From EL observation, the DSD of the LD is estimated to be $<3 \times 10^3$cm^{-2}. As this DSD is lower than D_c, even taking into account current spreading by the LD stripe, we consider that failure of this LD is not caused by degradation owing to pre-existing defects, but by REDR. Even for II-VI LDs grown on the GaAs substrate, by controlling the growth conditions of the II-VI/III-V interface, a long lifetime has been realised through the reduction of pre-existing macroscopic defects.

In conclusion, a lifetime >100h has been achieved at RT under CW operation for a ZnCdSe/ZnSSe/ZnMgSSe SCH LD with DSD $<3 \times 10^3$cm^{-2}. Despite possible rapid degradation mechanisms owing to the higher ionicity and lower covalency of II-VIs compared to III-Vs, the II-VI LDs have been proven, for the first time, to have a lifetime of more than 100h even though grown on GaAs. We have entered into a stage where the failure of II-VI LDs is ruled by REDR. We believe that this is a milestone that indicates the high potential of II-VIs as light emitters when well prepared.

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S. Taniguchi, T. Hino, S. Itoh, K. Nakano, N. Nakayama, A. Ishibashi and M. Ikeda (*Sony Corporation Research Center, 174 Fujitsuka-cho, Hodogaya-ku, Yokohama, 240 Japan*)

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Diode pumped CW Nd:YAG laser operating at 938.5nm

R. Koch, W.A. Clarkson and D.C. Hanna

Indexing terms: Solid lasers, Optical pumping

Efficient operation of a Nd:YAG laser on the quasi-three-level transition at 938.5nm, end-pumped by a 20W diode bar is reported. For the maximum available incident power of 13.6W we have obtained a CW laser output at room temperature of 2.0W in a near diffraction-limited TEM$_{00}$ beam.

Good progress in developing diode pumped Nd:YAG lasers at 1.064µm, and in frequency doubling them to produce visible sources, has stimulated interest in other Nd^{3+} transitions. The transition at 946nm attracts interest as it allows generation of blue light by frequency doubling [1, 2]. However, efficient lasing on this $^4F_{3/2} \rightarrow {}^4I_{9/2}$ transition ($R_1 \rightarrow Z_5$) is considerably more difficult to achieve than on the 1.064µm line. There is another, even weaker, $^4F_{3/2} \rightarrow {}^4I_{9/2}$ transition at 938.5nm ($R_2 \rightarrow Z_5$) [3, 4]. We report that with appropriate pumping conditions this transition can be made to operate very efficiently, with 2.0W of output demonstrated. The attraction of this line is its shorter wavelength compared with the 946nm line, and hence the potential for yet shorter wavelength blue light.

The primary difficulties with these transitions at ~940nm are their much lower stimulated emission cross-sections (~9 times lower for 946nm compared with 1.064µm); and the quasi-three-level nature resulting from the proximity of the lower laser level at 857cm^{-1} to the ground state, leading to a significant reabsorption loss at room temperature [5, 6]. The resulting stringent demands on the diode pump beam size and beam quality have constrained most work to the use of low power diodes, and CW operation of Nd:YAG at 946nm has generally been limited to power levels well below 1W [2]. Recently, we reported [7] a Nd:YAG laser at 946nm with a CW output of 3.0W at room temperature. This level of performance has been achieved by using a simple two-mirror beam shaping device to re-configure the highly elongated diode bar output into a more convenient form for end-pumping. This beam-shaping technique enables the output beam from a high power diode bar to be re-configured with nearly equal M^2 values for orthogonal planes without significant reduction in brightness [8]. The stability and good beam quality of the 946 nm output enabled efficient blue light generation by external frequency doubling in periodically poled lithium niobate [9].

The 938.5 and the 946nm lines both have the same lower laser level. The 938.5nm line has a lower stimulated emission cross-section, ~4.8 × 10^{-20}cm^2, which is ~0.9 times that of the 946nm line [4]. This results in a sligthly reduced reabsorption loss, ~0.7%/mm at room temperature (1.1% Nd doping) compared to ~0.8%/mm at 946nm. However, the reduced cross-section also reduces the gain, and this disbenefit outweighs the benefit of reduced reabsorption, with the result being that lasing usually occurs preferentially at the 946nm line. To the best of our knowledge, diode-pumped operation on the 938.5nm line has been restricted to relatively low powers of <30mW [10].

Suppression of oscillation on the much stronger transitions around 1.06µm can be achieved using the appropriate dielectric mirrors [5, 7]. To suppress lasing at the 946nm line in favour of the 938.5nm line we have used the frequency selection provided by an uncoated 80µm thick fused quartz etalon, inserted into the laser resonator.

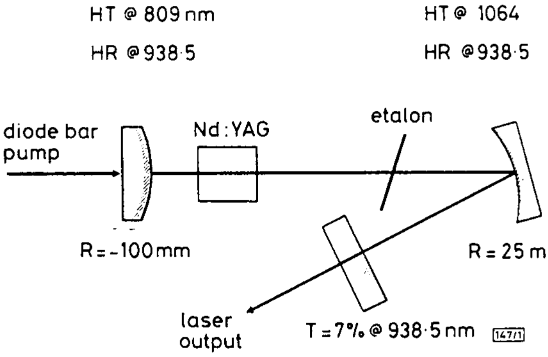

Fig. 1 *Schematic diagram of Nd:YAG laser resonator design*

Starting with a 20W CW diode bar (Opto Power Corporation OPC-A020-mmm-CS) and using the beam-shaping technique [8] we obtained the following spot sizes *w* (1/e^2 intensity radius) for the focused pump beam: 170 × 155µm with M^2 values of ~60 and ~95, respectively, for orthogonal planes. The overall transmission of 68% for the pump optics resulted in a pump power of ~13.6W at the focus. The Nd:YAG laser design is schematically shown in Fig. 1. The 5mm long by 2mm diameter Nd:YAG rod with 1.1 atm% doping was mounted in a water cooled heat sink. The lengths of the arms in the simple folded cavity were ~70mm and 12 – 13mm, the latter adjustable via motion of the output mirror mounted on a translation stage. The input mirror had convex curvature, chosen to give some compensation of the thermallyinduced lens in the laser rod, which was measured to have a focal length of ~6cm at the highest pump powers. This partial compensation, together with the facility to vary the length of the short arm, enabled matching of the mode spot size in the laser rod to ~165µm, as required.

Selection of 938.5nm (or 946nm) laser operation was performed by simply tilting the etalon. Without the etalon present the laser operated at 946nm only.

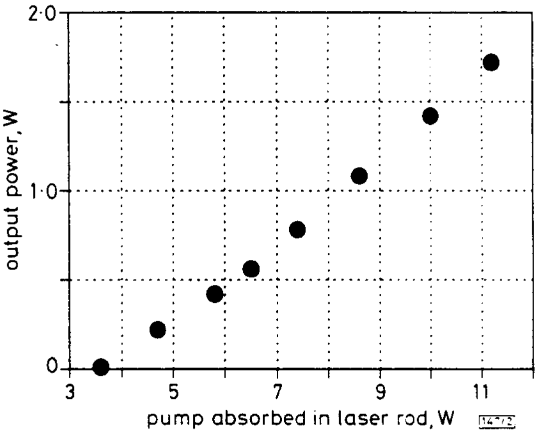

Fig. 2 *Output power against input power absorbed in Nd:YAG at room temperature*

Fig. 2 shows the output power for the 938.5nm transition against the absorbed pump power for a rod mount temperature of 19°C. The rather high threshold (3.6W) is, in part, caused by the fact that the resonator is optimised for the thermal lensing which occurs at the highest pump powers. The highest output power for the 938.5nm at 19°C is 1.72W for the maximum pump power of 13.6W incident, of which 11.2W is absorbed. The average slope efficiency is ~23% (~20%) with respect to absorbed (incident) pump power. For pump powers more than three times above threshold the slope efficiency increases to ~25% (~22%) with respect to absorbed (incident) pump power owing to saturation of the reabsorption loss [5]. The beam quality, even at the highest output power, is extremely good, with beam quality factors M_x^2 ~ 1.26 and M_y^2 ~ 1.17 in orthogonal planes indicating near diffraction-limited TEM_{00} performance.

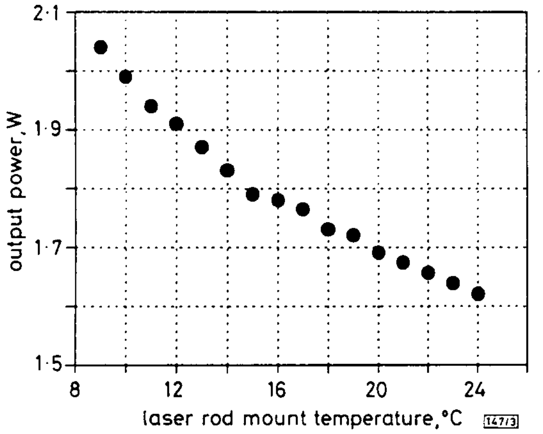

Fig. 3 *Output power against temperature of laser rod at maximum pump power*

Fig. 3 shows the temperature dependence of the laser output power at the maximum pump power of 13.6W. For a rod mount temperature of 9°C we obtained slightly more than 2.0W output at 938.5nm. The steady (almost linear) increase with decreasing temperature is mainly caused by a reduction of the reabsorption loss of ~0.1% mm^{-1} per 10K temperature decrease. At room temperature the unsaturated reabsorption loss is ~0.7%mm^{-1}.

In conclusion, we have demonstrated an efficient diode-bar pumped quasi-three-level Nd:YAG laser operating at 938.5nm. While this transition is even more difficult than the 946nm transition, we have shown here, that with intense pumping, operation on this transition can be very efficient with 2.0W output demonstrated. The reliable performance and good beam quality suggest that this will be an attractive source for efficient frequency doubling into the blue.

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R. Koch, W.A. Clarkson and D.C. Hanna (*Optoelectronics Research Centre, University of Southampton, Southampton SO17 1BJ, United Kingdom*)

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Experimental observation of self-pulsations in complex-coupled DFB laser diodes

M. Achtenhagen, R.O. Miles, B. Borchert and
F.K. Reinhart

Indexing terms: Distributed feedback lasers, Semiconductor junction lasers

The authors demonstrate the optical generation of self-pulsations in complex-coupled DFB laser diodes by selectively positioning the facet with respect to the internal grating. The self-pulsations are accompanied by a strong intensity noise enhancement which partly originates from mode competition. Applying a simple model they determine the imaginary part of the complex coupling coefficient from the self-pulsation frequency.

Introduction: Complex-coupled (CC) DFB laser diodes have been shown theoretically and experimentally to give higher singlemode yield, greater side mode suppression ratios and lower chirp than conventional DFB lasers [1 – 3]. However, these properties are still sensitive to the exact positioning of the laser facets in respect to the internal grating. With varying facet positions the overlap of the lasing mode with the absorptive DFB grating is altered. It has also been shown in an earlier Letter [4] that threshold gain varies with changing facet positioning.