Q:

I am confused about the relationship between MTF and background level in the image.

I am testing a lens that has a non-zero background level. In other words, the "black" area far away from the test target has a non-zero DC level. This appears to be due to veiling glare from room lighting. When I darken the room the background level goes to zero.

When I lower the "black" level by darkening the room, the measured contrast of a 3 bar target gets better, as I would expect. However, the measured MTF does not change.

This doesn't seem correct. Shouldn't the MTF degrade when there is veiling glare?

A:

No. The MTF curve should indeed remain constant. Veiling glare adds light to the image plane, and clearly degrades the quality of the image. However, it does not change the MTF.

This is a confusing, and non-intuitive result. There are a number of ways to explain it, none particularly satisfying. Here are two that I find most intuitive[1]:

One explanation

MTF is a measure of the lens's ability to reproduce sine wave targets. Adding a DC component from another source really has nothing to do with the lens's ability to resolve AC components of the test target. Thus it is sensible that the MTF remains unchanged when a DC component is added.

Another explanation

Consider a pinhole[2] target, with a very bright light source behind it. The test lens forms an image of this target, which we capture with the video microscope. We construct the "linespread" function by collapsing the image to a cross section line, which might look like this:

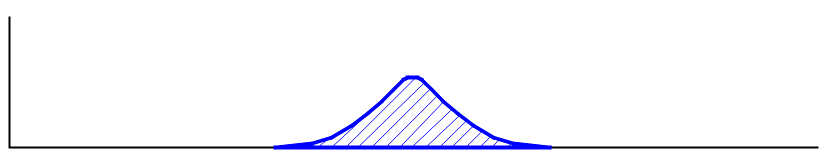

Figure 1

A lens with poorer MTF will have wider linespread, which might look like this:

[1] If you have a better way to explain this issue please share it with me (email to ben@wellsresearch.com)

[2] The OS100 uses an edge instead of a pinhole. However the line of argument is a little easier to follow for a pinhole, and the end conclusion remains the same.

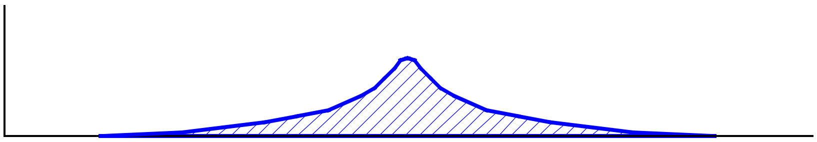

Figure 2

However, in both cases, the linespread eventually[3] falls to zero. In other words, the background level is black, as long as you capture a wide enough area. For the background area to have a DC component, the linespread would have to look like this:

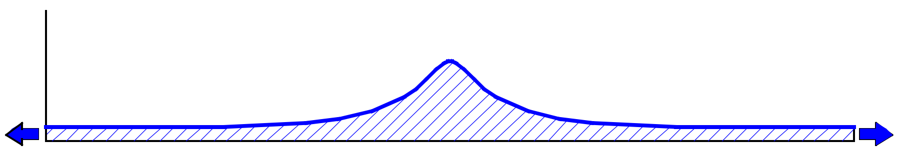

Figure 3 (the small arrows indicate that the linespread continues indefinitely.)

This is improbable[4]. More likely the "true" linespread is like figure 1 or 2, and the DC component is due to another source. If the DC component is not due to the target, then it is sensible that the MTF remains unchanged when the DC component is added.

Target choice

If the lens has a broad PSF, as shown in figure 2, than it may be difficult to make a satisfactory MTF test with a very "dense" target like the USAF target. Contact WRD for alternate targets[5] that may be more appropriate.

Summary

- Stray light is a critically important issue in most optical systems.
- MTF is a powerful tool to describe the imaging characteristics of a lens. However, it is not a test that challenges the lens to deal with stray light. Indeed, as we have seen, it is a test that is completely insensitive to any stray light problems the lens may have.

[3] The astute reader may disagree: Because of diffraction, the PSF does extend arbitrarily far. True enough, but the amount of energy contained in the tail of the distribution is small and falling fast. Very soon the tiny amount of energy in the tail is swamped by camera noise.

[4] The curious reader may wonder "but what if the PSF really does look like figure 3?" Isn't that possible? Yes it is possible. However, if you do the math you'll find that the lens is spending 99% of the light from the target to illuminate the background. Not a very useful lens.

[5] A simple square may be appropriate. WRD stocks 2mm squares, 1 mm squares, and 0.5 mm squares