Integrated Two-Wavelength DBR Lasers for Tunable Photomixing THz-Wave Generation

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***Abstract*— A 780-nm-band integrated tunable two-wavelength AlGaAs DBR laser with PN junction heaters was designed and fabricated. Tunable coherent THz wave generation in 0.8-1.2 THz using GaAs photomixers was demonstrated.**

Keywords-component; DBR lasers; two-wavelength lasers; tunalbe lasers; integrated optoelectoronics; THz-wave generation

I. INTRODUCTION

By mixing optical waves of slightly different wavelengths from two near-infrared semiconductor lasers in a low-temperature-grown (LT) GaAs-based photomixer, coherent THz waves at the beat frequency can be generated [1]. Monolithically integrated two-wavelength DBR lasers for beat signal generation were reported [2-4]. The advantages of using a monolithically integrated laser are the compactness, the good spatial mode matching and the high stability of the wavelength difference. In our previous work, an integrated two-wavelength laser was designed and fabricated, and coherent THz wave generation by photomixing was demonstrated [4].

In many applications of THz wave, frequency tunable coherent THz wave is required. Monolithic dual-mode DFB laser for this purpose was demonstrated [5]. In this work, we design and fabricate a 780-nm-band integrated tunable two-wavelength DBR laser, and demonstrate frequency tunable coherent THz wave generation by photomixing of the integrated two-wavelength laser output.

II. DEVICE DESCRIPTION

The integrated AlGaAs quantum-well tunable two-wavelength DBR laser is constructed with two tunable DBR lasers and a Y-branch waveguide amplifier, as shown in Fig. 1. Each DBR laser consists of a narrow ridge active channel and a surface relief DBR grating with a PN junction heater for wavelength tuning. The DBR lasers with slightly different grating periods of Λ_1 and Λ_2 oscillate at slightly different wavelengths. The optical waves from the two DBR lasers are combined into the single output channel of the Y waveguide amplifier and emitted from the output facet. By current injection to the heaters beside the DBRs, the lasing wavelength can be tuned through the Bragg wavelength change due to temperature rise.

For 0.4-nm difference between Λ_1 and Λ_2, for example, lasing wavelength difference of 2 nm, corresponding to beat frequency of ~1 THz, can be obtained. Preliminary test using DBR lasers fabricated from the same wafer used in this work showed that 1 nm lasing wavelength shift was obtained by 10°C temperature rise of the DBR. In order to design the heater, thermal conduction analysis was performed and temperature rise distributions in the lateral direction were approximately calculated. Then the size and the position of the heater were determined for obtaining 10°C temperature difference between the two DBR gratings. By current injection to the short wavelength side heater, the wavelength difference can be decreased to 1 nm. In contrast, by current injection to the other side heater, the wavelength difference can be increased to 3 nm. By current injection to one of the two heaters, the wavelength difference between 1 and 3 nm (frequency difference between 0.5 and 1.5 THz) can be expected.

III. DEVICE FABRICATION

At first, the slope structures were formed by RIE using shadow masks. The heater regions were covered by conventional SrF_2 masks for the vertical sidewalls. The first-order DBR gratings with different pairs of grating periods were fabricated by EB writing and two-step RIE. The ridge structures were then formed by EB writing and RIE using SrF_2 masks. Pad electrodes for the two DBR lasers, the two heaters and the Y-branch waveguide were formed on a BCB insulator layer, and an n-electrode was evaporated on the backside. After cleaving, HR and AR coatings were deposited on the rear and front facets. The laser was mounted on a Cu heatsink.

IV. EXPERIMENTAL RESULTS

The dependences of the output power from the output channel on the injection current to each DBR laser were measured at an amplifier current of 70 mA under CW operation. The two DBR lasers have slightly different light-current characteristics. The threshold currents were 40 and 47 mA, and the output powers were 12 and 9 mW at an oscillator current of 70 mA. The lasing spectra were measured under simultaneous current injections to the two DBR lasers and the Y waveguide

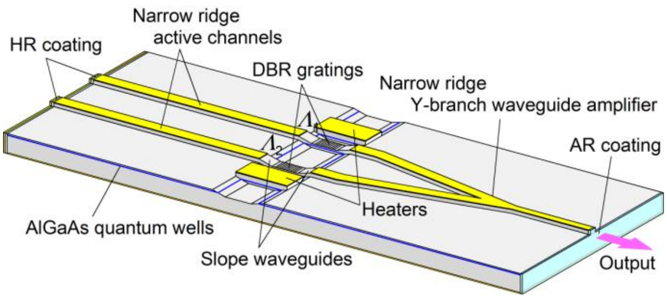

Figure 1. Schematic of integrated tunable two-wavelength DBR laser.

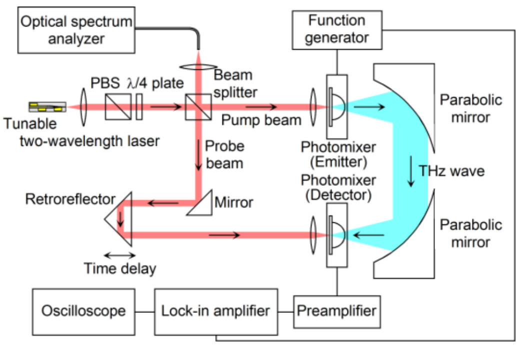

Figure 2. Experimental setup for coherent THz wave generation and detection using tunable two-wavelength laser and two photomixers.

amplifier. The wavelength difference of 2.0 nm (0.99 THz beat frequency) was obtained. By proper adjustment of the injection currents to the two DBR lasers, the same output level of about 8 mW and a side-mode suppression ratio of 25 dB were obtained. Good spatial overlap between the amplified lights from the two DBR lasers on the front facet was confirmed.

An experimental setup for coherent THz wave generation and detection using the tunable two-wavelength laser is shown in Fig. 2. Two LT-GaAs dipole-type photomixers (Hamamatsu Photonics K.K., G10620-11) were used as an emitter and a detector. A polarized beam splitter (PBS) and a λ/4 plate were inserted to reduce optical feedback. The laser beam from the two-wavelength laser was split into the pump and probe beams. The pump beam was focused onto the emitter. The emitter was biased with a rectangular voltage of ±15 V at a frequency of 10 kHz. The generated THz wave was collected and focused on the detector by a pair of off-axis parabolic mirrors. The probe beam was focused on the detector electrode gap, where the THz wave was focused. The detector photocurrent was detected by a lock-in amplifier. Delay time was scanned by moving a retroreflector on a translation stage.

Injection currents for the two DBR lasers and the Y waveguide amplifier were adjusted to obtain two-wavelength oscillation with almost equal powers. The lasing spectrum at oscillator injections of 59.5 and 64.0 mA and an amplifier injection of 80.0 mA is shown in Fig. 3(a) (no heater injection). The wavelength difference of 2.00 nm (0.99 THz beat frequency) was stable, while the optical power of each peak was not so stable. This may be due to insufficient reduction of the optical feedback. A total power before the PBS was measured as about 15 mW. By scanning the delay time, a periodic signal was obtained as shown in Fig. 3(b). This corresponds to the cross-correlation signal between the THz wave electric field and the photoexcited carrier number in the electrode gap [6]. The frequency determined from the period of the signal was 1.02 THz, which was in good agreement with the laser beat frequency.

With a current injection to the short wavelength side heater at 60 mA, a smaller wavelength deference of 1.62 nm (0.80 THz) was obtained, as shown in Fig. 3(a). By scanning the delay time, the periodic signal was also obtained and the frequency was estimated as 0.82 THz (Fig. 3(b)). On the other hand, a wider wavelength difference of 2.46 nm (1.21 THz) was obtained (Fig. 3(a)) with a current injection to the long wavelength side heater at 60 mA. The periodic signal was obtained and the frequency was estimated as 1.22 THz (Fig.

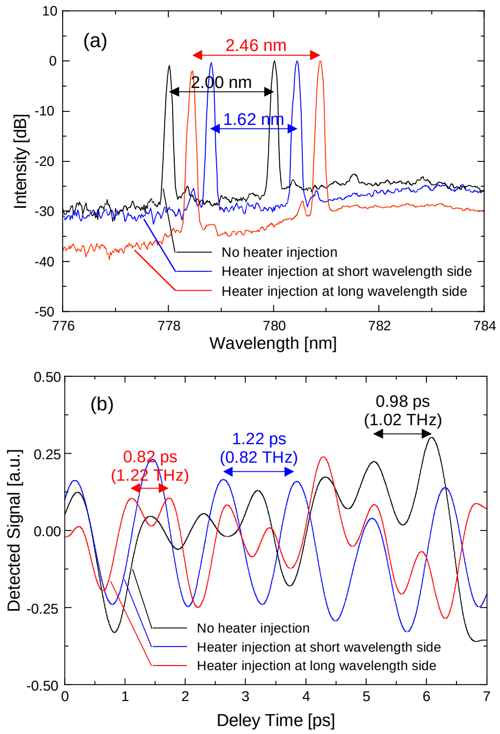

Figure 3. (a) Measured spectra of tunable two-wavelength oscillation, and (b) dependence of detected signals on delay time.

3(b)). The frequency of the generated THz wave was changed as the laser beat frequency was changed. Frequency tunable coherent THz wave generation was achieved by photomixing of the integrated tunable two-wavelength DBR laser.

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