Enhanced internal second harmonic generation in InGaAs/GaAs/AlGaAs strained single quantum well buried heterostructure laser diodes

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ABSTRACT

In this paper we report an indirect method based on photomultiplier response calibration to measure the radiant power of the internal second harmonic generation (ISHG) from InGaAs/GaAs/AlGaAs strained single quantum well buried heterostructure laser diodes (SQW BH LDs).

We observed enhanced ISHG radiant power, of the order of magnitude of 10^{-8} W. This phenomenon represents a signature of the beginning of the process of catastrophic optical degradation (COD) of the LD mirror facet layers, where the nonlinear optical interaction occurs.

KEYWORDS

internal second harmonic generation, InGaAs/GaAs/AlGaAs laser diodes

1. INTRODUCTION

In the thin semiconductor layers adjacent to the mirror facets of high power laser diodes the nonlinear optical phenomenon of internal second harmonic generation (ISHG) takes place.

Two major mechanisms share their contribution to the cause of this phenomenon: counterpropagating nonlinear optical interaction[1] and waveguiding[2] in the laser diode active region.

The efficiency of ISHG by the waveguiding effect is mainly limited by the absorption of the shorter wavelength second harmonic wave.

ISHG in InGaAs/GaAs/AlGaAs strained single quantum well buried heterostructure laser diodes (SQW BH LDs), emitting around 950 nm, received much attention[2,3] for the fact that the second harmonic (SH) radiation originating from the LD mirror layers could offer some important information regarding the mirror facet temperature and risk of mirror catastrophic optical degradation in conditions of high output power laser operation.

In Sec. 2 we present some theoretical considerations concerning the efficiency and the mechanisms of ISHG in the case of second order nonlinear optical processes for III - V semiconductor compounds.

Sec. 3 is dedicated to sample details and experimental setup while in Sec. 4 we report the conclusions of this paper.

2. THEORY

It was experimentally observed and theoretically confirmed [3] that two counterpropagating light waves incident on the interface between a linear and a nonlinear optical medium, in a total internal reflection geometry, determine the formation of a layer of nonlinear polarization, adjacent to that interface, having the thickness of the order of the radiation wavelength.

By this effect, two half-wave harmonics are generated as emerging into and out of the substrate. This phenomenon, termed as counterpropagating nonlinear optical interaction, was also studied for the particular situation when the nonlinear medium is a semiconductor[4].

In the case of a laser diode, such a nonlinear optical interaction occurs at the interface provided by the mirror facet.

According to the theory of counterpropagating nonlinear optical interaction, the thickness of the semiconductor material, close to the LD mirror facet, should be of the order of magnitude of the fundamental wavelength (i.e. ~ 1 μm for our LD's).

On the other hand, another efficient mechanism for second order nonlinear optical processes in III - V semiconductor compounds (that have almost zero birefringence) is the waveguiding effect for quasi-phase-matching[5].

The efficiency of ISHG by waveguiding is limited mainly by the absorption of the shorter wavelength second harmonic wave.

As a known fact of SHG theory, the dependence of the SH irradiance $I_{2\omega}$, on the fundamental wave irradiance, I_{ω}, is quadratic:

$$I_{2\omega}(L) = \frac{(2\omega)^2}{8\varepsilon_0 c^3} \cdot \frac{\left|\chi^{(2)}(-2\omega;\omega,\omega)\right|^2}{n_{\omega}^2 n_{2\omega}} \cdot I_{\omega}^2(L) \cdot L^2 \cdot \left[\frac{\sin\left(\frac{\Delta kL}{2}\right)}{\frac{\Delta kL}{2}}\right]^2 \qquad (1)$$

where ω is the fundamental wave angular frequency, ε_0 is the vacuum dielectric constant, c is the speed of light in vacuum, $\chi^{(2)}(-2\omega;\omega,\omega)$ is the