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HIGHLY TUNABLE MISMATCHED TWIN-CORE FIBRE FILTERS

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Abstract: We demonstrated a reproducible and accurate way for adjusting wavelength of mismatched twin-core filters over few hundred nanometres from the same fibre design. The wavelength control together with strength control by fibre length adjustment allows complex filter profiles to be implemented by cascading. These filters are highly stable to changes in temperature and strain.

Introduction

There are many applications of optical fibre filters in optical fibre systems e.g. filtering of amplified spontaneous emision after an erbium-doped fibre amplifier (EDFA) and loss filtering for gain-equalisation in an EDFA. All-fibre band-pass/stop filters based on mismatched twin-core (MTC) fibres designed to phase-match at the filtering wavelength were proposed and demonstrated some time ago [1,2,3]. In this paper, we demonstrate a highly reproducible and accurate way of tuning the filter wavelength of a MTC filter by reducing the fibre diameter on a fused coupler rig. The technique allows the filter wavelength to be accurately positioned at any wavelength over a few hundred nanometre wavelength range. We also present the strength-tuning of these filters by adjusting length of the twin-core fibre. An important advantage of this type of filters, especially over long period and Bragg gratings is its extremely low temperature and strain sensitivity, which allows easy packaging. The temperature sensitivity is ≈0.26 nm/100°C and strain sensitivity ≈$7.8 \cdot 10^{-3}$ nm/mStrain at 1.55 μm [4].

Characteristics and Tuning

In a mismatched twin-core fibre with cores with respective propagation constants β_1 and β_2, the mismatching between the cores is usually sufficient large to suppress any intrinsic coupling between them when the phase-matching condition is not met. Twin-core fibres can be designed to achieve phase-matching at a certain wavelength, where the two propagation constants are equal. The coupling only happens over a very small wavelength range. When light is launched into one core of the TC fibre, total coupling from one core to another happens at the phase-matching wavelength λ_C after a coupling length L_C, characteristics of the fibre. From codirectional mode-coupling theory, if the initial power is $P_0 = 1$, the power in the two cores P_1 and P_2 are, respectively:

$$P_1 = 1 - F^2 sin^2(Cz/F), \quad P_2 = F^2 sin^2(Cz/F)$$

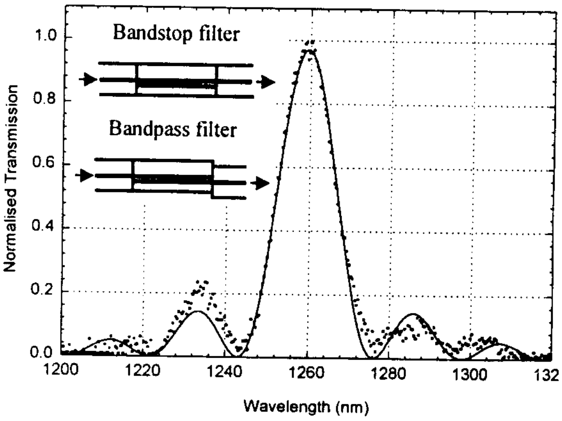
where C is the coupling coefficient, $L_C = \pi F/2C$ and F is defined by:

$$F = \frac{1}{\sqrt{1 + \frac{(\beta_1 - \beta_2)^2}{4C^2}}}$$

Bandpass and bandstop filters can be implemented by taking light out of the respective cores. The fibre we used was designed to have one of the cores placed in the centre to facilitate splicing with a standard telecommunication (ST) fibre. At one end, the central core of the TC fibre is spliced to the ST fibre in order to launch the light, and at the other end, one of the two cores is spliced to other ST fibre to achieve either bandstop or bandpass filter (fig. 1, inset).

A measured spectral response of a bandpass filter centred at 1259.6 nm with the theoretical fit is shown in fig.1. The TC fibre length is ≈ 1.8 cm. In this case, the FWHM bandwidth is ≈17.7 nm. The good fit shows the high spectral quality of the mismatched TC fibre filters.

Figure 1: Measured bandpass filter response and theoretical fit



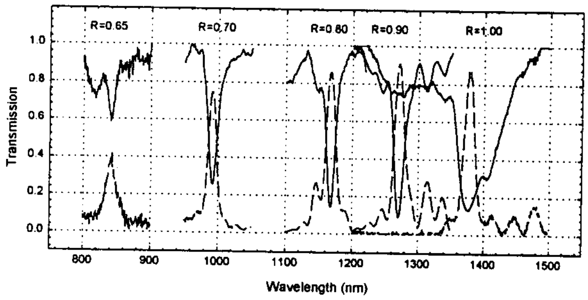
When the MTC fibre diameter is reduced from a_0 to $a = Ra_0$, it is easy to calculate the new coupling wavelength λ'_0,

$$\lambda'_0 = R\lambda_0$$

For the MTC fibre we used, the filter wavelength of the original fibre is at 1.394 μm. The fibre has a diameter of 125 μm. The diameter reduction of the MTC fibre is accurately achieved on a laboratory coupler rig with a oxygen-butane burner and a computer controlled linear translation stage. During the reduction process, the burner traverses to and fro over a distance of up to 7 cm at a speed of 5 mm/s. The translation stage stretches the fibre at a rate of 0.05 mm/s. The process is stopped once the the required elongation is reached to give a desired reduction ratio. Only the central part of the reduced fibre of guaranteed uniformity is used.

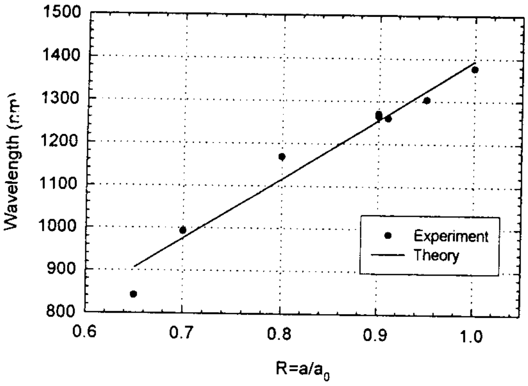
Responses at different R's are plotted in fig.2. A tuning range of at least 500 nm is easily achievable, where the upper limit is set by the coupling wavelength of the original fibre, but can be made to be ≈1.6 μm by fibre design. The non-ideal filter response at the upper wavelength limit is due to high OH absorption in this fibre at 1.4 μm. We did not attempt to make a device with coupling wavelength below 800 nm, because of the low sensitivity of our measurement set-up at those wavelengths. The tuning curve is given in fig. 3 along the theoretical prediction.

Figure 2: Filter characteristic at various reduction ratio



To demonstrate tuning of the filter strength by choosing appropiate length of the TC fibre, responses of filters with different TC fibres lengths are shown in fig. 4. The bandwidth of the filter becomes narrower as the TC fibre length increases as expected. With a length of 19 mm, more than 22 dB rejection was measured, more than 30 dB bandstop filter was achieved in another device.

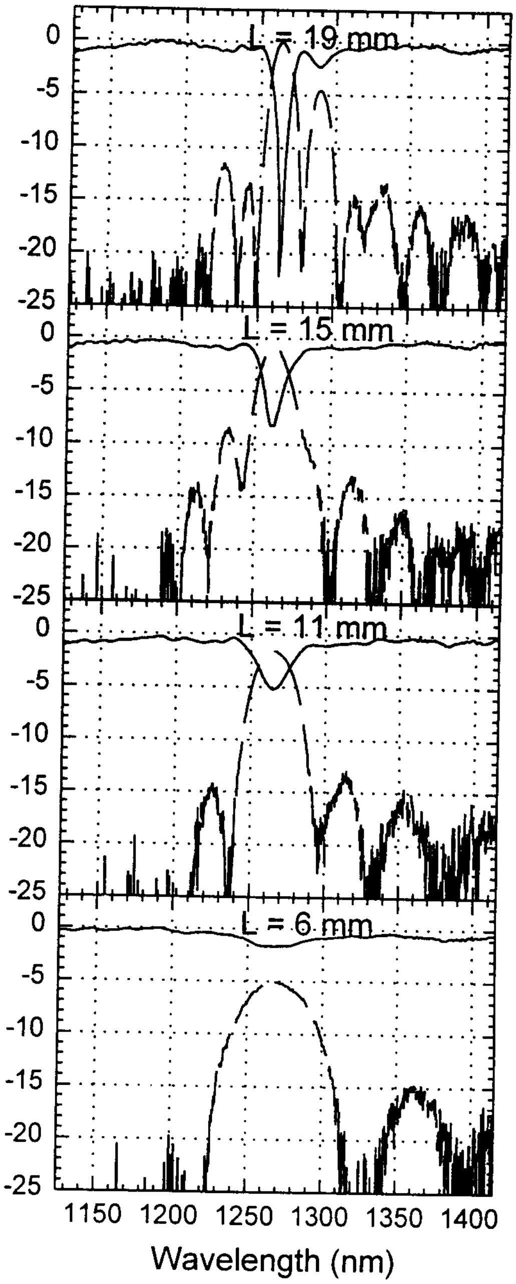
Figure 3: Tuning curve of the MTC fibre



Conclusion

We have demonstrated a novel reproducible and accurate way of tuning the coupling wavelength of a mismatched twin-core fibre filter. Low loss, high quality, highly stable, all-fibre bandpass or bandstop filter can be implemented at any desired wavelength over a range of few hundred nanometres from the same fibre. A 500 nm range is demonstrated, only limited by the measurement setup, not by the technique itself. Filter strength can be adjusted by choosing the length of the TC fibre. The accurate control of the filtering wavelength together with filtering strength control allows filters with designed spectral profiles to be implemented by cascading several filters.

Figure 4: Responses of filters with different TC fibre lengths



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