21C3-4

Single-Mode Fibre Grating Written into Sagnac Loop Using Photosensitive Fibre: Transmission Filters

D.P. Hand and P.St.J. Russell

Optical Fibre Group,
Department of Electronics and Computer Science,
University of Southampton,
Southampton SO9 5NH, U.K.

INTRODUCTION

Fibre-based narrow band filters are of great importance in wavelength division multiplexing. Although narrow band reflection filters have been reported[1,2] using in-fibre distributed grating reflectors, no experimental reports have been published so far of transmission filters.

An idea for a transmission filter was raised two years ago by Hill and co-workers, who postulated[3] that a Sagnac loop would function as a very narrow-band transmission filter if a distributed Bragg reflector could be introduced into the loop. Such a distributed reflector could be written if a photosensitive single-mode fibre were available that would permit holographic writing of a grating into its photosensitive core, perhaps via interference of the in-loop counter-propagating Sagnac modes. Hill and co-workers were unable to verify their prediction experimentally due to the unavailability of photosensitive single-mode fibre - essential for fabrication of low-loss 3dB fused taper couplers.

In this paper we report the first observation of photosensitivity in single-mode germanosilicate optical fibre (all previous reports have been in multi-mode fibre), and the first experimental realisation of a narrow-band transmission filter using a Sagnac loop.

EXPERIMENTAL PROCEDURE

A high germania (15 mol% GeO_2) fibre (numerical aperture 0.26, core diameter 0.76 μm, cut-off 420 nm), single-mode at 488 nm, was fabricated. Related studies of nonlinear transmission in such fibres[4] show that they exhibit substantial colour-centre related photosensitivity at blue/green wavelengths. Hence we thought it probable that they would be suitable for investigating in-fibre holographic grating formation at 488 nm.

After preliminary experiments had indicated that the fibre was indeed photosensitive, we formed a 0.85 m Sagnac loop by fabricating a 3 dB fused taper coupler. This was placed in a thermally isolated enclosure, and light from a Ar^+ laser oscillating single-frequency at 488 nm was launched into it (see Figure 1). An acousto-optical Bragg cell was used to isolate the laser from the strong Sagnac reflection. Initially (Figure 2a) the power level was kept very low, and the Sagnac loop perturbed using a small electrical heater. As expected of a Sagnac interferometer, there was no change in the transmitted or reflected powers, which remained at ~0% and ~100% respectively independent of the heating level.

The heater was then switched off, and the fibre left to reach thermal equilibrium. The laser power was then raised to ~5 mW (11 $mW/\mu m^2$ in-core intensity), and the transmitted and reflected powers monitored; again there was no perceptible change with time over 10 minutes of exposure.

However, upon reducing the optical power to ~1μW (2.2 $\mu W/\mu m^2$ in-core) and switching on the heater, the transmitted power level cycled strongly up and down as the temperature increased, slowing down as thermal equilibrium was approached (Figure 2b). Cooling had the expected reverse effect (Figure 2c). This indicates that the loop had become highly sensitive to environmental disturbance, and shows that a grating of substantial reflectivity had formed in it, destroying the Sagnac's insensitivity to perturbation.

DISCUSSION

Assuming the grating to be formed everywhere inside the loop, the bandwidth of the transmission filter may be estimated to be of the order of $\lambda^2 n/2L$ where L is the loop length, n the mode index and λ the vacuum wavelength. For the 0.85 m loop in experiment, this yields a pass-band of width ~2×10^{-4} nm or ~240

MHz. It seems likely that colour-centre formation via the trapping of electrons at Ge-related sites in the glass matrix[4] causes the observed photosensitivity; the mobile electrons are themselves supplied by breakage (through two-photon absorption) of oxygen-deficient Ge-Si bonds.

CONCLUSIONS

Holographic grating formation has been reported for the first time in photosensitive germanosilicate single-mode fibres. An experimental narrow-band Bragg transmission filter based on a Sagnac loop with an estimated bandwidth of 240 MHz has been realised.

ACKNOWLEDGEMENTS

We thank L.J. Poyntz-Wright for fabricating the fibre used in the experiments, and T. Birks for advice on making the fused taper couplers. D.P. Hand is supported by a grant from the U.K. Science and Engineering Research Council.

REFERENCES

1. B.S. Kawasaki, K.O. Hill, D.C. Johnson and Y. Fujii, Opt. Lett., 3 (66-68) 1978.

2. J. Stone, J.Appl.Phys., 62 (4371-4374) 1987.

3. K.O. Hill, D.C. Johnson, F. Bilodeau and S. Faucher, Electron, Lett., 23 (465-466) 1987.

4. L.J. Poyntz-Wright, M.E. Fermann and P.St.J. Russell, Opt. Lett., 13 (1023-1025) 1988.

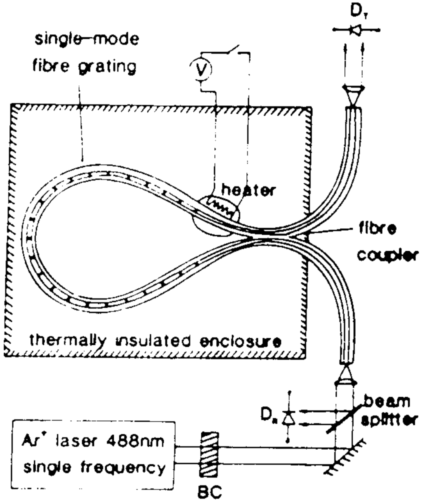

Figure 1

Experimental arrangement. A Bragg cell (BC) isolates the laser from the Sagnac loop, and the reflected and transmitted powers are monitored using diodes D_R and D_T.

Figure 2

Transmitted and reflected powers with time during heating (a)&(b) and cooling (c) a small section of fibre in the loop, close to the fused coupler. (a) is the behaviour before 10 min exposure to 5 mW at 488 nm, and (b)&(c) is the behaviour after exposure. The high sensitivity after exposure is due to the formation of a grating in the loop. The feature at A was caused by drift of the fibre launch and subsequent adjustment.