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Improving the spectral performance of extended cavity diode lasers using angled-facet laser diode chips

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Abstract

We present and compare theoretical and experimental results on the electro-optical performance of extended cavity diode lasers (ECDLs) that employ two ridge waveguide designs for the single-transverse mode GaAs laser diode chip. One facet of the laser diode chips serves as a partially reflective output coupler for the laser cavity. The other facet constitutes an intra-cavity interface which introduces spurious optical feedback to the laser diode chip. The waveguide designs differ with respect to the suppression of this spurious feedback. The first design employs a straight ridge waveguide intersecting both facets at normal incidence. The intra-cavity facet is anti-reflection coated and features a residual intensity reflectivity of the order 10^{-4}. The second design employs a bent ridge waveguide intersecting the anti-reflection-coated intra-cavity facet at an appropriate angle. This provides an additional suppression of the spurious intensity reflection to a value estimated to be less than 10^{-6}. We compare the electro-optical performance of both designs theoretically and experimentally. The utilization of a bent waveguide results in an improved spectral stability and purity, specifically a higher side mode suppression and a small intrinsic spectral linewidth over the whole investigated current range, of the external cavity diode laser without sacrificing other parameters such as the output power. The external cavity diode lasers under study exhibit no degradation of the measured frequency noise power spectra and intrinsic linewidths even if there is a drop of the side mode suppression ratio provided that it is not reduced to a very small value. Thus, the usage of a more readily accessible straight waveguide chip in an ECDL could be sufficient if only a limited tuning range and a particularly compact assembly are needed. For spectroscopic applications requiring a small intrinsic spectral linewidth over a large frequency range a bent waveguide chip could be the better choice.

1 Introduction

Owing to their availability over a broad spectral range, their tunability, and their ability to provide excellent spectral stability, diode lasers are best suited for precision spectroscopy applications involving cold atom-based quantum sensors, e.g., optical atomic clocks or matter-wave interferometers. Furthermore, diode lasers provide compactness, robustness, and energy efficiency which are important aspects for the operation of spectroscopy setups in the field or in space [1–4]. However, the spectral linewidth of monolithic, single longitudinal mode diode lasers such as distributed feedback (DFB) diode lasers or distributed Bragg reflector (DBR) lasers is usually limited to few 100 kHz (full width at half maximum) [5–7]. For cold atom-based applications the laser linewidth often has to be smaller than 100 kHz. Since extended cavity diode lasers (ECDLs) [8, 9] typically meet this requirement, they have become the workhorse for precision quantum optics experiments and devices [10].

However, the coexistence of multiple temporally stable modes is predicted for ECDLs by theory and is also observed experimentally [11, 12]. In case of strongly competing modes, especially in the vicinity of a mode-hop, ECDLs no

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