Optically Stimulated Luminescence Dosimetry Based on SrS:Ce,Sm Phosphor for High-Energy Physics Applications

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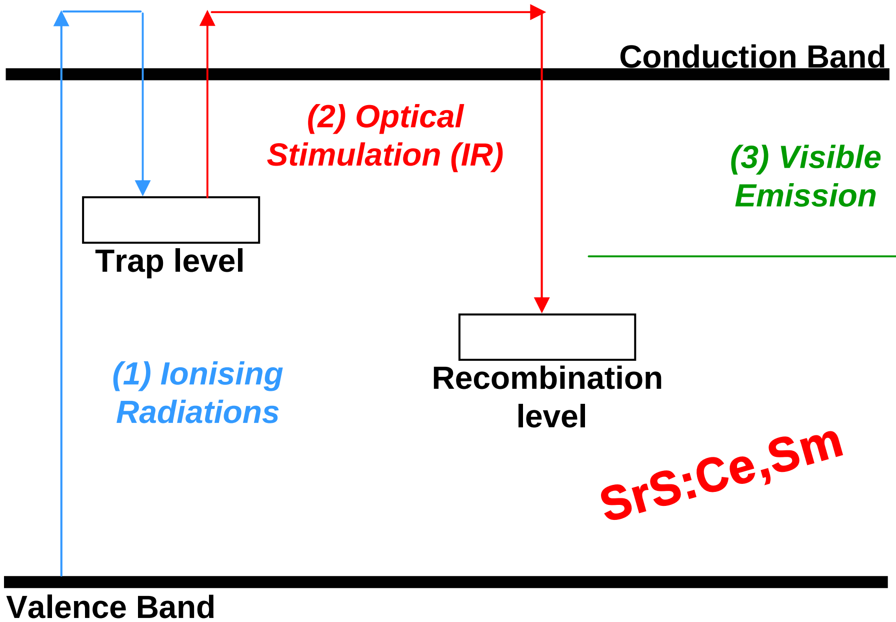
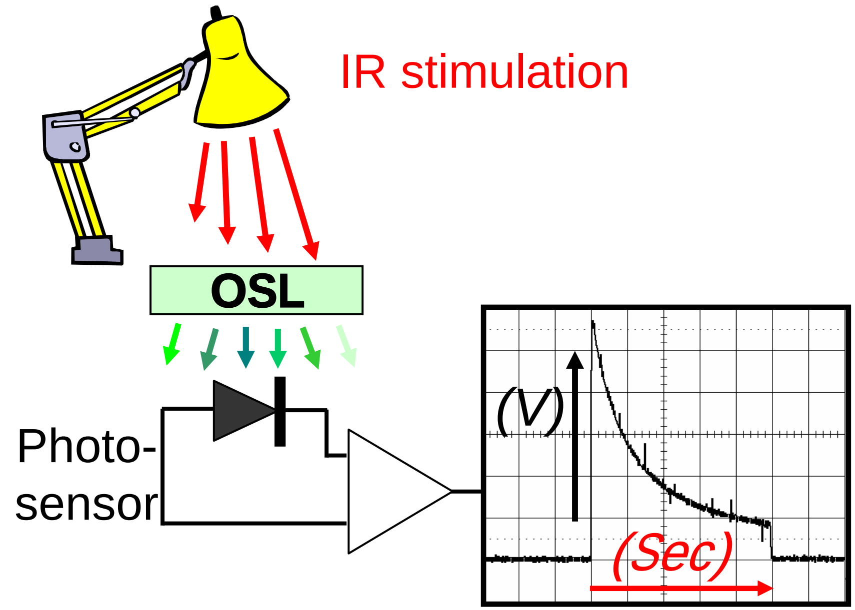
Why OSL ? A bit of History…

- 1950/1960: first suggestion of OSL as a dosimetry tool
- 80's years:
  - OSL technique became popular in archeological and geological dating community
  - Development of OSL imaging technique
- **<u>In Montpellier</u>**
  - 80's years: first research program on OSL phenomenon
  - 90's years: development of OSL materials
  - ⇒ Conception of dosimeters and developments of applications
  - 1998: first paper on OSL dose-mapping
  - 2001: first paper on integrated OSL sensor
  - 2007: first accepted paper on OSL fibered dosimetry system for RADECS Conference

OSL Phenomenon



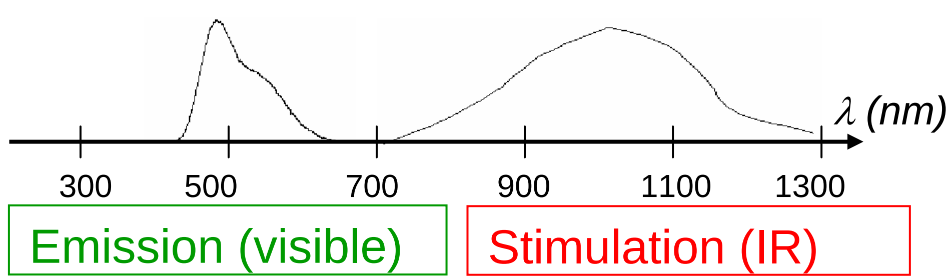


Readout "reset" the OSL!

(1) e^-/h^+ pair generation and trapping

(2) Infrared stimulation (700-1300 nm)

(3) Visible emission (450-650 nm)



OSL Material: SrS:Ce,Sm

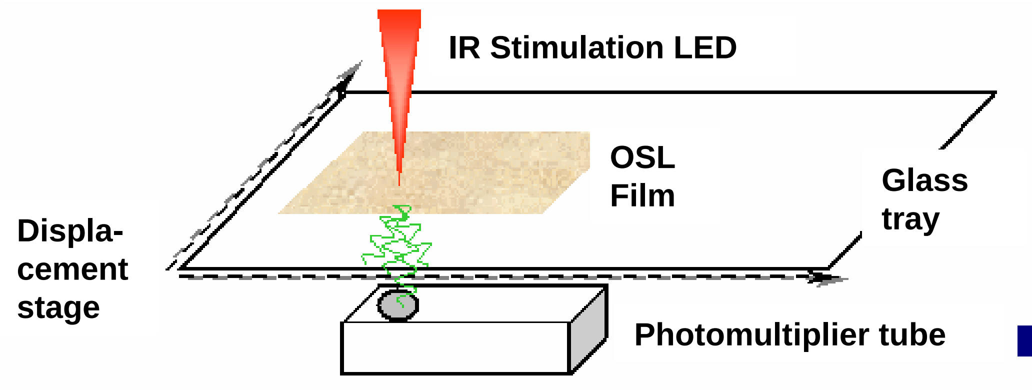
- **Features**
  - Broad dynamic range: 6 decades
  - Detection threshold: 10 µGy
  - Linear response with dose up to 500 Gy

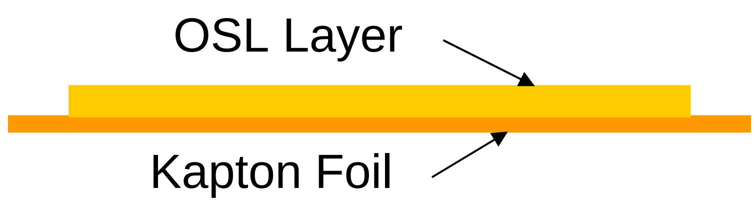
Raw OSL

- **Different packaging**
  - Integrated OSL sensor *(grain size ~ few 100 µm)* → **SPACE APPLICATIONS** *(Not presented here) (on-line dosimetry)*
  - OSL Films *(grain size ~50 µm)* → **BEAM IMAGING** ***OFF-LINE DOSIMETRY***
  - OSL deported by optical fibre *(cylindrical shape with a diameter ~900 µm)* → **HEP and Medical Applications** ***ON-LINE DOSIMETRY***

Dose-Mapping System

- **Principle**





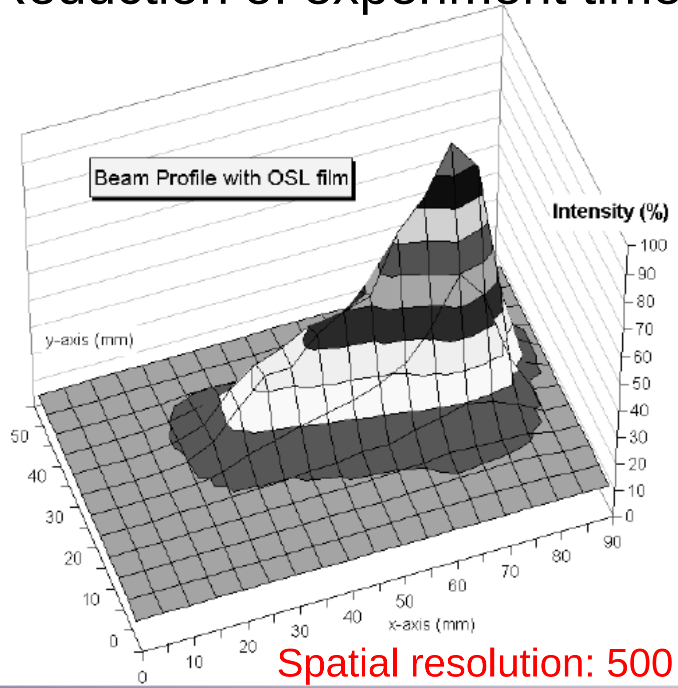
Film thickness from 80 to 250 µm

- **Aim:** Record of spatial distribution of the dose

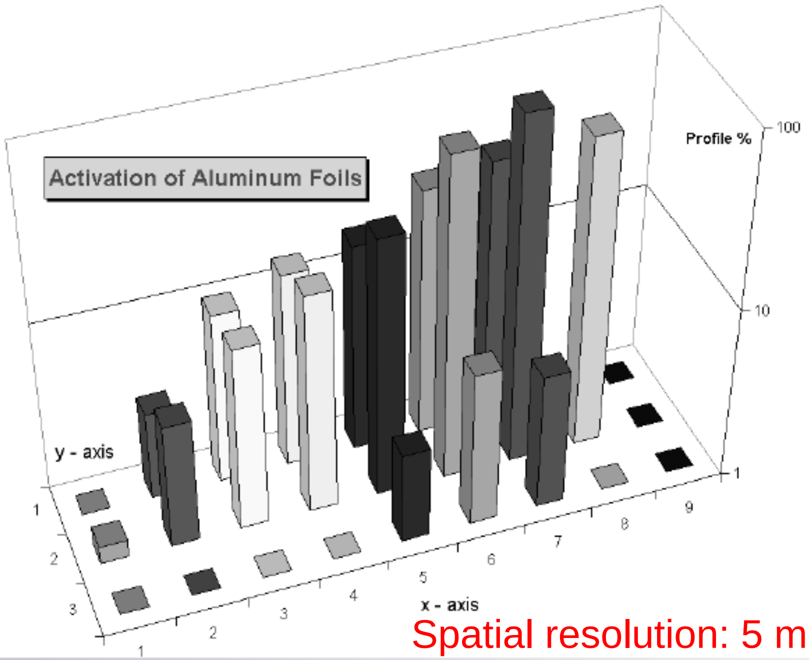
- **System Features**
  - Reproducibility: 5 %
  - Scan Area: 20x20 cm^2
  - Spatial Resolution: ~250 µm
  - Sensitivity: < mGy
  - Layer Homogeneity: 95%

Example of Beam Profiling

- 23 GeV proton beam (IRRAD1 - CERN)
- OSL films
  - Improvement of spatial resolution
  - Reduction of experiment time
- One method of beam profiling: measurement of activation of Al foils

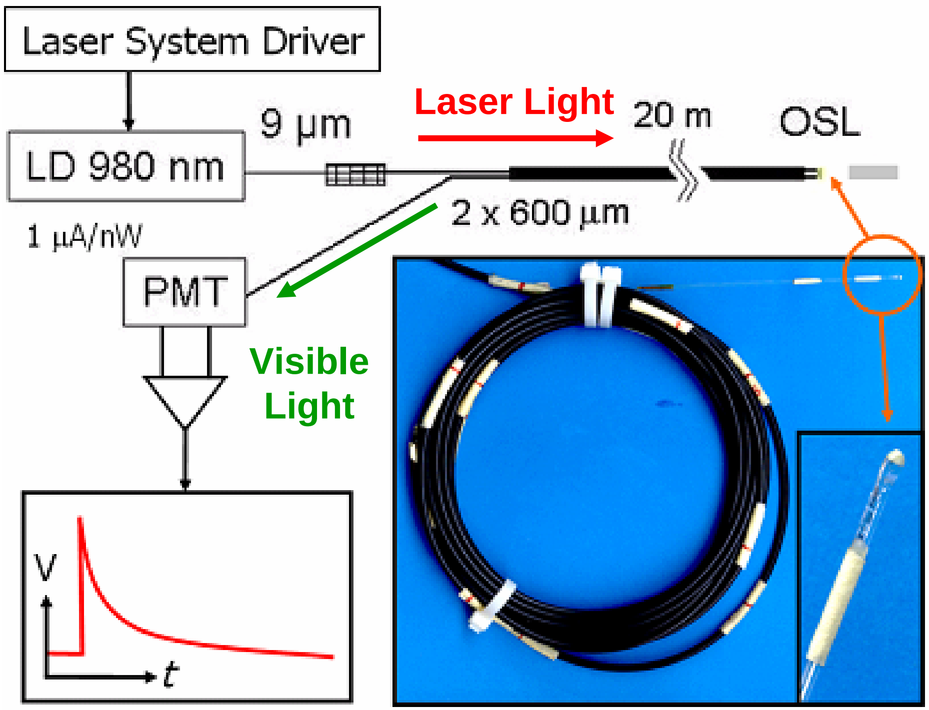


Spatial resolution: 500 µm

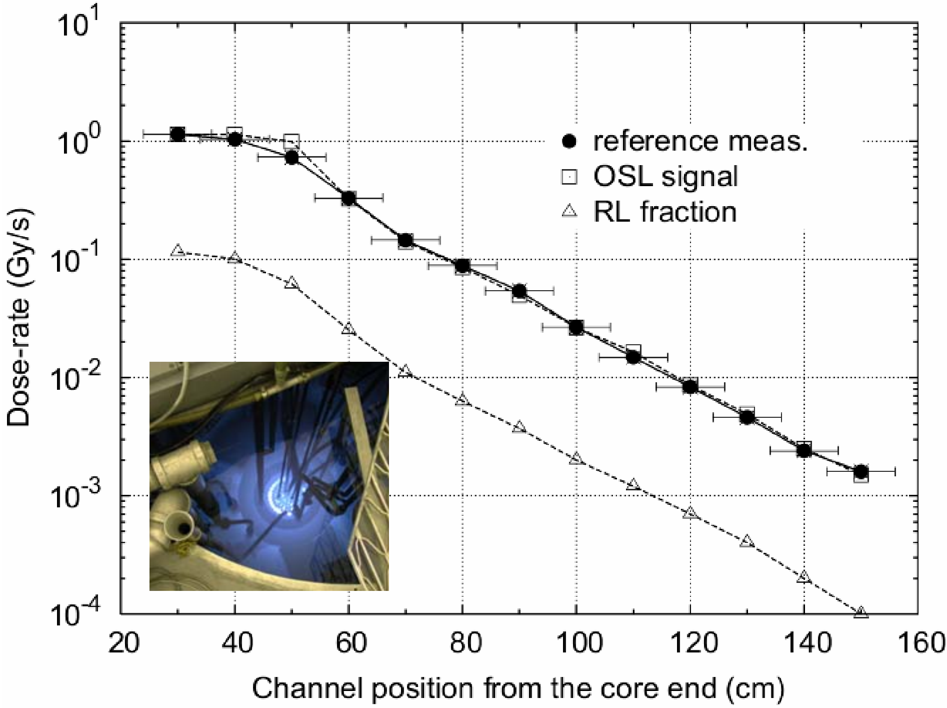


Spatial resolution: 5 mm

First Prototype of OSL-Fibered System



- **Repeatability: 2 %**
- **Reproducibility: 6 %**
- No evidence of radiation damage up to $\Phi_{eq} = 5 \times 10^{13}\ cm^{-2}$

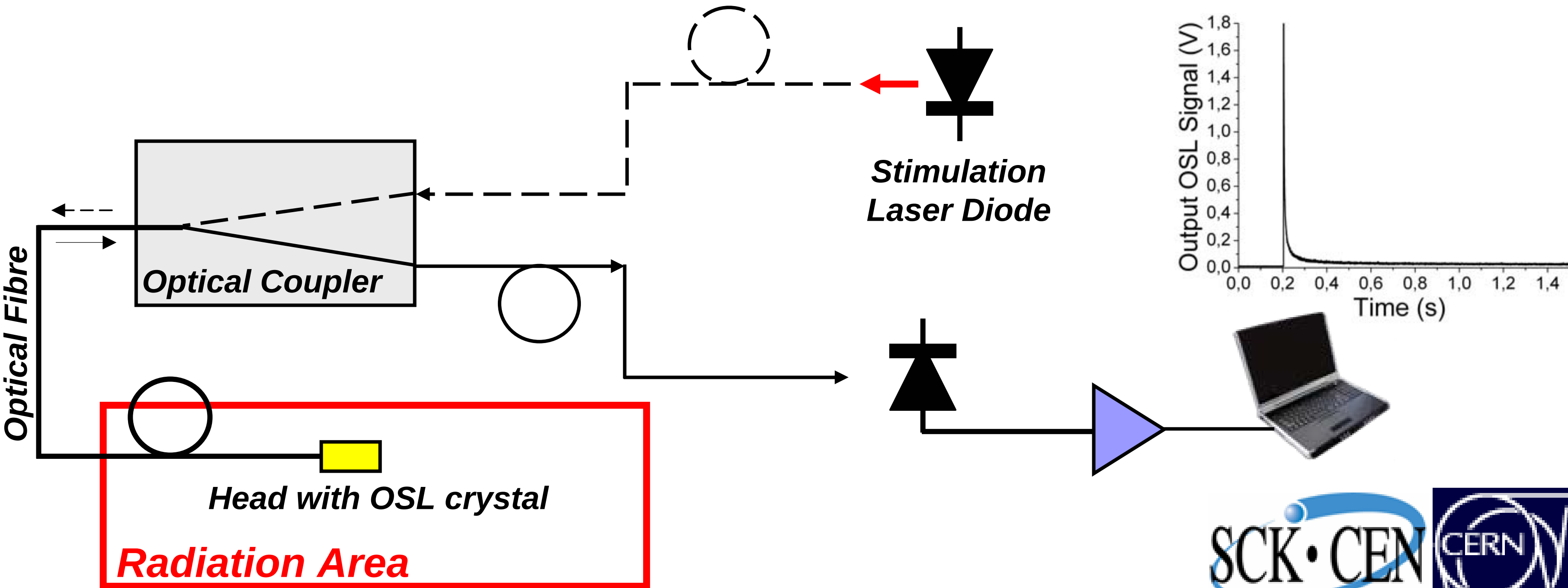


Polymicro fibre doesn't show significant attenuation at the OSL λ of interest

[Courtesy M. Glaser, CERN]

Second Prototype of Fibered System

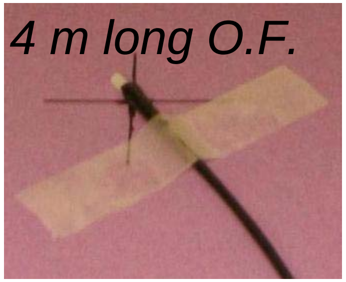
Collaboration between CERN, SCK-CEN and IES Montpellier

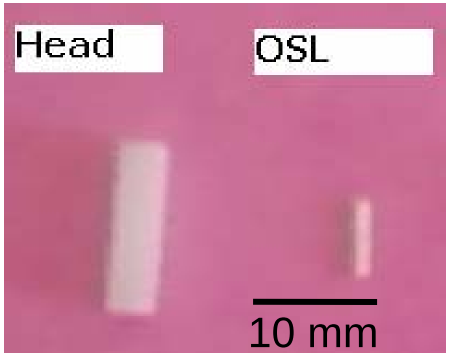


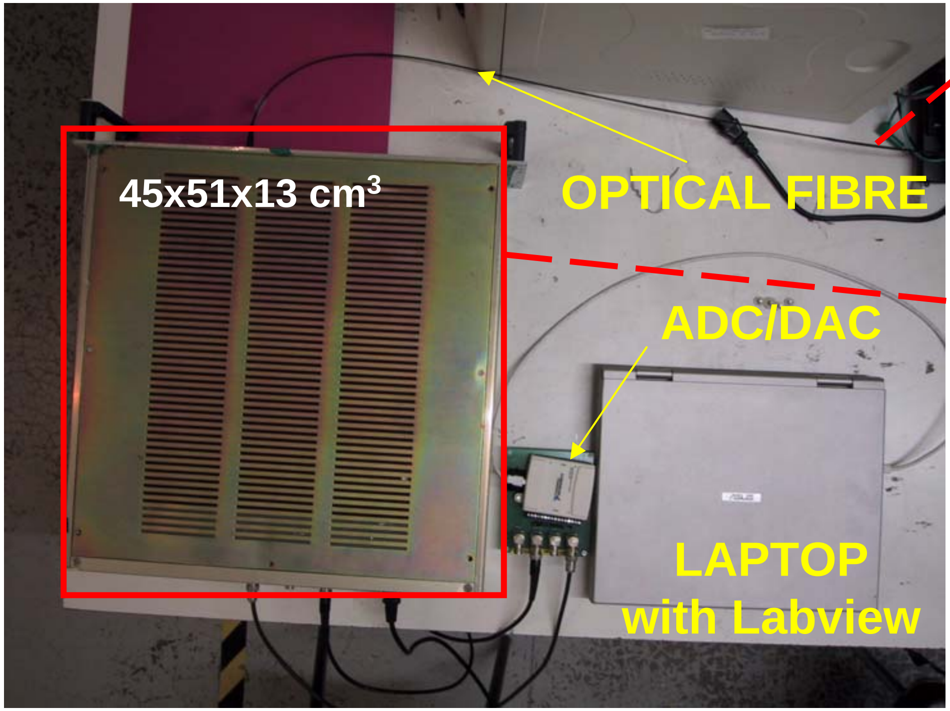
Main Advantages:

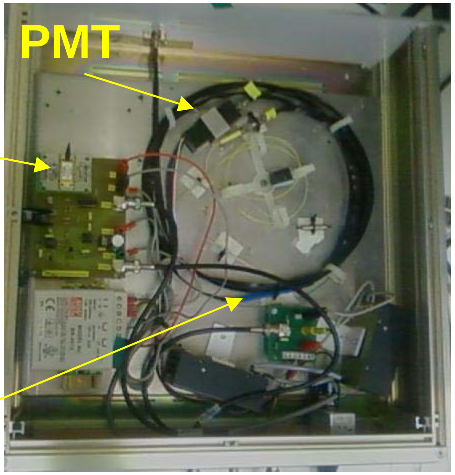
- Integrated system
- Single Optical Fibre (*Polymicro* fibres for fibres #02 and #03)
- Design of a head for introduction of OSL material

Overview of the System





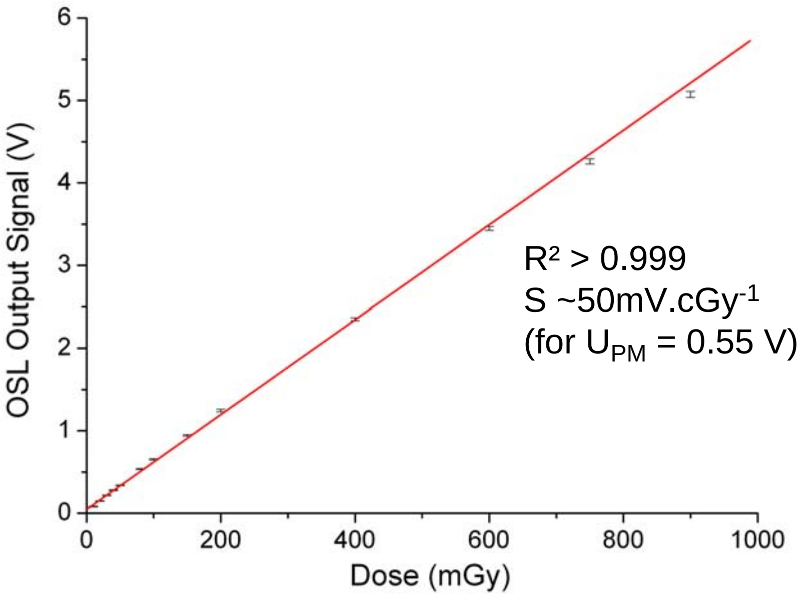




First Experimental Results with 60-Co

Calibration Curve

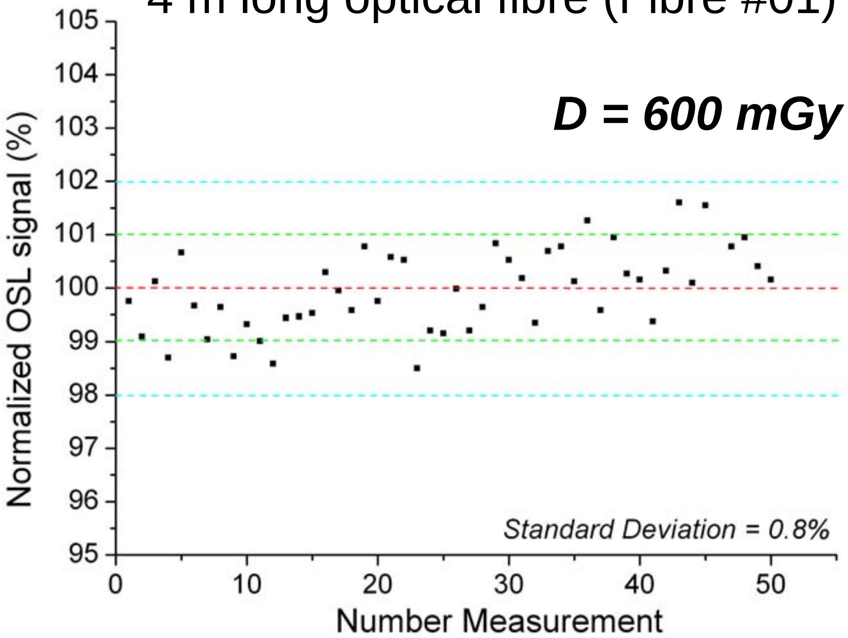
4 m long optical fibre (Fibre #01)



- Good linearity up to 1 Gy
- D > 1 Gy ➔ Modify the PMT sensitivity ➔ *Software control*

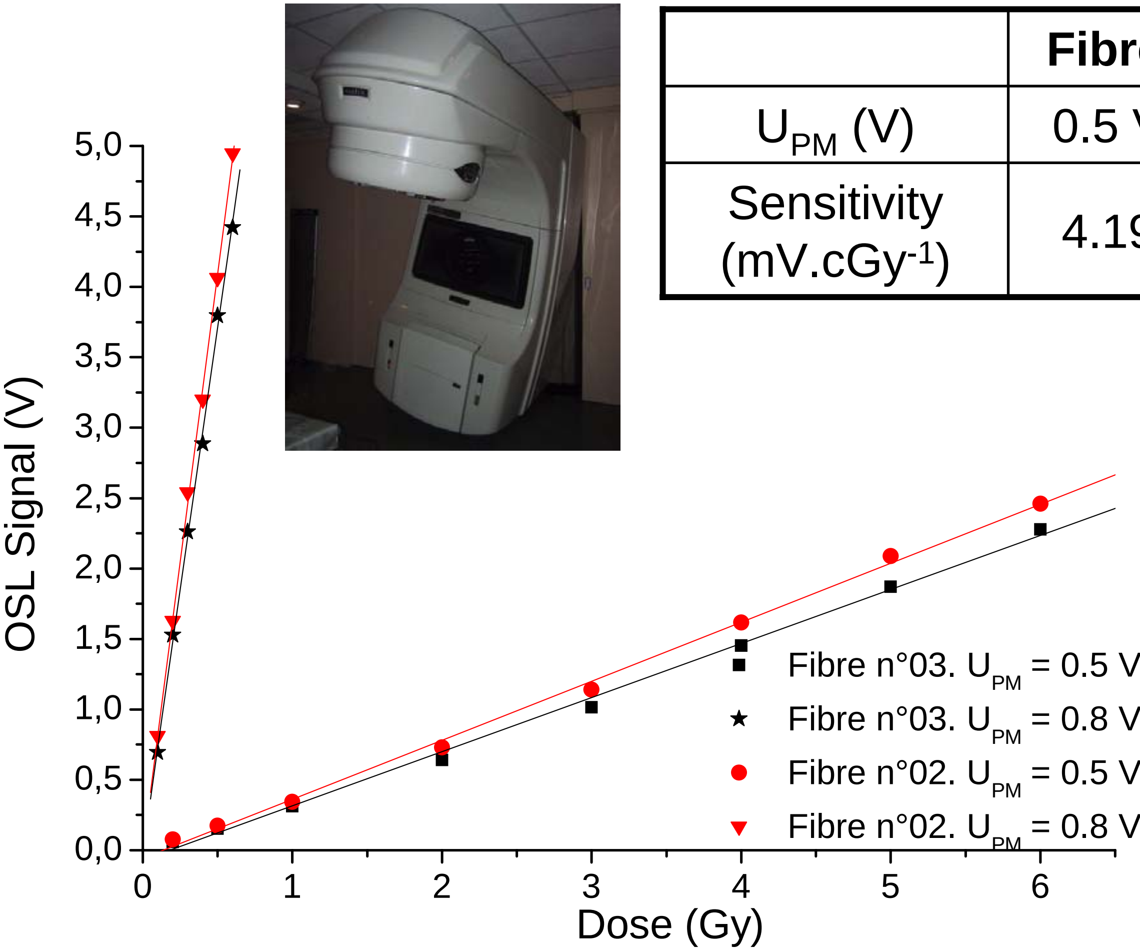
Repeatability

4 m long optical fibre (Fibre #01)



- Max. Error: 1.6 %
- Mean Error: 0.6 %
- 85% of values: ± 1%

Calibration with High Energy X-rays



	Fibre #02 (25 m)		Fibre #03 (15 m)	
U_{PM} (V)	0.5 V	0.8 V	0.5 V	0.8 V
Sensitivity (mV.cGy^{-1})	4.19	81.9	3.84	74.5

- Experimental Set-up
  - Medical LINAC
  - Energy X-rays: 6 MV
  - Dose rate: 2 Gy/min
  - PMMA Blocks

Good Linearity up to 6 Gy for the two optical fibres

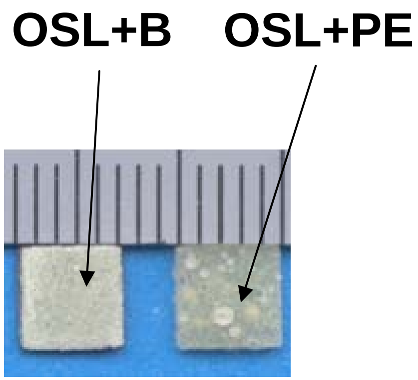
OSL Neutron-Sensitive Material

- Principle
  - Thermal and epithermal neutrons: OSL+B_2O_3

    $$^{10}B + n_{th}(E < 0.5eV) \rightarrow {}^{7}Li + \alpha$$

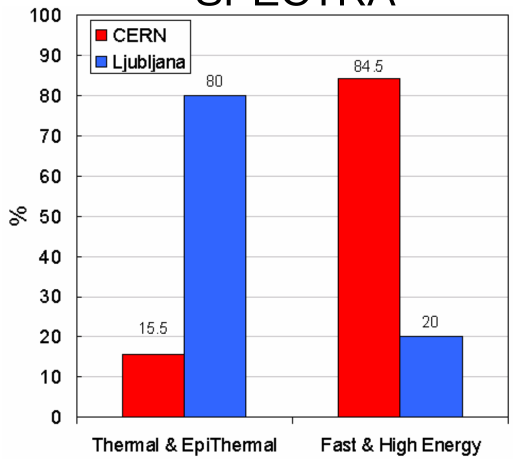
  - Fast neutrons: OSL+PE

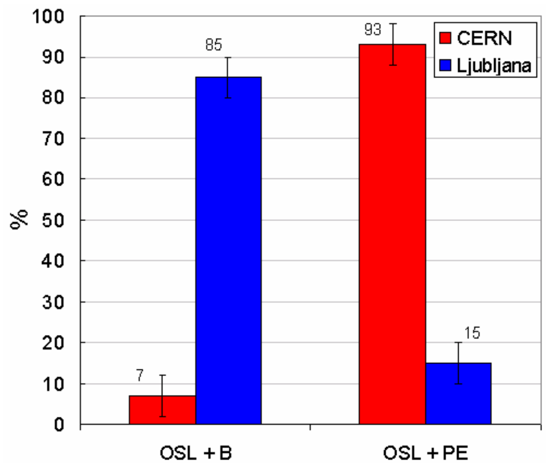
    Recoil protons following elastic scattering



- **First Results of two different neutrons fields**

FACILITIES NEUTRON SPECTRA





CERN → IRRAD2
Ljubljana → TRIGA Reactor

First **measurements** match very well with the **facility spectra**

Conclusions & Outlook

- OSL dosimetry
  - Interesting properties (sensitivity, dynamics, linear response with dose)
  - OSL Films: spatial distribution of the dose
  - OSL Fibered dosimetry system: real-time measurements in harsh environment
- Advantages
  - Material Advantages
    - Not needed to heat the sample (Optical readout)
    - High Radiation Hardness
  - Optical Fibre Advantages
    - Insensitive to electro-magnetic interferences
  - Possibility to build compact, low cost and flexible systems
- Outlook
  - Complete characterization of the system ongoing
  - Comparison of results with others dosimetric tools