Jaunu čukstošās galerijas modu mikrorezonatoru izstrāde optisko frekvenču standartu un biosensoru pielietojumiem, un to raksturošana ar femtosekunžu optisko frekvenču ķemmi

Projekta 12. atskaite par paveikto periodā

01.12.2019.- 29.02.2020.

I. Brice
A. Atvars
R. Viter
A. Ramanavicius
J. Alnis

NACIONĀLAIS ATTĪSTĪBAS PLĀNS 2020

EIROPAS SAVIENĪBA
Eiropas Reģionālās attīstības fonds

IEGULDĪJUMS TAVĀ NĀKOTNĒ

ERAF projekts Nr. 1.1.1.1/16/A/259

Par projektu

- **Projekta nosaukums:** Jaunu čukstošās galerijas modu mikrorezonatoru izstrāde optisko frekvenču standartu un biosensoru pielietojumiem, un to raksturošana ar femtosekunžu optisko frekvenču ķemmi.
- **Projekta numurs:** 1.1.1.1/16/A/259
- **Projekta mērķis:** jaunu zināšanu-zinātības iegūšana CGM rezonatoru izstrādē, stabilizēšanā un modelēšanā, un rezonatoru izmantošanā biomolekulu detektēšanai, tādējādi atbalstot Latvijas Viedās specializācijas mērķu sasniegšanu, zinātnes un tehnoloģiju cilvēkkapitāla attīstību un jaunu zināšanu radīšanu tautsaimniecības konkurētspējas uzlabošanai.

- **Projekta vadītājs:** J. Alnis
- **Projekta administratīvais vadītājs:** I. Brice
- **Projektu realizē** LU ASI Kvantu optikas laboratorija
- **Projekta īstenošanas laiks:** 01.03.2017. - 29.02.2020.

Projekta budžets

Projekta kopējās izmaksas: 648 252,61 EUR, to skaitā ERAF finansējums (85%) - 551 014,72 EUR.

- Izdevumi MP1 – 33 108.93 EUR
- Izdevumi MP2 – 46 967.37 EUR
- Izdevumi MP3 – 50 168.34 EUR
- Izdevumi MP4 – 19 164.77 EUR
- Izdevumu MP5 - 38 392.16 EUR
- Izdevumu MP6 - 84 367.70 EUR

- Izdevumi MP7 - 78 512.16 EUR
- Izdevumi MP8 - 34 725.76 EUR
- Izdevumi MP9 - 50 197.04 EUR
- Izdevumi MP10 - 79 500.27 EUR
- Izdevumi MP11 – 71 793.20 EUR
- Pēdējais MP12 ~ 48 766.80 EUR

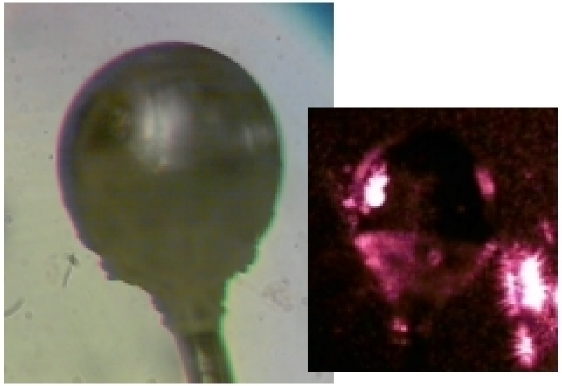
Kopā: 635 664.50 EUR
Atlikums: 12 588.11 EUR

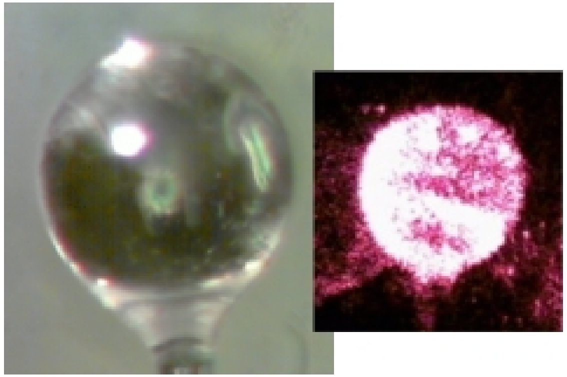
Summary of the project budget

Code	Cost item*	Type of costs	Costs		TOTAL		incl. VAT
			eligible	ineligible	EUR	%	
1.	**Project costs pursuant to the unified cost rate** *Indirect costs (for a project not related with economic activity) equal to 25% of the direct eligible costs*	**indirect**	125 359.80	135.00	125 494.80	19.7	0.00
3.	**Project implementation personnel costs**	**direct**	**444 641.67**	**1017.00**	**445 658.67**	**70**	**0.00**
3.1.	Project implementation personnel remuneration costs	direct	414 296.87	477.00	414 773.87	65.1	0.00
3.2.	Other project implementation personnel costs (business trips)	direct	30 344.80	540.00	30 884.80	4.9	0.00
6.	**Material, facility and equipment costs**	**direct**	**20 944.89**	**0.00**	**20 944.89**	**3.3**	**3 861.58**
8.	**Patents, licences, etc.**	**direct**	**3 133.90**	**0.00**	**3 133.90**	**0.5**	**543.90**
10.	**Costs of informative and publicity activities** (for a project not related with economic activity)	**direct**	**0.00**	**0.00**	**0.00**	**0**	**0.00**
12.	**Investments in kind** (for a project not related with economic activity)	**direct**	**32 716.15**	**0.00**	**32 716.15**	***5.1***	**0.00**
13.	**Other project implementation costs**	**direct**	**8 868.09**	**0.00**	**8 868.09**	***1.4***	**1 539.09**
	TOTAL		**635 664.50**	**1152.00**	**636 816.50**	**100**	**5 944.57**

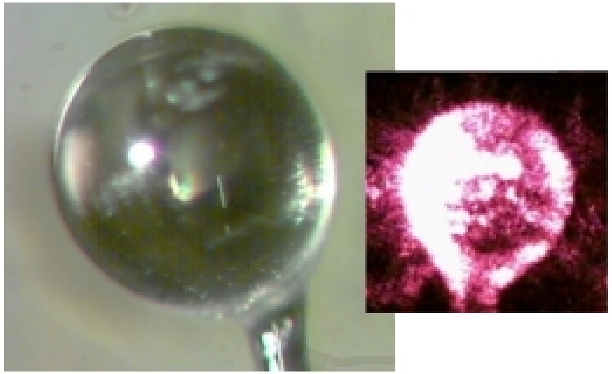
Zinātniskās darbības progress

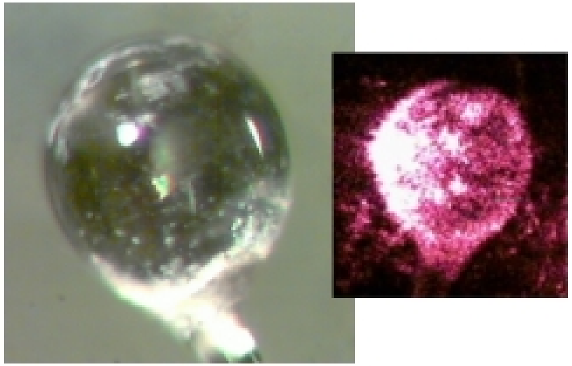
Rezonatoru pārklāšana ar ZnO

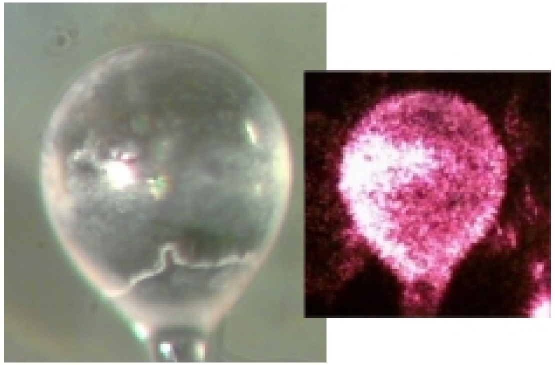

1x20µl of 4 mg/ml


1x20µl of 2 mg/ml

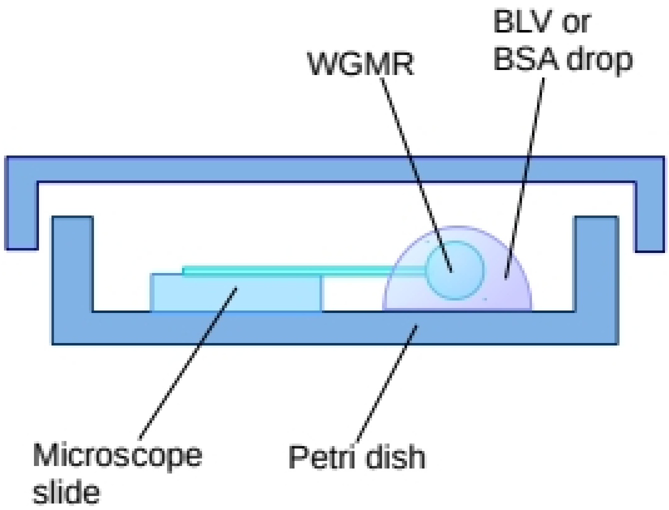

1x20µl of 1 mg/ml

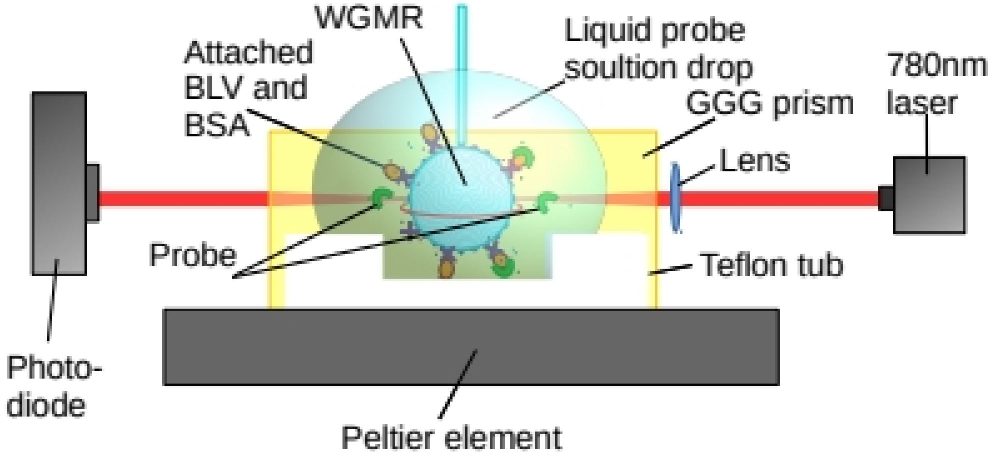

2x10µl of 2 mg/ml

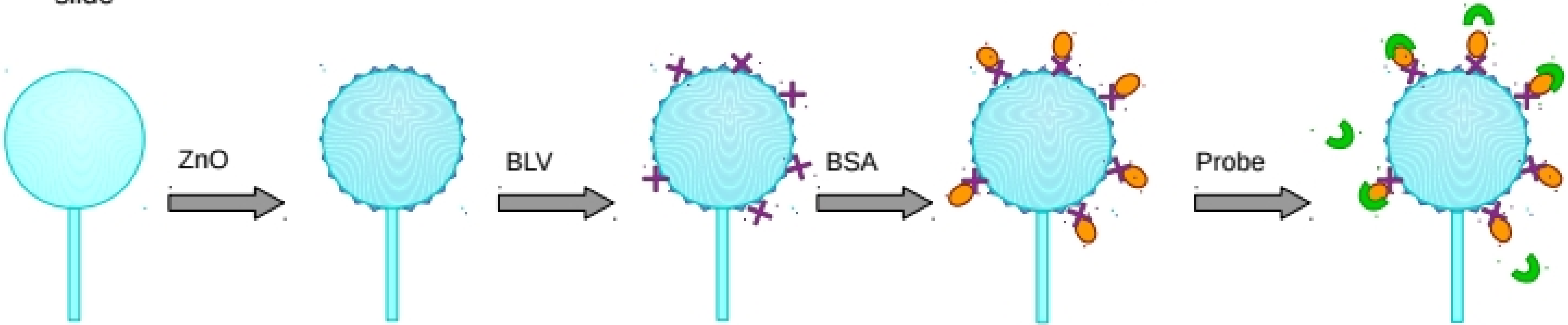

2x15µl of 2 mg/ml


1x30µl of 2 mg/ml

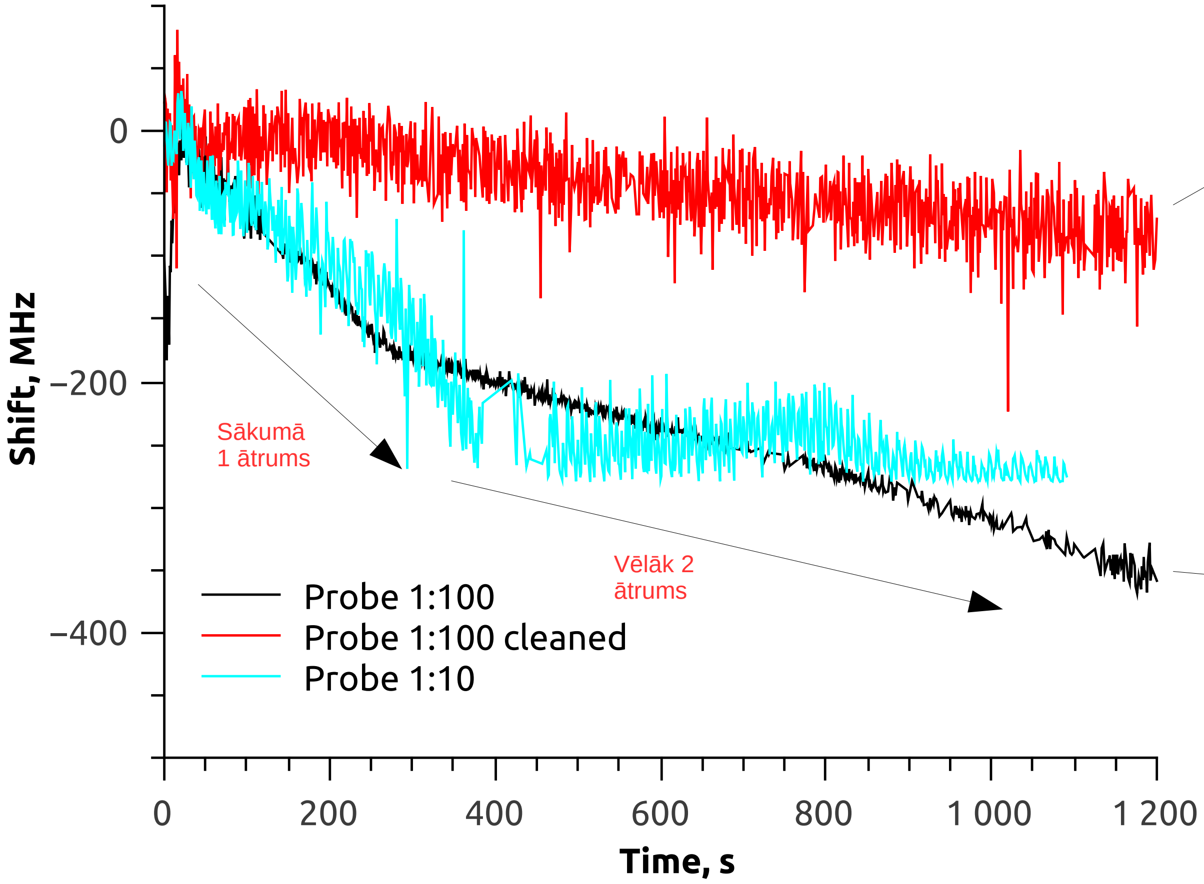
Rezonatoru pārklāšana un testēšana toksīna sensors

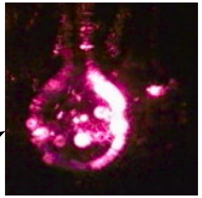




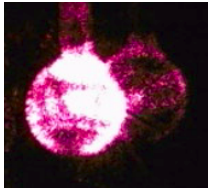


Mērījumu rezultāti



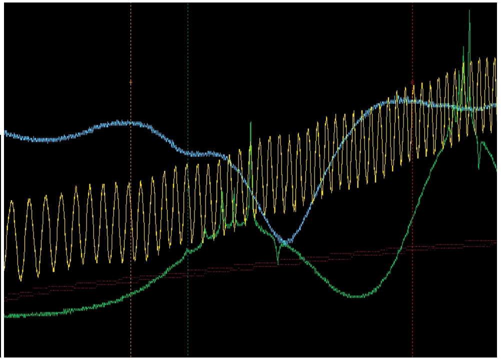


Pēc tīrīšanas



Pirms tīrīšanas

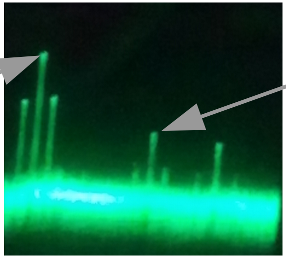
Pēc tīrīšanas praktiski nav vairs ZnO; pie virsmas nepieķeras bez ZnO?



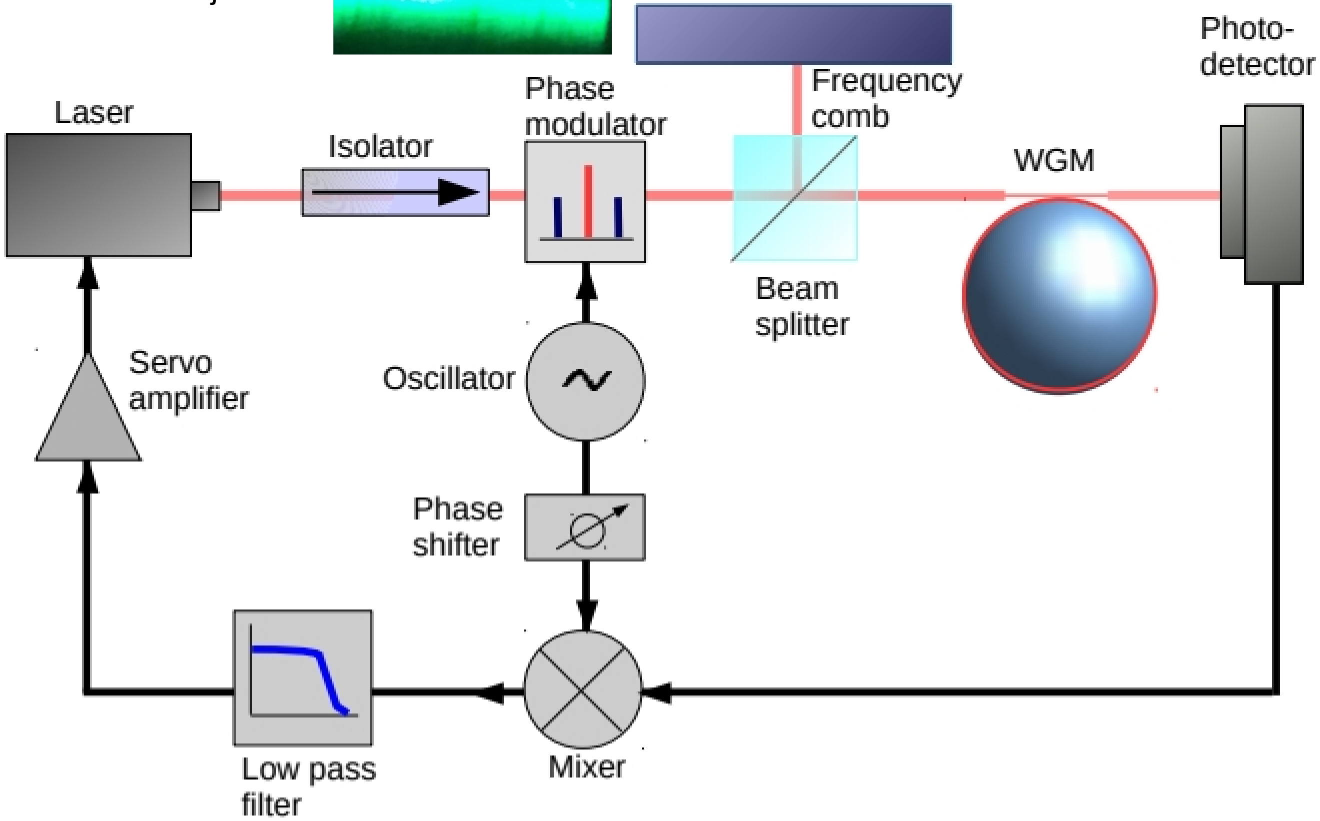
Ātrā rezonanses bīdīšanās notiek ilgāk lielākai koncentrācijai

Lāzera Stabilizēšana balstoties uz PDH metodi

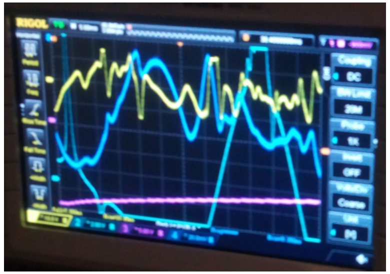
Signāls no ķemmes ar modulāciju



Beat note no lāzera ar modulaciju



ČGM un kļūdas signāls, stabilizācija izslēgta



ČGM un kļūdas signāls, stabilizācija ieslēgta, skenējot cenšas pieķerties modām

Svarīgākie sasniegtie rezultāti

Svaigākie sasniegtie rezultāti Darbība 1

Analytical classical description of resonances in Fabry-Perot and whispering gallery mode resonators

A. Atvars

Institute of Atomic Physics and Spectroscopy, University of Latvia, Raina boulv.19, LV-1050, Latvia

E-mail: Aigars.Atvars@lu.lv

Abstract. Whispering gallery mode optical resonators have attracted attention due to their simplicity and applicability for sensing. Analytical formulas are provided that describe resonance conditions in optical resonators. Basic terms are introduced - resonance wavelengths and frequencies, free spectral range, Q-factor, summation principle of Q-factors of various processes, Finesse. Description of interference of an infinite number of waves of progressively smaller amplitudes and equal phase differences is given. Description of Fabry-Perot resonator with nonequal reflection coefficients is given. Optical all pass and add drop filters are described, providing analytical formulas for summary amplitude of fields in different ports, intensity distribution, maximal and minimal intensities, resonance depth, resonance width, Finesse, Q-factor. Analytical description of resonators will help to analyse effects of optical resonators, to interpret results of experiments and will guide in the development of novel applications of microresonators.

Keywords: optical resonances, Q-factor, Fabry-Perot resonator, whispering gallery mode resonator

Submitted to: *Phys. Scr.*

Publikācija "Analytical classical description of resonances in Fabry-Perot and whispering gallery mode resonators" iesniegta žurnālā Physica Scripta (51%)

Prototips – ČGM rezonators ar vislabāko sniegumu

Zinātības apraksts

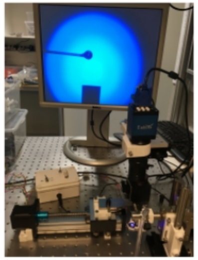
UNIVERSITY OF LATVIA

Intellectual Property Rights

Know-how on Optical microresonator fabrication device

I. Brice, K. Grundšteins, J. Alnis

ERDF Project No. 1.1.1.1/16/A/259 "Development of novel WGM microresonators for optical frequency standards and biosensors, and their characterization with a femtosecond optical frequency comb"



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2020

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Svaigākie sasniegtie rezultāti Darbība 2

Laser stabilization using Whispering gallery mode reference resonator

I Brice, A Atvars, A Cinins, and J Alnis

Institute of Atomic Physics and Spectroscopy, University of Latvia, Jelgavas str. 3, Riga LV1004, Latvia

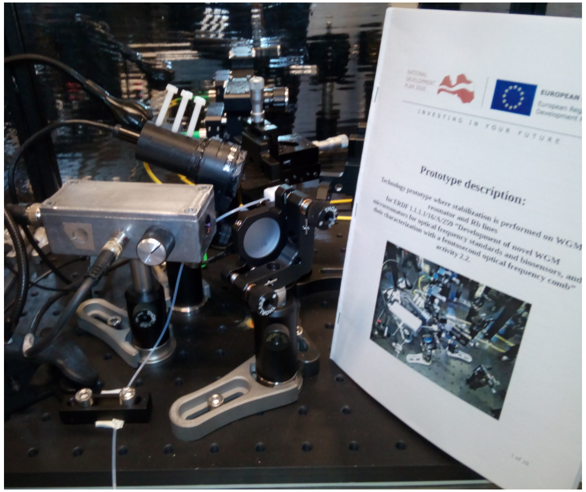
E-mail: arturs.cinins@lu.lv

February 2020

Abstract. A frequency stabilization system for an external cavity diode laser was built based on temperature stabilized whispering gallery mode microresonator. Stability of the system was measured using an optical femtosecond frequency comb. The system was tested in conjunction with Rb staturation absorption spectroscopy setup to evaluate resonator mode drift. For a fused silica microsphere temperature stabilized near room temperature, Allan deviation of $3 \cdot 10^{-10}$ was achieved at averaging time of 2 s.

Publikācija "Laser stabilization using Whispering gallery mode reference resonator" iewniegta žurnālā Journal of Physics B: Atomic, Molecular and Optical Physics (58%)

Prototips – Tehnoloģijas prototips, kurā stabilizācija tiek veikta uz ČGM rezonatora un Rb līnijas



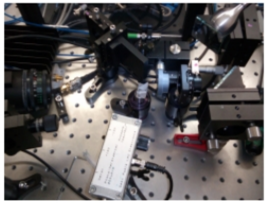
UNIVERSITY OF LATVIA

Intellectual Property Rights

Know-how on Testing of WGM resonators and the development of technology of optical standard

I. Brice, K. Grundšteins, J. Alnis

ERDF Project No. 1.1.1.1/16/A/259 "Development of novel WGM microresonators for optical frequency standards and biosensors, and their characterization with a femtosecond optical frequency comb"



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2020

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Zinātības apraksts

Svaigākie sasniegtie rezultāti Darbība 3

Publikācija “Whispering gallery mode resonators covered by ZnO nanolayer” iesniegta žurnālā Optik (59%)

Whispering gallery mode resonators covered by ZnO nanolayer

Inga Brice[1], Roman Viter[1], Kristians Draguns[1], Karlis Grundsteins[1], Aigars Atvars[1], Janis Alnis[1], Emerson Coy[2] and Igor Iatsunskyi[2]
[1]Quantum Optics Laboratory, Institute of Atomic Physics and Spectroscopy, University of Latvia, Raina Blv. 19, Riga, LV-1586, Latvia
[2]NanoBioMedical Centre, Adam Mickiewicz University, 3 Wszechnicy Piastowkiej str., 61-614, Poznan, Poland
e-mail: roman.viter@lu.lv

Abstract

The exceptional ability of the whispering gallery mode resonators (WGMRs) to confine light within make them interesting for sensing applications. The small size and high values of quality (Q) factors of the WGMR can be combined with a broad range of supporting optical elements. The surface of the resonator can be coated to enhance desired attributes.

In this paper the impact of the ZnO layer thickness on the Q-factor of the WGMR has been studied. WGMR were fabricated on a top of a standard telecom fiber melted with a hydrogen flame. The surface of the WGMR was coated with ZnO nanolayers of different thickness (5-100 nm) by using atomic layer deposition (ALD). The Q-factor of as prepared WGMR was in the range of 10^7 a.u., whereas Q-factor of ZnO-WGMR decreased 2-10 times. The optimal thickness of functional ZnO coating on WGMR was 10-60 nm. Mechanism of the ZnO layer thickness influence to Q-factor was based on two competing phenomena such as the change of refractive index and surface roughness due to ZnO growth. Effect of the ZnO as a protective coating against Q-factor degradation was studied. The thicker ZnO layers prevented degradation of Q-factor of the WGMR.

Introduction

ZnO is well known materials for different optoelectronic applications, such as sensors, biosensors and optical coatings [1–4]. Number of techniques has been developed for ZnO deposition, such as chemical bath deposition, pulsed laser deposition, etc. [5,6]. However, among these methods, Atomic layer deposition (ALD) is a powerful method for conformal deposition of ZnO with tailored structure and optical properties [3,7,8]. In our previous work we showed that ZnO thickness is an important parameter, influencing crystallization, grain size, band gap and defect concentration [3,7,8]. It was shown that the refractive index of ZnO enhanced with increase of the thickness due to amorphous-to-crystalline transition [3,7,8].

Whispering gallery mode resonators (WGMR) are solid-state cavities that confine light in small geometrical volumes for long periods of time [9]. It was achieved by total internal reflection of light within WGMR. The simplest way of production of WGMR is high temperature melting of optical fiber by using a heating source, for example, a CO_2 laser or a gas flame [10]. The only disadvantage is the requirement of a glass in form of rod or fiber and the fabrication of only one microsphere at a time. Due to the procedure, round shape WGMR with low surface roughness and high Quality factors (Q-factor) in the range of 10^6 to 10^9 is formed on tip of optical fiber [10,11].

ZnO microstructures (spheres, rods, etc.) have been used as WGMRs for laser and sensor applications due to high refractive index (important for light coupling), biocompatibility and functionality of the surface [12–14]. However, the integration of ALD ZnO nanolayers and WGMRs is still missing point. It is expected that ZnO nanolayers will limit Q-factor of WGMRs, protect it from dust and moisture and decrease Van der Vaals forces due to screening of surface charge of WGMR.

Prototips – ČGM biosensors ar vislabāko sniegumu

Publikācija “**Whispering gallery mode resonator based glucose sensor**” iesniegta žurnālā Sesnors and Actuators B (92%), Raksts tiek recenzēts

Whispering gallery mode resonator based glucose sensor

Inga Brice[a], Karlis Grundsteins[a], Aigars Atvars[a], Janis Alnis[a], Roman Viter[a],
Arunas Ramanavicius[a,b]*
[a] *Institute of Atomic Physics and Spectroscopy, University of Latvia, Jelgavas Street 3, Riga, LV-1004, Latvia*
[b] *Laboratory of Nanotechnology, State Research Institute Center for Physical Sciences and Technology, Sauletekio gatve. 3, LT-10257, Vilnius, Lithuania*

Abstract

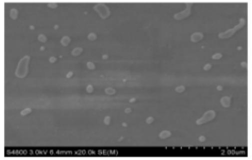
Whispering gallery mode (WGM) resonators (WGMRs) are very promising for sensing purposes, because a resonance frequency shift can be caused by the perturbation of the surrounding environment induced by different analyte concentrations. In this research WGM-resonators were applied in new concept of glucose sensor based on the shift of WGM resonance frequency induced by enzymatic oxidation of glucose by glucose oxidase (GOx), which was immobilized on WGM-resonator surface. During the enzymatic reaction catalyzed by GOx electrons from glucose via GOx are transferred towards co-immobilized gold nanoparticles (Au-NPs). WGM-resonators were fabricated from standard telecommunication optical-fiber melted in a hydrogen flame. Whispering gallery mode resonance based optical signals generated by these WGM-resonators were evaluated. These WGM-resonators, which were characterized by sufficient quality factors, were modified with Au-NPs using dip coating method in order to form hybrid WGM-resonator (WGMRs/Au-NPs) structure. Then WGMRs/Au-NPs structure was investigated using SEM and, after these investigations, the sensitivity of WGMRs/Au-NPs-based resonators towards glucose has been assessed by the evaluation whispering gallery mode resonance based optical signals. Then the next modification step of WGMRs/Au-NPs resonators by enzyme – GOx – has been performed in order to design WGMRs/Au-NPs/GOx-based resonator structure, which showed increased sensitivity towards glucose in comparison to that of WGMRs/GOx-based resonators, which were not modified by Au-NPs. WGMRs/Au-NPs/GOx-based glucose sensor was tested at several glucose concentrations in the range up to 2.4 mM and it was determined that WGM-resonance frequency shift rate significantly increases at higher glucose concentrations. Therefore, WGM-resonance frequency shift rate was determined as characteristic of analytical signal suitable for the

Zinātības apraksts

UNIVERSITY OF LATVIA

Intellectual Property Rights
“Know-how on The detection of biomolecules using WGM resonator”
I. Brice, K. Grundšteins, A. Ramanavičius, R. Viter

ERDF Project No. 1.1.1.1/16/A/259 “Development of novel WGM microresonators for optical frequency standards and biosensors, and their characterization with a femtosecond optical frequency comb”



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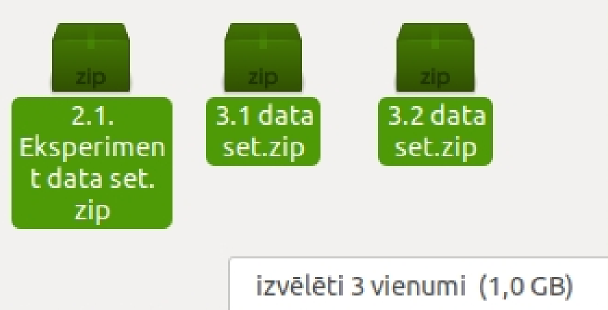
Svaigākie sasniegtie rezultāti Citi

Mērījumu datu komplekti - 3



Ziņas LU mājas lapā - 3

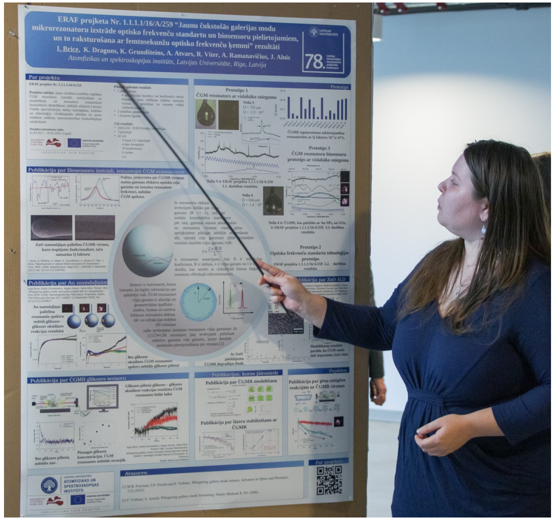
10.02.2020. Inga Brice

Kvantu optikas laboratorijas

Latvijas Universitātes (LU) Atomfizikas un spektroskopijas institūts (ASI) Kvantu optikas laboratorija akadēmiķa Jāņa Alņa vadībā Latvijā ir ieviesusi pētījumu tēmu par optiskajiem čukstošās galerijas modu rezonatoriem un to izmantošanu sensoru pielietojumos. 14. februārī plkst. 14.00 LU Zinātņu mājā, Jelgavas ielā 3, 6. stāvā norisināsies LU 78. starptautiskās zinātniskās konferences LU ASI un AI sekcija "Atomfizika, kosmiskās tehnoloģijas un medicīniskā fizika".

Kvantu Optikas laboratorija konferencē prezentēs sekojošus stenda referātus:

- I. Brice, D. Damberga, K. Grundšteins, U. Bērziņš, A. Atvars, R. Viter, J.Alnis. Čukstošas galerijas modas rezonanses gaisā un ūdenī, skenējot temperatūru// Temperature scanning the WGMR resonances in air and water



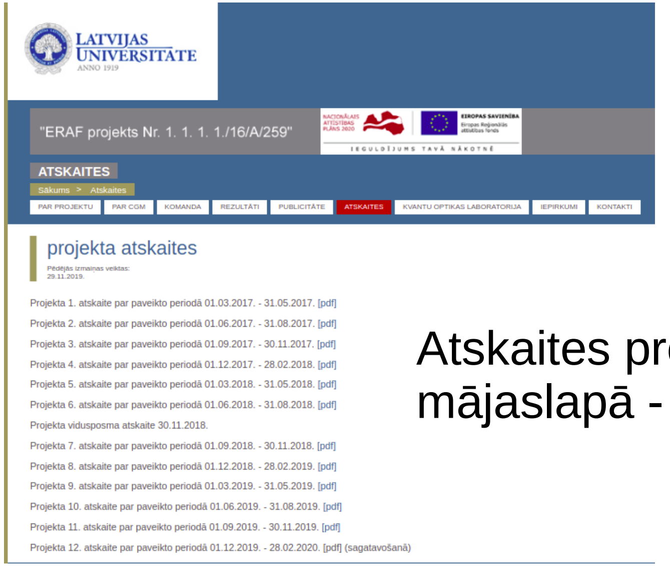
Semināri - 3

Datorprogrammu komplekti - 1

Natūra - **32 716.15 EUR**

Konferences - 10

Vizītes - 6



LATVIJAS UNIVERSITĀTE ANNO 1919

"ERAF projekts Nr. 1. 1. 1. 1./16/A/259"

ATSKAITES

Sākums > Atskaites

PAR PROJEKTU | PAR CGM | KOMANDA | REZULTĀTI | PUBLICITĀTE | ATSKAITES | KVANTU OPTIKAS LABORATORIJA | IEPIRKUMI | KONTAKTI

projekta atskaites

Pēdējās izmaiņas veiktas: 29.11.2019.

Projekta 1. atskaite par paveikto periodā 01.03.2017. - 31.05.2017. [pdf]
Projekta 2. atskaite par paveikto periodā 01.06.2017. - 31.08.2017. [pdf]
Projekta 3. atskaite par paveikto periodā 01.09.2017. - 30.11.2017. [pdf]
Projekta 4. atskaite par paveikto periodā 01.12.2017. - 28.02.2018. [pdf]
Projekta 5. atskaite par paveikto periodā 01.03.2018. - 31.05.2018. [pdf]
Projekta 6. atskaite par paveikto periodā 01.06.2018. - 31.08.2018. [pdf]
Projekta vidusposma atskaite 30.11.2018.
Projekta 7. atskaite par paveikto periodā 01.09.2018. - 30.11.2018. [pdf]
Projekta 8. atskaite par paveikto periodā 01.12.2018. - 28.02.2019. [pdf]
Projekta 9. atskaite par paveikto periodā 01.03.2019. - 31.05.2019. [pdf]
Projekta 10. atskaite par paveikto periodā 01.06.2019. - 31.08.2019. [pdf]
Projekta 11. atskaite par paveikto periodā 01.09.2019. - 30.11.2019. [pdf]
Projekta 12. atskaite par paveikto periodā 01.12.2019. - 28.02.2020. [pdf] (sagatavošanā)

Atskaites projekta mājaslapā - 12

Iznākuma rādītāji

No.	Indicator	Planned value	Received value	Post-monitoring period	Unit of measure
		value	value	value	
2.	Number of scientific articles for drawing up and publishing of which the support was granted	5	6	1	Number of scientific articles
2.1.	in scientific journals or conference proceedings, the citation index of which reaches at least 50 percent of the average citation index in the sector	4	4	1	Number of scientific articles
3.	Number of new marketable products or technologies the development of which was supported within framework of the project	3	3		Number of products and technologies
3.1.	prototype of the new product or technology	3	3		Number of prototypes
4.	Technology rights	3	3		Amount
5.	Intellectual property licence agreements	1	0	1	Amount
6.	Private investment matching public support in innovation or R&D projects	32 412.63	32 716.15	0	EUR
8.	Other project results (including data) that supplement the results provided in the indicators No. 2, 3.1,4, 5	42	45		Amount