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Dual-core Fibre Intermodal Coupler by Mechanical Gratings

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Introduction: Intermodal coupling in optical fibres by periodic bending[1,2,3,4] and twisting[5] has been investigated by various authors for its applications in optical filters. Here we report the first demonstration of intermodal coupling in a dual-core (DC) fibre by bending the fibre periodically by a fixed mechanical grating. The DC fibre had two cores with the same refractive index but different radii. Due to the mismatch between the two cores, the two fundamental normal modes in the DC fibre were very much like the fundamental modes of the two isolated fibres and were therefore physically separated, one in each core. The two modes could thus be separated with much less difficulty than in the previous schemes[1,2]. An ordinary fibre can be spliced to either core of the DC fibre to couple in/out a particular mode with a small insertion loss (0.1dB demonstrated). This new scheme has the potential of being developed into a tunable fibre filter or a signal tap in a WDM system without any requirement for precise optical alignment. The tunability of the device is also demonstrated.

Experiment: The fibre had a diameter of 90μm. The two cores had the same Δ of 0.00521. The diameter of the cores were 1.93μm and 1.66μm. The centre-to-centre core separation was 6.1μm. The two cores were made from the same MCVD preform. To prepare the preform, a MCVD preform was stretched on a glass lathe to an appropriate diameter. A stretched piece of preform and an unstretched piece of preform were milled into D shape and then combined to form a DC preform. The preform was then pulled on a conventional fibre pulling tower. The fibre beat length was within 10% of the designed value. The fibre was also designed to have an intrinsic coupling of a few percent.

To characterise the fibre, intrinsic coupling of the DC fibre was measured first. A combination of a white light source and scanning monochromator was used as the tunable light source. An ordinary fibre with a matched cut-off wavelength was spliced to one core of the DC fibre to launch light into that core. At the detection end, one of the DC fibre cores was butted to another ordinary fibre with a matched cut-off wavelength to allow light from that DC fibre core to be detected. The length of the fibre was one meter. The intrinsic coupling was then calculated as the percentage of output power in the launching core. The result is shown in figure 1. The experimental data fits reasonably well with the theoretical curve obtained from the conventional coupling theory.

The experimental set-up for measuring intermodal coupling is given in figure 2. The periodic bends were applied to the fibre by sandwiching the fibre between two aluminium blocks with a series of V-grooves. The depth of the V-grooves was 0.3mm and the pitch 1mm. There were 250 V-grooves in total. Four dowel pins were used to guide the top block so that the two blocks were complementary to each other. Four nuts were used to fix the two blocks together and also to adjust the degree of bending on the fibre. The same method as used for the measurement of intrinsic coupling was used to launch light into one core and to detect light from each individual cores. The fibre was also bent in the plane of the two cores to maximize the overlap between the perturbation and the fibre modes. The result was normalised against the transmission of the launching core. The outputs from the two cores are given in figure 3. A bending pitch of 1.01mm was applied. The FWHM bandwidth was about 25nm. There was about 74% coupling at 1.012μm. There were also three coupling side-bands at 860nm, 910nm and 970nm. The FWHM bandwidth calculated from the theory is 5.6nm. The theoretical curve is also given in figure 3 as the dotted line. The large discrepancy between the theory and measurement is due to the nonuniformities in the beat length (which depends steeply on the inter-core spacing) caused by nonuniform pressure along the fibre. 100% coupling has been observed by applying larger degree of bending on the fibre, however, with an increase of the side bands. The coupling was tuned by varying the angle between the fibre and the V-grooves. The tuning was limited by the size of the aluminium blocks. The tuning curve is showed in figure 4.

Conclusion: Intermodal coupling is a feasible technique for realising tunable narrow band filters in DC fibres by periodic bending. The coupling bandwidth in our experiments was limited by nonuniformities, but this may be substantially improved by apodising the grating strength and by closer control of the mechanical pressure. Applications to nonlinear switch are also of interest.

References

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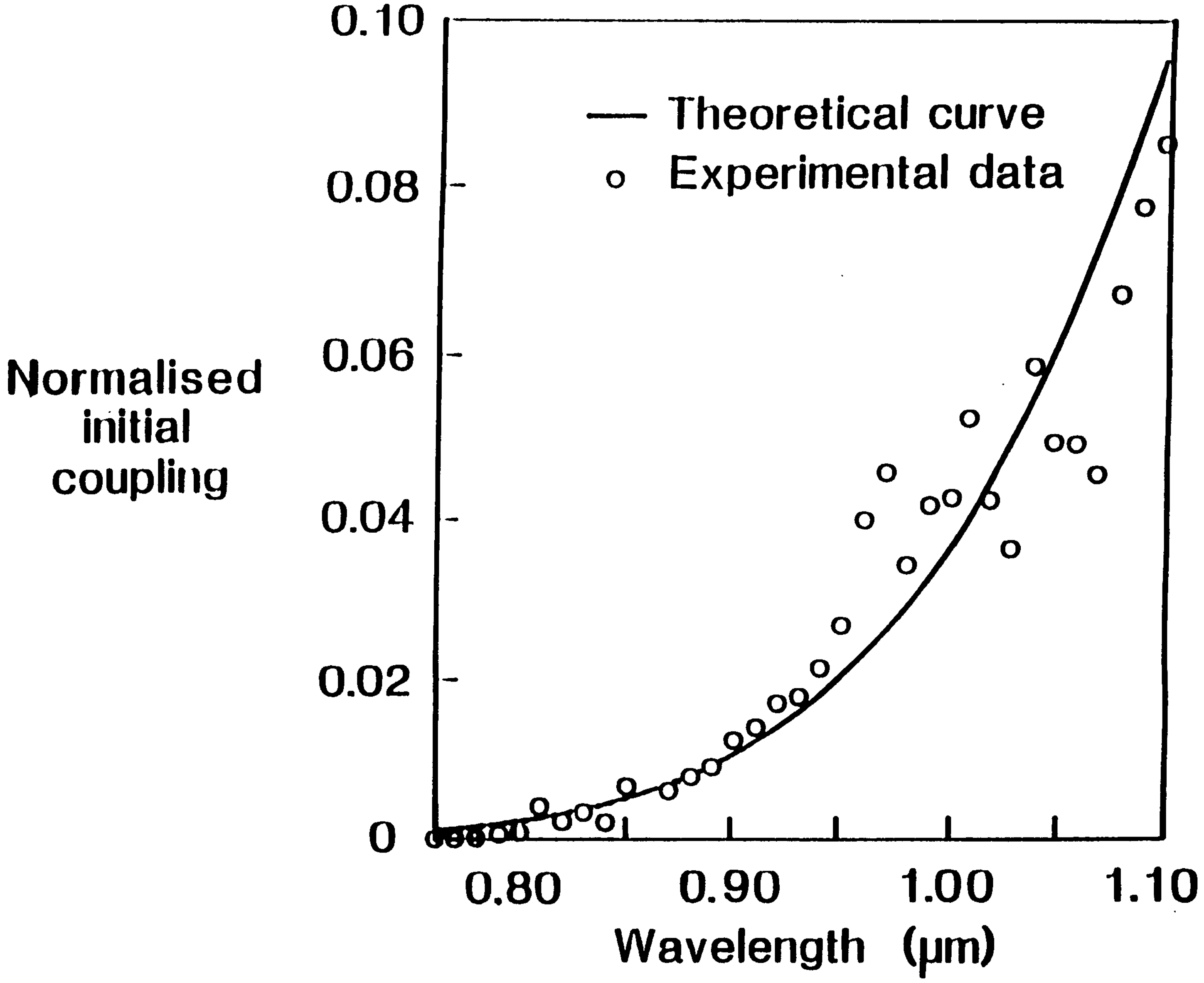

Figure 1 Initial coupling in the DC fibre.

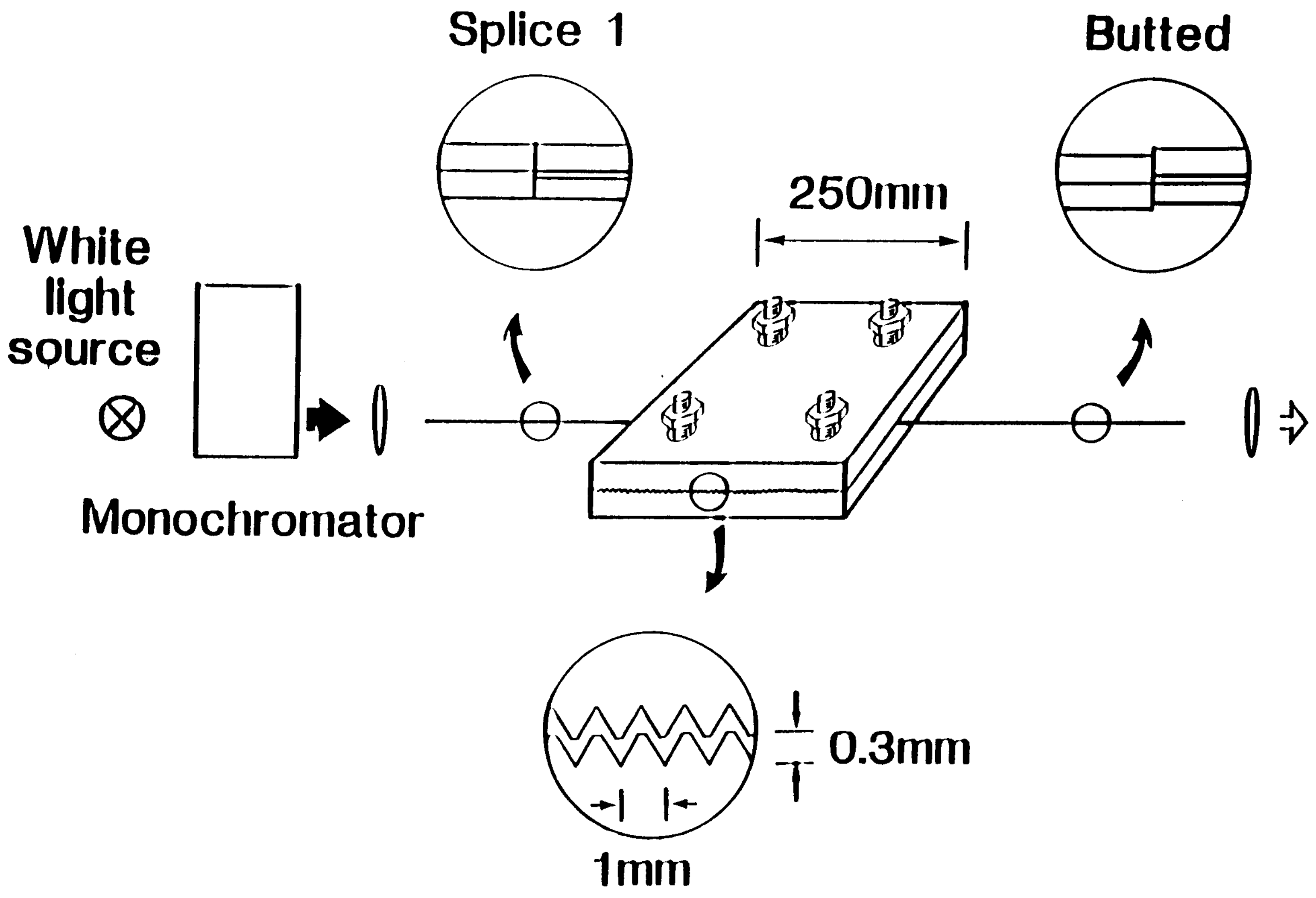

Figure 2 Experimental set-up for intermodal coupling measurement.

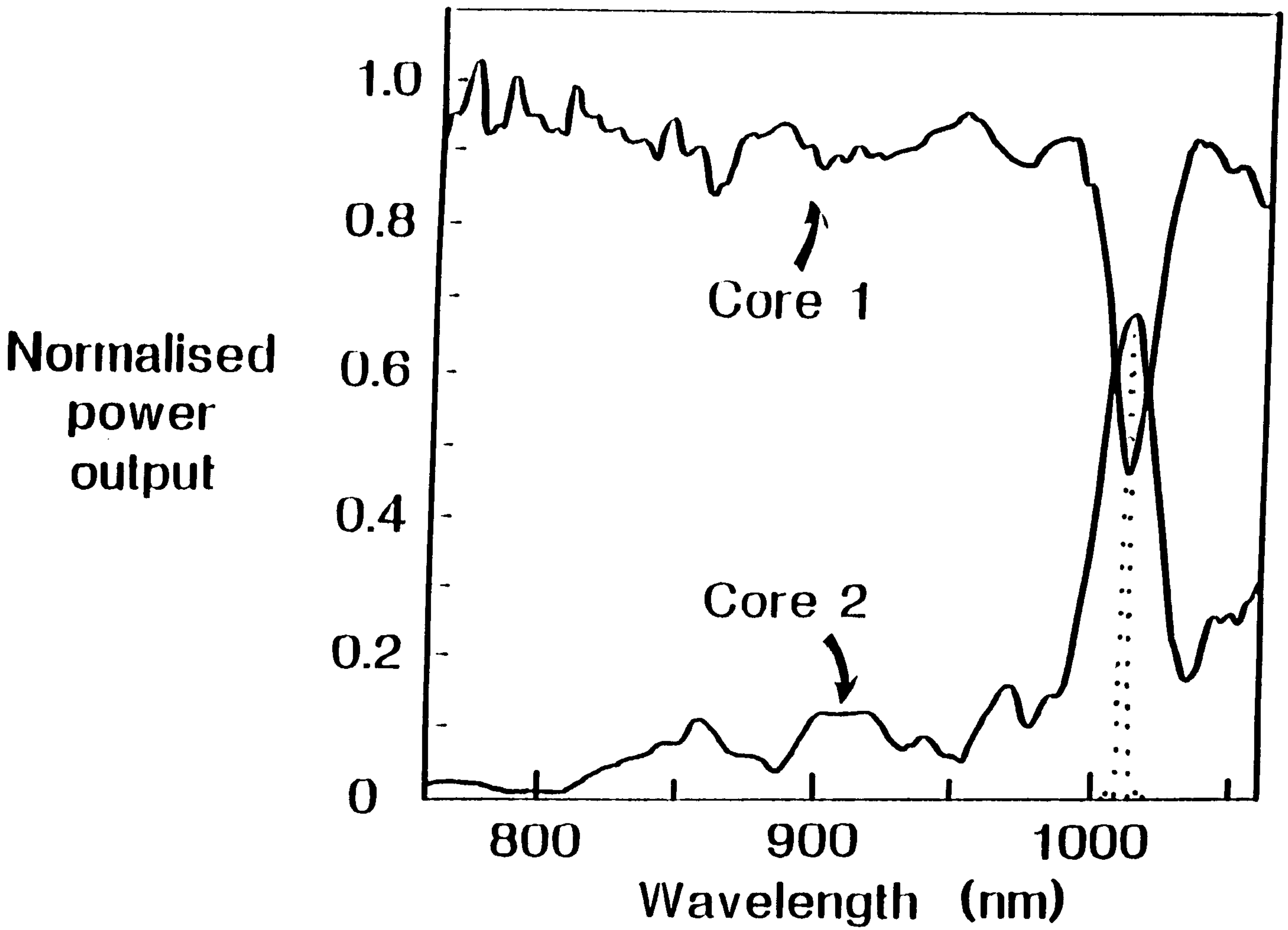

Figure 3 Modal coupling in the DC fibre with a grating pitch of 1.01mm. The dotted line is a theoretical fitting.

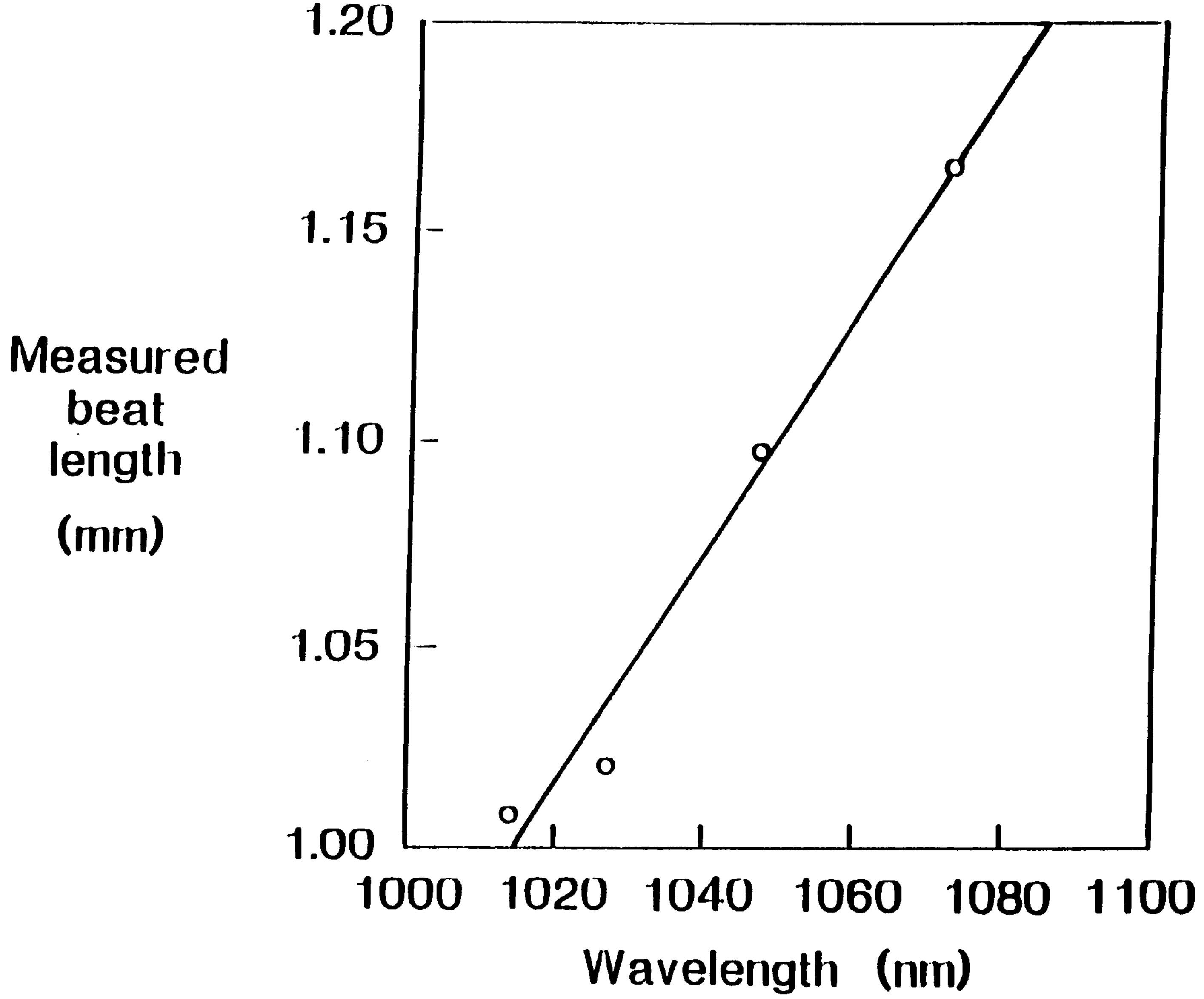

Figure 4 Tuning curve of the intermodal coupler