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Enhancement of Coherence and Intensity in a Broad-Area Semiconductor Laser Array with Injection Locking

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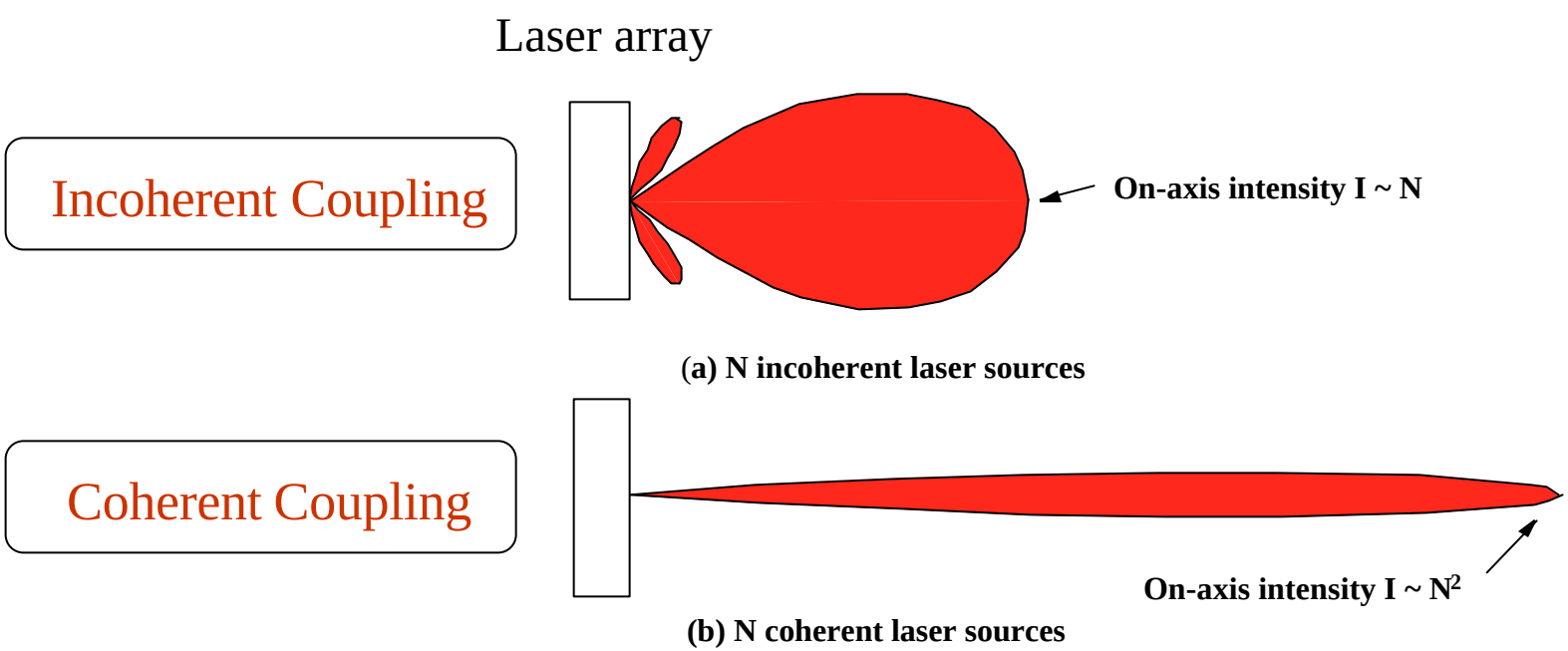
Coherent Beam Coupling of Laser Array

----- *Ultra high intensity ~ N^2*



Applications:

Material Processing, Directed Energy, Space Communications

Coherence Control of Laser Array

- Why coherence control?
  - Single mode operation
  - High beam quality
- Condition for coherent beam coupling
  - Frequency locking
  - Phase locking
- How ?
  - Optical injection
  - External mirror/grating

Broad-Area High-Power Laser Diode

Single Broad-Area Laser Diode

aperture < 100 μm ×1 μm, power: < 1 W

H. Horiuchi et al., *Appl. Phys. B* **68**, 1021 (1999).

Laser Array

overall array aperture < 100 μm ×1 μm

total output power < 1.2W

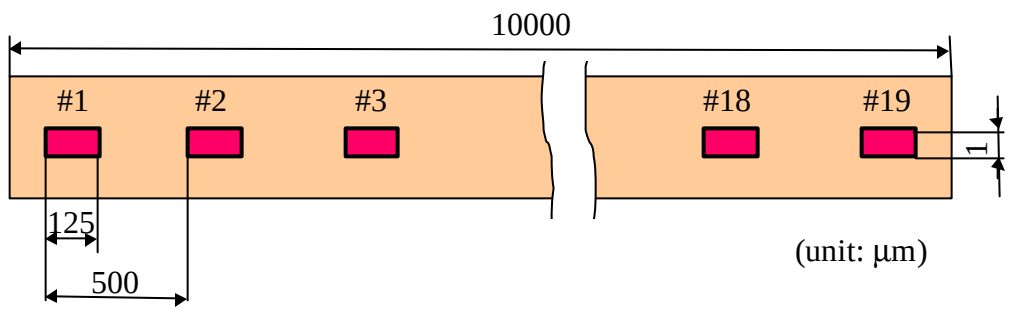
S. MacCormack et al., *Opt. Lett*. **19**, 120 (1994).

H. Tsuchida, *Opt. Lett*. **19**, 1741 (1994).

Our Target

achieve coherent coupling of a broad-area laser array using optical injection locking.

Commercial Broad-Area Laser Diode Array



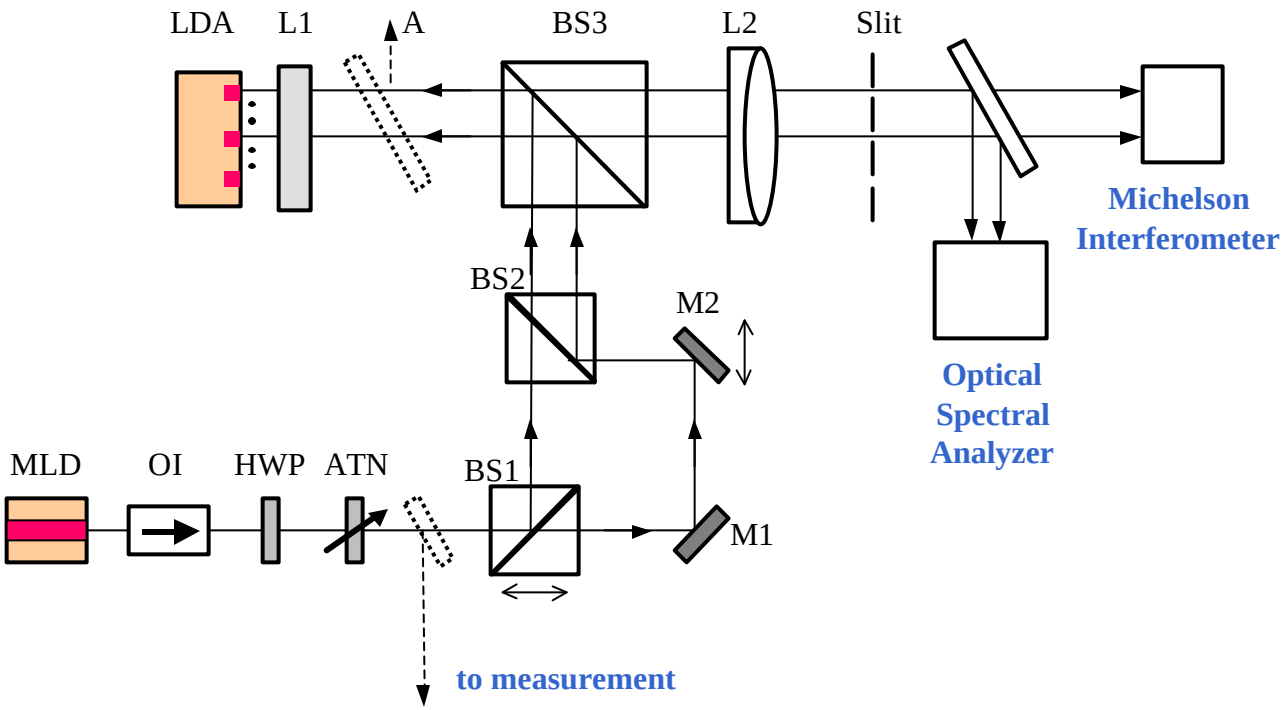
Maximum power: >1W (each laser)

Far-field angle: ~ 6×50°

Wavelength: 806~810 nm

Bandwidth: ~ 2 nm

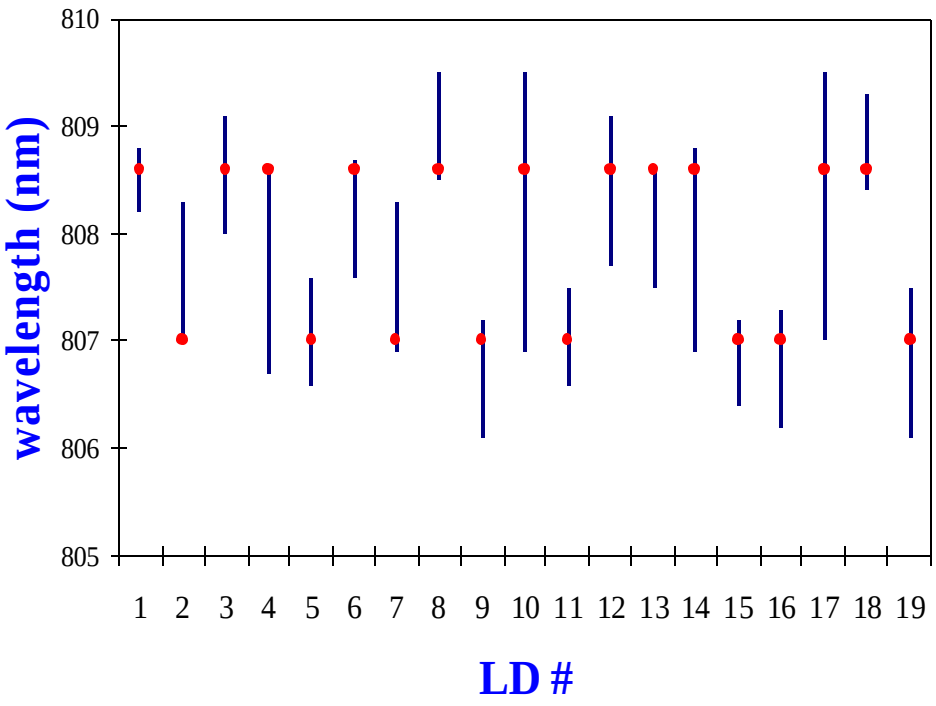
Experimental Setup for Injection Locking



- Separate Injection Access to each Laser
- Ability to Split and Control Injection

Wavelength Span of all 19 Lasers

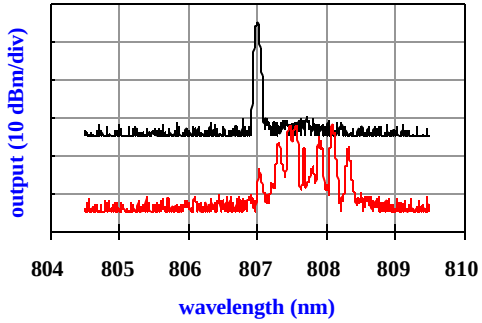
806 < l < 810 (nm)



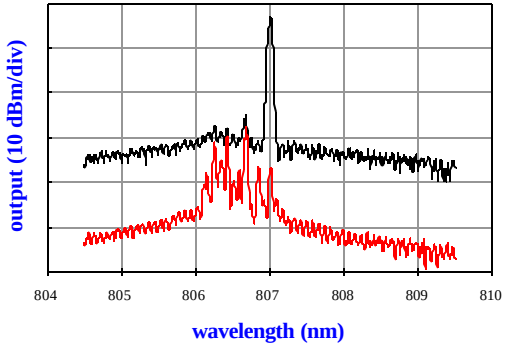
● : **injection locking frequency around the driving current I_d~1.5 I_{th}**

Successful Injection Locking of Individual Lasers

LD#2



LD#9



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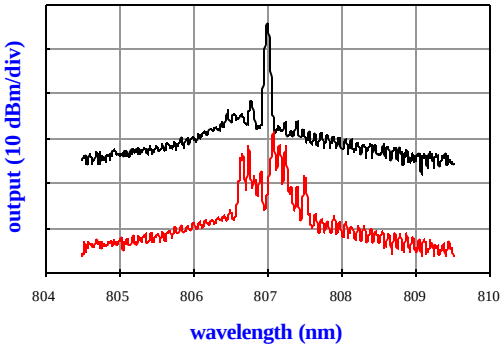

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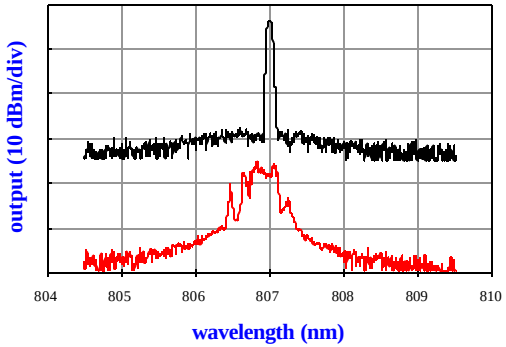
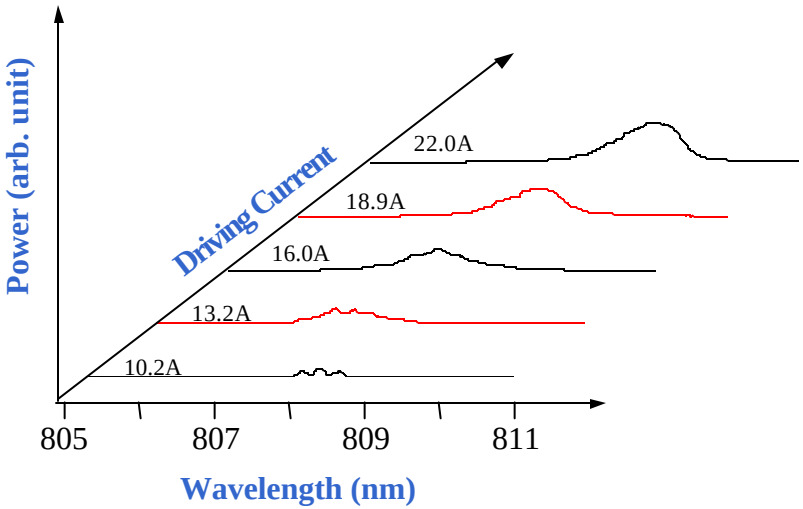
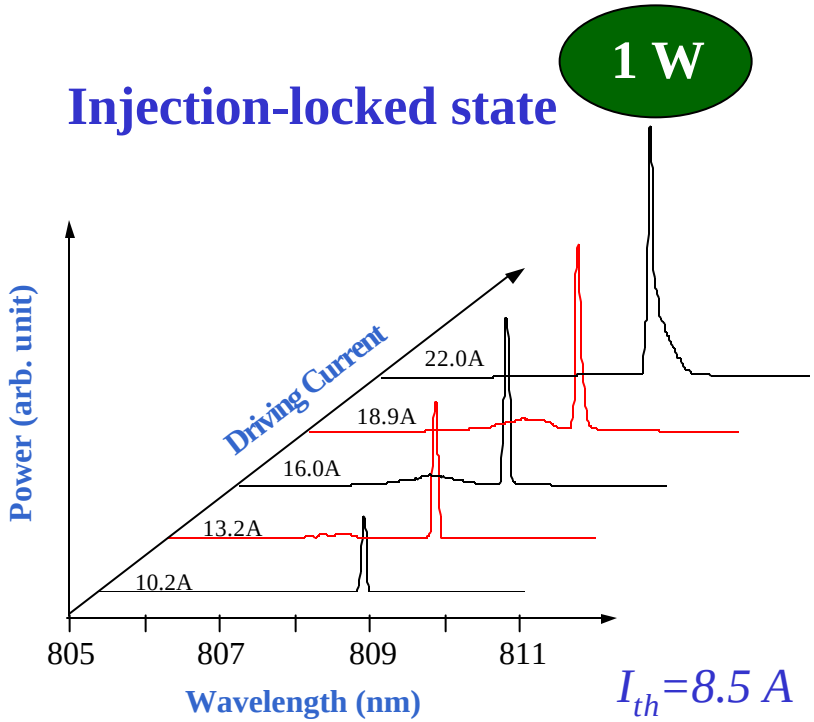


Robustness of Injection Locking

Free-running state



Injection-locked state



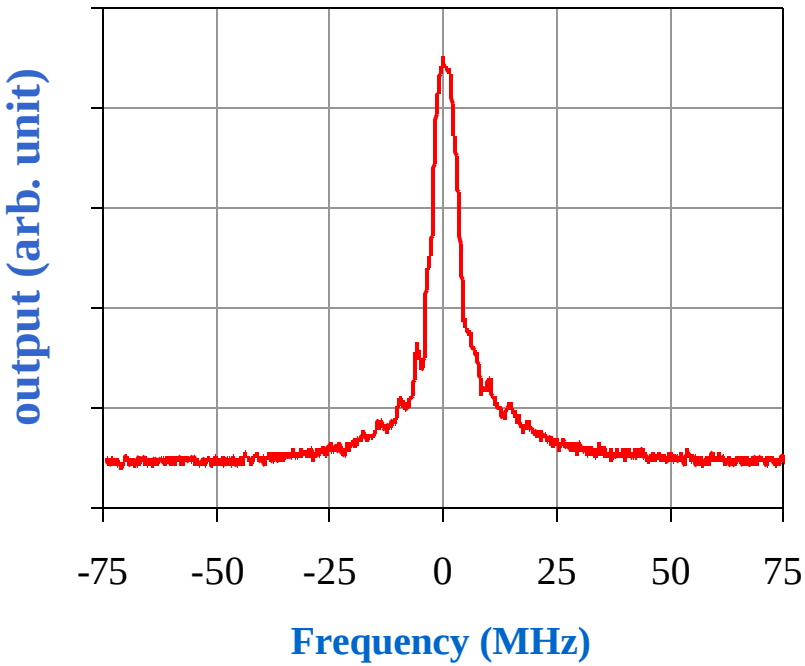
I_{th}=8.5 A

Condition for Injection Locking

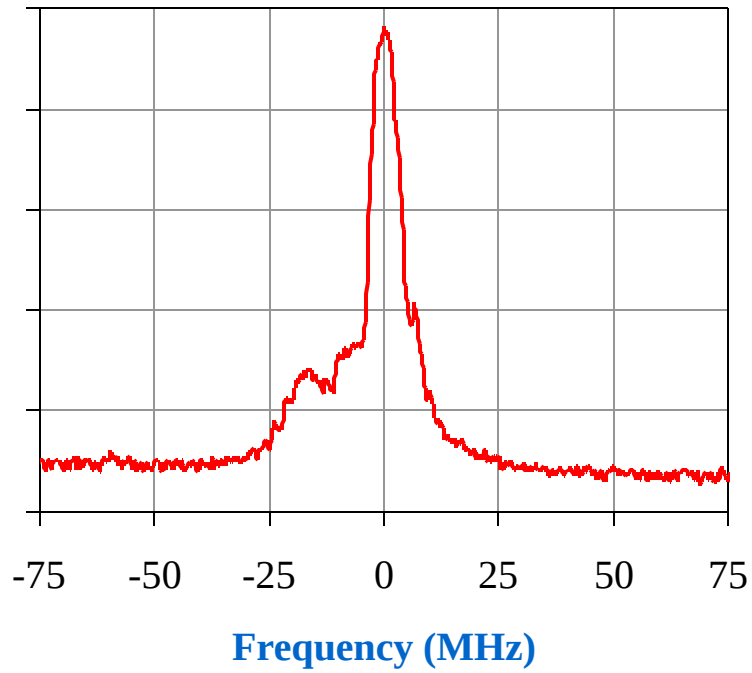
- Matching Between the Injection and Slave Laser Frequencies
- Less than 0.5 mW of Injection Power !

Narrow Line Width of Injection-Locked Lasers

Spectrum Bandwidth of the Order of 10 MHz

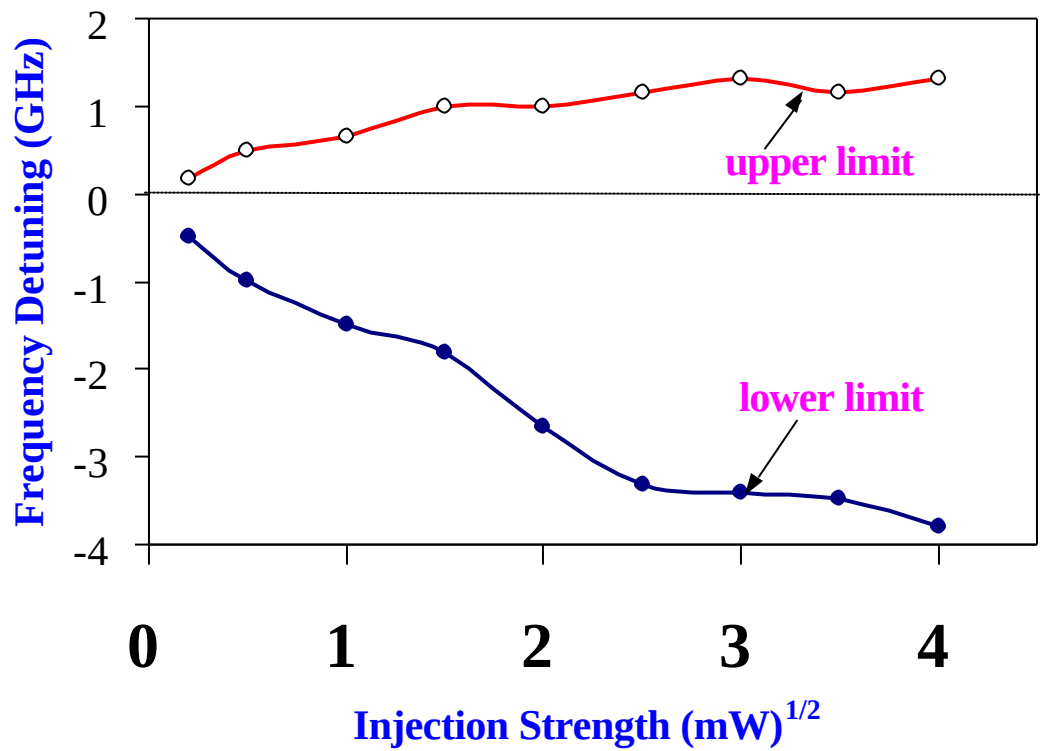


I_d=11.2A



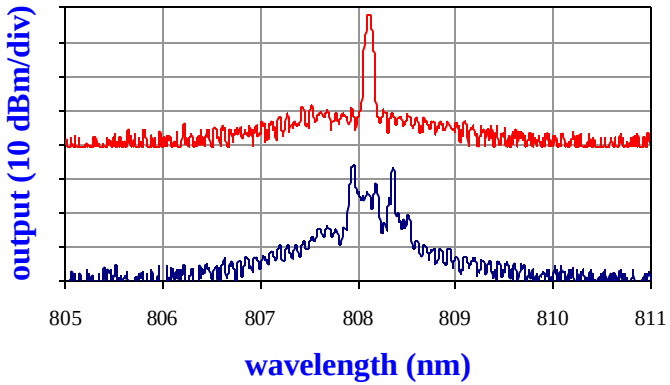
I_d=22.0 A

Injection Locking Range

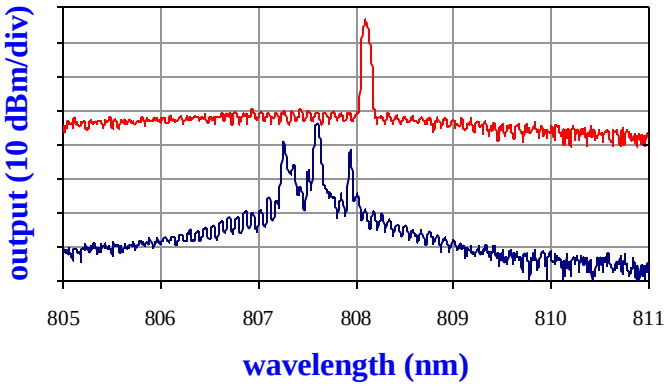


- Stable Locking Range
- At Low Drive Current, the Frequency Range for Stable Locking is Linear with the Injection Strength

Simultaneous Injection Locking of Two Lasers



LD#7

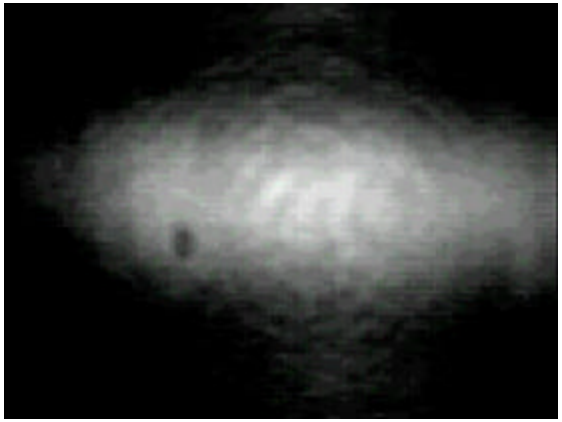


LD#12

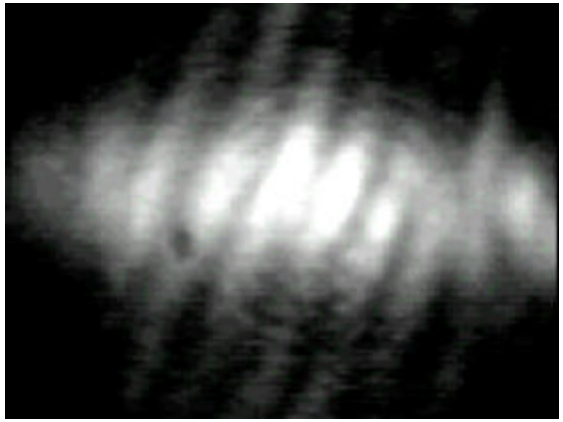
- Equally Split Injection Power into Two Lasers
- Control the Strength of Injection

Interference Picture of Injection-Locked Lasers

Stable Phase Relationship Between Lasers
Locking of Transverse Modes



Before Injection Locking



After Injection Locking

Summary

- **Proposed an experimental setup to injection-lock a broad-area laser diode array.**
- **Systematically investigated conditions for injection locking of broad-area lasers.**
- **Simultaneous injection of two broad-area lasers in a 19-laser array.**
- **Our experiments suggest the feasibility of achieving high intensity diffraction limited coherent radiation from an array of broad-area lasers.**

Acknowledgement

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