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Room Temperature Continuous Wave InGaAsN Quantum Well Vertical Cavity Lasers Emitting at 1.3 μm

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Abstract

Selectively oxidized vertical cavity lasers emitting at 1294 nm using InGaAsN quantum wells are reported for the first time which operate continuous wave at and above room temperature. The lasers employ two n-type $Al_{0.94}Ga_{0.06}As$/GaAs distributed Bragg reflectors each with a selectively oxidized current aperture adjacent to the optical cavity, and the top output mirror contains a tunnel junction to inject holes into the active region. Continuous wave single mode lasing is observed up to 55 °C. These lasers exhibit the longest wavelength reported to date for vertical cavity surface emitting lasers grown on GaAs substrates.

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Vertical Cavity Lasers Emitting at 1.3 μm

Vertical cavity surface emitting laser (VCSEL) sources emitting at 850 nm have been widely and rapidly adopted into Gigabit Ethernet applications. Short wavelength VCSELs are particularly suitable for multimode optical fiber local area networks due to their reduced threshold current, circular output beam, and inexpensive and high volume manufacture. However, there is strong interest in developing VCSELs emitting at 1.3 μm for longer optical networks in order to leverage high bandwidth single mode fiber that is often already installed as well as to operate at the dispersion minimum of silica optical fiber.

Monolithic InGaAsP/InP based VCSELs which can emit in the 1.3 to 1.6 μm regime are handicapped by relatively low refractive index contrast inherent to this material system leading to inferior distributed Bragg reflectors [1]. Wafer bonded VCSELs fabricated by combining InGaAsP active regions with AlGaAs/GaAs distributed Bragg reflectors have demonstrated impressive characteristics [2], but the manufacturability of this approach has not been verified. Recently, attention has been focussed on the development of VCSEL active regions which emit at 1.3 μm, but can be grown pseudomorphic on GaAs, such as InAs quantum dots [3], GaAsSb quantum wells [4], and InGaAsN quantum wells [5, 6]. These materials exhibit relatively low material gain, but allow the mature AlGaAs/GaAs distributed Bragg reflector mirror technology to be immediately exploited for long wavelength VCSELs. To date, VCSELs based on pseudomorphic GaAs materials have achieved lasing emission only slightly longer than 1.2 μm [4-6]. We report the first 1.3 μm selectively oxidized VCSELs using InGaAsN quantum wells which operate continuous wave at and above room temperature.

Shown in Fig. 1 is a sketch of the VCSEL structure. The VCSELs are grown on GaAs substrates using molecular beam epitaxy. The top and bottom n-type distributed Bragg reflector mirrors contain 28 and 33 periods, respectively, and are composed of quarter wavelength thick layers of $Al_{0.94}Ga_{0.06}As$ and GaAs. Utilizing two n-type mirrors reduces the free carrier absorption, which can be excessive at long wavelengths in p-type materials. A tunnel junction is positioned in the top mirror to convert electrons to holes for injection into the active region [7, 8]. The high index layers immediately adjacent to each side of the optical cavity are AlAs and are selectively oxidized to provide efficient electrical and optical oxide aperture confinement [9]. The optical cavity contains InGaAsN quantum wells designed for emission at nominally 1.3 μm.

Shown in Fig. 2 are the room temperature output characteristics of a representative VCSEL with 4.5 x 4.5 μm oxide apertures. The corresponding spectrum showing single transverse mode lasing emission at 1294 nm with 28 dB side mode suppression is depicted in Fig. 3. Single mode output power of 60 μW is obtained at 20°C and continuous wave operation is observed up to 55°C. Interestingly, the threshold current monotonically decreases with decreasing temperature (down to 5°C), which implies that the laser gain maximum is *longer* than 1294 nm. The submilliwatt maximum output in Fig. 2 is the combined result of the high reflectivity output coupler and the spectral misalignment between the cavity resonance and the laser gain. The high diode voltage in Fig. 2 can be reduced by incorporating compositional mirror grading into our simple mirror design.

In summary, motivated by demands of emerging VCSEL network applications, continuous wave operation of 1.3 μm VCSELs grown on GaAs substrates has been observed up to 55°C. These VCSELs employ the mature AlGaAs/GaAs distributed Bragg reflector mirror technology, including selective oxidation for efficient cavity designs. Moreover, by incorporating a tunnel junction near the optical cavity, both mirrors are doped n-type, which provides the benefits of low optical loss as demonstrated in other VCSEL materials and wavelengths. With further improvements in the mirror and cavity design, we expect appropriate long wavelength VCSEL performance can be achieved to fuel the next generation of applications.

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Figure Captions

Figure 1. Sketch of 1.3 μm VCSEL structure showing top and bottom n-type mirrors with selectively oxidized apertures and a tunnel junction in the top output coupler.

Figure 2. Laser characteristics from a VCSEL with a 4.5 x 4.5 μm aperture at 20 °C; the threshold current (voltage) is 1.95 mA (4.9 V).

Figure 3. Lasing spectrum of long wavelength VCSEL showing emission at 1294 nm with 28 dB of side mode suppression.

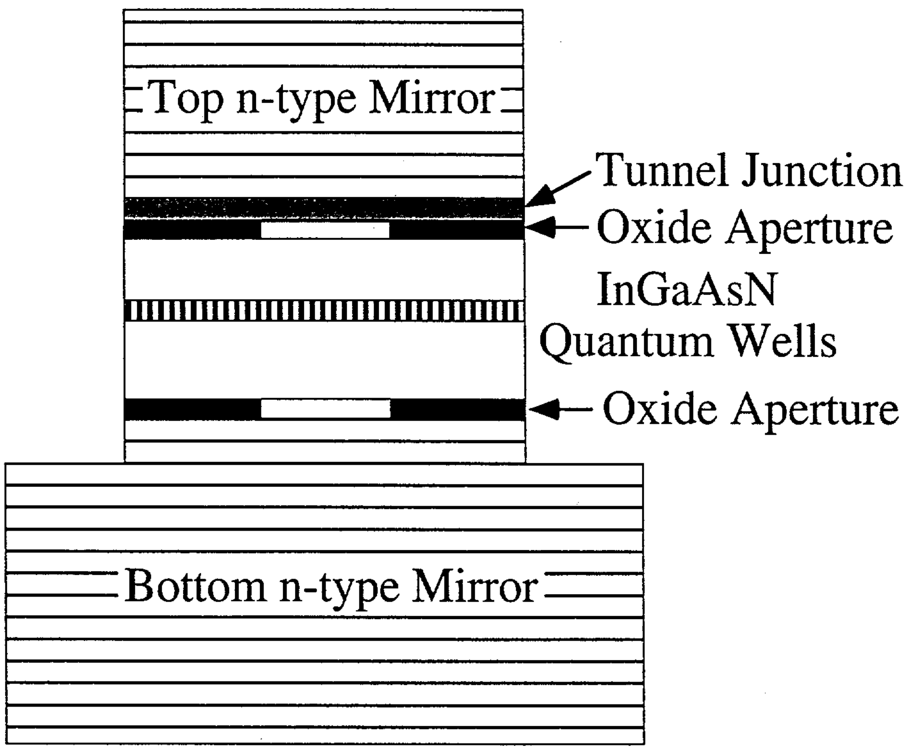

Figure 1
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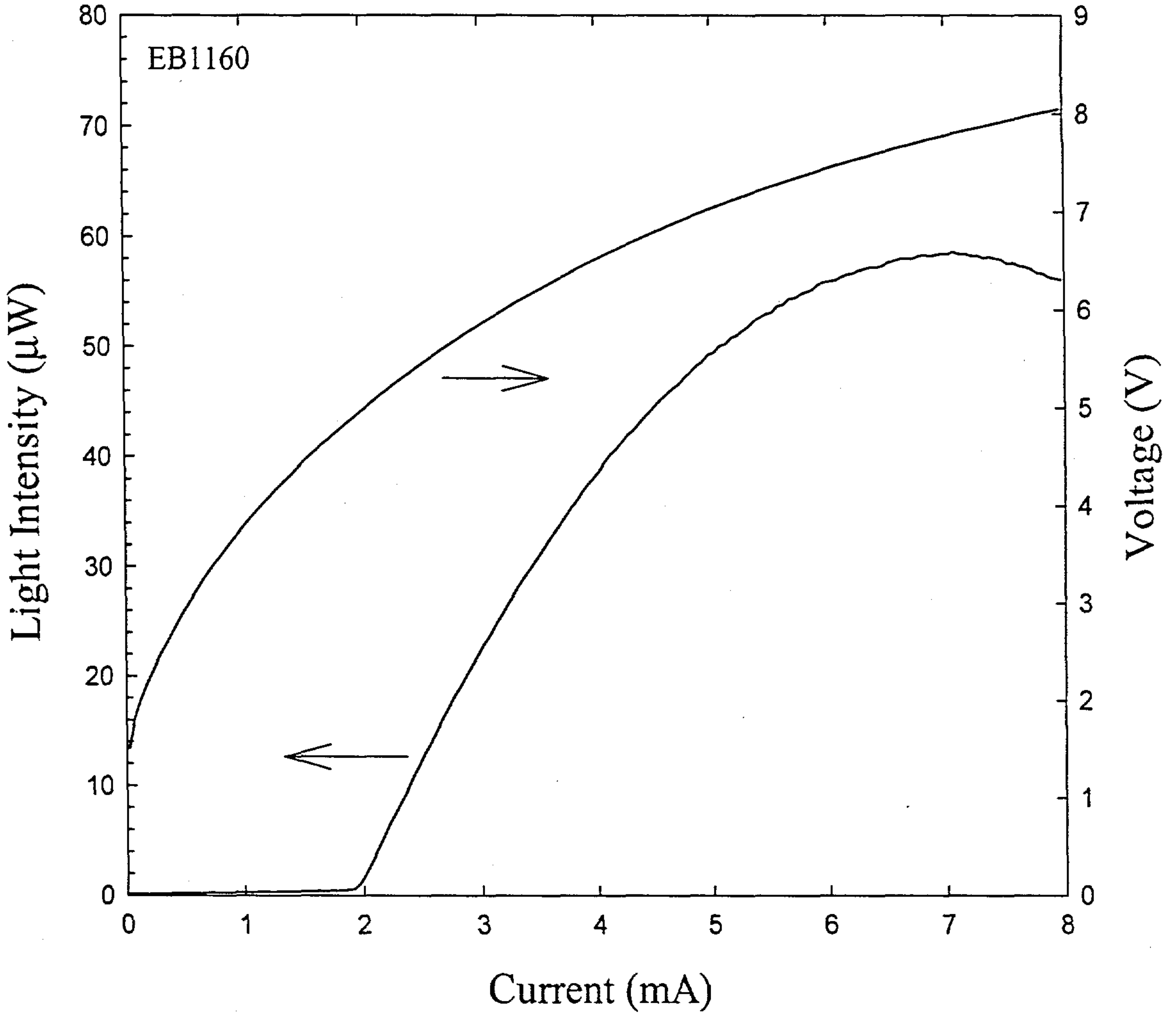

Figure 2
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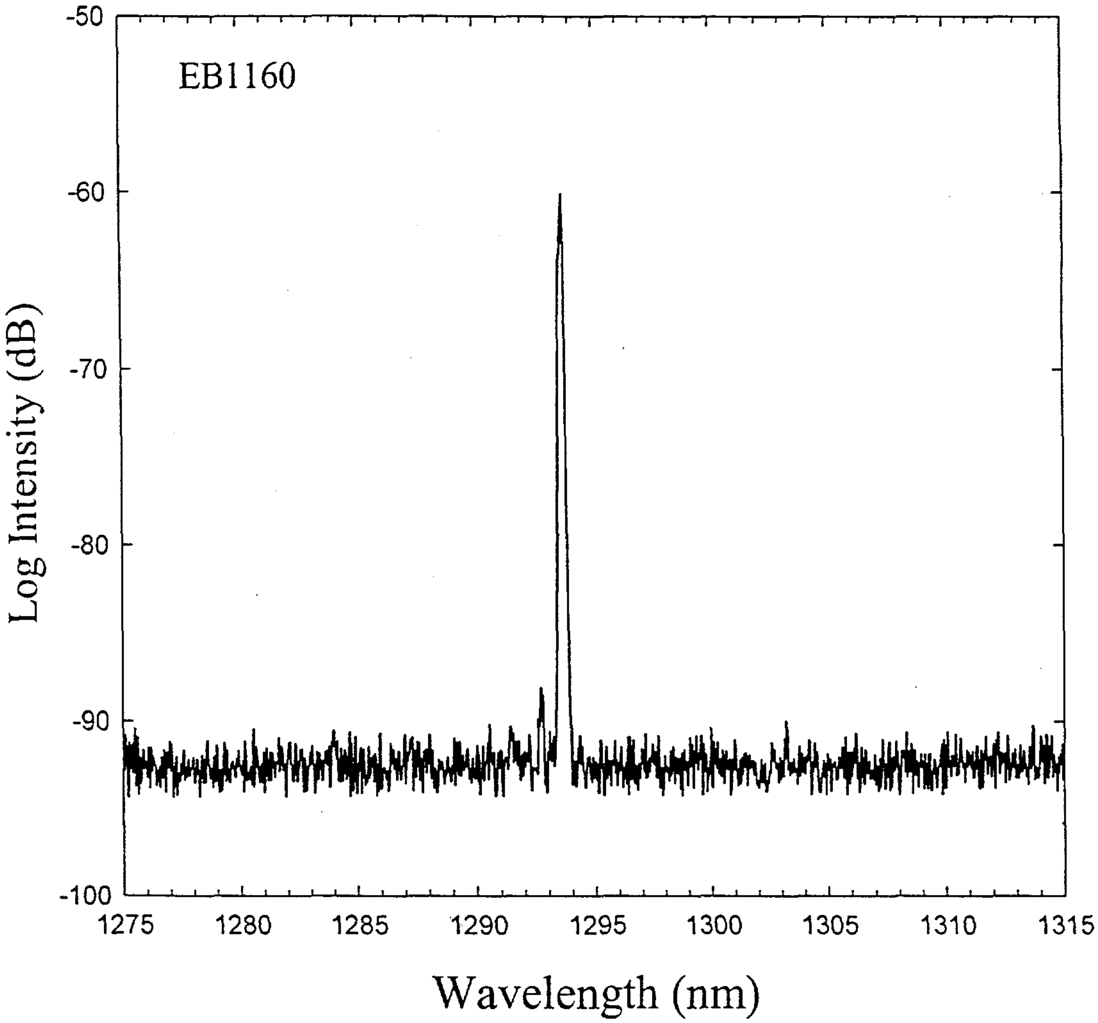

Figure 3
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