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Coherently Combined Diode Laser Arrays and Stacks

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Abstract: We have coherently combined up to 7.2 W CW using an individually addressable 10-element-array of 960-nm Slab-Coupled Optical Waveguide Lasers (SCOWLs). We are currently scaling the phase-locked output power to 100 W using SCOWL stacks.

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Coherent beam combination (CBC) promises the ideal power and brightness scaling of diode lasers [1]. Implementation, however, has been challenging. The primary difficulty is the requirement to maintain precise (better than $\lambda/10$) control on the optical path difference (OPD) of the diode laser elements. For this work, CBC is approached by using Slab-Coupled Optical Waveguide Lasers (SCOWLs) as the diode lasers used for combination [2]. Improvements have been made to the SCOWL design, resulting in improved device efficiency and reliability, while maintaining the power and brightness of earlier SCOWL devices. Recently, the peak CW Power Conversion Efficiency (PCE) of a 960-nm GaAs-based SCOWL device was increased to greater than 40%, and we have improved the single-mode performance. See Fig. 1 for a CW L-I characteristic of a recent SCOWL device exhibiting a peak PCE of 47%. We are currently working to implement such devices as sources for coherently combined arrays.

Control of the OPD in SCOWL devices is essential for CBC. Our approach for OPD control is individual current adjustment of each SCOWL array element. By direct measurement of the phase shift of a SCOWL-based device under bias, it was determined that a modest phase control requirement of ≈ 10 mA per element is required for $\lambda/10$ phase control. Therefore, individually addressable (IA-) SCOWL arrays were constructed, in which the current of each device can be adjusted independently.

Two distinct approaches to CBC of IA-SCOWL arrays were investigated. In the first approach, reported previously [3] the Talbot self-imaging effect is used to construct an external cavity, in which coupling for the CBC is provided by Fresnel diffraction between neighboring elements in the array. With the Talbot cavity, 7.2 W CW coherently combined power was demonstrated using a 10-element, 100- μm -pitch IA-SCOWL array. This represents, to our knowledge, the highest output power that has been coherently combined using a diode laser array.

In the second approach, amplifier arrays are utilized instead of laser arrays. A frequency-stabilized master laser is used to seed the IA-SCOWL-based amplifier array. In-situ monitoring of the device L-I characteristic during the deposition of the AR-facet coating of the amplifier array was developed. This allowed for the reduction of the reflectivity of the output facet in order to minimize chip-mode oscillation. This was an enabling technique, allowing for the demonstration of 4.9 W CW from a 10-element SCOWL amplifier array, with a narrow-bandwidth spectrum centered at 960 nm. The experimental setup, measured spectrum, and far field profile of the amplifier array coherent combination are shown in Fig. 2. An earlier generation of SCOWL devices was used, and these devices are not as efficient as those we are currently developing (Fig. 1). It is believed that the amplifier approach is scalable to larger numbers of elements than the Talbot approach.

Currently, we are working on a demonstration to scale the coherent power from a stack of IA-SCOWL amplifier arrays to 100 W CW in a single, nearly diffraction-limited spot with narrow bandwidth. Our baseline architecture for this demonstration uses the amplifier architecture with a 2-D stack of IA-SCOWL-based amplifiers.

References

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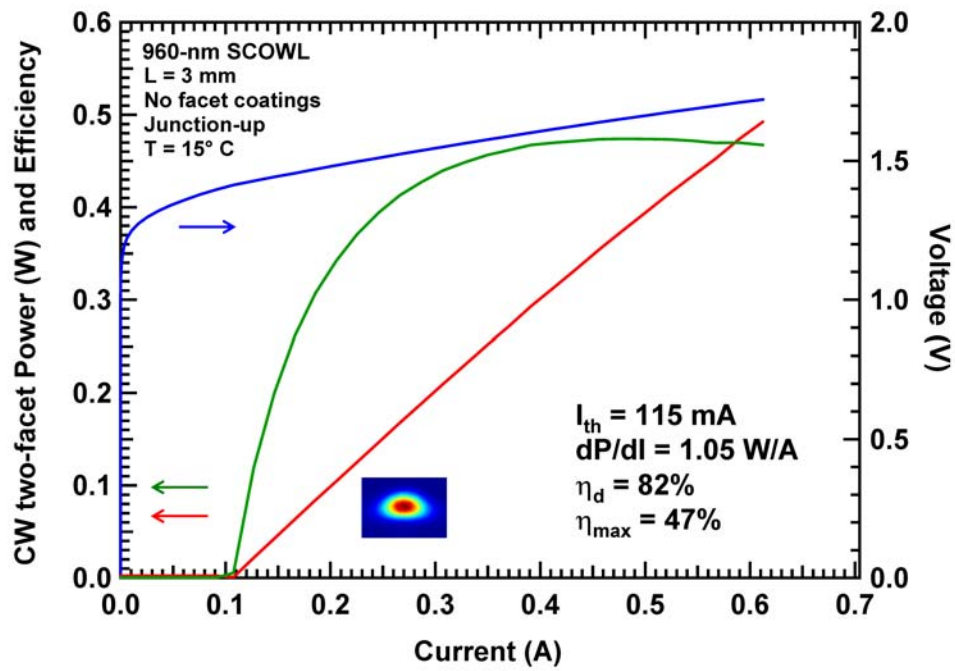


Fig. 1: CW L-I-V characteristic of an improved 960-nm SCOWL device. This device has no facet coating, and has been mounted junction-side up. The inset shows the near field profile of the device.

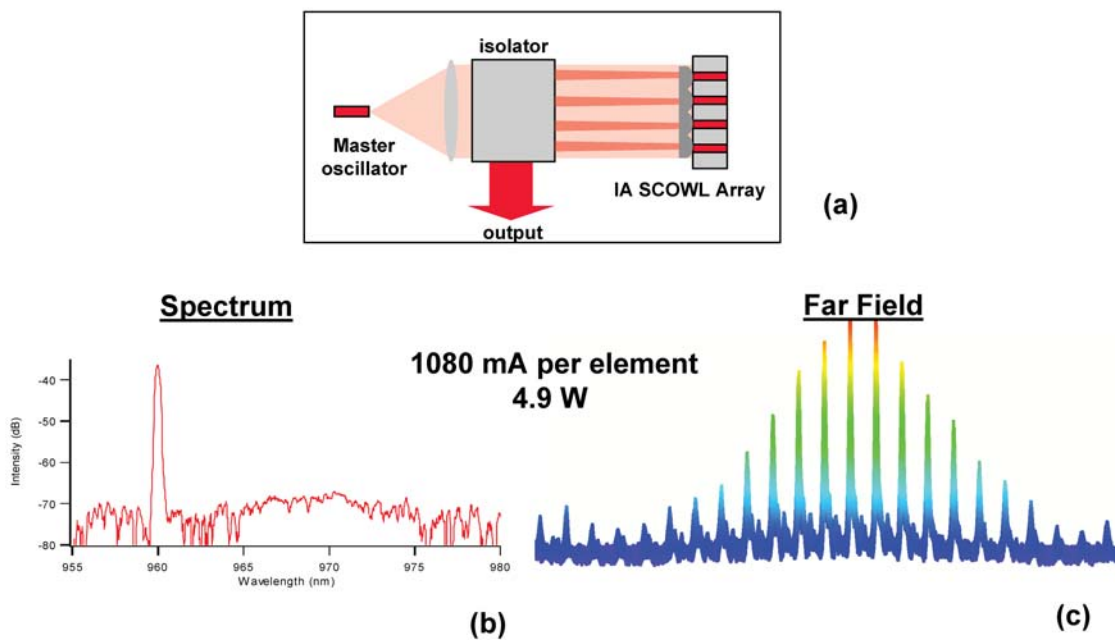


Fig. 2: (a) Schematic setup for amplifier approach for coherent beam combination. (b) Spectrum of combined output of amplifier array. (c) Far field profile of coherently combined amplifier array.