

# OPTICALLY MULTIPLEXED TRANSMITTER FOR HYBRID BASEBAND AND SUBCARRIER MULTIPLEXED SIGNALS

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*Abstract: A novel transmitter architecture for hybrid baseband data and subcarrier multiplexed control signals is described. Experimental results show no measurable penalty suffered by the baseband data as a consequence of the presence of the subcarrier signal.*

## Introduction

Optical subcarrier multiplexing (SCM), wherein baseband signals are combined with microwave subcarrier signals, has been shown to be a valuable technique for the transmission of control information in optical networks /1/, /2/. In addition, SCM signals have been used for optical performance monitoring such as the measurement of crosstalk between channels /3/ as well as accumulated dispersion affecting individual channels. /4/

Several methods have been published for the generation of hybrid baseband/SCM signals. These include combining baseband and subcarrier signals electronically, followed by direct laser modulation /1/, /5/ or combining these signals electrooptically with a differentially driven Mach-Zehnder integrated-optic modulator /6/. Both of these methods have drawbacks. Electronic summation requires a high extinction ratio linear modulator in order to achieve good baseband performance without intermodulation products. The electro-optic technique, while simple to implement, introduces a power penalty in the baseband data for all but the smallest amplitude subcarrier signals, resulting in a tradeoff between baseband and subcarrier performance, and does not permit chirp free modulation.

In this paper we describe a transmitter architecture

that overcomes the problems associated with previously published techniques. In our transmitter the subcarrier and the baseband optical signals are generated separately and combined optically using a three port fiber loop mirror filter (LMF). As a result, subcarrier signals with amplitude limited only by the maximum extinction of the filter can be combined with baseband data without introducing a subcarrier amplitude-dependent penalty in the baseband signal.

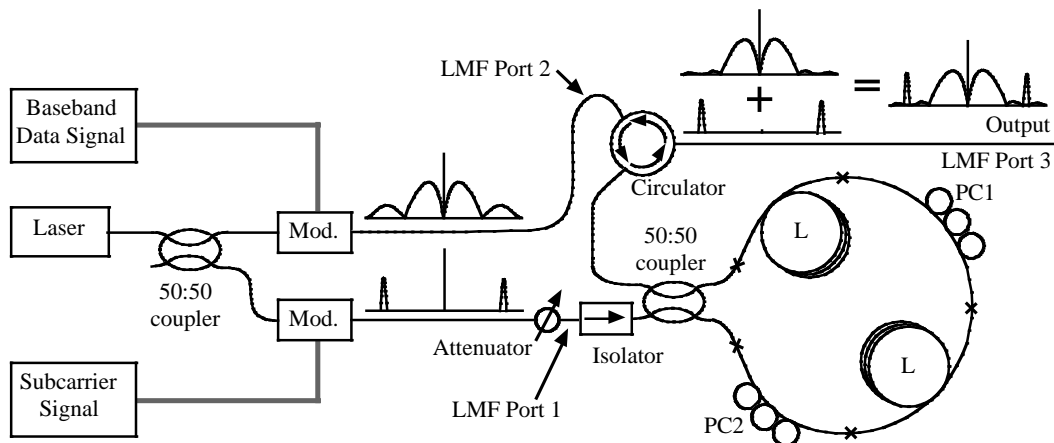
## Transmitter design

A schematic diagram of the transmitter is shown in Fig. 1. At the heart of the transmitter is a polarization independent fiber loop mirror filter /7/ that employs two pieces of birefringent fiber of equal length and two polarization controllers (PC1 and PC2). The ideal transmission of such a filter is given by

$$T_{2 \rightarrow 3} = \frac{1}{4} \left[ 1 + \cos\left(\frac{2\pi f}{F}\right) \right]^2 \quad (1)$$

$$T_{1 \rightarrow 3} = 1 - T_{2 \rightarrow 3} \quad (2)$$

provided that the coupler is 50:50, the polarization axes of the fibers are oriented at 45 degrees relative to one another (this is accomplished through adjustment of PC1) and that PC2 is adjusted to produce a polarization transformation equivalent to a



**Fig. 1: Diagram of subcarrier multiplexed transmitter employing a loop mirror filter to optically multiplex baseband and subcarrier signals.**

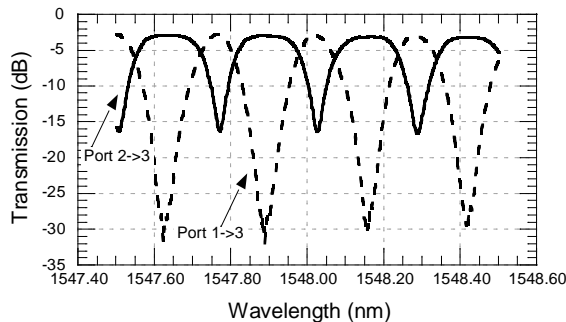


Fig. 2: Optical transfer function of LMF.

half wave retarder with principal axis oriented at 45 degrees to the principle axes of the birefringent fiber. The filter transfer function is periodic in frequency with a free spectral range,

$$F = c/\Delta nL. \quad (3)$$

Where  $\Delta n$  is the birefringence of the fiber and  $L$  is the length of each fiber segment. The periodic nature of the filter response makes the device ideal for WDM signals where multiple baseband and subcarrier signals can be combined using the same filter. The subcarrier frequency is  $f_{sc} = F/2$ . We chose a subcarrier frequency of 16.667 GHz since this frequency is compatible with a 10 GB/s baseband data rate and an LMF suitable for 100 GHz spaced WDM channels. The birefringent fibers in our filter were each 18.02 meters in length.

### Experiment

Fig. 2 shows the measured transmission spectrum of the LMF. The spectrum was measured using a broadband input source and a high-resolution optical spectrum analyzer (OSA). The notch depth in the figure is limited by the resolution of the OSA. The transmission of the LMF from ports 1 to 3 (the subcarrier signal) is shown in Fig. 3. The input to the filter is shown in Fig. 3a and the output in Fig. 3b. We see from the figure that the filter provides greater than 40 dB of suppression of the optical carrier in the subcarrier signal. This suppression is more than adequate to prevent interference in the output of the transmitter from degrading the baseband signal. The strength of the subcarrier signal relative to the baseband signal is easily adjusted by changing the relative optical power at the input of the LMF.

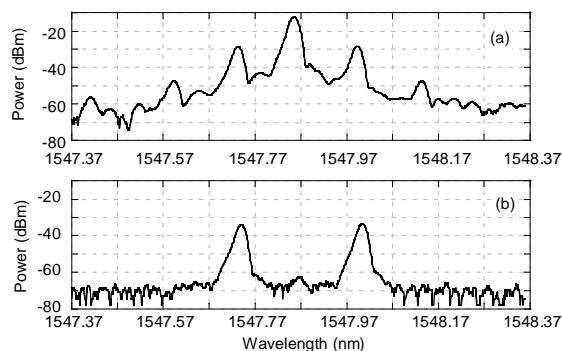


Fig. 3: Input (a) and output (b) subcarrier signals from ports 1 and 3 respectively of LMF.

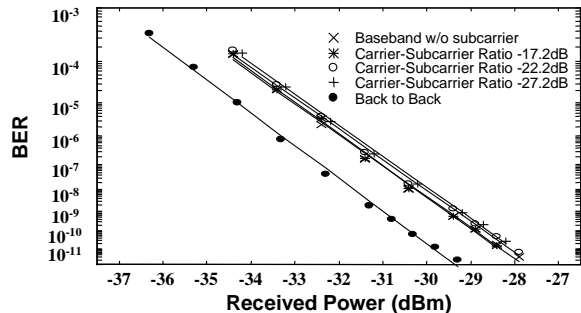


Fig. 4: BER performance of baseband data channel at several subcarrier levels.

The transmitter was tested by measuring the BER at the receiver as a function of received power for baseband carrier to subcarrier ratios of  $-17.2$ ,  $-22.2$  and  $-27.2$  dB. The ratio of the optical carrier to subcarrier power was measured with an optical spectrum analyzer and adjusted using a variable optical attenuator at port 1 of the LMF. The results are plotted in Fig. 4. Also shown in the figure is a back to back sensitivity measurement made with the loop mirror filter removed and a sensitivity measurement made with the subcarrier signal disconnected. As indicated in the figure, the sensitivity was not dependent on the amplitude of the subcarrier signal. A penalty of 1.5 dB was incurred by the baseband signal due to transmission through the LMF but this was independent of the amplitude of the subcarrier signal and was likely due to band limiting of the baseband signal by the LMF.

### Conclusion

We have demonstrated a novel transmitter for hybrid baseband and subcarrier multiplexed signals. Our transmitter employs a three port fiber loop mirror filter to both optically filter and multiplex the baseband and subcarrier signals. The strength of the subcarrier signal relative to the baseband signal is easily controlled with an optical attenuator. Experimental results show no measureable power penalty suffered by the baseband data as a consequence of the presence of the subcarrier signal.

### References

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