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A multichannel diode laser spectrometer for *in situ* study of atmosphere near the Martian surface for the ExoMars-2020 mission Landing Platform

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Abstract

An application of tunable diode laser absorption spectroscopy (TDLAS) in combination with integrated cavity output spectroscopy (ICOS) has been suggested for Martian atmosphere study as an experiment, named Martian multichannel diode laser spectrometer (M-DLS), by a team of researchers from IKI RAS, MIPT, GPI RAS. M-DLS has been proposed for scientific payload of the ExoMars-2020 mission Landing Platform [1, 2], and further modified into a very compact and lightweight instrument for continuous *in situ* study of chemical and isotopic composition variations of atmosphere near the Martian surface at short-term and seasonal time scales.

1. Introduction

In the M-DLS experiment, Martian atmosphere study will be based on regular measurements of molecular absorption spectrum in an optical cell, filled with ambient gas sample, taken at the stationery Landing Platform location. TDLAS flexibility and radical optical path enhancement of ICOS will be combined in the M-DLS instrument for fine measurement of weak absorption values at low pressure of the Martian atmosphere. H_2O and CO_2 molecular content and isotopic ratio variations will be retrieved from absorption data continuously during one Martian year.

2. Measurement method

The optical cell with the gas sample will be sounded by highly monochromatic radiation of two tunable distributed feedback diode lasers, emitting at IR range near 2.7 microns. Measurements will be carried out sequentially in series of 1 cm^{-1} wide intervals at 2.65 microns for H_2O and at 2.79 microns for CO_2 with spectral resolution of 3 MHz (~ 0.0001 cm^{-1}), providing for fine recording of molecular absorption line contours of H_2O and CO_2 main molecules and isotopologues HDO, $HO^{18}O$, $^{13}CO_2$, $CO^{17}O$, $CO^{18}O$. Examples of simple modelling for Martian atmosphere absorption are shown right below.

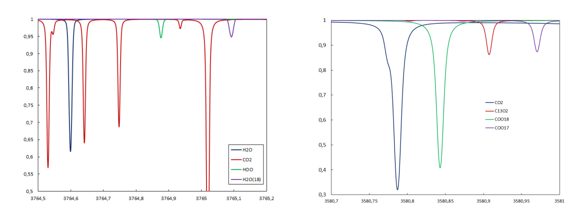

Figure 1. Absorption spectra for CO_2 and H_2O mixture, modelling atmosphere near the Martian surface: H_2O isotopologue lines for ~ 1 km effective optical path (left), CO_2 isotopologue lines for 2.5 m effective optical path (right).

Table 1: Sensitivity estimations for 95% CO_2 and 200 ppm H_2O gas sample in the ICOS cell.

Isotopologue	Wavelength, cm^{-1}	Precision
CO_2	3580.786	~ 0.2%
$^{13}CO_2$	3580.843	~ 0.2%
$CO^{18}O$	3580.907	~ 0.2%
$CO^{17}O$	3580.970	~ 0.2%
H_2O	3764.599	< 0.2%
$H_2^{18}O$	3765.091	< 2%
HDO	3764.876	< 2%

Modelling of the absorption spectra has shown noticeable temperature dependence of the line amplitudes, which demands for a fraction of a degree precision for the gas sample temperature control in the optical cell, corresponding to adequate molecular concentration retrieval and isotopic ratio measurement accuracy of: D/H < 2%, $^{18}O/O < 2\%$ (H_2O), $^{18}O/^{17}O/O < 0.3\%$ (CO_2), $^{13}C/C \sim 0.3\%$.

General ICOS cell design views for the M-DLS experiment are shown in Figure 2. High reflection R = 99.9% of the cell mirrors at 2.65 microns results in ~ 220 m effective optical path in a compact cell for H_2O isotopologue weak absorption lines. A few meters long effective optical path at 2.79 microns is considered for CO_2 isotopologue strong absorption lines.

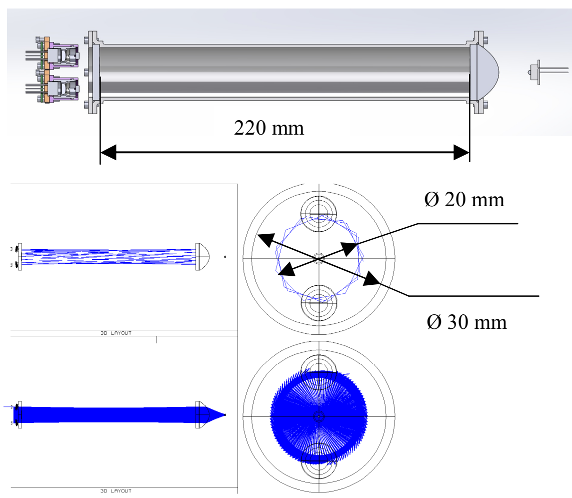

Figure 2. A cross-section model of the optical cell with partially shown input laser and output photodetector interfaces (up). Calculated beams and optical field pattern at the ICOS cell mirrors (down).

Special system of gas sampling for the M-DLS instrument will be shared with Martian Gas Analytic Suite (MGAS), which is another instrument, proposed for the same Landing Platform. Gas sampling inlet will be lifted up by a telescopic tube to a point, 15 cm higher than the Landing Platform top. The sampling system will efficiently refresh ambient Martian atmosphere gas sample in the ICOS cell analytical volume and will optionally enhance measurement accuracy by increasing ~ 5 times up concentration of sampled gas in the ICOS cell.

Following the M-DLS experiment idea, we are carrying out industrial design of a compact and lightweight M-DLS instrument for the ExoMars-2020 mission Landing Platform scientific payload, see Figure 3. M-DLS is aimed to continue *in situ* study of atmosphere near the Martian surface after the TLS/SAM/MSL instrument of the NASA Curiosity rover [3].

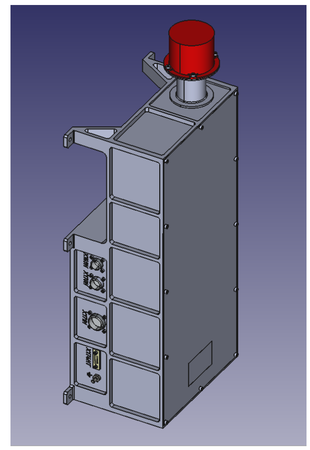

Figure 3: 3D-model of the M-DLS instrument external view.

3. Summary and Conclusions

The idea of M-DLS experiment, combining TDLAS and ICOS methods, has been proposed for continuous study of atmosphere near the Martian surface during the ExoMars-2020 mission. M-DLS instrument aims for measuring of H_2O and CO_2 molecule content and of D/H, $^{18}O/^{17}O/^{16}O$, $^{13}C/^{12}C$ isotopic ratio variations with ~ 1% accuracy *in situ* at the stationery Landing Platform location.

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