Method and portable bench for tests of the laser optical calibration system components for the Baikal-GVD underwater neutrino Cherenkov telescope

Konrad A. Kopański

Wojciech Noga, Dariusz Góra, Apoorva Bhatt, Paweł Malecki, Jarosław Stasielak, Mateusz Wiśniewski

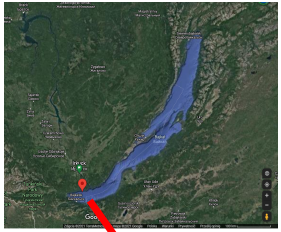
on behalf of the Baikal-GVD Collaboration

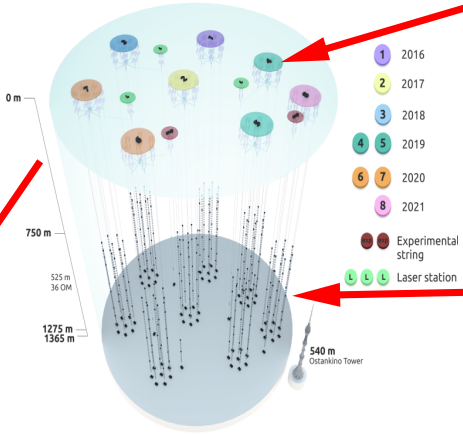
International Cosmic Ray Conference 12-23 July 2021

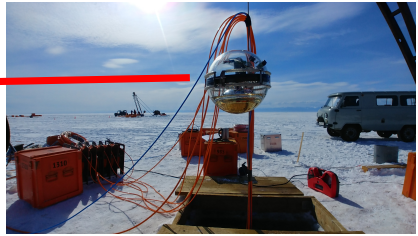
THE HENRYK NIEWODNICZAŃSKI
INSTITUTE OF NUCLEAR PHYSICS
POLISH ACADEMY OF SCIENCES

BAIKAL-GVD

Baikal **G**igaton **V**olume **D**etector



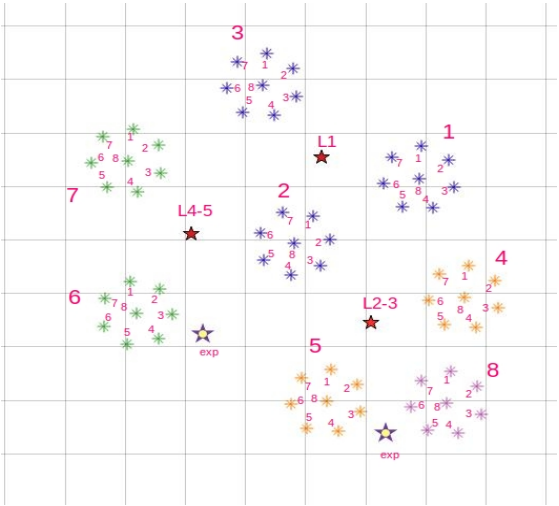




0.4 km^3 effective volume

2304 **O**ptical **M**odules

Baikal-GVD Laser



LASER:

DPSS Q-switched YAG: ND3

wavelength: **532 nm**

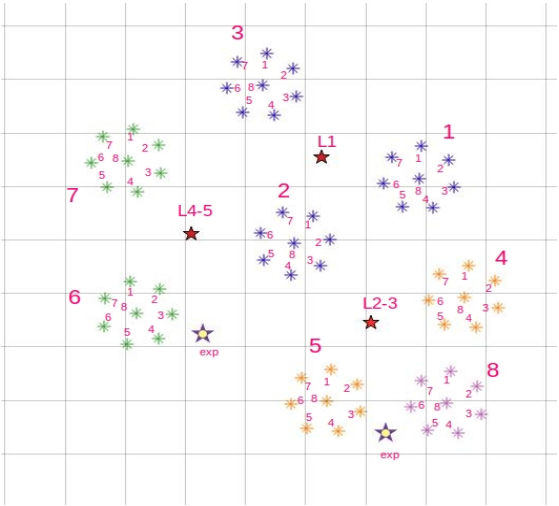
pulse duration: (FWHM: $\sim$**1 ns**)

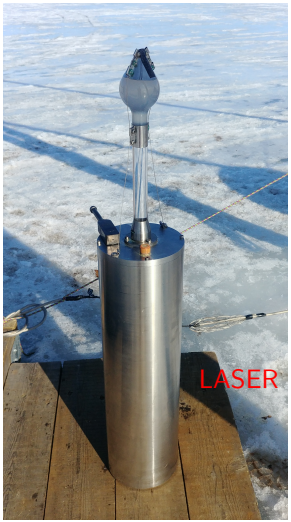
pulse repetition: **10 Hz**

pulse energy: **370 µJ**

pulse intensity: **5e14** photons

Baikal-GVD Laser





LASER:

DPSS Q-switched YAG: ND3

wavelength: **532 nm**

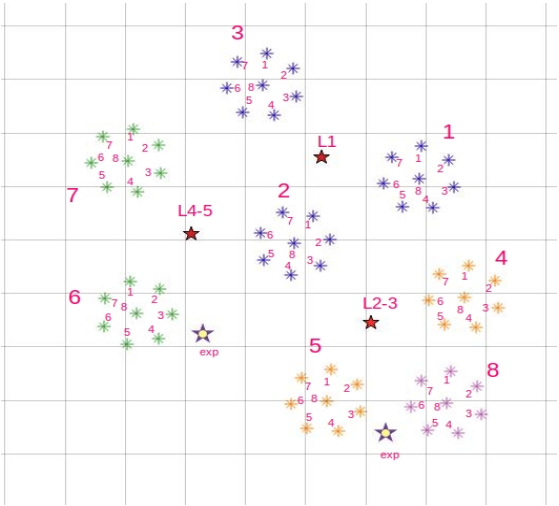
pulse duration: (FWHM: $\sim$**1 ns**)

pulse repetition: **10 Hz**

pulse energy: **370 µJ**

pulse intensity: **5e14** photons

Baikal-GVD Laser



LASER:

DPSS Q-switched YAG: ND3

wavelength: **532 nm**

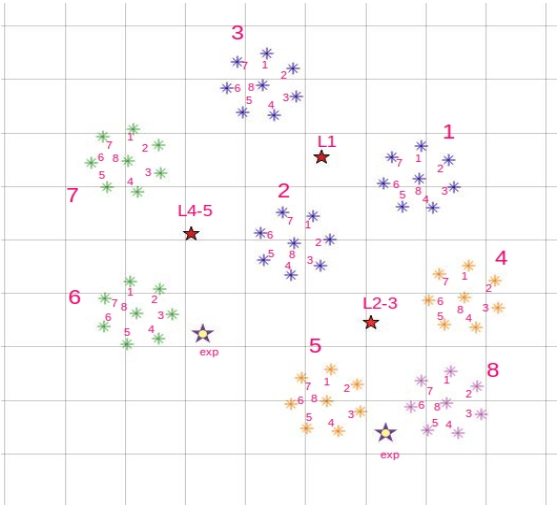
pulse duration: (FWHM: $\sim$**1 ns**)

pulse repetition: **10 Hz**

pulse energy: **370 µJ**

pulse intensity: **5e14** photons

Baikal-GVD Laser



LASER:

DPSS Q-switched YAG: ND3

wavelength: **532 nm**

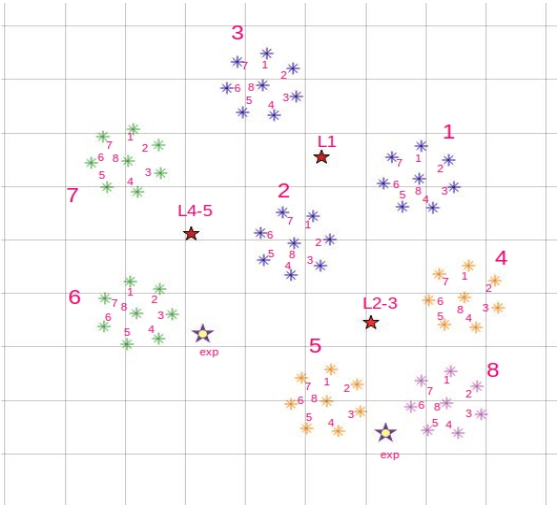
pulse duration: (FWHM: $\sim$**1 ns**)

pulse repetition: **10 Hz**

pulse energy: **370 µJ**

pulse intensity: **5e14** photons

Baikal-GVD Laser



LASER:

DPSS Q-switched YAG: ND3

wavelength: **532 nm**

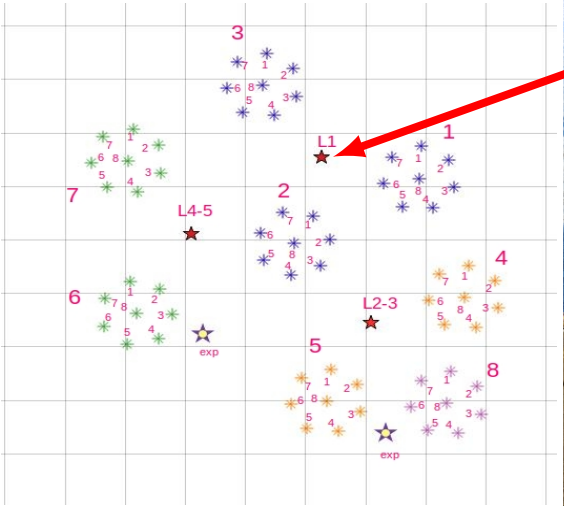
pulse duration: (FWHM: $\sim$**1 ns**)

pulse repetition: **10 Hz**

pulse energy: **370 µJ**

pulse intensity: **5e14** photons

Baikal-GVD Laser



LASER:

DPSS Q-switched YAG: ND3

wavelength: **532 nm**

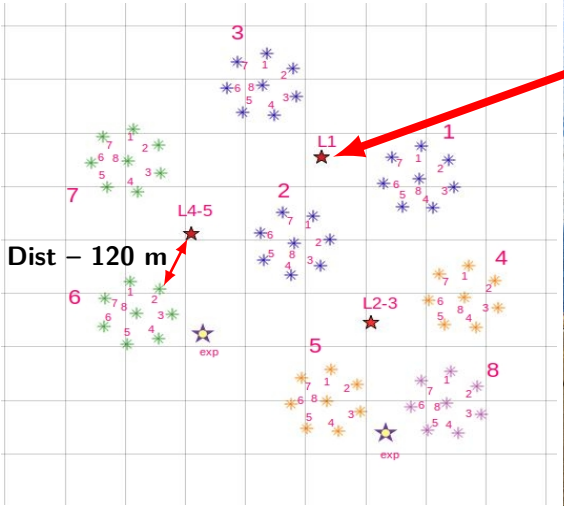
pulse duration: (FWHM: $\sim$**1 ns**)

pulse repetition: **10 Hz**

pulse energy: **370 µJ**

pulse intensity: **5e14** photons

Baikal-GVD Laser



LASER:

DPSS Q-switched YAG: ND3

wavelength: **532 nm**

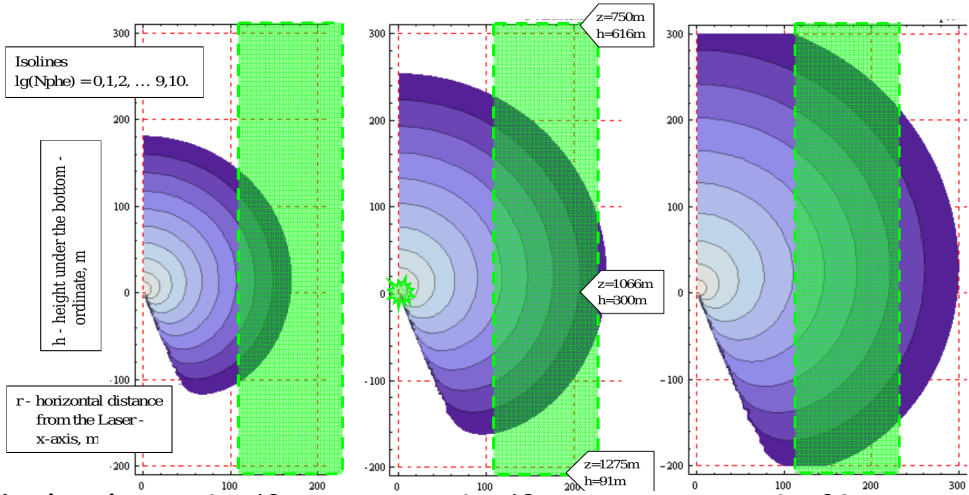
pulse duration: (FWHM: $\sim$**1 ns**)

pulse repetition: **10 Hz**

pulse energy: **370 µJ**

pulse intensity: **5e14** photons

Laser Calibration System – diffuser



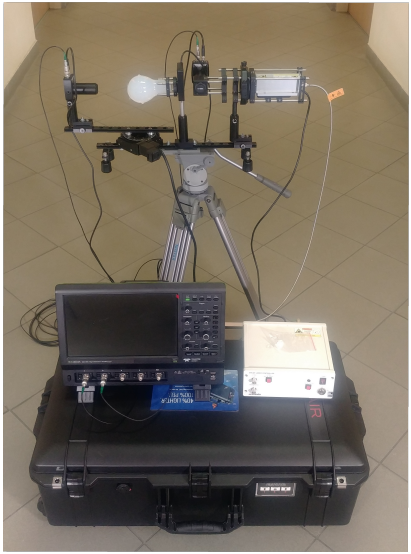
Absorption length: **L_a: 12 m** **L_a: 18 m** **L_a: 24 m**

A.I Panfilov Dubna 2016-12-01

Task description

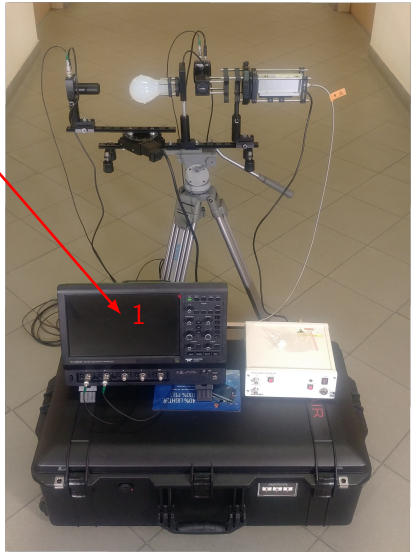
- **Optical diffusers tests, to propose modifications improving their parameters**, including improving the illumination of distant optical modules without overexposing the nearest ones (in laser horizon).
- **Digital testing data are the input for a dedicated simulation** of photon propagation in water
- **Testing of the laser sets under the BGVD Winter Expedition conditions ("on ice", without darkroom) on existing lasers, used in the experiment**, to map the whole sets.
- The **test bench**, combined with the **simulation**, is a **fully comprehensive solution** that facilitates work both at the level of experiment planning (virtual modification) and at the level of the system operator (service data).

Portable measuring station



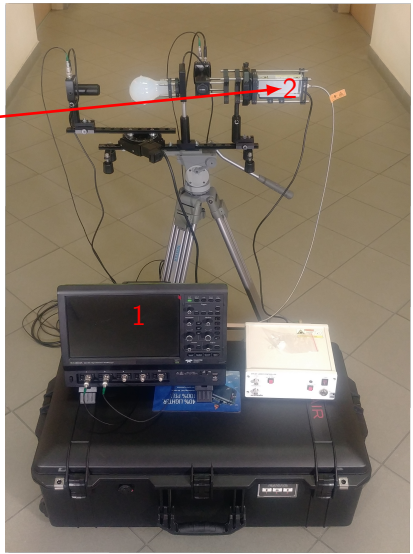
Portable measuring station

1. Teledyne Lecroy HDO 4034A oscilloscope for bench control and measurement



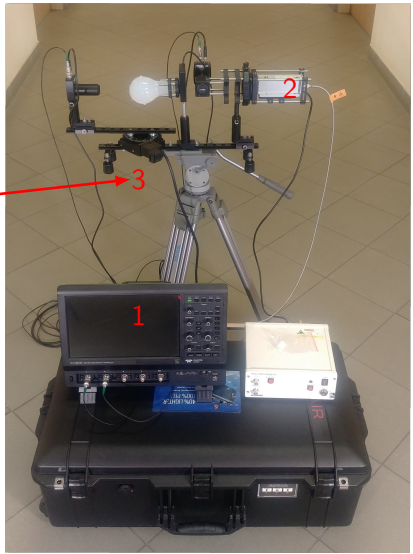
Portable measuring station

1. Teledyne Lecroy HDO 4034A oscilloscope for bench control and measurement
2. Q-switched DPSS Laser (532 nm, 137 µJ) or calibration system lasers



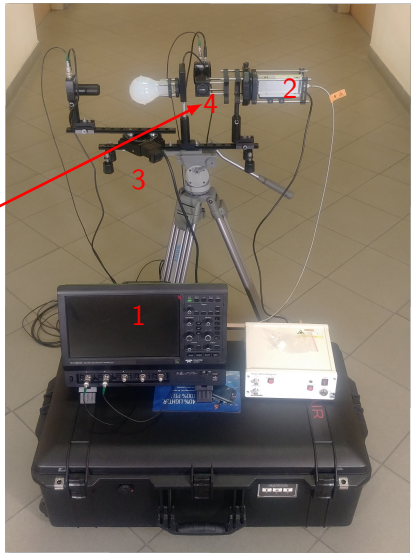
Portable measuring station

1. Teledyne Lecroy HDO 4034A oscilloscope for bench control and measurement
2. Q-switched DPSS Laser (532 nm, 137 µJ) or calibration system lasers
3. Modular bench with rotary platforms



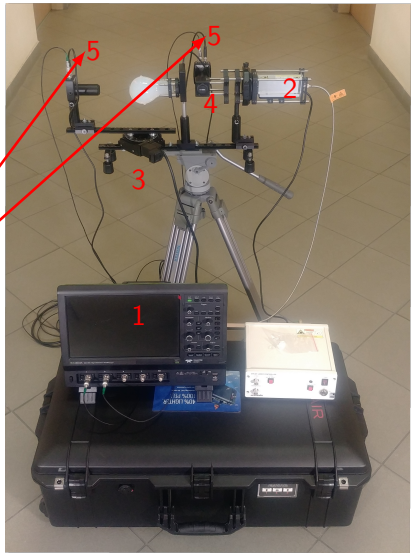
Portable measuring station

1. Teledyne Lecroy HDO 4034A oscilloscope for bench control and measurement
2. Q-switched DPSS Laser (532 nm, 137 µJ) or calibration system lasers
3. Modular bench with rotary platforms
4. Beam splitter with attenuators sets



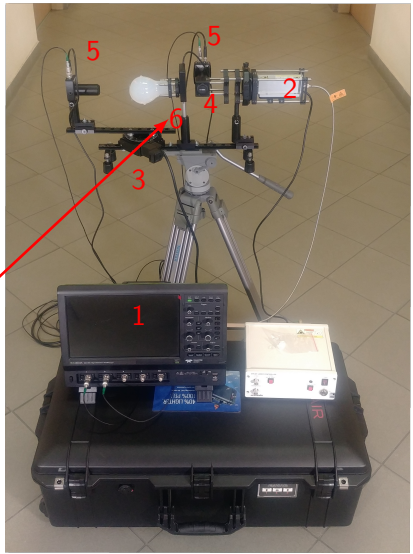
Portable measuring station

1. Teledyne Lecroy HDO 4034A oscilloscope for bench control and measurement
2. Q-switched DPSS Laser (532 nm, 137 µJ) or calibration system lasers
3. Modular bench with rotary platforms
4. Beam splitter with attenuators sets
5. Amplified Si Detectors (PDA 100A2)



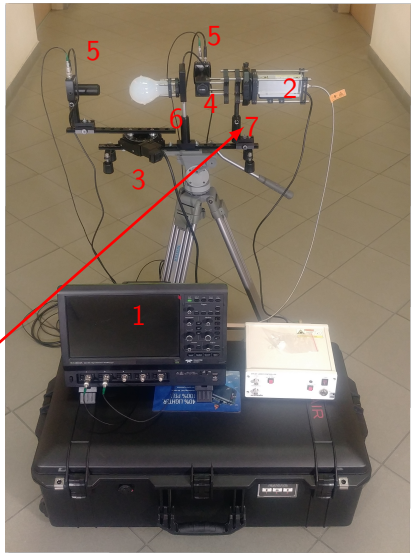
Portable measuring station

1. Teledyne Lecroy HDO 4034A oscilloscope for bench control and measurement
2. Q-switched DPSS Laser (532 nm, 137 µJ) or calibration system lasers
3. Modular bench with rotary platforms
4. Beam splitter with attenuators sets
5. Amplified Si Detectors (PDA 100A2)
6. Universal holder for tested components



Portable measuring station

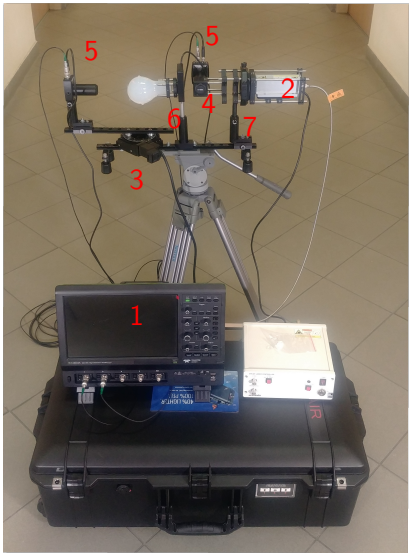
1. Teledyne Lecroy HDO 4034A oscilloscope for bench control and measurement
2. Q-switched DPSS Laser (532 nm, 137 µJ) or calibration system lasers
3. Modular bench with rotary platforms
4. Beam splitter with attenuators sets
5. Amplified Si Detectors (PDA 100A2)
6. Universal holder for tested components
7. Universal positioning bracket for lasers



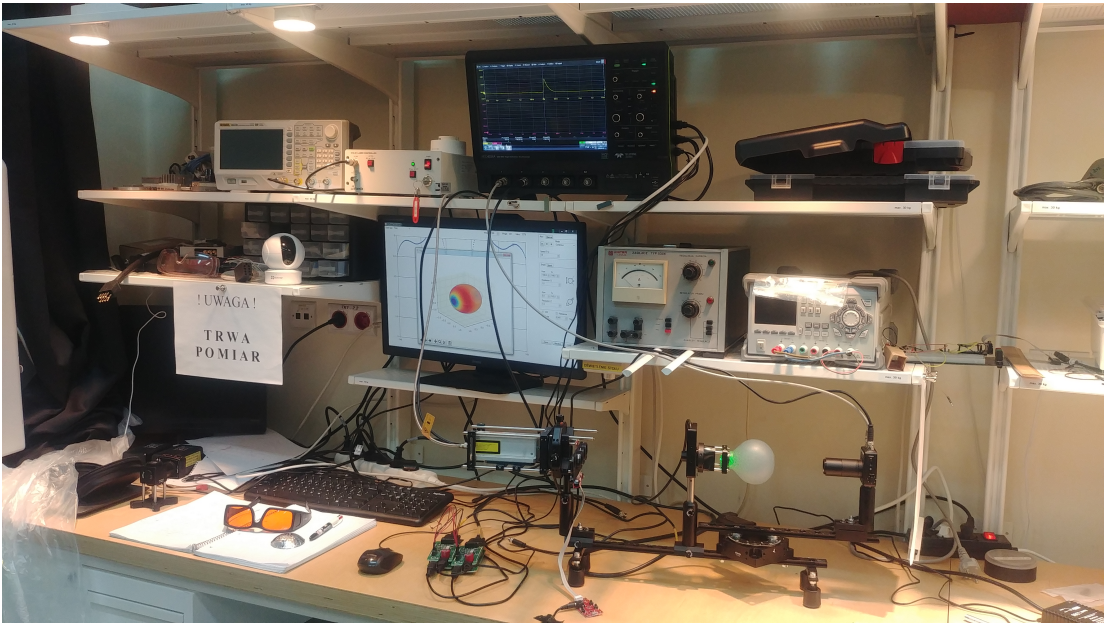
Portable measuring station

1. Teledyne Lecroy HDO 4034A oscilloscope for bench control and measurement
2. Q-switched DPSS Laser (532 nm, 137 µJ) or calibration system lasers
3. Modular bench with rotary platforms
4. Beam splitter with attenuators sets
5. Amplified Si Detectors (PDA 100A2)
6. Universal holder for tested components
7. Universal positioning bracket for lasers

Beam Energy Meter (PM100USB + ES11C)

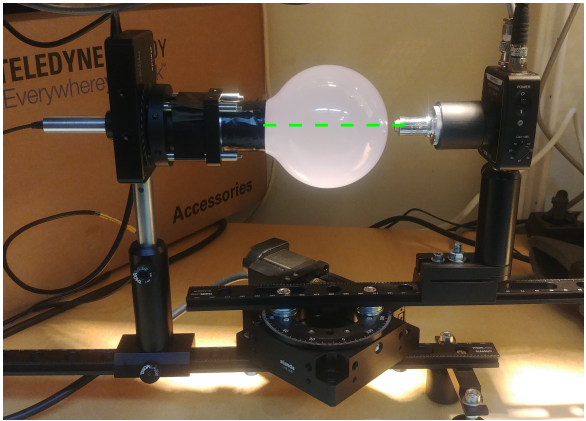


LABORATORY MEASUREMENTS


!UWAGA!
TRWA
POMIAR

Near scan

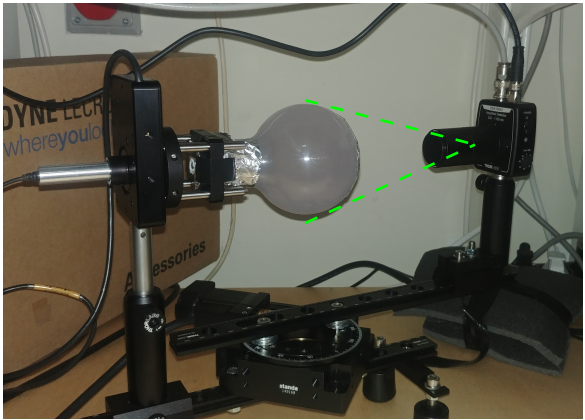
- DIFFERENTIAL SCANNING
- Study of the **light emission directly from the diffuser** surface in a very narrow angular range (almost collimated beam).
- **Examination of the diffuser material** (determining the optical parameters of the material), as well as determine the impact of minor imperfections of the structure for the final effect.



Far scan

- INTEGRAL SCANNING
- Effect of **"observing" the whole diffuser from a distance** along with taking into account the absorption and scattering of the medium in which the measurement is carried out.

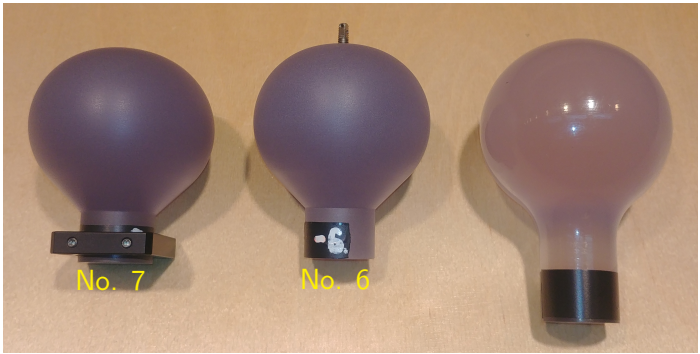
Preliminary tests using simulations have shown, that having two types of measurements may give a quite complete set of data for accurate simulation.



Research objects

The presented measurements were made on a set of three diffusers.

- Two **"gray"** diffusers have differed in parameters.
- The **"white"** diffuser in its original configuration in telescope structure was equipped with a metal hood.

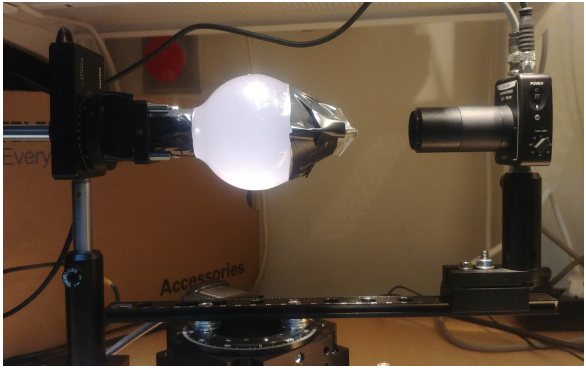


TEST RESULTS

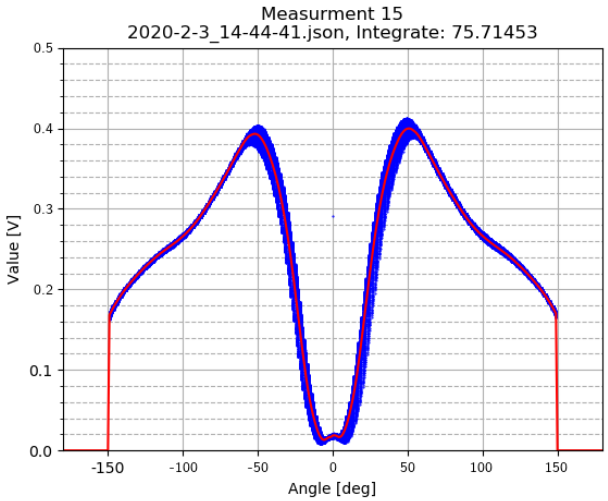
Test bench measurement

The measurement consisted of placing the diffuser with a metal hood in a motorized holder, enabling rotation around its symmetry axis. The silicon detector was located on the arm, placed on the motorized stage allowing the detector to rotate around the diffuser (scanning). The light source was a DPSS laser with a wavelength of 532 nm.

- Medium: air
- Distance: 14 cm
- Detector "see" only the entire surface

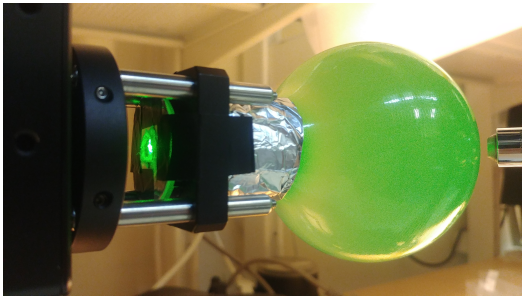


Test bench measurement result

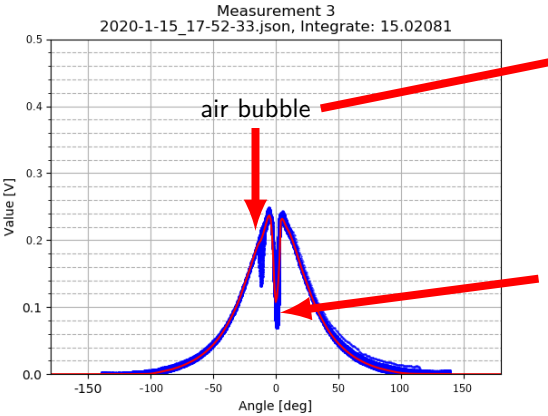


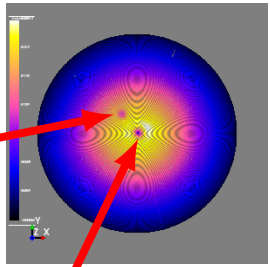
- The graph shows the results of the diffuser scan for many planes (blue envelope), the red curve shows the average result. Data was collected automatically every 1 deg (encoder readouts).
- In the presented test stand "0" represents the top of the diffuser. Such markings significantly simplified the positioning and calibration of the stand due to its universality.

White diffuser – near scan

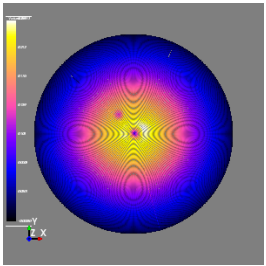


White diffuser – near scan results

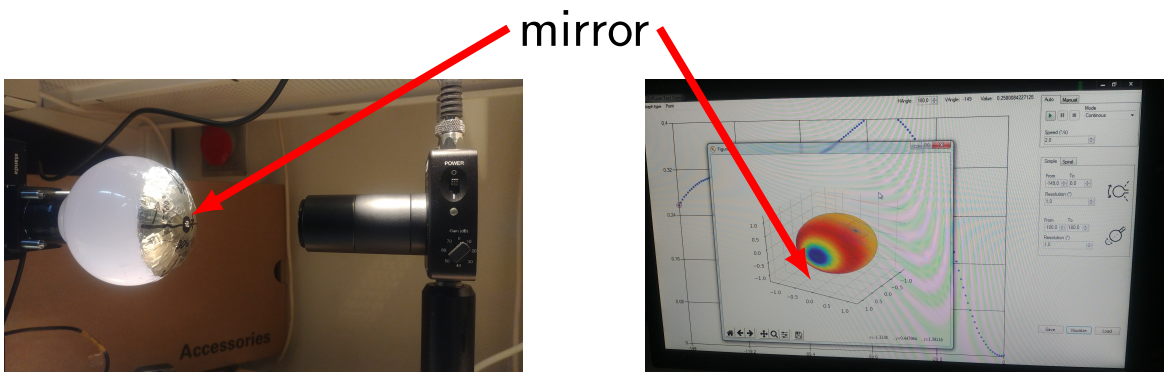




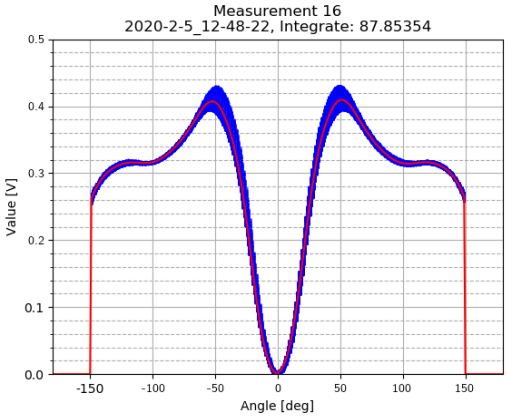
Azimuth 0 deg
Elevation 0 deg

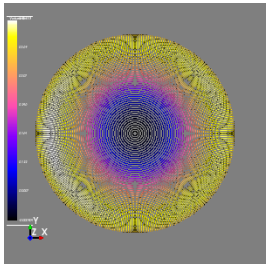


White diffuser – far scan

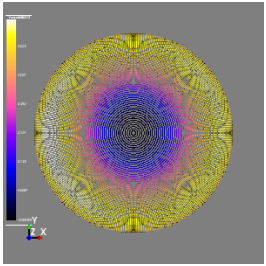


White diffuser with mirror – far scan result

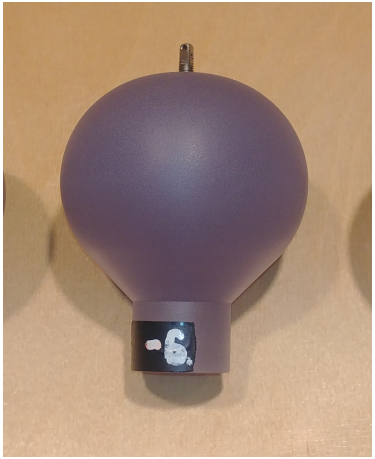


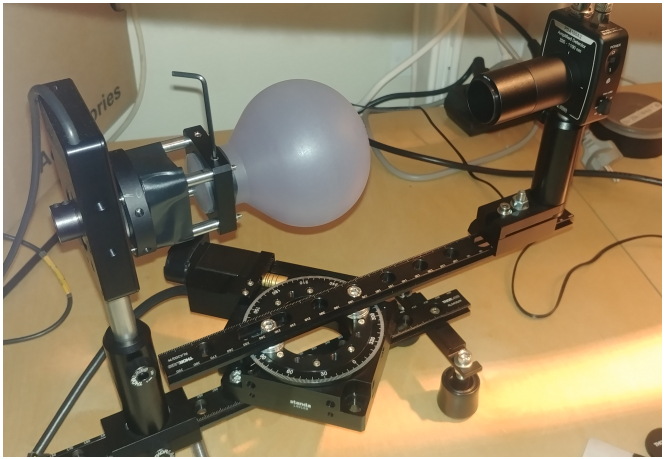


Azimuth 0 deg
Elevation 0 deg

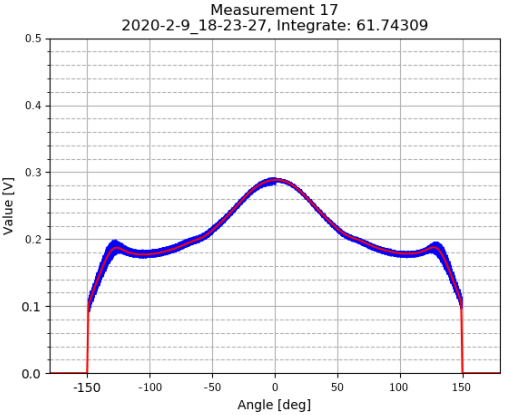


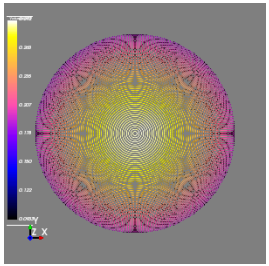
Diffuser No. 6 – far scan



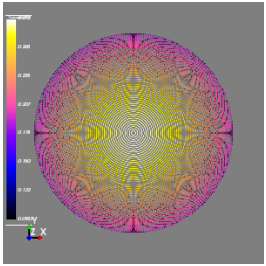


Diffuser No. 6 – far scan results





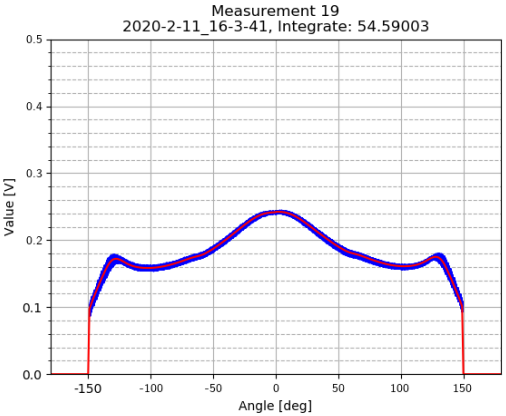
Azimuth 0 deg
Elevation 0 deg

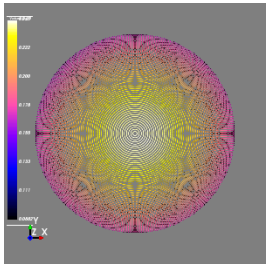


Diffuser No. 7 – far scan

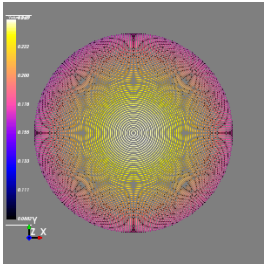
- Diffuser No. 7 does not have a screw on a top.
- The **cage system mounting bracket** is visible at the bottom. The use of this system enables very fast replacement of a diffusers in the test stand

Diffuser No. 7 – far scan results

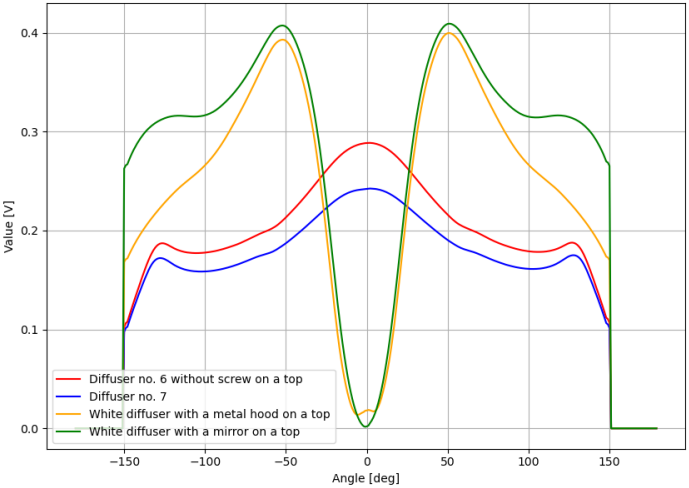




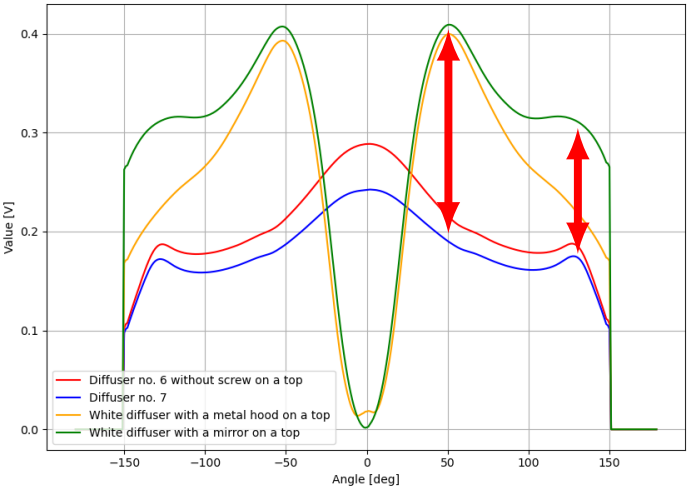
Azimuth 0 deg
Elevation 0 deg



Diffusers scans – results comparison

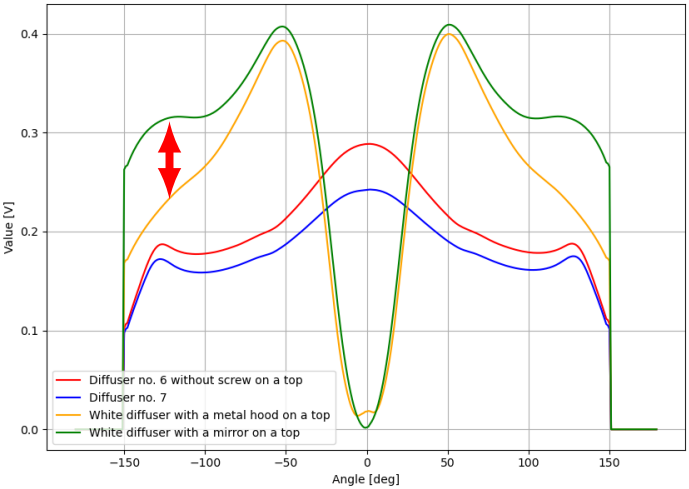


Diffusers scans – results comparison



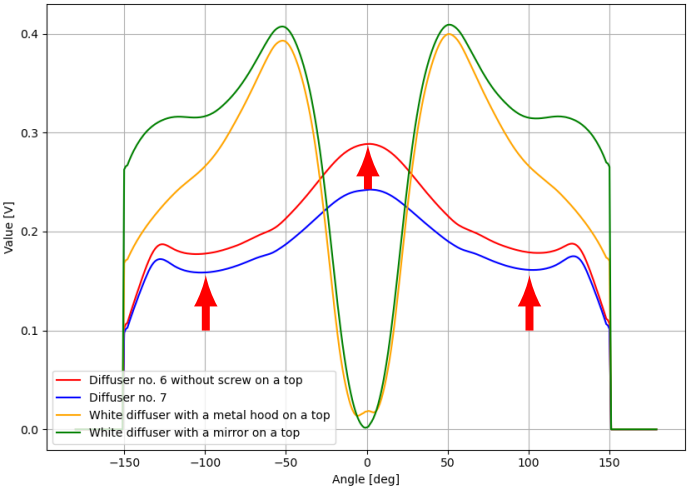
- Big difference in attenuation between "white" and "grey" diffusers materials

Diffusers scans – results comparison



- Big difference in attenuation between "white" and "grey" diffusers materials
- The mirror on top improves isotropy in the backward region

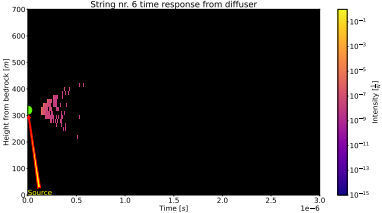
Diffusers scans – results comparison



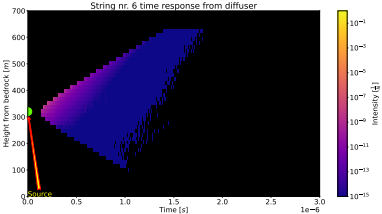
- Big difference in attenuation between "white" and "grey" diffusers materials
- The mirror on top improves isotropy in the backward region
- Visible doping effect in a "grey" diffusers material

SIMULATION - PRETORIAN

Pretorian - hybrid method

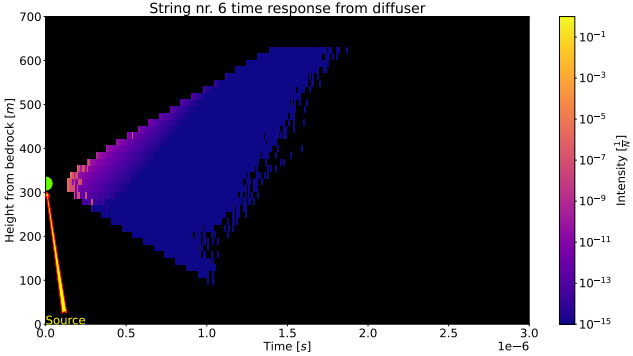


Only RT



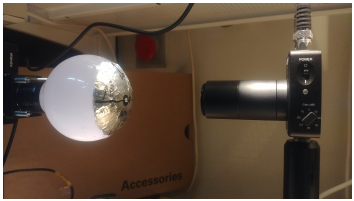
Approximation

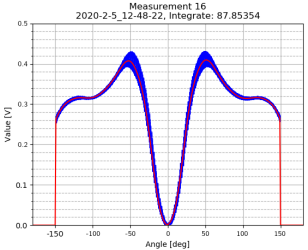
Simulation of diffuser, 5 ns bin, results generated for similar time.



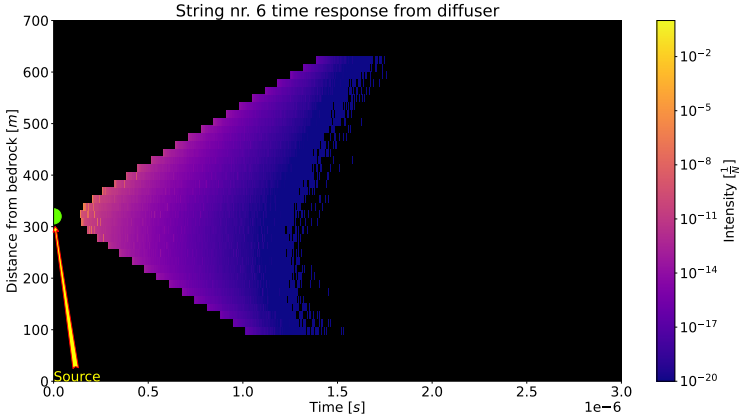
Hybrid method

Diffuser simulation

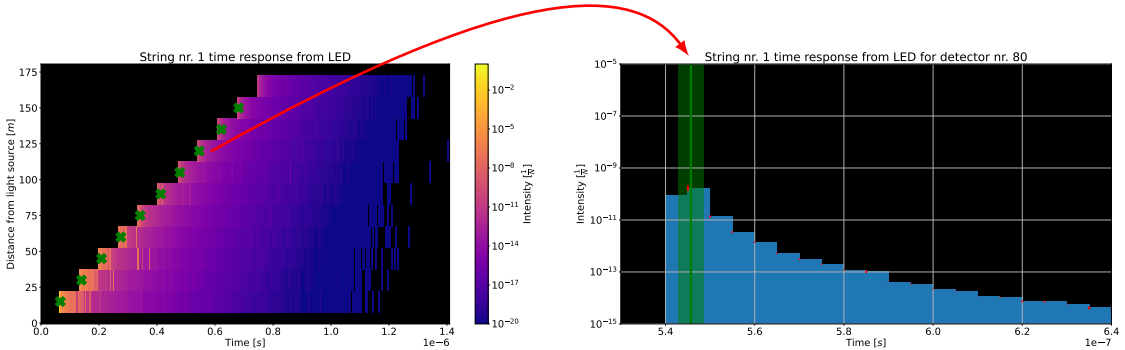




Input for simulation



LED test run


String nr. 1 time response from LED
Distance from light source [m]
Time [s]
1e−6
Intensity [$\frac{1}{m^2}$]
String nr. 1 time response from LED for detector nr. 80
Intensity [$\frac{1}{m^2}$]
Time [s]
1e−7

Conclusions

- An automated test bench has been built for **studies of directional properties of laser diffusers**
- Combined with simulations, it allows for quantitative assessment of new diffuser designs and their optimization for particular purposes (e.g. **time calibration** or **in-situ water absorption and scattering measurements**)
- The test bench allows the **testing of new light distribution methods**, such as cone emission, which may allow even more precise time calibration, in-situ water parameters measurements and positioning of the modules inside the clusters

Test bench application possibilities

- The test stand in the current configuration allows to **perform the tests with the lasers used in BGVD** (the stand is equipped with quartz rod mounting brackets).
- The use of the Si detector and the energy detector (together with the monitor) **allows for accurate mapping of each laser - diffuser set**.
- The stand is **fully reconfigurable and software independent** (in case of software failure allows to manual operation).
- **Scans do not require darkroom!** Tests can be performed even in a sunlight (thanks to the Q-switched laser).
- Output files are saved in **TXT and JSON format**
- Laser set scans, as a kind of "passports" can be used for later comparative tests (**simulation vs data from laser test runs**)

Thank you for your attention