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Human factor during surface NDE, physiological aspects & visual ergonomics.

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for COFREND Scientific & Technical Committee

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1) Introduction / Genesis

COFREND had anticipated the need to review EN ISO 3059, last release feb. 2013 (ISO 3059 dec. 2012) and worked on an internal "Guide to recommended practice of lighting in penetrant and magnetic particle testing"* explaining the principles of visual ergonomics for ensuring the inspectors' efficiency, comfort and safety for better POD.

*available in english.

This Guide is therefore a pre-normalisation document used

- **to raise discussions during the EN ISO normalisation meetings CEN TC138 WG4 & WG5,**
- **used as a basis for CEN TR 17108 «good practice in lighting»**
- **to update trainings programs (french common & specifics branches)**
- **to propose up to date topics for reviewing ISO/CD TS 25107 Non-destructive testing - Guidelines for NDT training syllabus.**

BOTH Visible & Fluorescent methods were taken into account, dealing with all sectors including aerospace.

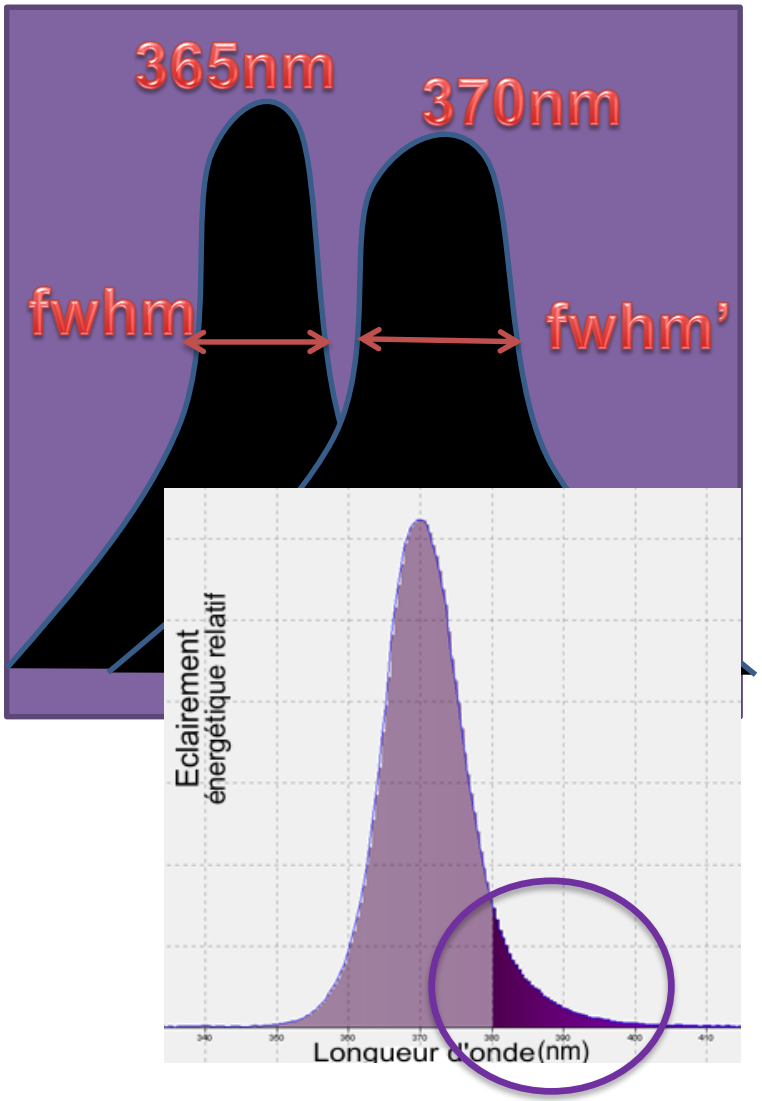
Let's see some topics relevant to LED UV-A products

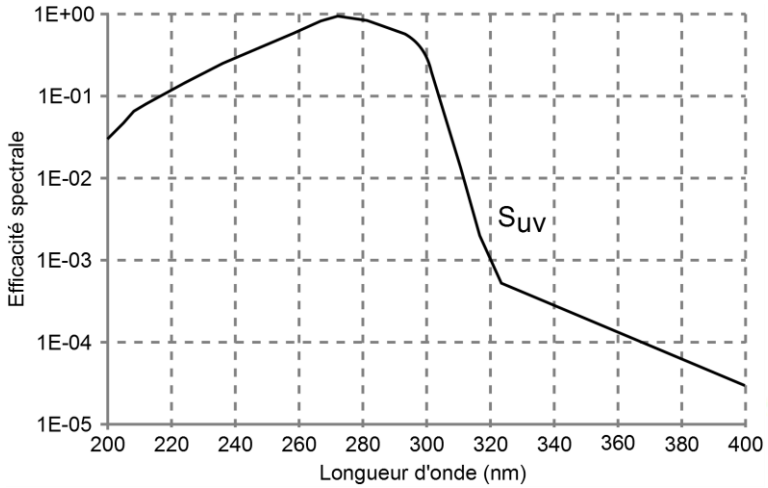
2) Eye in darkness / fluorescent techniques

a) Violet light

New UV-A Led products are showing an ‘unstable’ spectrum from cold start to warm – up: a slip of peak and a slight increase of **F**(ull) **W**(idth) at **H**(alf) **M**(aximum);
It leads to an increase of unwanted violet **UP TO 10%** of the beam energy.

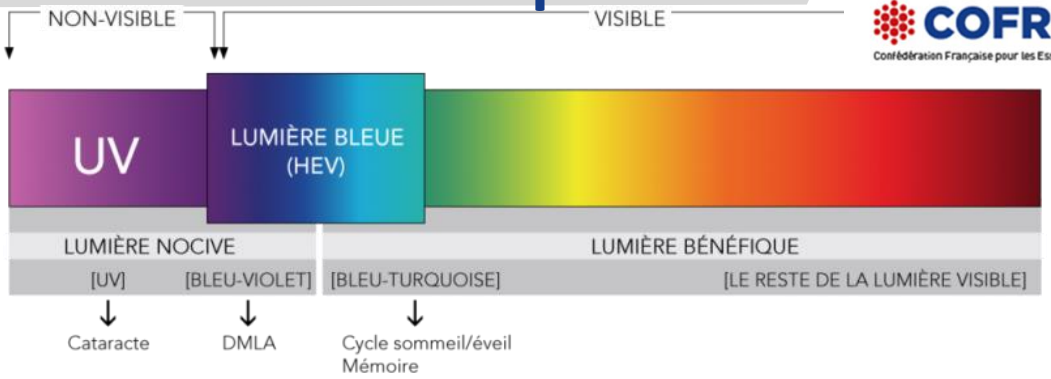
- It obviously decreases contrast (violet is visible unwanted light)
- It is also a H&S risk (i.a.w. IEC/EN 62641, risk is close to UV-A 365nm)





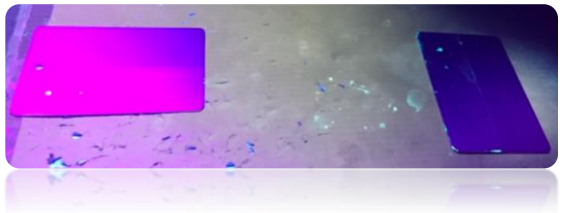
2) Eye in darkness / fluorescent techniques

a) Violet light

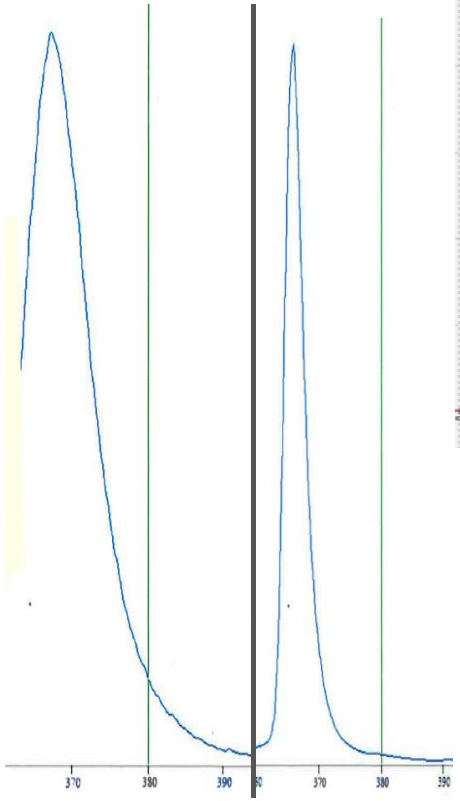


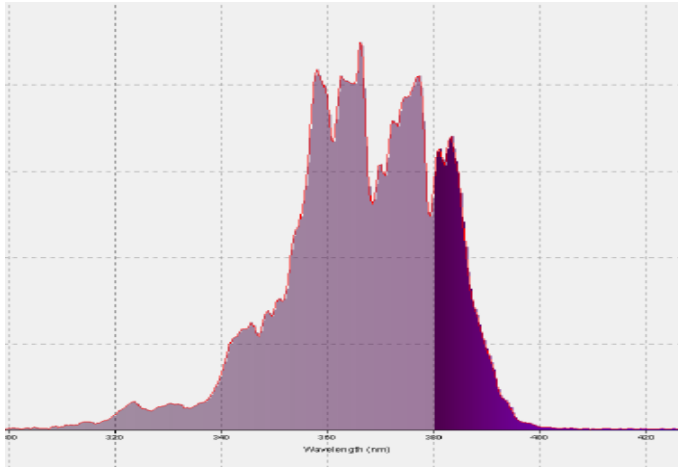
Pictured right (scans)

- LED lamp, violet hue **12%**@380nm
- HID mercury Par38 bulb, violet hue : **1,5%**@380nm



Example of detrimental violet hue (left) reducing contrast & PoD





- µ-Xenon bulb: HUGE amount of violet

WHAT are related physiologic human factors ?

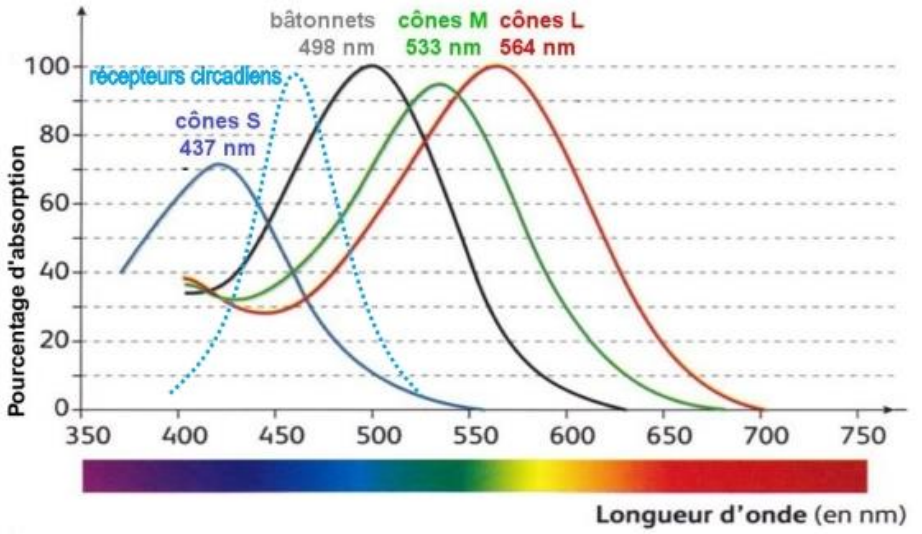
2) Eye in darkness / fluorescent techniques

a) Violet light : negative physiological human factors

Preamble

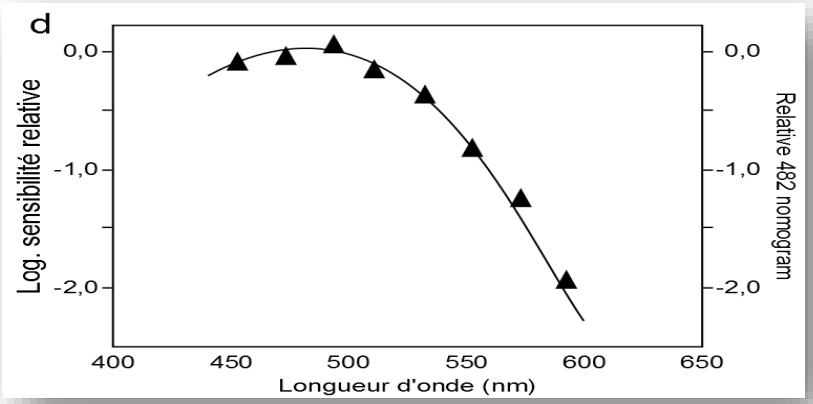
The pupil constriction is driven by the circadians receptors AND 'S' cones, present in the eye:

- Non visual cells Circadians receptors are sensitive to **blue light**, role is to synchronize human rhythm (day/night)
- Visual cells 'S' cones (are also sensitive to **blue light**) part of the RGB trichromic photopic vision.



The physiological human factor induced by presence of violet will be:

- Blue haze: internal eye **blue** fluorescence (proteins fluorescence due to **violet** & UV-A of vitreous humor & cristaline lens & cornea).
- Pupil constriction and darkness adaptation will break-up immediately



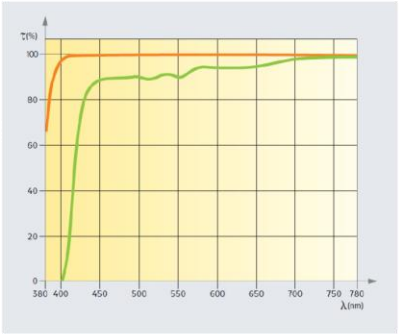
2) Eye in darkness / fluorescent techniques

a) Violet light : negative physiological human factors

What says normalisation in order to 'master & minimise' detrimental violet

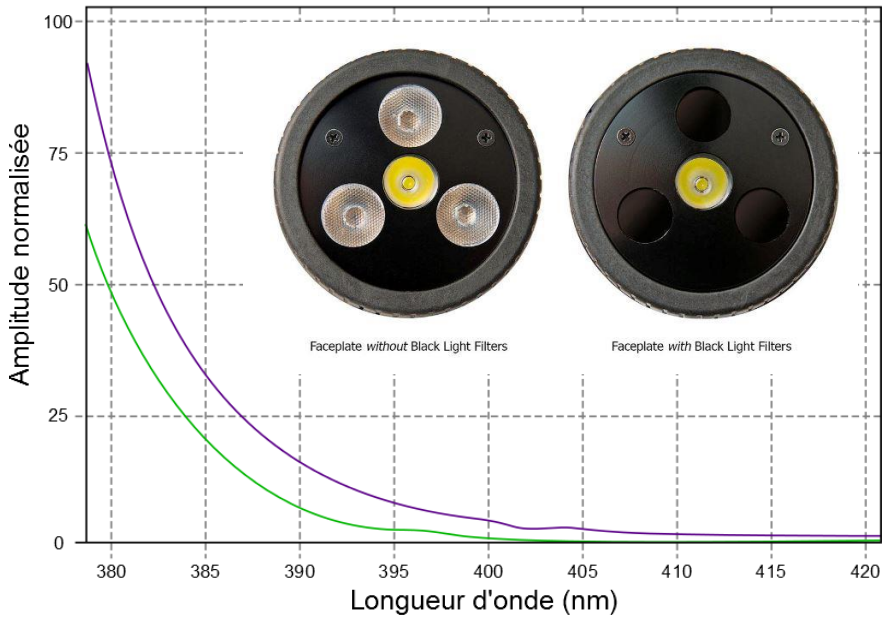
- Impose the presence of a filter (Wood's filter or other type more efficient)
- Specify, violet/UV-A ratio for each lamp (type test by manufacturer), and set a limit on this ratio. **5% is reasonnable.** (UV-A irradiance vs violet irradiance)
- Give a guidance to choose convenient clear glasses with UV-A AND violet blocker.

Note : presence of wood's filter reduce amount of violet but do not ensure a low ratio UV-A/violet.



Example of filtration of a UV-A tube by suitable goggles, blocking UV-A fully and violet partially (green curve), to be preferred to the red curve (blocking UV-A only).
(Photo credit: Babb-Co) (Curves credit: Essilor)

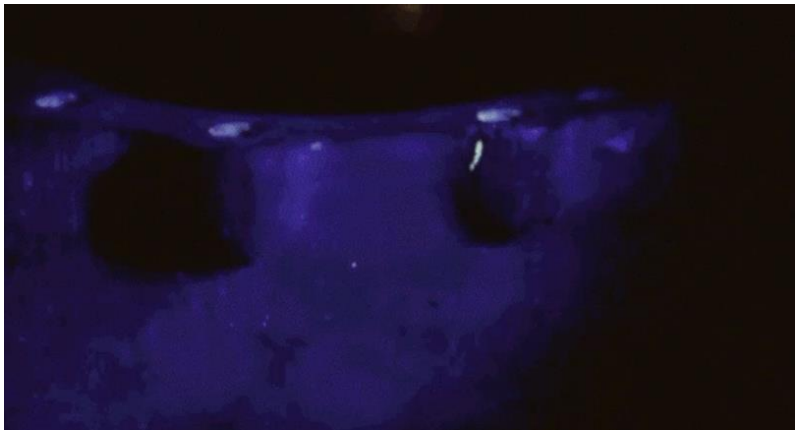
Spectres UV-A avec (courbe verte) et sans filtre de Wood dans leur partie violette



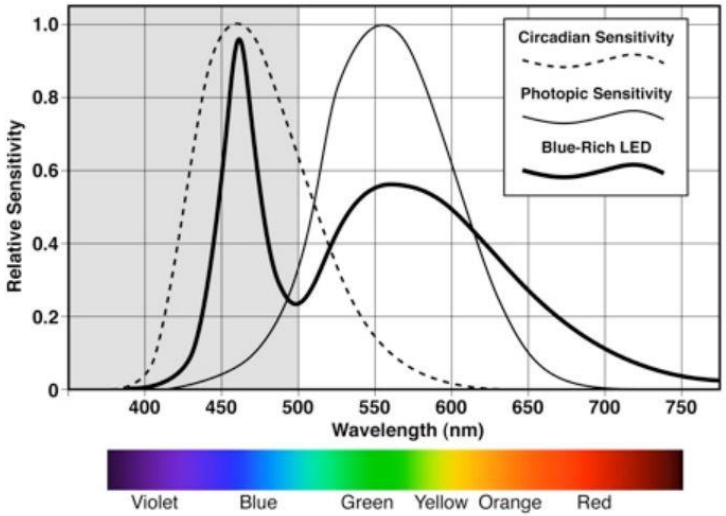
2) Eye in darkness / fluorescent techniques

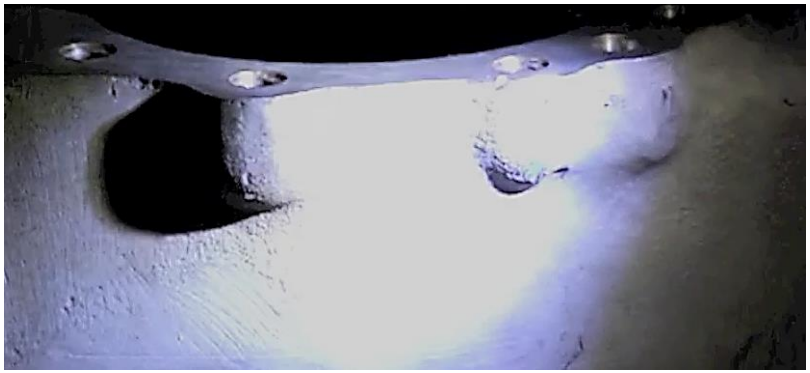
b) Blue light : negative physiological human factors

During inspection, black light and white light are alternatively used, respectively to see the fluorescent indication and evaluate the defect.
White torches/lamps are more & more LED based…..with a huge amount of blue photons in the white spectrum.



White LED's are primarily blue, topped with fluorescent yellow coating.
Spectrum of a "white" LED reveals blue light directly emitted by the GaN (Gallium Nitride) LED and the other colors of light emitted by the Ce:YAG (Yttrium Aluminium Garnet) phosphor.





- Pupil constriction and darkness adaptation break-up immediately

Again, pupil constriction stops due to blue light excitation (S cones + circadians receptors).

2) Eye in darkness / fluorescent techniques

b) Blue light : negative physiological human factors

Good practice and inspector education are of importance to reduce darkness adaptation break-ups

- **CEN TR 17108** Give a guidance for white light use, i.a.w. AFNOR NFX 35-103, for additional white light, color temperature & intensity should be respectively < 3000K (warm light) and 300lx.

Specify FPI line organisation in EN ISO 3452-4 to avoid errors in engeneering like a sun-tunnel in between washing station and Inspection booth (all day long eye + pupil of inspectors are blinking leading to fatigue & decreased detectability)

- Follow visual ergonomics advice per NF X35-103: 2013 for transitions from dark to bright places - and reverse - progressive transition with a luminance ratio < 1 to 5

Note that it perfectly matches the authorised visible ambiant light at washing stations (100lx) to inspection booth (20lx)

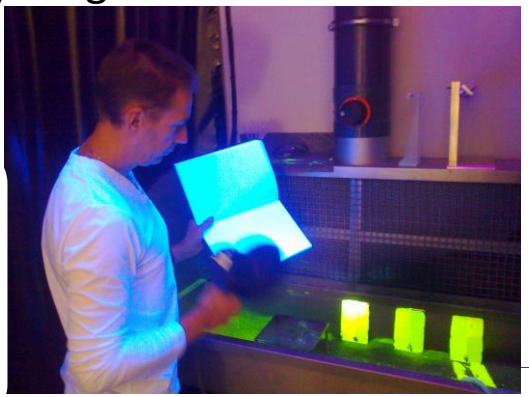
2) Eye in darkness / fluorescent techniques

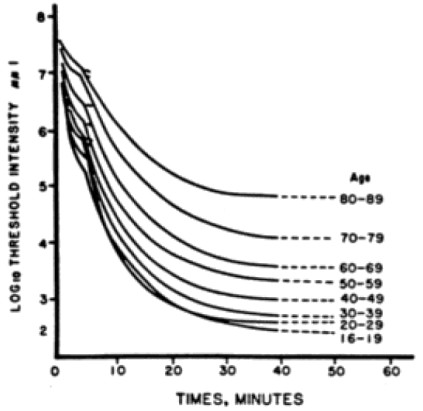
b) Blue light : negative physiological human factors

Anecdote / paradoxal requirement

We know now why bluish paper under UV-A is detrimental (like all other bluish sources : bright screens ect..): brightener fault!

The bluish wite paper check for homogeneity is not to be done just before inspection!
-> another color is smarter (yelow, orange, or even safer: red).





courbe d'adaptation à l'obscurité en fonction de l'âge (McFarland, cité par Owsley, 1987)

Uneven beam pattern

B. Even beam pattern

Another Human factor; age of inspector:
Note that eyes dark adaptation take 5 mins for cones (photopic RGB vision) and 25mn for rods (scotopic vision) with less effective adaptation for the older inspectors that must be more preserved from glare.

2) Eye in darkness / fluorescent techniques

b) Blue light : positive physiological human factors

As explained in slide 4 circadians receptors sensitive to blue, are partially responsible for pupil constriction but their main role is to regulate circadian rythm, that mean they're driving the awakeness-sleep cycle.
When **not excited** by blue light, they're responsible for starting the sleep cycle (melatonin production begins) and reversely when excited they WAKE UP the inspector and keep the attention and the focus active.

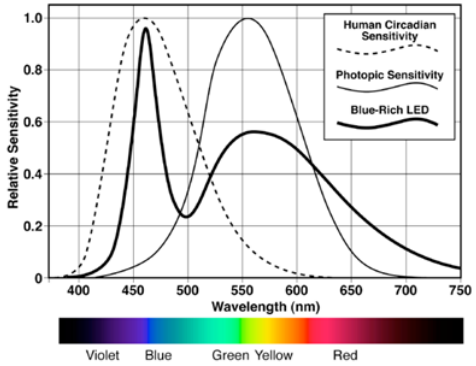


Figure 3. Human photopic and circadian sensitivity curves displayed against a typical blue-rich LED light source spectrum.

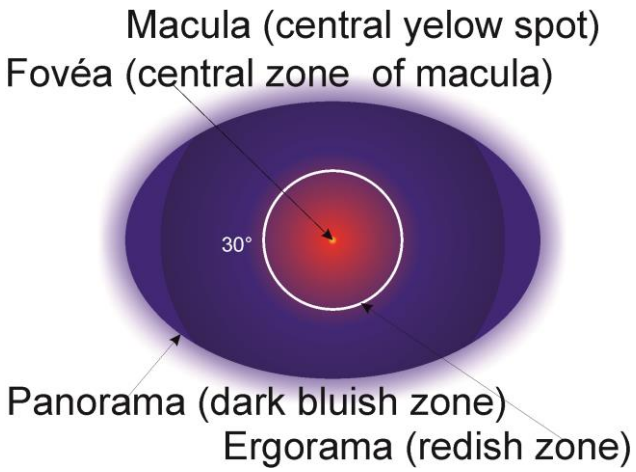
- Too long working periods in darkened zones (inspection, washing) are detrimental for the POD
- Pauses – breaks- are mandatory and must be taken in high-lighted zones (outside for example) with large amount of natural or artificial bluish light (cold light)
- NDT report can be written in a specific area with bright screens or ambiant high intensity rooms.

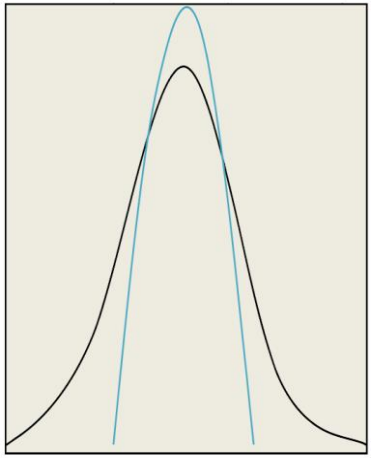
3) Tools/ fluorescent techniques

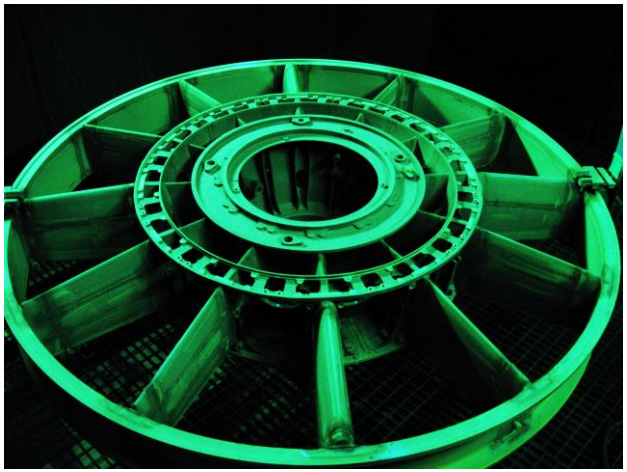
a) UV-A sources: Beams, which shape ?

Eyes spacial sensibility is of importance, NDT uses the fovea & macula central zones for inspecting in detail small parts & indications, but on large parts detection of indications comes from the pericentral vision: ergorama.
For large parts, using large beams with 'soft edges' can speed up detection and increase comfort, but SIZE also matters.

On the contrary, for small parts or localised NDT, hard edges can be usefull to the inspector by focussing the view on the areas to be tested. -> **up to Level 2&3 do decide. There is no 'ideal shape'.**







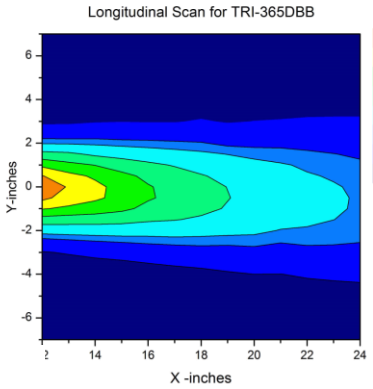
3) Tools/ fluorescent techniques

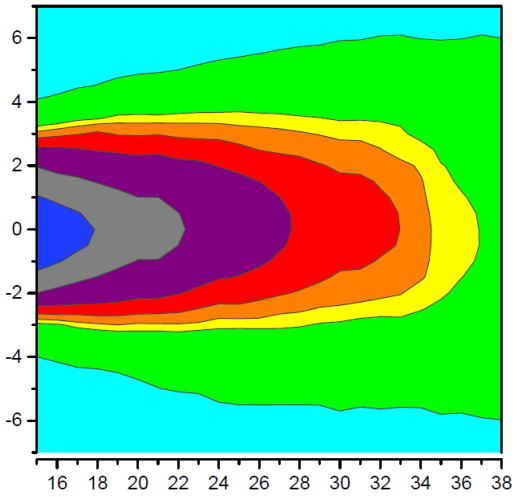
b) UV-A sources : Beams spread

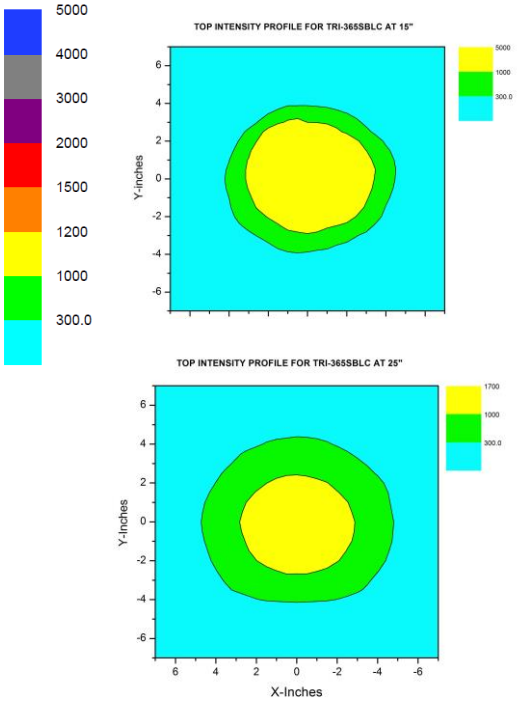
<u>Beam Transversal Mapping is not bringing enough information</u>

To know what will be the usefull beam size when lamp is moved toward or away from the part ONLY the LONGITUDINAL mapping can tell you if the usefull size

1. is growing, (divergent beam)
2. gets smaller (convergent beam)
3. keeps constant (parralel beam)







On this example, from 15 to 35 Inches beam diameter remains CONSTANT : It's non disturbing and provides good conditions to the inspector.

SOFT edges or not? Discussion.

When an indication appears very progressively due to too soft edges, brain attention is NOT activated, visual ergonomics (eye + brain behaviour) is NOT AS GOOD versus a more sudden income that 'light' zones in cerebral visual cortex. Again there is not 'ONE' convenient beam shape.

3) Tools/ fluorescent techniques

c) Meters : no critéria?!

Luxmeters

ASTMe3022 states

NOTE 2— Photometers or visible light meters are not considered adequate for measuring the visible emission of UV-A lamps, which generally have wavelengths in the 400 nm to 450 nm range. (NB: it's more 400/420nm violet)

-> True, but at least luxmeter must show unsensitivity to UVA and sufficient reliability on V(λ) (NFC 42-710, DIN 5032 , EN 13032).

Parameters like the cosine correction must also be mentioned.

Radiometers

To avoid multiple readings of the same energetic irradiance when mesuring a beam, and to have engineering depts. KEEPING confidence in PT& MT methods – the relative response curve has to be fixed -like luxmeters- , not only a peak response over a range,

- Cosine factor must be mentioned

➢ ASTMe2297 + EN ISO 3059 must be updated accordingly.

4) Conclusion

- ❑ New UV-A LED products open the door for better visual ergonomics during PT & MT
- ❑ It's time to implement the physiological human factors in the training of levels 1/2/3, to achieve that:

A Technical Report Working Item is released during 2017: CEN TR 17108 "**Non-destructive testing — Lighting in penetrant and magnetic particle testing, good practice »** *CEN organisation (planned to be ISO)*

- ❑ A COFREND Working Group is working to implement training courses, table of contents, introducing all majors physiological human factors for PT & MT in order to introduce and explain for levels 1, 2 & 3 peoples (ISO TS/CD 25107).

Thank you.

Nov. 2017

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5) Follow-up

The Working Group ended the job and the EN ISO 25107 (Guidelines for the NDT Training Syllabus was implemented with many new topics, for example:

Content noise			Level 1	Level 2	Level 3
Physical principles + associated knowledge	Penetrant Systems	Basic fluorescence and absorption principles in dyed penetrants		X	
	Properties & characteristics	Fluorescence of material roughness		X	X
		Variable values (Ra + Rz)			X
		Multiple roughness			X
		SNR concept	X	X	X
		Residual background noise (over-/under washing risks)	X	X	X
Product knowledge + related capability of method & derived techniques		Test conditions	X	X	X
		Lighting in work and surrounding areas		X	
		Adaptation to black light environment		X	
		Transistion between bright and darkened areas		X	
		Viewing conditions	X	X	X
		Role of dark-adaptation		X	
		Cleanliness		X	

Example

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