THB3 Concatenated tapered coaxial coupler filters

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Tapering of single-mode optical fibers has attracted much attention, since high-quality and low-cost fiber devices can be made in this manner. Optical fiber coaxial couplers[1] have the waveguides, i.e., the core and secondary cladding coupled coaxially. Due to dissimilar geometry, phase matching does not always naturally occur, but it can be achieved with tapering. The coupling effects observed[1] can be used for fabricating narrow passband filters.[2]

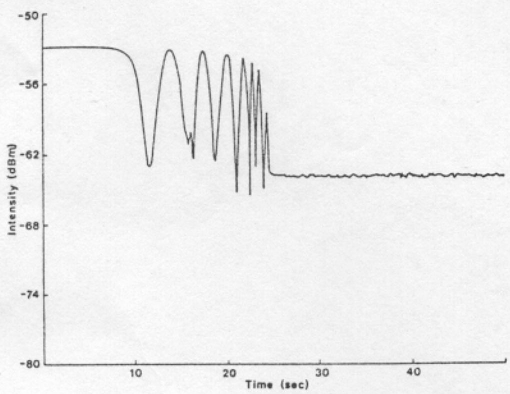
Concatenated couplers offer a means of modifying the filtering characteristics of the individual couplers. Dual-core[3] and fused biconical[4] couplers have been reported in concatenation experiments. We present new experimental results of the filtering behavior associated with concatenated tapered coaxial couplers.

Tapered coaxial couplers can be made at low cost with single-mode fibers of communication grade with a profile having a slight inner cladding depression. Such fibers can be easily accessible and are of low cost. Low-loss tapers can be made by appropriately heating and pulling the fiber using a motorized jig and an oxybutane flame.[2] The transmitted power through the taper is monitored, and by counting the number of output power oscillations the desired filtering characteristic can be obtained.

Figure 1 shows a typical trace of seven power oscillations during fiber tapering. The wavelength transmission of this tapered coupler is shown in Fig. 2. A sinusoidal wavelength response matching the period of the observed oscillation is also shown. To a good approximation the wavelength transmission can be expressed by

$$P(\lambda) = \tfrac{1}{2}\left[1 + \sin\frac{2\pi}{\Delta\lambda}(\lambda - \lambda_q)\right],$$

where $\Delta\lambda$ is the period of the tapered filter, and $(2\pi\lambda q)/(\Delta\lambda)$ is a phase parameter. Narrow passband filters (<30 nm) can be made by allowing a large number of power oscillations (20–40) to occur resulting in a long taper. In manufacture the production of long tapers could result in a lower yield of quality filters. Although this may not be a true limitation, the alternative is to use a cascade of shorter-length tapers of higher yield to fabricate narrow passband filters.



THB3 Fig. 1. Tapered coaxial coupler filter fabrication: power oscillations during tapering.

The wavelength response $P(\lambda)$ of cascaded tapes is given by

$$P(\lambda) = \frac{1}{2n}\left[1 + \sin\frac{2\pi}{\Delta\lambda_1}(\lambda + \theta_1)\right] \times \left[1 + \sin\frac{2\pi}{\Delta\lambda_2}(\lambda + \theta_2)\right] \ldots n \text{ terms.}$$

By choosing suitable values for $\Delta\lambda_i$ the wavelength response can be significantly modified.

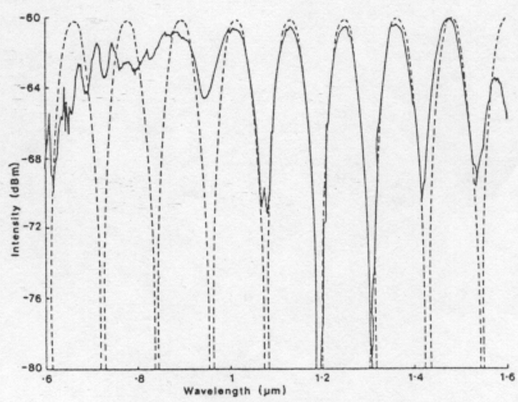
The fabrication of the tapers was achieved with the aid of an Anritsu optical spectrum analyzer which automatically allows examination of the wavelength response of the cascade *in situ*.

It also provides flexibility in the choice of fabrication wavelength by appropriate setting of the grating. Four successive tapers were fabricated in such a manner. The four tapers were pulled to one, two, three, and four oscillations, respectively. The wavelength response of the combination is shown in Fig. 3. This clearly shows that passband peaks of ~20 nm at 3 dB are possible.

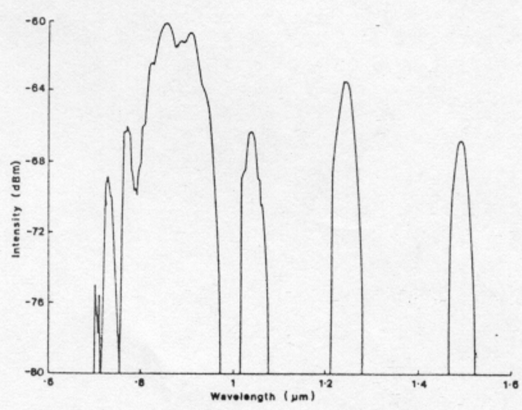
We can, therefore, fabricate narrow passband filters suitable for WDM applications using fibers tapered to about five oscillations rather than 20–40. This is desirable, but care must be taken to avoid elimination of wanted passband peaks.

In summary: concatenation of a number of tapered coaxial couplers offers a practical and low-cost method for synthesizing narrow passband filters suitable for a number of applications including WDM. **(12 min)**

1. A. C. Boucouvalas and G. Georgiou, "Biconical Taper Coaxial Optical Fibre Couplers," Electron. Lett. **21**, 864 (1985).
2. A. C. Boucouvalas and G. Georgiou, "Biconical Taper Coaxial Coupler Filters," Electron. Lett. **21**, 1033 (1985).
3. K. Okamoto and J. Noda, "Fibre Optic Spectral Filters Consisting of Concatenated Dual Core Fibres," Electron. Lett. **22**, 211 (1986).
4. M. S. Yataki, D. N. Payne, and M. P. Varnham, "All-Fibre Wavelength Filters Using Concatenated Fused-Taper Couplers," Electron. Lett. **21**, 248 (1985).



THB3 Fig. 2. Wavelength response of taper of Fig. 1: – – –, matched sinsoidal wavelength response.



THB3 Fig. 3. Wavelength response of the cascade of four tapered coaxial couplers.