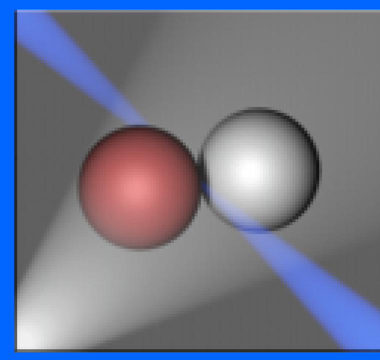
Software development for alexandrite laser - seeded - diode laser: rotational spectroscopy of the $A^1 0^+_u(5^1P_1) \leftarrow X^1 0^+_g(5^1S_0)$ transition in Cd_2

Jagiellonian University in Kraków

Department of Photonics



Molecular Spectroscopy and Quantum Information Group

K. Puczka, T. Urbańczyk and J. Koperski

Smoluchowski Institute of Physics, Jagiellonian University
Łojasiewicza 11, 30-348 Kraków, Poland

Email adresses: krystian.slawomir.puczka@gmail.com, tomek.urbanczyk@uj.edu.pl

Introduction

Molecular rotational energy structure is an important source of information for spectroscopists. To resolve rotational structure, a narrowband, well controlled laser source, such as a pulsed alexandrite ring laser is needed. Parameters of the alexandrite laser depend strongly on its seeding system, in this case a tuneable diode laser. Developing software for the seeding diode laser allows changing and controlling its parameters such as **wavelength**, **power of the beam** or **tuning time**. The seeding diode laser software is combined with other parts of the software devoted to the detection of molecular LIF excitation spectra. The most important aspect of the software are measurements with the smallest driving-current step available which corresponds to the smallest change of the generated wavelength. The software is written in C# programing language with full graphical interface. To test the stability and precision of the seeding laser, measurement of absorption in rubidium was performed. The long-term goal is to resolve rotational structure in the $A^1 0^+_u(5^1P_1) \leftarrow X^1 0^+_g(5^1S_0)$ transition in Cd_2 van der Waals dimer.

Parameters of diode laser

What is the smallest possible change in the wavelenght of diode laser?

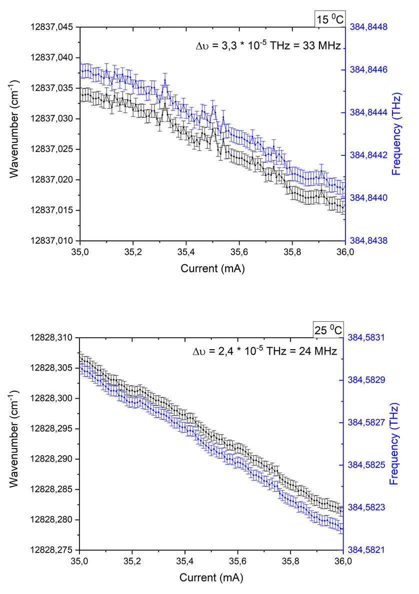


Fig 1. Dependence of the generated wavelength on the applied current in constant temperature of the diode.

The smallest change in wavelength is observed when the change of the current is 0,01 mA that corresponds to ~0,0005 cm^{-1}. Value of standard deviation show high dependence of actual temperature applied on the diode.

What is the power of the beam in different temperatures and currents?

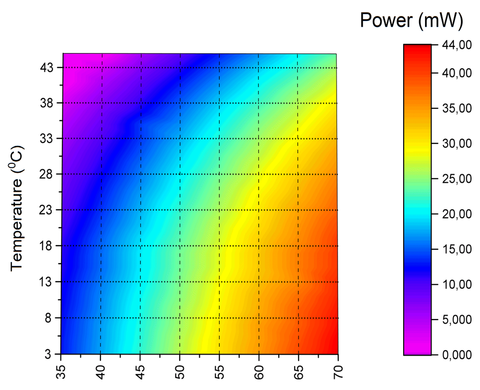


Fig 2. Dependence of power of the beam on the temperature and current.

Power of the laser beam shows largest values at low tempe-ratures and for high currents; as the temperature incre-ases, power of the beam slowly decre-ases.

At temperatures around 40 ^{0}C, larger currents are needed to generate the beam.

How does the wavelength change for different parameters and currents?

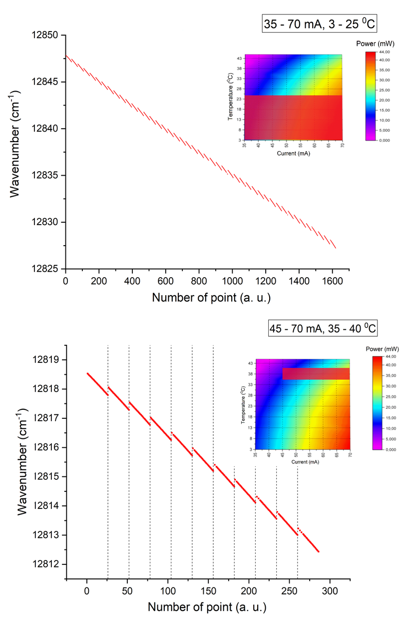


Fig 3. Dependence of the laser wavenumber during the tuning loop. Vertical dashed lines show when the temperature change occurs.

During the current tuning, changes in the laser wavenumber are linear in a wide range of temperatures.

As the temperature changes, a step-change in the laser wavenumber occurs.

Is the beam stable for wide range of temperatures and currents?

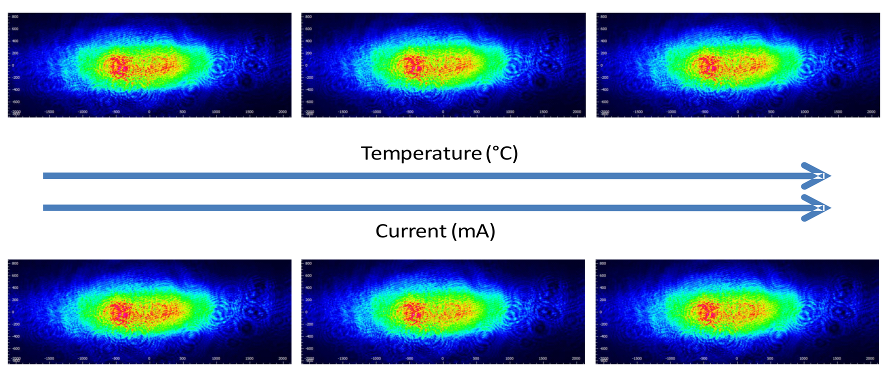


Fig 4. Diode laser beam profiles for different parameters.

As shown in the beam profiles above, during the tuning no change in their cross section occurs; it is especially important during the alexandrite ring laser seeding process.

$A^1 0^+_u(5^1P_1) \leftarrow X^1 0^+_g(5^1S_0)$ transition in Cd_2

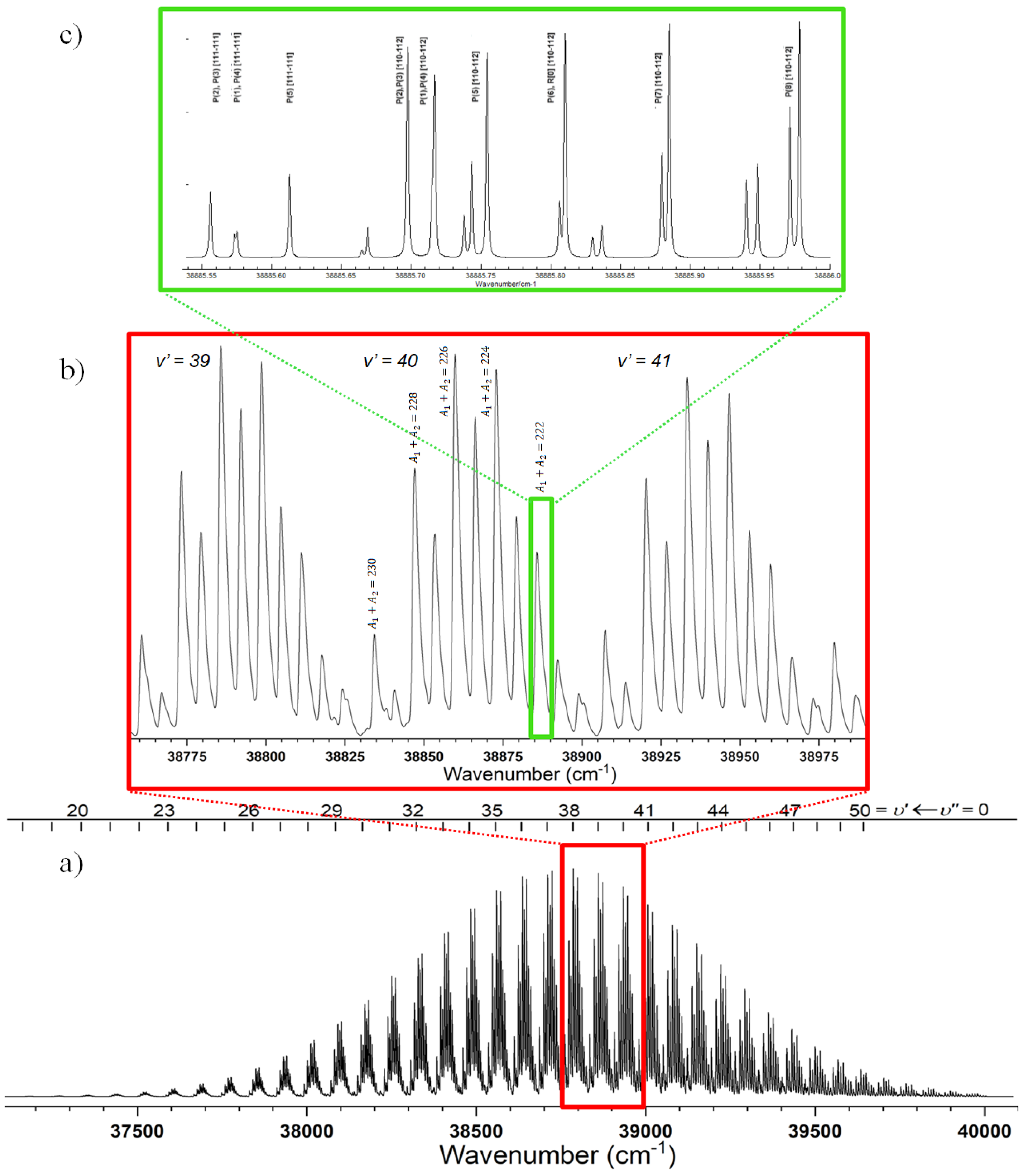


Fig 5. **a)** Simulation of the vibrational progression $A^1 0^+_u(5^1P_1), v' \leftarrow X^1 0^+_g(5^1S_0), v''=0$ in Cd_2 performed assuming for the $A^1 0^+_u$ state representation a shifted Morse potential $U = D'_e(1 - e^{-\beta'(R-R'_e)})^2$ with $D'_e = 7882{,}5$ cm^{-1}, $\beta' = 1{,}0072$ Å^{-1} and $R'_e = 2{,}75$ Å. **b)** Isotopic structure of few (v', v''=0) vibrational components. **c)** Simulation of rotational structure of the band-head of the (v'= 40, v''=0) vibrational component in $^{222}Cd_2$; P(J') and R(J') components of two rotational branches are shown for several A_1Cd-A_2Cd isotope combinations.[1]

To resolve the rotational structure, a narrowband source of laser radiation is needed, such as e.g., an alexandrite laser in ring configuration of the resonator. The pulsed alexandrite laser emits light with wavenumbers from 12500 cm^{-1} to 14000 cm^{-1}. If the 3rd harmonic generation is applied, the resolving of the rotational structure will be possible. To efficiently seed the alexandrite laser, a DFB diode laser (DL 100, Toptica) is used. Parameters of the alexandrite laser strongly depend on quality of the seeding laser beam.

Software development

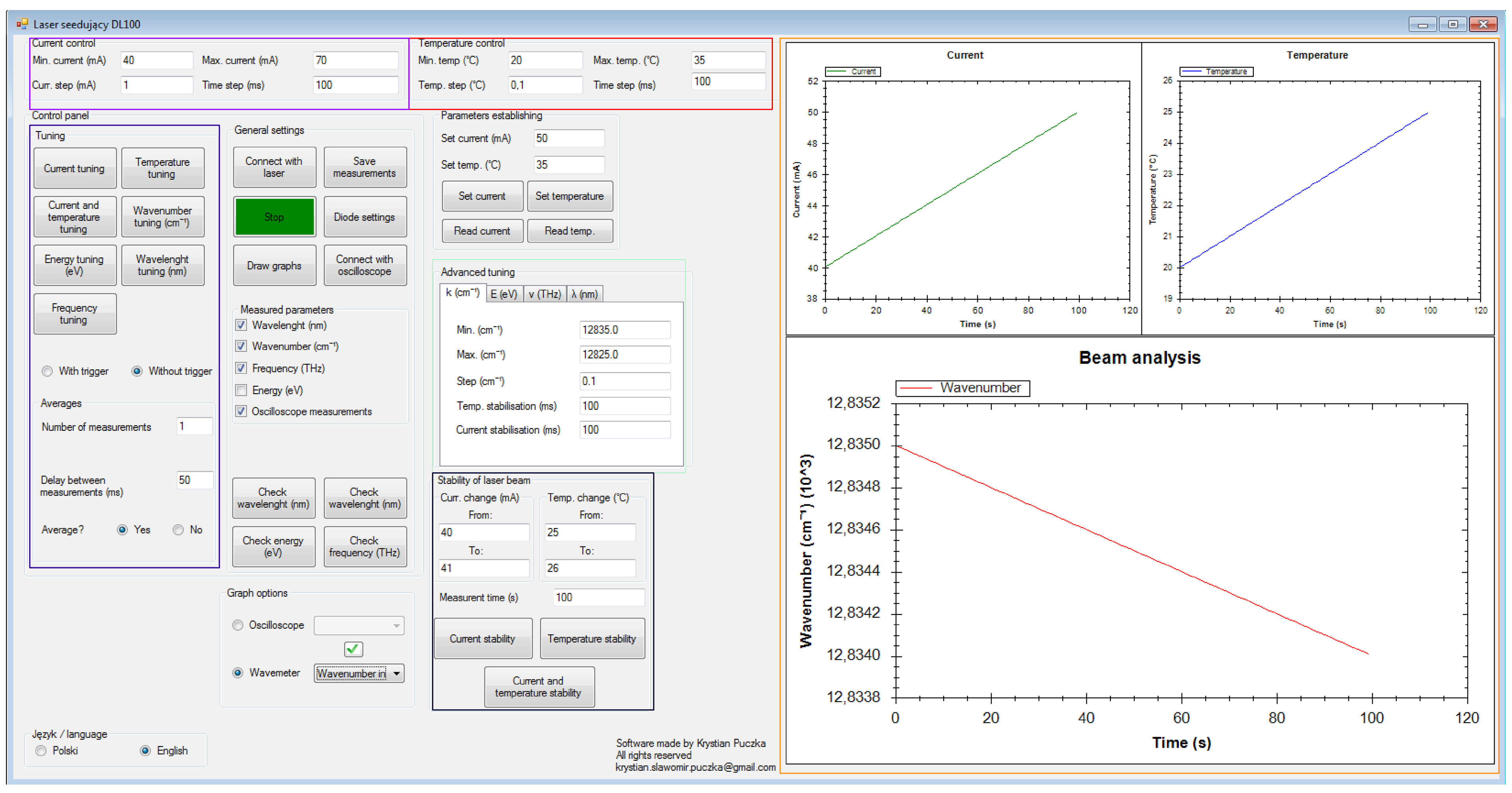


Fig 6. GUI (Graphical User Interface) of software devoted for tuning of the seeding diode laser.

The most important elements of the designed software are the following:

Current change - responsible for parameters included in the current loop, which directly corresponds to the smallest change of the wavelength.
Temperature change - responsible for parameters in temperature loop that control larger wavelength change.
Tuning options - tuning type selection and averages options; *trigger* is responsible for communication with LIF excitation measurement software.
Advanced loop parameters - parameters for the direct tuning in the chosen parameter (in the development phase).
Stabilisation measurements - used to check beam stabilisation in a selected time period.
Graphs generation - during the tuning, actual temperature, current and wavelength are shown.

Absporption spectroscopy in rubidium

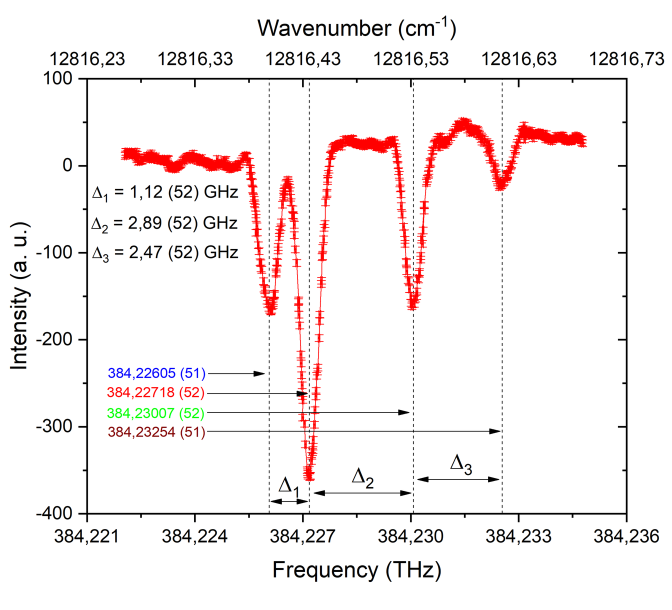


Fig 7. Results of rubidium absorption spectroscopy.

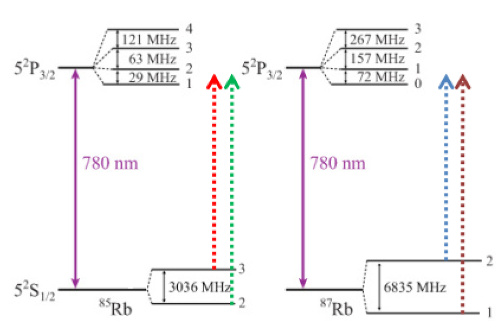


Fig 8. Scheme of the ^{85}Rb and ^{87}Rb D_2-line hyperfine structure.[2][3]

Absorption spectroscopy in rubidium was performed to confirm quality of the beam. Hyperfine structure has been resolved. Main source of uncertainty is Doppler broadening.

Summary

The software developed in this work allows controlling the seeding diode laser during tuning its wavenumber using temperature and/or current. The current-tuning process was tested in the absorption spectroscopy experiment in rubidium. The beam is also stable in a wide range of temperatures. Next step of the software development will make it more user friendly and easier to modify. To resolve rotational structure, the seeding process of the alexandrite ring laser needs to be performed.

References

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[2] D. A. Steck, *Rubidium 85 D Line Data, Rubidium 87 D Line Data* (2003).
[3] R. C. Pooser et al., *Quantum correlated light beams from non-degenerate four-wave mixing in an atomic vapor: the D1 and D2 lines of ^{85}Rb and ^{87}Rb*, Opt. Express **17** (2009) 16722.

Acknowledgement

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