Optically Stimulated Luminescence Dosimetry

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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

- In Montpellier
  - 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

- OSL applications: dosimetry, imaging, archeological dating
OSL Principle

(1) Ionizing Radiation

(2) Optical Stimulation

(3) Visible Emission

Conduction Band

Trap Level

Recombination Level

Valence Band

Quantity of emitted light is proportional to dose
MATERIAL ASPECT

OSL Material: SrS:Ce,Sm

- **Features**
  - Broad dynamic range: 6 decades
  - Detection threshold: 10 μGy
  - Linear response with dose up to 500 Gy
  - Emission and stimulation spectra are well separated

- **Different packaging**
  - Integrated OSL sensor
    (grain size ~ few 100 μm)
  - OSL deposited by optical fibre
    (cylindrical shape with a diameter ~900 μm)
  - OSL Films
    (grain size ~50 μm)
  - OSL thin-layer: coming soon
    (poly crystalline layer)

![Raw OSL](image-url)
Integrated OSL Sensor
Principle of Integrated OSL Sensor

- **Aim:** On-line dose measurements (fractioned or not)

- **Features**
  - Sensitivity < mGy
  - COTS Components
  - Electrical Power < 200 mW
  - Reset (Fractioned measurements)
Space Applications

- **Aim:** On-line dose measurements (fractioned or cumulated) in order to evaluate the dose on onboard electronics
- Support from CNES: French Spatial Agency
- Collaboration with NASA

- Next missions with OSL sensors onboard satellites
  - DIME (Clemson University) launch in 2008 on NASA’s SET1
  - ICARE NG (CNES) launch in 2008 on Jason2
Proton Beam Monitoring

- Experiments performed at Université Catholique de Louvain

![Graph showing dose vs. time](image)

- Experimental Set-up
  - Proton Energy: 60 MeV
  - Fluence Rate: $10^6$ s$^{-1}$.cm$^{-2}$
  - Fluence: $10^{10}$ cm$^{-2}$
  - Total Dose: 180 Gy

- Less than 2% discrepancy between the results obtained with UCL dosimetry system and the single OSL sensor
OSL Fibered Dosimetry System
Architecture of the System

System is issued of a collaboration between the CERN, the SCK-CEN and our group.

- Optical Coupler
- Optical Fibre
- Head with OSL crystal
- Radiation Area
- Stimulation Laser Diode
Overview of the System

OSL FIBERED DOSIMETRY SYSTEM

LASER (980 nm)

PMT

OPTICAL FIBRE

ADC/DAC

LAPTOP with Labview

Head

OSL

10 mm

1st Workshop on Instrumentation for Charged Particle Therapy - May 9th 2007, London, UK
OSL Dose-mapping System
System of Dose-Mapping

- **Principle**

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

- **System Features**
  - Reproducibility: 95%
  - Scan Area: 20x20 cm²
  - Spatial Resolution: ~250 μm
  - Sensitivity: < mGy
  - Layer Homogeneity: 95%

Film thickness between 80 to 250 μm
Applications to High Energy Physics

- Beam profiling of 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
Macula and Retina Treatment High Resolution Dose-mapping

OSL dosimeter

Plexiglas block

Collimator with hole

$e_i = 2; 3; 6$ or $7$ mm

63 MeV proton beam

Biomedical Cyclotron Nice (France)

Dose behind the hole is function of the thickness of the eye-collimator

Collimator with 2 mm of Plexiglas

Dose behind the hole is function of the thickness of the eye-collimator

Collimator with 2 mm of Plexiglas

profile

OSL signal (a.u.)

- 6 mm Plexiglas
- 3 mm Plexiglas
- 2 mm Plexiglas

position (μm)
Appl. in Conformal Radiotherapy

**Aim:** measure the spatial dose distribution with high dose gradient

- **Quality Control of IMRT fields**
- **Intra Operative Radiation Therapy**
  - Marker for positioning
  - Outside of primary beam

- OSL Films are flexible and match the tumoral localisation
- OSL Films are placed into sterile package
Appl. In Stereotactic Radiosurgery

- **Aim:** Quality Control of Gamma Knife
  
  *Comparison between OSL measurements and KULA calculation software*

- Results are in good agreement between the two methods
Conclusions

- Interest of OSL dosimetry
  - Interesting properties (sensitivity, dynamics, linear response with dose)
  - OSL Films: spatial distribution of the dose
  - Single OSL sensor: on-line space dose measurements
  - Different applications in medical physics, beam monitoring

- OSL advantages
  - Not needed to heat the sample
  - Flexibility
  - Adaptability

- OSL is suitable for
  - On-line dosimetry
  - Dose imaging
  - Operational dosimetry
  … But not for passive personal dosimetry!
Thanks for your attention

OSLMan
Advantages of this OSL material

- **Compared to thermoluminescence (TL)**
  - No need to heat the sample
  - Reading systems are compact, low cost and low power
  - Possibility to use OSL material as active sensors for on-line dosimetry

- **Compared to Al₂O₃**
  - Emission and stimulation spectra are well separated
  - No very deep traps. SrS is fully reset after reading
  - Little stimulation energy is needed (Laser diode, LED…)
  - Drawback: information is erased after reading

![Emission (visible)](image1.png) ![Stimulation (IR)](image2.png)
Boron Doping of the OSL Material

- Boron-doped OSL material
  - Doping by **diffusion process**: Mix $\text{B}_2\text{O}_3$ (5% by mol) and OSL
  - Detection principle: $^{10}B + n_{th}(E < 0.5\text{eV}) \rightarrow ^7\text{Li} + \alpha$

- First Results of $n / \gamma$ Irradiations

Quantification of the thermal neutrons component in a mixed field after addition of $^{10}\text{B}$ is possible
Advantages: single optical fibre and real-time measurements

Features
- Good linearity until few Gy at this time (tested at SCK-CEN)
- Sensitivity <10 mGy
- Wide dynamic

Currently: Optimisation of the system for applications in Radiation Therapy (in vivo dosimetry)
- Sensors head
- OSL / fibre link

Characterization is needed!
- Dosimetric parameters
- Temperature
- Spatial Resolution
- Reproducibility
Applications in Proton Therapy

- **Aims**
  - 110 MeV proton beam monitoring with the single OSL sensor  
    *(Proton Therapy Centre, Orsay, France)*
  - Characterize a 63 MeV proton beam with OSL film  
    *(Anticancer Centre, Nice, France)*

- **Results**
  - Results are encouraging
  - The slight shift between the two curves is due to different measurements conditions *(air for diode and Plexiglas for OSL)*

\[Signal\ OSL\ (u.a.)\]
\[Z\ plexiglas\ (mm)\]
\[x\]
\[z\]

\[0\ 5\ 10\ 15\ 20\ 25\ 30\]
\[0\ 200\ 400\ 600\ 800\ 1000\ 1200\]

- **Signal OSL (u.a.)**
- **Z plexiglas (mm)**
- **x**
- **z**