long-wavelength VCSELs advance in Asia

Short-haul optical fiber systems increasingly use vertical-cavity surface-emitting lasers (VCSELs) that emit near 0.85 µm. The development of VCSELs with long-wavelength active regions has proved more elusive, however. Viable short-wavelength lasers tend to use highly reflective and thermally conductive, all-epitaxial gallium-arsenide (GaAs)-based mirrors and efficient transverse confinement through aluminum-arsenide (AlAs) oxide dielectric apertures. If the wavelength of these commercially established lasers could be lengthened to the 1.3 to 1.6 µm range, networks could achieve dramatically increased transmission bandwidth and distance in conventional single and multi-mode fiber, says Michael Larson of Agility Communications (Santa Barbara, CA).

Several approaches have demonstrated 1.2 to 1.3 µm laser emission with such novel material alloys as gallium indium nitride arsenide (GaInNAs) and gallium arsenide antimonide (GaAsSb), Larson notes. For example, a research team at the Microsystems Research Center of the Tokyo Institute of Technology (TI Tech) has achieved continuous-wave (CW) operation of GaInNAs/GaAs VCSELs in the 1.2-µm range with an output exceeding 1 mW.

“Room temperature CW operations of 1.2 to 1.3 µm GaInNAs/GaAs VCSELs have been reported,” says Kenichi Iga, leader of the TI Tech team. “However, their performance—namely output power—was insufficient for practical use.” Iga says his group’s chemical beam epitaxy method of growing laser chips resulted in GaInNAs/GaAs VCSELs that exhibit CW emissions at 1125 nm. “These devices show low-threshold current, high-slope efficiency, high-output power, and high-output single-mode power,” he says.

The TI Tech team has taken significant steps toward a viable 1.2-µm range VCSEL. For example, they achieved a threshold current of 1.2 mA, the lowest ever for a GaInNAs/GaAs VCSEL, and the threshold current density of 2.6 kA/cm², the 1 mW of output power, and the slope efficiency of 0.23 W/A were the best such values ever achieved under CW conditions.

A research team at NEC’s Optical Interconnection Laboratory (Tsukuba, Japan) has met with considerable suc-
**VCSELs continued from page 13**

cess using GaAsSb quantum wells. They have demonstrated CW 1.27-µm VCSELS that operate at above room temperature. The threshold current was at about 0.7 mA at room temperature, and the maximum CW operating temperature did not exceed 70°C.

“VCSELs emitting at 1.3 µm are attractive for use in high bandwidth fiber communications,” says NEC’s Takayoshi Anan. “Our 1.23-µm GaAsSb VCSEL not only has a low threshold current of 0.7 mA, but its long wavelength is what’s required for 10 Gigabit Ethernet [applications].”

Anan’s team first grew n-type and p-type distributed Bragg reflectors (DBRs) on a silicon-doped GaAs substrate with metal-organic vapor phase epitaxy (MOVPE). The cavities, including the GaAsSb quantum-well active layers, were grown by molecular beam epitaxy. They used MOVPE for its high growth rate and its ability to grow low-resistivity p-DBRs with grated interfaces and carbon doping.

According to Anan, one potential problem was solved in a unique way. The 2-D to 3-D incoherent growth-mode transition limits the thickness of highly strained GaAsSb. “This kind of critical thickness can be increased by lowering the growth temperature and increasing the growth rate,” Anan says. Accordingly, the team increased the growth rate to 0.8 µm/h and lowered the growth temperature to 490°C.

Other changes included the use of a strain-compensated structure for the active layer and formation of 45-µm diameter mesas by wet chemical etching. AlAs oxidation at 400°C formed a 7-µm diameter current-flowing aperture, and the top p-DBR was coated with gold to increase reflectivity.

The GaAsSb VCSELs are viable low-cost light sources for high-bandwidth fiber communications. “The lasers will undoubtedly see their first commercial use in local-area networks (LANs),” Anan says.

To fulfill their promise, though, these VCSELs require improved efficiency, reliability, and high-temperature operation.

— Charles Whipple