CNES-ESA Radiation Final Presentation days, 09-10 mars 2015

PROTONS EFFECTS ON COMMERCIAL EUROPEAN LIGHT EMITTING DIODES

R-S12-MT4-138
R-S13/MT4-138

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OUTLINE

- CONTEXT
- COTS REFERENCES
- DIE MATERIAL VS WAVELENGTH
- EXPERIMENTAL CONDITIONS
- RESULTS
- CONCLUSION

CONTEXT (1/2)

Most of LEDs used in space equipment come from US or japanese manufacturer.

Those R&T contracts aim to assess commercial LED with regards to specific space environment, and especially radiative constraints.

Two contracts:

- RS12/MT4-138: ESA / CNES co-funded study: European Commercial LED space assessment

- RS13/MT4-138: CNES study on one enropean manufacturer identified through previsous R&T

CONTEXT (2/2)

Those R&T contracts aim to assess commercial LED with regards to specific space environment, and especially radiative constraints.

RS12/MT004-138

Focus on red and NIR wavenlength [670-880nm]
3 EU manufacturers:
- OSRAM
- Epigap
- OSA-Optolight

One very promising refence:
OCL400-GE545 from OptoLight

RS13/MT004-138

Radiations assessment of other refences from OCL400 series

Results published in NSREC 2014
Radiation Effects Data Workshop (REDW)
DOI 10.1109/REDW.2014.7004557
"Commercial Light Emitting Diodes Sensitivity to Protons Radiations"

REFERENCES (1/2)

R-S12/MT4-138

OSRAM REFERENCES SELECTED

Reference	Technology	Wavelength (nm)	I_F (mA)	Total Output Power (mW or mcd)
LH R974	AlGaAs	645	20	71 mcd typ 0.35mW
SFH 4350	AlGaAs	850	100	23 mW min (70 typ)
SFH 464	AlGaAs	660	50	11 mW

EPIGAP REFERENCES SELECTED

Reference	Technology	Wavelength (nm)	I_F (mA)	Total Output Power (mW or mcd)
EOLD-670-523	AlGaAs	670	20	780 mcd typ 4 mW
EOLD-850-525	AlGaAs	850	100	45 mW
EOLD-880-525	AlGaAs	880	100	45 mW

OSA-OPTOLIGHT REFERENCES SELECTED

Reference	Technology	Wavelength (nm)	I_F (mA)	Total Output Power (mW or mcd)
OIS-170-660	AlGaAs	660	30	1.2 mW
OIS-170-850	AlGaAs	850	30	2 mW
OIS-170-880	AlGaAs	880	30	2.5 mW
OCL-400-GE545	(Ga,In)N Blue chip + green phosphor	545	20	850 mcd 2 mW

REFERENCES (2/2)

R-S13/MT4-138

OSA-OPTOLIGHT REFERENCES SELECTED

Reference	Technology	Wavelength (nm)	I_F (mA)	Total Output Power (mW or mcd)
~~OIS-170-660~~	~~AlGaAs~~	~~660~~	~~30~~	~~1.2 mW~~
~~OIS-170-850~~	~~AlGaAs~~	~~850~~	~~30~~	~~2 mW~~
~~OIS-170-880~~	~~AlGaAs~~	~~880~~	~~30~~	~~2.5 mW~~
OCL-400-GE545	(Ga,In)N Blue chip + green phosphor	545	20	850 mcd 2 mW
OCL-400-MSD-X-T	AlGaInP	624	20	400 mcd 1.25mW
OCL-400-MY-X-T	AlGaInP	589	20	400 mcd 0.5 mW
OCL-400-GC525	InGaN / Saphire	525	20	400 mcd 0.6 mW
OCL400-SW-XD-T	X	white	20	600 mcd 1.25 mW
OLS-330-GB525	InGaN *	525	20	1700 mcd

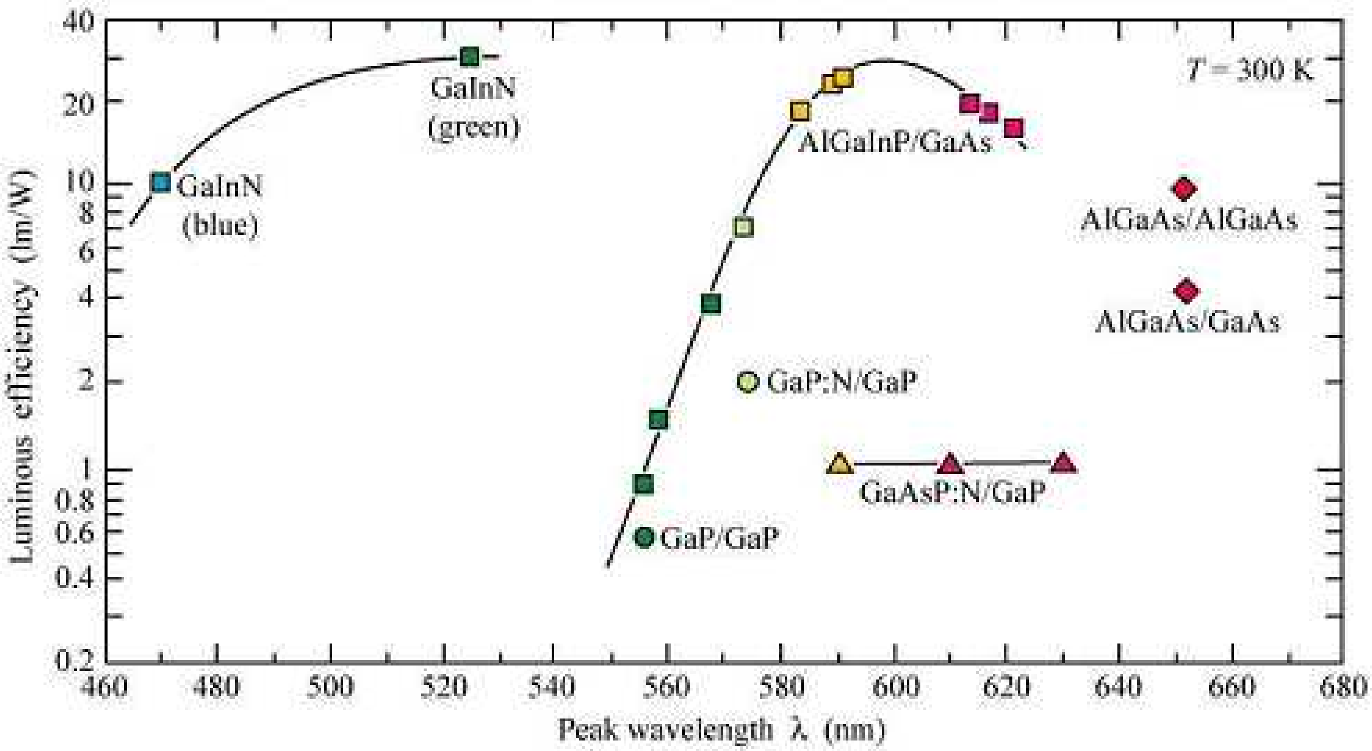
Same package various dies

Same die Different package

ENV Space and Atmospheric Environment

cnes

DIE MATERIAL VS WAVELENGTH (1/2)



From violet to green: preferred material system is InGaN grown on sapphire.

Potentially covers [380 – 600nm], from GaN to InN

From green to red : AlGaInP on GaAs can also be used

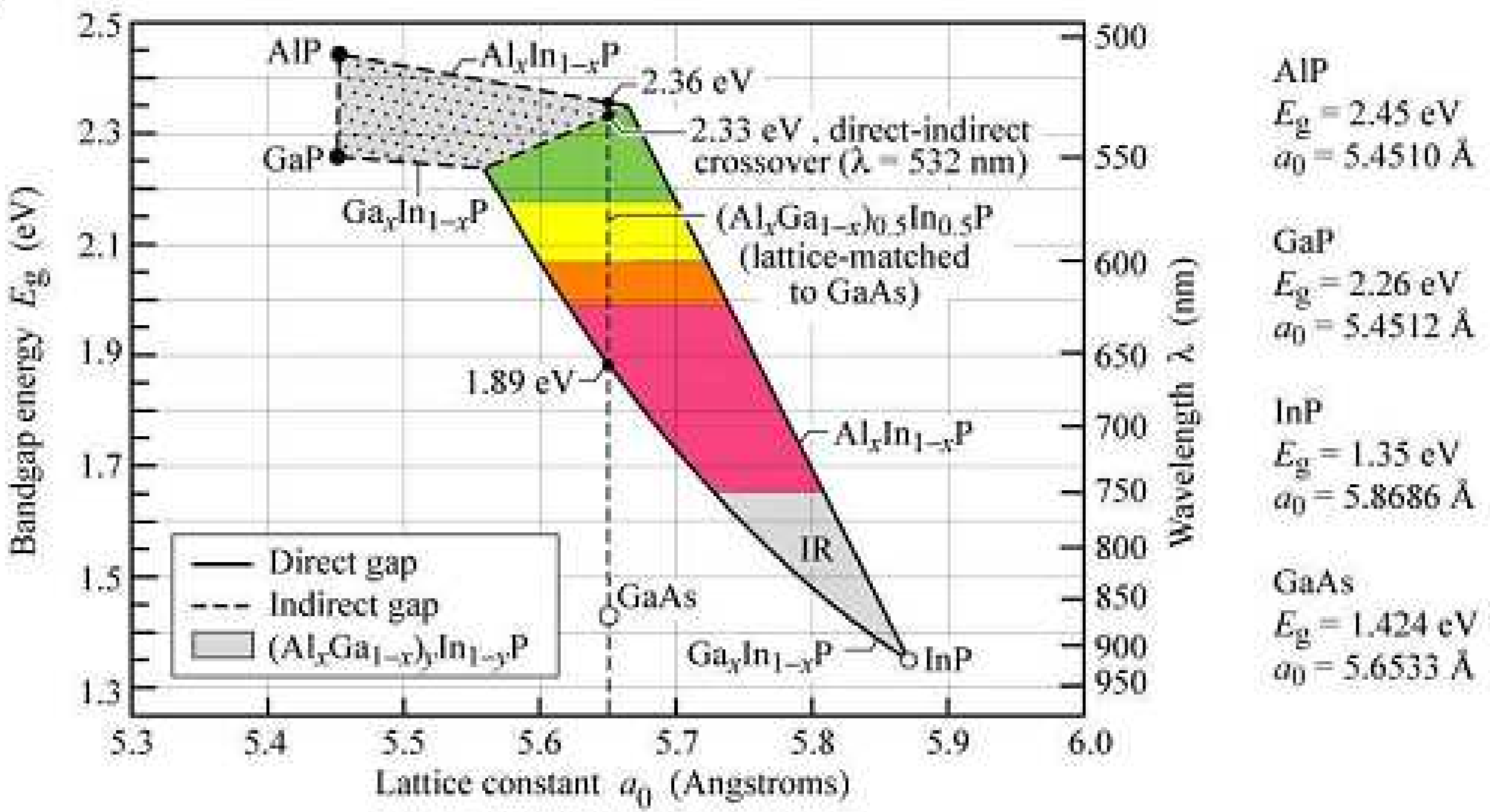
Covers [550 - 655nm] from $Al_{0,5}InP$ to $Ga_{0,5}InP$

From Red to infrared: preferred material system is Al_xGaAs grown on GaAs (x<0,45)

Covers [625 – 880nm] from AlAs to $Al_{0,45}GaAs$

DIE MATERIAL VS WAVELENGTH (2/2)

Material constraints in AlGaInP: active material has to be lattice matched on GaAs, reducing alloys composition availables



EXPERIMENTAL CONDITIONS

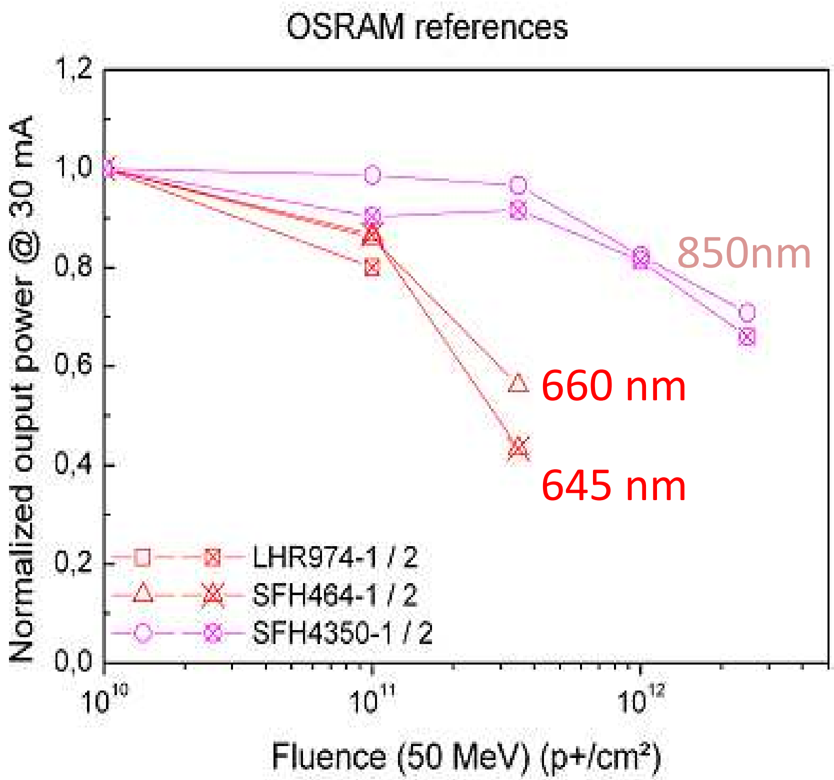
- Protons radiations only (LED only affected by displacement damages)
- Facility: KVI
- Energy: 50 MeV
- Bias: No (pins shorted)
- Fluence: cumulative fluences
  - $\Phi1 = 10^{11}$ p+/cm²
  - $\Phi2 = 3{,}5\ 10^{11}$ p+/cm² (cumulated)
  - $\Phi3 = 10^{12}$ p+/cm² (cumulated)
  - $\Phi4 = 2{,}5\ 10^{12}$ p+/cm² (cumulated)
- Eo measurements
  - I-V
  - Pout @ 30mA injection current
  - Emission spectra

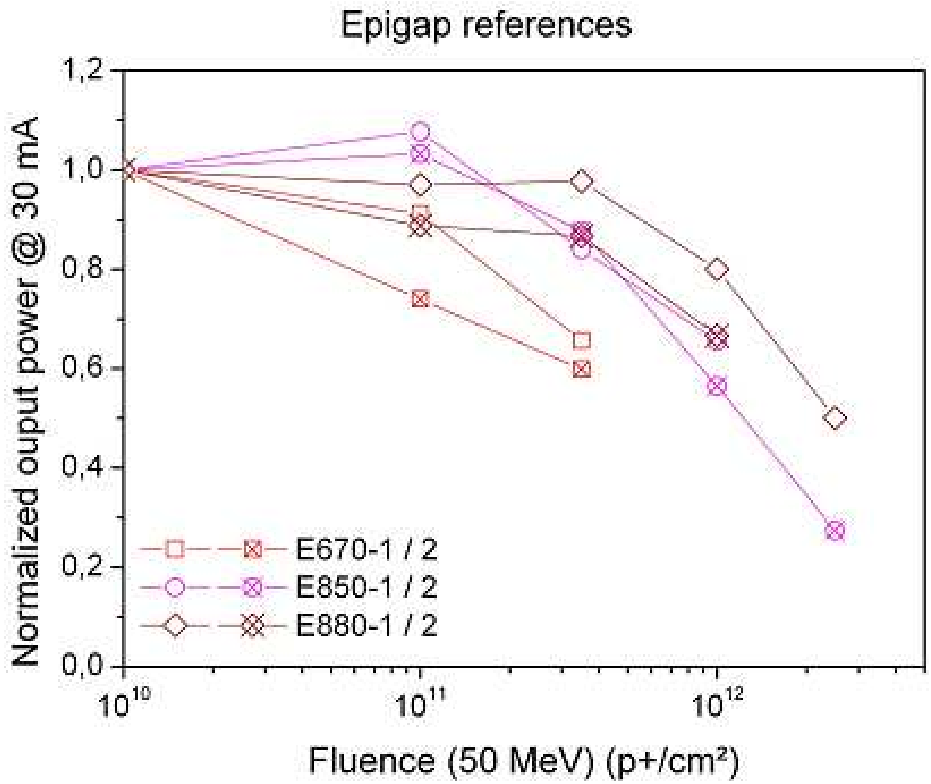
PROTON RADIATION TEST PLAN TABLE

Reference	DUT	I_F (mA)	Φ1	Φ2	Φ3	Φ4
LH R974	1 & 2	30	Yes			
SFH 4350	1 & 2	30	Yes	Yes	Yes	Yes
SFH 464	1 & 2	30	Yes	Yes	Yes	
EOLD-670-523	1 & 2	30	Yes	Yes		
EOLD-850-525	1 2	30	Yes	Yes	Yes	No Yes
EOLD-880-525	1 2	30	Yes	Yes	Yes	Yes No
OIS-170-660	1 & 2	30	Yes	Yes		
OIS-170-850	1 & 2	30	Yes	Yes		
OIS-170-880	1 & 2	30		Yes	Yes	
OCL-400-GE545	1 & 2	30	Yes	Yes	Yes	Yes
OCL-400-MSD-X-T	1 & 2 3	20	Yes	Yes	Yes	Yes No
OCL-400-MY-X-T	1 & 2 3	20	Yes	Yes	Yes	Yes No
OCL-400-GC525	1&2&3	20	Yes	Yes	Yes	Yes
OCL400-SW-XD-T	1&2&3	Yes	Yes	Yes	Yes	Yes
OLS-330-GB525	1&2&3	Yes	Yes	Yes	Yes	Yes

RESULTS – OSRAM & EPIGAP

As expected from litterature, only P_{out} is affected by protons radiations.

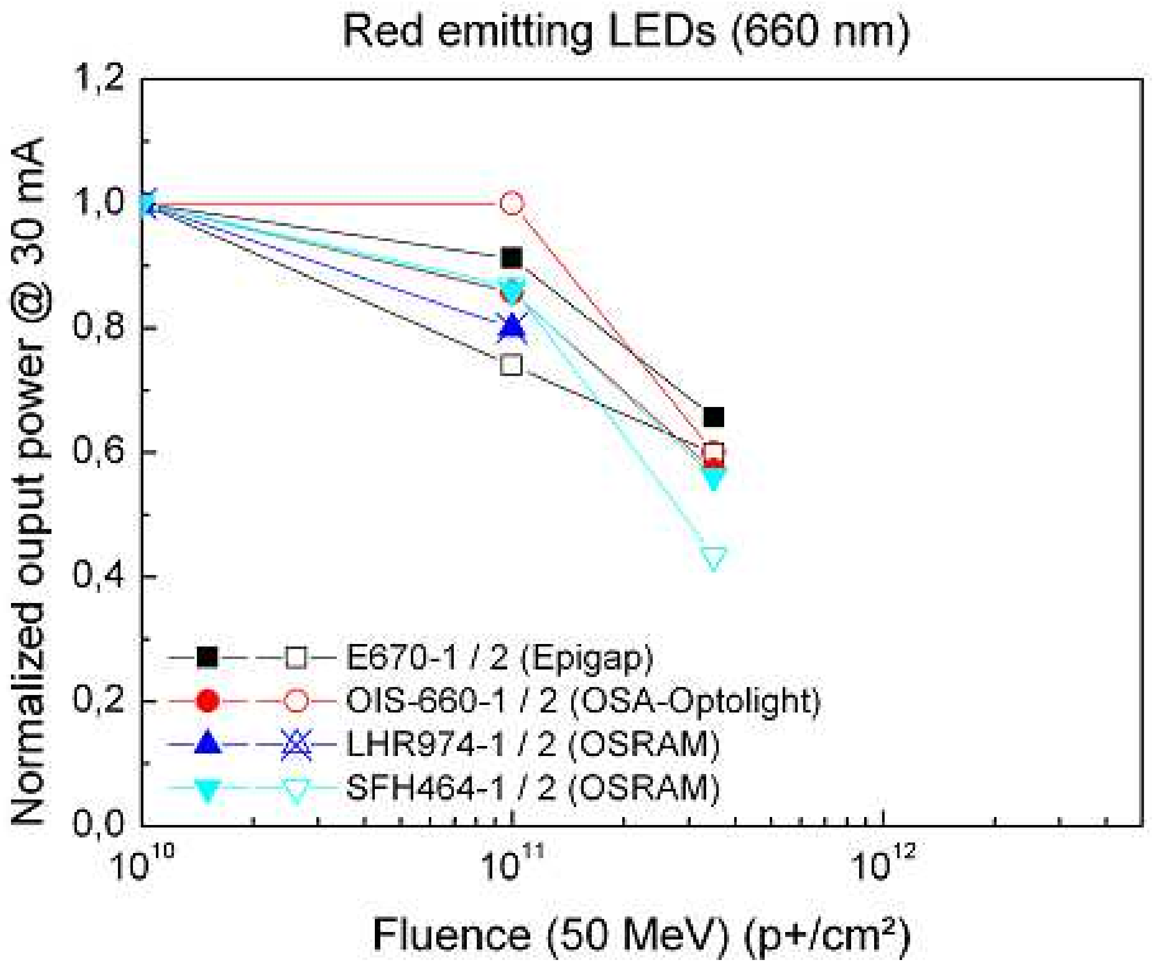




For both manufacturers, red emitting LEDs are more impacted than near infrared ones.

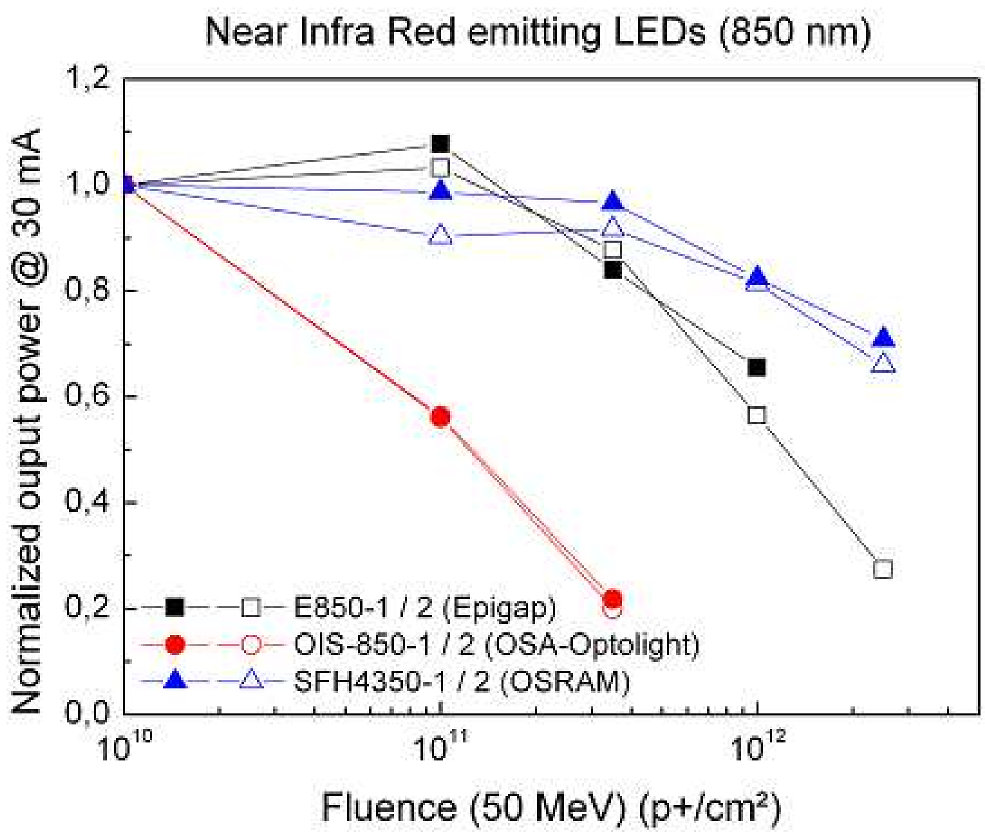
GaAs more radiations tolerant than AlGaAs?

RESULTS – 660 NM



For red emitting LED, we observe roughly the same sensitivity for all manufacturers.

RESULTS – 850 NM



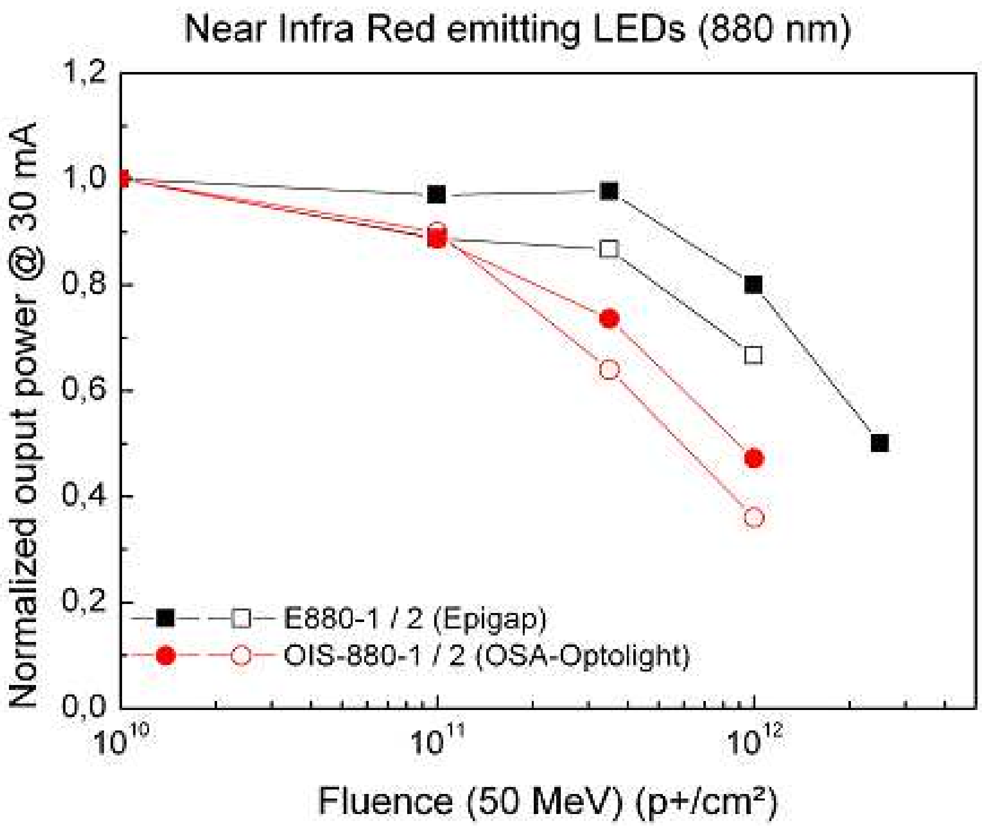
From datasheet

SFH4350	70mW @ 100mA
E 850	45mW @ 100mA
OIS 850	2mA @ 30mA

@850nm: OSRAM > Epigap > Osa optolight
Emission wavelength is not the only criteria for proton sensitivity.

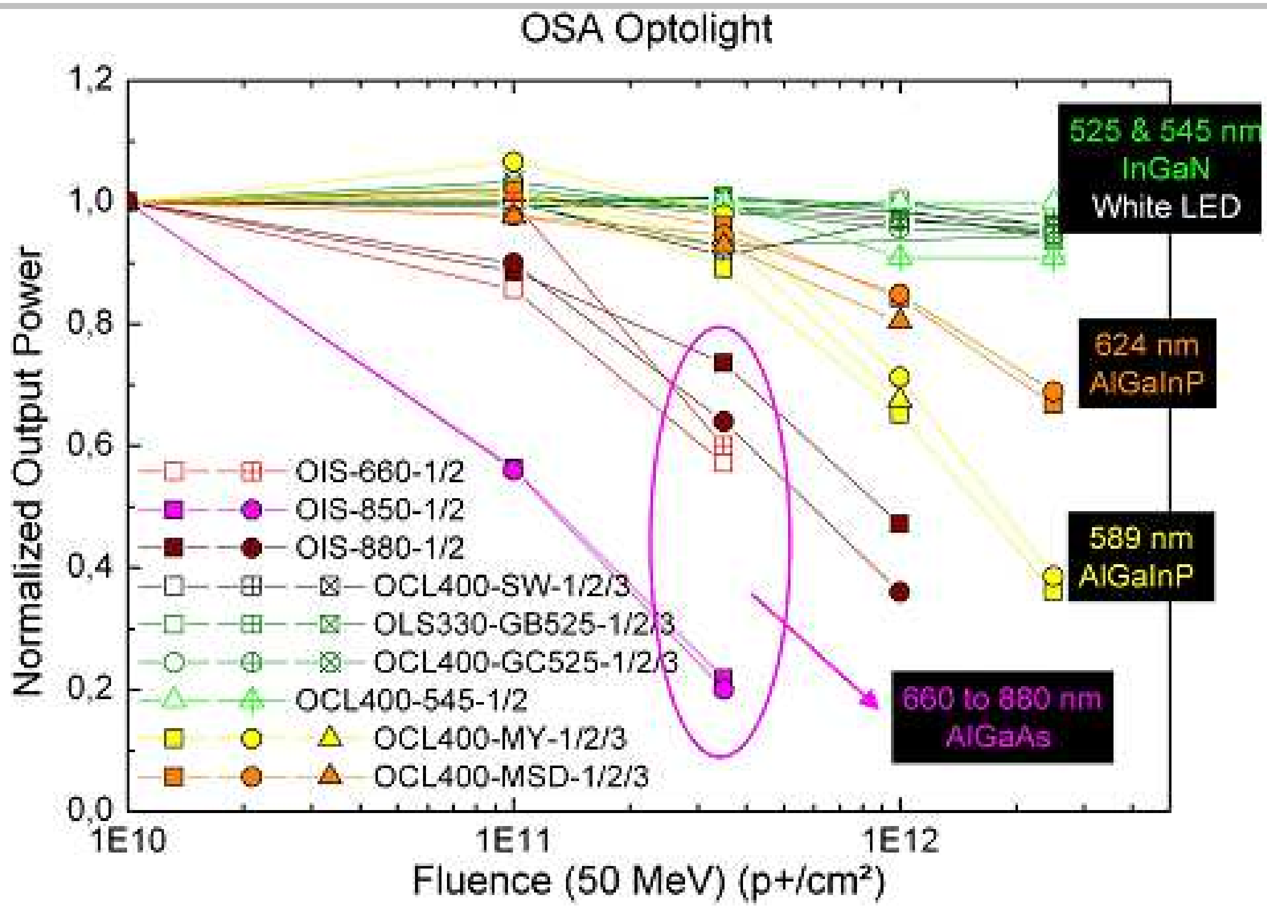
The radiation hardness is also design dependant
Higher output power, harder the device?

RESULTS – 880 NM



Same trend as for 850 nm emitting LED

RESULTS – OSA-OPTOLIGHT



AlGaAs: different trend as for OSRAM & Epigap: 850nm is the worst device in proton

AlGaInP: higher wavelength, more radiation tolerant

GaInN: : almost insensitive to protons in our fluence range of interest

CONCLUSIONS (1/2)

We observe a very good hardness of green and white LEDs. Both are based on close technologies : phosphor converted LEDs, from blue emitting LED. This good hardness to protons may be attributed to two aspects

- Active material itself: (In)GaN presents a smaller carrier lifetime damage factor compared to other classical III-V semiconductor compound based on GaAs material system [1].

- Carrier injection mechanisms: for GaAs based LED operating current is dominated by diffusion mechanism. On the other hand in GaN based LED a different mechanism generally governs current transport: trap-assisted tunneling. In that case, the lifetime damage relationship no longer applies. This point may also explain the good robustness of those LED to displacement damages [1]

[1] A. H. Johnston , "Radiation Effects in Optoelectronic Devices" IEEE Trans. Nucl. Sci vol. 60, no3, june 2013

CONCLUSIONS (2/2)

COTS LEDs have been assessed with regards to their robustness to displacement damages. Data obtained during in this study are in accordance with other COTS review [2],

Green and white references tested present almost no degradation in their output power up to a fluence of 2.5 x 10^{12} p+/cm² (50 MeV).

For the tested references, AlGaAs 660 nm emitting diodes are more radiations sensitive than AlGaAs NIR emitting ones.

LED made with quaternary AlGaInP active layer give promising results with degradation around 30% in output power for a fluence of 10^{12} p+/cm².

Some of the tested references are suitable for space applications from a radiations point of view

[2] J. J. Jimenez,et al, “Proton radiation effects in high power LEDs and IREDs for Optical Wireless Links for intraSatellite communications (OWLS)” RADECS 2006 workshop, Athènes (Greece), 27-29 september 2006.