Coherent combining of two high-brightness laser diodes phase-locked by a Michelson-type external cavity (Orale)

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Coherent beam combining (CBC) is a powerful technique to scale up the brightness of arrays of laser diodes [1]. As compared to spectral beam combining, it maintains a narrow spectral bandwidth. We investigate a new CBC architecture using a common external cavity on the back side of the lasers for phase locking, while coherent beam superposition of the phase-locked beams is realized on the front side. This technique leads to a separation of the phase-locking stage – which takes place in the common external cavity - and the beam combining stage – which is achieved outside the cavity. As a consequence, the electrical-to-optical efficiency of the phase-locked laser array is increased as compared to standard external cavity configurations.

As a proof-of-principle, the experiment has been first demonstrated with two single-mode ridge waveguide lasers emitting around λ = 950 nm. It has been then implemented with two high-brightness tapered lasers emitting at λ = 976 nm [2], for which this technique becomes even more attractive as taper lasers do not tolerate strong optical feedback on their front side. The emitters are especially designed to this experiment with access to their both sides and an AR-coating on their rear side. On the rear facet of the lasers, the external cavity is based on a Michelson interferometer: the two laser beams are collimated by high NA asphere lenses and combined on a beamsplitter (BS), a HR mirror on one port closes the laser cavity. A doublet focuses the laser beams on the HR mirror to reduce the sensitivity of the laser operation to misalignments of the external cavity. The two lasers undergo minimum losses through the cavity when the two beams are in phase at the beamsplitter, as then interferences are constructive on the P port, and destructive on the other one (see Figure 1). On the front facet, a similar Michelson configuration is implemented with one beamsplitter. As the coherence is ensured by the cavity, a phase plate – a simple anti-reflection coated plane silica plate with a thickness of 0.5 mm – is added on one port to adjust the phase relationship between the two laser beams. Rotating the plate allows the fine tuning of the phase difference, and the maximizing of the combined power at the output port P'.

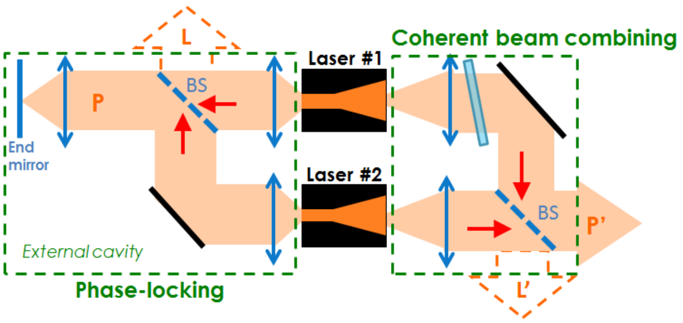

Fig. 1 Experimental set-up of the phase-locking and coherent combining of two lasers; BS : 50/50 beamsplitter; L,L' : losses ports

With both kind of lasers, passive phase-locked operation in the Michelson external cavity has been observed for operating currents up to three times the laser threshold. The phase-locking efficiency is limited by residual mismatches between the two beam profiles, and reaches 97% with the ridge lasers. Under phase-locked operation, the laser line is narrow ($\Delta\lambda_{-3dB}$ < 30 pm) and corresponds to a single-frequency operation of both lasers in the external cavity. The common external cavity ensures a passive stabilization of the phase-locking which is able to compensate for phase fluctuations up to π/15. Finally, in order to improve the long term stability of the CBC efficiency, a low-bandwidth (< 1 Hz) random exploration algorithm has been implemented which finely adjusts the laser currents to maximize the output optical power on P'.

References

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