Methodological Aspects of OSL Technique Applied to Space Dosimetry

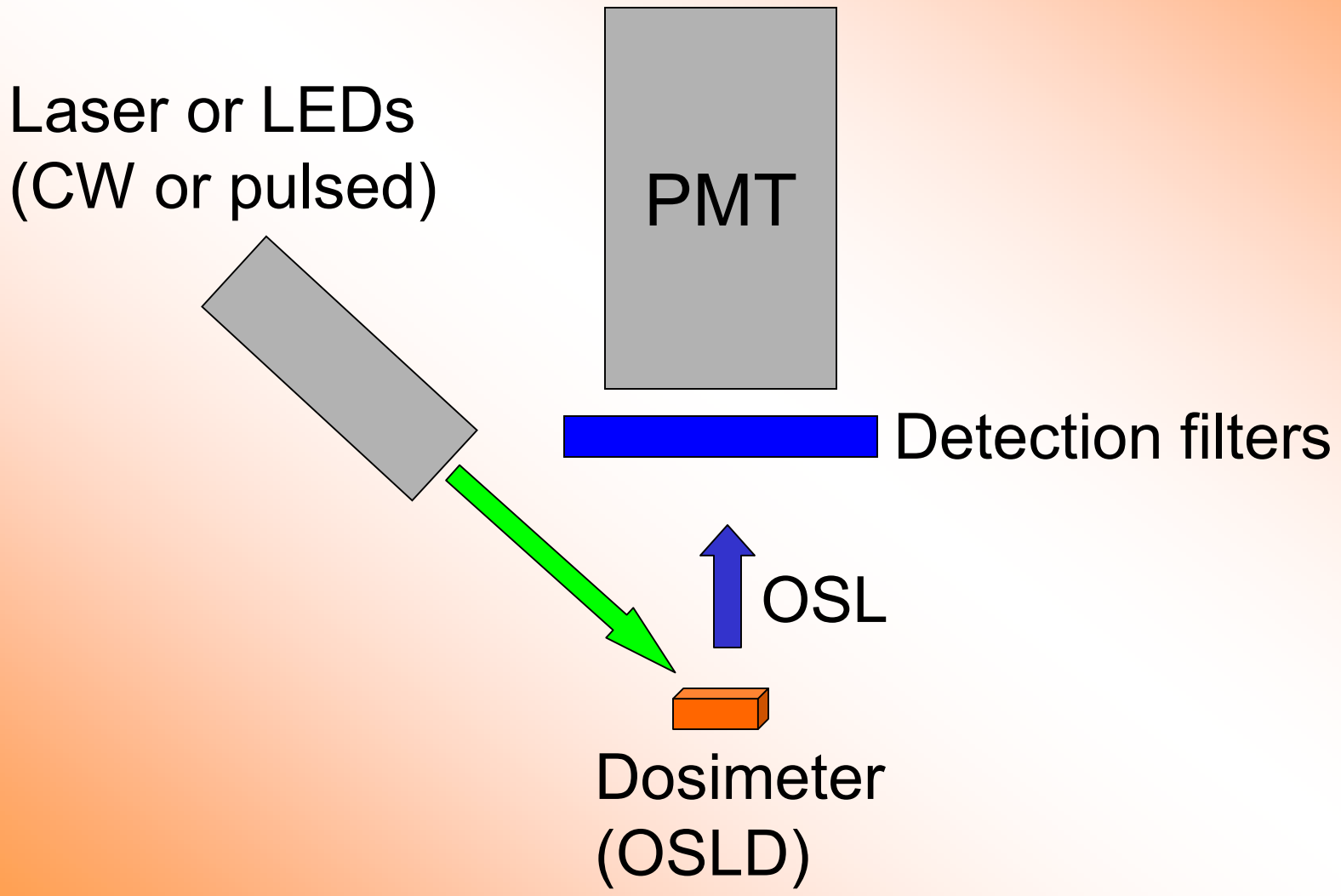
Eduardo G. Yukihara, G. O. Sawakuchi, and S. K. Guduru

Department of Physics, Oklahoma State University

Outline

- Overview of the technique
- Methodological developments
- Recent results
- Future (and present) research

The OSL technique



Materials

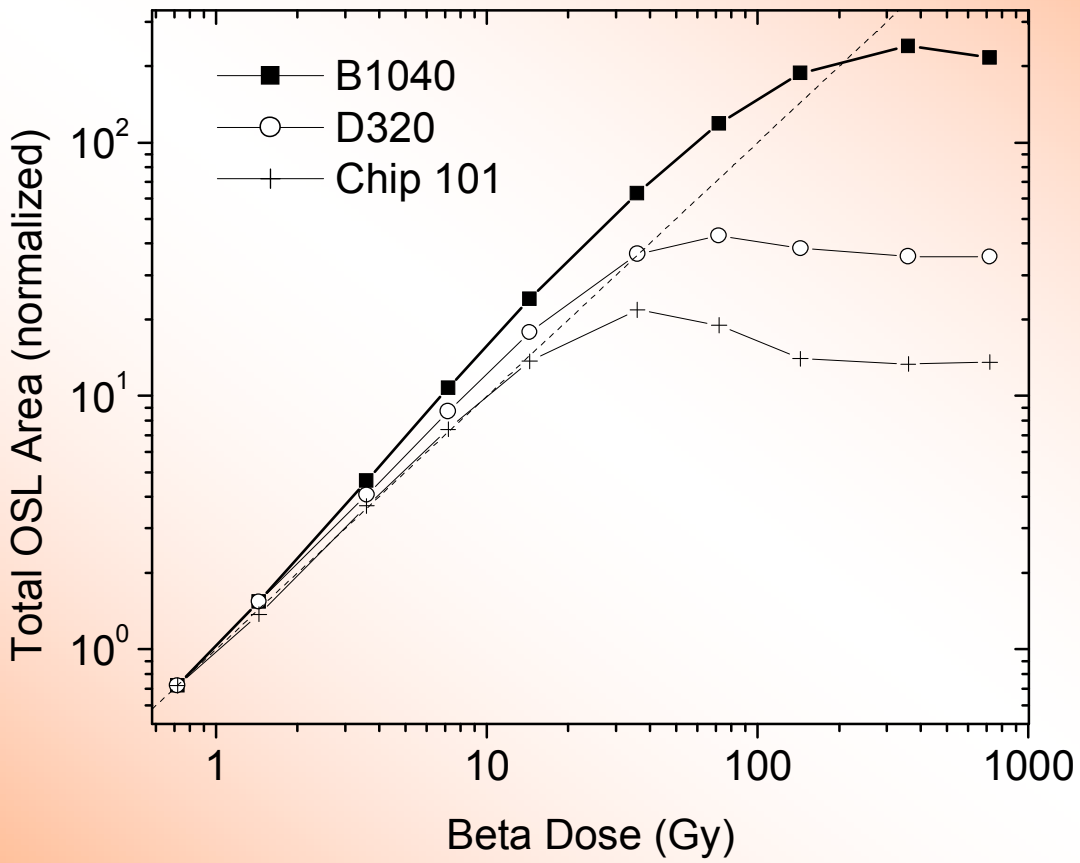
Small crystals or fibers
(single crystals)

Chips
(single crystals)

Luxel tapes
(powder in plastic film)

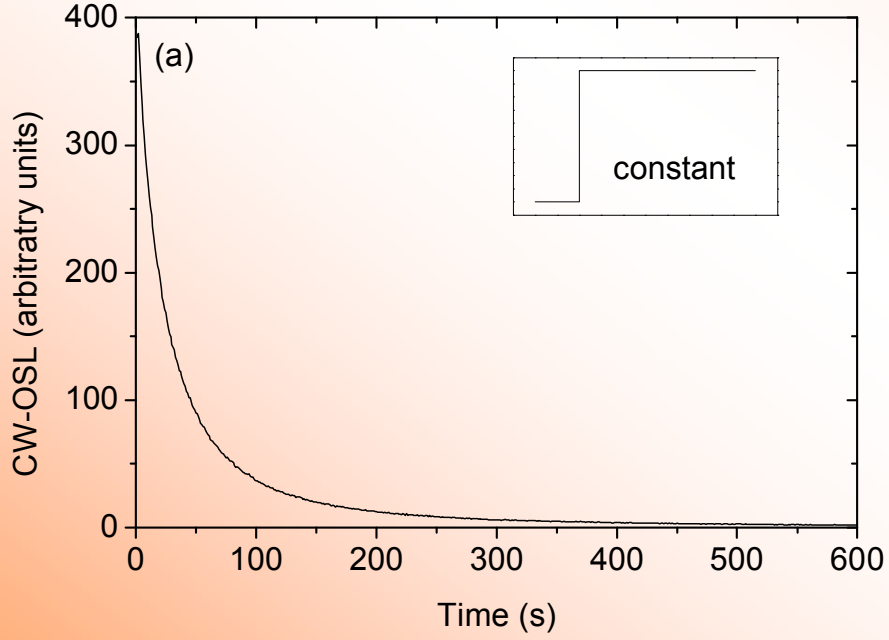
Samples provided by Landauer Inc.

Materials

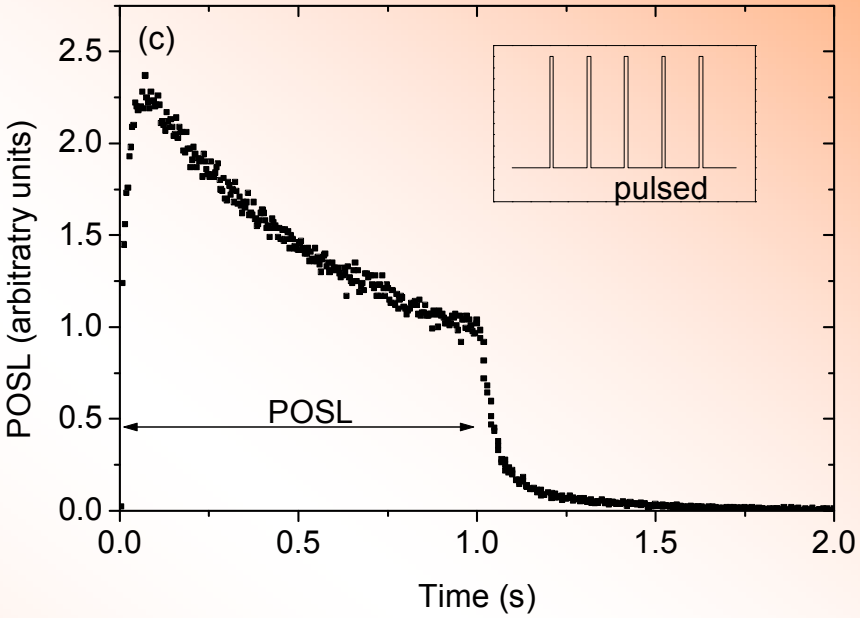

B1040
D320
Chip 101
Total OSL Area (normalized)
10^2
10^1
10^0
1
10
100
1000
Beta Dose (Gy)

Stimulation modes

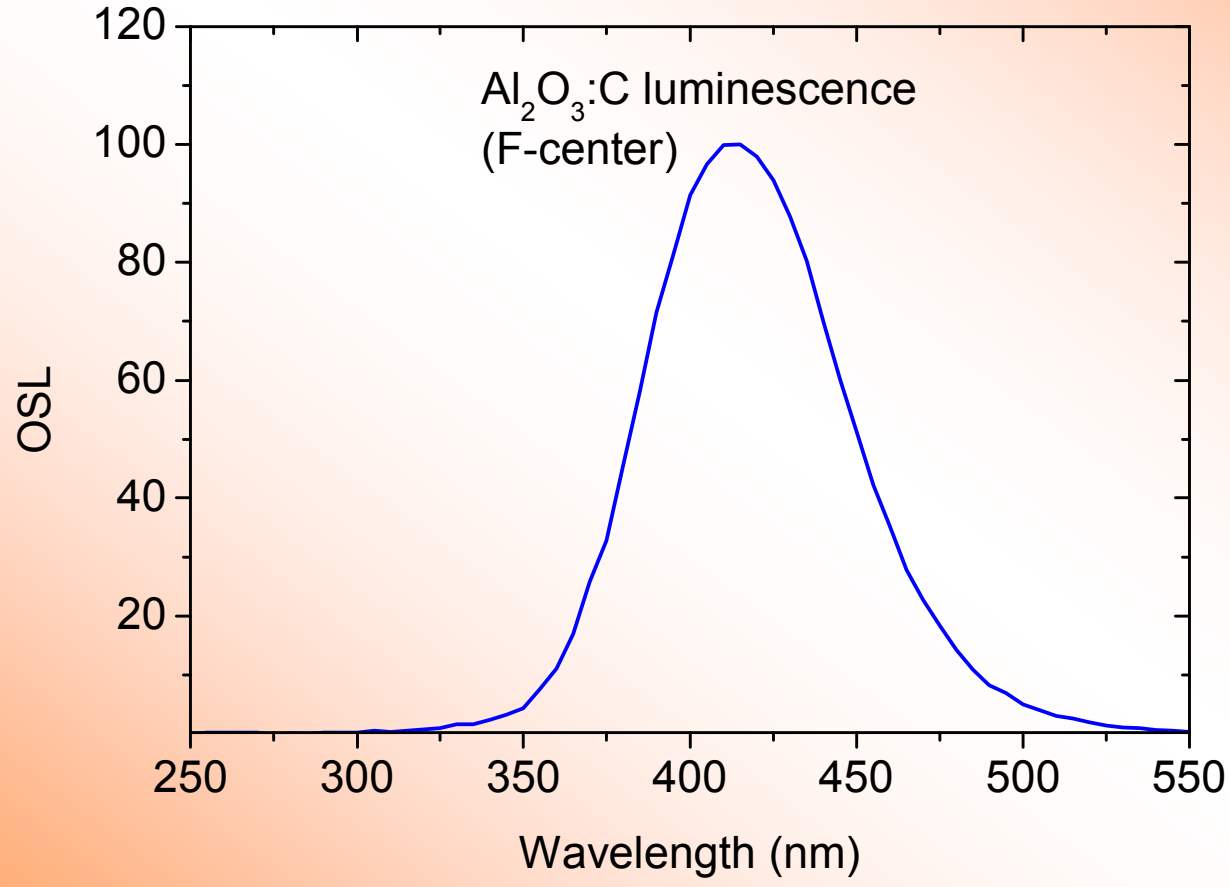
CW-OSL



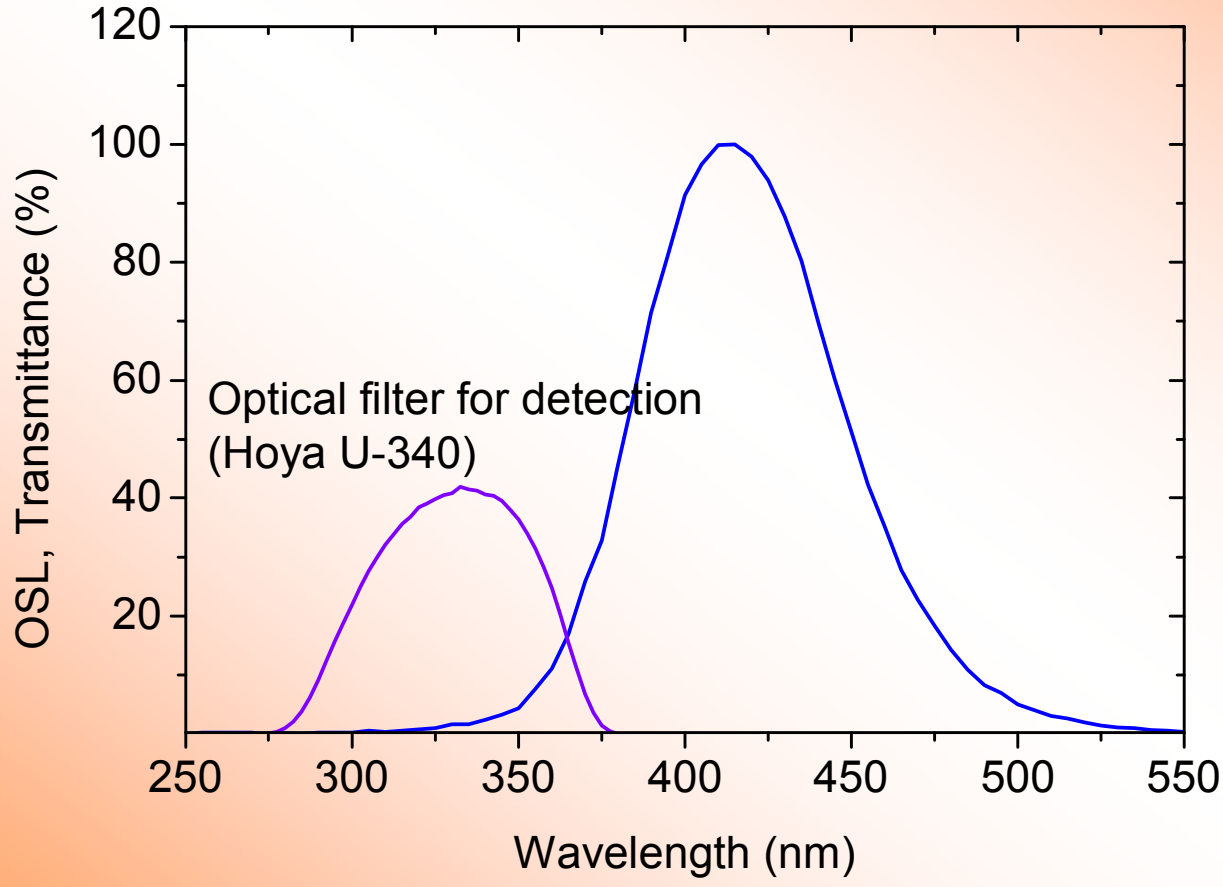
POSL



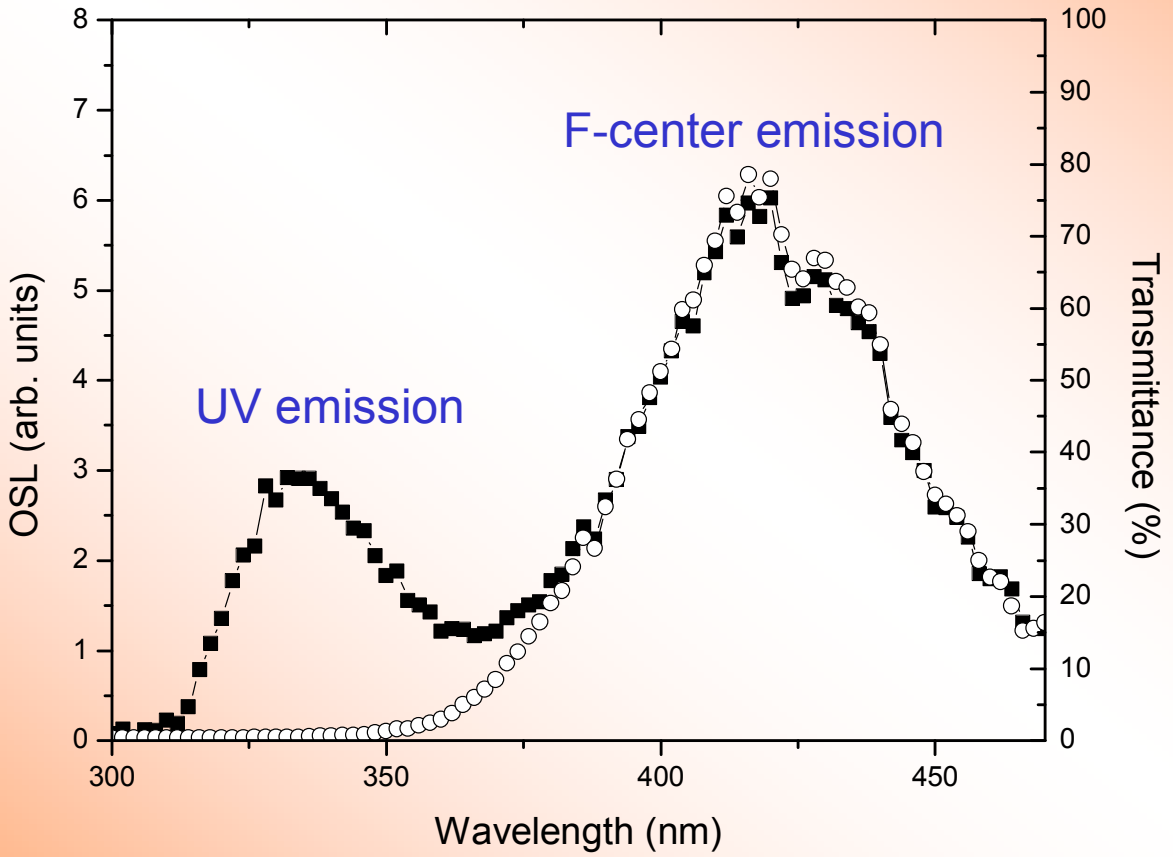
Detection


120
100
80
60
40
20
OSL
Al2O3:C luminescence
(F-center)
250
300
350
400
450
500
550
Wavelength (nm)

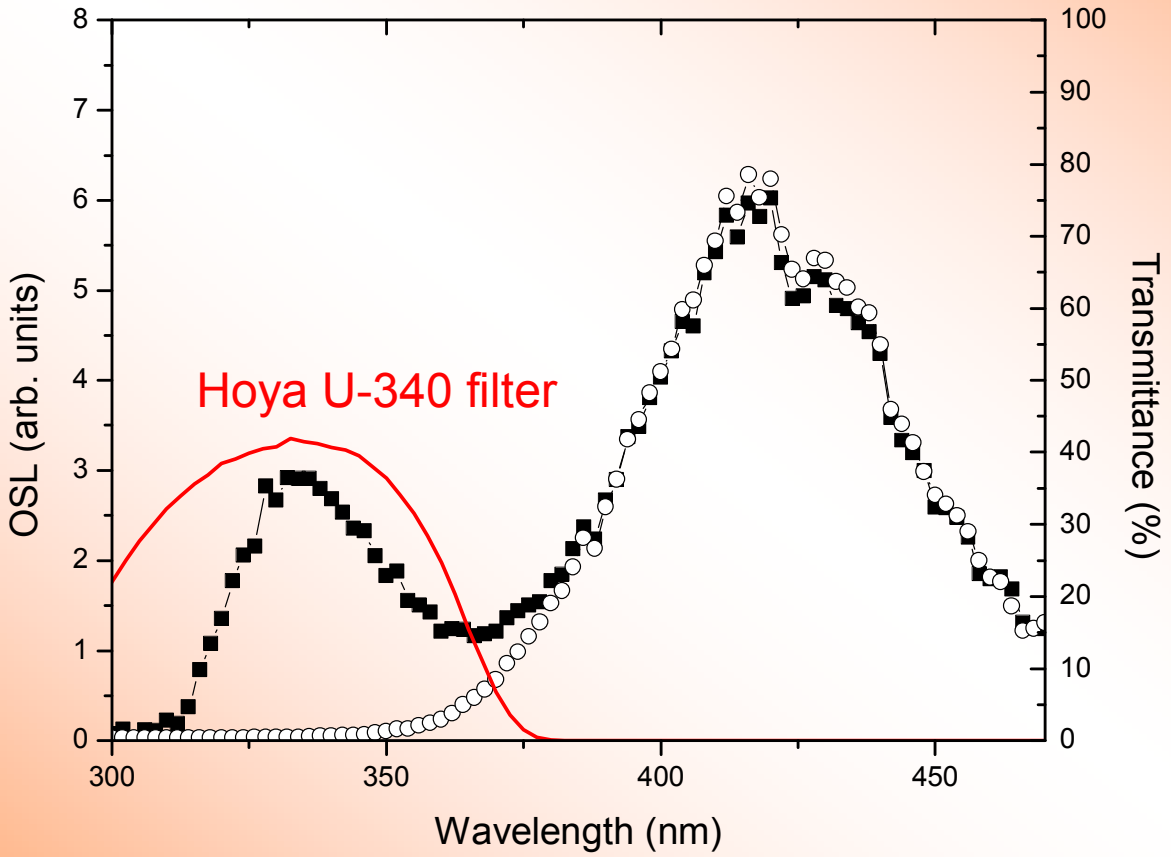
Detection


120
100
80
60
40
20
OSL, Transmittance (%)
Optical filter for detection
(Hoya U-340)
250
300
350
400
450
500
550
Wavelength (nm)

Detection


F-center emission
UV emission
OSL (arb. units)
Transmittance (%)
Wavelength (nm)
0
1
2
3
4
5
6
7
8
0
10
20
30
40
50
60
70
80
90
100
300
350
400
450

Detection


Hoya U-340 filter
OSL (arb. units)
Transmittance (%)
Wavelength (nm)
0
1
2
3
4
5
6
7
8
0
10
20
30
40
50
60
70
80
90
100
300
350
400
450

Groups working with OSL

Group	Material	Stimulation	Technique	Detection
SCK-CEN	New chips	Ar ion laser (488nm)	CW-OSL	400nm (Δ10nm)
SRAG (NASA)	Luxel™	LEDs	CW-OSL	Hoya U-340 (290-390nm)
OSU	Old chips Luxel™	Green LEDs Nd:YAG laser (532nm)	CW-OSL POSL	Hoya U-340 (290-390nm) Corning 5-58 (410Δ60nm)
Landauer-Nagase	Luxel™ (?)		POSL (?)	?

Ionization density effects

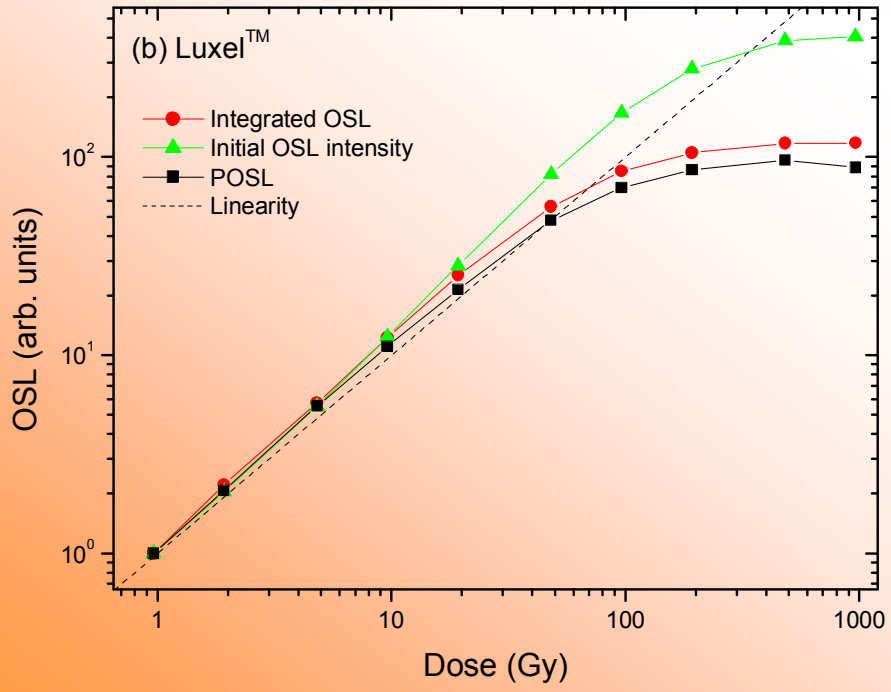
Efficiency

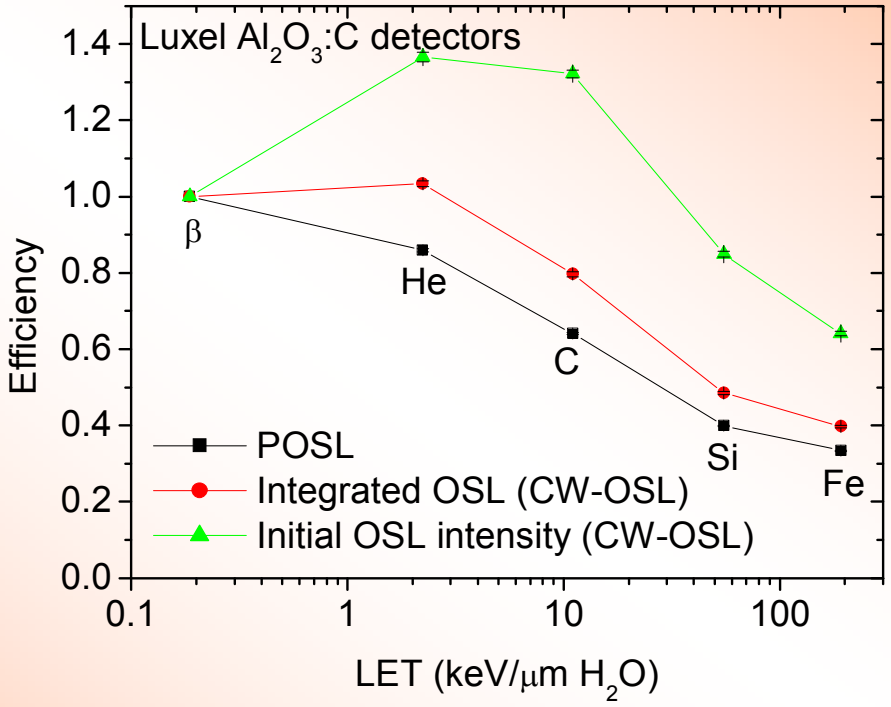
OSL curve

Emission spectrum

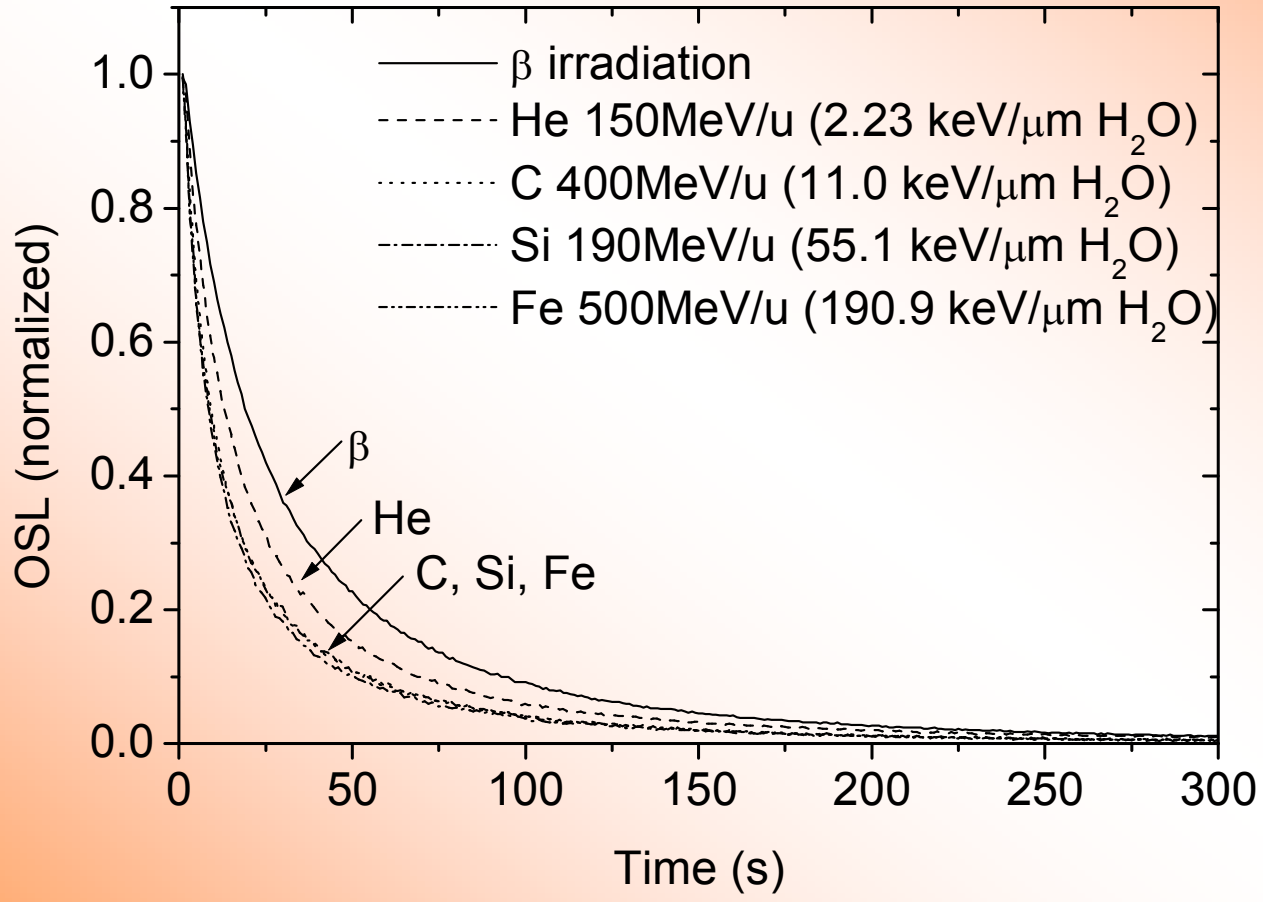
Efficiency

$$\eta_{HCP,\gamma} = \frac{D_{TL/OSL}}{D_{HCP}}$$

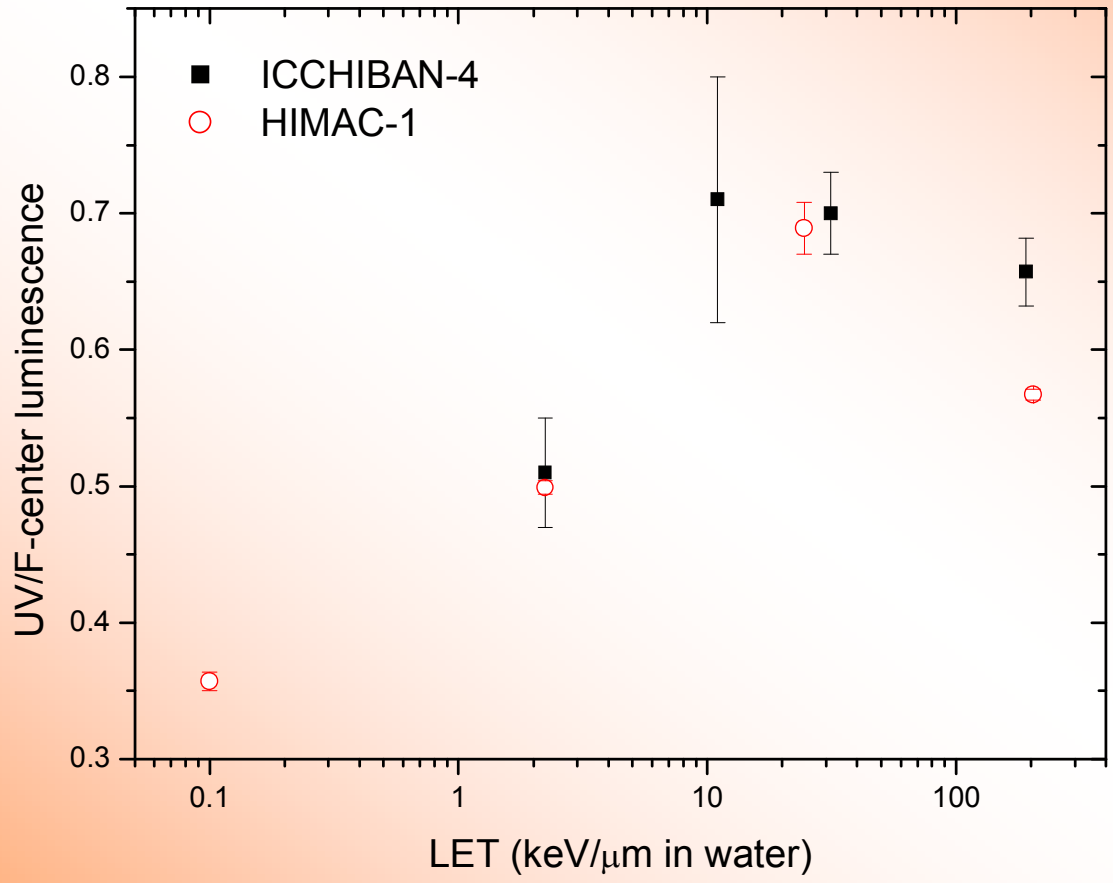




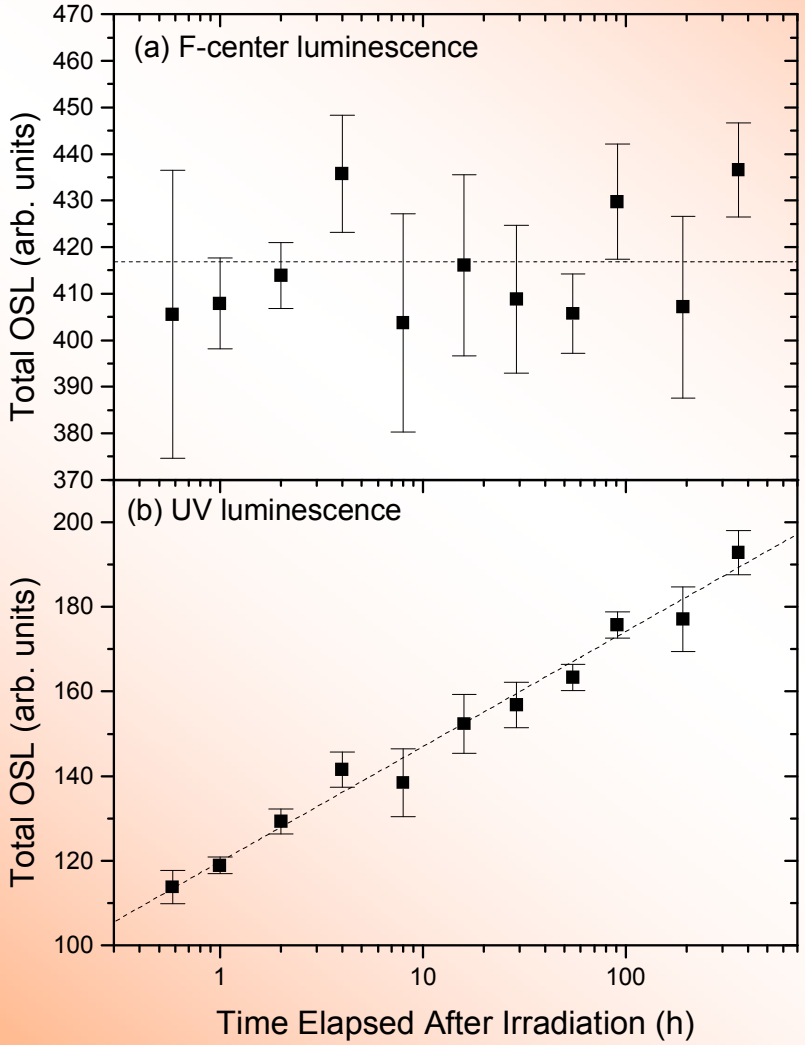
OSL curve


β irradiation
He 150MeV/u (2.23 keV/μm H2O)
C 400MeV/u (11.0 keV/μm H2O)
Si 190MeV/u (55.1 keV/μm H2O)
Fe 500MeV/u (190.9 keV/μm H2O)
β
He
C, Si, Fe
OSL (normalized)
Time (s)
0.0
0.2
0.4
0.6
0.8
1.0
0
50
100
150
200
250
300

Emission spectrum



Emission spectrum



Brief summary so far…

Efficiencies will depend on:

- Material
- Emission band selected
  - Detection filter
  - Readout technique (CW-OSL or POSL)

Approach:

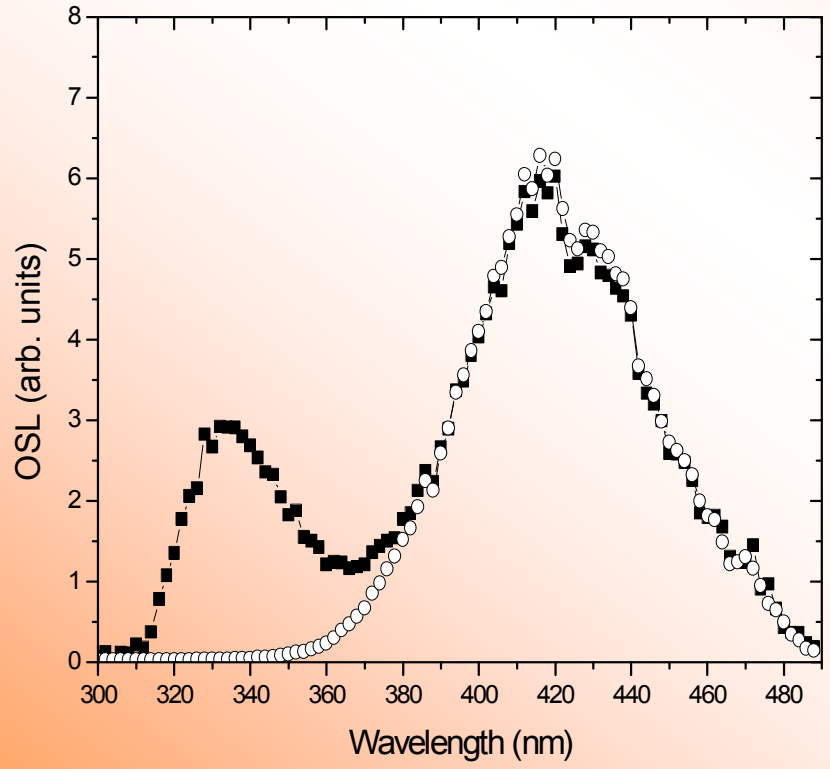
- Focus on Luxel™
- Reduce possibility of variations in the efficiency:
  - Focus on F-center band at 420nm (CW-OSL with appropriate filters or POSL)
  - Use whole OSL curve (does not depend on stimulation power)

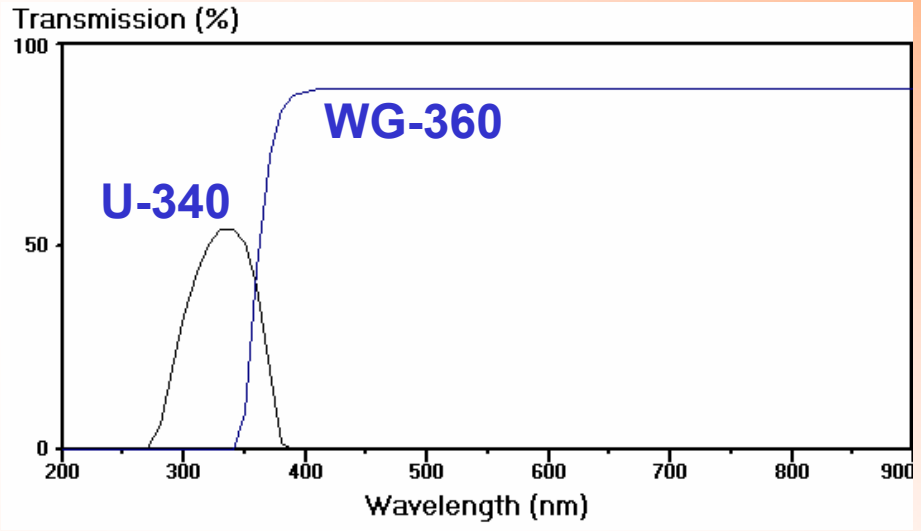
Methodological developments

Major problems:

- UV emission band
  - Time dependence
  - Different ionization density dependence
- Sensitization effects

Eliminating the UV band





Eliminating sensitization problems

No sensitivity changes:

$$S = a\,\alpha_{equip}\,m\,D$$

$$S_R = a\,\alpha_{equip}\,m\,D_R$$

$$\Rightarrow \quad \frac{S}{S_R} = \frac{D}{D_R}$$

With sensitivity changes:

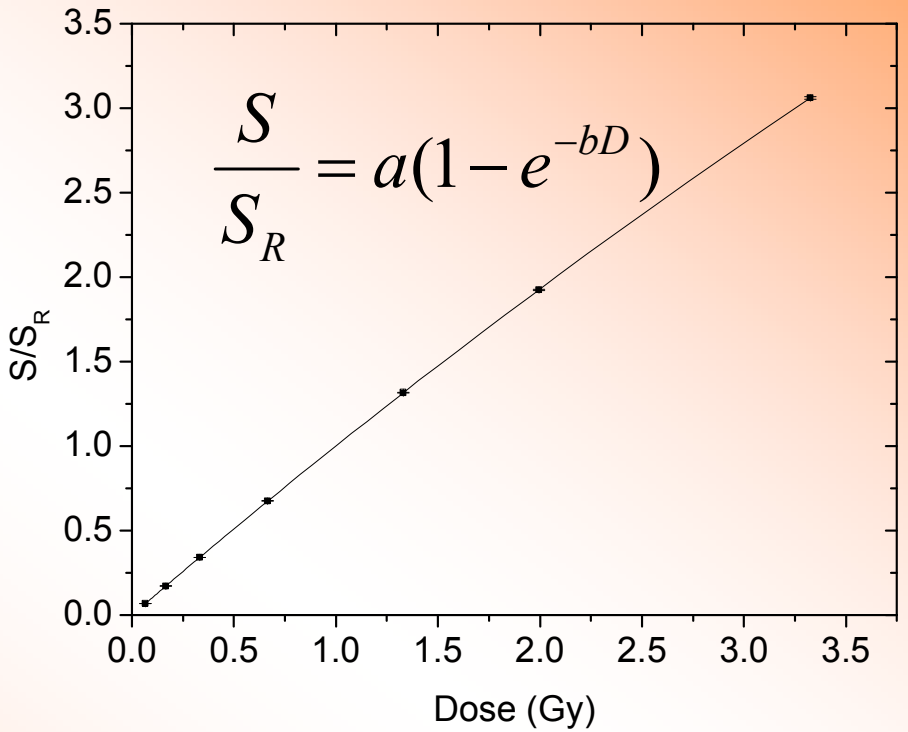
$$S = a(D)\,\alpha_{equip}\,m\,D$$

$$S_R = a(D, D_R)\,\alpha_{equip}\,m\,D_R$$

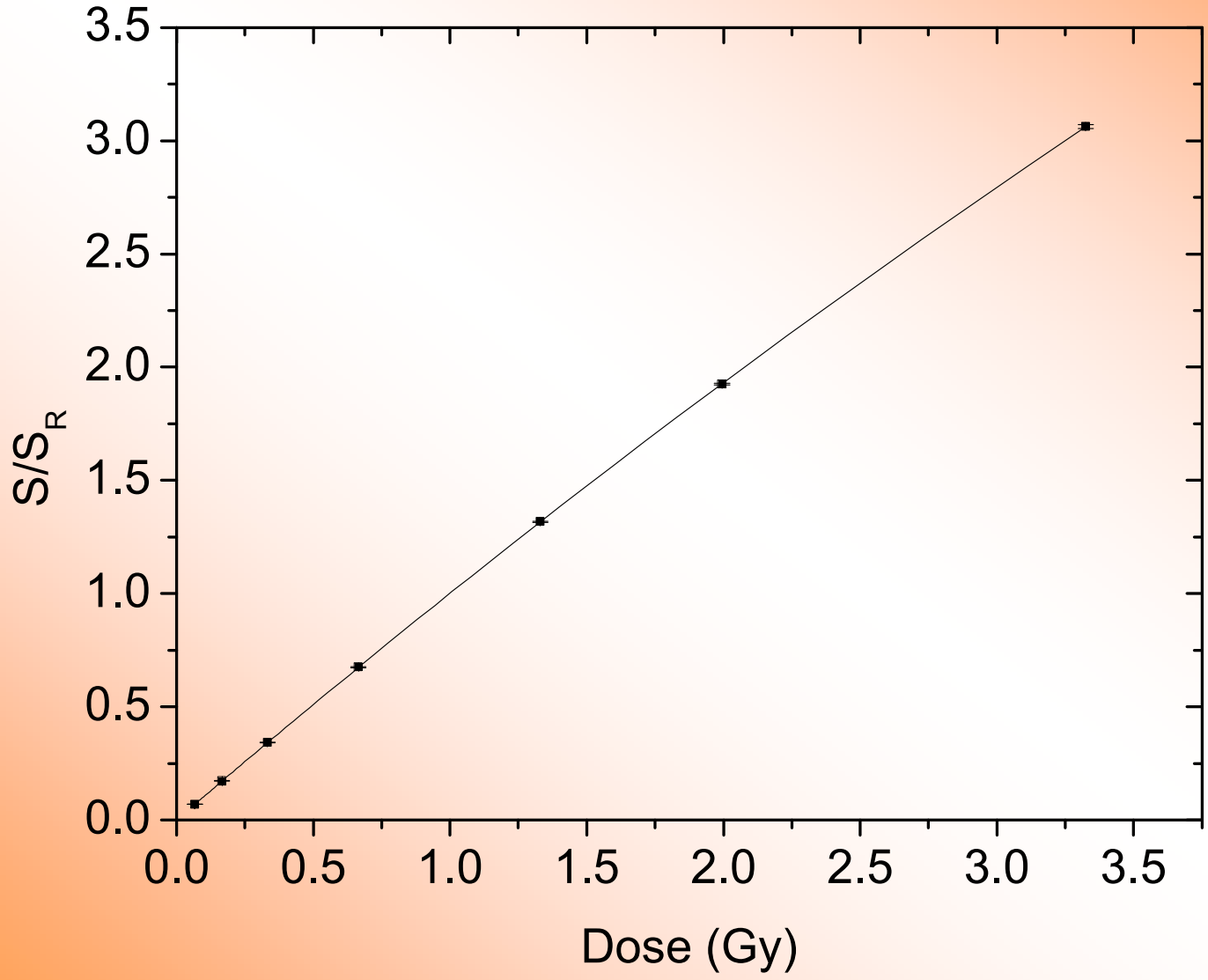
$$\Rightarrow \quad \frac{S}{S_R} = f(D)$$

Eliminating sensitization problems

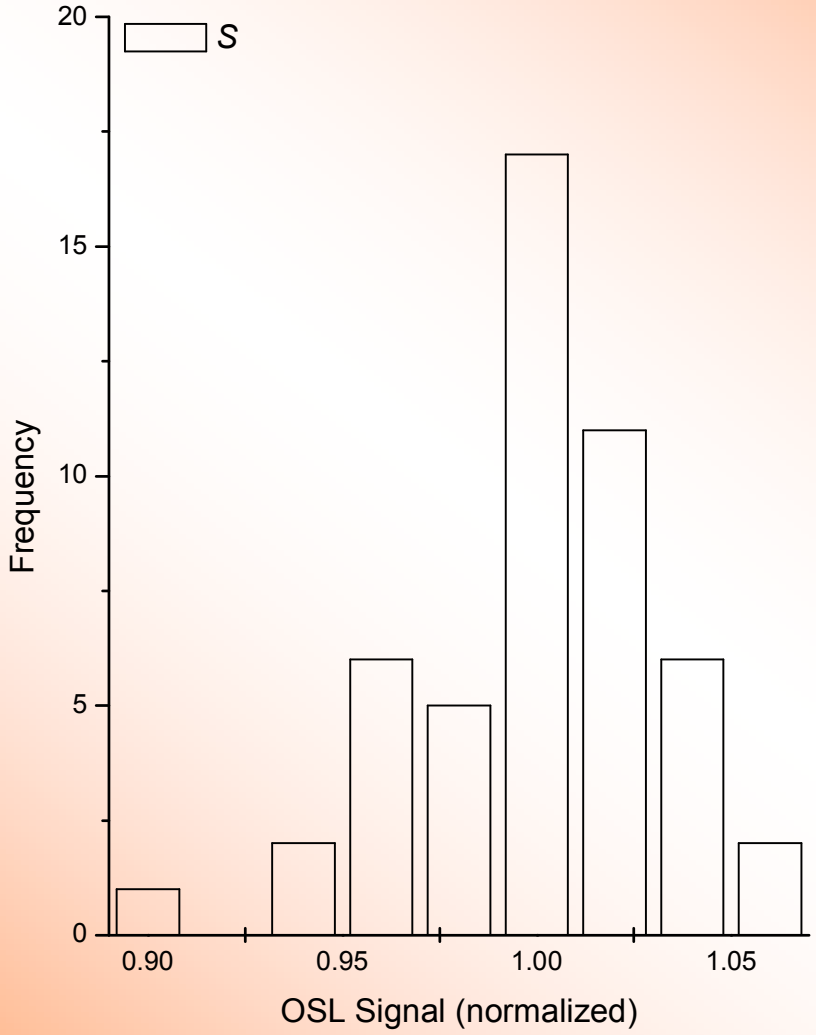
(1) Measure S (OSL readout)
(2) Irradiate with reference dose D_R
(3) Measure S_R
(4) Calculate **S/S_R**



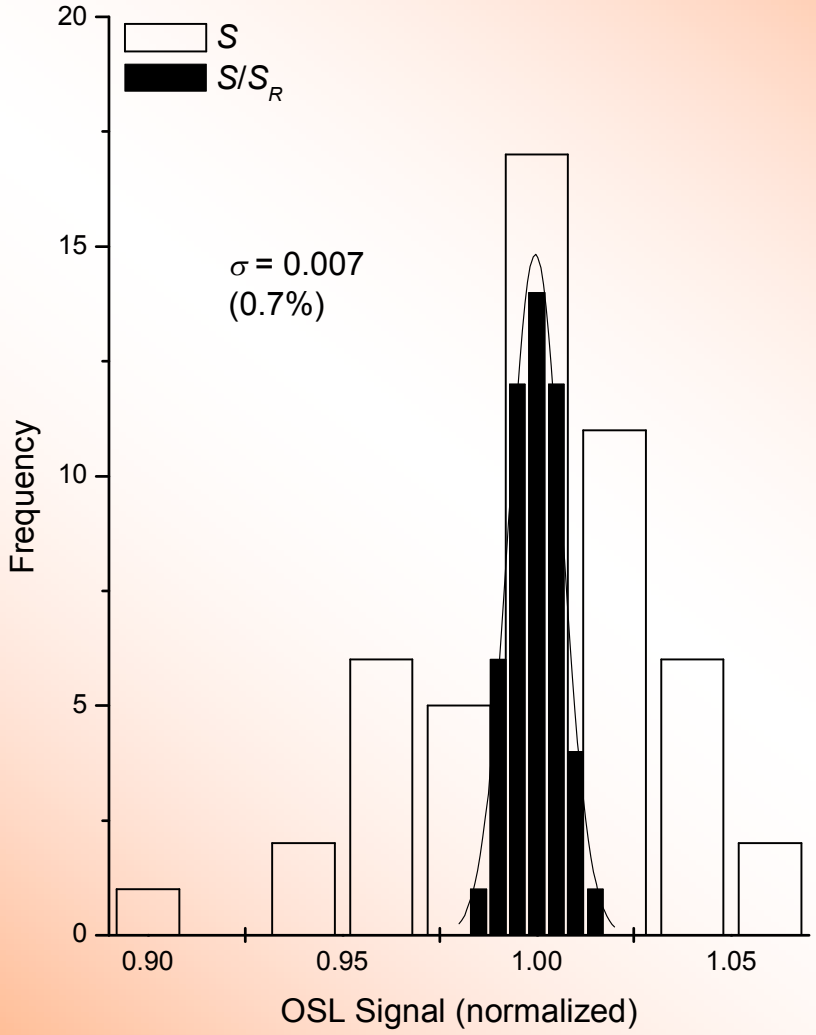
Eliminating sensitization problems



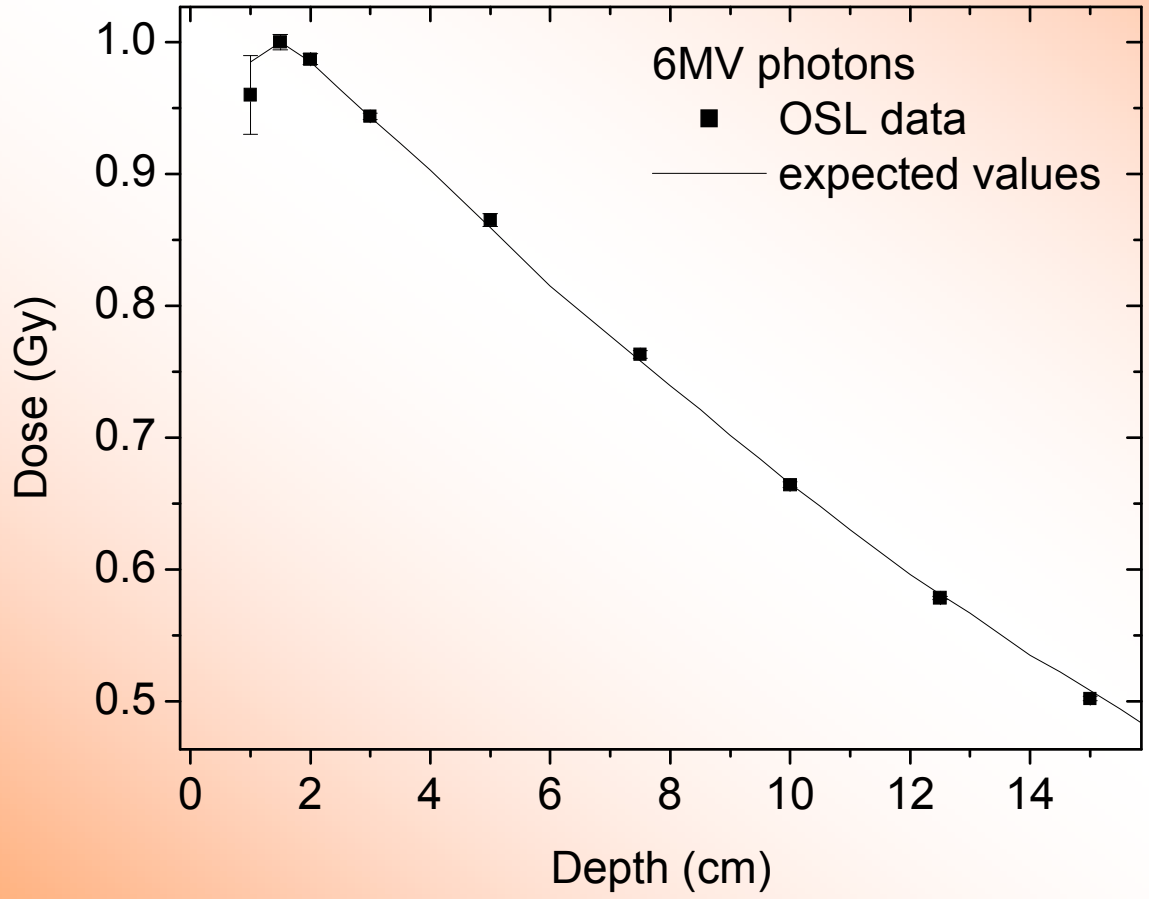
Eliminating sensitization problems



Eliminating sensitization problems



Results: depth dose profiles



Results: reproducibility

He 150MeV/u

D_{HCP} (mGy)	η	
100.5	0.909 0.919 0.910	
100.4	0.911 0.893 0.903	
100.5	0.907 0.930 0.905	
100.0	0.929 0.910 0.893	
100.5	0.904 0.917 0.923	

Results: reproducibility

He 150MeV/u

D_{HCP} (mGy)	η	SD (%)
100.5	0.909 0.919 0.910	0.6%
100.4	0.911 0.893 0.903	1.0%
100.5	0.907 0.930 0.905	1.5%
100.0	0.929 0.910 0.893	1.9%
100.5	0.904 0.917 0.923	1.0%

Results: reproducibility

He 150MeV/u

D_{HCP} (mGy)	$\eta_{average}$	SD (%)
100.5	0.912	0.6%
100.4	0.902	1.0%
100.5	0.914	1.5%
100.0	0.910	1.9%
100.5	0.915	1.0%

σ = 0.6%

Results: reproducibility

C 400MeV/u

D_{HCP} (mGy)	η	SD (%)
100.5	0.676 0.671 0.666	1.7%
100.4	0.660 0.671 0.684	0.7%
100.4	0.673 0.662 0.675	1.3%
100.6	0.662 0.666 0.674	1.6%
100.7	0.663 0.672 0.652	0.9%

Results: reproducibility

C 400MeV/u

D_{HCP} (mGy)	$\eta_{average}$	SD (%)
100.5	0.656	1.7%
100.4	0.660	0.7%
100.4	0.660	1.3%
100.6	0.663	1.6%
100.7	0.671	0.9%

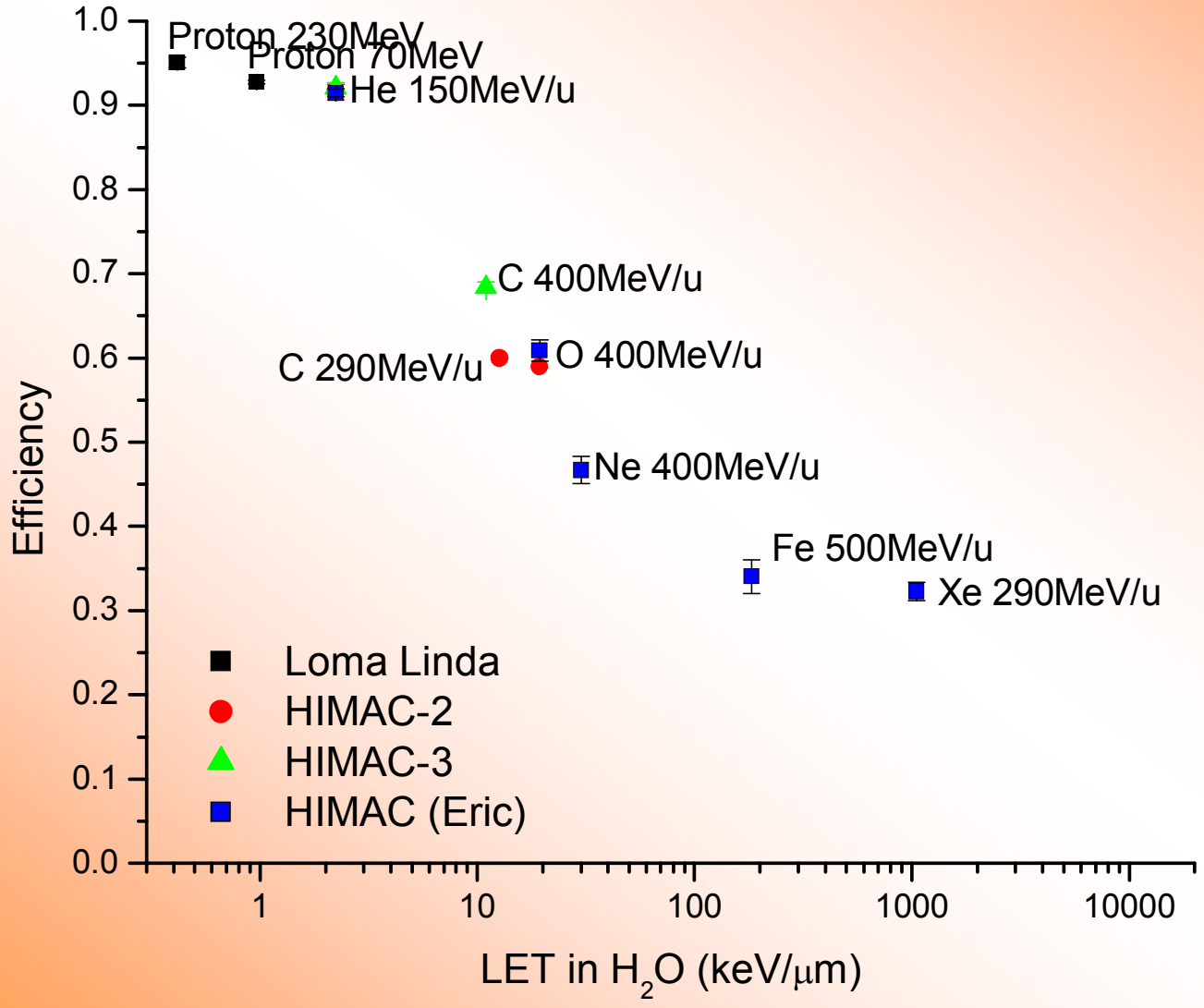
σ = 0.9%

Results: beam uniformity

He 150MeV/u

-1.5%			1.1%			0.9%
			0.3%			
		-1.8%	-0.6%	-0.2%		
2.5%	-0.5%	-0.1%	-0.6%	-0.3%	0.6%	0.01%
		-0.5%	-2.3%	0.1%		
			0.3%			
2.5%			0.1%			-0.1%

Results: efficiencies



Conclusions

- With new methodology, efficiency for most groups should be comparable
- Time-dependence of the UV emission band is avoided
- Higher precision is achieved

Future (and present) research:

- Efficiency different than 1 for low LET particles should be investigated for various materials
- Ionization-density-dependent phenomena may help to correct for these variations

Acknowledgements

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- NIRS
- WRMISS organizers

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