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Hydrogen implanted 1.3 μ m vertical cavity surface-emitting lasers with dielectric and wafer-boned GaAs/AlAs mirrors

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Abstract

A 1.3 μ m wavelength vertical-cavity surface-emitting laser (VCSEL) containing proton implanted isolation regions and a dielectric top mirror and a wafer-bonded GaAs/AlAs bottom mirror was fabricated. A room temperature pulsed threshold current density of 1.13 kA/cm² and a threshold current of 2 mA have been demonstrated.

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We demonstrate a new structure for long wavelength (1.3 micron) VCSELs using hydrogen implantation for current confinement and wafer-bonded GaAs/AlAs Bragg mirrors and ZnSe/MgF dielectric mirrors for top and bottom mirrors. A p-GaAs/AlAs Bragg mirror was wafer bonded to the strain-compensated InGaAlAs quantum wells as the bottom mirror since GaAs/AlAs mirrors have a lager index difference and better thermal conductivity than InGaAsP/InP mirrors lattice-matched to InP. Protons were implanted through the InP cladding layers and the quantum wells and stopped at the p-GaAs/AlAs mirror to provide lateral current confinement. Compared to VCSELs with double-bonded GaAs/AlAs mirrors, the single-bonded structure with implanted current confinement is easier to fabricate and more tolerable in device design, favorable for volume production of long wavelength VCSELs.

Fig. 1 shows the schematic of the VCSEL. The design of the strain-compensated quantum wells and the p-GaAs/AlAs Bragg mirror is the same as those in Ref.1. Briefly speaking, the laser cavity consists of 1.3 μ m strain-compensated AlGaInAs multiple quantum wells (MQWs) and n- and p-InP cladding layers. The p-GaAs/AlAs Bragg mirror was wafer-bonded to the p-InP. After wafer bonding and the removal of the InP substrate and the InGaAs etch stop layer, the p- and n- ohmic contacts were formed. Protons were implanted through the top n-contact alloy and the InP and quantum well layers and reside in the p-GaAs/AlAs mirror. A relatively low dosage of the order of $4x10^{14}$ cm⁻² and an implanted depth approximately 1.65 μ m were used to minimize the damage in the cavity layers while achieving efficient current confinement. The implantation confined circular apertures have diameters of 15, 12, 11, and 7 μ m. After implantation, the devices were annealed at 400 °C for 30 seconds to recover damages in the cavity layers. Finally, six pairs of ZnSe/MgF layers were deposited to form the top mirror.

The VCSELs were characterized by making probe contacts without being mounted to heat sinks. All measured devices except those with a 7 μ m diameter lase at room temperature, pulsed condition. As shown in Fig. 2, a threshold current density (J_{th}) of 1.13 kA/cm² has been achieved for a 15 μ m device. This is the lowest threshold current density for 1.3 μ m VCSELs to date. The threshold currents were below 7 mA for all measured devices with diameters of 15, 12, 11 μ m; and the lowest threshold current was 2 mA, obtained from a 15 μ m device. However, the high threshold voltage (8V) and the lack

of heat sinks prevent the devices from achieving room temperature cw operation. All devices operated at a single longitudinal mode, and most at multiple transverse modes. Fig. 3 shows a logarithmic lasing spectrum of a 15 μ m device under 2.5 times of its threshold current. The side mode suppression ratio is above 35 dB.

In summary, we demonstrated a 1.3 μ m VCSEL using implantation for current confinement and wafer bonding and dielectric layers for mirrors. A pulsed threshold current density of 1.13 kA/cm² and a pulsed threshold current of 2 mA have been achieved at room temperature.

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Figure Captions:

Fig. 1. Schematic structure of a new long wavelength VCSEL.

Fig. 2. Room temperature pulsed L-I characteristics for a 15 μ m device. The inset shows the dependence of threshold current density (J_{tb}) on device diameters.

Fig. 3. Logarithmic lasing spectrum of a 15 µm device under room temperature pulsed

operation at 5 mA (=2.5 I_{th}).



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Current (mA)

Fig. 2 Hydrogen implanted..... Y. Qian et. al.



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Wavelength (µm)

Fig. 3 Hydrogen implanted ... Y. Qian et. al.