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# Wavelength-insensitive couplers using dispersive materials

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It is shown that the coupling coefficient in optical couplers can be made insensitive to wavelength by the choice of materials having appropriate dispersive characteristics. The coupling coefficient between the dispersive slab waveguides is calculated and compared with the results obtained for nondispersive materials.

Existing slab and fiber optical couplers have characteristics that change with wavelength. However, for many applications, such as spectral measurements and wavelength-division multiplexing, it is desirable that the coupler properties be independent of wavelength. In a normal coupler the light-guiding and substrate (or cladding) materials have similar dispersive characteristics, with the result that the spot size of the propagation mode increases with wavelength. Thus low-loss optical waveguide couplers, which have only a weak interaction between the waveguides, operate satisfactorily only over a small range of wavelengths because of the change in coupling coefficient with wavelength.

By the use of a complex structure a 3-dB coupler having reduced sensitivity to wavelength changes has been achieved. However, the methods by which this was done are not useful for directional couplers,[1,2] and the insertion loss is relatively large, 1.5 dB.[2] By choosing guiding and substrate materials of suitable dispersions the change of spot size with wavelength can be greatly reduced, and the coupling coefficient then becomes almost constant.

If two parallel planar waveguides are brought into close proximity the electromagnetic fields of the fundamental modes begin to overlap significantly, and coupling of power takes place. For a constant degree of coupling to be maintained, the spot sizes of the modes should remain unchanged. With nondispersive materials the spot size increases with wavelength, and therefore the coupling ratio also changes. One method of reducing the wavelength dependence is to select guiding and substrate materials having a difference in refractive index that increases with wavelength.

Consider the specific example of a planar optical coupler in which the waveguide and the substrate are made of LaKN18 and SF10 glasses, respectively. The variations of refractive index with wavelength are calculated from data in the Schott Optical Glass catalog and are shown in Fig. 1. The index difference increases monotonically from 0.19% at 644 nm to 0.58% at 1014 nm. The coupling coefficient[3] calculated for this structure is shown by the solid line in Fig. 2. For comparison, the dashed line indicates the coupling coefficient for nondispersive materials having the same (and constant) refractive indices as LaKN18 and SF10 at 800 nm. It can be seen that the variation of coupling coefficient with the dispersive combination over the wavelength range 600–900 nm is only 25% of that in the nondispersive case.

The splitting ratio between the two output ports for a 3-dB planar coupler has been calculated[4] from the coupling coefficient values of Fig. 2. Figure 3 shows that the splitting ratio is constant to within ±1 dB over the large wavelength range of 600–840 nm. This wavelength tolerance is nearly six times broader than

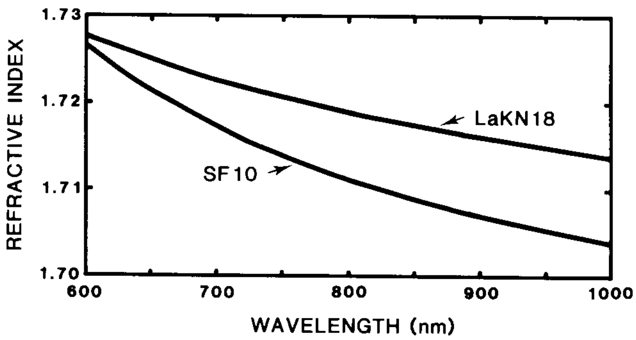


Fig. 1. Chromatic refractive indices of LaKN18 and SF10 calculated from data in the Schott Optical Glass catalog.

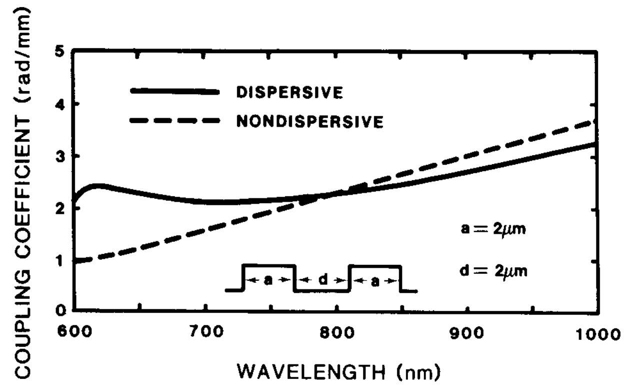


Fig. 2. The coupling coefficient between two identical slab waveguides. The thickness of the two slabs is 2 $\mu$m, and the spacing between the two slab waveguides is 2 $\mu$m.

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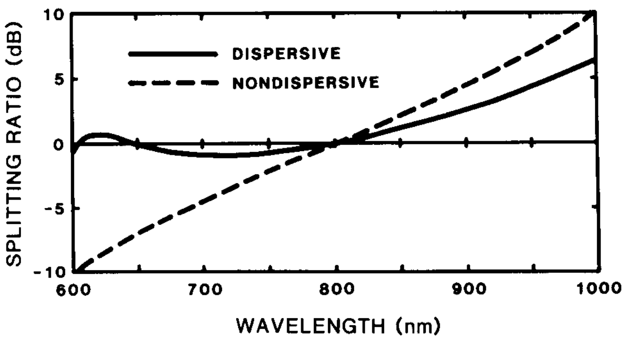


Fig. 3. Chromatic characteristics of 3-dB couplers.

for the case of the corresponding nondispersive coupler, shown by the dashed curve. The useful wavelength range can be shifted to longer wavelengths by a choice of other dispersive materials.

The technique can be extended to produce wavelength-insensitive fiber couplers by immersing a fused-taper coupler[5] into a dispersive oil or by fabricating the coupler from fibers produced from dispersive materials, possibly by the rod-in-tube technique. For planar couplers the normal integrated-optic fabrication techniques are available.

A technique for realizing wavelength-insensitive optical couplers is proposed. The coupling coefficient between two dispersive slab waveguides has been calculated and the results compared with those for nondispersive materials. It is shown that the variation of coupling coefficient with wavelength can be greatly reduced and the splitting ratio maintained nearly constant over an appreciable wavelength range.

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