High-power, high-efficient 1150nm quantum well laser

G. Erbert*, F. Bugge, J. Fricke, P. Ressel, R. Staske, B. Sumpf, H. Wenzel, M. Weyers and G. Tränkle

Ferdinand-Braun-Institut für Höchstfrequenztechnik, Gustav - Kirchhoff - Str. 4, 12489 Berlin, Germany

An efficient laser structure was realized using highly strained InGaAs quantum wells and thick GaAs waveguide layers. A low divergence of 20° FWHM and reliable 5W output power from a 60µm stripe laser was achieved.

Introduction

High power diode lasers with wavelength above 1100nm are of increasing interest for pumping Raman amplifiers in telecommunication. Additionally, very efficient, highly reliable, high power lasers will open applications in material processing systems without transfer of optical power to fibre- or solid state lasers. In this contribution we will show that a structure with highly strained InGaAs quantum wells (QWs) embedded in thick GaAs waveguide layers is a very efficient gain structure with low vertical far field divergence and high reliability at output powers of up to 80mW per µm stripe width - two times the value offered for state of the art 980nm BA pump lasers.

Design and fabrication of 1150nm laser structures

Typically modern diode lasers are realised with ternary or quaternary waveguide and claddings layers. These materials have a drastically lower thermal and electrical conductivity in comparison to the binary GaAs. Therefore using conventional high power laser structures there is a trade-off between high slope efficiency on the one hand and a low series and thermal resistance on the other hand. Looking for small vertical divergence this conflict will be enhanced. So all diode lasers with more than 60% wall plug efficiency have a high vertical divergence of about 60° including 95% of output power. /1,2/

Using GaAs waveguides the thickness of the waveguide can be increased strongly due to the higher electrical and thermal conductivity of the binary material. The drawback is the low barrier for the carriers due to the small band gap difference in the most familiar wavelength range near 980nm. These barriers can be increased simply by shifting the emission wavelength into the range above 1100nm. The challenge at this wavelength range is to find a gain medium with high internal efficiency. Best results are achieved using quantum dots or highly strained InGaAs QWs /3,4,2/. We have demonstrated a high output power using highly strained InGaAs QWs at 1120nm in a structure with large confinement factor and a standard divergence of 32° FWHM /2/.

The new structure (Fig. 1) consists of a 3.5 µm thick GaAs waveguide embedded in thin $Al_{0.25}Ga_{0.75}As$ cladding layers. The waveguide core is intentionally undoped (below $10^{17}cm^{-3}$). A highly p-doped GaAs contact layer completes the structure. The structure is grown by low pressure MOVPE. As gain material we used a highly strained InGaAs - double QW (DQW) grown at low temperature. The thick GaAs waveguide supports several modes, but only the lowest order mode has no radiation leakage to the substrate.

Results

From length dependent measurements the main characteristic laser parameters were deduced. The transparency current density is $130A/cm^2$, that means $65A/\ cm^2$ per well. We achieved a high internal efficiency of about 90% . The low internal loss of $0.5\ cm^{-1}$ allows a resonator length of 4mm and longer with minor losses in slope efficiency. In Fig. 2 the vertical far field pattern is shown. The FWHM is 20° and more than 95% of power are included in an angle smaller than 35°. This is important as cheaper fast axis collimators with lower NA i.e. 0.5 and relatively large tolerances can be used for beam collimation.

Using this wafer material we fabricated BA-lasers with 60µm, 100µm and 200µm stripe width. The resonator length was chosen to 4mm. After a passivation process the output facet is AR coated to 7% reflectivity and the back facet to >95%. The chips were mounted p-side down on CuW submounts with AuSn solder and then onto standard C-mounts. In Fig. 3 the CW light -/ current- characteristics for different stripe width are shown. We achieved a threshold current density slightly below $200A/cm^2$ and a slope efficiency of 0.75W/A. At 7A operating current the output power was about 5W for all stripe widths. The wall plug efficiency at this power level is slightly above 50%. The spectra are typical for broad area devices with FWHM of about 2nm at 1155nm (Fig. 4).

In quasi CW operation with 0.5ms pulse length we tried to test the catastrophic optical mirror damage (COMD) level. We achieved a power of more than 20W from a 100µm stripe which was limited by thermal roll over and no indication of (COMD) was found. To the best of our knowledge this is the highest power in quasi CW regime of 100µm stripe lasers ever published.

Preliminary results of life time tests over a time scale of nearly 1000h are shown in Fig. 5. We started testing reliability at a power level of 5W for 60µm- , 100µm- and 200µm- stripe lasers. This means 80mW per µm stripe width in the case of the 60µm stripe laser. There was no evidence of any degradation.

*erbert@fbh-berlin.de

Summary

We have demonstrated a new promising approach for high power, high efficieny diode lasers. Using a highly strained InGaAs DQW, to our knowledge for the first time in this wavelength region, the vertical divergence was reduced below 35° including 95% of output power. Further development of edge emitters based on this material will result in very efficient, high brightness and highly reliable devices which can be used in telecommunication and laser technology for material processing.

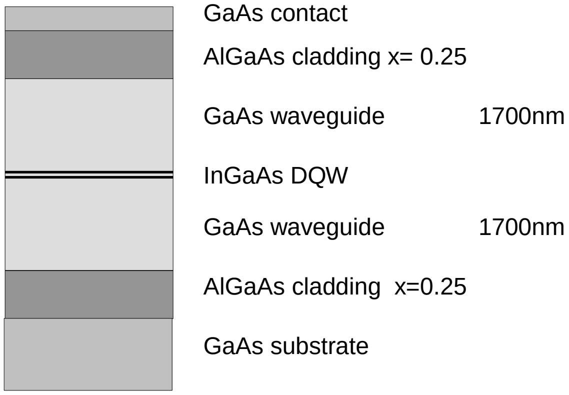

Fig. 1 Structure of 1150nm diode laser with 3.5µm thick waveguide core

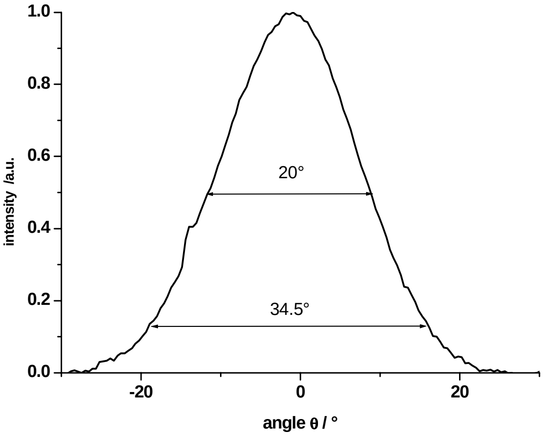

Fig. 2 Vertical far field distribution of 1150nm diode lasers

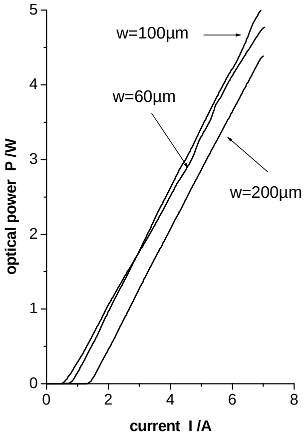

Fig.3 Power current characteristics of 1150nm – BA diode lasers, 4mm resonator length

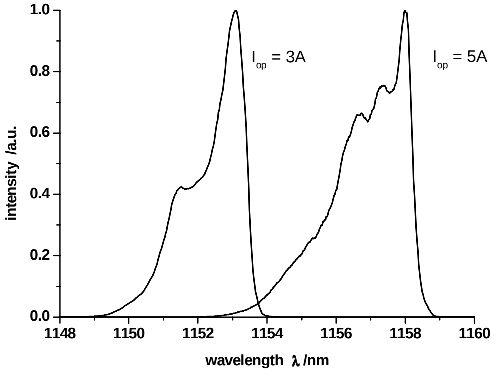

Fig.4 Spectra of 1150nm diode lasers (60µm stripe width)

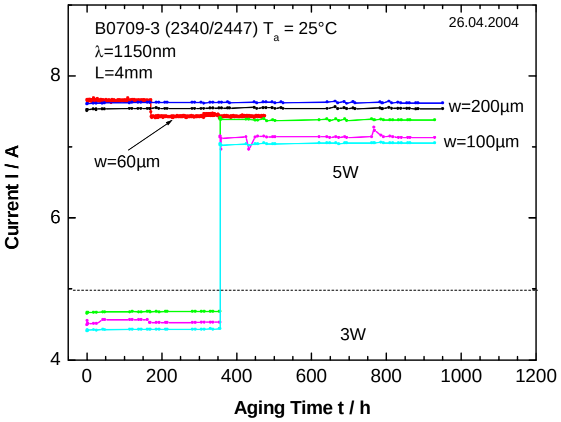

Fig. 5 Life time test of 1150nm BA – Lasers

References

/1/ D. Botez et. al. “66% CW wall plug efficiency from Al-free 0.98µm-emitting diode lasers” Electr. Lett. **32**, p.2012 (1996)

/2/ F. Bugge et. al. “12W CW diode lasers at 1120nm with InGaAs QWs” Appl. Phys. Lett **79**, p.1965 (2001)

/3/ F. Heinrichsdorff, et. al. “High-power quantum-dot lasers at 1100 nm” Appl. Phys. Lett **76**, p.556 (2000)

/4/ N. Tansu and L. J. Mawst, “High-Performance Strain-Compensated InGaAs–GaAsP–GaAs (λ=1.17µm) QW Diode Lasers
IEEE Photon. Techn. Lett. **13**, pp. 179-181 (2001)