transverse tolerances at 1dB loss of their peak efficiencies are estimated to be ±2.2, ±4.5 and ±5.5μm for the fibres with radii of 100, 135 and 160μm, respectively. All of the tolerances are greater than those without the aid of the LPFG. It is noted that such tolerances are also greater than obtained using butt-coupling, which typically has a transverse tolerance of ~ ±1.8μm at 1dB loss [5]. The coupling efficiency depends on several parameters including the magnitude of the transmission loss of the LPFG, the wavelength difference between the laser and LPFG, and the separation between the lens and the LPFG and lens radius, which is currently under study for optimisation. To the first-order calculation, it is found that the separation between the lens and the LPFG plays an important role for obtaining optimal efficiency. An experimental technique for identifying the exact location of the LPFG is therefore required.

Conclusion: We have demonstrated a new scheme for optically coupling singlemode fibres by utilising a lensed fibre and an LPFG. This coupling scheme has several unique features. First, over a range of long working distances, > 50% coupling efficiency with large transverse tolerance can be obtained, which is helpful in the packaging process as well as in reducing optical back reflection. Secondly, the use of a lens with a relatively large radius may relax the stringent requirements on the fabrication process as compared to that for conventional lensed fibres, which generally have small radii. Other applications for this new coupling scheme are also expected, for example, in the coupling of output light from a laser diode to a singlemode fibre.

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Suppression of cladding mode coupling in Bragg gratings using GeO2-B2O3 codoped photosensitive cladding optical fibre


A new type of photosensitive optical fibre codoped with GeO2-B2O3 in both the core and cladding has been fabricated for applications in Bragg gratings. Coupling of the fundamental core mode into the cladding modes was suppressed with a narrow 3dB bandwidth in the Bragg grating. An increase in photosensitivity was also achieved by using high reflectivity Bragg gratings imprinted without the need for any hydrogen treatment.

Photoinduced fibre Bragg gratings (FBGs) have received consistent attention in areas of application such as narrowband reflection filters, add-drop filters, dispersion compensators and sensors [1].

In a high reflectivity grating, however, a wide loss band due to cladding mode coupling restricts the use of FBGs particularly dense wavelength division multiplexing (WDM) systems. Coupling from the forward-propagating fundamental core mode into a cladding backward-propagating cladding modes has been attributed to non-uniform effective index modulation over the fibre cross-section and the inherent asymmetry of the biased FBGs resulting in significant losses below the Bragg wavelength [2].

Various optical fibre designs have been proposed to reduce cladding mode coupling [3–5]. In particular, in terms of uniform index modulation, it has been proposed that the photosensitive area be extended into the inner cladding region by codoping with GeO2 and F [3]. This approach is of interest because two profiles, the refractive index profile and photosensitivity profile, can be designed separately such that the guiding properties of the fundamental core modes are determined by the refractive index profile while the overlap integral between the core mode a cladding modes is determined by the photosensitivity profile.

Among various silica based glass hosts, silica codoped with B2O3 with GeO2 has been reported to have enhanced photosensitivity by an order of magnitude [6]. However only a few applications of this glass composition in FGBs have been reported.

In the work described in this Letter, uniform index modulation over the inner cladding region has been achieved by utilising highly photosensitive GeO2-B2O3 codoped silica glass, leading to a new type of photosensitive optical fibre for FBGs in WDM devices. The fibre was designed to suppress cladding mode coupling as well as to enhance the photosensitivity by adjusting the content of the GeO2 and B2O3 concentration both in the core and cladding regions, which is reported for the first time, to the best of our knowledge.

The preform was made by a modified chemical vapour deposition process using BCl3 and GeCl4 as precursors of their oxides. The structure of the preform is shown in Fig. 1. The core doped with 7mol% GeO2 and 20.13mol% B2O3. The inner cladding was doped with 1.25 mol % GeO2 and 5.8mol% B2O3. Ni that the inner cladding diameter to core diameter ratio was kept to 4 to increase the photosensitive area. The total index difference was set to 0.294%, similar to that of conventional singlemode fibre, to reduce the splicing loss. The optical fibre was drawn from the preform with LP1 mode cutoff at 900nm.

Without any hydrogen treatment, a Bragg grating was formed in the fibre by irradiating it with 248nm KrF laser at 165mJ pulse, at a pulse repetition rate of 20Hz over a phase mask. The transmission spectrum of the imprinted Bragg grating is shown in Fig. 2. To utilise the Bragg reflection filter in dense WDM systems, both narrow bandwidth and high reflectivity are required as well. The maximum cladding mode coupling loss was achieved at 3dBm wavelength of 990nm. In conventional hydrogen treated FBG teres, post-annealing is necessary to stabilise the spectral response. The intrinsic high photosensitivity of the fibre in this study allowed the need for not only the hydrogen loading process but irmination of the FBGs but also the post-annealing process.
High-order fractal characterisation of sea-scattered signals and detection of sea-surface targets

D. Gan and Z. Shouhung

A novel method for identifying radar targets and clutter is presented. Instead of the traditional fractal dimension, the lacunarity, which is a high-order fractal feature, is used in this method. The formula for lacunarity in additive noise is also given. The experiments show that higher detection accuracy can be obtained by using the lacunarity feature than by using the fractal dimension.

Introduction: Much effort has recently been devoted to the analysis of radar signals by fractal geometry. Blackledge [1] used the fractal dimension for the segmentation of SAR images. Lo et al. [2] used the fractal dimension to characterise sea scattered radar signals and for the detection of sea surface targets. It has been found, however, that use of the fractal dimension alone does not provide sufficient information to enable targets and clutter to be identified correctly, especially when the signal-to-noise ratio (SNR) is small. Mandelbrot [3] introduced the term lacunarity to describe the characteristic of fractals which have the same dimension but different appearances or textures.

The definition of lacunarity is

$$\Lambda(L) = E \left[ \left( \frac{M(L)}{E[M(L)]} - 1 \right)^2 \right]$$

(1)

where $M(L)$ is the mass of the fractal set at scale $L$, and $E[M(L)]$ is the expected mass. This represents a measure of the discrepancy between the actual mass and the expected mass. As a high-order fractal feature, lacunarity has successfully been used in the analysis and classification of medical imagery [4], and texture of images of all kinds [5]. In this Letter, we introduce it to the field of radar signal analysis and use it to detect sea surface targets.

Theory and analysis: Sea clutter is a typical kind of fractal noise, so studying the lacunarity feature in additive fractal noise is necessary and important. To this end, we have developed the following theorem:

Theorem: Assume $x_1, x_2$ are two independent fractal signals. At scale $L$, the lacunarity of $x_1$ and $x_2$ are $\Lambda_1(L)$ and $\Lambda_2(L)$, respectively. Let $y = x_1 + x_2$, at scale $L$, the lacunarity of $y$ is $\Lambda_3(L)$. We then have the following relation:

$$\Lambda_3(L) < \max\{\Lambda_2(L), \Lambda_1(L)\}$$

(2)

Proof of theorem:

Let $a = E(M_1(L))$, $b = E(M_2(L))$.

$$\Lambda_3(L) = E \left[ \left( \frac{M_3(L)}{E[M_3(L)]} - 1 \right)^2 \right]
< \max\{\Lambda_1(L), \Lambda_2(L)\}$$

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