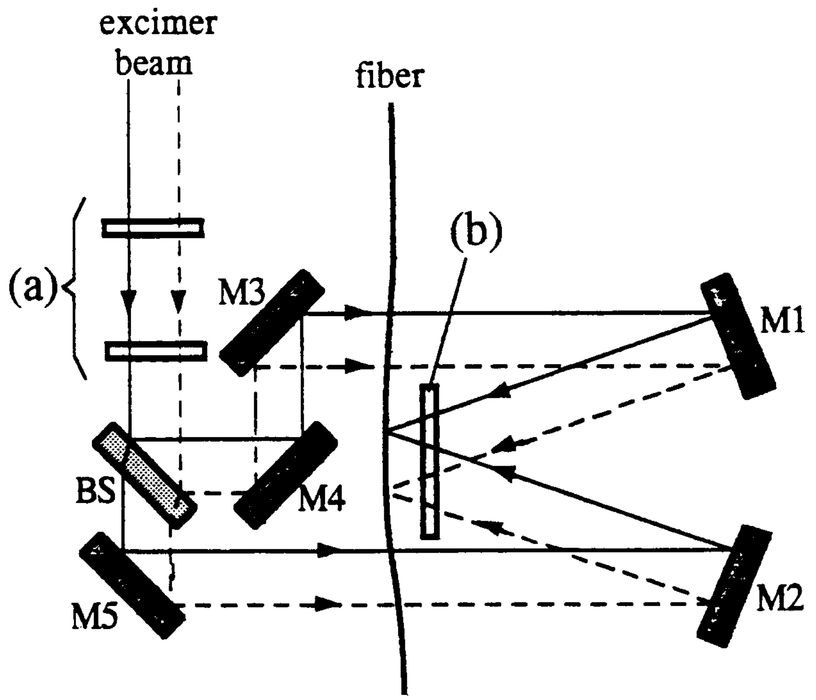

Fig. 1 Grating writing interferometer. Cylindrical lenses are used in either (a) or (b) to focus the two beams onto the fibre.

Arrangement (a) had the advantage that the lenses affected the two interfering beams equally; however, the beam spotsize in the focal plane was large (a few hundred microns). The highest single-pulse grating reflectivity obtained using (a) was 15%. A typical reflection spectrum is shown in Fig. 2. With (a), the grating bandwidths were invariably smaller than 0.15 nm (resolution of our spectrum analyser). Using a single-mode laser diode and temperature-tuning the grating while monitoring the transmission, we measured a bandwidth of ~0.05 nm (6 GHz), corresponding to an effective grating length of ~15 mm and maximum index modulation of 3×10^{-5}. Successive single-pulse gratings written under the same conditions were very repeatable, which allowed us to compare the photosensitivity of several fibre specimens [3].

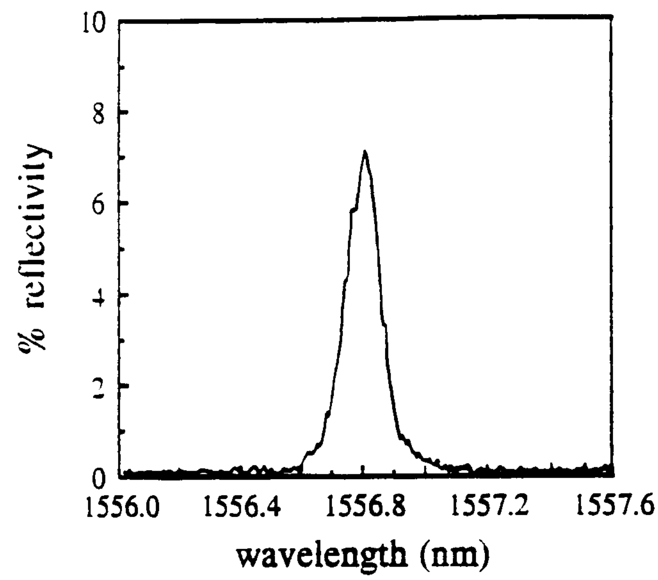

Fig. 2 Reflection spectrum of a typical single-pulse grating obtained with the lenses as in figure 1(a). The actual bandwidth is about 0.05 nm, smaller than the 0.15 nm resolution our spectrum analyser.

With arrangement (b), the size of the focused beam was much smaller and we could increase the amount of energy absorbed by the core. We were limited only by the damage threshold of the fibre. Thus, we were able to produce very large index changes ($>10^{-3}$) and reflectivities of up to 65%. The reflection spectra of these single-pulse gratings were very broad, between 0.3 and 2 nm, and often multi-peaked (Fig. 3), indicative of non-uniform gratings. This non-uniformity was probably caused by lens aberrations which were distorting the phase fronts of the two beams unevenly. A 15 mm long uniform grating with similar index modulation would reflect almost 100% of the incident light at the Bragg condition.

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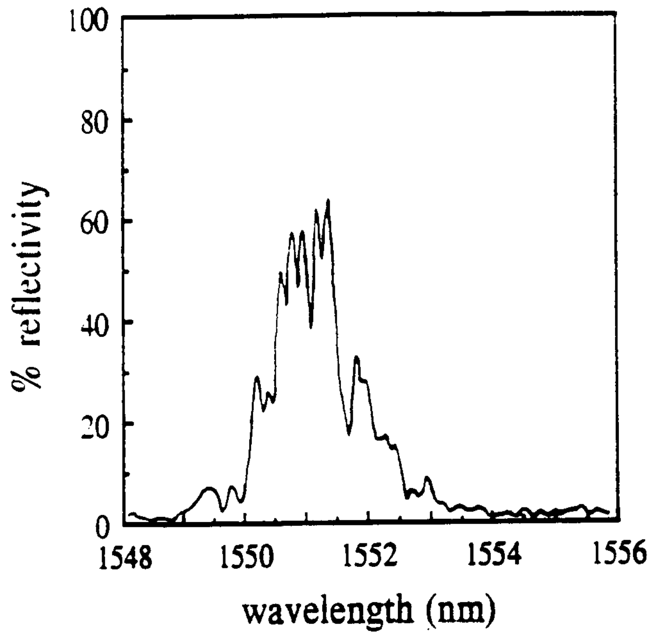

Fig. 3 Reflection spectrum of a high reflectivity single-pulse grating obtained with a single lens as in figure 1(b).

In summary, we have produced long, uniform gratings with up to 15% reflectivity and broadband gratings with very large index modulations and up to 65% reflectivity, each written by a single pulse from a 248 nm KrF excimer laser. Our results clearly show that ~100% reflectivity single-pulse fibre gratings should soon be obtained, since both long gratings and large index modulations can been achieved.

References

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3. L. Dong, J.-L. Archambault, L. Reekie, P.St.-J. Russell and D.N. Payne, "Bragg gratings in Ce^{3+}-doped fibres written by a single excimer pulse", submitted to OFC, San Jose (Jan. 1993).