Holey Fibre Mode-Selective Couplers

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Abstract Summary

Mode-selective coupling in an asymmetric holey fibre coupler is demonstrated both numerically and experimentally for the first time. The coupler's performance is shown to be ultra-broadband, with significant potential existing for the use of such couplers in high bandwidth few-mode fibre networks.

Keywords- holey fibre, microstructured optical fibre, mode-division multiplexing, mode-selective couplers.

I. INTRODUCTION

Currently there is rapidly growing interest in the potential use of few-mode fibres for meeting the ever-increasing demand for bandwidth in long distance optical networks. The idea is that each mode of a few-mode fibre can be used as a unique data channel in what is referred to as mode-division multiplexing [1]. A major technological challenge for mode multiplexed few-mode fibre networks is the excitation and detection of individual modes at either end. There are several potential solutions to this problem using simple light-processing waveguide devices such as asymmetric Y-junctions, multimode interference devices or mode-selective couplers [2].

In this paper we consider mode-selective couplers, which involve evanescent coupling between a higher-order mode of one core and the fundamental mode of another closely-positioned core, or vice versa [1, 3]. The mode-selective functionality of these devices is achieved via matching of the modal propagation constants, by using dissimilar diameter cores.

II. HOLEY FIBRE MODE-SELECTIVE COUPLERS

In particular, mode-selective coupling is demonstrated for the first time using holey fibre technology. Holey fibres are index-guiding photonic crystal fibres with a lattice of air holes forming the cladding [4]. The broadband characteristics of these fibres, allows for the design of ultra-wideband mode-selective couplers.

A. Numerical Simulations

The two-core polymer holey fibre coupler design is shown in Fig. 1(b) with mode intensities superimposed. The two cores are each defined by two rings of air holes that provide sufficiently strong guidance to ensure minimal light leakage (~ 10^{-4} dB/cm) over the few-centimetre coupling length. The coupling occurs between the second anti-symmetric LP_{11a} mode of the larger core and the degenerate (i.e. propagation constant matched) fundamental LP_{01} mode of the smaller core. The coupler was designed for operation at a wavelength of λ = 633 nm to facilitate characterization, with suitable performance permitted across the visible spectrum (see Fig. 1(a)).

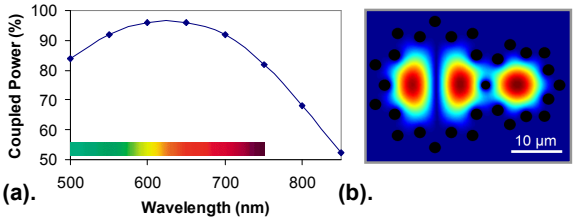

Figure 1. (a) BPM calculated [5] wavelength dependent power transfer between the LP_{01} mode of the smaller core and the LP_{11a} mode of the larger core of the holey fibre mode-selective coupler shown in (b).

The broadband nature of holey fibre couplers is however not limited to just the visible spectrum, and similar performance could be realized over entire telecommunications bands. For the present coupler the coupling efficiency exceeds 96% at the nominal wavelength, with a coupling length close to 3 cm.

B. Fabrication of Holey Fibre Coupler

The holey fibre coupler was fabricated via drilling and drawing [4] of a solid PMMA preform rod. The cross-sectional slice of Fig. 2 shows the onset of coupling between the fundamental LP_{01} mode of the smaller core and the second LP_{11a} mode of the larger core. At the appropriate coupling length almost total power transfer can be realized and the coupling performance is also found to be highly broadband as predicted. Such mode-selective couplers therefore have considerable potential for application in wideband mode-division multiplexing for increasing optical fibre capacity.

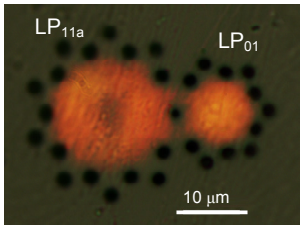

Figure 2. Cross-section of PMMA holey fibre mode-selective coupler showing mode coupling when using a broadband source.

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