Solid-State Lasers for High-Resolution Spectroscopy

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In recent years solid-state lasers have started to replace dye lasers as light sources for high resolution spectroscopy. From a user perspective the turn-key, low maintenance operation of these lasers combined with their compactness and good spectral characteristics offer significant advantages over dye lasers. The characteristics of these lasers typically include a smooth tuning range of several gigahertz with discontinuous tuning over several nanometers with a sub-megahertz linewidth and significant output powers.

There are two major classes of solid-state lasers of particular interest for high resolution spectroscopy: diode lasers operating in an external cavity and optical parametric oscillators (OPOs). We will present details of both classes of lasers and the complementary spectroscopy which can be performed by them.

Free-running diode lasers are not typically useful for high resolution spectroscopy because they have relatively large linewidths (10-100MHz), are sensitive to environmental fluctuations and are difficult to tune smoothly. These problems can be addressed by exploiting the diode's suspectibility to feedback using either a diffraction grating or a Fabry Perot cavity. We will report a simple method of constructing an external cavity diode laser in a Littrow geometry which we have used to construct systems operating at a range of wavelengths as listed below.

Table 1: Littrow Geometry Diode Lasers.

Wavelength Range	Output Power	Tuning Range	Linewidth
392.0-394.7nm	3.5mW	6GHz	< 5MHz
630-637nm	10.8mW	21.6GHz	< 450kHz
661-674nm	10mW	8GHz	< 630kHz
780nm	40mW	10GHz	135kHz (100ms)
846-859nm	70mW	8GHz	570kHz (100ms)

We will present details of the operating characteristics of these lasers, which include the first reported operation of a violet laser in a Littrow geometry [1] and one of the largest continuous tuning ranges reported for a visible diode in a single grating Littrow geometry [2]. These lasers have also been used to investigate the hyperfine spectroscopy of a number of gases including rubidium, caesium and iodine and several locking techniques have been employed to stabilise their frequencies to absorption features in these gases. Details of these schemes and their effectiveness for atom trapping will be reported.

The second class of lasers sources, OPOs, are of particular interest to ultra-high resolution spectroscopy because of their inherent narrow linewidth (<40kHz [3]), broad tunability, high output powers and extensive spectral coverage.

At the University of Konstanz we are developing a frequency-doubled doubly-resonant OPO (DRO) for ultra-high resolution spectroscopy of Eu^{3+}:Y$_{(}$2)SiO$_{(}$5) with wavelength range 565-590nm [3]. The OPO is pumped by a frequency-doubled single-mode Nd:YAG ring laser, which gives an output of more than 500mW at 532nm with a linewidth of approximately 1kHz and is smoothly tunable by 16GHz. The frequency stability of the green light is determined by environmental variables, with a typical free-running modulation of less than 500MHz over one day.

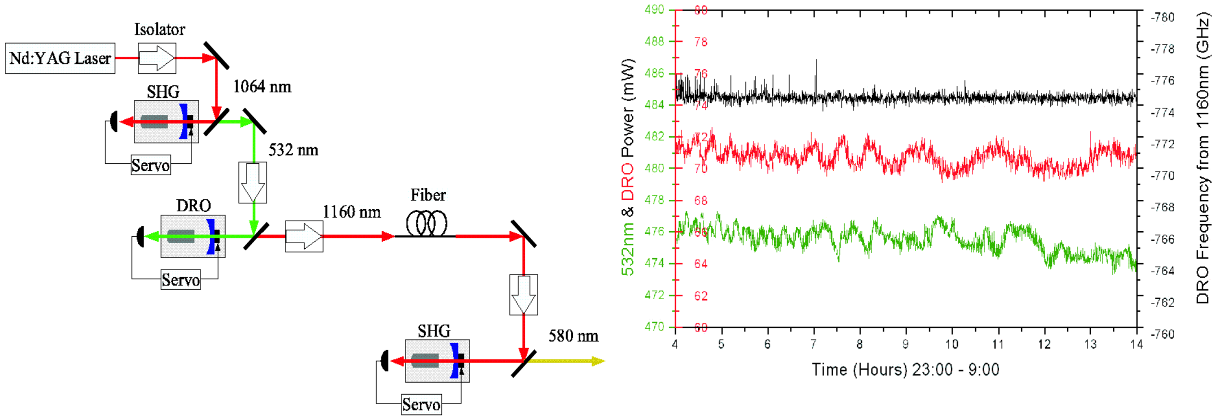

Figure 1: Setup (left) and stability results (right) of DRO.

The DRO illustrated above is locked using the Pound-Drever-Hall method to a single mode-pair with the idler wavelength around 1160nm.

The stability of the DRO (i.e. absence of mode hops) is governed by that of the 532nm pump light. By minimizing the power and frequency fluctuations of the pump light to less than 0.3%/hour and 10MHz/hour respectively, we have found that the DRO can stay locked to a single mode-pair for in excess of twelve hours with a frequency instability of <70MHz and an idler output power of 65mW.

We are in the process of frequency-doubling the output of the DRO using a resonant cavity, to 580nm to carry out FM spectroscopy and persistent spectral hole burning of the $^5D_0 \rightarrow ^7F_0$ transition of Eu^{3+}.

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