engineering proceedings

MDPI

Abstract

Design and Development of a Miniature Mid-IR Spectrometer for Environmental Sensing and Food Safety Applications †

Filip Łabaj [1,2,*], Jerzy Kalwas [2], Adam Górski [2], Dawid Stępień [2], Paweł Leszcz [2] and Ryszard Piramidowicz [1,2]

[1] Faculty of Electronics and Information Technology, Warsaw University of Technology, 00-661 Warszawa, Poland
[2] VIGO Photonics, 05-850 Ożarów Mazowiecki, Poland
* Correspondence: filip.labaj.dokt@pw.edu.pl
† Presented at the 9th International Symposium on Sensor Science, Warsaw, Poland, 20–22 June 2022.

Keywords: mid-infrared spectrometer; linear-variable filters; linear detector array; InAsSb; environmental sensing; food safety

In this work, we present the recent results of designing and developing a miniaturized mid-IR spectrometer designed to detect and identify specific markers, which may provide crucial information on air/water/food quality, human health, production line condition, etc.

The device is designed to operate in the spectral range of 3–5 µm or 7–9 µm, depending on the detector used, with a spectral resolution of approx. 20–100 nm, chosen appropriately for the targeted applications. Specific focus has been placed on the potential for the further miniaturization and cost optimization of the device.

The heart of the spectrometer, determining its spectral selectivity, is a 32-element, thermoelectrically cooled linear detector array (LDA) and a linear-variable filter (LVF). The LDA consists of InAsSb photodiodes, which, for a temperature of 230 K, offer a specific detectivity D* of the order of $10^{10}/10^{8}$ cmHz$^{-1/2}$W^{-1} for the spectral range of 3–5 µm and 7–9 µm, respectively. The LVF's spectral response changes linearly along its length—since it is placed parallelly and near the LDA, this effectively restricts the spectral response of each pixel to a narrow peak, shifted by a constant value with regard to its neighbors.

To test the applicability of the device, a standalone demonstrator was developed, consisting of a thermal light source, beam-forming optics, a light beam modulator and an optoelectronic detection setup. To prove the proper operation of this device, several tests were performed, evaluating, among other aspects, its detection limits for different substances. Various measurement configurations (transmissive, reflective, and multi-pass) were tested to improve the flexibility of the developed solution.

Since the presented work is a part of a bigger project focusing on the development of fully integrated micro-spectrometers, the perspectives for further miniaturization will also be discussed, with specific focus placed on the potential of photonic integrated circuits (PICs).

Author Contributions: Conceptualization, F.Ł., P.L. and J.K.; methodology, F.Ł., A.G. and D.S.; software, F.Ł.; validation, F.Ł. and J.K.; formal analysis, F.Ł.; investigation, F.Ł. and J.K.; resources, A.G. and D.S.; data curation, F.Ł.; writing—original draft preparation, F.Ł.; writing—review and editing, J.K. and R.P.; visualization, F.Ł.; supervision, P.L. and R.P.; project administration, P.L. and R.P.; funding acquisition, P.L. and R.P. All authors have read and agreed to the published version of the manuscript.

Funding: This work was supported by the National Centre for Research and Development project MIRPIC (TECHMATSTRATEG-III/0026/2019).

Institutional Review Board Statement: Not applicable.

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Citation: Łabaj, F.; Kalwas, J.; Górski, A.; Stępień, D.; Leszcz, P.; Piramidowicz, R. Design and Development of a Miniature Mid-IR Spectrometer for Environmental Sensing and Food Safety Applications. *Eng. Proc.* **2022**, *21*, 49. https://doi.org/10.3390/engproc2022021049

Academic Editors: Piotr Lesiak, Tomasz Woliński and Leszek Jaroszewicz

Published: 1 September 2022

Publisher's Note: MDPI stays neutral with regard to jurisdictional claims in published maps and institutional affiliations.

Informed Consent Statement: Not applicable.

Data Availability Statement: The data that support the findings of this study are available from the corresponding author, F.Ł., upon reasonable request.

Conflicts of Interest: The authors declare no conflict of interest.