81st International Scientific Conference of the University of Latvia 2023

Atomic, molecular and optical physics section (LU FMOF Laser Centre section)

Book of Abstracts

Tuesday, 31st of January 2023, 10.00 AM, online

Laser Centre

UNIVERSITY OF LATVIA

81st International Scientific Conference of the University of Latvia 2023

Atomu, molekulu un optiskas fizikas sekcija
(LU FMOF Lāzeru Centra sekcija)

Atomic, molecular and optical physics section
(LU FMOF Laser Centre section)

Tuesday, **31st of January 2023, 10.00 AM**, online

Programma/Programme

Chairpersons: Prof. Ruvins Ferbers, Prof. Mārcis Auziņš			**Page**
10.00–10.20	***K. Pukitis***, *L. Zacs, J. Sperauskas*	Recent observations of stars by the Laboratory of Astrospectroscopy	3
10.20–10.40	***A. Lapins***, *I. Klincare, M. Tamanis, R. Ferber*	Studies of the $c^3\Sigma^+$ state in RbCs based on Fourier-transform high resolution spectroscopy data	4
10.40–11.00	***M. Tamanis***, *I. Klincare, R. Ferber, G. Başar, S. Kröger*	Determination of relative oscillator strengths from line intensities in atomic spectra of Tm	5
11.00–11.20	**Break, discussions**		
11.20–11.40	***A. Nikolajevs***, *A. Mozers, L. Busaite, D. Osite, F. Gahbauer, M. Auzinsh*	The impact of pump and probe light intensity on the signal shapes for magnetic field detection	6
11.40–12.00	***O. Rudzītis***, *R. Lazda, A. Asare, F. Gahbauer, M. Auzinsh*	High DC current stabilization using NV centers in diamond	7
12.00–12.20	***E. Šmits***, *R. Lazda, F. Gahbauer, M. Auzinsh*	Microwave antenna design for wide frequency range ODMR measurements	8
12.20–12.--	**Conclusions, discussions**		

Recent observations of stars by the Laboratory of Astrospectroscopy

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Recent observations of late type stars by the Laboratory of Astrospectroscopy as well as data provided by collaborators has resulted in a large collection of stellar spectra to be analyzed for years to come. Most notable are the numerous spectra of the well-known post-AGB star HD 235858, multiple near infrared spectra the post-AGB objects IRAS Z02229+6308 and IRAS 20000+3239, and spectra of RV Tauri type stars that are practically not studied as of yet. The observations were done at Moletai Astronomical Observatory and with world-class instruments in Spain.

We acknowledge the support from the Latvian Council of Science, project "Advanced spectroscopic methods and tools for the study of evolved stars", project No. lzp-flpp-2020/1-0088.

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Studies of the $c^3\Sigma^+$ state in RbCs based on Fourier-transform high resolution spectroscopy data

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High-resolution laser induced fluorescence (LIF) spectra of the $c^3\Sigma^+ \rightarrow a^3\Sigma^+$ transition ($c \rightarrow a$ in short) of RbCs molecule were recorded for the first time. The LIF spectra were recorded with Fourier-Transform spectrometer IFS125-HR (Bruker) using InGaAs detector. The spectral resolution was set as 0.03 cm^{-1}. RbCs molecules were produced in a linear heat-pipe at about 250^{o}C. The TiSph laser SolsTis (MSquared) operated within 13200 - 12500 cm^{-1} range was exploited to excite the spin-forbidden $X \rightarrow c$ transitions and the spin-allowed $c \rightarrow a$ LIF was recorded in the spectral range from 9000 to 10 000 cm^{-1}. Assignment of the $c \rightarrow a$ progressions was based on the $a^3\Sigma^+$ state potential energy curve obtained in [1] and the measured rotational-vibrational energy differences. At present we have obtained a set of *c*-state term values containing about 500 *e*- component values and 100 *f*-component values of ^{85}Rb^{133}Cs isotopologue, as well as 80 *e*- component values and 10 *f*- component values of another isotopologue ^{87}Rb^{133}Cs with accuracy of about 0.01 cm^{-1}, see Figure, which are covering the range of rotational quantum numbers N' from 14 to 185. At present the approximate range of observed vibrational levels covers v_c from 15 to 35. The obtained data will be used for construction of the effective empirical potential of the $c^3\Sigma^+$ state in RbCs.

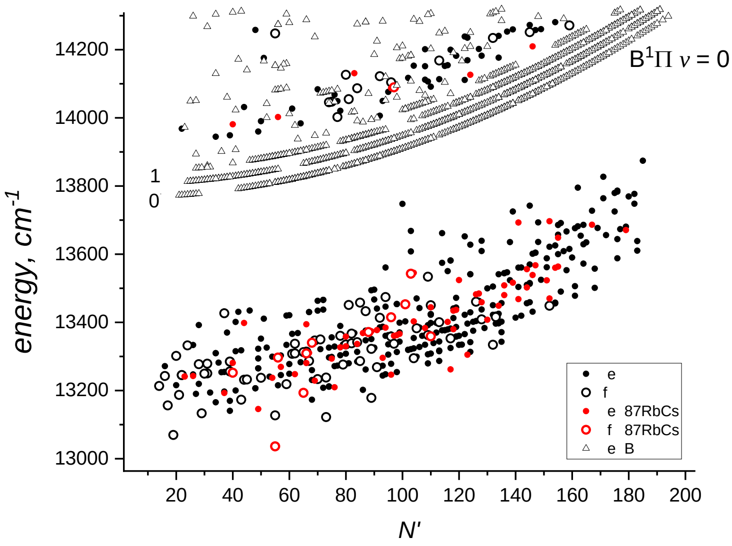

Figure. The RbCs $c^3\Sigma^+$ state term values as dependent on N'. ^{85}RbCs: black full - *e* levels, black empty - *f* levels; ^{87}RbCs: red full - *e* levels, red empty - *f* levels. Empty triangles belong to the $B^1\Pi$ state.

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Determination of relative oscillator strengths from line intensities in atomic spectra of Tm

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In present study, we report on measurements of relative lines intensity distributions in recorded emission spectra of atomic thulium (Tm), which allow to determine relative oscillator strengths and compare them with *ab initio* calculated values. Transition probabilities of heavy elements, e.g., Tm, along with other spectroscopic data (identified transitions, hfs constants,) are important both from point of view of fundamental physics, as well as for astrophysical purposes. The lanthanide Tm is one of the very few elements that have only one stable isotope. The nuclear spin of this isotope, ^{169}Tm, is I = ½ yielding a rather simple hyperfine structure. The hfs of atomic Tm has been studied experimentally by several authors (see [1] and references therein). In present work we have determined relative intensity distributions in branches of Tm emission lines originating from a common upper state to check experimentally a reliability of complicated all-electronic calculations of the respective oscillator strengths.

The emission spectra of thulium atom were produced in a hollow cathode discharge lamp and were recorded by Fourier Transform (FT) spectrometer in the visible wavelength region from 400 nm to 700 nm. The high-resolution Bruker IFS 125 HR FT spectrometer at the Laser Centre of the University of Latvia has been used. The spectra were recorded several times in presence of either Ar or Ne buffer gases at different discharge current values. Exploiting two different gases facilitated identification of those Tm lines, which exhibit completely overlapping hf transitions. The information presented in [1] was useful to find in the spectra several groups of lines originating from the same upper level; overall 5 branches with upper state levels in energy range from 32217.195 cm^{-1} to 42080.152 cm^{-1} have been analysed. The line intensity was determined by fitting two strongest hfs lines with given positions and widths to the recorded spectral line profile. Overall four spectra (two with Ar and two with Ne) were used to obtain averaged line intensity distributions in 5 branches, which were compared with their calculated counterparts [2].

This study has been funded by Latvian Council of Science, project No. lzp-2020/1-0088 "Advanced spectroscopic methods and tools for the study of evolved stars" and by Scientific Research Projects Coordination Unit of Istanbul University, Project No.30048.

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The impact of pump and probe light intensity on the signal shapes for magnetic field detection

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In this work we studied experimentally the interaction of ground-state atomic angular momentum with linearly polarized light. The experimental geometry (see Figure 1a) is based on [1] which requires only one optical access for both pump and probe beams. As caesium atoms interact with the linearly polarized D1 pump beam, an aligned state is created. When an external magnetic field (B_x or B_y) is applied this initially aligned state precesses around the axis of the applied magnetic field. This change in angular momentum distribution in turn is probed by a low intensity probe beam whose polarization axis (E_x or E_y) makes a 45 degree angle with respect to the pump beam polarization (E_p). As a result, dispersive probe beam absorption signals are obtained (see Figure 1b). Signal dependence on probe and pump beam intensity as well as laser frequency was studied. The implemented geometry allows for almost simultaneous measurement of magnetic field in two orthogonal directions by rotating the polarization of the probe beam from E_x to E_y using an electro-optic modulator. We have experimentally determined that the signal shape has strong dependence not only on the pump beam intensity (Rabi frequency), but also on the probe beam intensity because the probe beam perturbs the initially aligned state created by the pump beam.

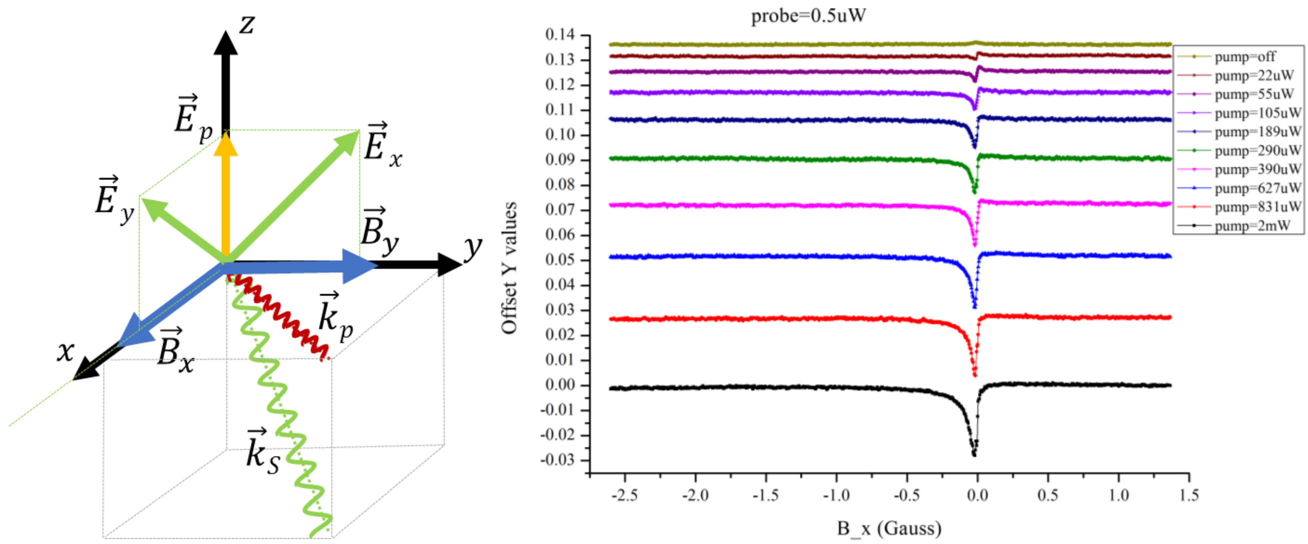

Figure 1: (a) The pump-probe geometry for measuring two orthogonal field components. (b) The transmission signal dependence on the pump beam power with fixed probe power 0.5 μW. Laser frequency was stabilized to the Cs D1 $F_g = 4 \rightarrow F_e = 4$ hyperfine transition.

We acknowledge the support from the Latvian Council of Science, project No. lzp-2020/1-0180: “Compact 3-D magnetometry in Cs atomic vapor at room temperature”

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High DC current stabilization using NV centers in diamond

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In this work NV centers in diamond are used to perform magnetic field measurements using the Zeeman effect of the ground state energy levels (See Fig. 1) in combination with the method of ODMR [1] for developing a high DC current stabilization prototype device.

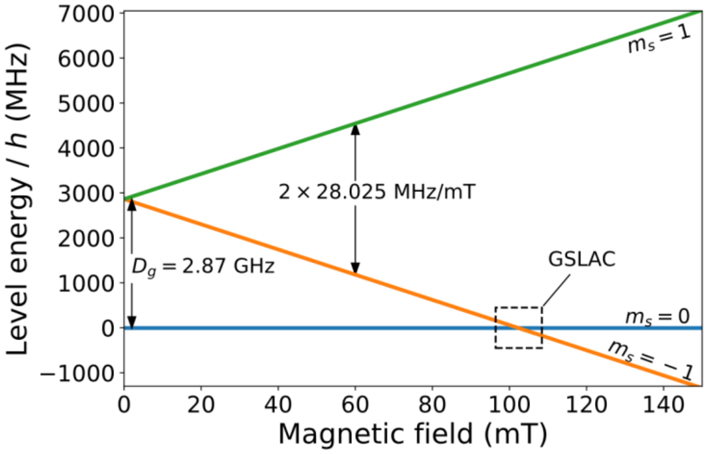

Figure 2: Levels of the NV centers' electron-spin magnetic sublevels in the ground state [1].

The bias magnetic field (planned to be generated by a current flowing through a wire close to the diamond) is aligned along one of the 4 possible directions in the diamond crystal lattice giving a linear response in the change of the ODMR frequencies depending on the measured magnetic field.

A dual resonance modulation technique is used to enhance the stability (including mitigation of temperature caused drifts and exciting laser power fluctuations) and sensitivity of the magnetic field measurements [1].

The measured magnetic field will be used as an input for a PID algorithm to stabilize a DC current.

We acknowledge the support from the Latvian Council of Science, project No. lzp-2021/1-0379: "A novel solution for high magnetic field and high electric current stabilization using color centers in diamond".

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Microwave antenna design for wide frequency range ODMR measurements

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To use the favorable properties of diamond nitrogen vacancy centers the electronic spin of NV^- centers can be manipulated, which is best done by using electromagnetic waves with a frequency in the microwave range using the method of ODMR [1]. To achieve that in an efficient way, an antenna with certain properties is needed: it must create a uniform magnetic flux density distribution in a region with an area on the order of 1 mm^2, it has to generate the microwaves with a specific polarization, it has to have a resonant frequency of about 2.87 GHz and it also has to have a wide enough bandwidth for practical use.

Previously, in most cases for this task simple coil or wire antennas that could achieve varying degree of efficiency were used. In recent years there has been an increasing number of studies with more intelligent type of antennas for this specific application of manipulating NV centers. One of such studies is the basis for an antenna design for a high DC current stabilization experiment, where using COMSOL Multiphysics simulation software we modeled an antenna as described in [2], see Figure 1.

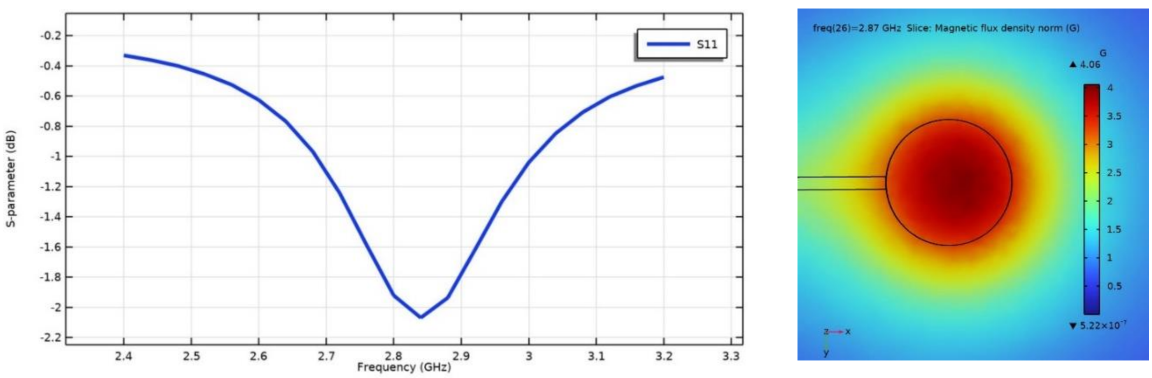

Figure 1: Left, S-parameter graph of modeled antenna. Right, magnetic flux values on modeled antenna.

Using the simulation software, the antenna's resonance frequency and bandwidth will be tailored for the needs of developing a high DC current stabilization prototype device.

We acknowledge the support from the Latvian Council of Science, project No. lzp-2021/1-0379: "A novel solution for high magnetic field and high electric current stabilization using color centers in diamond".

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