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Simple Simultaneous Modulation for Red, Green and Blue Laser Lights Using Surface-Acoustic-Wave-Driven Acoustooptic Modulator
弾性表面波を用いた音響光学変調素子による簡易なRGB光同時変調

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1. Introduction

A waveguide-type acoustooptic modulator (AOM) driven by a surface acoustic wave (SAW) using Bragg diffraction in a tapered crossed-channel proton-exchanged (PE) waveguide on a $LiNbO_3$ substrate has been proposed for an optical wavelength of 1.55 μm.[1] In contrast with a bulk-type AOM, the waveguide-type AOM can perform modulation for a wide range of wavelengths at the same driving frequency.[2] To realize an AOM in which laser light of the three primary colors of red, green, and blue (RGB) can be modulated by the same modulator and at the same driving frequency, the waveguide-type AOM was applied to the visible range.[3] For red and green laser lights, according to the analytical results, a maximum diffraction efficiency ranging from 73 to 85% was obtained. In contrast, the maximum diffraction efficiency for a blue laser light was as small as 47%. This problem is considered to be caused by the light power leaked to the outside of the waveguide.

In this study, first, to suppress the leakage, the waveguide-type AOM with a deeper waveguide was fabricated and the optical diffraction properties were measured for red, green, and blue laser lights. Next, by utilizing the rapid switching time of the order of several tens of nsec, a simple simultaneous modulation for RGB laser lights was proposed and demonstrated.

2. SAW-Driven AOM for RGB Laser Lights

The overall configuration of the waveguide-type AOM is shown in **Fig. 1**. To suppress the leakage of light power to the outside of the waveguide, the depth of the proton-exchanged waveguide was increased from 1.0 μm in the previous AOM to 3.5 μm.

The method of fabricating the AOM and the setup for measuring the diffraction properties were the same as reported previously.[3] The channel waveguide fabricated by first forming an RF-sputtered SiO_2 mask with a film thickness of 0.25 μm by the liftoff method on a 128°-rotated Y-cut $LiNbO_3$ substrate followed by the PE process and postannealing. The PE time and annealing time were determined to be 40 min in a solution of benzoic acid containing 0.2 mol% lithium benzoate at 240°C and 40 min at 400°C, respectively, so that a Gaussian index profile with Δn_e = 0.02 and a depth of 3.5 μm was obtained. The width of the waveguide of each port was 6 μm.

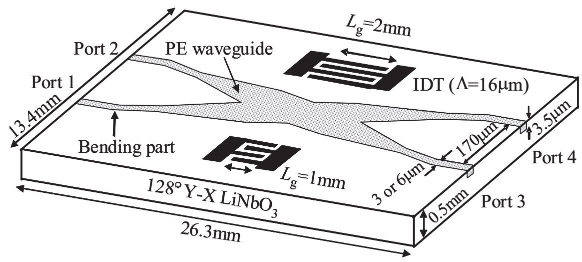

Fig. 1 Configuration of SAW-driven AOM.

After polishing the end face of the waveguide, for the excitation of the SAW, a pair of normal interdigital transducers (IDTs) with a period length Λ of 16 μm and an overlap length L_g of 1 (30 finger pairs) or 2 mm (20 finger pairs) was formed on the substrate using aluminum thin film with a thickness of 0.3 μm.

A red (633 nm), green (532 nm), or blue (473 nm) laser beam was guided into the end face of the PE waveguide through an objective lens with a magnification of x40. A pulse-modulated RF voltage was supplied to the input IDT. The diffracted light power as a function of the input voltage of an RF burst signal was measured using a photomultiplier. The driving frequency of 245.5 MHz was fixed for all wavelengths.

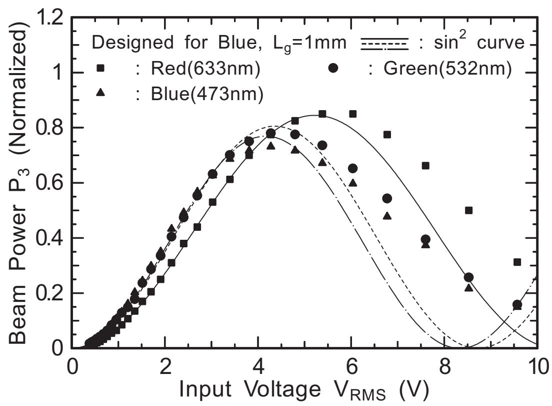

Fig. 2 Measured diffraction properties.

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Figure 2 shows the measured diffraction properties in the case of L_g = 1 mm. In the experimental results, the measured diffracted power P_3 was normalized by the output light power in Port 4 without an input voltage.

The peak diffraction efficiencies for optical wavelengths of 633, 532, and 473 nm were 85, 78, and 73%, respectively. The maximum diffraction efficiency for the optical wavelength of 473 nm was improved from 47% in the previous AOM.

3. Simple Simultaneous Modulation for RGB Laser Lights

By utilizing the AOM, a simple simultaneous modulation system was proposed and constructed as shown in **Fig. 3**. In this system, the modulation takes steps as follows. Red, green, and blue laser beams are formed by a wavelength division multiplexing (WDM) coupler and guided into the AOM through a visible optical fiber. The AOM simultaneously modulates all optical wavelengths so that the beam power modulated by the continuous three burst signals have the desired intensity ratio I_R:I_G:I_B. The output beam is separated into red, green, and blue lights by the WDM coupler. The red, green, and blue lights are delayed by $2\tau_G$, τ_G, and 0, respectively, by fiber delay lines, and are combined again by the WDM coupler. Color signals of the desired color and intensity are generated every $3\tau_G$. Surplus signals remaining between those color signals are removed by another AOM or optical switch.

The switching time of the AOM is basically equivalent to the time (15 nsec) required for the propagation of the SAW through the width of the interaction region (60 μm). In addition to the rise time of the beam diffraction, the rise time of the SAW amplitude distribution corresponding to the SAW propagation time through the IDT width is required for the switching time. When the number of pairs of IDT is 3, the sum of those rise times is 27 nsec and the delay times are determined to be τ_B = 0, τ_G = 54, and τ_R = 108 nsec. Therefore, the color

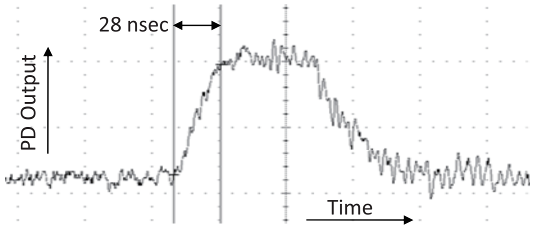

Fig. 4 Measured time response of the output signal from the simultaneous modulation system.

signal can be obtained every 162 nsec. For instance, if the system is used for a retinal scanning display (RSD)[4] with 50 frames/sec, color signals with 120,000 pixels/frame (400 × 300) can be generated.

Figure 4 shows the time response of the output signal from the constructed system equipped with the AOM with the 3 finger pairs IDT, which was measured using a photodetector. According to the designed properties, the switching time of 28 nsec and the delay times due to the delay lines were observed.

4. Conclusions

To suppress the light power leaked to the outside of the waveguide, a waveguide-type AOM with a 3.5 μm-depth waveguide was fabricated. The RGB laser lights were modulated with the diffraction efficiencies of 73−85% at the same driving frequency of 245.5 MHz. By utilizing the AOM, a simple simultaneous modulation was proposed and demonstrated with a switching time of 28 nsec.

Acknowledgment

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References

1. S. Kakio *et al*, Jpn. J. Appl. Phys. **42** (2003) 3063.
2. S. Kakio *et al*, IEICE Trans. **J-86-C** (2003) 1263 [in Japanese].
3. S. Kakio *et al*, Jpn. J. Appl. Phys. **48** (2009) 07GE02.
4. M. Watanabe *et al*, J. SID. **11** (2003) 511.

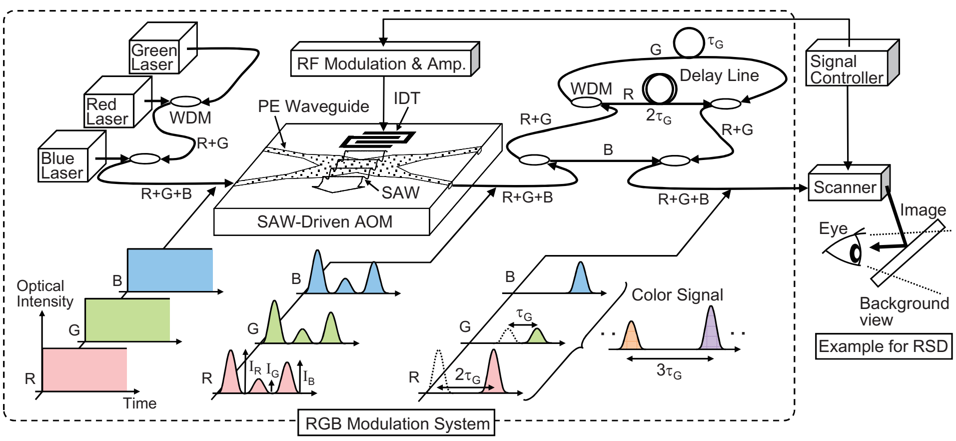

Fig. 3 Simultaneous modulation system for RGB laser lights using SAW-driven AOM.