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.

NATIONAL DEVELOPMENT PLAN 2020

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ERDF project Nr. 1.1.1.1/16/A/259

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

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ERDF project Nr. 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

Report for the first three months
1. Project Managment and Publicity

30.05.17.
LU ASI
I. Brice

NATIONAL DEVELOPMENT PLAN 2020
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INVESTING IN YOUR FUTURE

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

- COMCOL Multhipysics 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 clarificaton of the procurement rules is needed;
- Purchase of materials procurement 1. (under development)
- Instrument rental procurement. (in developement)

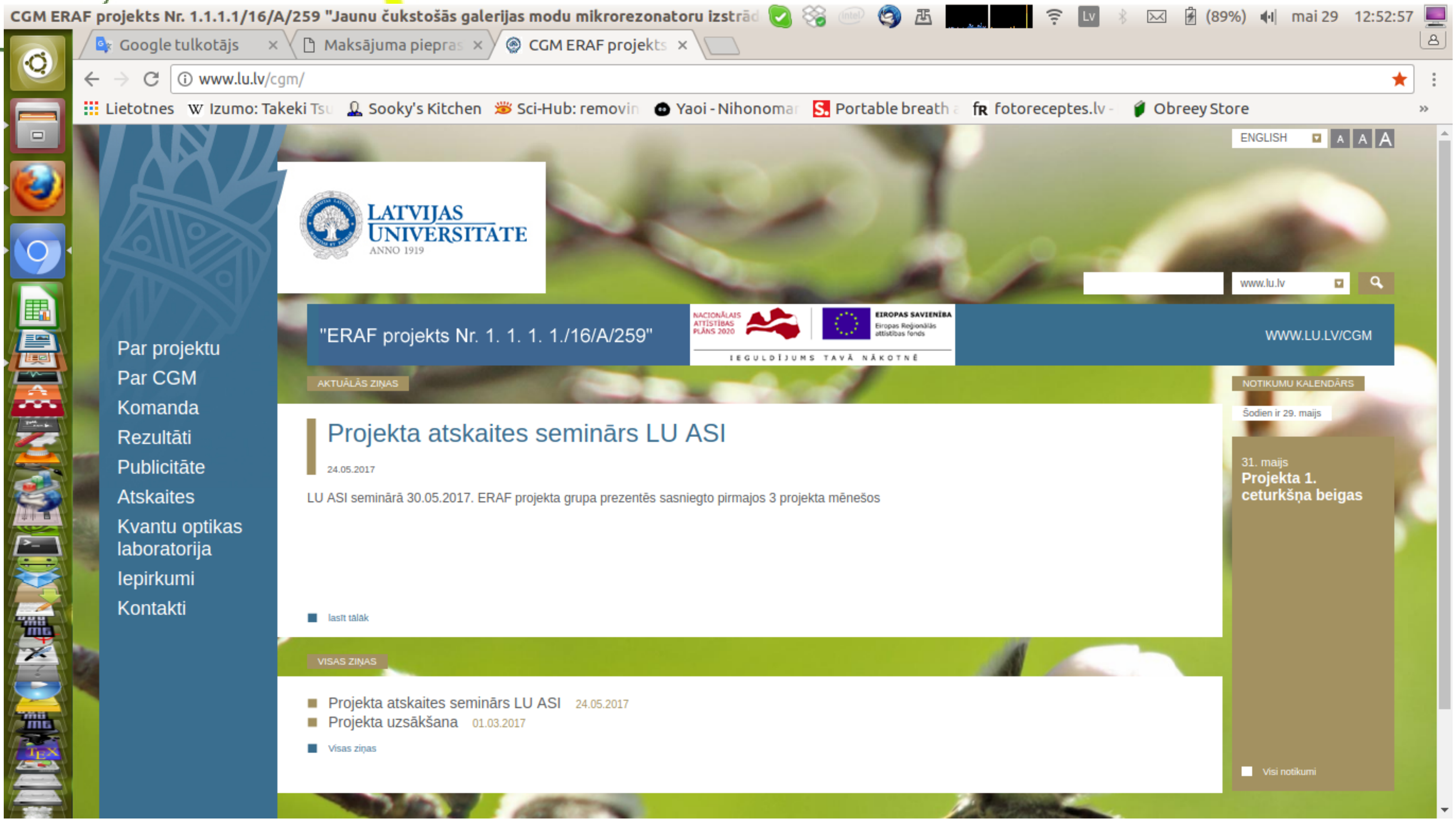
Employees

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

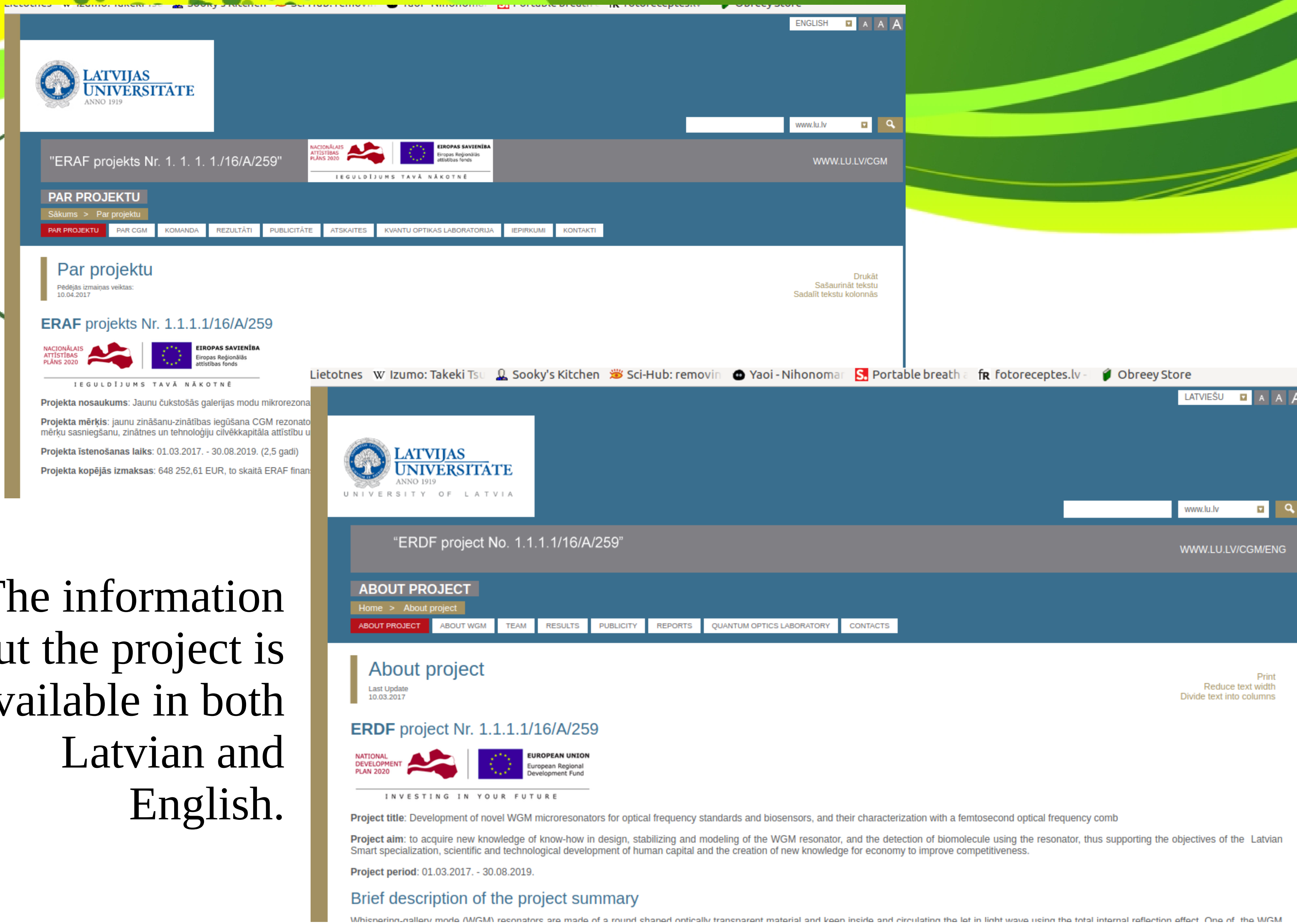
Project team group photo (april 2017).

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.

ERDF project Nr. 1.1.1.1/16/A/259


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

NACIONĀLAIS ATTĪSTĪBAS PLĀNS 2020 | EIROPAS SAVIENĪBA Eiropas Reģionālās attīstības fonds

IEGULDĪJUMS TAVĀ NĀKOTNĒ

WWW.LU.LV/CGM

IEPIRKUMI

Sākums > Iepirkumi

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

Iepirkumi

Pēdējās izmaiņas veiktas:
24.05.2017

Drukāt
Sašaurināt tekstu
Sadalīt tekstu kolonnās

1. Comsol datorprogrammas iepirkums.

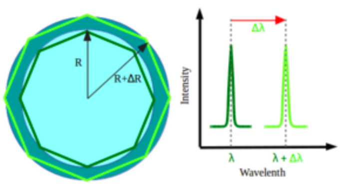
a) Izludināts 27.04.2017. IUB. LU specifikācija. Projektam vajadzīgā iepirkuma sadaļa tika pārtaukta sakarā ar jaunas COMSOL programmatūras versijas iznākšanu 25.04.2017. un līdz ar to nepieciešamību precizēt iepirkuma nolikumu;

2. Materiāli iegādes iepirkums 1. (izstrādes stadijā)

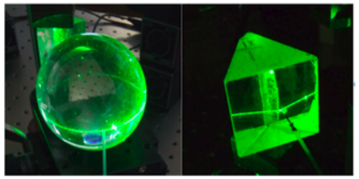
3. Instrumentu nomas iepirkums. (izstrādes stadijā)

Information available on the website is regularly refreshed.
For example, the Purchases section was added and new information about WGM written.

Čukstošo galeriju modu (ČGM) rezonatori ir izpelnījušies īpašu pētnieku uzmanību savu unikālo īpašību dēļ. ČGM veidojas gaismai atstarojoties no ieliektas virsmas, un modas trajektoriju rezonatorā var iedomāties kā vienādmalu daudzstūri, ko ierobežo tā virsma. Rezonatora ģeometrijas simetriskās prasības ir vienkārši apmierināt, jo nepieciešama vai nu sfēriska simetrija (mikrosfēra, mikroburbulis), vai arī cilindriska simetrija (mikrodisks, mikrogredzens, mikrotoroīds). Tā kā ČGM rezonatora rezonanses frekvence ir atkarīga gan no tā izmēra R, gan refrakcijas koeficienta n, tad nelielas izmēra izmaiņas ΔR vai refrakcijas koeficienta izmaiņas Δn rada ievērojamu rezonanses frekvences modas nobīdi $\Delta\lambda$. Šī augstā jutība paver iespēju ČGM rezonatorus izmantot dažādiem pielietojumiem, gan kā filtrus, gan kā lāzeru rezonatorus, gan arī kā sensorus.

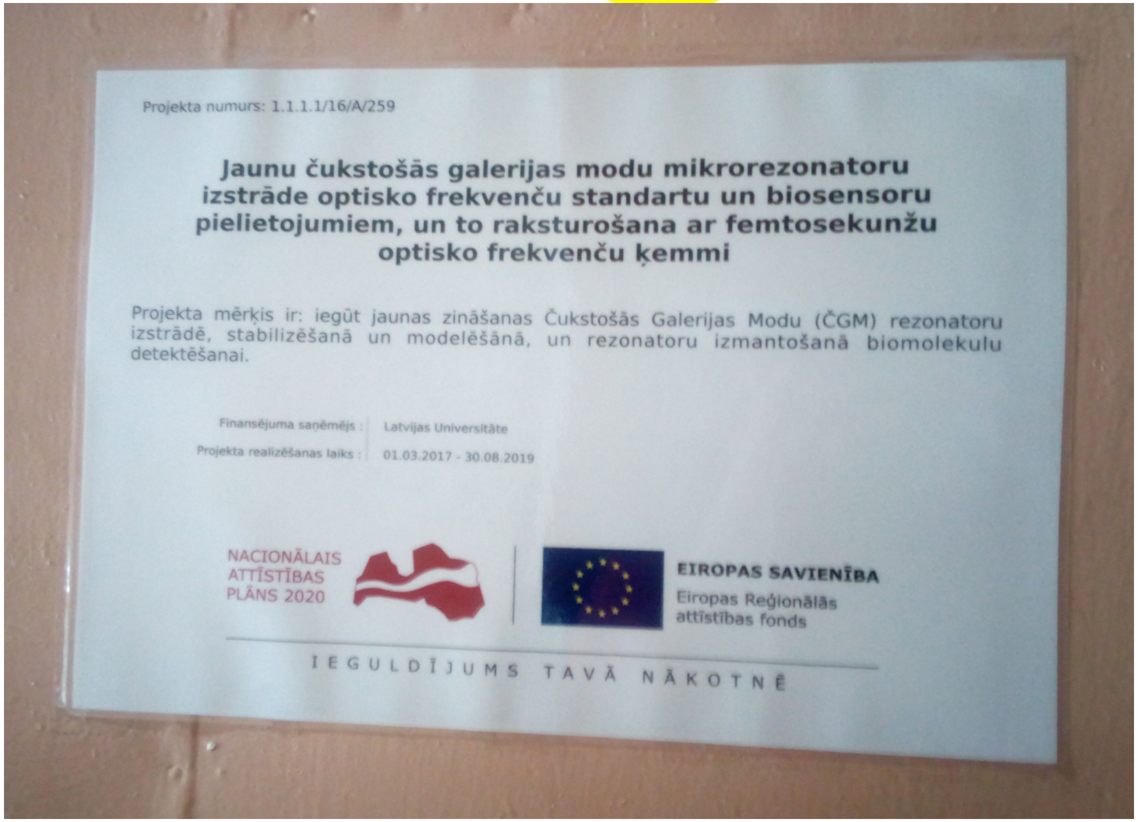


Lai praktiski pielietotu mikrorezonatorus, ir nepieciešamas efektīvs veids kā gaismas staru ievadīt rezonatorā. Viens no veidiem kā sapārot gaismu ir izmantot prizmu ar lielu laušanas koeficientu. Gaismas stars nonāk prizmā un pilnīgas iekšējās atstarošanās dēļ atstarojas no prizmas virsmas. Tomēr gaismas elektromagnētiskais lauks nedaudz izspiežas ārpus prizmas un var pārklāties ar gaismas lauku, kas izspiežas ārpus rezonatora.



Attēlā pa kreisi redzams, kā ar prizmas palīdzību sfēriskā stikla lodē, kuras diametrs ir 6 cm, ievadīts lāzera stars. Spīdošā zaļā josla lodes vidū tad arī ir ČGM. Attēlā pa labi tika atkārtos eksperiments ar ievērojami mazāka izmēra lodi, kuras diametrs ir tikai aptuveni milimetrs.

Publicity



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

ERDF project Nr. 1.1.1.1/16/A/259

Publicity


Lietotnes   Izumo: Takeki Tsu   Sooky's Kitchen   Sci-Hub: removin   Yaoi - Nihonomar   Portable breath

ENGLISH

LATVIJAS UNIVERSITĀTE ANNO 1919

ĀTRĀS SAITES   www.lu.lv

ZIŅAS

Sākums > Ziņas >

LU Atomfizikas un spektroskopijas institūts aicina uz kolokviju par sasniegto trīs mēnešos

Inga Brice
25.05.2017

Drukāt
Sašaurināt tekstu
Sadalīt tekstu kolonnās

LU Atomfizikas un spektroskopijas institūts 30. maijā plkst. 10:00 - 11:00 aicina uz FOTONIKA-LV CXXXVI kolokviju, kurā klāstīs par sasniegto projekta pirmajos 3 mēnešos.

Semināra programma:

10:00 A. Ūbelis. Runātāja cildināšana (Welcome)

10:15 J.Alnis, A.Atvars, R.Viter, I.Brice, A.Ūbele, A.Pirktiņa, K.Grundšteins, ERAF projekts "Jaunu čukstošās galerijas modu mikrorezonatoru izstrāde optisko frekvenču standartu un biosensoru pielietojumiem, un to raksturošana ar femtosekunžu optisko frekvenču ķemmi". Pirmajā ceturksnī sasniegtais.

11.00 - 11.30 Diskusija un kafija

Vieta: LU Atomfizikas un Spektroskopijas institūts, Rīgas Fotonikas Centrs, Šķūņu iela 4 (Vecrīga), 4. stāva auditorija

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.

Plānotie projekta galvenie rezultāti: 4 publikācijas, 3 zinātību apraksts, 1 licences līgums.

Projekta īstenošanas laiks: 01.03.2017. - 30.08.2019. (2,5 gadi)

Īss populārzinātnisks apraksts:

Londonas svētā Pētera katedrāles kupola iekšienē ir sastopama īpaša parādība – čuksti, kuri ir izteikti tuvu kupola sienas malai, ir labi dzirdami sienas tuvumā pat kupola diametrāli pretējā pusē. Šo efektu izraisa skaņas viļņi, kuri ceļo pa kupola riņķi, atstarojoties no sienas. Izrādās, ka šāda parādība sastopama arī gaismai. Tādā gadījumā gaismas "skriešana pa riņķi" notiek pilnīgas iekšējās atstarošanās dēļ. Vienkāršākā šāda sistēma ir redzama Attēlā 1. Tur lāzera stars caur prizmu tiek ievadīts stikla lodē. Prizma ir nepieciešama, lai "viltīgi" ievadītu gaismu lodē. Pa tiešo lāzera staru spīdinot uz lodi, šāds "gaismas riņķis" neveidosies. Te svarīga ir vēl viena parādība - pilnīgās iekšējās atstarošanas gadījumā gaisma tomēr "iespiežas" otrā vidē par attālumu, kurš ir mazāks par viļņa garumu. Tieši šī gaisma (evanescent wave) ir tā, kura nokļūst no prizmas lodē. Šis efekts attiecas arī uz pašu lodi – tajā cirkulējošā gaisma nedaudz "iespiežas" ārējā vidē un mijiedarbojas ar šo vidi. Tādēļ šādus rezonatorus var izmantot kā ārējās vides sensorus.

Čukstošās galerijas modas rezonatori var būt ar dažādu formu – lodveidīgi, diskveidīgi, torīdveidīgi, pudeļveidīgi u.c. – un ar dažādu izmēru – diametrs no 4 mm līdz 10 μm. Projekta ietvaros ir plānots viedot un testēt dažādus šādus rezonatorus.

Projekta pirmajā ceturksnī ir izveidots stends mikrorezonatoru testēšanai, veikti skaitliskie aprēķini, testēti dažādi materiāli biosensoru izstrādei, kā arī vākta un analizēta literatūra.

Projekta mājas lapa: www.lu.lv/cgm

Čukstošās galerijas modas starojums lielā lodes rezonatorā, d = 6 cm

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.

ERDF project Nr. 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

2. Overview and experiments

1. WGM resoantor 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 Ūbele / **Antons Pribitoks** bachelor student
Andra Pirktiņa bachelor student

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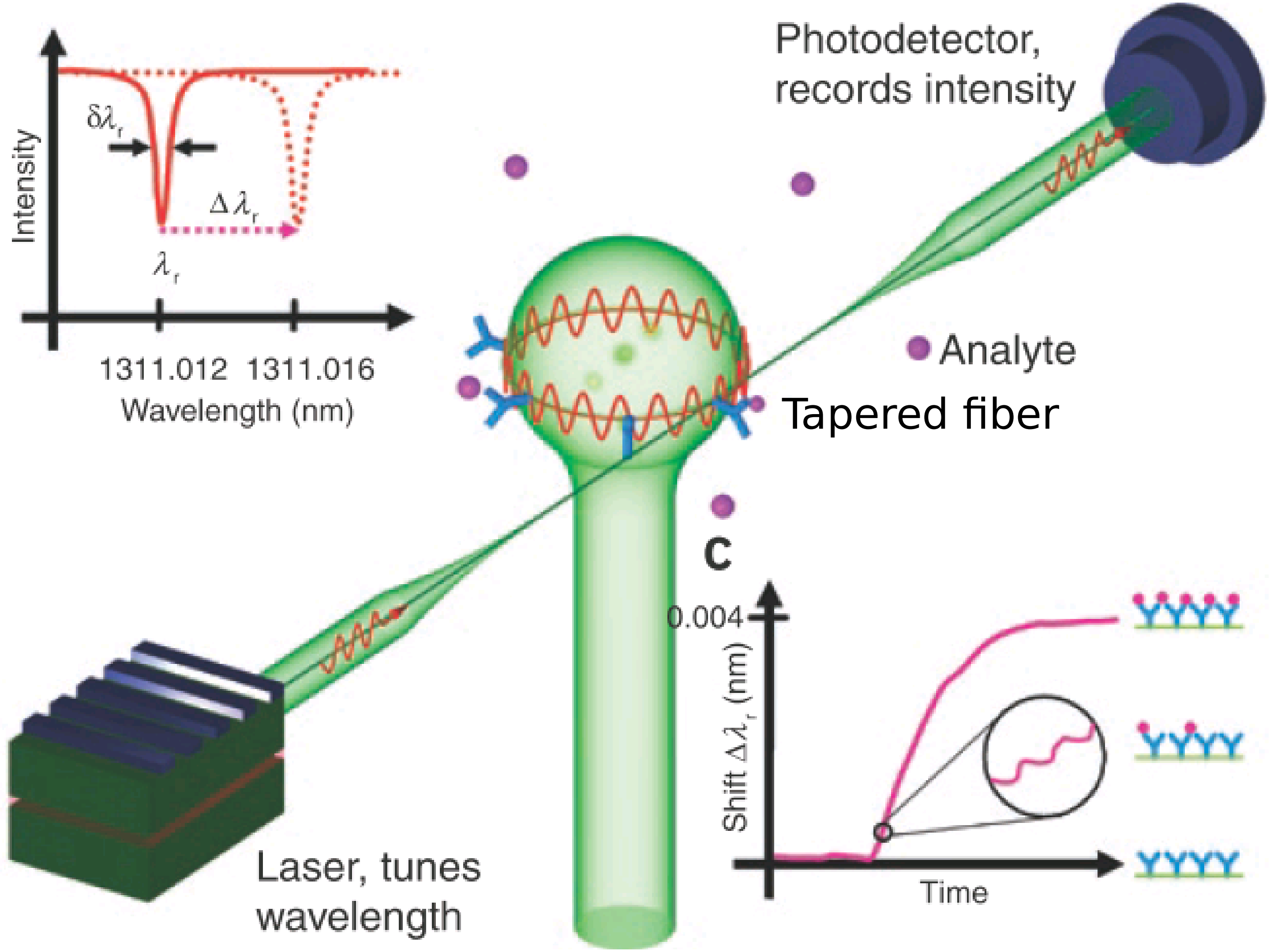
30.05.17.
LU ASI
J. Alnis

WGMR biosensor, light coupled using optical fiber

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

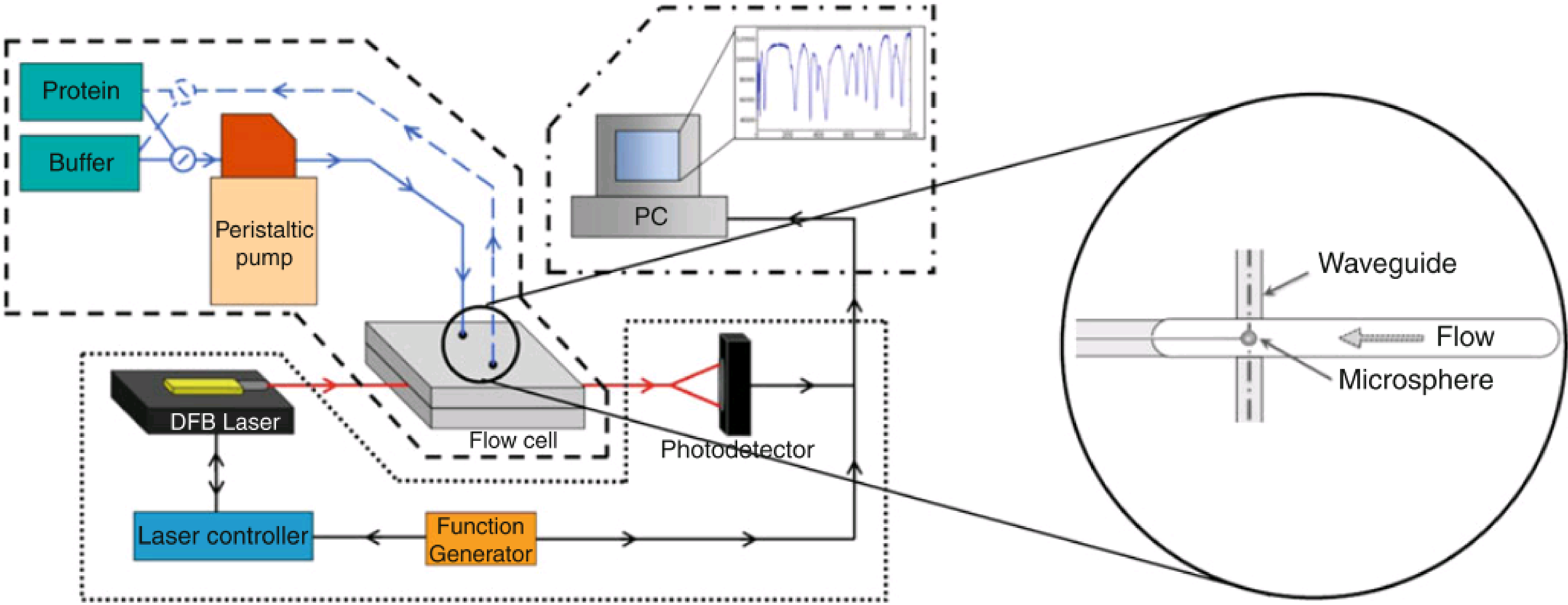


F. Vollmer Nature 2008

WGM biosensor experiment

We will repeat during ERDF. R. Viter will deal with biological parts and coatings.

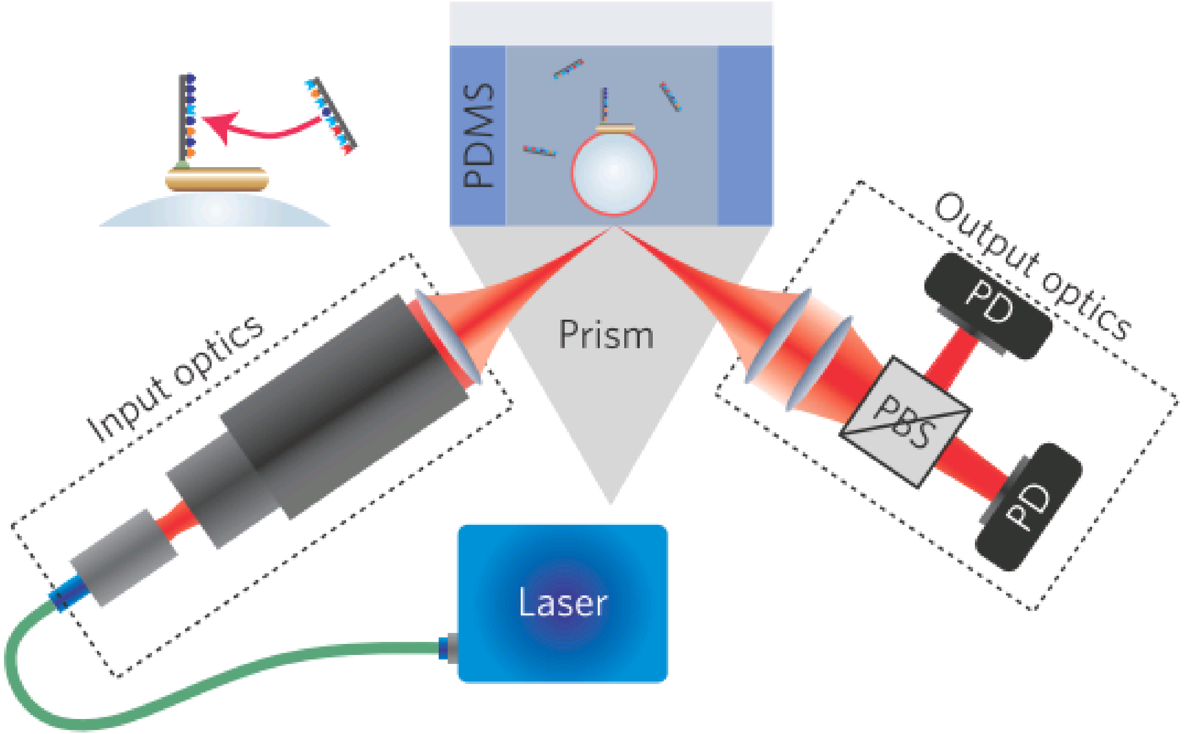
Whispering Gallery Mode Resonator Biosensors

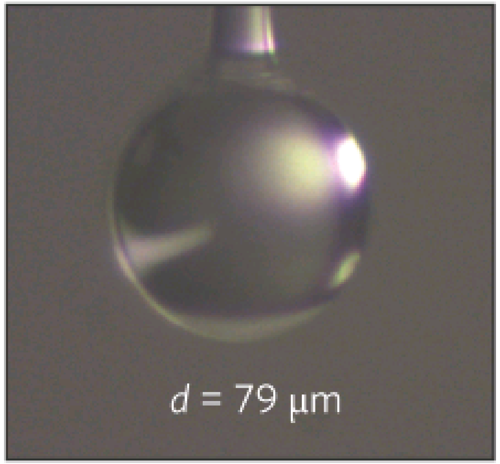


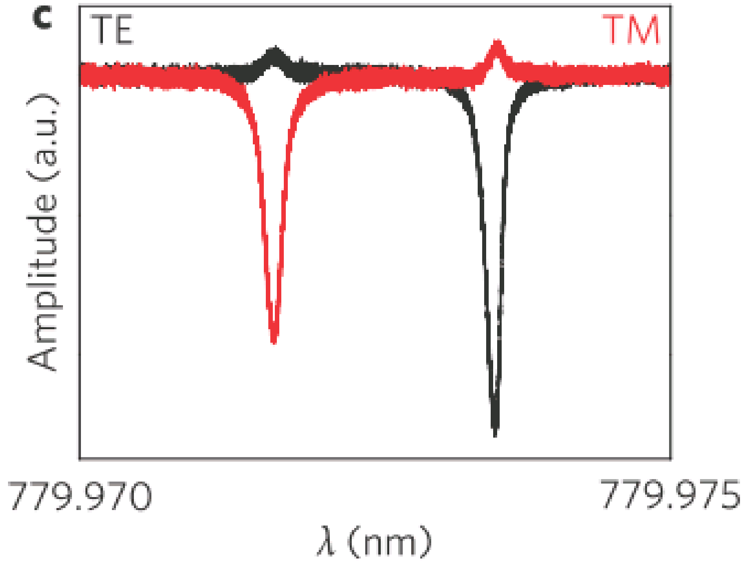
Book by Frank Vollmer

WGMR biosensors, light coupled using a prism

We will make during ERDF. R. Viter deal with biological parts and coatings.

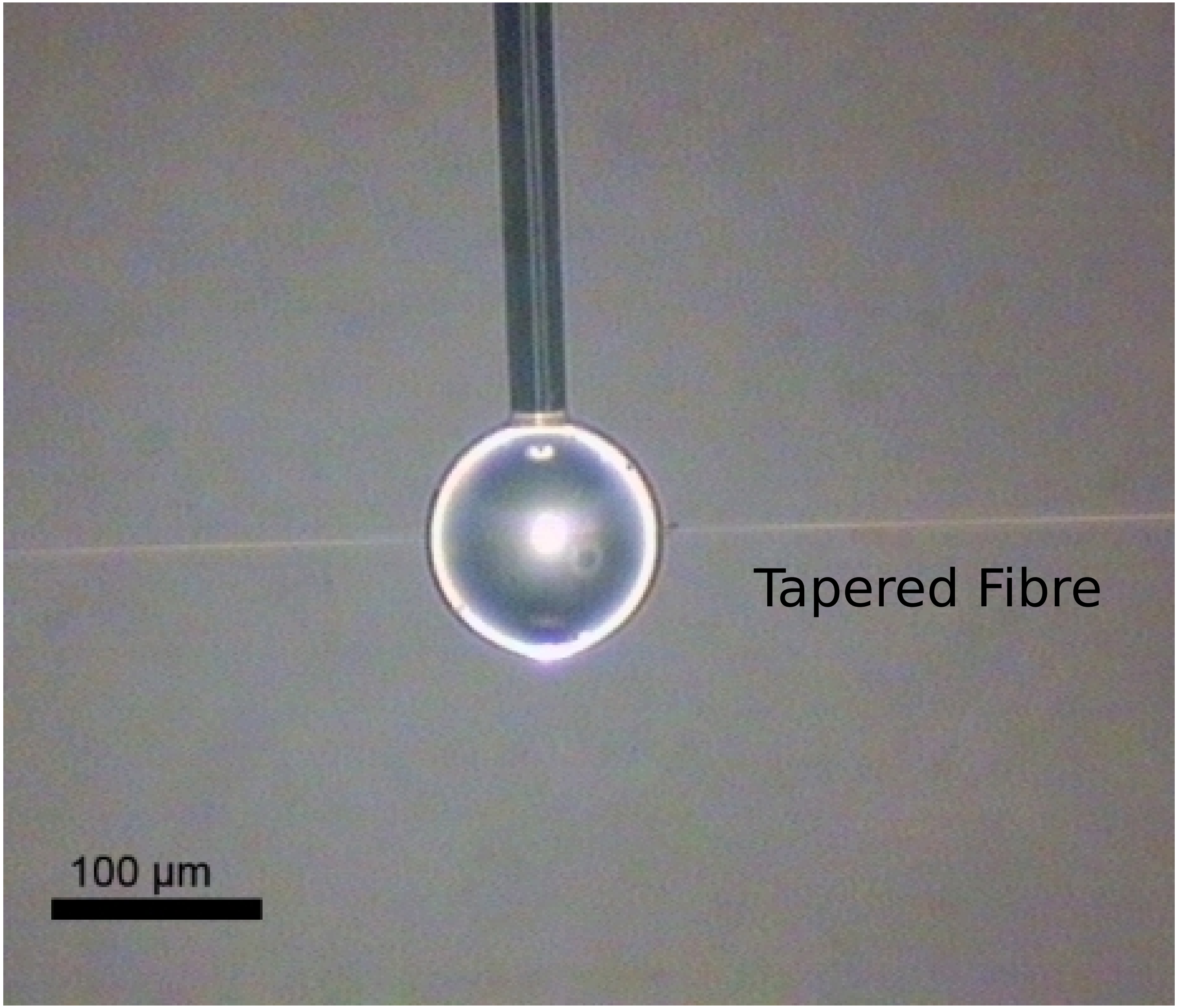






F. Vollmer Nature Nanotechnology 201

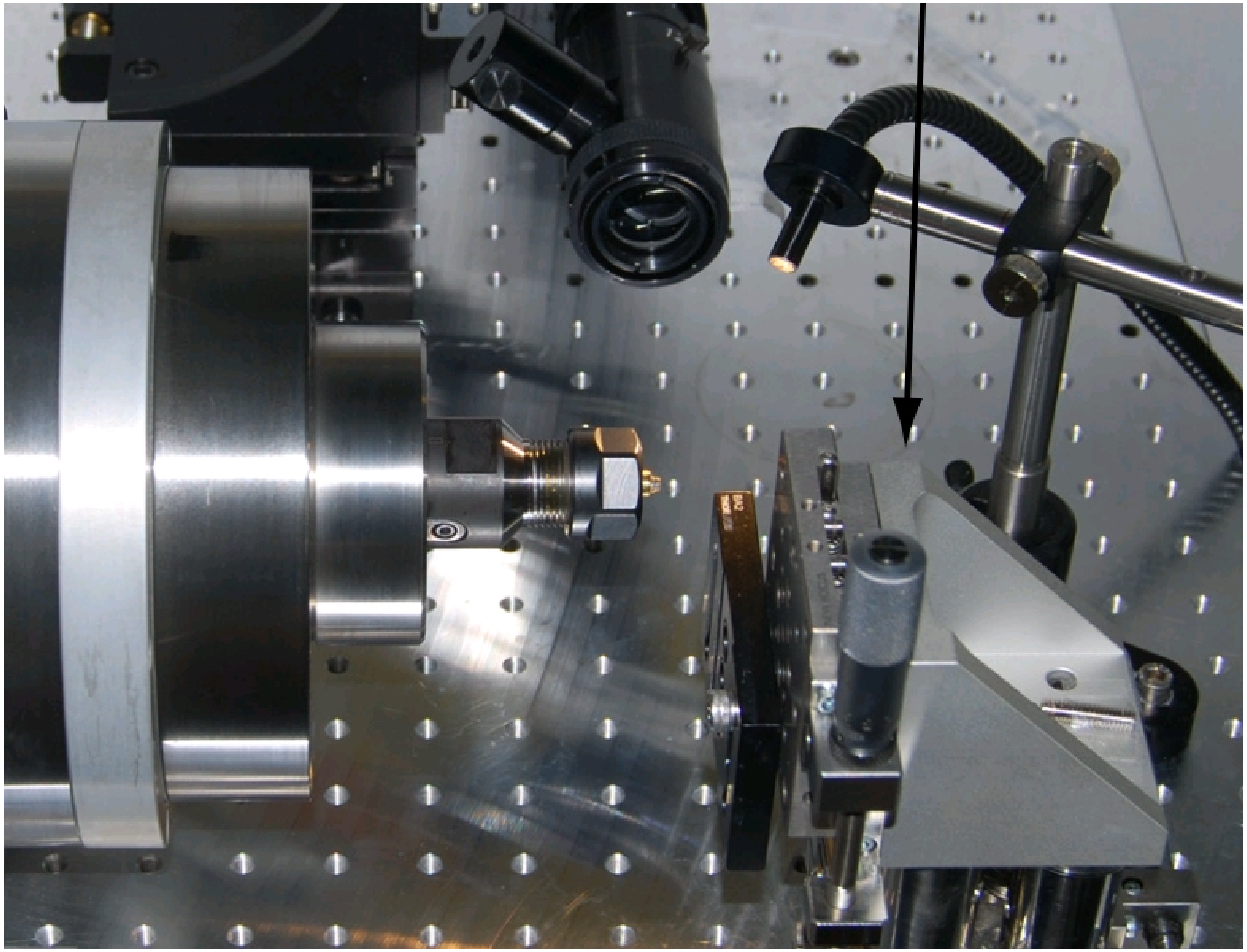
We will start with a glass or quartz ball melting at the IAPS glass blower workshop. A. Atvars, J. Alnis.



Grinding stand for CaF_2 un MgF_2 WGMRs

J.Alnis et al, Phys Rev. A 2011, I.Feschenko et al.Opt. Expr. 2012

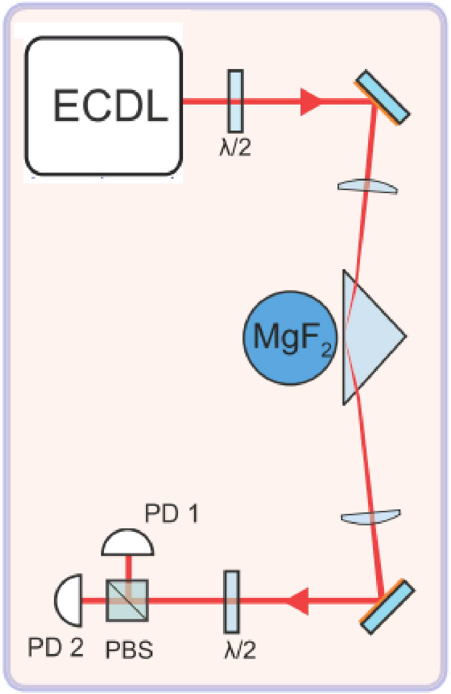
We will make it in LV during ERAF. J. Alnis, I.Brice.

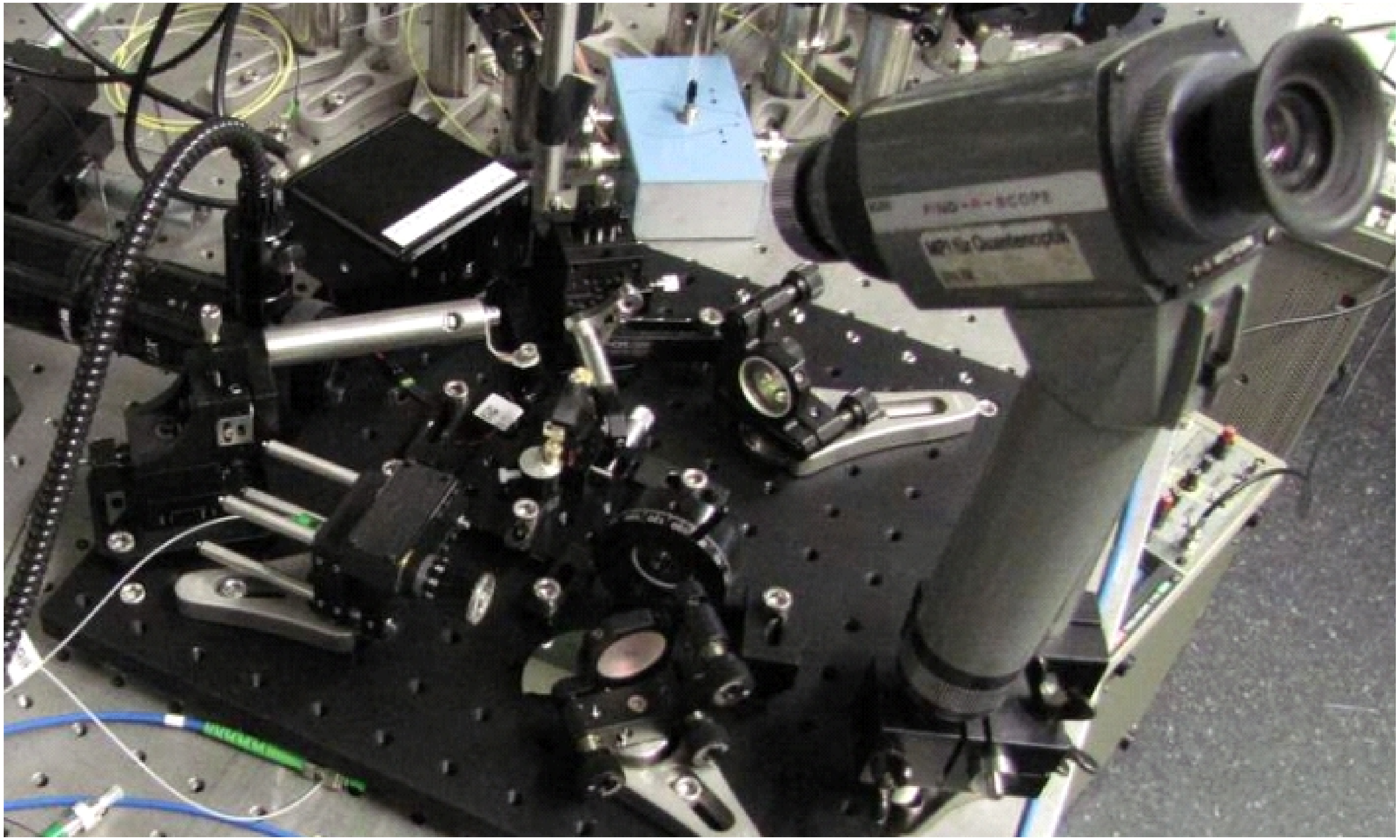


CaF_2 un MgF_2 GWMRs for stabilizing lasers

J.Alnis et al, Phys Rev. A 2011, I.Feschenko et al.Opt. Expr. 2012

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.

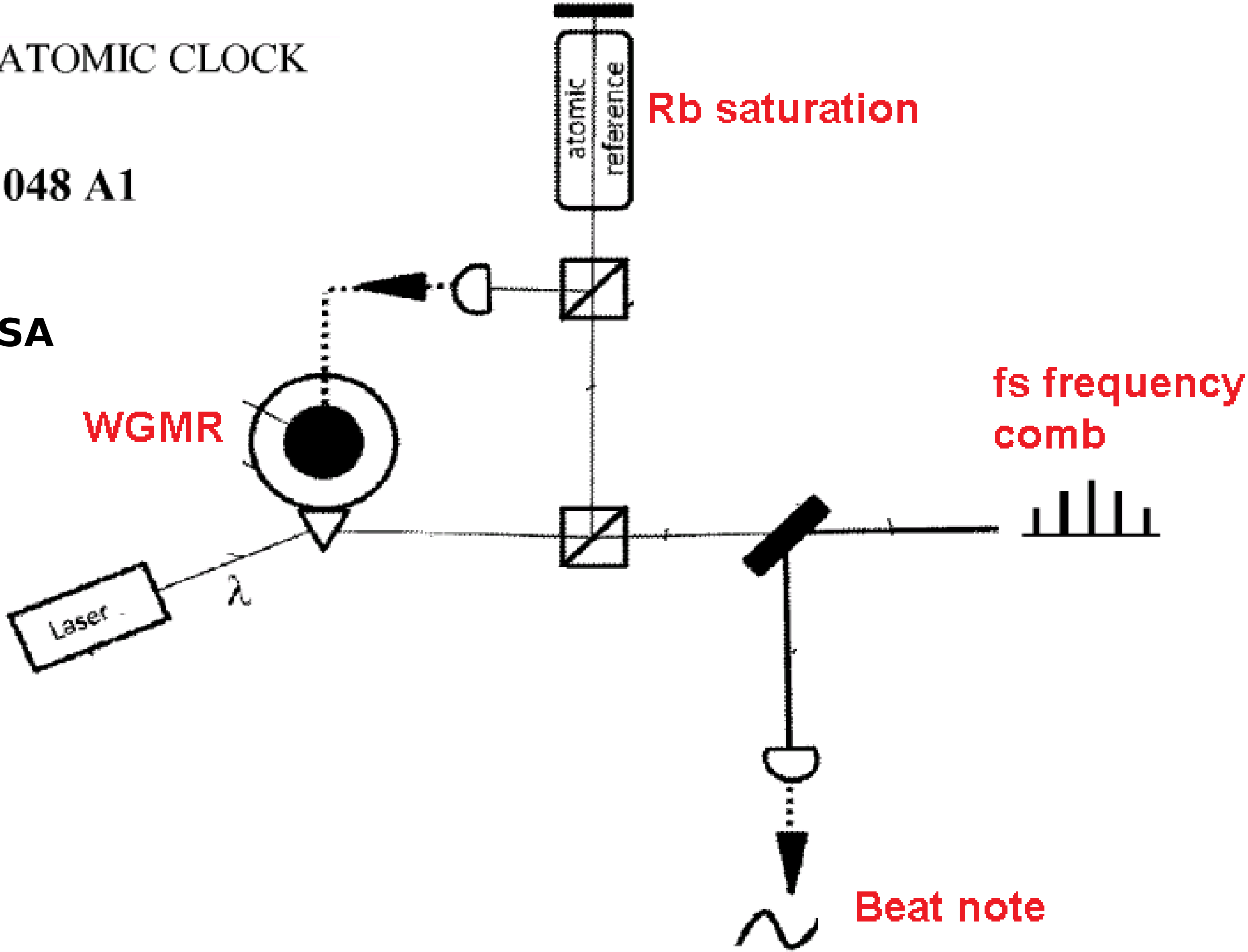
Title: OPTICAL ATOMIC CLOCK

Patent

WO 2015/143048 A1

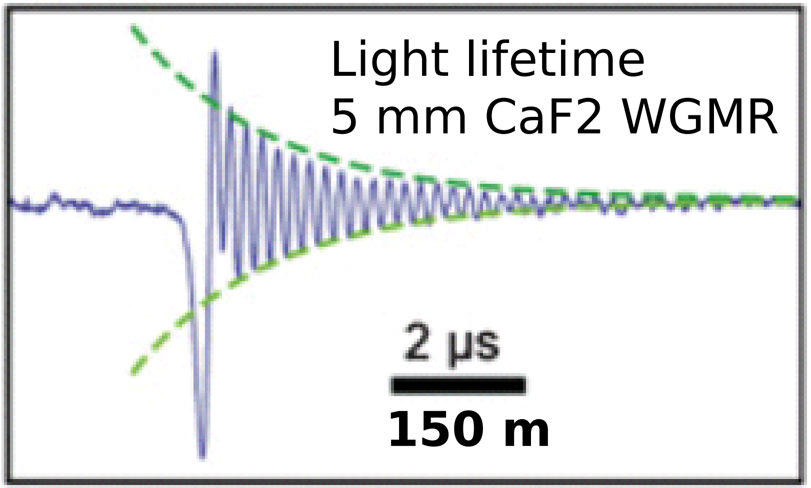
(24.09.2015)

OEwaves inc. USA



Good and bad qualities of the WGMRs

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



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

Try lithography grating production on WGM surface for light incoupling?

Report at the conference

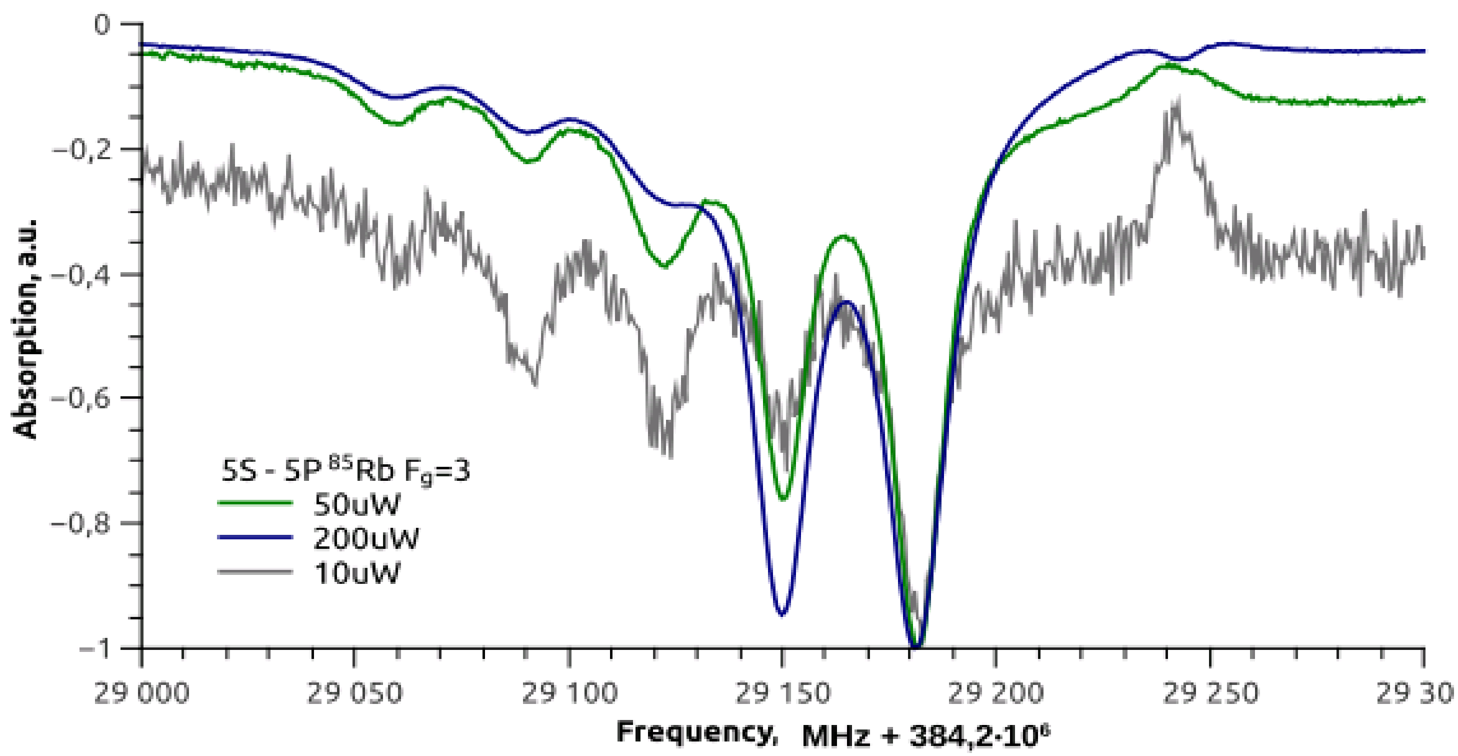
Open Readings 2017

TOWARDS WGM RESONATOR STABILISED ON RB 5S-5P TRANSITION LINES

Inga Brice, Antons Pribitoks, Janis Alnis

Institute of Atomic Physics and Spectroscopy, University of Latvia, Riga, Latvia
inga02@inbox.lv

Frequency stability is regarded as absence of frequency drift or maintaining a single fixed frequency as long as



Report at the conference

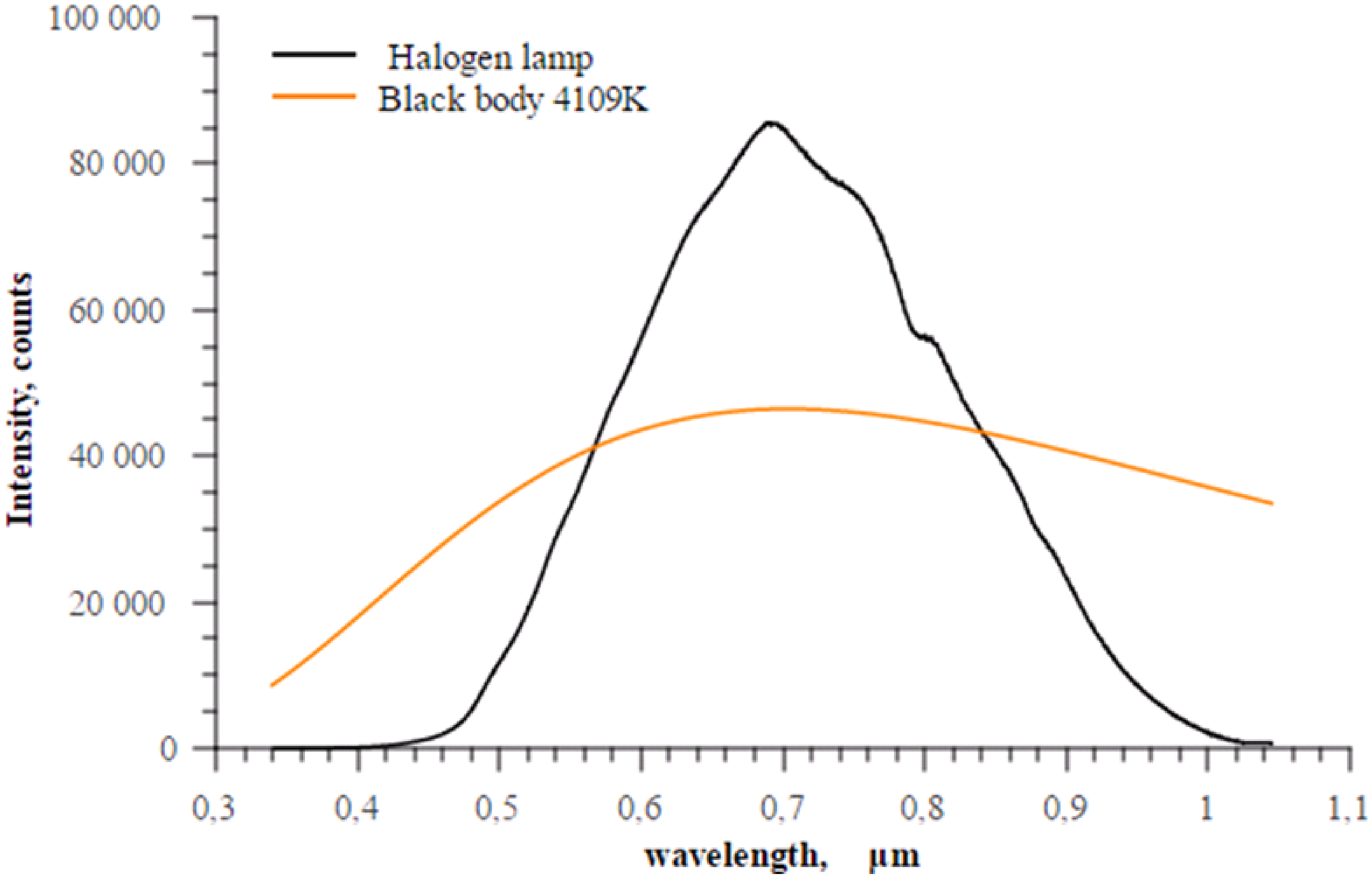
13th International Young Scientist conference

Developments in Optics and Communications 2017

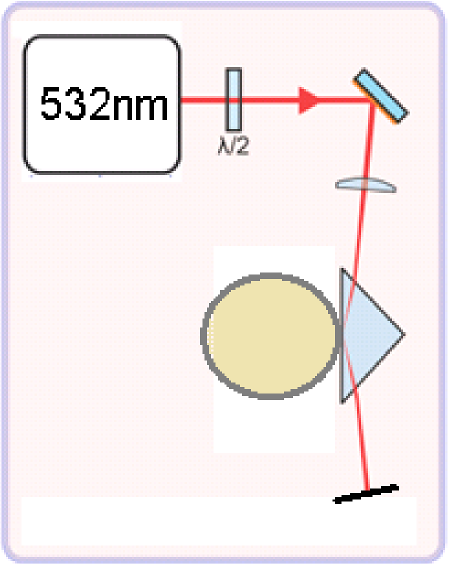
Riga, Latvia, April 6 – 7, 2017

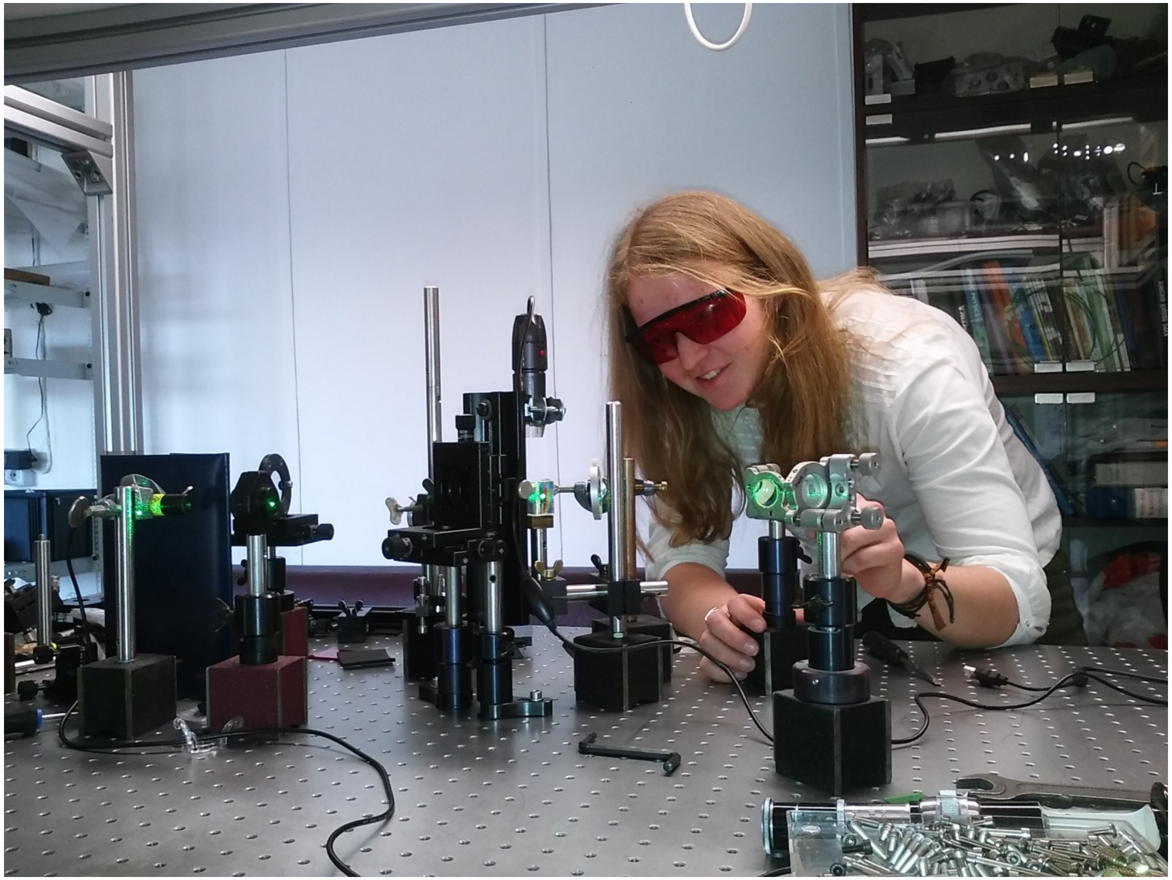
Fitting the Planck formula

$$I(\lambda, T) = \frac{2\pi hc^2}{\lambda^5 \left(e^{\frac{hc}{\lambda k_B T}} - 1\right)}$$



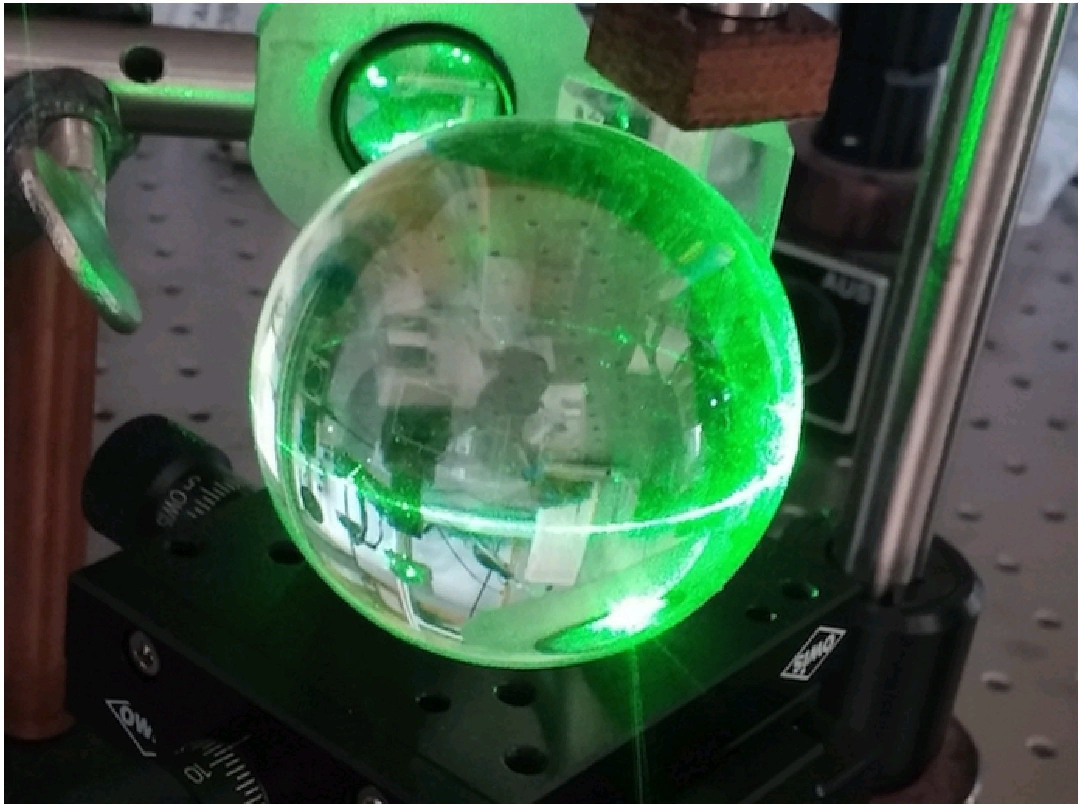
Prototype equipment assembly and adjustment for coupling the green laser light onside the WGMR.





Whispering gallery modes inside a large spherical resonator, d ≈ 6 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, he light passes through the surface instead of inside the volume.



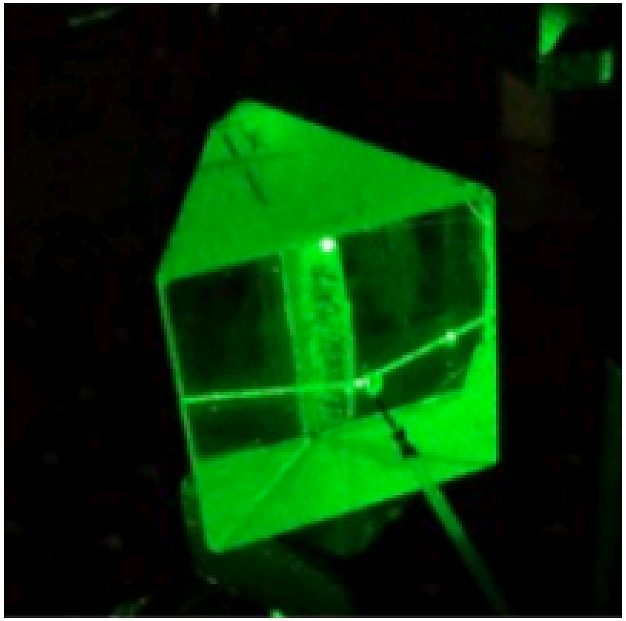
- Recorded a Youtube video

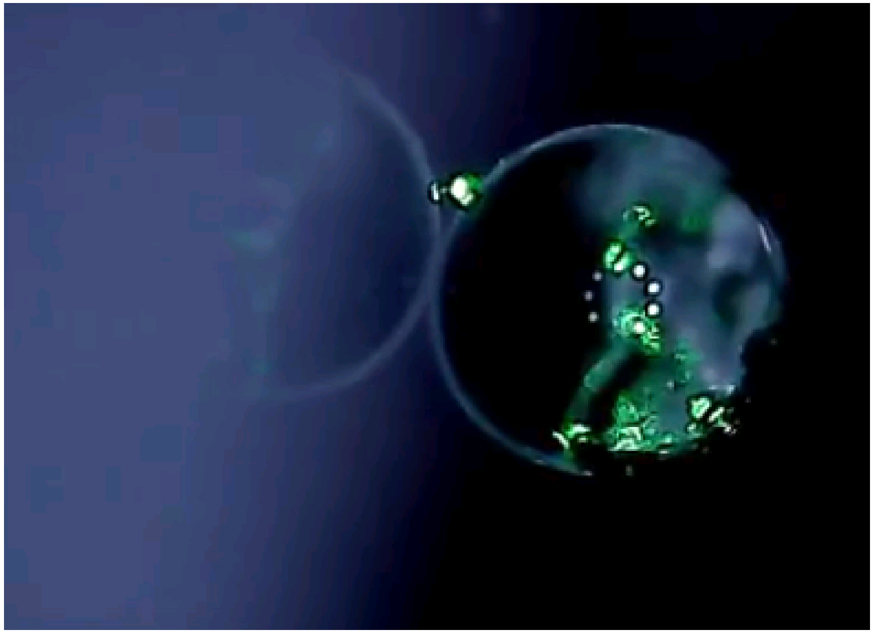
https://www.youtube.com/watch?v=j7MxQRNx8-U

Whispering gallery modes inside a small spherical resonator, d ≈ 1 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 and USB microscope and computer. A video was recorded. Green laser light from laser and a glare of the Resonater 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.

ERDF project Nr.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".

Report for the first three months

3. Theory and Modelling

30.05.2017., LU ASI, A.Atvars

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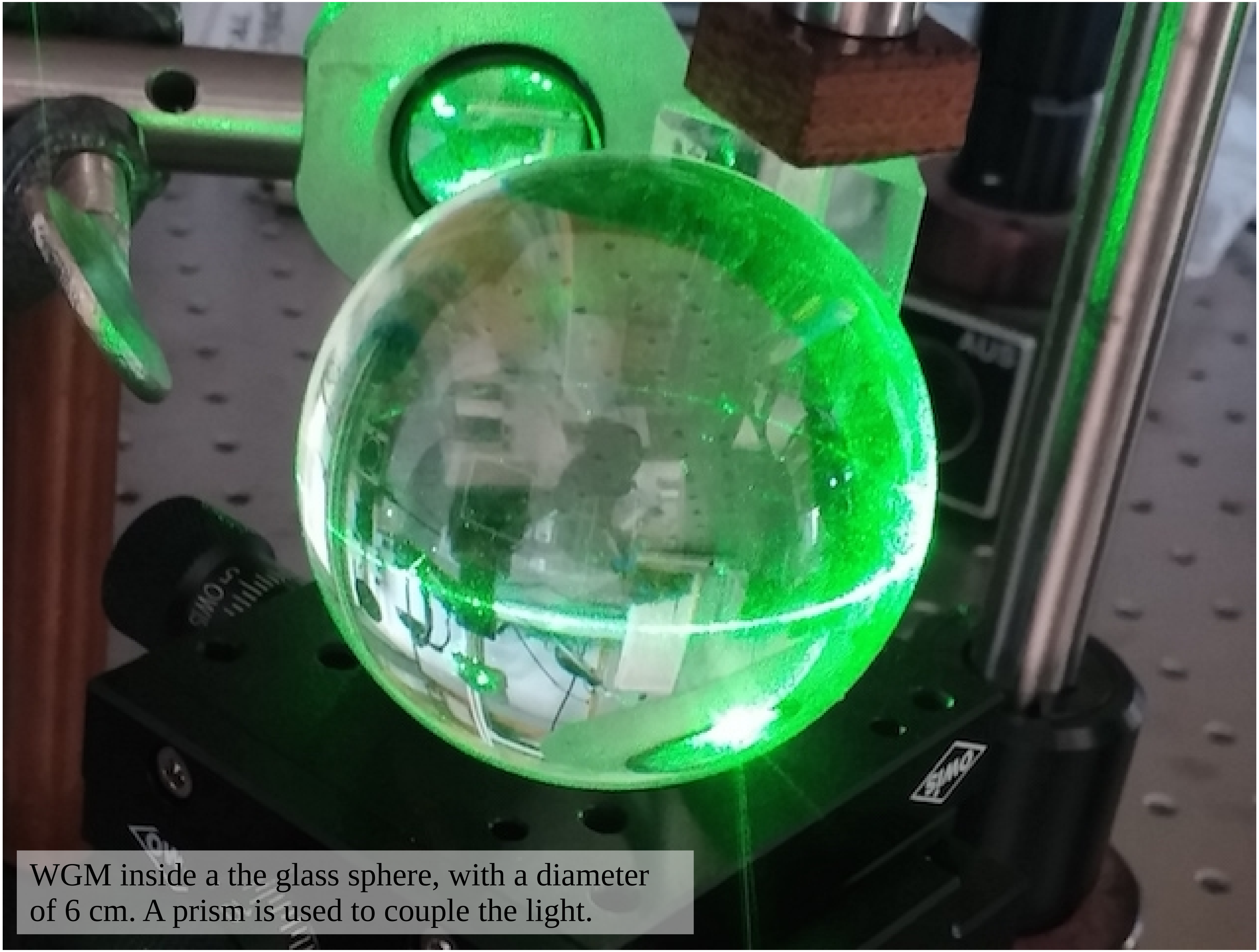
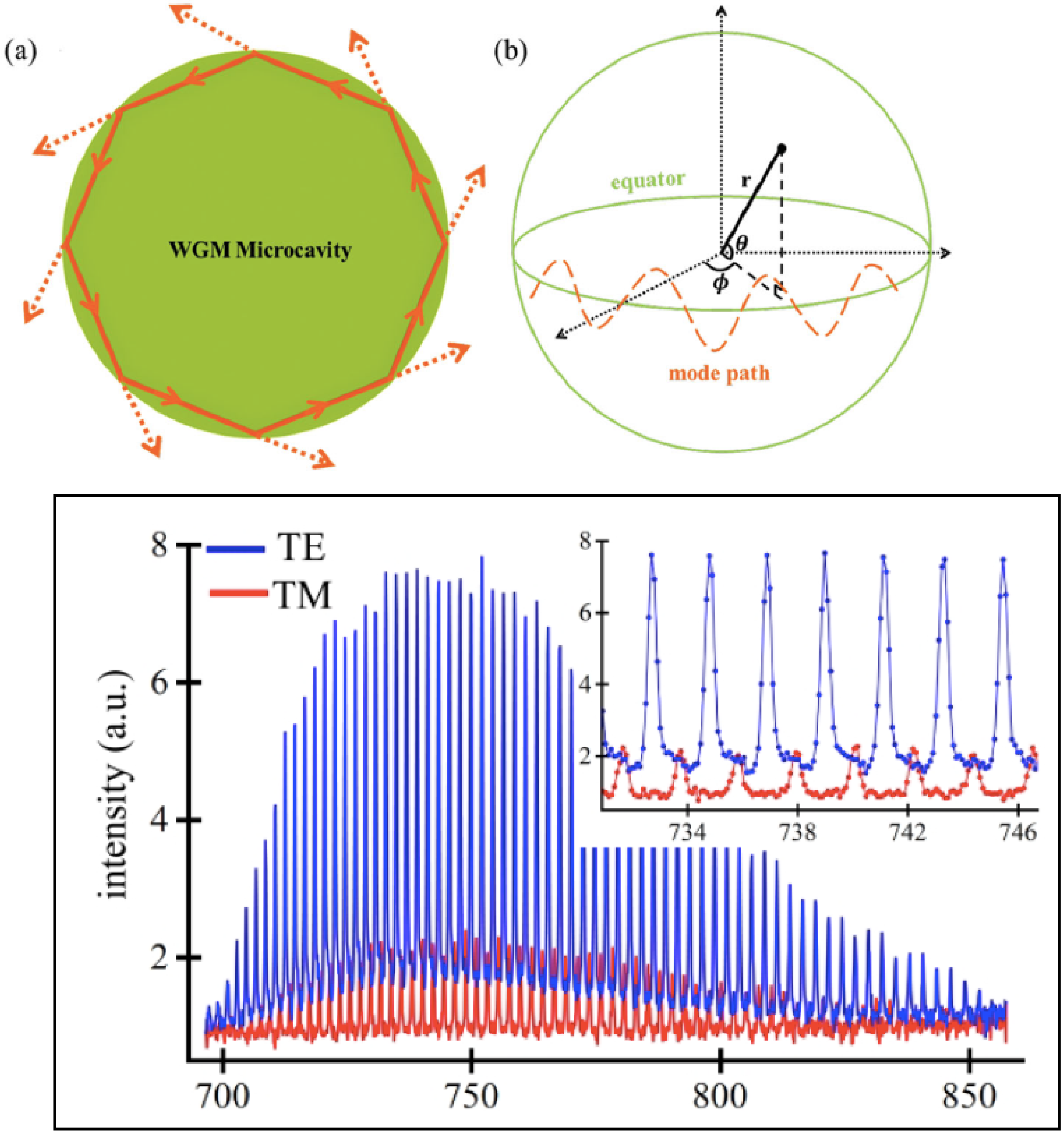


WGM inside a the glass sphere, with a diameter of 6 cm. A prism is used to couple the light.



$$\boxed{2\pi r n = \lambda N}$$

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

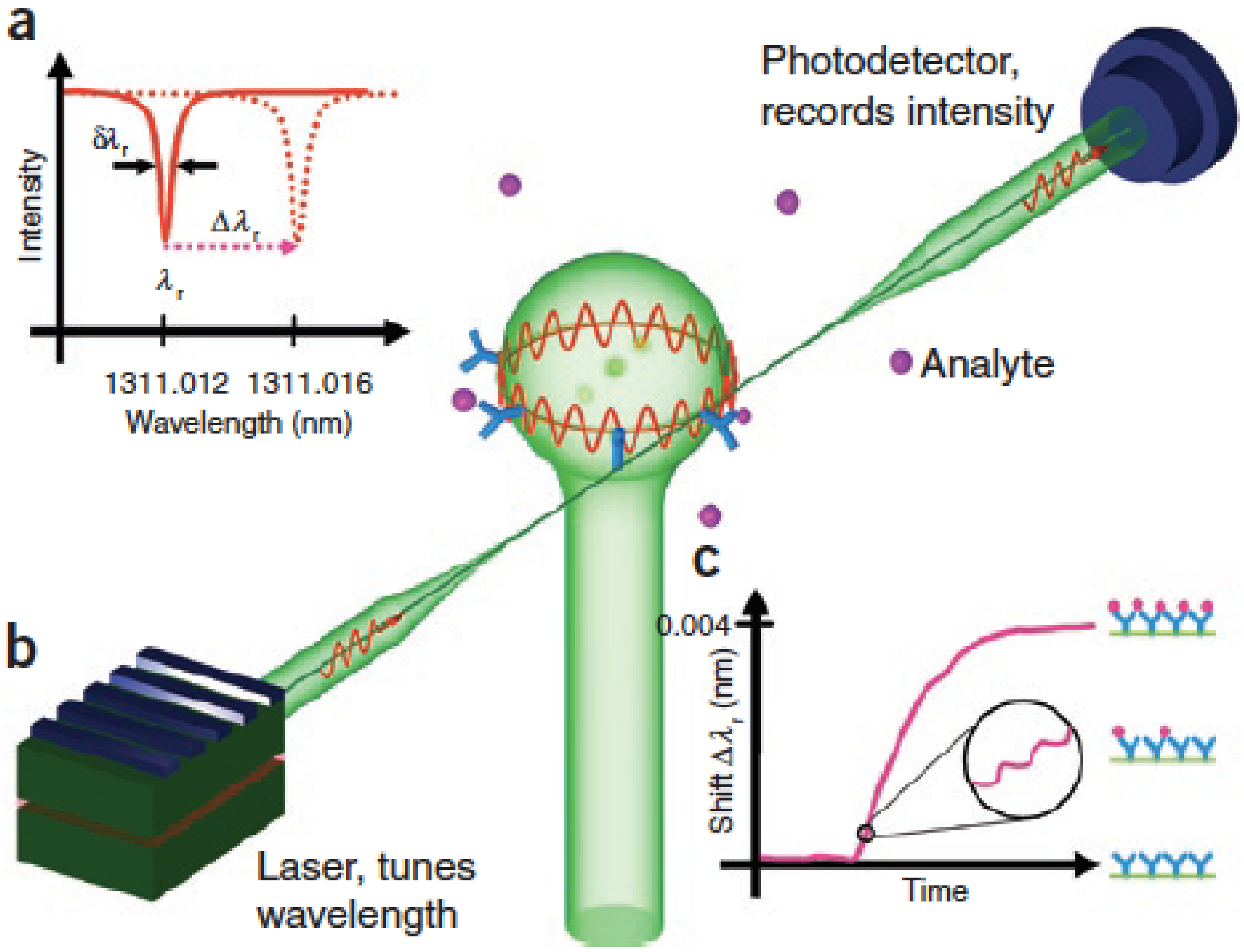
$$\boxed{\Delta\lambda \approx -\frac{\lambda^2}{2\pi r n}}$$

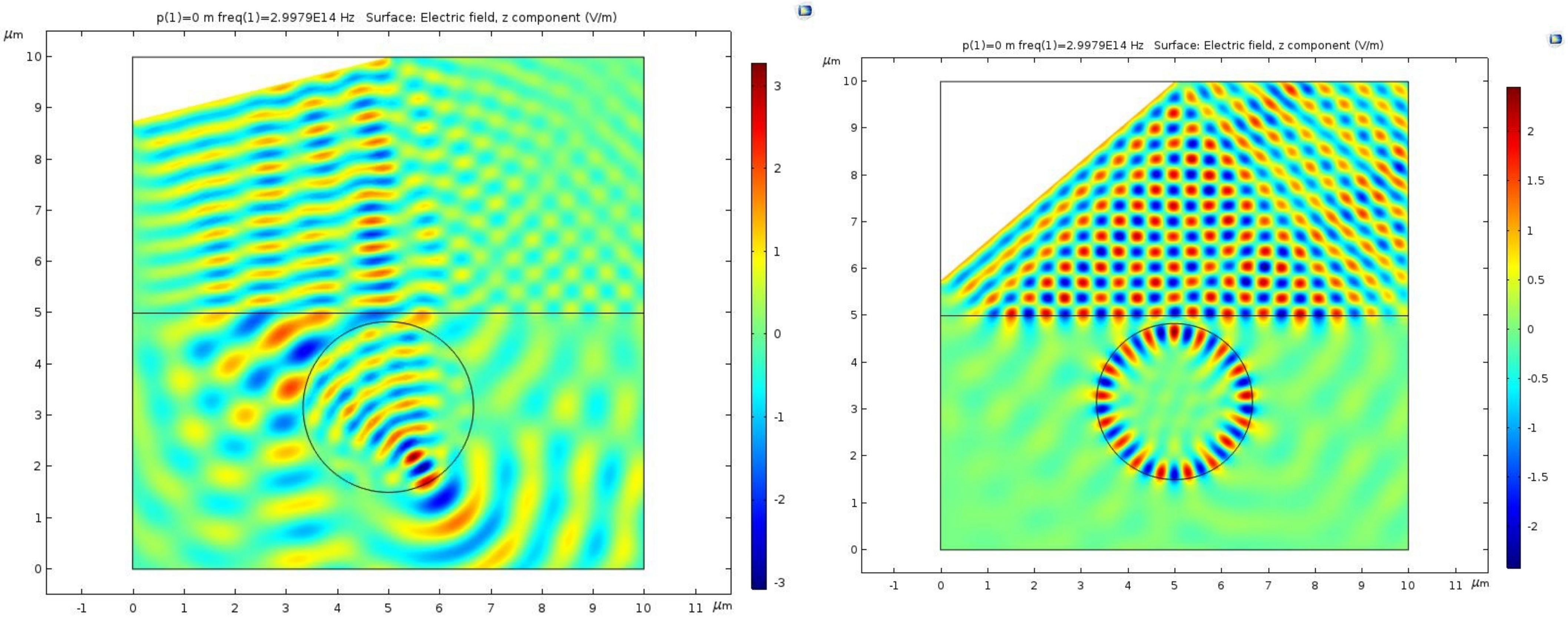
$$\boxed{\Delta\nu = \frac{c}{2\pi r n}}$$

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

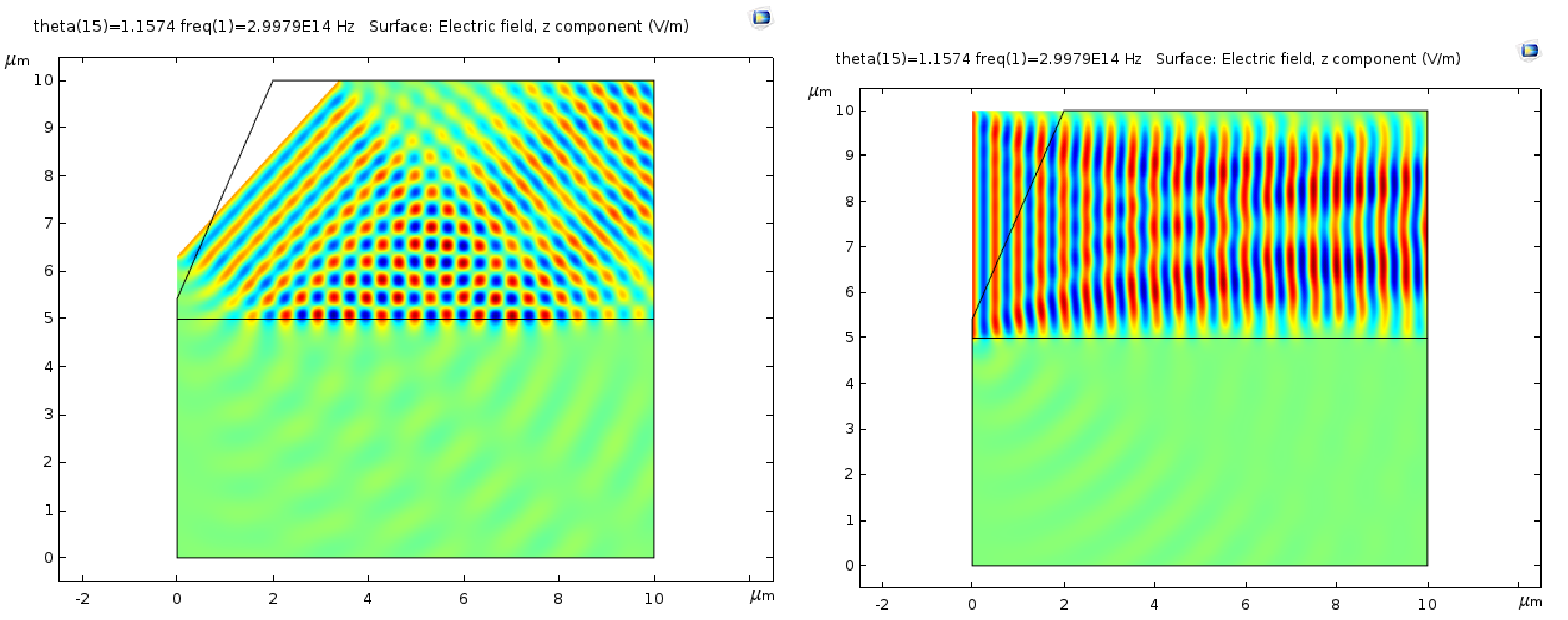
Figure 1.2: Spectra of Whisperring gallery mode sphere https://sites.ualberta.ca/~ameldrum/science/science4a.html

Whispering gallery mode microresonator

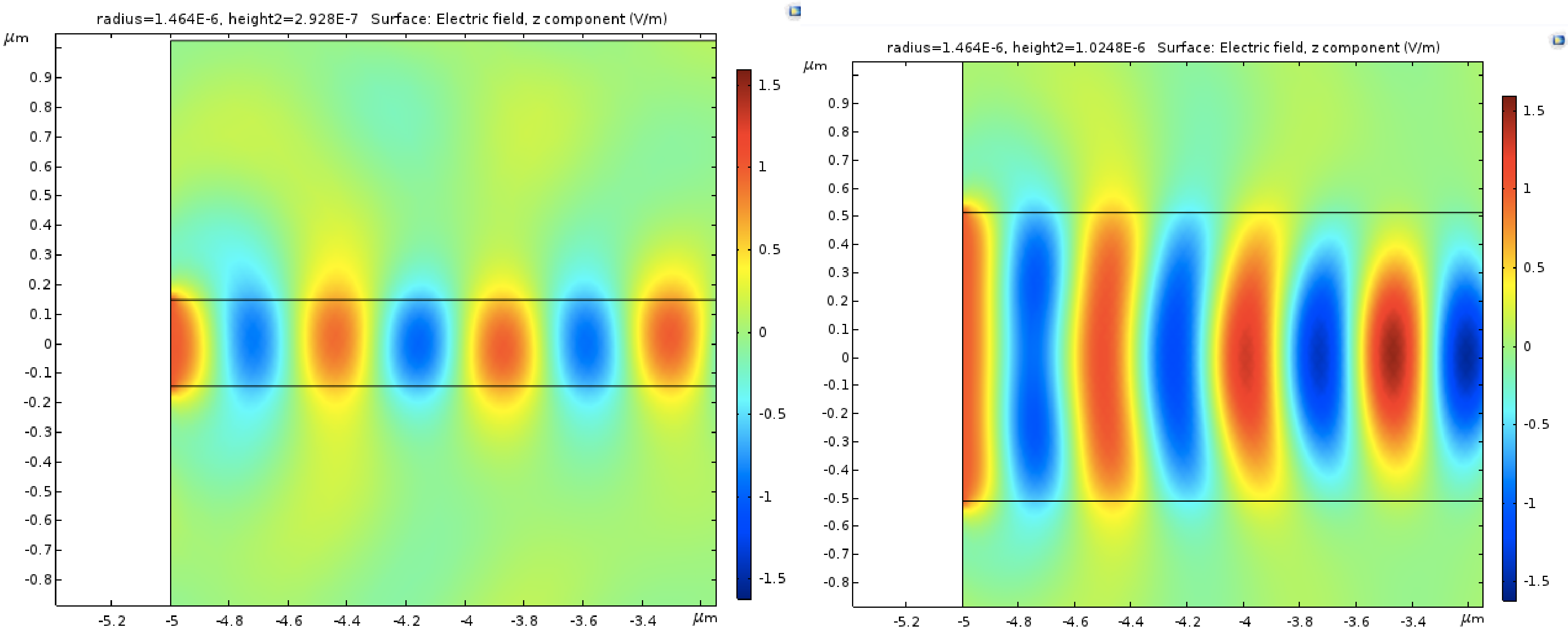




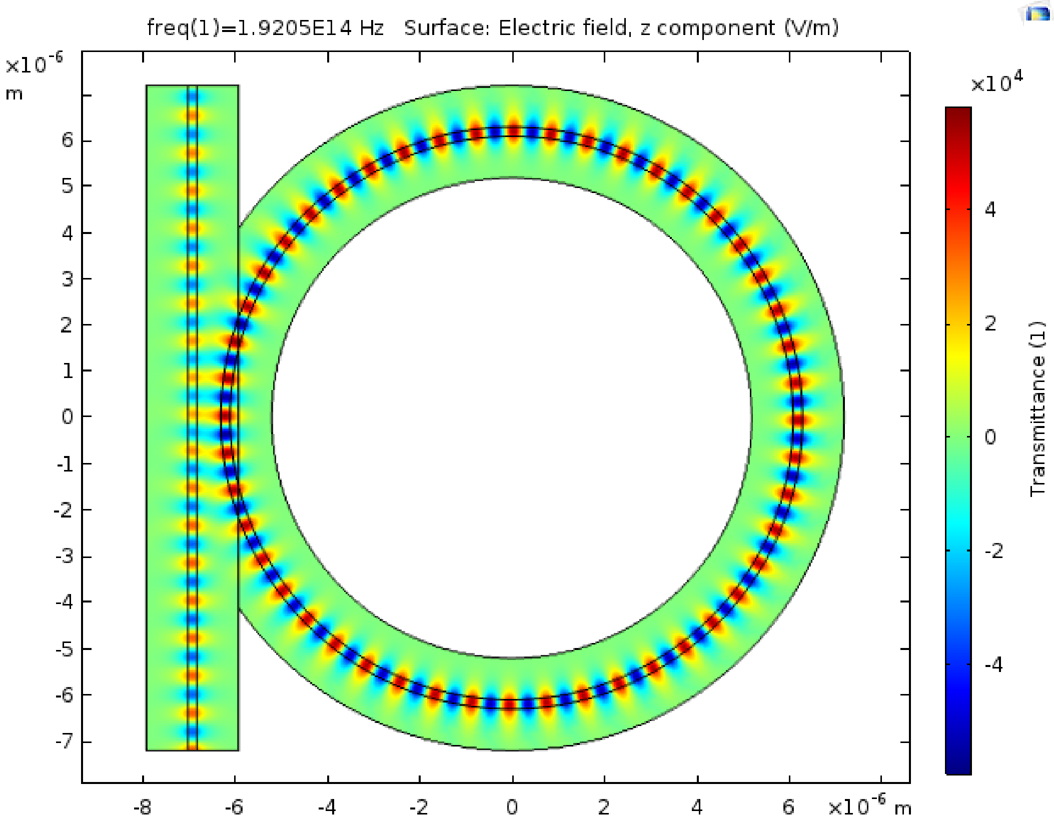
Light coupled to the micro resonator using a prism. Images obtained with COMSOL Multiphysics program.

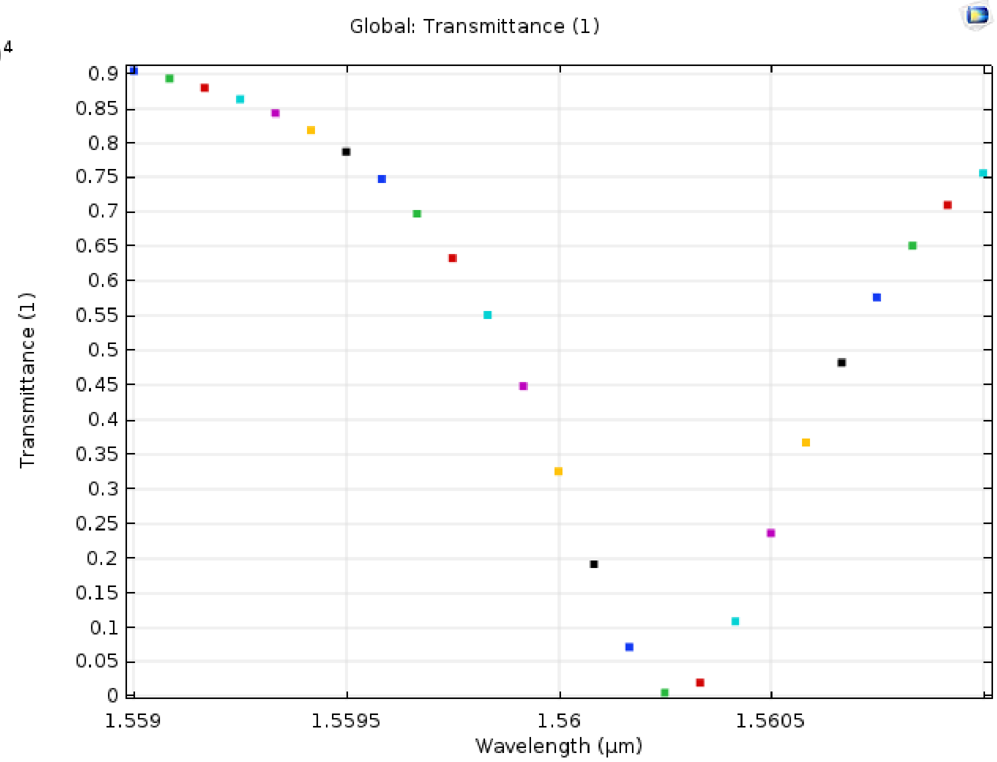


Light propagation. Images obtained with COMSOL Multiphysics program.

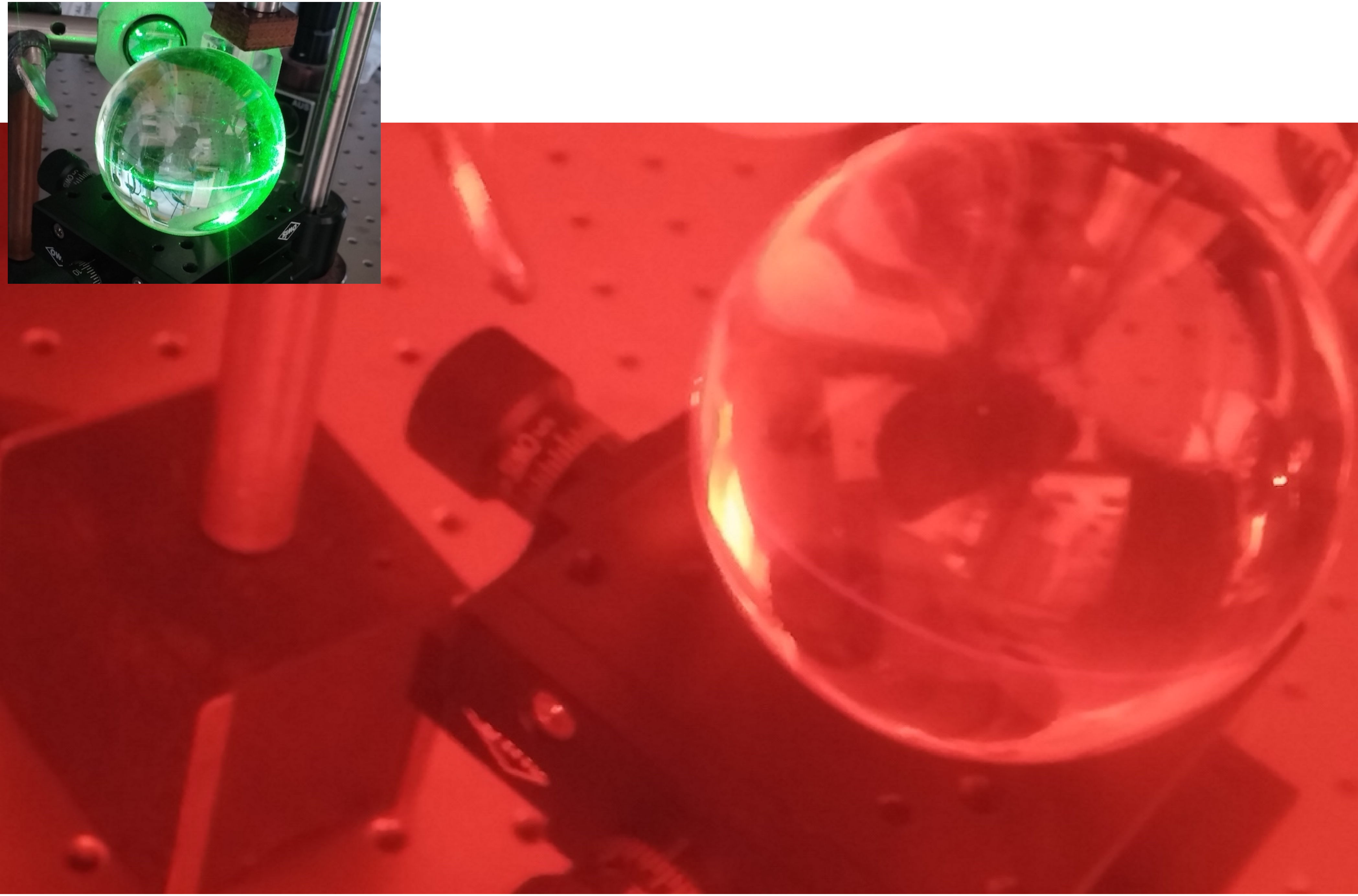


Light propagation inside an optical fiber with different diameters.
Images obtained with COMSOL Multiphysics program.





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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NATIONAL DEVELOPMENT PLAN 2020

EUROPEAN UNION
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INVESTING IN YOUR FUTURE

WP3

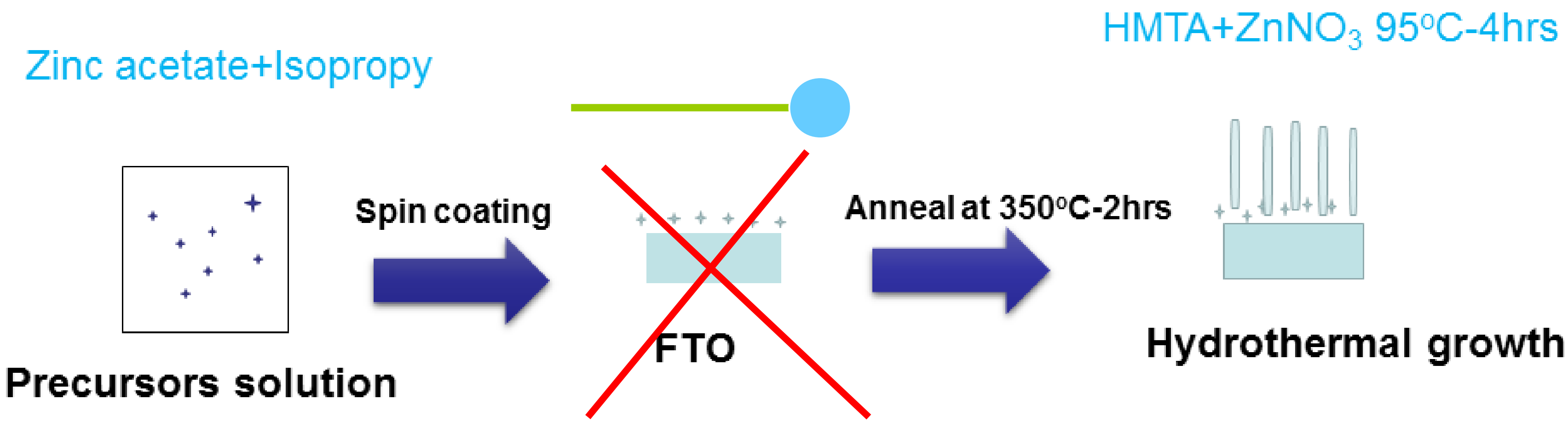
- -Literature analysis
- -Development of resonators on optical fibers
- -Development of nanomaterials as optical transducers and their transfer on WGM resonators
- -Functionalization of the biosensor surface
- -Biosensor testing

Chemical growth of ZnO nanorods on WGM resonator, based on optical fiber

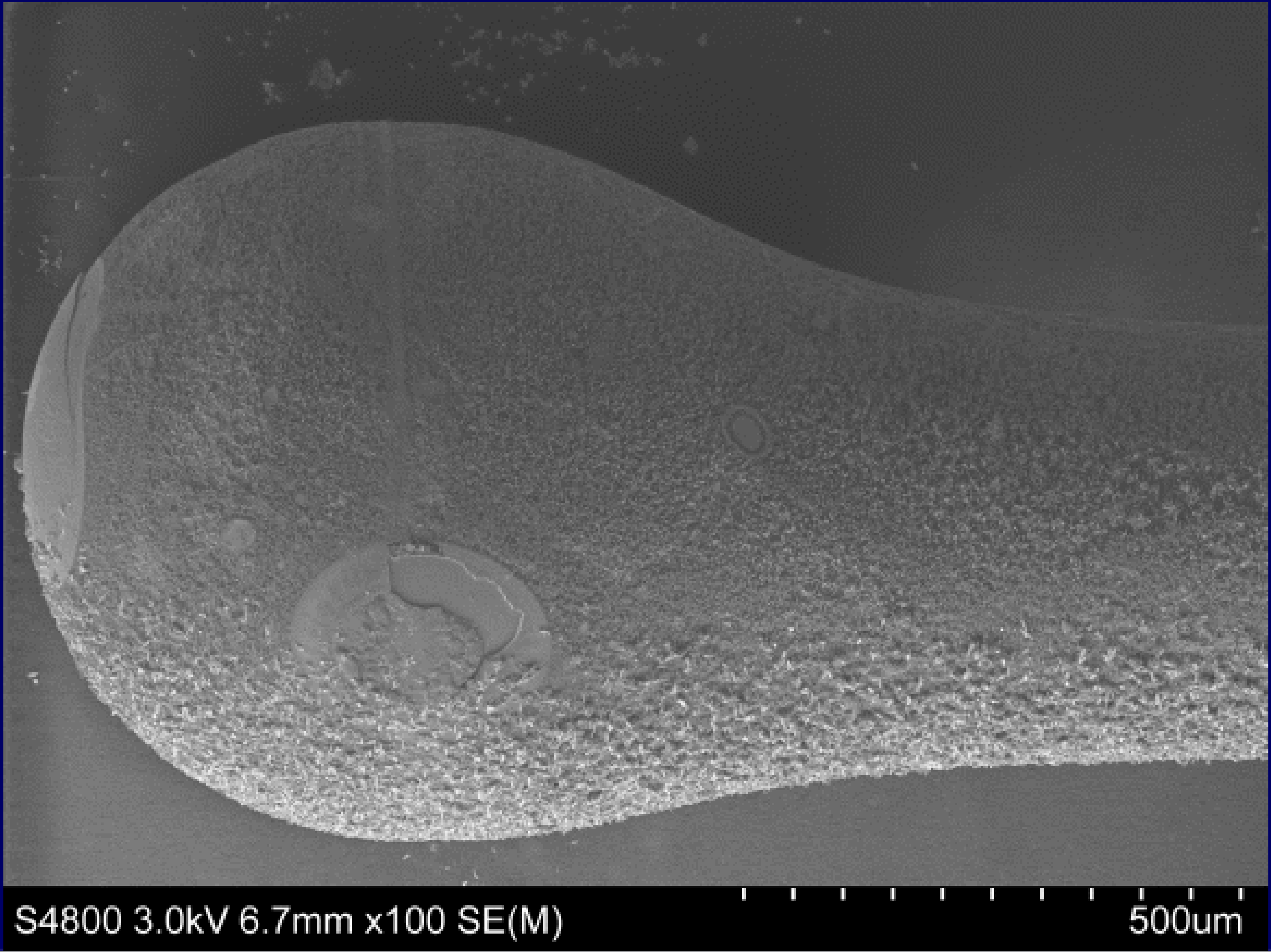
Hydrothermal Synthesis of ZnO

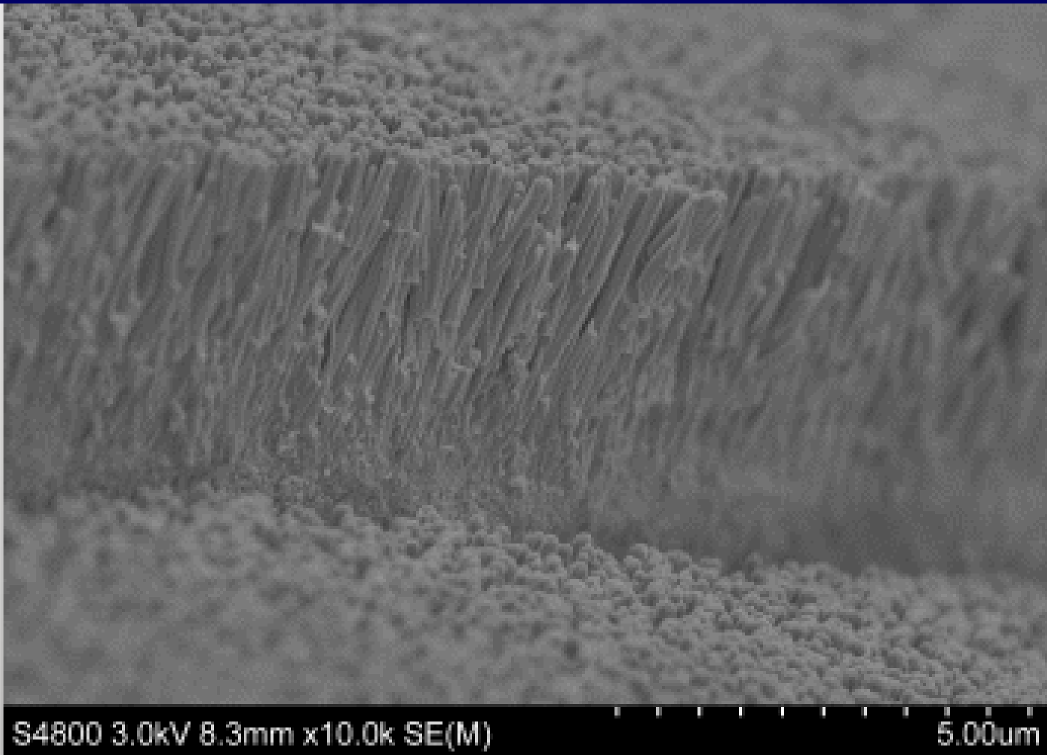
Step 1: **Plasma cleaning of FTO glass**

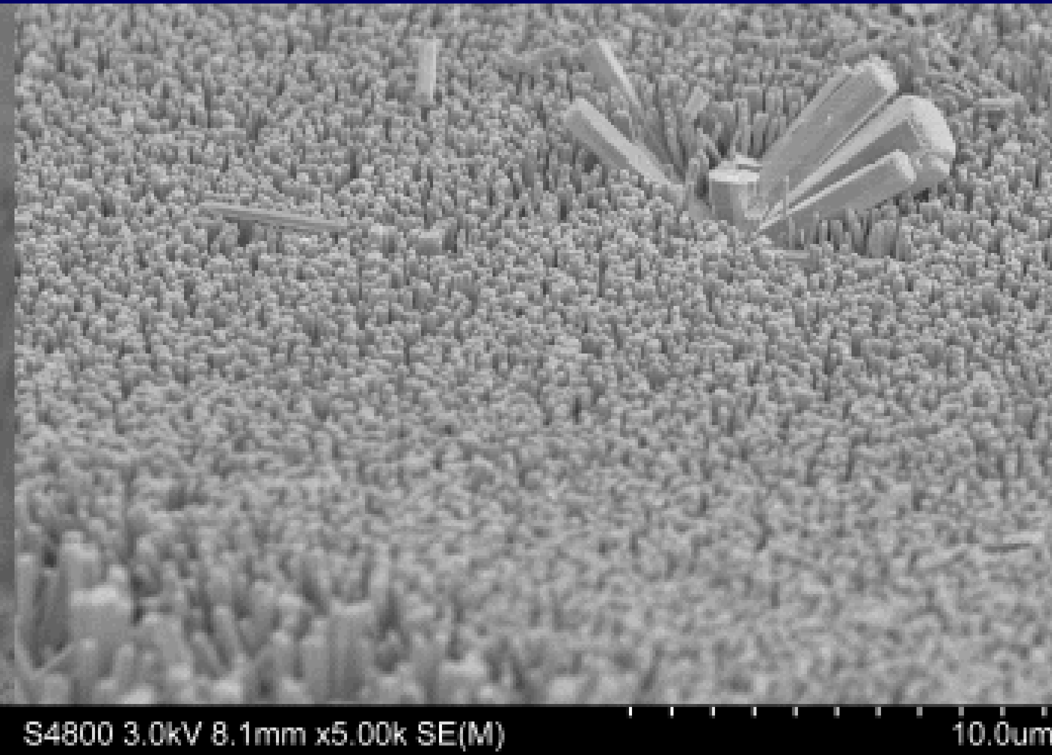
- Deionised water-isopropanol

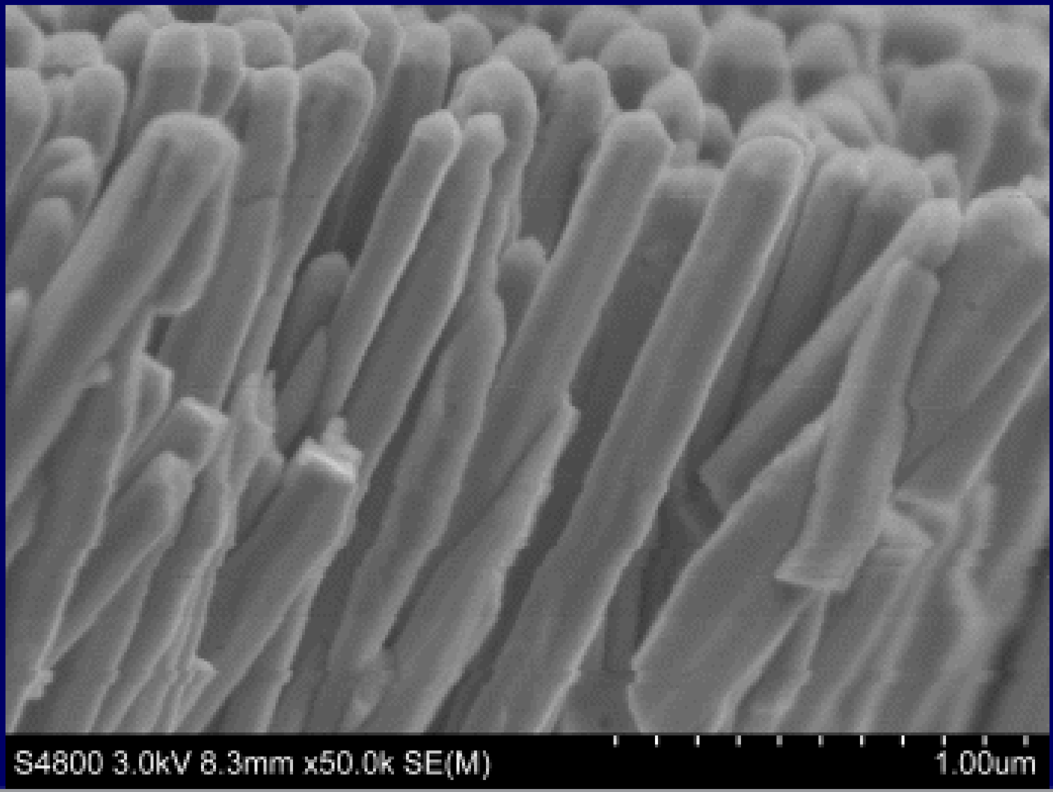


SEM of ZnO NRs on WGM resonator

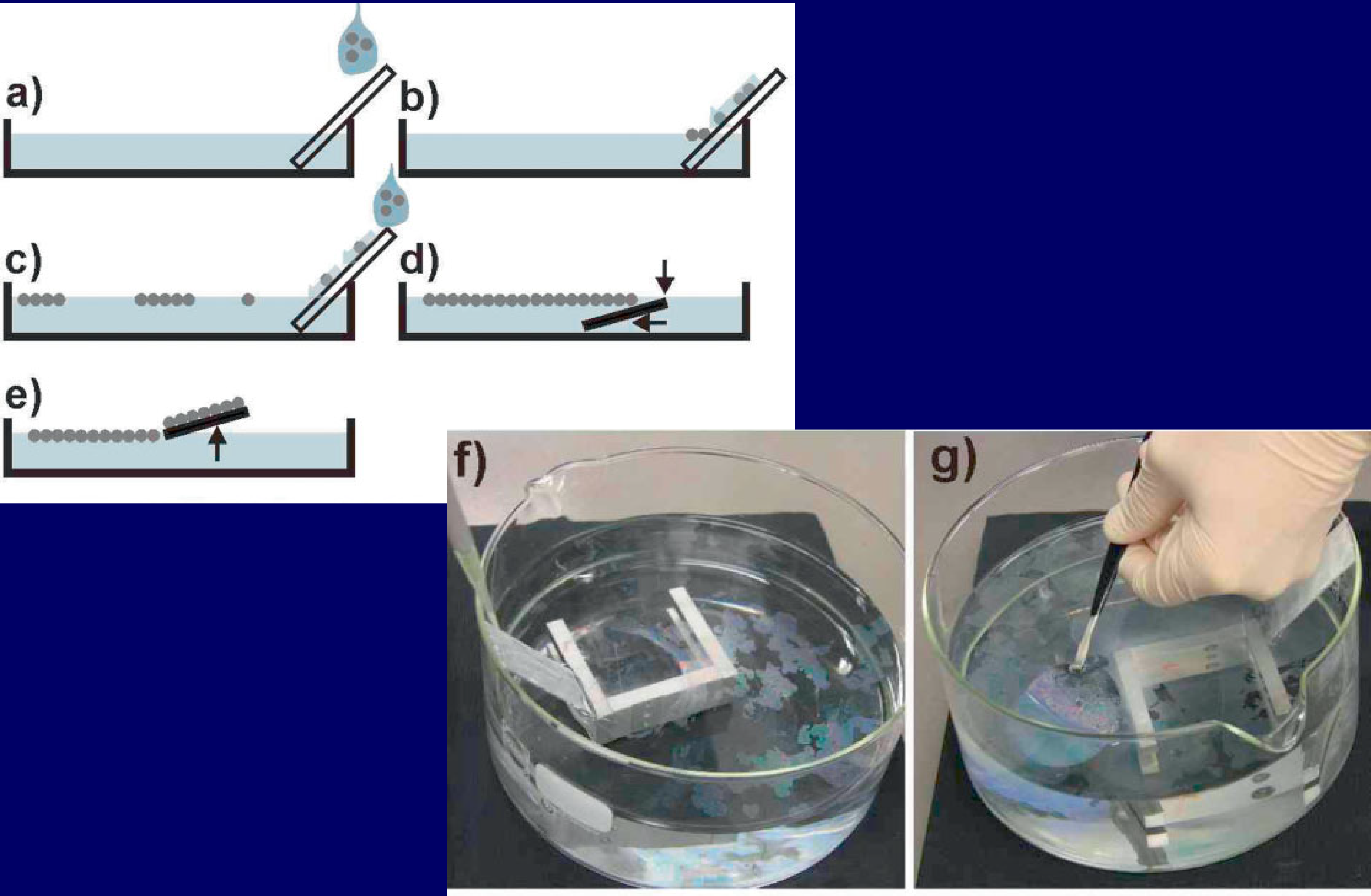


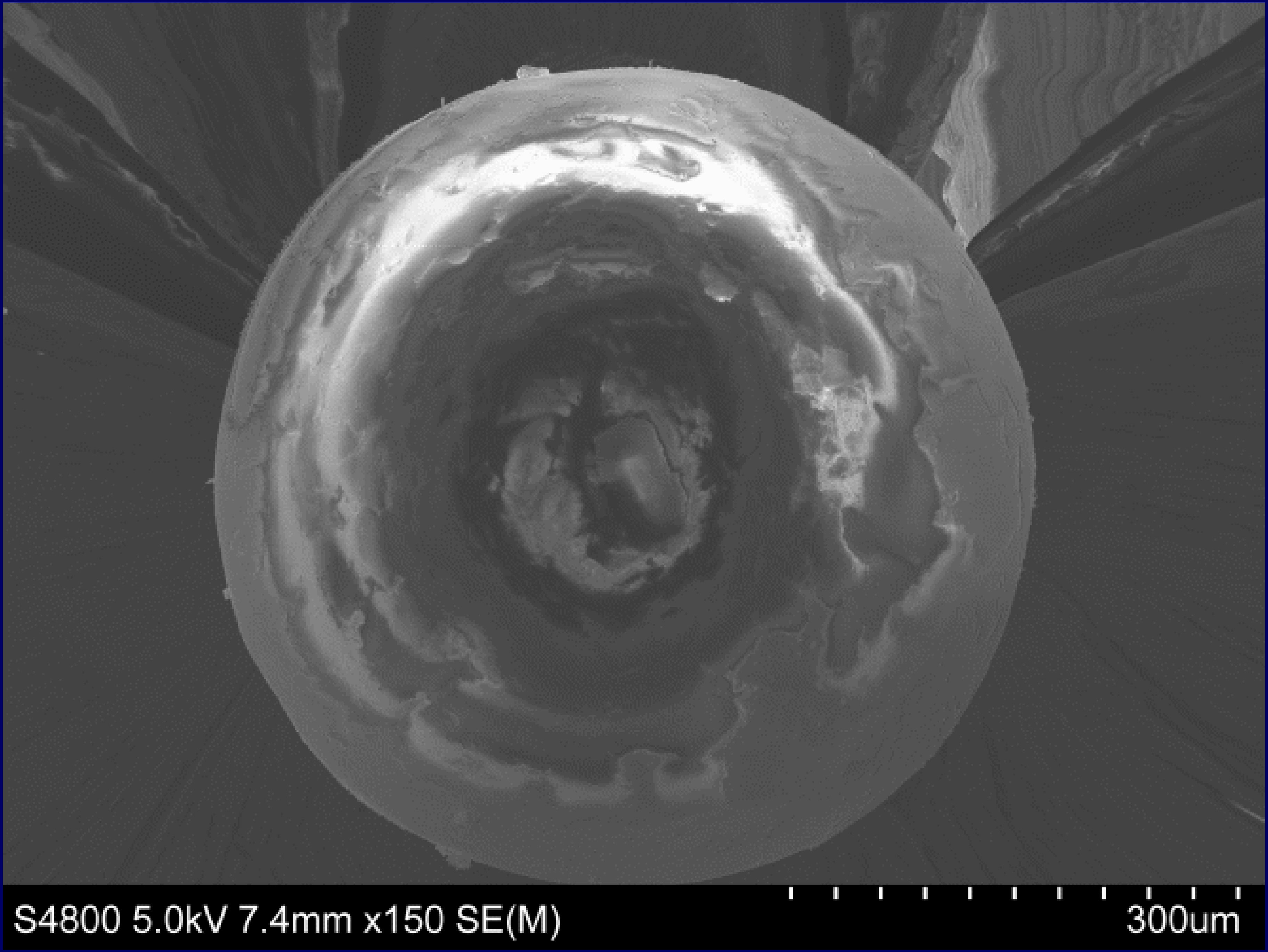

S4800 3.0kV 8.3mm x10.0k SE(M)
5.00um

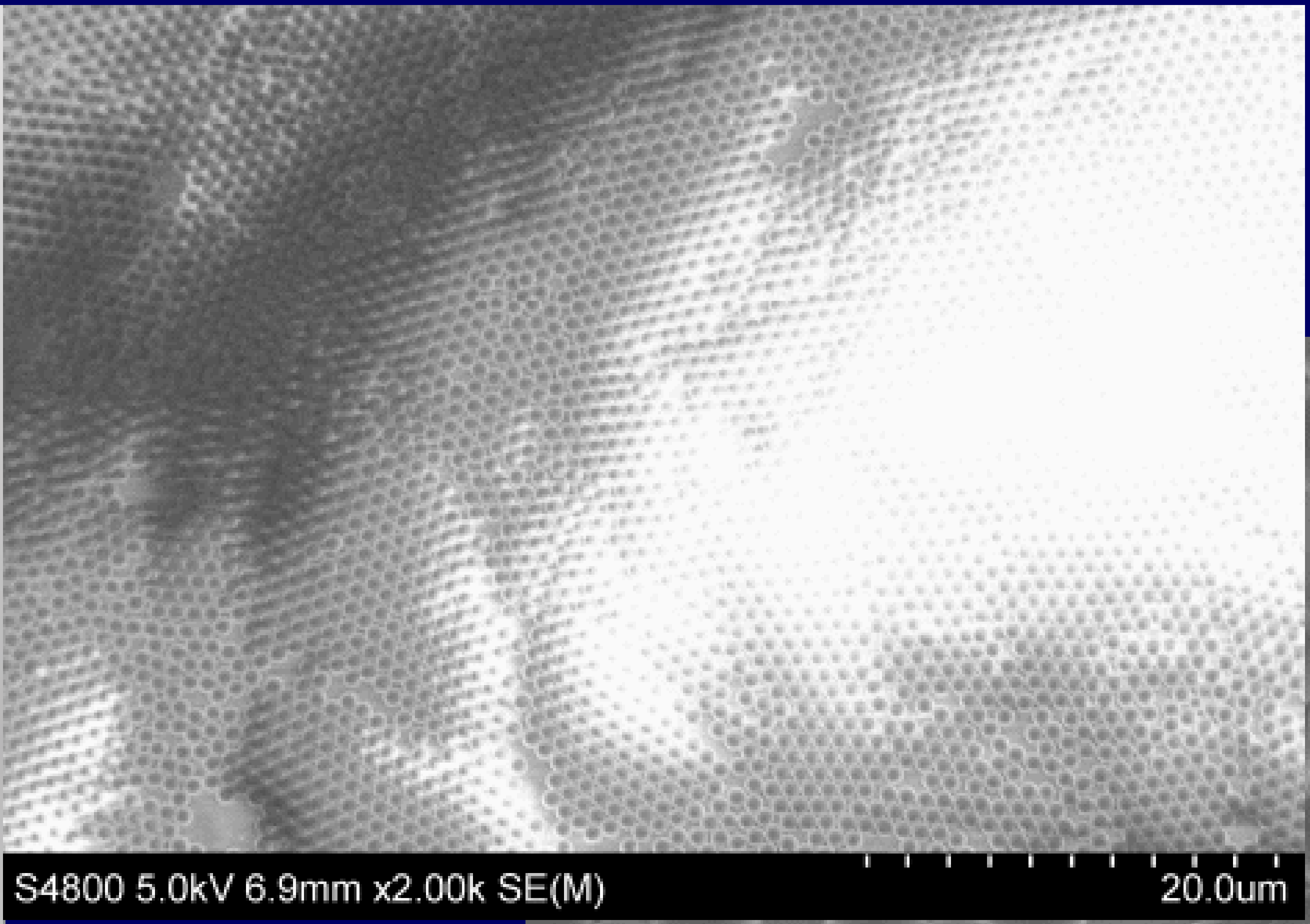
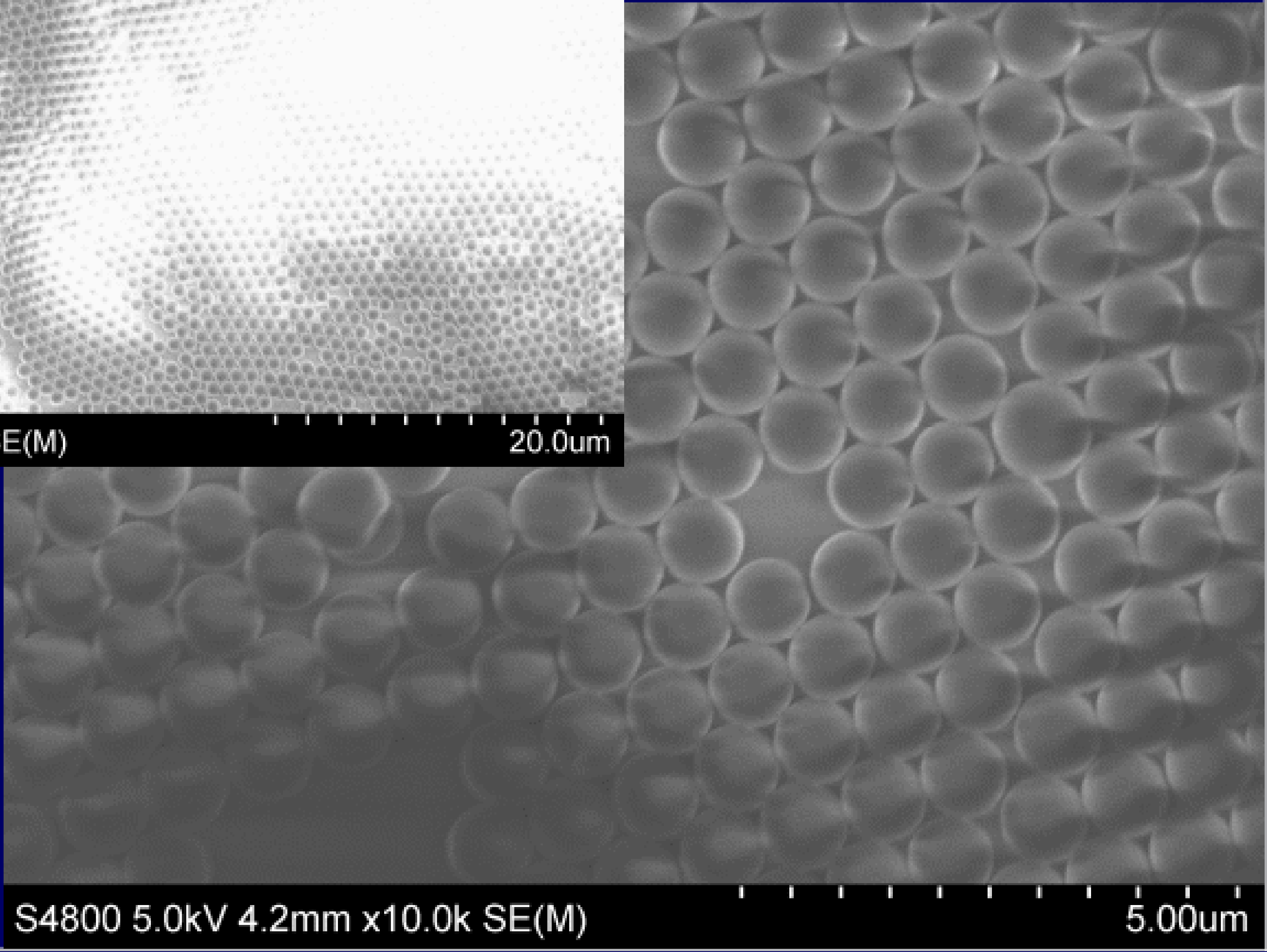

S4800 3.0kV 8.1mm x5.00k SE(M)
10.0um


S4800 3.0kV 8.3mm x50.0k SE(M)
1.00um

Nanospheres lithography




S4800 5.0kV 7.4mm x150 SE(M)
300um


S4800 5.0kV 6.9mm x2.00k SE(M)
20.0um

S4800 5.0kV 4.2mm x10.0k SE(M)
5.00um

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