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Tuneable, stabilised diode lasers for compact atomic frequency standards and precision wavelength references

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Abstract

We describe the ongoing activities in Observatoire Cantonal de Neuchâtel in the fields of precision laser spectroscopy and metrology of Rb atomic vapours. The work is motivated by the potentials of highly stable and narrowband laser light sources for a variety of technical and scientific applications. We describe the use of extended-cavity diode lasers for the realisation of such narrowband light sources and the basic schemes under study for their stabilisation, with focus on Doppler and sub-Doppler laser spectroscopy. The resulting laser systems offer good frequency stabilities and can be effectively miniaturised. This makes them interesting for direct applications of these techniques, as well as the presently developed precision instruments: compact atomic frequency standards for ground and space applications (GALILEO satellite positioning system), secondary optical frequency standards, transportable extended cavity diode lasers as seeding lasers, and others.

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1. Introduction

The past years have shown tremendous advancements in the field of compact and spectrally well-controlled diode laser sources, concerning both spectral narrowing of the laser emission and frequency control. These developments make it interesting to exploit the availability of such compact lasers sources for, e.g. secondary wavelength references [1,2], or for performance improvements of precision instruments like, e.g. compact atomic frequency standards [3,4] or atomic magnetometers [5,6].

Here we will discuss the realisation of a compact single-mode laser source, a quantitative comparison of different schemes for frequency stabilisation of the laser to an atomic Rb reference, and application examples of the resulting compact and stabilised laser heads. Applications to secondary wavelength standards, laser-pumped Rubidium gas-cell atomic clocks and high spectral resolution LIDAR (light detection and ranging) instruments will be considered.

2. Frequency-stabilised laser modules

Many applications not only require well-controlled laser emission spectra, but also small size and low power consumption of the laser source. Here semiconductor diode lasers are an excellent choice, being available in a huge variety of types spanning large ranges of emission wavelengths, output powers, and spectral characteristics. Promising advances have been made towards intrinsically single-mode and narrowband diode lasers like, e.g. distributed feed-back (DFB), distributed Bragg reflector (DBR) or vertical-cavity (VCSEL) lasers, but still these devices are not always commercially available at the desired wavelength or are compromised by spectral linewidths of a few MHz or more, too large for applications aiming for ultimate performance in optical instrumentation and spectroscopy. Here we therefore focus on the realisation of compact external-cavity grating stabilisation of standard Fabry–Perot type laser diodes [7], whose linewidth is spectrally narrowed by the optical feedback [8] and where there is usually a large choice of diodes commercially available.

2.1. Compact diode laser modules

We have built two types of extended-cavity diode lasers (ECDL) using the Littrow configuration [9], which can be realised very compact [10,11] and still offer the good frequency tuning behaviour and spectral linewidths around 300 kHz required for subsequent stabilisation to atomic or molecular resonances: Fig. 1 shows the CAD design and the final realisation of an ECDL for laboratory use. Coarse adjustment of the external cavity is achieved by aligning manually a modified commercial mirror mount supporting the diffraction grating, while fine tuning and frequency scanning is realised using a piezo actuator acting on the grating support (see Fig. 2b for a schematic view of the ECDL). The laser implements two separate temperature controls which allow independent stabilisation of the external cavity and