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Increasing the output power of single 808-nm laser diodes using diamond submounts produced by microwave plasma chemical vapour deposition

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Abstract. **We have designed and fabricated submounts from synthetic diamond grown by microwave plasma chemical vapour deposition and developed an economical process for metallising such submounts. Laser diode chips having an 808-nm emission wavelength, 3-mm-long cavity and 130-μm-wide stripe contact were mounted on copper heat sinks with the use of diamond submounts differing in quality. The devices were tested for more than 150 h in continuous mode at an output power of 8 W on diamond with a thermal conductivity of 700 W m^{-1} K^{-1}, and no changes in their output power were detected. On diamond with a thermal conductivity of 1600 W m^{-1} K^{-1}, stable cw operation for 24 h at an output power of 12 W was demonstrated.**

Keywords: *laser diode, diamond submount.*

1. Introduction

The purpose of this work was to increase the output power, brightness, efficiency and operating life of high-power laser diodes (LDs). Solving this set of problems, one will potentially be able to bring the brightness of systems combining the outputs of diode lasers closer to the level of state-of-the-art CO_2 lasers and diode-pumped solid-state and fibre lasers and move to large-scale materials processing using the LD output.

An integral and key part of this issue is the ability to raise the effectiveness of heat removal from the active region of LDs, which has been the focus of many studies, including those reported in Refs [1–3]. The removal of extremely high heat flux densities (above 3–5 kW cm^{-2}) at minimum possible temperature differences between the active region and heat sink (due to the strong temperature dependence of the emission characteristics of the semiconductor medium) is the most important fundamental limitation to the most complete realisation of the energy potential of the active element of a high-power LD.

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2. Synthetic diamond and submounts for laser diode mounting

The record high thermal conductivity of diamond among all known materials, 2000–2400 W m^{-1} K^{-1} at room temperature, is the most attractive of its parameters for us. It should be emphasised that diamond as a thermal conductor has appreciable inherent reserves: the thermal conductivity of isotopically pure diamond may reach 3300 W m^{-1} K^{-1} (natural crystals contain 1.1% ^{13}C). Note that the thermal conductivity of copper, which is currently widely used as a heat sink material, is about 370 W m^{-1} K^{-1}.

The use of diamond as a heat dissipation material for mounting high-power laser chips required solving a number of serious problems: growth of diamond wafers more than 300 μm in thickness; wafer cutting, grinding and polishing with necessary parameters; application of adhesive and solder layers for double-sided metallisation; diamond mounting on a heat sink base and laser chip mounting on the diamond; wiring of the lower (positive) electrode because diamond is an insulator; and thermal expansion matching (at 300 K, the thermal expansion coefficient of diamond is 1×10^{-6} K^{-1}, that of copper is 16.7×10^{-6} K^{-1}, and that of semiconductor heterostructures is about 6×10^{-6} K^{-1}).

Diamond films were grown by microwave plasma chemical vapour deposition (CVD), a relatively economical process, on silicon substrates preseeded with ultradispersed diamond under sonication.

Diamond wafers for injection lasers were prepared through microwave plasma CVD of diamond on silicon substrates, separation of the diamond wafers from the substrates by chemical etching in an acid, laser cutting of the wafers into submounts and polishing. The process involved the decomposition of a hydrocarbon mixture (methane + hydrogen) and carbon deposition on a preheated substrate.

3. Results

LD chips for an 808-nm wavelength had a 3-mm-long cavity and 130-μm-wide stripe contact. The diamond submounts were $2 \times 4 \times 0.3$ mm in dimensions.

Figure 1 shows power–current characteristics of a cw LD mounted directly on a copper C-mount (LDC) and on an identical C-mount with the use of a diamond submount (LDD). Our life test statistics indicate that the guaranteed maximum output power of the LDC is 7 W. According to preliminary test results, the LDD provided a stable output of 12 W for 24 h. After producing a statistically relevant number of devices and evaluating all their parameters, we will con-

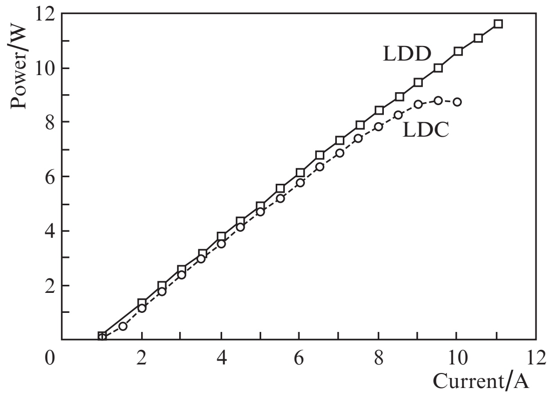

Figure 1. Power–current characteristics of the LDD and LDC.

tinue testing, determine the maximum power of the LD design in question and find out its limitations.

Figure 2 shows the peak emission wavelength as a function of pump current for the spectral envelopes of the LDC and LDD. It is seen that, at a current of 8 A, the peak in the spectrum of the LDD is shifted to shorter wavelengths by almost 2 nm relative to the spectrum of the LDC, which points to a more effective heat removal from the chip through the diamond submount because it acts as a 'negative thermal lens'. The heat from the 130-μm-wide laser stripe contact is more effectively spread over the entire width (2 mm) of the diamond submount.

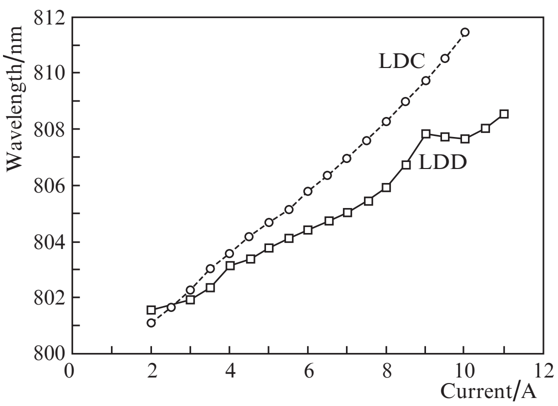

Figure 2. Peak emission wavelength as a function of pump current for the envelopes of the emission spectra of the LDD and LDC.

Comparison of the full width at half maximum (FWHM) as a function of pump current for the spectral envelopes of the LDC and LDD (Fig. 3) demonstrates the advantageous effect of the lower active region temperature in the LDD at high currents.

Thus, mounting an LD chip on a copper C-mount with the use of a synthetic diamond submount we achieved stable cw operation of a 12-W LD at 808 nm for 24 h. Output power data and emission spectra demonstrate that diamond submounts improve the effectiveness of heat flux removal from high-power LDs.

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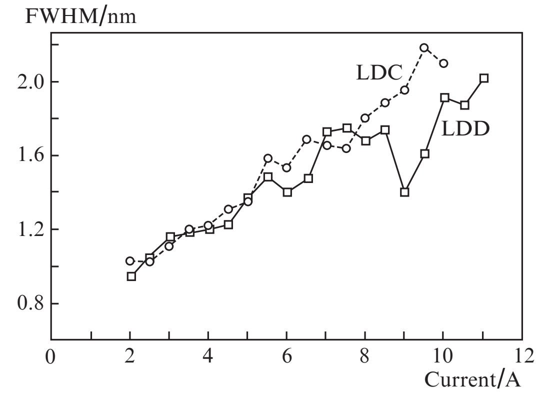

Figure 3. FWHM as a function of pump current for the spectral envelopes of the LDD and LDC.

References

1. Seurin J.F., Xu G., Khalfin V., Miglo A., Wynn J.D., Pradhan P., Ghosh C.L., D'Asaro L.A. *Proc. SPIE Int. Soc. Opt. Eng.*, **7229**, 722903 (2009).
2. Parashchuk V.V., Ryabtsev G.I., Belyaeva A.K., Bez'yazychnaya T.V., Baranov V.V., Telesh E.V., Vu Doan Mien, Vu Van Luc, Pham Van Truong. *Kvantovaya Elektron.*, **40**, 301 (2010) [*Quantum Electron.*, **40**, 301 (2010)].
3. Ashkinazi E.E., Bezotosnyi V.V., Bondarev V.Yu., Kovalenko V.I., Krokhin O.N., Oleshchenko V.A., Pevtsov V.F., Popov Yu.M., Cheshev E.A. *Trudy konf. 'Poluprovodnikovye lazery i sistemy'* (Book of Papers, 8th Belorussian–Russian Workshop 'Semiconductor Lasers and Systems') (Minsk, 2011) p. 29.