37th RD50 Workshop,
November 18-20, 2020, Zagreb

TPA/SPA SET UP AT ELI BEAMLINES

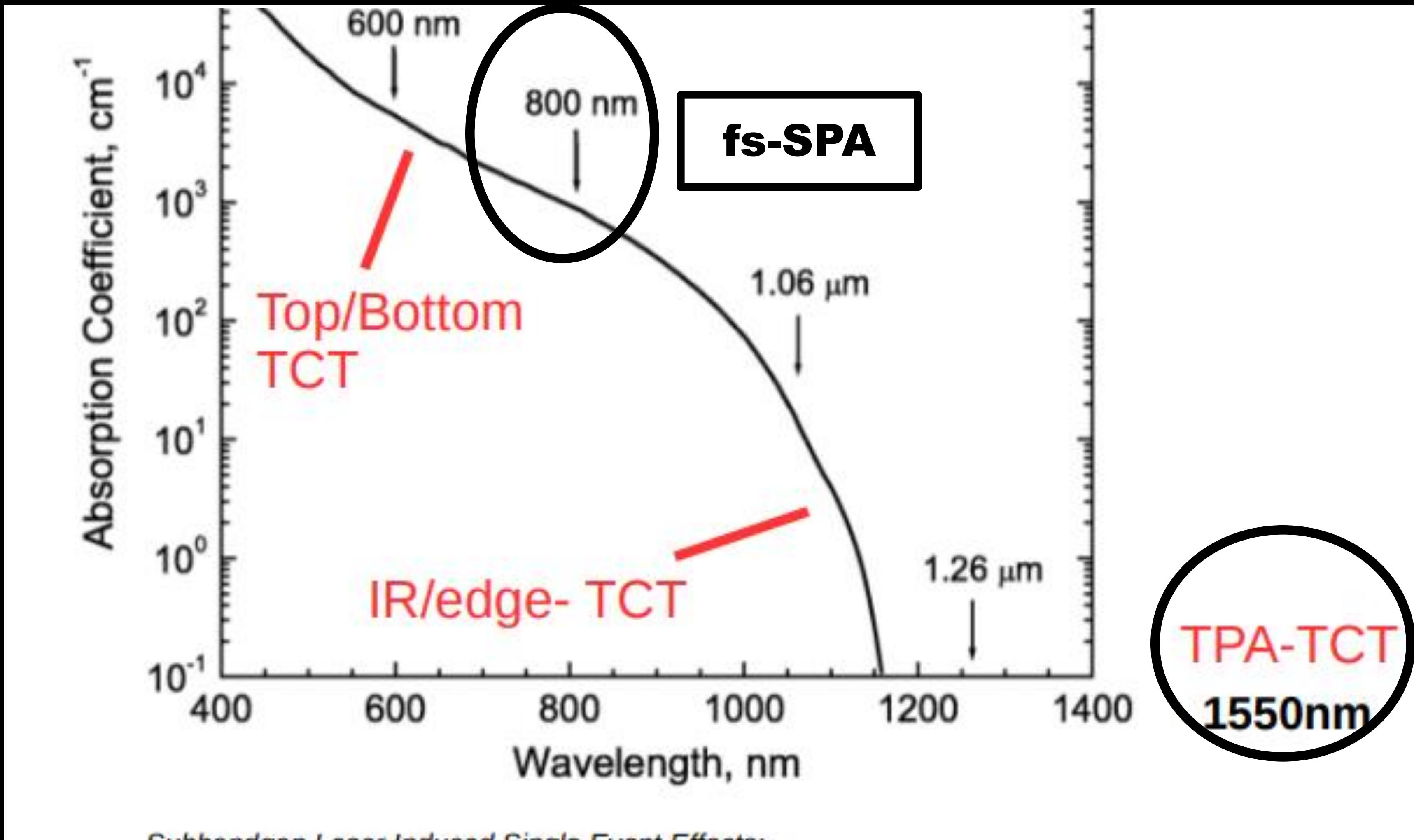
Presented by Gordana Medin on the behalf of ELI-RD50 groups:
UCG, INFN-Torino, JSI, ELI, CAS

Collaboration/People & Institutions

- **ELI Beamline, CZ** – RP4 group (Application in Molecular, Bio-medical and Material Science) and BIS group
  - Mateusz Rebarz, Jakob Andreasson
  - Tomáš Laštovička, Kamil Kropielniczki
- **Institute of Physics, Academy of Sciences, CZ**
  - Jiří Kroll, Michal Tomášek
- **University of Montenegro**
  - Gordana Medin
- **JSI**
  - Gregor Kramberger
- **INFN Torino**
  - Nicolo Cartiglia, Valentina Sola

Motivation

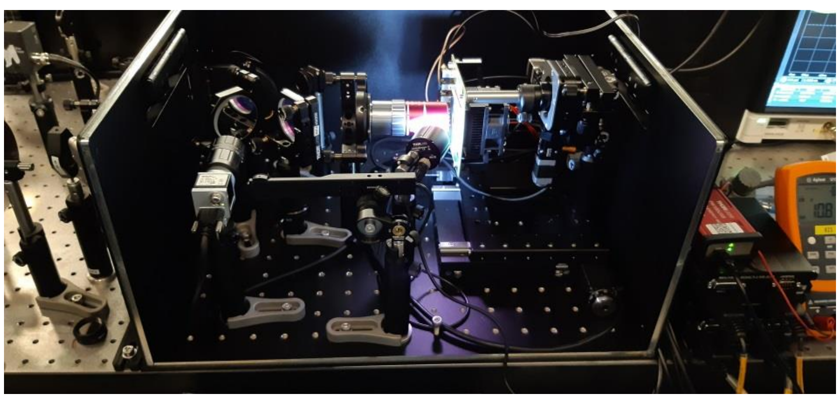
To build unique fs-TCT with both lines, Single Photon Absorption at 800 nm the and Two Photon Absorption at the 1550 nm of fs-laser

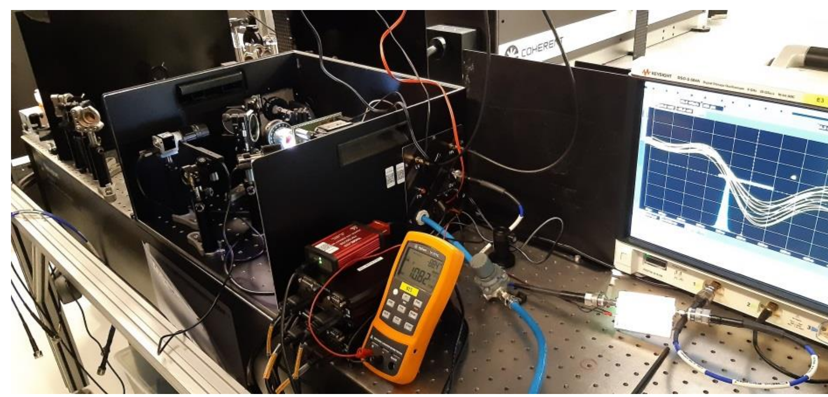


SPA/TPA-TCT setup at ELI Beamlines

Czech Republic
Dolní Břežany (on the outskirts of Prague)

Experimental hall E1
Research program: Bio and Material Applications

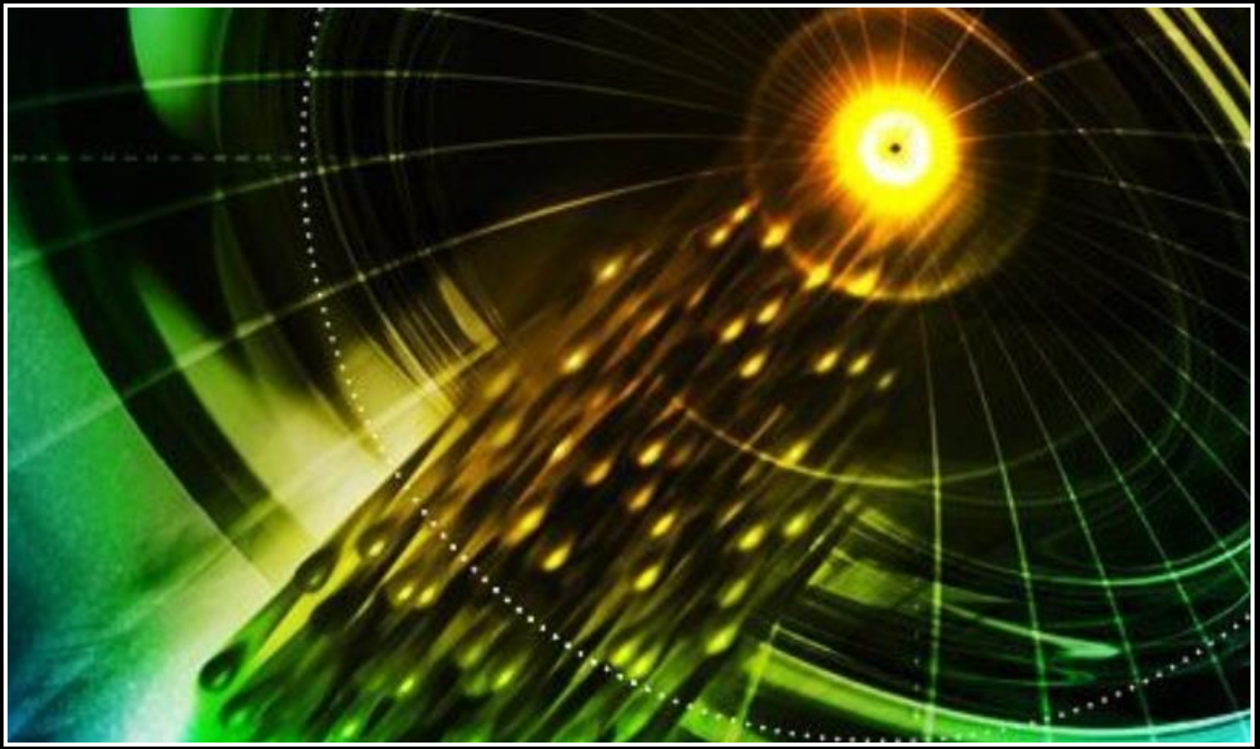




Project supported by: Advanced research using high intensity laser produced photons and particles (ADONIS) Reg. n.: CZ.02.1.01/0.0/0.0/16_019/0000789

ADONIS Project

- allows performing new investigations spanning the range from fundamental to applied sciences and medicine, ultimately leading to a better understanding of nature and providing future societal benefits.



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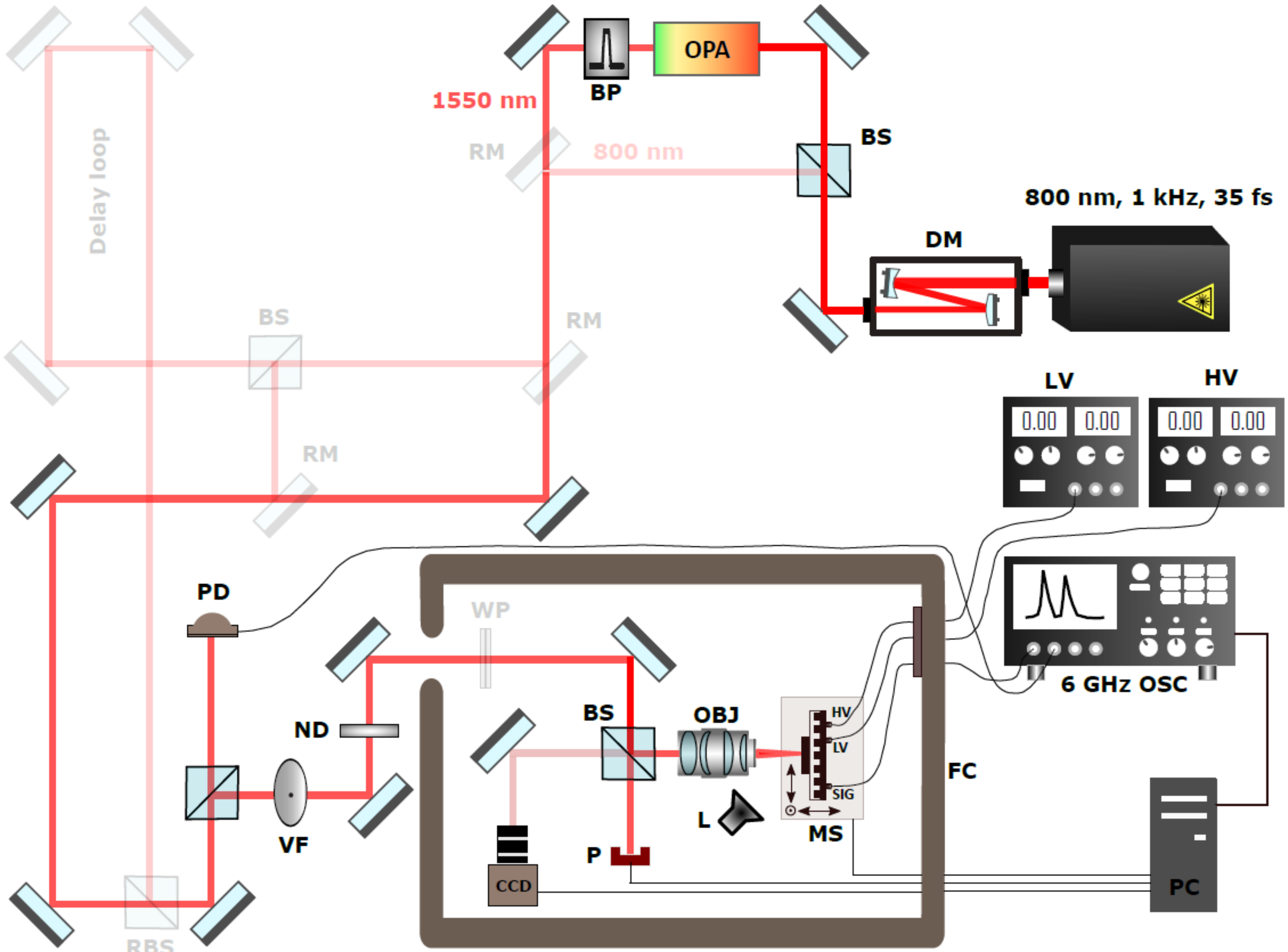
- ELI's worldwide competitiveness will increase considerable, making it the foremost user installation in the European landscape and at the same time positioning the Czech Republic at the forefront of photonic research.

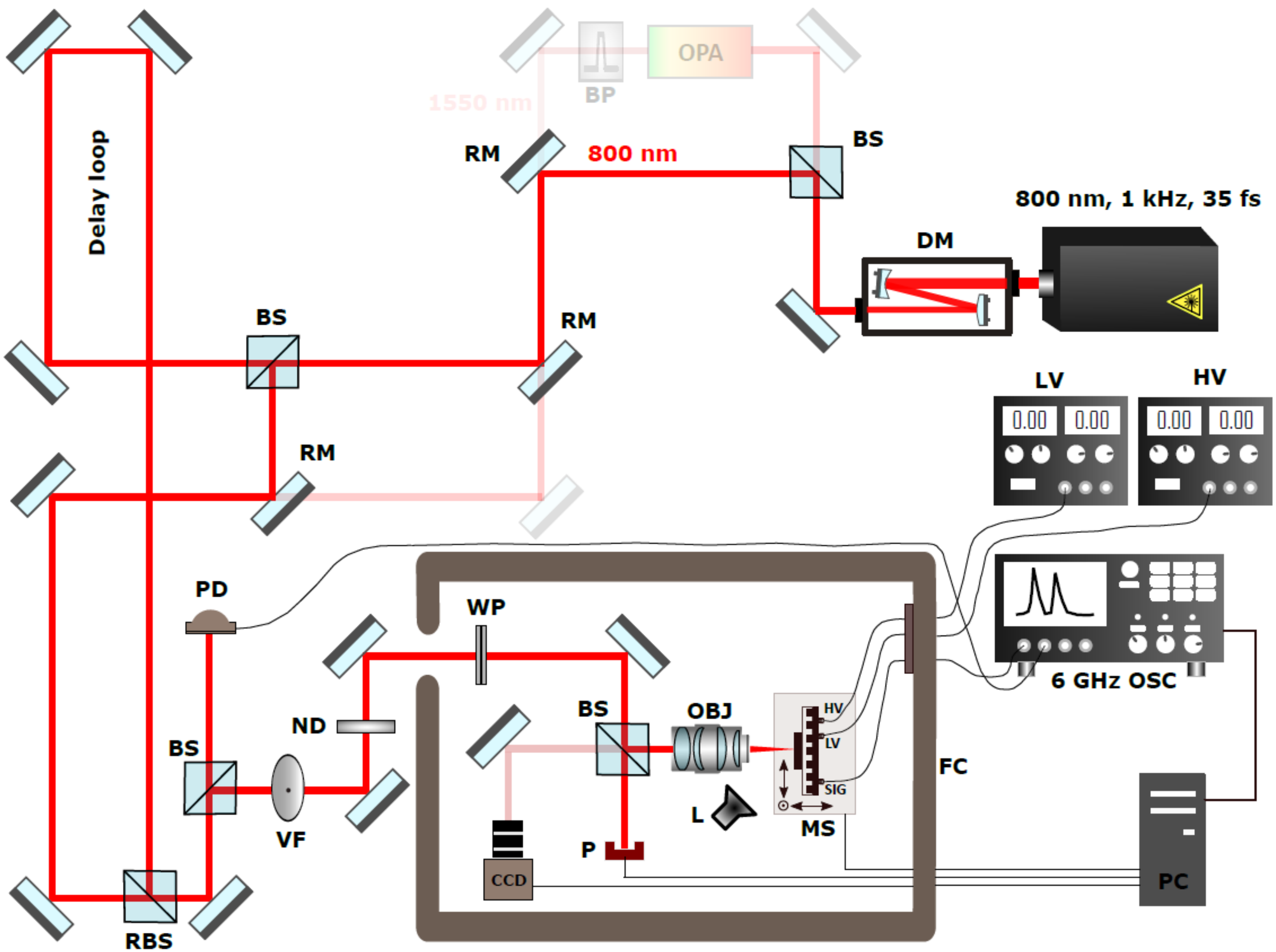
- It will enhance the capabilities and versatility of the laser systems and subsequently use these improved lasers for new experimental applications. Improving the lasers leads directly to improving the endstations, beamlines and platforms of ELI-Beamlines.

A NEW Experimental setup: **TPA** configuration



DM – demagnifier, **BS –** beamsplitter, **OPA -** optical parametric amplifier, **BP -** bandpass filter, **RM -** removabe mirror, **RBS -** removable beamsplitter, **PD -** reference photodiode, **VF -** variable gradient ND filter, **ND -** fixed neutral density filter, **WP -** half waveplate, **P –** powermeter, **OBJ -** 100X objective **L-** lamp, **MS -** motorized XYZ stages, **LV -** low voltage power supply, **HV -** high voltage power supply, **FC -** Faraday cage

Experimental setup: **SPA** configuration



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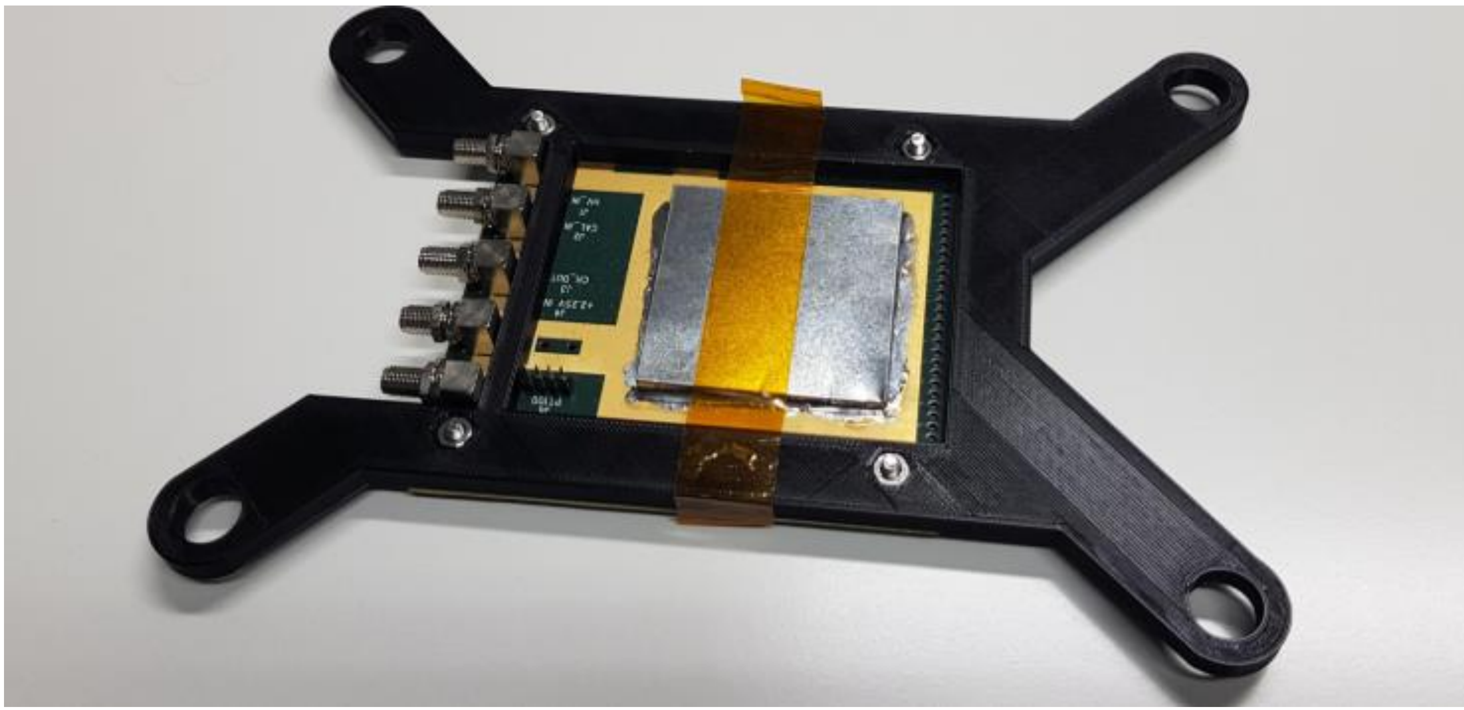
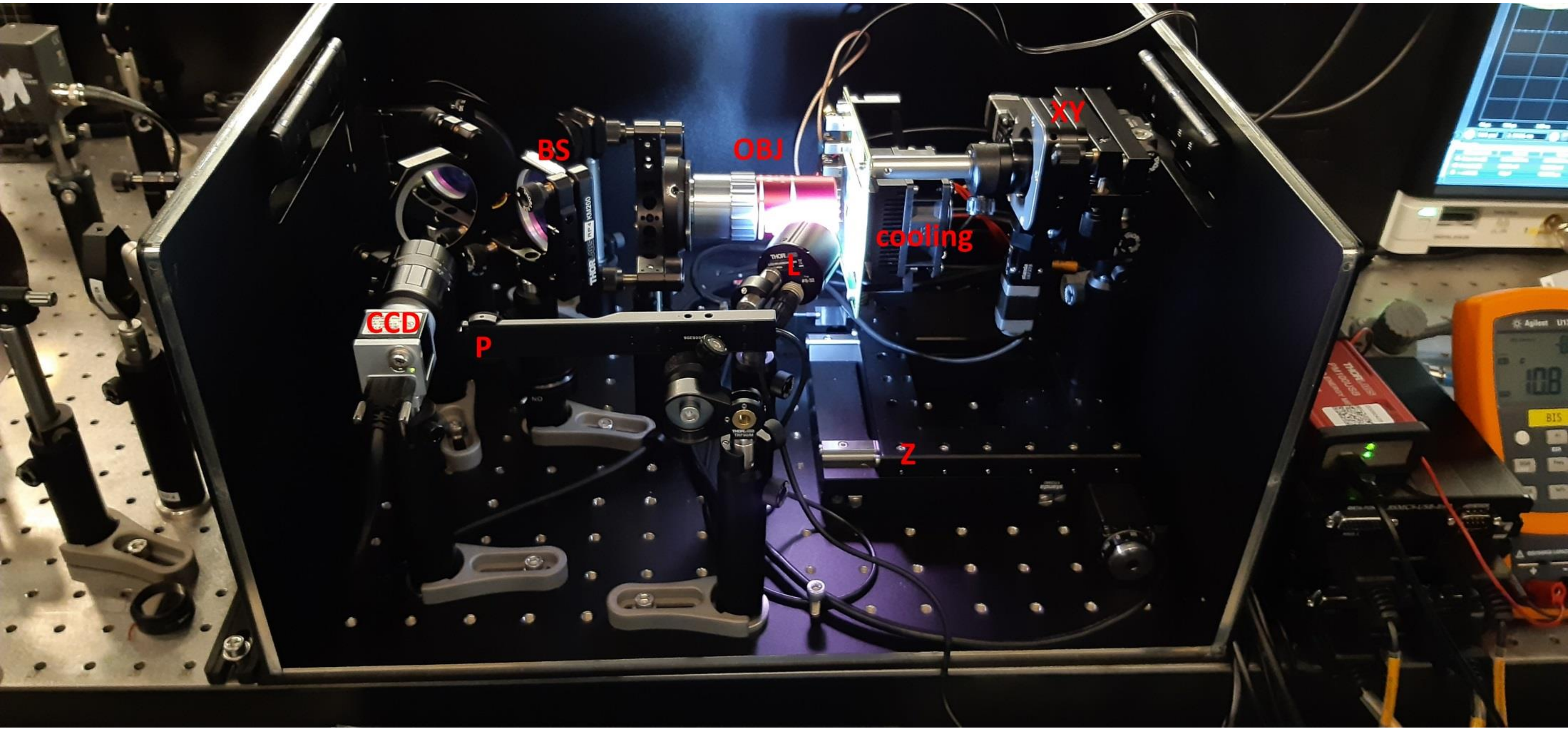
Comments:

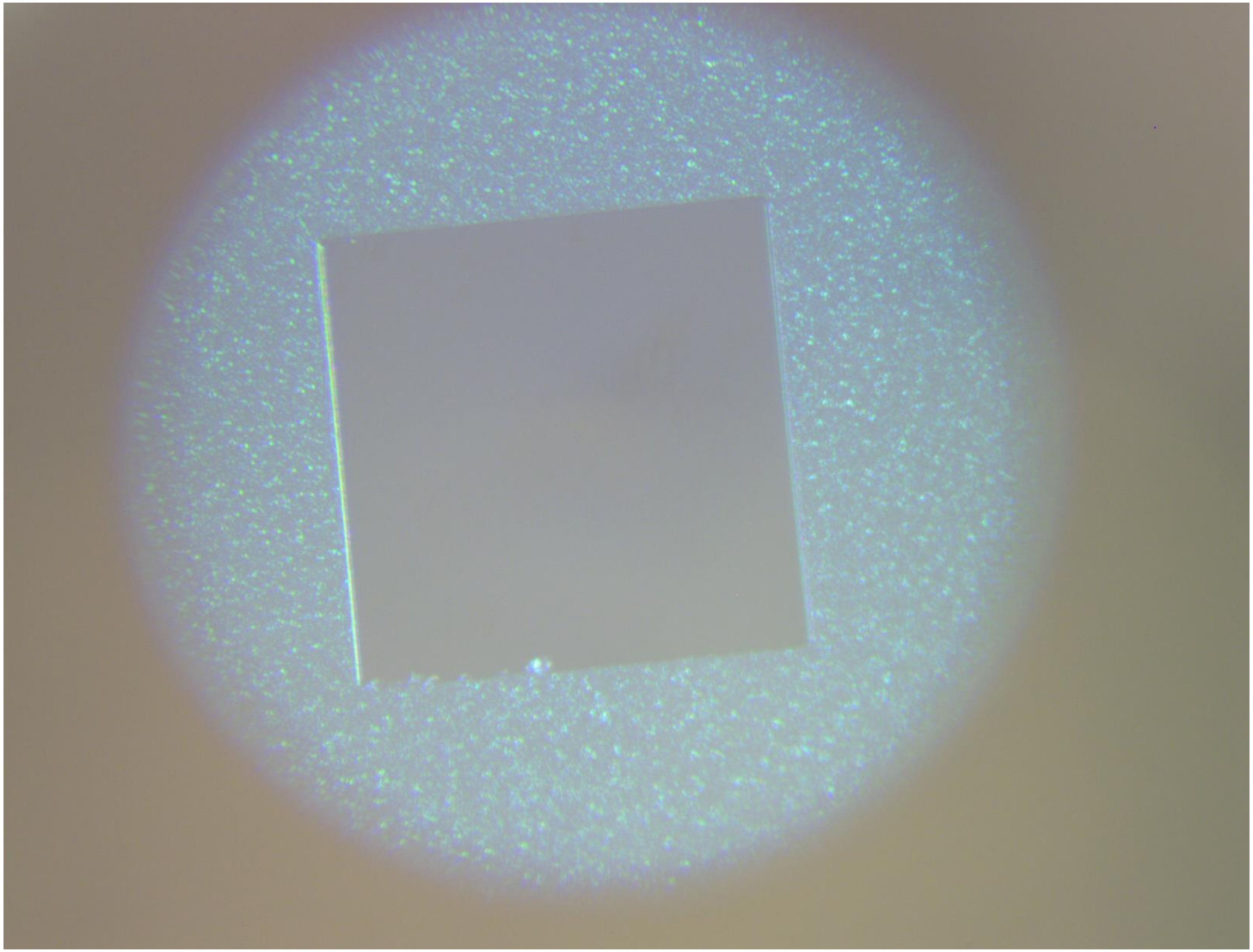
- setup contains a few removable elements on magnetic mounts to quickly change between 800 nm and 1550 nm beam
- for 800 nm optional half wave plate is used to flip polarization (the same S-polarization (vertical) is kept for all measurements)
- beam splitter in the front of objective is exchangeable, different ones are used for 800 and 1550 nm to give 50/50 split in both cases
- power is measured after the beam splitter (it enables constant monitoring of power during measurements)
- at 1550 nm power is measured by S132C Thorlabs power meter
- at 800 nm power is measured by PD300 Thorlabs power meter (much more sensitive at this wavelength
- if the most sensitive power meter is not enough in SPA (that was the case in mortality study where pW power gives already high signal) the additional ND filter OD=1 is insert in the front of objective (the actual power is attenuated by factor 10 in comparison to measured value)
- InGaAs reference diode is used to correct the laser fluctuations (it's important especially for long measurements: for xy scans for example) and to trigger the scope
- CCD camera with imaging lens (plus illuminating lamp) monitor when exactly we shoot. This system is used to precisely align position of detector and then is off (in principle illuminating lamp is off) during measurements
- cooling is provided by Peltier module 19.2 W (RS Components) installed on the backside of the board. Theoretically it's good enough (T difference 75 C) but in practice we are not sure yet
- temperature is measured by PT100 installed on the board
- the box is ventilated with dry air (humidity 5%) so condensation is not a problem

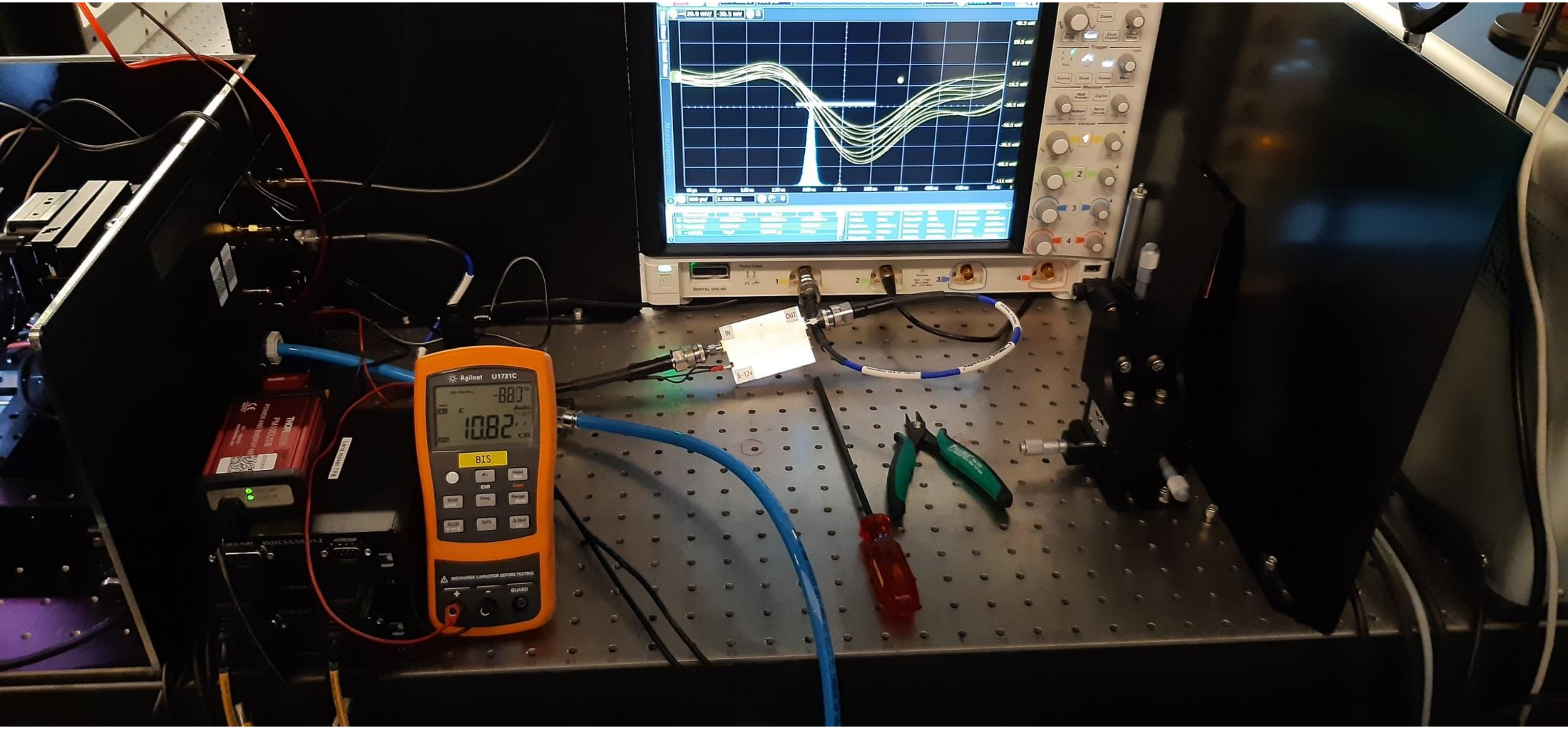
Kamil’s 3D printed holder for LGAD




BS
OBJ
XY
cooling
L
CCD
P
Z

Pad of LGAD visible by imaging system




Agilent U1731C
10.82
BIS
DISCHARGE CAPACITOR BEFORE TESTING
GUARD
IN
OUT
B-12V
DIGITAL DTS-300

Beam waist parameter

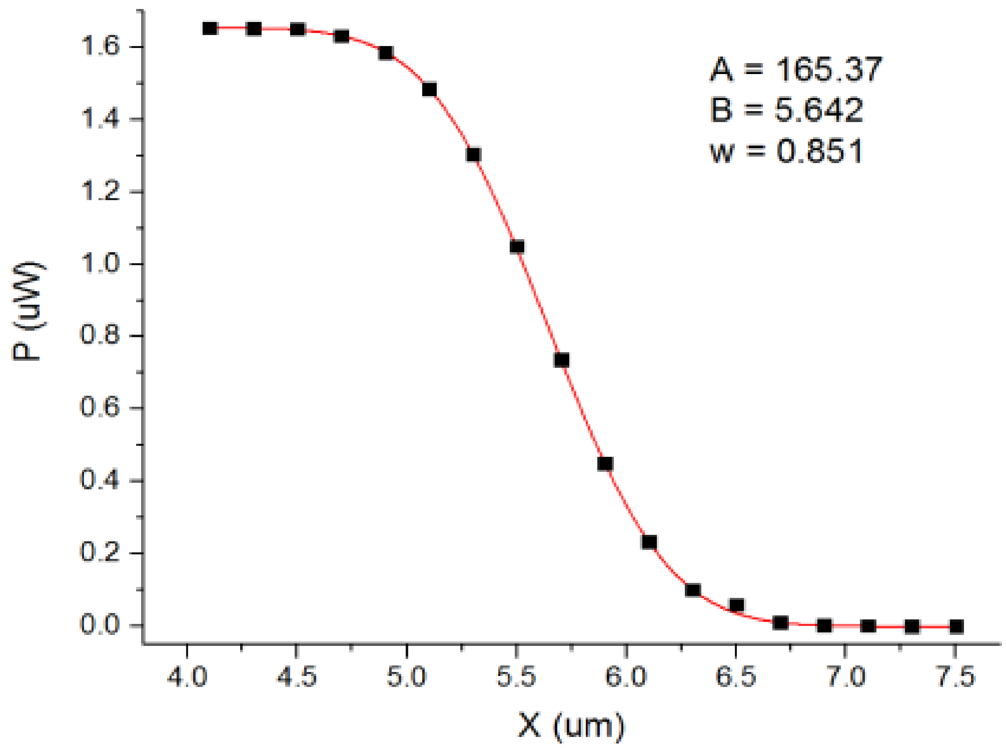
800 nm (SPA)

$$w - 1/e^2 \ radius \ Gaussian \ beam$$

$$P_{measured} = \frac{A}{2}\left[1 - erf\left(\frac{\sqrt{2}(x-B)}{w}\right)\right]$$

- **Rayleigh length is z_0=3.31 um.**
- **The waist** radius looks quite good **w_0=0.85 um.**
- **The beam diameter (1/e2) is 1.7 um** and this is actually limit of our resolution (stations are more precise).

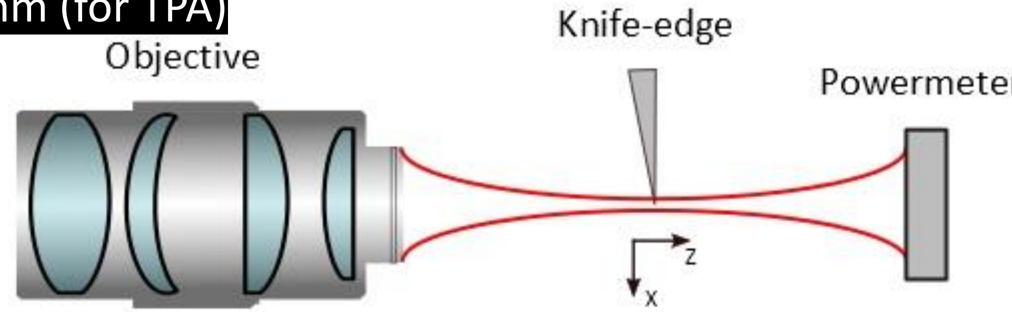
All these data are for 800 nm



Beam profile and parameters at 1550 nm (for TPA)

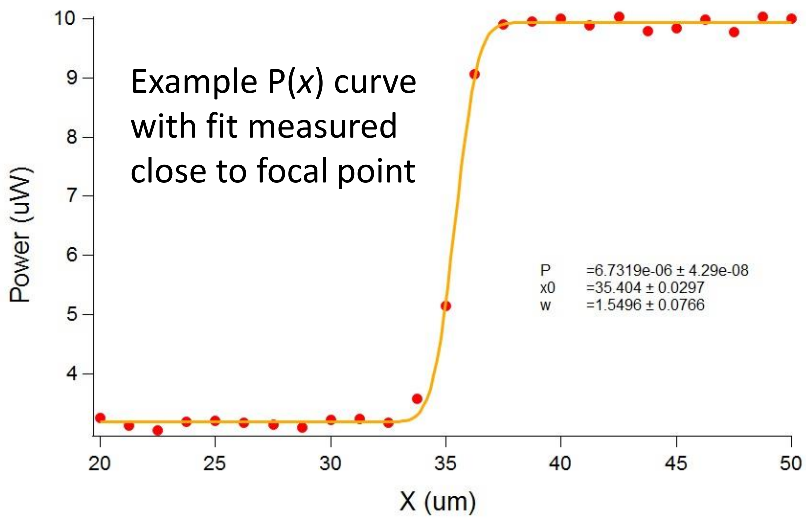
$$P_{measured} = \frac{P}{2}\left[1 - erf\left(\frac{\sqrt{2}(x - x_0)}{w}\right)\right]$$

$$w - 1/e^2\ radius Gaussian beam$$



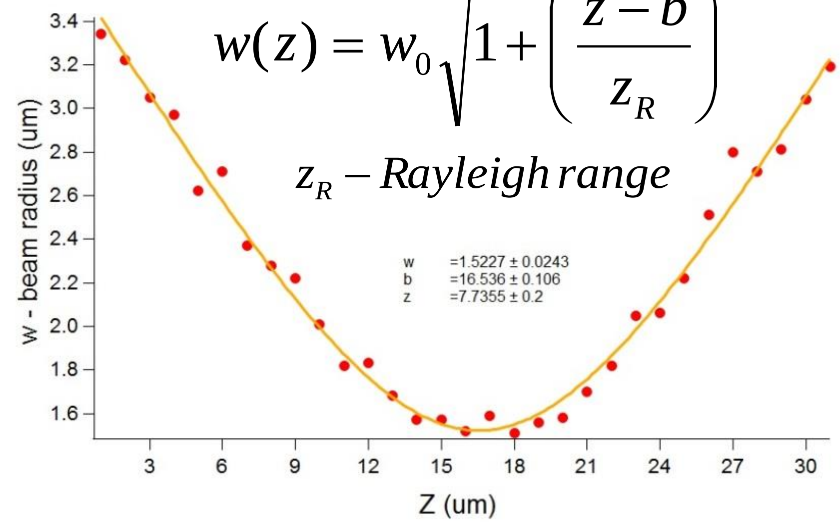
100X Mitutoyo Plan Apo NIR HR
Infinity Corrected Objective
λ = 1550 nm

1. P(x) measured for series of Z points around focal point
2. w(Z) obtained by fitting for every Z
3. w_0 and Z_R obtained by fitting w(Z) curve



$$w(z) = w_0\sqrt{1 + \left(\frac{z - b}{z_R}\right)^2}$$

$$z_R - Rayleigh\ range$$



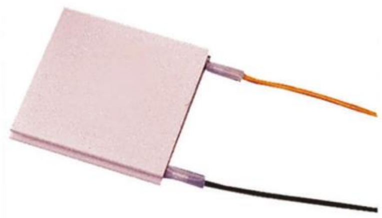
Final parameters (in air):
$w_0 = 1.52\ \mu m$
$Z_R = 7.74\ \mu m$

In Si : refractive index correction needed
$n = 3.48$ *at 1550 nm*

$NA = 0.31$ (nominal NA=0.7 but probably not valid for focal point)

Cooling system

Components:



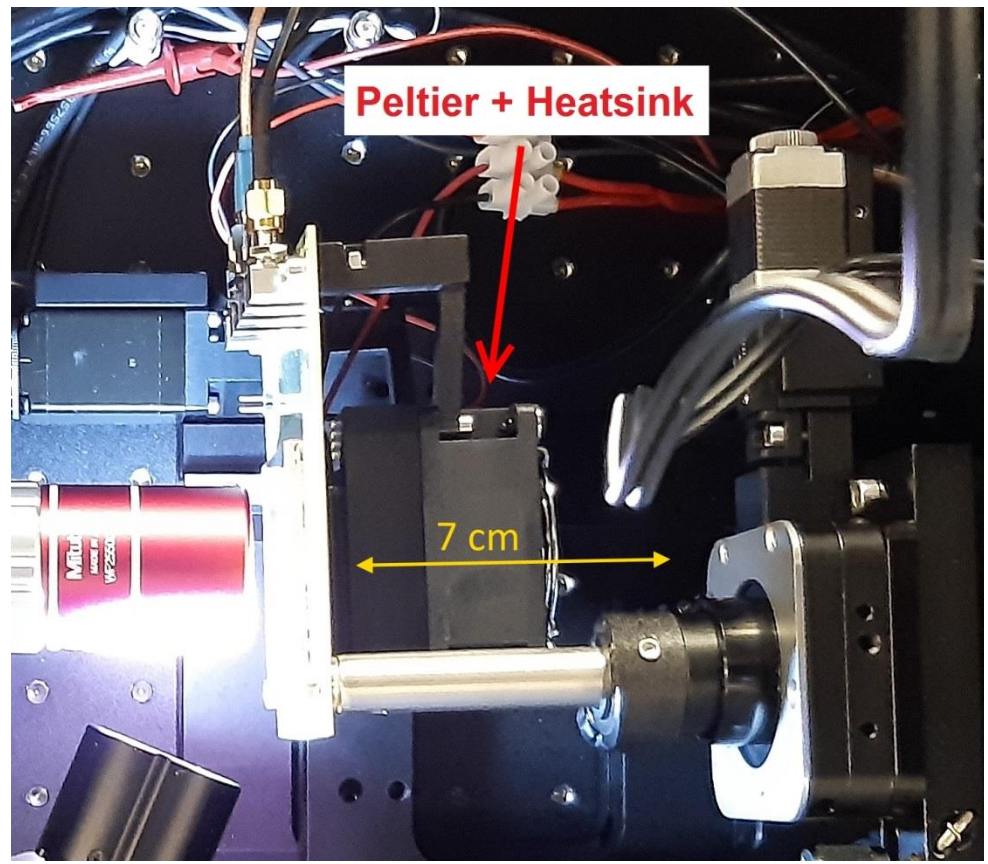
Peltier Module
19.2W, 8A, 3.8V, 30 x 30mm

Heatsink, Universal Square Alu with fan, 0.5K/W, 60 x 60 x 47mm

Non-Silicone Thermal Grease, 2.5W/m·K

Cooling is not powerful enough and should be improved to be able to reach -30°C

- Liquid cooled warm Peltier side (copy of JSI cooling plate)
- Close circuit chiller with coolant at -20C (e.g. Julabo)
- Replacement of UCSC boards with Al housing with second stage amplifiers only – enough signal with lasers) – easier mounting/shielding/cooling
- Isolation of housing/boards for more efficient use
- Currently dry air is flushed through the system – if required also LN2 can be used



Conclusion/Future plans

- ❑ Good progress on setup made in spite of difficult times
- ❑ TCT system functional, first measurements performed, optics understood
- ❑ Excellent beam parameters (waist, diameter) achieved for both fs-beam at 800nm and 1550 nm; Rayleigh length determined.
- ❑ Automated measurement and data acquisition built in.
- ❑ Cooling for measurements of irradiated devices under development.
- ❑ Both lines, fs-800 nm & fs-1550 adjusted, integrated well, functional
- ❑ TPA signal confirmed; Contribution from Three-Photon Absorption indicated (see next talk)

Future plans:

- ❑ Microscope setup to integrate in
- ❑ Intensity autocorrelation for independent pulse length measurement

More to come!

Acknowledgement

Special thanks to **Jakob Andreasson** from **ELI Beamlines, CZ – RP4 group** for providing us with fs-laser and instrumentation and a space in their lab that allowed us to perform this experiment.

Special thanks to **Mateusz Rebarz from ELI Beamlines, CZ – RP4 group, the "father" of the set up.** Thanks also for provided photos and slides.

Special thanks to **Kamil Kropielniczki from ELI Beamlines, CZ – RP4 group, for developing the cooling system**.

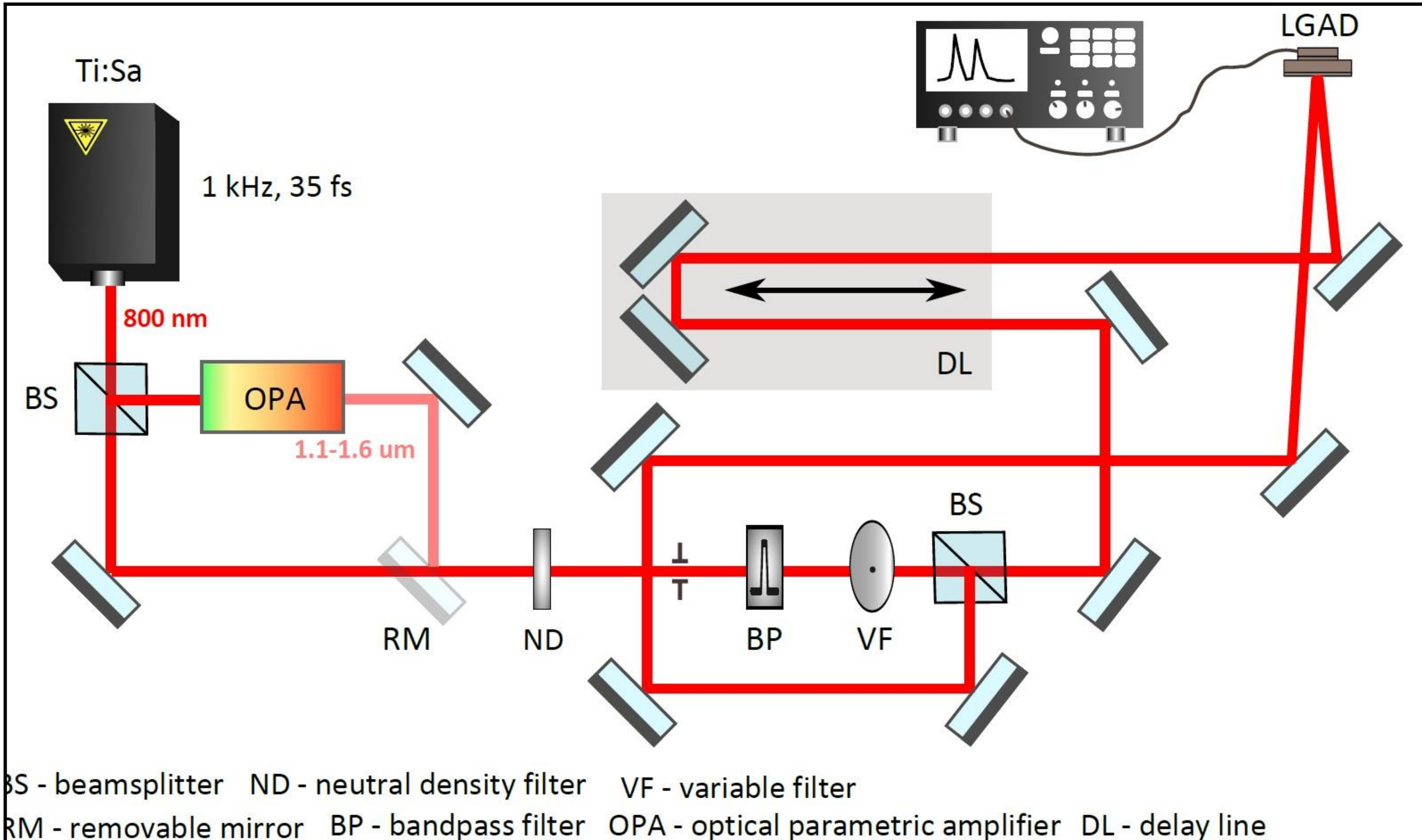
Thank you to all involved

BACKUP SLIDES

News for RD50

Montenegro team got an access to the ELI Beamline; application summitted to the ELI User Call was selected and priority given.

Reminder:
June 2020; 36th RD50 Workshop
Set up at ELI



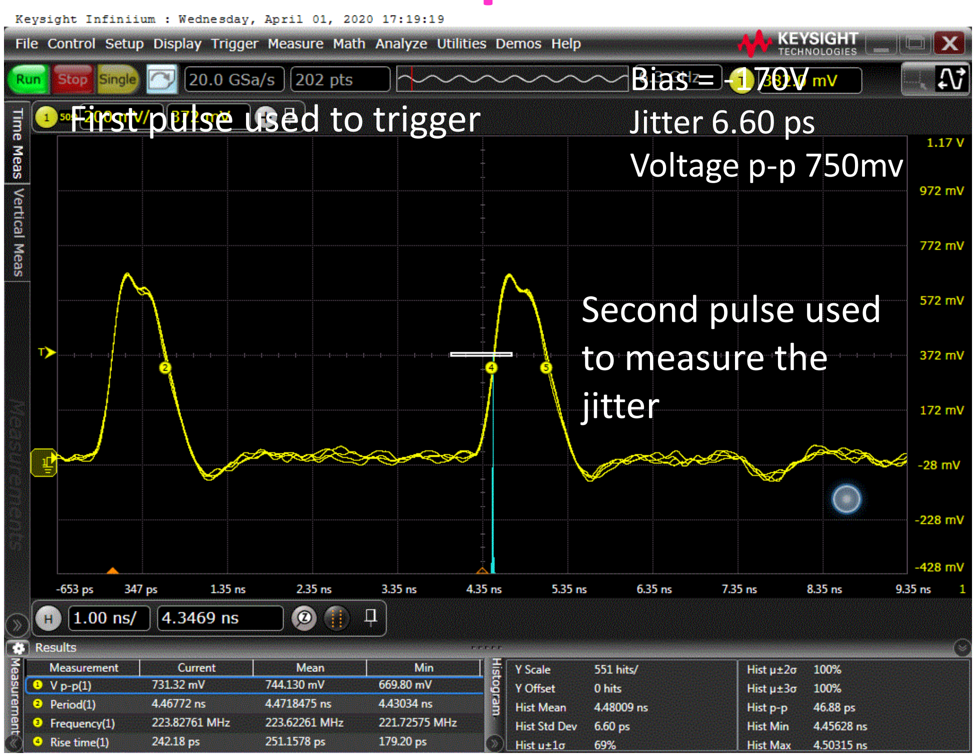
Reminder:

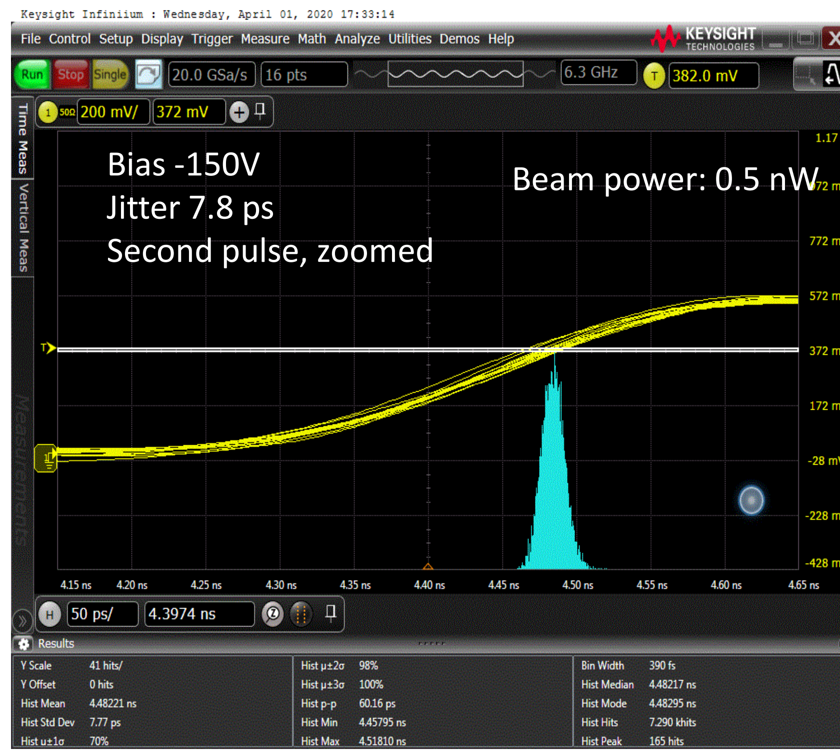
June 2020; 36th RD50 Workshop

First Jitter Measurement: SPA at 800 nm

beam 4mm^2
Power - below 1nW
Temp 22.4 C
Jumping amplitude up to 25 mV
Noise jumping cca 11mV

Jitter: 6.6 - 7.8 ps





https://indico.cern.ch/event/918298/contributions/3880602/attachments/2049401/3434665/RD50_talk_LGAD_ELI-02.06.2020.pdf

Key components

Laser: Astrella (Coherent) - 800 nm, 7 mJ, 35 fs, 1 kHz

OPA: Topas (LightConversion) – tunable 1160-2600 nm

Objective: 100X Plan Apo NIR
Infinity Corrected (Mitutoyo)
(New investment: 11.000 EUR)

Osciloscope: 6 GHz (Keysight Infinium)
DSOS604A

HV power supply: EB12003050400000200 (Iseg)
(New investment: 10.000 EUR)

Powermeter: S132C Slim Ge Photodiode
700 - 1800 nm with USB interface (Thorlabs)
(New investment: 1400 EUR)

XY stage: 8MTOM2-1 (Standa)
Resolution: 156 nm, Range: 4 mm
(New investment: 1.700 EUR)

ZX stage: 8MTF (Standa)
Resolution: 310 nm, Range: 75 mm

Faraday cage: Al box (Entwicklungsbuero)
(New investment: 1.400 EUR)

Imaging system CCD: acA1600-20um (Basler)

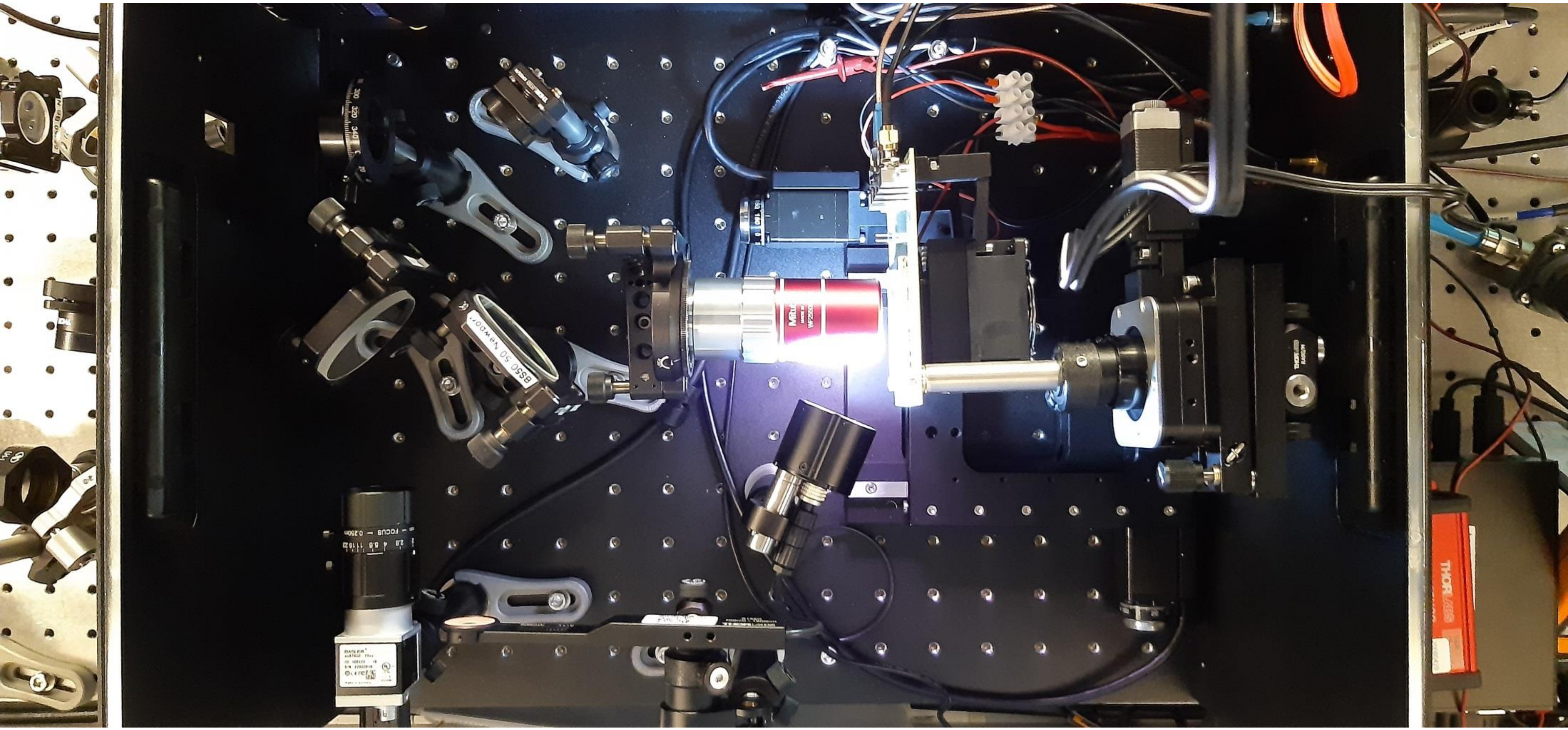
Small optics investment

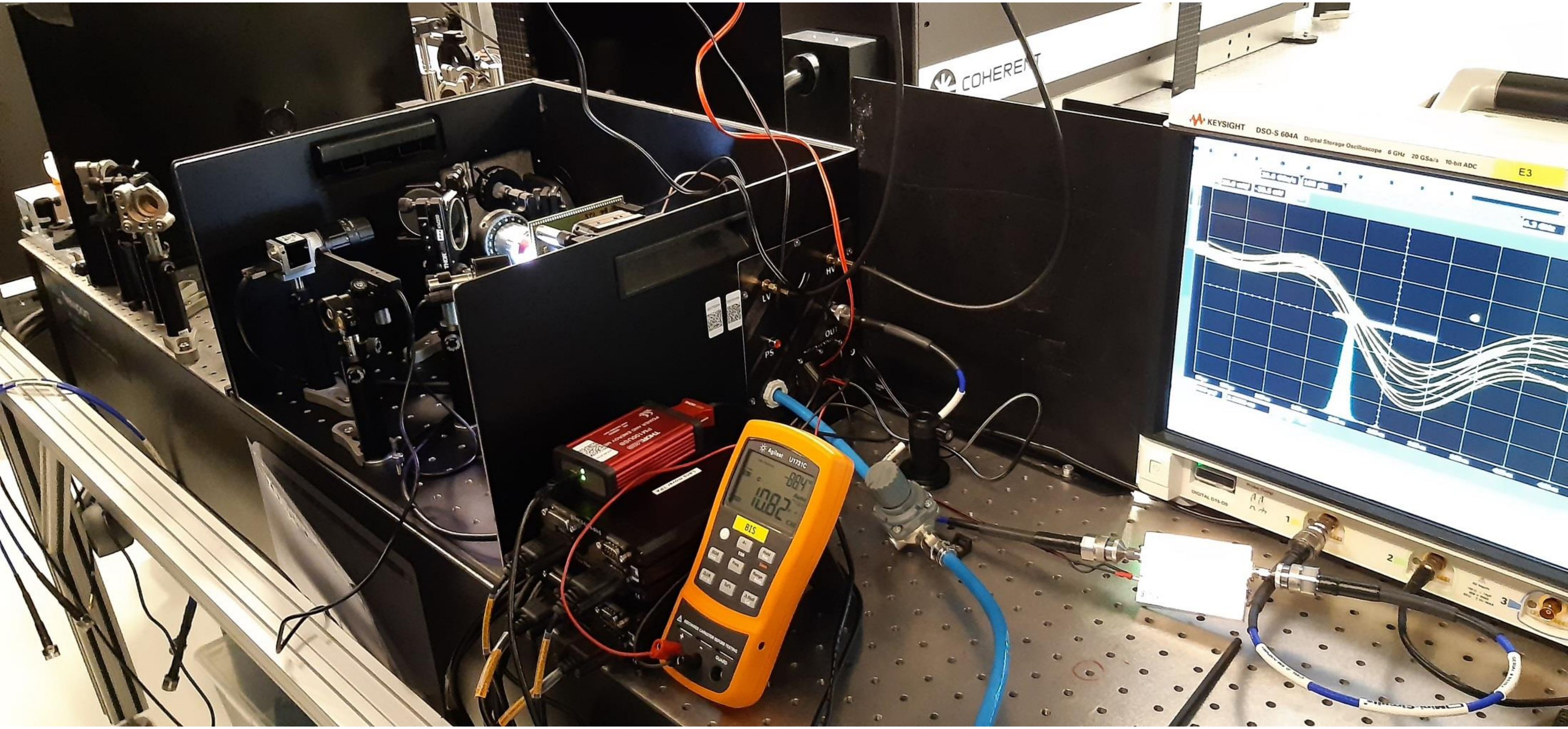
Optics		Price
Broadband beamsplitter 1290 – 1580 nm	10Q40BS.3 (Newport)	295 EUR
Bandpass filter 1550 nm	FB1550-40 (Thorlabs)	90 EUR
Circular Variable ND Filter 250-2500 nm	100FS04DV.4 (Newport)	470 EUR
NIR Absorptive ND filter 0D=0.3	NENIR03A (Thorlabs)	55 EUR
NIR Absorptive ND filter 0D=1	NENIR10A (Thorlabs)	55 EUR
NIR Absorptive ND filter 0D=2	NENIR20A (Thorlabs)	55 EUR
NIR Absorptive ND filter 0D=3	NENIR30A (Thorlabs)	55 EUR
Longpass filter cut on 1100 nm	FELH1100 (Thorlabs)	150 EUR
Longpass filter cut on 1400 nm	FELH1400 (Thorlabs)	150 EUR

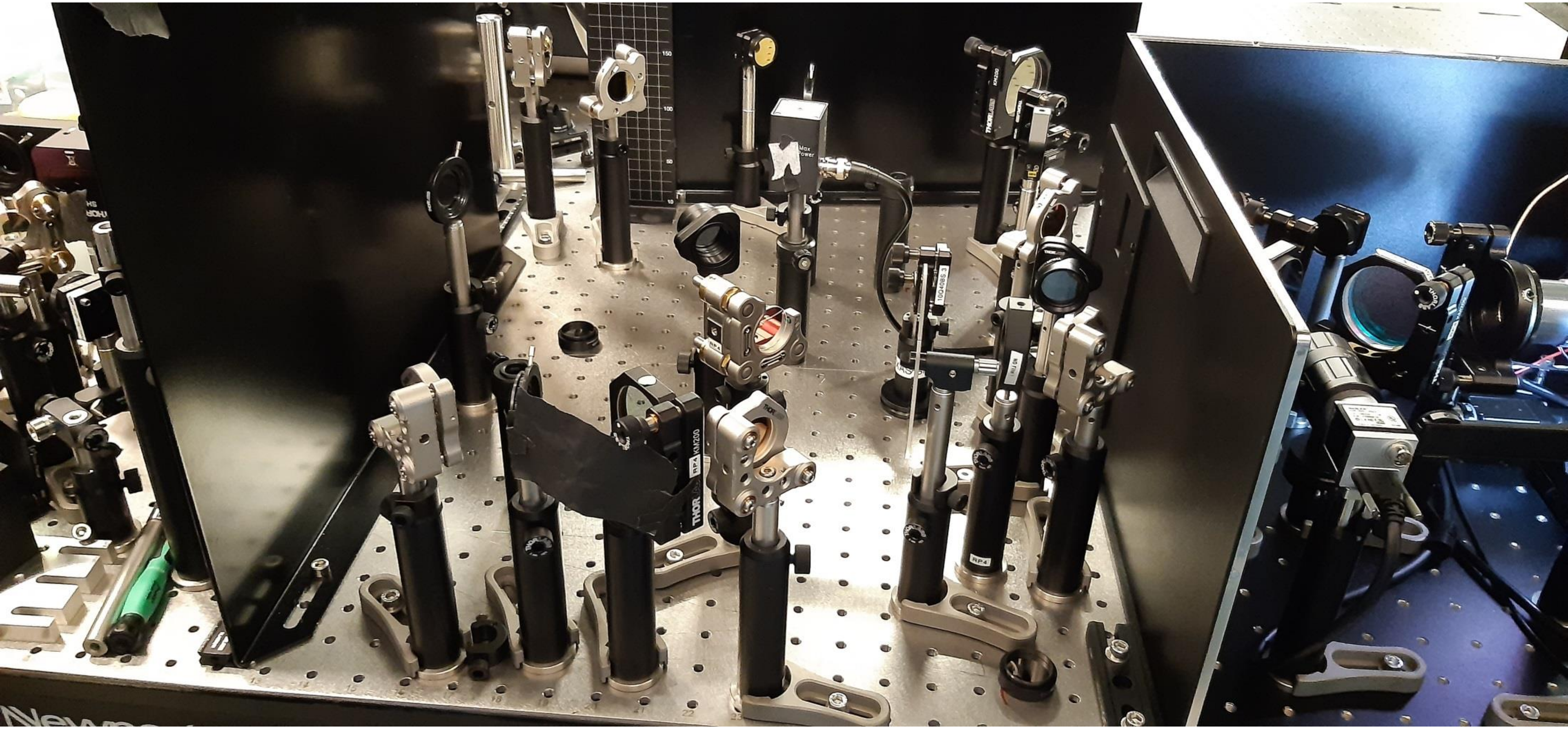


Additional remarks

- Initially the dichroic mirror was brought but then it was realized that is not optimal solution because illumination, imaging and power measurement cannot be done at the same time. This mirror went to another setup so it Is not counted as investment for our setup.
- Instead I bought beam splitter which gives exactly 50/50 at 1550 nm (included in the list).
- It was also found that the long pass filters are not very useful for the moment. It was hoped to use them to reject OPA residuals without narrowing pulse bandwidth. Unfortunately these filters don't reject fully residuals so we use 1550 nm bandpass filter which clean up the beam very well. Anyway we kept the long pass filters at this setup because they can be potentially useful for additional filtering.
- It is clear that bandpass filter limits the bandwidth (in our case from 60 to 40 nm) and stretch the pulse from 60 fs to about 90 fs (it's estimate not measurement).
- ELI Beamlines/R4 group plan to buy set of pulse diagnostic devices next year to their lab so we'll be able to measure pulse duration in TPA/SPA experiment. However **90 fs** (possibly a bit longer) is still good enough to easily achieve TPA regime and it's much shorter than response of studied systems.

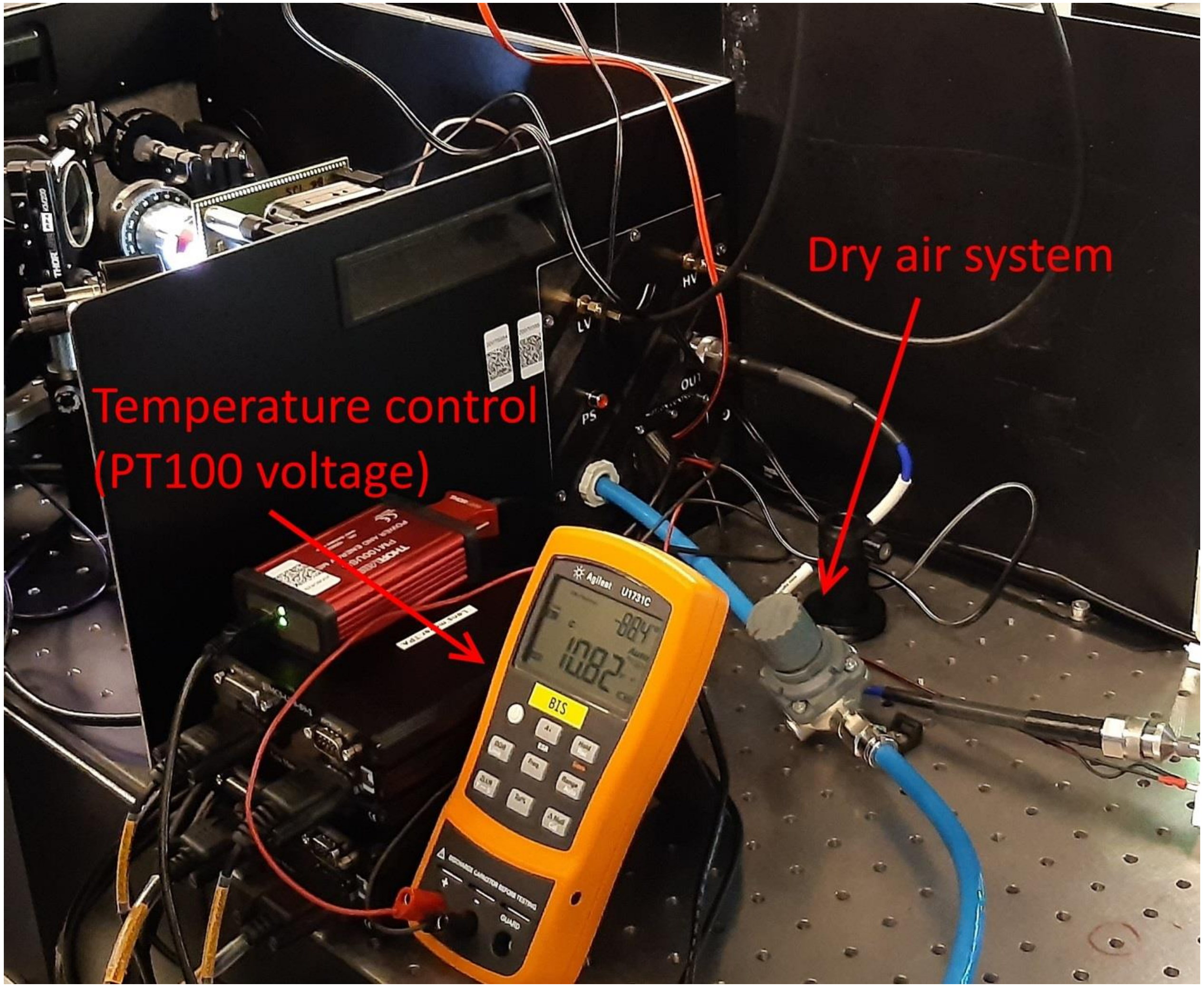



COHERENT
KEYSIGHT
DSO-S 604A Digital Storage Oscilloscope 6 GHz 20 GSa/s 10-bit ADC
E3
Agilent U1731C
LV
HV
OUT
PS


150
100
50
KM200
RP4

Cooling system (II)

Facility is equipped with dry air system: RH 5%   Dew point: - 21 °C
Lab Temperature: 20 °C   (if -30 °C is required nitrogen can be used)



Temperature is measured by PT100 installed on the board.

So far the system is not reliable. It shows wrong temperature where standard PT100 tables are used. For example it shows +3 °C when clear frostiness appears on the board. Hopefully proper calibration with a reference sensor will solve the problem.