STUDY OF OSL DOSIMETERS IN ULTRA-HIGH PULSE DOSE RATES PARTICLE BEAMS AT ELI BEAMLINES LASER FACILITY

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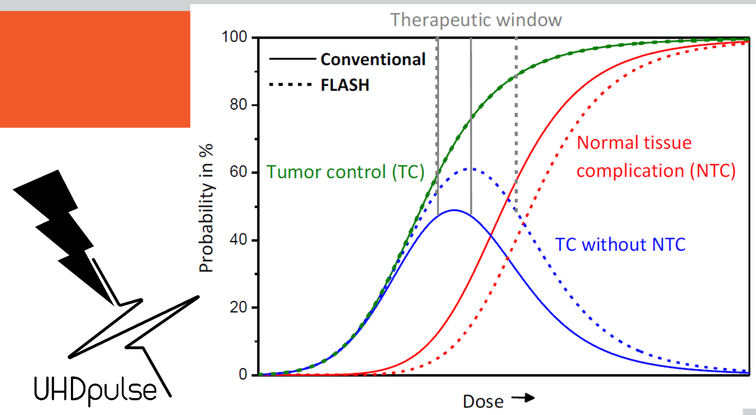
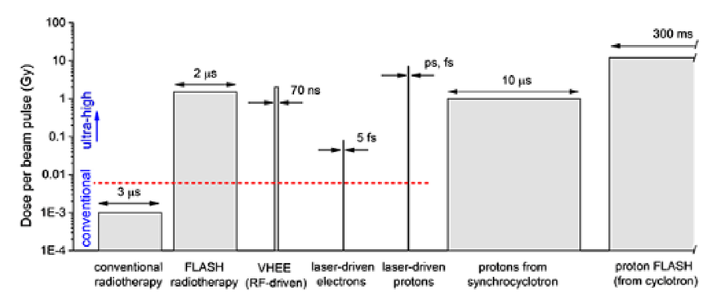
The Extreme Light Infrastructure (ELI) Beamlines is a laser based research facility located in the outskirts of the city of Prague. With its state-of-the-art lasers, it will be able to accelerate particle beams of femtosecond duration up to tens of GeV. This new frontier of laser-driven particle production creates new challenges for radiation protection, due to the very short duration of the pulsed fields and the associated electromagnetic pulses. There is, therefore, the need to define a metrology for the use of dosimetric systems in ultra-high pulse rate radiation fields. This is one of the goals of UHDpulse, a joint research project within the European Metrology Programme for Innovation and Research (EMPIR).

Beryllium oxide optically stimulated luminescence (BeO-OSL) dosimeters, used for photon dosimetry, are placed throughout the experimental building at ELI Beamlines. OSL dosimeters have been successfully tested in pulsed field thus making them ideal for use at laser-driven accelerators. BeO-OSLs are also used for long term environmental monitoring around the facility premise.

EMPIR PROJECT - UHDPULSE

- UHDpulse – **Metrology for advanced radiotherapy using particle beams with ultra-high pulse dose rates** is a joint research project within the European Metrology Programme for Innovation and Research (EMPIR).
  - Start date:1st September 2019 – End date: 31st August 2022.
- Several animal studies demonstrated that delivering the radiation dose in ultra-high dose pulses, may dramatically reduce adverse side effects, while the anti-tumoral efficacy is preserved. This is called FLASH effect.
  - Performance, safety and effectiveness of FLASH therapy need to be reliably measured and optimized.
  - **Accurate dosimetry is vital in delivering successful radiotherapy**.
- Flash facilities and **laser-driven accelerators pose significant metrological challenges related to the ultra-high pulse dose rates**.
- Laser-driven accelerators are the next generation of cost-effective accelerators for radiotherapy
  - Pulse duration much shorter and the pulse dose rate can be orders of magnitude higher than that of conventional clinical accelerators.





PROJECT OBJECTIVES

1. Develop a metrological framework for dosimetry measurements for particle beams with ultra-high pulse dose rates.
2. Characterize the response of available detector systems in particle beams with ultra-high dose per pulse or with ultrashort pulse duration.
3. Develop traceable and validated methods for relative dosimetry and for the characterization of stray radiation outside the primary pulsed particle beams.
4. Provide input data for Codes of Practice for absolute dose measurements in particle beams with ultra-high pulse dose rates.
5. Facilitate the uptake of the achievements of the project by the measurement supply chain, standards developing organizations (e.g. those associated with International Atomic Energy Agency (IAEA) and International Commission on Radiation Units (ICRU) reports) and end users (clinical and academic laboratories, hospitals and radiotherapy manufacturers).

PROJECT PARTNERS

PTB · Czech Metrology Institute · Central Office of Measures · iba · CHUV · CSIC · Institut Curie · eli beamlines · PTW The Dosimetry Company · Carl von Ossietzky Universität Oldenburg · Sun Nuclear Corporation · METAS · NPL National Physical Laboratory · ADVACAM Imaging the Unseen · Politecnico Milano 1863 · Queen's University Belfast · USC Universidade de Santiago de Compostela · HZDR Helmholtz Zentrum Dresden Rossendorf · varian · lpc caen

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OPTICALLY STIMULATED LUMINESCENCE (OSL)

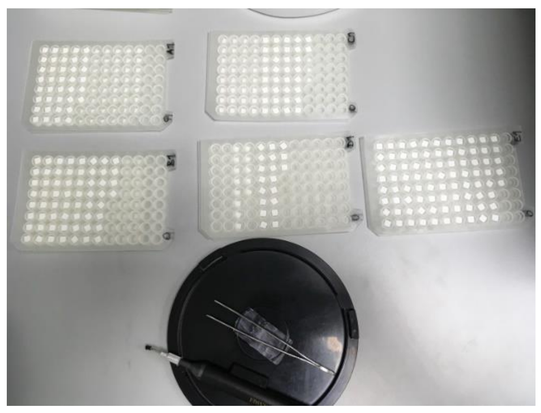
The **OSL dosimetry** is applicable to situations where real-time information is not needed, but precise accumulated dose monitoring records are desired for comparison to field measurements or for assessing the potential for long term health effects.

OSL dosimeters have been successfully tested in pulsed field thus making them promising for use at laser-driven accelerators.

OSL materials (e.g. BeO ceramic) contain defects in their crystal structure that trap electrons released by exposure to radiation. Trapped electrons are subsequently freed by stimulation **with light**. The stored energy in the form of light is directly related to the dose.

BeO OSL dosimeters are

1. high sensitivity to ionizing radiation;
2. wide linear dose response from 1 µGy up to a few Gy;
3. effective atomic number similar to human soft tissue (Zeff=7.2).



At ELI Beamlines, BeO is used for OSL dosimeters in 4.7 x 4.7 x 0.5 mm chips (shown above)

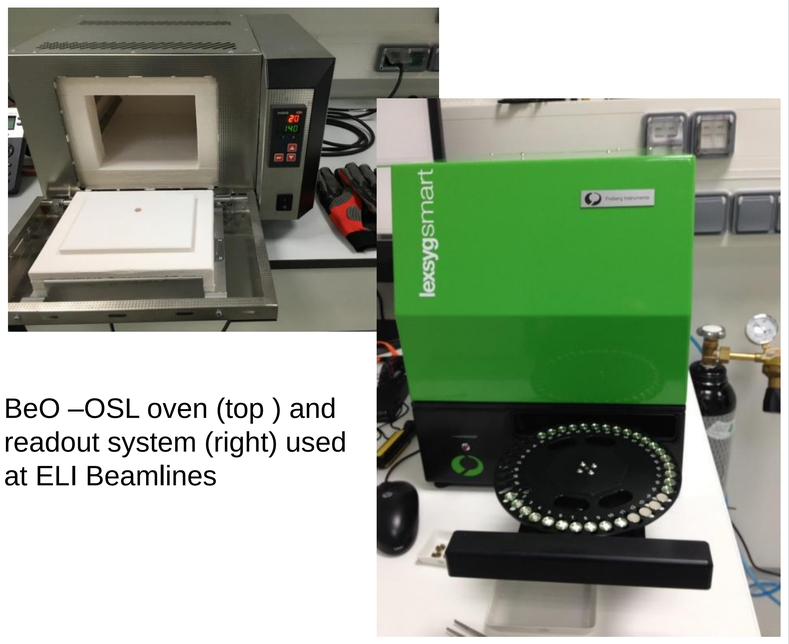
OSLS AT ELI BEAMLINES

BeO OSL dosimeters play an central role at ELI Beamlines.

- Environmental monitoring system and for the dose characterization of complex radiation fields produced.
- Ten sets are placed in the surrounding areas and are read every 3 months.
- Several dosimeters are located inside the experimental halls to monitor the ambient dose.

Their calibration is performed using a ^{137}Cs source. Before being used, the chips are annealed at 700°C for ~15 minutes. The chips are wrapped in a thin aluminum foil shielding them from visible light.

Readout is performed using a Lexsyg Smart Reader by Freiberg Instruments



BeO –OSL oven (top) and readout system (right) used at ELI Beamlines

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