Streszczenie pracy w języku angielskim

Antiresonant hollow-core fibers (ARHCF) are a type of fiber that allows for broadband and single-mode light transmission in multiple spectral ranges simultaneously. Due to their air hollow-core structure, ARHCFs can be used as low-volume, single-pass absorption cells in laser gas spectroscopy systems. These optical fibers, due to their ability to guide light in the mid-infrared, can be used to detect strong absorption lines of many gases in this range. Thanks to the above-mentioned features, they are a potential alternative to widely used multi-pass cells. One of the interesting issues in terms of the use of this type of fibers in spectroscopic systems is their filling. Due to the small cross-sections of photonic structures in ARHCF, this process becomes a non-trivial issue that requires appropriate optimization.

This paper is devoted to the implementation of these extremely interesting photonic structures in laser gas spectroscopy systems. The main focus is placed on the use of ARHCF in spectroscopic systems designed for the detection of trace concentrations of gases in more than one spectral range, on their detection in the mid-infrared range and on the analysis of the problems of their filling.

The first chapter of the dissertation describes theoretical issues related to laser gas spectroscopy, such as the types of excitation of a molecule by light or observable phenomena which allowing to determine the concentration of the studied gas. This chapter also presents methods of extending the optical path in spectroscopic systems, including ARHCF, which is the main topic of this work. The second chapter describes the basics of selected techniques of laser spectroscopy of gases, including those that have been used in the dissertation.

The third chapter of the paper focused on the research carried out on the problem of filling ARHCF with the target gas sample. Two basic methods of filling fibers with a hollow core are presented: the diffusion method and the method based on pressure-driven flow. The mechanisms of gas transport and the classification of the observed flows are presented. As part of the work on pressure filling, the world's first research on the dynamics of the nodeless type ARHCF filling was presented This research shows that, unlike other types of hollow-core fibers, in which the core area is surrounded by a closed photonic structure, in the case of nodeless ARHCFs, an accurate geometric model is necessary to obtain the correct characteristics of the flows occurring in them. In addition, the paper also indicates that in the case of a long nodeless ARHCF section (14.73 m) and a pressure range allowing for relatively fast filling of the optical fiber, the use of a compressible gas model is necessary to correctly reproduce the filling characteristics of the optical fiber. The second of the papers discussed in the third chapter concerned the optimization of ARHCF diffusion filling by fabricating micro-holes in their structure. In this work, thanks to this procedure, a 65-times reduction in ARHCF filling time was achieved. It was also indicated that a simple computational model based on Fick's second law allows for rapid modeling of the dynamics of diffusion filling of nodeless ARHCFs. Both papers also showed the possibility of using the free OpenFOAM® package to simulate flows in photonic structures.

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The fourth chapter presents the experimental work on the implementation of ARHCF in the form of absorption cells in laser gas spectroscopy systems. 5 measurement systems were implemented and characterized, using the following techniques: 2f-WMS, LITES and CLaDS. In each of the systems, ARHCF was used as an absorption cell. In the experiments, the detection of CO_2, N_2O, CH_4 and C_2H_6 was performed. 2 different models of ARHCF fiber were used, for both of which the possibility of dual-band gas detection in the near and mid-infrared was presented. The parameters of the developed systems were analyzed and compared to those obtained in analogous measurement systems presented in the literature. In the case of each of the systems, the limits for detecting subsequent molecules were lower than their average concentration in the atmosphere. The NEA of the systems built ranged from 1.7×10^{-6} cm^{-1} (CO_2 - LITES detection in the near-infrared) to 3.5×10^{-10} cm^{-1} (C_2H_6 - CLaDS detection in the mid-infrared). The detection limits obtained in almost each of the implemented systems were at a similar or better level than for analogous systems using other methods of optical path extension, which indicates a high potential for the use of ARHCF fibers in laser gas spectroscopy.

The results presented in the paper have been published in seven scientific articles from the JCR list (in three of them the Author is the lead author), and have been presented by the Author of the work at six national and international conferences.

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