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

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Abstract

A 1.3 μm 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/cm^2 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 μm 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 4×10^{14} cm^{-2} and an implanted depth approximately 1.65 μm 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 μm. 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 μm diameter lase at room temperature, pulsed condition. As shown in Fig. 2, a threshold current density (J_{th}) of 1.13 kA/cm^2 has been achieved for a 15 μm device. This is the lowest threshold current density for 1.3 μm VCSELs to date. The threshold currents were below 7 mA for all measured devices with diameters of 15, 12, 11 μm; and the lowest threshold current was 2 mA, obtained from a 15 μm 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 μm 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 μm VCSEL using implantation for current confinement and wafer bonding and dielectric layers for mirrors. A pulsed threshold current density of 1.13 kA/cm^2 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 μm device. The inset shows the dependence of threshold current density (J_{th}) 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}).

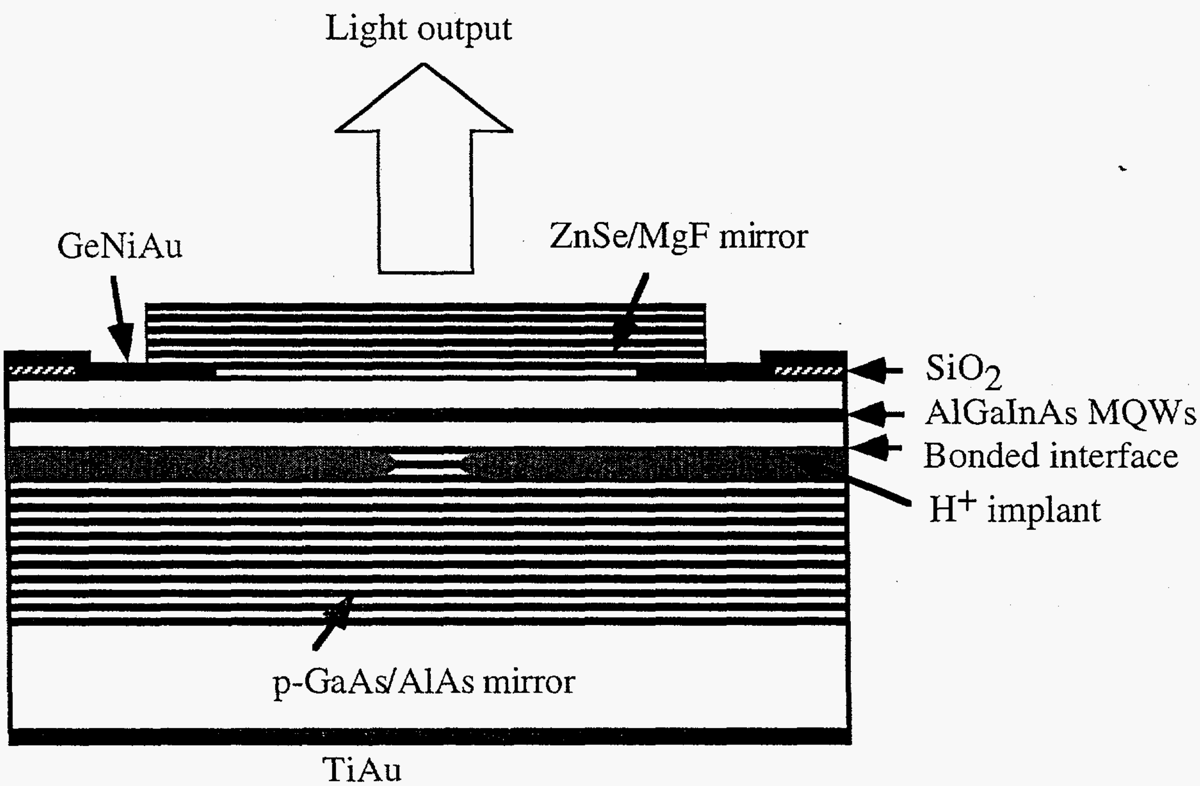

Fig. 1, Hydrogen implanted ... Yi Qian et. al.

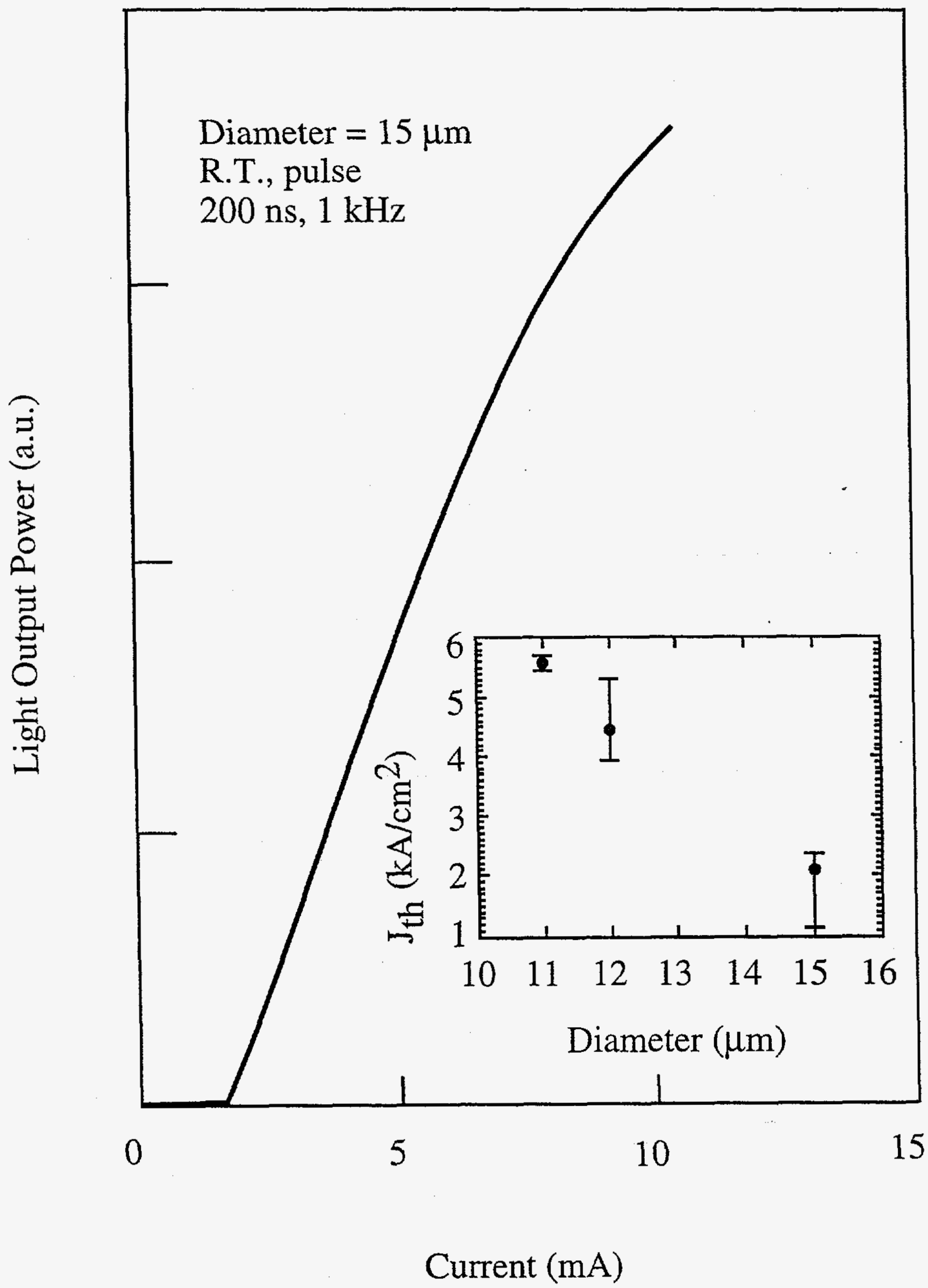

Fig. 2 Hydrogen implanted..... Y. Qian et. al.

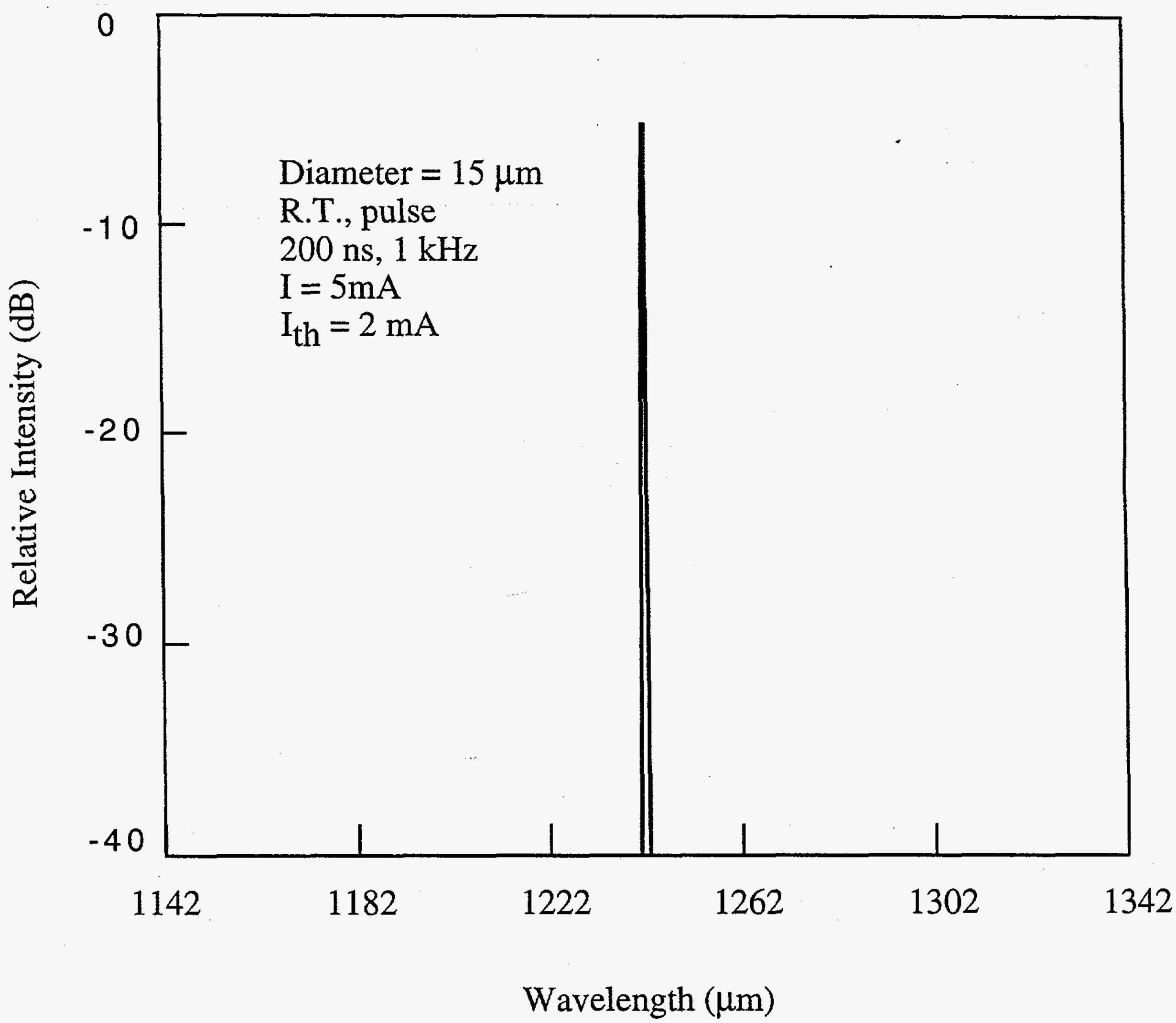

Fig. 3 Hydrogen implanted ... Y. Qian et. al.