Four channel fibre grating demultiplexer

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The authors demonstrate a four channel all-fibre demultiplexer based on a 1x4 fused fibre coupler followed by strong fibre grating passband filters.

With the success of erbium fibre amplifiers there is increased interest in wavelength division multiplexed (WDM) optical communications systems. One of the most difficult devices to manufacture to the tight tolerances required for dense WDM applications is the demultiplexer (DEMUX). For example, a recent proposal to the International Telecommunication Union calls for channel spacings based on multiples of 100 GHz (~8A at 1.55um). Here we demonstrate a simple four channel all fibre DEMUX which can meet such requirements.

The concept for the DEMUX, illustrated in Fig. 1, is to use a single commercial fused fibre 1x4 splitter followed by a fibre grating transmission filter in each of its output ports. The filters are designed to pass one signal wavelength at each port, while rejecting the three adjacent signal channels. With the recent introduction of low temperature hydrogen loading [1], it is now possible to make high bandwidth grating reflectors. Low loss grating reflectors with 10nm bandwidths have been reported [2]. By pairing gratings which do not overlap in wavelength, we have made a simple bandpass transmission filter in which each of the two gratings rejects a broad range of wavelengths, but the desired transmission wavelength passes unaltered between the grating stopbands. The use of a Gaussian spatial profile grating eliminates the spectral sidelobes that might otherwise interfere with the signal transmission. Previous workers have demonstrated fibre grating transmission [3] and channel dropping filters [4] which require a four port coupler for each filter. Although the channel dropping filter approach avoids the insertion loss of our 1x4 splitter, neither filter has the excellent passband and crosstalk characteristics reported below.

The basic concept illustrated in Fig. 1 is simple, yet many subtleties exist, necessitating careful grating design and fibre optimisation. For example, high resolution measurements [5] reveal that strong Gaussian profile fibre gratings generally exhibit a pronounced fine structure within their stopbands, which would render the filter 'leaky'. This structure is a consequence of the non-uniform increase in the average refractive index of the fibre core, which follows from writing the grating with a UV laser beam having a Gaussian-like spatial profile. The local Bragg wavelength, which is proportional to the local effective index, is therefore longer in the centre of the grating than at the wings. The wings then act as a Fabry-Perot resonator, with deep resonances that modulate the reflection spectrum of the Bragg grating on the short wavelength side of the grating stopband. To eliminate this problem the gratings were written with a strong linear chirp. An extrin-
A device was assembled and packaged with access through ST connectorised jacketed fibre cables. A high resolution measurement (0.2Å step size) of one channel of the packaged device is shown in Fig. 2. The 1.4dB insertion loss includes the gratings, the splitter, the splices, and the connectors. Wavelengths which conform to the proposed international standard, based on a 100GHz (-16A) channel spacing, are indicated by solid dots. The horizontal line on each dot indicates 8Å, and suggest that a similar filter could be made for a DEMUX based on 100GHz channel spacings. The peak attenuation of the filter in the stopband region has been measured to be in excess of 80dB, with calculations indicating an even substantially greater true attenuation. (The apparent 35dB peak attenuation of Fig. 2 is an artifact resulting from ASE noise from the tunable semiconductor laser used in making the high resolution measurements). This high attenuation results in unparalleled crossstalk performance. Particularly attractive is the flat transmission band of the grating filter for each desired signal wavelength. The broad passband is also close to the ideal width for this channel spacing. When coupled with the small temperature sensitivity of the fibre grating Bragg wavelengths (-1Å shift per 8°C of temperature variation), this could eliminate the need for temperature stabilisation. Further, there is no significant polarisation dependence to these filters as the fibre gratings are highly isotropic [8]. Another advantage is ease of packaging, as the filters were readily spliced to the fused fibre splitter, eliminating tricky fibre alignment issues. The splice losses averaged 0.3dB each, with a significant reduction possible after filter optimisation.

Two concerns for this DEMUX design immediately suggest themselves. First, the splitter loss is unavoidable in this design. However, optically amplified systems generally have a post-system amplifier with sufficient margin to compensate for the splitter loss, without introducing any significant performance degradation. Secondly, the filters back reflect the light from unwanted channels. This apparent disadvantage is in practice not significant because a post-system amplifier invariably has an optical isolator at its output, which eliminates DEMUX return loss as an issue.

In conclusion, we have developed a first generation all-fibre four channel demultiplexer. The device is polarisation insensitive, has a flat passband, unparalleled crossstalk performance, and offers total fibre compatibility (ease of packaging).

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References


Polarisation referencing in refractometry using fibre to planar waveguide couplers incorporating thin metal layers

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The wavelength response of fibre to metal clad planar waveguide couplers has been investigated as a function of superstrate index. The TE resonance wavelengths remain fixed with superstrate index variation while the TM resonance position demonstrates good superstrate index sensitivity. Such a technique may be used for polarisation referencing and temperature compensation in refractometry.

Introduction: Fibre to planar waveguide couplers have attracted considerable interest for use as wavelength selective elements [1,2] (bandstop filters), modulators [3] and switches [4]. The attraction lies in the 'continuous fibre' structure which is free from fibre to device interfacing problems, giving advantages of low loss, low back reflections and excellent mechanical reliability. The basic wavelength response of these devices is that of a periodic resonant bandstop filter as individual high-order modes of the planar waveguide overlay are successively tuned with wavelength in and out of resonance with the fibre mode. At the resonance wavelengths, phase-matched coupling of power to the overlay occurs and the power transmitted to the output fibre drops to a minimum. The wavelength positions of the resonance maxima are highly sensitive to the refractive index of any material in contact with the top surface of the overlay (i.e. the superstrate index) and this phenomenon has been investigated for refractometry [5]. Owing to waveguide (and/or material birefringence) in the planar overlay, overlay positions and their sensitivity to superstrate index are polarisation dependent, with the transverse electric (TE) and transverse magnetic (TM) states in the overlay demonstrating marked differences. Indeed, this observation has been suggested as a means of achieving temperature compensation and self-referencing and it was proposed that the incorporation of metal layers into the structure may enhance the polarisation diversity via surface plasmon interactions with the TM mode.

In this Letter we report the experimental investigation of a polarisation referencing technique in refractometry, based on a fibre to planar waveguide coupler incorporating a thin metal layer (<10nm thick) vacuum deposited onto the top surface of the overlay waveguide (Fig. 1). The interaction of light propagating in singlemode optical fibre with surface plasmon polaritons in thin metal films has been well characterised in previous work on the development of optical fibre polarisers [6]. Indeed, from this work it is well known that TM polarisation fields strongly interact with and, under resonance conditions, couple to the lossy symmetric surface plasmon polariton in thin metal layers (<10nm thick) bound by material of index greater than the fibre index on one side and less than the fibre index on the other. On the other hand little or no interaction is observed for the TE field [6]. It was proposed that, for the structure investigated here (Fig. 1), the TM polarisation state, under resonance conditions, will couple to the metal clad dielectric waveguide and penetrate the metal layer via surface plasmon excitation to interact with the superstrate. Hence TM resonance will demonstrate sensitivity to the superstrate index. The TE field will couple to the metal clad dielectric