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Wavelength Stabilized Fiber-coupled Laser Modules for DPSS and Fiber Laser Pumping

Wavelength Stabilized Fiber-coupled Laser Modules for DPSS and Fiber Laser Pumping

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Abstract

It is well documented that increases in pump module power enable higher power DPSS or CW fiber lasers, but it is important to recognize that increasing the efficiency by which the DPSS or CW fiber laser is pumped drives down both system complexity and cost. Additionally due to the narrow absorption band of the common laser mediums like Yb:KBr and Nd:YAG, it is advantageous to maximize the spectral overlap between the emission of the pump module and the absorption band of the host medium, one way to accomplish this is by the use of Volume Bragg Gratings (VBGs) to both narrow and stabilize (locking) to an emission change with current and/or temperature the emission of the diode pump module. To this end, we report on the continued progress by nLIGHT to develop and deliver the highest efficiency wavelength-stabilized, diode-laser pump using single-emitter technology at 488nm for resonant DPSS pumping, and 885nm for fiber-laser pumping. The keys for these improvements is the creating the optimal structure of the laser diode is optimized not only for efficiency and power but is also properly optimized to maintain the amount of spectral shift with current. Due to the proprietary nature of our optical structures, we are unable to provide exact details. However, throughout this paper, we will abstractly discuss the improvements made to our epitaxy, and how these changes directly affect, and improve upon the module level performance with VBGs, and provide COG and module level results for our "classical" packages with VBGs to support these claims, with key examples being: at 999nm on a 2x6 module with 100 μm fiber, 305 μm - 0.16 beam NA, and a 668nm on 408 μm 2x12 into 200 μm - 0.16 beam NA, along with 885 nm diode module, in a 2x12 layout outputting a maximum of 370 W with 52 % electro-optical efficiency when coupled into 200 μm - 0.16 beam NA.

Key words: Diode stability, wavelength stabilized, VBG, fiber-coupled diode laser, pump diodes, diode lifetime, E-beam, brightness, fiber laser, ytterbium, efficiency

1. INTRODUCTION

In our prior paper [1] we discussed the improvements to the laser diode epitaxy which generated not only more power but reduced the voltage to significantly improve the efficiency for 975 nm devices coupled into 200 μm fibers. Over the past year we have applied variations of these optimal improvements across our family of laser diodes, at 920 and 970 nm for efficient 100 μm fiber coupling, at 920 and for efficient 200 μm fiber coupling, and finally at 878 and 885 nm (also collectively referred to as "885" nm) for efficient 200 μm fiber coupling.

Changes to the laser diode optical structure and COG (chip on substrate) assembly were made to firstly reduce the voltage, which directly drives efficiency and thus reduces the junction temperature of the laser diode. By reducing the junction temperature, the laser diodes output more optical power, have less wavelength shift with operating current, which is conducive to wavelength locking with a VBG, and per the Arrhenius equation (Eq. 1) have better reliability. Before proceeding, we should define what it means to "lock" a laser diode with an external VBG. To begin with, a VBG can be thought of a mirror with a very narrow optical window over which it reflects, while also having a very tightly controlled reflectivity percentage. The VBG is then placed after the free-emitter diode collimator (FDC) or slow-wave diode collimator (SWC) and forms an external cavity for the laser diode. The effect of the VBG on the spectral content of the laser diode is demonstrated below in Figure 1 (left) where we can see the emission of the free-emitting laser diode module has a peak at 973.61 nm, and a FWHM value of 2.49 nm, and after insertion of the VBG the FWHM emission spectrum has been narrowed by an order of magnitude to 0.31 nm, and the peak of the emission has been "traced" by the VBG to 977.27nm, the wavelength of the VBG itself. On the right, we can now observe how the emission content of the free-emitting laser diode module changes by ~0.5 nm/nA, and after insertion of the VBG the shift drops to ~0.02

nLIGHT continues to drive innovation in multi-emitter diode modules, as demonstrated by successfully reducing our laser diode voltage by means of a revised epitaxy across multiple wavelengths, and then demonstrating module level results of these new devices by successfully productizing 465 W with a beam NA of 0.16 at 920 nm, in a 24-emitters module with 200 μm fiber, and also achieving 265 W at 53 % efficiency with VBG stabilized 885 nm devices in 24-emitter module coupled into 200 μm fiber, all while measuring an extremely broad locking range.

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