Solid-state Beam Scanner Based on VCSEL Integrated Amplifier with Scan Resolution of over 200

(D)Shanting Hu, (M2)Masashi Takanohashi, Xiaodong Gu, (D)Keisuke Shimura and Fumio Koyama
Laboratory for Future Interdisciplinary Research of Science and Technology, Tokyo Institute of Technology
4259-R2-22 Nagatsuta, Midori-ku, Yokohama 226-8503, Japan
hu.s.ab@m.titech.ac.jp

INTRODUCTION

An optical beam scanner is a key element for various applications such as LiDAR and structured light sensing [1]. Since mechanical beam scanners have difficulties such as low scan speed, large module size, high cost and so on, a non-mechanical scanner is attracting more and more interests. Phased array beam scanners based on silicon photonics were reported [2, 3], but there still remain critical issues to be solved. We proposed and demonstrated a beam steering device based on a VCSEL structure, showing the record high-resolution beam steering [4, 5]. In this paper, we propose and demonstrate a novel integrated platform for large tuning angle, high resolution and amplified power.

SCHEMATIC STRUCTURE

The schematic structure of our integrated beam scanner is illustrated in Fig. 1. Firstly, proton is implanted between a single-mode seed VCSEL and amplifier section on the half-VCSEL structure for electrical isolation. Then the top phase control layer of the seed VCSEL section is partly etched to form a resonant wavelength detuning of the VCSEL and amplifier sections. Then a SiO_2/Ta_2O_5 dielectric DBR is evaporated on the top of the half-VCSEL. As we already presented the modeling in [6], in order to achieve unidirectional coupling from the VCSEL to the amplifier, a shorter resonant wavelength of the seed VCSEL is needed. We fabricated 850nm amplifier-integrated VCSELs. The oxide aperture width is 3um and the length of the VCSEL and the amplifier sections are 3um and 900um, respectively.

EXPERIMENTAL MEASUREMENTS

Figure 2 shows the measured far field pattern (FFP) with pumping the VCSEL and amplifier sections both, showing a narrow beam divergence at a FFP angle of around 19.5°. With pumping the amplifier with 100mA under CW current and seed light from the VCSEL, we could get a single-peak narrow beam divergence of 0.06°. It is almost diffraction-limited. Figure 3 shows the measured L/I when the amplifier is pumped with coupled seed light from the VCSEL. The photodiode is tilted from the vertical axis by 25° so that the vertical lasing power of the amplifier is not captured. An output power of 7mW under 100mA CW current was obtained. Higher output power can be expected by some device optimizations including top mirror reflectivity design. Continuous beam steering can be seen in Fig. 4. The lasing wavelength of the seed VCSEL can be tuned continuously through changing current injection thanks to a thermal effect. By simply changing the injection current at the seed VCSEL, we can continuously change the output beam angle while fixing the amplifier current at 100mA. At the same time, the refractive index of the amplifier section can be changed through changing the injection current, which offers differential operations of beam steering. The total steering range through push-pull pumping is around 16°with a number of resolution point of around 200. It is a record number among VCSEL-based beam scanners

CONCLUSIONS

We carried out the lateral integration of a slow-light beam scanner/amplifier and a seed VCSEL with an in-plane resonant wavelength detuning. We demonstrated 16° of beam steering, 200 resolution points and 7mW single-mode output power. Through optimizing the designs, fabrication processes and increasing the scanner length, further improvements of steering angle and single mode power can be expected for 3D sensing.

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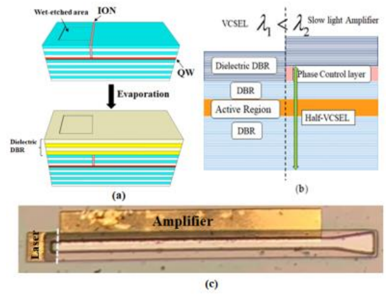

Fig. 1 Schematic structure of the proposed device

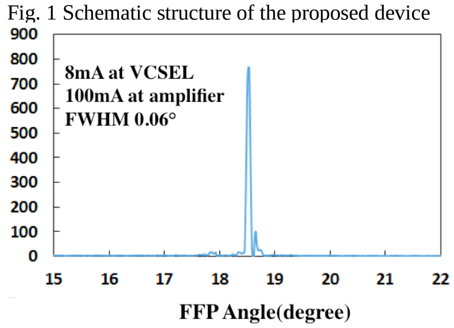

Fig. 2 Measured FFP with amplification

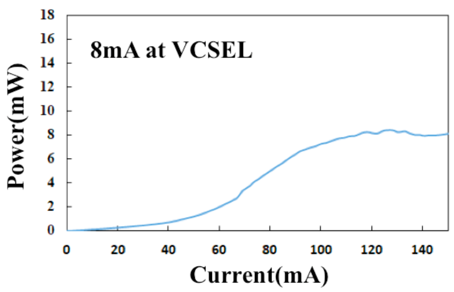

Fig. 3 I/L of the device with a seed light from the VCSEL

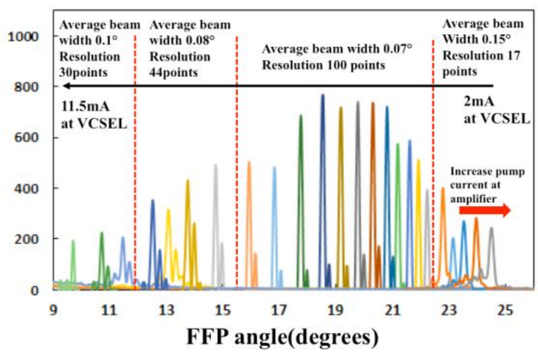

Fig. 4 Continuous beam steering