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The Mutual Coherence of Simultaneously Injection-Locked Laser Diode Arrays

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Abstract

The modulus of the mutual coherence function, $|g_{12}(\tau)|$, has been measured for two physically separated laser diode arrays that were simultaneously injection locked to the same master laser. The measured value, $|g_{12}(\tau)| = .96 \pm .06$, is close to ideal.

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Injection locking of a laser diode bar by a master single mode diode laser may provide a high power, narrow bandwidth, coherent source of cw laser radiation. By laser diode bar we mean a set of equally spaced laser diode arrays sharing a common substrate. In this experiment we have injection locked[1] two physically separated laser diode arrays to the same single mode master laser. The modulus of the mutual coherence function for the two injection locked beams was measured to determine how well they could be coherently combined. The measured value .96 ± .06 was extremely close to the ideal value of unity.

A simplified drawing of the experimental apparatus is shown in Fig. 1. Light from a cw single mode diode laser was split into two beams, and each was used to injection lock a gain guided cw laser diode array. The injection locked output from each array was picked off using a mirror and sent to beamsplitter 2 where the beams were recombined.

The spatial intensity profiles of each of the collimated injection locked beams $I_1(x)$, $I_2(x)$, and the interfering beams I(x), were separately recorded by a Reticon detector. These three pieces of data were used to determine the modulus of the mutual coherence function by a least squares fit to the following Young's type interference formula:

$$I(x) = I_1(x) + I_2(x) + 2|g_{12}(\tau)|\sqrt{I_1(x)I_2(x)} \cdot cos(c \cdot x + \Delta\phi) \qquad (1)$$

The normalized mutual coherence function $g_{12}(\tau) = < E_1(t+\tau)E_2^*(t) > / \sqrt{<|E_1|^2><|E_2|^2>}$ where $E_{1,2}(t+\tau)$ is the electric field from laser diode array 1,2 at time $t+\tau$, $<>$ denotes a time average, and $||$ denotes the modulus of $g_{12}(\tau)$. c is proportional to the spatial interference frequency and $\Delta\phi$ is the phase difference between the two beams.

To gain some confidence in the above technique the laser diode arrays were replaced by mirrors and the mutual coherence or "self coherence", $g(\tau)$, of the master laser was measured as the relative path difference between the interfering beams was varied. The spectrum of the master laser, $g(\nu)$, which is the Fourier transform of $g(\tau)$ was also measured. Born and Wolf[2] have defined the rms coherence time, $\Delta\tau$, and bandwidth, $\Delta\nu$, for Gaussian $g(\tau)$ and $g(\nu)$ such that $\Delta\tau\Delta\nu \sim 1/(4\pi)$. By fitting $g(\tau)$ and $g(\nu)$ to gaussian functions we have measured $\Delta\tau = 5.6 \pm .25$ nsec, $\Delta\nu = 14.7 \pm .7$ Mhz for the master laser. The product $\Delta\tau\Delta\nu = 0.082 \pm .008$ compares very well with the expected value $1/(4\pi) = 0.080$.

In Fig. 2 we show the spatial intensity profile of the injection locked output from each laser diode array and the resulting interference pattern. The dots are a least squares fit of Eq. 1 to the data. The modulus of the mutual coherence function determined from the fit is $|g_{12}(\tau = 1\ nsec)| = .96 \pm .06$. We can draw several conclusions about the injection locked arrays from this data: 1.) They have the same frequency, 2.) Their mutual coherence is close to ideal, and 3.) The spatial phase distribution of each injection locked beam must be approximately the same, to within a constant phase. This research was performed under the auspices of the U.S. Department of Energy by the Lawrence Livermore National Laboratory under contract W-7405-Eng-48.

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[1] L. Goldberg and J.F. Weller, Appl.Phys.Lett. 50, 1713 (June 1987)

[2] M. Born and E. Wolf, Principles of Optics, Pergamon Press, Sixth Edition, 1987, pg. 543

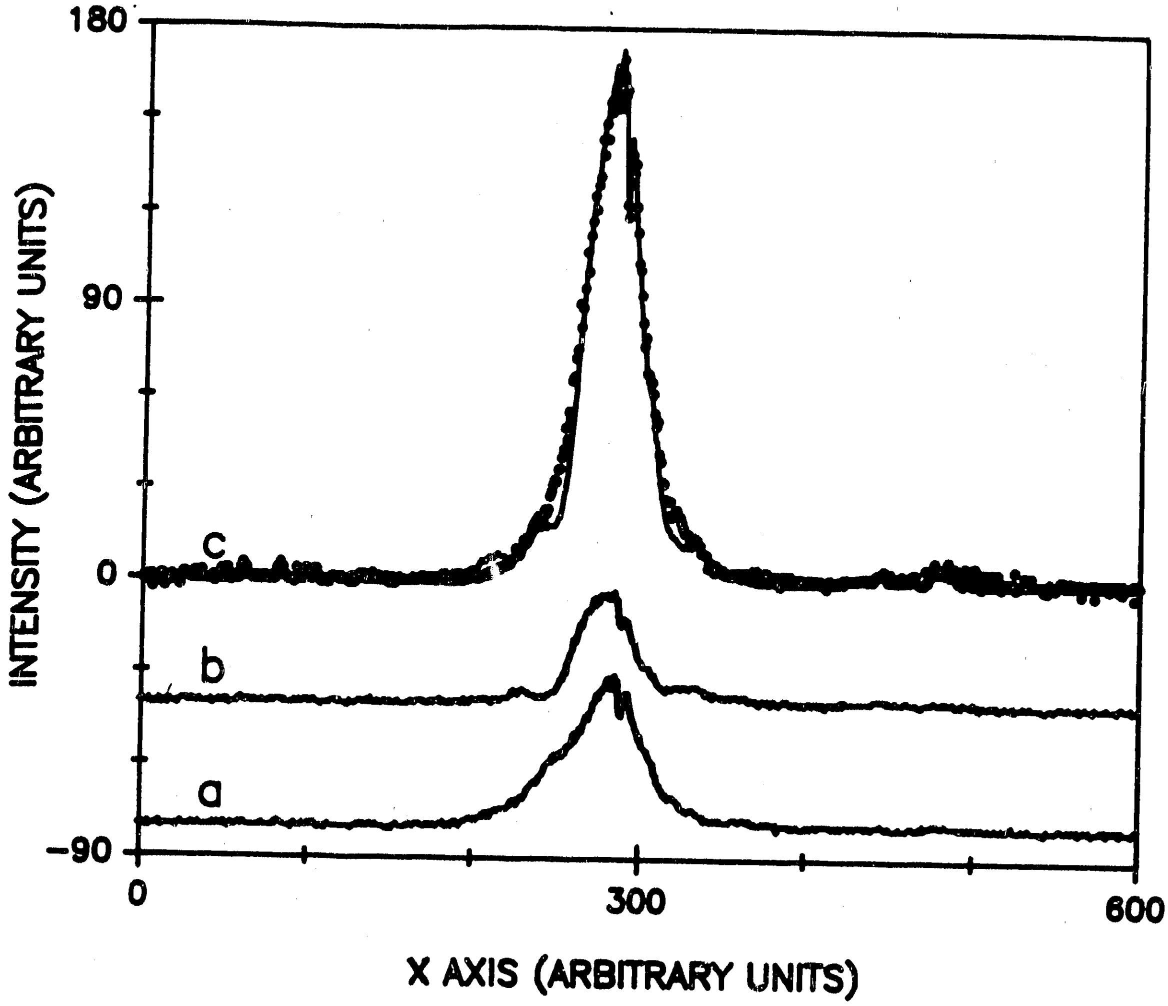

Figure 2. The spatial intensity profiles of the individual injection locked beams from array 1 (a), array 2 (b), and the interference between them (c). The modulus of the mutual coherence function derived from the fit (dots) is $|g_{12}(\tau = 1\ nsec)| = .96 \pm .06$.

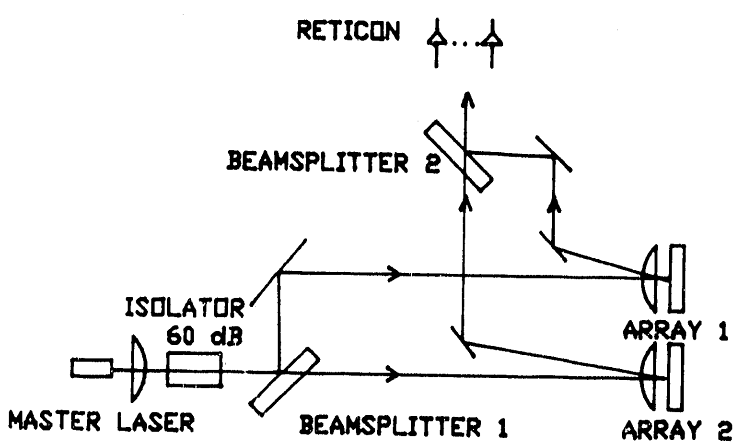

Figure 1. Schematic of the experiment. The cw power of array 1 and 2 was 50 and 38 mW respectively. Approximately 1 mW of light from the master laser was injected into each array.

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