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Thermo-optic Tuning of Hybrid III-V/Si DFB Laser by Direct Heating of Si Waveguide for FMCW LiDAR Light Sources

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Introduction

Recently, LiDAR (Light Detection and Ranging) is extending its role in various applications such as autonomous cars and drones. Current LiDAR products use mechanical scanning systems, however, non-mechanical scanning systems with very compact sizes are expected to be realized. In our project, we are developing a one-chip Si photonics FMCW (Frequency Modulated Continuous Wave) LiDAR system with slow-light grating couplers and hybrid lasers [1, 2]. In this system, a tunable DFB laser with <1 nm tuning range (unlike full C-band telecom lasers), ~100 kHz scanning speed, while maintaining high power (>100 mW) and narrow linewidth (~few hundred kHz), is required. In this work, thermo-optic tuning of hybrid III-V/Si DFB laser by direct heating of the Si waveguide underneath the III-V structure is proposed for the first time, via lateral current injection to the Si waveguide through a thin slab layer.

Results

The layer structure is shown in Fig. 1. The III-V layer structure is the same as the GaInAsP/SOI hybrid laser reported by our group [3], thus, it is used in this work to evaluate the 2-D temperature distribution inside the device. A DFB structure is constructed by introducing grating corrugations to the Si-waveguide underneath the III-V structure. By doping both sides of the Si-waveguide, micro-heater action is expected by heating up due to current injection [4]. By this structure, relatively fast tuning is expected compared with structures that put a metal micro heater near the laser due to the reduced distance between the heat source and the Bragg grating.

The dependence of the Bragg wavelength (λ_B) on the tuning temperature is obtained by the equivalent-index method, and the grating period is calculated to achieve a Bragg wavelength of 1550 nm (without tuning). The Bragg wavelength shift is found to be linear with the tuning temperature, with a calculated temperature coefficient of 0.074 nm/°C. Hence, 1 nm wavelength shift is expected by increasing the temperature of the Si waveguide by around 13 °C, this corresponds to a very sufficient range resolution of 1 mm according to the FMCW radar equation:

$$\Delta z = \{2\ln(2/\pi)\}(\lambda_0^2/\Delta\lambda) \quad \cdots\cdots (1)$$

To confirm the speed of tuning, the Bragg wavelength shift for two types of tuning signals, rectangular and triangular pulse trains, with equal peak values are compared in Fig. 2. It is found that the triangular signal exhibits better output in terms of linearity with time. As shown in Fig. 2(b), a typical pulse repetition frequency of 100 kHz can be achieved at a peak tuning power of 44 mW for a wavelength shift of 1 nm.

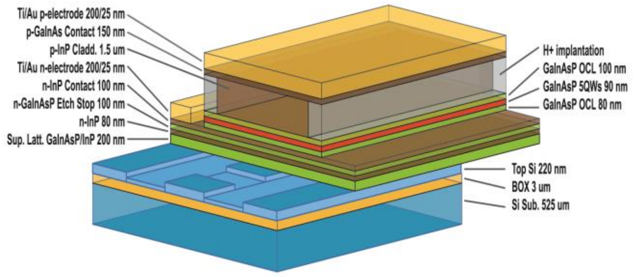
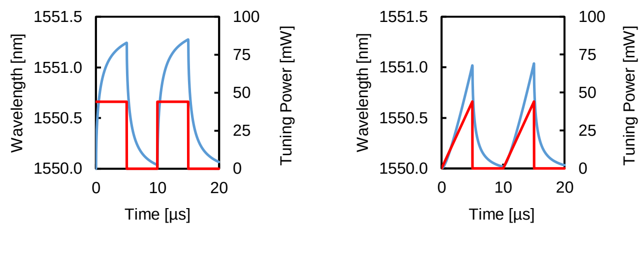


Fig. 1. Structure of GaInAsP/SOI hybrid DFB laser, tuning current is injected to the Si waveguide in the lateral direction.



(a) (b)

Fig. 2. The optical output signal (blue) for two different tuning signals (red), (a) rectangular signal, and (b) triangular signal.

Acknowledgments

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