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Marcin Motyka

Auto-report

Prepared for the purpose of applying for habilitation

Wrocław 2017

Marcin Motyka

This document contains:

I. Personal data

Name and surname	Marcin Motyka
Date and place of birth	26.01.1980, Ząbkowice Śląskie, Poland
Curriculum Vitae:	
1999 - 2004	Studies at Wrocław University of Science and Technology, Faculty of Fundamentals Problems of Technology, Physics.
2004	Master of Physics (Solid State Physics). Master Thesis: *„Optical properties of InGaAs/GaAs quantum wells with nonuniformities in well plane”* Promotor: Prof. dr hab. inż. Jan Misiewicz
2004 - 2008	Ph. D. at Wrocław University of Science and Technology, Institute of Physics.
2006 - 2008	Employment as independent physicist in European project 'ZODIAC' (*Zero order dimension based industrial components applied to telecommunicationss*).
2008	Receiving Ph. D. at Wrocław Universtity of Science and Technology. Topic of thesis: *„Application of electromodulation spectroscopy for investigating semiconductor structures based on gallium nitride”*. Supervisor: Prof. Jan Misiewicz
2008 - 2009	Research-didactic assistant at Wrocław University of Science and Technology, Faculty of Fundamental Problems of Technology, Intitute of Physics.
2009 - 2012	Employment within European project SensHy'(*Photonic sensing of hydrocarbons based on innovative mid infrared lasers*).
2009 - 2014 Od 2014	Assistant professor at Wrocław University of Science and Technology, Faculty of Fundamental Problems of Technology, Institute of Physics. Assistant professor at Wrocław University of Science and Technology, Faculty of Fundamental Problems of Technology, Department of Experimental Physics.
2012 - 1015	Employment within European project 'Widelase' (*Monolithic widely tunable interband cascade lasers for safety and security*)
Od 2015	Employment within European project 'iCspec' (*In-line Cascade Laser Spectrometer for Process Control*)
Conducted research:	
	Optical spectroscopy of semiconductors and semiconductor low-dimensional structures such as quantum wells and quantum dots. Modernisation of active region of semiconductor lasers designed to work in mid-infrared range.
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II. Summary of scientific achievements.

(Bibliometric date 14.01. 2017 according to Web of Science)

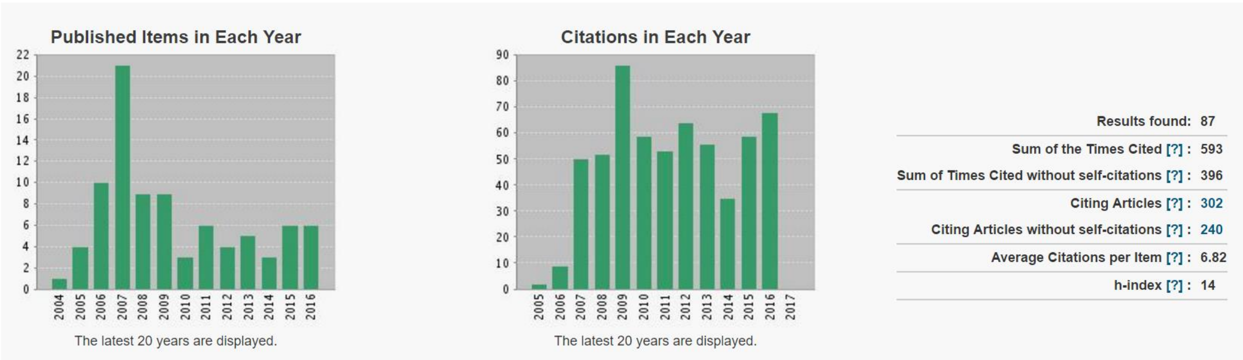
Number of publications in journals from the Master Journal List **87**

Summarized impact factor of publications   **~150**

Hirsh Index **14**

Number of article citations

Number of article citations excluding auto citations **396**



2.1 Summary of scientific achievements.

Most chosen journals:

Applied Physics Letters (IF=3.15, MNiSW points=40) - 17 articles
Journal of Applied Physics (IF=2.1, MNiSW points=30) -17 articles
Physica status solidi A (IF=1.5, MNiSW points=25) -5 articles
Journal of Physics D: Applied physics (IF=2.7, MNiSW points=35) - 3 articles

3. Course of previous scientific activity

3.1 Scientific activity before receiving Ph. D.

I have started my research work in Laboratory for Optical Spectroscopy of Nanostructures under the direction of prof. Jan Misiewicz on third year of physics studies, specialty solid state physics, on Faculty of Fundamental Problems of Technology at Wrocław University of Science and Technology. The subject of my research was application of spectroscopic optical techniques, such as photoreflectance, electroreflectance, and photoluminescence, for measuring properties of structures used for construction of semiconductor lasers based on semiconductor low-dimensional structures.

First conducted research was concluded with master thesis titled ***„Optical properties of InGaAs/GaAs quantum wells with nonuniformities in well plane”***. The research was realised in collaboration with McMaster University (Canada) and the results were published in Journal of Applied Physics in article '*Probing the indium clustering in InGaAs/GaAs quantum wells by room temperature contactless electroreflectance and photoluminescence spectroscopy'*[1].

I began my doctoral studies in Institute of Physics at Wrocław University of Science and Technology under supervision of prof. Jan Misiewicz in 2004. First phase of studies was dedicated to continuing research regarding lasing structures and developing spectroscopic techniques. Developing modulation spectroscopy was conducted in two ways, firstly, by implementing improvements in the contactless electroreflectance experiment, and secondly, by realising numerous measurements, purposed at understanding of mechanisms of modulation of built-in electric field in examined semiconductor structures. Experiments conducted in a manner of a function of wavelength and excitation power of excitating laser allowed to understand mechanisms of modulation in photoreflectance experiment [2], which were connected with generation of carriers on interface. In case of contactless electroreflectance it has been shown that the probing depth is significantly lower than in photoreflectancce due to external field screening caused by excessive carriers in examined structures[3]. On the other hand, it has been shown that lower probing depth allows to eliminate so called „below bandgap oscillations" often observed in photoreflectance spectra which complicate data analysis. Conclusions made allowed to apply both experiments in future research regarding degree of complication and types of investigated structures.

In years 2006-2008 I took part in projects regarding investigating active areas of laser structures designed for second and third telecommunication windows (1.3- 1.55 μm). The purpose was to establish emission and absorption properties of properly designed assemblies of quantum dots made of group III/V semiconductors. It involved, among others, investigating the nature of optical transitions of InGaAs/GaAs column quantum dots[4] and energetic structure of quantified levels and carrier escape processes in InAsN quantum dots set up in assembled in GaInAsN/GaAs quantum well[5].

Simultaneously I researched structures utilizing gallium nitride. This efforts led to doctoral thesis titled ***„Application of electromodulation spectroscopy for investigating semiconductor structures based on gallium nitride"*** and its defence summa cum laude. Results included in thesis concerned investigating AlInN/GaN quantum wells, important for manufacturing telecommunication lasers utilizing intrasubband transitions[6], and AlGaN/GaN heterostructures important for manufacturing high power field transistors. The most important results are

[1] M. Motyka, G. Sęk, R. Kudrawiec, P. Sitarek, and J. Misiewicz, J. Wójcik, B.J. Robinson, D.A. Thompson and P. Mascher, Journal of Applied Physics 101, 116107 (2007)

[2] M. Motyka, G. Sęk, R. Kudrawiec, J. Misiewicz, B. Alloing, L. H. Li, A. Fiore, Journal of Applied Physics 100, 073502 (2006)

[3] M. Motyka, R. Kudrawiec, J. Misiewicz, Physica Status Solidi A 204, 354-363 (2007)

[4] M. Motyka, G. Sęk, K. Ryczko, J. Andrzejewski, J. Misiewicz, L. H. Li, A. Fiore, G. Patriarche, Applied Physics Letters 90, 181933 (2007)

[5] M. Motyka, R. Kudrawiec, G. Sęk, J. Misiewicz, D. Bisping, B. Marquardt, A. Forchel, M. Fischer, Applied Physics Letters 90, 221112 (2007)

[6] M. Motyka, R. Kudrawiec, G. Cywiński, M. Siekacz, and C. Skierbiszewski, Applied Physics Letters 89, 251908 (2006)

determining of impact of dielectric overlap over shape of surface potential[7]; showing the effect of field screening by two dimensional electron gas[8]; and showing possibility of formation of surface quantum well in AlGaN/GaN heterostructures[9].
Mentioned research was conducted in collaboration with foreign centres IMEC (Belgium) and Wurzburg University (Germany), and domestic Institute of High Pressures Polish Academy of Science in Warsaw as well as Faculty of Microsystems and Photonics (WEMiF) of Wrocław University of Science and Technology.

Based on the results presented in my PhD thesis and other research I became author or co-author of 40 articles in journals such as: *Applied Physics Letters, Journal of physics D, Semiconductor Science and Technology.* Two of them were chosen to be published in prestigious electronics journal *Virtual Science and Technology*. Moreover, during doctoral studies I gave 10 conference talks regarding undergoing research.

During doctoral studies I took part in European research project *Zero Order Dimension based Industrial components Applied to telecommunication* (**ZODIAC**) realised under Sixth European Union Framework Programme. I was also employed in two domestic project of Ministry of Science and Higher Education, research project no. **N202 410933** (*Impact of built-in electric field on selection rules in polar Ga(In)N/Al(In)N quantum wells*), and **N515 07431/3896***, (Application of contactless electroreflectance and photoreflectance for investigating semiconductor structures designed on near and medium infrared range).*

In the last year of my doctoral studies (2008) I received Wrocław Max Born scholarship and START scholarship founded by Foundation for Polish Science for young scientists.

3.2. Scientific activity after receiving Ph. D.

Having received Ph. D. degree, on 1st October 2008 I was employed as a research-didactic assistant, and a year later, as an associate professor in the Institute of Physics at Wrocław University of Science and Technology. By that time I had started a new research field, associated with optical detection in medium infrared, which occupies mi until now. Conducted research realised under numerous domestic and European research projects purposed to manufacturing devices such as lasers and semiconductor detectors used for construction of optical gas sensors. This area of science fits in leading trends in contemporary solid state physics, being extraordinarily relevant in many aspects of life, such as medicine, or environment preservation. In those particular cases, optical sensors are utilized for monitoring harmful substances, or illness diagnostics by optical analysis of exhaled air. Nonetheless, manufacturing such sensors requires advance analytic tool, letting searching for new material solutions, and from the other side developing knowledge about optical properties of ingredient materials, in order to improve work parameters of devices.

First step after doctorate was creating measuring settlement allowing realising effective research in aforementioned spectral area. Conducting classic spectroscopic measurements realised with usage of lenses and diffraction grating in wavelengths above 3 μm is very difficult because of

[7] Kudrawiec, B. Paszkiewicz, M. Motyka, J. Misiewicz, J. Derluyn, A. Lorenz, K. Cheng, J. Das, and M. Germain, Journal of Applied Physics 104, 096108 (2008)

[8] M. Motyka, R. Kudrawiec, M. Syperek J. Misiewicz, M. Rudziński, P.R. Hageman, P.K. Larsen, Thin Solid Films, 515, 4662-4665 (2007)

[9] M. Motyka, M. Syperek, R. Kudrawiec, J. Misiewicz, M. Rudziński, P. R. Hageman, and P. K. Larsen, Applied Physics Letters 89, 231912 (2006)

factors such as: i) absorption of light by gas particles present in air, ii) absorption of light on optic devices (e.g. lenses), iii) requirement of cutting off higher diffraction orders (need for using filters), iv) lower sensitivity of detectors compared to ones used in near infrared. All those factors cause that realisation of experiments such as photoluminescence or photoreflectance in mid and far infrared is difficult or even impossible. Innovatory solution eliminating most of mentioned difficulties was starting measuring settlement using vacuum Fourier spectrometer[10]. Such solution created possibility of conducting experiments requiring high spectral resolution, as well as space for creation new experiments such as fast differential reflectance[11]. This experiment, realised using rapid scan option, allows to significant reduction of acquisition time of optical spectra, with simultaneous maintaining high signal-to-noise ratio. It has been shown, that compared to measurements conducted in conventional monochromator setup, measurement time has been reduced from couple hours to single minutes[12].

Launching this measurement settlement opened possibilities to research many types of semiconductor material types supplied by different domestic and foreign centres, such as:

- AlGaAs/GaAs superlattices

[Institute of Electron Technology, Warsaw]

Growth MBE: **Appations**: optoelectronics, quantum cascade lasers

Research conducted for this material type were conducted in two ways. Firstly, by using photoreflectance measurements supported by calculations of energetic structure quantified energy levels, optical verification of growth parameters of test AlGaAs/GaAs superlattices with different thickness of both AlGaAs and GaAs layers has been made. Based on analysis of optical transitions measured in both Γ well as Π points of Brillouin zone it has been shown a few percent of discrepancy in layers' thickness regarding assumed plan[13]. The other approach was to optically verify intrasubband transitions for superlattices imitating scheme of final active areas for quantum cascade lasers. In this approach, distances between levels, between which the laser action is to appear, were verified directly by measuring photoluminescence in area of intrasubband transitions[14]. It is worthy to emphasise, that mentioned research was conducted on samples manufactured in the Institute of Electron Technology in Warsaw, and now are being continued for superlattices designed for emission in terahertz range[15].

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[10] M. Motyka, G. Sęk, J. Misiewicz, A. Bauer, M. Dallner, S. Höfling, and A. Forchel, Applied Physics Express 2, 126505 (2009)

[11] M. Motyka, G. Sęk, F. Janiak, J. Misiewicz, K. Kłos, J. Piotrowski, Measurement Science and Technology 22, 125601 (2011)

[12] M. Motyka and J. Misiewicz, Applied Physics Express 3, 112401 (2010)

[13] M. Motyka, F. Janiak, J. Misiewicz, M. Wasiak, K. Kosiel, M. Bugajski, Opto-Electronic Review 19, 151–154 (2011)

[14] F. Janiak, M. Dyksik, M. Motyka, J. Misiewicz, K. Kosiel, M. Bugajski, Optical and Quantum Electronics 47, 945–952 (2015)

[15] M. Dyksik, M. Motyka, W. Rudno-Rudziński, G. Sęk, J. Misiewicz , D. Pucicki, K. Kosiel, I. Sankowska, J. Kubacka-Traczyk and M. Bugajski, Journal of Infrared, Terahertz and Millimeters Waves, DOI 10.1007/s10762-016-0259-8

- InAs/GaSb Superlattices
[Military University of Technology, Warsaw]
Growth MBE: **Applications**: optoelectronics, infrared detectors

Research on InAs/GaSb superlattices was performed under project conducted by me titled *"Optical properties of low-dimensional semiconductor structures probed by Fourier spectroscopy in infrared"*. Performed experiments focused mainly on photoluminescence measurements of series of samples with different layer thickness. The most relevant results were discovering photoluminescence signal with energy 140 meV lower than fundamental optical transition for 10 monolayers/10 monolayers superlattice[16]. Further research allowed to determine the nature of this signal, and connect it with presence of localised states in these superlattices[17]. It is a very valuable piece of information because presence of such states may affect tunnelling processes through these states, and in consequence negatively increase dark currents in detectors with active area utilizing these superlattices.

- InGaAsSb/Al(In)GaAsSb quantum wells
[University Montpellier 2-CNRS, Montpellier, France]
Growth MBE: **Applications**: optoelectronics, semicoductor lasers

These structures were researched under European project titled '*Photonic sensing of hydrocarbons based on innovative mid infrared lasers'* (SensHy). The purpose of the project was creating a laser source emitting at 3.4 µm wavelength, for application in methane sensing. One of considered active areas was InGaAsSb/AlGaAsSb quantum wells. Performed experiments allowed to determine band discontinuity for this type of quantum wells and in consequence showing limits in tunability of emission wavelength in this material setup[18]. Research conducted in following years has shown that incorporation of fifth element into barrier in InGaAsSb/Al(In)GaAsSb material setup allows for receiving emission in desired 3-4 µm range with simultaneous maintenance of band discontinuity allowing to good hole confinement in confining potential. Moreover, by using temperature dependent photoluminescence measurements, main quenching mechanisms of photoluminescence has been determined as delocalisation of excitons in temperatures lower than 100 K and carrier escape through excited states in temperatures higher than 100 K[19].

- AlSb/InAs/InGa(As)Sb/InAs/AlSb type II quantum wells.
[Wurzburg University, Germany]
Growth: MBE **Application**: optoelectronics, interband cascade lasers.

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[16] J. Wróbel, E. Plis, W. Gawron, M. Motyka, P. Martyniuk, P. Madejczyk, A. Kowalewski, M. Dyksik, J. Misiewicz, S. Krishna and A. Rogalski, Sensors and Materials 26, 235-244 (2014)

[17] J. Wróbel, Ł. Ciura, M. Motyka, F. Szmulowicz, A. Kolek, A. Kowalewski, P. Moszczyński, M. Dyksik, P. Madejczyk, S. Krishna and A. Rogalski, Semiconductor Science and Technology 30, 115004 (2015)

[18] M. Motyka , G. Sęk, K. Ryczko , J. Misiewicz , S. Belahsene , G. Boissier, Y. Rouillard, Journal of Applied Physics 106, 066104 (2009)

[19] G. Sęk, M. Motyka, K. Ryczko, F. Janiak, J. Misiewicz, S. Belahsene, G. Boissier, and Y. Rouillard, Japanese Journal of Applied Physics 49, 031202 (2010)

Research conducted over this type of objects are being realised under long-term collaboration with Wurzburg University, where aforementioned type-II quantum wells are manufactured by using molecular beam epitaxy method. Experiments in this area were conducted in numerous aspects, both in terms of optimising growth parameters (including improvement in uniformity of wave emission), as well as modernisation of active areas in laser devices utilising this type of quantum wells[20]. It is worth to mention, that research has been conducted under European Union programme Horizon 2020, project ICSPEC (In-line Cascade Laser Spectrometer for Process Control). Experiments were purposed for optimisation of work parameters of interband cascade lasers designed for optical detection of gases such as methane, formaldehyde or methanol.

- InAs/GaInAsSb heterojunctions.
[IOFFE Institute, Saint Petersburg, Russia]
Growth: LPE: **Applications**: junction lasers

This type of heterojunction is also using type-II material setup as mentioned before InAs/InGa(As)Sb quantum wells. Experiments of these structures result from recently developed collaboration with IOFFE Institute, concerned on determining energy of spin-orbit coupling for InGaAsSb layers deposited with liquid phase epitaxy method on indium arsenide substrate. Acquired information on relation of band gap energy and spin-orbit coupling energy are to supply information on possibility of minimisation of Auger process impact, and in consequence increasing work temperature of junction lasers utilising this material type[21]. More information will be shown in next chapter, as research on material setups utilising band discontinuity are vital part of habilitation process.

4. Indication of the scientific achievement based on art. 16 par. 2 act from 14 March 2003 on scientific degrees and the scientific title and on degrees and title in arts (Dz.U.nr 65, poz. 595 ze zm.).

4.1. As a scientific achievement according to the aforementioned act I point **monothematic cycle of publications** pt. "*Optical properties of active areas of semiconductor lasers designed for mid infrared range, utilizing structures with type-II band discontinuity"*

4.2. Publications consisting of the scientific achievement:

Presented 10 monothemtatic publications featuring contemporary solid-state physics particularly regarding optical investigating semiconductor low-dimensional structures used as active areas of lasers designed for mid-infrared range.

[20] M. Motyka, K. Ryczko, G. Sek, F. Janiak, J. Misiewicz, A. Bauer, S. Höfling, A. Forchel, Optical Materials 34, 1107–1111 (2012)

[21] M. Motyka, F. Janiak, G. Sęk, J. Misiewicz, K.D. Moiseev, Applied Physics Letters 100, 211906 (2012)

Series of **10** publications forming habilitation dissertation with information on impact factor (in year of publishing) and current ministerial punctation.

A1. **M. Motyka,** G. Sęk, K. Ryczko, J. Misiewicz, T. Lehnhardt, S. Höfling, and A. Forchel, *'Optical properties of GaSb-based type II quantum wells as the active region of mid infrared interband cascade lasers for gas sensing applications'*, **Applied Physics Letters** 94, 251901 (2009) [Impact Factor = 3.6, Lista MNiSW=35]

A2. **M. Motyka,** G. Sęk, J. Misiewicz, A. Bauer, M. Dallner, S. Höfling, and A. Forchel, *'Fourier transformed photoreflectance and photoluminescence of mid infrared GaSb-based type II quantum wells',* **Applied Physics Express** 2, 126505 (2009) [Impact Factor = 2.2, Lista MNiSW=30]

A3. **M. Motyka** and J. Misiewicz, *'Fast Differential Reflectance Spectroscopy of Semiconductor Structures for Infrared Applications by Using Fourier Transform Spectrometer'*, **Applied Physics Express** 3, 112401 (2010) [Impact Factor = 2.8, Lista MNiSW=30]

A4. **M. Motyka**, K. Ryczko, M. Dyksik, G. Sek, J. Misiewicz, R. Weih, M. Dallner, S. Höfling and M. Kamp, *'On the modified active region design of interband cascade lasers'*, **Journal of Applied Physics** 117, 084312 (2015) [Impact Factor = 2.1, Lista MNiSW=30]

A5. F. Janiak, G. Sek, **M. Motyka**, K. Ryczko, J. Misiewicz, A. Bauer, S. Höfling, M. Kamp, and A. Forchel, *'Increasing the optical transition oscillator strength in GaSb-based type II quantum wells'*, **Applied Physics Letters** 100, 231908 (2012) [Impact Factor = 3.8, Lista MNiSW=35]

A.6. F. Janiak, **M. Motyka**, G. Sek, M. Dyksik, K. Ryczko, J. Misiewicz, R. Weih, S. Höfling, M. Kamp, and G. Patriarche, *'Effect of arsenic on the optical properties of GaSb-based type II quantum wells with quaternary GaInAsSb layers'*, **Journal of Applied Physics**, 114, 223510 (2013) [Impact Factor = 2.2, Lista MNiSW=30]

A7. **M. Motyka***,* G. Sęk, K. Ryczko, M. Dyksik, R. Weih, G. Patriarche, J. Misiewicz, S. Höfling and M. Kamp, *'Interface intermixing in type II InAs/GaInAsSb quantum wells designed for active regions of mid-infrared emitting interband cascade lasers',* **Nanoscale Research Letters** 10:471 (2015) [Impact Factor = 2.6, Lista MNiSW=30]

A8. **M. Motyka**, M. Dyksik, K. Ryczko, G. Sęk, J. Misiewicz, R. Weih, M. Dallner, M. Kamp and S. Höfling, *'Type II QWs with tensile strained GaAsSb layers for interband cascade lasers'*, **Applied Physics Letters**, 108, 101905 (2016) [Impact Factor = 3.15, Lista MNiSW=35]

A9. **M. Motyka**, F. Janiak, G. Sęk, J. Misiewicz, K.D. Moiseev, *'Temperature dependence of the energy gap and spin-orbit splitting in a narrow-gap InGaAsSb solid solution',* **Applied Physics Letters** 100, 211906 (2012) [Impact Factor = 3.8, Lista MNiSW=35]

A10. **M. Motyka**, M. Dyksik, F. Janiak, K. D. Moiseev, J. Misiewicz*, 'The spin–orbit splitting band in InGaAsSb alloys lattice-matched to InAs',* **Journal of Physics D: Applied Physics** 47, 285102 (2014) [Impact Factor = 2.7, Lista MNiSW=35]

4.3. Discussing scientific purpose of aforementioned works and achieved results and showing applications of those.

Introduction

Precise optical detection of numerous substances, especially gases is based on molecular absorption of light in infrared range. It is connected with possibility of measuring of absorption of characteristic wavelength dependent on certain molecular vibration modes of individual gases. For performing such measurements it is required to use precise light sources with specified optical properties. In terms of optical detection of gases the most important features are output power and mode (impulse or continuous). On the other hand, when discussing usability of a sensor it is vital that such source wouldn't require cooling with cryogenic liquid and had low power consumption. All those aspects create constant need for improvement of work parameters of laser sources. Research shown in below articles is regarding improvement, reorganisation or proposals of new active areas for two types of semiconductor lasers utilizing second type band discontinuity. First type is the interband cascade laser (ICL), which theoretical concepts and prototypes came out in the 1990s[22,23].

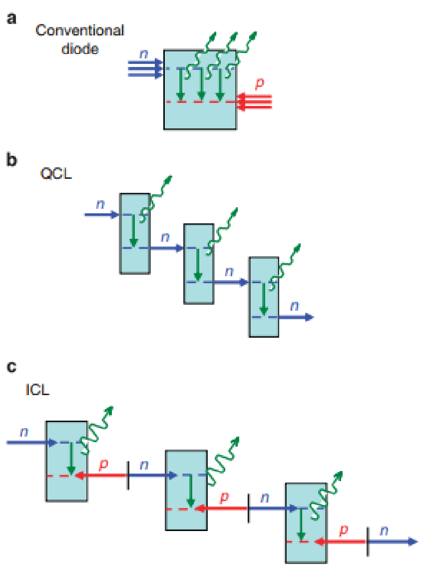


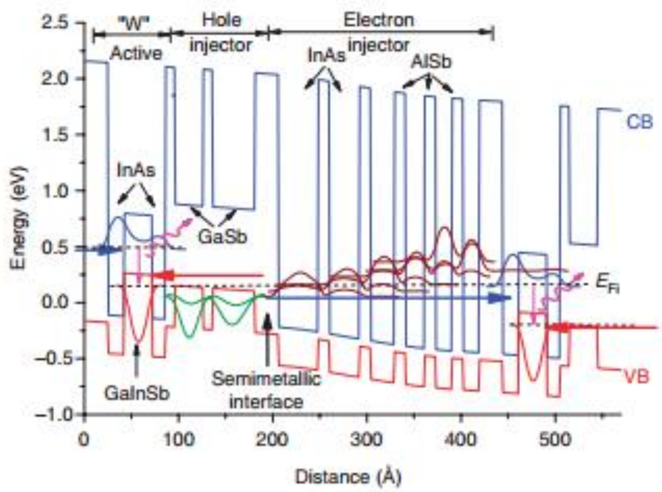
Fig. 1. Laser action in a conventional diode (a), quantum cascade laser (b) and interband cascade laser(c)[27].

[22] R. Q. Yang, *'Infrared lasers based on intersubband transitions in quantum wells'*, Superlattices Microstruct. 17, 77–83 (1995).

[23] J. R. Meyer, C. A. Hoffman, F. J. Bartoli, and L. R. Ram-Mohan, *'Type II quantum well lasers for mid wvelength infrared'*, Appl.Phys. Lett. 67, 757 (1995).

It has been shown that such laser can be successfully utilized for atmosphere monitoring (e.g. methane leakage detecting[24]), but also in medical diagnostics (analysis of exhaled air[25]).

Describing the idea of action of interband cascade laser one may say, that it is a hybrid of quantum cascade laser and conventional laser diode[26]. In an ICL both types of carriers are being used for laser action both electron and holes as in typical diodes, but they are injected onto lasing levels thanks to systems of cascades as in the quantum cascade lasers. Scheme of action is shown in figure 1, where lasing processes are shown for diode laser (fig. 1a), quantum cascade laser (fig. 1b), and interband cascade laser (fig. 1c).Typical active area in such laser is shown in figure 2, along with probability density for carriers confined in layers. Characteristic feature of this system is the fact of confinement of electrons and holes in neighbouring layers, electrons in InAs and holes in GaInSb. Such a solution allows to independently modify energy levels in layers with changing their thickness and compositions affecting energy of fundamental optic transition. Additionally, injecting carriers into active area is performed in means of tunnelling carriers through properly designed areas of superlattice both for electrons, as well as holes.



Rys. 2. Scheme of layer allignment in typical ICL with marked electron and holes injection layers and active area, in which emission occurs[27].

Obtaining further longer wave emission requires for example widening well layers in order to lower energy levels. On the other hand, change in thickness causes wavefunctions to separate, and as a consequence, decrease of wavefunction overlap. It is a relevant fact having impact on oscillator

[24] L. Dong, C. Li, N. P. Sanchez, A. K. Gluszek, R. J. Griffin, and F. K. Tittel, '*Compact CH4 sensor system based on a continuous-wave, low power consumption, room temperature interband cascade laser'*, Appl. Phys. Lett. 108, 011106 (2016)

[25] T. H. Risby & F. K. Tittel, *'Current status of midinfrared quantum and interband cascade lasers for clinical breath analysis'*, Optical Engineering 49, 111123 (2010)

[26] I. Vurgaftman, W.W. Bewley, C.L. Canedy, C.S. Kim, M. Kim, C.D. Merritt, J. Abell, J.R. Lindle, J.R. Meyer, *'Rebalancing of internally generated carriers for mid-infrared interband cascade lasers with very low power consumption'*, Nature Communications DOI: 10.1038/ncomms1595

strength, and in consequence laser gain of final device[27]. For optical transitions in quantum wells wavefunctions of carriers can be expressed as a product of so called Bloch function U(r) and an envelope function in direction of structure growth F(z). In such approach oscillator strength is proportional to:

$f \sim \frac{P_{if}^2}{E^f - E^i} \left| \langle F_f(z) | F_i(z) \rangle \right|^2$, where P_{if}^2 -is a matrix element and $\left| \langle F_f(z) | F_i(z) \rangle \right|$ - is the overlap of wavefunctions. Assuming that in proposed changes of potential part $\frac{P_{if}^2}{E^f - E^i}$ doesn't change significantly (less than 10%) then oscillator strength is proportional to square of wavefunctions overlap integral:

$$f \sim \left| \langle F_e(z) | F_h(z) \rangle \right|^2 = \left| \int_{-\infty}^{\infty} F_e^*(z) \cdot F_h(z) \mathrm{d}z \right|^2$$

This value becomes useful for theoretical verification of proposed changes in confining potential, predicting their impact on intensity of optical transitions. On the other hand, oscillator strength is verified experimentally via photoreflectance experiment. Absorption features measured in spectra are modelled in terms of their shape by expression:

$$\frac{\Delta R}{R}(E) = \mathrm{Re}\left[\sum_{j=1}^{n} C_j \cdot e^{i \cdot \vartheta_j} \left(E - E_j + i \cdot \Gamma_j \right)^{-m_j} \right],$$

where n defines the number of optical transitions, C_j - amplitude, θ_j - phase, E_j - energy a Γ_j - broadening of transition. Parameter m captures character of critical point in Brillouin zone. Parameters received in analysis are shown as function modulus, which allows to connect oscillator strength of optical transition with area under curve:

$$\Delta\rho(E) = \frac{|C|}{\left[(E - E_0)^2 + \Gamma^2 \right]^{\frac{m}{2}}}.$$

Conducted research regarding active areas in interband cascade lasers were focused mainly on verification of impact of proposed changes in confining potential, such as additional number of InAs layers, change of composition, or even change of material for confining holes, on fundamental optical transition oscillator strength. Evaluating of quality of proposed changes were achieved by optical measurements conducted on properly designed and manufactured quantum wells. These measurements were possible thanks to long-year collaboration with Wurzburg University, where examined quantum wells are manufactured by molecular beam epitaxy technique.

Second interesting type of structures using type II are heterostructures InGaAsSb/GaInAsSb/InAs forming active area in junction laser for 3-4 µm range. This type lasers

[27] Guobin Liu and Shun-Lien Chuang, '*Modeling of Sb-based type-II quantum cascade lasers*', Phyical Review B 65, 165220 (2002)

has been firstly manufactured in the beginning of 21st century[28]. As per now, it has been shown that it is possible of obtaining laser action in range only 3-4 µm with application of various schemes of heterostructures, nevertheless two facts need to be emphasised: Firstly, even in such narrow spectral range we find absorption lines of a few relevant gases, particularly hydrocarbons. Secondly, those lasers are manufactured with vapour phase epitaxy, significantly cheaper than molecular beam epitaxy, which is required for precise growth of quantum wells in interband and quantum cascade lasers.

Regarding second type of lasers, since this type of laser is based on typical p-n junction formed by two bulk semiconductors, the most relevant parameters, from the viewpoint of emission wavelength, but also emission efficiency, are parameters such as band gap of both semiconductors, energy of donor and acceptor states, as well as energy of the spin-orbit level. For now, no room temperature emitting InGaAsSb/GaInAsSb/InAs junction lasers had been manufactured, which is probably related to Auger processes. Let's consider two types of such processes (figure 3.). In first, an electron and a hole are interacting generating another electron into the conduction band (a) and a process in which interacting carriers generate a hole through spin-orbit level into the valence band (b). In narrow-gap materials, particularly important is the process happening in the valence band. It has been shown, that when energy of a band gap is nearly equal to energy of the spin-orbit coupling level (c) availability of this level significantly grows for the Auger processes, causing an increase to their intensity[29].

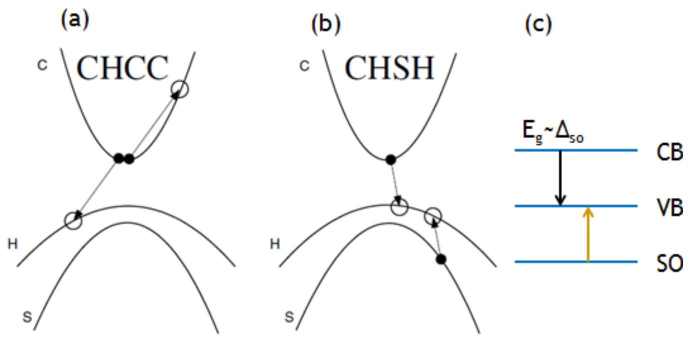


Fig. 3. Scheme for Auger processes with electron generation (a), and hole generation (b). Illustration of a situation of equalizing energies of band gap an spin orbit level (c).

Such situation is disadvantageous from the viewpoint of emission, because part of energy is wasted, which causes intensity losses, and increases device temperature. Additionally, which needs to be emphasised, equality of energy gaps causes an increase to interband absorption in this band which in consequence increases optical losses in emitter. In conducted research realised within described heterojunctions, main focus was centred on determination of correlation between band gap energy and spin-orbit interaction energy for InGaAsSb layers of wide range of compositions. Obtaining such an information allows to improve layers composition of a heterojunction in order to reduce

[28] K.D. Moiseev, M.P. Mikhailova, Yu.P. Yakovlev, *'Mid-infrared lasing from self-consistent quantum wells at a type II single broken-gap heterointerface'*, Physica E 20, 491–495 (2004)

[29] M. P. Mikhailova, I. A. Andreev,*' Mid-Infrared Semiconductor Optoelectronics'*, ed. A Krier (Berlin:Springer) p 547(2006)

Auger processes an intersubband absorptions, increasing work temperature of such lasers. Research in this field was realised on semiconductor structures manufactured in the IOFFE institute.

Discussing aforementioned work and achieved results

A1. This work shows results of two year research realise within international project **„***Photonic sensing of hydrocarbons based on innovative mid infrared lasers"* (SensHy), concerning searching and verification of growth parameters of active areas for interband cascade lasers. Results posted in the paper concern experiments on series of samples of AlSb/GaInSb/InAs quantum wells deposed on GaSb substrate. Conducted research for quantum wells with different InAs width from 1 to 3 nm has shown possibility for emission wavelength tuning in broad range 2-6 µm. It is very important result showing wide spectrum of application possibilities for this type of quantum wells. It is known, that infrared 2-6µm range is an area in which many gases have their absorption lines, such as methane (3.4 µm) or carbon dioxide (4.1 µm). On the other hand, it has been observer, that change in width of one monolayer shifts emission wavelength for (0.5 µm), which points to possibility of manufacturing lasers emitting in broad spectral range. Moreover, measurements of temperature dependent photoluminescence have been performed, that pointed towards small change (range of 25meV) of energy of fundamental transition in temperature (in range 10-300K), compared to e.g. first type InGaSb/GaSb quantum wells, where the shift is at least twice bigger[30]. An additional confirmation of possibility of application such quantum wells as an active area in interband cascade lasers, was receiving photoluminescence signal in room temperature. As a consequence, a laser structure has been manufactured, and later construction of first cascade laser manufactured at Wurzburg University emitting at 3.4µm in room temperature[31].

My contribution in work A1 consisted of performing experiments in the field of optical spectroscopy, interpretation of the results of experiments and writing the manuscript. I estimate my contribution at 60 %.

A2. In this work has been performed experiments on AlSb/InAs/GaInSb/InAs/AlSb "W-shape" quantum wells (called so owing to the shape of potential for electrons). Compared to active areas studied in work A1 modification has been made by applying additional InAs layer. This research confirmed wide tunability of emission wavelength in such material system and shown significant improvement of choice of growth parameters compared to quantum wells which had been researched before (e.g. choice of pressure in arsenic effusion cells). Spectra received in room temperature had high intensity and signal-to-noise ratio, which is of great significance in terms of quantum efficiency in researched W-shaped layer system. Conducted photoreflectance experiments allowed additionally to detect a transition with the participation of higher electron state. High

[30] M. Motyka, R. Kudrawiec, J. Misiewicz, M. Hümmer, K. Rößner, T. Lehnhardt, M. Müller, and A. Forchel, *'Photoreflectance and photoluminescence study of $Ga_{0.76}In_{0.24}Sb$/GaSb single quantum wells: Band structure and thermal quenching of photoluminescence'* Journal of Applied Physics 103, 113514 (2008)

[31] A. Bauer, F. Langer, M. Dallner, M. Kamp, M. Motyka, G. Sęk, K. Ryczko, J. Misiewicz, S. Höfling, and A. Forchel, *'Emission wavelength tuning of interband cascade lasers in the 3–4um spectral range'*, Applied Physics Letters 95, 251103 (2009)

energy of this transition allow to conclude that this state does not participate in escape of carriers from quantum well. It has been confirmed[32] with later experiments, which tied carrier escape mechanisms to escape of hole into GaSb layer.

Additionally, this work showed measurement setup for photoluminescence and photoreflectance spectra, utilizing Fourier spectrometer. This approach uses co called „step-scan mode" in which the mirror moves in steps. Assembled system (shown in figure 4) had been designed in a way to entirely eliminate the impact of absorption of atmospheric gases. Due to usage of vacuum pomp, before a measurement air is pumped out of system, and experiments are realized under 1,5 hPa pressure. Combination of available light sources and detectors allows to realise modulation spectroscopy experiments in range 0.5-17 µm including unavailable earlier spectral ranges, that is mid- and far-infrared.

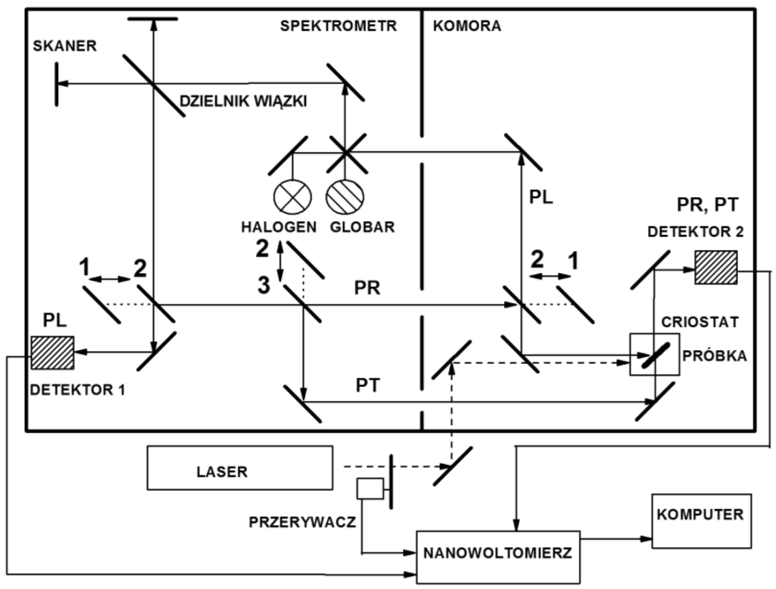


Fig 4. Scheme of experimental setup using Fourier spectrometer.

My contribution to work A2 consisted of setting up experimental setup, conducting experiments in the field of optical spectroscopy, interpretation of the results and writing a manuscript. I estimate my contribution at 60%.

A3. In this paper there have been shown details of realisation of Fast Differential Reflectance (FDR) experiment. It's an experiment in the field of absorption spectroscopy and is in a sense a variety of a photoreflectance experiment. The acquisition of data is based on measurement of two reflectance spectra, one of which is measured with additional lightning with a laser beam. Because the essential spectra are collected with natural mirror mode in a spectrometer, so called rapid scan, acquisition even of broad spectra takes only single minutes. This works show results of conducted

[32] G. Sek, F. Janiak, M. Motyka, K. Ryczko, J. Misiewicz, A. Bauer, S. Höfling, A. Forchel, *'Carrier loss mechanisms in type II quantum wells for the active region of GaSb-based mid-infrared interband cascade lasers',* Optical Materials 33, 1817–1819 (2011)

FDR on i.e. type II AlSb/InAs/GaInSb quantum wells. The research has proven that it is possible in this experiment remaining high detectivity allowing to measure optical transitions even connected with excited states (up to 300K) with simultaneous reduction of measurement time (including measurements in LWIR[33]). Realisation of such experiments allows to receive vital information associated with calibration of growth parameters, such as layer thickness, important from a viewpoint of designing shape of confining potential or energies of quantified level in short time. Moreover, using the Berreman effect, FDR experiment realised as a function of probing light polarisation can be used for optical verification of doping level of waveguide layers in interband cascade lasers[34]. Such an approach can be very useful from a viewpoint of other laser sources, in which doped layers are being utilized e.g. for a proper carrier injection into active area.

My contribution to work A3 was invention and realisation of the FDR experiment, interpretation of results and writing a manuscript. I estimate my contribution at 85%**.**

A4. This work is a continuation of research on active area of interband cascade lasers shown i papers A1 and A2. The purpose of proposed modernisation were to obtain higher oscillator strength, and as a consequence wider gain range in laser. It is worth to mention, that the research was conducted within European Project WideLase, *"Monolithic Widely Tunable Interband Cascade Lasers for Safety and Security"*, concluded with manufacturing of optical detectors of ethanol, using a interband cascade laser. Compared to typically used combination of layers creating shape of letter "W" (called „double" from the number of InAs layers), this new approach there has been manufactured quantum wells with additional layers of InAs and GaInSb (called „triple"). This research has been conducted for structures deposed on two different types of substrates, and two different ranges of emitted radiation (~3.5 µm i ~6.5 µm). Research shown reduction of energy of the fundamental transition, that is shifting wavelength towards longer waves for modified wells. Moreover, detailed analysis of PR spectra allowed to experimentally confirm assumed improvement of oscillator strength for fundamental optical transition in modified potential. Achieved results shown, that applying of this solution can have significant matter particularly for designing active areas of lasers emitting in LWIR. To obtain emission in range beyond 8 µm there is need to apply comparably wider layers, which causes the wavefunction overlap to deteriorate, and as a consequence lack of ICL emitting in room temperature in this spectral range. Significant ease in this matter could be applying triple layers, thanks to which it would be avoided to additionally widen layers, with simultaneous increase to oscillator strength for fundamental optical transition, which could increase temperature for lasing action.

My contribution to this work was planning the experiment, interpreting the results and writing the manuscript**.** I estimate my contribution at 40%.

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[33] M. Motyka, G. Sęk, F. Janiak, J. Misiewicz, K. Kłos, J. Piotrowski, *'Fourier-transformed photoreflectance and fast differential reflectance of HgCdTe layers. The issues of spectral resolution and Fabry–Perot oscillations'*, Measurement Science and Technology 22, 125601(2011)

[34] M. Dyksik, M. Motyka, G. Sęk, J. Misiewicz, M. Dallner, S Höfling, M. Kamp, '*Influence of carrier concentration on properties of InAs waveguide layers in interband cascade laser structures*', Journal of Applied Physics, 120, 043104 (2016)

A5. In this publication there has been shown results focused on aspect of increasing oscillator strength of fundamental optical transition in AlSb/InAs/GaInSb/InAs/AlSb quantum wells. Experiments has been conducted for several structures with different concentration of indium in GaInSb layers as well as different layers' thickness confining both electron as well as holes. Conducted experiments showed possibility of increasing oscillator strength by reduction of indium content in GaInSb layers, with simultaneous reduction of fundamental transition energy. Moreover, there has been proposed modification of active area in valence band, by applying quaternary layer containing GaInAsSb. Deployment of arsenic into GaInSb layers should, owing to the reduction of strain, lower the energy of fundamental transition with simultaneous improvement of wavefunction overlap of electron and holes. Thanks to comparison of optical spectra of reference quantum wells with GaInSb layers with modified GaInAsSb quantum wells there has been concluded, that application of arsenic improves oscillator strength of the fundamental optical transition.

> My contribution to this work was planning the experiments, interpreting the results and making redaction corrections in the manuscript**.** I estimate my contribution at 30%.

A6. The continuation of efforts on quantum wells with GaInAsSb was aspect of localised states. Photoluminescence experiments have shown presence of low energy signal with energy lower than fundamental optical transition. Analysis of temperature-dependent spectra of both signals have shown that intensity of signal from a quantum well is increasing, while low-energy signal is decreasing. Such a behaviour shows possibility of carrier transfer into quantum well area from localised states on InAs/GaInAsSb interface. To support this thesis of presence of localised states in arsenic induced quantum wells, several experiments have been conducted, which have shown that low-energetic signal observed in PL spectra is not related with band structure of confining potential. For example, PL measurements in function of excitation power have been made, and they showed, that for the low-energy signal there happens quicker saturation of intensity in excitation power function compared to quantum wells signal, which points to localised character of this emission. Because there has been observed, that energy of this signal is slightly changes with temperature, localisation of this states has been connected with InAs/GaInAsSb interface. Presence of such states can be a source of dispersion in laser structure deteriorating emission intensity, which pointed towards necessity of further optimisation of growth of such wells with emphasis of minimization of generation of states localised on interfaces.

> My contribution to this work was planning the experiments and partially performing them, interpreting of the results and making redaction corrections in the manuscript. I estimate my contribution at 40%.

A7. This publication is entirely devoted to research of properties of InAs/GaIn(As)Sb interfaces in type II quantum wells. Conducted PL and PR experiments have shown unexpected growth of fundamental transition in quantum well with GaInAsSb (fig. 5b) layer, compared to reference quantum well with GaInSb layer (fig. 5a). Calculated location of spectra for expected transition energy after insertion of arsenic atoms, assuming rectangular shape of well, is shown with dotted line.

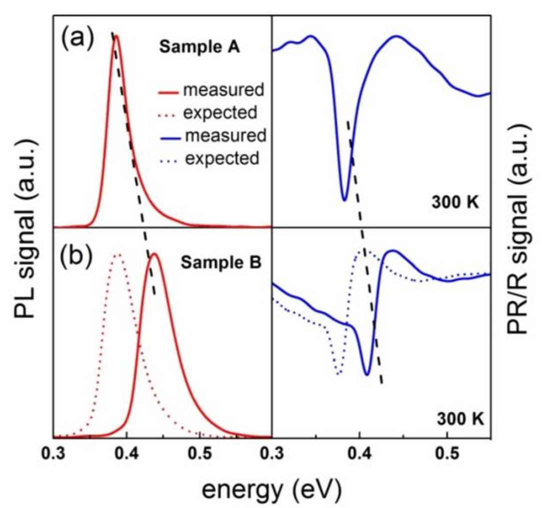

Fig. 5. PL (left panel) and PR (right panel) for quantum wells with GaInSb (a) and GaInAsSb (b) layers [A7].

It has been shown, that instead expected shift towards lower energies (longer waves) after induction of arsenic noticeable growth of transition energy has been noticed. Further experiments of roentgen spectroscopy and transmission electron microscopy have shown that addition of arsenic atoms into GaInSb layer changes not only band gap energy or strains, but has significant impact on shape of confining potential intensifying processes of interface intermixing. This situation implies necessity of additional modelling of shape of confining potential regarding diffusion of elements comprising neighbouring layers InAs and GaInAsSb. Proposed solution includes e.g. using the error functions in the simulations of shape of interface with localisation effects. Properly modified shape of quantum well potential allows to change energy of levels, and as a consequence, increase of energy of fundamental transition and resulting in compatibility with experimental data.

My contribution into this work was performing PL and PR experiments, interpreting the results and writing the manuscript. I estimate my contribution at 60%.

A8. In this work there has been shown results of research of new type of active area of ICL with active layer with GaAsSb. In this type of quantum wells introducing GaAsSb layer instead of typically used GaInSb layers changes of type of strain from compressive to tensile, which along with right composition and thickness of layers allows to energy change between heavy and light holes. In limit case, with sufficiently large arsenic content (approx. 20-25%) and width of GaAsSb (over 5 nm) there is a possibility of realisation of fundamental optical transition only with light hole state. Research was conducted on series of samples with different layer thickness and different arsenic content. The most important results, illustrated on figure 6, was obtained for quantum wells with 25% arsenic.

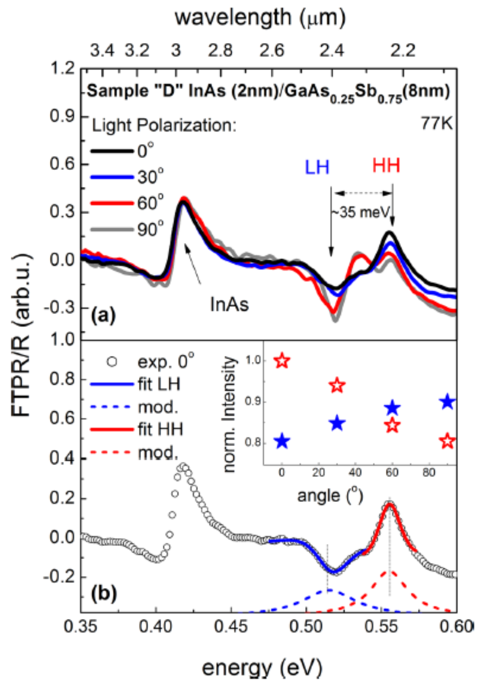

Fig. 6. PR spectra as a function of degree of polarisation of probing light for AlSb/InAs/$GaAs_{25}Sb_{75}$ /InAs/AlSb quantum well (panel a) with analysis (panel b) [A8]

Interpretation of intensity behaviour measured in optical transition spectra (for different polarisations of probing light), in terms of polarisational selection rules, shown separate character of measured signals and allowed to tie them with heavy and light holes levels in quantum well (assuming that fundamental transition has a light hole character). Achieved results allows to conclude, that application of GaAsSb layers increase degree of freedom in designing active areas of ICL, including possibility of manufacturing MIR emitter with polarisation independent laser beam. Such a situation can take place with proper designing values of strain and layer thickness, for ensuring proper contribution of wavefunctions of heavy and light holes in forming fundamental laser emission.

My contribution in this work was partially performing the experiments, interpreting the results and writing the manuscript**.** I estimate my contribution at 60%.

A9. This work concerns optical research of second type heterojunctions used as active areas of junction p-GaInAsSb/n-InGaAsSb lasers for a MIR range. Conducted PL measurements allowed to determine temperature coefficient of band gap energy changes for $In_{0.86}Ga_{0.14}As_{0.83}Sb_{0.17}$ layer deposed on InAs substrate (-0.41meV/K). Additionally, thanks to detection of low temperature signal connected with donor-acceptor previously unknown transition energy of acceptor level has been determined (E_A=27meV). Further research was focused on the aspect of determining energy of spin-orbit interaction for a layer. It was possible due to obtaining optical spectra, in which besides transition based on absorption from band gaps observer also transition between valence band and spin-orbit band. Thanks to analysis of these spectra energy of spin-orbit interaction has been determined (Δ_{so}= 460meV). Additionally, it has been shown that energy of spin-orbit interaction does not changes with temperature. This property seems important regarding suppression of Auger processes, realised by change of relation between energy of band gap, and energy of spin-orbit split-off by proper choice of temperature.

My contribution into this work was performing PL and PR experiments, interpreting the results and writing the manuscript. I estimate my contribution at 70%.

A10. This work is a continuation of research begun in work A9 focused on type II heterojunctions, used as active areas of junction lasers in MIR range. Vast research has been conducted in the area of fundamental transition E_0 and $E_0+\Delta_{so}$ transition for several samples of InGaAsSb layers with different composition. It has been observed that in range of gallium content varying from 5% to 17% energy of band gap changes only for 10 meV, while energy of spin-orbit transition changes in range of tens of meV. Results of this research are shown on figure 7. Modelling of course of changes of spin-orbit interaction energy by polynominal of second degree resulted in function $E_{SO} = 0.39 + 0.67x - 0.35x^2$ with value of C=-350meV co called bowing parameter. This parameter has been determine for the first time for InGaAsSb layers deposed on InAs substrate.

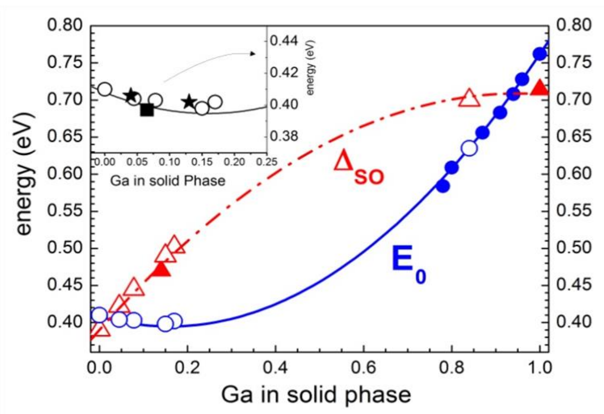

Fig. 7. Dependence of band gap and spin orbit interaction in function of InGaAsSb composition [A10]

Moreover, composition of two layers has been determined, that is $In_{0.97}Ga_{0.03}As_{0.96}Sb_{0.03}$ and $In_{0.07}Ga_{0.93}As_{0.14}Sb_{0.86}$, in which band gap energies are overlapping with spin-orbit split-off energy $E_0=\Delta_{so}$. Such situation is favourable from a viewpoint of manufacturing avalanche photodiodes. Particularly interesting application may be manufacturing of „bicolour" light detectors, based on simultaneous two layers of mentioned compositions.

My contribution in this work was partially performing the PR experiments, interpreting the results and writing the manuscript. I estimate my contribution at 70%.

4.4. Summary

Aforementioned scientific achievement entitled, *"Optical properties of active area of semiconductor laser designed for mid-infrared range, utilizing structures with type II band discontinuity*" is a cycle of ten papers. Publications A2 and A3 are of scientific-technical character, as they partially describe previously set measurement system using Fourier spectrometer. This setup allowed to perform spectroscopic experiments in mid and long wave infrared, opening possibilities of realising research, which had not been possible using classic experiments of photoluminescence and photoreflectance.

Research shown in the articles were realised for material systems utilizing band discontinuity of the second type. Works A1, A4-A8, regard research over type II quantum wells AlSb/InAs/InGa(As)Sb used as active areas in interband cascade lasers for emission range 2-8 µm. Paper A1 shows research focused on determining growth parameters, which led to receiving photoluminescence signal in room temperature, and in consequence manufacturing first interband cascade laser emitting at 3.4µm. Other papers are proposal of modification of active area regarding improvement of oscillator strength of fundamental optical transition and as a consequence improvement of work parameters of those lasers. In this area there have been several experimental verifications of modifications such as applying triple InAs layers (A4), adding arsenic atoms into GaInSb layers (A5-A7) or changing the type of strain in the active area by applying GaAsSb layers (A8). Research shown that applying of additional layers allows to increase oscillator strength of fundamental transition with simultaneous shifting emission towards longer waves. Similar effect has been achieved after using quaternary layers for confining holes, nevertheless in this approach it has been shown that there is still need for optimization of growth parameters in order to reduce localised states on InAs/GaInAsSb interfaces, which modify the shape of confining potential. Applying GaAsSb layers on the other hand increases degree of freedom in designing emission wavelength and creates possibility of manufacturing lasers with polarisation independent light beam.

Works A9 and A10 contain results of experiments of type II heterojunctions GaInAsSb/InGaAsSb, utilized in junction lasers for 3-4µm range. The research focused on determining relations between band gap energy and energy of spin-orbit split off are supplying vital information for designing layer compositions in order to mitigate the impact of Auger processes and increasing lasing temperature. Junction lasers, manufactured by liquid phase epitaxy, emitting in room temperature, and therefore not requiring cryogenic fluids, could become part of cheap sensors (as compared to sensors using lasers manufactured by MBE method used for optical detection of e.g. hydrocarbons.

5. List of other (not included in the achievement described in par. 4) published (after receiving Ph. D.) scientific works

5.1. Publications in journals from Journal Citation Reports (JRC) database

5. 1.1. Publications after receiving Ph. D.

	Punkty MNISW 2016	Impact Factor 2015	
2016			
1.	30	2.05	M. Dyksik, **M. Motyka**, G. Sęk, J. Misiewicz, M. Dallner, S Höfling, M. Kamp, *'Influence of carrier concentration on properties of InAs waveguide layers in interband cascade laser structures '*, **Journal of Applied Physics**, 120, 043104 (2016)

			My contribution: 25% (partial analysis of the experimental data, text corrections)
2.	25	1.3	M. Dyksik, **M. Motyka**, M. Kurka, K. Ryczko, M. Dallner, S. Hofling, M. Kamp, G. Sęk, J. Misiewicz, *'Photoluminescence quenching mechanisms in type II InAs/GaInSb QWs on InAs substrates'*, **Optical and Quantum Electronics** (2016) 48:401 DOI 10.1007/s11082-016-0667-y My contribution: 25% (partial analysis of the experimental data, text corrections)
3.	25	1.3	M. Kozub, **M. Motyka**, M. Dyksik, G. Sek, Jan Misiewicz, Kazuichi Nishisaka, Toshihiko Maemoto, and Shigehiko Sasa, *'Carrier concentration determination in InAs thin films for THz radiation generating devices using fast differential reflectance spectroscopy'*, **Optical and Quantum Electronics** (2016) 48:384 DOI 10.1007/s11082-016-0653-4 My contribution: 25% (partial analysis of the experimental data, text corrections)
4.	25	1.9	M. Dyksik, **M. Motyka**, W. Rudno-Rudziński, G. Sęk, J. Misiewicz , D. Pucicki, K. Kosiel, I. Sankowska, J. Kubacka-Traczyk and M. Bugajski, *'Optical properties of active regions in terahertz quantum cascade lasers'*, **Journal of Infrared, Terahertz and Millimeters Waves,** 37 (2016) 710-719 My contribution: 25% (partial analysis of the experimental data, text corrections)
2015			
5.	40	3.15	M. Gębski, M. Dems, A. Szerling, **M. Motyka**, L. Marona, R. Kruszka, D. Urbańczyk, M. Walczakowski, N. Pałka, A. Wójcik-Jedlińska, Q. J. Wang, D. H. Zhang, M. Bugajski, M. Wasiak, T. Czyszanowski, *'Monolithic high-index contrast grating: a material independent high-reflectance VCSEL mirror',* **Optics Express** 23, 11674 (2015) My contribution: 15% (performance of the reflectance measurements)
6.	30	2.6	M. Dyksik, **M. Motyka**, G. Sęk, J. Misiewicz, M. Dallner, R. Weih, M. Kamp, S. Höfling, *'Submonolayer uniformity of type II InAs/GaInSb W-shaped quantum wells probed by full-wafer photoluminescence mapping in the mid-infrared spectral range'*, **Nanoscale Research Letters** 10:402 (2015) My contribution: 25% (partial analysis of the experimental data, text corrections)
7.	30	2.1	J. Wróbel, Ł. Ciura, **M. Motyka**, F.Szmulowicz, A. Kolek, A. Kowalewski, P. Moszczyński, M. Dyksik, P. Madejczyk, S. Krishna and A. Rogalski,*' Investigation of near mid-gap trap energy level in a mid-wavelength InAs/GaSb type-II superlattices',* **Semiconductor Science and Technology** 30, 115004 (2015) My contribution: 20% (photoluminescence spectra analysis, text corrections)
8.	25	1.3	F. Janiak, M. Dyksik, **M. Motyka**, J. Misiewicz, K. Kosiel, M. Bugajski, *'Optical properties of AlGaAs/GaAs superlattices for active regions in quantum cascade lasers'*, **Optical and Quantum Electronics** 47, 945–952 (2015) My contribution: 20% (partial analysis of the experimental data, text corrections)
2014			
9.	15	0.45	J. Wróbel, E. Plis, W. Gawron, **M. Motyka**, P. Martyniuk, P. Madejczyk, A. Kowalewski, M. Dyksik, J. Misiewicz, S. Krishna and A. Rogalski, *'Analysis of temperature dependence of dark current mechanisms in mid-wavelength infrared pin type-II superlattice photodiodes'*, **Sensors and Materials** 26, 235-244(2014) My contribution: 15% (photoluminescence spectra analysis, text corrections)
2013			

10.	30	2.2	G. Zatryb, A.Podhorodecki, J. Serafińczuk, **M. Motyka**, M. Banski, J. Misiewicz, N. V. Gaponenko, *'Optical properties of Tb and Eu doped cubic YAlO3 nanophosphors synthesized by sol-gel method'*, **Optical Materials** 35, 2090–2094 (2013) My contribution:15% (performance, analysis of the reflectance measurements)
11.	35	2.8	A.Podhorodecki, N. V. Gaponenko, G. Zatryb, I. S. Molchan, **M. Motyka**, J. Serafinczuk, L. W. Golacki, L.S. Khoroshko, J. Misiewicz, G. E Thompson, *'Ion-ion interaction in two dimensional nanoporous alumina filled with cubic YAlO3:Tb3+ matrix'*, **Journal of Physics D:** Appl. Phys. 46, 355302 (2013) My contribution: 10% (performance, analysis of the reflectance measurements)
12.	35	3.15	M. Latkowska, R. Kudrawiec, F. Janiak, **M. Motyka**, J. Misiewicz, Q.-D. Zhuang , A. Krier , W. Walukiewicz, *'Temperature dependence of photoluminescence from InNAsSb layers: The role of localized and free carrier emission in determination of temperature dependence of energy gap'*, **Applied Physics Letters** 102, 122109 (2013) My contribution: 15% (partial analysis of the experimental data)
			2012
13.	20	0.9	M. Welna, R. Kudrawiec, **M. Motyka**, R. Kucharski, M. Zając, M. Rudziński, J. Misiewicz, R. Doradziński, and R. Dwiliński, 'Transparency of GaN substrates in the mid-infrared spectral range', **Crystal Research Technology** 47,347 – 350 (2012) My contribution: 20% (partial measurements and analysis of the data)
14.	30	2.2	**M. Motyka**, K. Ryczko, G. Sek, F. Janiak, J. Misiewicz, A. Bauer, S. Höfling, A. Forchel, *'Type II quantum wells on GaSb substrate designed for laser-based gas sensing applications in a broad range of mid infrared'*, **Optical Materials** 34, 1107–1111 (2012) My contribution: 35% (experimental data analysis, manuscript preparation)
			2011
15.	30	1.5	**M. Motyka**, G. Sęk, F. Janiak, J. Misiewicz, K. Kłos, J. Piotrowski, *'Fourier-transformed photoreflectance and fast differential reflectance of HgCdTe layers. The issues of spectral resolution and Fabry–Perot oscillations'*, **Measurement Science and Technology** 22, 125601(2011) My contribution: 50% (partial performance of the measurements, and data analysis, manuscript preparation)
16.	20	1.6	**M. Motyka** F. Janiak, J. Misiewicz, M. Wasiak, K. Kosiel, M. Bugajski, '*Deternination of the energy difference and width of the minibans in GaAs/AlGaAs superlattices by using Fourier transform photoreflectance and photoluminescence'*, **Opto-Electronic Review** 19, 151–154(2011) My contribution: 50% (partial performance of the measurements, and data analysis, manuscript preparation)
17.	30	2.2	G. Sek, F. Janiak, **M. Motyka**, K. Ryczko, J. Misiewicz, A. Bauer, S. Höfling, A. Forchel,*'Carrier loss mechanisms in type II quantum wells for the active region of GaSb-based mid-infrared interband cascade lasers'*, **Optical Materials** 33, 1817–1819 (2011) My contribution: 20% (performance of the photoluminescence measurements)
18.	20	1.1	K. Ryczko, G. Sek, **M. Motyka**, F. Janiak, M. Kubisa, J. Misiewicz, S. Belahsene, G. Boissier, and Y. Rouillard, *'Effect of Annealing-Induced Interdiffusion on the Electronic Structure of Mid Infrared Emitting GaInAsSb/AlGaInAsSb Quantum Wells'*, **Japanese Journal of Applied Physics** 50, 031202(2011) My contribution: 20% (performance of the photo-reflectance measurements)

19.	20	1.6	M. Wesołowski, W. Strupiński, **M. Motyka**, G. Sęk, E. Dumiszewska, P. Caban, A. Jasik, A. Wójcik, K. Pierściński and D. Pierścińska, *'Study of MOCVD growth of InGaAsSb/AlGaAsSb/GaSb heterostructures using two different aluminium precursors TMAl and DMEAAl'*, **Opto-Electronic Review** 19, 137–139(2011) My contribution: 20% (performance of the photoluminescence measurements)
2010			
20.	30	2.05	R. Kudrawiec, G. Sek, **M. Motyka**, J. Misiewicz, A. Somers, S. Höfling, L. Worschech, and A. Forchel, *'Contactless electroreflectance of optical transitions in tunnel-injection structures composed of an In0.53Ga0.47As/In0.53Ga0.23Al0.24As quantum well and InAs quantum dashes'*, **Journal of Applied Physics** 108, 086106 (2010) My contribution: 20% (performance of the electro-reflectance measurements)
21.	20	1.1	G. Sęk, **M. Motyka**, K. Ryczko, F. Janiak, J. Misiewicz, S. Belahsene, G. Boissier, and Y. Rouillard, *'Band Offsets and Photoluminescence Thermal Quenching in Mid-Infrared Emitting GaInAsSb Quantum Wells with Quinary AlGaInAsSb Barriers'*, **Japanese Journal of Applied Physics** 49, 031202(2010) My contribution: 25% (partial performance of the measurements)
2009			
22.	35	3.15	A. Bauer, F. Langer, M. Dallner, M. Kamp, **M. Motyka**, G. Sęk, K. Ryczko, J. Misiewicz, S. Höfling, and A. Forchel, *'Emission wavelength tuning of interband cascade lasers in the 3–4um spectral range'*, **Applied Physics Letters** 95, 251103 (2009) My contribution: 15% (performance of the photoluminescence measurements)
23.	30	2.05	**M. Motyka** , G. Sęk, K. Ryczko , J. Misiewicz , S. Belahsene , G. Boissier, Y. Rouillard *'Optical transitions and band gap discontinuities of GaInAsSb/AlGaAsSb quantum wells emitting in the 3 μm range determined by modulation spectroscopy'*, **Journal of Applied Physics** 106, 066104 (2009) My contribution: 50% (performance of the photoluminescence and photo-reflectance measurements)
24.	15	0.6	**M. Motyka**, G. Sęk, F. Janiak, K. Ryczko, J. Misiewicz, K. Kosiel, M. Bugajski, *'Photoreflectance study of Al0.45Ga0.55As/GaAs superlattice: optical transitions at the miniband Γ and Π points'*, **Optica Applicata** Vol. 39, No. 4,(2009) My contribution: 50% (partial performance of the measurements, manuscript preparation)
25.	15	0.6	**M. Motyka,** L. Gelczuk, M. Dabrowska-Szata, J. Serafińczuk, R. Kudrawiec, J. Misiewicz, *'Photoreflectance study of partially relaxed epitaxial InGaAs on GaAs'*, **Optica Applicata**, Vol. 39, No. 3 (2009) My contribution: 40% (measurements performance and data analysis)
26.	25	2.1	R. Kudrawiec, P. Podemski, **M. Motyka**, J. Misiewicz, J. Serafinczuk , A. Somers, J.P. Reithmaier, A. Forchel, *'Electromodulation spectroscopy of In0.53Ga0.47As/In0.53Ga0.23Al0.24As quantum wells'*, **Superlattices and Microstructures** 46, 425-434(2009) My contribution: 20% (partial performance of the measurements)
27.	20	0.9	R. Kudrawiec, M. Gladysiewicz, **M. Motyka**, J. Misiewicz, G. Cywiński, M. Siekacz, C. *Skierbiszewski 'Contactless electroreflectance of GaInN/AlInNmultiquantumwells: The issue of broadening of optical transitions '*, **Microelectronics Journal** 40, 392–395(2009) My contribution: 20% (performance of the electro-reflectance measurements)
28.	20	0.9	R. Kudrawiec, **M. Motyka**, J. Misiewicz, B. Paszkiewicz, R. Paszkiewicz, M. Tłaczała, „*Contactless electroreflectance study of band bending for undoped, Si-*

			and Mg-doped GaN layers and AlGaN/GaN transistor heterostructures", **Microelectronics Journal** 40, 370–372(2009) My contribution: 25% (performance of the electro-reflectance measurements)

5. 1.2 Publications before receiving Ph. D.

2008			
1.	30	2.05	R. Kudrawiec, B. Paszkiewicz, **M. Motyka**, J. Misiewicz, J. Derluyn, A. Lorenz, K. Cheng, J. Das, and M. Germain, *'Contactless electroreflectance evidence for reduction in the surface potential barrier in AlGaN/GaN heterostructures passivated by SiN layer'*, **Journal of Applied Physics** 104, 096108 (2008) My contribution: 20% (performance of the electro-reflectance measurements)
2.	30	2.05	R. Kudrawiec, H. B. Yuen, S. R. Bank, H. P. Bae, M. A. Wistey, James S. Harris, **M. Motyka**, and J. Misiewicz,*' On the Fermi level pinning in as-grown GaInNAsSb/GaAs quantum wells with indium content of 8%–32%'*, **Journal of Applied Physics** 104, 033526 (2008) My contribution: 20% (performance of the electro-reflectance measurements)
3.	35	2.8	R. Kudrawiec, **M. Motyka**, J. Misiewicz, B. Paszkiewicz, R. Paszkiewicz, M. Tłaczała, *'Contactless electroreflectance study of band gap renormalization for Mg- doped GaN'*, **Journal of Physics D**: Appl. Phys. 41, 165109 (2008) My contribution: 25% (performance of the electro-reflectance measurements)
4.	30	2.05	**M. Motyka**, R. Kudrawiec, J. Misiewicz, M. Hümmer, K. Rößner, T. Lehnhardt, M. Müller, and A. Forchel, *'Photoreflectance and photoluminescence study of Ga0.76In0.24Sb/GaSb single quantum wells: Band structure and thermal quenching of photoluminescence'*, **Journal of Applied Physics** 103, 113514 (2008) My contribution: 40% (performance of the measurements, text corrections)
5.	30	2.3	L. Gelczuk, **M. Motyka**, J. Misiewicz, M. Dabrowska-Szata*,'Deep traps and optical properties of partially strain-relaxed InGaAs/GaAs heterostructures'*, **Materials Science & Engineering B**, 147, 166-170 (2008) My contribution: 25% (performance of the photo-reflectance measurements)
6	35	3.15	R. Kudrawiec, **M. Motyka**, J. Misiewicz, M. Hümmer, K. Rößner, T. Lehnhardt, M. Müller, and A. Forchel, *'Room temperature contactless electroreflectance of the ground and excited state transitions in Ga0.76In0.24As0.08Sb0.92 /GaSb single quantum wells of various widths'*, **Applied Physics Letters** 92, 041910 (2008) My contribution: 25% (performance of the electro-reflectance measurements)
2007			
7.	30	2.05	R. Kudrawiec, H. B. Yuen, S. R. Bank, H. P. Bae, M. A. Wistey, James S. Harris, **M. Motyka**, J. Misiewicz, *'Contactless electroreflectance approach to study the Fermi level position in GaInNAs/GaAs quantum wells'*, **Journal of Applied Physics** 102, 113501 (2007) My contribution: 5% (performance of the electro-reflectance measurements)
8.	30	2.05	**M. Motyka**, R. Kudrawiec, G. Sęk, J. Misiewicz, D. Bisping, B. Marquardt and A. Forchel, *'Photoluminescence from InAsN quantum dots embedded in GaInNAs/GaAs quantum wells'*, **Journal of Applied Physics** 101, 113539(2007) My contribution: 40% (performance of the measurements, text corrections)
9.	30	2.05	**M. Motyka,** G. Sęk, R. Kudrawiec, P. Sitarek, J. Misiewicz, J. Wojcik, B. J. Robinson, D. A. Thompson, and P. Masher, *'Probing the indium clustering in InGaAs/GaAs quantum wells by room temperature contactless electroreflectance and photoluminescence spectroscopy'*, **Journal of Applied Physics** 101, 116107(2007)

			My contribution: 40% (performance of the measurements, manuscript preparation)
10.	35	3.15	**M. Motyka,** R. Kudrawiec, G. Sęk, J. Misiewicz, D. Bisping, B. Marquardt and A. Forchel, *'Contactless electroreflectance investigation of energy levels in an 1.3-um emitting laser structure with the gain medium composed of InAsN quantum dots embedded in GaInNAs/GaAs quantum wells',* **Applied Physics Letters 90, 221112 (2007)** My contribution: 40% (performance of the measurements, data analysis)
11.	35	3.15	**M. Motyka** G. Sęk, K. Ryczko, J. Andrzejewski, J. Misiewicz, B. Alloing, L. H. Li, A. Fiore, G. Patriarche, *'Optical and electronic properties of GaAs-based structures with columnar quantum dots'*, **Applied Physics Letters** 90, 181933 (2007) My contribution: 50% (performance of the measurements, data analysis)
12.	30	2.05	G. Sęk, K. Ryczko, **M. Motyka**, J. Andrzejewski, K. Wysocka, J. Misiewicz, B. Alloing, L. H. Li, A. Fiore, G. Patriarche, *'Wetting layer states of InAs/GaAs self-assembled quantum dot structures: effect of intermixing and capping layer'*, **Journal of Applied Physics** 101, 063539(2007) My contribution: 20% (performance of the measurements)
13.	35	3.15	R. Kudrawiec, S.R. Bank ,H.B. Yuen, H.P. Bae, M.A. Wistey, L.L. Goddard, James S. Harris, M.Gladysiewicz, **M. Motyka** and J. Misiewicz,*' Conduction band offset for GaInNAsSb/GaNAs/GaAs systems emitted at 1.5-1.65 um'*, **Applied Physics Letters** 90, 131905, (2007) My contribution: 5% (performance of the measurements)
14.	30	1.8	**M. Motyka**, R. Kudrawiec, M. Syperek, J. Misiewicz, M.Rudziński , P.Hageman , P.K. Larsen,' Screening effect in contactless electroreflectance spectroscopy observed for AlGaN/GaN heterostructures with 2DEG', **Thin Solid Films** 515, 4662-4665(2007) My contribution: 40% (performance of the measurements, text corrections)
15.	35	3.15	R. Kudrawiec, H. B. Yuen, S. R. Bank, H. P. Bae, M. A. Wistey, James S. Harris, **M. Motyka** and J. Misiewicz, 'Fermi level shift in GaInNAsSb/GaAs quantum wells upon annealing studied by contactless electroreflectance', **Applied Physics Letters** 90, 061902, (2007) My contribution: 5% (performance of the measurements)
16.	20	1.45	**M. Motyka**, R. Kudrawiec, J. Misiewicz ,*'On the deepness of contactless electroreflectance probing in semiconductor structures'*, **Physica Status Solidi A** 204, 354-363 (2007) My contribution: 40% (performance of the measurements, data analysis)
17.	20	1.45	G. Sęk , **M. Motyka**, R. Kudrawiec, J. Misiewicz, F. Lelarge, B. Rousseau, G. Patriarche,*'Modulated reflectivity probing of quantum dot and wetting layer states in InAs/GaInAsP/InP laser structures'*, **Physica Status Solidi A**, 204, 496-499 (2007) My contribution: 25% (performance of the measurements)
18.	20	1.45	G. Sęk, R. Kudrawiec, **M. Motyka**, P. Poloczek, W. Rudno-Rudziński, P. Podemski, J. Misiewicz,*'Contactless modulated reflectivity of quasi 0D self-assembled semiconductor structures'*, **Physica Status Solidi A**, 204, 400-411 (2007) My contribution: 20% (performance of the electro- reflectance measurements)
19.	20	1.45	R. Kudrawiec, H.B. Yuen, S.R. Bank, H.P. Bae, M.A. Wistey, James S. Harris, **M. Motyka**, M.Gladysiewicz, and J. Misiewicz,*'The influence of antimony on the optical quality of highly strained GaInNAs/GaAs QWs investigated by contacless electroreflectance',* **Physica Status Solidi A**, 204, 543-546(2007) My contribution: 5% (performance of the electro-reflectance measurements)
20.	20	1.45	R. Kudrawiec, H.B. Yuen, S.R. Bank, H.P. Bae, M.A. Wistey, James S. Harris, **M. Motyka**, M.Gladysiewicz, and J. Misiewicz,'Electromodulation spectroscopy of interband transitions in GaInNAsSb/GaAs quantum wells with high indium content',

			Physica Status Solidi A 204, 364-372(2007) My contribution: 5% (performance of the electro- reflectance measurements)
21.	30	2.05	R. Kudrawiec, **M. Motyka**, J. Misiewicz, A. Somers, R. Schwertberger, J. P. Reithmaier, and A. Forchel, *'Contactless electroreflectance of InAs/In0.53Ga0.23Al0.24As quantum dashes grown on InP substrate: Analysis of the wetting layer-related transition'*, **Journal of Applied Physics** 101, 013507(2007) My contribution:25% (performance of the electro- reflectance measurements)
22.	30	2.05	R. Kudrawiec, H.B. Yuen, **M. Motyka**, M. Gladysiewicz, J. Misiewicz, S.R. Bank ,H.P. Bae , M. Wistey , J.S. Harris, *'Contactless electroreflectance of GaInNAsSb/GaAs single quantum wells with In content changing from 8% to 32%'*,**Journal of Applied Physics** 101, 013504 (2007) My contribution: 20% (performance of the electro- reflectance measurements)
2006			
23.	35	3.15	**M. Motyka**, R. Kudrawiec, G. Cywinski, M. Siekacz, C. Skierbiszewski, J. Misiewicz,*' Energy difference between electron subbands in AlInN/GaInN quantum wells studied by contactless electroreflectance spectroscopy'*, **Applied Physics Letters** 89, 251908 (2006) My contribution: 40% (performance of the measurements, data interpretation)
24.	35	3.15	**M. Motyka,** M. Syperek, R. Kudrawiec , J. Misiewicz , M.Rudziński , P.Hageman , P.K. Larsen, *'Investigations of GaN surface quantum well by contactless electroreflectance spectroscopy'*, **Applied Physics Letters** 89, 231912 (2006) My contribution: 40% (performance of the measurements, text corrections)
25.	35	3.15	R. Kudrawiec, **M. Motyka**, M. Gładysiewicz, P. Sitarek, and J. Misiewicz, *'Photoreflectance and contactless electroreflectance spectroscopy of GaAs-based structures: The below band gap oscillation features'*, **Applied Surface Science** 253, 266-270(2006) My contribution: 25% (performance of the electro- reflectance measurements)
26.	35	3.15	R. Kudrawiec, M. Gladysiewicz, **M. Motyka**, J. Misiewicz, H.B. Yuen, S.R. Bank, M.A.Wistey, H.P. Bae, and James S. Harris Jr, *'Contactless electroreflectance spectroscopy of Ga(In)NAs/GaAs quantum well structures containing Sb atoms'*, **Applied Surface Science** 253 (2006) 152-157 My contribution: 20% (performance of the electro- reflectance measurements)
27.	35	3.15	R. Kudrawiec, J.A. Gupta, **M. Motyka**, M. Gladysiewicz, J. Misiewicz, and X. Wu,*' Contactless electroreflectance of GaN0.025As0.975-xSbx/GaAs QWs with high Sb content: The determination of bandgap discontinuity'*, **Applied Physics Letters** 89, 171914 (2006) My contribution: 20% (performance of the electro- reflectance measurements)
28.	30	2.05	**M. Motyka**, G. Sęk, R. Kudrawiec, J. Misiewicz, B. Alloing, L. H. Li, A. Fiore, *'On the modulation mechanism in photoreflectance of self-assembled InAs/GaAs quantum dots'*, **Journal of Applied Physics** 100, 073502 (2006) My contribution: 40% (performance of the measurements, data interpretation)
29.	30	2.1	**M.Motyka,** R. Kudrawiec, G. Sek, J. Misiewicz, I.L. Krestnikov and A. Kovsh, *'Room temperature Contactless electroreflectance characterization of InGaAs/InAs/GaAs quantum dot wafers'*, **Semiconductor Science and Technology** 21, 1402-1407(2006) My contribution: 40% (performance of the measurements, data interpretation)
30.	35	3.15	R. Kudrawiec, **M. Motyka**, M. Gladysiewicz, J. Misiewicz, H.B. Yuen, S.R. Bank, H.P. Bae, M.A. Wistey, and James S.Harris Jr, *'Band gap discontinuity in Ga0.9In0.1N0.027As0.973-xSbx/GaAs single quantum wells with 0 □ x □ 0.06 studied by contactless electroreflectance spectroscopy'*, **Applied Physics Letters** 88, 221113 (2006) My contribution: 25% (performance of the spectroscopic measurements)

31.	30	2.05	R. Kudrawiec, M. Syperek, **M. Motyka**, J. Misiewicz, B. Paszkiewicz, R. Paszkiewicz, M. Tlaczała, *'Contactless electromodulation spectroscopy of AlGaN/GaN heterostructures with a two-dimensional electron gas: A comparison of photoreflectance and contacless electroreflectance'*, **Journal of Applied Physics** 100, 013501 (2006) My contribution: 20% (performance of the spectroscopic measurements)
32.	20	1.5	Kudrawiec, **M. Motyka**, M. Gladysiewicz, J. Misiewicz, J.A. Gupta, *'Contactless electroreflectance of GaNxAs1-x/GaAs multi quantum wells: The band offset and electron effective mass issues'*, **Solid state communications** 138, 365-370 (2006) My contribution: 25% (performance of the electro-reflectance measurements)
2005			
33.	30	2.05	R. Kudrawiec, **M. Motyka**, J. Misiewicz, H.B. Yuen, S.R. Bank, M.A. Wistey, H.P. Bae, and James S. Harris Jr, *'Photoluminescence from as-grown and annealed GaN0.02As0.87Sb0.11/GaAs single quantum wells'*, **Journal of Applied Physics** 98, 063527 (2005) My contribution: 25% (performance of the spectroscopic measurements)
34.	20	0.9	J. Misiewicz, R. Kudrawiec, **M. Motyka**, J. Andrzejewski, D. Gollub, A. Forchel, *'Photo and contactless electroreflectance spectroscopies of step like GaInNAs /Ga(In)NAs /GaAs quantum wells'*, **Microelectronic Journal** 36, 446-449 (2005) My contribution: 20% (performance of the spectroscopic measurements)
2004			
35.	N/A	N/A	R. Kudrawiec, **M. Motyka**, J. Andrzejewski, J. Misiewicz, D. Gollub, and A. Forchel, *'Photoreflectance and photoluminescence study ofstep-likeGaInNAs/GaInNAs /GaAs quantum wells'*, **IEE Proceedings Optoelectronics** 151, 313-316 (2004) My contribution: 25% (performance of the optical measurements)

5..2. Publications from journals others than from JCR database

5.2.1 Post-conference publications after receiving Ph. D.

1.	F. Janiak, **M. Motyka**, G. Sek, K. Ryczko, M. Dyksik, J. Misiewicz, R. Weih, S. Hofling, M. Kamp,*' Optical characterization of type II quantum wells for long-wavelength mid-infrared interband cascade lasers'*, **Proceedings of SPIE** 9134, 91340V (2014) My contribution: 25% (partial performance of the optical measurements)
2.	**M. Motyka**, *'Lasery pracujące w schemacie kaskadowym w kontekście zastosowania w szeroko przestrajalnych opto-elektronicznych czujnikach gazów'*, **Elektronika** nr 11/2014, s. 54-56 My contribution:: 100% (measurements, spectra interpretation, manuscript preparation)
3.	G. Sęk, **M. Motyka**, F. Janiak, K. Ryczko, J. Misiewicz, A. Bauer, M. Dallner, R. Weih, S. Höfling, A. Forchel, S. Belahsene, G. Boissier, Y. Rouillard, *'Recent advances in GaSb-based structures for mid-infrared emitting lasers: spectroscopic study'*, **Proc. of SPIE** Vol. 8631, 86312O-1(2013) My contribution: 25% (partial performance of the optical measurements)
4.	**M. Motyka**, G. Sęk, J. Misiewicz, *'Fourierowska spektroskopia fotoluminescencyjna i fotoodbiciowa struktur półprzewodnikowych przeznaczonych na zakres średniej i długofalowej podczerwieni'*, **Elektronika** 10, 35-39(2011) My contribution: 50% (performance of the optical measurements, manuscript preparation)
5.	M. Wesołowski, W. Strupiński, E. Pruszyńska-Karbownik, **M. Motyka**, G. Sęk, A. Wójcik-Jedlińska, K. Pierściński, D. Pierścińska, A. Mirowska, R. Jakieła, I. Jóźwik, A. Piątkowska, K. Kościewicz, P. Ceban, M. Bugajski, *'Zastosowanie technologii MOCVD w dziedzinie laserów antymonowych z hetero złączem I-go rodzaju'*, **Elektronika** 10, 25-28(2011) My contribution: 10% (partial performance of the optical measurements)
6.	F. Janiak, **M. Motyka**, G. Sęk, K. Ryczko, J. Misiewicz, K. Kosiel, M. Bugajski, *'Optyczne właściwości supersieci GaAs/AlGaAs badane za pomocą spektroskopii modulacyjnej'*, **Elektronika** 10, 46-48(2011) My contribution: 25% (partial performance of the optical measurements)

7.	J. Misiewicz, **M. Motyka**, G. Sęk, R. Kudrawiec, *'Spektroskopia modulacyjna nanostruktur półprzewodnikowych w zakresie bliskiej i średniej podczerwieni'*, **Elektronika** 5 (2009) My contribution: 25% (partial performance of the optical measurements)

5.2.2 Post-conference publications before receiving Ph. D.

1.	R. Kudrawiec, **M. Motyka**, G. Cywinski, M. Siekacz, C. Skierbiszewski, L. Nevou, L. Doyennette, M. Tchernycheva, F. H. Julien, J. Misiewicz, *'Contactless electroreflectance spectroscopy of inter- and intersub-band transitions in AlInN/GaInN quantum wells'*, **Physica Status Solidi C** 5, No. 2, 503–507 (2008) My contribution: 25% (performance of the electro-reflectance measurements)
2.	G. Sęk, **M. Motyka**, K. Ryczko, J. Andrzejewski, R. Kudrawiec, J. Misiewicz, F. Lelarge, B. Rousseau, G. Patriarche,*'Modulation spectroscopy characteryzation of InAs/GaInAsP/InP quantum dash laser structures'*, **Proc. SPIE** 6481, 64810D (2007) My contribution: 25% (performance of the optical measurements)
3.	**M. Motyka**, R. Kudrawiec, J. Misiewicz,, D. Pucicki, M. Tlaczala, M. Fisher, B. Marquardt, A. Forchel, *'Contactless electroreflectance and photoluminescence of InAs quantum dots with GaInNAs barriers grown on GaAs substrate'*, **Physica Status Solidi** C 4, 625-627(2007) My contribution: 40% (performance of the optical measurements, text preparation)
4.	**M. Motyka**, W. Rudno-Rudziński, G. Sęk, R. Kudrawiec, J. Misiewicz, A. Somers, R. Schwertberger, J.P. Reithmaier, A. Forchel, *'Photoreflectance and contactless electroreflectance of an InAs quantum dash laser structure'*, **Physica Status Solidi C** 4, 350-352 (2007) My contribution: 40% (partial performance of the optical measurements, text preparation)
5.	M. Syperek, **M. Motyka**, R. Kudrawiec, J. Misiewicz, M.Rudziński , P.Hageman , P.K. Larsen, *'Investigation of built-in electric field in AlGaN/GaN heterostructures grown on misoriented 4H-SiC substrate by contactless electroreflectance'*, **Physica Status Solidi C** 4, 366-368(2007) My contribution: 25% (partial performance of the optical measurements)
6.	A. Podhorodecki, J. Andrzejewski, **M. Motyka**, R. Kudrawiec, J. Misiewicz, J. Wójcik, B.J. Robinson,*'Optical properties of InGaAsP quantum well for infrared emission investigated by modulation spectroscopy'*, **Optica Applicata** Vol. XXXV, No. 3, (2005) My contribution: 20% (partial performance of the optical measurements)
7.	**M. Motyka**, G. Sęk, J. Andrzejewski, R. Kudrawiec, J. Misiewicz, B. Ściana, D. Radziewicz, M. Tłaczała, *'Optical properties of InGaAs/GaAs quantum wells with different distance from Si-delta doping layer'*, **Optica Applicata** Vol. XXXV, No. 3, (2005) My contribution: 50% (performance of the optical measurements, data analysis, manuscript preparation)

5.3. Managing and participating in scientific projects

Index	Number and title of project	Character of employment
1.	**National Centre of Science project(Opus) nr UMO-2014/15/B/ST7/04663 (2015)** pt. „*Optical properties and carrier dynamics in the type II semiconductor structures devoted for active region of lasers and detectors operating in the mid-infrared spectral range".*	Leader
2.	**National Centre of Science project (SONATA) nr UMO-2011/03/D/ST3/02640 (2012)** pt. *" Optyczne właściwości półprzewodnikowych struktur nisko wymiarowych badane przy pomocy Fourierowskiej spektroskopii w podczerwieni"*	Leader

3.	**MNISW project Iuventus Plus nr 0370/IP3/2011/71 (2012)** *„Fourierowska spektroskopia modulacyjna struktur półprzewodnikowych w zakresie średniej podczernieni”*	Leader
4.	**Project ICSPEC (2015)** *"In-line Cascade Laser Spectrometer for Process Control",* realizowany w ramach programu Unii Europejskiej Horyzont 2020	Main contractor
5.	**Project COST (European Cooperation In Science and Technology) Action MP1204** *“TERA-MIR Radiation: Materials, Generation, Detection and Applications”*	Contractor
6.	**Project WIDELASE (2012-2014) “***Monolithic Widely Tunable Interband Cascade Lasers for Safety and Security”* realizowany w ramach 7 ramowego programu Unii Europejskiej	Main Contractor
7.	**Project PBZ-MNiSW-02/I/2007 Nr. N515 074 31/3896 (2008-2011)** *„Zaawansowane technologie dla półprzewodnikowej optoelektroniki podczerwieni*”,	Contractor
8.	**Project SensHy Nr. 223998 (2008-2011)** „*Photonic sensing of hydrocarbons based on innovative mid infrared lasers***”,** realizowany w ramach 7 ramowego programu Unii Europejskiej	Main Contractor
9.	**Project Zodiac FP6/017140 (2005-2008)** „*Zero Order Dimension based Industrial components Applied to teleCommunication* ,realizowany w ramach 6 ramowego programu Unii Europejskiej,	Contractor
10.	**MNISW project N515 07431/3896,** *"Zastosowanie bezkontaktowego elektroodbicia oraz fotoodbicia do badania struktur półprzewodnikowych na zakres bliskiej i średniej podczerwieni***"**	Contractor
11.	**MNISW project N202 410933,** *"Wpływ wbudowanych pól elektrycznych na reguły wyboru przejść międzypasmowych oraz wewnątrzpodpasmowych w polarnych studniach kwantowych Ga(In)N/Al(In)N"*	Contractor

5.4. Awards for scientific activity

(a) Iuvenes Wratislaviae Award (2016), founded by Wrocław department of Polish Academy of Sciences
(b) Scholarship for young scientists founded by Ministry of Science and Higher Education, Physics (2015-2017)
(c) Scholarship financed by European Social Fund „Młoda Kadra 2015” (2012-2013)
(d) Scholarship financed by European Social Fund „Młoda Kadra 2015”, (2011-2012)
(e) Scholarship financed by European Social Fund „Młoda Kadra” (2010-2011), Second edition

(f) Scholarship financed by European Social Fund „Młoda Kadra” (2009-2010), First edition
(g) START scholarship (for young scientistc) Foundation for Polish Science in physics, 2009
(h) START scholarship (for young scientistc) Foundation for Polish Science in physics, 2008
(i) Wrocław Max Born city scholarship in physics in 2008

5.5. Invited talks and seminars

Invited talks:

1. *On the way to improved active part of interband cascade lasers*, Photonics West, San Francisco, USA (2017)

2. *Optical properties of various types of active regions for mid-infrared lasers based on type II low dimensional semiconductor structures*, Semiconductor Nanostructures for Optoelectronics and Biosensors, Rzeszów, Poland (2016)

3. *On the way to improved performance interband cascade lasers*, Photonics Europe, Bruksela, Belgium (2016)

4. *Recent developments in interband cascade lasers,* VI Workshop on Physics and Technology of Semiconductor Lasers, Kraków, Poland (2015)

5. *GaInAsSb semiconducting alloy predicted for active region of mid-infrared lasers*, Seminarium Powierzchnia i Struktury Cienkowarstwowe, Szklarska Poręba, Poland (2015)

6. *Optical properties of type II quantum wells predicted to active region in interband cascade lasers*, EMN- Energy Materials Nanotechnology Conference, Cancun, Mexicok (2015)

7. *On the active region improvement in interband cascade lasers,* SMMO conference and COST Action MP1204 meeting, Praga, Czech Republic (2015).

8. *Type II quantum well structures for tuneable interband cascade lasers for mid-infrared optical gas sensing applications*, 10th Integrated Optics - Sensors, Sensing Structures and Methods, Szczyrk, Poland (2015)

9. *Lasery pracujące w schemacie kaskadowym w kontekście zastosowania w szeroko przestrajalnych optycznych czujnikach gazów*, Krajowa Konferencja Elektroniki, Darłówko Wschodnie, Poland (2014)

10. Type *II quantum wells for mid-infrared interband cascade lasers: advanced spectroscopic studies*, PhoBiA Annual Nanophotonics International Conference & Symposium on Photoactive Synthetic Materials, Wroclaw, Poland (2014)

11. *Fourier transformed infrared spectroscopy in the mid and long wavelength spectral range*, VI Krajowa Konferencja Nanotechnologii, Szczecin, Poland (2013).

Invited seminars

1. *Optyczne właściwości obszarów aktywnych laserów półprzewodnikowych na zakres średniej podczerwieni*, Uniwersytet Rzeszowski, Polska (2017)

2. *Optimizing the active region of interband cascade lasers- the band gap, strain and wave functions engineering,* Department of Physics, Cavendish Laboratory, University of Cambridge, United Kingdom (2015)

3. *Optymalizacja właściwości optycznych półprzewodnikowych heterozłączy i studni kwantowych z nieciągłością pasm typu drugiego*, Instytut Fizyki Politechniki Łódzkiej, Poland (2015)

4. *Optymalizacja obszarów aktywnych niskowymiarowych układów półprzewodnikowych na zakres średniej podczerwieni*, Vigo S.A., Warszawa (2015)

5.6. Speeches at domestic and international thematic conferences.

1. *Type II quantum wells with tensile-strained GaAsSb layers for interband cascade laser: energy structure determination and carriers diffusion*, 4 th Annual Conference of COST Action MP1204 & SMMO2016 Conference, Lizbona, Portugal (2016)

2. *On the improvements in the active region of interband cascade lasers*, MIRSENS III- International workshop on opportunities and challenges in mid-infrared laser-based gas sensing, Wurzburg, Germany (2015)

3. *Fourier transformed infrared spectroscopy*, International Conference on Semiconductor Mid infrared Materials and Optics, Warszawa, Polanda 2013)

4. *Developments in Fourier-transform-based optical characterization of mid to far infrared semiconductor materials*, MIRSENS II- International workshop on opportunities and challenges in mid-infrared laser-based gas sensing, Wrocław, Poland (2012)

5. *GaSb-based type II "W-shaped" quantum wells for the active region of interband cascade lasers in mid infrared*, IV Workshop on Physics and Technology of Semiconductor Lasers, Kazimierz dolny, Poland (2011)

6. *Fourierowska spektroskopia fotoluminescencyjna i fotoodbiciowa struktur półprzewodnikowych przeznaczonych na zakres średniej i długofalowej podczerwieni*, Polska Konferencja Optyczna, Międzyzdroje, Poland (2011)

7. *Type I and II quantum wells based on GaSb for the application in mid-infrared hydrocarbons detection*, 4th Integrated Optics - Sensors, Sensing Structures and Methods, Szczyrk, Poland (2010)

8. *Fourier mode modulation spectroscopy characterization of mid-infrared semiconductor structures*, MIRSENS - International workshop on opportunities and challenges in mid-infrared laser-based gas sensing, Wrocław, Poland(2010)

9. *Fourier transformed modulation spectroscopy in the long wavelength spectral range,* International Conference on Semiconductor Mid infrared Materials and Optics, Warszawa, Poland (2010)

10. *Broken gap InAs/GaInSb heterostructures for the application in mid-infrared lasers: Type II optical transition oscillator strength and temperature sensitivity*, Narrow Gap Semiconductors Conference, Sendai, Japan (2009)

11. *Fourier Transformed Infrared (FTIR) modulation spectroscopy of low dimensional semiconductor structures designer for laser applications in mid and far infrared region*, III Workshop on Physics and Technology of Semiconductor Lasers, Kruklanki, Poand (2009)

12. *Optyczne właściwości studni kwantowych na podłożu z GaSb do zastosowań laserowych w zakresie 3-3.5um*, Seminarium Powierzchnia i Struktury Cienkowarstwowe, Szklarska Poręba, Poland (2009)

13. *Optical properties of type II QWs for 3 µm emiters*, II Workshop on Physics and Technology of Semiconductor Lasers, Kazimierz dolny, Poland (2008)

14. *Contactless electroreflectance spectroscopy in UV region,* EMRS, Warszawa (2007).

15. *On the deepness of contacless electroreflectance probing in semiconductor structures,* Modulated Semiconductor Structures, Wroclaw Poland (2006)

6. Didactic and popularizing achievements and information about international collaboration of candidate.

6.1. Participation in organising committees of science conferences.

- Organizing committee member of the MIRSENS 4 conference, Wrocław (2017)
- Member of organising committee of PhoBiA Annual Nanophotonics International Conference “PANIC”, Wroclaw (2015)
- Member of organising committee of 3rd International Workshop on Modulation Spectroscopy of Semiconductor Structures, Wrocław (2008)
- Co-organiser of 2nd International Workshop on Modulation Spectroscopy of Semiconductor Structures, Wrocław (2006)

6.2. Membership in science organisations and societies.

- Member of faculty elector college at Faculty of Fundamental Problems of Technology at Wroclaw University of Science and Technology.
- Member of Polish Physics Society.
- Member of council of Institute of Physics at Wrocław University of Technology.

6.3. Didactic and science popularizing achievements.

- Didactics on subjects as Nanoscale Physics, Solid State Physics, Semiconductor Physics, General Physics, Optical Spectroscopy of Nanostructures.
- Lecture "Quantum Cascade Lasers" inaugurating school year 2014/2015 at High School in Gilowice.
- Popularising lecture "Infrared – area of wide application possibilities", Wrocław University of Science and Technology (2013).
- Multiple organisation of visits of laboratories in Institute of Physics for students and pupils of schools.
- Participation in Lower Silesia Festival of Science. (2006, 2007).
- Participation in educational fair TARED (2005, 2006).
- Co-organising of science event ”Physical Circus” (2006).

6.4. Scientific supervision of students

- Supervisor of **five master theses:**

  mgr Marcin Kurka
  mgr Mateusz Dyksik
  mgr Aleksandra Barylak
  mgr Alicja Leśniewska
  mgr Jarosław Barylak

- Supervisor of **seven engineer theses.**

  inż. Wojciech Bełza
  inż Mateusz Kłys
  inż Piotr Kobus
  inż. Alicja Leśniewska
  inż Jarosław Barylak
  inż Aleksandra Drążkiewicz
  inż Łukasz Dusanowski

- **Supervisor of student internships**:

  Aleksandra Grzegorek (2014), Student of Poznan University of Technology
  Justyna Szydełko (2015), Student of Wrocław University of Science and Technology

Adam Klimont (2012), Student of Wrocław University of Science and Technology
Mateusz Dyksik (2012), Student of Wrocław University of Science and Technology

6.5. Supervision over Ph. D. students as an auxiliary supervisor.

dr inż. Filip Janiak, Supervisor: Prof. Grzegorz Sęk
mgr inż. Mateusz Dyksik, Supervisor: Prof. Grzegorz Sęk

6.6. Scientific internships

L.P.	Date	Number of days	Place	Country
1.	2009	5	Karlsruhe, training at Bruker company	Germany
2.	2003	10	Summer European workshop: European Summer University 2003, Fundamentals of Nanoscience, Strasbourg	France
3.	2002	14	Summer workshop organised by Institute of Low Temperatures of Polish Academy of Sciences, Wroclaw	Poland

6.7. Prepared expertise and other elaborations on request

I wrote an expertise for Military University of Technology, Warsaw. It concerned i.e. realising photoluminescence experiments for InAs/GaSb superlattices and analysis of received optical spectra.

6.8. Reviewing of publications in scientific journals.

As per now I have revised ~20 publications in scientific journals such as:

a) Nanoscale
b) Journal of Applied Physics
c) Optica Applicata

d) Semiconductor Science and Technology
e) Physica Status Solidi B
f) Opto-electronic Review
g) Materials Science-Poland
h) Optical and Quantum electronics
i) Vacuum

6.9. International and domestic collaboration.

- ➢ Technische Physik and Wilhelm-Conrad-Röntgen-Research Center for Complex Material Systems, University of Würzburg, Germany
- Prof. Martin Kamp, dr Sven Hoffling

- ➢ IOFFE Institute, Sankt Petersburg, Russia
- Prof. Konstantin Moiseev

- ➢ Laboratoire de Photonique et de Nanostructures, CNRS, Université Paris-Saclay, France
- dr Gilles Patriarche

- ➢ Institut d'Electronique du Sud, Université Montpellier 2-CNRS, France
- Prof. Yves Rouillard

- ➢ Instytut Technologii Elektronowej, Warszawa
- Prof. Maciej Bugajski, dr hab. Kamil Kosiel, dr Anna Szerling, dr Kamil Pierściński

- ➢ Instytut Fizyki Wojskowej Akademii Technicznej w Warszawie
- Prof. Antoni Rogalski, dr hab. Piotr Martyniuk, dr Waldemar Gawron

- ➢ Instytut Fizyki Politechniki Łódzkiej
- dr hab. Tomasz Czyszanowski, dr Michał Wasiak

- ➢ Wydział Elektroniki Mikrosystemów i Fotoniki Politechniki Wrocławskiej
- Prof. Marek Tłaczała, dr Damian Pucicki

- ➢ VIGO S.A. Ożarów Mazowiecki
- Profesor Józef Piotrowski, dr Adam Piotrowski

- ➢ Nanoplus, Germany
- dr Mark Fisher, dr Robert Weih

- ➢ Airoptc, Poznań
- dr Paweł Kluczyński

Marcin Motyka