Characterization of strained quantum well InGaAs/AlGaAs buried heterostructure lasers using internal second-harmonic generation

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ABSTRACT

In this paper the investigation of internal optical second harmonic generation (SH) of buried heterostructure (BH) InGaAs/AlGaAs strained quantum well laser diodes is performed for additional characterization of these devices which are capable to operate at high power densities as high as 3 MW/cm^2 at room temperature and 0.1 MW/cm^2 at 190 ^{0}C. The blue-green emission level is of the order of 10^5 photons per second for laser diodes with 3 μm active layer width at fundamental optical power of 2.0 mW. This relatively high SH intensity level makes it possible to observe the light spot in optical microscopes and to detect SH signal with a standard photon counting system in wide operation current and ambient temperature intervals. For laser diodes with stable near-field patterns the power of SH signal is proportional to the square of the fundamntal harmonic (FH) power and does not depend on temperature in the interval of 20÷140^{0}C as well as on the FH wavelength in the interval of 1020÷1035 nm. For constant FH power the SH signal does not depend on temperature in the interval of 20÷140 ^{0}C as well as on FH wavelength in the interval of 987÷1043 nm. Variation of the SH signal at a constant FH power indicates that changes in the near field occur: the greater SH power corresponds to greater FH near field nonuniformity. SH far-field patterns of laser diodes reflect the effects of SH radiation spot size reduction in comparison with FH radiation spot size and FH waves nonlinear interactions in the waveguide material.

1. INTRODUCTION

In the emission spectra of the semiconductor lasers the fundamental harmonic at the frequency ω is accompanied by second harmonic radiation at the frequency 2ω. The internal SH generation was observed for the first time almost thirty years ago.[1-5] The efficiency of this process is very low and does not influence the fundamental beam characteristics.[6] This is a possible reason why the interest to the SH emission in semiconductor lasers decreased rapidly after the first publications and SH is not

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used for characterization of the laser diodes. The weak SH radiation, that can be observed in the output beam spectrum along with the fundamental frequency originates in a thin near-surface layer, adjacent to the mirror facet of a laser. The thickness of this layer is determined by the absorption constant of the waveguide media at the SH frequency 2ω. This thickness for AlGaAs waveguide and second harmonic wavelength of 0.5 μm is very small: $d_{SH} = \alpha^{-1} = 100$ nm.[7]

As it was shown in Ref.8 the study of SHG in AlGaAs SQW lasers may give some important information about the laser mirror surface state and can be used for *in situ* control of the semiconductor laser facet degradation.

Recently a novel method for growth and fabrication of high performance strained InGaAs/AlGaAS QW BH lasers was reported.[9,10] It was shown, that CW power densities on the mirror facets as high as 3 MW/cm^2 at room temperature and 0.1 MW/cm^2 at 190°C can be obtained.[10] Here we report the investigation of the internal SHG in CW InGaAs/AlGaAs BH lasers with strained QW up to 100 mW output power at room temperature and 5 mW at 140°C. The usefulness of the SH measurements for the laser diodes characterization is also discussed.

2. EXPERIMENTAL

We have studied FH and SH emission properties of BH lasers fabricated by a new method, that involves growth of the initial laser structure by MBE, meza formation by in-situ melt-etching and regrowth of p^{-}p-n $Al_{0.3}Ga_{0.7}As$ isolating layers by the low temperature LPE.[9-11] The initial multiquantum well structure consists of the following layers: 0.5 μm - thick n-GaAs buffer layer, 0.1 μm - thick superlattice buffer layer of five periods of 100 Å GaAs /100 Å AlGaAs, 2.0 μm - thick n-$Al_{0.35}Ga_{0.65}As$ cladding layer, a 0.15 μm thick linearly graded index $Al_1Ga_{1-x}As$ layer with x and n decreasing from 0.6 to 0.15 and $5x10^{17}$ to $1x10^{16}$ cm^{-3}, respectively, 600 Å - thick undoped $Al_{0.15}Ga_{0.85}As$ layer, three 80 Å InGaAs/100Å GaAs undoped quantum well active region, 600 Å - thick undoped $Al_{0.15}Ga_{0.85}As$ layer , 0.15 μm thick linearly graded index $Al_xGa_{1-x}As$ layer with x and n increasing from 0.15 to 0.6 and $1x10^{16}$ to $5x10^{17}$ cm^{-3}, respectively,a 2.0 μm - thick p-$Al_{0.35}Ga_{0.65}As$ cladding layer, and 0.2 μm thick p-GaAs contact layer. The p and n dopants were the Be and Si, respectively.

The threshold current and the output power were respectively 2-3 mA and up to 100 mW at 20 °C and 5 mW at 140 °C for lasers with 2-3 μm active region width and 400 - 1000 μm cavity lengths. Light-current characteristics were linear up to 10 kA/cm^2 current densities through the active region.

The total power of the SH signal as well as SH signals in the far field and near field measurements were detected with the help of a double monochromator and a cooled photo multiplier tube and a standard photon-counting system.[8] Optical filters were used in order to eliminate the errors that might appear in the detection of a weak SH