In-phase output beam from broad-area diode array using Talbot cavity

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The robust phase locking of a linear diode array consisting of 49 broad-area emitters was demonstrated. The single lobe in the far field with output power of 0.83 W was observed. The far-field divergence was reduced to 2.0 mrad. The spectral bandwidth was reduced from 1.7 to 0.13 nm.

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High-power diode laser arrays (DLAs) characterized by compact construction, high efficiency, and long operating lifetime are extremely attractive for many applications. However, the full potential has yet to be realized. This is mainly due to poor output beam quality and large free-running spectral bandwidth. A typical commercial DLA has a beam quality factor M^2 near to 1 in the fast-axis, and above 2000 in the slow-axis, with a free-running spectra bandwidth of 1.5—3 nm[1]. For example, in material processing DLAs are typically used in the welding, cutting, and surface processing of mostly nonmetal materials, but are not used in welding, cutting, and drilling of metals[2]. Thus, the applications of semiconductor will be greatly expanded if the beam quality and spectral bandwidth can be improved.

There are various incoherent methods that improve the beam quality and spectral bandwidth of the diode arrays. For example, using wavelength or spectral beam combining, Chann *et al.* obtained 35 W in a single-lobe diffraction-limited output beam, however, this method inherently gives multi-wavelength output beam[3]. Various groups demonstrated spectral narrowing of diode arrays and stacks in an external-cavity[4,5]. However, in all cases the beam quality of the arrays and stacks remained the same. The only method that improves both spectral and spatial properties of the laser array is through coherent beam combining. Using fractional Talbot cavity Apollonov *et al.* demonstrated 10 W coherently phase-locked from a single diode array[5,6]. The array was operating in an out-of-phase mode as characterized by two dominant central lobes. In our previous work, we demonstrated single-lobe far-field from a diode array[7]. The pedestal, however, was very high. In this letter we report the improvement work. We measured a single lobe in the far field with the output power of 0.83 W and divergence of 2.0 mrad. The spectral bandwidth reduced from 1.7 to 0.13 nm.

An array of N phase-locked emitters can oscillate in N different collective super modes. Among them, the out-of-phase mode usually has the lowest loss in a Talbot cavity of length $L = Z_{\mathrm{T}}/4$, where Z_{T} is the Talbot distance[8,9]. In-phase mode selection can be obtained by tilting the external cavity[7]. Figure 1 illustrates the experimental setup. The cavity consists of a fast-axis collimated diode array and a partially reflecting output coupler. The laser array has 49 elements. The dimension of each emitter was 1 × 100 (μm). The pitch was 200 μm and thus the quarter Talbot distance is 25 mm. The array was packaged in the patented sandwich structure to reduce the 'smile' effect. The back-facet and the front-facet of the array were optically coated with high-reflection coating and anti-reflection coating (< 1%),

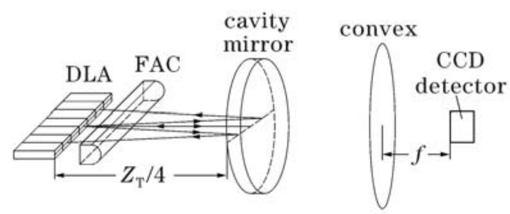

Fig. 1. Experiment setup for the phase locking of a DLA with an external cavity.

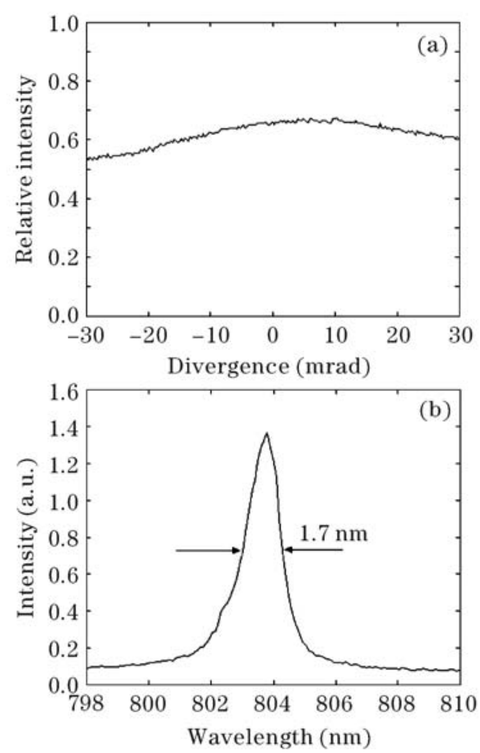

Fig. 2. (a) Far-field intensity distribution and (b) the spectral profile of the free-running output beam.

respectively. We used a 50% reflectivity output coupler. Typically we operated the array at 18.1 A with the heat sink temperature of 15 °C.

Figure 2 shows the far-field distribution and the spectral profile of the DLA. This is expected since the emitters were not phase-locked in the absence of external cavity.

Figure 3 shows the far-field distribution emitted by the diode array in the Talbot cavity. The width of the center lobe in the far-field distribution was reduced to 130 μm or 2.0 mrad. At this operating current we measured the output power of 0.83 W. The measured far-field divergence was larger than the diffraction limit of the array (theoretical value is about 0.1 mrad), indicating that not all of the emitters were completely locked to the fundamental cavity mode. The broad pedestal in the far-field indicated that some emitters were partially phase-locked. This suggests that the degree of coherence of cavity was limited by some emitters that were not locked to the uniform mode or were not locked. Thus, improving precision of the apparatus to generate global phase locking is a way to increase phase locking efficiency.

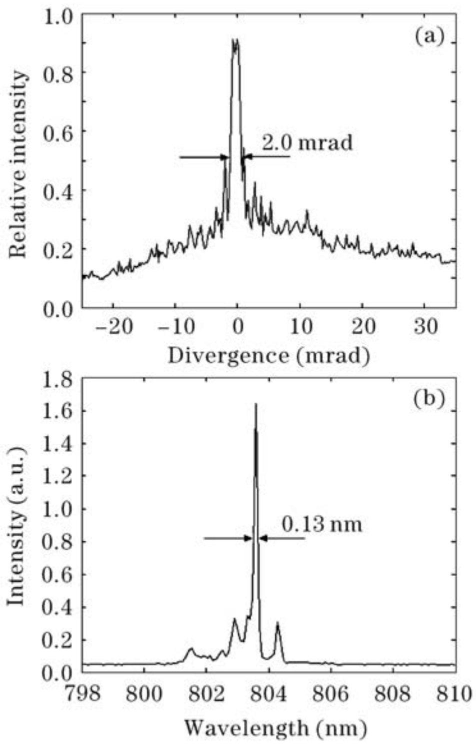

Fig. 3. (a) Far-field intensity distribution and (b) the spectral profile of the phase-locked output beam.

In summary, we have demonstrated a simple and effective method of improving the beam quality and free-running spectrum of diode arrays. We obtained the in-phase output power of 0.83 W with the far-field divergence of 2.0 mrad. The spectral bandwidth was reduced from 1.7 to 0.13 nm. The efficiency of the cavity was low due to the edge effect resulting from the limited number of the phase-locked emitters. Further experiments with the system of in-phase mode selection such as phase compensation and amplitude compensation at higher injection current will improve the bandwidth and divergence angle at higher output power.

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