ASI

LATVIJAS UNIVERSITĀTE
ANNO 1919

NATIONAL DEVELOPMENT PLAN 2020

EUROPEAN UNION
European Regional Development Fund

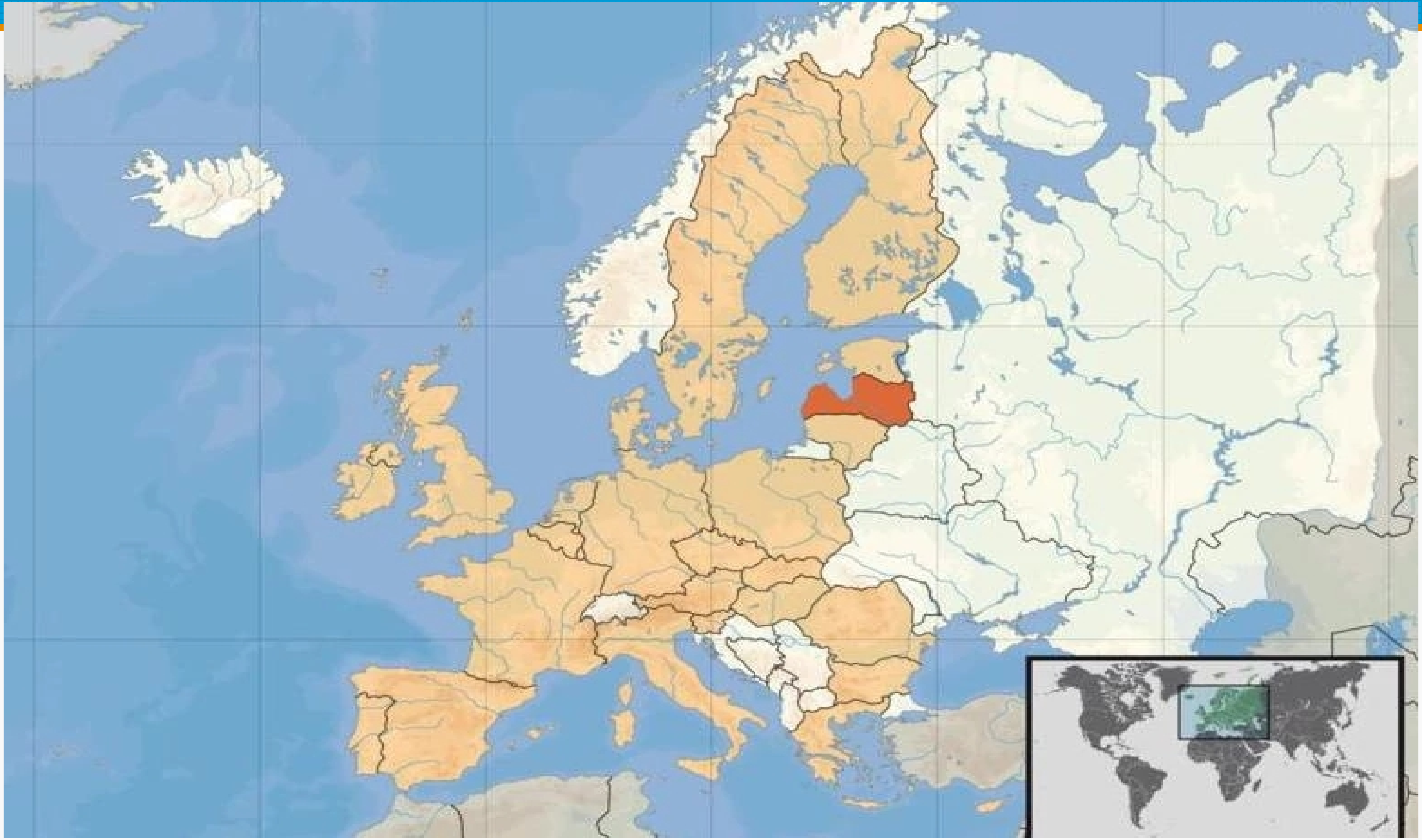
INVESTING IN YOUR FUTURE

University of Latvia

Laboratory of Quantum optics

April 2018

Latvia



Latvia

Total population:
~ 1.9 million

Researchers
~ 8000 part time
~ 5000 full time equivalent

Main research institutions/
Universities:
University of Latvia (Riga)
Riga Technical University
Riga Stradins University
Daugavpils University

University of Latvia

Number of Students ~ 13 000
Academic Personnel ~ 1100

Physics:

- Faculty of Physics and Mathematics (~30 researchers)
- **Institute of Atomic Physics and Spectroscopy (~ 40)**
- Institute of Solid State Physics (~100)
- Institute of Chemical Physics (~ 30)
- Insitute of Physics (~ 20)

Institute of Atomic Physics and Spectroscopy of University of Latvia

Academic Staff ~ 40

www.asi.lv

Laboratories

1. Laboratory of theoretical physics - Dr. R. Veilande (~ 3 researchers)
2. Biophotonics laboratory - Prof. J. Spigulis (~ 15)
3. Laboratory of high-resolution spectroscopy and light source technology - Dr. A. Skudra (~5)
4. Laboratory of atomic and atmospheric physics and photochemistry - Dr. A. Ubelis (~ 10)
5. **Quantum Optics Laboratory** - Dr. J. Alnis (~5)

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 period:** 01.03.2017. - 30.08.2019.

Our team

Project team group photo (April 2017).

leading researchers

- J. Alnis
- A. Atvars
- R. Viter

scientific assistant

- I. Brice

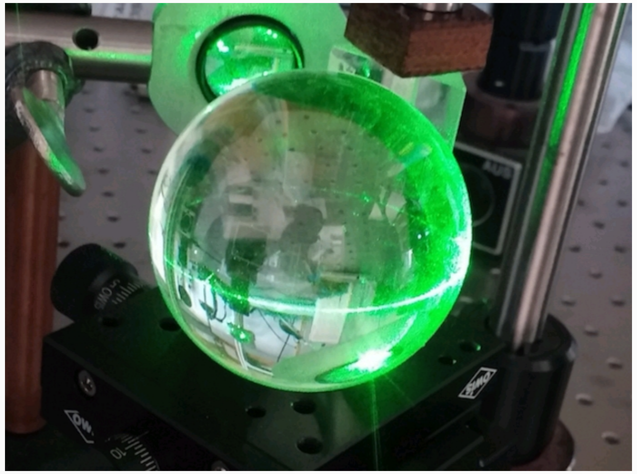
laboratory assistants

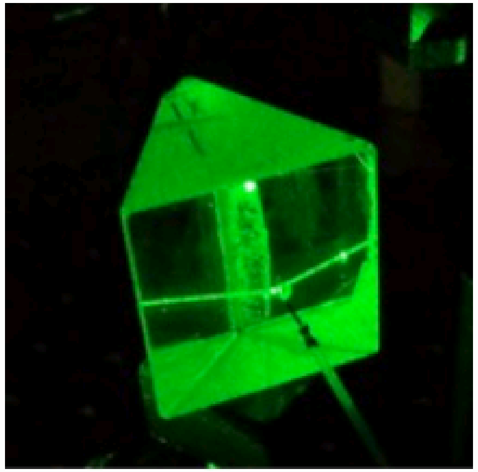
- K. Grundšteins
- A. Pirktiņa
- A. A. Ūbele substituted by H. Baumanis

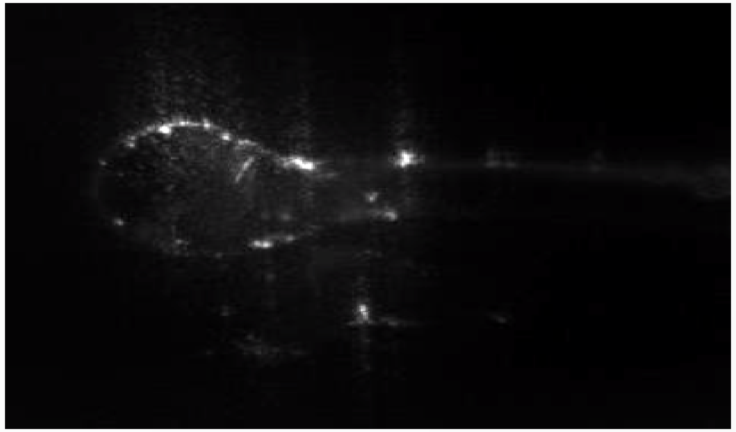
Project homepage

https://www.lu.lv/cgm/eng/

We started big







- First, experiments with a huge sphere and visible laser

  (d ~ 6cm)

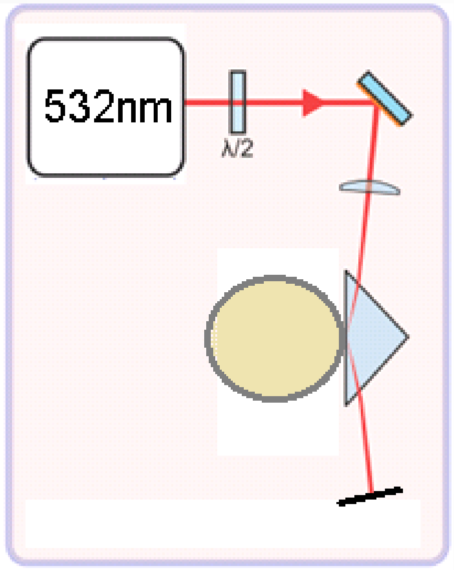
- Second, experiments with a small sphere and visible laser

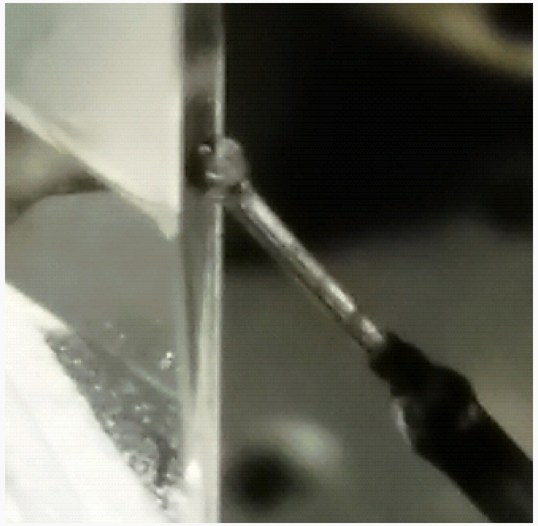
  (d ~ 1 mm)

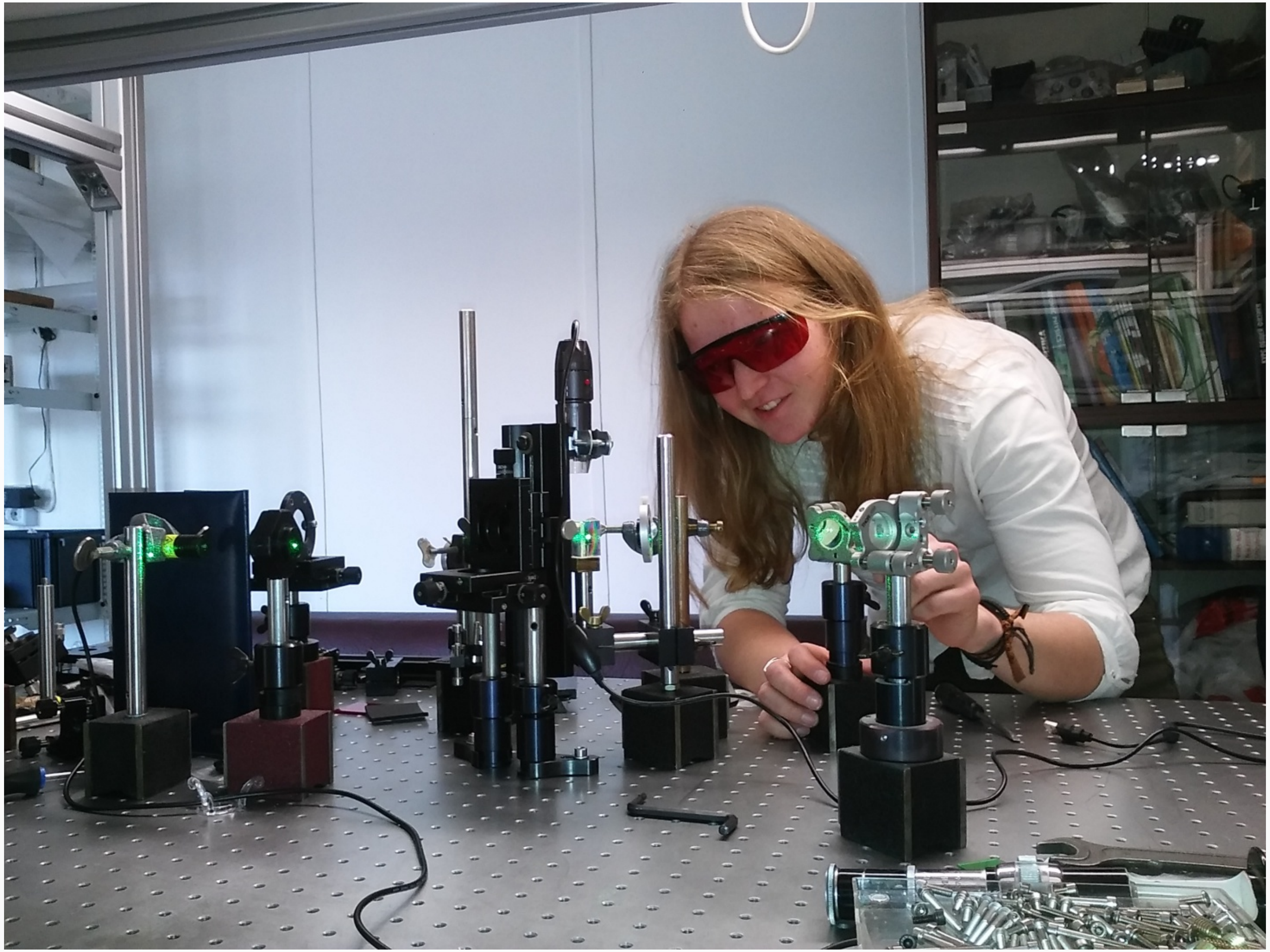
- Third, experiments with a small micro-sphere and infrared light

  (d ~ 0,5 mm)

Set-up for exciting WGMs

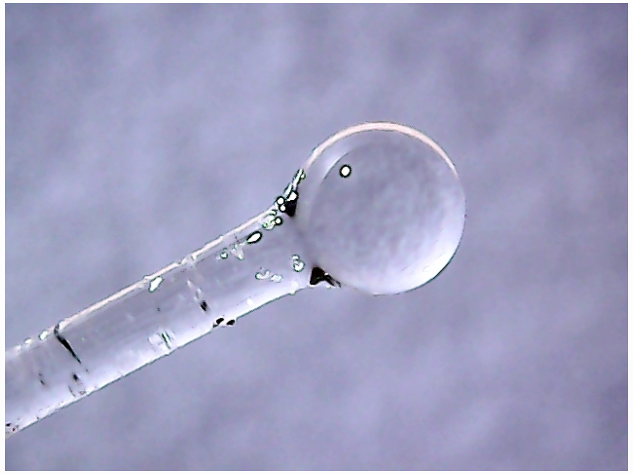




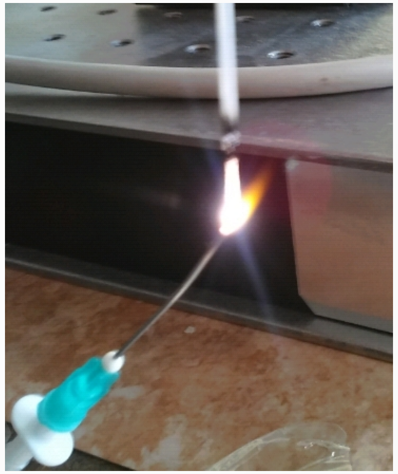


H_2 flame

Resonator melted using propane-oxygen flame

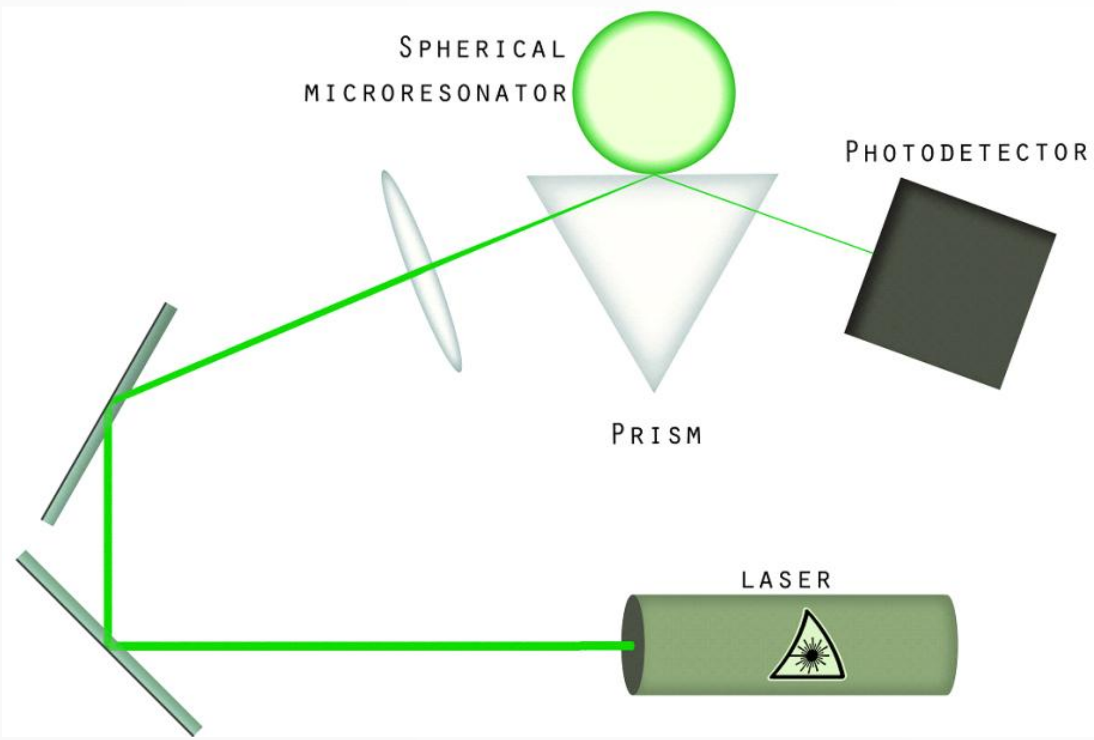


Resonator melted using hydrogen-oxygen flame

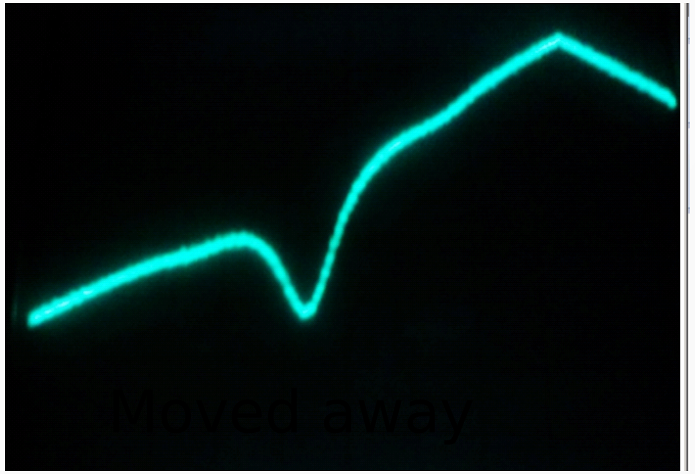


Manufacturing a resonator at the tip of a fiber (multi-mode fiber)

Resonator testing

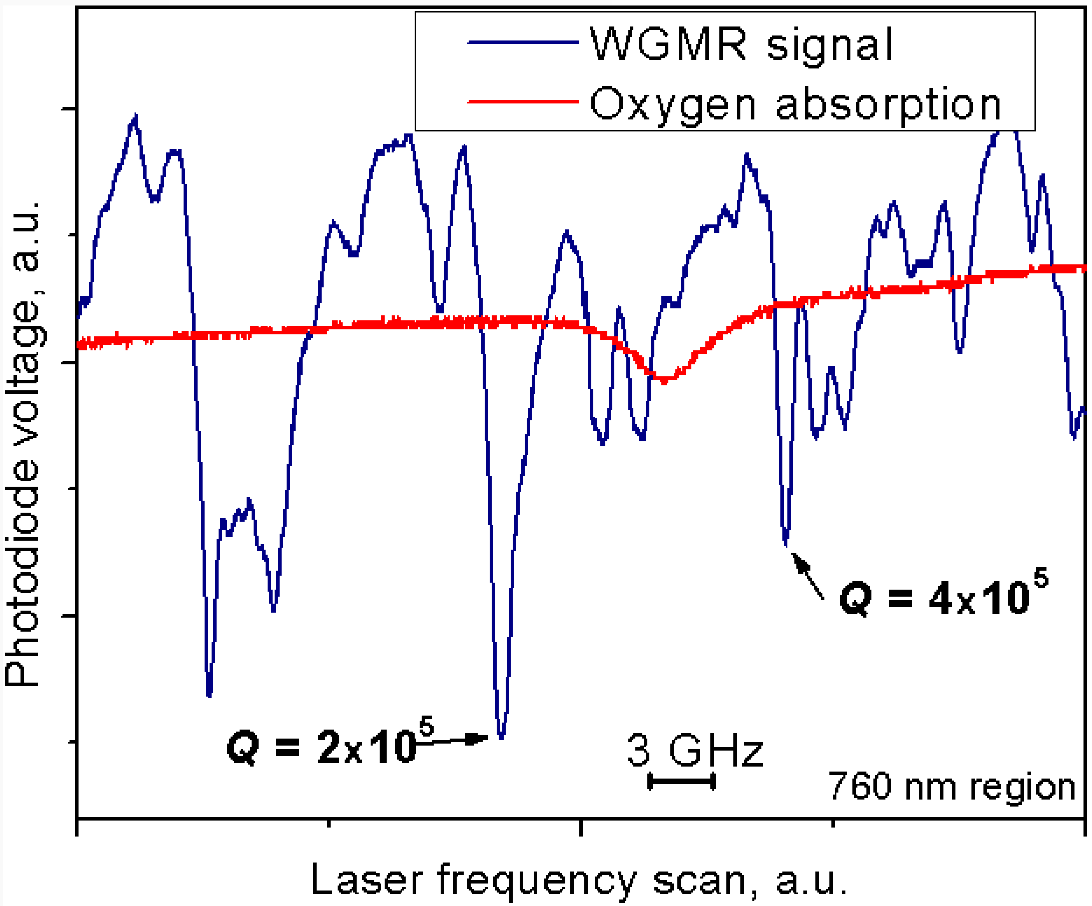


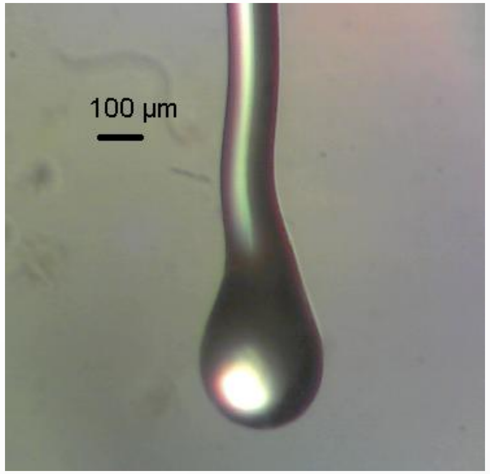
When measured with a scan-wavelength VCSEL laser in an area of 760 nm, the visible photo-diode signal changes when the resonator is pressed into the prism and moved further away.



O_2 absorption line

Calculating the Q factor
First results

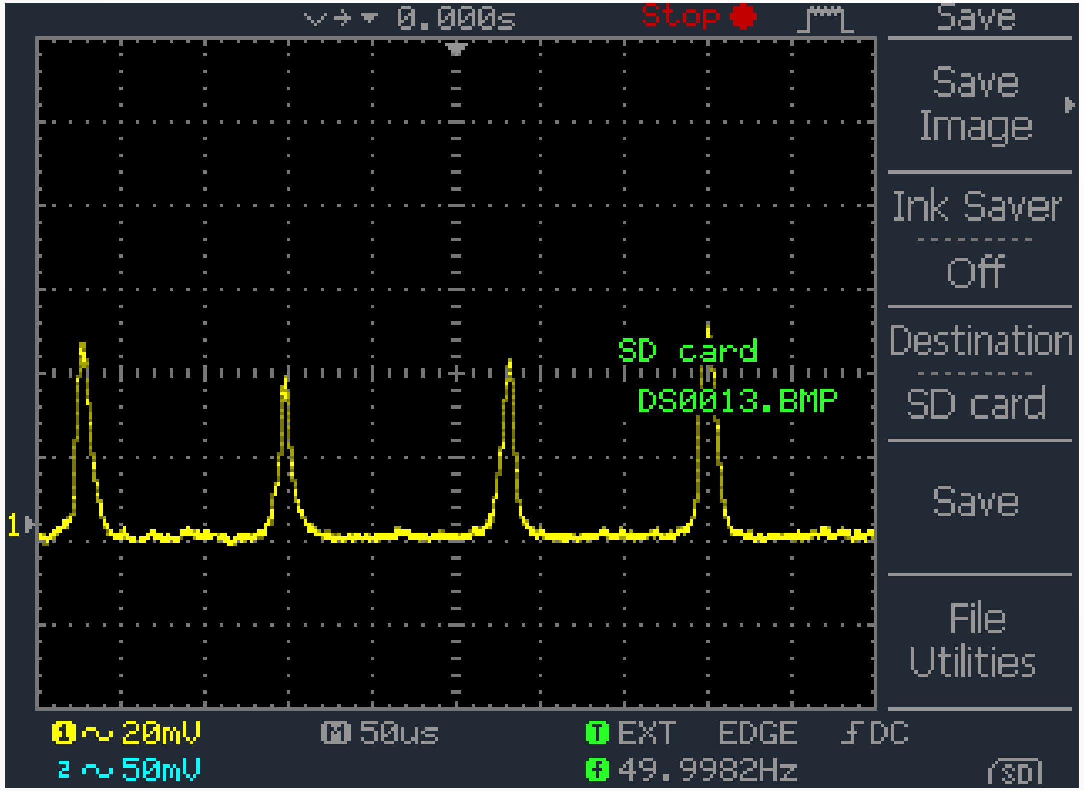


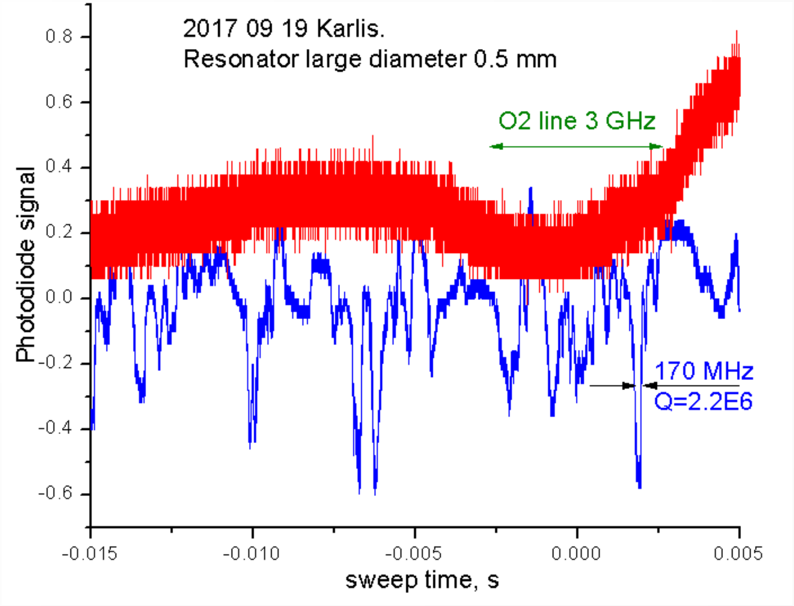


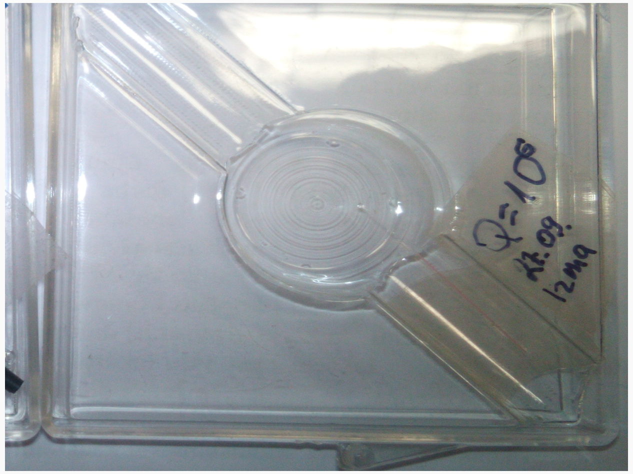
First measured Q factor 10^5

Calculating the Q factor Limit of VCSEL laser

Between the interferometer peaks at 1 GHz.
Peak width = Laser line width 40 ... 70 MHz.
The laser limits the measurement of WGM Q to
2 ... 4 × 10^6.

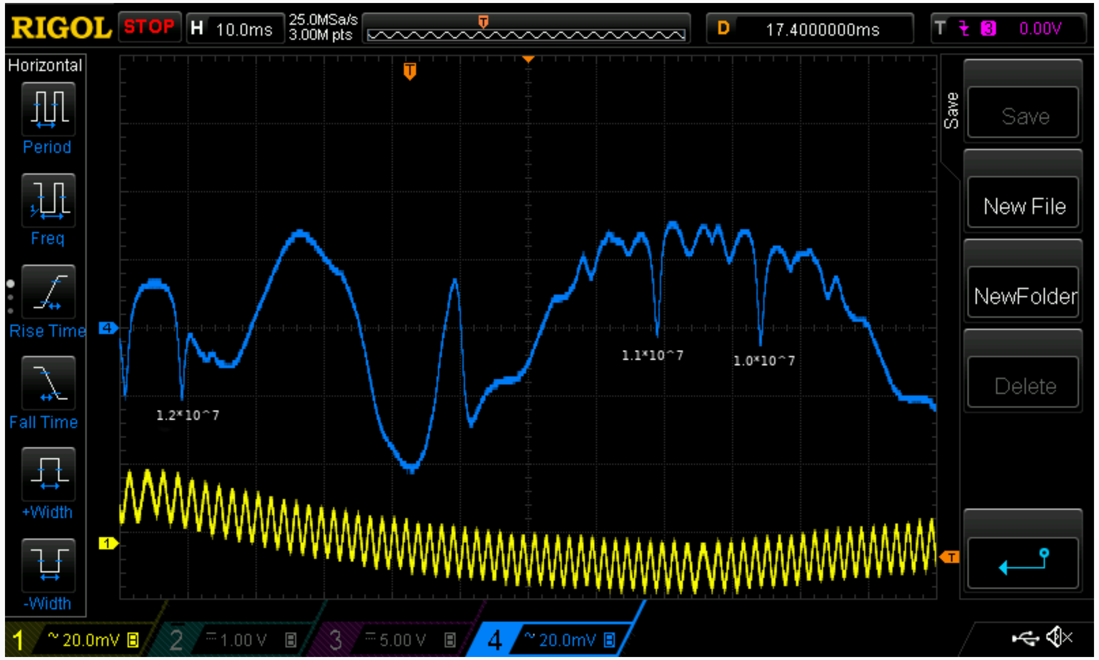


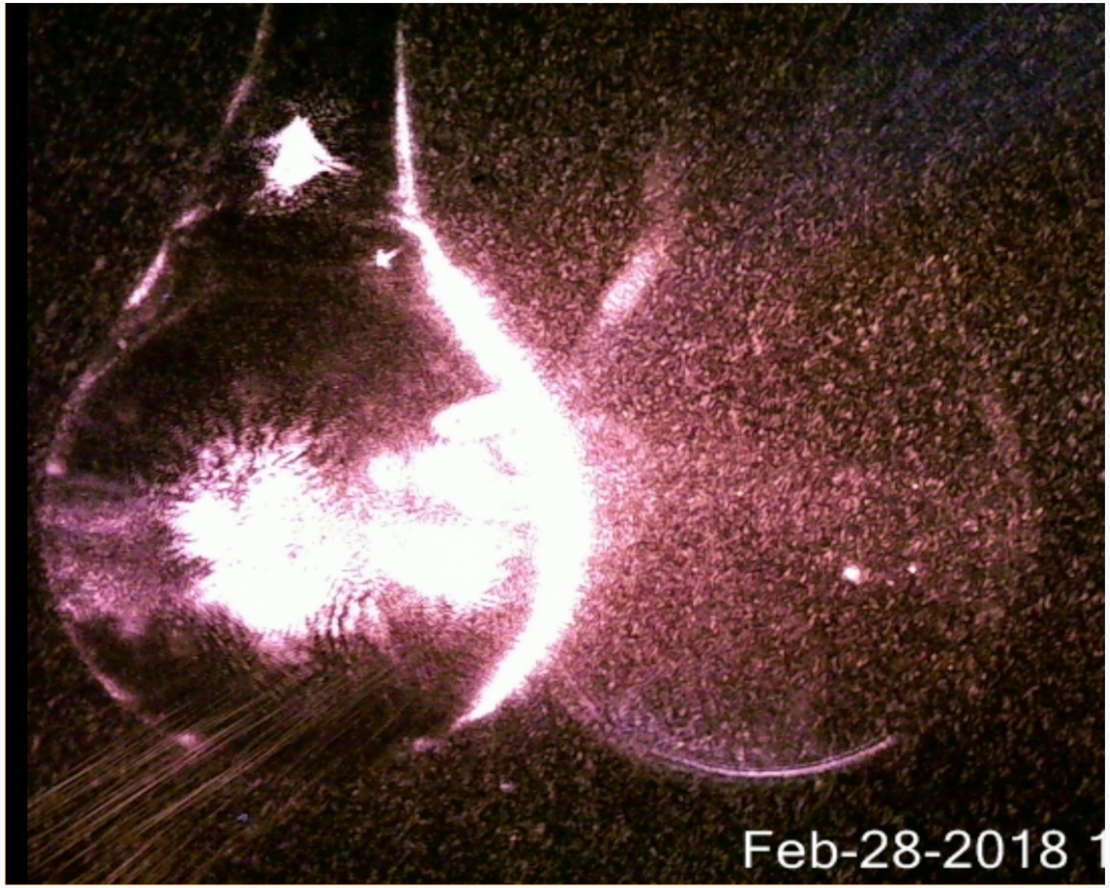




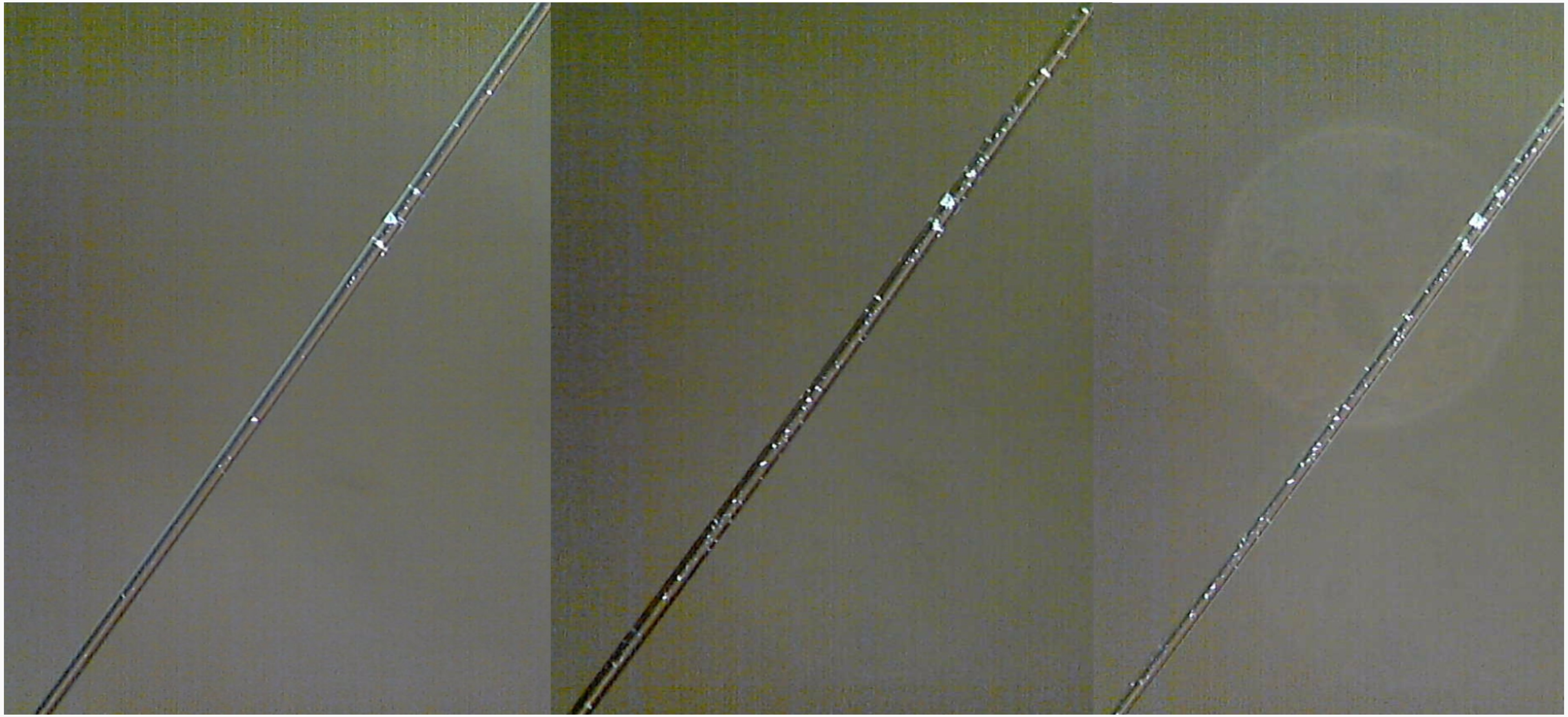
Calculating the Q factor ECDL laser

780nm ECDL laser. For this laser, the spectral line <1MHz, which is much narrower than the VCSEL laser, allows the measurement of higher Q-factors of WGMR.





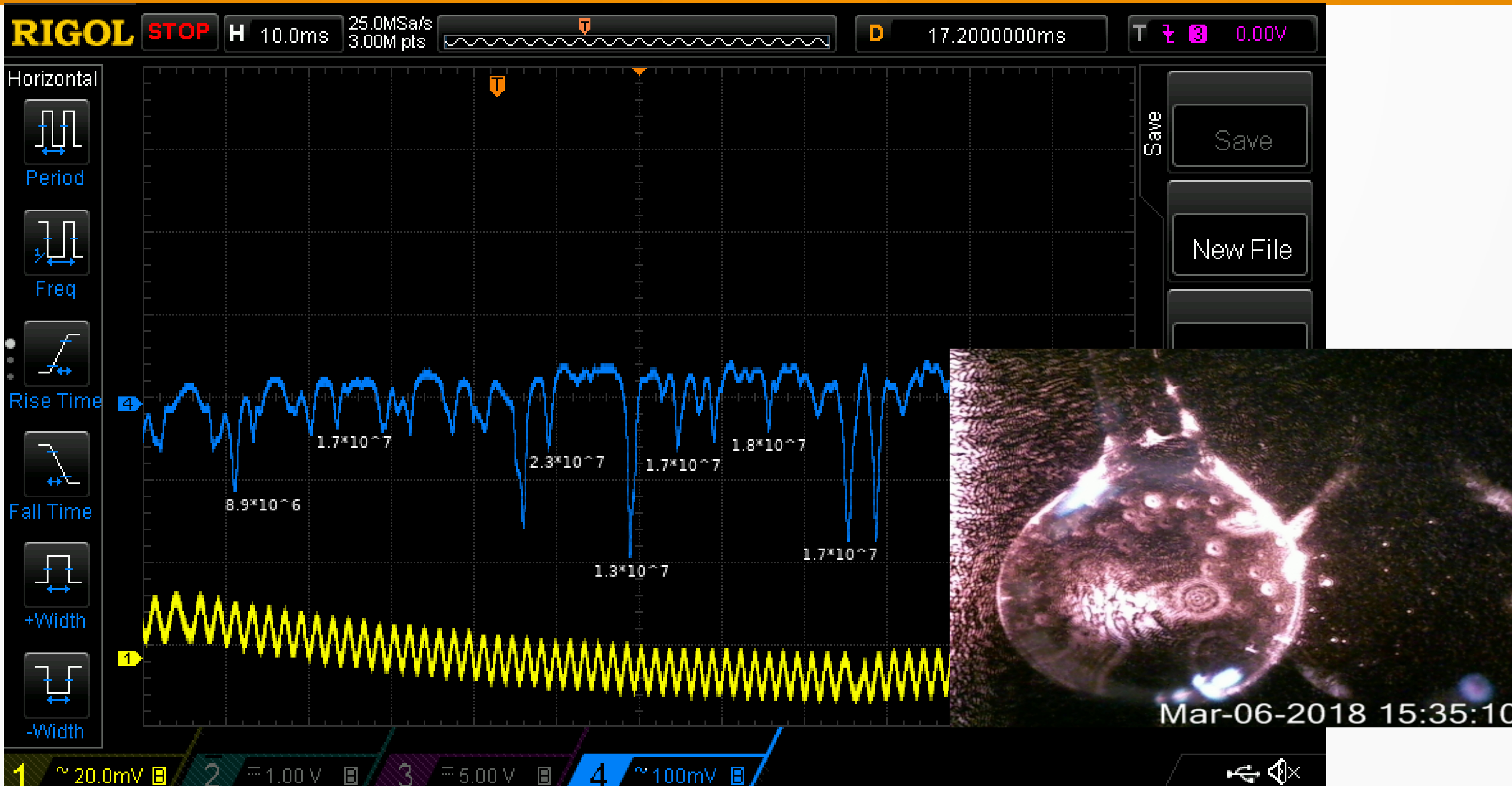
Fighting with dust



4 h later

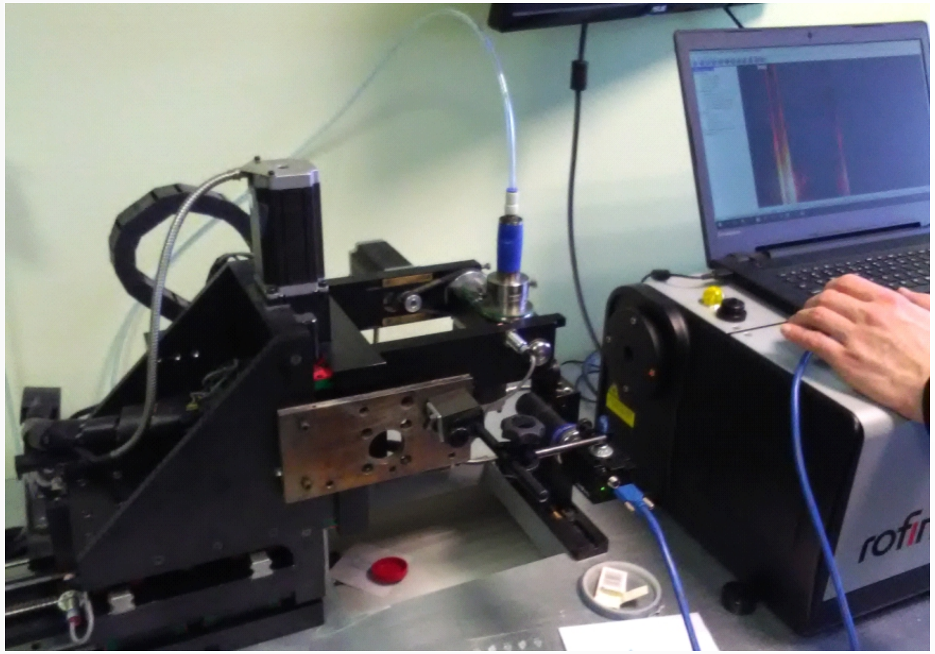
16 h later

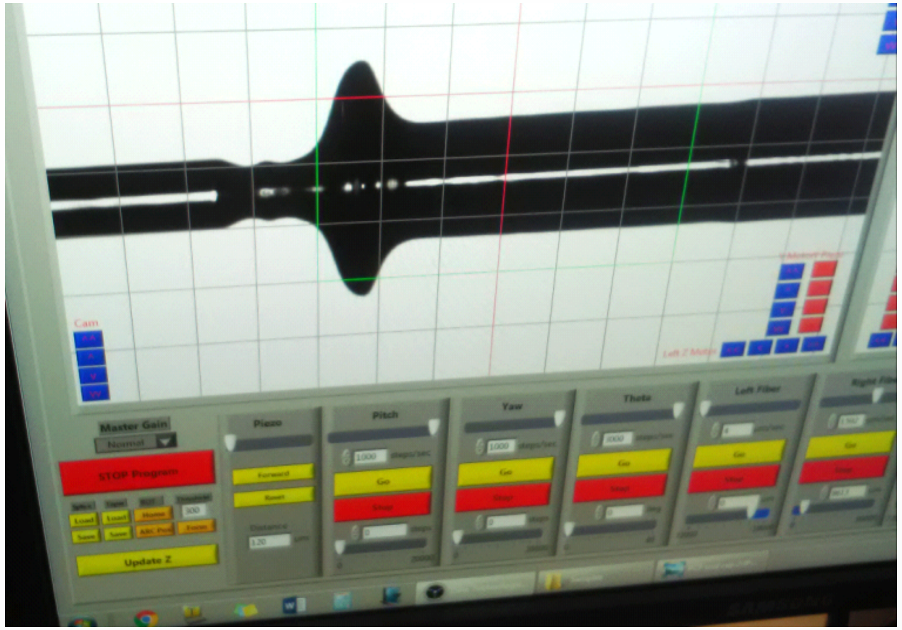
Achieving better Q factors



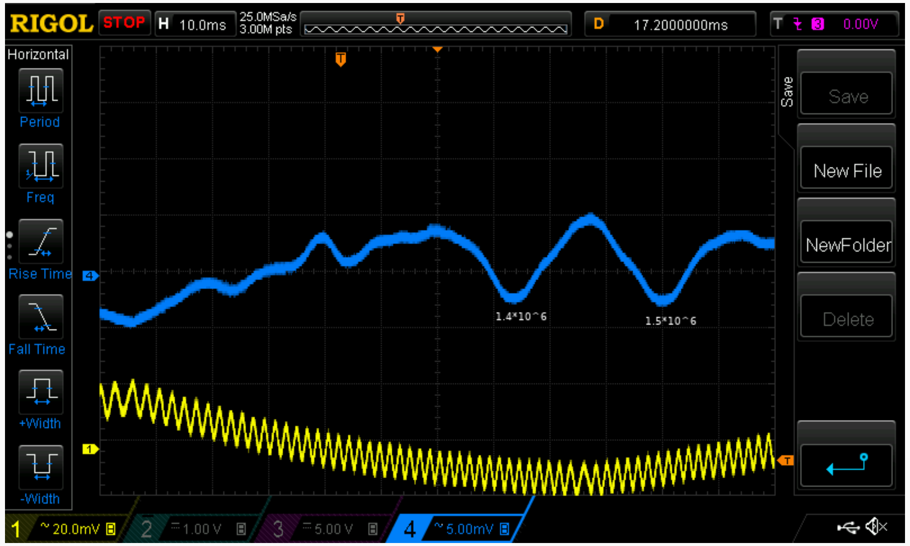
Achieving better Q factors

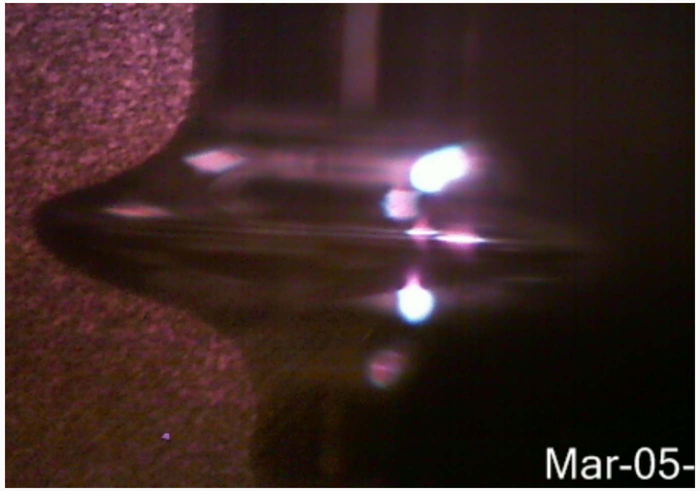
Resonators made in Līvani by "Lightguide Photonics"

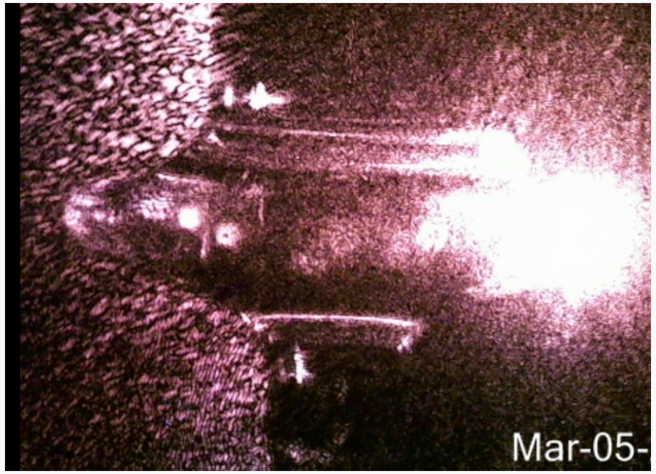




WGM disk resonator made from a 1mm diameter quartz rod, with CO_2 laser



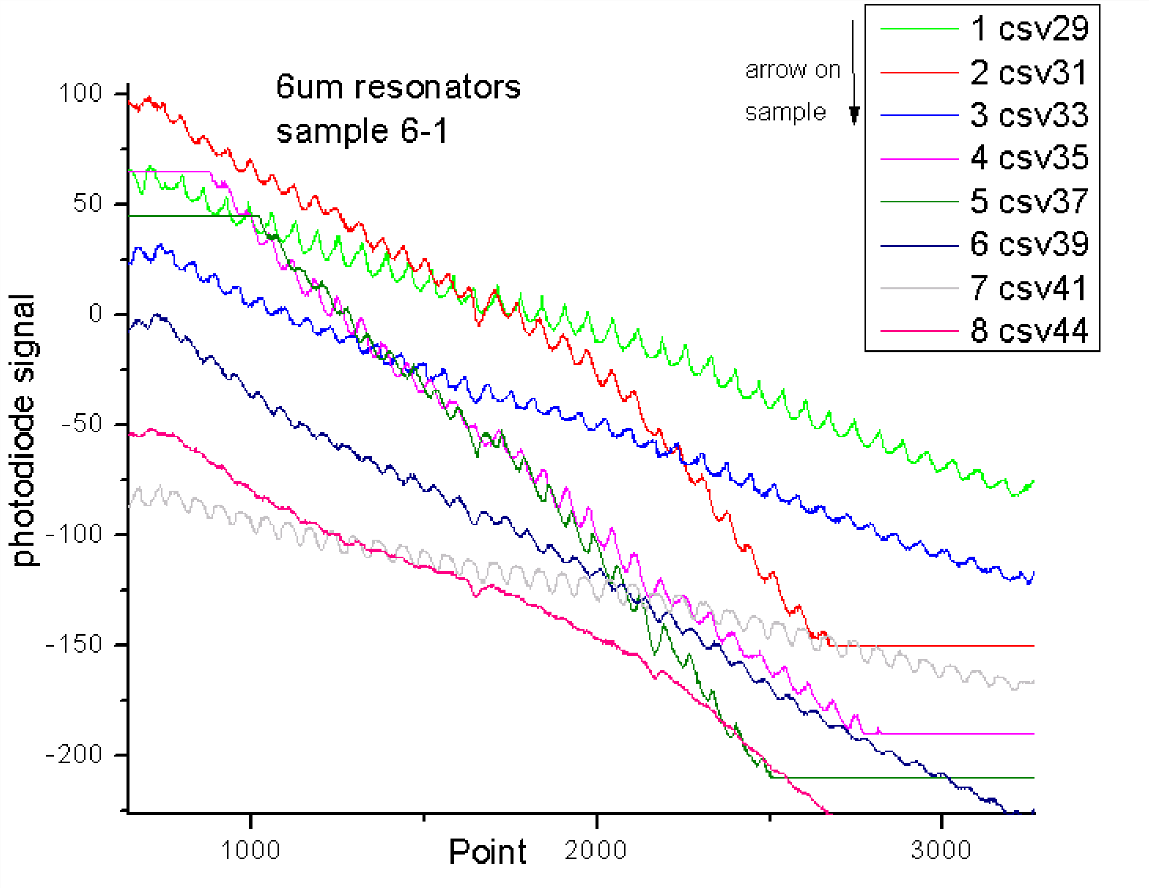




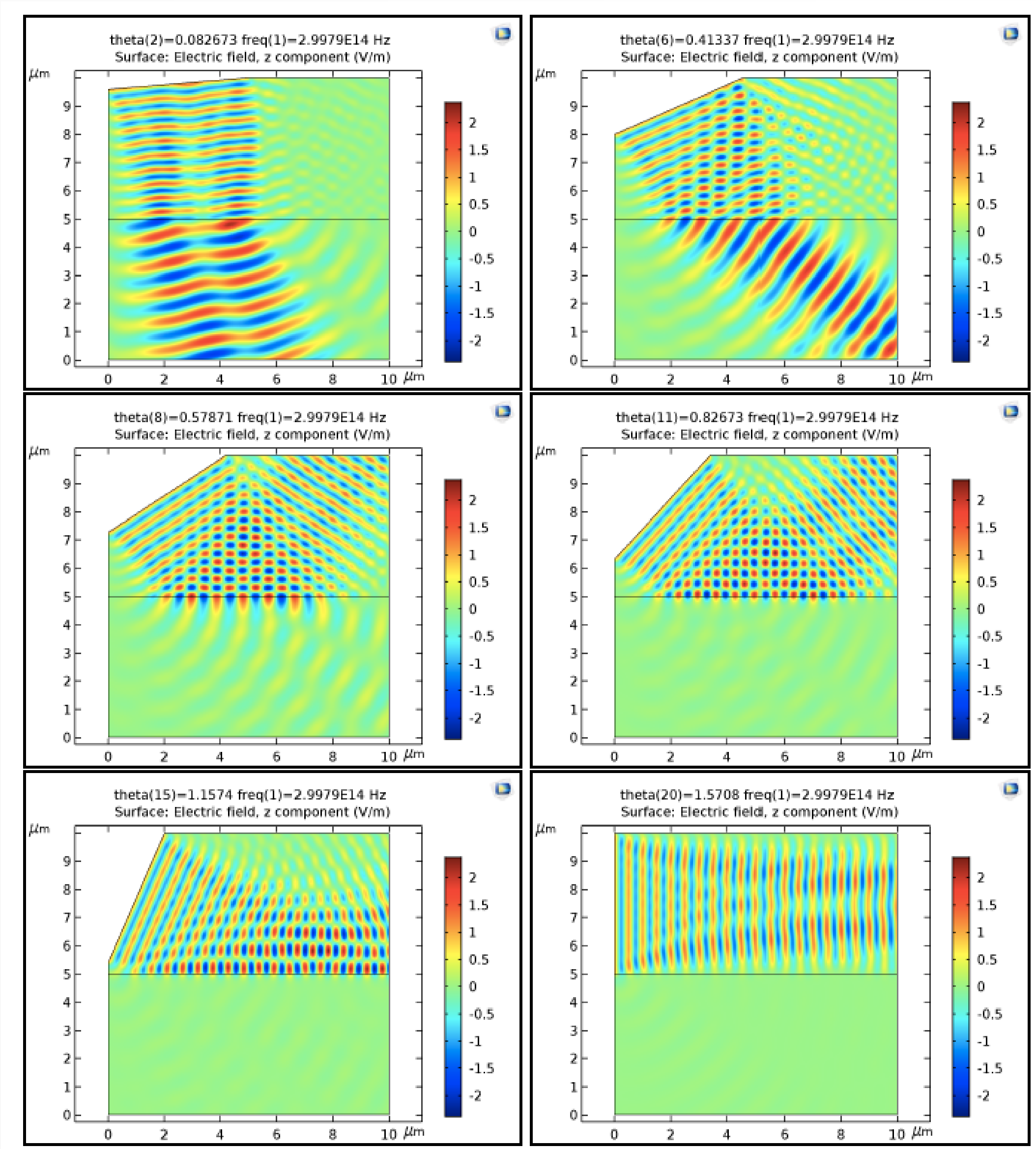
Waveguides

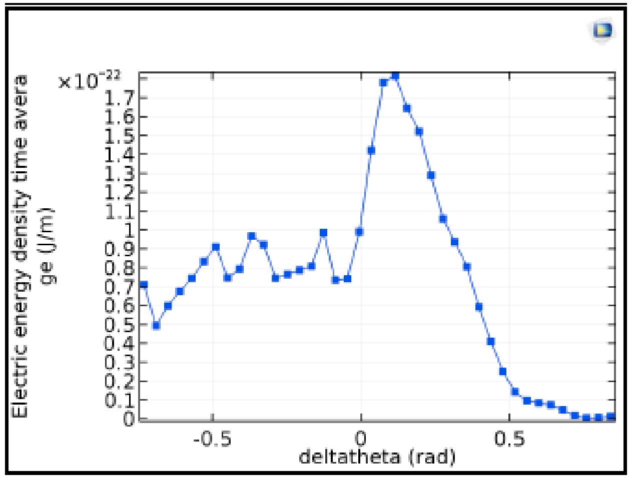
WGM resonators and waveguides made From SU8 photoresist with photolithography.

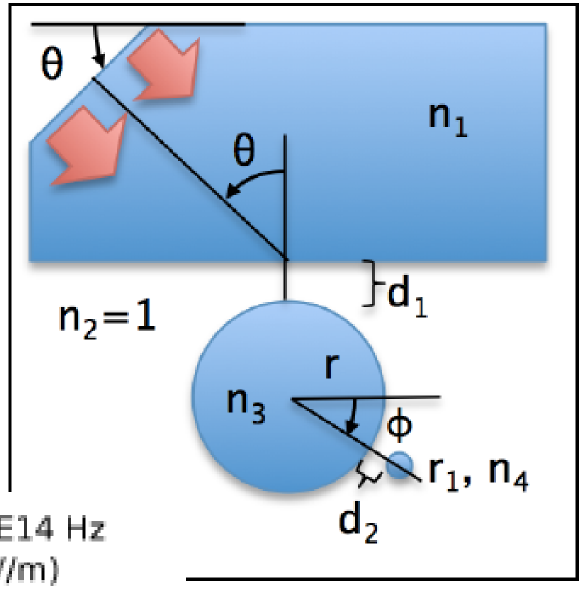
Tested: Laser light can be coupled into waveguides. Failed to see resonances, only interference waves from the ends of the waveguide.

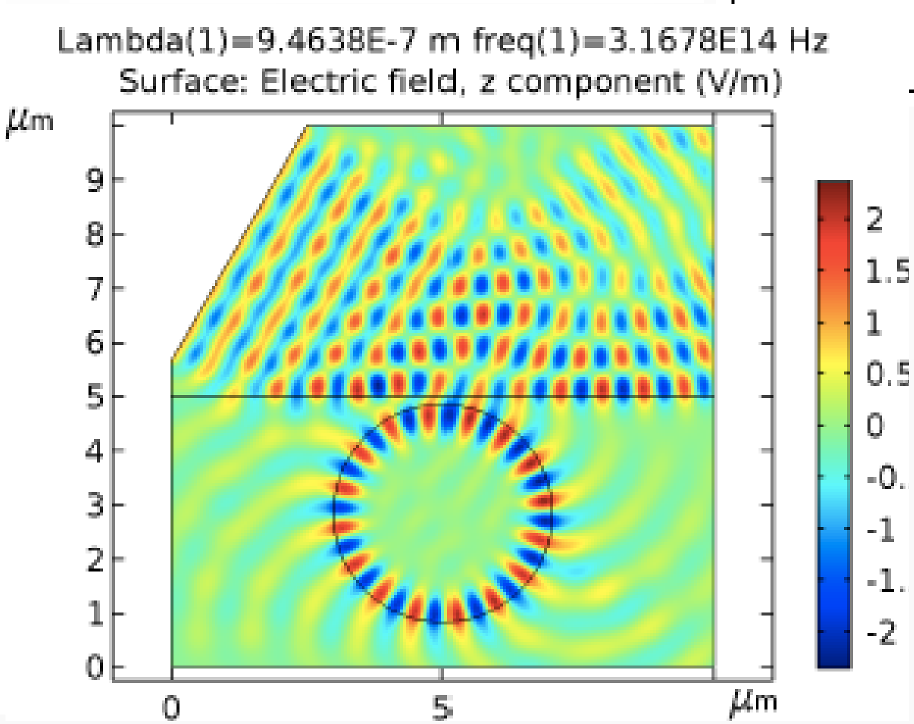


Modeling total internal reflection









Modeling small “bio”-molecules

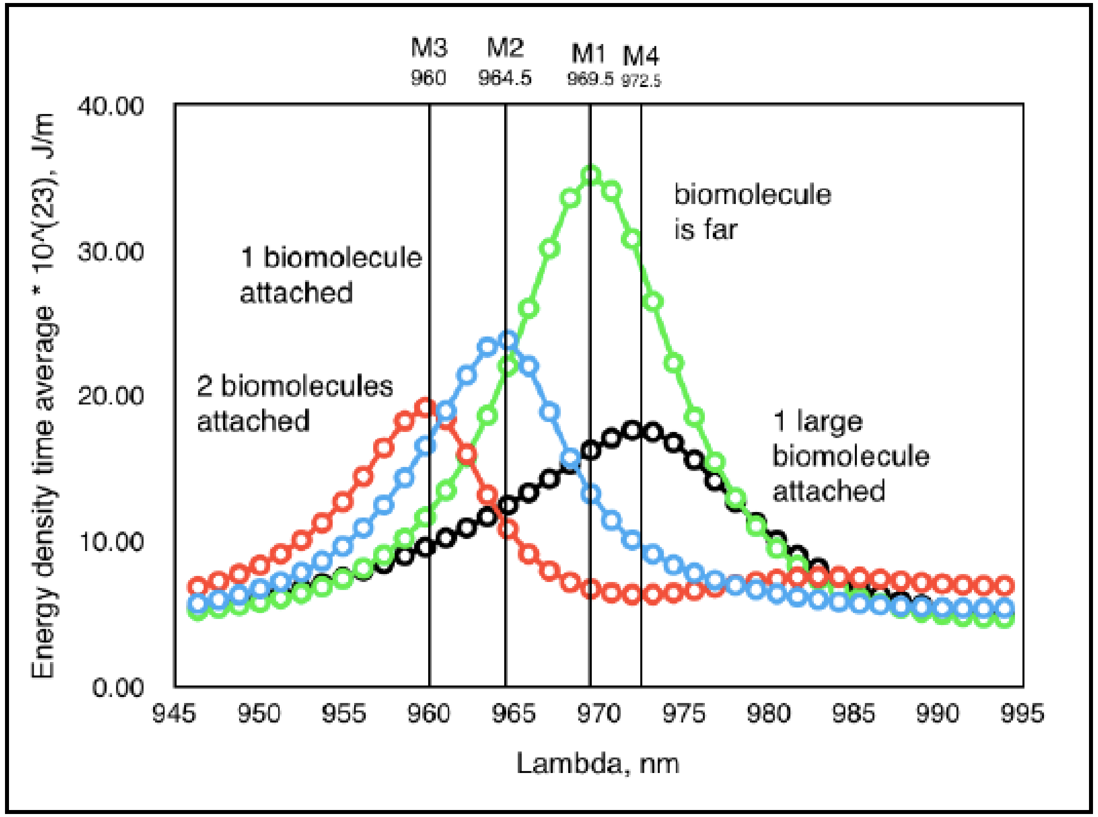
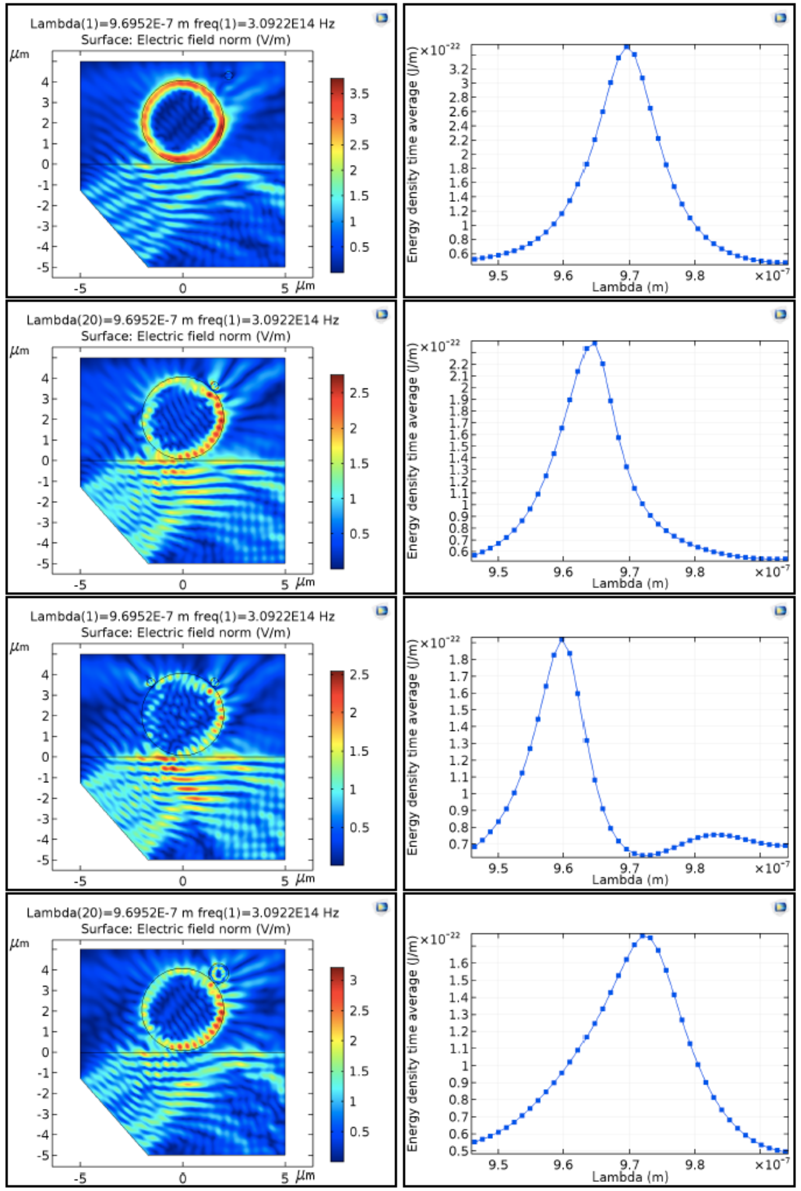


Figure 8.18: Simulation in Comsol Multiphysics. $n_1 = n_3 = 1.5$, $n_2 = 1$, $n_4 = n_{bio} = 3$, $r = 2\ \mu m$, $\theta_{light} = 0.846$ rad, $d_1 = \lambda_0/13$, $\phi = 3pi/4$, (M1) $d_2=\lambda_0$, $r_2 = 0.2\ \mu m$ (M2) $d_2=0$, $r_2 = 0.2\ \mu m$ (M3) $d_{21}=0$, $\phi_1 = 3\pi/4$, $d_{22}=0$, $\phi_2 = 5\pi/4$, (M4) $d_2=0$, $r_2 =969.52$ nm $\approx \lambda_0$



Modeling non-spherical molecule

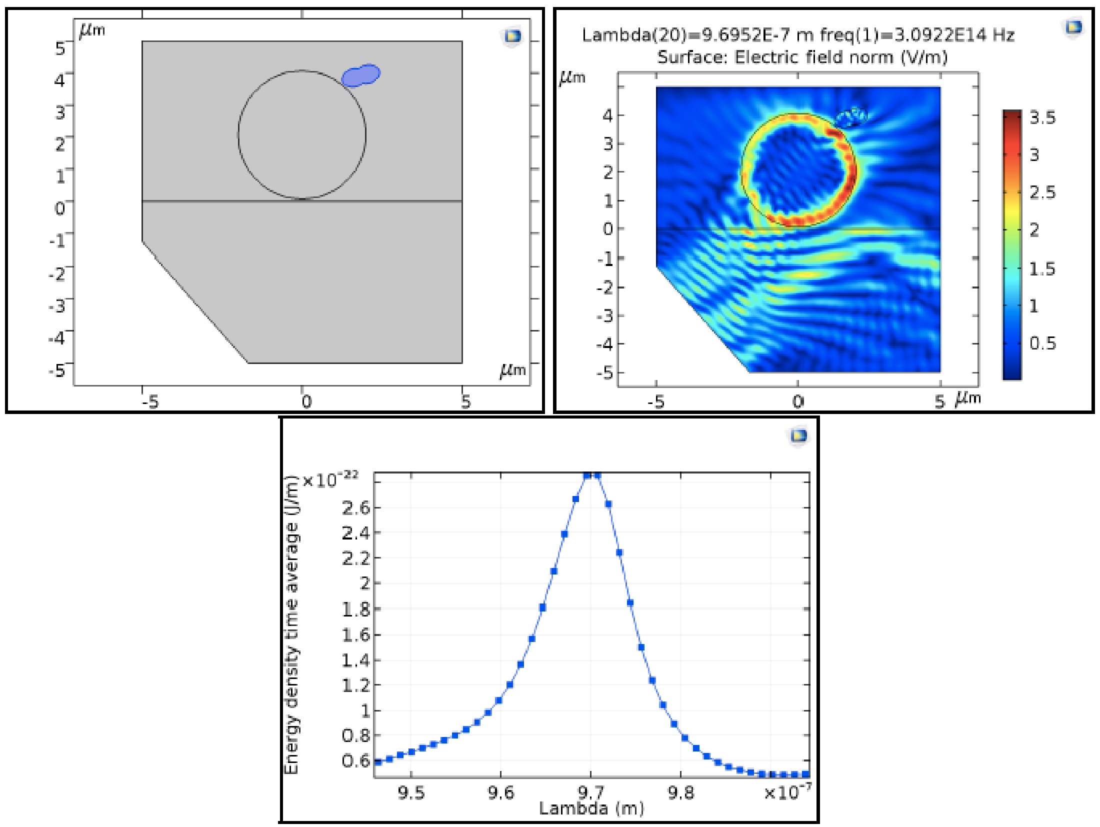


Figure 8.19: Simulation in Comsol Multiphysics. $n_1 = n_3 = 1.5$, $n_2 = 1$, $n_4 = n_{bio} = 3$, $r = 2\ \mu m$, $\theta_{light} = 0.846$ rad, $d_1 = \lambda_0/13$, $\phi = 3pi/4$, d_2=0, r_1 is changed (in horizontal axes as r_0). Lambda is a bit shifter to larger wavelengths compared to non-bio environment

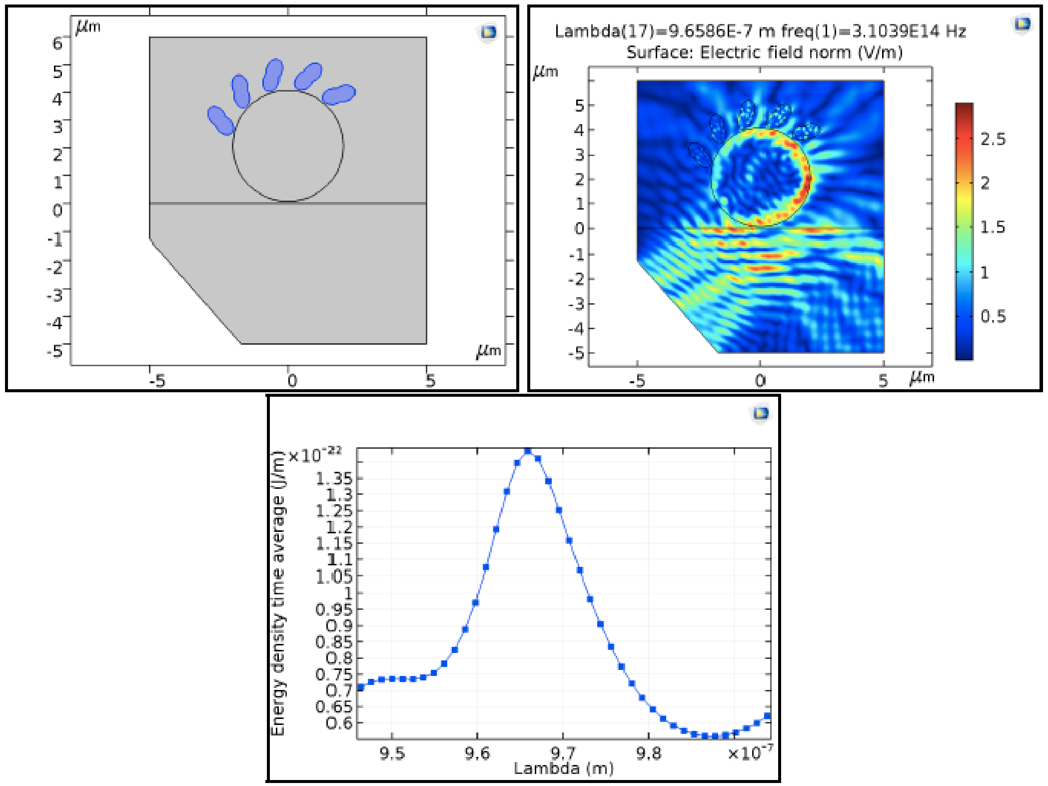


Figure 8.20: Simulation in Comsol Multiphysics. $n_1 = n_3 = 1.5$, $n_2 = 1$, $n_4 = n_{bio} = 3$, $r = 2\ \mu m$, $\theta_{light} = 0.846$ rad, $d_1 = \lambda_0/13$, $\phi = 3pi/4$, d_2=0, r_1 is changed (in horizontal axes as r_0).

Modeling the signal dependence on the N

N=16

N=32

N=64

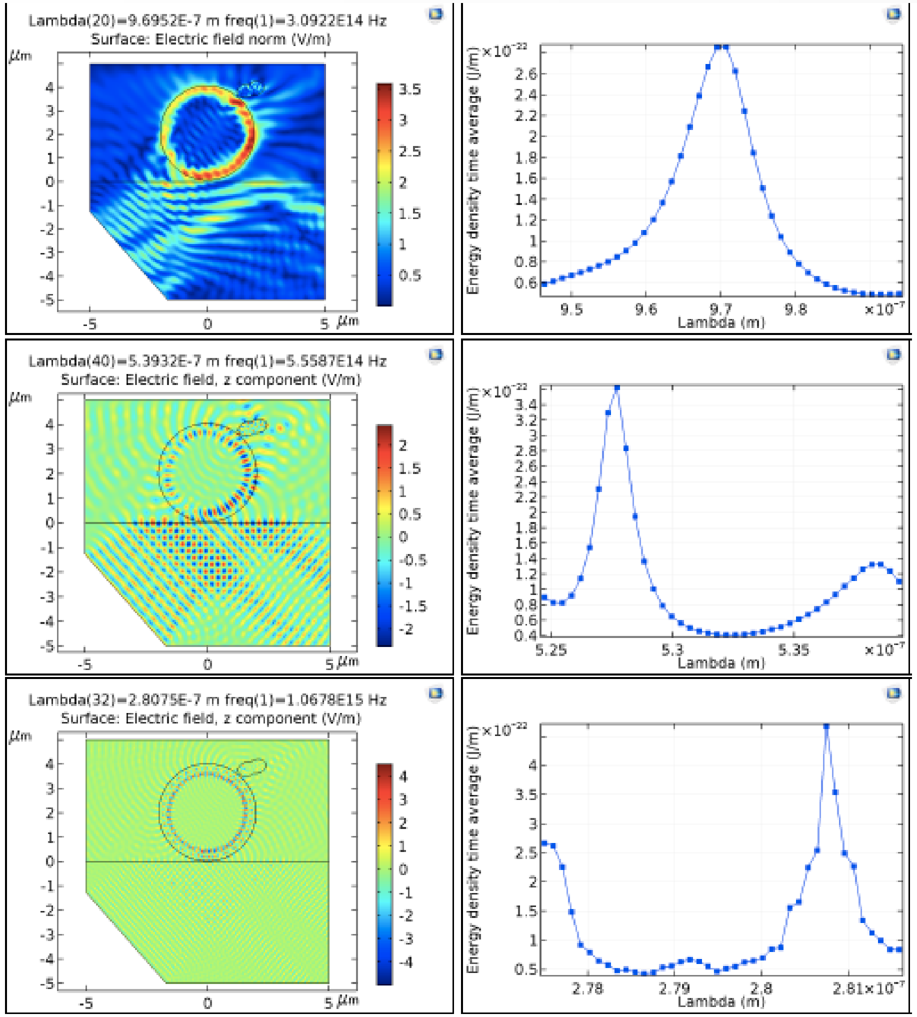
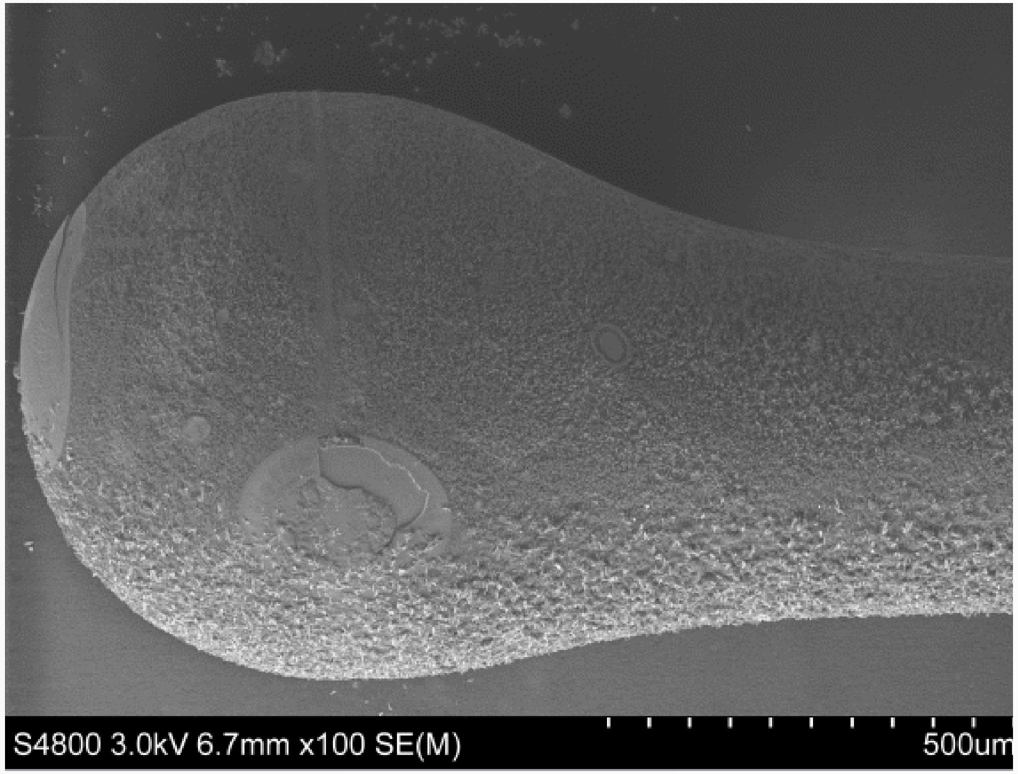
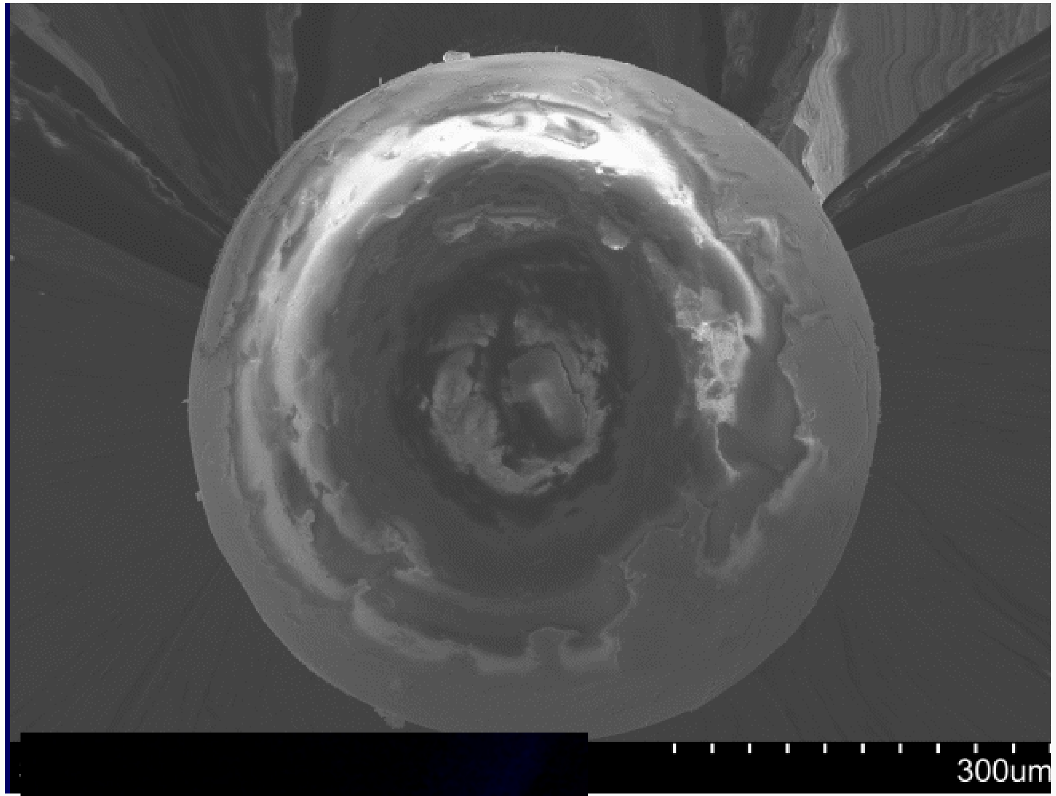


Figure 8.21: Simulation in Comsol Multiphysics. $n_1 = n_3 = 1.5$, $n_2 = 1$, $n_4 = n_{bio} = 3$, $r = 2\ \mu m$, $\theta_{light} = 0.846$ rad, $d_1 = \lambda_0/13$, $\phi = 3pi/4$, d_2=0, r_1 is changed (in horizontal axes as r_0). Lambda is a bit shifter to larger wavelengths compared to non-bio environment (A) N=16, (b) N=32 ; (c) N=64

Coating the resonators



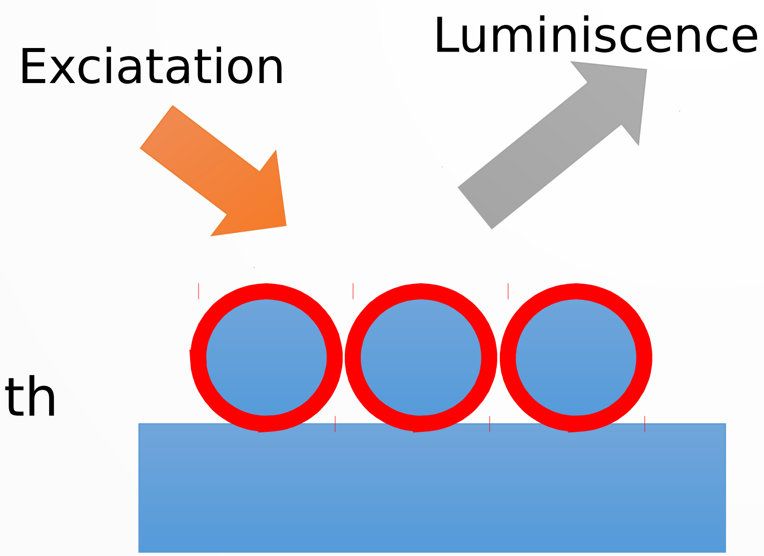
ZnO NRs – no resonances observed



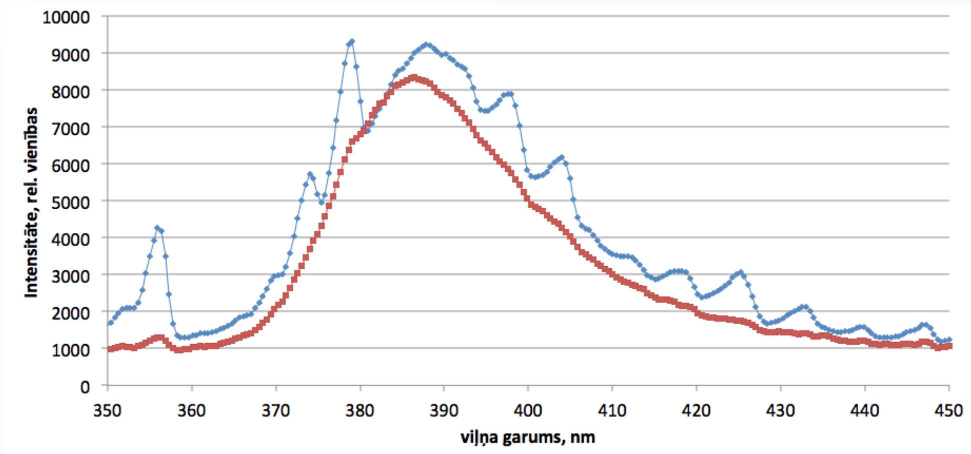
Polystyrene spheres – no resonances observed

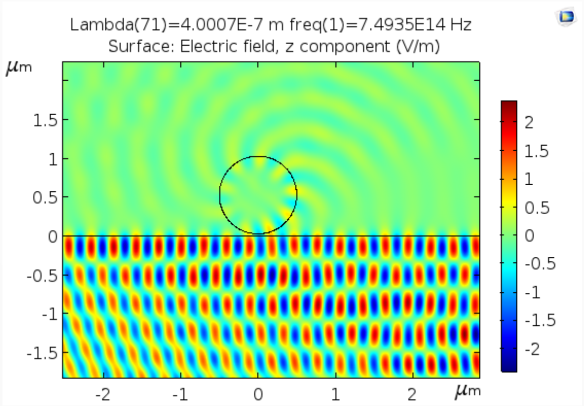
Experiment VS Modelling

WGMR signal modeling with Comsol 1µm spheres coated with ZnO ZnO luminescence excited with 337 nm



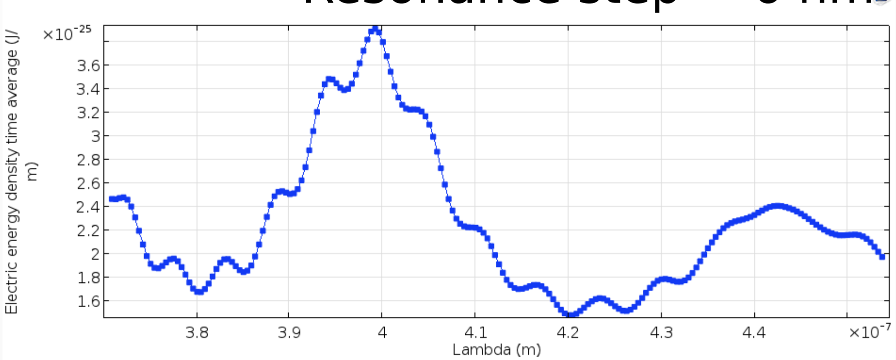
Experiment Resonance step ~ 6 nm



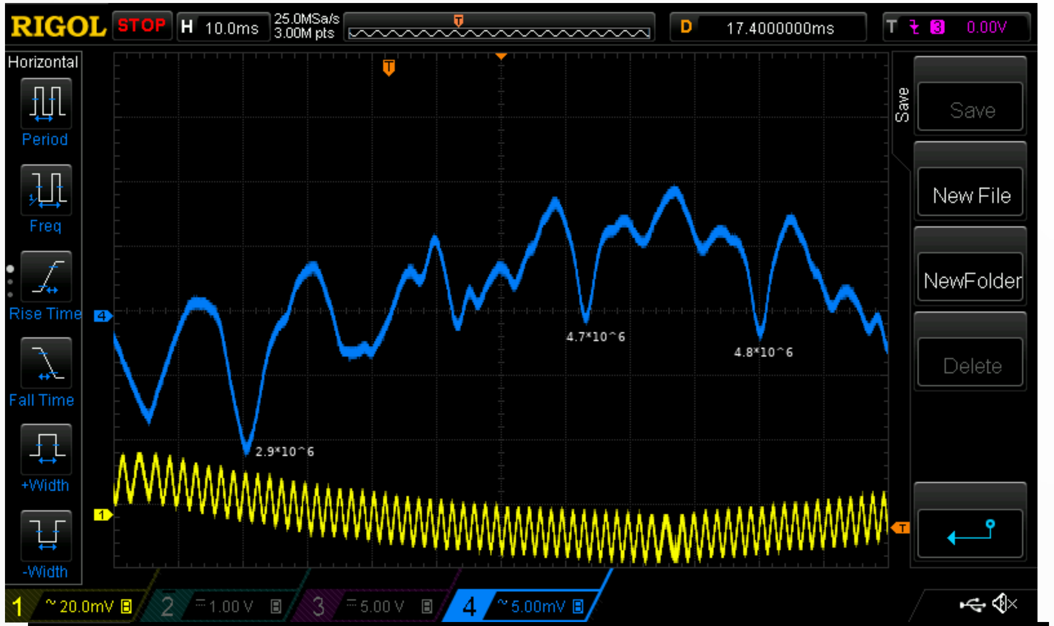


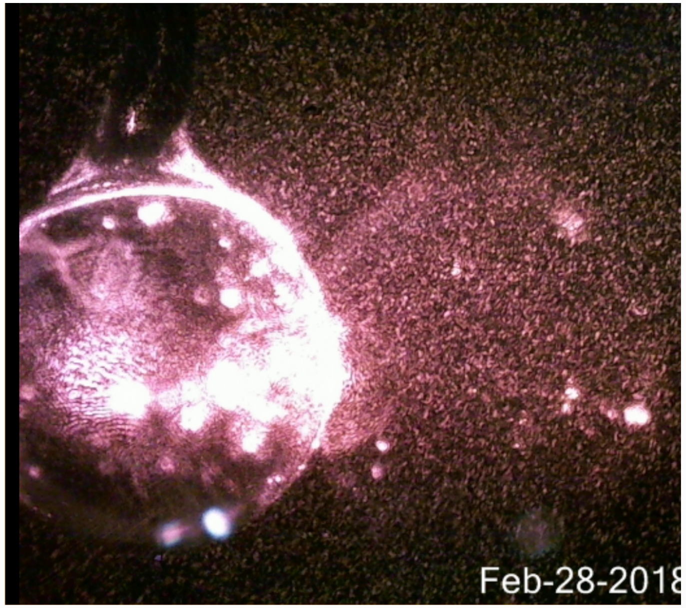
sphere diameter - 1 µm

Modelling Resonance step ~ 6 nm

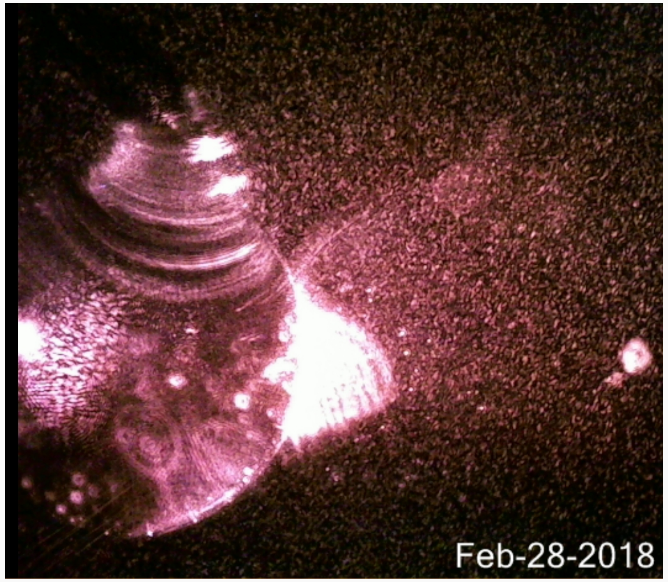


Testing resonators Coated with ZnO mono-layer



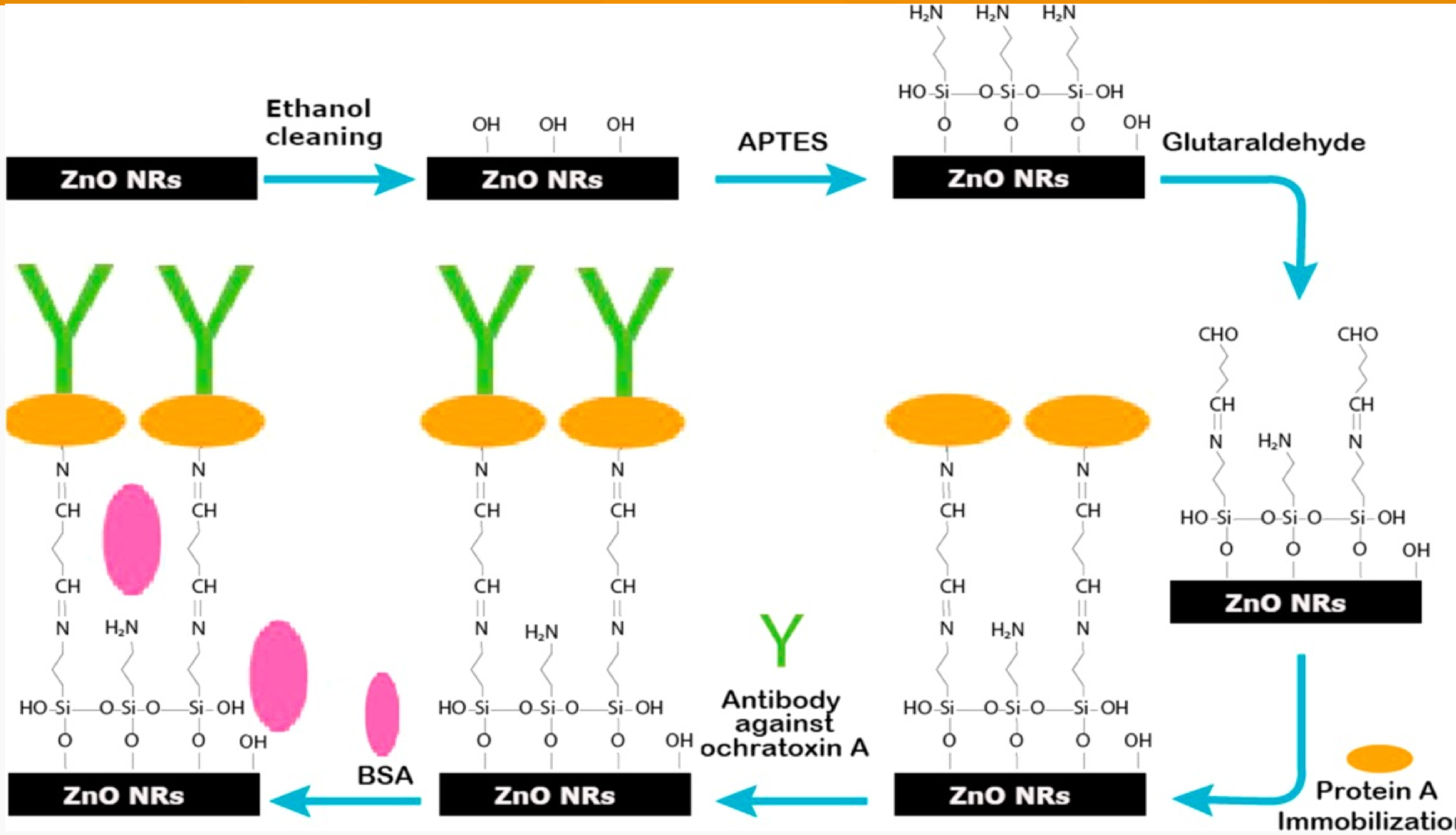


5 nm ZnO

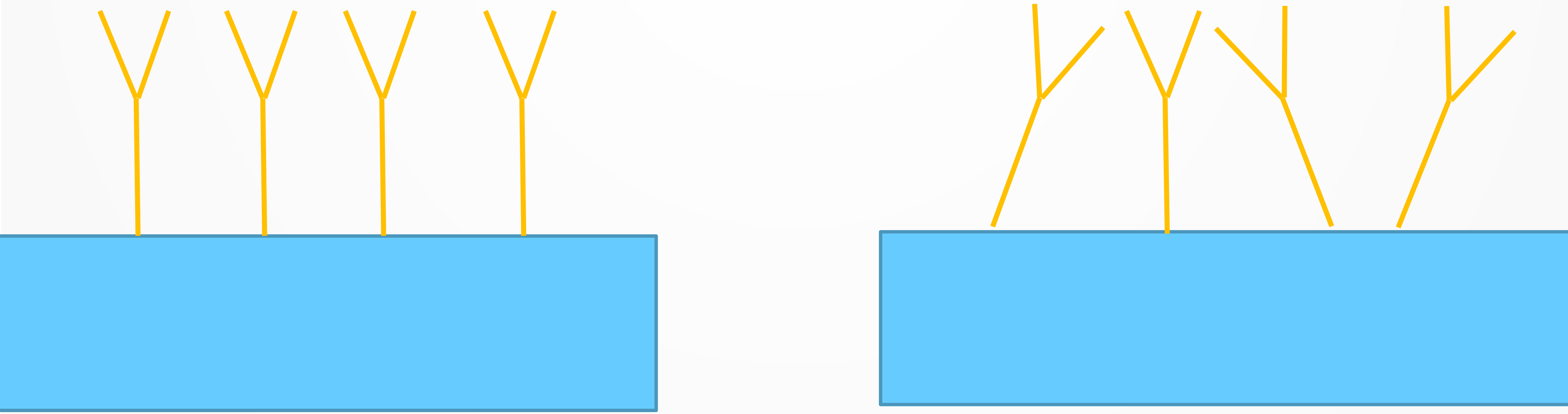


20 nm ZnO

Silanization of the samples

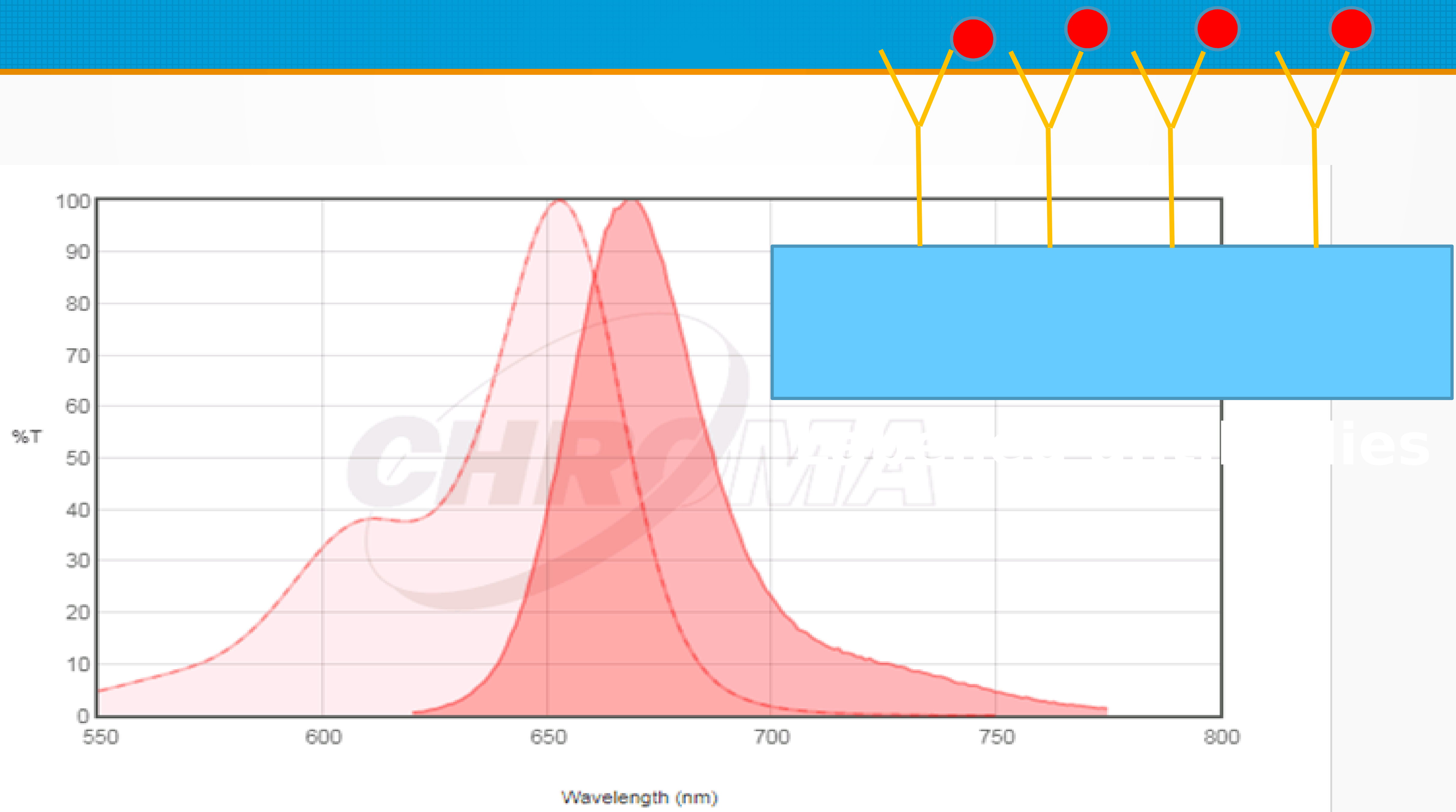


Types of Antibody binding to the metal oxide surface

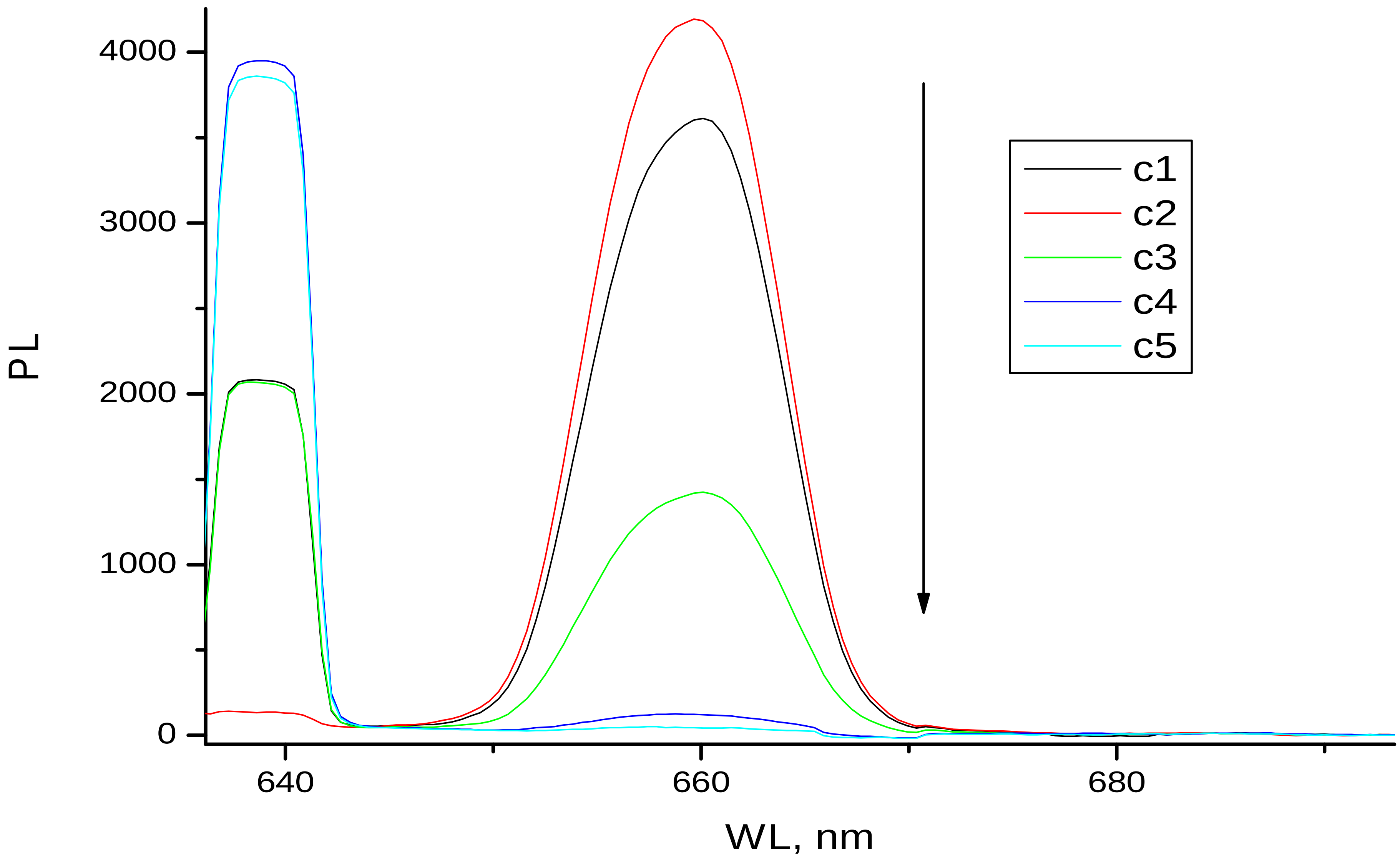


Covalent binding (left) and non covalent (right)

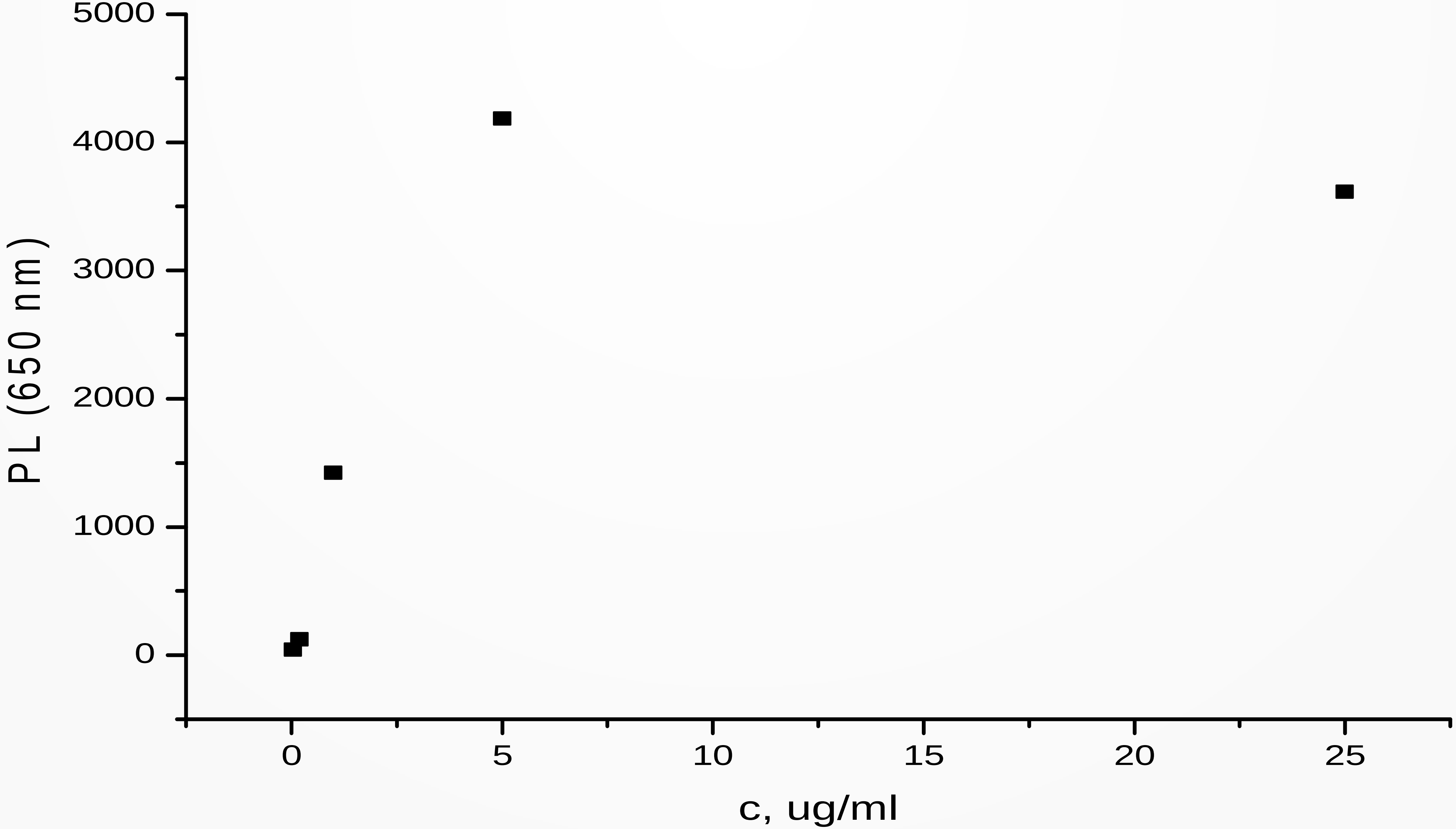
Immobilization control



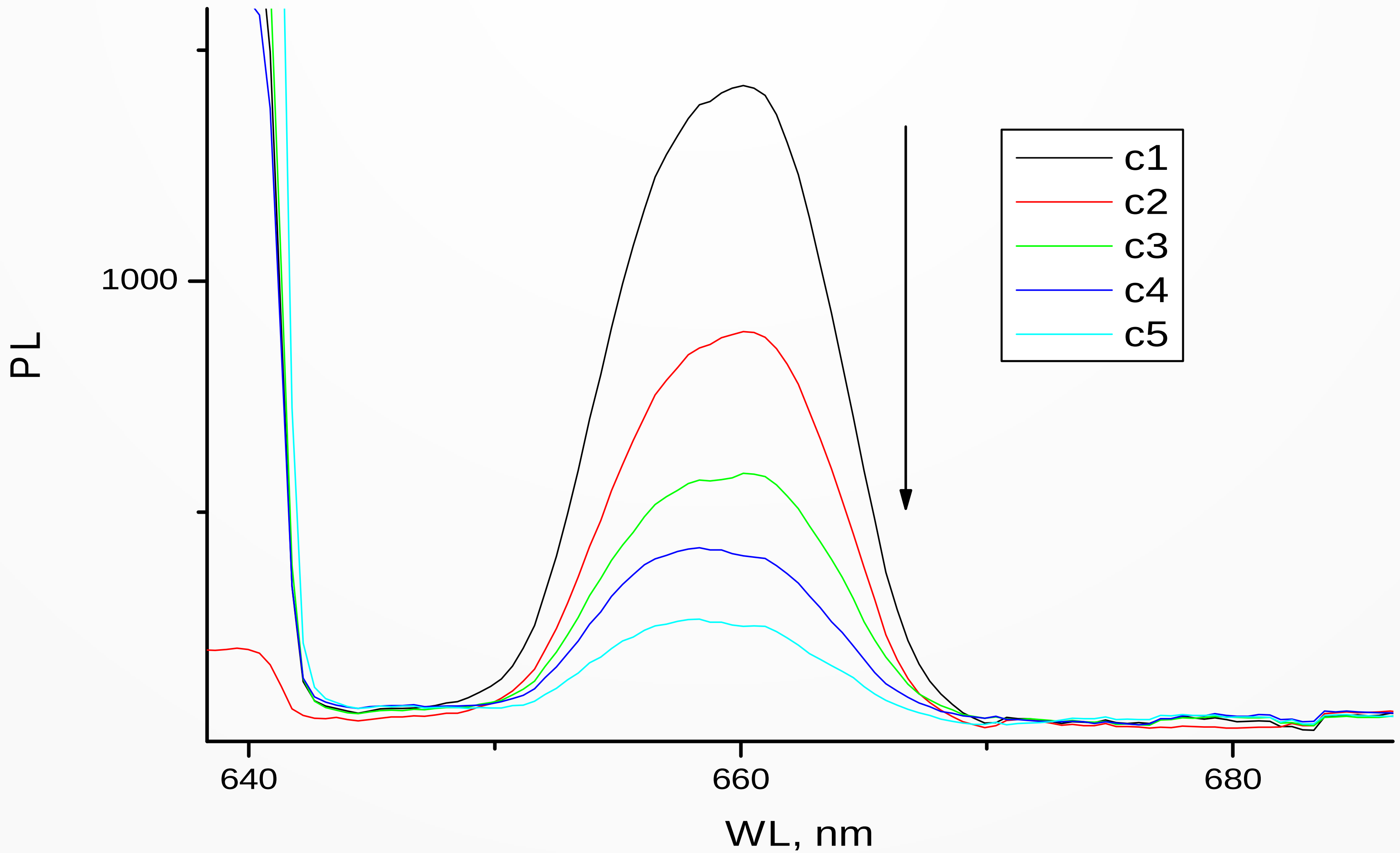
Characterization of non silanized ZnO-Antibody



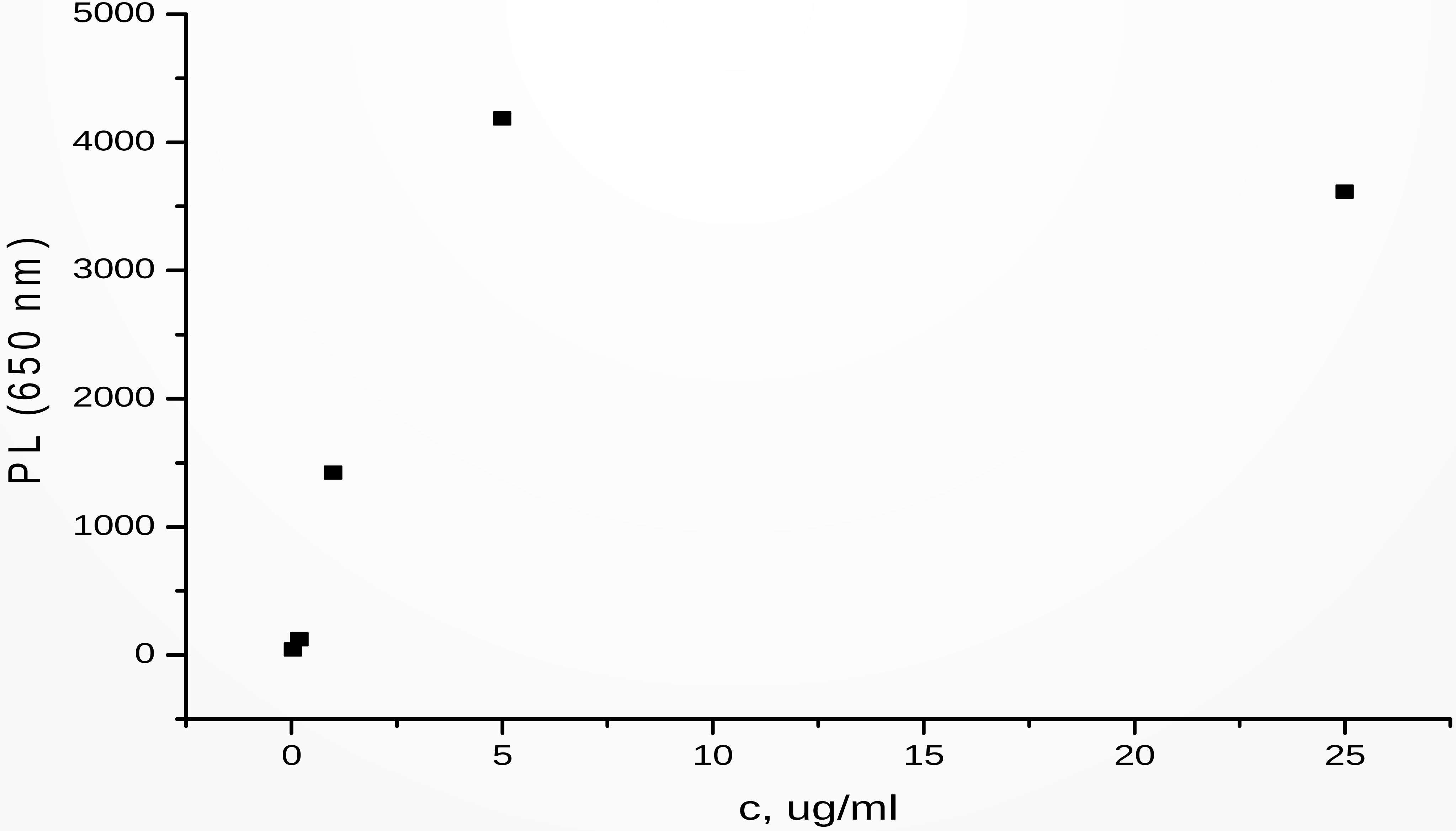
Surface coating



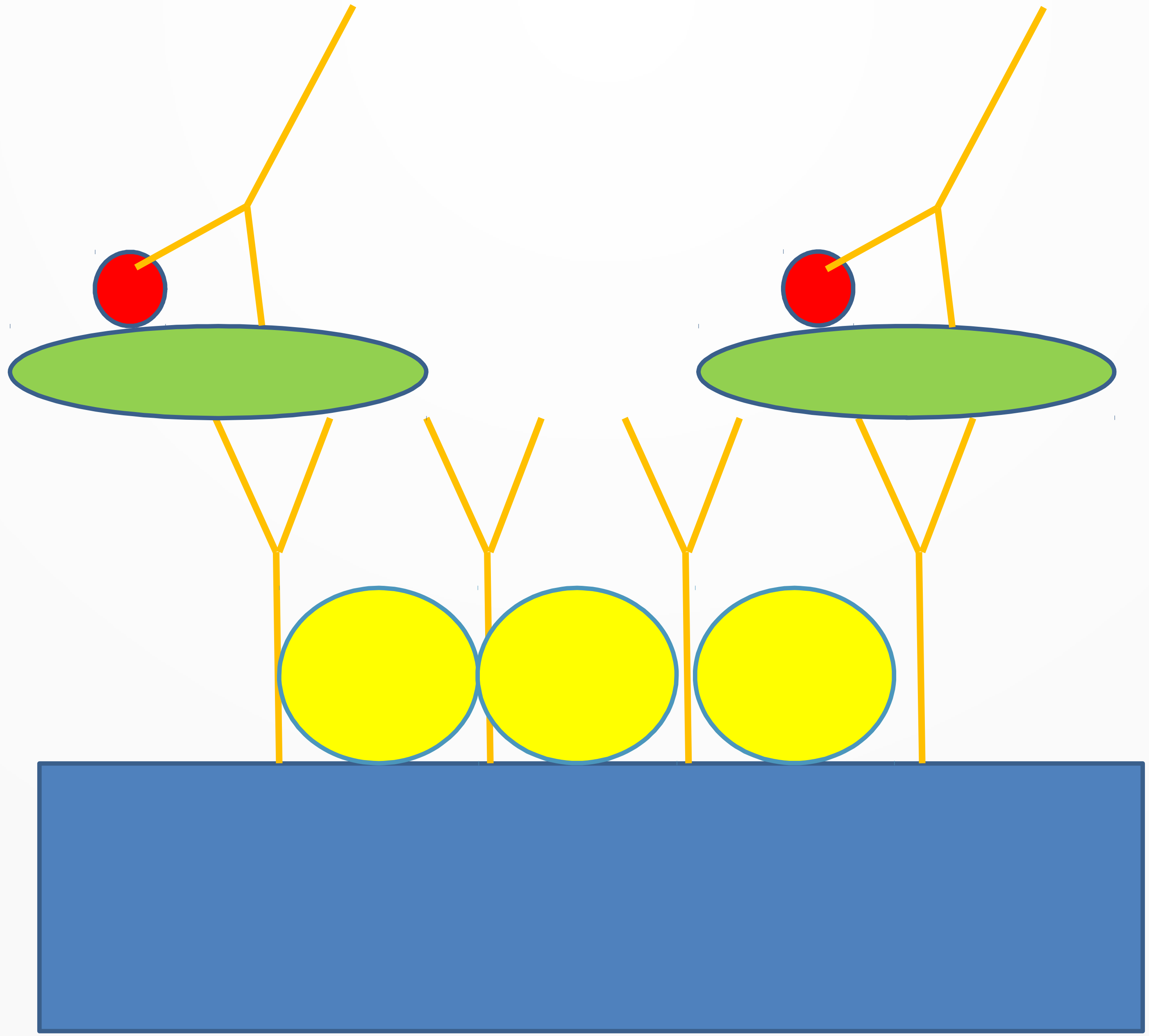
Characterization of silanized ZnO-Antibody



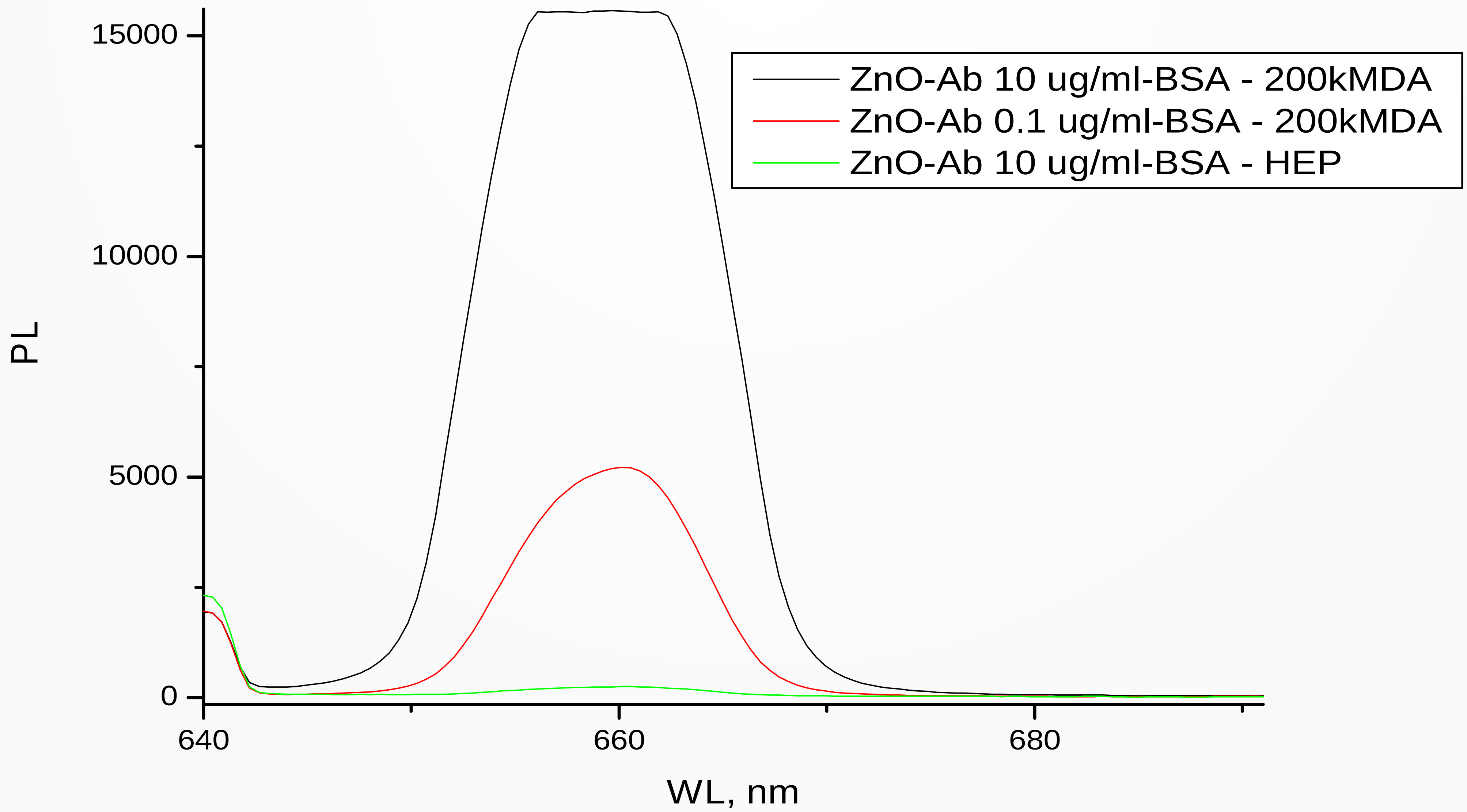
Surface coating



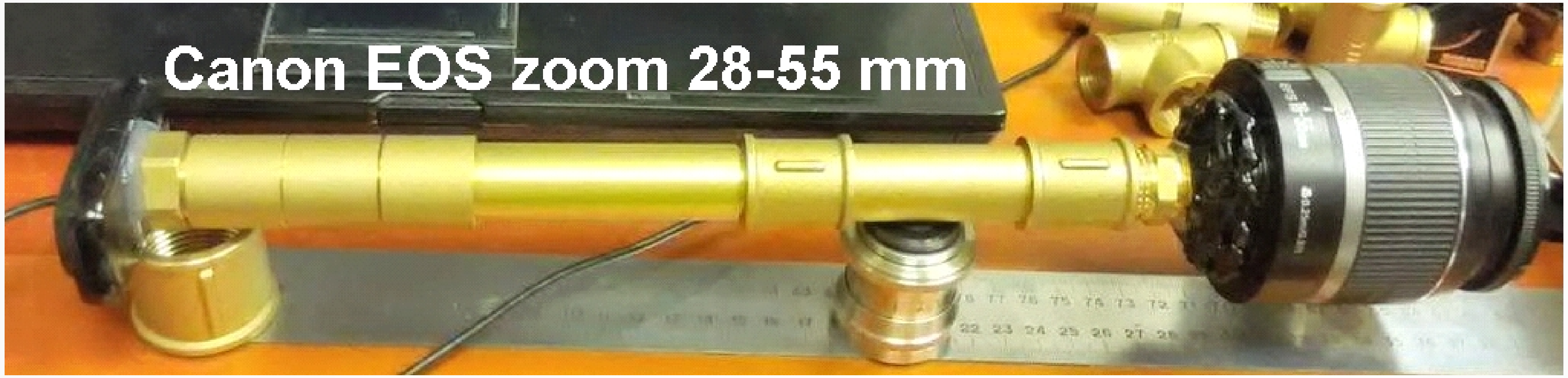
Testing to cancer cells

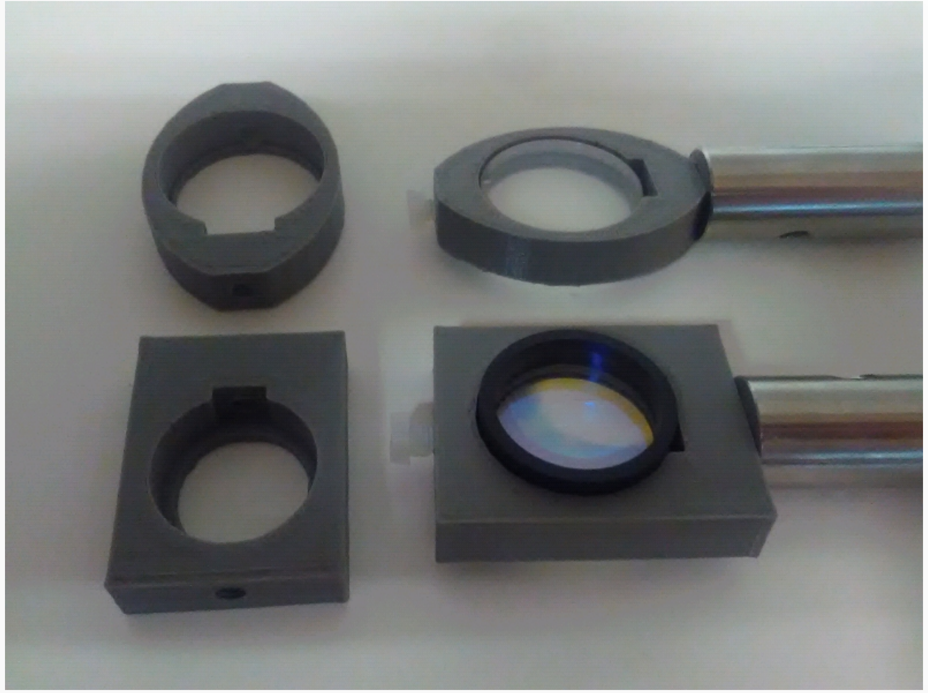


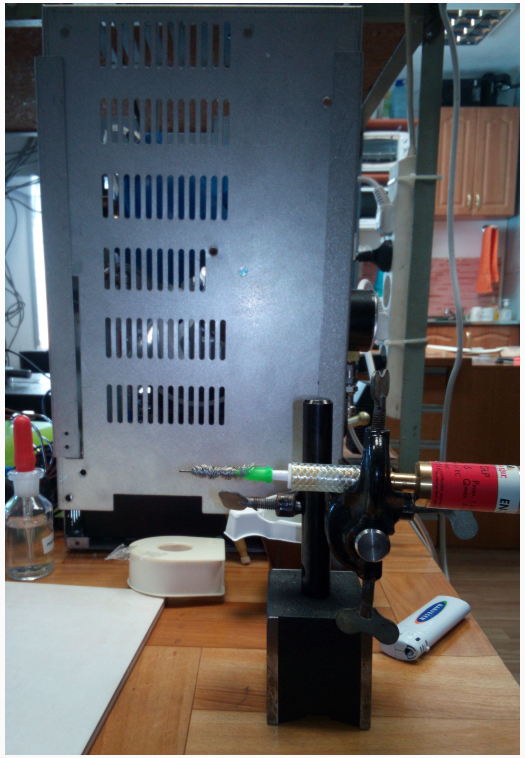
Cell coating of the surface



Different DIY

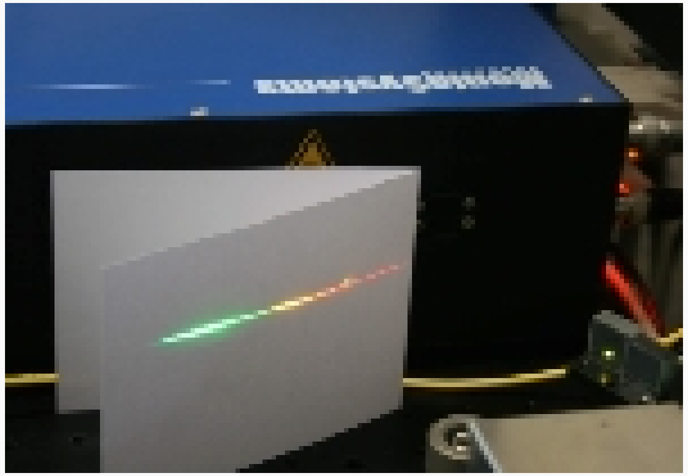


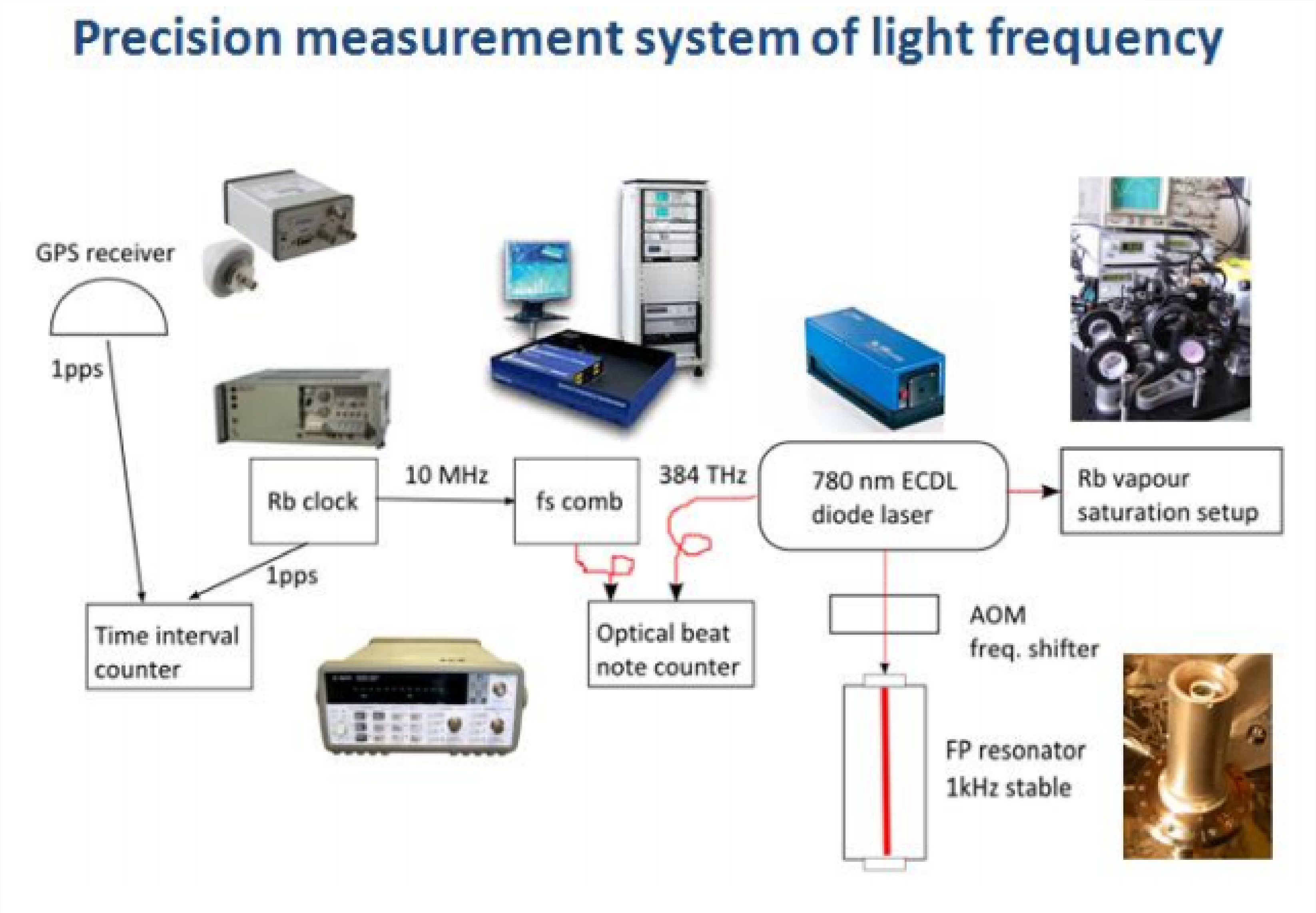




Fabri-Perot resonator

Frequency comb





Thank You for Attention!