B-6-1 GaAs Rib-Waveguide Directional-Coupler Switch with Schottky Barriers

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INTRODUCTION A GaAs electro-optic directional coupler (EDC) switch is a fundamental component necessary for the development of GaAs-based monolithic integrated optical circuits. A few types of GaAs EDC switch has been demonstrated.[1~5] This report describes a new type of GaAs EDC switch. The switch was fabricated from a pair of closely spaced single-mode rib-waveguides with an Au Schottky barrier as shown in Fig. 1. The guides are synchronous and the device length was one coupling length, so that muximum power transfer to the coupled guide can be obtained at zero bias. The optical switching is achieved by reverse biasing the Au Schottky barrier of input guide. The applied electric field alters the propagation constant through the electro-optic effect, and this spoils the syncronism, reducing the coupling and causing the light to emerge from the input channel.

EXPERIMENTS A n^--GaAs guiding layer had a concentration of 6×10^{14} cm^{-3} and was grown by VPE growth on a n^+-(100)-GaAs substrate. The layer surface was clad with Au Schottky electrode by vacuum-evaporating. The rib-waveguides are made by PL masking, etching the exposed Au and the n^--GaAs layer. Radiation from a He-Ne 1.15 μm laser was forcused on the cleaved input face to excite the TE_{00} mode. A magnified image of the near-field pattern was focused on an IR vidicon. Propagation losses, coupling coefficients and extinction ratios were measured by photomultiplier. The modulator bandwidth was estimated from the measured capacitance.

RESULTS The attenuation of these devices was determined by measuring the total power in two channels of several lengths of the same sample. The attenuation constant was about 2.2 dB/cm. Though the rib-waveguide surface was clad with metal, the measured loss was lower than those of previous reported switches. The main reason was that the real part of the refractive index of Au is smaller than other Schottky electrode. To determine the coupling length L_0, the relative power in each channel was measured. Figure 2 shows the relative output power from coupled guides as a function of device length. The measured values agreed with the calculated values from L_0 shown in the top-left portion of the figure. L_0 as a function of the spacing between the strips are shown in Fig.3. The theoretical values are shown also in the figure. In this calculation, the effective refractive index difference between the rib-region and the surround was 2×10^{-4}. This value was based the calculation on the waveguide structure which was used in experiment. To evaluate switching performance, directional-couplers were cleaved to one coupling length. The 99.9 % (30 dB) power coupled from the input channel to the coupled channel.

This value indicated that the difference between the device length and the coupling length was smaller than 0.2 mm. The phase-match condition of a directional coupler can be altered by reverse biasing the Schottky barrier of the input guide. This effect is illustrated by the photographs in Fig.4(a) of the near-field intensity. The switch had a length of 8.5 mm (=coupling length). At the device input the laser was focused on the right channel. When no bias was applied 99.9 % light emerged from the left channel. With 28 V, most of the light (84 %) emerged from the right channel. In Fig.4(b), the power output vs bias from the coupled channel; Pc, and input channel; Pi, are plotted. The capacitance of the device was 1.58 pF at 5 V. This implies a bandwidth of 2 GHz and $P/\Delta f$ of 250 mW/GHz.

CONCLUSIONS A new type of GaAs EDC switch was demonstrated. The devices were fabricated from low-loss (≃2.2 dB/cm at 1.15 μm) rib-waveguides with Au Schottky barriers. A 30 dB extinction ratio in the input channel was measured at a reverse-bias voltage of 24 V and the switches have a potential bandwidth of 2 GHz.

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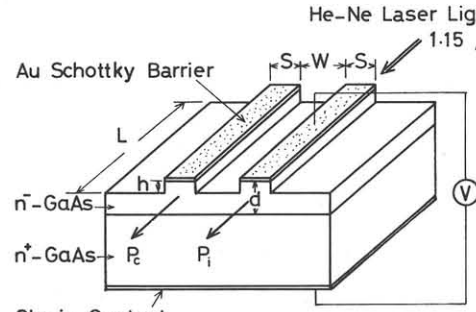

Fig.1 EDC switch with Au Schottky barriers

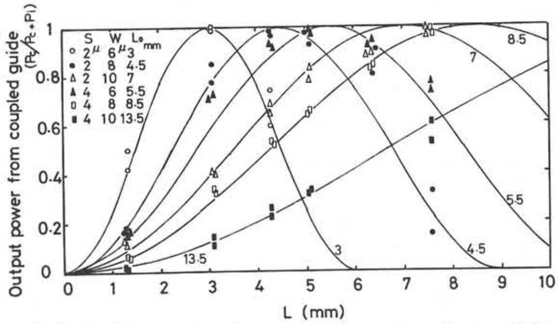

Fig.2 Relative output power from coupled guide of directional coupler.

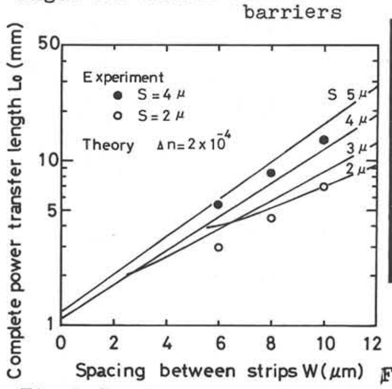

Fig.3 Complete power transfer length of directional coupler

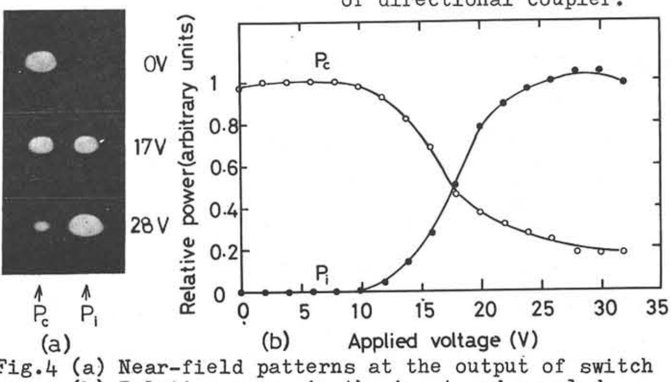

Fig.4 (a) Near-field patterns at the output of switch
(b) Relative power in the input and coupled channels as a function of an applied bias
(S=4 μm, W=8 μm, d=4 μm, h=1 μm)