



# Proposed Increase in Exposure Limits for UV-C Wavelengths – Measurement Issues

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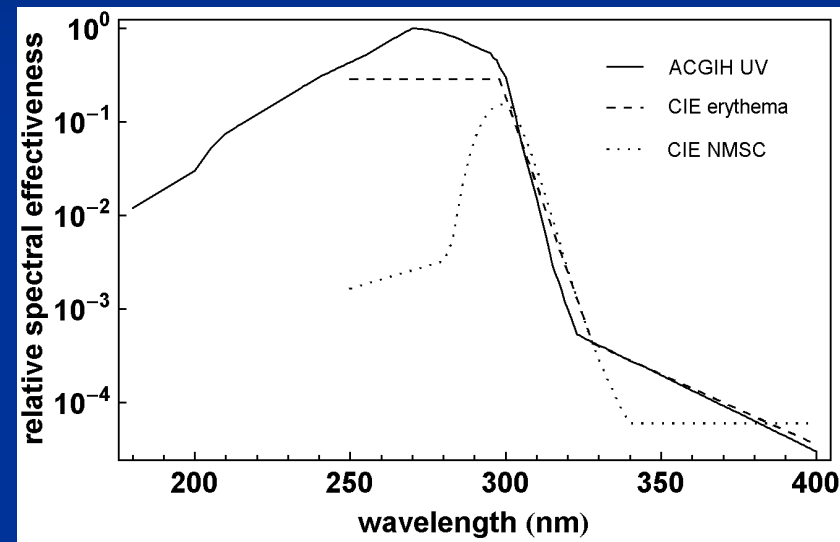
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# What are the safety guidelines for human exposure in the GUV UV – C Band?

- Action spectrum for safety is the ACGIH/ ICNIRP/CIE/ISO & IEC action spectrum  $S(\lambda)$

$$E_{eff} = \sum_{180}^{400} E_{\lambda} \cdot S(\lambda) \cdot \Delta\lambda$$

- $S(\lambda)$ -spectral weighting leads to a *radiant exposure* of 3.0 mJ/cm<sup>2</sup> (30 J/m<sup>2</sup>)
- Limit is daily – including multiple exposures
- Time-weighted average (TWA) over a day
- At 254 nm this is 6 mJ/cm<sup>2</sup> (60 J/m<sup>2</sup>)
  - Or, time-averaged irradiance of 0.2 μW/cm<sup>2</sup>
- Large safety margin for human skin in the UV-C – so:
- Should there be two limits? – *For Eye, For Skin?*



- ACGIH UV  $S(\lambda)$  spectral weighting function (action spectrum) is the solid line.
- $S(\lambda) = 1.0$  at 270 nm



# Ultraviolet Safety has been a very important issue!



## ■ Accidental exposure of skin & eyes:

- Photokeratitis (“welder’s flash,” or “snowblindness”
  - with symptom of “sand in the eyes”
  - *Cornea is most sensitive tissue*
- Erythema – reddening of the skin
  - Can be severe if penetrating UV-B rays (“sunburn”)
  - Mild if UV-C – very superficial absorption



■ Photokeratoconjunctivitis

## ■ Delayed Effects

- Skin Cancer?
  - UV-B in sunlight penetrates to basal (germinative) layer of epidermis and is the recognized cause of most skin cancers
  - UV-C heavily absorbed in superficial epidermis & stratum corneum



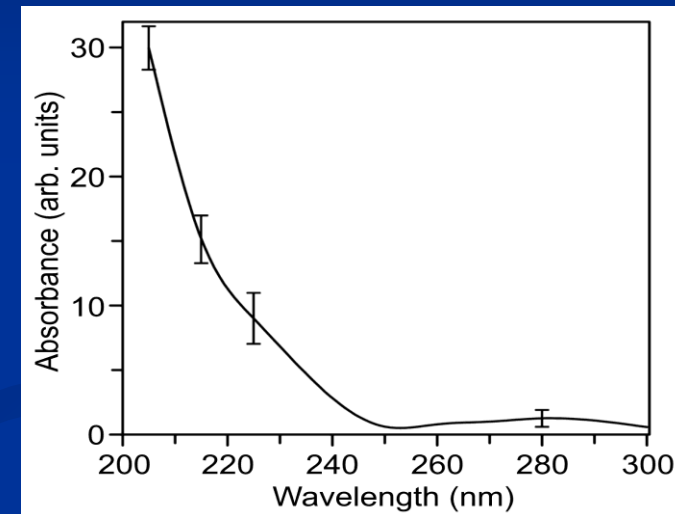
■ Erythema (skin reddening)



# Rationale for Changing the TLV in the Far-UV & all UVGI Applications



- Studies of Far UV-C health effects on eye and skin show wavelengths below  $\sim 230$  nm are substantially safer than longer UV-C wavelengths.
- Consistent with biophysical considerations regarding a much shorter penetration depth of Far UV-C radiation than longer wavelength UV-C

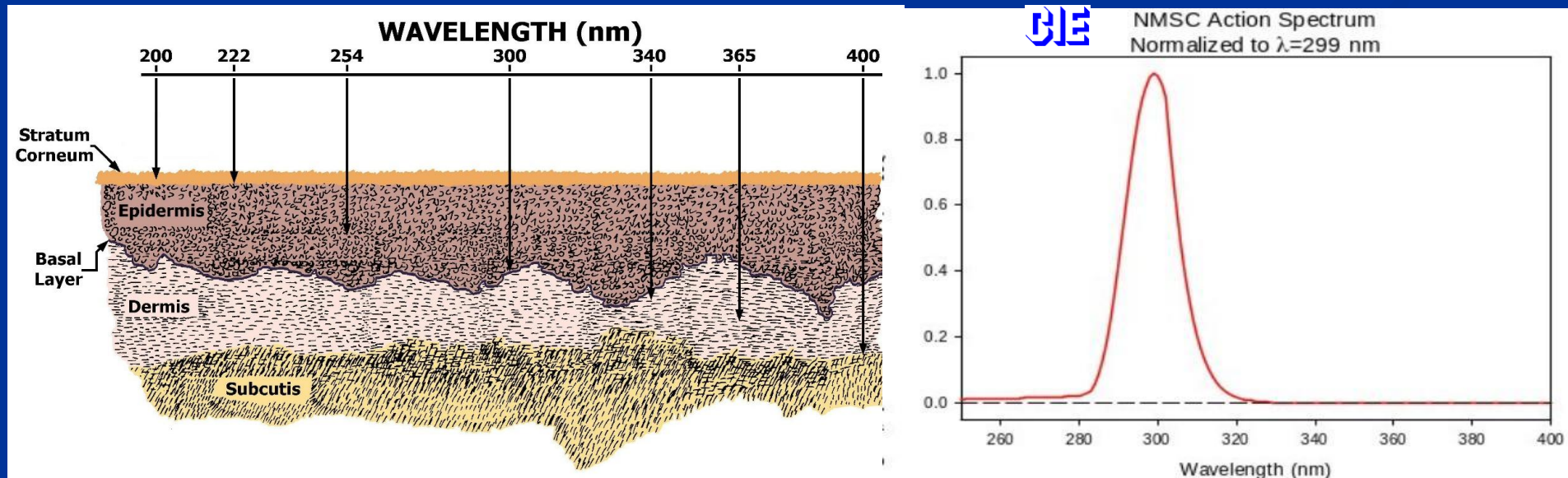


Absorption of proteins and other biological molecules becomes very high at  $\lambda < 230$  nm



# The Skin – Far UV-C is absorbed superficially

- A risk of skin cancer (“photocarcinogenesis”) exists if significant rays reach the germinative (“basal”) layer of the epidermis. That occurs from UV-B in sunlight.

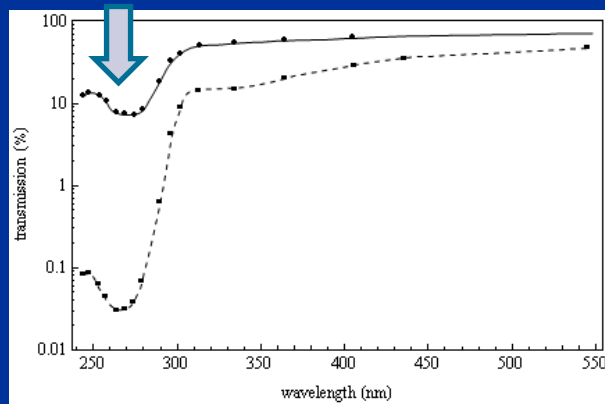


- UV-C has a very low risk compared to UV-B (in sunlight).

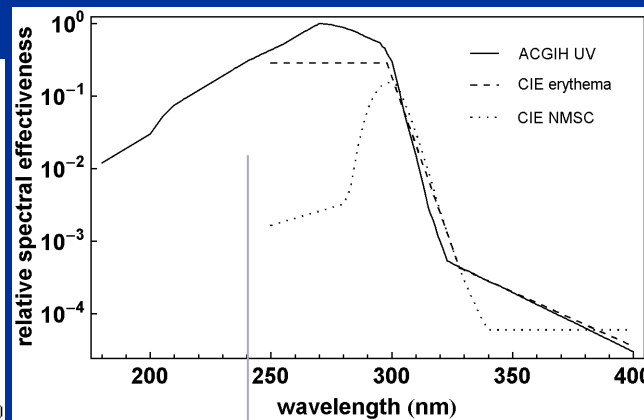
# Is there a Realistic skin cancer risk? -

*The first Law of Photobiology – Photons have to be absorbed to produce an effect – and they have to reach the target Molecules*

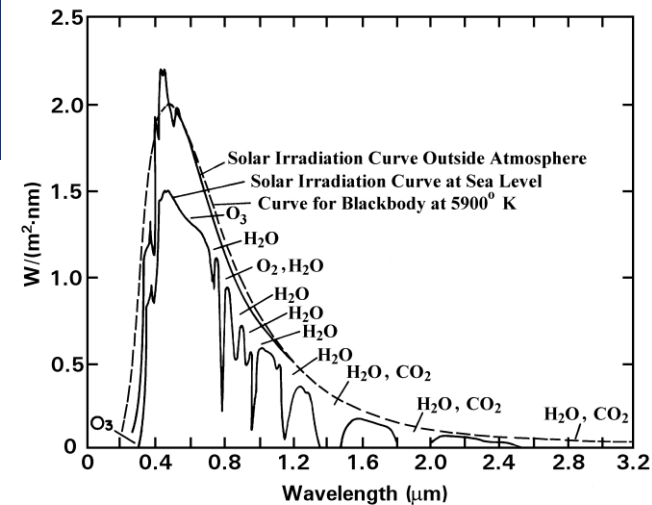
- TYPICAL CONCERN – If UV-C has highest photon energy why is it not more phototoxic and a more severe skin cancer risk!??
  - UV-B photons are less energetic but they penetrate deeper



Bruls transmission measurements thru stratum corneum (upper curve) & epidermis (lower curve)



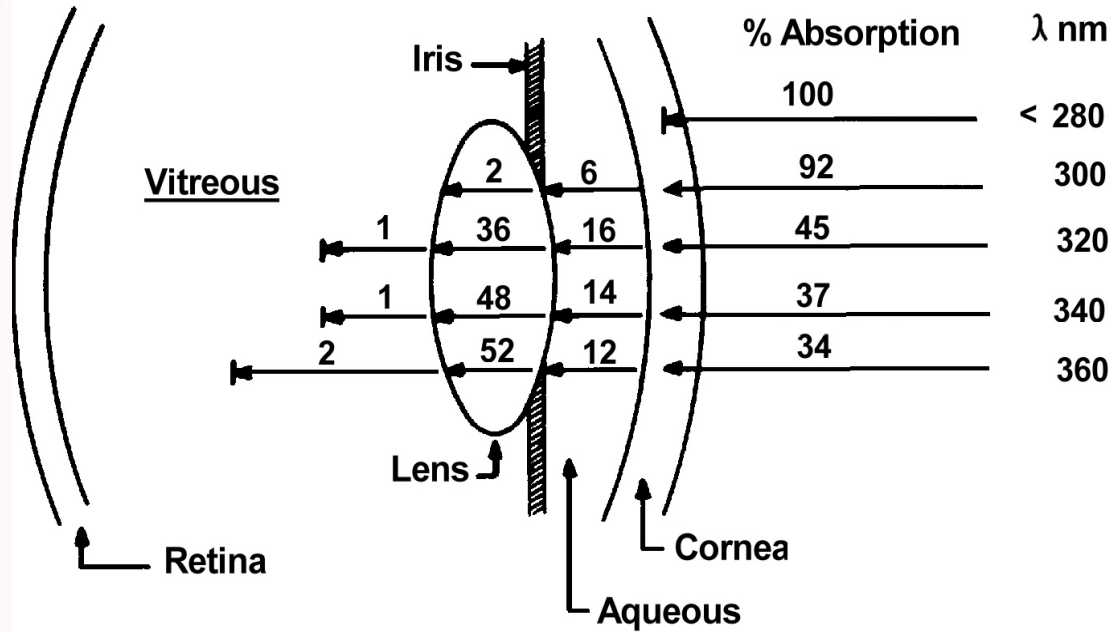
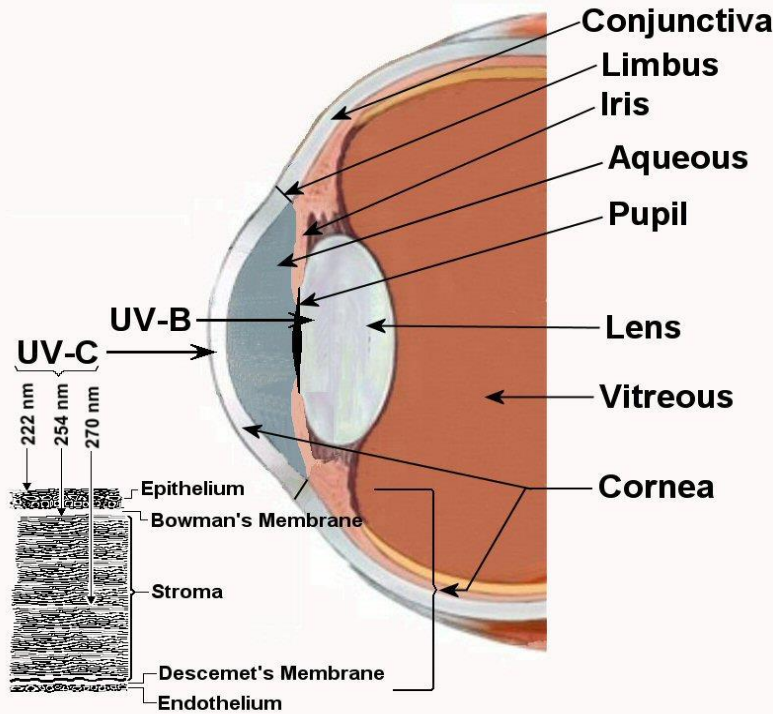
254 nm



Sunlight spectrum – only trace amounts of UV-B reach ground level and no UV-C at all (Slney & Wolbarsht, 1980)

**See: CIE 187:2010 – UV-C Photocarcinogenic Risks from Germicidal Lamps**

# UV Spectral Absorption in Ocular Tissues — Successive Filtration by Layers



David Sliney

UV-A produces visible lens fluorescence from the proteins in the crystalline lens

- Occupational exposure to UVR is a significant risk from solar UV-B exposure of most outdoor workers
- Indoor works are normally fully protected to avoid acute effects
  - Hence there is no traditional human exposure to UV-C
  - *Note the potential exposure to scattered UVR in this case!*
- *Safety limits are based on laboratory studies and basic biological principles plus acute dermatological studies*

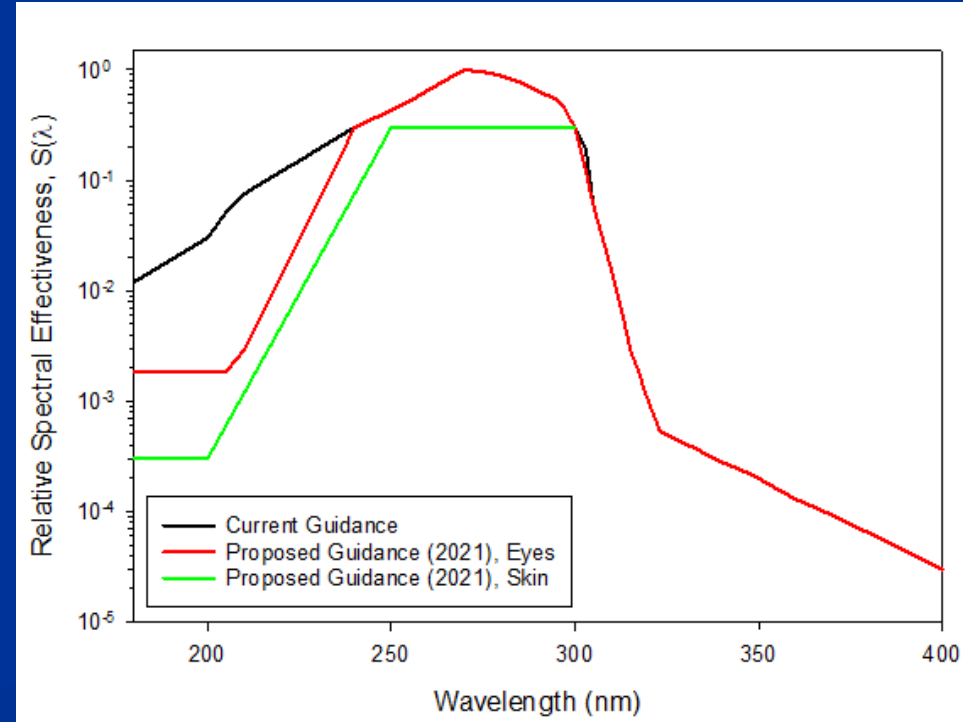
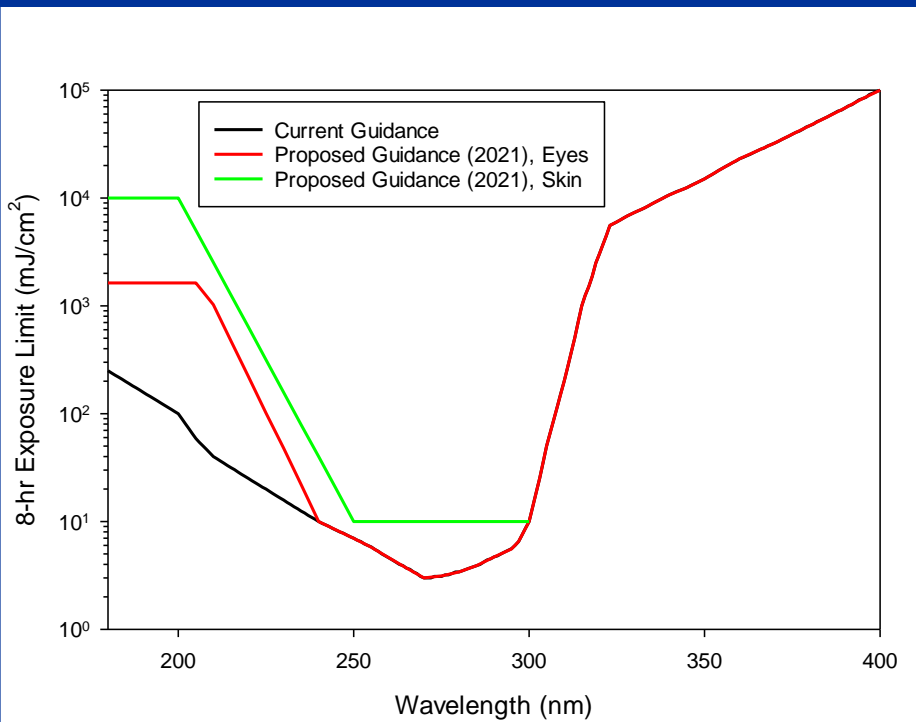




# Human Exposure Limits (2021) – Proposed Revision In UV-C (ACGIH)



- Revision of TLVs Expressed as Limit Values (left)
- Revision Expressed as TLV Action Spectrum (right)

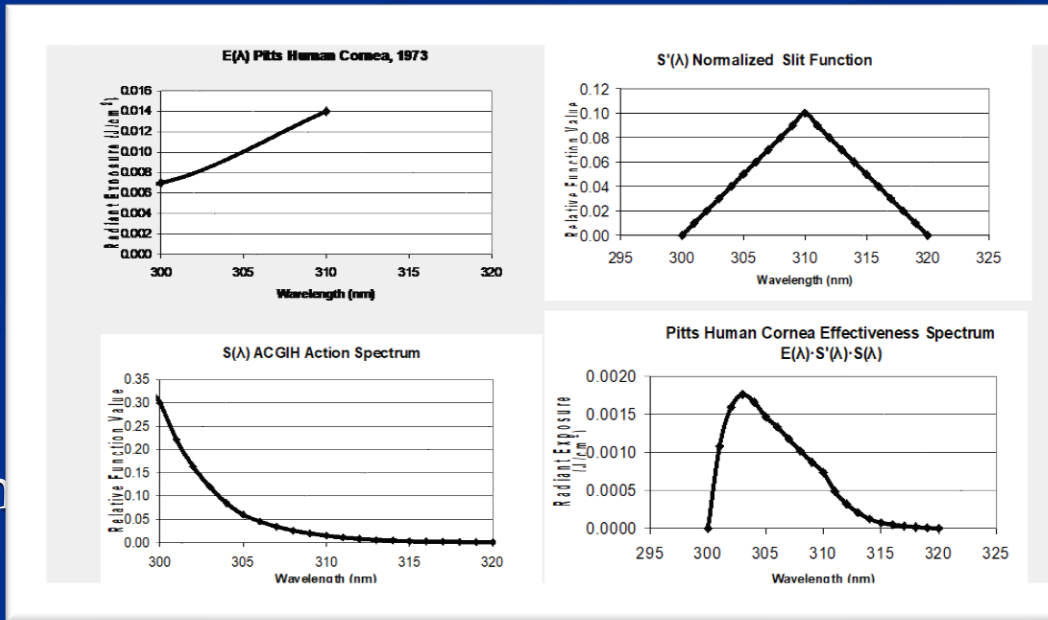




# Measurement Issues: Spectroradiometric Errors in Spectral Regions around 200-230 nm and 300-320 nm



- Because of steep slope of  $S(\lambda)$  in these regions, the spectral bandwidth needs to be quite small to weight
  - 1 nm spectral bandwidth would actually be desired!
  - Significant error would occur during spectral weighting with  $S(\lambda)$
  - Figure to the right is an example of impact at 310 nm by 10 nm width
  - Bioeffect at  $\sim 305$  nm





People Ask:

## Are there sensitive individuals to UV-C?



- Photosensitivity – Really applies to UV-A and UV-B wavelengths; there are some very sensitive individuals who must avoid sunlight exposure and even near-ultraviolet – UV-A exposures.
- Threshold exposures for erythema vary with skin phototypes and pigmentation. Thus, skin cancer risks from sunlight vary enormously
- However, since all UV-C wavelengths have shallow skin penetration, individual skin sensitivities are insignificant. Photosensitizers are out of reach largely in the dermis. This is absolutely true for Far UV-C.
- Individual variations in eye sensitivity are currently under study

■ 2021

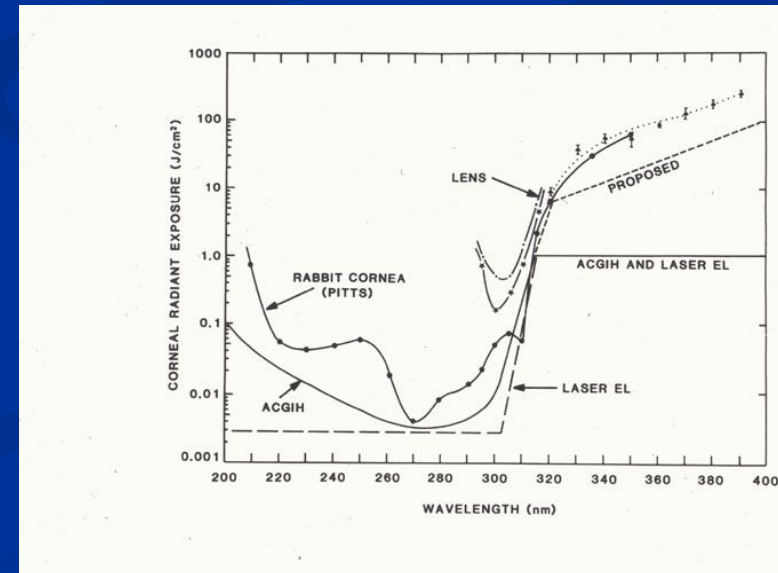




# ICNIRP/ACGIH Exposure Guidelines and TLVs for UV - *fixed since circa. 1985*



- Hazard action spectrum  $S(\lambda)$  applied to spectrally weight UV exposure spectrum to produce an “Effective Irradiance.”
- **Two criteria:**
  - 1. The spectrally weighted “effective” radiant exposure is limited to  $3 \text{ mJ/cm}^2$
  - 2. The total (un-weighted) irradiance is limited to  $1 \text{ J/cm}^2$  in 1000 s for ACGIH (or work day for ICNIRP)
- **Examples:**
  - At 254 nm: Limit of  $0.2 \mu\text{W/cm}^2$  for 8-hr exposure, or  $6 \text{ mJ/cm}^2$  for shorter periods;
  - At 222 nm –  $0.75 \mu\text{W/cm}^2$  and  $23 \text{ mJ/cm}^2$
  - Free downloads of guidelines:  
[www.ICNIRP.org](http://www.ICNIRP.org)





# Changing the ICNIRP/ACGIH UV Hazard Function $S(\lambda)$ will Aid Far UV-C Acceptance

