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TUNABLE INFRARED LASERS FOR BIOMEDICAL AND ENVIRONMENTAL APPLICATIONS

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ABSTRACT

This paper discusses the development of an infrared quantum cascade laser emitting in the range from 9.6 to 12.5 µm. The laser is made according to a circuit with an external cavity (Littrow scheme). It is shown that the selected laser design, its energy characteristics (peak pulse power 150 mW and 8 average radiation power mW), wide tuning range (from 9.6 to 12.5 µm), tuning step 2 cm^{-1}, linewidth of 2 cm^{-1}, which allows the developed device to be used in a wide range of applications in the field of spectroscopy.

INTRODUCTION

The analysis of chemical compounds in a solid or liquid state is one of the most important tasks, which has not only fundamental but also applied significance. At the same time, analysis methods are largely determined by the final goal of the study, the conditions of the experiment and the time allotted for it.

At the moment, there are many common methods for solving problems of identifying liquid and solid substances. The most common approach is Raman spectroscopy [1, 2]. Due to the high selectivity of Raman spectra, as well as the ability to study substances even through transparent packaging, this method has become widespread.

Methods for identifying powder samples without prior sample preparation include diffuse reflectance Fourier transform infrared spectroscopy (DRIFTS). The sample is placed in a special cup, then the IR radiation incident on the sample is reflected to varying degrees through the sample. Diffuse reflectance is collected on a parabolic mirror and enters a photodetector. DRIFTS is convenient to use in laboratory settings [3].

Another classical spectral method used in the analysis of chemical compounds is absorption spectroscopy. This method has become especially widespread for the analysis of substances in the gas phase, in particular for the identification of vapors in an open atmosphere using the passive method of FTIR spectroscopy [4, 5].

Currently, significant progress has been made in the development of quantum cascade lasers (QCLs) [6]. QCLs are unipolar semiconductor lasers with the ability to tunable wavelengths over a wide spectral range. Some QCLs are capable of tuning in a range of more than 1000 cm^{-1} and, operating in a pulsed mode, generate peak power up to 150 mW. The use of such lasers makes it possible to obtain fairly informative spectra of diffuse reflection of substances and, as a result, to successfully identify chemical compounds [7].

RESULTS

The developed quantum cascade laser (Fig. 1) generates radiation in the wavelength range 9.6-12.5 µm with a tuning step of 2 cm^{-1} and an output peak power of up to 200 mW, a pulse duration of 300 ns. The laser is built according to the Littrow scheme (external cavity quantum cascade laser).

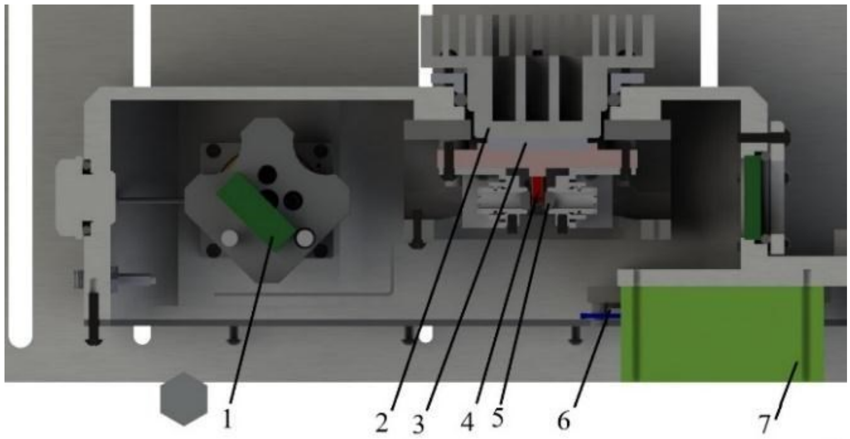

Figure 1: *Quantum-cascade laser. 1 – diffraction grating; 2 – radiator; 3 – Peltier element; 4 – QC chip; 5 – aspherical collimating lens; 6 – control board for the CC chip; 7 – cooling control board.*

To record the signal, a thermoelectrically cooled mercury cadmium telluride (MCT TE) photodetector is used. The system is equipped with a 24-bit analog-to-digital converter.

The developed laser has the following technical characteristics (Table 1).

Table 1. Technical characteristics of a quantum cascade laser.

Radiation range	μm	9,6-12,5
Maximum average radiation power	mW	8,0
Maximum peak pulse power	mW	150
Pulse duration	ns	300
Time interval between radiation pulses	μs	5,7
Tuning step, no more	cm^{-1}	2
Spectral pulse width, no more	cm^{-1}	2
Beam divergence, no more	mrad	5
Output beam size	mm	3,5x5,0
Power consumption (220 V 50 Hz)	W	50
Overall dimensions (LxWxH)	mm	130x150x250
Weight	kg	6

In Figure 2 shows the spectral characteristic of the output power of a quantum cascade laser.

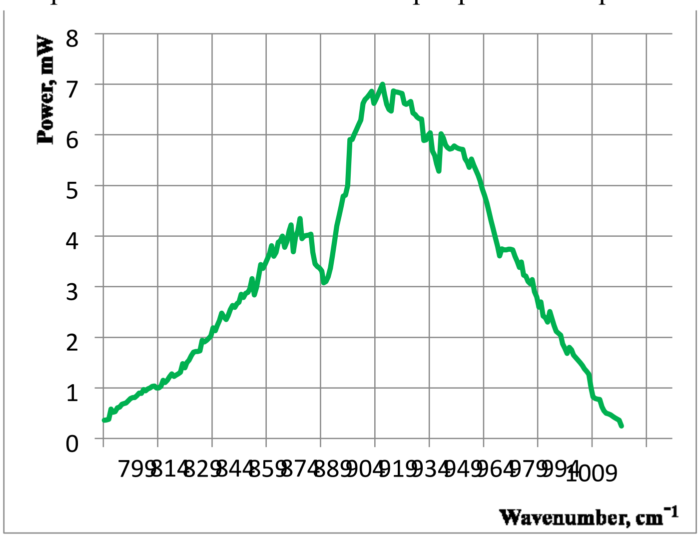

Figure 2: *Dependence of output optical power on wavenumber T= 18°C, Pulse ratio 5%, 14 V.*

CONCLUSIONS

This work presents a prototype of a quantum cascade laser in the range from 9.6 to 12.5 μm. The design features and technical characteristics of the laser are presented. The paper presents a diagram of an experimental setup, namely a laser spectrometer, for research in the field of diffuse reflectance spectroscopy [8, 9] (as an alternative to Raman spectroscopy [10]) and laser absorption spectroscopy.

The developed experimental setup can be used in the chemical industry [11], pharmacology, medicine, industrial production, ensuring chemical [12] and biological safety, and inspection activities.

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