NACIONĀLAIS ATTĪSTĪBAS PLĀNS 2020

EIROPAS SAVIENĪBA
Eiropas Reģionālās attīstības fonds

IEGULDĪJUMS TAVĀ NĀKOTNĒ

5. atskaite par posmu no 13.04.2021. līdz 13.10.2021.

Par Latvijas Universitātes projekta "**Uz čukstošās galerijas modas mikrorezonatora bāzes veidota optisko frekvenču ķemmes ģeneratora izstrāde un tā pielietojumi telekomunikacijās**" Nr. 1.1.1.1/18/A/155 **norisi**

Projekta vispārējais mērķis: Veikt pētniecību, kas veicina Latvijas viedās specializācijas stratēģijas mērķu sasniegšanu, cilvēkkapitāla attīstību zinātnē un tehnoloģijās un jaunu zināšanu radīšanu, lai uzlabotu konkurētspēju tautsaimniecībā.

Projekta mērķis ir: iegūt jaunas zināšanas par čukstošo galeriju modu rezonatoru optiskajām frekvenču ķemmēm (WCOMBs) un izstrādāt, konstruēt un testēt ķemmes ģeneratora prototipu telekomunikāciju pielietojumiem.

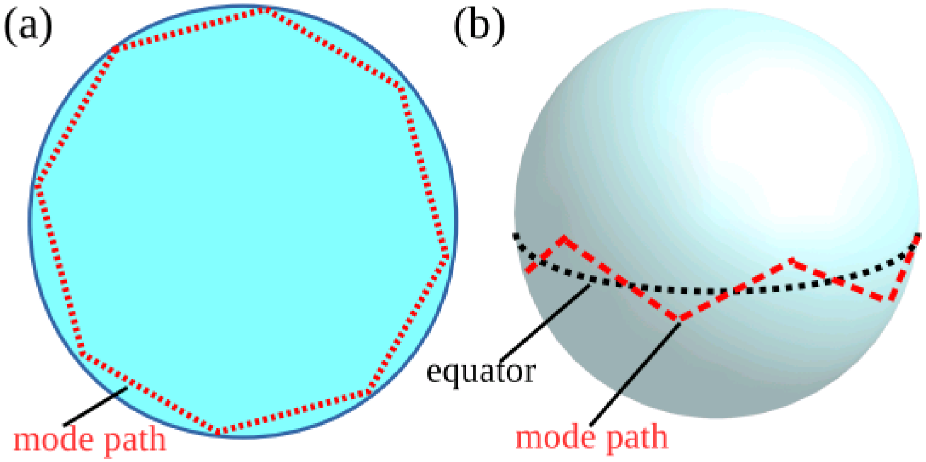
Prezentēja: Jānis Alnis, MS Teams, LU ASI 2021. g. 28. oktobrī.

Whispering gallery mode microresonators

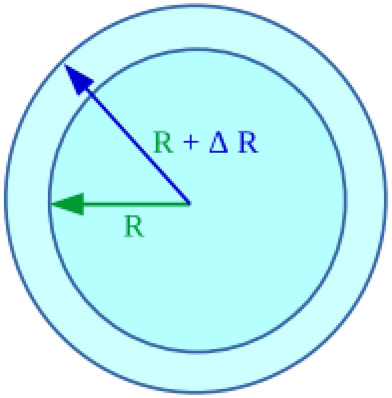
- Based on total internal reflection
- Do not need mirror coatings
- Work in broad wavelength range
- WGMR sensors, nonlinear optics

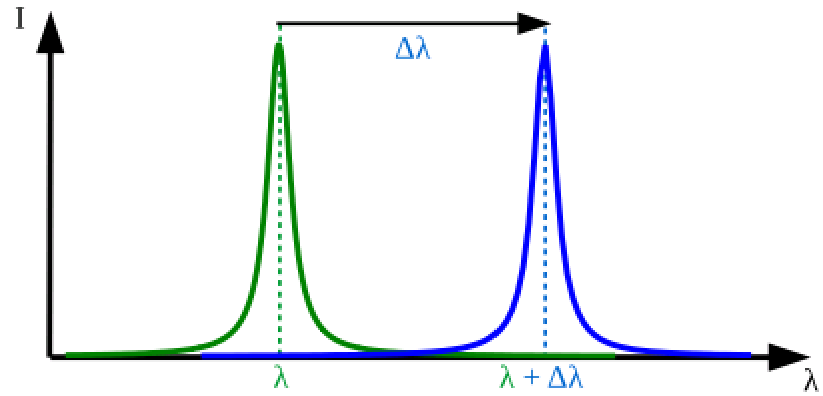
Accoustics

Classical optics



Whispering gallery mode resonators





Optical quality factor Q

Q = $\boldsymbol{\upsilon / \Delta\, \upsilon}$ where υ is optical frequency $\Delta\, \upsilon$ linewidth

Q = $\boldsymbol{\omega\, \tau}$ where $\boldsymbol{\tau}$ is the phton lifetime

Q = 2π L / λ where L is the photon path length.

Examples.

Resonator Q factor 10^8 . Light runs 25 m in 1 mm sphere.

We demonstrated:

Whispering gallery mode resonator and glucose oxidase based glucose biosensor
I. Brice et al Sensors and Actuators B, 2020

Silica microsphere resonator combs

For Kerr effect (modifying the index of refraction) intensities ~ 1 GW/cm^2 are necessary
Kerr effect has been usually observed with pulsed lasers
In microspheres it is possible with a CW laser

Peak intensity and circulating power calculations

power circulating $$P_{circ} = P_{in} Q \frac{\lambda}{\pi^2 n R} \frac{K}{(1+K)^2}$$

λ is the resonance wavelength, R is the devic
Q is the quality factor of the device,
n is the effective refractive index
K is the coupling coefficient

transmission : $$T = \frac{(1-K)^2}{(1+K)^2}$$

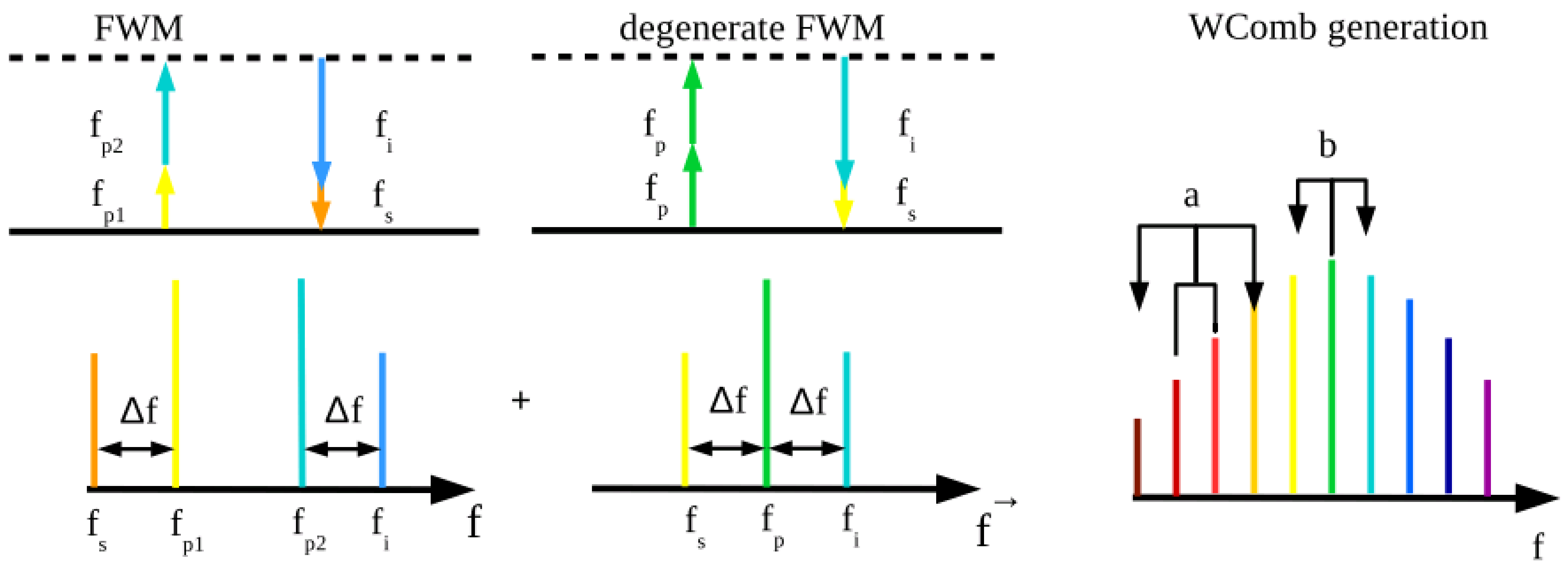
intensity circulating P_{circ}/A_m,

mode area $$A_m = \frac{\int \varepsilon(r)|E|^2 dA}{\max(\varepsilon(r)|E|^2)}$$

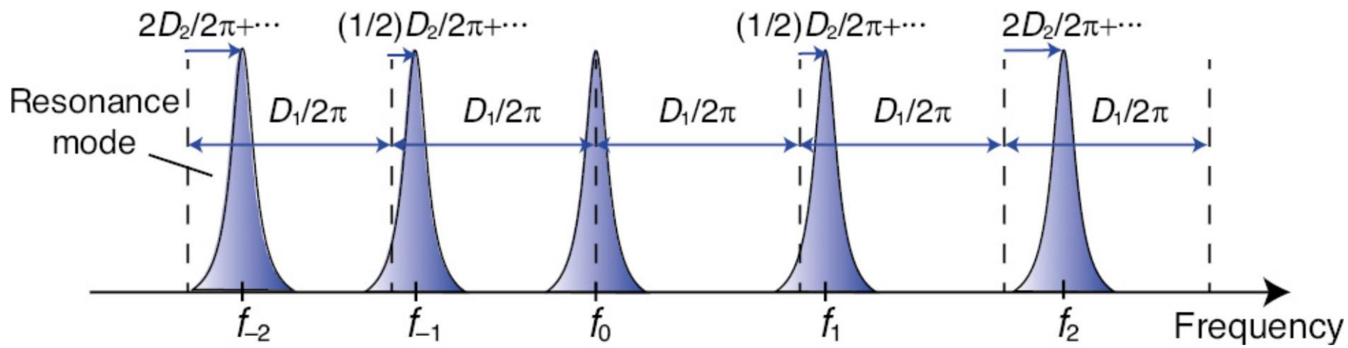
Power and optical intensity circling inside the WGMR from 0.1 W input laser power.

R, μm	Q $\cdot 10^7$	T	K	Q_{intr} $\cdot 10^7$	P_{circ} W	A_{eff}, μm^2	I_{circ}, GW/cm^2
135	2.0	0.17	1.69	5.4	1016	36.15	2.8
60	1.2	0.26	2.05	3.7	1468	18.45	8.0
85	4.6	0.54	3.89	22.0	4671	24.62	19.0
83	5.2	0.14	1.61	13.6	4217	24.14	17.5

Four Wave mixing (FWM) is a nonlinear process
only wavelengths supported by the resonator can be made

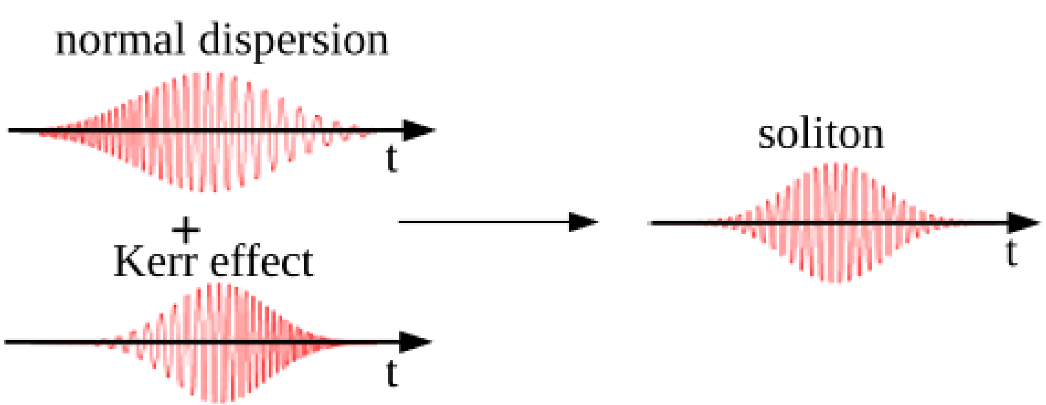


Dispersion causes detuning between comb and WGM lines and limits the spectral width of the comb



[S. Fujii, T. Tanabe, (2020) Dispersion engineering and measurement of whispering gallery mode microresonator for Kerr frequency comb generation, Nanophotonics 9, 1087–1104]

Dispersion compensation to make a broader comb

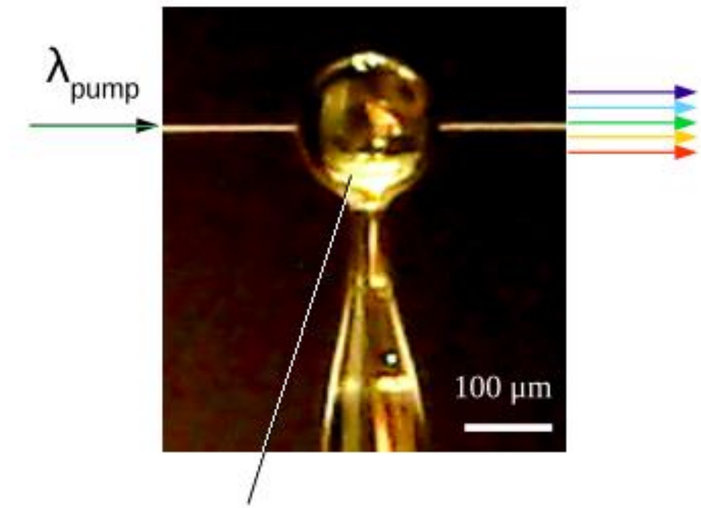


In soliton regime Kerr effect compensates dispersion.
In such case dispersion is 0 and pulse circulates without changing length.

Soliton regime is the most stable regime, **hard to get.**
Needs high Q factor and certain microsphere size

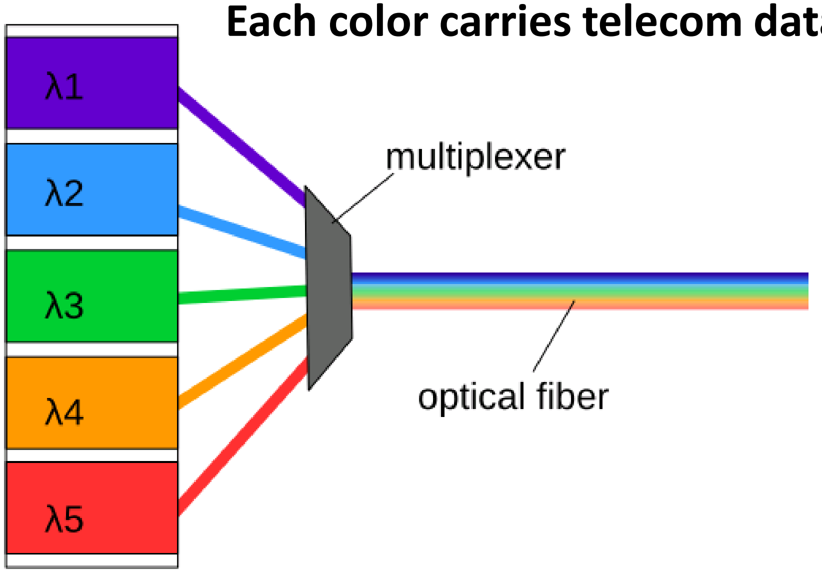
Our Vision for use in telecom

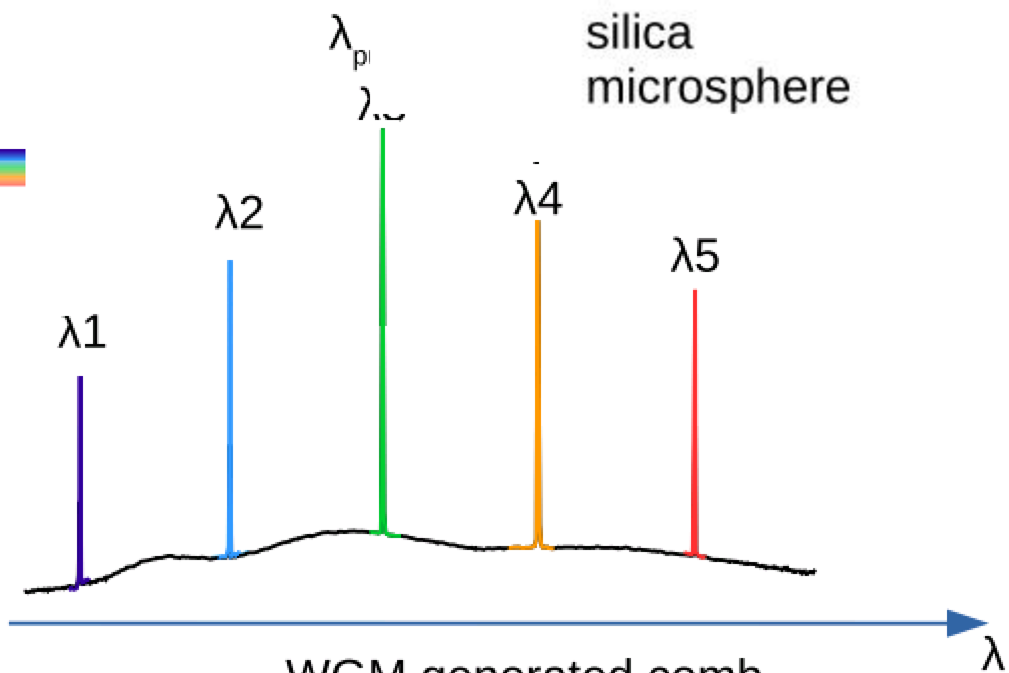
Replace laser array with frequency comb generated inside WGM resonator.



Wavelength Division Multiplexing

Send many colors through the same fiber
Each color carries telecom data





ERAF Projekta darbības

1. WCOMB izstrāde, modelēšana, testēšana un optimizēšana

1.1.Dažādu ČGM rezonatoru izstrāde un iegūšana: SiO_2 mikrosfēras, mikrostieņi, uz čipa.

1.2.WCOMB sistēmas, kur tiek izmantota prizma, izveide, testēšana un optimizēšana
Noslēdzās augustā, nodevums – zinātības apraksts tiks pievienots maksājuma pierasījumam.

1.3.WCOMB sistēmas, kur tiek izmantota izstieptā šķiedra, izveide, testēšana un optimizēšana
Noslēdzās augustā, nodevums – zinātības apraksts tiks pievienots maksājuma pierasījumam.

1.4.ČGM rezonatoru efektu un WCOMB sistēmas matemātiskā modelēšana. Noder publikācijām.

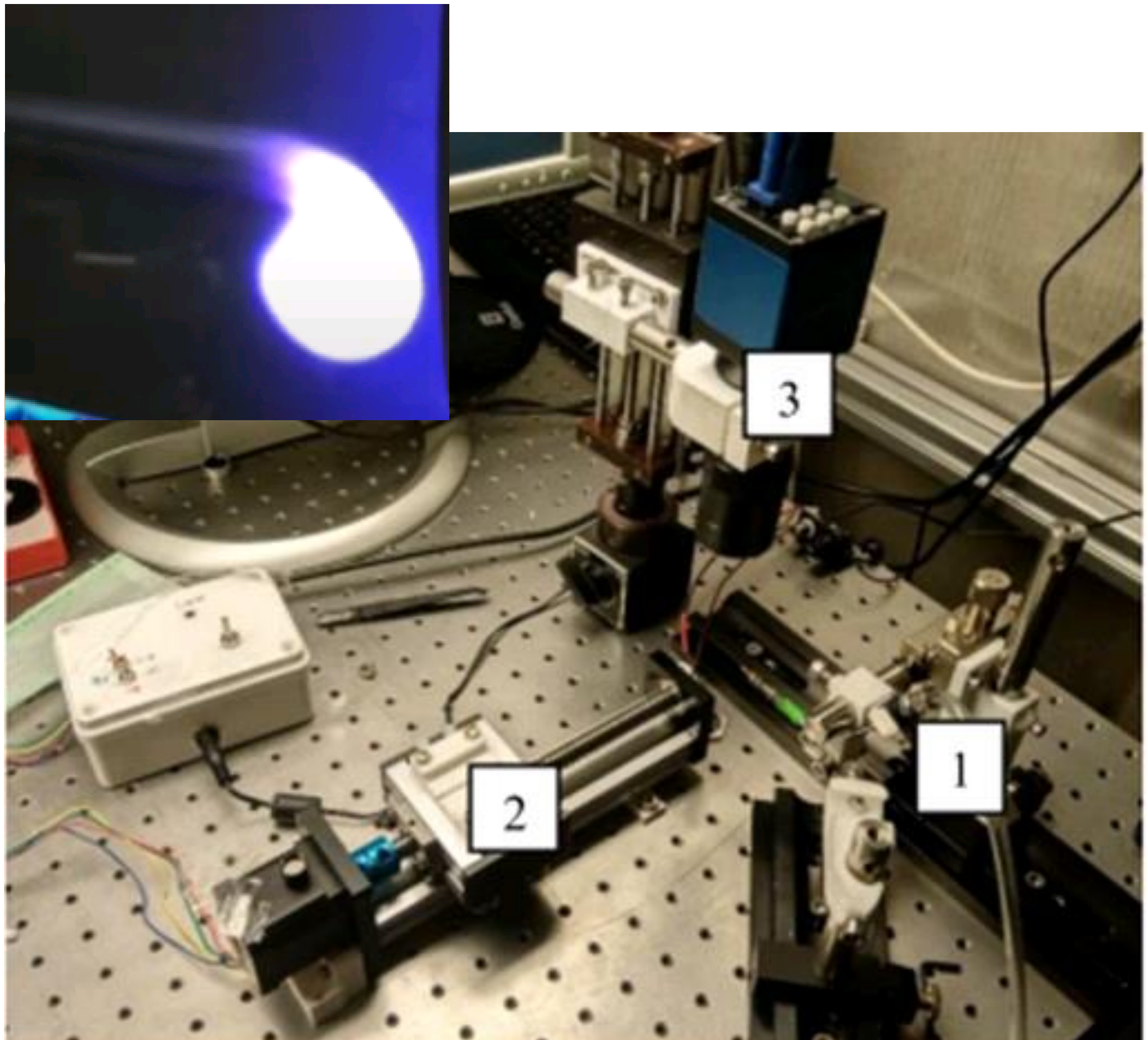
1.5. Uzlabota WCOMB izveide, testēšana un optimizēšana universālam pielietojumam. Uzsākts

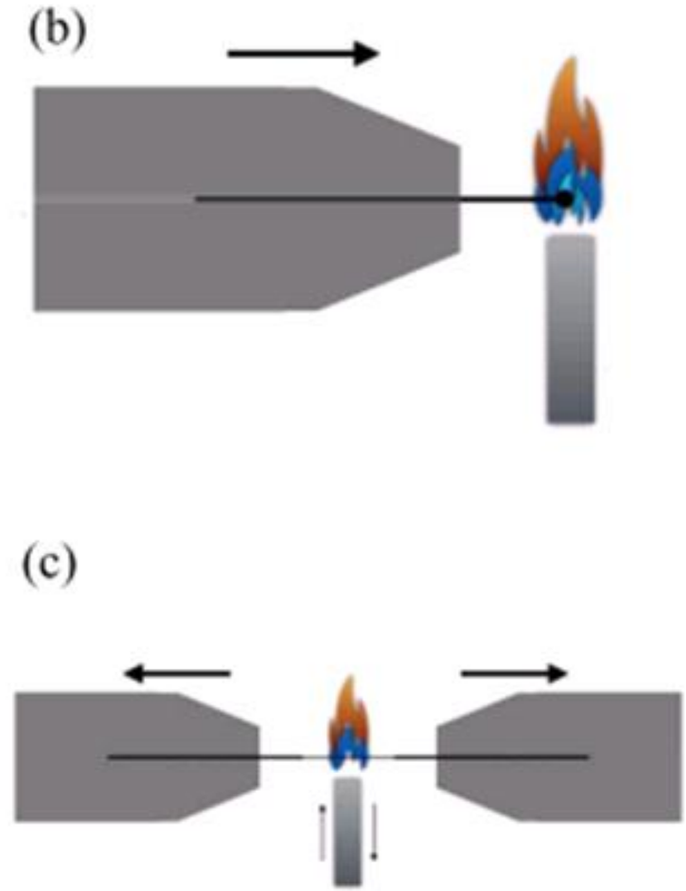
2. Portatīva WCOMB izstrāde, izveide un testēšana pielietojumiem šķiedru optisko sakaru sistēmās
2.1. Eksistējošo WCOMB ģeneratoru veidu, risinājumu un realizāciju izpēte šķiedru optiskajās sakaru sistēmās
2.2. Portatīva WCOMB kā daudzviļņu gaismas avota izstrāde un izveide pielietojumiem šķiedru optisko sakaru sistēmās
Braucam no LU uz RTU šķiedru optikas laboratoriju laboratoriju, kopā ar SIA Affoc Solutions.

4. Projekta rezultātu izplatīšana
4.2. Intelektuālā īpašuma tiesību pārvaldīšana. Tehnoloģiju tiesību **- zinātības apraksts. Patents jāraksta.**
4.5. Publicitāte: publikāciju **skaits būs sasniegts uz gada beigām**, pēdējo šobrīd gatavojam iesniegšanai.

Aktivitāte 1.1. Dažādu rezonatoru izgatavošana.

Stends mikrolodīšu izgatavošanai ar H_2+O_2 liesmu no ūdens elektrolīzes. Izmēra kontrole notiek mikroskopā.

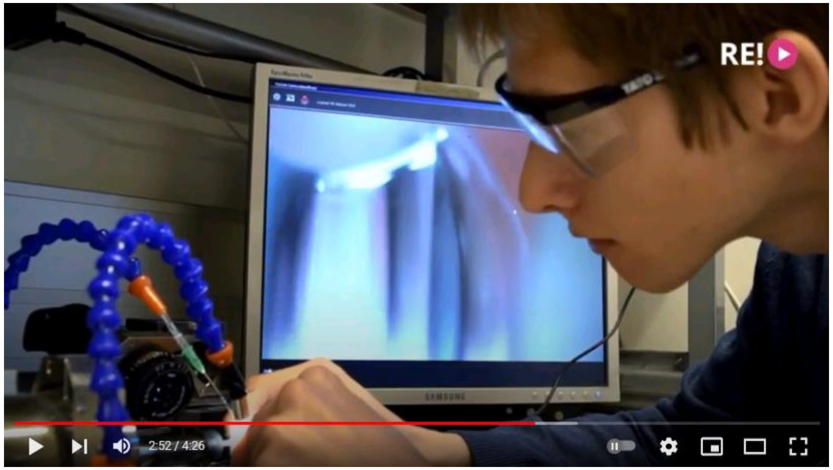


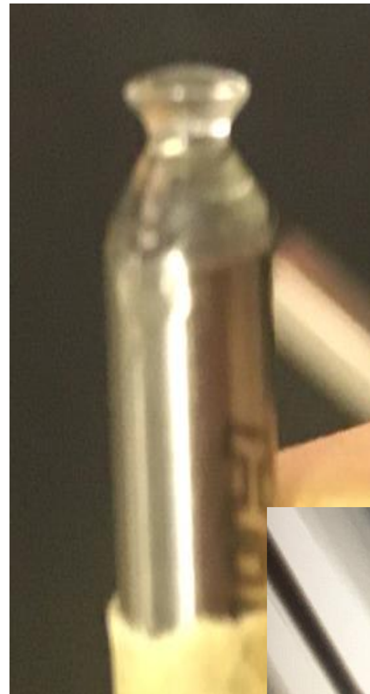


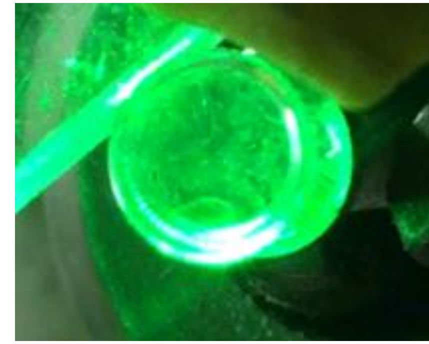
Aktivitāte 1.1. Dažādu rezonatoru izgatavošana.

Izgatavots stends rezonatoru slīpēšanai un pulēšanai ar abrazīviem gaisa gultņa virpā ar vibrācijām < 100 nm.

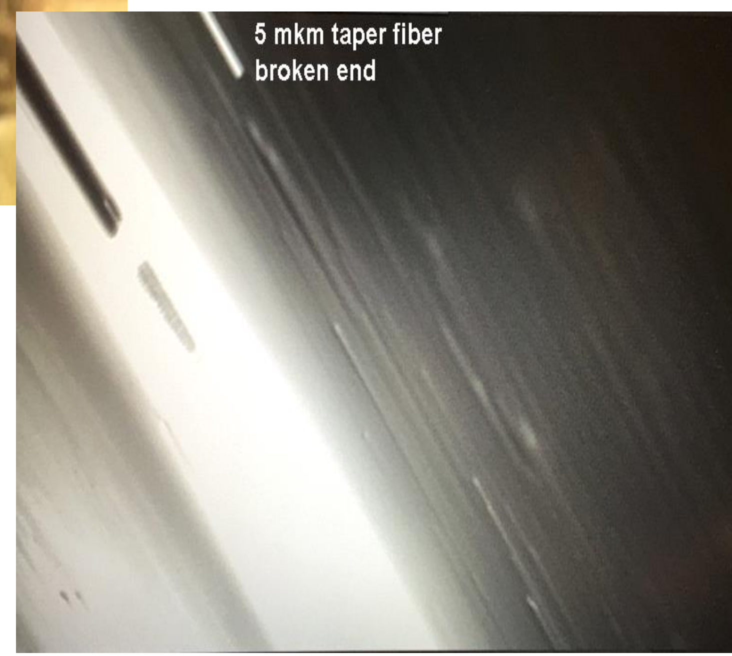
Rezonatoriem no CaF_2 un MgF_2. SiO_2 neder, jo virsma bojājas no ūdens.







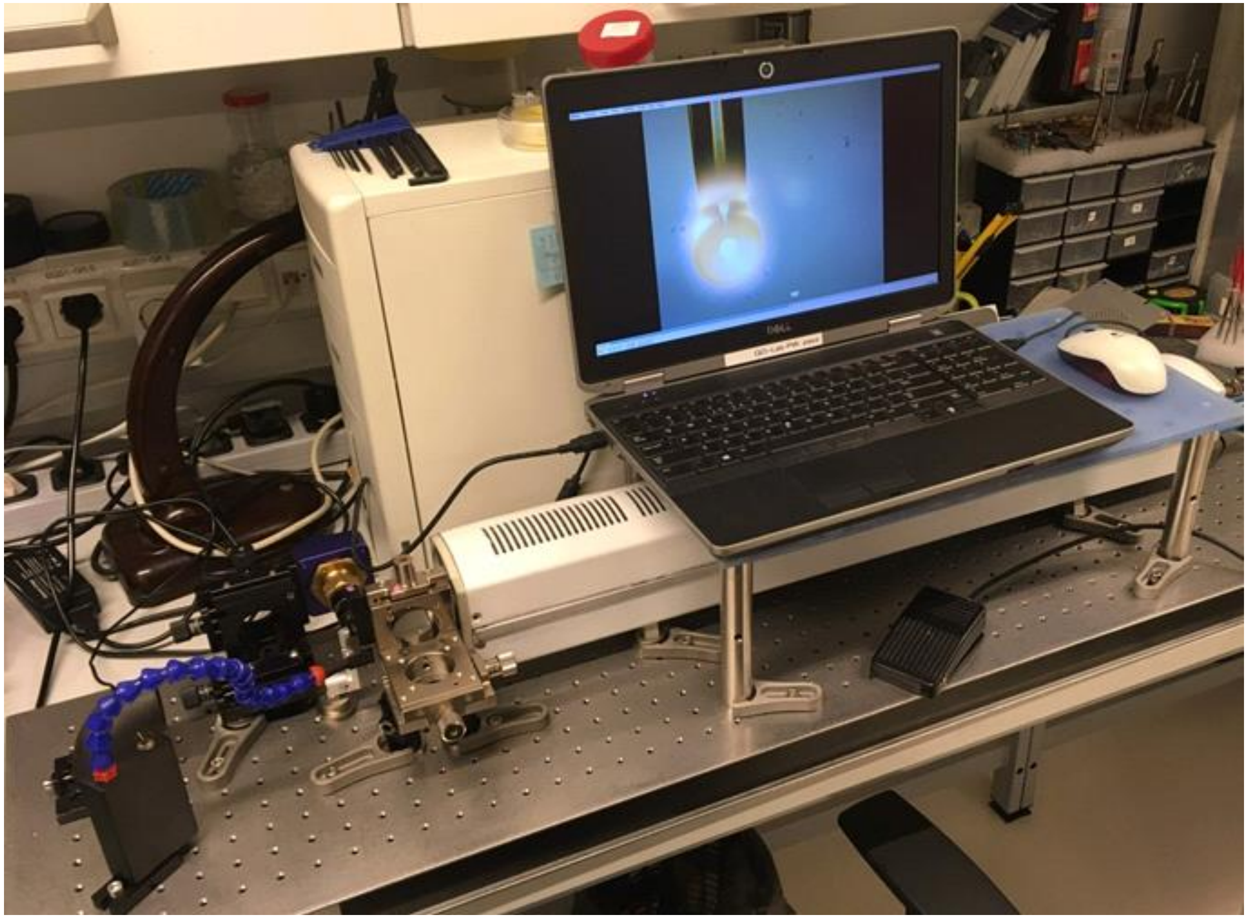
Mikroskopā redzamas ap 1 mkm dimanta daļiņas, kas ierakušās virsmā

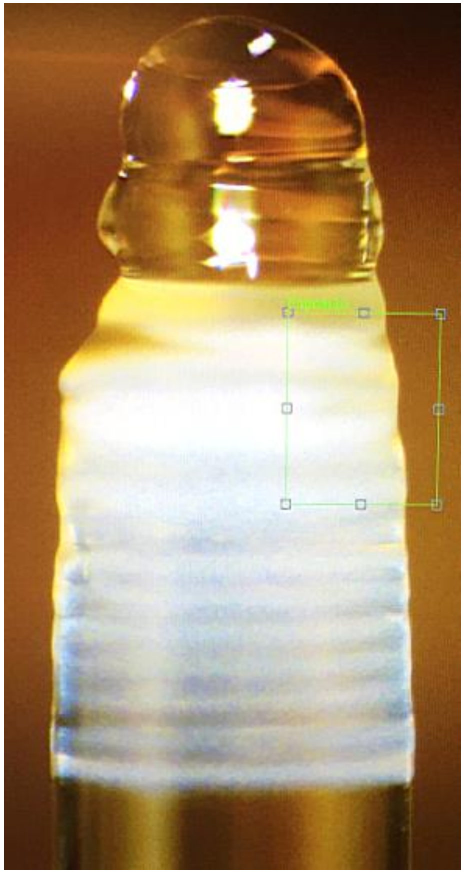


Aktivitāte 1.1. Dažādu rezonatoru izgatavošana.

Izgatavots stends mikrolodīšu lodīšu kausēšanai un mikrostienīšu virpošanai ar CO_2 lāzeri.

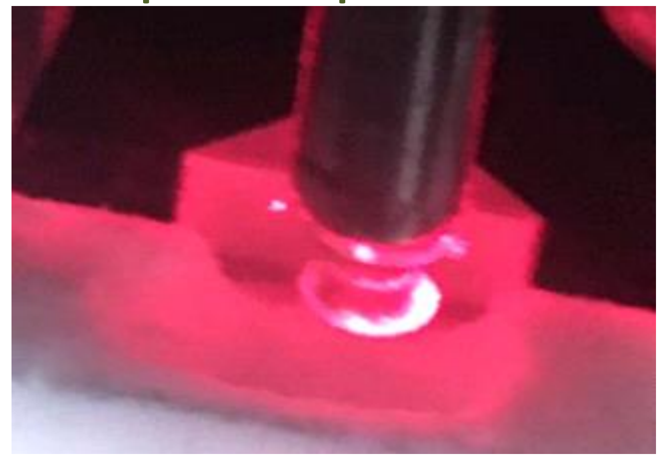
Nav vŗēja un piesārņojuma no liesmas, nosēžas balti kvarca putekļi , tā sauktais kristobalīts. Jāpūš ar gaisu prom izgatavošanas laikā.



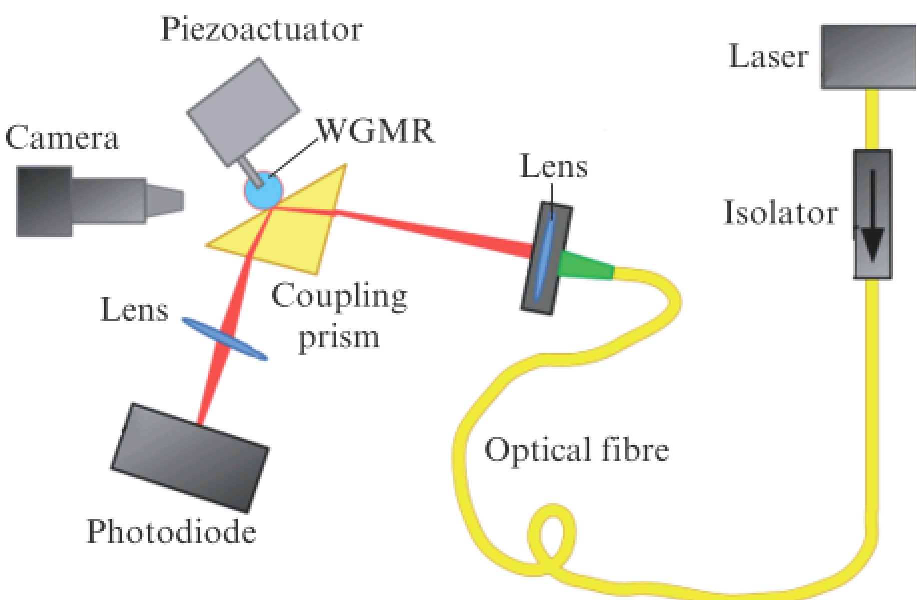


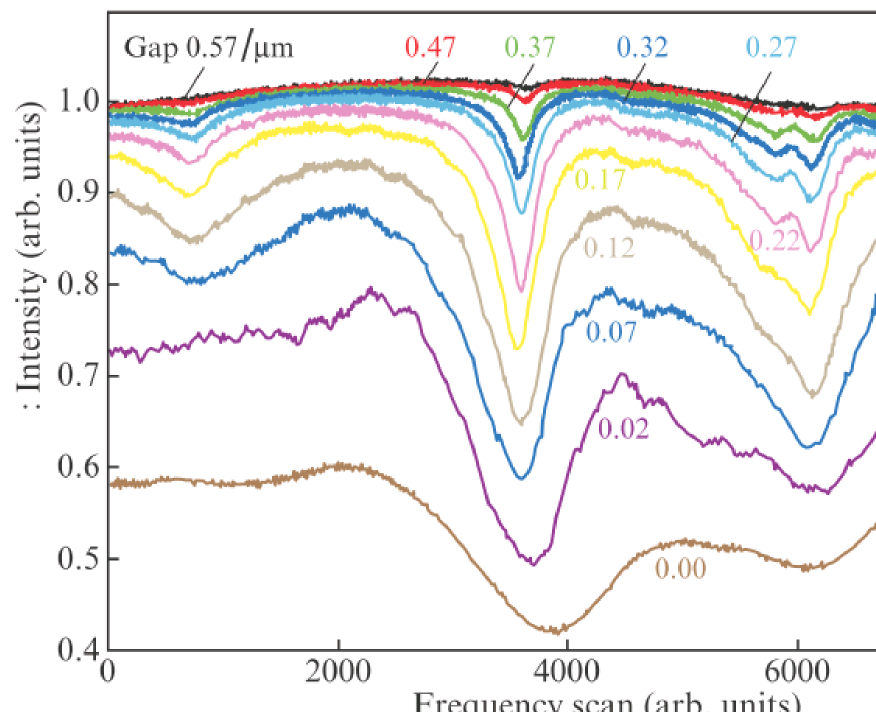
1.2. WCOMB sistēmas, kur tiek izmantota prizma, izveide, testēšana un optimizēšana

Mikrolodītes un mikrostieņa rezonators pieskaras prizmai:



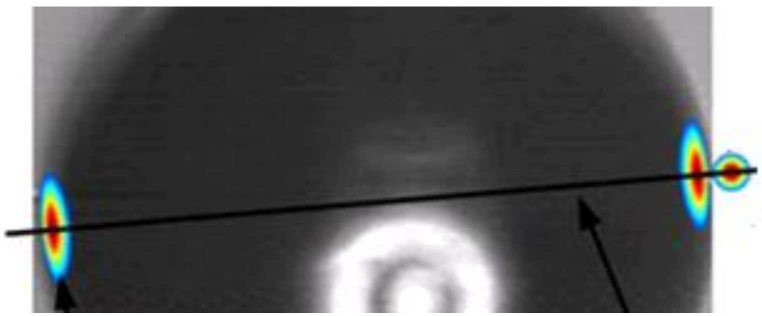
Optimālo attālumu 120 nm uzstāda ar piezo nanopozicionieri, bet grūti ilgi noturēt nemainīgu.





Aktivitāte 1.3. WCOMB sistēmas, kur tiek izmantota izstieptā šķiedra, izveide, testēšana un optimizēšana.

Tievā šķiedra nepieciešama efektīvai gaismas ievadīšanai rezonatora modā no tievās šķiedras gaistošā lauka (COMSOL)



SiO_2 mikrostienis ar diametru 660 mkm pieskaras patievinātajai šķiedrai d=3 mkm FSR 100 GHz.

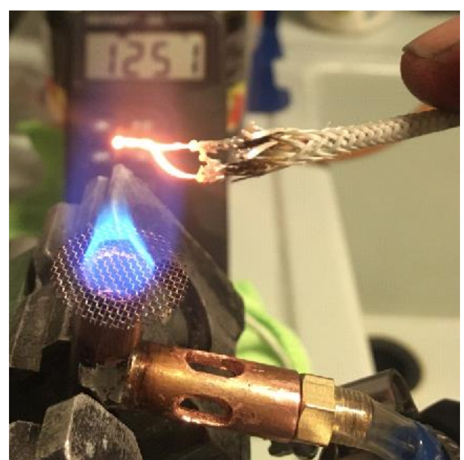
SiO_2 mikrolodīte ar diametru 166 mkm pieskaras patievinātajai šķiedrai d=3 mkm FSR 200 GHz.

Aktivitāte 1.3. WCOMB sistēmas, kur tiek izmantota izstieptā šķiedra, izveide, testēšana un optimizēšana.

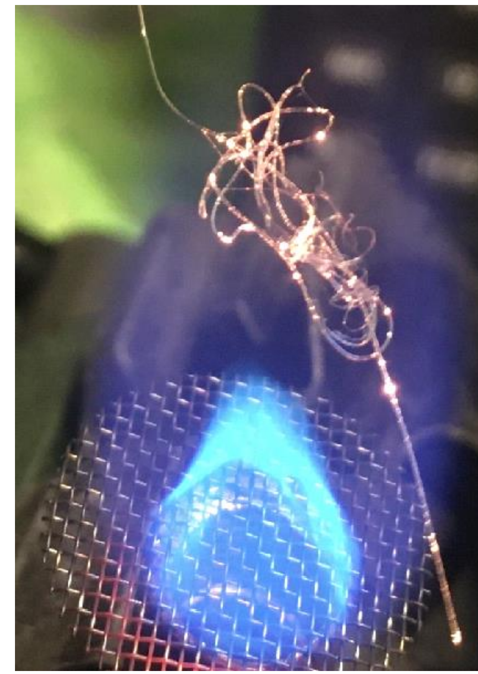
Apmēram 2 mikrometru diametrā tievas kvarca šķiedras izvilkšana no 125 mkm diametra šķiedras, karsējot ar ūdeņraža un propāna degļiem

Tīra ūdeņraža deglis
1 caurums 0.8 mm.

Tīrs ūdeņradis, 8 adatas rindā – gara šaura liesma.

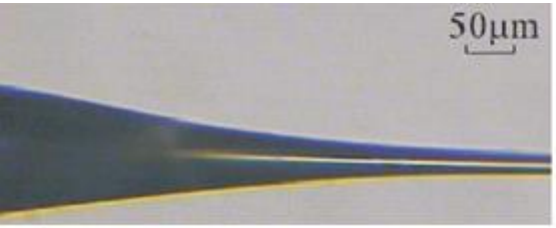


Propāna liesma
Deglis ar sietiņu

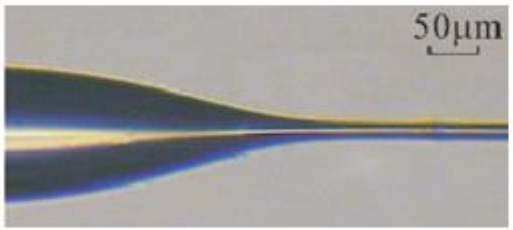


Temperatūru mēra ar termopāri
H_2 >1400 C.
Propāns ~1250 C.

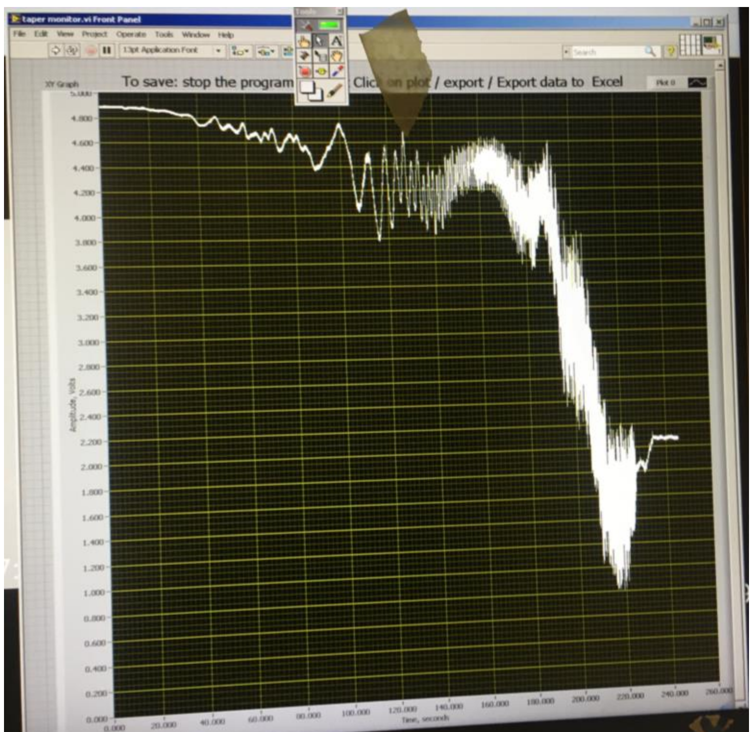
Rezultāts: izstiepjot *tapered fiber* ar mazu liesmu iegūst ~40 % transmisijas saglabāšanās. Ar platāku liesmu transmisija saglabājās 90% no sākotnējās.

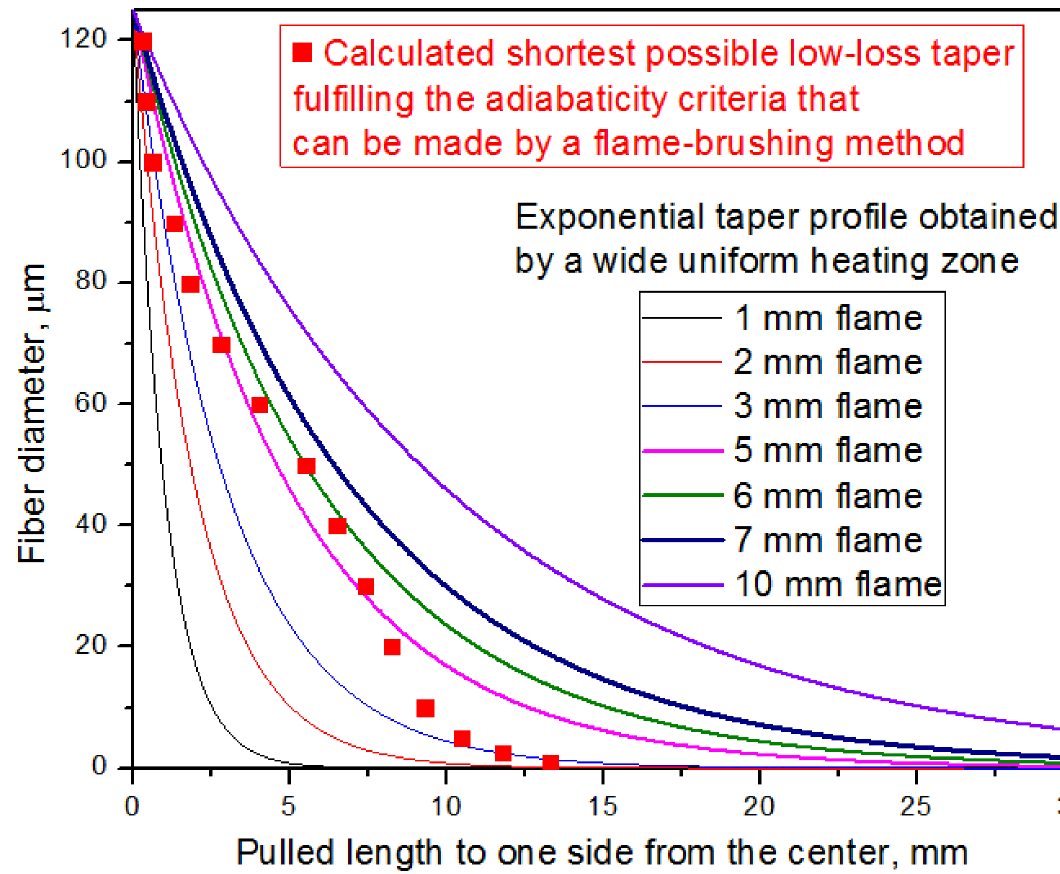


Adiabātiski pašaurināta šķiedra saglabā transmisiju



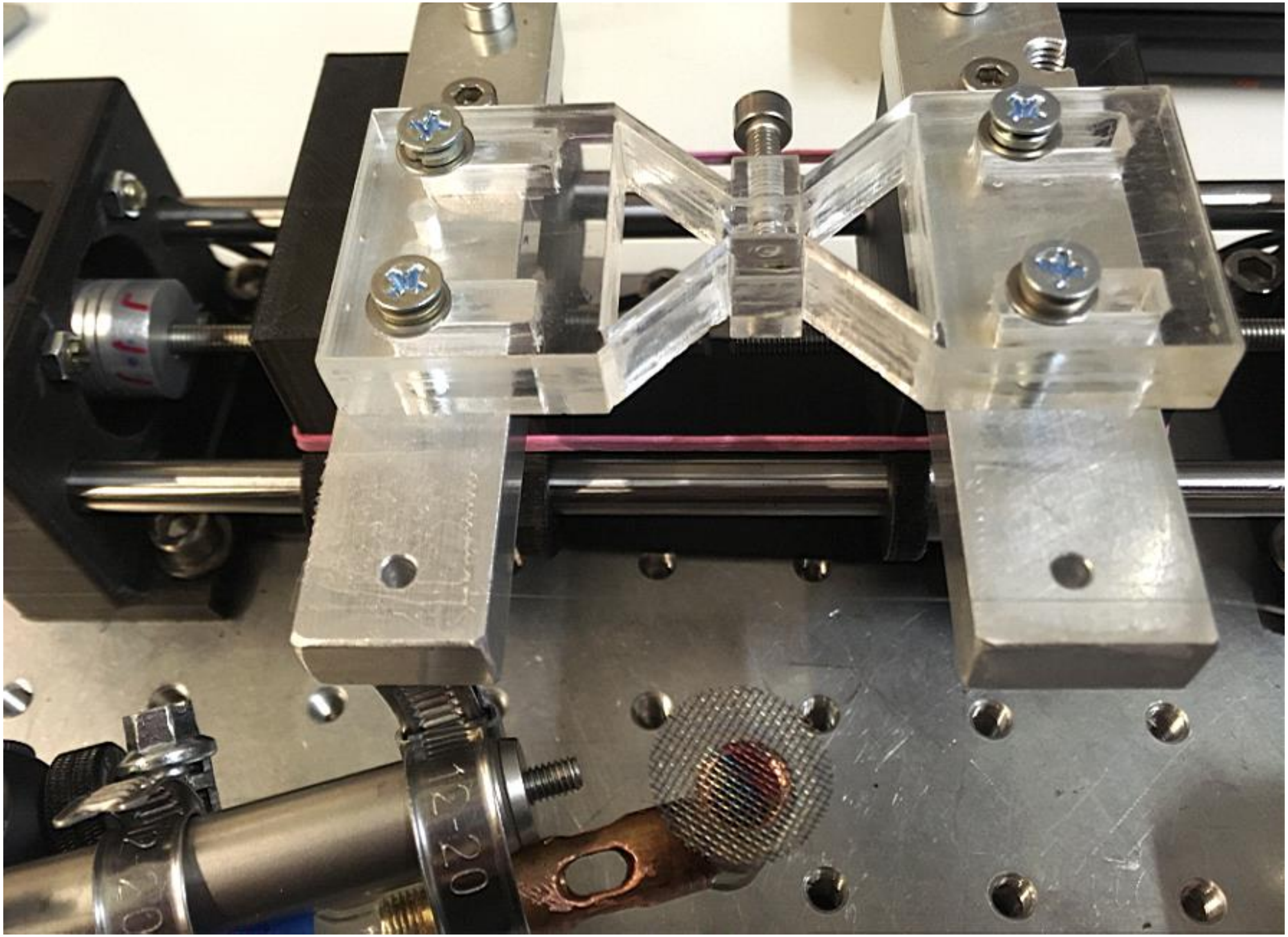
Pārāk strauji pašaurināta šķiedra (leņķis pārsniedz pilnīgas iekšējas atstarošanās leņķi)





Tievās šķiedras stiepšana ar jaunizgatavoto propāna degli un nofiksēšana pēc stiepšanas, lai varētu nocelt no motorizētā stiepšanas stenda.

Tievā izstieptā šķiedra iztur transportu ar automašīnu.



Mitruma ietekmē kvarca šķiedras degradējas paliek trauslas un slikti vada gaismu.

Journal of Non-Crystalline Solids 297 (2002) 91–95

The fatigue of high-strength fused silica optical fibers in low humidity ☆

Janet L. Mrotek *,1, M. John Matthewson, Charles R. Kurkjian

The strength and dynamic fatigue of UV-acrylate coated silica optical fibers were measured as a function of relative humidity in the range ~0.025–13% at 25 °C. The degradation kinetics of silica in low humidities was investigated and it was found that the reaction order was approximately first-order with respect to humidity. In our previous work, a second-order reaction was found in the humidity range 20–95% RH at 25 °C and the process for obtaining this reaction

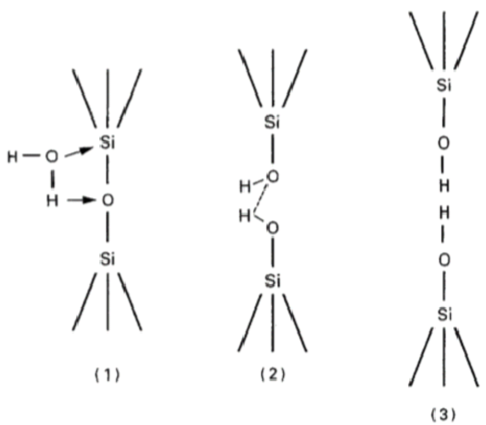


Figure 2 Molecular model of the glass/water interaction. (1) Interaction of a water O–H bond with a glass Si–O bond; (2) Si–O bond and O–H bond formation; (3) rupture of the (assumed) weak O–H bonds (after [14]).

Implicit in this interpretation is the requirement of strained Si–O–Si bonds [16]. Removal of liberated products from the crack tip is not required for the process to continue so supporting the reasoning of

to protect the fibre from mechanical damage. However, owing to the extremely small amounts of water involved and the ability of the various cable materials to absorb and/or allow water permeation, sufficient water will nearly always be present at the fibre surface to allow static fatigue to occur. It is for this reason that the inert strength of fibres (i.e. the "true" strength without degradation due to static fatigue) is difficult to measure and is usually done at liquid nitrogen temperature, under very high vacuum or by drying and rapidly testing the dry fibres.

Reducing humidity via low temperatures or high vacuum is effective but not practicable to an entire optical network and so the presence of water at the fibre surface must be accepted in ordinary cables. In practice then, minimizing static fatigue in fibres is achieved by minimizing tensile stresses on the fibres and so some attention has been focused on determining the stress below which static fatigue does not occur (i.e. the fatigue limit). If that stress were found to be acceptable from an engineering standpoint, fibres could be installed and manufactured at stresses less than the fatigue limit thereby eliminating the possibility of static fatigue.

A fatigue limit has been observed in soda-lime glass [26] and borosilicate glasses [27, 28] fuelling specula-

Fatigue is important considering that most applications of glass involve some kind of applied force and some contact with air or aqueous environments. The fatigue of silica and silicate glass is of interest because of their wide applications. A well accepted concept is that the failure of glasses in wet environments is controlled by stress corrosion due to the chemical reaction between water and strained bonds at the crack tip [31]. Silica is considered inert to water at zero strain, but when the Si-O-Si bond is strained, it can hydrolyze by reacting with water [32,33]:

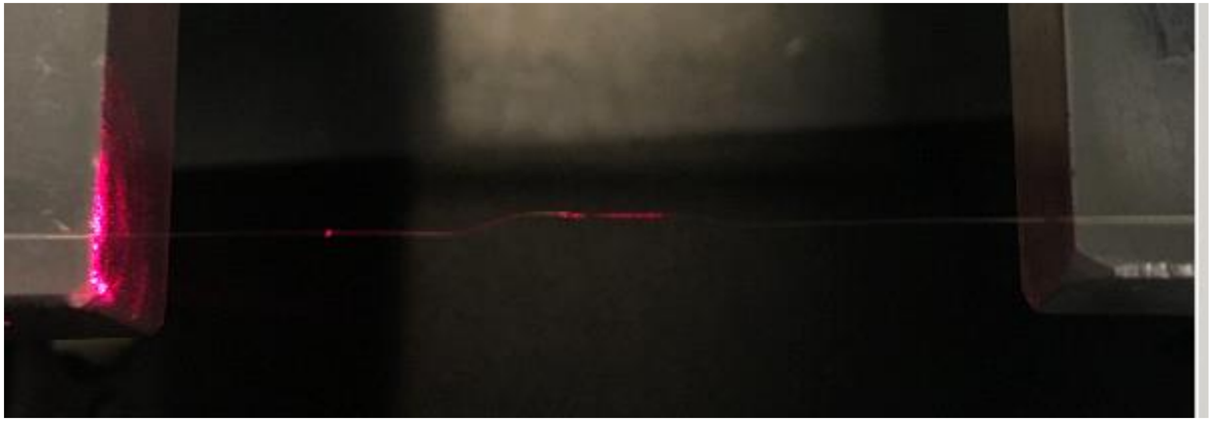
$$-\overset{|}{\underset{|}{Si}}-O-\overset{|}{\underset{|}{Si}}- + H_2O \rightarrow 2\left[-\overset{|}{\underset{|}{Si}}-OH\right] \quad (5)$$

Silica is more susceptible to fatigue in the presence of basic solutions because hydroxyl ions further attack the glass network [34]:

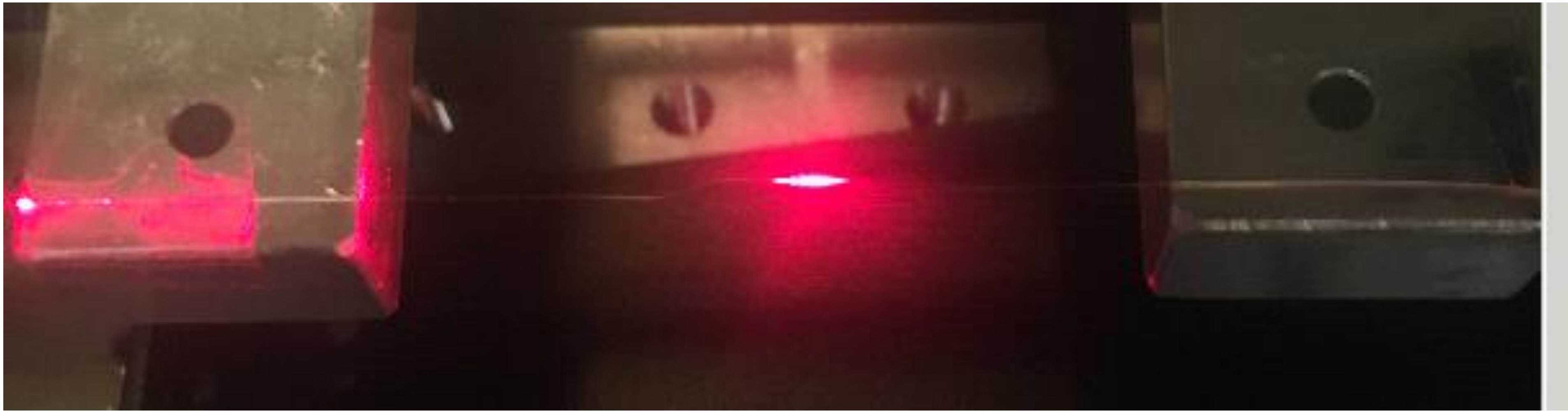
$$-\overset{|}{\underset{|}{Si}}-O-\overset{|}{\underset{|}{Si}}- + OH^- \rightarrow -\overset{|}{\underset{|}{Si}}-O^- + -\overset{|}{\underset{|}{Si}}-OH \quad (6)$$

Mūsu testi: Silica surface degradation by humidity

Tapered fiber - freshly made scatters little light



and one hour later at 70 % RH humidity

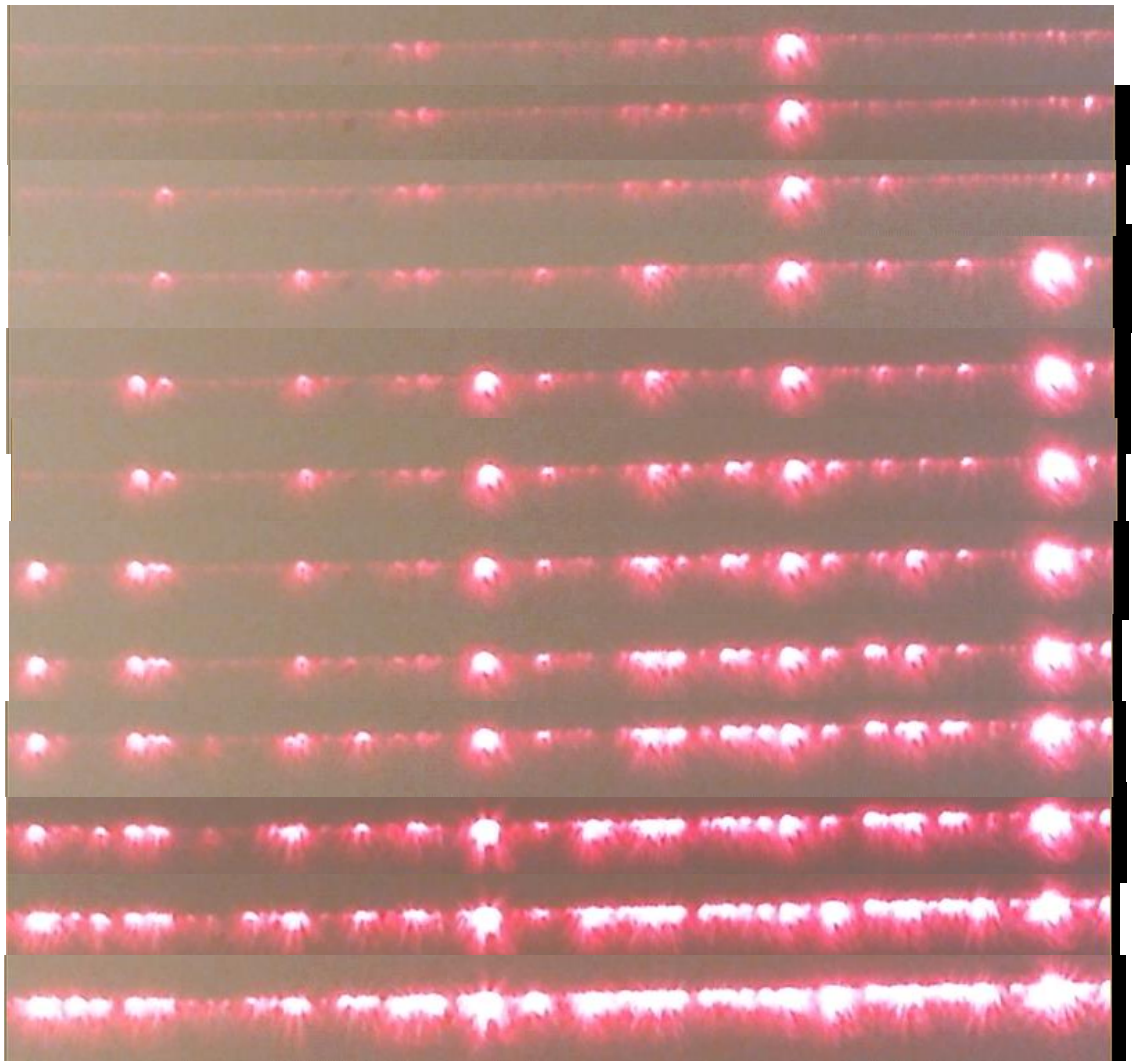


Tapered fiber degraded in 65 % RH within 2 hours

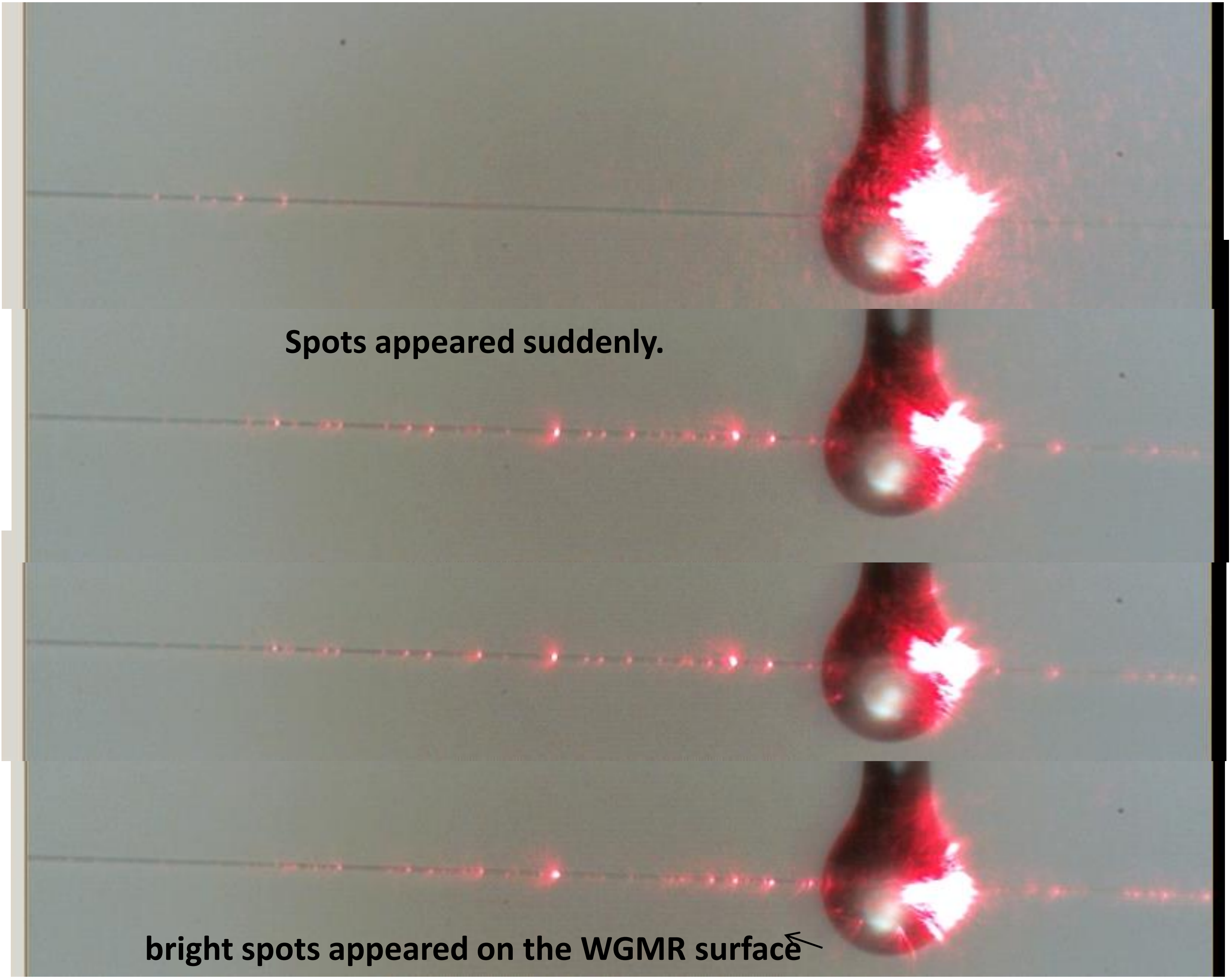
Cracks or quartz nanocrystals? Can not see cracks in microscope.

Sylanol sites (-OH) (Raman specdtroscopy),

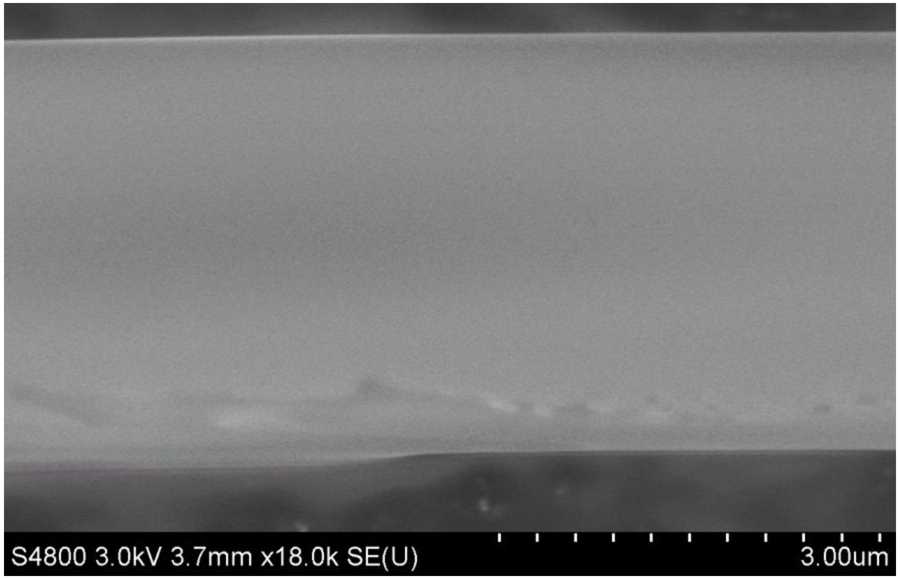
crystobalite? red fluorescence

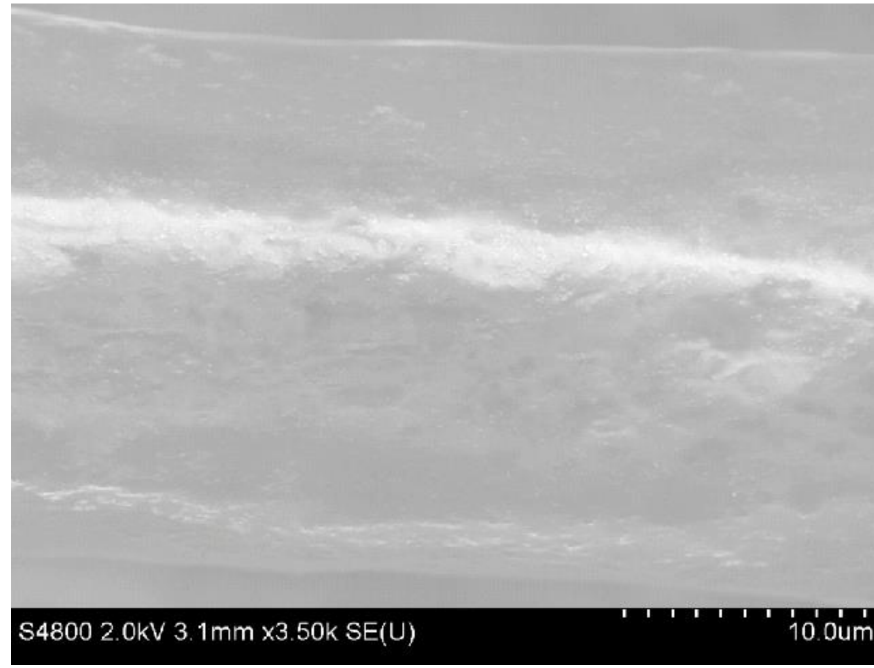


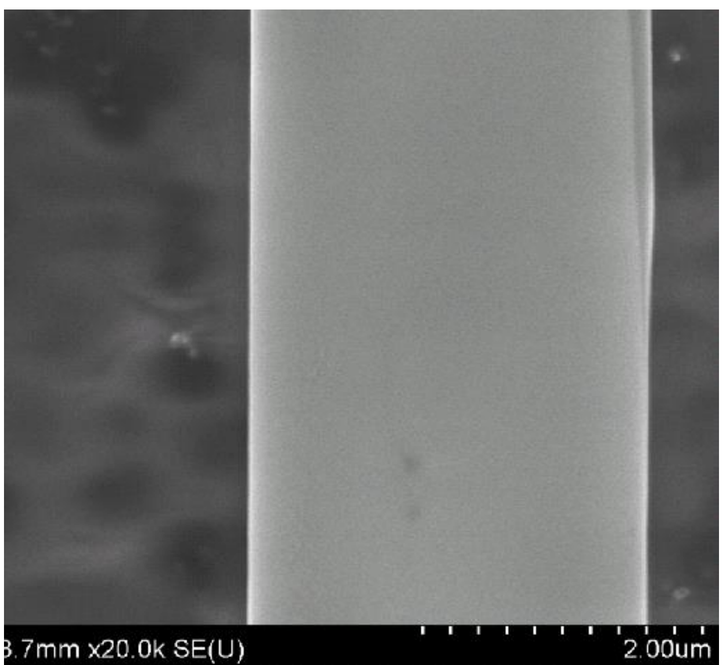
Microsphere degradation – bright spots appeared on the WGMR surface

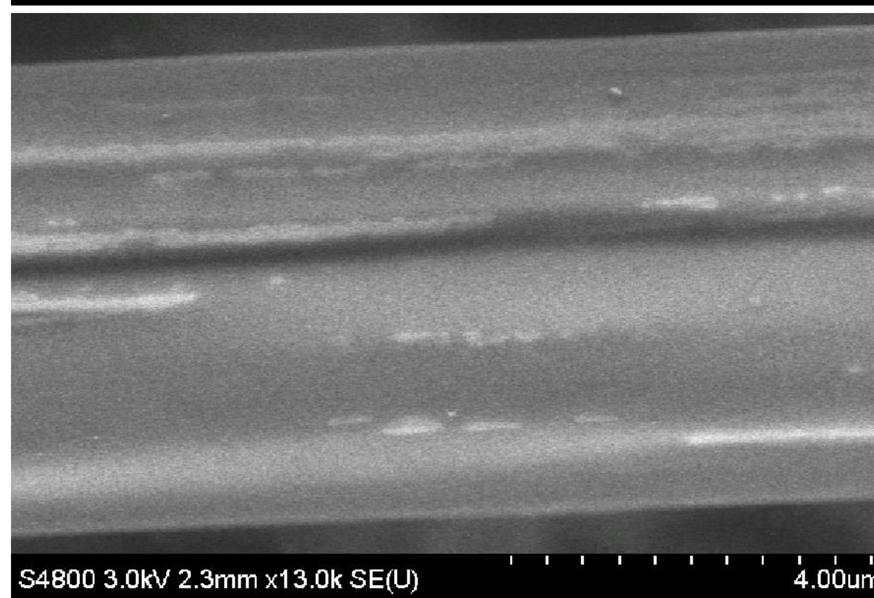


Tapered fiber after exposure to moisture fog in electron microscope estimated fiber edge straightness variations ca 100 nm

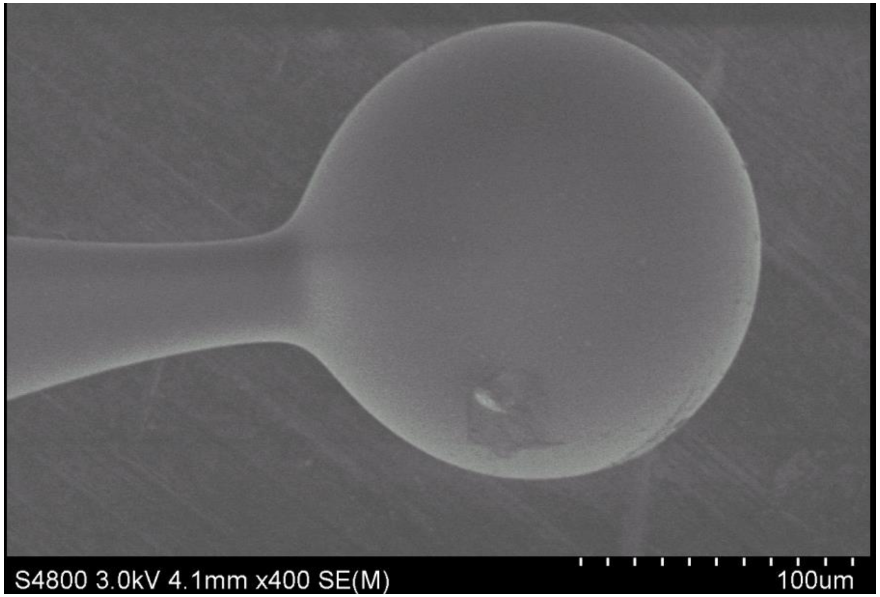


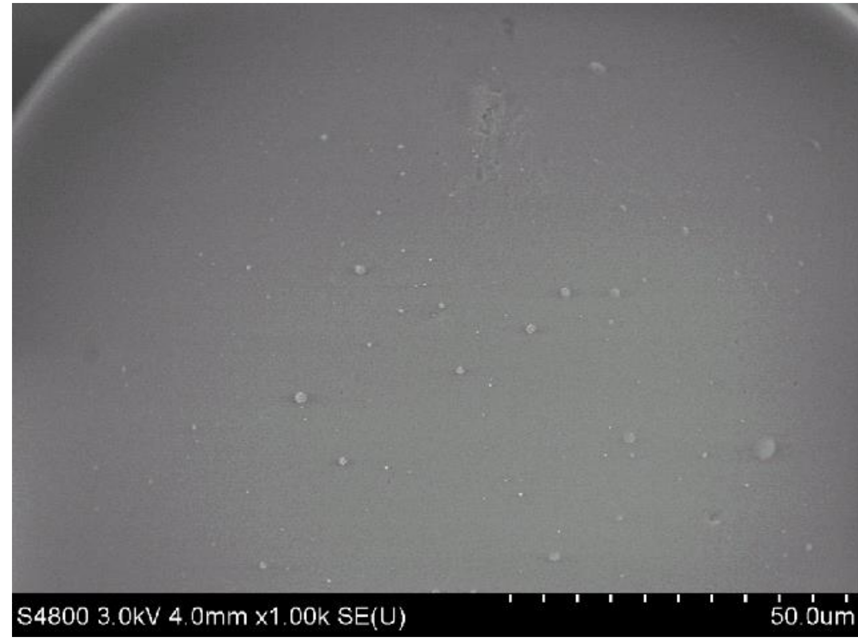


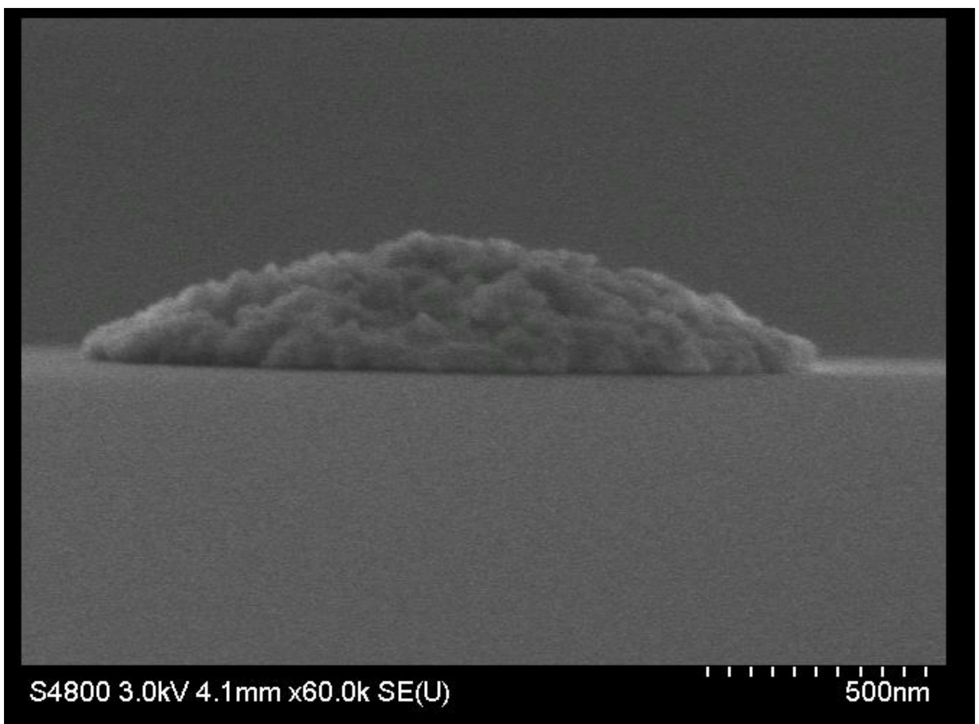


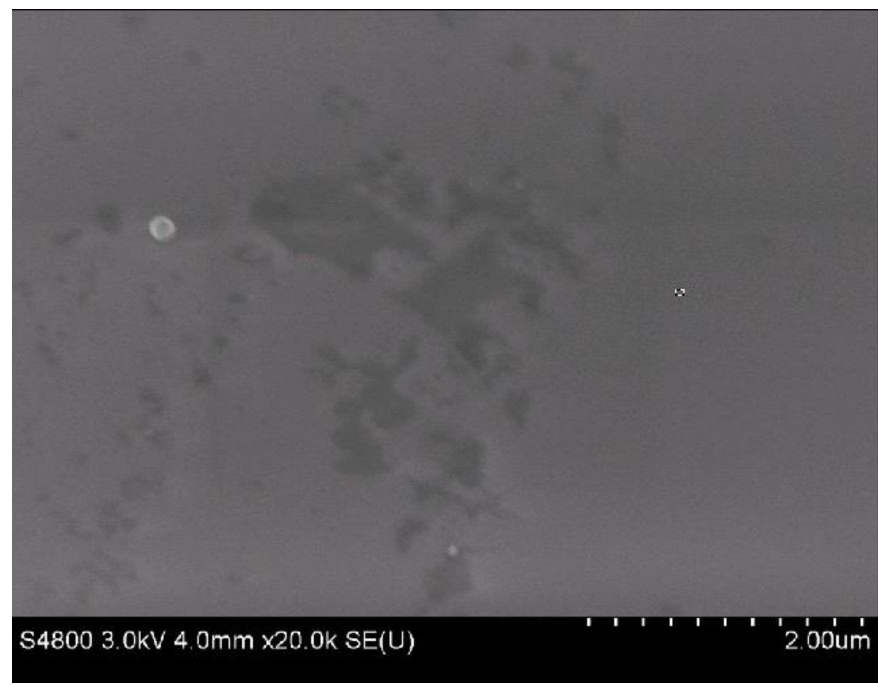


SEM of a resonator . It has been in humidity fog for 5 sec.









Discussion with Dr. Linards Skuja from CFI expert on glasses.

During silica melting and streching color centers can form. White dust is crystobalite. Red Fluorescence of quartz crystabloite can be excted by UV or green light.

2

Vahala makes SiO2 rings chips on Si pedestals and anneals in oven at 1000C for 10 hours. That helps to relieve stressed bonds. Stressed places are where bonds usually break and cause defects for example from water. Stikla fiktīvā temperatūra, zemāka labāk, ātrāk deformācijas izlīdzinās.
Once E. Nitiss asked L. Skuja to make SiO2 layer on Si by thermal oxidation (high temp + water vapour). The result was not good many nano crystal defects. This is basic step of chip making. Technology needs to keep good control on parameters to make really mirror-shiny and uniform surface. Actually radioelectronic quartz crystals are slowly grown from silica at high temperature, pressure and moisture for weeks.

Water makes silica brittle.
Livani company Z-Light first fibers had pure SiO2 core and no glass cladding, but protected with low refractive index silicone resin cladding. If this silicone rubber was damaged by scratching the fiber easily broke in that place.
Present fibers are immediately coated during manufacture with acrilate coating or polymide (capton). Capton is hard to remove and can be removed by chemical etching. Uncoated fibers easily break (that we know from telecom splicing. Splice place is protected by a thermal glue jacket after splicing.

<u>porous silica (for sensors and, probably, protection against degradation)</u>
TEOS. Dr. Skuja tried to coat diamonds in the Project. Need vacuum oven with nots o high vacuum and flow of O2 and TEOS vapour. (called LP CVD method).

Reccomended N_2 atmosphere flushing. Nitrogen CFI use from AGA.
Also organic vapours deposit on the silica surface within an hour (smells, aroma, oil).
Slight etching with 0.1% HF. Silica removal 0.05 nm/s. Used in high power laser mirror substrate finish to remove subsurface damage after polishing layer contaminated with Ce (Cerium) and Cu. Such lasers are used for nuclear sinthesis.
Plasma cleaning and excimer lamp cleaning at 157 nm effective. CFI has an excimer lamp in cleanroom. UV breaks organic bonds. Also UV removes hydrogen from –OH group and ohygen radical bonds are very strong that makes surface hydrophilic and good wetting (Good wetting is when surface energy is much larger than the liquid surface energy).
<u>Fluoride doped fibers:</u>
GeO2 causes some absorption . Nowadays best telecom fibeers with lowest absorption use with pure SiO2 core and clad doped with F that has lower refractive index. CFI has some 200 mkm diameter samples.

Core from pure SiO2, clad doped with F that has lower index than SiO2. Molecule can twist back-forth easier, restore back from defects. Stikla fiktīvā temperatūra, zemāka labāk, ātrāk deformācijas izlīdzinās.
Fluoride doped glass is used in excimer optics. In UV high power lasers oxygen comes out from glass, can be measured by mass spectrometer. Single Si-O3 molecule does not absorb, but many can form clasters that start absorbing. That we experienced at the MPQ 243 nm 300W UV enhancement cavity.

```
   O
O-Si-O
   F
```

During silica melting and streching color center can form 1.5 μ.

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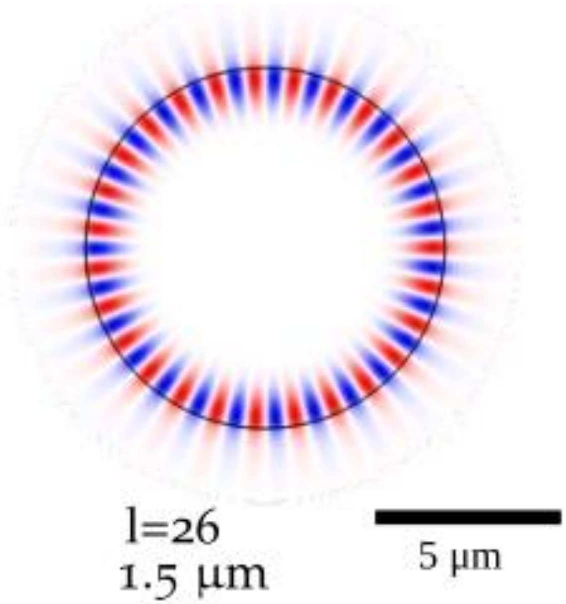
                I
Si-O°      ° - Si -
                I
```

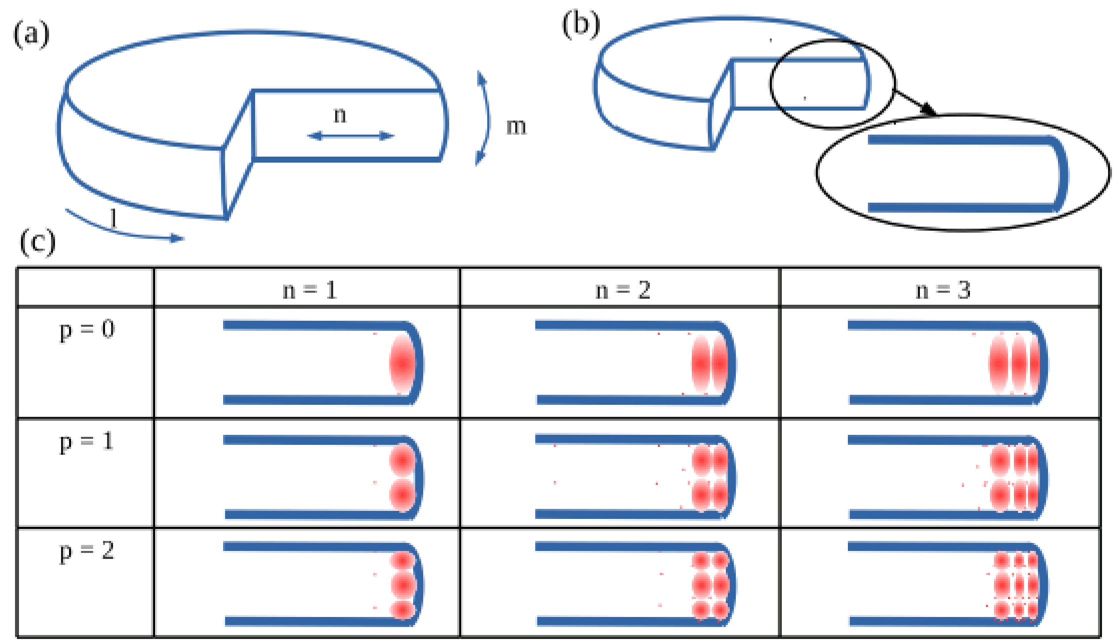
Cristobalite density=2.6 slightly different from glass. Probably will not see in SEM as surface changes. Cristobalite can be diagnosed by electron microscopy difraction setup as causing difraction rings.
Cristobalitye is the white "dust" during quartz glassblowing.
Can be removed by flame polishing.
Alcali metals are precursors of cristabalite formation. More severe for low OH silica (telecom fibers). That is why fibers for UV are having high OH content.

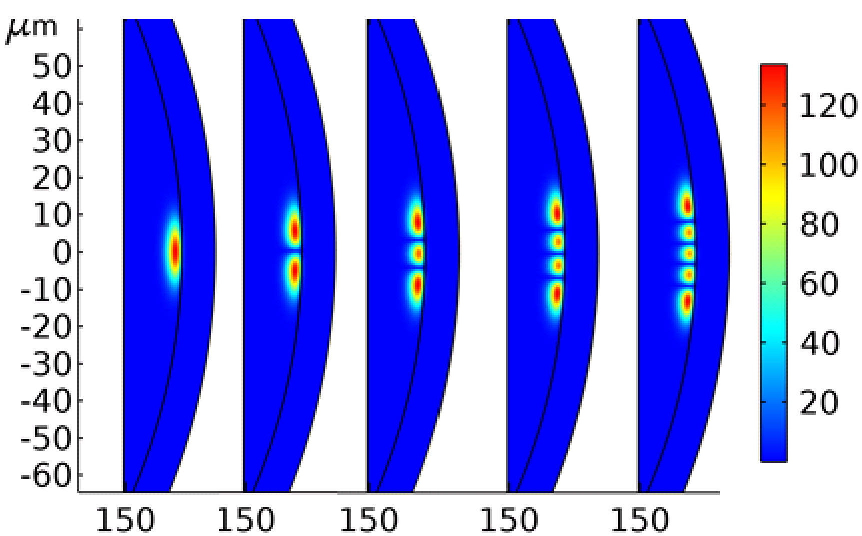
Cristabalite causes red luminiscencee when UV passes through silica. Can be good seen with a 266 nm laser. Green laser can be used too as green edge slightly excites crisatalobalite too. Also with red laser excitation can check if spectrum is shifted and sometimes can see bokes stokes and anti-stokes. -OH radicals do not luminess just scatter.
Taper fiber defektu spīdēšanas spektru paskatīt ar Horiba spektrometru vai spīd jauni ʎ.
SiO2 nanowires (nanodiegi) were popular 10 years ago. Probably studied there.

Aktivitāte 1.4. ČGM rezonatoru efektu un WCOMB sistēmas matemātiskā modelēšana

Wave optics, COMSOL modelling

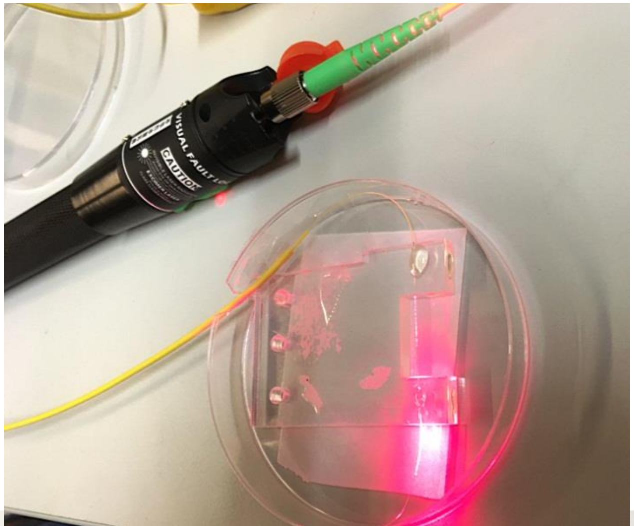


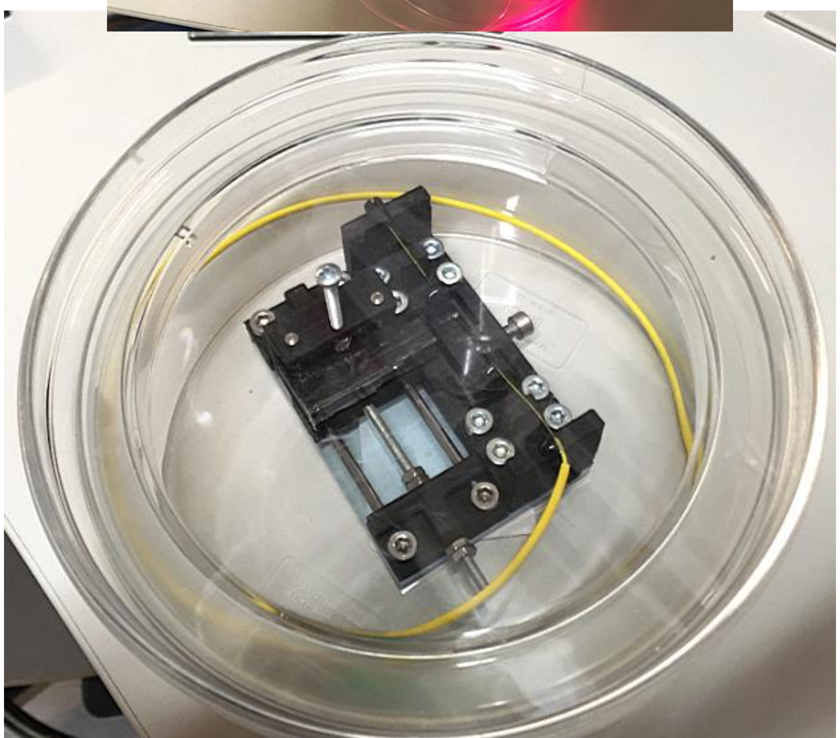


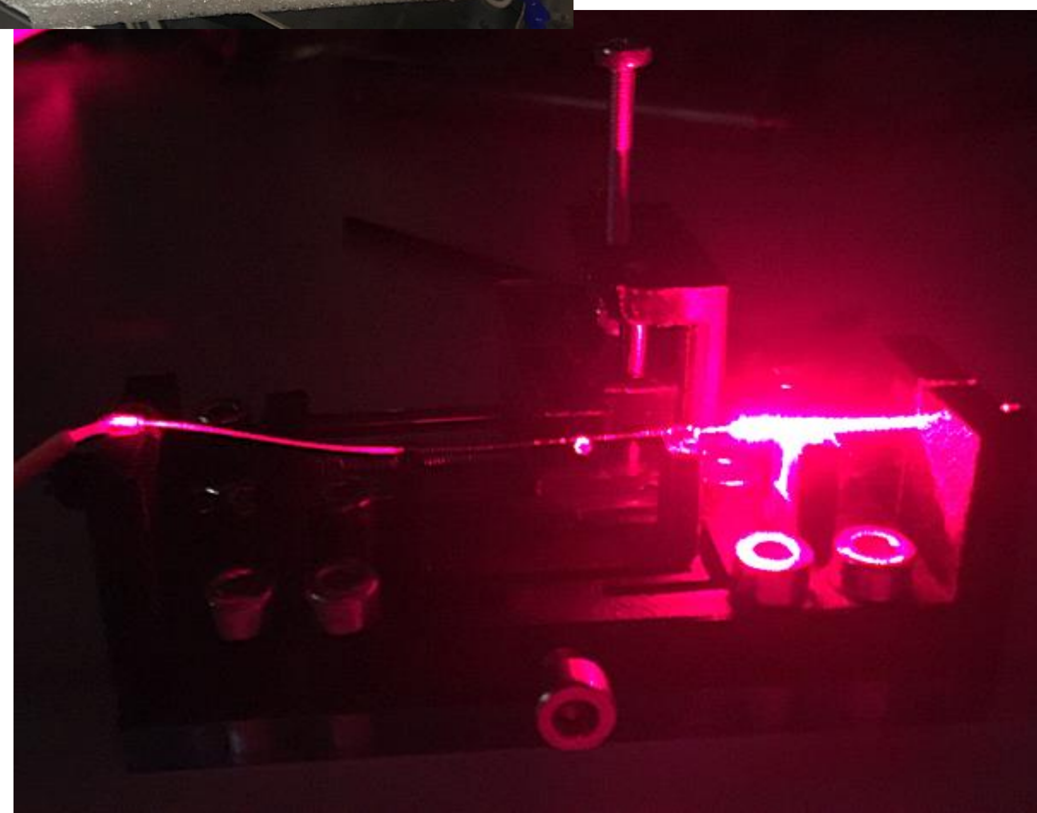


Understanding different WGMs: (a) radial mode number n, azimuthal mode number l and polar mode number m dirctions; (b) the region for plane sliced from a microsphere WGM resonator and (c) the intensity distributions for various modes in the slice.

Aktivitāte 4.2. Tēma patentam. Iekapsulēts ķemmes modulis. Rezonatora - taper fiber modulis ar 3D printētu mikro pozicionēšanu







Aktivitāte 4.4. Projekta rezultātu izplatīšana konferencēs

Dalība ar 2 ziņojumiem konferencē NWP-2021
Niznij Novgorod, online caur Zoom

International Symposium
TOPICAL PROBLEMS OF NONLINEAR WAVE PHYSICS (NWP-2021)
Nizhny Novgorod, Russia 19–22 September, 2021

11.20–13.20 **Workshop “Nonlinear and quantum optics in confined systems” 2**

11.20–11.50 *E. Anashkina (Russia)*. Theoretical and experimental study of rare-earth ion-doped tellurite glass microlasers (invited)

11.50–12.20 *P. Del'Haye (Germany)*. Bound states of dark and bright soliton pairs in microresonators (invited)

12.20–12.50 *J. Alnis (Latvia)*. Kerr comb generation in silica WGM micro-resonators and application to telecommunications (invited)

12.50–13.05 *M. Marisova (Russia)*. Dispersion engineering and four-wave mixing in silica microresonators covered by a germanosilicate microlayer

13.05–13.20 *A. Sorokin (Russia)*. The analysis of quantum noise squeezing for soliton pulses in optical fibers

13.30–12.30 *Lunch*

18.05–18.20 *T. Salgals (Latvia)*. Microsphere-based OFC-WGMR multi-wavelength source and its applications in telecommunications

Projektā iesaistīto darbinieku vēlēšanas amatos LU

Atomfizikas un spektroskopijas institūts, zinātniskie amati:

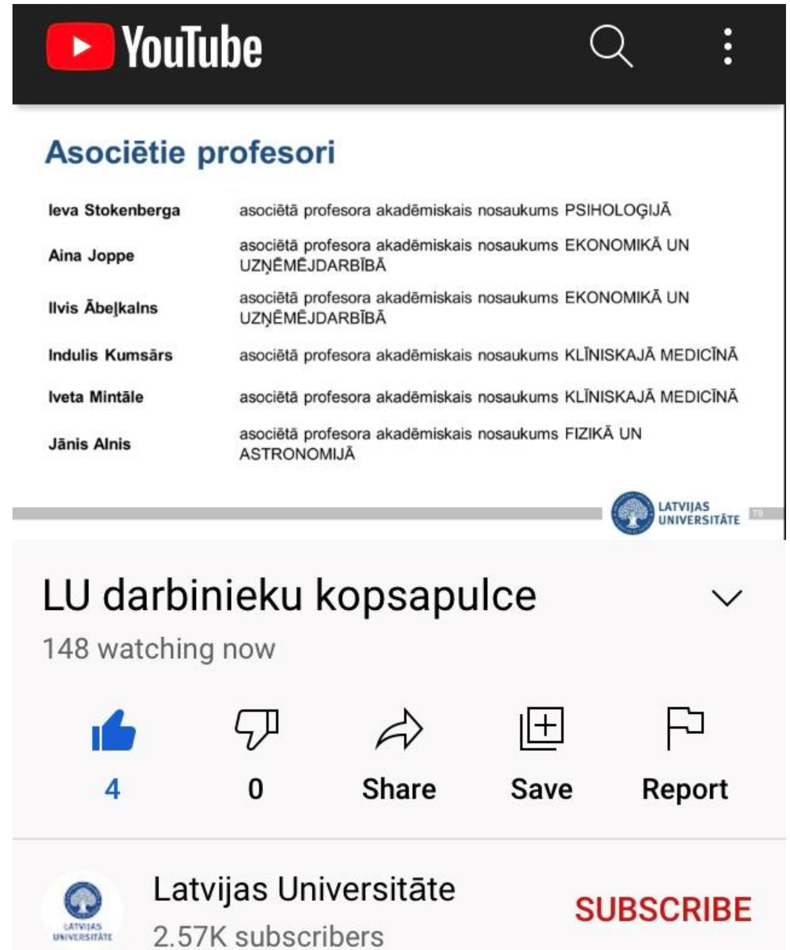
Jānis Alnis - vadošais pētnieks (novembris)

Inga Brice – pētniece (aprīlis)

Kristiāns Dragūns - zinātniskais asistents (aprīlis)

Fizikas, matemātikas un optometrijas fakultāte, akadēmiskais nosaukums:

Jānis Alnis - asociētais profesors (jūnijs)



2021.06. Sagatavots un iesniegts promocijas darbs
Aizsākts 2013. g.

Aizstāvēšana notiks 2021. g. 17. decembrī.

INGA BRICE

WHISPERING GALLERY MODE SILICA MICROSPHERE RESONATOR APPLICATIONS FOR BIOSENSING AND OPTICAL FREQUENCY COMBS

INGA BRICE

ČUKSTOŠĀS GALERIJAS MODAS SILĪCIJA DIOKSĪDA MIKROSFĒRAS REZONATORU PIELIETOJUMI BIOSENSOROS UN OPTISKO FREKVENČU ĶEMMĒM

PROMOCIJAS DARBA KOPSAVILKUMS

Doktora grāda iegūšanai fizikā

Apakšnozare: Lāzeru fizika un spektroskopija

Rīga, 2021

The research results of the dissertation have been used for the implementation of scientific research projects:

- ERDF No. 1.1.1.1/16/A/259
- ERDF No. 1.1.1.1/18/A/155
- LZP No. Lzp-2018/1-0510

2021.06. Kristians Draguns aizstāvēja maģistra darbu, iestājās doktorantūrā

LATVIJAS UNIVERSITĀTE

FIZIKAS, MATEMĀTIKAS UN OPTOMETRIJAS FAKULTĀTE

FIZIKAS NODAĻA

DISPERSIJAS INŽENIERIJA ČUKSTOŠĀS GALERIJAS MODU MIKROREZONATORIEM

MAĢISTRA DARBS

Autors: **Kristians Draguns**

Darba vadītājs: Dr. Phys. Aigars Atvars

RĪGA 2021

Šī darba tapšanā nozīmīgs bija finansējums no projektiem lzp-2018/1-0510 “Optiski čukstošās galerijas modu mikrorezonatoru sensori” un ERAF Nr. 1.1.1.1/18/A/155 “Uz čukstošās galerijas modas mikrorezonatora bāzes veidota optisko frekvenču ķemmes ģeneratora izstrāde un tā pielietojumi telekomunikācijās”.

2021.06. Arvīds Sedulis aizstāvēja bakalaura darbu, iestājās maģistratūrā

LATVIJAS UNIVERSITĀTE
FIZIKAS, MATEMĀTIKAS UN OPTOMETRIJAS FAKULTĀTE
FIZIKAS NODAĻA

ČGM REZONATORU IZSTRĀDE UN PIELIETOŠANA OPTISKO FREKVENČU ĶEMMES ĢENERĒŠANAI

BAKALAURA DARBS

Autors: **Arvīds Sedulis**

Darba vadītājs: *Dr. Phys.* Jānis Alnis

Darbs izstrādāts LU Atomfizikas un spektroskopijas institūtā

RĪGA 2021

Pateicība ERAF projektam Nr. 1.1.1.1/18/A/155 "*Uz čukstošās galerijas modas mikrorezonatora bāzes veidota optisko frekvenču ķemmes ģeneratora izstrāde un tā pielietojumi telekomunikācijās*" par finansējumu.

A. Sedulis pieteicās konferencei, pēc kuras plānots raksts SPIE proceedings

SPIE. PHOTONICS EUROPE

3 - 7 April 2022
Strasbourg, France

Investigation of Silica-WGMRs based OFC for telecommunication applications

Different kinds of whispering gallery mode (WGM) micro-resonators for optical frequency combs (OFCs) provide an attractive solution for various applications, especially for telecommunications. For the realization of data transmission in wavelength - division-multiplexed (WDM) fiber optical networks, potentially cost effective solutions are OFC generation in silica whispering gallery mode resonators. These include microspheres manufactured from Corning SMF-28e telecom fiber and resonators manufactured on the silica micro-rod. We propose a silica microsphere-based OFC generator with a free spectral range (FSR) of 200 GHz and 400 GHz and silica micro-rod based OFC with an FSR of 100 GHz as laser source for the WDM data transmission systems. We experimentally demonstrate WGM micro-resonator based OFCs which are driven by a single continuous wavelength laser source. Experimentally three various soliton-like WGM resonator OFC output spectrum scenarios were observed: Stimulated Brillouin scattering (SBS), Four-Wave-Mixing (FWM) and Stimulated Raman Scattering (SRS). For our experiments we used silica microsphere resonators with sizes of 170 µm and 320 µm, as well as silica microrods with a diameter of 660 µm . These correspond to 400, 200 and 100 GHz inter-channel space and meet ITU-T G694.1. spectral grid requirements. Our group observed generation of FWM and SRS in all resonator parameter types. We did not however observe the SBS effect in 400 GHz FSR samples.

Vidusposma ziņojums

- Pozitīvi izvērtēts.
- Recenzenti saka, ka ķemmes setups vēl ir tālu no kompakta un portabla prototipa.
- Nepieciešams veikt patentu literatūras izpēti par mūsu tēmu.