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Noise Tolerance in Acoustooptic Switching for High-Symbol-Rate Optical DQPSK Pulse Train

高シンボルレート光DQPSKパルス列の音響光学スイッチングにおけるノイズ耐性の検討

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1. Introduction

Wavelength-selective switching and signal processing of WDM optical packets are required in photonic networks. The authors have studied on weighted acoustooptic (AO) switches and on their application to optical packet routing and optical label recognition of high bit-rate packets.[1,2) In this paper, we clarify noise tolerance in switching of optical differential quadrature phase-shift-keying (DQPSK) pulse trains.

We consider 40 and 100G symbol/s DQPSK pulse trains having 75 and 150GHz bandwidth, respectively. As the symbol rate increases, AO switching induces distortion in pulse shape and phase,[3) which results in increase of bit error rate (BER). We consider two types of weighted AO switches. The BER of the switched DQPSK pulse trains with these two kinds of AO switches is numerically analyzed by the Monte-Carlo method.

2. Weighted AO device

A collinear AO device with a tapered SAW waveguide is shown in Fig. 1(a).[4) The tapered SAW waveguide is employed to realize weighted AO coupling along the interaction region of length l_{SW}. We assume a weighting parameter α to be 0.5. It is noted that the sidelobe is decreased to -20dB.

The AO filter having Butterworth filtering characteristics was reported to be realized by employing a SAW directional coupler and a SAW absorption film or by employing a lossy SAW directional coupler, as shown in Fig.1(b).[5)

The filtering response in wavelength-selective switching with these devices is shown as a function of the optical frequency shift from the Bragg condition in Fig.2(a), where $|f_{AO}|^2$ and $|f_{AO}^{res}|^2$ denote output intensities at the switched output port and the unswitched port, respectively. When the optical frequency shifts from the Bragg condition for the interacting SAW frequency, the mode conversion ratio decreases, which limits the bandwidth of the switched optical signal. The full bandwidth of the pass band in the tapered SAW waveguide device and the Butterworth-type device is almost 230GHz. It is found that the pass band is flatter for the Butterworth-type device. However, as shown in Fig.2(b), the phase of the switched output signal is nonlinear in the Butterworth-type device. The phase in the tapered SAW waveguide device has a discontinuity at around 230GHz, which is caused by the fact that the switched output is too small to calculate the phase precisely. Except for this discontinuity, the phase relation in the tapered SAW waveguide device is almost linear like the phase relation in the conventional device. It is noted that the linearity in the phase relation is

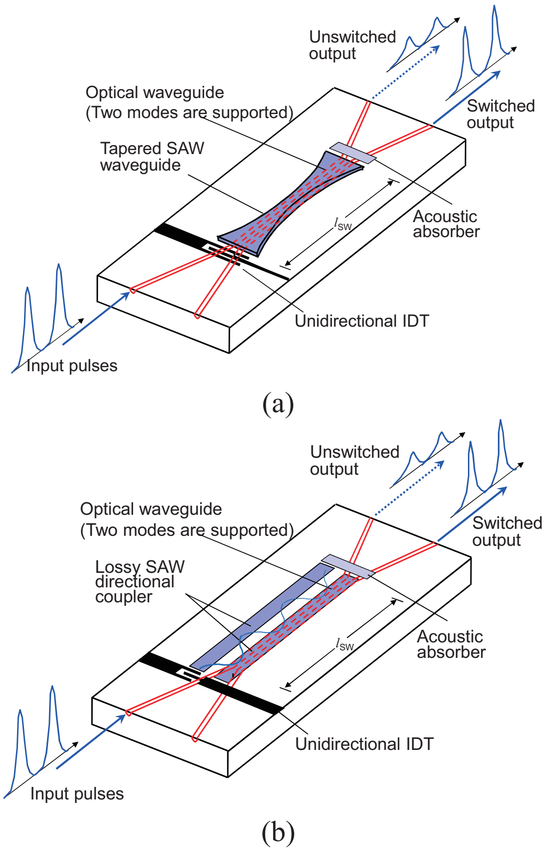
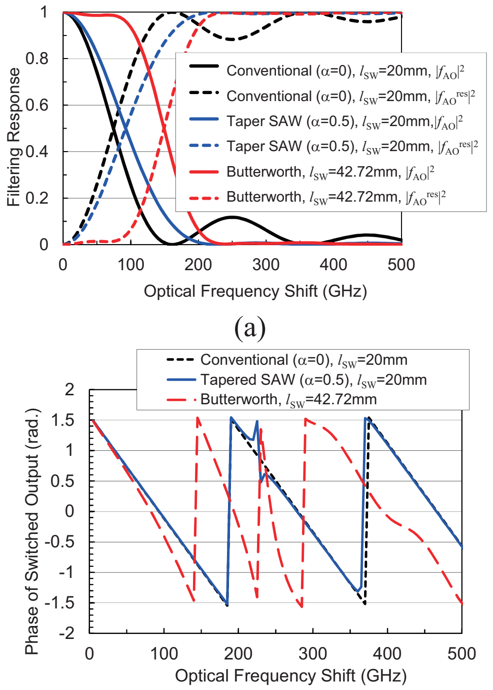


Fig.1 Weighted collinear AO devices (a) with a tapered SAW waveguide, and (b) with a lossy SAW directional coupler (Butterworth type).



(a)

(b)

Fig.2 Filtering characteristics; (a) intensity and (b) phase.

important for maintaining the pulse shape in switching.

3. Noise tolerance in switching of DQPSK pulse train

We consider QPSK optical pulse trains at 40 and 100G symbol/s. To conserve high-symbol-rate pulse trains through AO processing, the filtering bandwidth has to be enough wide to transmit all the frequency components. We consider QPSK pulse trains. The phases of the pulses are assumed to be "0, π/2, 3π/2, π, 0, 3π/2, π/2".

To evaluate the affection of AO switching in the transmission system on detection of QPSK codes, we consider a DQPSK transmission model shown in Fig.3. Original binary bit sequence b_k is interleaved to odd and even numbered bit sequences, $u_k=b_{2k-1}$ and $v_k=b_{2k}$, respectively. These two sequences u_k and v_k are differentially encoded to I_k and Q_k using previous values of I_{k-1} and Q_{k-1} as given by

$$\begin{cases} I_k = (\overline{u_k \oplus v_k})(u_k \oplus I_{k-1}) + (u_k \oplus v_k)(v_k \oplus Q_{k-1}) \\ Q_k = (\overline{u_k \oplus v_k})(v_k \oplus Q_{k-1}) + (u_k \oplus v_k)(u_k \oplus I_{k-1}) \end{cases}.$$

These pre-coded sequences I_k and Q_k are fed to phase modulators placed in a Mach-Zehnder interferometer. The $I_{r,k}$ and $I_{s,k}$ are found to be equal to $(2u_k-1)A'$ and $(2v_k-1)A'$, respectively.

The BER performance was simulated by the Monte-Carlo method. Gaussian noise was added before the AO switching. The SNR at the entrance of the AO switch was evaluated as SNR=$f_0^2(t_k)/(2\sigma_n^2)$, where σ_n^2 is the variance of the Gaussian noise. The simulated BER as a function of SNR is shown in Fig.4.

4. Conclusion

Noise tolerance in switching for high-bit-rate QPSK pulse train with collinear AO devices was theoretically discussed. Bit error rate analysis for DQPSK pulse processing was investigated. Wavelength-selective processing with integrated AO devices for use in photonic routers will be investigated in future.

Acknowledgment

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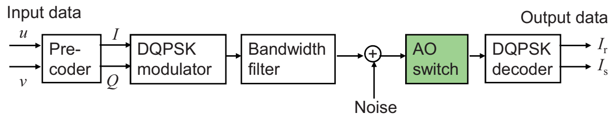

Fig.3 Model of DQPSK transmission system.

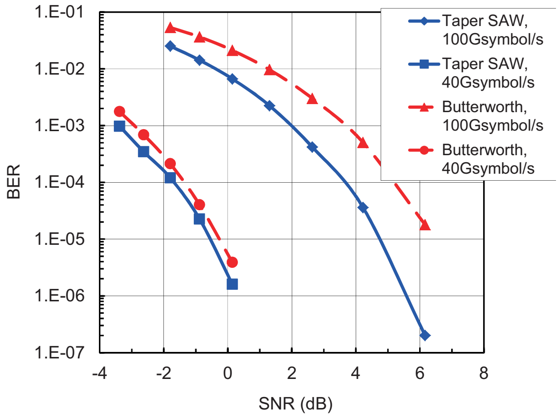

Fig.4 BER performance as a function of SNR.