Widely Tunable Vertical Cavity Surface Emitting Lasers Near 1.55 μm Emission Wavelength

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Vertical Cavity Surface Emitting Lasers (VCSELs) have been explored for several years for use in many applications, ranging from chemical sensing [1] to data transmission [2]. Currently, VCSELs with wavelengths shorter than 1 μm are employed in Very Short Reach (VSR) data communications over optical fibers. Because of the low power of the lasers as well as the dispersion and attenuation present in the silica optical fibers that are typically used, the transmission distance is limited to several hundred meters for a VCSEL with around 850 nm emission wavelength [3]. VCSEL sources have been attractive in these applications despite the distance limitation due to economic advantages associated with much lower production costs for VCSELs as compared with edge-emitting lasers.

However, applications requiring longer transmission distances must use sources with wavelengths greater than 1 μm, with two separate bands centered at 1310 nm and 1550 nm being the most often employed. Until recently, edge-emitting lasers (either Fabry-Perot type or using a distributed feedback structure or a distributed Bragg reflector) have been the only commercially available solution for these longer-reach applications. Several difficulties in developing long-wavelength VCSELs have limited their technological evolution. Notably, the creation of lattice-matched semiconductor mirrors that are of suitably high reflectivity (typically > 98%) at the lasing wavelength has proven difficult. Related to this problem is the difficulty of ensuring good thermal performance, as the thermal conductivity of the semiconductor mirror stacks tends to be low in comparison with the cladding regions of edge-emitting lasers.

Despite the challenges, several approaches have been demonstrated to be capable of producing long-wavelength VCSELs. These fall into three categories, loosely described as employing different mirror materials, using different active region materials, or wafer bonding. Active region materials including InGaAsN, GaAsSb, and InAs quantum dots have all been employed successfully in research laboratories. Higher contrast mirror materials, including dielectrics (ZnSe/MgF or SiO_2/TiO_2), as well as semiconductor materials like AlGaAsSb/GaAsSb and InAlAs/InGaAsP have also been employed. Finally, double wafer bonding has allowed the integration of lattice-mismatched materials so that high contrast mirrors (such as AlAs/GaAs) can be bonded to an InGaAsP/InP quantum well active region. Each of these approaches suffers from disadvantages that have so far prevented their commercial manufacture (although several companies have announced testable prototypes).

In considering the problem of long-wavelength VCSEL manufacture, the authors studied the results of previous research, and have been able to combine several of the previously mentioned techniques to produce a monolithic tunable VCSEL that emits in the 1.55 μm telecom transmission window (both C and L band). The optically-pumped external cavity device, based on InP technology, has been successfully demonstrated to produce more than 1.5 mW of output power, tunable over an approximately 30-nm range around 1.55 μm. Figure 1 illustrates the power output as a function of input for the device. The output power at 10 °C exceeds 20 mW. At room temperature the device has demonstrated greater than 1.8 mW of fiber-coupled output power, enough for use in metropolitan telecommunications links, where the price advantage of a VCSEL provides a motivation for utilizing the device in next-generation telecommunications hardware. To date, the device has demonstrated data transmission over single-mode fiber at a data rate of 2 Gbps, when coupled with an external lithium niobate optical modulator.

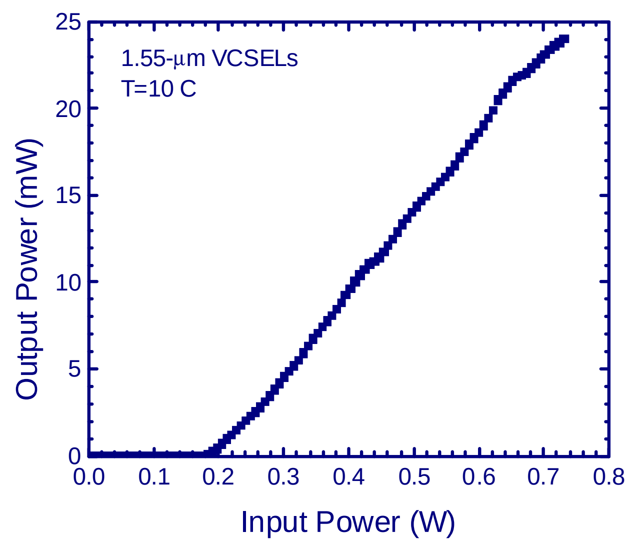

Figure 1. Output power of the device as a function of input power. The device was maintained at 10 °C. Pumping was achieved with a 980-nm laser diode.

Details of the device design as well as performance will be discussed. In particular, the importance of broad tunability and power flatness over the tuning region will be emphasized, with an eye towards the system issues that will ultimately determine the commercial viability of the device.

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