



THE APPLICATION OF ADVANCED OPTICAL TECHNIQUES TO CREATE LOW-COST SURGICAL MAGNIFIERS

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WARWICK

Plastic Optics

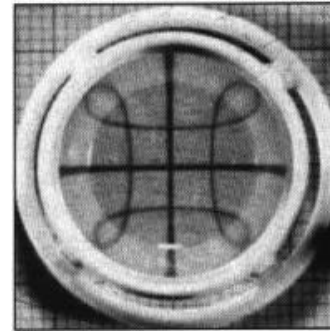
Advantages:

- ❖ Low Cost / High Volume.
- ❖ Lightweight.
- ❖ Design Flexibility.
- ❖ Higher Impact Resistance.
- ❖ Do not Splinter.
- ❖ Aspheric Lens Moulding Easily Achievable.
- ❖ Reduced Assembly Costs.
- ❖ Large Number of Optical Components Available.

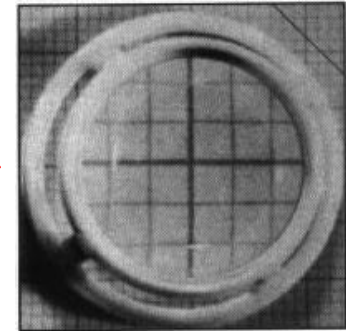
Disadvantages:

- ❖ Comparative Intolerance to Large Temperature Fluctuations.
- ❖ Smaller Range of Materials.
- ❖ The quality of optical materials is determined by the refractive index and the Abbe number.

$$\text{AbbeNumber} = V_d = \frac{n_d - 1}{n_F - n_C}$$



Aspheric
Correction. →



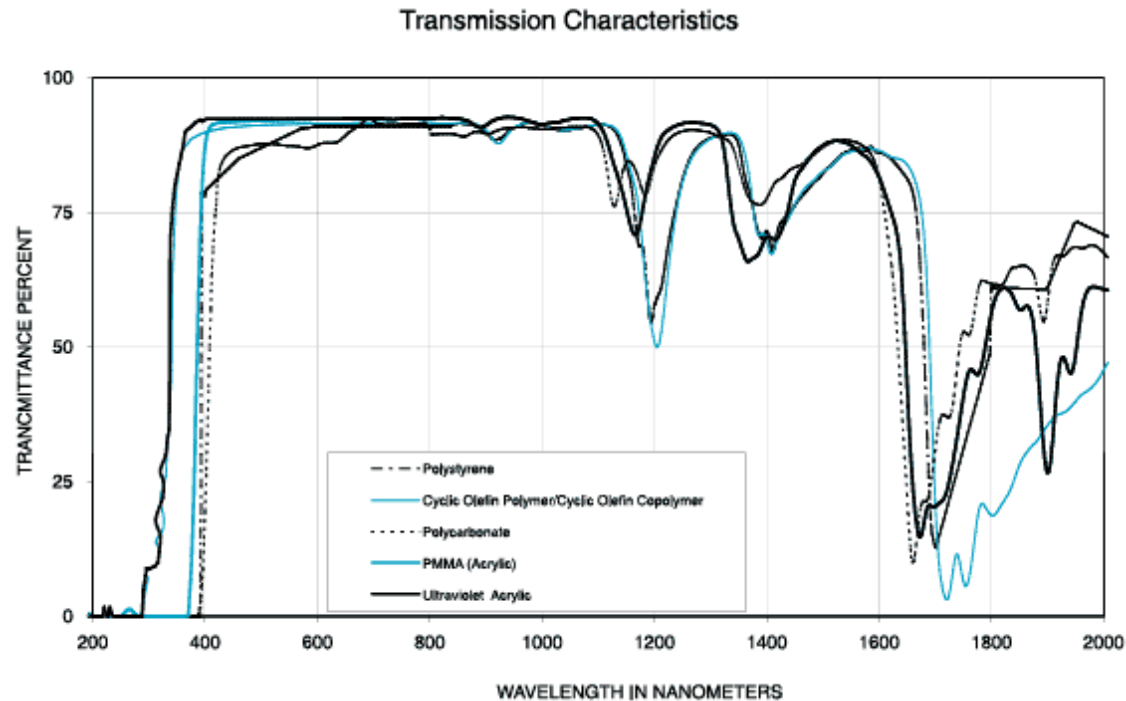
Common Materials

Acrylic:

- ❖ Very Hard (M97)
- ❖ Very Mechanically Stable
- ❖ Very Good Clarity
- ❖ Excellent Transmission
- ❖ High Abbe Number (55.3)

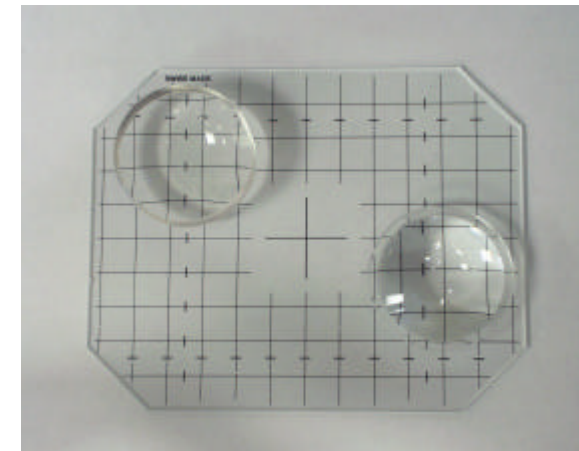
Polystyrene:

- ❖ Less Hard Than Acrylic (M90) Therefore Less Scratch Resistant
- ❖ Less Expensive Than Acrylic
- ❖ Good Transmission (some absorption in the blue region)
- ❖ Low Abbe Number (30.8) Can Be Used As Second Lens In Achromatic Doublet



NAS:

- ❖ Copolymer
- ❖ 70% polystyrene; 30% acrylic
- ❖ Cheaper Alternative To Acrylic



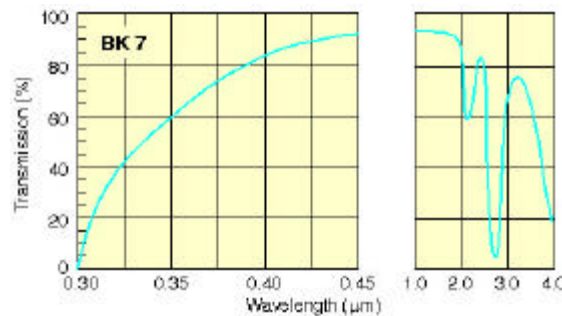
How Do Plastics Compare To Glass?

BK7

BK7 is one of the most common borosilicate crown glasses used for visible and near infrared optics. Its high homogeneity, low bubble content, and straightforward manufacturability make it a good choice for transmissive optics. The transmission range for BK7 is 380—2100 nm. It is not recommended for temperature sensitive applications, such as precision mirrors

Refractive Index:
Nf (486nm) 1.522
Nd (589nm) 1.517
Nc (651nm) 1.515

Abbe No. : 64.17



Acrylic

Acrylic is one of the most commonly used optical plastics. This material is very hard and has very good mechanical stability. It has an index at 588nm of 1.49, and an Abbe number of 55.3. Acrylic is also known for its very good clarity and excellent transmission properties throughout the visible portion of the spectrum.

Vs.

Refractive Index:
Nf (486nm) 1.497
Nd (589nm) 1.491;
Nc (651nm) 1.489

Abbe No. : 57.2



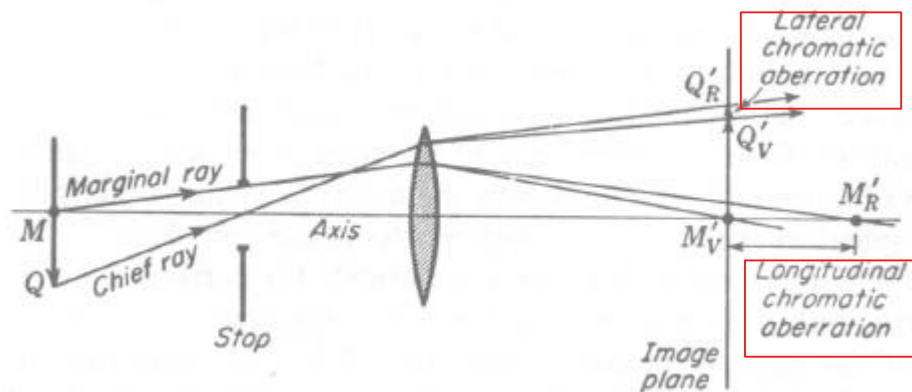
Aberrations

Chromatic Aberrations

Two Types:

- ❖ Longitudinal. $\longrightarrow$ $(LChr) = F/NU$
- ❖ Transverse. $\longrightarrow$ $TChr = (LChr)(y)$

Where F = Lens Power; NU = Abbe Number;
 y = Height of incident ray

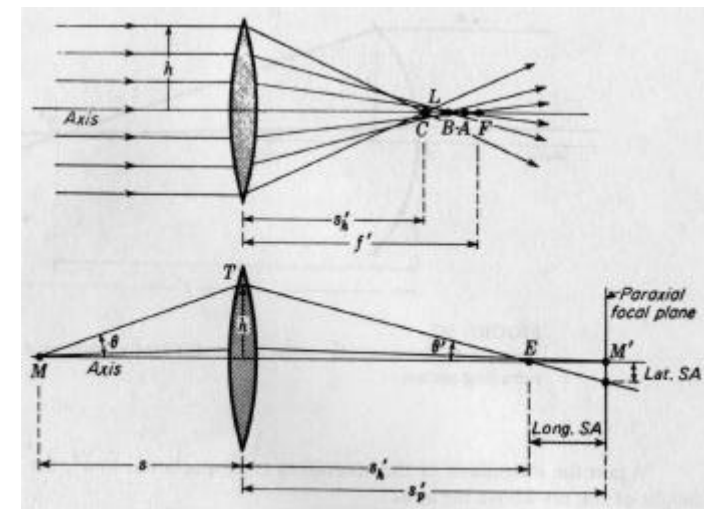


Monochromatic Aberrations

Five Main Types:

- ❖ Spherical Aberration.
- ❖ Coma.
- ❖ Astigmatism.
- ❖ Field Curvature.
- ❖ Distortion.

Example : Spherical Aberration: Rays traversing a refracting system at a greater distance above the optical axis, will in the aberrated system be focused nearer the refracting surface.



Correction Techniques

For a given power and material, Spherical Aberration is minimised if the radii, r_1 and r_2 in the shape factor equation

$$q = \frac{r_2 + r_1}{r_2 - r_1}$$

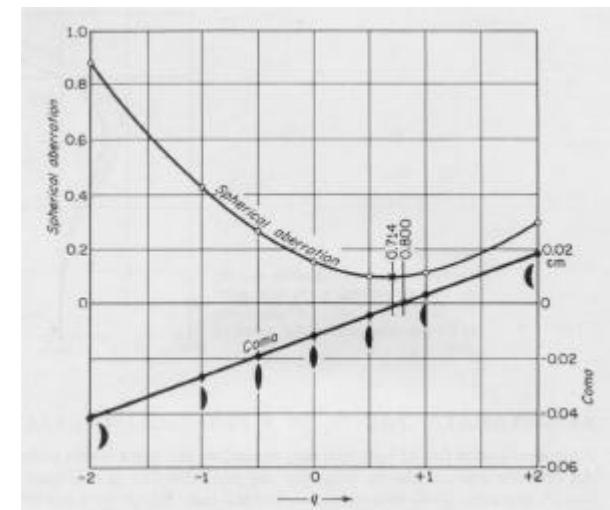
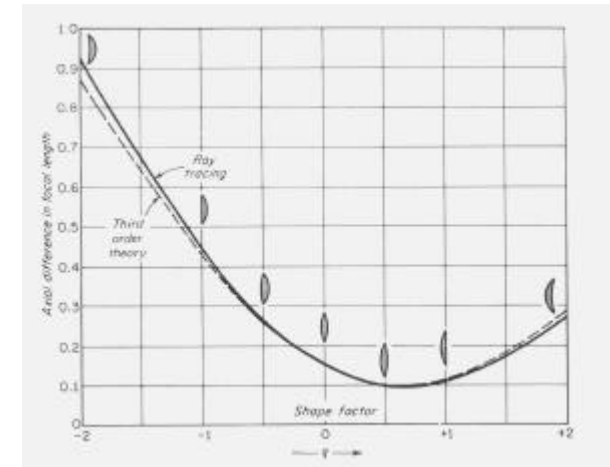
is in the ratio of approximately: $r_2 = 6 r_1$

This means that the shape of the lens can effect the degree of Spherical Aberration.

- ❖ However this only provides a correction for Spherical aberration.
- ❖ If the lens or surface displays the effects of coma, etc., an Aplanatic solution is required.
- ❖ Namely; one free of both Spherical Aberration and Coma.

One solution is the use of aspheric surfaces

Spherical Aberration

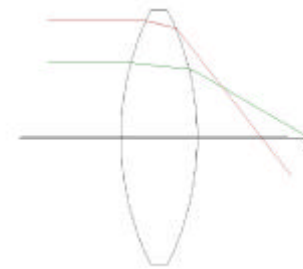


Plastic Aspheric Optics

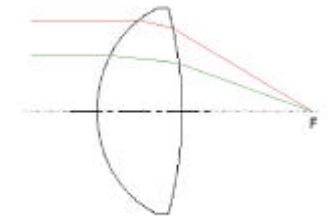
- ❖ Use aspheric surfaces to reduce monochromatic aberrations.
- ❖ The term aspheric is used to define a surface where the properties of a mean radius are modified to provide varying optical power across the lens.
- ❖ Most aspheric surfaces obey the even asphere function.
- ❖ This function takes the common spherical surface & using the extended series modifies the surface accordingly.

$$Z = \frac{cr^2}{1 + \sqrt{1 - (1+k)cr^2}} + a_1r^2 + \dots + a_8r^{16}$$

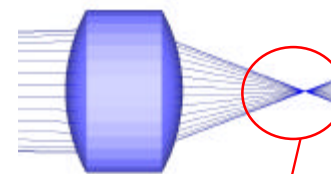
Where: c = curvature (1/radius)
 r = radial coordinate.
 k = conic constant (e.g. 0 = sphere)



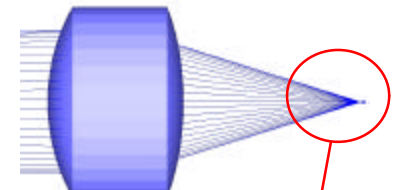
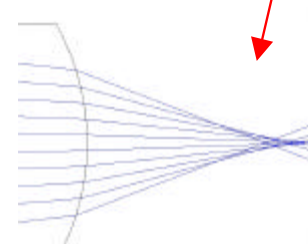
Spherical Biconvex Lens



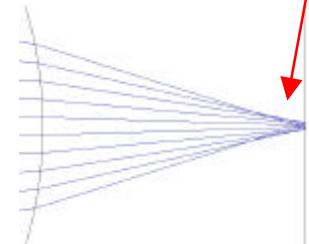
Aspherical Biconvex Lens



Modifies This.



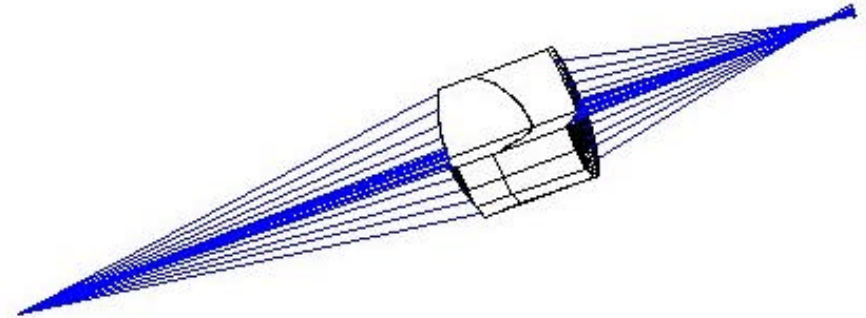
To This.



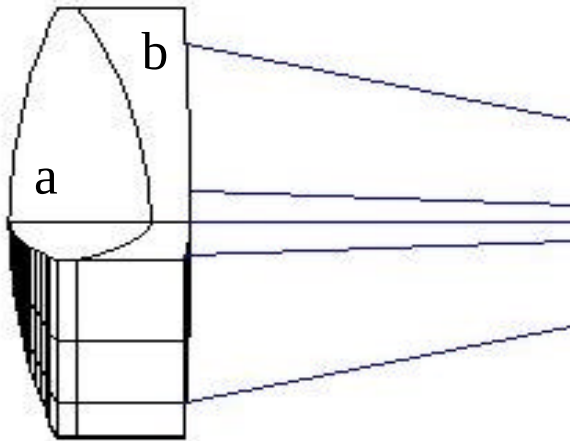
Plastic Achromatic Optics

- ❖ The aim of the achromatic doublet is to combine two lenses of having opposite powers and different refractive indices to yield a common focal length across the wavelength bandwidth of the lens.
- ❖ Consists of two lenses.
- ❖ One with a high Abbe number.
- ❖ The second of opposite sign and low Abbe number.
- ❖ Transverse Primary Chromatic Aberration Function:

$$\text{TPAC} = -y f_{ab} \left[\frac{f_a}{V_a} + \frac{f_b}{V_b} \right]$$



- ❖ Setting TPAC to zero & rearranging yields the optical powers:



$$f_{ab} = f_a + f_b$$

$$f_a = \frac{V_a}{f_{ab} (V_a - V_b)}$$

$$f_b = \frac{-V_b f_a}{V_a}$$

Intelligent Filtering

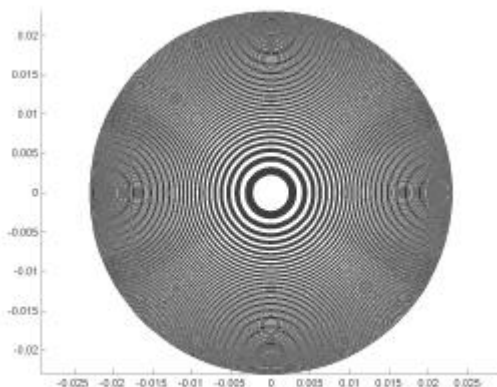
Current Research

- ❖ Chromatic Aberration Normally Corrected Using Achromatic Systems.
- ❖ For Low Cost Systems This Is Not Always Practical.
- ❖ Could Use Diffractive Optical Components Configured as Air-spaced Doublet.
- ❖ Aberration of Front Lens Corrected By Rear Element.

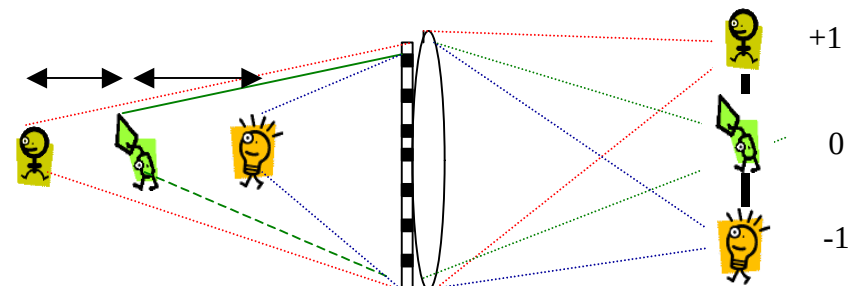
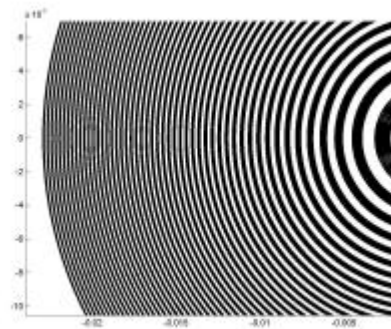
Two Approaches:

- ❖ Wavelength Attenuation using wavelength selective zone plate.
- ❖ Image defocusing using diffractive grating (based on work by M. Chang UPR).

$$\frac{dP}{dn} = K_1 + K_2 - 2d(n-1)K_1K_2 = 0$$



Zone Plate

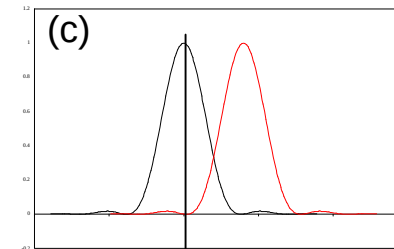
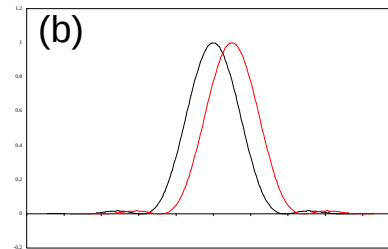
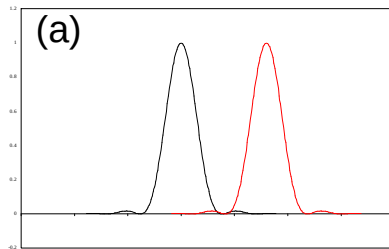


Imaging of multiple objects to single plane (Chang UPR)

Lens Testing

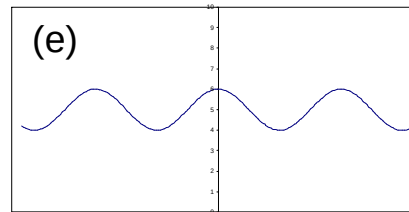
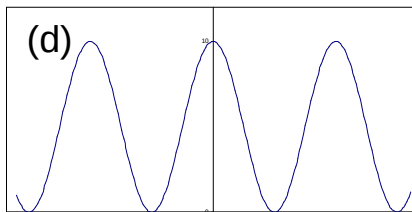
Raleigh Criterion

- ❖ Two separate incoherent point/slit sources are said to be just resolved when the peak of one distribution falls on the first minimum of the second distribution, as shown in figure c.
- ❖ This is the Raleigh criterion for the limit of resolution of an optical system.



Modulation Transfer Function (MTF)

- ❖ Modulation Transfer Function: The ratio of the image modulation (figure e) to the object modulation (figure d) at all spatial frequencies (lines/mm).
- ❖ Modulation: The ratio of the maximum to the minimum of the sinusoidal object or image.

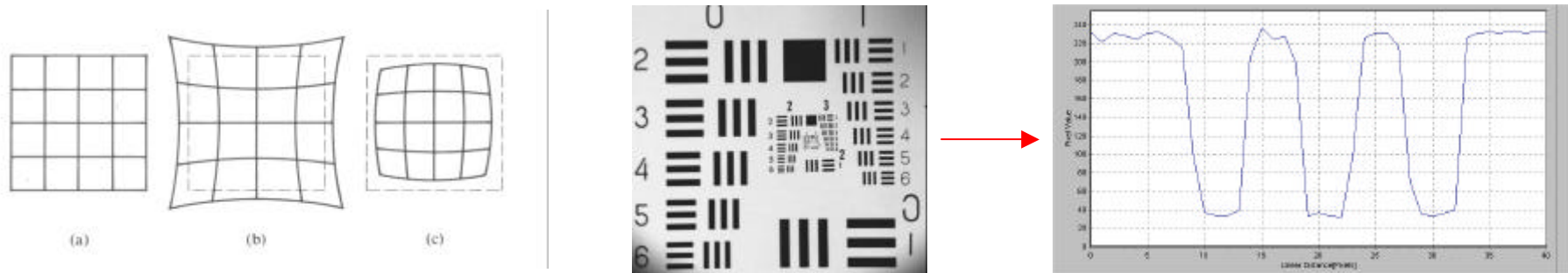


$$\text{Modulation} = \frac{I_{\text{max}} - I_{\text{min}}}{I_{\text{max}} + I_{\text{min}}}$$

Lens Testing

Lens Distortion.

- ❖ Positive or pincushion distortion: Each image point is displaced outward from the centre, with the most distant points moving the most as shown in figure b.
- ❖ Most commonly seen with positive (convex) lenses.
- ❖ Negative or barrel distortion: Each image point is displaced inward toward the centre.
- ❖ Barrel distortion is most commonly seen with negative (concave) lenses.



Resolution Chart Testing.

- ❖ Provides a rapid assessment of the limit of resolution of an optical system.
- ❖ A chart consisting of a number of areas of light and dark parallel lines of varying separation.
- ❖ Due to diffraction effects in the lens, a limit will be reached whereby the degree of blurring in the image will be such that the parallel lines are no longer discernable and separate items. This is the limit of resolution for the optical component.