High Megapixel DSLR Lens Limitations

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Bob Young was not happy with my last lot of homework so he sent me off to do some more work, this time on the performance of lenses mounted on high megapixel cameras. He had a suspicion that his old Nikkor telephotos might not be allowing the superb sensor in his new Nikon D800 to show its best. He was right – his old telephotos are not up to the job but, surprisingly, most of the current lenses are not much better. This is not a criticism of Nikon, it is more an indication of what a big jump the company has made with the 36.3 megapixel D800 sensor, manufactured to Nikon specifications by Sony. To understand the discussion, it will be an advantage to re-read my contribution, 'Sharpness Explained' in the April 2013 Photography Group newsletter. However, for readers not so technically inclined, I will try to bring out the important conclusions in an easily understood way.

High megapixel cameras have smaller pixels than the previous generation and it is the relatively small size of the pixels that is important, not the pixel count. This means that the discussion also applies to the current generation of 24 megapixel cropped sensor cameras which have pixels even smaller than the D800. The size of the sensor pixels limits the resolution of fine details (sharpness) recorded in the image formed by the camera lens. For many years, good telephoto lenses have been capable of producing images with detail finer than could be recorded by digital camera sensors. However, with the introduction of the D800 and some other cameras, we are seeing for the first time, in some cases, a reversal of the situation with lens performance now limiting the resolution of fine detail. The extent to which this is happening and what can be done to ameliorate the problem is the focus of this article.

Since we are exploring the limits to lens performance, we can rule out zoom lenses as they are already too compromised for serious consideration. If you must use a zoom lens, then make sure the zoom range is less than about 3x, preferably 2x, and always use it with the aperture closed down at least one stop. That brings us to fixed focal length telephotos – the flagship lenses of the major manufacturers. These lenses have been designed with fewer compromises and usually have residual optical aberrations that are insignificant except at full aperture where they are just discernable. The effect of residual aberrations is often so small that it goes un-noticed in the field where there are usually other factors that can limit performance such as movement blur and poor light. But if one is working with a camera like the D800 in a controlled set-up, such as an 'outdoor studio', then one may find that the sharpness is not quite as good as expected because of lens limitations.

There are a number of ways of characterizing the sharpness of a lens/camera combination and the subject was thoroughly discussed in the April 2013 newsletter. In the present article it is convenient to use the results of the American camera and lens testing company, DxO Labs, whose optical engineers have tested the D800 in combination with the Nikon flagship telephotos of 300, 400, 500 and 600 mm focal length. This data set provides an unparalleled overview of the performance of the D800 when combined with these lenses. They have also measured the sharpness of the Canon 5DIII with the equivalent Canon lenses. The two data sets measured at full aperture are shown below in the table (source: http://www.dxomark.com/ see tests and reviews for Nikon and Canon telephoto lenses).

Before looking too closely at the data, a few words of explanation are in order. The DxO sharpness is a measure of 'perceptual megapixels' (P-Mpixels) which the company explains is 'equal to the pixel count of a sensor that would give the same sharpness if tested with a perfect theoretical optics [sic], as the camera/lens combination under test' (http://www.dxomark.com/Reviews/Looking-for-new-photo-gear-DxOMark-s-Perceptual-Megapixel-can-help-you). In other words, if a perfect lens were mounted on the D800, the measured P-Mpixel rating would be 36.3 megapixels, a theoretical performance benchmark against which to compare the sharpness of actual lenses. Similarly, for the 5DIII, the benchmark would be 22.3 P-Mpixel.

Nikon Lens on D800 (36.3 Megapixels)	DxO Sharpness (P-Megapixels)	Canon Lens on 5DIII (22.3 Megapixels)	DxO Sharpness (P-Megapixels)
AF-S Nikkor 300 mm f/2.8G ED VR II	24	EF 300 mm f/2.8L IS II USM	22
AF-S Nikkor 400 mm f/2.8G ED VR	25	EF 400 mm f/2.8L IS II USM	21
AF-S Nikkor 500 mm F/4G ED VR	16	EF 500 mm f/4L IS II USM	19
AF-S Nikkor 600 mm F/4G ED VR	18	EF 600 mm f/4L IS II USM	20

Direct comparisons using the DxO data are only useful for combinations of lens and camera with the same focal length and sensor format. For example, the Nikkor 300 mm f/2.8 mounted on the full-frame D800 should be compared with the Canon EF 300 mm f/2.8 mounted on the full-frame 5DIII or with other 300 mm lenses mounted on full-frame bodies. In this example, the data shows that the Nikkor 300 mm f/2.8 on the D800 is noticeably sharper (24 P-Mpixels) than the Canon 300 mm f/2.8 on the 5DIII (22 P-Mpixels). However, it also shows that the Nikkor 300 mm f/2.8 falls well short of the theoretical benchmark (36 P-Mpixels) indicating that the lens is not allowing the full potential of the D800 sensor to be realized. This is the case for all of the Nikon flagship telephotos which fall well short of fully realizing the sharpness potentially available from the sensor. This is particularly noticeable for the Nikkor 500 mm and 600 mm f/4 lenses which have a P-Mpixel rating even less than the equivalent Canon lenses on the 5DIII body. This observation did not escape the notice of the DxO test engineers who reported that the 'sharpness is somewhat disappointing given the huge pixel count of the Nikon D800' (http://www.dxomark.com/Reviews/Nikon-AF-S-Nikkor-500mm-and-600mm-f-4G-ED-VR-lens-reviews-legendary-performers-in-the-range).

While the test results reveal that the flagship Nikkor lenses are falling short when mounted on the D800, we have no comparable data for the Canon flagship telephotos because, as yet, Canon have not released a similar high megapixel camera body. It may well turn out that the Canon lenses also fall short when mounted on a body with a sensor like the one in the D800. It is clear that the Nikkor lenses were designed for the previous generation of cameras with 12–16 megapixel sensors for which they were perfectly suited.

All of the foregoing discussion relates to testing done at full aperture. Most of the time, bird photographers adjust the aperture to control the depth of field and exposure and it is only in desperate situations with poor light that one would contemplate shooting wide open. When the aperture is closed down more than about a stop, the marginal rays, which are the source of most of the residual lens aberrations, are blocked by the aperture stop. The resulting image quality will be much better with a consequent improvement in the sharpness. In these circumstances we would expect to find that the Nikkor lenses perform significantly better than the DxO Labs measurements might suggest. When stopped down to say f/5.6, all of the Nikkor lenses mentioned above should be capable of producing images with detail finer than the sensor can faithfully record. Whether this is achieved in practice will probably depend upon the extent to which mirror/shutter vibrations impact on image quality.

In my article ‘Sharpness Explained’, I discussed the role played by residual lens aberrations, diffraction from the aperture stop, and the anti-aliasing filter. Their combined effect is to slightly blur the image of a point source of light. If the amount of blur can be mathematically characterized (point spread function) and if the image is in focus with low noise, then it is possible to perform a post-processing operation known as deconvolution which works backwards to ‘undo’ the blur. If deconvolution is applied to an entire image, pixel by pixel, then it is possible to remove the blur and hence sharpen the image. The point spread function (PSF) needs to be known for every point and it varies from place to place in the image depending upon the mix of residual aberrations which in turn are determined by the lens design. The lens design is usually proprietary information and not available to use to calculate the PSF. However, Canon make available the PSF data for a large number of lenses that can be downloaded and used in the Digital Photo Professional (DPP) software supplied in the box with all EOS series cameras. This is a really powerful capability that seems to be little used. An excellent tutorial on the Digital Lens Optimizer (DLO) embedded within the DPP software, is available at http://web.canon.jp/imaging/dlo/factor/index.html DLO is most useful in two situations, firstly, sharpening images taken with full or nearly full aperture where image quality is adversely affected by residual lens aberrations. This is just the situation described earlier and is a way to improve the DxO perceptual megapixel rating. The second situation arises when one must close down the aperture more than about f/11 in order to get a useful depth of field for close shots. In this case, diffraction begins to spoil resolution and the DLO deconvolution algorithm is very effective in restoring the image to acceptable sharpness. The latter capability is also available in some third-party software and is even used in-camera, especially phone cameras and some point-and-shoot cameras, where the effective aperture is often between f/11 and f/20. In the future, it is likely that this capability will migrate to all cameras and will become a familiar part of the camera menu alongside peripheral illumination (vignetting), chromatic aberration (colour fringing), and distortion correction.

Getting the best out of a high megapixel camera like the D800 is a bit like changing from driving a family sedan to a racing car – it takes some getting used too. One must learn to accommodate the idiosyncrasies and understand the limitations to safely achieve the full potential. In this article we have pointed to the fact that in some circumstances the flagship Nikkor telephotos are not all that they might be, having been left behind by the giant step forward made in sensor development. We should probably not expect new lenses in the near future that will match the sensor’s full potential so we need to learn to make the best with what we have. This means closing down the lens aperture one or two stops and relying on the high sensitivity and dynamic range of the sensor to make up for the lost light. Developments in image processing will also help, especially deconvolution, which promises to increase the contrast of fine detail in the image and go some way to making up for the shortcomings of contemporary lenses. Deconvolution can also be used to correct a small amount of motion blur caused by camera or subject movement and this option is making its way into popular image processing packages.