Spectral power distribution optimization of headlights

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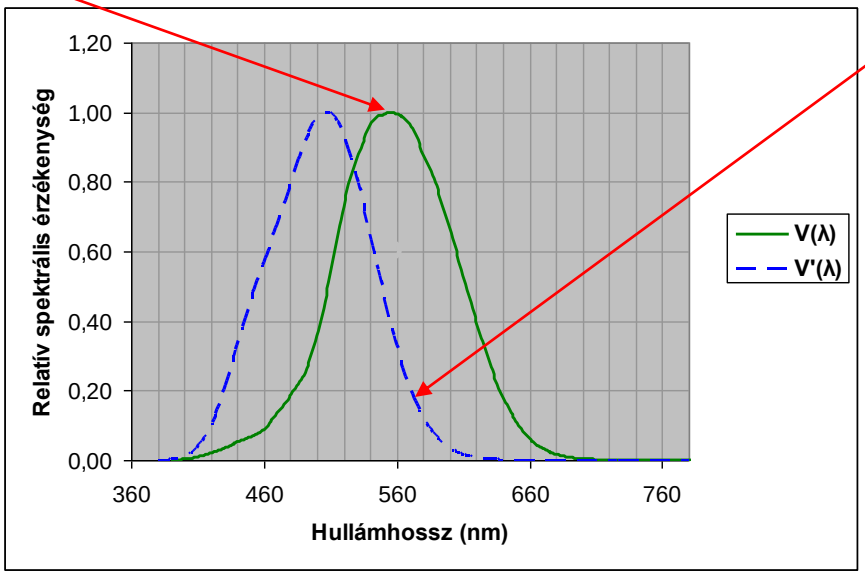
Spectral sensitivity of the human eye

- Daytime spectral sensitivity (photopic vision)
  - >10 cd/m^2
  - *V(λ)* – CIE* 1924
    - Flicker photometry
    - Heterochromatic brightness matching
  - Main role: cones
    - 3 type, sensitive for long-, middle- and short wavelengths (L,M,S)
- Twilight vision (mesopic vision)
  - 10 cd/m2 > .. >0,01 cd/m2
  - $V_{mes}(\lambda)$ – not defined and agreed, yet
  - Main role: cones and rods
    - Sophisticated mechanism
- Night-time spectral sensitivity (scotopic vision)
  - <0,01 cd/m^2
  - *V'(λ)* – CIE* 1951
    - Brightness matching
  - Main role: rods
    - 1 type („colorblind”, highly sensitive for contrast and motion)



A typical mesopic task: night-time traffic

- Lighting for night-time traffic
  - Electric pylon (poles),
  - Mainly headlamps (rural environment)
- Contrary aims at Headlamps
  - More intensity - more far sight,

  - Less disturbing, less glare

Aim of the experiments

To determine mesopic spectral sensitivity under

a. normal mesopic conditions,
b. mesopic conditions with disturbing glare (hereafter: glare mesopic conditions)

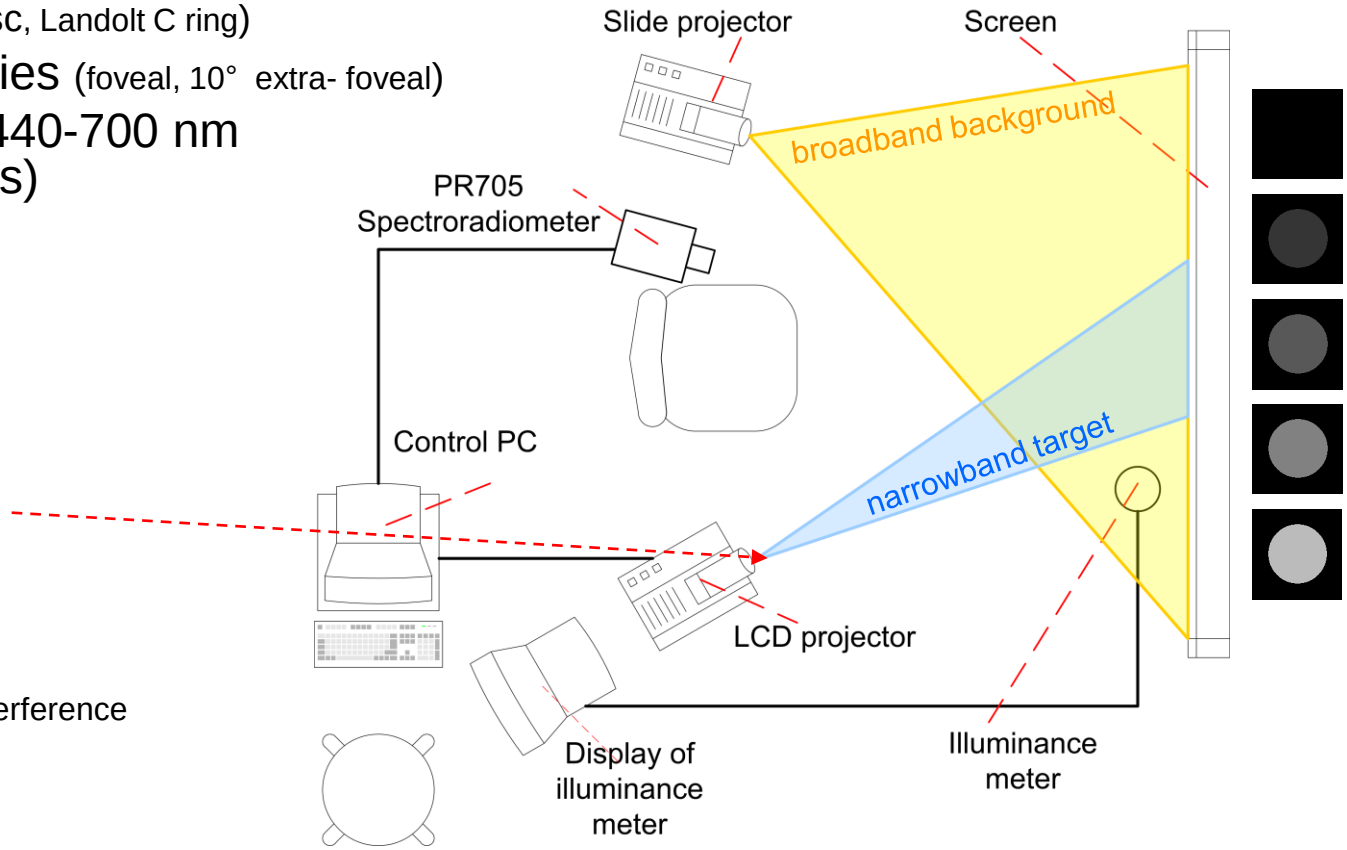
Normal mesopic condition
Target

- Detection threshold (contrast threshold)
  - 2° disc
    - Foveally and
    - 10° extra-foveally

Normal mesopic condition Experimental setup

- Three luminance levels
  (0,01 cd/m^2, 0,1 cd/m^2, 1 cd/m^2)
- Two targets (disc, Landolt C ring)
- Two eccentricities (foveal, 10° extra- foveal)
- Wavelengths: 440-700 nm
  (10/20 nm steps)

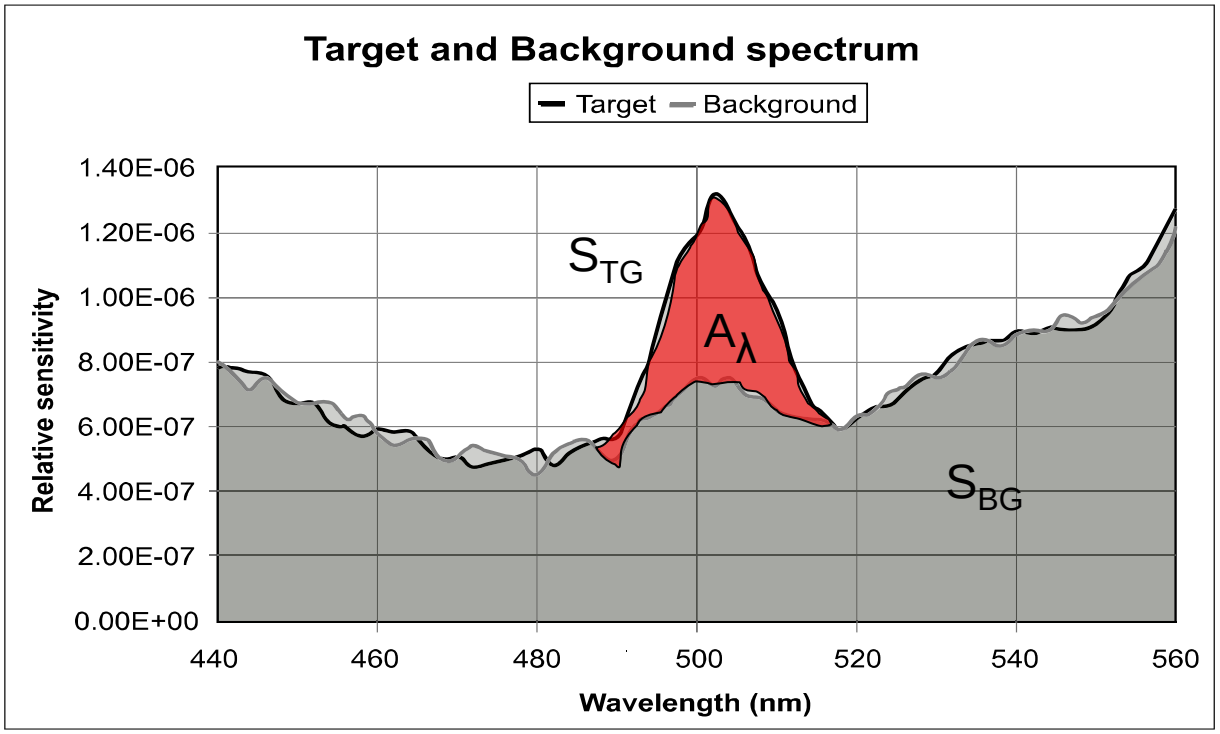
Quasi-monochromatic interference filters (Andover Corp.)



Normal mesopic condition Measure of threshold

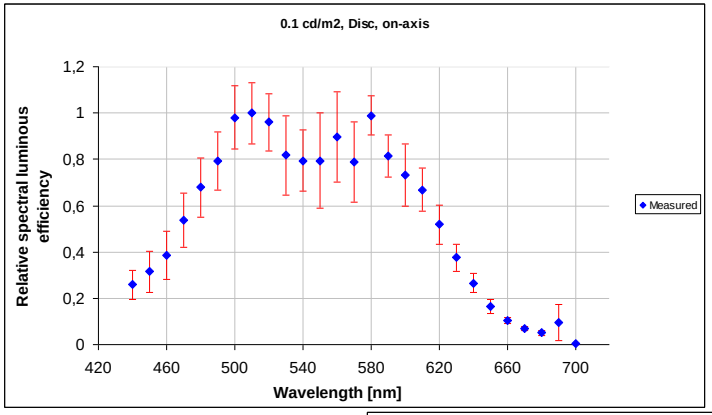
- Emerging narrowband area around λ

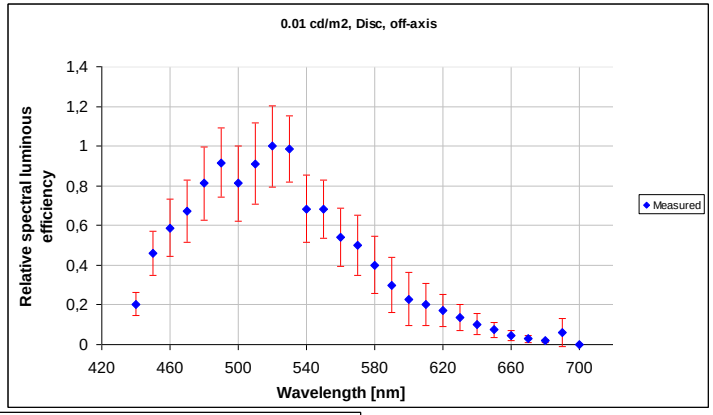
$$A_\lambda = \sum_{n=-10}^{10} \left(S_{TG}(\lambda + n) - S_{BG}(\lambda + n) \right)$$

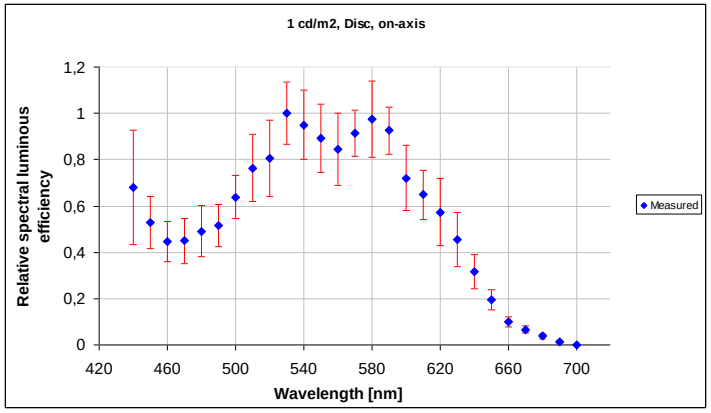


Normal mesopic condition Sensitivity curves

- 1/Area gives 6 sensitivity curves
  (3 luminance levels * 2 eccentricities)
- Examples:







Normal mesopic condition Chromatic channels

- Curves have more maxima
  - →Not only the fast magnocellular pathways (intensity) but the slow parvo- and koniocellular pathways (opponent color information) add to mesopic spectral sensitivity

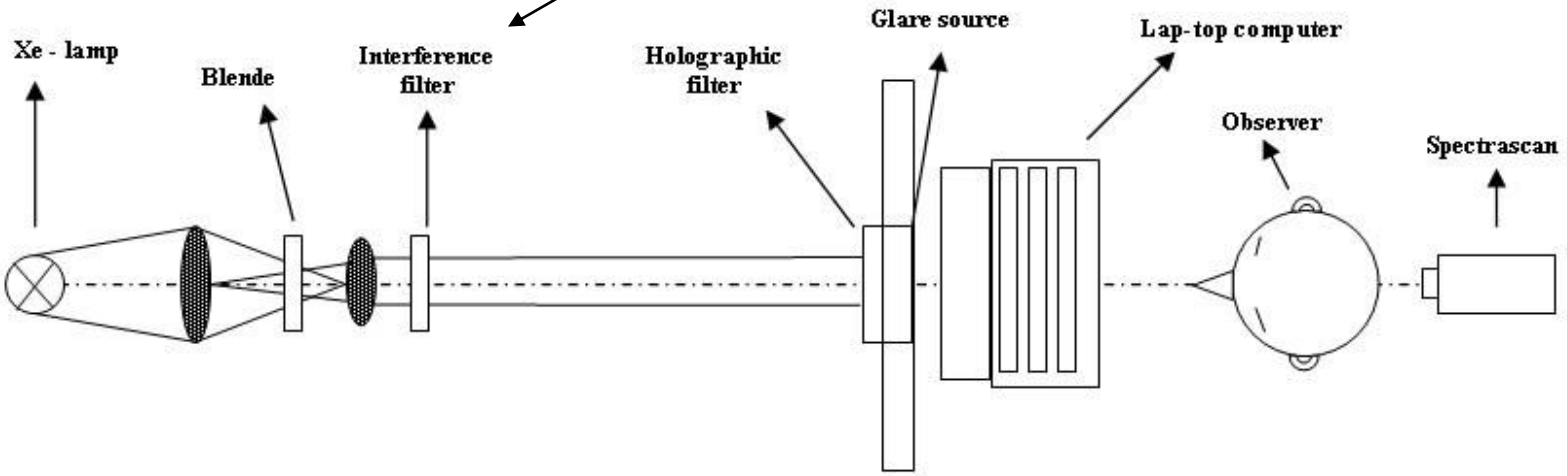
Glare mesopic condition
Target

- Similar as previously:
- Detection threshold (contrast threshold)
    - 2° disc
        - Foveally

Glare mesopic condition Experimental setup

- A typical mesopic luminance level:
  0,1 cd/m^2
- Target: disc
- Eccentricity: foveal
- Wavelengths: 420-660 nm (10 nm steps)

Quasi-monochromatic interference filters (Andover Corp.)

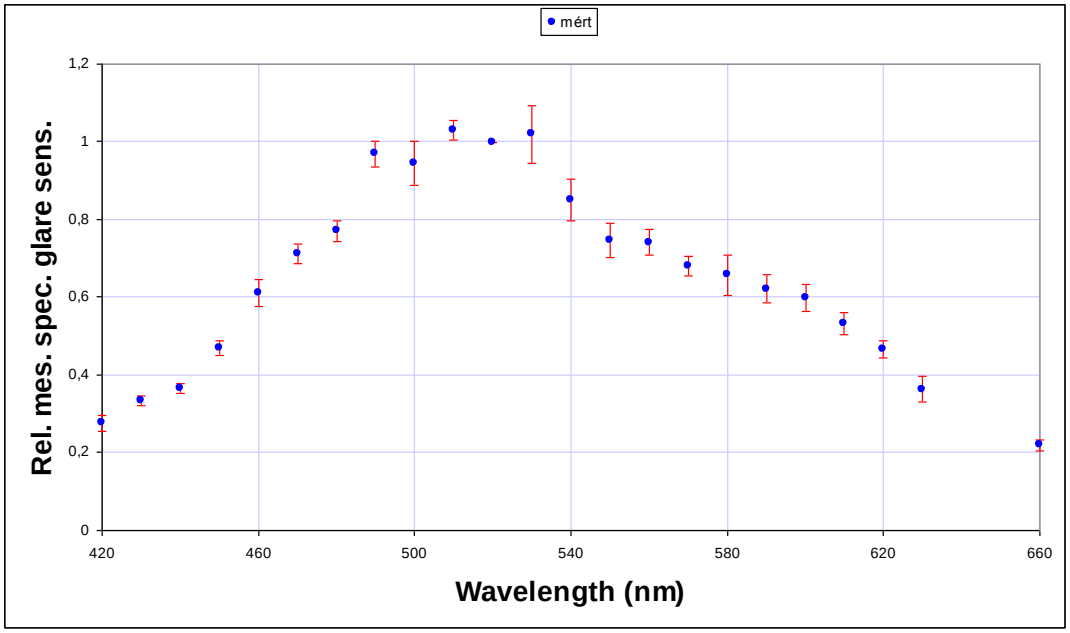


Glare mesopic condition Experimental setup

- Task:
  - To set the intensitiy of the glare (blende) until it is „disturbing”
- Different tasks with the disc target on the computer screen to achieve a level of „disturbing” – more than „discomfort” but less than „disability”

Glare mesopic condition Measure of threshold

- Similar as at normal conditions
- There is a curve constructed, which we call „mesopic spectral glare sensitivity”



Glare mesopic condition Chromatic channels

- As in the „normal” case, the curve has more maxima
  - →not only the fast magnocellular pathways (intensity) but the slow parvo- and koniocellular pathways (opponent color information) add to mesopic glare spectral sensitivity as well

Conclusion

- Normal and glare mesopic detection threshold sensitivities involve chromatic channels, ie. colour vision. It is reasonable to use a model - similar introduced by *Kurtenbach et al.* and/or the *MOVE Project* and/or *Várady* – with chromatic terms for calculations regarding night-time driving and outdoor lighting,
- Parameters and final form of a proposed model with chromatic channels which describes our measured data (normal and glare situations) well is under construction,

Conclusion

- Considering the normal and glare mesopic spectral sensitivities, it could be possible to give an optimized spectral power distribution for headlamps, which do not cause disturbing glare but provides best vision during night-time driving,
- To be able to do this, a further question has to be clarified: are these functions additive (is Abney's law valid)?
- Preliminary experiments show that mesopic visiblity additivity doesn't hold (*Vas Z,Bodrogi P*), but can be used as a first approximation.

Thank you for your attention