Lyot spectral filter for polarization beam combining of high-power, broad-area diode lasers: modeling, simulations, and experiments

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Recent improvements in design and development have significantly increased the relevance of high-power, broad-area laser diodes and laser diode bars in the market for industrial, high-brightness materials processing applications, like welding, soldering and cutting. Here, we present, experimentally [1] and, for the first time, in direct simulations [2], a polarization beam combining scheme, which maintains the linear polarization of the individual sources, and, unlike common wavelength multiplexing schemes, is insensitive to spectral drifts caused by variations of temperature or injection current. In our setup, two laser diodes are operated with optical reinjection from a common external cavity containing a Lyot spectral filter; cf. the setup shown in Fig. 1a). Our time-domain direct numerical simulations take into account both, the lateral, and longitudinal dimensions of the laser emitters [3]. The optical reinjection from the common external resonator was modeled by suitable Fresnel integrals in the paraxial regime, accounting for the different phase- and group retardations of ordinary and extraordinary beam components within the birefringent crystal (calcite) [4]. Using a half-wave plate for polarization rotating the emission of diode 2, the spectrally filtered feedback enforces lasing of both diodes on interleaved frequency combs. The spectrum of each diode is then localized in the respective transmission window of the Lyot filter, determined by $\cos^2\pi\Delta nL/\lambda$ (diode 1) and $\sin^2\pi\Delta nL/\lambda$ (diode 2), where Δn is the phase birefringence of the crystal. In consequence, both beams can be combined with maintained linear polarization and high optical coupling efficiency. Simulated and experimental results for two coupled laser diodes are shown in Figs. 1b) and c). Indeed, simulations and experiments show that the usable output power in the combined beam is 86% (simulations) and 80% (experiment).

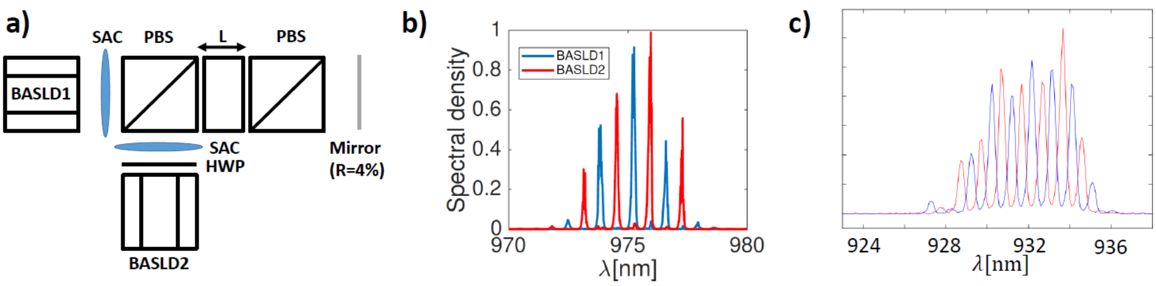

Fig. 1 a) experimental setup, consisting of broad-area semiconductor laser diode bars (four emitters per laser bar, BASLD), polarizing beam splitters (PBS), birefringent crystal (calcite), length L, slow-axis collimating lenses (SAC), external resonator mirror; b) simulated spectra of BASLD1 (blue) and BASLD2 (red); c) experimental spectra.

As the combined beam is linearly polarized, our scheme can be furthermore cascaded by using a simple polarizing beam-splitter, to obtain an (unpolarized) combined beam containing nearly four-fold optical power and brightness compared to the individual laser diodes. Using state-of-the-art laser diode bars, which gather some twenty emitters on a single semiconductor chip and deliver optical output-powers of some hundred Watts with high electro-optic conversion efficiency, the demonstrated beam combining scheme paves the way towards cost-efficient materials processing applications with semiconductor laser diodes and optical powers in the kW-range.

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