Optimizing Aperture Selection

We tolerate visible diffraction more readily than visible circles of confusion because diffraction affects the entire image uniformly. When the circles of confusion at the near and far limits of Depth of Field reach a size that is resolvable (by the human eye) for a given combination of enlargement factor and viewing distance, their failure to deliver apparent sharpness becomes obvious in the presence of those areas of the subject space that were closer to the plane of sharpest focus. When circles of confusion get too large, they are readily detectable against acceptably sharp surroundings. Resolvable diffraction softens the *entire image* and thus goes unnoticed unless we have a comparison print alongside, whose Airy disks are smaller than can be resolved.

Visible diffraction is destructive to image clarity even when it goes unnoticed.

The point at which diffraction becomes visible and thus destructive (though not readily observable perhaps) occurs when the diameter of the Airy disks reach the reciprocal of about 7 lp/mm in a print to be viewed at a distance of 10 inches. This is considered by many to be the limit of resolution of the average adult with healthy vision.

If it is our goal to force Airy disks to be truly unresolvable in a final print intended for viewing at a distance of 10 inches, we should also make it our goal to limit circles of confusion to this same diameter in the final print.

DoF calculators/spreadsheets/java scripts/whatever that permit you to specify the on-film maximum permissible diameter for circles of confusion can be exploited if we begin by using this formula:

Desired maximum permissible on-film CoC = 1 / enlargement factor / desired print resolution

For example, if after cropping, we anticipate an 8x enlargement factor and desire a final print resolution of 7 lp/mm, the CoC value we should use for DoF calculations would be:

Desired maximum permissible on-film CoC = 1 / 8 / 7 = 0.0179mm

Recommendation: I strongly encourage the use of CoC values calculated in this manner for subsequent use in DoF calculations instead of treating CoC diameter as a constant within each format, as so many DoF calculators do (0.03 for 35mm, 0.06 for 6x6cm, etc.) Remember to take cropping into account when coming up with your enlargement factor.

Using this CoC value in DoF calculations will tell us how far we have to stop down to get just enough DoF for the near and far sharps in our subject space -AND- will take into account our desire to deliver a resolution of 7 lp/mm in the final print.

If you can anticipate a minimum viewing distance greater than 10 inches, then you do not have to stop down as much when shooting. For a minimum viewing distance of 30 inches, for example, we can reduce our desired on-print resolution to 7/3 lp/mm, or only 2.333 lp/mm. At a distance of 30 inches, the 2.333 lp/mm print will look like a 7 lp/mm print viewed at 10 inches. With an 8x enlargement factor and a 2.333 lp/mm desired print resolution, our maximum permissible on-film circle of confusion would be:

1 / 8 / (2.333) = 0.0536 mm

(A much larger CoC than calculated before, for the same format and enlargement factor.)

Once you've determined what your maximum permissible on-film CoC should be, you can calculate at what aperture diffraction's Airy disks will reach the same diameter (when stopping down) by using this formula:

f-stop at which diffraction becomes visible = max. permissible CoC / 0.00135383

So, for the first example above, where we must limit our spread functions to 0.0179 mm, we can limit our CoC's by adhering to DoF tables calculated with this diameter and we can avoid visible diffraction by not stopping down below:

Visible diffraction stop = 0.0179 / 0.00135383 = 13.22 (We can't stop down below f/13.22.)

We can use f/11, but not f/16, in this example.

For the second scenario, where we anticipate a minimum viewing distance of 30 inches, we get:

Visible diffraction stop = 0.0536 / 0.00135383 = 39.59

Here, we can stop down to f/32, but not f/45 without fear of resolvable Airy disks (and our DoF will have a more generous range as well.)

By never stopping down more than necessary, three sources of image degradation are avoided:

1) Airy disks will be unresolvable.

2) Exposure times will be shorter, thus reducing vulnerability to subject and camera motion and perhaps reciprocity failure.

3) You will most likely be shooting at an aperture that's closer to the aperture of best resolution offered by your lens.

I encourage you to avoid compromises. Film is cheap, but all the effort and expense of getting there and setting up the shot can be lost to using ballpark guestimates. The hard part isn't being meticulous in the field - it's taking the time at home to equip yourself with tools and techniques that will allow you to bring home the bacon every time you shoot.

I enthusiastically recommend Don Fleming's *DoFMaster* software: http://www.dofmaster.com/. Use the Window's version of *DoFMaster* to make a spinning disk calculator for each combination of focal length and print size you anticipate, labeling each with the separately calculated f/stop at which diffraction would become visible. Unlike many DoF calculators, *DoFMaster* allows you to specify the maximum permissible CoC diameter. Use the formulas provided above to calculate the desired CoC and the visible diffraction stop.

In the field, equipped with a *DoFMaster* spinning disk calculator for each combination of focal length and print size you anticipate using, you can optimize your aperture selection by simply making sure that the subject space fits the range of distances indicated for a given aperture AND that that aperture is not smaller than the visible diffraction stop. That's all there is to it. If the indicated stop is small enough to induce visible diffraction, you'll have to back away from the nearest subject, reduce your focal length, or commit to making a smaller print.

Near subject distances can be accurately measured using a very affordable laser rangefinder called the STANLEY® FatMax® TruLaser™ TLM 100 Distance Measurer. This $95.00 tool can also be used to precisely locate targets in the subject space that at the hyperfocal distance indicated by your DoF calculations. I'm very pleased with the one I ordered at http://www.laserstreet.com/stanley-tlm100.htm, where shipping is free. The TLM 300 is every bit as accurate out to a distance of 650 feet: http://www.laserstreet.com/stanley-tlm300.htm