Mode Selective Fibre Coupling Using Long-Range Surface-Plasmons

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Introduction

A number of in-line single-mode fibre devices, including polarizers[1] and fibre sensors[2], have been reported using long-range surface plasmons (LRSP's). In these devices, a side-polished fibre half-coupler block is coated with a thin metal layer supporting a LRSP mode that phase-matches to the fibre mode. This produces a resonance condition at which light is coupled from the fibre mode to the LRSP. In this paper, we explore the use of this resonance condition (which under certain conditions has high finesse) for mode-selective coupling into a dual-mode fibre; envisaged applications include to modal division multiplexing.

Device Design

The device (Fig. 1) consists of a thin silver film evaporated on to a side-polished dual-mode fibre, the distance between the polished surface and the fibre core being $\sim 3\ \mu m$. Assuming weak coupling between the fibre and LRSP mode, the phase-matching condition is obtained by requiring the phase-index of the LRSP (symmetric bound) mode to match that of the desired fibre mode. The LRSP mode exists only within a limited range of superstrate indices n_1, and its loss falls as the film thickness is reduced or the wavelength is increased. Below a certain critical thickness (markedly dependent on n_1 and λ) the LRSP cuts off and a growing mode appears[3]. Good fibre mode selection occurs when the phase-matched LRSP has very low attenuation.

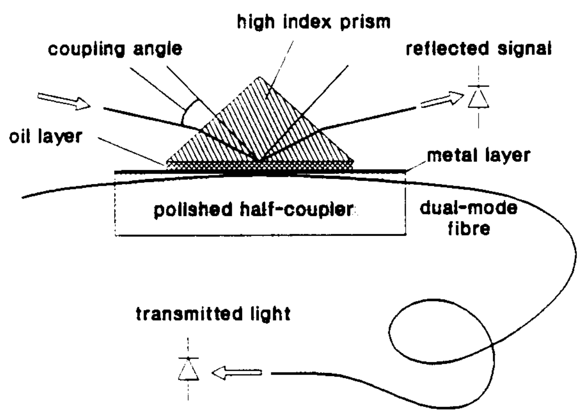

Fig. 1 The mode-selective prism coupling experiment.

Experimental results

A computer-controlled prism-coupling set-up was used to characterize the device (Fig. 1). In the absence of any metal film, light can be coupled weakly into either fibre mode by choosing the appropriate prism coupling angle. In the presence of a metal film, only those fibre modes that simultaneously phase-match to the LRSP mode are strongly excited; this provides the basis for selective mode excitation. Figures 2(a), (b) and (c) show the photodiode signals generated by the light reflected from the base of the prism and the light emerging from the fibre end as the prism coupling angle (i.e., the effective excitation index) varies. In Fig. 2(a) there is no silver film; the coupling strengths of TE and TM polarised beams are similar and very low. In Fig. 2(b) the index of the oil ($n_1 = 1.410$) was chosen to match the LRSP to the LP_{11} mode; TM-polarized light couples strongly to LP_{11} and almost nothing couples to LP_{01} (-18 dB). Notice the huge enhancement in signal in going from Fig. 2(a) to Fig. 2(b). In Fig. 2(c), $n_1 = 1.424$ and the LRSP now matches LP_{01} mode; TM-polarized light couples strongly to LP_{01} but some cross-coupling to LP_{11} is also present. No detectible coupling of TE-polarized light was observed.

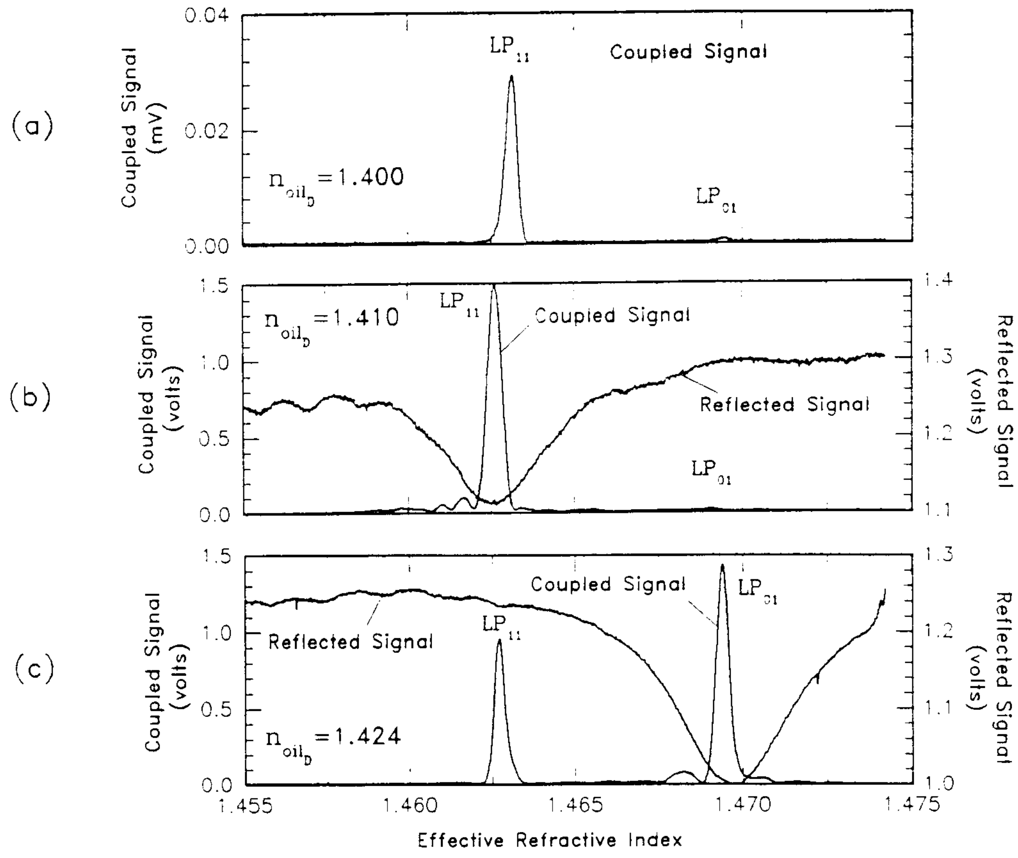

Fig. 3 Experimental prism coupling to a side-polished dual-mode fibre without silver film (a) and with a 26 nm thick silver film on top of the polished cladding for two different values of oil index, matching the LRSP to the LP_{01} (b) and LP_{11} (c) modes respectively. The attenuated-total-reflected light is also shown in (b) and (c).

Conclusions

In conclusion, good modal discrimination has been obtained experimentally for excitation of the LP_{11} mode when the LRSP resonance is resonant with it. When it is resonant with the LP_{01} mode, however, the measured modal discrimination is less good; theory predicts that this situation can be improved by optimising the device length and prism coupling parameters (we plan to present this work in a future publication). The device can, however, already be used as a mode-selective coupler if the configuration of the multiplexing system permits electronic compensation of the rather poor LP_{01} mode discrimination[4]; alternatively, the power carried in the LP_{01} channel can be boosted. Tunability could be achieved by replacing the index matching oil with a nematic liquid crystal or an electrooptic polymer.

Acknowledgements

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