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CHIRPED FIBRE BRAGG GRATINGS FABRICATED USING ETCHED TAPERS

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Abstract: We have demonstrated a technique which is capable of controllably producing fibre Bragg gratings with arbitrary chirp profiles using etched tapers. Gratings with 4.8 nm linear chirp have been produced. Nonlinearly chirped gratings have also been demonstrated.

Background: There has been a surge of interest in photosensitive fibre Bragg gratings, chiefly due to their ease of fabrication and numerous applications. The strong dispersion of a chirped fibre Bragg grating has been used to compensate for dispersion in an optical fibre link and for optical pulse shaping. Such gratings can also be used as broad band reflectors in fibre and semiconductor lasers.

Many techniques have been demonstrated to make chirped gratings [1-6]. A chirp can be introduced either during or after a grating is written. Although very large chirps have been demonstrated [1], there are usually many difficulties in obtaining a controllable chirp. For dispersion compensation and pulse shaping, gratings with a relatively small chirp of several nanometres but very well defined chirp profile are required. So far, the techniques using a chirped phase mask [2], a cantilever [3,4], a temperature gradient and an etched taper [5,6] have been able to give good chirp control. The phase-mask technique can, however, only give a stepped chirp profiles and lacks tunability after the grating has been made. The cantilever technique offers tunability but is polarisation-sensitive. It is alos very difficult to obtain chirp much more than 1 nm using the temperature gradient technique.

The newly demonstrated technique using etched tapers [5,6] is capable of controllably producing gratings with any chirp profile and is polarisation-insensitive. Both the chirp and the central wavelength of the grating are widely tunable. This is very useful in applications where gratings have to be tuned to the parameters of a particular system. The technique is also easy to implement. We have demonstrated linearly chirped fibre gratings with up to 4.8 nm bandwidth and also gratings with nonlinear chirps. Such linearly chirped gratings are ideal for use in dispersion compensation in an optical fibre link and optical pulse shaping.

Experiment: A taper is first made on the outer cladding of a section of photosensitive optical fibre by differential etching along the length of the fibre. The small end of the taper usually has a diameter between 50 μm to 100 μm. The etching rate is linear with time, therefore any desired taper profile can be produced by controlling the movement of the beaker. Two buffer oils were used both under (trichloroethylene) and above (decahydronaphtalene + 10% dichlorotoluene) the HF solution, therefore only the part of the fibre in contact with the HF solution was etched. This was necessary to obtain good fibre diameter control at the two ends of the taper and to protect the rest of the fibre from being etched. The fibre core is not affected by the process and the fibre strength is not significantly affected.

A grating is then written over the taper in the conventional manner with either zero (method A) or some applied tension (method B) on the fibre. Tension will create a strain gradient along the length of the taper because the local strain is inversely proportional to the local fibre cross-sectional area. In method A, this strain gradient is used to introduce a chirp after a grating is written over the taper. In method B where a tension is applied during writing, the strain gradient introduces a chirp due to the index gradient from the stress-optic effect, but the grating pitch remains uniform during writing. When the tension is released after writing, the chirp from the stress-optic effect disappears with the strain gradient but another chirp develops as different parts of the taper relax differently. The chirped grating can be used strain-free. A larger chirp can be achieved in method B than in method A for the same applied tension. This is because, in method A, the chirp from fibre lengthening (the main effect) has an opposite sign to the chirp from the stress-optic effect and this results in a smaller chirp than in method B where only the lengthening effect plays a part. Although no tension is required in the final device when using method B, tension on the fibre can be used to tune the central wavelength and chirp bandwidth if desired. The final device is easy to package and the process for making the taper can be easily modified for batch production.

A taper length of 25 mm was used in our experiment and the grating length was ~19 mm, slightly less than that of the taper to ensure that the grating was entirely within the taper. Fig.1 shows a good fit between the measured taper profile (dots) and the design (solid line) to give a linearly chirped grating. The fibre was loaded with H_2 at room temperature. A grating was written on this taper with a phase mask while a tension of 94 g was applied to the fibre. Fig. 2 gives the reflection spectra of the grating when different tension was applied after writing. The peak reflectivity of the grating was very close to 100%. The chirp bandwidth was ~2.5 nm when all tension was released. Fig.3 shows the time delay measurement in another grating using a technique described in [7]. The grating has a chirp of ~1.4 nm. The time delay shows good linearity and a slope of -170 ps/nm. We have achieved linearly chirped gratings with bandwidth as large as 4.8 nm using a stronger taper. By introducing a step in the middle of a taper similar to that in fig.1, we have also demonstrated band-pass filters [6].

Conclusions: We have demonstrated a simple and flexible technique capable of accurately producing fibre Bragg gratings with arbitrary profiles. Linearly chirped gratings with bandwidths up to 4.8 nm have been made to demonstrate the controllability of the technique. Unlike techniques which use a temperature gradient, no active control is required in the final device. The strength of the fibre is not significantly affected by the tapering.

References:

1. M.C. Farries, K. Sudgen, D.C.J. Reid, I. Bennion, A. Molony and M.J. Goodwin: "Very broad reflection bandwidth (44 nm) chirped fibre gratings and narrow bandpass filters produced by the use of an amplitude mask", Elect. Lett., vol.30, 891(1994).
2. R. Kashyap, P.F. McKee, R.J. Campbell and D.L. Williams: "Novel method of producing all fibre photoinduced chirped gratings", Elect. Lett., vol.30, 996(1994).
3. D. Garethe, W.S. Lee, R.E. Epworth, T. Bricheno, and C.P. Chew:"Practical dispersion equaliser based on fibre gratings with a bit rate length product of 1.6 Tbits/s.Km", the Proc. of ECOC '94, vol.4, 11(1994).
4. M. Le Blanc, S.Y. Huang, M.M. Ohn and R.M. Measures: "Tunable chirping of a fibre Bragg grating using a tapered cantilever bed", Elect. Lett., vol.30, 2163(1994).
5. M.A. Putnam, G.M. Williams and E.J. Friebele: "Fabrication of tapered, strain-gradient chirped fibre Bragg gratings", Elect. Lett., vol.31, 309(1995).
6. L. Dong, J.L. Cruz, L. Reekie and J.A. Tucknott: "Fabrication of chirped gratings using etched tapers", submitted to Electronic Letters.
7. S. Barcelos, M.N. Zervas, R.I. Laming and D.N. Payne: "Interferometeric fibre grating characterisation", Proc. IEE Colloquium on Fibre Gratings and their Applications, London, Jan. 1995.

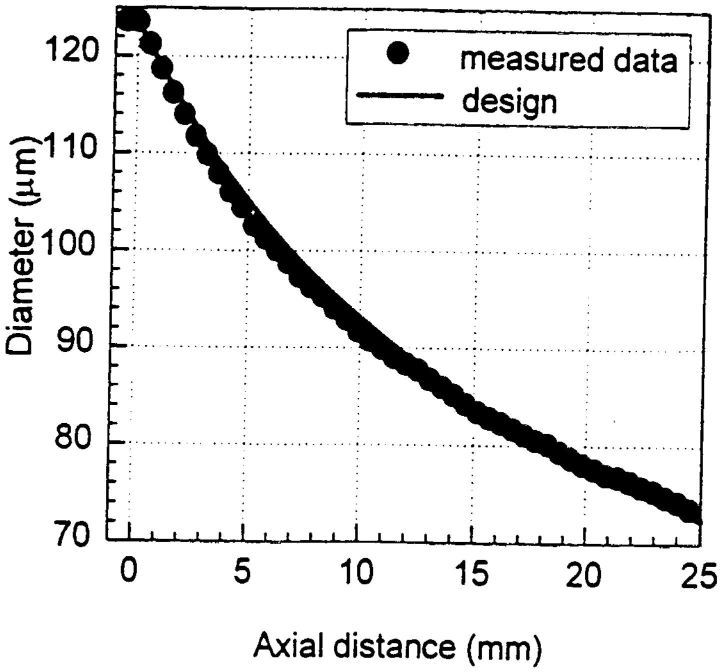

Fig.1 The measured taper profile (dots) and the design (solid line) for a linearly chirped grating are plotted for comparison.

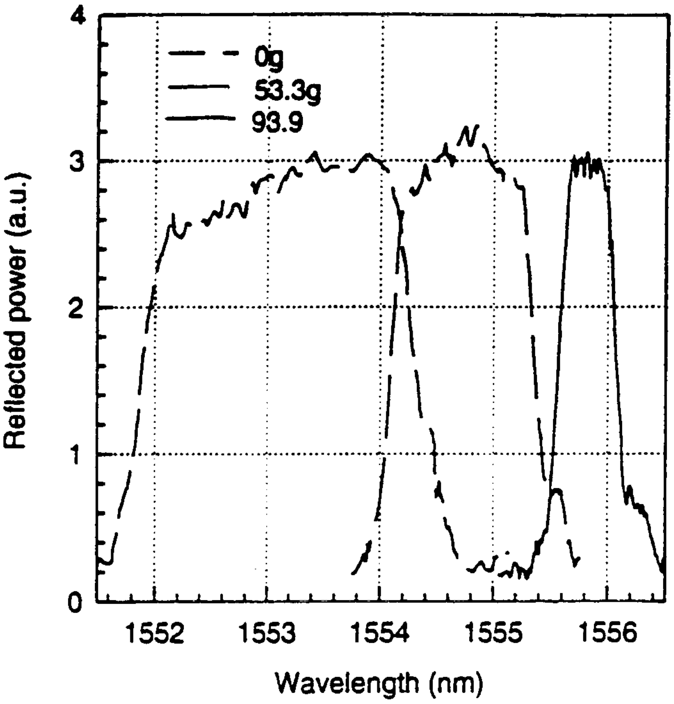

Fig.2 The reflection spectra are from a grating fabricated with 93.9 g of tension applied to the fibre during writing (method B). The fibre was hydrogenated. The different curves show the reflection spectra with different applied tension.

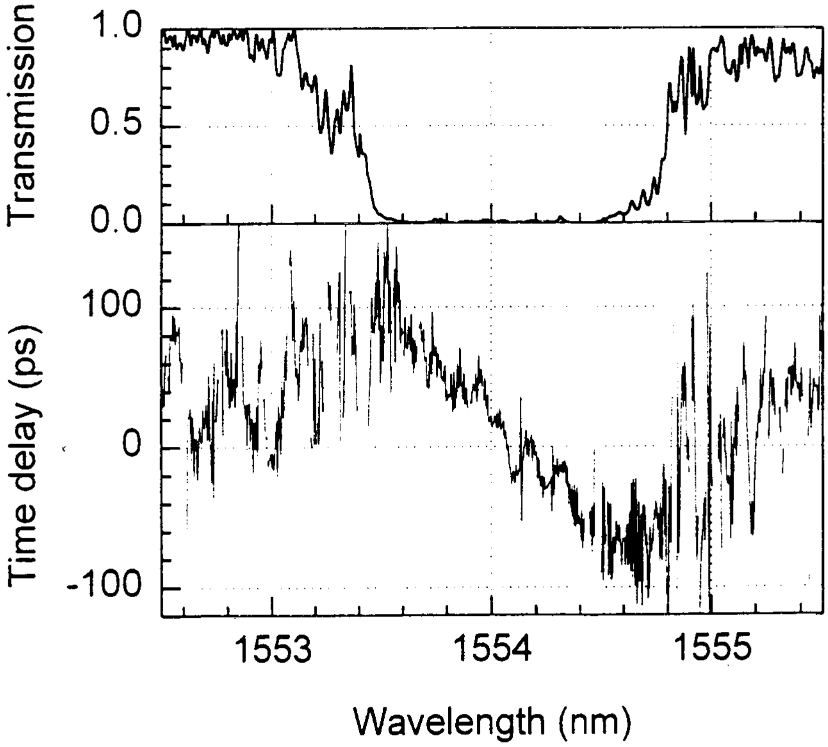

Fig.3 Dispersion measurement in a linearly chirped grating.