シリコン上量子ドットレーザにおける 10 Gbps 直接変調動作

10 Gbps Direct Modulation of Quantum Dot Lasers on Silicon

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Wafer-bonded quantum dot (QD) laser on Si [1, 2] is an excellent candidate for being an active silicon photonic device by QD laser's superiorities on its low threshold condition and temperature stability [3]. In a communication system, high-speed transceiver with low power consumption is desirable. Direct modulation of laser diodes is thus more fascinating due to its low cost, simpler fabrication, and system compactness, compared to the use of external electro-absorption or electro-optic modulators integrated with lasers. In the previous presentation [4], we have shown the first direct modulation in QD lasers on Si, in which the metal bonding layer was adapted for the integration. In this report, we further demonstrate the direct modulation in the direct-bonded QD lasers on Si with 10 Gbps non-return-to-zero signal at room temperature, and 6 Gbps modulation is also achieved at 60 °C without any current adjustment. The laser was integrated to Si without any intermediate layer included, which may benefit the optical mode coupling to Si waveguide in our future work.

In the fabrication, both InAs/GaAs QD laser wafer and Si wafer were first cleaned and the surfaces were activated by UV-ozone treatment, which hydrophilized the bonding surfaces and thus brought strong bonding strength here. Then the laser was directly bonded onto Si by annealing at 300 °C in ambient air for 3 hours under a uniaxial pressure of 0.1 MPa. After removing GaAs substrate, a 5-μm-wide ridge structure was fabricated on the bonded laser. The laser device was then finished by cleaving into a 500 μm × 500 μm chip without any HR/AR coatings on the facets. Figure. 1 shows a cross-sectional SEM image of the bonded laser, where the laser is tightly bonded on Si. Figure. 2 shows light-current curves of the bonded laser under continuous-wave (CW) operation at various temperatures, where the clear kink shows a threshold current of 41 mA at room temperature; the inset gives an electroluminescence spectrum indicating a lasing at around 1.3 μm. Figure. 3 gives the measured eye patterns showing that the bonded laser is directly modulated with a 10 Gbps at room temperature. Furthermore, 6 Gbps modulation is achieved at temperatures up to 60 °C without any current adjustment.

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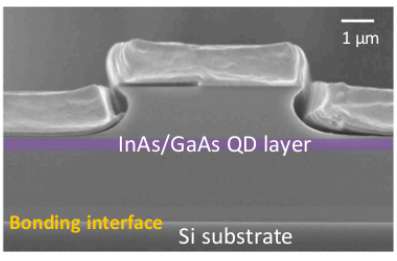

Fig 1. Cross-sectional SEM image of the direct-bonded QD laser on Si substrate.

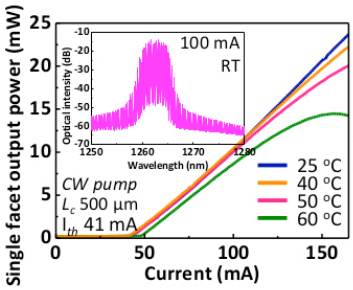

Fig 2. Room-temperature L-I curve and (inset) electroluminescence spectrum of the 500-μm-long bonded laser under CW pumping.

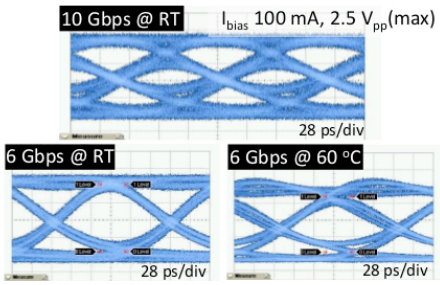

Fig 3. Eye patterns of a directly modulated bonded QD laser at 10 Gbps under room temperature, and 6 Gbps under room temperature and 60 °C.

References

[1] K. Tanabe, K. Watanabe, and Y. Arakawa, Sci. Rep. **2**, 349 (2012).
[2] Y. H. Jhang, K. Tanabe, S. Iwamoto, and Y. Arakawa, IEEE Photon. Technol. Lett. **27**, 875 (2015).
[3] Y. Arakawa and H. Sakaki, Appl. Phys. Lett. **40**, 939 (1982).
[4] Y. H. Jhang, R. Mochida, K. Tanabe, K. Takemasa, M. Sugawara, S. Iwamoto, and Y. Arakawa, 63rd JSAP Spring Meeting, Tokyo Institute of Technology, Ookayama Campus, 14a-H10-2, Tokyo (2016).