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Vertical-external-cavity surface-emitting lasers (VECSEL), or semiconductor disk lasers (SDL), are attractive laser source for a wide range of applications owing to unique possibility to combine high output power with an excellent beam quality [1]. The intrinsic features of InAs quantum dots (QD) can offer low threshold, broad wavelength tunability, fast carrier dynamics and low temperature sensitivity. Recently, continuous wave (CW) operation of QD-based VECSEL emitting at 1.25 µm with output powers reaching multi-watt levels were achieved at room temperature [2]. However, extending the emission wavelength to 1.3 µm and beyond becomes more challenging. To date, QD-based VECSEL with optical power greater than 0.5 mW at 1305 nm has been demonstrated [3]. Here, we present a record-high power InAs/InGaAs QD-based VECSEL operating at the wavelength of 1.3 µm.

The VECSEL gain structure was grown by molecular beam epitaxy on an undoped GaAs substrate and consists of a 33-pair undoped $Al_{0.94}Ga_{0.06}Al$/GaAs bottom distributed Bragg reflector (DBR) and 3λ-thick AlGaAs-based optical subcavity surrounded by AlAs barrier layers that improve carrier confinement. The active region employed 9 Stranski–Krastanow QD layer, each layer consisting of an 2.5 ML-thick InAs QDs covered by 5-nm-thick InGaAs QW to obtain emission at 1.3 µm. According to the transmission electron microscopy, the actual QD density per layer estimated greater than $5\cdot10^{10}$ cm^{-2}. To provide efficient optical pumping and eliminate negative effects of the strain accumulation (misfit dislocation, inhomogeneous broadening), the multi-QD layer per antinode design with 30 nm-thick spacer was used (three sets of triple-stacked InAs/InGaAs QDs).

For thermal management, a 300 nm-thick chemical vapor deposition (CVD) intracavity diamond heat spreader was mounted to the top surface of the 2×2 mm^2 gain element. The VECSEL chip assembly was pressed against a water-cooled copper heat sink and the top surface of the diamond heat spreader was covered by antireflection (AR) coating. A V-cavity configuration was used, in which the resonator consisted of the VECSEL chip acting as an end mirror, an external curved high-reflective mirror with a radius of curvature of 150 mm and a plane output coupler with a transmission <0.25%. The gain chip was optically pumped by 808 nm fiber-coupled diode laser at incident angle of 30° and a 200 µm spot diameter.

CW QD-based VECSEL lasing at 7°C was achieved with a threshold pump power of ~1.1 W and a maximum output power of 220 mW. Increasing the heat sink temperature up to 30°C lead to a more than 2-fold decrease in the output optical power, while the threshold pump power rose up to 1.6 W. Note that the output powers was limited by of thermal rollover at high pump powers. The output beam shape hardly depended on pump power and had small asymmetry due to the curved mirror. QD-based VECSEL demonstrated multimode operation via the longitudinal modes caused by the intracavity diamond heat spreader. Increasing the pump power resulted in the spectra broadening due to the inhomogeneous QD broadening, which in combination with self-heating effects shifted of the center wavelength from about 1285 nm to 1296 nm. For higher heat sink temperature the center wavelength of the QD-based VECSEL shifts to 1300 nm.

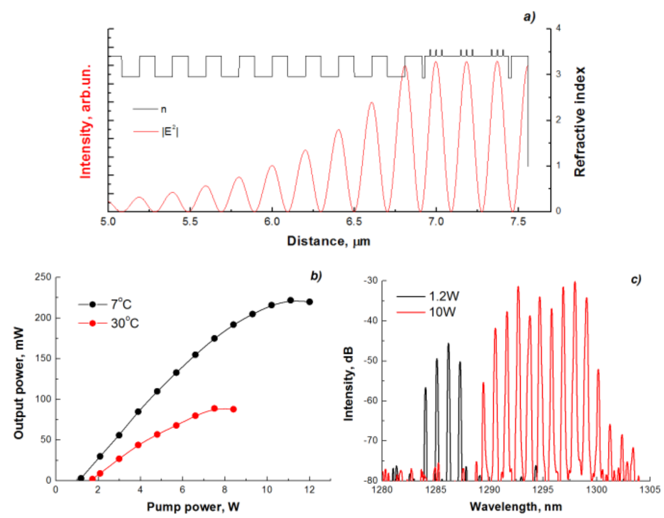

Fig. 1. a) Index of refraction and magnitude of electrical field standing wave in gain structure plotted along growth direction; b) The output power as a function of pump power at different heat sink temperatures; c) The output spectra at the different pump power.

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