Injection locking of broad-area semiconductor laser arrays

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Optical injection has been widely used to improve coherence in semiconductor lasers. Several experiments demonstrated injection locking of a laser diode array [1-3] and a single broad-area laser diode [4,5] to achieve a single far-field lobe and a narrow spectrum. In this work, we utilize the optical injection technique to substantially improve the beam quality of a broad-area laser array. We experimentally demonstrate injection locking of a few multi-mode broad-area laser diodes assembled on a compact laser array with a single-mode laser diode. To the best of our knowledge, this is the first experimental evidence of successful injection locking of the array of broad area lasers.

A schematic experimental design of a broad-area laser array with light injection is demonstrated in Figure 1. Our laser array has 19 broad-area laser diodes assembled in one dimension with the spacing of 500 μm between neighboring lasers. Each laser diode has the emitting area of 150 μm wide and 1 μm thick and is capable of emitting maximum output power of the order of 1W. The wavelength of each laser is around 808 nm with a spectral width about 1 nm. Since the far-field angle of the broad-area laser diode along the fast axis (perpendicular to the laser junction plane) is about 50° while the angle along the slow-axis (parallel to the laser junction plane) is only 3°, we use two cylindrical lenses with different focal lengths to collimate the output beam from the laser array.

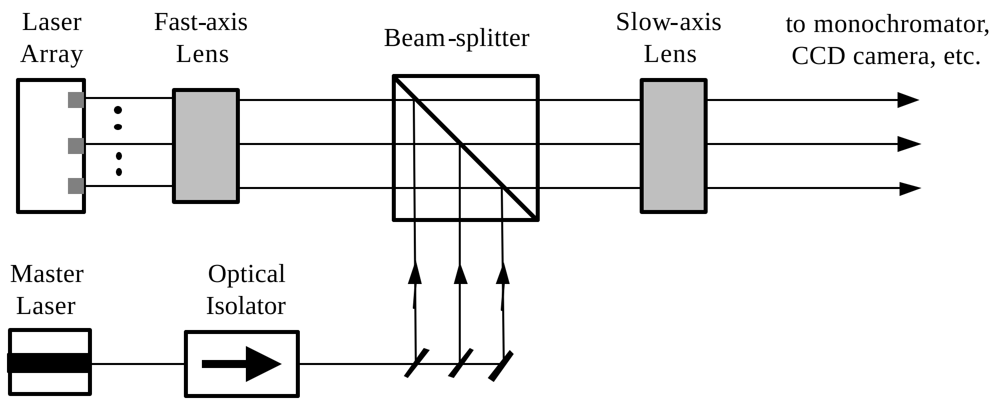

Fig.1 Schematic of injection locking broad-area laser diode array.

A single-mode wavelength tunable laser diode is used as a master laser in the experiment and this laser has the linewidth about 1 MHz and the output power of 30 mW. To avoid the unwanted optical feedback to the master laser, an optical isolator with the isolation of 60 dB is used right after the master laser. In order to obtain an efficient light injection, we split the master laser output beam into multiple parallel beams and inject each of them into a different broad-area laser of the array. As the first step, we use a couple of beam-splitters to split the injection beam into multiple parts with each injected into a different broad-area laser as shown in Fig.1. A computer-generated-hologram (CGH) will be later used to split the injection beam.

We demonstrate a typical example of light injection into the cavities of two broad-area lasers in the array. Fig. 2 shows the optical spectra of lasers #7 and #12 before and after the injection-locking. The wavelength of the mater laser is set to be 808.0 nm, and we observe (Fig.2) that two lasers are simultaneously locked to the same injection wavelength. We further verified that, when injection locking occurs, most of the output power is concentrated on one longitudinal and transverse mode determined by the injection. A considerable improvement on both temporal and spatial coherence is verified.

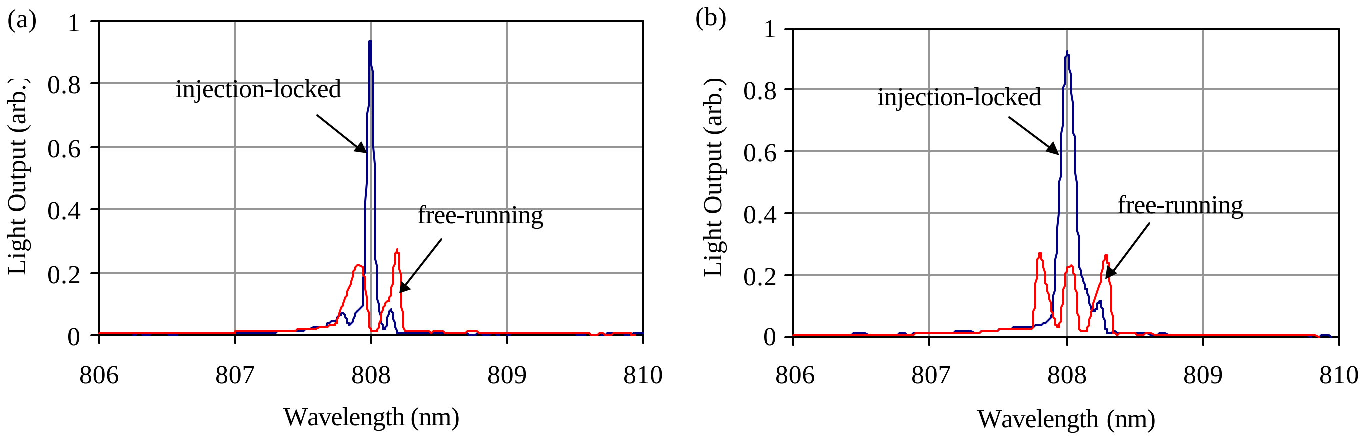

Fig.2 Optical spectra (a) LD #7 and (b) LD #12 before and after injection locking.

Potential applications of injection locking of a laser array include optical communications, measurement, and material processing where high intensity and high coherence are required. The total output intensity emitted from the optically injected and in-phase synchronized coupled array of N lasers is proportional to N^2 [6]. Considering the large power and compact configuration of the broad-area array used, a high power density (at the order of MW/cm^2) can be achieved by appropriately coupling output beams from different broad-area laser diodes locked by the same injection frequency.

Recent theoretical work reveals that the total output intensity emitted from the array shows a nonmonotonic response to the amplitude of the injected light. In particular, a small variation of the intensity of the injected light can cause a dramatic change in the total output intensity emitted from the array [7]. This feature can (in principle) be applied to all-optical high power communication, signal processing and gate control.

In conclusion, injection locking of multiple broad area lasers is observed and a dramatic enhancement of the total power density of a laser array is achieved by appropriately coupling output beams from different laser diodes. Our experimental results demonstrate feasibility of achieving high intensity diffraction limited coherent radiation from an array of lasers. This research was supported in part by the U.S. Department of Energy, Office of Basic Energy Sciences, and by the Office of Naval Research. The Oak Ridge National Laboratory is managed for the U.S. DOE by UT-Battelle, LLC, under contract No. DE-AC05-00OR22725.

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