Development of novel WGM microresonators for optical frequency standards and biosensors, and their characterization with a femtosecond optical frequency comb

Achievements of the first quarter

FOTONIKA-LV CXXXVI colloquium
30.05.17.
Content

1. Project management and publicity I. Brice
2. Overview and experiments J. Alnis
3. Theory and modelling A. Atvars
4. Development of biosensors R. Viter
Development of novel WGM microresonators for optical frequency standards and biosensors, and their characterization with a femtosecond optical frequency comb

Report for the first three months

1. Project Management and Publicity

30.05.17.
LU ASI
I. Brice

ERDF project Nr. 1.1.1.1/16/A/259
About Project

- **Project title**: Development of novel WGM microresonators for optical frequency standards and biosensors, and their characterization with a femtosecond optical frequency comb
- **Project number**: 1.1.1.1/16/A/259
- **Project aim**: to acquire new knowledge of know-how in design, stabilizing and modeling of the WGM resonator, and the detection of biomolecule using the resonator, thus supporting the objectives of the Latvian Smart specialization, scientific and technological development of human capital and the creation of new knowledge for economy to improve competitiveness.

- **Project Manager**: J. Alnis
- **Project Administrative Manager**: I. Brice

- The project is realized by UL IAPS Quantum optics laboratory
- **Main results** planned for the project: 4 publications, 3 know-how descriptions, 1 license agreement
- 9 conference visits and 6 scientific visits are designated
- **Project period**: 01.03.2017. - 30.08.2019.
Project Budget

- Total project cost: 648 252.61 EUR, including the ERDF (85%) - 551 014.72 EUR.
- 1st Advance Request 64972 EUR
- Expenditure on salaries 26,487.07 EUR + 25% of indirect costs. Total 33,108.93 EUR
- 2nd Advance request 71 266.25 EUR (ongoing)
Purchases

• COMC LOL Multihysics software procurement.
  a) Announced 27.04.2017. IUB. LU specification. The project required procurement section was paused due to the new software version of COMSOL was released on 25.4.2017. and the clarification of the procurement rules is needed;

• Purchase of materials procurement 1. (under development)

• Instrument rental procurement. (in development)
Employees

- leading researchers
  - J. Alnis
  - A. Atvars
  - R. Viter
- scientific assistant
  - I. Brice
- laboratory assistants
  - K. Grundšteins
  - A. Pirkština
  - A. A. Ūbele

Project team group photo (April 2017).

ERDF project Nr. 1.1.1.1/16/A/259
Project Homepage

www.lu.lv/cgm/

ERDF project Nr. 1.1.1.1/16/A/259
The information about the project is available in both Latvian and English.
Information available on the website is regularly refreshed. For example, the Purchases section was added and new information about WGM written.
Publicity

Informative plaque and poster for the project can be found at UL IAPS.
Publicity

At the University website news section an article about the FOTONIKA-LV CXXXVI colloquium was published, inviting to the Report of the progress made in the first three months.
Development of novel WGM microresonators for optical frequency standards and biosensors, and their characterization with a femtosecond optical frequency comb

2. Overview and experiments

1. WGM resonator development and modelling.
2. WGM optical standard stabilized on Rb.
3. WGM for biomolecule detection.

Jānis Alnis Research Manager
Romāns Viters Senior researcher
Aigars Atvars Senior researcher
Inga Brice Phd student
Kārlis Grunšteins master student
Alma Übele / Antons Pribitoks bachelor student
Andra Pirktiņa bachelor student

30.05.17. 
LU ASI 
J. Alnis
WGMR biosensor, light coupled using optical fiber

We are planning something similar. R. Viter will be coatings WGMRs with antibodies.

F. Vollmer Nature 2008
WGM biosensor experiment

We will repeat during ERDF. R. Viter will deal with biological parts and coatings.
WGMR biosensors, light coupled using a prism

We will make during ERDF. R. Viter deal with biological parts and coatings.
We will start with a glass or quartz ball melting at the IAPS glass blower workshop. A. Atvars, J. Alnis.
Grinding stand for CaF$_2$ un MgF$_2$ WGMRs

We will make it in LV during ERAF. J. Alnis, I.Brice.
CaF$_2$ un MgF$_2$ GWMRs for stabilizing lasers

We will make it in LV during ERAF. J. Alnis, I. Brice.
WGMR thermal drift prevention by using the Rb atom lines

We will make it in LV during ERAF. J. Alnis, I. Brice.

Title: OPTICAL ATOMIC CLOCK
Patent
WO 2015/143048 A1
(24.09.2015)
OEwaves inc. USA
Good and bad qualities of the WGMRs

+ Can be hand-made
+ No mirror coating necessary
+ High Q factors - long ring-down lifetime
+ Compact - optics on chip, space applications

- Prism coupling - hard to align
- Tapered fiber coupling - brittle
- Surface degrades

Try lithography grating production on WGM surface for light incoupling?
Towards WGM resonator stabilised on RB 5S-5P transition lines

Inga Brice, Antons Pribitoks, Janis Alnis

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Frequency stability is regarded as absence of frequency drift or maintaining a single fixed frequency as long as...
Report at the conference

13th International Young Scientist conference

Developments in Optics and Communications 2017
Riga, Latvia, April 6 - 7, 2017

P03  Andra Pirkina
Estimation of optical fiber melting temperature from the Planck’s law using a grating spectrometer

18
Fitting the Planck formula

\[ I(\lambda,T) = \frac{2\pi hc^2}{\lambda^5(\lambda k_B T) - 1} \]
Prototype equipment assembly and adjustment for coupling the green laser light onside the WGMR.
Whispering gallery modes inside a large spherical resonator, \(d \approx 6\ \text{cm}\)

- If the light is coupled without a prism, points of total internal reflection can be observed.
- We made sure that we can couple the light through the prism surface. Red fluorescence was observed after smearing the surface with colored marker. Important fact, the light passes through the surface instead of inside the volume.

- Recorded a Youtube video
  
  [https://www.youtube.com/watch?v=j7MxQRNx8-U](https://www.youtube.com/watch?v=j7MxQRNx8-U)
Whispering gallery modes inside a small spherical resonator, $d \approx 1 \text{ mm}$

After using the big sphere we switched to coupling the light in a small sphere that was made by melting an end of an optical fiber.

This resonator was observed using an USB microscope and computer. A video was recorded. Green laser light from laser and a glare of the resonator can be seen.

https://www.youtube.com/watch?v=EEZHJD82Z2M
We studied a variety of optical microscope resolution and working distances:

USB microscope, medical microscope, jewelers microscope electronics microscope.

The challenge to overcome is that the microscope lens scould not be close to the sample. We need at least 1 cm gap, because we want to look under the microscope while manufacturing the resonator and through the window of an vacuum camera.

The conclusion: a calibration object is necessary with 10 ... 1 micron structures.
“Development of novel WGM microresonators for optical frequency standards and biosensors, and their characterization with a femtosecond optical frequency comb”.

Report for the first three months

3. Theory and Modelling

30.05.2017., LU ASI, A.Atvars
WGM inside a the glass sphere, with a diameter of 6 cm. A prism is used to couple the light.
Equation 1.2: Spectra of Whispering gallery mode sphere

\[ 2\pi r n = \lambda N \]

\[ 2\pi r n = (\lambda + \Delta \lambda)(N + 1) \]

\[ \Delta \lambda \approx -\frac{\lambda^2}{2\pi r n} \]

\[ \Delta \nu = \frac{c}{2\pi r n} \]

\[ \lambda_{TE} \approx \frac{2\pi R n_1}{m + 1.856m^3 + \left(\frac{1}{2} - \frac{n_1}{\sqrt{n_1^2 - 1}}\right)} \]

Figure 1.2: Spectra of Whispering gallery mode sphere

[Note: The reference URL provided is a placeholder and is not visible in the image.]
Whispering gallery mode microresonator
Light coupled to the micro resonator using a prism. Images obtained with COMSOL Multiphysics program.
Light propagation. Images obtained with COMSOL Multiphysics program.
Light propagation inside an optical fiber with different diameters. Images obtained with COMSOL Multiphysics program.
Condition of resonance. Images obtained with COMSOL Multiphysics program.
Development of novel WGM microresonators for optical frequency standards and biosensors, and their characterization with a femtosecond optical frequency comb

4. Development of biosensors

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- Literature analysis
- Development of resonators on optical fibers
- Development of nanomaterials as optical transducers and their transfer on WGM resonators
- Functionalization of the biosensor surface
- Biosensor testing
Chemical growth of ZnO nanorods on WGM resonator, based on optical fiber

Hydrothermal Synthesis of ZnO

Step 1: Plasma cleaning of FTO glass
- Deionised water-isopropanol

Zinc acetate+Isopropy
Spin coating
Precursors solution

HTMA+ZnNO₃ 95°C-4hrs
Anneal at 350°C-2hrs
Hydrothermal growth
SEM of ZnO NRs on WGM resonator
Nanospheres lithography
Next steps

- Deposition of thin metal oxide films over PS microspheres
- Deposition of metal oxide nanolaminates over WGM resonators
- Coating of thin layers on internal surfaces of quartz capillaries
- Fabrication of microresonators using lithography
- Structure and optical characterization
- Preparation of paper draft on new coatings for WGM biosensors