High power pulse operated QW lasers with temperature tunable wavelength

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Long time ago the semiconductor lasers have been recognised as very useful light sources for spectroscopy due to many advantages typical for these devices. However, it is required in this particular application that they must be tunable to specific wavelengths. Such tuning can be attained in many ways [1, 2] but the most straightforward one, although restricted only to limited wavelength range, is a change of the laser temperature. Temperature dependence of the spectrum emitted by a semiconductor laser originates from two effects. First, the optical gain spectrum shifts to longer wavelengths as temperature rises because of the change of semiconductor bandgap. For GaAs this shift is about of $5.4\cdot10^{-4}$ eV/K and it corresponds to a thermal wavelength shift which is on average equal to 0.3 nm/K. Second, the FP cavity properties depend on the effective refractive index and geometrical dimensions - both subjects to change with temperature. In result, the FP modes shift with temperature according to the formula:

$$\frac{1}{\lambda}\frac{\partial\lambda_q}{\partial T}=\left[\frac{1}{n}\left(\frac{\partial n}{\partial \mathrm{T}}\right)_{\lambda_q}+\frac{1}{L}\frac{\partial L}{\partial \mathrm{T}}\right]\Big/\left[1-\frac{\lambda_q}{n}\left(\frac{\partial n}{\partial\lambda_q}\right)_{\mathrm{T}}\right]$$

where λ_q is q-th longitudinal mode wavelength, λ is central emission wavelength, T is temperature, n and L are resonators refractive index and length, respectively.

The mode shift calculated from this formula is about 0.05 nm/K for GaAs. Quantum well lasers behave in the way similar to that observed for double heterostructure lasers with the difference that emission in them takes place between intraband electron and hole levels in the conduction and valence bands, respectively [3].

The aim of the work reported here was to develop a high power pulse operated laser tunable in the 800 nm wavelength range. A QW GRIN structure shown in the inset of Fig. 1 was used. The laser had coated mirrors and a broad contact geometry. It was soldered p-type down on a copper heat sink and then on a thermoelectric cooler (Marlow Industries, Inc., Model MI2022T). A 10 kΩ thermistor was attached to the copper heat sink and the device was assembled in a TO-8 housing as displayed in Fig. 2. Temperature of the chip was thus monitored with the accuracy of ±0.2°C and could be changed from +24°C to -18°C by controlling the thermoelectric cooler current (Fig. 3).

The laser was designed to operate with current pulses 300 ns wide and duty factor below 0.03%. Typical light - current characteristics for two heat sink temperatures are plotted in Fig. 4. As can be seen, the output power at the repetition rate 1 kHz exceeds 3.5 W and the slope quantum efficiency is 1.35 W/A. No temperature effect on the quantum efficiency could be detected within the attainable change of the heat sink temperature.

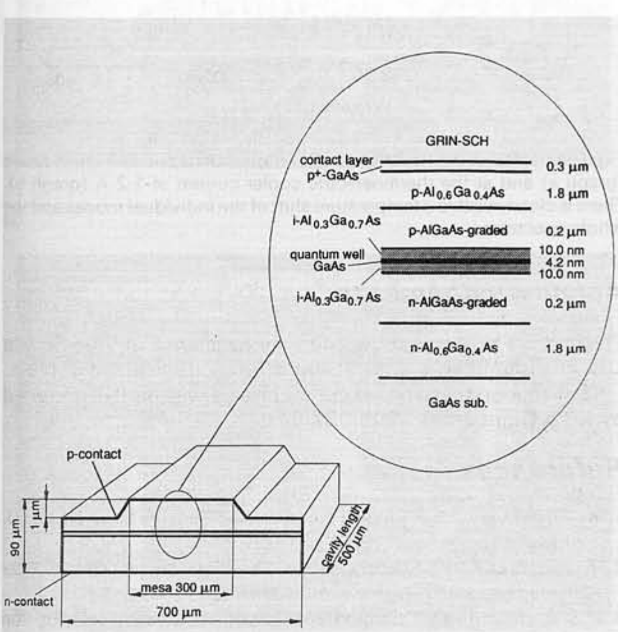

Fig. 1. Geometry of a broad contact laser diode with the QW GRIN SCH active region shown in the inset

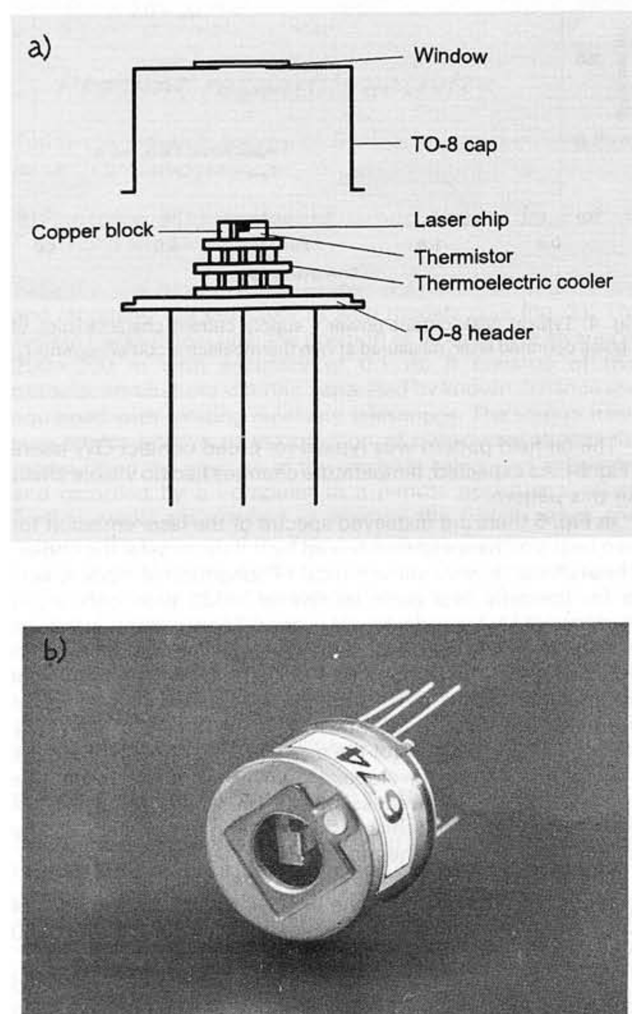

Fig. 2. Schematic view of the assembled laser (a) and its photograph (b)

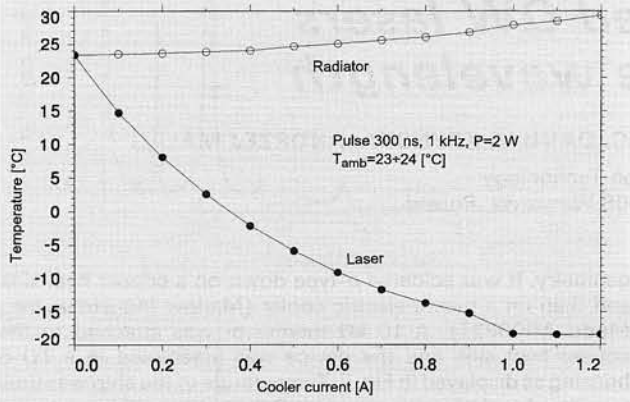

Fig. 3. Temperature of the laser diode and of the external radiator versus thermoelectric cooler current. The temperature was measured with a thermistor attached to the laser diode heatsink. The laser was driven with 300 ns current pulses at the repetition rate of 1 kHz and the output peak power 2 W. The laser header (TO-8) was attached to a standard radiator of 7 cm wide and 6 cm long

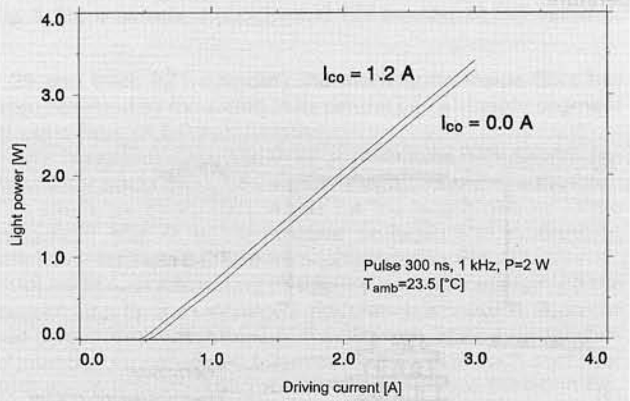

Fig. 4. Typical peak output power - supply current characteristics of a pulse operated laser, measured at two thermoelectric cooler currents I_{co}

The far field pattern was typical for broad contact QW lasers (Fig. 5). As expected, temperature changes had no visible effect on this pattern.

In Fig. 6 there are displayed spectra of the laser emission for two heat sink temperatures forced by the thermoelectric cooler. These characteristics show typical FP longitudinal mode spectra for basically first order transverse mode with only slight evidence of higher order lateral modes. The spectrum envelope is roughly of the Gaussian shape as expected and shifts with temperature at the average rate of 0.22 nm/K. The individual longitudinal modes move into the longer wavelength range with estimated rate of 0.5 nm/K. This movement is not easily distinguishable because of the mode hoping effect [4] and the shift of the whole envelope. However, as a net result, the spectrum of the laser emission can be tuned within 9.1 nm wavelength range and the emission is temperature stabilised by simple control of the thermoelectric cooler current.

The lifetime tests carried out on the lasers at room temperature for so far over 2500 hours have not shown any signs of laser degradation. Further tests are under way but at least 10000 hours lifetime for these lasers can be predicted.

In summary, temperature tunable high power pulse-operated lasers that emit in the wavelength range of 815 nm have been developed. These lasers have been designed for applications in spectroscopy but can be used in many other systems that require high power optical pulses.

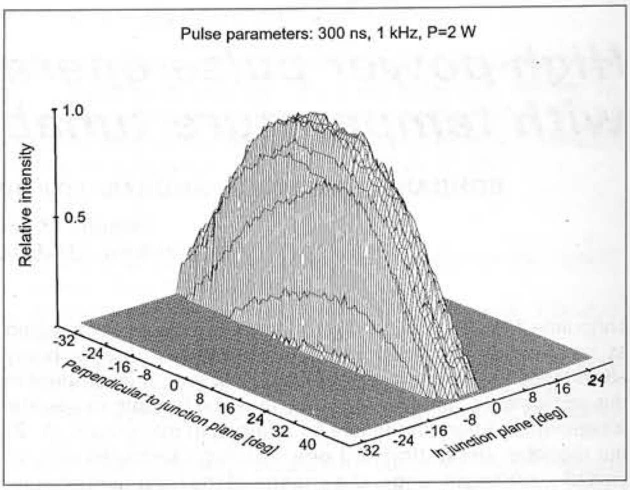

Fig. 5. Typical far field pattern of a laser operated at room temperature and the output power of 2 W. The laser generated in a single-transverse and multi-lateral modes

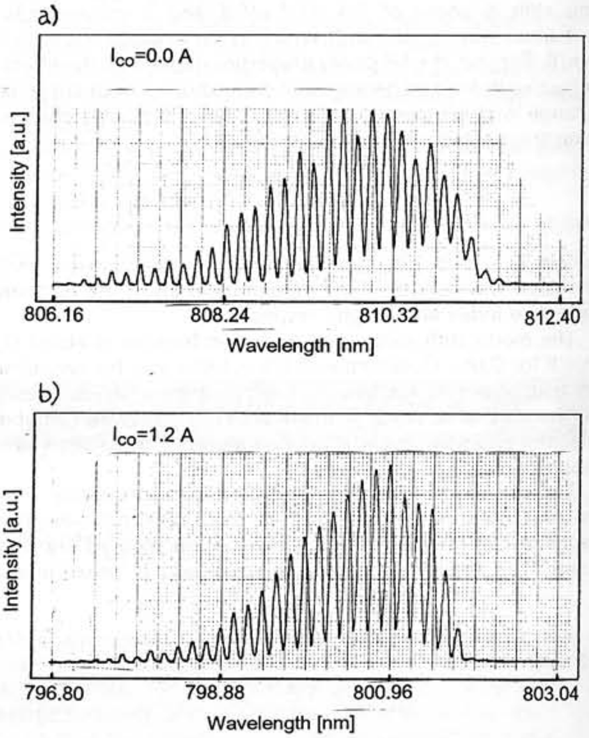

Fig. 6. Spectral characteristics of a laser measured at room temperature (graph a) and at the thermoelectric cooler current of 1.2 A (graph b). There is clearly visible a temperature shift of the individual modes and the whole spectrum

Acknowledgements

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