



Metrology Lens Requirements for Near-Eye Displays

Kilian Kirchhoff, Tobias Porsch, Ingo Rotscholl, Stefan Schramm, Udo Krüger

TechnoTeam Bildverarbeitung GmbH, Germany

Motivation

The human eye

Sensitivity	Brightness and color perception
Eye size	2–5 mm entrance pupil, eye and pupil rotation [1; 2]
Resolution	Up to 47 lp/deg foveal under achromatic viewing [3], dropping to ~20 lp/deg at 10° eccentricity [3; 4]
Distortion	Perception depends on magnitude, on its consistency between the eyes [5] and on how abruptly it varies across the field [6]
Focus	0 to +10 dpt, geometrically stable [7]

Mechanics and photometry

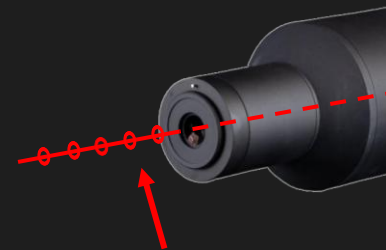
Standardized requirements for AR/VR ILMDs

Physical or virtual entrance pupil at fixed position

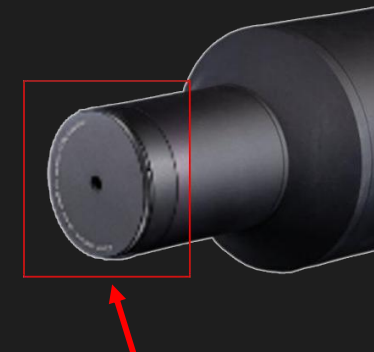
IEC 63145-20-10 [8]

IDMS 1.3 [9]

Standardized for years



Virtual entrance pupil



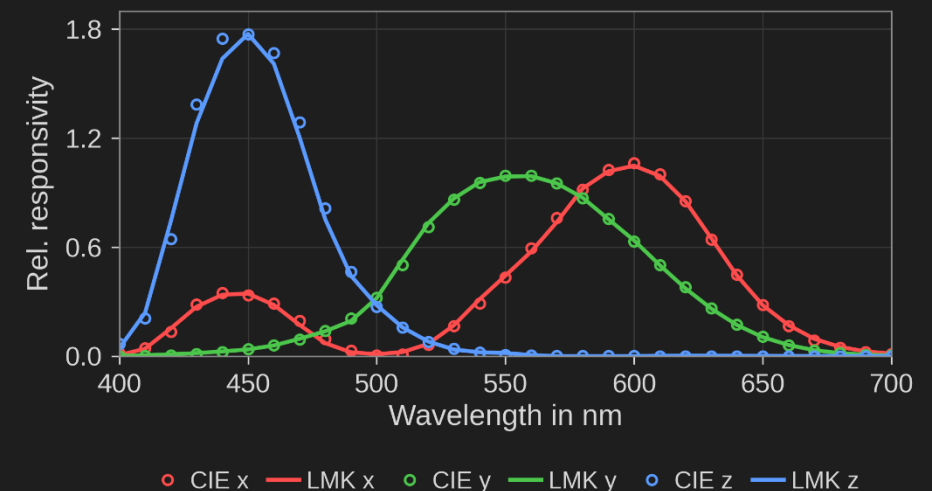
Physical entrance pupil

Absolute luminance, color and performance values

CIE 244 [10]

Accredited lab (ISO 17025),
certificate per system

Applies to photo- and colorimetry in general



Optical performance

Resolution, focus and distortion

Mechanical focus

- Moving parts
- Pupil shift during focusing

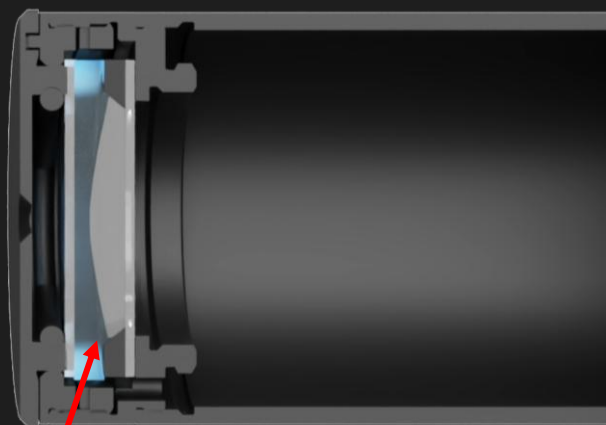


Optical performance

Resolution, focus and distortion

Our focus mechanism (liquid lens) [11]

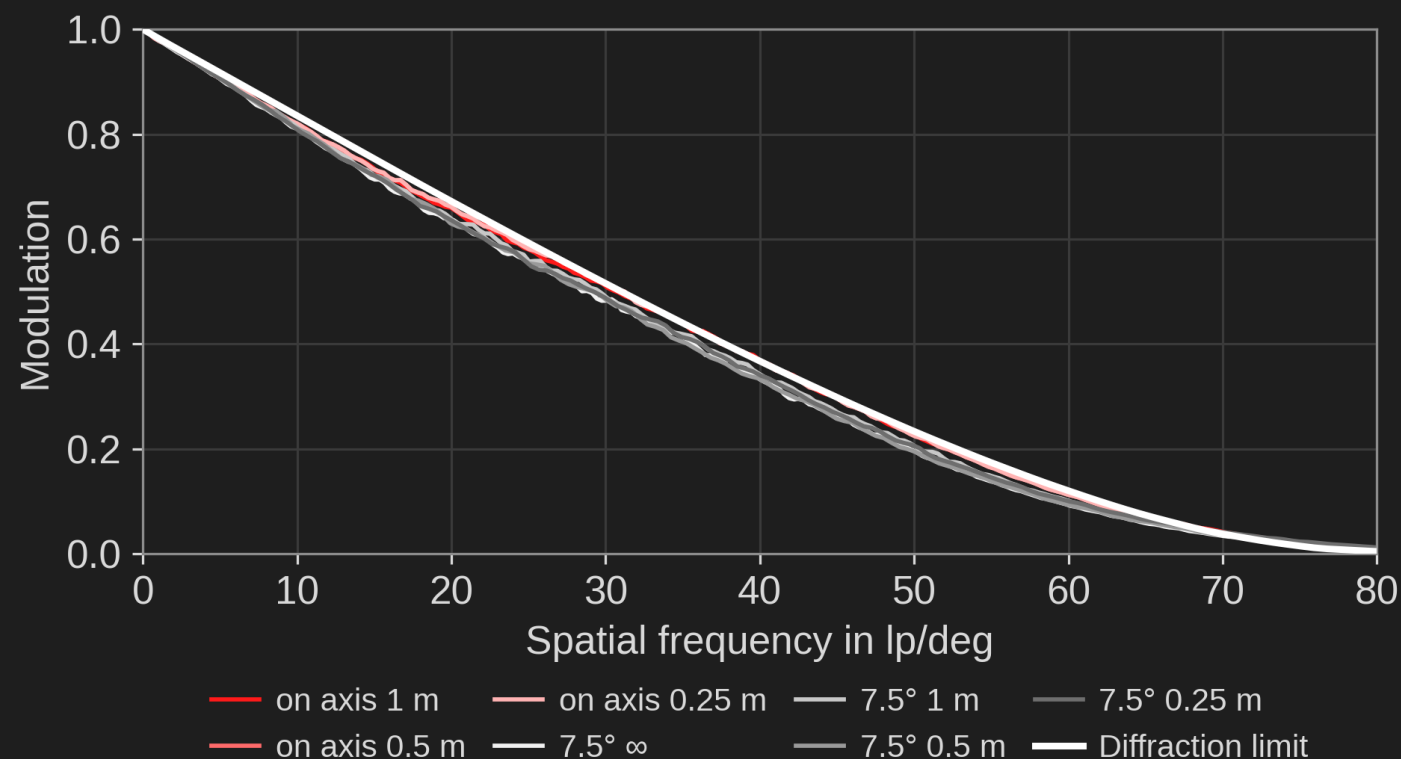
- No MTF drift during refocus or static hold
- About -5 to +10 dpt (40 mm lens)



Liquid lens

Diffraction limited MTF

- Measured at different distances, on and off axis

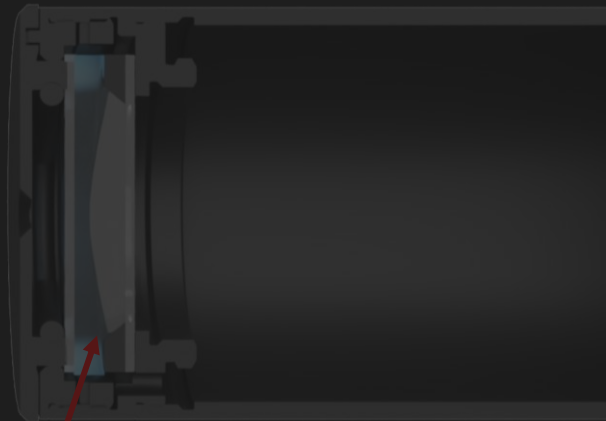


Optical performance

Resolution, focus and distortion

Our focus mechanism (liquid lens) [11]

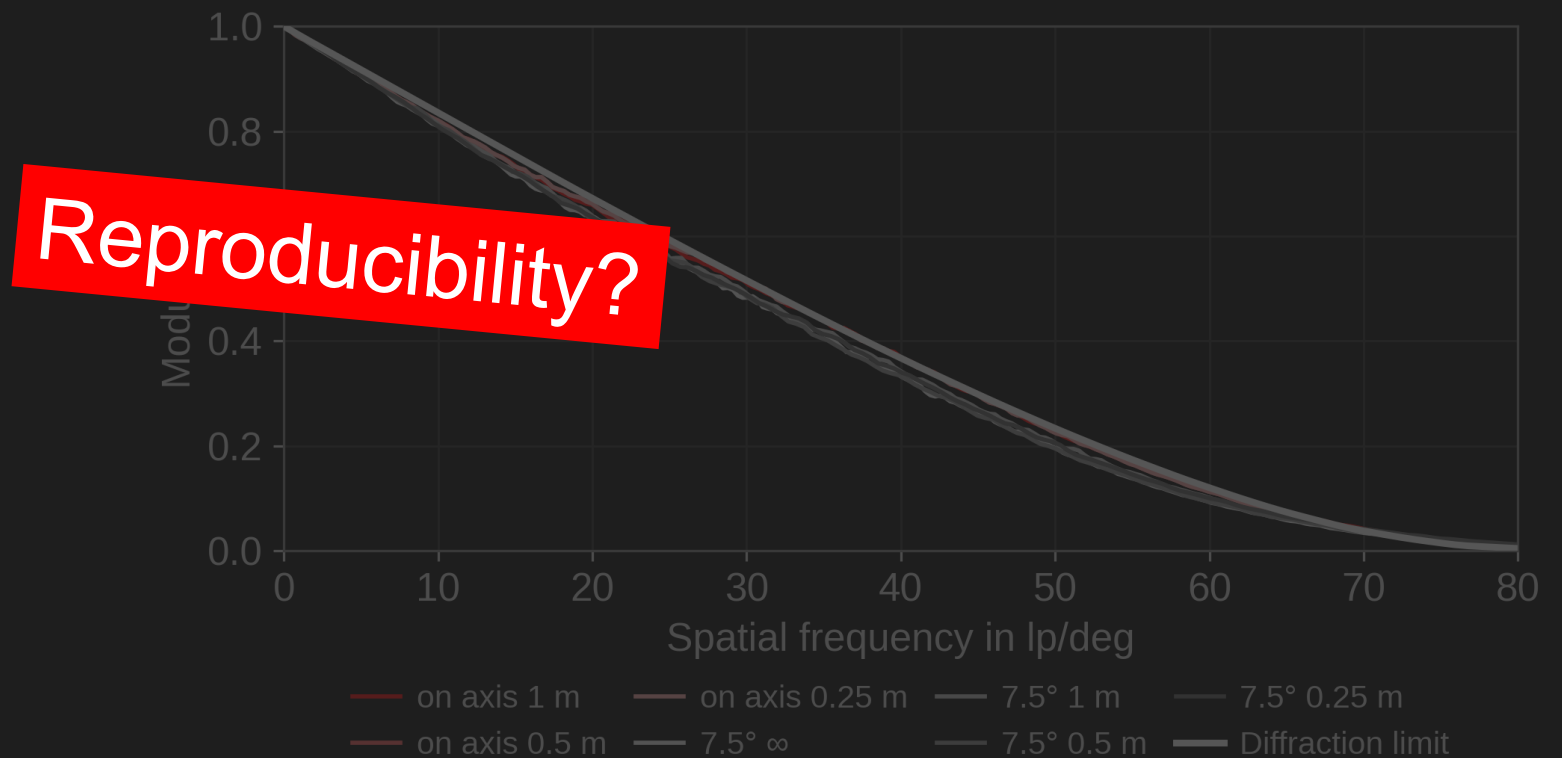
- No MTF drift during refocus or static hold
- About -5 to +10 dpt (40 mm lens)



Liquid lens

Diffraction limited MTF

- Measured at different distances, on and off axis

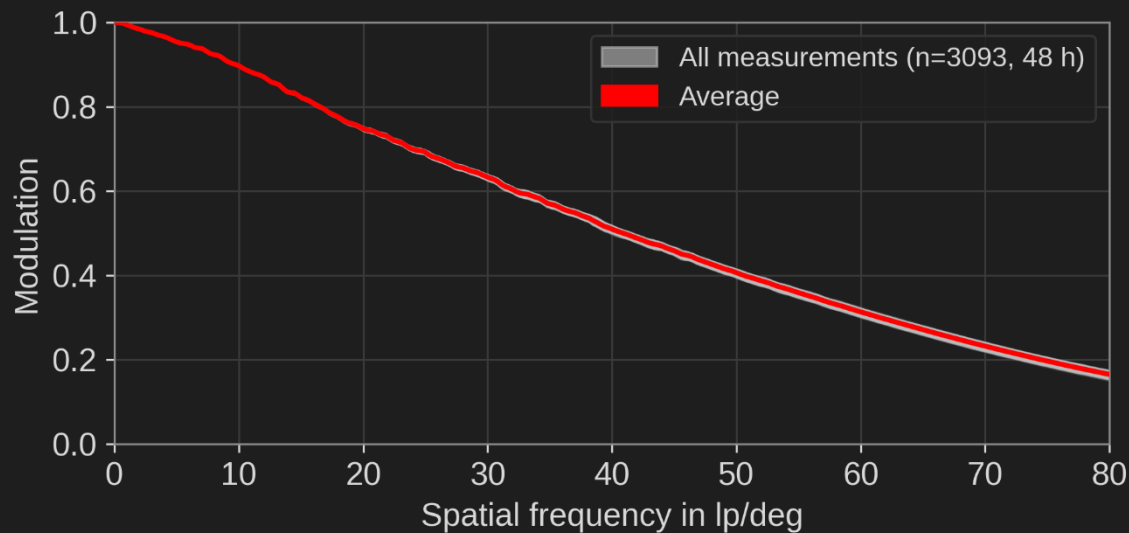


Optical performance

Resolution, focus and distortion

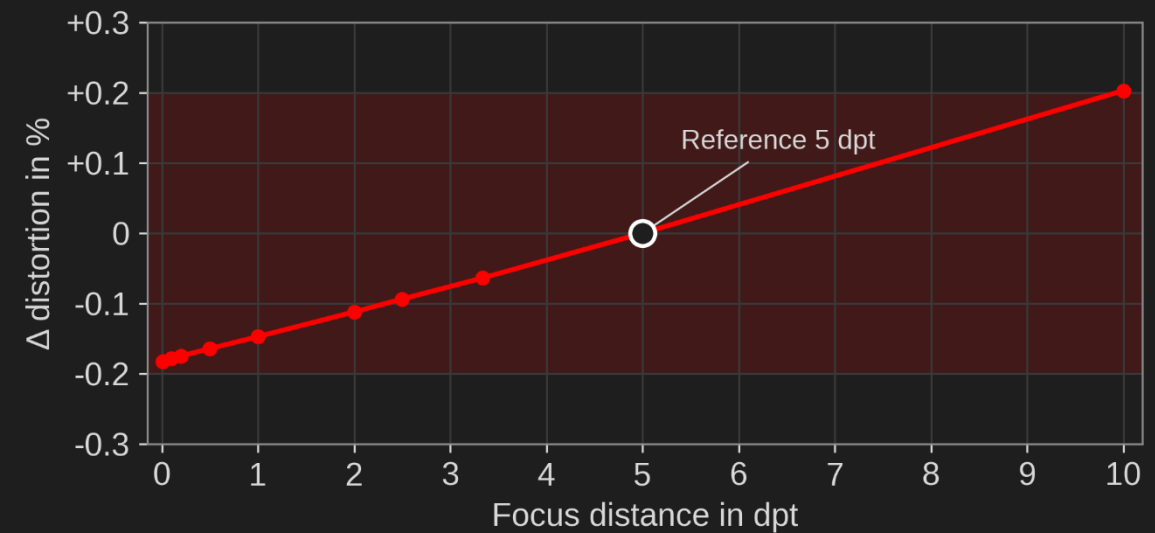
Focus repeatability

Tested for static focus and with refocusing
over time: 48 h, >3000 measurements
Example measurement with refocusing:



Distortion vs focus

Uncorrected distortion change within ± 0.2 %
Low native f-theta distortion by design
Validated away from calibration distance, ISO 17850 [12]
About -5 to +10 dpt (40 mm lens)



Summary

The human eye and our answer

The human eye

Our metrology lens

Sensitivity

Brightness and color perception



Absolute luminance and color calibration

CIE 244, accredited lab (ISO 17025)

Eye size

2–5 mm pupil, eye and pupil rotation



Defined physical or virtual entrance pupil

IEC 63145, IDMS 1.3

Resolution

Up to 47 lp/deg foveal



Diffraction limited MTF over FOV and focus

On and off axis

Distortion

Magnitude, binocular consistency, gradients



Distortion change within ± 0.2 % over focus

ISO 17850

Focus

0 to +10 dpt, geometrically stable



Liquid lens about –5 to +10 dpt: no MTF drift static or refocused

48 h, over 6000 measurements

References

1. Guillon, M., Dumbleton, K., Theodoratos, P., Gobbe, M., Wooley, C.B. and Moody, K. (2016), The Effects of Age, Refractive Status, and Luminance on Pupil Size. *Optom Vis Sci*, 93: 1093–1100
2. De Groot, S. G., Gebhard, J. W. (1952), Pupil Size as Determined by Adapting Luminance*, *J. Opt. Soc. Am.* 42, 492–495
3. Ashraf, M., Chapiro, A. & Mantiuk, R.K. (2025), Resolution limit of the eye — how many pixels can we see? *Nat Commun* 16, 9086
4. Guirao, A., González, C., Redondo, M., Geraghty, E., Norrby, S., Artal, P. (1999), Average optical performance of the human eye as a function of age in a normal population. *Invest Ophthalmol Vis Sci*. 1999 Jan;40(1):203–213
5. McLean, I. R., Erkelens, I. M., Sherbak, E. F., Mikkelsen, L. T., Sharma, R., & Cooper, E. A. (2023), The contribution of image minification to discomfort experienced in wearable optics. *Journal of Vision*, 23(8):10.
6. Jennings, B. J., Wang, K., Menzies, S., & Kingdom, F. A. A. (2015), Detection of chromatic and luminance distortions in natural scenes. *Journal of the Optical Society of America A*, 32(9), 1613–1622.
7. Duane, A. (1922), Studies in monocular and binocular accommodation with their clinical applications, *Transactions of the American Ophthalmological Society*. Vol. 20, 132–157
8. International Electrotechnical Commission, IEC 63145-20-10:2019 - Eyewear display - Part 20-10: Fundamental measurement methods - Optical properties, 2019
9. International Display Measurement Standard v1.3 Chapter 19, International Committee for Display Metrology, 2025
10. CIE 244:2021 Characterization of Imaging Luminance Measurement Devices (ILMDs), International Commission on Illumination, 2021
11. Patent: DE 10 2023 113 210 B3 "Objektivanordnung, Messvorrichtung und Verfahren zur Vermessung eines Near Eye Displays", 2024
12. ISO 17850:2015 Photography — Digital cameras — Geometric distortion (GD) measurements, International Organization for Standardization, 2015

Thank you for your attention

Contact TechnoTeam Germany and Europe:

kilian.kirchhoff@technoteam.de

ingo.rotscholl@technoteam.de

Partner contacts

Seoul: apple@is-soft.co.kr

Shanghai: Bob-liu@light-all.com

Taipei: kerson.wang@i-boson.com

Tokyo: shimizu@physix-tech.com

Orlando: Jason.Adams@TechnoTeamVision.com



LMK

EyeFit

Scan for more »

