Quantum-dot lasers provide high performance near 1.15 microns

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Distributed feedback laser diodes with a quantum-dot active region show the potential of GaAs-based devices for applications in the wavelength range from 1100–1200nm.

Monomode laser diodes in the wavelength range around 1.15µm are of particular interest for applications such as sensing (of moisture, for example) and for frequency doubling into parts of the spectrum that are currently largely inaccessible. Coherent green and yellow light from frequency-doubled lasers would be very useful for gas sensing and other industrial instrumentation, as well as biomedical and fluorescence applications. An essential prerequisite for efficient frequency conversion, however, is single-frequency laser light, such as could be provided by distributed feedback (DFB) laser diodes. One particular challenge at the range around 1.15µm is to produce a gain medium with high internal efficiency. For broad area lasers, good results have recently been achieved using quantum dots (QDs) or high strained InGaAs quantum wells (QWs). In general, devices that use QDs can provide a variety of advantages compared to conventional QW-based devices.

DFB devices are ideally suited to provide longitudinal and transverse single-mode emission at a precise wavelength with an extremely narrow linewidth. They guarantee high output power and mode-hop-free tunability. Our DFB concept shown in Figure 1 is based on an overgrowth-free technology, which can easily be adapted to a variety of independent epitaxial designs. Based on this approach, we are manufacturing DFB laser diodes from 760nm up to 2800nm.

Device fabrication makes use of a GaAs-based laser structure grown by molecular beam epitaxy with an undoped active region consisting of self-organized InGaAs/GaAs QD layers. The spectral gain properties of this underlying QD active region allow us to make DFB lasers with emission spanning a broad wavelength range. We fabricated a ridge waveguide structure using photolithography and an electron-cyclotron-resonance as-

Figure 1. Schematic of a laterally-coupled distributed-feedback (DFB) laser with a metal grating structure and an active region incorporating quantum dots (QDs).

Figure 2. QD DFB lasers with various detuning, all made with an identical QD laser structure, covering a wavelength range of >100nm. All spectra taken at an injected current of 20mA.

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By varying the grating periods between 161.2nm and 179.8nm, we developed DFB laser diodes with various detunings based on the identical QD laser structure. We investigated unmounted laser bars—under continuous wave (CW) operation—with cavity lengths between 600 and 1200µm and as-cleaved (AC) facets as well lasers in which one facet was treated with a high-reflectivity (HR) coating.

The spectral gain properties of the QD active region allow the realization of DFB lasers with emission wavelengths spanning a wide range of >100nm. The accessible wavelengths range from around 1095nm to 1205nm as shown in Figure 2. All devices show a high side-mode suppression ratio (SMSR) of ≥40dB.

Figure 3 shows a DFB laser emitting at around 1130nm exhibiting a threshold current of 25mA with efficiency of 0.23W/A per facet (uncoated, AC-AC). The total output power of this unmounted metal-grating DFB device reaches 80mW and is limited by thermal roll-over.

Figure 4 shows the temperature dependent properties of various DFB lasers with emission wavelengths of 1110nm, 1135nm, and 1190nm, respectively. We observed a threshold current <25mA and output power >10mW for operating currents <50mA at room temperature for devices of each wavelength. Stable monomode emission with high SMSR is observed in a temperature range between 25–60°C for 1110nm devices, 25–75°C for 1190nm devices and 25–85°C for the 1135nm devices.

The temperature dependence of the threshold current—in this case based on a laser structure with undoped QD active region—

![Figure 3. Power-current characteristic and emission spectrum of a metal-grating DFB laser at 1.13μm fabricated on a QD laser structure, with two as-cleaved (AC) facets. The laser operated continuously (CW), at room temperature. LD: laser diode. RT: room temperature.](image)

Figure 4. Temperature-dependent light-current characteristics and emission spectra of three metal-grating DFB CW lasers at 1110nm (left), 1135nm (middle) and 1190nm (right). All have a cavity length of 900µm, with one highly-reflective facet. Continued on next page
could in principle be improved by making use of a $p$-type modulation-doped QD active material.\textsuperscript{5}

In conclusion, we demonstrated high-performance DFB lasers based on an InGaAs/GaAs QD active region. Competitive DFB device performance was demonstrated at wavelengths from 1100–1200nm based on a single QD laser structure.

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**References**