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Switching Characteristics of Optical High-Bit-Rate Pulses with Weighted Acoustooptic Devices
重み付け音響光学素子による高ビットレート光パルスのスイッチング特性

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1. Introduction

In photonic network nodes, optical signal processing is expected to improve the processing speed with lower power consumption. In particular, efficient processing of WDM pulse train is required. Acoustooptic (AO) devices using collinear interaction between guided optical pulses and guided surface acoustic waves (SAWs) provide wavelength-selective processing capability though the switching speed is limited to an order of micro seconds.

We have studied AO switch and its applications to recognition of optical labels encoded in spectral and time domains.[1,2] For high-bit-rate pulses, the switched pulses suffer from distortion due to the wavelength-selectivity. In this report, the pulse distortion with weighted AO switches designed for low sidelobes or for flat-top passband is discussed.

2. Weighted AO switches

An example of collinear sidelobe-suppressed AO devices with a tapered SAW waveguide is shown in Fig.1.[3] Alternatives to achieve weighted AO interaction include employment of a tilted SAW waveguide[4] and a SAW directional coupler[5]. An AO filtering having Butterworth filtering characteristics was reported by employing a SAW directional coupler and a SAW absorption film.[6]

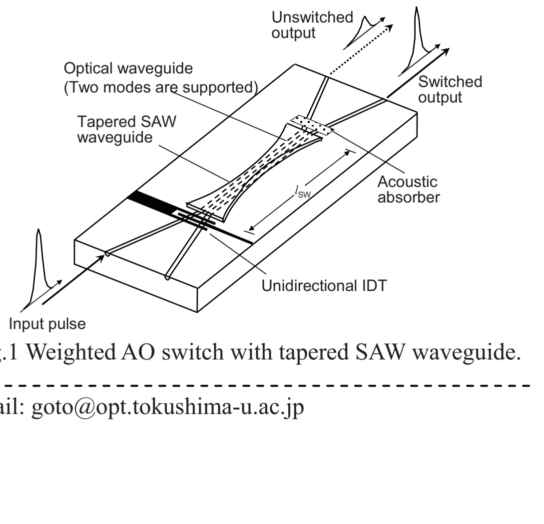

Fig.1 Weighted AO switch with tapered SAW waveguide.

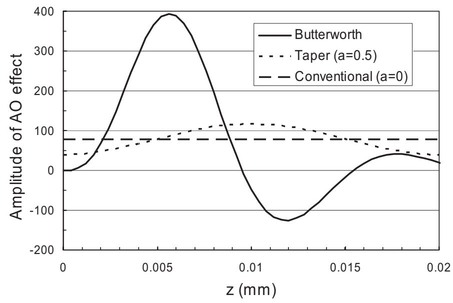

Fig.2 Distribution of AO coupling.

Distributions of AO coupling along the interaction region for conventional coupling, weighted coupling with a tapered SAW waveguide, and weighted coupling for Butterworth filtering are plotted in Fig.2. The AO coupling $g(z)$ for the tapered SAW waveguide is assumed to be given by

$$g(z) = g_0\left[1-\alpha\cos\left(2\pi z/l_{SW}\right)\right] \quad (1)$$

where α is a parameter indicating the weighting strength, l_{SW} is the interaction length. For complete switching, g_0 is set to be $g_0\ l_{SW} = \pi/2$. We assume α=0 for the conventional coupling and α=0.5 for a weighted one. The filtering characteristics for α=0.5 are shown in Fig.3, where f_{AO} and f_{AO}^{res} denote switched and unswitched amplitude, respectively. It is noted that the sidelobe for the conventional coupling with α=0 is as large as -9.3dB. For Butterworth filtering, we assume $g(z)$ given by

$$g(z) = g_0 \sin\left\{\kappa_\infty\left[z-\frac{\sqrt{\pi}}{2}z_t erf\left(\frac{z}{z_t}\right)\right]\right\}e^{-\beta_{im}z} \quad (2)$$

and

$$\kappa_\infty = \frac{N\pi}{l_{SW}-\frac{\sqrt{\pi}}{2}z_t erf\left(\frac{l_{SW}}{z_t}\right)} \quad (3)$$

where N is the number of sections with alternating polarities and z_t is an entrance taper length of the AO coupling. We set these parameters as N=3, g_0=26.228/l_{SW} and z_t=0.19l_{SW}.[6] The filtering

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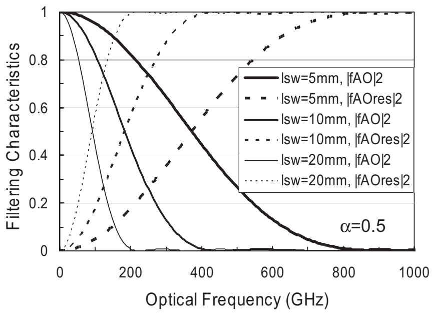

Fig.3 Filtering characteristics with weighted coupling by tapered SAW waveguide.

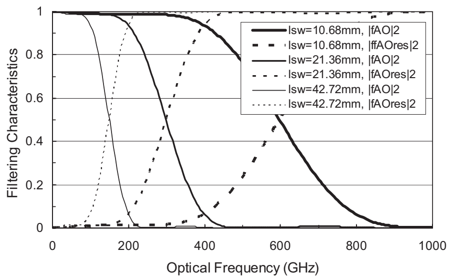

Fig.4 Filtering characteristics with weighted coupling for Butterworth filter.

characteristics are shown in Fig. 4. Flat-top characteristics are obtained.

3. Pulse switching characteristics

We consider optical pulses at 40Gbps, 160Gbps and 320Gbps. To conserve these pulse shape through switching, the filtering bandwidth in switching has to be enough wide to transmit all these frequency components.

The pass bandwidth of the collinear AO switches is inversely proportional to the interaction length l_{SW} as shown in Figs.3 and 4. Therefore, to process pulses at high-bit-rate, the interaction length of the switch has to be enough short, which results in increase of the control SAW power because the required power for switching is inversely proportional to l_{SW}.

Fig.5 shows the optical output from the switch with the tapered SAW waveguide of a=0.5 for the input at 160Gbps and 320Gbps. The output from the switch with Butterworth filtering characteristics is shown in Fig.6. To conserve the pulse shape for pulse trains and to suppress unswitched output at 320Gpbs, l_{SW} has to be as short as about 5mm and 10mm with weighted coupling at α=0.5 and with weighted coupling for Butterworth filter, respectively.

4. Conclusion

Switching characteristics for high-bit-rate pulses with collinear AO devices were theoretically discussed. Design parameters of the switches suitable for switching of optical pulses at 40Gbps, 160Gbps and 320Gbps were determined from the theoretical results. Wavelength-selective processing with integrated AO devices for use in photonic routers will be investigated in future.

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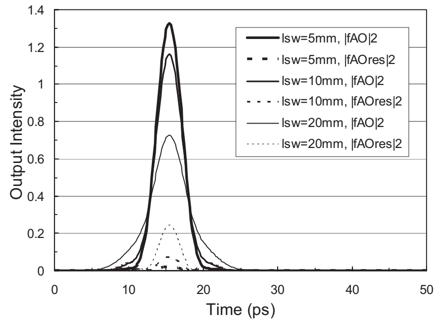
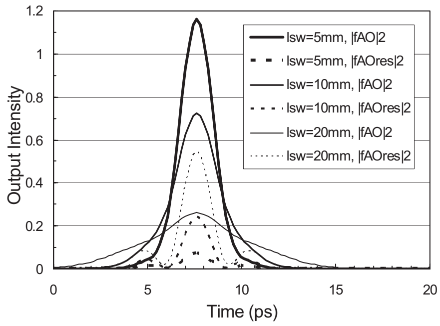


(a) at 160Gbps



(b) at 320Gbps

Fig.5 Optical output intensities from switched and unswitched ports with weighted coupling by tapered SAW waveguide of α=0.5.

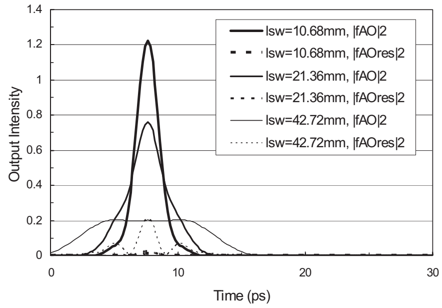


Fig.6 Optical output intensities from switched and unswitched ports with weighted coupling for Butterworth filter.