High-power 783 nm distributed-feedback laser

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A ridge-waveguide GaAsP/AlGaAs laser, emitting an optical power of up to 200 mW in a single lateral and longitudinal mode at a wavelength of 783 nm, is presented. The distributed feedback is provided by a second-order grating, formed into an InGaP/GaAsP/InGaP multilayer structure. The laser is well suited as a light source for Raman spectroscopy.

Introduction: Diode lasers emitting in the wavelength range between 760 and 790 nm are of particular interest for applications in nonlinear frequency conversion, state selection in rubidium atomic clocks, Doppler laser cooling of rubidium atoms, absorption spectroscopy and Raman spectroscopy. These applications require a stable lasing frequency, which can be ensured by a frequency-selective feedback. It can be realised, for example, with a common Fabry–Perot (FP) type of diode laser placed together with a grating into an external cavity configuration, which necessitates, however, expensive mechanical and thermal stabilisation measures. Another possibility is the integration of a Bragg grating directly into the internal laser cavity, which results in so-called distributed Bragg reflector (DBR) or distributed feedback (DFB) lasers. Their fabrication requires additional technological efforts. The achievement of an output power (P) of more than 100 mW in a single transversal mode or a small spectral linewidth of less than 1 MHz are additional challenges, which exclude the use of vertical-cavity surface emitting lasers (VCSELs).

DFB or DBR lasers can be fabricated either in single or in multiple growth steps. Single-growth DFB and DBR lasers use laterally coupled or deeply etched gratings, respectively. So far, operation at high output power has not been demonstrated. Additionally, laterally coupled DFB lasers favour the first-order lateral mode and hence might exhibit mode instabilities or beam steering at high output power.

DBR lasers suffer from periodic nonlinearities in the light–current characteristics owing to longitudinal mode hopping. In contrast, DFB lasers can operate in the same longitudinal mode over a large current range. In the late 1980s and early 1990s, in several laboratories 750–790 nm DFB lasers were developed, cf. [1, 2] and the references therein. The highest output power reported was 10 mW in [1] and 25 mW in [2]. In this Letter, a DFB laser operating at 783 nm is presented with an output power of up to 200 mW.

Device structure and fabrication procedure: The DFB laser wafer was grown by low pressure metal organic vapour phase epitaxy (MOVPE) in two steps similarly as described in [3]. The first step consisted of an n-GaAs buffer, n-$Al_{0.53}Ga_{0.47}As$ cladding, 250 nm n-$Al_{0.50}Ga_{0.50}As$ waveguide, 14 nm GaAsP active quantum well (QW), 250 nm p-$Al_{0.50}Ga_{0.50}As$ waveguide, 550 nm p-$Al_{0.53}Ga_{0.47}As$ cladding and an InGaP/GaAsP/InGaP layer sequence in which the second-order grating (period 235.6 nm) was formed by holographic photolithography and wet-chemical etching. After surface cleaning, in the second step the remainder of the p-$Al_{0.53}Ga_{0.47}As$ cladding and a p-GaAs contact layer were grown.

Lateral optical confinement is provided by a 2 µm-wide ridge waveguide (RW) with an effective-index step of $\Delta n_{eff} \simeq 0.005$. The device structure and fabrication procedure is similar to that of the FP RW lasers described in [4]. The cavity length L is 1.5 mm and the front and rear facets are anti- and high-reflection coated, respectively. The devices were mounted p-up on an AlN submount and attached to a copper heatsink.

Results: Fig. 1 shows the continuous-wave (CW) optical power against injection current at a heatsink temperature T of 25°C. The threshold current is 29 mA and the slope efficiency is 1 W/A near threshold. This high efficiency is the result of the small coupling coefficient κ of the Bragg grating. From a fit of the emission spectrum measured below threshold to a theoretical model a real part of κ of 2 cm^{-1} was determined resulting in a κL value of only 0.3. Owing to the tensile-strained active QW the laser operates steadily in the TM mode (degree of polarisation >92%).

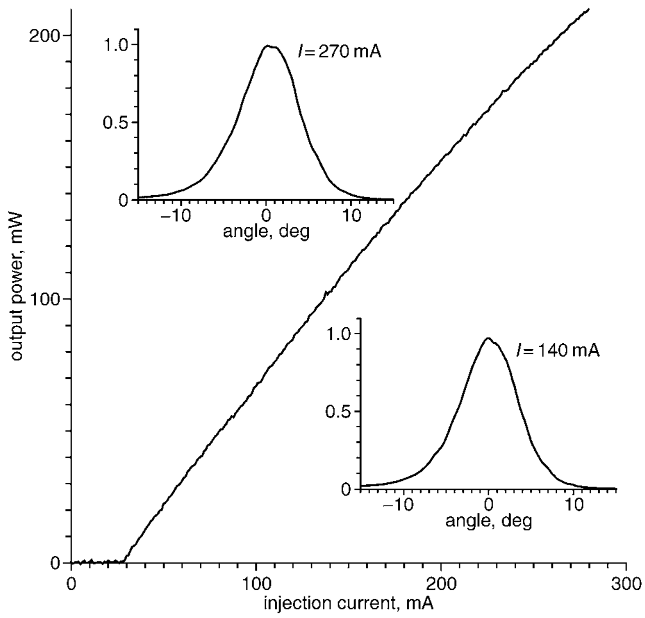

Fig. 1 *CW light–current characteristic of DFB laser at 25°C heatsink temperature*

Insets: Normalised lateral far-field profiles

Lateral far-field profiles measured at injection currents of 140 and 270 mA (corresponding to output powers of approximately 100 and 200 mW, respectively) are shown in the insets of Fig. 1. The nearly Gaussian shape with a full width at half-maximum (FWHM) of about 8° and the lack of beam steering indicate stable fundamental lateral mode operation. The FWHM of the vertical far-field profile, not shown, is about 21°.

Fig. 2 shows optical spectra measured at 40, 100 and 160 mW output power and 25°C heatsink temperature. The sidemode suppression ratio is greater than 50 dB, indicating stable operation of one of the two possible Bragg modes and complete suppression of the FP modes, despite the low κL value. The lasing wavelength varies with optical power at a rate of 3.5 nm/W for $P < 100$ mW and 5.2 nm/W for $P > 100$ mW. This tuning rate increases with power owing to a nonlinear temperature rise in the chip caused by Joule heating and an increasing thermal resistance.

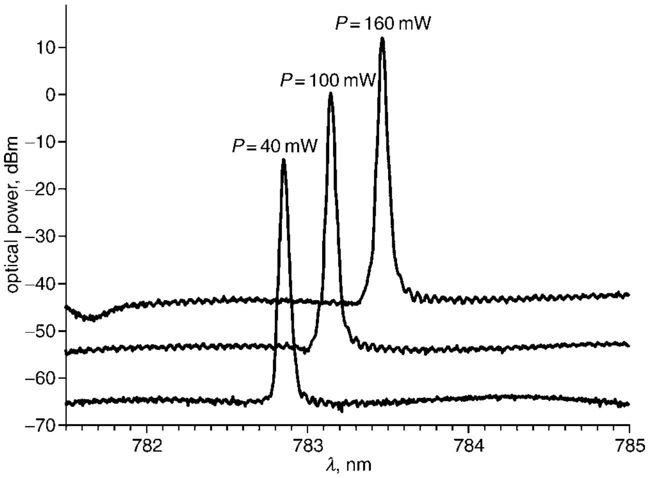

Fig. 2 *Optical spectra of DFB laser measured at different output powers and 25°C heatsink temperature*

Spectra offset by 10 dBm for clarity

Fig. 3 shows optical spectra measured between 15 and 50°C heatsink temperature with an increment of 5K at an injection current of 150 mA. The lasing wavelength tunes with temperature with a rate of 0.055 nm/K. Measurements of the temperature dependence of the light–current characteristic revealed that the power decreases from 108 mW at 15°C to 86 mW at 50°C. It should be noted that the spectra in Figs. 2 and 3 were obtained using different optical spectrum analysers.

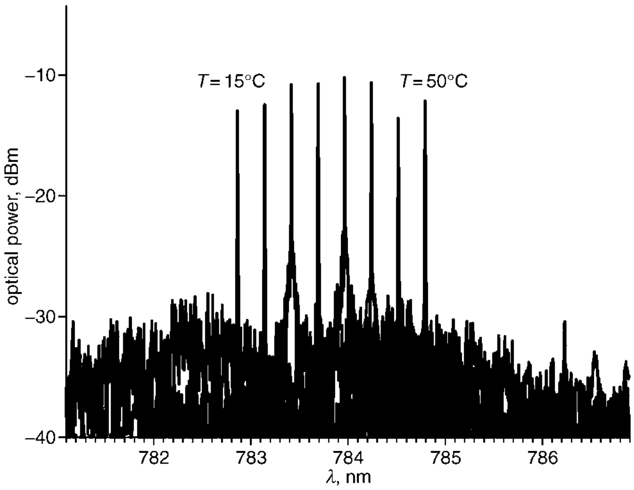

Fig. 3 *Optical spectra of DFB laser measured at different temperatures (increment 5K) and injection current of 150 mA*

Conclusions: We have demonstrated singlemode single-frequency operation of a 783 nm RW DFB laser up to 200 mW CW output power. Owing to the stable lasing frequency and the large sidemode suppression the diode laser is well suited for Raman spectroscopy as already demonstrated with a device emitting 50 mW output power [5]. The higher output power reported here improves the application range considerably. DFB lasers emitting at adjacent wavelengths of interest (e.g. 780 nm for rubidium absorption) can be easily fabricated by slight variations of the grating period.

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