Abstract—High-power diode lasers in the mid-infrared wavelength range between 1.8µm and 2.9µm have emerged new possibilities for solid-state pumping and direct material applications based on water absorption with favoured wavelengths at 1.94µm and 2.9µm. GaSb based diode lasers are naturally predestined for this wavelength range.

We will present results on MBE grown (AlGaIn)(AsSb) quantum well diode lasers at different wavelengths between 1.8µm and 2.9µm. We achieved output powers up to 1.3W with peak efficiencies of 32% and optical far fields below 80°.

Keywords—diode laser, high-brightness, high-power, mid-infrared, (AlGaIn)(AsSb) laser, semiconductor

I. INTRODUCTION

High power diode lasers emitting at wavelengths between 1.8µm and 3.0µm open up a wide range of applications as compact and efficient light sources in the fields of pumping of solid state and optically pumped semiconductor lasers [1] emitting in the 2-4µm regime, laser surgery [2], laser drying processes as well as direct materials processing such as plastics or aqueous varnish processing [3]. For all these applications output powers in the multiwatt range, high wall-plug efficiencies and small far field widths are required in combination for practical purposes due to optics and fiber coupling demands. Therefore, there is a strong request to improve the brightness, means the power per emitting area, of existing diode lasers in this wavelength range. Diode lasers based on the (AlGaIn)(AsSb) material system offer clear advantages in comparison to InP based diode lasers in terms of output power and wall plug efficiency. Output powers beyond 1W can be achieved with broadened waveguide designs with the drawback of high far field beam divergences of more than 120° (95% power included). Narrow symmetric waveguide designs have been introduced some years ago[4][5] and offer high output power in combination with a reduced far field angle of less than 90° which is feasible for pump stacks or fiber coupled modules.

II. WAVELENGTH AND MATERIAL COMPOSITION OF MID-INFRARED DIODE LASERS

The emission wavelength of the laser diode is mainly addressed by the thickness and mechanical stress in the quantum well (QW). There are several wavelength regimes requiring different material compositions. Between 1.8µm and 2.0µm, ternary GaInSb QW’s and quaternary AlGaAsSb barrier layers are used. Between 2µm and 2.5µm the material system in the QW is expanded by adding Arsenide. In the wavelength region between 2.5µm and 3µm it is beneficial to use quinary AlGaInAsSb barrier layers for increased hole confinement [6].

The broadened waveguide design having high aluminum content in the cladding shows a high confinement factor in the QW and hence a high modal gain. This results in reduced internal losses but in practice not usable far field angles of more than 120°.

This design can be improved by decreasing the aluminum content in the cladding and thus reducing the confinement factor. The doping of the cladding layers in this so called narrow waveguide design has to be reduced in order to decrease the internal losses due to free carrier absorption. With this design actually far field beam divergences of less than 80° can be achieved. A drawback are higher internal losses compared to the broadened waveguide design. Fig. 1 shows the far field in the fast axis of a diode laser with a narrow waveguide design.

The narrow waveguide design can be further improved by using asymmetric waveguide structures. The asymmetric confinement factor of p- and n-cladding results in a higher overlap of the optical mode with the n-cladding. The p-cladding thickness can be reduced and the n-cladding thickness has to be increased in order to avoid substrate modes. With this design the thermal and electrical resistance is reduced as well as the internal losses.
III. SINGLE EMITTER PERFORMANCE

The laser structures were grown on (100)-orientated 2-inch n-type GaSb:Te substrates by means of molecular beam epitaxy. Gain-guided broad-area lasers with stripe widths of 100µm have been fabricated using standard optical lithography in combination with dry etching and lift-off metallization for p-contact formation. The backside process started with wafer thinning followed by the deposition of the n-contact metallization and annealing. The wafers were chipped into single emitters with 1.5mm resonator length and mounted on gold-coated copper heat sinks. The diodes were measured within the current regime up to 4A where the optical far field angles in the slow axis are still small and meet the requirements of applications like fiber coupling or pump stacks.

Diode lasers at 1908nm are capable of pumping Ho:YAG solid state lasers. At this wavelength we measured output powers of 1.3W at 4A in cw mode with a peak efficiency of 32% at 0.3W (Fig. 2). The efficiency at 1.3W is still at 25%.

![Fig. 2. Cw output power vs. current characteristics of single emitters at 1908nm.](image)

At 2250nm many plastics and aqueous varnishes possess absorption lines which allow material processing. At this wavelength we measured output powers of 0.96W at 4A and peak efficiency of 24% at 1.1A in cw mode (Fig. 3).

![Fig. 3. Cw output power vs. current characteristics of single emitters at 1908nm mounted p-side down and p-side up.](image)

The absorption line of water at 2900nm offers many interesting applications in medicine or laser drying. We achieved an output power of 360mW at 35°C and 5A in cw mode (Fig. 4). Fast axis far field angles could be reduced from 120° to 92° by reducing the aluminum content in the cladding layers. The concept of the narrow waveguide design has to be further improved at this emission wavelength.

![Fig. 4. Cw output power vs. current characteristics of single emitters at 1908nm mounted p-side down and p-side up.](image)

REFERENCES


