Passive coherent combining of two high-brightness tapered laser diodes in a Michelson external cavity

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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 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 [2]. As a consequence, the electrical-to-optical efficiency of the phase-locked laser array is increased as compared to standard external cavity configurations.

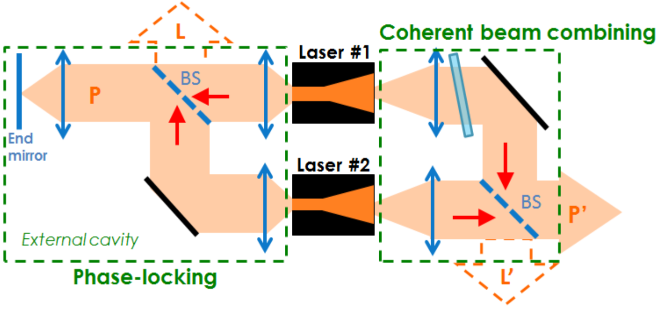

***Fig. 1** : Experimental set-up of the phase-locking and coherent combining of two lasers; BS : 50/50 beamsplitter; L,L' : losses*

For this experiment we used high-brightness tapered laser devices emitting around $\lambda = 976$ nm [3]. For such lasers, our external-cavity configuration becomes very attractive as the taper lasers do not tolerate strong optical feedback on the front side. The lasers used are especially designed to this experiment with access to both sides of the media – the rear facet is AR-coated. 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. The two lasers share the same external cavity, they undergo minimum losses when the two laser 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). A doublet focused the laser beams on the HR mirror to reduce the sensitivity of the laser operation to misalignments of the external cavity. 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 of 0.5 mm thick – is added on one port to adjust the phase relationship between the two laser beams, since their optical paths are different. Rotating the plate allows the fine tuning of the phase difference, and the maximizing of the combined power at the output port. The maximum combined optical power at the P' output of the front interferometer is 6.5 W at $I_T = 6$ A and $I_R \simeq$ 400 mA, corresponding to a combining efficiency as high as $\eta'_{P'} = 81\%$ of the total output power. Since the combining stage on the front facets operates as a second spatial filter, the beam quality of the combined beam is enhanced to $M^2 \leq 1.2$. Indeed only identical transverse profiles can be combined. We implemented a spatial filtering stage on the combined beam to select only the central lobe. Thereby 92% combining efficiency is achieved, corresponding to a combined power of 5.9 W for an extracted power of 6.4 W from the two devices in the central lobe.

The short-term stability of the phase-locking is ensured by the common cavity, as the lasing frequency passively self-adapts to maintain a zero-phase difference between the two beams on BS_1. However to ensure a long-term stability, a semi-active feedback loop is implemented on the ridge-section currents of both devices: the power L' on the front side is measured at a 10 Hz rate, and the currents are automatically changed to minimize it if needed.

References

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