Introduction

High power single frequency, single spatial mode lasers have important applications in communication, in the domain of non-linear frequency conversion, and in spectroscopy, specifically in laser cooling, precision spectroscopy, and optical metrology. A prominent example is the application of diode lasers for the implementation of microwave and optical atomic clocks. In the class of the single frequency lasers, ridge waveguide (RW) distributed feedback (DFB) diode lasers have become the optimal source of coherent radiation for many applications because of their compactness, the high energy conversion efficiency they provide, their reliability, and because of the large frequency modulation bandwidth that can be achieved. Especially, the solitary RW-DFB diode lasers emitting at 780 nm are of particular interest for some specific applications, e.g. rubidium spectroscopy [1], [2], Raman spectroscopy [3]-[5], Bose-Einstein condensation [6], and atom interferometry [7].

For Raman spectroscopy, a spectral width of 1 cm^{-1} or less is sufficient for most applications [8] so that single longitudinal mode DFB diode lasers can be applied. However, for other applications, for example for the spectroscopy of the D1 and D2 line of Rubidium, a spectral linewidth at the MHz scale or below is mandatory in order to resolve the natural lineshape of the corresponding transition (6 MHz) [9]. Further, high resolution spectroscopy requires good wavelength tuneability with high spectral resolution. Good tuneability can be achieved by implementing a Fabry-Perot laser diode together with a grating in an extended cavity configuration (ECDL) [10]-[12]. A spectral stabilization of (high power) laser diodes can be also realized by using volume holographic Bragg gratings (VHBGs) [13], [14]. A drawback of an extended cavity configuration is its high optomechanical complexity, which limits the mechanical stability. This is an important issue specifically for the design of portable devices and space applications of lasers

Our work is mainly motivated by the requirements that are posted by the following two applications:

- High resolution Rubidium spectroscopy near 780 nm as described in detail in Refs [1], [2].

- Projects QUANTUS (QUANTen Gase Unter Schwerelosigkeit) and LASUS (LASer Unter Schwerelosigkeit) [14]-[18]. These projects aim at an implementation of a compact, robust, and mobile experimental setup for the realization of a Bose-Einstein condensate and experiments related to it in a micro-gravity environment. The final step will be to operate the experimental setup in space. However, the existing laser technology is not yet ready for precision quantum optics experiments under micro-gravity conditions or in the space, because the laser systems are too large, too heavy, too power consumptive, and too complex, so that their suitability, reliability and robustness under space conditions are questionable. Therefore, miniaturization and improvement of reliability and robustness is urgent request. One of the goals of the above mentioned projects is to realize solitary DFB diode lasers emitting at 780 nm with an optical output power exceeding 50 mW and a spectral short term linewidth of less than 200 kHz.

At the Ferdinand-Braun Institut several technological steps are applied to realize high power DFB diode lasers for the above mentioned applications [19]. The epitaxial structure of the lasers is grown by low-pressure metal-organic vapour-phase epitaxy (MOVPE) in two steps. After the first step, the grating implementation process is inserted before the second step completes the wafer growing. The lateral structure of DFB diode lasers is implemented by standard processing steps applied for the realization of a RW laser structure. Fabrication is finished by the packaging process, which offers several package configurations, namely C-mount, TO3, and SOT. DFB diode lasers emitting near 785 nm region show a highly reliable operation, e.g. a life time of 8800 h at an optical power in excess of 150 mW [20]. The same level of reliability is expected for the DFB diode laser, that emits near 780 nm and are used throught the thesis work. The characterization of DFB diode lasers first starts with the fundamental characterisation of the electrical and electro-optical properties. Depending on the results of this characterization the short-term, intrinsic spectral linewidth is analyzed. The spectral linewidth is investigated by the means of a self-delayed heterodyne and a heterodyne technique. The first version of the heterodyne linewidth measurement setup at FBH is implemented as part of this thesis work. The laser structure, i.e. the cavity length, the grating coupling coefficient, and the front facet coating are varied and optimized for maximum output power and minimum intrinsic linewidth.

The thesis is organized as follows:

- First, a brief introduction on the fundamental concepts and properties of DFB diode lasers is given in chapter 1. The chapter focuses specifically on high power diode lasers. Further, the dependence of the intrinsic linewidth on the laser design and operating parameters is dicussed, and the results of a simulation of the linewidth of high power 780 nm DFB diode lasers are presented.

- The experimental aspects of this thesis work are presented in chapter 2. The first section describes the technological approach applied for the realization of DFB diode lasers. After that, the measurement setup used for basic characterization is presented. The final section of this chapter focuses on the introduction of advanced characterization methods, namely on the self-delay heterodyne and heterodyne techniques, to characterize the spectral stability of narrow linewidth, high power DFB diode lasers.
- In chapter 3, experimental data gathered for this thesis work are presented, analyzed, and discussed. First, the results of the fundamental characterization, namely of the electro-optical and optical properties, are shown. Then, the extraction of DFB diode laser parameters from amplified spontaneous emission (ASE) spectra is explained. The characterisation of the spectral linewidth and the discussion of the corresponding results follow. Specifically the dependence of the linewidth on laser output power is analyzed. The linewidth-power product is then used in the following to analyze and discuss how the different laser parameters affect the laser linewidth. The main parameters considered are the cavity length, the coupling coefficient, and the front facet reflectivity. Based on these results, at the end of chapter 3, a strategy is proposed how to optimize the DFB laser parameters for the high power, narrow linewidth emission.

The last chapter concludes the discussion and presents an outlook to future work.