FINDING FOCUS

The choice of criterion for determining best focus depends on the application.

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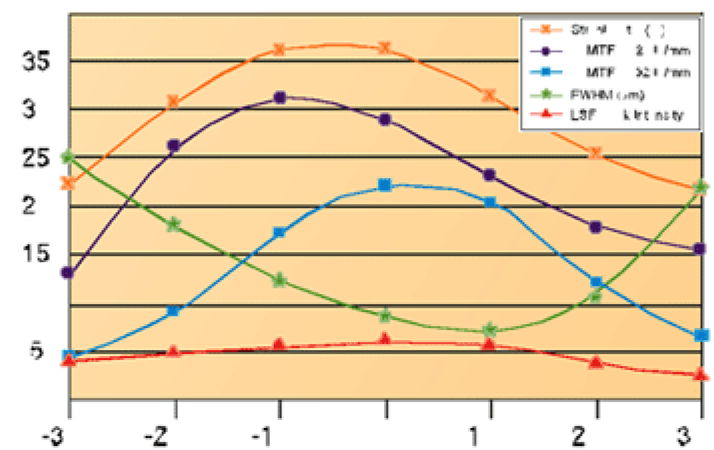
When testing lenses and optical systems, it is best to simulate the conditions of use while testing. Set the object conjugate correctly (infinite or finite),
choose the correct spectral content of the source (visible light, near IR, LED, etc.), and choose the optimal focal plane. There are many ways to determine the plane of best focus. The choice depends on the application.Since most detectors are flat, we generally optimize the plane of focus across the field of view (across the image plane). Even if we concern ourselves only with the on-axis field point (in the middle of the field of view), there are many criteria that we can use to define the plane of best focus—each leading to a different optimal focal plane. Let's consider the most common criteria, analyzing the image of a point source at infinity to obtain the results.

Peak Modulation Transfer Function (MTF)

Using this criterion, we plot the MTF at a given spatial frequency for several focal planes near the nominal focal plane. We can analyze the resultant data using curve-fitting techniques to determine the plane of peak MTF. Note that the particular polynomial fitting order chosen can lead to different results. This method also is spatial-frequency dependent; indeed, the planes of best focus for low and high spatial frequencies may be separated by some distance.



In plot of through-focus data obtained from a 35-mm plano-convex lens, the location of the plane of best focus varies.

Peak Line Spread Function (LSF) Intensity

Here, we plot the intensity of the peak of the LSF curve through focus. Only the intensity of the brightest part of the image is tracked in this method; it does not include the effects of veiling glare and stray light.

Minimum LSF Full Width Half Max (FWHM)

In this method, we plot the width of the LSF curve at half its maximum. This technique is useful when comparing the width of the LSF with the detector pixel size.

Peak Strehl Ratio

The Strehl ratio is defined as the ratio of the light intensity at the peak of the diffraction pattern of an aberrated image to the intensity at the peak of an aberration-free image.1 It provides a good measure of how close the lens performance is to that of a diffraction-limited lens. Plotting Strehl ratio as a function of focus generally yields a focal plane producing a good compromise focus across all spatial frequencies.

Peak Ensquared/Encircled Energy

We can also use the amount of energy contained in a square or circle of given dimension to determine best focus. This method is particularly useful for nonimaging applications in which the purpose of the lens is to focus energy onto a detector for maximum signal. It is also useful in maximizing the amount of energy falling onto single pixels in an array.

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Peak Resolution

Here, we choose the focal plane producing the highest resolvable spatial frequency. This focal plane will generally produce the sharpest image of very small details in the image at the expense of contrast at lower spatial frequencies.

Consider through-focus data for a 35-mm focal length, plano-convex lens (see figure). The plane of best focus varies depending on the criterion chosen, separated in some cases by as much as 100 µm. For optimal results, you must understand the requirements and characteristics of your application before choosing a criterion for best focus, paying particular attention to spatial-frequency requirements and detector types.

References

1. W. Smith, Modern Optical Engineering, p. 368, McGraw- Hill/SPIE Press, New York (2000).

|October 2005| SPIE's oe magazine |29

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