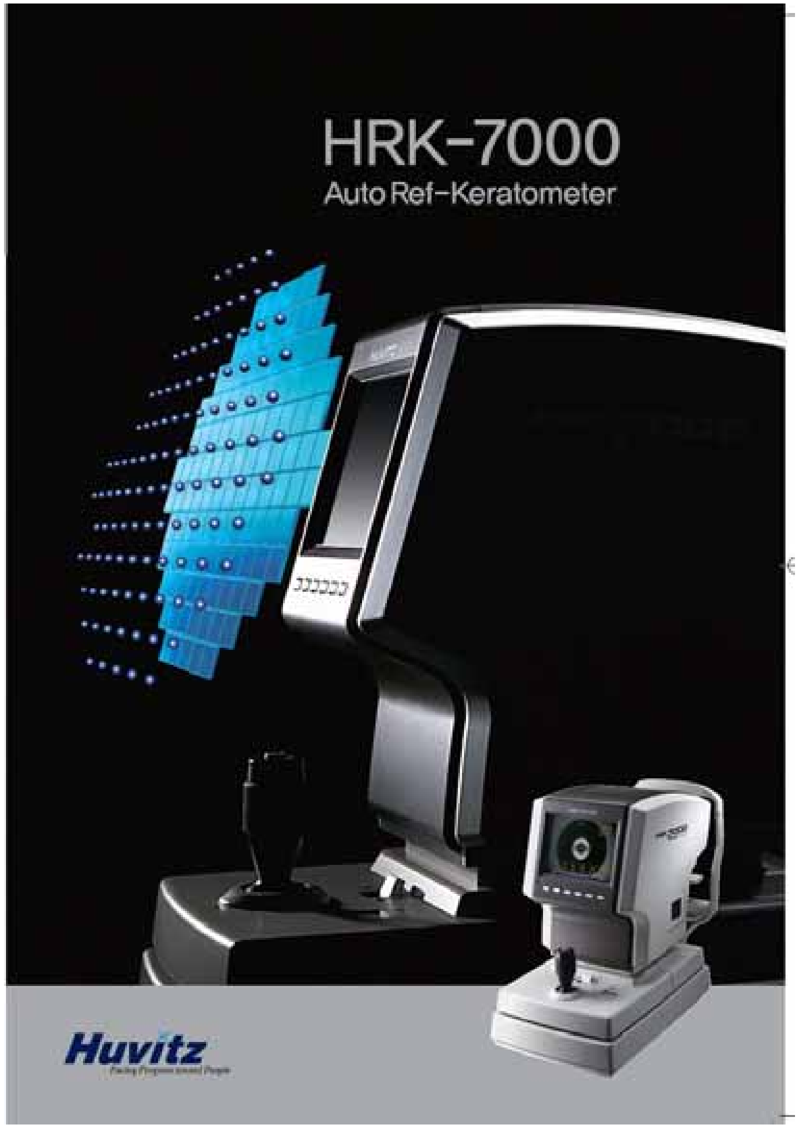
Wavefront Analyzing Technology
&
Huvitz Auto Ref/Keratometer HRK-7000

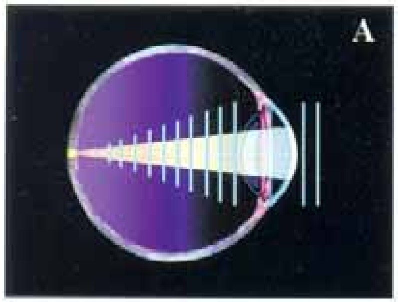
June 12, 2007

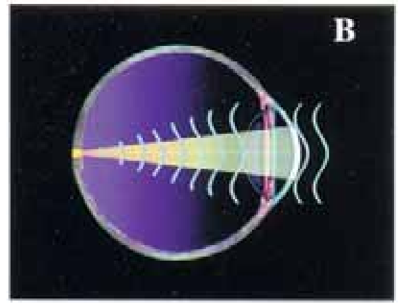
Modern science is providing us with faster and more accurate ways to measure refractive errors. Alternative technique that has seen growing popularity in recent years is the Hartmann-Shack wavefront sensor. It measures distortions in a wavefront of light emitted from the eye after it has passed through the eye's optics and determines the eye's complete refraction error. Therefore, in addition to measuring the lower order spherocylinder refractive errors, the eye's higher order aberrations (spherical aberration, coma, etc.) can be measured and have already been incorporated into wavefront-guided refractive surgery.

Huvitz's Auto Ref/Keratometer HRK-7000 based on Hartmann-Shack principle focuses on measuring second-order aberrations , which result in myopia or hyperopia and regular astigmatism. Because correcting second-order aberrations has the highest impact on acuity, which is the eye's ability to distinguish object details and shape.



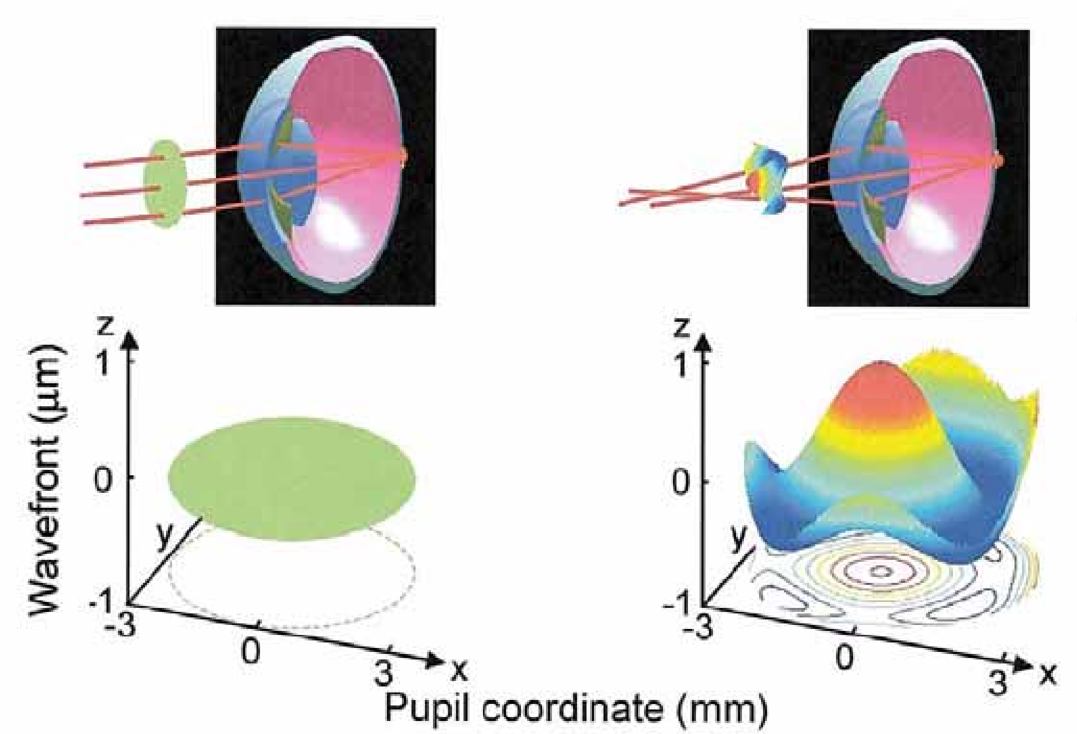
Propagation of wavefront passed through eye





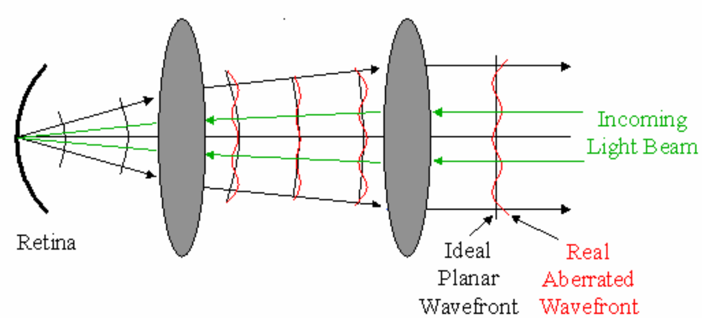
Refractive errors of the eye can be described in terms of the shape of a wavefront of light that has passed through the eye's optics.

In an eye with no refractive error of any kind, the optical wavefronts that pass out of the eye are perfectly flat (A). The eye with an aberration produces an undulating exting wavefront(B)



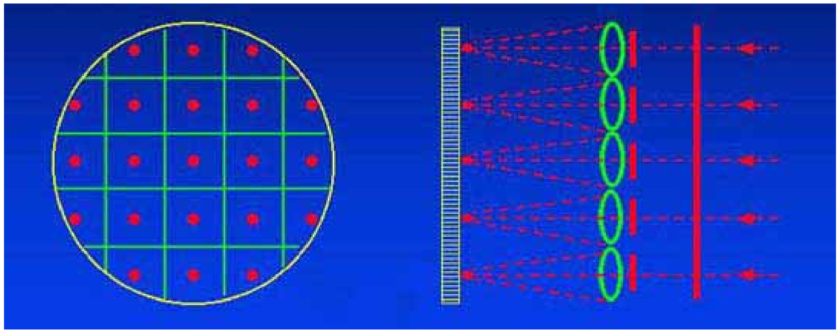
An ideal optical system has a flat aberration map.

An aberrated eye has an undulating map.

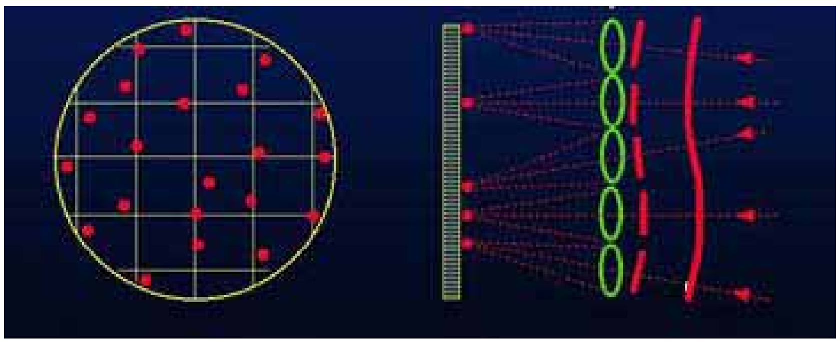


<REFERENCE>
Xu Cheng, Larry N. Thibos, Arthur Bradley, Estimating Visual Quality from Wavefront Aberration Measurements

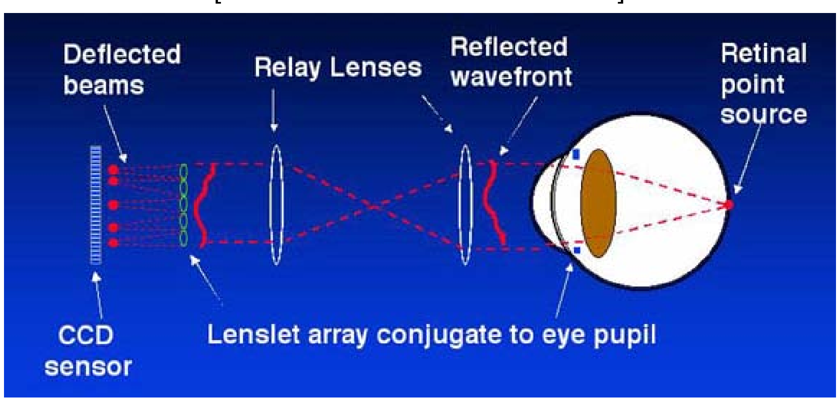
Principle of Harmann-Shack Wavefront Sensor



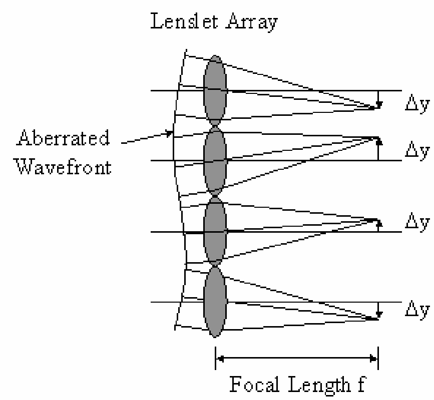
[Ideal Planar Wavefront]

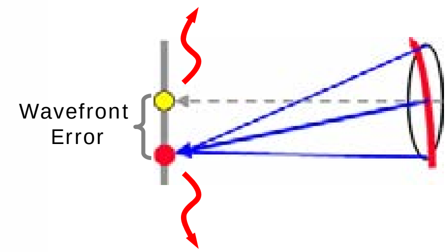


[Real Aberrated Wavefront]



[Principle of Hartmann-Shack Wavefront Sensor]



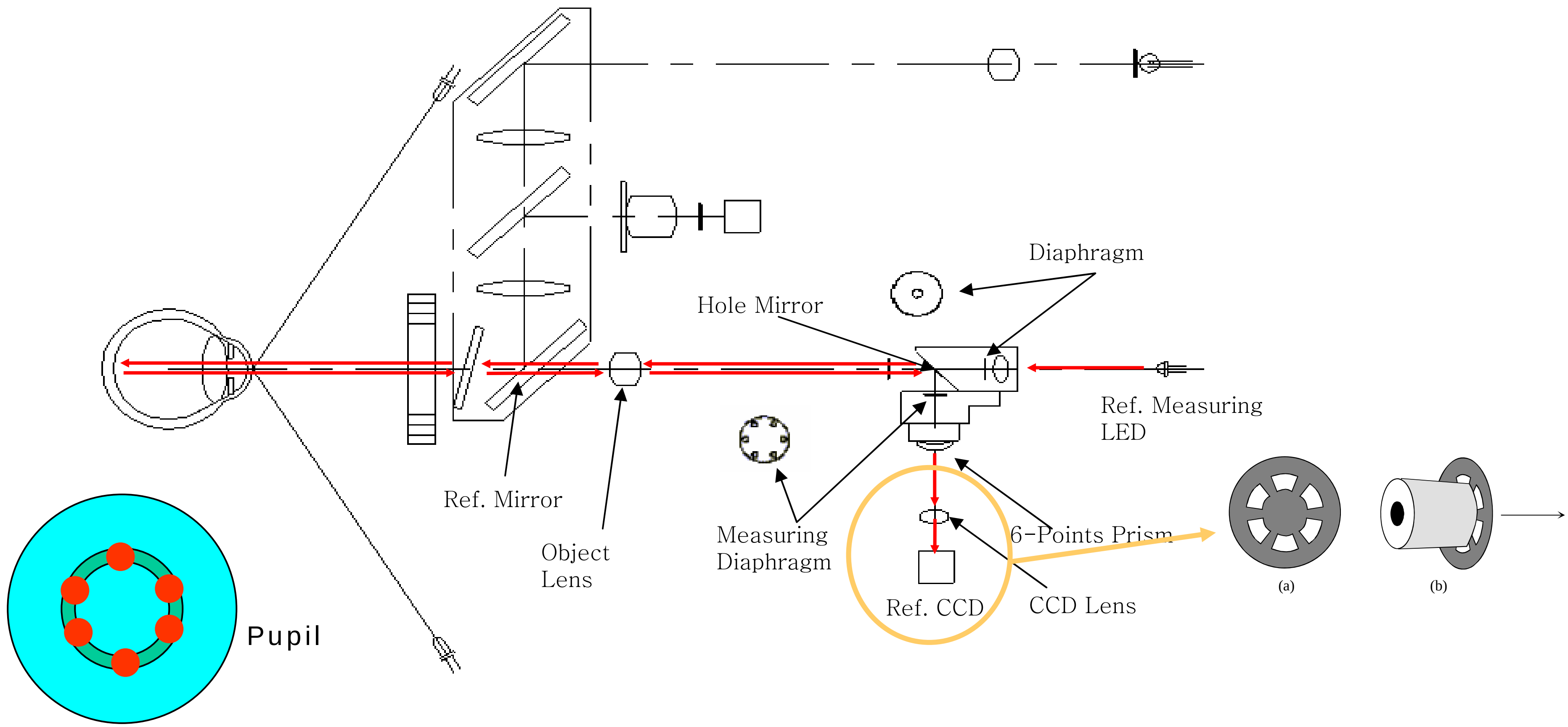


Wavefront error(△y at the above figure) is the distance between the real warvefront and the reference plane, at many locations across the pupil. A Hartmann-Shack wavefront error consists of a large array of numbers for different pupil locations.

The purpose of the lenslet array is to divide the broad beam of light exiting the eye into many sub beams for measurement. Each lenslet focuses one of these sub-beams to a tiny spot on the surface of the video sensor(CCD), which records an image of the spots. By analyzing the position of each spot, we can determine the shape of the waverfront.

<REFERENCE>
Larry N. Thibos, Representation of Wavefront Aberration
Thomas O. Salmon, A primer on Using Wavefront Analysis for Refractive Surgery and Other Ophthalmic Applications
Patrick Y. Maeda, Zernike Plynomials and Their Use in Describing the Wavefront Aberrations of the Human Eye

Limitation of Conventional ARK
(The structure and feature of MRK-3100P)

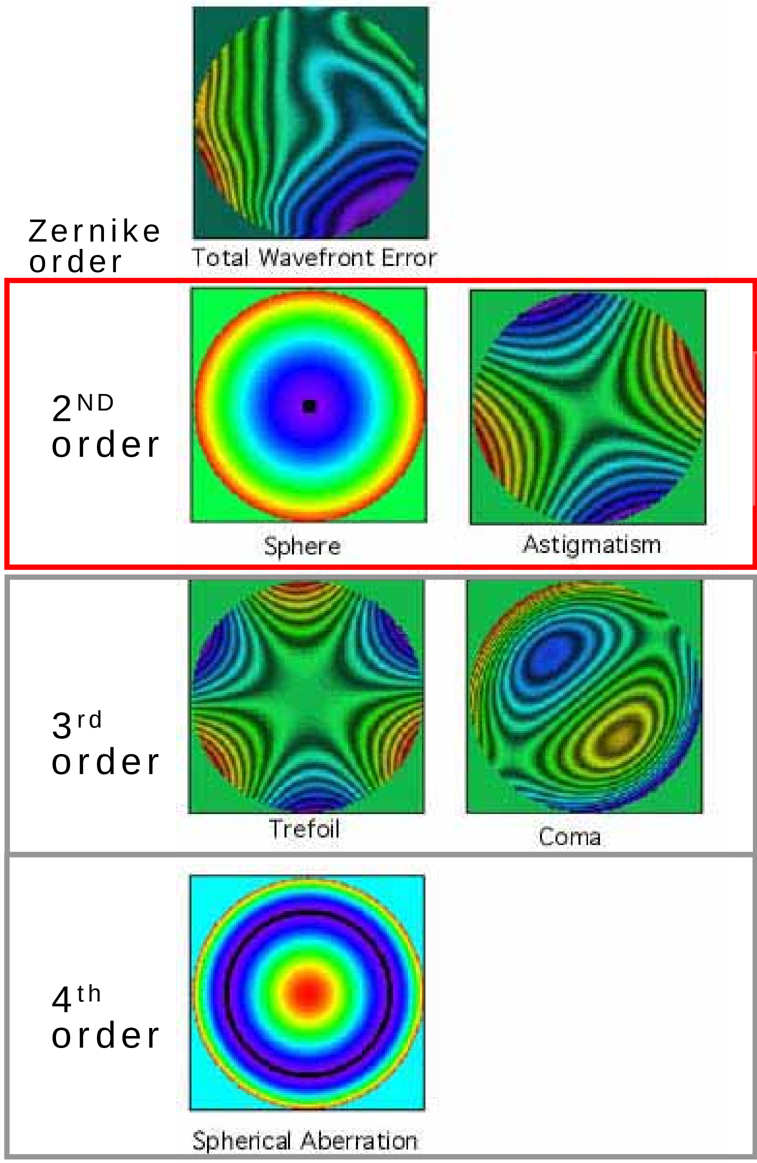


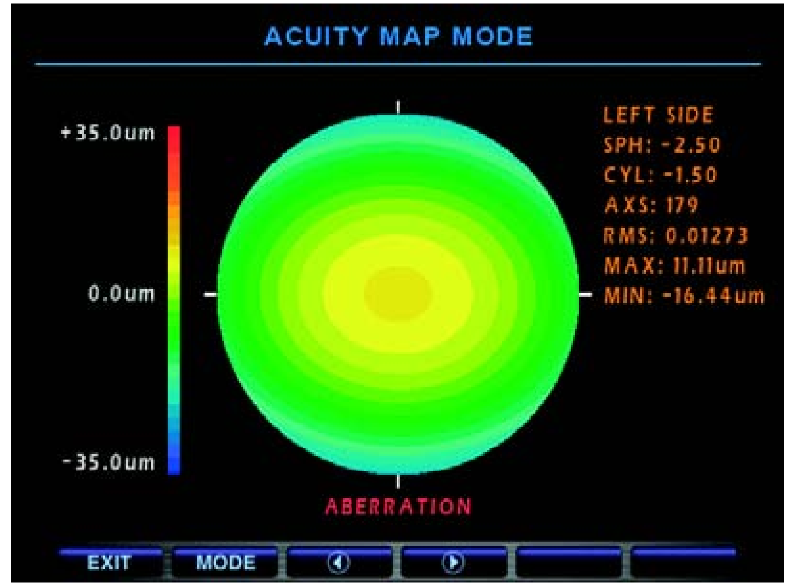
Measures localized pupil region with only 6 points

Low spatial resolution

Limited measuring points for recent demands of high accuracy

Aberration Map Of Zernike Polynomial





Most eyes have a complex combination of refractive errors that may have an irregular, asymmetric shape, such as that shown in left picture.

Wavefront measurements that identify vision errors can be calculated in the ways called Zernike polynomial. The each Zernike polynomial describes the aberration existing at a specific point on a wavefront of light. It is delivered in the form of a Zernike prescription and a topographic map, which is a detailed drawing of the shape of the aberrated wavefront.

HUVITZz HRK-7000 graphically shows the second-order aberrations including spherical defocus and astigmatism.

<REFERENCE>
Thomas O. Salmon, A primer on Using Wavefront Analysis for Refractive Surgery and Other Ophthalmic Applications
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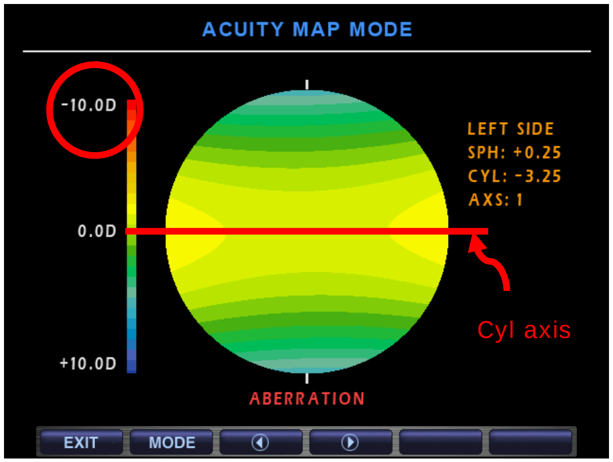
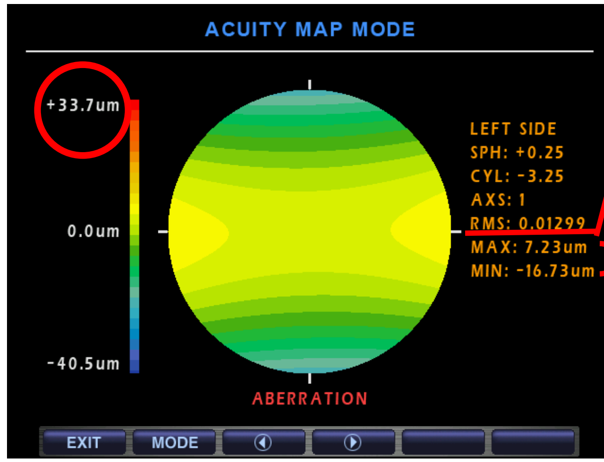
Aberration Map of HRK-7000(Z-MAP)

HRK-7000 graphically shows the second-order aberrations including myopia, hyperopia and astigmatism. It leads better understanding for patients' eye conditions. It can be printed out.



The color express refraction error in dioptor



The colors express wavefront error in micron

RMS (root mean squared)

It is one of the ways to quantify the amount of aberration.

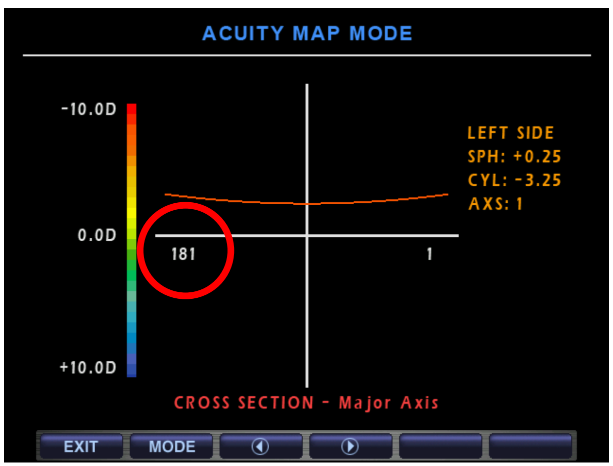
<u>In the HRK-7000, RMS describes the magnitude of an eye's second order aberration for 3.0 mm pupil size</u>.

MAX/MIN

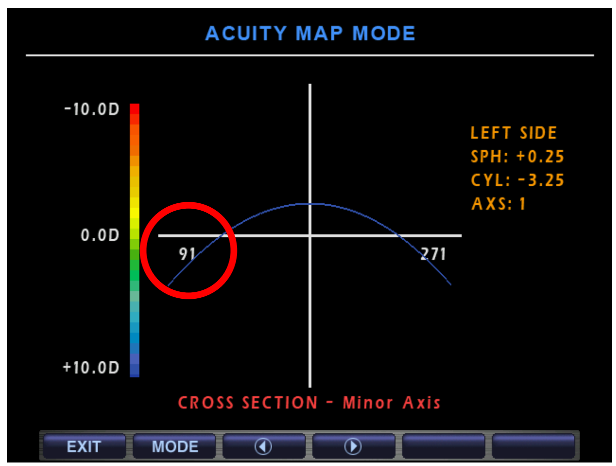
It is the maximum departure of the actual wavefront from the desired wavefront in both positive and negative directions.

In myopia, MAX is the peak of parabola and

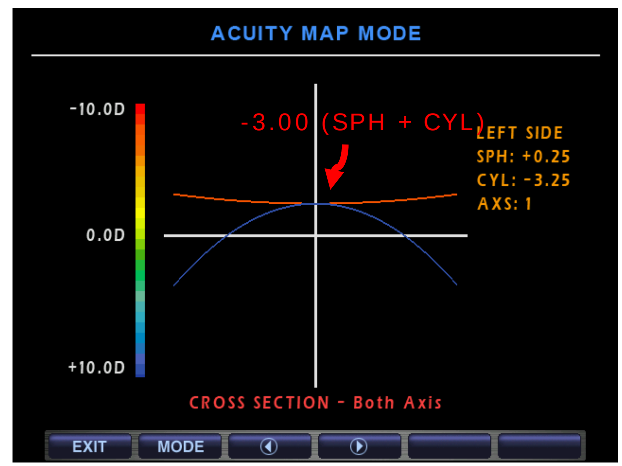
in hyperopia, MAX is the lowest point of parabola.



Cross sectional view of major axis(181°)



Cross sectional view of minor axis(91°)

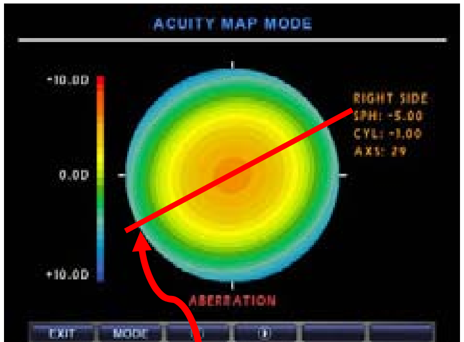


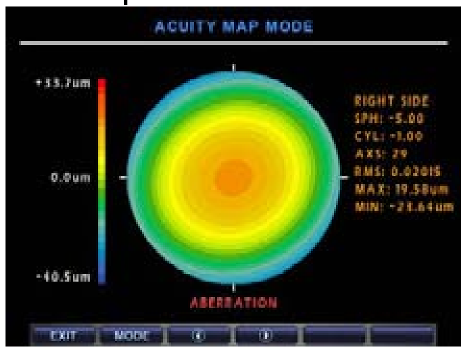
Comparison view between major axis and minor one

Aberration Map (Example : Myopic Astigmatism)

Huvitz — *Pacing Progress toward People*

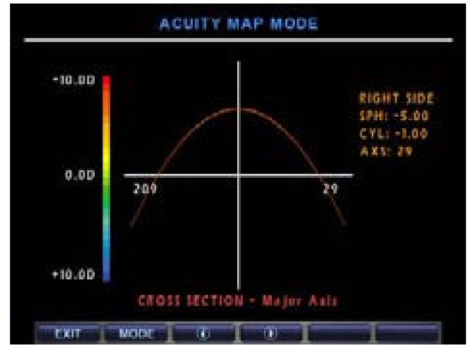
❑ 2 dimensional aberration map

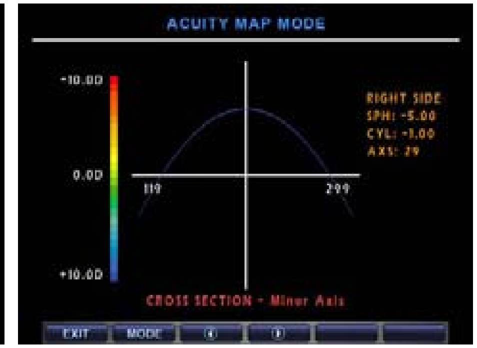


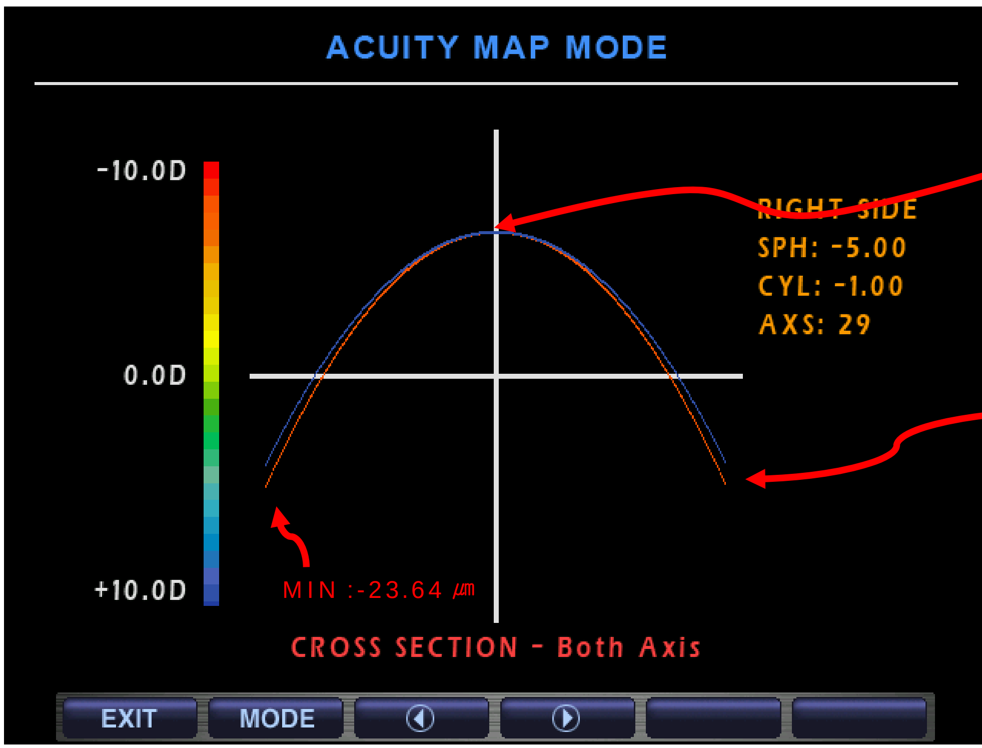


Cylindrical Axis

❑ Cross sectional view





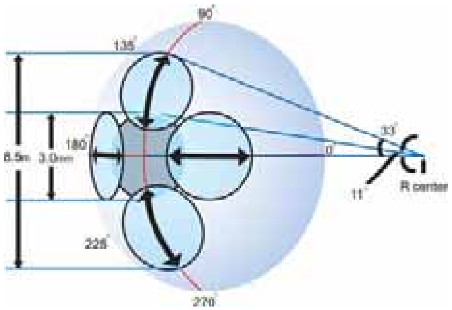


-6.00 D (SPH + CYL)
MAX :19.58 ㎛

The parabola of major axis (red, 29º, -6.00D) is steeper than the parabola of minor axis (blue, 119º, -5.00D)

Ker. Peripheral Measurement

- ✓ Total 5 direction Measurements (Center/Temple/Superior/Nasal/Inferior)
- ✓ Measurement region : Φ8.5 mm at cornea
- ✓ Better contact lens fitting by measuring the peripheral regions.



Improved accuracy when measuring minimum sized pupil (2mm)

Exclusion of the measurement which is interfered by an eyelid

Measurement of Remaining Cylindrical Value

- ✓ In K&R measurement mode, Remaining Cylindrical Value can be printed out by calculating the total Cyl value and corneal Cyl value.

Continuous Measurement Function

- ✓ While pressing joystick button, continuously measurement can be done without pause of fogging.

Faster Measuring Speed

Refractometry	
SPH.	-25.00 ~ +22.00D
CYL	0.00 ~ ±10.00D
Pupil Dis.(PD)	10 ~ 85mm
Minimal Measurable Pupil Diameter	2.0 mm
Keratometry	
Curvature Radius	5.0 ~ 10.2mm
Corneal Power	33.00 ~ 67.50D
Corneal Astigmatism	0.00 ~ -15.00D
Others	
Measurable Pupil/Iris Size	2.0 ~ 14.0mm
Memory of Data	10 for each eye
Retro Illumination	