NON-DESTRUCTIVE CHARACTERISATION OF FIBRE COUPLERS

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Abstract: A technique for the non-destructive characterisation of couplers is proposed. A CO₂ laser beam is scanned along the coupler length inducing a local perturbation to the coupler eigenmodes. Asymmetric and symmetric perturbations can give accurate mapping of power-evolution and coupler-waist shape.

Introduction

Couplers are components of extreme importance in optical communication systems. They are used to split the power of an optical channel /1/ (of a certain wavelength) or combine/split the power of different channels, corresponding to different wavelengths /2/ (wavelength division multiplexing (WDM) splitters/combiners). Recently, fibre and integrated-optic couplers have been combined with reflective Bragg gratings to provide add/drop multiplexers for WDM systems /3/. These devices depend on the exact position of the grating within the coupler waist relative to the points where the power is equally split between each individual waveguide (50-50% power points).

Methods for probing different parameters of directional couplers have been reported in the literature. Bourbin et al. /4/ reported a method for characterising couplers in planar waveguides that consists of inducing a small loss in one of the coupled waveguides only. The differential loss is induced to one of the waveguides by scanning a small mercury drop along its length and covering the other waveguide with a resist film to avoid contact with the mercury. In this way the coupling-constant profile can be extracted. Gnewuch et al. /5/ reported a method for measuring the beat-length of uniform couplers in buried planar waveguides that consists of inducing a local perturbation in one of the waveguides by heating it with an incident 980nm laser diode. To facilitate the 980nm radiation absorption by the transparent waveguides, a 1µm thick layer of black ink was spin-coated onto the surface of the waveguides.

In this paper we describe a new versatile method for non-destructive characterisation of fibre couplers. The method does not involve any post-fabrication treatment of the coupler. It consists of scanning a local perturbation along the coupler waist by heating it using the radiation of CO₂ laser (or another heat source) to perturb locally the lowest even and odd eigenmodes of the coupler. Firstly by applying a symmetric perturbation between the two lowest order coupler eigenmodes, information about the waist uniformity along the coupler and tapered regions can be obtained. Secondly, by applying an asymmetric perturbation between the two lowest order eigenmodes, the complex power evolution along the entire coupling region can be measured. By controlling the asymmetric-perturbation strength, the coupler waist shape can be mapped.

Description of the proposed technique

The basic principle of the proposed technique is illustrated in Fig.1. Light of the appropriate wavelength is launched in ports (#1 or #2) and detected at the output ports (#3 and #4). The characterisation method consists in inducing a local perturbation along the coupling region and monitoring the change in power at the output ports (Fig.1a). The perturbing element induces a temperature gradient across the coupler waist. The temperature gradient (represented by the shaded area in Fig.1b) can be asymmetric or symmetric with respect to the power distribution of the even and odd eigenmodes of the coupler. Each configuration provides information about different coupler parameters.

![Figure 1: (a) Principle of operation of the coupler characterisation technique. (b) Schematic of the coupler-waist perturbation using an asymmetric (top) or symmetric (bottom) configuration.](image)

The method was studied using coupled mode theory. The even and the odd eigenmodes of the coupler are propagated along the coupler length with propagation constants βₑ and βₒ. The total phase difference between the propagating eigenmodes Δβ(z)dz=[βₑ-βₒ]dz gives the evolution of power along the coupler length. The perturbation of these modes at a certain position in the coupler is described by the well known coupled mode equations for two co-propagating modes using self-coupling coefficients kₑₑ and kₒₒ and the cross-coupling coefficients kₑₒ and kₒₑ. These coefficients are proportional to the overlap integral between the refractive index change distribution due to the heat gradient and the coupler eigenmodes.

In the asymmetric configuration (see Fig.1b), both the cross-coupling and self-coupling coefficients are in general non-zero (kₑₒ≠kₒₑ≠0) and (kₑₑ≠kₒₒ≠0) respectively. Using a symmetric configuration (see Fig.1b), the cross-coupling coefficients are kₑₒ=kₒₑ=0 and the self-coupling coefficients are in general kₑₑ,kₒₒ≠0.

Using the transfer matrix method for slightly detuned couplers Δβdz=πΔφ (where Δφ=0 is the coupler
The characterisation of a half-cycle coupler is shown in Fig. 2. The change in the port power due to the symmetric perturbation was normalised to \( \pi \) and used as the coupling profile, \( k(z) \), to fit theoretically the asymmetric perturbation data. The asymmetric perturbation follows the power distribution along the coupler length and its maximum corresponds to the 50-50% point of the coupler. The agreement between the experimental data and theoretical fit was very good.

Fig. 3 illustrates the characterisation of a full-cycle coupler. The symmetric perturbation was normalised to \( 2\pi \) and used as the coupling profile to fit the asymmetric perturbation data showing again a good fit.

The asymmetric perturbation has two extreme values (these appear in Fig. 3 as minima due to the signal being inverted). The difference in these peak heights along the coupler can be due to small variations of the coupler-waist radius. Such variation is also shown in the symmetric perturbation trace.

**Conclusions**

We have demonstrated a novel non-destructive method for the full characterisation of fibre couplers. The evolution of power along the coupler and information about the tapered regions and uniformity of the coupler waist can be obtained using this method. The method can be used to optimise the performance of add/drop multiplexers based on the inscription of gratings in the waist of fused couplers or as a tool for the identification of errors in the coupler fabrication procedure.

**References**