

# Design of Highly Efficient High-Power Optically Pumped Semiconductor Disk Lasers

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**Abstract**—In this paper, we present a carefully elaborated layer design for semiconductor disk lasers. Experimental results of devices mounted on simple copper heat spreaders reveal a conversion efficiency of 54% at 13.2 W for 980-nm wavelength laser emission and a differential quantum efficiency of 7.3%.

**Index Terms**—Cavity resonators, distributed Bragg reflector lasers, electromagnetic propagation, laser beams, laser excitations, laser resonators, optical films, optical propagation in absorbing media, semiconductor epitaxial layers, semiconductor lasers.

## I. INTRODUCTION

OPTICALLY pumped semiconductor disk lasers (SDLs) with extended resonators offer a combination of advantageous properties that is unique in the class of semiconductor lasers. Nearly fundamental Gaussian non-astigmatic circular laser emission with several watts of output power can be achieved. The easily accessible intracavity beam offers the possibility to include nonlinear optical crystals for second harmonic generation (SHG), which expands the range of usable wavelengths that can be obtained in the visible spectrum [1]–[5]. Although maximum output powers of several ten watts have already been demonstrated since the first promising publication by Kuznetsov *et al.* in 1997 [6], compared to vertical cavity surface emitting lasers (VCSELs) [7], the conversion efficiencies are still fairly poor. Optical power conversion efficiencies and slope conversion efficiencies of 52% and 56%, respectively, have been reported for devices with diamond heat spreaders [8], [9]. Particularly, since most publications do not mention absorption efficiencies, to our knowledge, the best reported value for barrier-pumped devices is 80%, which was achieved by a device with a double-band Bragg reflector (DBBR) [8].

## II. DEVICE DESIGN

In this section, the layer structure of an SDL that was designed for an emission wavelength of  $\lambda_e = 980$  nm and optical pumping

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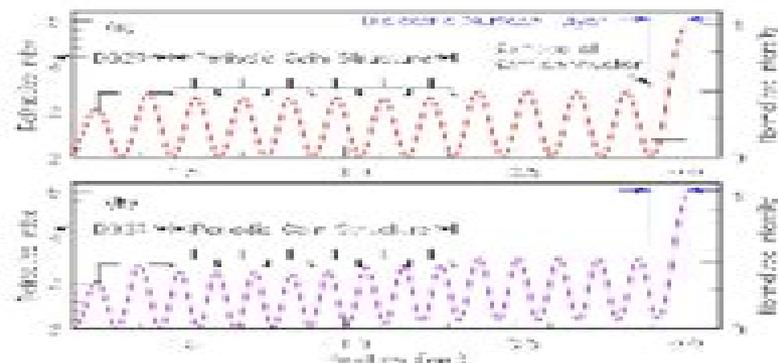


Fig. 1. Designed the top region of the semiconductor disk laser, visualized by the index of refraction, beginning from the surface layer to the first layers of the rear DBBR. (a) Electric field intensities for the design wavelength  $\lambda_e = 980$  nm in case of perpendicular propagation. (b) Pump wavelength  $\lambda_p = 808$  nm and angle of incidence  $\theta_i = 25^\circ$ .

with a wavelength of  $\lambda_p = 808$  nm under an incidence angle of  $\theta_i = 25^\circ$  is presented. According to Fig. 1, in which the top region of the structure is represented by the index of refraction, the layer structure of the device includes the following functional regions.

- 1) **Surface layer:** The surface of the semiconductor structure is covered by a dielectric quarter-wavelength  $\text{TiO}_2$  coating, related to the laser's emission wavelength  $\lambda_e$ .
- 2) **Resonant periodic gain (RPG) structure:** Six 6.2-nm-thick  $\text{In}_{0.125}\text{Ga}_{0.875}\text{As}$ –GaAs quantum wells (QWs) are assembled with an optical path length periodicity of a half emission wavelength. Strain compensation is realized by GaAs $_{0.7}$ P $_{0.3}$  layers that are located at a central position between the QWs and at the boundaries of the structure.
- 3) **Rear reflector:** A total of 66 epitaxially grown layers build up the DBBR that is supported by the rear metallization (Ti/Au/Pt/Au, 5/50/50/50 nm). The structure is numerically optimized to provide high reflectivity at the emission wavelength as well as for the pump light. In Fig. 2, the optical thickness of each layer  $nd$  is represented in units of a quarter-wavelength optical thickness by  $d_{\text{QW/DBR}} = 4nd/\lambda_e$ . The spectral reflectivity function, which is shown in Fig. 3, was calculated by the matrix formulation for isotropic layered media and monochromatic plane waves [10].

# Optically Pumped Semiconductor Disk Lasers For High Power

**Michael Brown**



## **Optically Pumped Semiconductor Disk Lasers For High Power:**

## **Optically Pumped Semiconductor Disk Lasers For High Power** Book Review: Unveiling the Magic of Language

In an electronic era where connections and knowledge reign supreme, the enchanting power of language has been apparent than ever. Its power to stir emotions, provoke thought, and instigate transformation is truly remarkable. This extraordinary book, aptly titled "**Optically Pumped Semiconductor Disk Lasers For High Power**," published by a highly acclaimed author, immerses readers in a captivating exploration of the significance of language and its profound impact on our existence. Throughout this critique, we shall delve into the book's central themes, evaluate its unique writing style, and assess its overall influence on its readership.

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