

With the Pupil Wider Than 1.85 mm, the Eye's Limit of Fineness Is Set Not by Diffraction but by the Spacing of Cones

— the limit passed by diffraction at the pupil and the limit picked up by the retinal mosaic lie in the same range, and which comes first swaps with pupil size — the separator is whether the pupil diameter is above or below the boundary set by wavelength, eye length and cone spacing — [Paper 919]

Yuuki YAMAGISHI (山岸 勇輝)

Yamagishi Complexity Torus Lab, Japan

September 2026

YOI: <https://www.yamagishiyuuki.com/yoi/919>

— *From thinking to syncing.* —

Abstract

The fineness of stripes the eye can tell apart has two limits, one on the side of light and one on the side of the retina. This paper puts the finest stripes passed by diffraction at the pupil and the finest stripes picked up by the mosaic of retinal cones into the same units (stripes per degree and visual acuity), and counts by pupil diameter which becomes the ceiling first. No new theorem or law is claimed. First, the fineness the retinal mosaic picks up corresponds to an acuity near 2: with representative values of wavelength 555 nm, cone centre spacing 2.5 μm and 16.7 mm from nodal point to retina, one cone subtends 30.8780 arcseconds, the Nyquist fineness is 58.2940 stripes per degree, and in acuity this is **1.943133** (Section 2). Second, the two limits are equal at a pupil diameter of 1.853700 mm: the limit passed by diffraction is the pupil diameter divided by the wavelength, and the diameter at which it equals the Nyquist fineness was **1.853700 mm** (Section 2). Third, with a wider pupil, the retinal mosaic becomes the ceiling first: at a 3 mm pupil the diffraction limit corresponds to acuity **3.144737**, and stripes at the Nyquist fineness pass with contrast **0.266680**. At 2 mm the contrast is 0.023487, and for pupils of 1.5 mm or less the Nyquist fineness did not pass (Section 3). Fourth, the boundary moves with cone spacing: with a cone spacing of 2.0 μm the boundary is 2.317125 mm and the acuity 2.428917; with 3.0 μm , 1.544750 mm and 1.619278 (Section 3). Fifth, the separator is whether the pupil diameter is above or below the boundary set by wavelength, eye length and cone spacing: below the boundary, diffraction is the ceiling and a wider pupil sees finer. Above it, the retinal mosaic is the ceiling, and widening the pupil does not raise it (Section 4). **Keywords:** visual acuity, diffraction limit, cone spacing, Nyquist fineness, modulation transfer function, pupil diameter.

Scope of this paper (scope note): No new theorem or law is claimed: the modulation transfer function of a circular aperture under diffraction and its cutoff, the Nyquist fineness of sampling, and the definition of visual acuity by the Landolt ring are all standard. The values are representative: wavelength 555 nm, cone centre spacing 2.5 μ m and 16.7 mm from nodal point to retina are representative and vary between people and across the retina. Values with other cone spacings are also set down. No aberration is included: spherical and chromatic aberration of the eye, the tear film and scattering are not included. Optics with diffraction only is assumed. Processing in the brain is not treated: how the signal picked up by the mosaic is used, and the procedure of acuity testing, are not treated. No acuity limit is applied to a person: the numbers show how two limits compare and predict no one's acuity. Relation to earlier papers: Paper 837 showed, for two-point discrimination by touch, that narrowing the receptive field never brings the threshold below the receptor spacing. Here the same pattern is counted for the eye, where the other ceiling is the diffraction of light and moves with pupil diameter. Paper 775 showed that what decides a telescope's resolution is not the size of the aperture but its ratio to the wavelength. Here the same ratio decides the diffraction limit of the pupil, which competes with the retinal mosaic. Paper 757 showed that which of wavelength, numerical aperture and factor buys the resolution decides what the depth of focus pays. Here it is counted that the fineness bought by widening the pupil has another ceiling, the retinal mosaic. What is added: putting the diffraction limit and the mosaic limit into the same units, finding the pupil diameter of 1.853700 mm at which they are equal, setting down by pupil diameter the contrast passed at the Nyquist fineness, finding how far the boundary moves with cone spacing, and placing the separator on "pupil diameter above or below the boundary".

1. Notation and the Question

Setting: let the wavelength be λ , the pupil diameter D , the length from nodal point to retina f , and the cone centre spacing s . The upper limit of stripe fineness passed by optics with diffraction only (the cutoff) and the upper limit picked up by the cone mosaic (the Nyquist fineness), in stripes per radian, are:

$$\nu_c = \frac{D}{\lambda}, \quad \nu_N = \frac{f}{2s}, \quad \nu_c = \nu_N \iff D^* = \frac{\lambda f}{2s}$$

Acuity 1.0 is a Landolt-ring gap of 1 arcminute, taken as 30 stripes per degree. The diffraction modulation transfer function is that of a circular aperture, $MTF(x) = \frac{2}{\pi} (\arccos x - x\sqrt{1-x^2})$ with $x = \nu/\nu_c$, from which the contrast passed at the Nyquist fineness is found.

Question: is the ceiling of the eye's fineness set by diffraction at the pupil, or by the retinal mosaic?

2. Two Limits

Computation 2.1: with representative values ($\lambda = 555$ nm, $s = 2.5$ μ m, $f = 16.7$ mm), one cone subtends 30.8780 arcseconds, the Nyquist fineness is 58.2940 stripes per degree, and in acuity **1.943133**.

Computation 2.2: the pupil diameter at which the two limits are equal is $D^* = 1.853700$ mm, where the difference between the two finesses was 0.

Observation 2.3

the two limits lie in the same range. The mosaic limit is near acuity 2, and the diffraction limit at a 2 mm pupil is a little above acuity 2, which becomes the ceiling swaps with pupil size.

3. Varying the Pupil

Computation 3.1: the diffraction limit for each pupil diameter, and the contrast passed at the Nyquist fineness.

pupil diameter	diffraction limit (per deg)	as acuity	Rayleigh angle (arcsec)	contrast at Nyquist fineness
1.0 mm	31.4474	1.048246	139.6619	0.000000
1.5 mm	47.1711	1.572369	93.1079	0.000000
2.0 mm	62.8947	2.096492	69.8310	0.023487
3.0 mm	94.3421	3.144737	46.5540	0.266680
4.0 mm	125.7895	4.192983	34.9155	0.431808
6.0 mm	188.6842	6.289475	23.2770	0.612983
8.0 mm	251.5790	8.385966	17.4577	0.707636

For pupils smaller than the boundary of 1.853700 mm the contrast at the Nyquist fineness was 0, and for larger pupils positive.

Computation 3.2: varying the cone spacing moved the boundary to 2.317125 mm (acuity 2.428917) at 2.0 μ m and 1.544750 mm (acuity 1.619278) at 3.0 μ m.

Observation 3.3

with a pupil wider than the boundary, the retinal mosaic becomes the ceiling first. Diffraction at a 3 mm pupil delivers stripes at the Nyquist fineness to the retina with contrast 0.266680, but the mosaic cannot pick up anything finer: widening the pupil to 8 mm raises that contrast to 0.707636, but the ceiling fineness of 58.2940 stripes per degree does not move.

4. The Separator

Observation 4.1

the separator is whether the pupil diameter is above or below the boundary set by wavelength, eye length and cone spacing. Below the boundary, the diffraction limit is coarser than the retinal mosaic, and widening the pupil makes visible stripes finer: above it, the mosaic is the ceiling, and widening the pupil only raises the contrast of stripes coarser than the ceiling. For touch in Paper 837 the ceiling was also the receptor spacing, but in the eye the other ceiling moves with pupil diameter.

Observation 4.2

what is not said. Aberrations, the tear film, processing in the brain, the procedure of acuity testing and individual acuity are not treated. What is shown is that two limits, diffraction and the retinal mosaic, lie in the same range, and which comes first swaps with pupil diameter.

5. Roll Call and Closing

1. $\nu_c = D/\lambda$, $\nu_N = f/2s$ (Section 1): **two limits.**
2. Nyquist fineness 58.2940 per degree, acuity **1.943133** (Computation 2.1): **the retinal mosaic.**
3. boundary $D^* = 1.853700$ mm (Computation 2.2): **the pupil at which the two are equal.**
4. contrast **0.266680** at a 3 mm pupil (Computation 3.1): **diffraction passes it, the mosaic cannot pick up finer.**
5. boundary from 1.544750 to 2.317125 mm with cone spacing (Computation 3.2): **sensitivity to the representative values.**
6. pupil diameter and the boundary (Observation 4.1): **the separator; Papers 837, 775, 757.**

Closing: With the pupil wider than 1.85 mm, the eye's limit of fineness is set not by diffraction but by the spacing of cones. With representative values, the fineness the retinal mosaic picks up is 58.2940 stripes per degree, acuity 1.943133, and the pupil diameter at which the diffraction limit equals it is 1.853700 mm: diffraction at a 3 mm pupil delivers stripes of that fineness with contrast 0.266680, and widening the pupil to 8 mm did not move the ceiling fineness. The boundary moves from 1.544750 to 2.317125 mm with cone spacing: the separator is whether the pupil diameter is above or below the boundary set by wavelength, eye length and cone spacing. Placed among the earlier papers: the ceiling of receptor spacing that Paper 837 saw in touch was counted for the eye, the aperture-to-wavelength ratio of Paper 775 was applied to the pupil, and the retina was added as another ceiling to the ways of buying resolution in Paper 757. To be honest: no one's acuity is predicted. Which of two ceilings comes first, and no further.

References

1. Atchison, D. A., & Smith, G. (2000). *Optics of the Human Eye*. Butterworth-Heinemann.
 2. Born, M., & Wolf, E. (1999). *Principles of Optics*. Cambridge University Press.
 3. Yamagishi, Y. (2026). *Which of Three Quantities Buys the Resolution Decides What the Depth of Focus Pays* [Paper 757]. YOI: <https://www.yamagishiyuuki.com/yoi/757>; DOI: 10.5281/zenodo.23015169
 4. Yamagishi, Y. (2026). *What Sets Resolving Power Is Not the Size of the Aperture but Its Ratio to the Wavelength* [Paper 775]. YOI: <https://www.yamagishiyuuki.com/yoi/775>; DOI: 10.5281/zenodo.23015274
 5. Yamagishi, Y. (2026). *Two-Point Discrimination Has Two Limits: Narrowing the Receptive Field Never Beats the Receptor Spacing* [Paper 837]. YOI: <https://www.yamagishiyuuki.com/yoi/837>; DOI: 10.5281/zenodo.23015616
-

— *From thinking to syncing.* —

Yuuki YAMAGISHI (山岸 勇輝)

© 2026 Yamagishi Complexity Torus Lab, Japan · Licensed under Creative Commons Attribution 4.0 International (CC BY 4.0)