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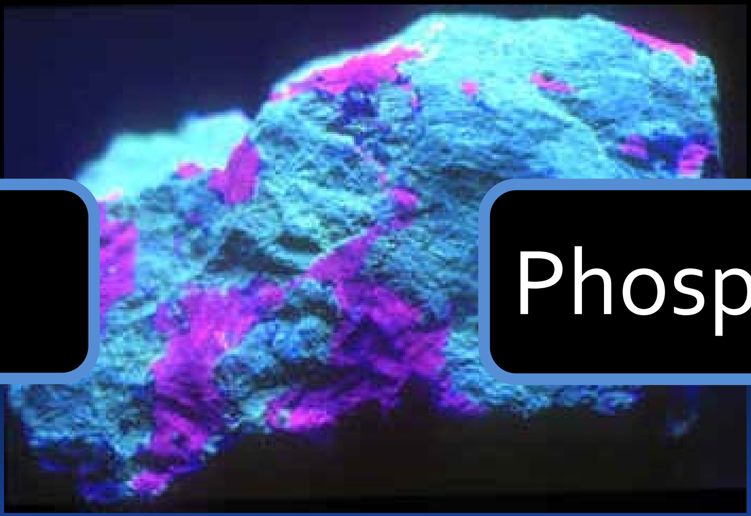
STUDIES FOR THE DEVELOPMENT OF A CUSTOMIZED READER FOR THE CHARACTERIZATION OF THERMOLUMINESCENT MATERIALS

Dr. Epifanio Cruz Zaragoza
ecruz@nucleares.unam.mx
Instituto de Ciencias Nucleares-UNAM

Luminescence

Light emission from an insolator or semiconductor because an energy absorption ocurred (cover UV to IR radiation)

Fluorescence



Phosphorescence

V. Cascariolo of Bologna, 1603: Bolognian stone (Barium sulphate).
(**De Phaenomenis in Orbe Lunae, G.C.Lagalla,1612**)

Fluorescence

$\tau \leq 10^{-8}$ s
Independent of T

Afterglow

Phosphorescence *

$\tau \geq 10^{-8}$ s $\tau = s^{-1}\exp(E/kT)$
Dependent of T

Short (large) periods

THERMOLUMINESCENCE
min $\leq \tau \leq 4.6*10^{9}$ years

V. Cascariolo of Bologna, 1603: Bolognian stone (Barium sulphate).
(De Phaenomenis in Orbe Lunae, G.C.Lagalla,1612)

TL and OSL ?

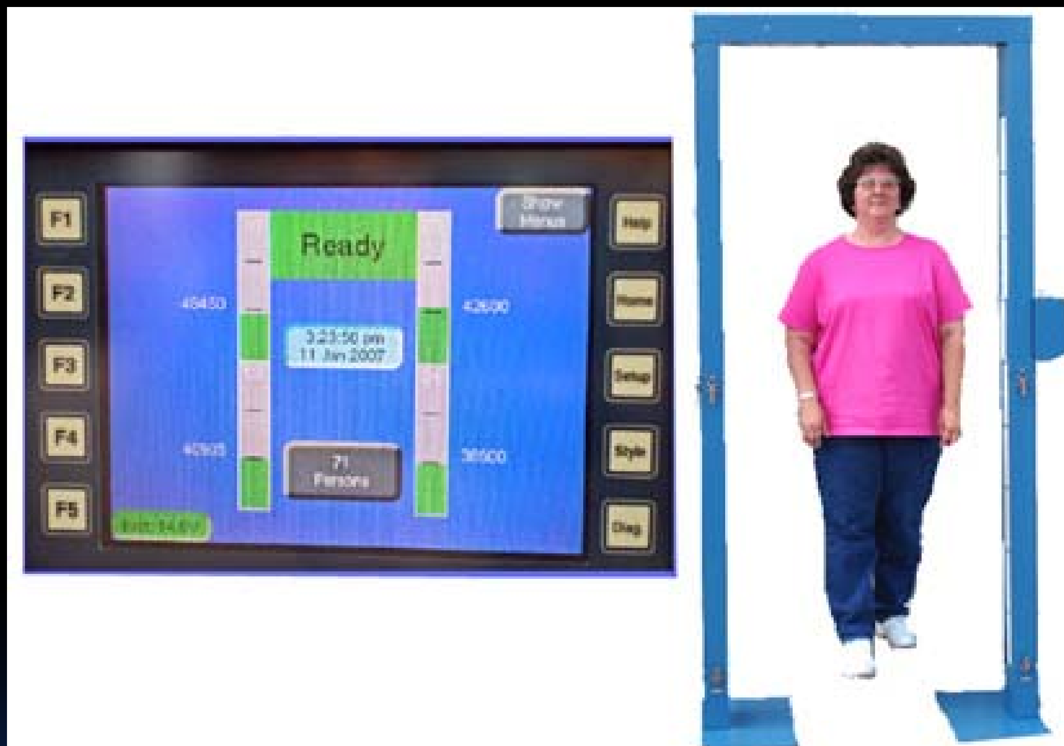
In TL the material is stimulated by heating which provokes the recombination among trapped charges in the defects and the information about the irradiation dose is given.
Anyway in TL it is impossible to maintain the dose information in the material after successive readouts; on the contrary, the optically stimulated luminescence (OSL) technique gives the possibility for multiple readouts concerning the given dose.

In this stage it is important to develop a customized reader for the characterization of luminescent materials that currently are used in dosimetry field and for TL material research.
In this seminary some results of TL property and design in lab of an OSL equipment will be present.

Why is necessary to investigate phosphor material?

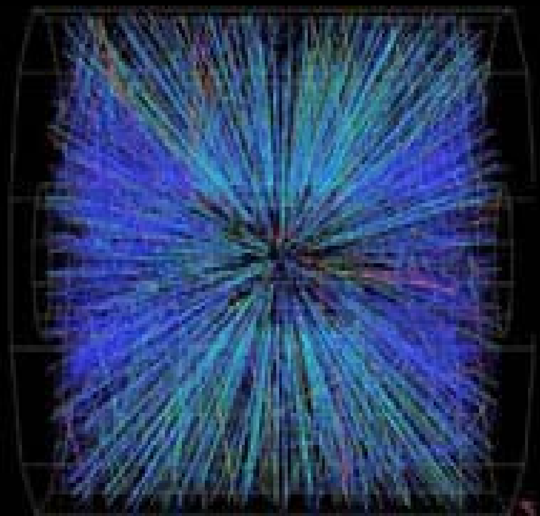
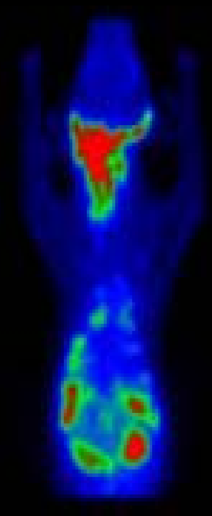
Application: detectors and dose assessment
Research: luminescence properties

AM-801 Portal Monitor
Collapsible and portable



Sensitivity: Meets FEMA requirements less than 1 uCi Cs-137 source during walk through . Cost: $10,995 USD
Processing Rate: Approximately 500 persons per hour
Detectors: Four Plastic Scintillation, 36” L x 3” W x 1.5” D, placed in four quadrants of the body. **Scintillators:** W/PMT Detector, 162 cubic inches, each detector is 648 cubic inches

Application: Nuclear Medicine

ST360W Scintillation Counter for Wipe & Tube Samples

Energy Range: <20kev to>2MeV
Resolving Time: Less than 1µsec
High voltage: 0 to +1200 volts, digitally selectable in 20 volt increments

PD-10i Electronic dosimeter

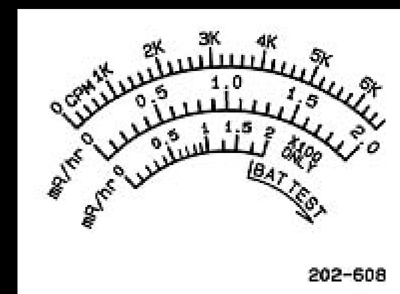
Dose range: 0 uR to 999 R **Dose Resolution:** < 2 uR

Dose Rate Range: ± 15% of 20 uR/hr from background to 500 R/hr. Weight: 130 g

Detector: Miniature Geiger-Mueller tube

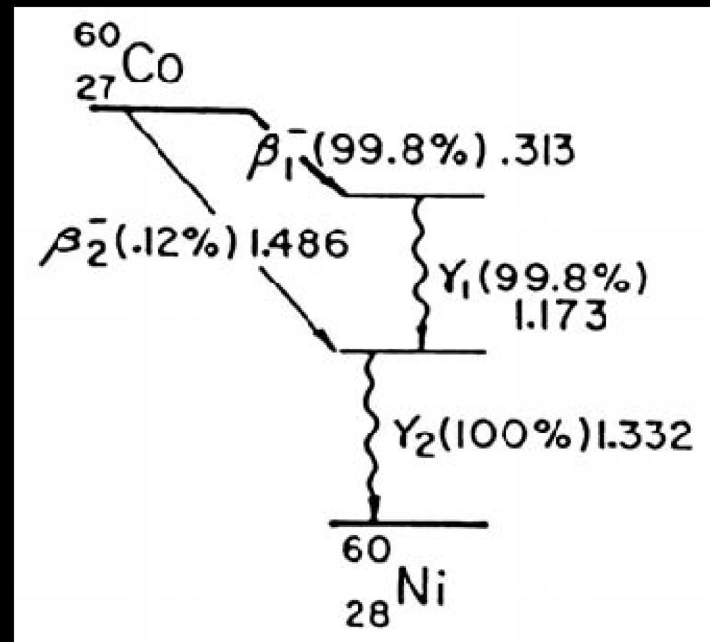
Energy Response: Tissue equivalent to within ± 25% from 55 keV to 6 MeV (70% response at 40 keV)

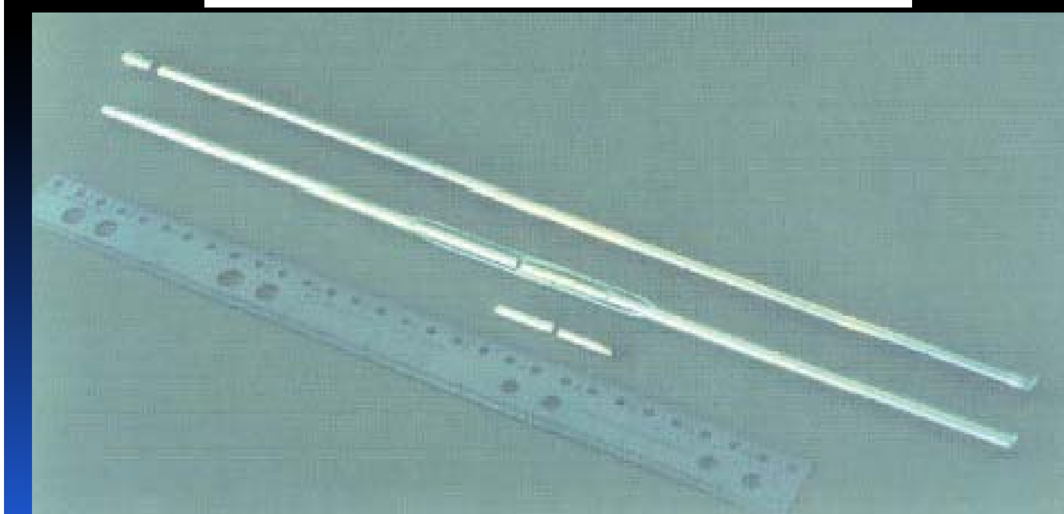
Nuclear Emergency, Model 14CRK



- LudLum detectors: 5 Range Survey Meter
- Internal High Range G-M Detector
- Alpha Beta Gamma Pancake G-M
- 1" X 1" NaI(Tl) Gamma Scintillator
- Check Source
- Total Range from 0 - 2000 mR/hr

Dose control: Sources production





Irradiator design

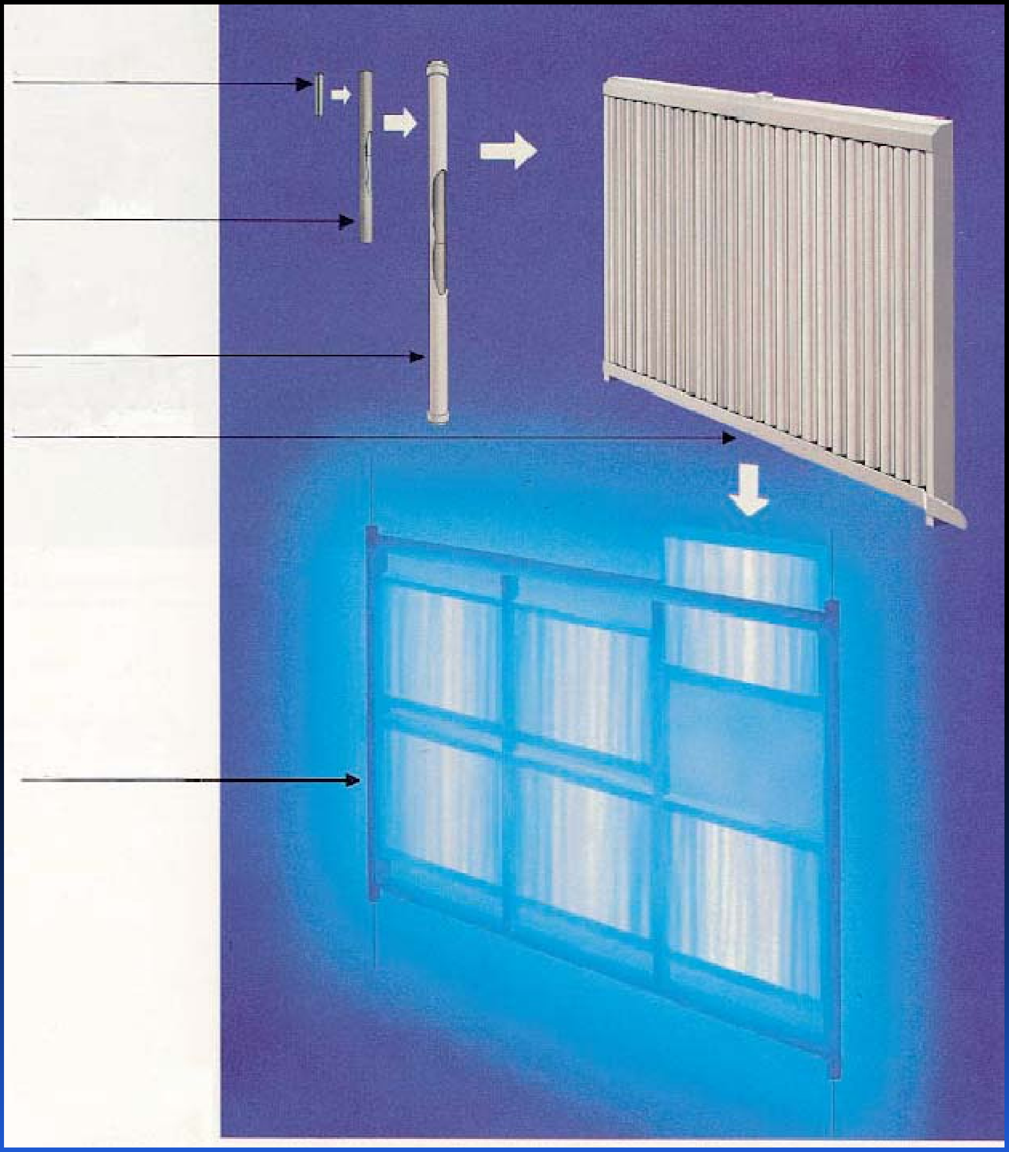
Co-60

Sources element

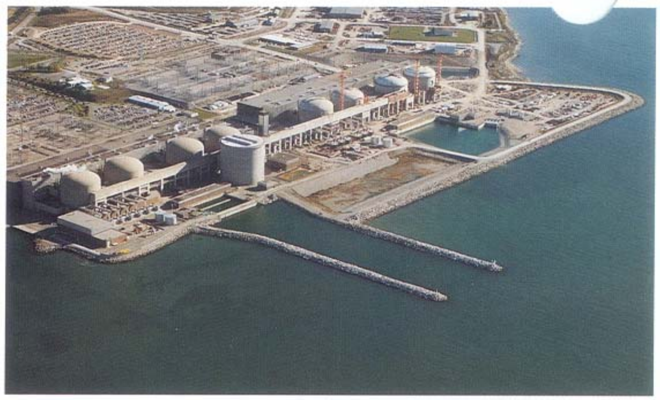
Pencil: 2 elements

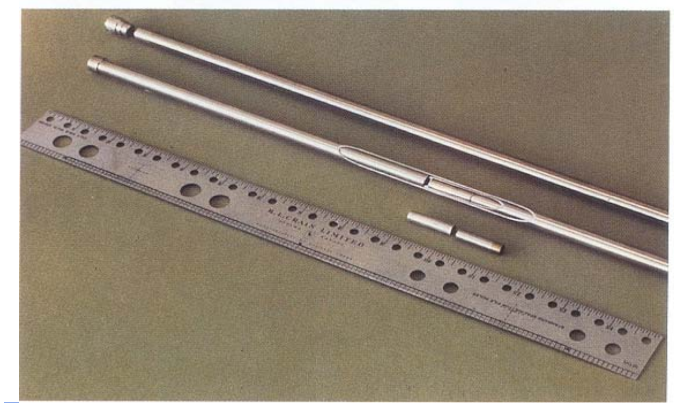
Module

Rack with modules

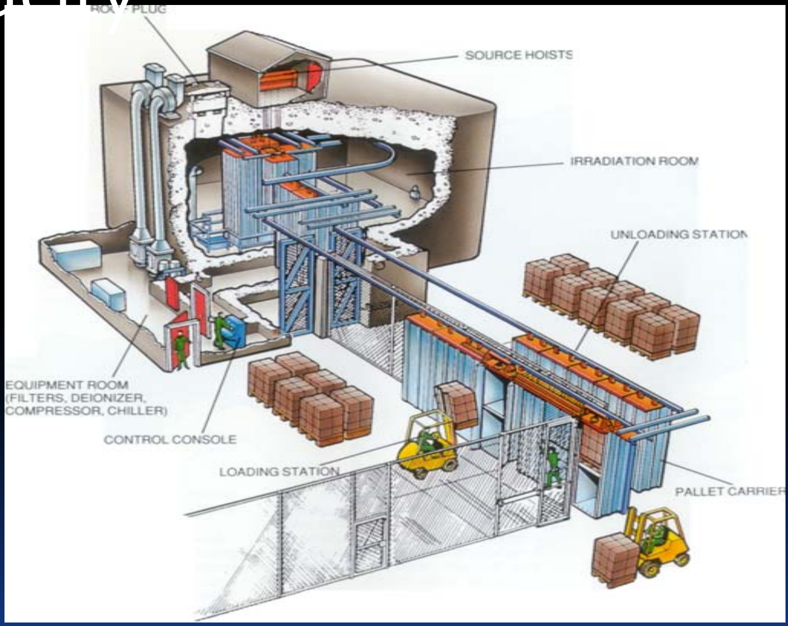


Technology processing of Co-60

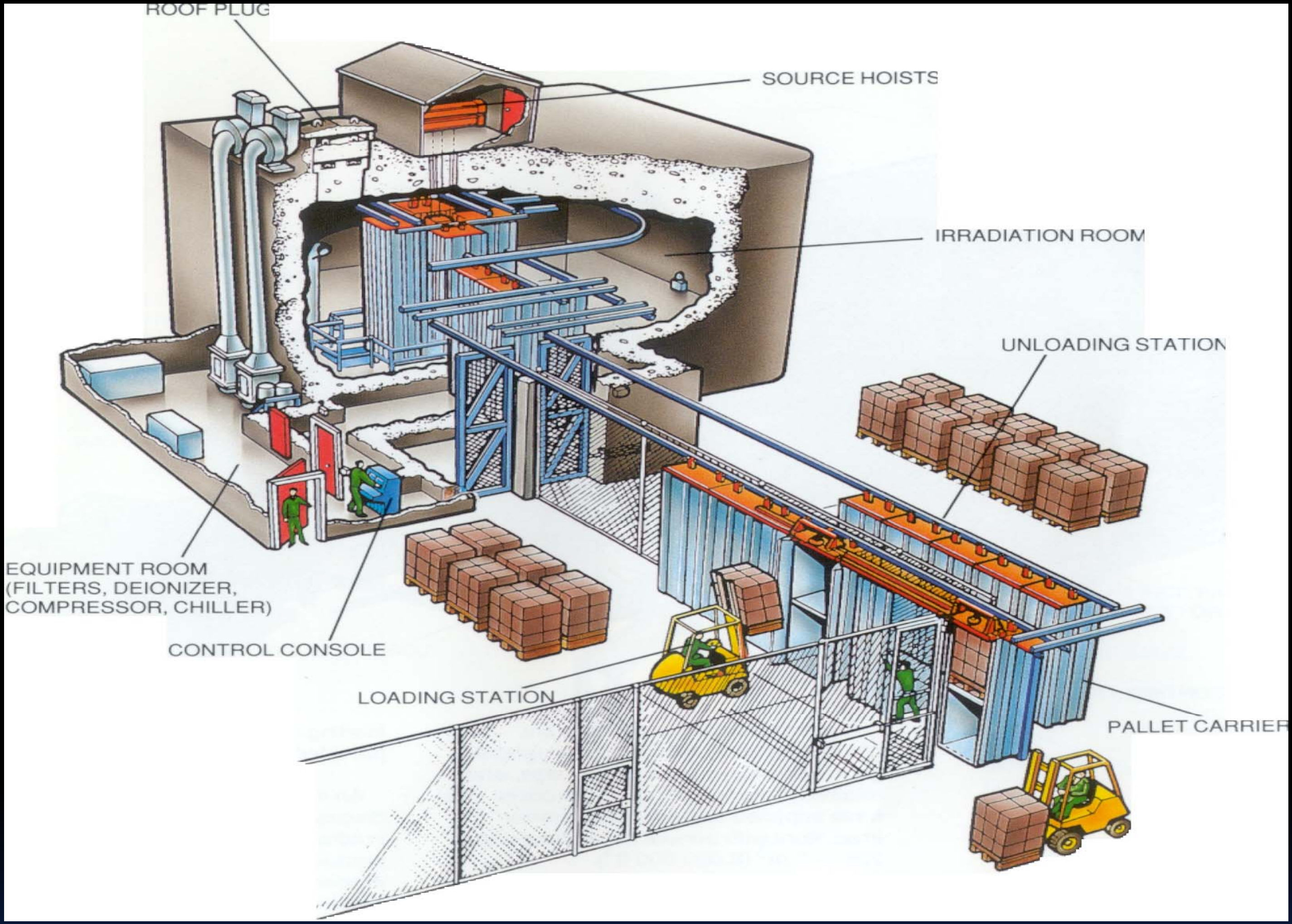




- Irradiator: Co-60 and Cs-137
- Gamma and neutron radiation
- Large irradiators, Uniform doses
- High capacity



- Accelerator: e^- (<10MeV) and x-ray (5MeV) with different arrays

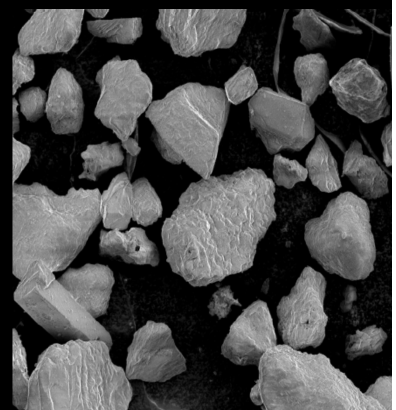


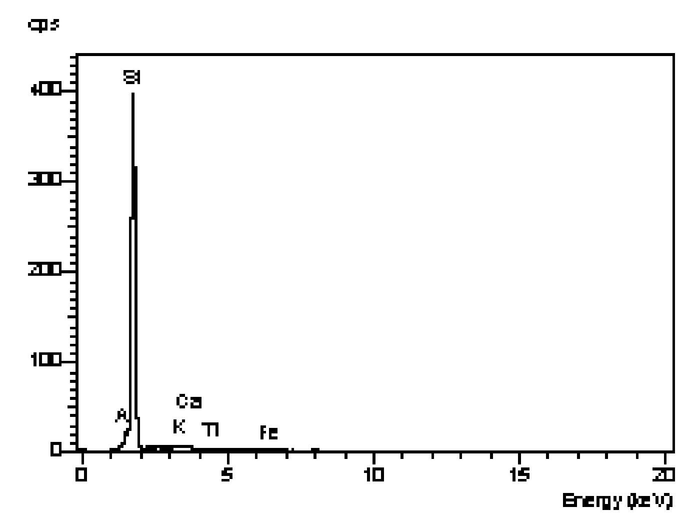
- Log-book Dosimetry
- Irradiation capacity 60,000 Ton/y
- 0.05-0.3 kGy to 2.5 kGy

Dose control for Preservation

- Extension of shelf-life of fruits (0.5-1.5 kGy)
- Control of harmful bacteria in fresh meat and poultry (1.5-4.5 kGy)
- Control of insects, parasites or micro-organisms (0.15 < 1kGy)
- Delay of ripening (0.5-2 kGy)
- Inhibition of sprouting (0.05-0.15 kGy)

Identification of Irradiated Food: fruit, spices, eggs,…





Vegetables, fish

Detection methods

- **Chemical**
- **Biological**
- **Physical**

- Electron spin resonance (ESR or EPR) (Onori S. and Pantaloni M. 1995 Int.Food Sci. And Techn.29, 671)
- Impedance (Ehlerman, D. 1972 J. of Food Science 37, 501)
- Viscosimetry
- Photostimulated luminescence (PSL)
- Thermoluminescence (TL), OSL

Dosimetry: Dating

The dose experienced by a pottery fragment during burial comes from radiation emitted by the natural isotopes of uranium, thorium, and potassium contained within the pottery fabric itself and in the surrounding soil medium.

Thypical levels of radioactive content in pottery fabric and soil are

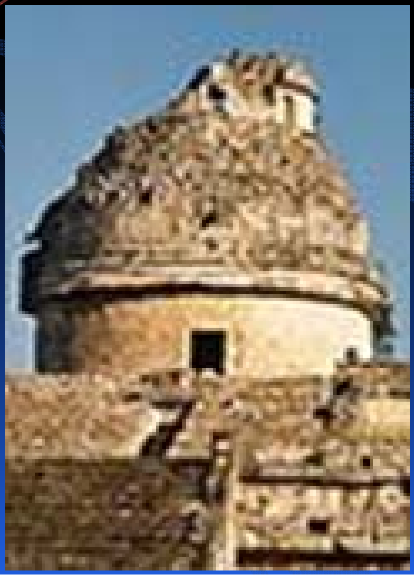
3 ppm of uranium
12 ppm of thorium
2 ppm of potassium-40

In volcanic regions is probably provide clays which are as much as five times richer in these impurities.

The radiation dose absorbed by pottery minerals depends upon various factors such as grain size, sherd water content, and efficiency of response to alpha-radiation.

The normal range of annual dose-rates encountered in TL dating is

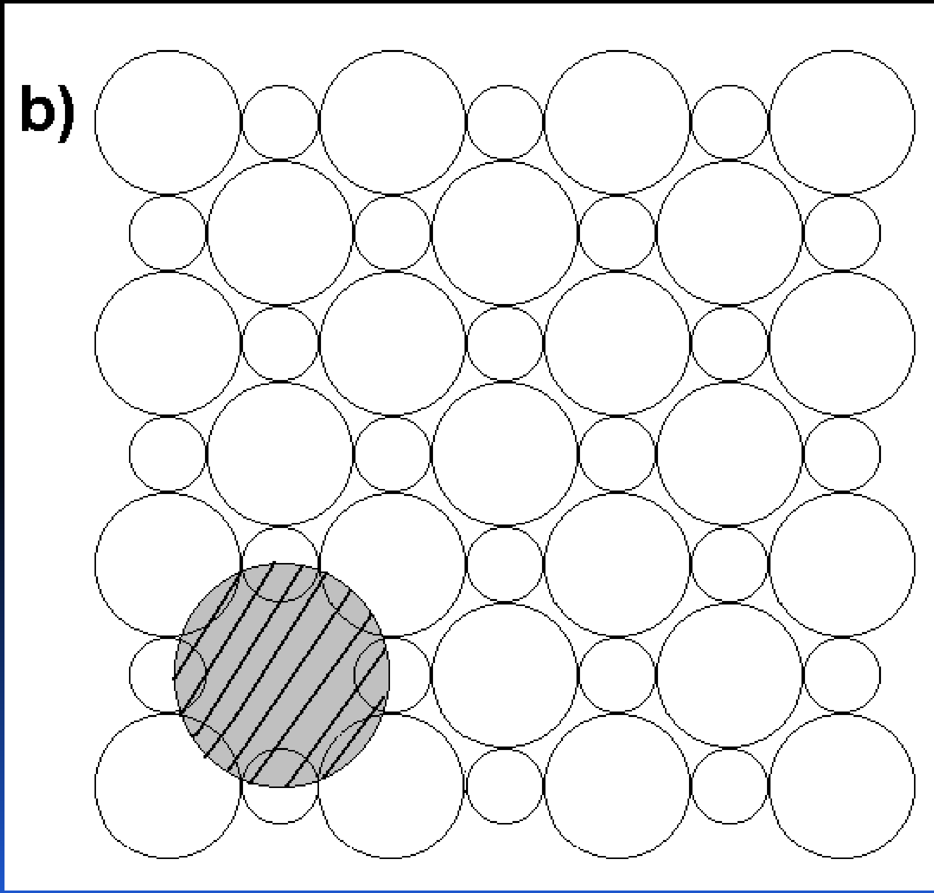
0.2 to 0.7 rad/y

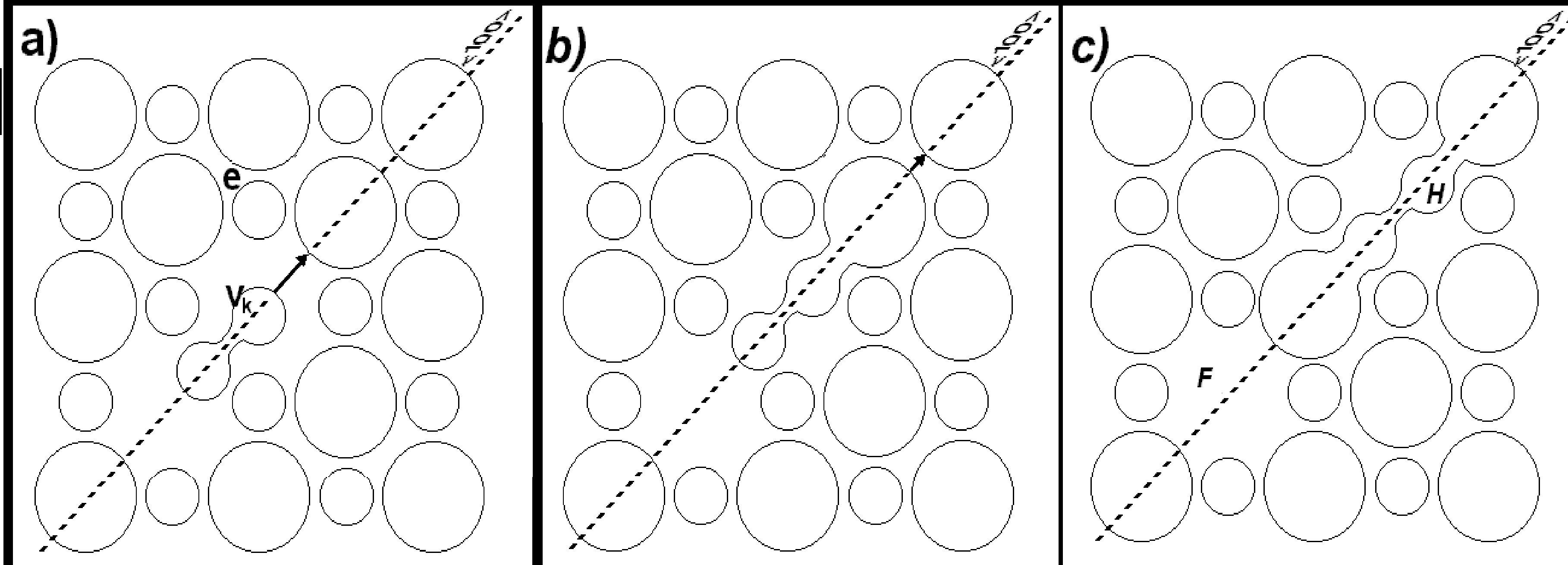


Chichen Itza

Anual dose 0.36 ± 0.01 mGy/y

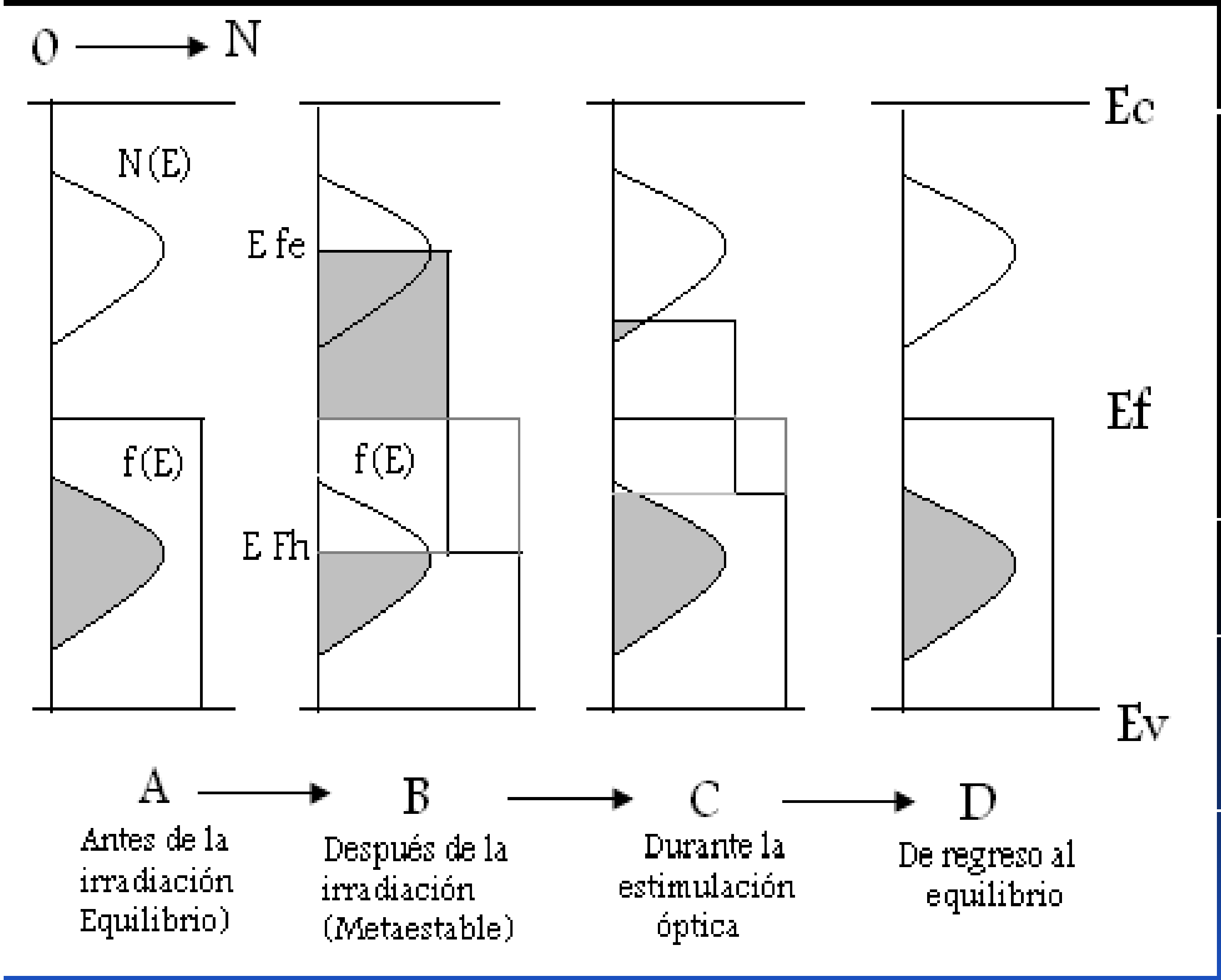
The Luminescence phenomena are directly connected to the band structure of solids and particularly to the effects of impurities and lattice irregularities





- a) El hueco auto-atrapado (centroV_k) y el electrón libre después de irradiación (Ionización). b) Disociación del excitón auto-atrapado, la molécula X_2^- se dirige en dirección <110> siguiendo recombinación no radiactiva del e^- y del V_k c) El centro H (intersticial X^{3-}) es capturado por un ion X- y es formado a cierta distancia del centro F.

Band Model: during irradiation and after stimulation

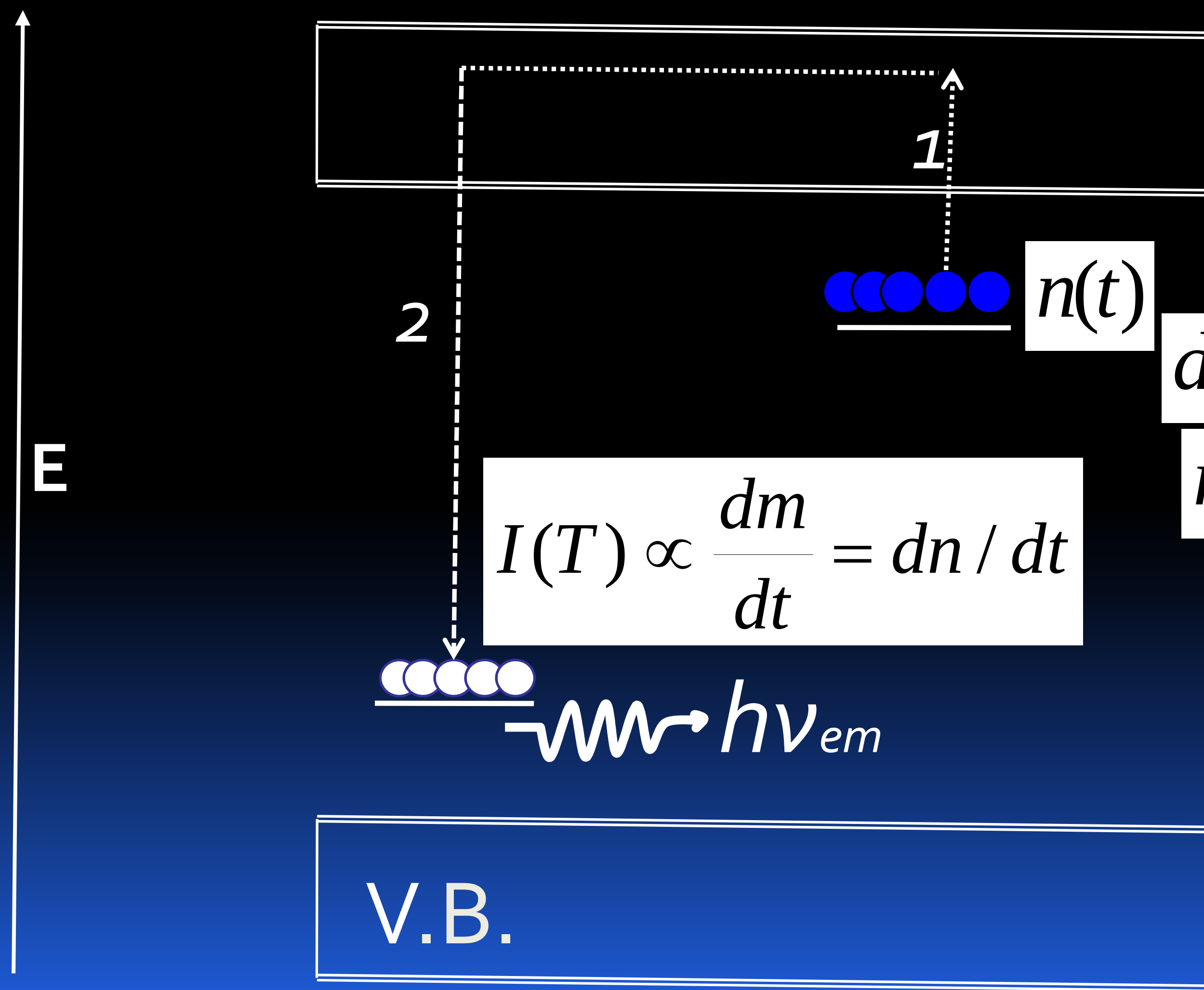


CB

VB

First order model:

1: detrapping 2: recombination



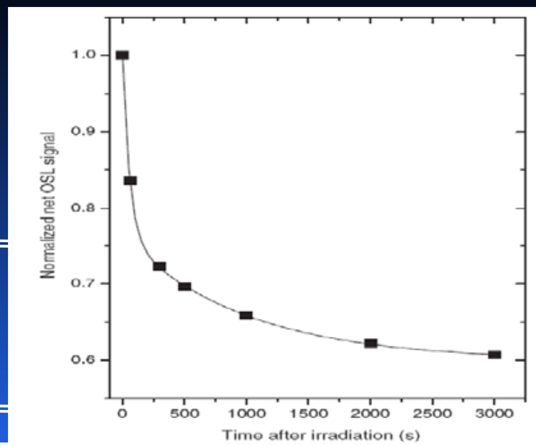
$$p = \sigma\phi$$

$$dn/dt = -n\sigma\phi$$

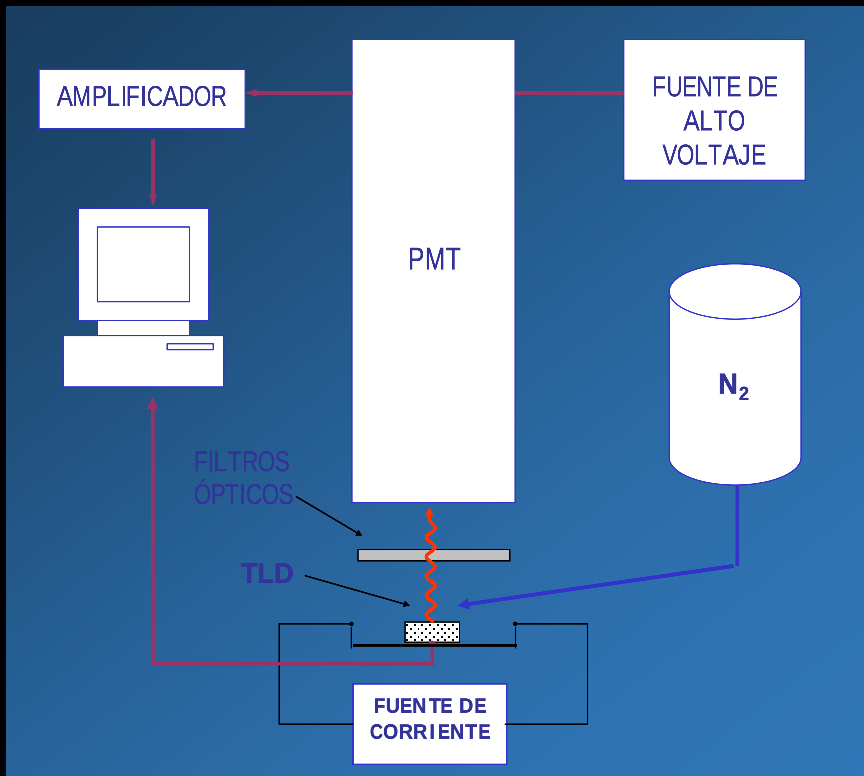
$$n = n_0 \exp(-\sigma\phi t)$$

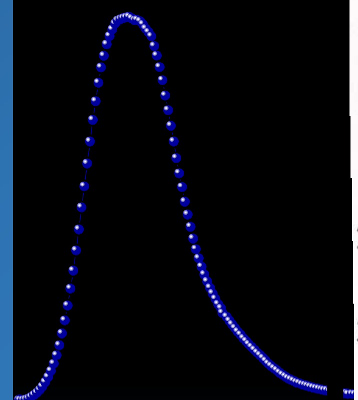
$$I(T) \propto \frac{dm}{dt} = dn/dt$$

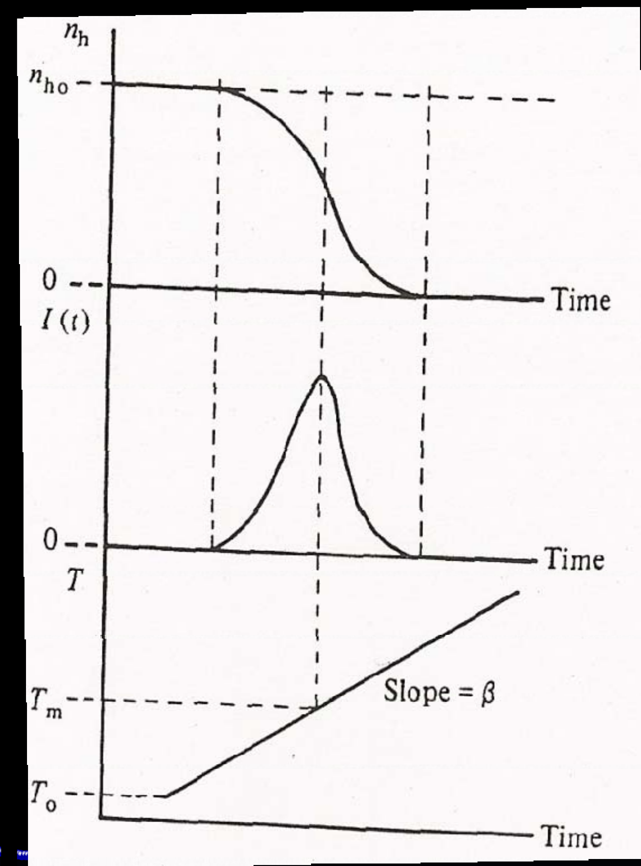
$\int(\infty)Idt \propto n_0$



TL measurement -Harshaw







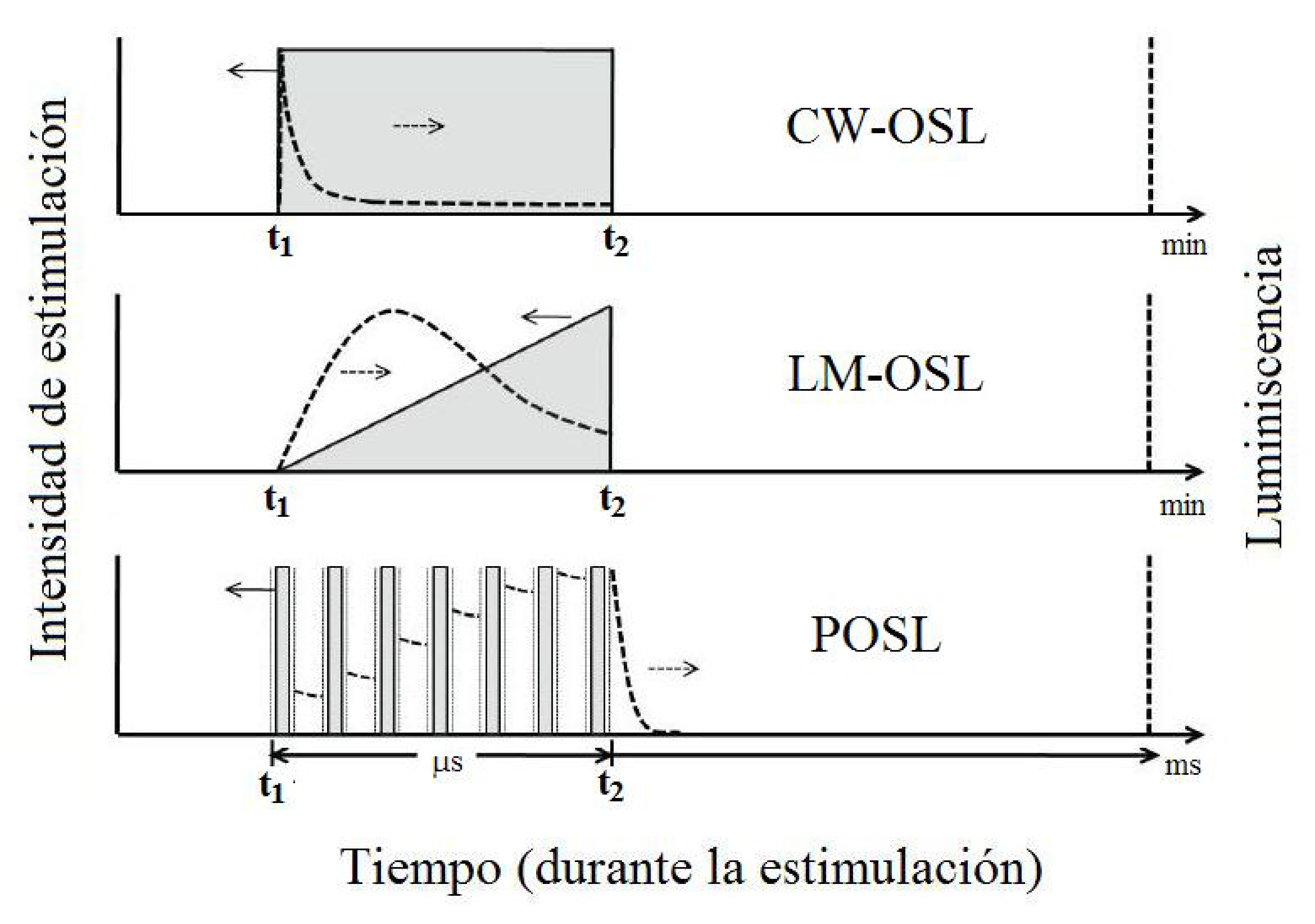
Initial Rise Method

$$I(TL) \approx \exp^{(E/kT)}$$

$$m = E/k$$

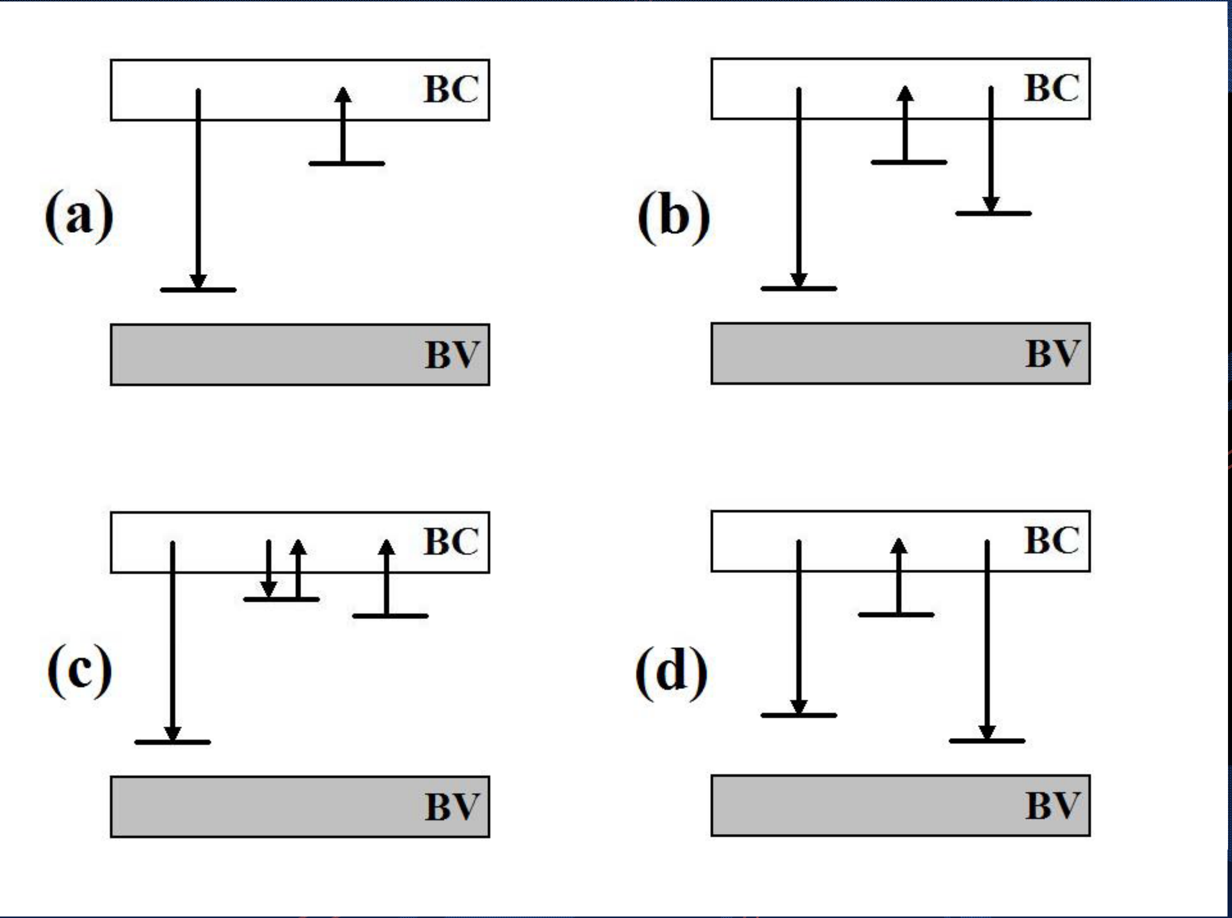
$$E\beta/kT^2_{màx.} = s\ \exp(-E/kT^2_{màx.})$$

OSL methods



CW-OSL
LM-OSL
POSL
Intensidad de estimulación
Luminiscencia
t_1
t_2
min
μs
ms
Tiempo (durante la estimulación)

OSL- singles models



(a) The most single model: One trap and One recombination centre
(b) Model with additional deep trap competitive
(c) Model with additional shallow tramp competitive
(d) Model with a recombination non-radiative centre and competitive

Framework: TL and OSL

- Thermally stimulated process

$$p = s\exp\left(-\frac{E}{kT}\right)$$

- Optically stimulated process

$$p = \sigma\phi$$

σ: photoionization cross-section (cm2)

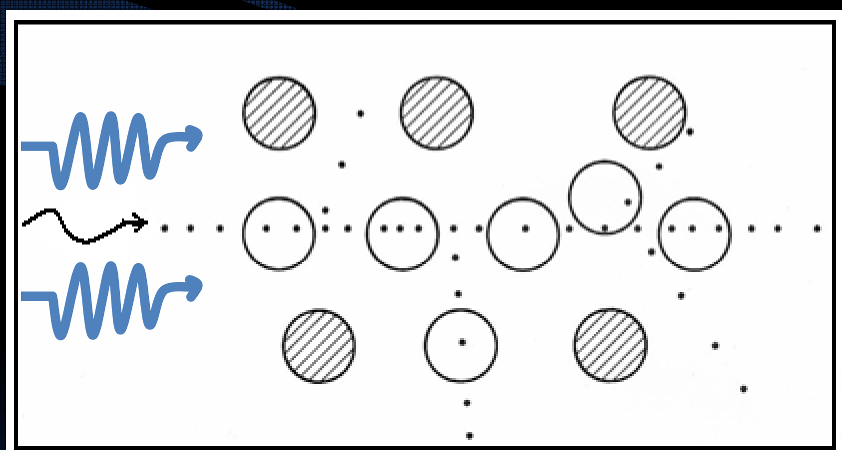
ϕ: photon flux (photons cm-2s-1)

Involve: Localized and delocalized energy levels, and optical transitions

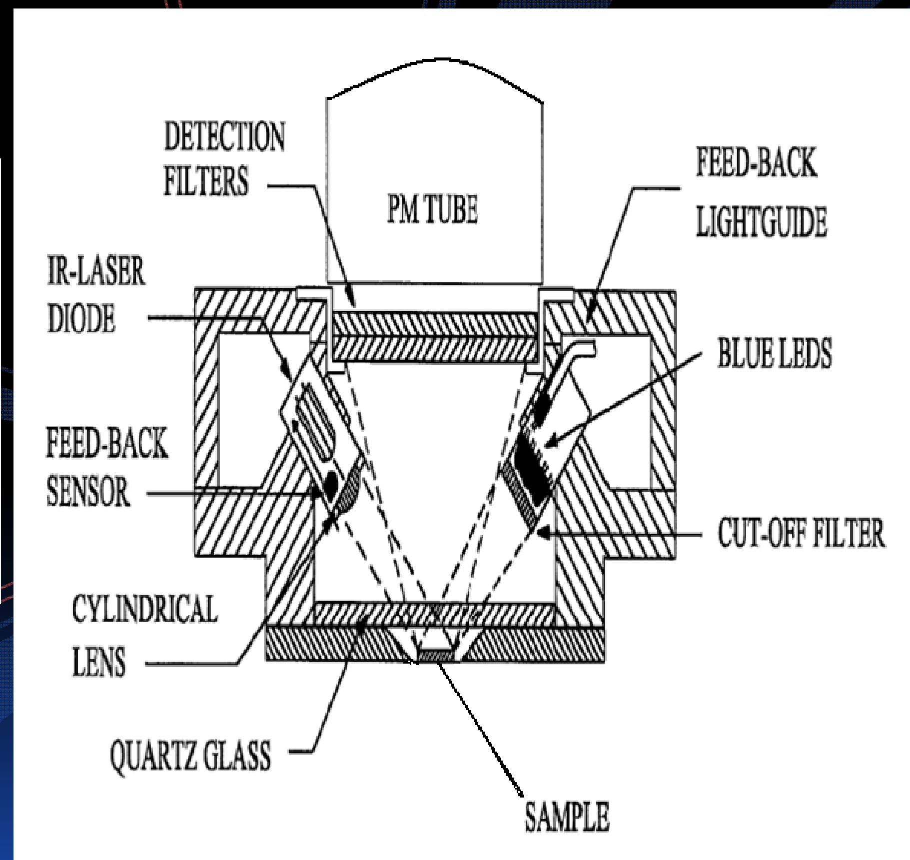
- The area under the decay curve is proportional to the absorbed dose.
- Initial intensity depends on the dose and stimulation power.
- The trapping mechanism during irradiation is the same already seen for TL.
- The OSL signal is obtained from the recombination of charges which have been optically released from electron traps within the crystal.
- During light stimulation the OSL signal is generally observed to decrease to a low level as the trapped charge is depleted: so we have a decay curve.

Experimental part

Ionization

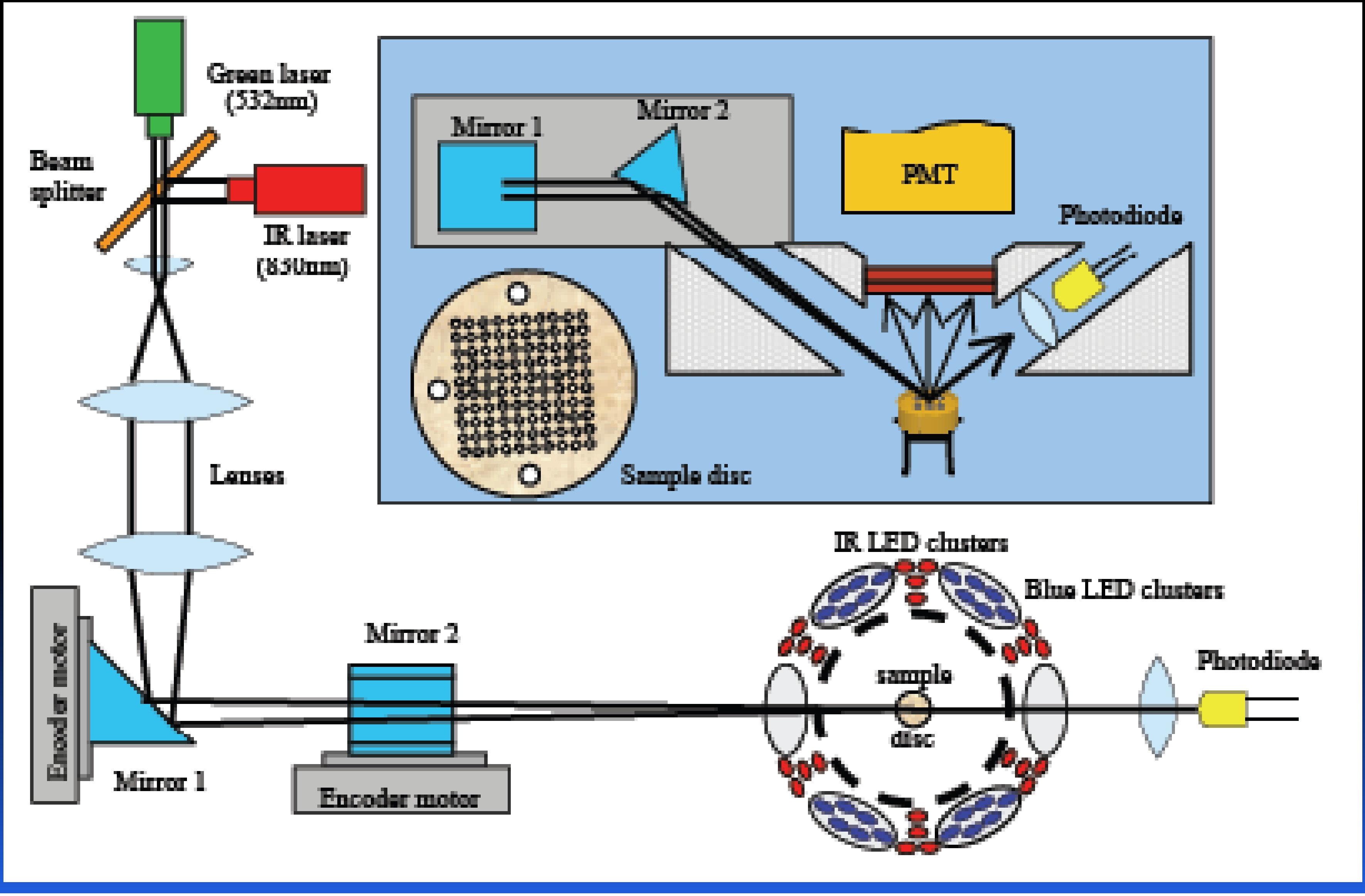


Detection

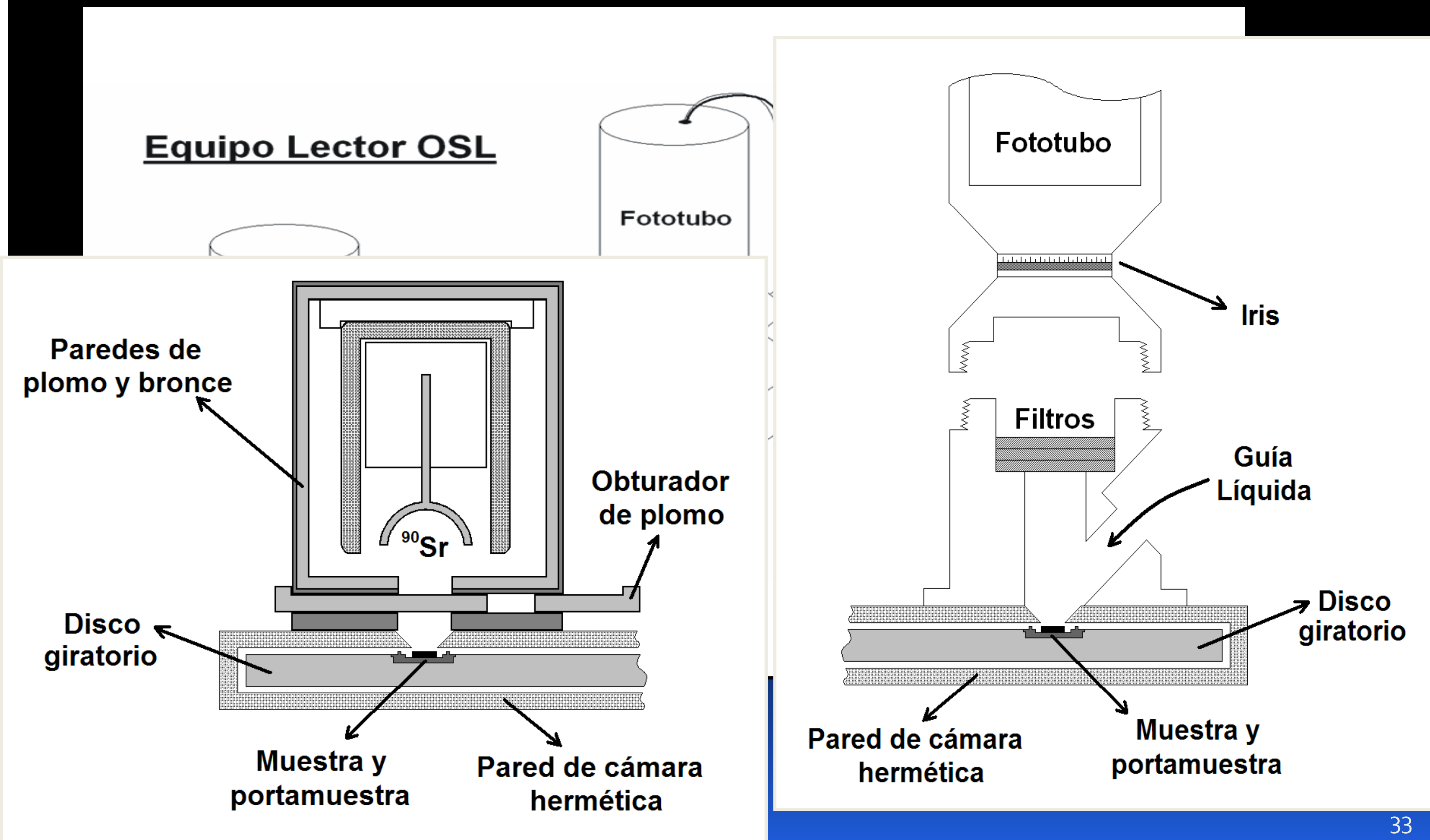


Bøtter-Jensen, L., Murray, A.S., 2001. Optically stimulated luminescence techniques in retrospective dosimetry. Radiat. Phys. Chem. 61, 181-190.

OSL measurement

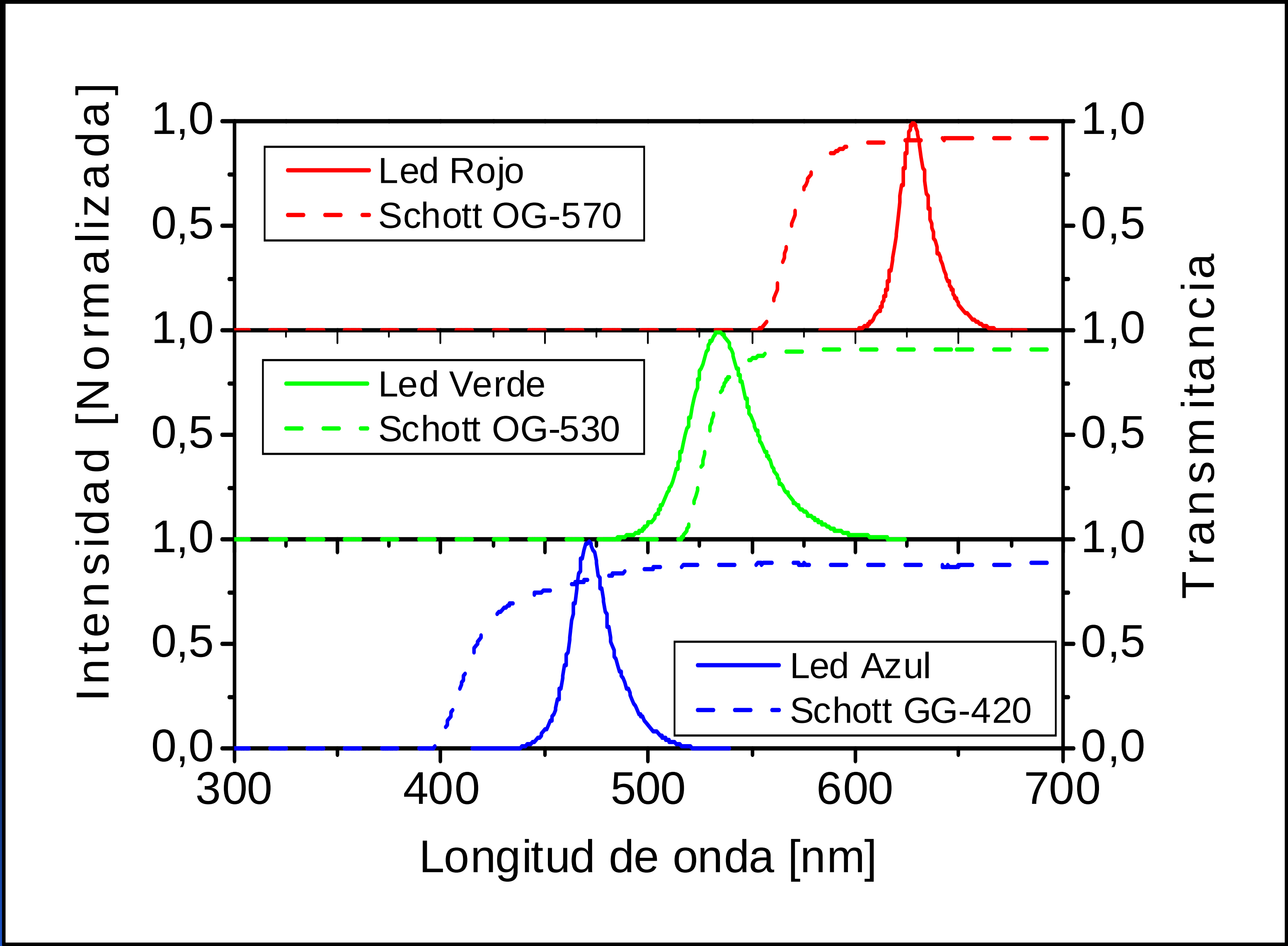


Design


Equipo Lector OSL
Fototubo
Paredes de plomo y bronce
^{90}Sr
Obturador de plomo
Disco giratorio
Muestra y portamuestra
Pared de cámara hermética
Fototubo
Iris
Filtros
Guía Líquida
Disco giratorio
Pared de cámara hermética
Muestra y portamuestra

First desing

- Stimulation light



Characteristics

- Guía optica liquida de alta transmitancia Newport VIS 77631
- 1 m de longitud y 8 mm de diametro, transmitancia del 80% entre 340-800 nm.
- Tubo fotomultiplicador
- Electron Tubes P25PC-02. Opera en modo de conteo de fotones
- (photon counting), ventana de transmision entre 180 y 630 nm y el fotocatodo con maxima sensibilidad en 350 nm.

Design problem

- La luz de estimulacion puede llegar a ser hasta 10 ordenes de
- magnitud mas intensa que la luz emitida por la muestra, es necesario
- un conjunto de filtros de emision, hasta lograr la atenuacion necesaria de la luz de
- estimulacion.

Iris for closed

iris con cierre completo que permite intercambiar los filtros de emision sin que llegue luz al detector.

C-Mount Iris Diaphragm Mount Barrel modelo NT03-623 de Edmund Optics

Apertura maxima de 10 mm. La lectura del conteo de fotones se realiza mediante un contador Electron Tubes CT2 y los datos de la medicion con se adquirieron mediante una laptop.

Leds

Luz de estimulacion: leds Luxeon de alta potencia con emision en el azul, rojo y verde.
Led azul Luxeon V Star (emision max 470 nm)
Led verde Luxeon V Star (emision max 530 nm)
Led rojo Luxeon III Star (emision max 627 nm).

Alimentacion corriente de 500 mA, mediante un controlador de diodos laser Newport modelo 525B. Dicha corriente da lugar a un flujo luminoso efectivo en la posicion de la muestra de 128, 56 y 38 lm para los leds verde, rojo y azul, respectivamente.

Light stimulation Control

El shutter electronico TTL es un Newport modelo 71455.

El conjunto del led, el alojamiento para los filtros de estimulacion, el shutter y la guia optica se encuentran alineados opticamente y montados sobre un bastidor externo a la camara hermetica

Filters

Stimulation: LED VERDE, dos filtros pasa-alto Schott OG530 cuando
LED ROJO dos filtros pasa-alto Schott OG570
AZUL dos filtros pasa-alto Schott GG420 .

El filtro Schott OG530 con transmitancia de 0.91 para longitudes de onda mayores a la longitud onda de corte (530 nm) y una transmisi´on menor a 10−6 para longitudes menores a 530 nm.

El filtro Schott OG570 con transmitancia de 0.92 para longitudes de onda mayores a la longitud de onda de corte (570 nm)
y una transmisi´on menor a 10−6 para longitudes menores a 570 nm.

El filtro Schott GG420 con transmitancia de 0.90 para longitudes de onda mayores a la longitud de onda
de corte (420 nm) y tambien una transmision menor a 10−6 para longitudes menores a la longitud de corte.

Attention to the colour

Los filtros usados en el sistema de filtros de emision no solo dependen del color caracteristico del led usado para la estimulacion sino tambi´en del espectro de emision de cada muestra.
Por tal motivo, los filtros de emisi´on empleados en cada muestra se deben especificar en cada caso.

Sin embargo se pueden usar dos filtros pasa-banda: Hoya B-390 o el Hoya U-340.

El filtro Hoya B-390 permite el paso de luz entre 320 y 500 nm y tiene el max de transmision (0.77) a 390 nm.

Por otro lado, el filtro Hoya U-340 es un filtro UV que deja pasar luz entre 250 y 390 nm y tiene el max de transmisi´on (0.80) a 340 nm

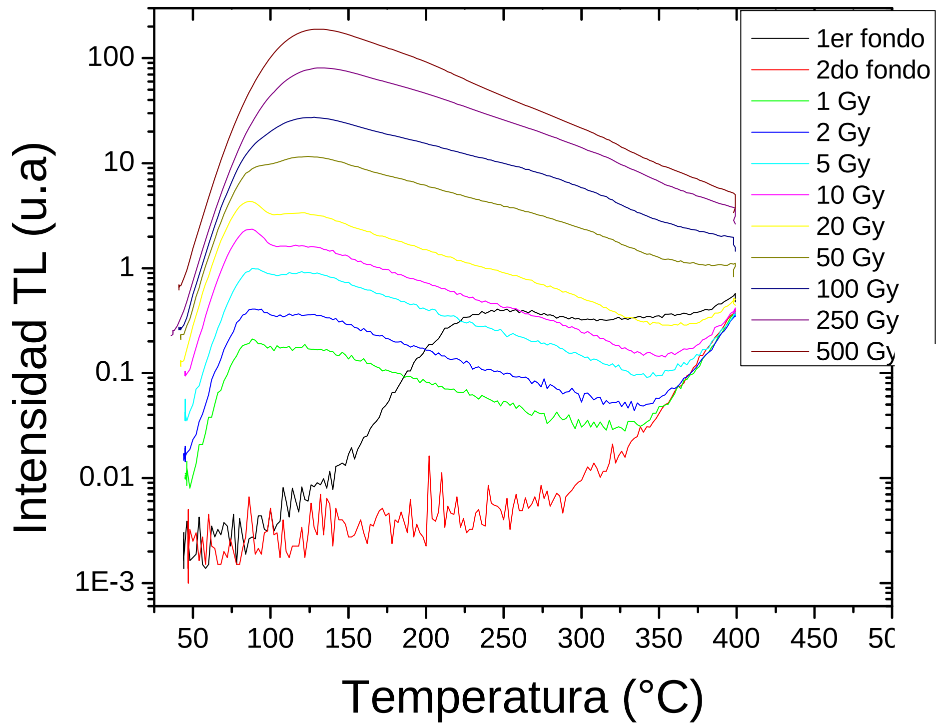
Spectral measurement

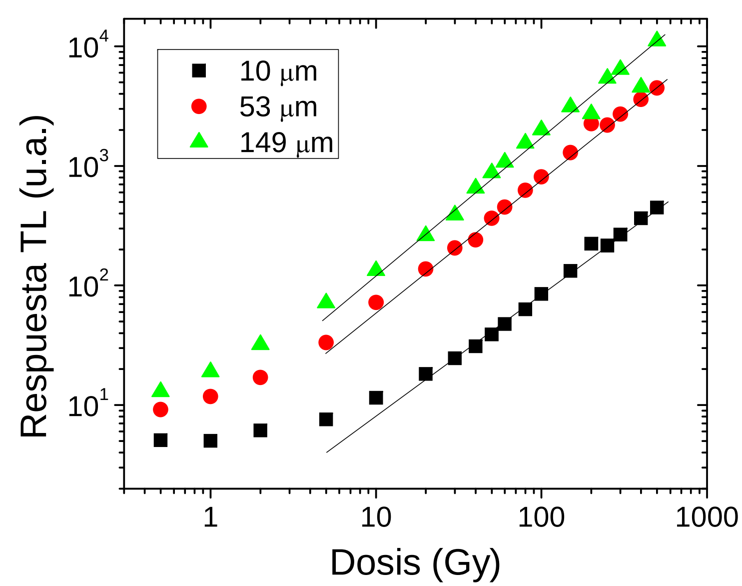
Monocromador Acton Research VM-504 0.39m con fototubo Electron Tubes P25PC-02 .

Las rendijas de entrada y salida del monocromador se abrieron con un ancho de 3 mm, lo cual da
como resultado una resolucion aproximada de 5 nm.

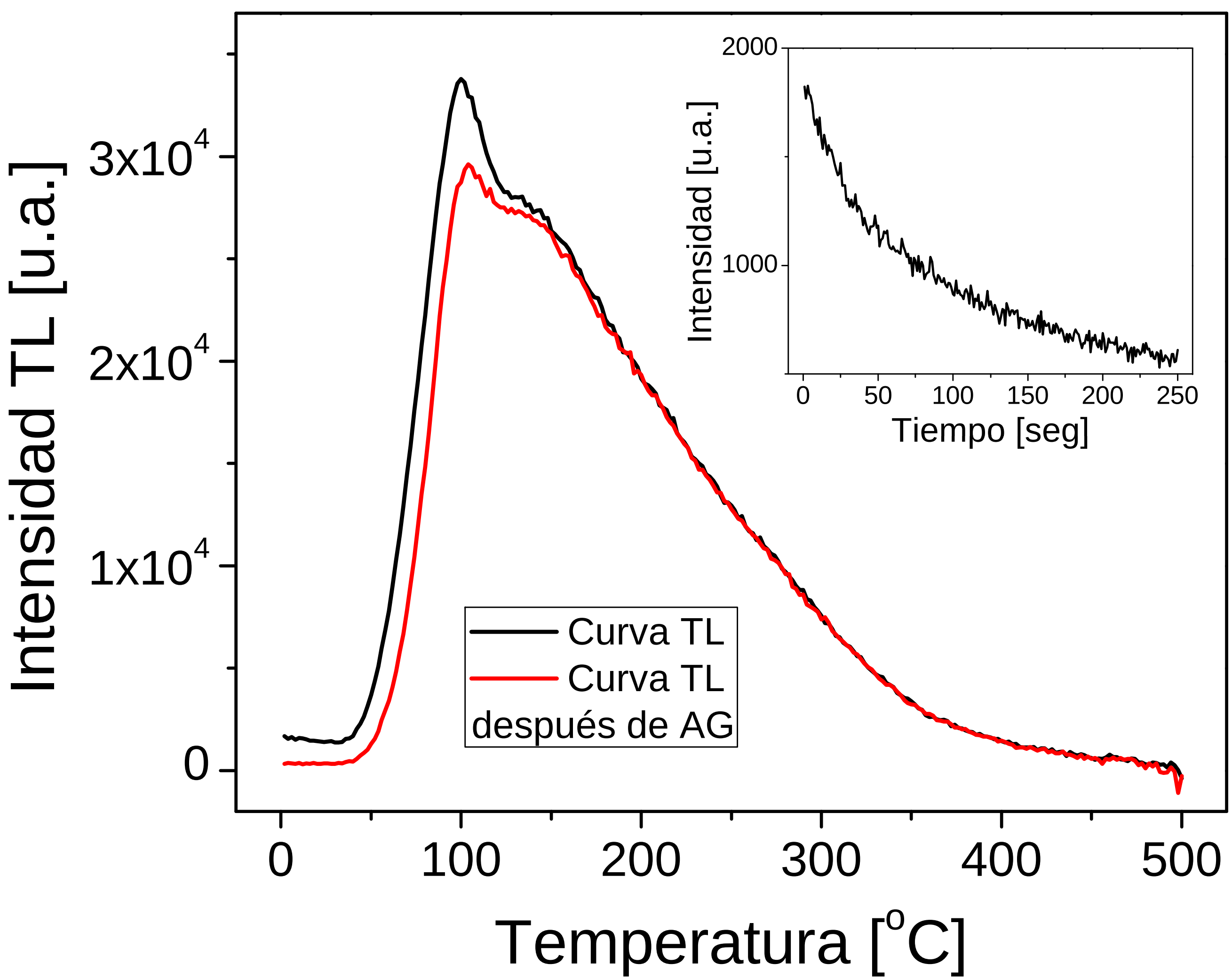
La luz emitida por la muestra fue colectada por un bundle de fibras opticas de silica de 3.2 mm de diametro con transmitancia a partir de
los 280 nm (Newport modelo 77563) y proyectada a la rendija de entrada del monocromador

An example

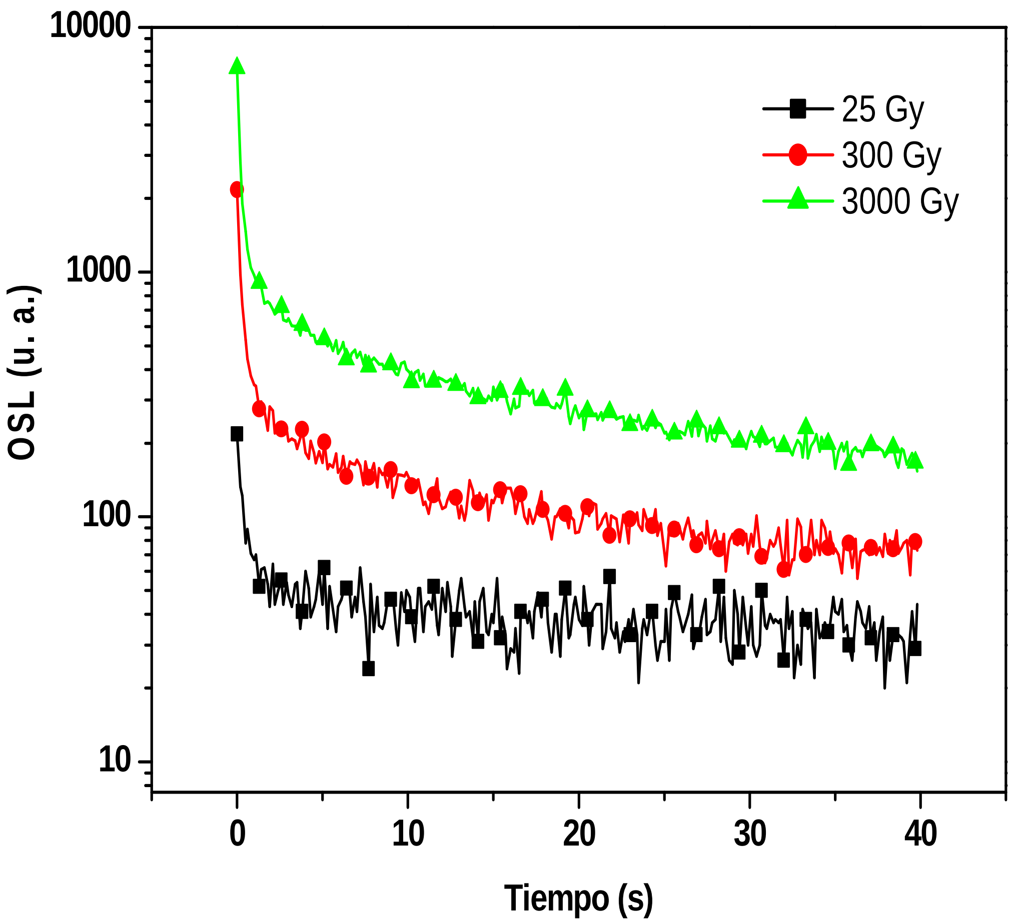


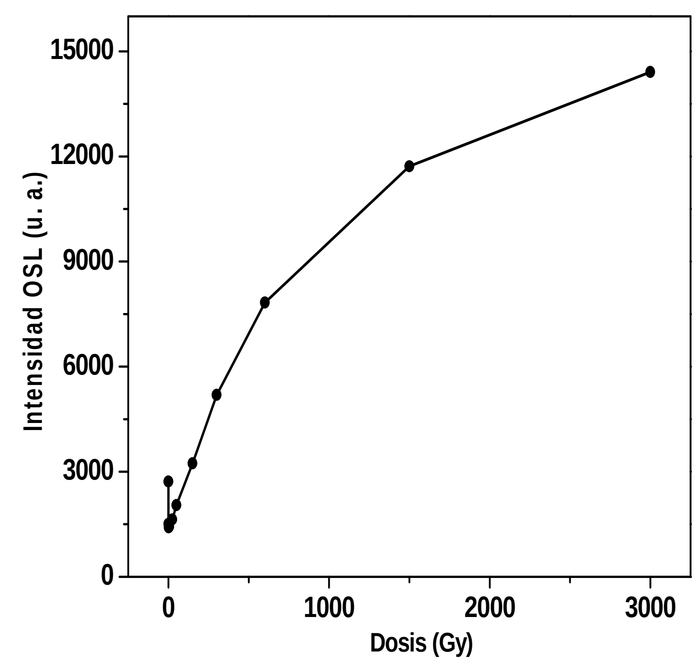


Glow curves of (*Cuminum cyminum L*), 149μm. Dose-response (10, 53, 149 μm) at 0.5-500 Gy gamma radiation.

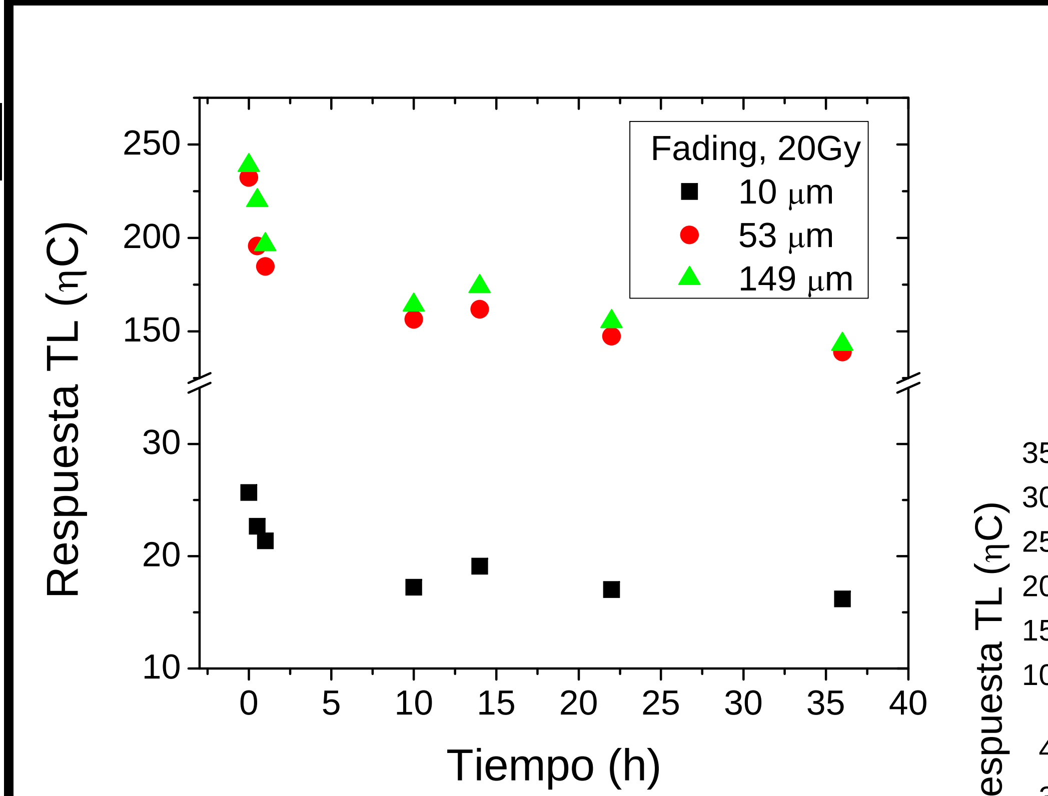


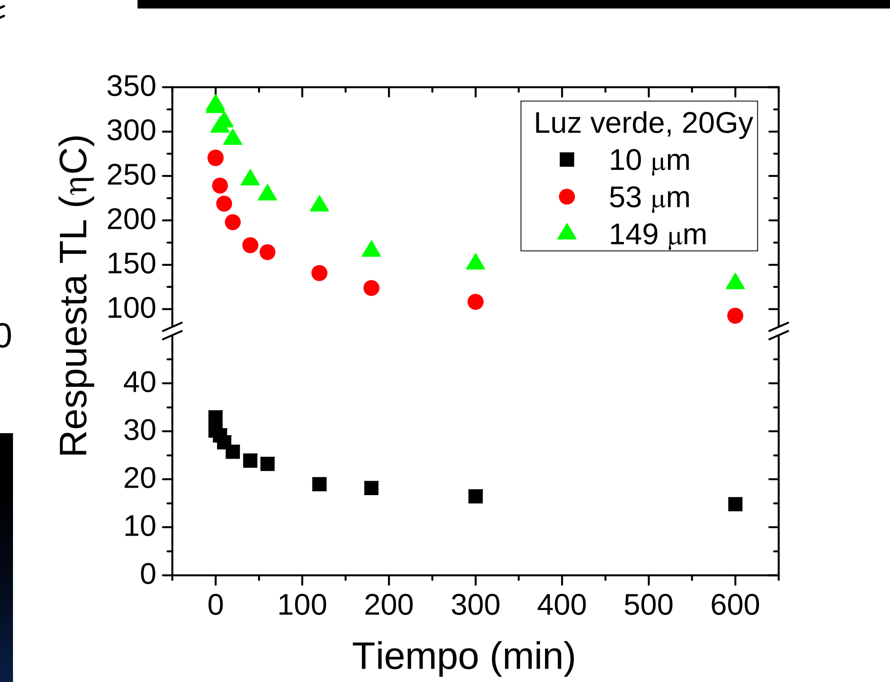
Afterglow (AG) response, and the OSL signal





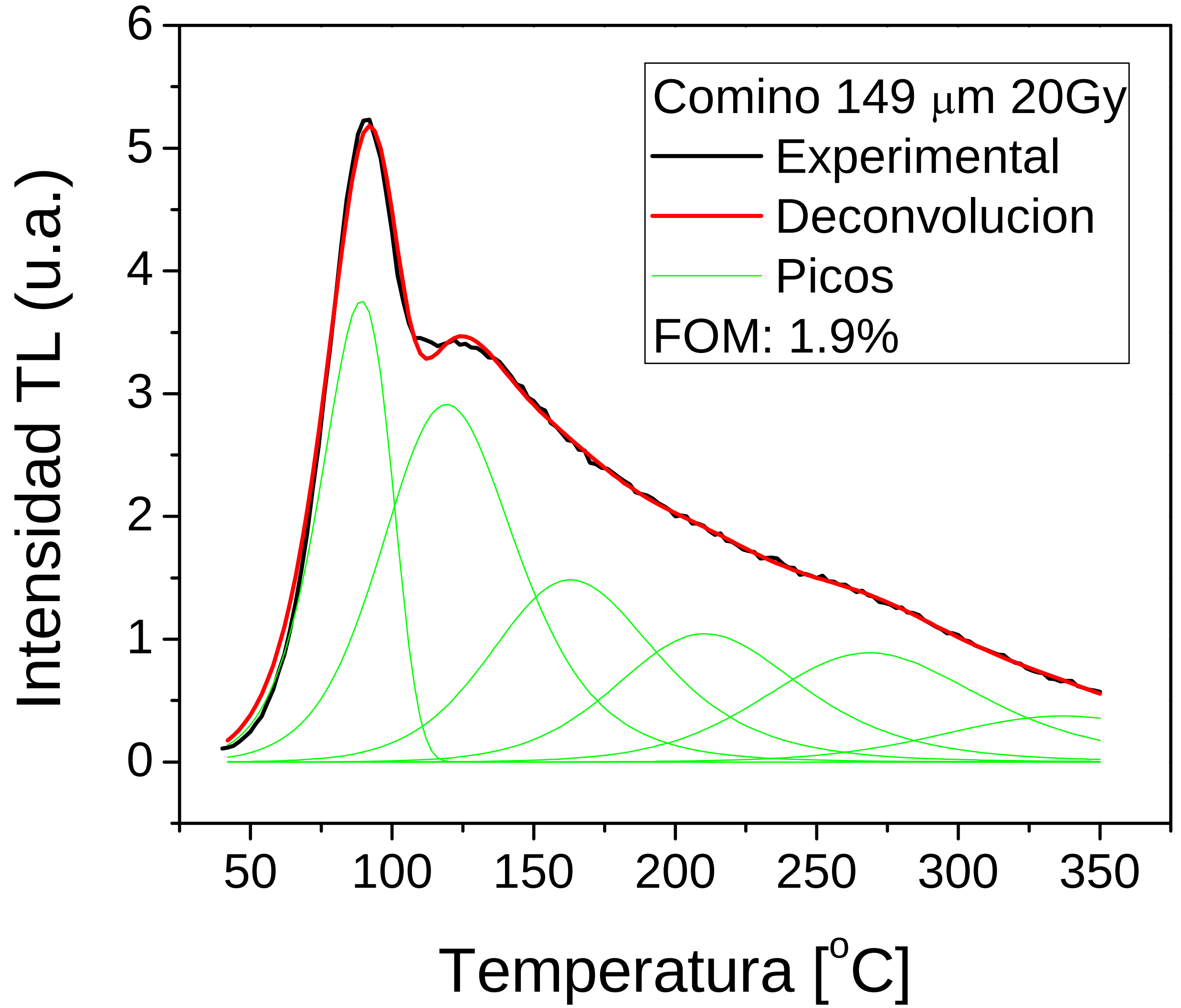
OSL signals for different doses for Cummins, and OSL response. The samples were photostimulated with blue light (470 nm) during 40 s, for OSL detection. The TL/OSL-DA-15 system was programed in automatic stage for to do the photostimulation, and 50 $mWcm^{-2}$ output power.





Fading up to 36 h, fast decreasing during first 10 h.
UV bleaching under green light (514nm) during 0-600min and fast decreasing during the 3h.

Deconvolution by using GOK



Activation energy: 0.76 – 0.97 eV.

Kinetics parameters for Cominum using GOK model

Peak#	T_{max} [ºC]	E [eV]	s[s^{-1}]	b	n_0/N
1	89	0.88	2.85×10^{11}	1.00	5.98×10^{-5}
2	120	0.77	7.92×10^{12}	1.99	9.37×10^{-5}
3	163	0.76	9.57×10^{11}	2.00	6.23×10^{-5}
4	210	0.84	1.01×10^{12}	2.00	4.90×10^{-5}
5	270	0.89	2.35×10^{11}	1.98	4.61×10^{-5}
6	337	0.97	2.35×10^{11}	1.98	1.96×10^{-5}
FOM					1.9 %

May, C.E., Partridge, J.A. (1964). Thermoluminescent kinetics of alpha irradiated alkali halides. Journal of Chemical Physics, 40, 1401–1409

As conclusion
Comments about some problems in OSL

Light sensitivity
Lack of suitable materials
Fading of OSL signal

Huntley D. J., Godfrey-Smith D. I.. and Thewalt M. L. W. *Optical Dating of Sediments. Nature* ***313, 105-107 (1985).***

"The use of thermoluminescence as a method for the dosimetry of ionising radiation has been established for many decades and has been unquestionably successful. It is therefore difficult to imagine how any new technique could easily supplant it.

Perhaps OSL dosimetry should not be characterised as an entirely new technique, but rather a development of the well established technology that may be considered superior in some respects. ..,

No doubt, many of us will have similar discussions in our own institutions as we weigh the advantages and disadvantages of TLD versus OSL."

S.W.S.McKeever and M. Moscovitch. *On the advantages and disadvantages of OSL and TL dosimetry*. Radiat. Prot. Dosim. **104** (3), 263-270 (2003).

Some OSL materials-dosimeters

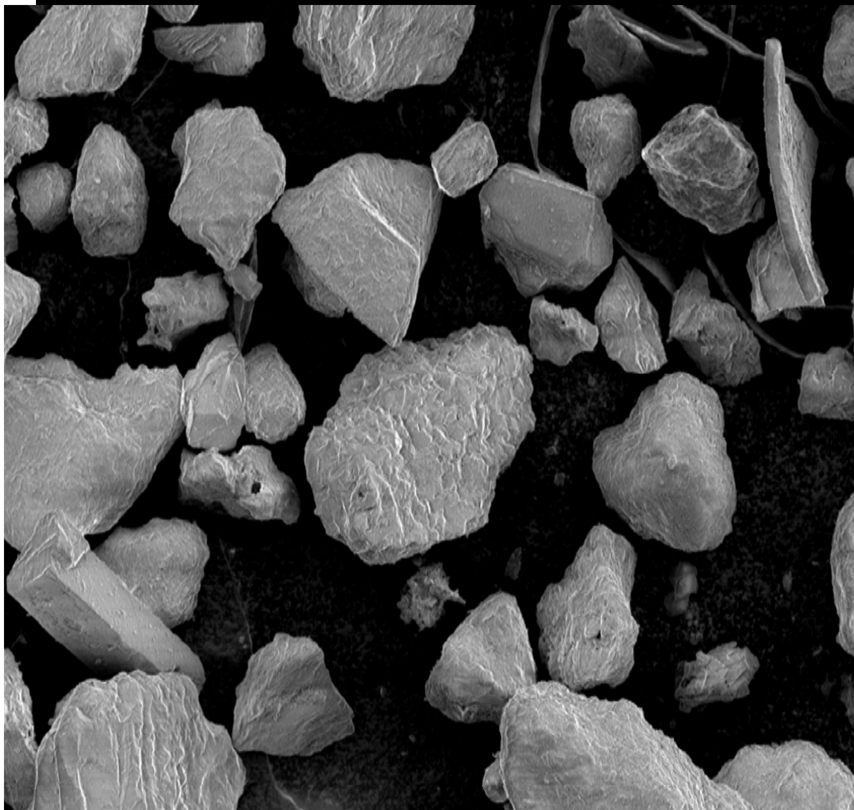
- K_2YF_5:Pr^{3+}, CsY_2F_7:Tb, $CsGd_2F_7$:Tb, MgO:Tb, Mg_2SiO_4:Tb, $KMgF_3$:La, SrB_4O_7:Eu y PbB_4O_7:Eu.

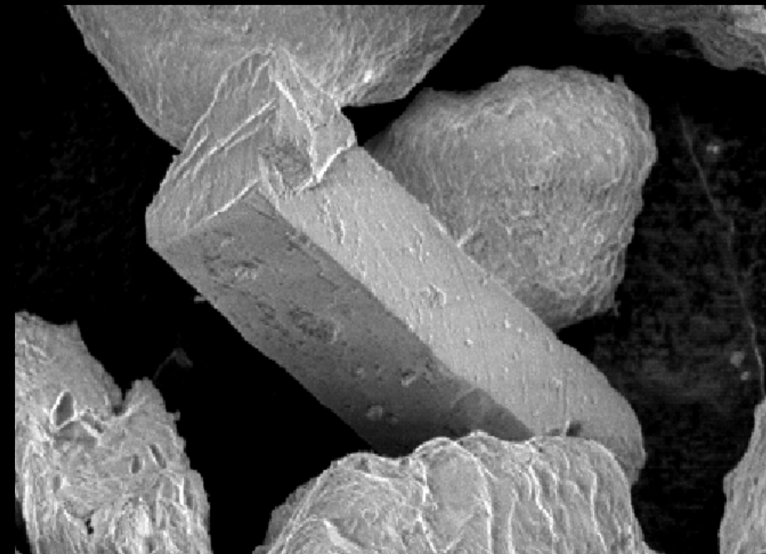
- IN WORKS:
- Determine the best stimulation wavelenght for obtain the largest OSL signal.
- Filters more adecuate for measurements.

Commercial: OLS Materials

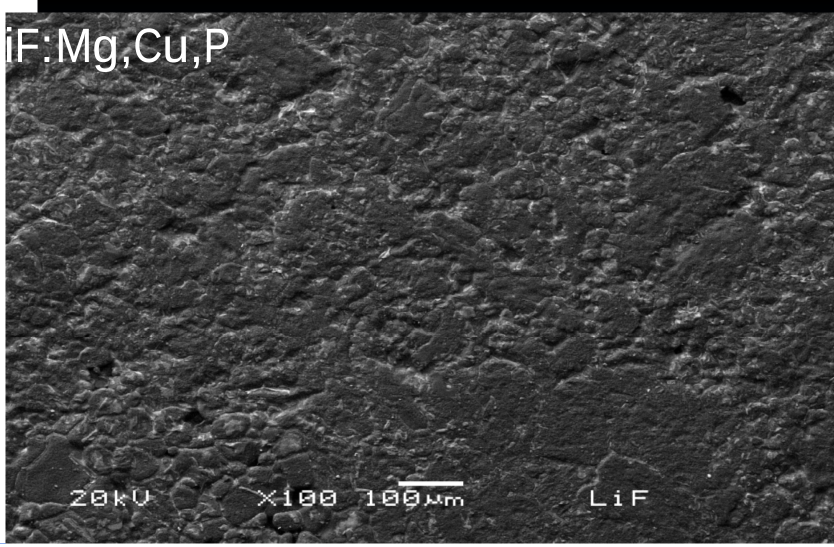
- Al_2O_3:C (InLight dosimeter, Landauer Inc.)
- BeO (Thermalox 995, Brush Ceramic Products)
- LiF:Mg,Ti (TLD-100) Harshaw
- CaF_2:Dy (TLD-200) Harshaw

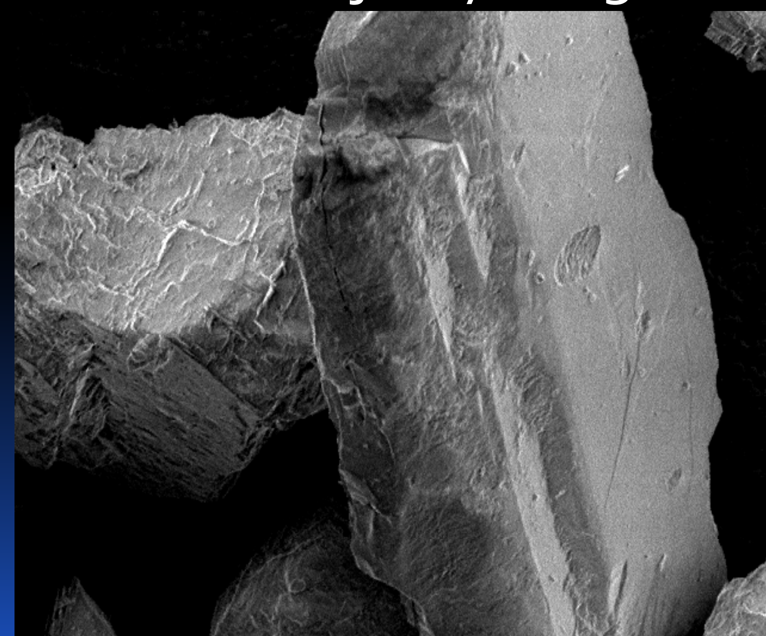
✓TL and OSL measurements can be useful for study the glow curve´s structure and irradiated foodstuffs identification, Dosimetry, Dating, …





Minerales en Guajillo y Orégano





Application in polymers

Properties of polymers.

Radiation effects in polymers.

Single crystal in PTFE irradiated.

Biomedical application.

Biodegradable polymers.

Implant materials.

Medical applications polymers

Have been used in medicine with the major purpose to assist damage tissues for their healing.

Two kinds of bioabsorbable suture are currenly used.

Catgut from the regenerated collagen and the other is synthetic sutures.

(Y. Ikada, Bioabsorbable fibers for medical use, in: Handbook of Fiber Science and Technology Fibers, Part B, eds. M. Lewin, J. Preston (Marcel Dekker, Inc. 1989) pp. 253-301.

Design and synthesis of artificial radiological equivalent tissue and bone materials.

(X-Rays descovered in 1895)
PE phantom was made in 1956

Developing the model by using the relationship between the mass attenuation coefficient and the photon energy. The model is used for designing the simulated equivalent materials.

Irradiators types

a) Industrial: Large irradiators
b) Medium: fruits and foodstuffs
c) Small: for researcher

Portable Irradiator in shop