Amplitude Instability in Coupled Nd:YVO_4 Microchip Lasers

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Two coupled semimonolithic Nd:YVO_4 microchip lasers exhibit an amplitude instability in the vicinity of the phase-locking threshold. Different phase-locking states and pulsation types can be observed, depending on coupling strength and mutual detuning.

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Arrays of coupled lasers, especially semiconductor laser arrays, are of considerable technical importance. However, both experiment and theory have shown that already two single-mode lasers that are stable individually can exhibit a chaotic instability when coupled. While the dynamical time scales in semiconductor lasers prohibit measurements in the time domain, solid state lasers like coupled Nd:YAG lasers [1], are much better suited for studying the basic dynamics of coupling instabilities. Here, we use a very compact Nd:YVO_4 microchip resonator which enables us for the first time to investigate the whole significant parameter space for the dynamics of this system. This includes in particular the regime of small mutual detuning, where, due to severe fluctuations, only indirect observations have been possible up to now.

We study two coupled lasers in the semimonolithic Nd:YVO_4 microchip resonator shown in Figure 1. The system is pumped by two parallel beams from a Titanium:Sapphire laser at 808 nm, creating, by thermal lensing, two stable, separate cavities emitting TEM_{00} infrared laser beams at 1064 nm. The lasers are coupled through the lateral overlap of the fields, whose amount can be continuously varied by the spacing between the pump beams. The detuning between the two lasers is adjusted by slightly tilting the output coupler. Phase correlation is measured through the visibility of the fringe pattern obtained by superimposing the two beams under a small angle.

At pump powers of about twice the threshold, four regimes of different dynamical behavior can be distinguished as are shown in Figure 2: For large spacings and detunings both lasers run independently; with decreasing detuning and/or spacing, fringes and bursts of pulsations appear gradually, until almost continuous pulsing at completely synchronized optical phase is observed. Finally, at very small detuning or spacing, the intensity pulsations disappear and the lasers remain in a stationary, phase-locked state. The pulsations may exhibit alternating amplitudes in the two beams – resembling the localized synchronization state recently predicted for this kind of system [2] – or may be completely synchronized. The scenario is quite similar to the one predicted and observed in Ref. [1]; in our setup, it was possible for the first time to observe, *at a given spacing*, the transition from phase-locked intensity pulsations to the stationary phase-locked state.

The Nd:YVO_4 microchip laser system appears to be very well suited for studying the dynamics of coupled lasers, and further investigations will include more than two lasers, laser diodes as pump sources, and fiber optics for variable two-dimensional arrangements.

1. K. S. Thornburg, Jr., M. Möller, R. Roy, T. W. Carr, R.-D. Li, and T. Erneux, *Phys. Rev. E* 55, 3865 (1997)
2. R. Kuske and T. Erneux, *Opt. Commun.* 139, 125 (1997)

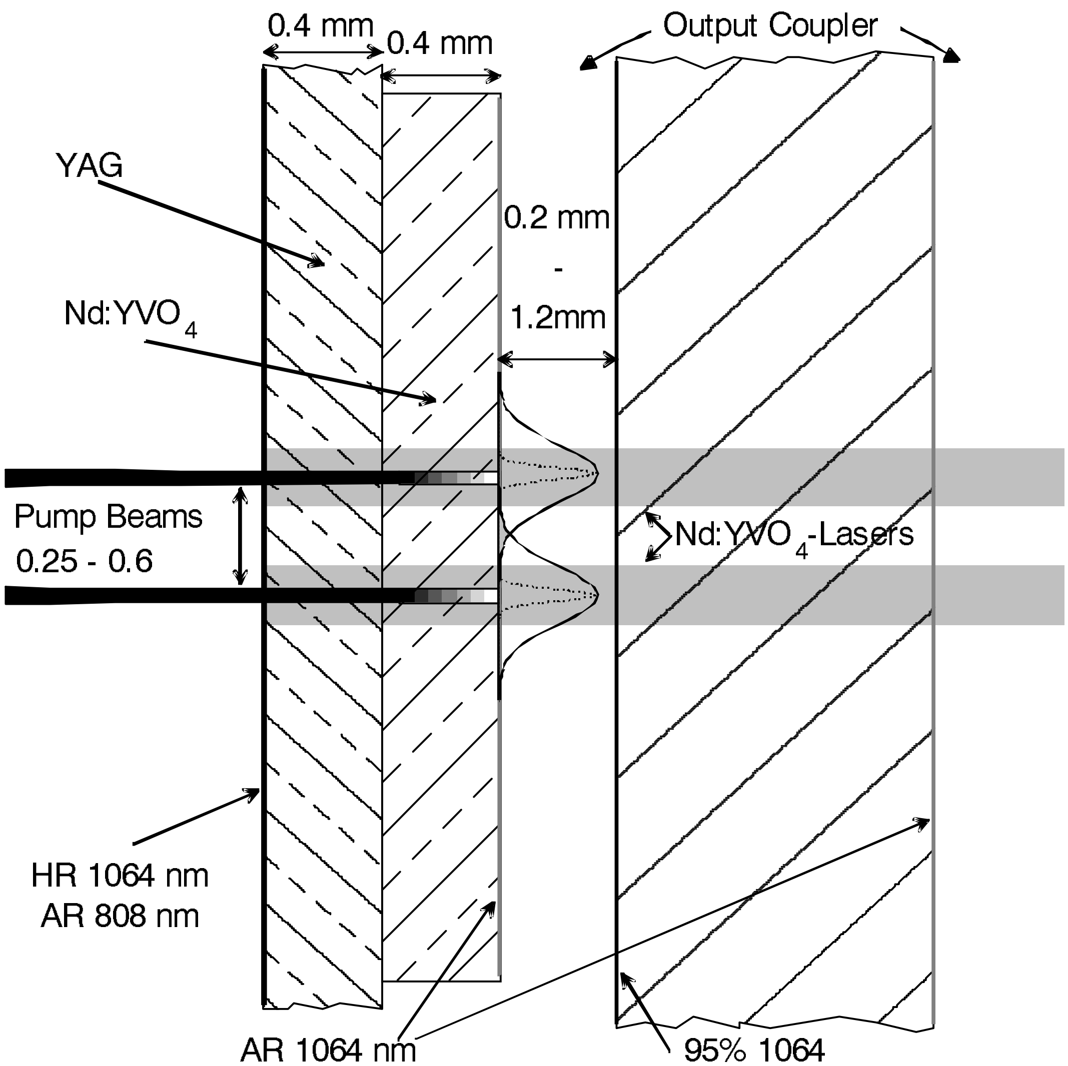

Fig. 1: Laser resonator. The 3×3 mm Nd:YVO_4 crystal is bonded to an undoped YAG disk of 9 mm diameter which itself is mounted to a heat sink. The output coupler can be tilted by very small angles to control the mutual detuning.

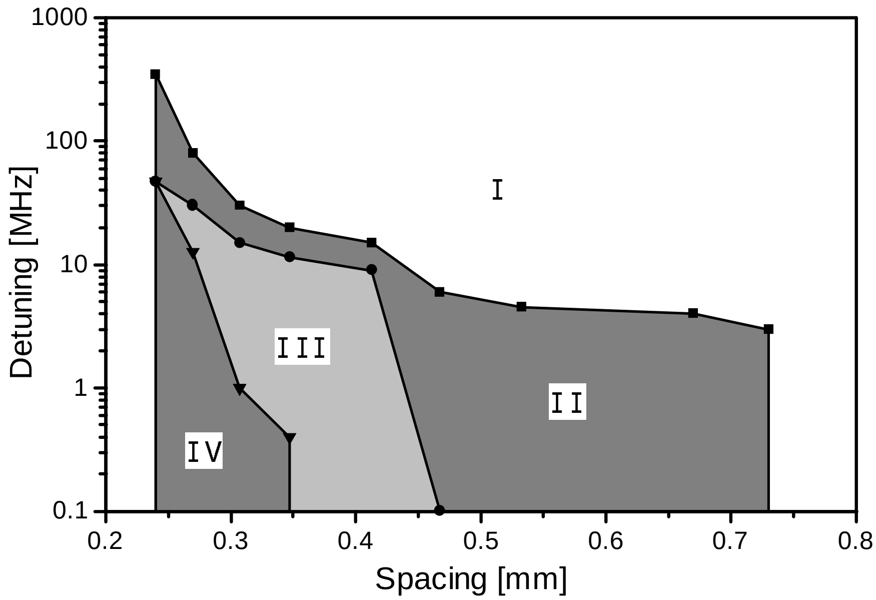

Fig. 2: Different regimes of the detuning/spacing parameter space. I: stationary intensity, zero fringe visibility, II: intermediate visibilities, III: amplitude instability, maximum visibility, IV: stationary intensity, maximum visibility.

Figure Captions

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