82nd International Scientific Conference of the University of Latvia 2024

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

Book of Abstracts

Tuesday, 1st of February 2024, 10:00 AM
University of Latvia, Jelgavas iela 3, room 801/802

Laser Centre

UNIVERSITY OF LATVIA

82nd International Scientific Conference of the University of Latvia 2024

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

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

Thursday, **1st of February 2024, 10:00 AM**,
Jelgavas iela 3, 801/802 room

Programma/Programme

Chairpersons: Prof. Ruvins Ferbers, Prof. Mārcis Auziņš		
10:00–10:20	***K. Korenika**, K. Puķītis*	Spectroscopy of a sample of RV Tauri stars without IR excess: First results
10:20–10:40	***D. Jermacane**, A. Lapins, I. Klincare, M. Tamanis, and R. Ferber*	Determination of absolute numbering of vibrational levels in triplet $c^3\Sigma^+$ state of RbCs molecule
10:40–11:00	***L. Seržane-Sadovska**, A. Mozers*, F. Gahbauer and M. Auzinsh*	Probing angular momentum alignment in atomic ^{133}Cs with radio frequency field
11:00–11:30	**Kafijas pauze, diskusijas/Coffee break, discussions**	
11:30–11:50	***E. Šmits**, R. Lazda, F. Gahbauer and M. Auzinsh*	Microwave antenna design optimization for use in wide frequency range ODMR measurements
11:50–12:10	***R. Lazda**, M. Jani, A. Asare, E. Šmits, F. Gahbauers and M. Auzinsh*	NV based magnetometer sensitivity optimization for one-dimensional magnetic field measurements
12:10–12:30	***S. Filatovs**, M. Auzinsh*	Towards two Bloch sphere representation of two qubit states and unitaries
12:30–13:--	**Noslēgums, diskusijas Conclusions, discussions**	

Spectroscopy of a sample of RV Tauri stars without IR excess: First results

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RV Tauri type stars are pulsating variables with alternating deep and shallow minima present in their light curves. Many of them possess a peculiarity called depletion – those chemical elements that have high dust condensation temperature are systematically underabundant in the photosphere. It is known that the peculiarity can be caused by re-accretion from a surrounding dust and gas disc [1]. This structure causes IR excess in spectral energy distribution of RV Tauri type objects. However, the depletion is detected also for a few RV Tauri stars that have no such excess [2].

We have observed high-resolution spectra of 11 RV Tauri stars that have no IR excess with the main goal of searching for depletion patterns. We present first results of spectroscopic analysis for five of them: V399 Cyg, V894 Per, AA Ari, HD 172810, and V457 Cyg. By using equivalent widths of absorption lines, we calculate photospheric parameters and chemical element abundances. Derived effective temperatures are in range of 4000 to 8000 K, surface gravities are no higher than log g = 2.5 and iron abundances range from [Fe/H] = -1.5 to +0.3. Only in the case of V457 Cyg the abundance pattern indicates depletion (Figure 1).

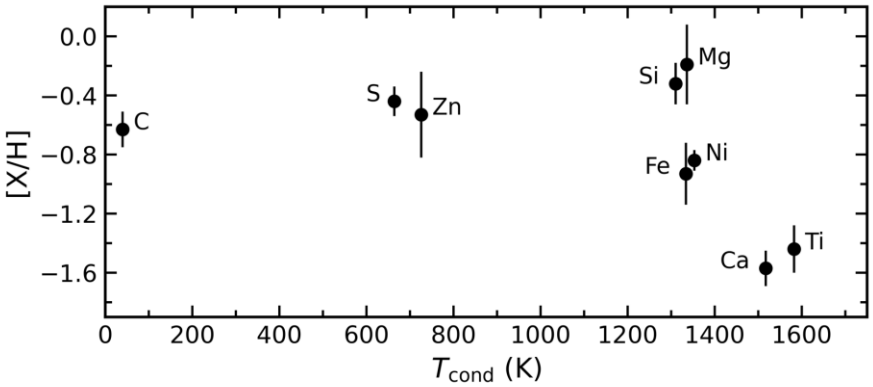

Figure 1: Photospheric abundances of V457 Cyg as a function of dust condensation temperature.

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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Determination of absolute numbering of vibrational levels in triplet $c^3\Sigma^+$ state of RbCs molecule

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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 recently recorded with spectral resolution 0.03 cm^{-1} [1]. Identification of LIF progressions basing on the accurate empirical $a^3\Sigma^+$ state potential energy curve [2] allowed us to determine the energy (term value) of the $c^3\Sigma^+$ rovibronic levels with accuracy about 0.01 cm^{-1}. The LIF spectra contained progressions of $^{85}Rb^{133}Cs$ and $^{87}Rb^{133}Cs$ molecules, thus the term values for both isotopologues were determined. The observed energy differences between rovibronic *v,J* levels of $^{85}Rb^{133}Cs$ and $^{87}Rb^{133}Cs$ molecules with the same vibrational *v* and rotational *J* quantum numbers made it possible to determine absolute numbering of vibrational levels of the $c^3\Sigma^+$ state. Preliminary molecular constants of the $c^3\Sigma^+$ state will be reported.

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Probing angular momentum alignment in atomic ^{133}Cs with radio frequency field.

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In this work, we experimentally investigated the effect of radio frequency on magneto-optical absorption signals in the caesium 133 isotope. Usually, circularly polarized light is used in these type of double resonance experiments, although a similar effect can be created with linearly polarized light [1]. When a linearly polarized light (E || z) is absorbed, it creates symmetric population distribution among $\pm m_F$, but unequal between neighboring magnetic sublevels $\Delta m_F = \pm 1$. When a magnetic field (B_0) is applied along the quantization axis z, it shifts the energies of the magnetic sublevels and the angular momentum distribution starts to precess about the applied magnetic field. Under these conditions this produces negligible change in the absorption signal in the small magnetic field regime (<10 G). However, when an additional linearly polarized radiofrequency (RF) is applied perpendicular to the magnetic field (B_0) and the RF value corresponds to the splitting of the magnetic sublevels (i.e. to the Larmor frequency), an increase in the absorption signal can be observed, because the RF transfers the population between sublevels with $\Delta m = \pm 1$. The excitation geometry described above is shown in Figure 1(a).

We have obtained the dependencies of absorption signals on different experimental parameters. First, the dependence on the laser frequency was acquired. The relatively largest changes in the signal amplitudes can be observed for the transition $F_g = 4 \rightarrow F_e = 3$ and $F_g = 4 \rightarrow F_e = 4$. Next, we observed the impact of the RF amplitude on the absorption signals (Fig. 1b). These results show that by increasing the amplitude of the radio frequency, the amplitude of the absorption signal also increases and that at higher RF amplitudes an additional structure can be noticed. We also observed the influence of the RF value on the absorption signal. Finally, the dependencies on the laser power and diameter were obtained at two radio frequency amplitudes, 0.5 Vpp and 10 Vpp. In both cases the resonance signal increased at a higher laser power values. The dependence on the beam diameter was implemented by introducing a beam expander. The results demonstrate that by increasing the beam diameter, the absorption signal resonances become narrower.

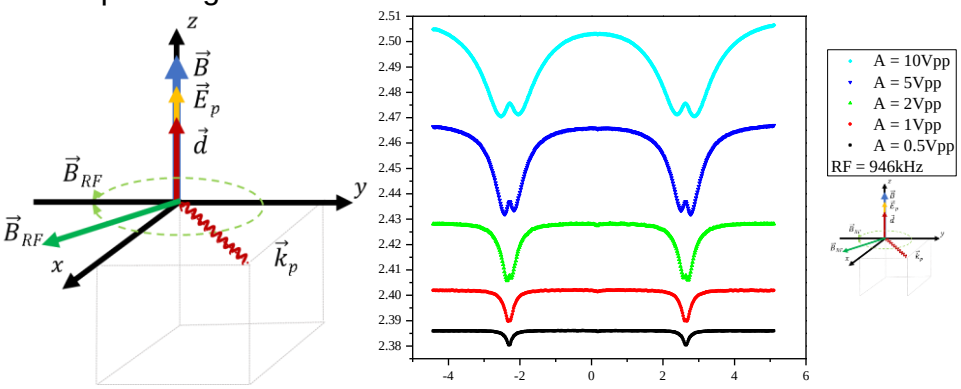

Figure 1: (a) The geometry for measuring dependence of radio frequency on the absorption signal. (b) ^{133}Cs D1 $F_g4 \rightarrow F_e4$ absorption signal dependence on radio frequency amplitude

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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Microwave antenna design optimization for use in wide frequency range ODMR measurements

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To harness the advantageous magnetic field detection capabilities of nitrogen-vacancy (NV) centers in diamond, it is imperative to modulate the ground state electronic spin energy levels. This modulation can be achieved through the application of a dual optically detected magnetic resonance (ODMR) technique [1]. Enhancement of microwave energy transmission to NV centers within a diamond necessitates the utilization of a microwave antenna that should be capable of generating a spatially uniform magnetic flux density, resonating at approximately 2.87 GHz, and possessing a sufficiently broad bandwidth to facilitate effective dual-resonance operations. Additionally, the construction of the antenna should incorporate non-combustible materials, such as ceramics, to ensure resilience against the high-energy laser illumination employed in experimental setups.

The present investigation extends prior research focused on the impact of geometric parameter alterations on promising antenna designs developed by other scholars [2]. The current study delves into the exploration of additional parameter alterations to preserve the optimized electromagnetic attributes of the finely-tuned antenna while incorporating innovative ceramic materials as the substrate of the antenna.

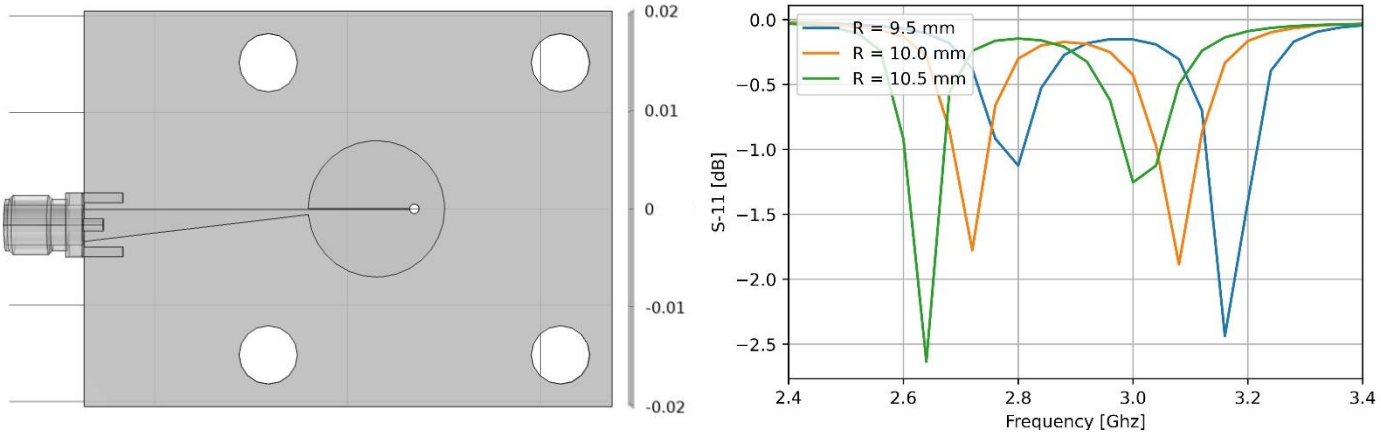

Figure 1: Left, antenna prototype. Right, S11 values on modeled antenna.

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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NV based magnetometer sensitivity optimization for one-dimensional magnetic field measurements

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NV centers in diamond are point-like defects consisting of one substitutional nitrogen atom and an adjacent lattice vacancy next to it, their physical properties make them suitable for use as quantum sensors for magnetic field [1, 2].

Here we report how the experimental parameters affect the determined magnetic field sensitivity for a one-dimensional magnetic field measurement using NV centers in diamond.

The experimental parameters considered in this work are:

- the exciting green (532 nm) laser power, Figure 1 shows how the magnetic field sensitivity changes depending on the applied laser power;
- the applied microwave power;
- lock-in amplifier time constant.

During the experiment we observed that the magnetic field sensitivity is dependent on the excitation spot on the diamond by itself (this is due to the fact that the NV center distribution in the used diamond samples is not completely homogeneous) and with respect to the position of the microwave antenna (indicating that homogeneous microwave delivery to the spot where the NV centers are excited in the diamond is important as well).

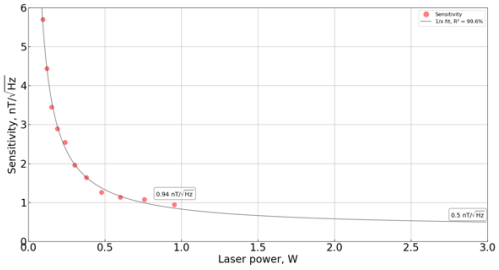

Figure 1: Magnetic field sensitivity for measurements in one dimension depending on the applied excitation laser power, 1/*x* trend.

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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Towards two Bloch sphere representation of two qubit states and unitaries

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We extend Bloch Sphere formalism to two Qubit systems. Combining insights from Geometric Algebra and analysis of entanglement in different conjugate bases we identify Two Bloch Sphere geometry that is suitable for representing maximally entangled states. It turns out that relative direction of coordinate axes of the two Bloch Spheres may be used to describe the states. Moreover, axes of one Bloch sphere should be rignt-handed and of the other one – left-handed. We describe and depict separable and entangled states as well as entangling and non-entangling rotations. We also offer graphical representation of workings of a CNOT gate for different inputs. Finally we provide a way to also represent partially entangled states and describe entanglement measure related to the surface area of the sphere enclosing the state representation.

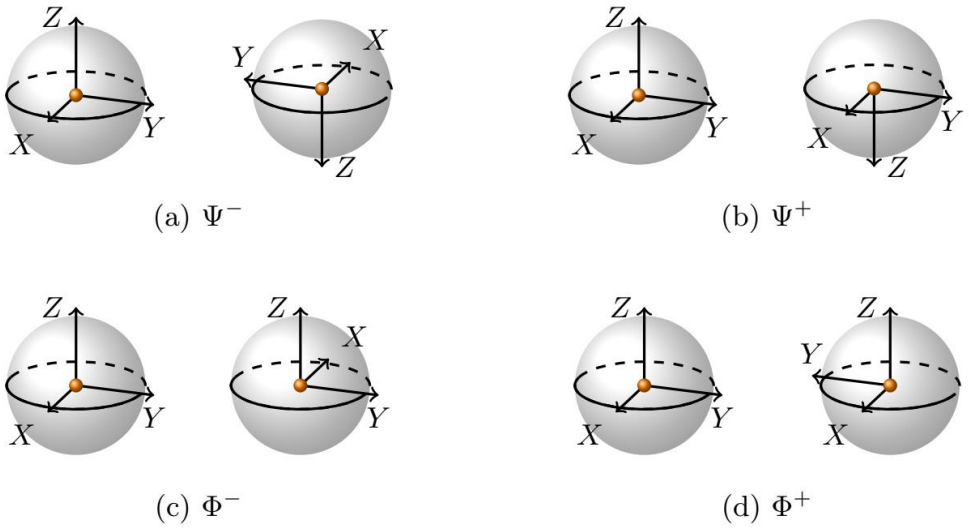

Figure 1: Bell states depicted using two Bloch spheres. A pair of Bloch Spheres, with differing handedness in their coordinate axes, represents each state. Odd number of coordinate axes is always inverted on the second BS.

References

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