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Novel High Performance All-fibre Optical Add/Drop Multiplexer Based on a Selective Fused Coupler and a Single Fibre Bragg Grating

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Wavelength-division-multiplexing (WDM) systems is the key technology for the next generation high speed optical fibre systems. Technologies for routing on a channel to channel basis in such systems are under intensive research. All-fibre channel add/drop filters with low insertion loss are required. The dominant approach is a device based on two Bragg gratings in the arms of two concatenated 3 dB fused fibre couplers [1]. The position of the two identical gratings has to be accurately controlled to provide in-phase reflection in the two arms of each coupler. This interferometric set-up requires path-length trimming during device fabrication and the correct optical phase needs to be maintained during the device lifetime.

In this paper, we report the demonstration of a novel method for an all-fibre add/drop device based on a selective twin-core coupler and a single Bragg grating. The technique is non-interferometric, and therefore no balancing of the optical path length by trimming is required. In addition, the grating and the fused coupler are completely de-coupled and can be made separately. Apart from a specially designed twin-core (TC) fibre, the selective fused coupler and Bragg grating are based on well developed technologies. Due to the fact that the grating is potentially written in a normal fibre as for other Bragg gratings, all the well developed techniques, e.g. compression tuning [2], apodisation and chirping, can be readily used to achieve all-fibre tunable add/drop filters and filters with special designed transmission or dispersion characteristics. Another important characteristic of this technique is that it allows multiple gratings at different wavelengths to be written to achieve dropping of a group of channels. This is useful, especially for demultiplexing a large number of channels.

The selective coupler is essentially a fused coupler made on a conventional coupler rig with a mismatched TC fibre and a single core (SC) fibre with standard telecommunication specifications. Light launched into the SC fibre is completely coupled into the high NA core, with no coupling into the low NA core of the TC fibre. Light in the low NA core of the TC fibre essentially goes through the TC/SC coupler without any coupling with a typical loss of ~0.2 dB. The characteristics of a coupler are plotted in fig.1. We have demonstrated over 99% coupling between the high NA core of the TC fibre and the SC fibre with insertion loss as low as 0.04 dB, although 0.2 dB is more typical. We have also demonstrated excellent repeatability of the process using a standard fused coupler set-up with no effort for any special angular alignment.

A schematic of an add/drop filter is shown in fig.2. In an optimised design, the low NA core of the TC fibre is placed in the centre of the fibre and has the same dimension and NA as the SC fibre to ease splicing with another SC fibre, while the high NA core is doped with non-photosensitive dopants. This is important for reducing back-reflection in this core. Two TC/SC couplers in series are used. Multiple channels are fed in via port 2 and coupled to the high NA core of the TC fibre before the grating. The grating reflects the dropped channel into the low NA core of the TC fibre, heading back to the coupler. The dropped channel will eventually emerge from port 1. The remaining channels will go through the second coupler to emerge at port 4. An added channel can be fed in from port 3 and will be reflected by the same grating to join the transmitted channels at port 4. With ~0.2 dB insertion loss in the coupled and uncoupled path in each coupler, and negligible grating loss, insertion loss as low as 0.4 dB is expected for the dropped and transmitted channels. If a simple add or drop function is required, only half of the configuration in figure 2 is needed.

The TC fibre has a high NA and low NA core with respective effective modal refractive indices of n_1 and n_2. The grating has a pitch of Λ. For light in core 1, the Bragg wavelength is represented as $\lambda_1=2n_1\Lambda$. This back-reflection is substantially suppressed when this core is non-photosensitive. At $\lambda_0=(n_1+n_2)\Lambda$, the grating vector phase-matches the mode in one core with the counter-propagating mode in the other core, and the light in core 1 is reflection-coupled into core 2. This cross-reflection from one core to another is reciprocal. For light in core 2, the Bragg wavelength is represented as $\lambda_2=2n_2\Lambda$, where light is reflected back in the same core.

In implementation, the characteristics of the two cores of the TC fibre are 0.14 NA and 3.3 µm radius and 0.22 NA and 2.1 µm radius. The TC fibre has a centre-to-centre core separation of 7 µm. All the fibres that we used for this work have a nominal cladding diameter of 125 µm. The low NA core of the TC fibre was made of boron co-doped germanosilicate to achieve a high photosensitivity in the core. The high NA core was made of phosphorous co-doped germanosilicate to reduce the photosensitivity of the core. This composition does not render the core completely non-photosensitive at a grating writing wavelength of 193 nm, producing a larger than expected back-reflection in this core. In future fibre, this core can be made completely germania free to ensure the total absence of photosensitivity. The grating writing is done with an ArF excimer system and phasemask. No hydrogen treatment was necessary.

The device performance when the SC fibre (port 2) is illuminated is shown in fig.3. The peak at λ_0=1554.25 nm is the cross-reflection peak. The light at this wavelength emerges in core 2 at port 1 with an insertion loss of ~1.1 dB of which 0.7 dB is from the imperfect coupler (85%) and 0.4 dB is from the double passes through the coupler. This cross reflection is well over 99.9% and gives better than 30 dB isolation between the drop and the add channels. The peak at λ_1=1555.75 nm is the Bragg reflection peak in core 1. This light is reflected back to port 2. The peaks at the shorter wavelength side of the cross - reflection in the transmission is from coupling to cladding modes, this can also be improved by further improvement of fibre design. To simulate the add function, core 2 at port 1 is illuminated, and the performance of this function is shown in fig.4. Again the peak at λ_0=1554.25 nm is the cross-reflection peak. This light comes out of port 2. The insertion loss for this added channel is ~1.1 dB the same as the dropped channel. The transmission loss at λ_2=1552.75 nm is due to the Bragg reflection in this core.

We have demonstrated a high performance all-fibre add/drop multiplexer based on a selective fused coupler and a fibre Bragg grating. A low insertion loss of ~1.1 dB has been was demonstrated with a potential to be as low as ~0.4 dB. Better than 30 dB isolation is also achieved between the dropped and added channels. The method is noninterferometric, and therefore does not need critical alignment or trimming.

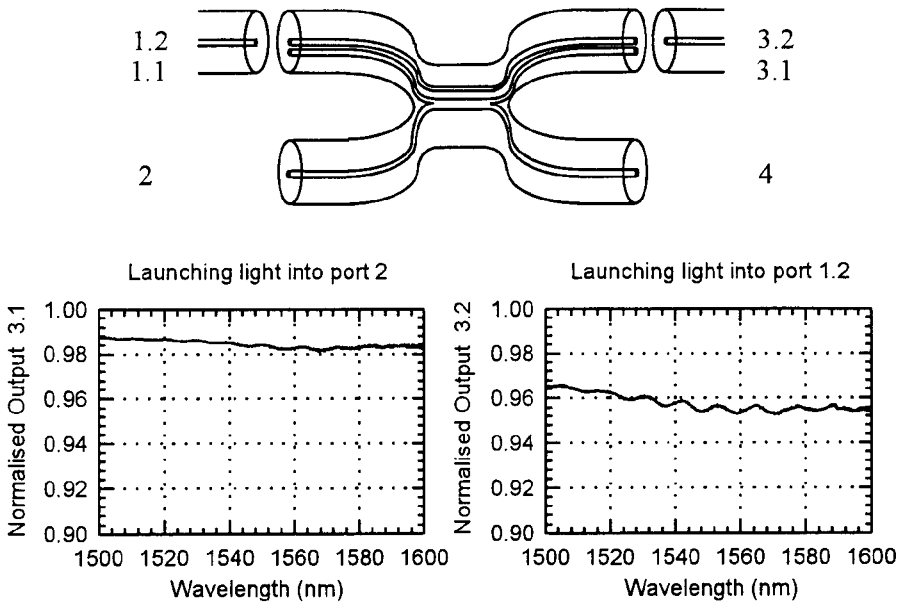

Fig.1 Performance of a typical selective coupler.

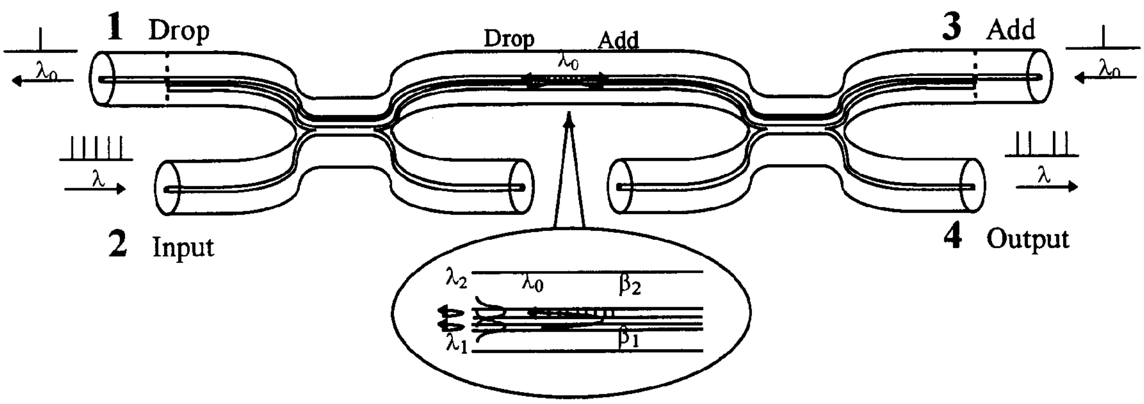

Fig.2 (a)The configuration of an add/drop multiplexer.
(b) Illustration of the grating in a TC fibre.

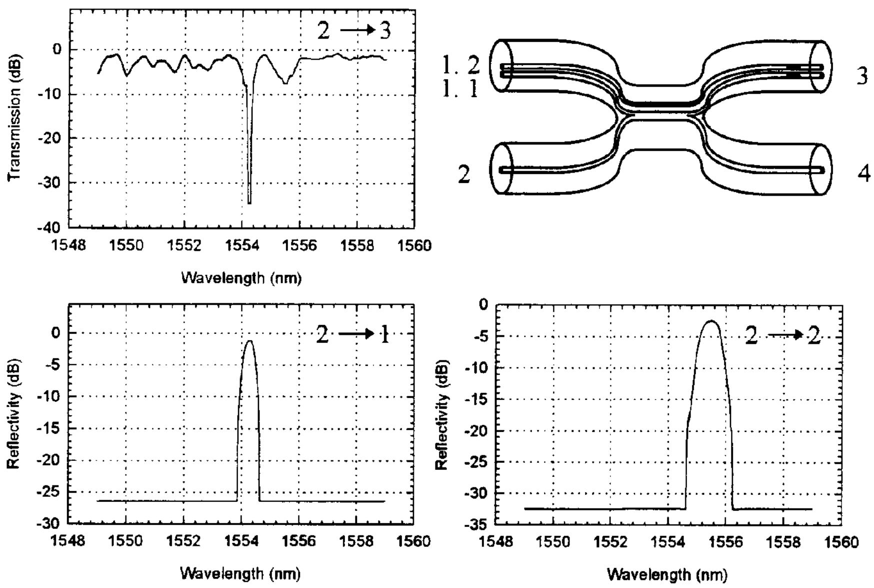

Fig.3 The performance of the implementation device when port 2 is illuminated.

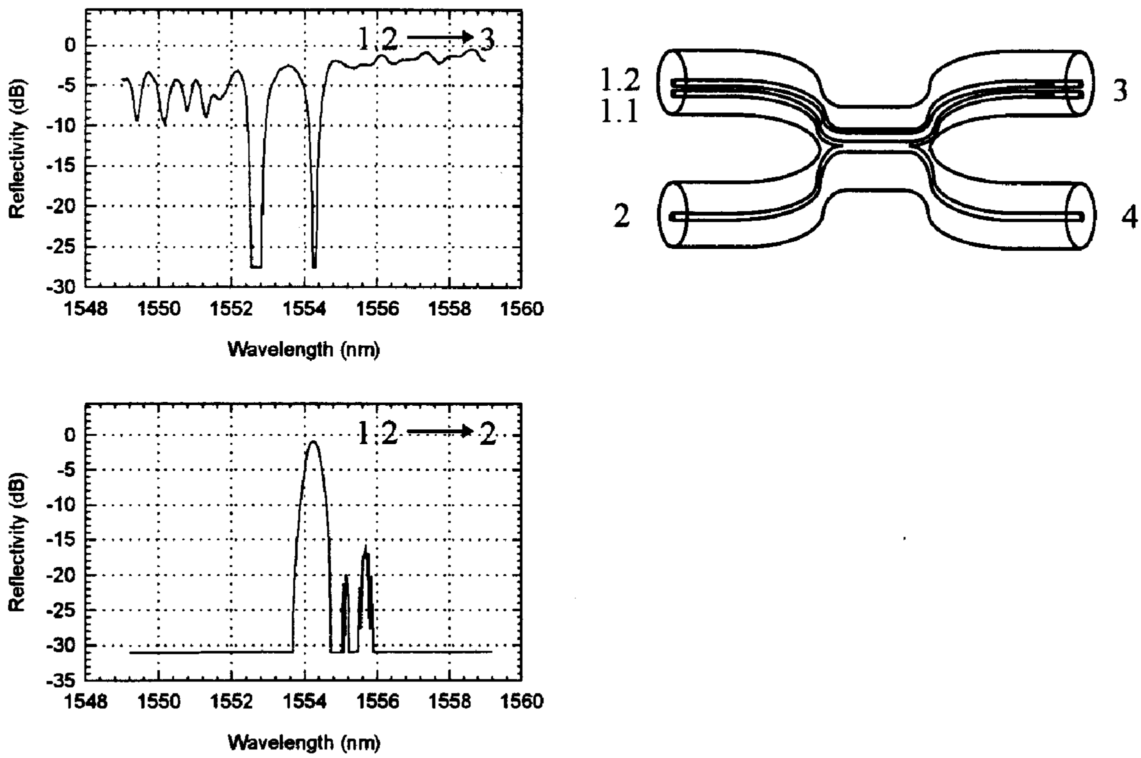

Fig.4 The performance of the device when core 2 at port 1 is illuminated.

References:

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[2] G.A. Ball and W.W. Morey, Optics Letters, 19, 1994, pp.1979-1981.