High-bandwidth membrane III–V lasers on SiO_2/Si

Researchers boost 3dB frequency by 26% to 60GHz, enabling 200-400Gbs performance for 2-channel system.

Nippon Telegraph and Telephone Corporation (NTT) and Waseda University in Japan have reported a 26% increase in 3dB bandwidth to 60GHz for its two-channel energy-efficient directly modulated membrane laser (DML) arrays on a silicon dioxide/silicon (SiO_2/Si) platform [Nikolaos-Panteleimon Diamantopoulos et al, IEEE Journal of Lightwave Technology, published online 23 February 2022].

Such arrays are being developed for higher data rates in data centers and high-performance computing systems linked by optical fiber. The 60GHz bandwidth brings in sight 200–400 gigabit per second (Gbps) transmission with simple modulation techniques.

DMLs on much more expensive high-thermal-conductivity silicon carbide (SiC) can achieve 108GHz 3dB bandwidths, but the team sees the deployment on silicon as "being a critical step towards achieving low-cost production via large silicon wafers".

The researchers increased the bandwidth by enhancing photon-photon resonance (PPR) effects through careful design of the longitudinal modes of the laser cavity.

The laser cavity consisted of a rear distributed Bragg reflector (DBR-r) that was detuned from one of the two main resonant wavelengths of the distributed feedback (DFB) section on the multiple quantum well structure (Figure 1). The front section consisted of a DBR (DBR-f) with a similar wavelength response as the DFB. The aim of the detuning was to single out the non-detuned wavelength.

The lengths of the sections were optimized to increase the PPR frequency to 50GHz, a 10GHz increase over the group's previous work. In particular, the DFB section length was reduced to 80μm from 100μm previously.

The membrane DBR laser consisted of a buried MQW heterostructure between lateral p- and n-type indium phosphide (InP), giving a PiN junction (Figure 2) on SiO2/Si substrate. The total thickness of the III–V membrane was 350nm. The laser structure itself consisted of a 600nm core of indium gallium aluminium arsenide (InGaAlAs) layers with 103nm MQW active region aimed at O-band operation (1260–1360nm). NTT/Waseda use selective-area growth on directly bonded InP on SiO_2/Si to produce such structures.

The light from the 2-laser array was coupled into standard single-mode fibers (SSMFs) using a spot-size converter consisting of an InP taper and SiO_x waveguide in SiO_2 cladding. The channels were separated at 250μm pitch to avoid electrical and thermal crosstalk.

The laser output under modulation varied with frequency for both devices at 25°C, falling by 3dB relative to the DC performance at around 60GHz. The 3dB bandwidth of the group's previous work was around 47GHz.

With a view to practical implementation, the team performed a number of short-reach tests using 112Gbps non-return to zero (NRZ) and 100GBaud four-level pulse-amplitude modulation (PAM-4) (200Gbps) signals. No crosstalk was detected between the

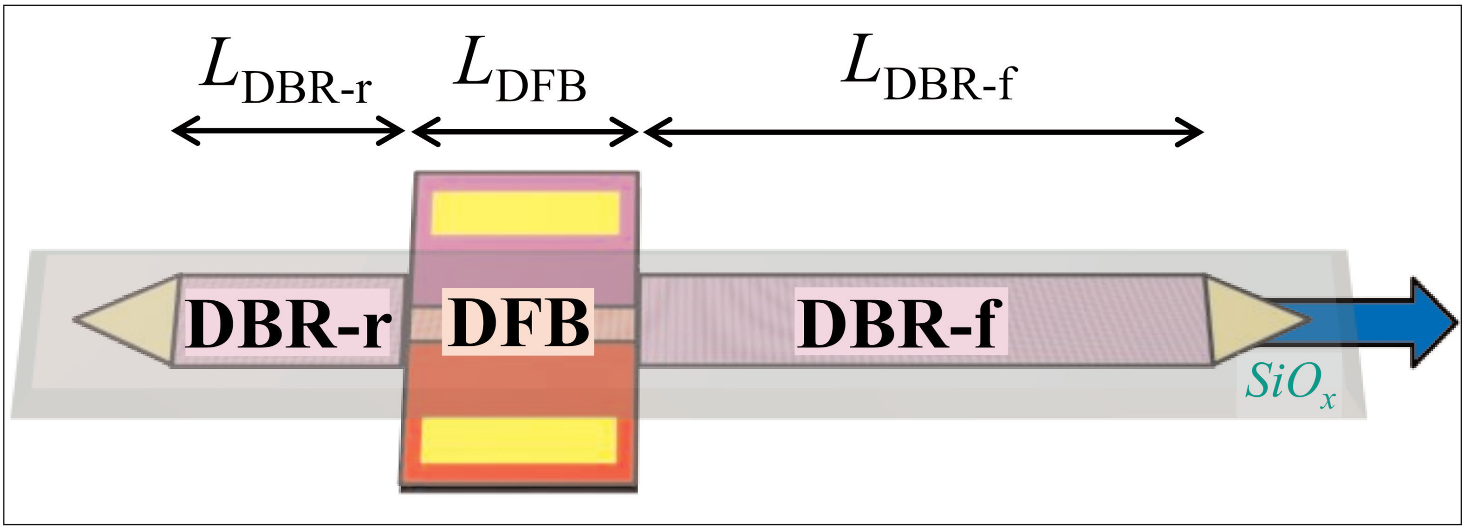

Figure 1. Longitudinal laser design for photon-photon resonance.

two channels. The operating powers for NRZ signals were around 26mW and 35mW for the separate devices. The difference in power was due to fabrication variations.

The bit-error rates (BERs) after NRZ transmission over 2km of SSMF met the standards for 200/400Gbps Ethernet with KP4 forward-error correction (KP4-FEC). The laser operating powers were equivalent to 0.24pJ/bit and 0.31pJ/bit for the respective channels, or 0.29pJ/bit combined.

The PAM-4 modulation did not manage the BER needed for KP4-FEC, but it did manage, with respective BERs of 1.58E−2 and 7.25E−3, the more relaxed threshold for hard-decision FEC (HD-FEC), but with higher power consumption and latency.

The researchers also considered the performance at up to 75°C with a view to implementations without special cooling systems. At the higher temperature, the 3dB bandwidth reduced to 45GHz, which could be adequate for 100Gbps-class PAM-4 signals, according to the team. The optimum bias current was increased slightly to 16.3mA from 14.1mA at 25°C. The researchers comment: "Since the bias current deviation is only within ±1.1mA, simple control electronics, typically found in DML transmitters, can be utilized as real-time adjustment mechanisms for the bias currents, without any need for costly and extra power-consuming heaters." ■

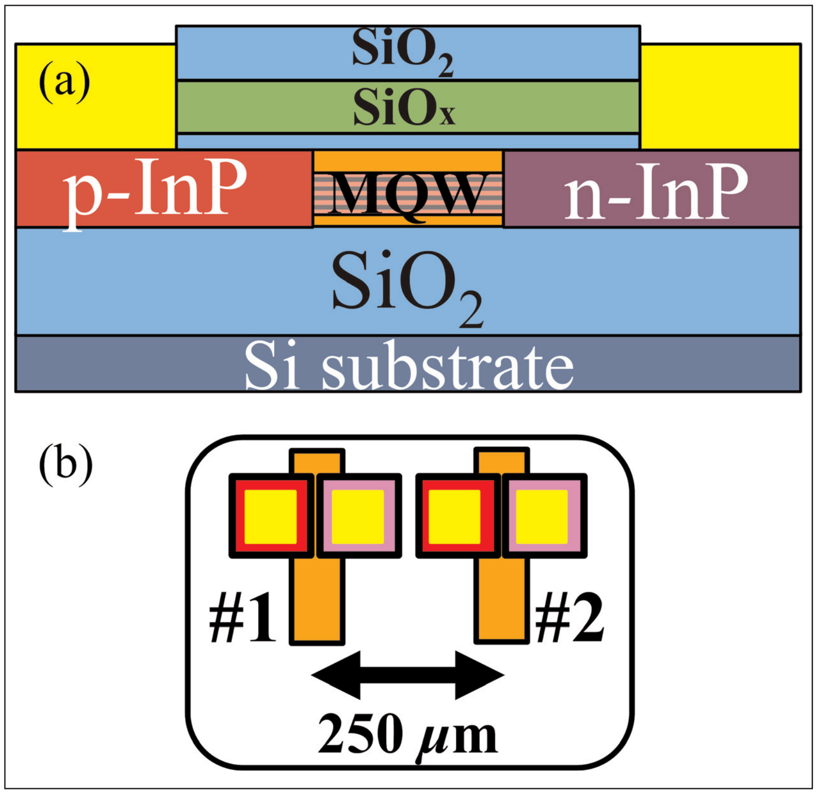

Figure 2. Fabricated laser array structure: (a) cross section; (b) two-channel laser array chiplet.

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