Pixel Perfect III:
Digital Camera Test 2003

By Paul Lindström, Digital Dots, pl@digitaldots.org

There has been a subtle breakthrough in digital photography over the last few years. From being reasonably good, the professional high-end camera backs now surpass analogue film in terms of actual pixel quality and colour depth. Especially if you take into the account that analogue film needs to be scanned at some point to enter a wholly digital workflow. The number of f-stops achievable between underexposure and over exposure is also greater when using a professional digital camera back than when shooting with analogue film.

There are basically three classes of digital cameras: compact cameras designed for consumers, SLR-cameras with exchangable lenses for more demanding applications and photojournalism. Finally we have the mid-size or large format studio cameras used in professional photography. The test presented here is made with selection of cameras in the latter group.

The large format cameras can be equipped with either a digital back containing an area matrix sensor (for one-shot or multiple shot exposures) or a scanning back containing a linear array sensor. The scanning backs have very much in common with flat bed scanners in the way they operate. While they can reach very high resolution they have the serious disadvantage of not being able to use flash during exposure, and not being able to shoot live, "one shot" images.

In most of today's photography therefore the area matrix array sensors are the most interesting technology to use for a digital studio. The limitation of an area matrix sensor is that when doing one-shot exposures you only achieve about half of the actual resolution possible. This is because of the need to filter the image into the three components red, green and blue. The more common way to achieve this is to mount a mosaic filter in front of the sensor. A conventional type of filter used is the Bayer pattern filter. It has an array of red and green patches over each CCD element in one row, and under that a series of blue and green

patches (see figure 1). This means that the green signal has about 50% of all the image information from the sensor, while the red and blue channels only contain 25% of the image information. The manufacturers have brought different smart algorithms to work on this, and can "guess" the value of an unknown pixel by using the information from nearby pixels. After this signal processing it's reasonable to say that we achieve about 50% "useful" resolution in all channels, compared with the resolution in the sensor. A technology that differs from this principle is the Foveon X3 sensor, which uses a different type of filtering technology. The Foveon sensor is supposed to achieve full resolution in all three channels already in one-shot mode. We will come back with results after testing the Sigma D9, containing a Foveon X3 sensor.

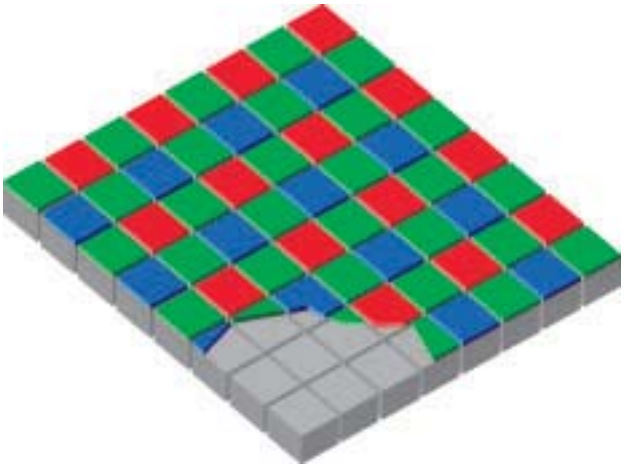


Figure 1 – colour filter; In most sensors there is a Bayer pattern filter mounted to split the light into the three base colours rgb. Note that you only get a fourth of the total image data in the red and blue channels, not all the pixels available in the sensor.

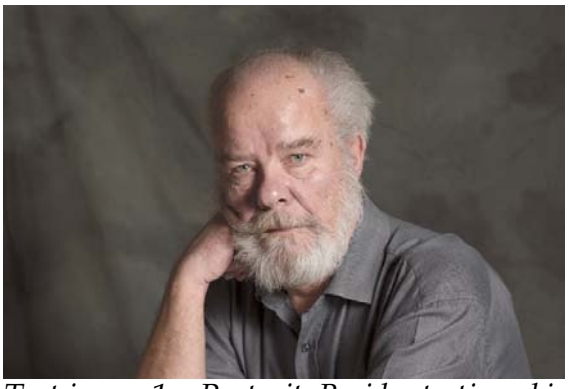
To reach full resolution when using an area matrix sensor you can go about in several ways. One obvious one is to shoot the image three times, each time with a different filter mounted in front of the sensor. Or you can do as several vendors do today – move the sensor one pixel at the time, covering the Bayer pattern. After making a composite of those four exposures we have a full resolution picture in rgb. Some manufacturers offer a mode where you do a supersampling of the image, shooting 4 x 4 times to achieve an even better image quality. In our test we will evaluate weather this 4x4-mode really accomplish any useful image data compared to normal four shot mode. Of the participating cameras it's only the Sinarback 54 H that can do multi-shot mode.

The scope of the test

We invited all the manufacturers of digital camera back with a resolution of at least 11 megapixel. All vendors agreed to participate except for Megavision who wanted to postpone the test until they had access to a full format sensor (50 x 40 millimeter or similar) instead of the present 35 millimeter sensors. Eyelike finally skipped the test since it was conducted at a Swedish photographic studio, and at present they don't have a Scandinavian distributor. intended to participate in the tests but wanted to complete their multiple shot mode function in the Ixpress first. The cameras tested include the DCS Proback 645H from Kodak, the Valeo 11 from Leaf, H10, H20 and H101 from Phase One and finally Sinarback 54 H from Sinar.

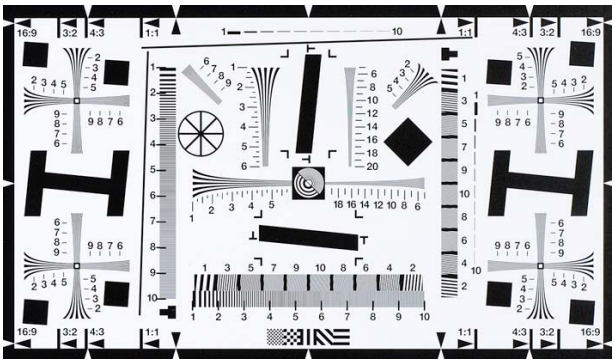
These were the tests

Our tests are based on four different images: *one portrait shot*, a "live situation" with a human being of blood and flesh to check among other the rendering of things skin tones etecetera. One *stilleben*, still life (the breakfast scene) including some "difficult" colours in the scene. The flower is on purpose out of focus to create soft gradual tones. One black and white *resolution test* (the TU 170 test chart, part of the ISO 12233 resolution test) and finally a colour test chart of our own design to evaluate signal processing of colours at high resolution.

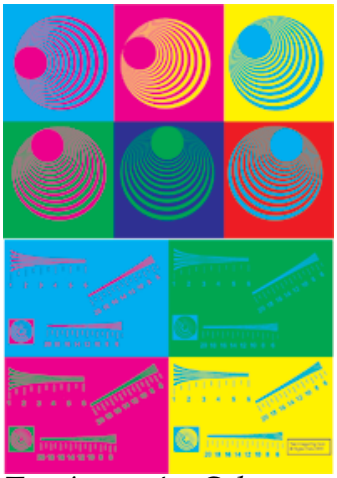


Test image 1 – Portrait. Besides testing skin tone rendering, the shirt may cause more or less moiré.

Test image 2 – Still life. This image contains a range of checkpoints. The big red flower is deliberately out of focus in order to check the rendering of gradual tones.



Test image 3 – Black and white resolution test. This image is part of the ISO 12233 test of digital still photo.

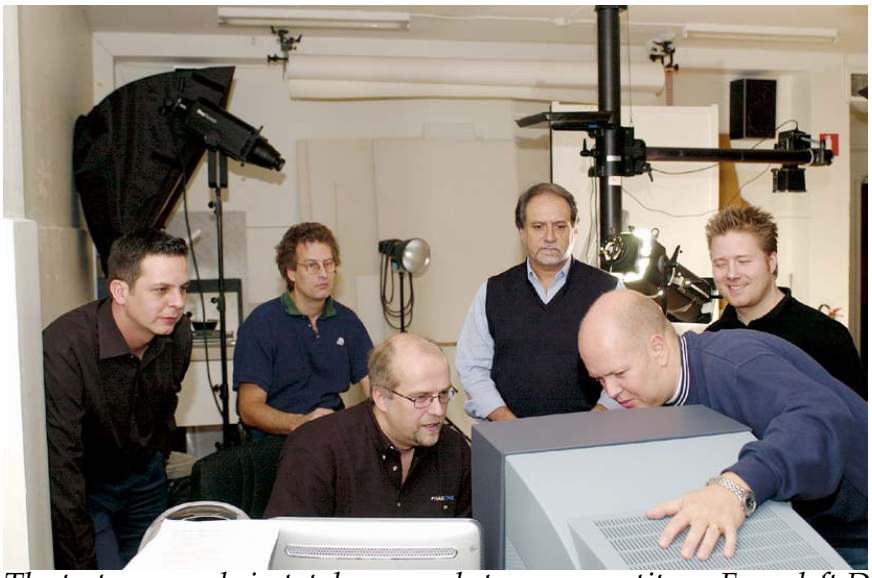


Test image 4 – Colour resolution test. This image is designed to help evaluate the colour rendering at very high resolution.

The portrait image was of course captured in one-shot mode, while the other images also were taken in multiple shot mode where possible. All the vendors have used the same cameras and lenses when possible, but were also allowed to make an extra session with camera and lens of their own choise for camparison. When shooting multiple shot exposures a vendor often suggest a certain camera or lens for best result. There is a debate going on about how crucial the choise of lens is to the final result. We think we used top quality equipment when using the Hasselblad's ELD 555 and H1 cameras to provide a common base for all test participants. The lenses used were the CFi 4/120 lens with the Hasselblad ELD 555, and the HC 2.8/80 with the H1 camera. However test participants were allowed to use any camera and/or lens in addition to this configuration, as an extension of the test. The power supplies and flash systems were from Broncolor and Profoto.

The team behind the tests

Configuring and evaluating the test was a team consisting of Paul Lindström from Digital Dots, for ten years the technical editor for AGI Sweden, as well as Thomas Wilke from Studio CA and Andreas Bohlin from Binuscan. The tests were made at Studio CA in Stockholm – a studio that has worked digitally for over ten years by now. One of their digitally shot images was published already in 1992 in the newspaper Dagens Nyheter. Andreas Bohlin is a formed scanner operator and part of Binuscan R&D team, and a devoted amateur photographer. In his ongoing work for Binuscan he has buildt up an impressive know how and experience in image processing and colour management. Previous tests by Digital Dots have evaluated high end scanners, and as a technical editor of AGI Scandinavia, Paul Lindstrom also have tested digital cameras and image processing software over the years.



The test was made in total openess betwen competitors. From left Daniel Densinger, Sinar, Paul Lindström (in the background), Digital Dots, Martin Widén (at the monitor), distributor Phase One, Cedrik Muscat (standing), Creo-Leaf, Thomas Wilke (adjusting the monitor), Studio CA, Niklas Blyberg (to the far right), distributor Sinar. Photo by Christofer Landberg

Beside visual evaluation of the images we also used software developed by Kodak to evaluate the pixel quality of the pictures taken of the TU170 testchart. Part of the ISO 12233 test of electronic still picture cameras is a numeric analyze of the SFR (Spatial Frequency Response), and the Kodak software is one possibility to perform this analyse.

One trend among the vendors of high-end studio camera systems is to improve portability. While this is hard to evaluate we at least describe the options at hand regarding portability in our report.

The questions we focused on was what type of workflow the vendor suggested in the software, the optical resolution achieved in the system (sensor, camera back, lens and signal processing), image quality in a wider sense (colour accuracy, smooth gradual tone changes, tendencies of moiré or blooming etcetera). We also wanted to check weather 4x4 shot mode added any real image quality.

The cameras – Leaf Valeo 11

Leaf is part of Creo but has its company head quarter in Israel since they were bought by Scitex 1992. Leaf is among the pioneers of scanning and digital photography. They brought products to market as early as 1984 when they were founded in Massachusetts, US. Leaf was among the first to use a CMOS sensor (Complementary Metal-Oxide Semiconductor) in a professional digital camera back. The Leaf Valeo 11 tested has ”conventional” 11 Megapixel CCD sensor from Dalsa (former Philips) with 4056x2684 pixels.

Creo-Leaf Volare 11

The Valeo 11 can be connected to the palmtop computer Compaq Ipaq that is by this used as a ”Digital Polaroid”. There are two models of the Valeo, Valeo 6 with a 6 MP sensor and Valeo 11 with an 11 MP sensor. The connection to the Ipaq is made through Firewire which according to Leaf make the data transfer three times faster than to a Compact Flash memory or Mircodrive. There is also the possibility to attach extra storage and battery capacity to the camera back.

The control software is Leaf Capture V8. Beside the typical signal processing functions the software also contain a tool called the Magical Eraser. This tool is used to reduce moiré directly in the 16 bit raw data and will according to Leaf preserve the sharpness in the original image.

Kodak DCS Proback 645H

Kodak has a quite unique situation in the fact that they both deliver sensors for several of their competitors, and build camera systems as well. The DCS Proback 65H is buildt to match the new Hasselblad H1. The sensor is a 16 Megapixel Kodak buildt CCD (4080x4080) equipped with a removable IR-filter. Among the options is an anti moiré filter (anti aliasing).

Kodak DCS Proback 645H

Most of the settings are made directly on the camera using the built in LCD monitor. The is two processing software to choose among – the DCS Photo Desk 3.0 for both Mac OS and Windows, and the Capture Studio 2.0 for Mac OS only, including Mac OS X.

The DCS Proback capture images at 12 bit colour depth with the CCD and A/D conversion and then export the images as 8 bit or 16 bit data. Thus you can achieve images of 48 respectively 96 MB rgb. The light sensitivity is equivalent to ISO 100 and can be set to up to ISO 400. The camera back has an internal storage capacity of 256 MB and sockets for Compact Flash memory card. It also has a Firewire connector.

Phase One H10, H20 and H101

Phase One is one of the two Danish manufacturers of digital camera backs. Like with most other manufacturers the scanning backs dominated the product portfolio for a long time, but lately the one-shot camera backs are the best sellers.

Phase One H10

Phase One H20


Phase One H101

Phase One has several camera backs in their portfolio and were together with Kodak among the first manufacturers to launch a digital back to the new Hasselblad camera H1. Both the H10, H20 and H101 meet the criteria of at least 11 megapixel resolution to enter the test.

Phase One use sensors from both Dalsa and Kodak. The H10 have an 11 Megapixel Dalsa sensor (same model as in the Valeo 11), while the H20 contains the 16 Megapixel Kodak sensor (same model as in the Kodak DCS Proback 645H). The Phase One H101 is built for the Hasselblad H1 camera, and has the same 11 Megapixel sensor as the H10. In the summer Phase One will launch the H25 with a 22 MP CCD sensor from Dalsa. This camera back however wasn't ready for testing in this round. The Phase One H101 is intended for the Hasselblad H1 and contains the same type of sensor as in the H10, an 11 MB sensor that is.

The control software for the Phase One digital backs is Capture One. Phase One also provides a plugin to Photoshop for reducing moiré in the images. The software Capture One can process raw image data from both Phase One camera backs as well as from Canon 1D-series and the Nikon D1- and D100-series.

Sinarback 54 H

Sinar is a Swiss company with a tradition within photography that goes a long way back in time. They started their line of digital camera backs in cooperation with Leaf, but today they build camera backs on their own.

Sinarback 54H

Sinar have several digital backs in their portfolio with a resolution of 11 MP or more, but chosed to participate with their top model only. The Sinarback 54 H contains the new 22 megapixel Kodak CCD (5440x4080 pixels), custom built for Sinar with the exclusive right of twelve months from the release at Photokina autumn 2002. Sinar build their own cameras and lenses, but the 54 H can be fitted onto most any viewfinder camera through an adaptor. In our test Sinar used the Sinar p3 camera with a Sinaron Digital lens as well as the Hasselblad camera and lens.

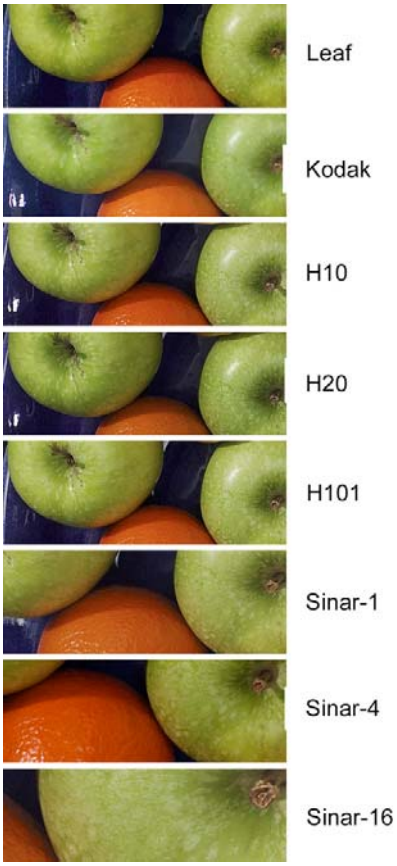
What is especially interesting with the Sinarback 54 H, apart from the very high resolution, is the actual size of the sensor. It's very close to the analogue film format which, according to some photo experts, mean that you really make use of the mid- to large format cameras with this digital camera back.

The control software is Sinar Captureshop. Depending on the digital back in use it can handle one-shot, 4-shot and up to 16-shot exposures. The multi-shot modes is by Sinar called Microscan respectively Macroscan mode. For the multi-shot mode to make the best use of the sensor Sinar recommend you to use the lenses of their own make, with a resolving power of at least 100 linepairs per millimeter

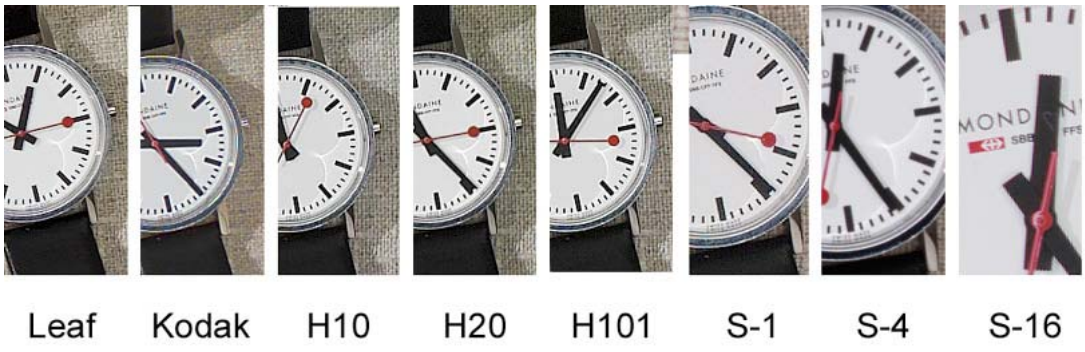
in the center of the lens, and at least 60 linepair per millimeter in the periferical of the lens. Like the other vendors Sinar offer several solutions to achieve portability when shooting digitally. One of the solutions is the special laptop called Sinar CyberKit which is an alternative to using more general portable computers.

Evaluated images

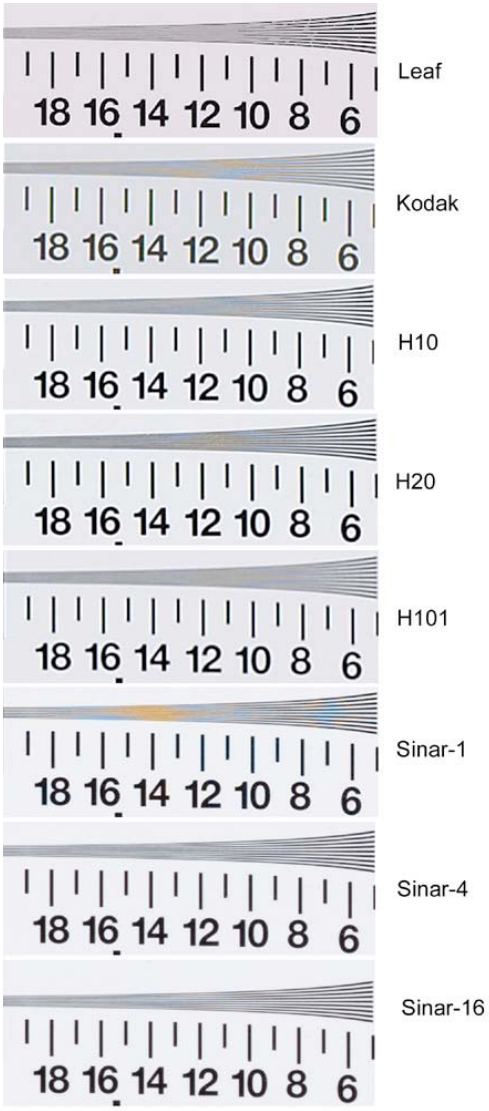
Portrait – crops; because of limited space we can't publish the whole un-cropped image from each camera back (this portrait image is of up to 64 MB file size, which mean a A3 size image at 300 ppi. But the crops gives a fairly good idea about the character of the kind of image quality the camera back and software offer processing the raw data files.



Still image, crop A (fruit). These crops are reproduced scaled 1:1 at 300 ppi. The largest image, the Sinar 16-shot image, is originally a 254 MB rgb-image, big enough to produce a 700x1000 mm poster att 300 ppi resolution.

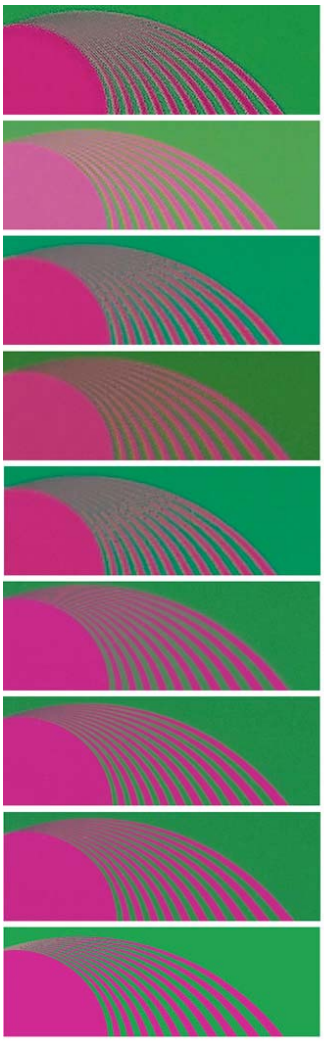


Still image, crop B (the clock). These crops are reproduced scaled 1:1 at 300 ppi. The Sinar 4-shot image for some reason is slightly out of focus. The resolution tests by comparison shows a much better result – more in line with what could be expected from the Sinar camera back.



Resolution test – black & white test image; The ISO certified test chart TE170 contain several different test objects and patterns. Here a crop of a pattern with lines that get closer and closer each other. Depending of the distance to the camera you will get moiré at some point. That aside you get a pretty good idea of the actual resolving power in the camera system. All crops has been interpolated up to match the resolution of the Sinar 16 shot mode (shown at the bottom part of the picture).

Note: To properly evaluate the result you need to look at the original image in for example Adobe Photoshop, at 100% (1:1 ratio).



Resolution test – colour test image; this test image we designed to check the resolution reached for colour images. A fenomena that might occur in some camera systems is that very small coloured object are turned into greyscale (the Leaf camera has this tendency). Another problem might be that contrasting colours might produce colours that actually don't exist in the original image (the Kodak camera show this tendency). The original image is the last image down, an Illustrator generated vector graphics rendered into pixels in Photoshop.

Evaluating SFR (Spatial Frequency Response)

Beside making a visual evaluation we wanted, if possible, to use some numeric or computer based way to analyze the image quality, especially in regard to true optical resolution. Some objects in the TU170 testchart lend itself to such analysis, and with the help of the Kodak software we created diagrams for each camera back. While objections have been raised against analyzing the SFR by some imaging specialists, for exampel Anders Uschold at Digitaltechnik, Germany, we actually found a good correlation between poor SFR results and poor visual results. The Kodak Proback show a significatly poorer result both for the b/w

test image and the stilleben (the text in the newspaper show heavy moiré). It is also the Kodak Proback that have a questionable result in the SFR analysis.

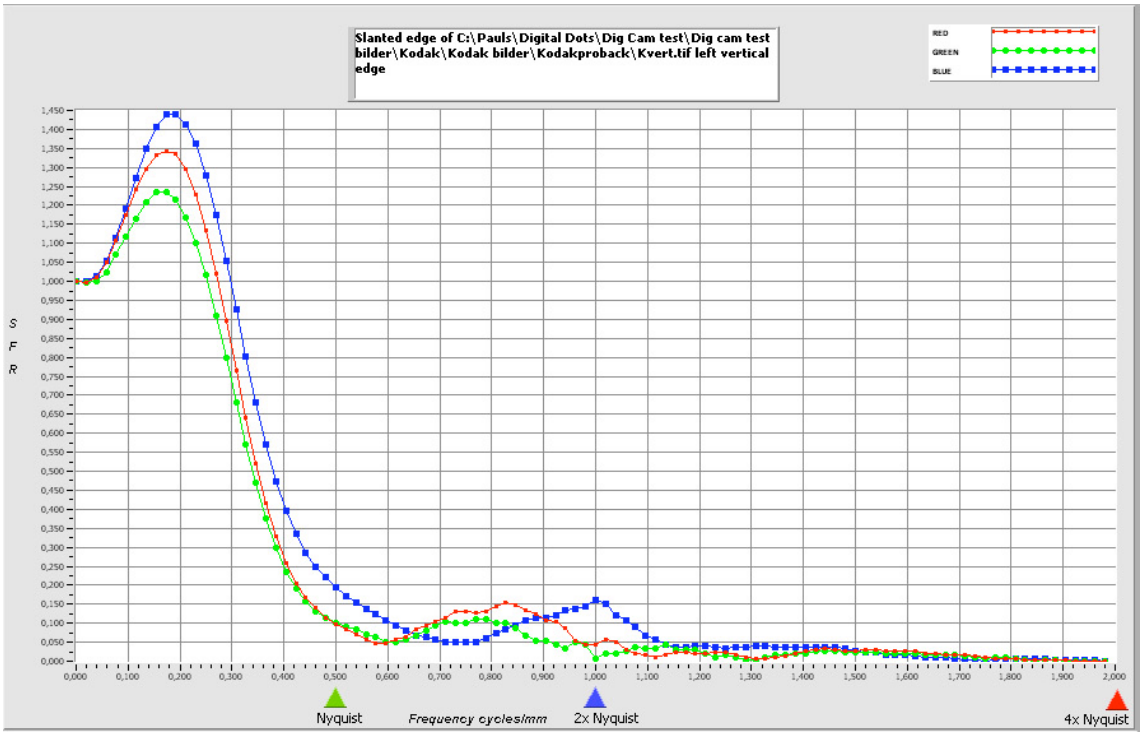


Diagram – Analysis; Among the evaluations we made was a numeric analysis of the real resolution in the black & white test image. This is a sample of the values for SFR (Spatial Frequency Response). The curves should ideally keep close together and not be below 0.1 at the Nykvist value (green triangle).

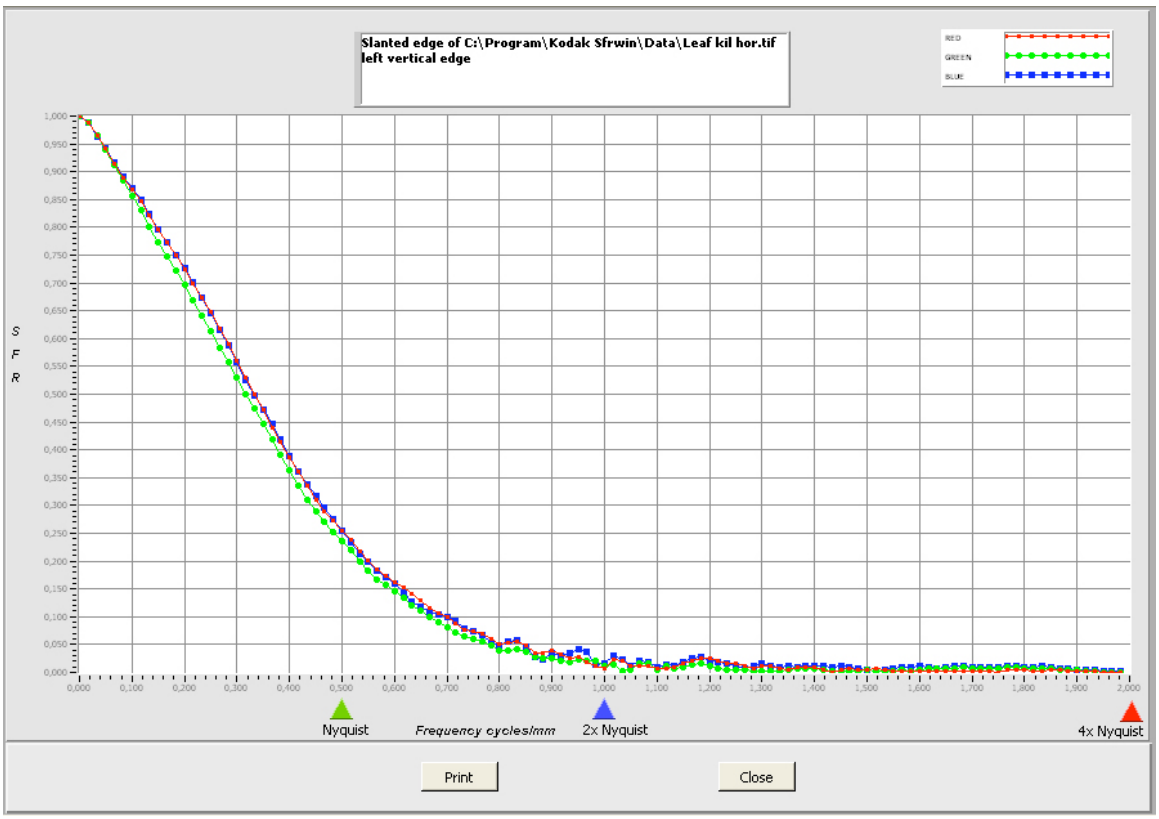
The sample above show the results from Kodak Proback and the red and green curves touch the 0.1 point exactly or slightly below Nykvist—not fully acceptable. Also the curves for rgb are too separated.

But we agree with Uschold that the analysis is quite tricky to do. For example the 16-shot image from Sinar also got a poor SFR result. In short one could say that the SFR analysis judge the contrast of and image at a certain resolution. As long as the resolution is roughly equal between cameras the comparison is fair. But since the resolution is so much higher for the 16-shot Sinar image, the poor SFR value is to some extend understandable. The contrast for objects wich you zoom in on that much will be visually lower, but the image is still very useful (as can be seen when comparing the 260 MB Sinar 16-shot image with the Kodak 48 MB image).

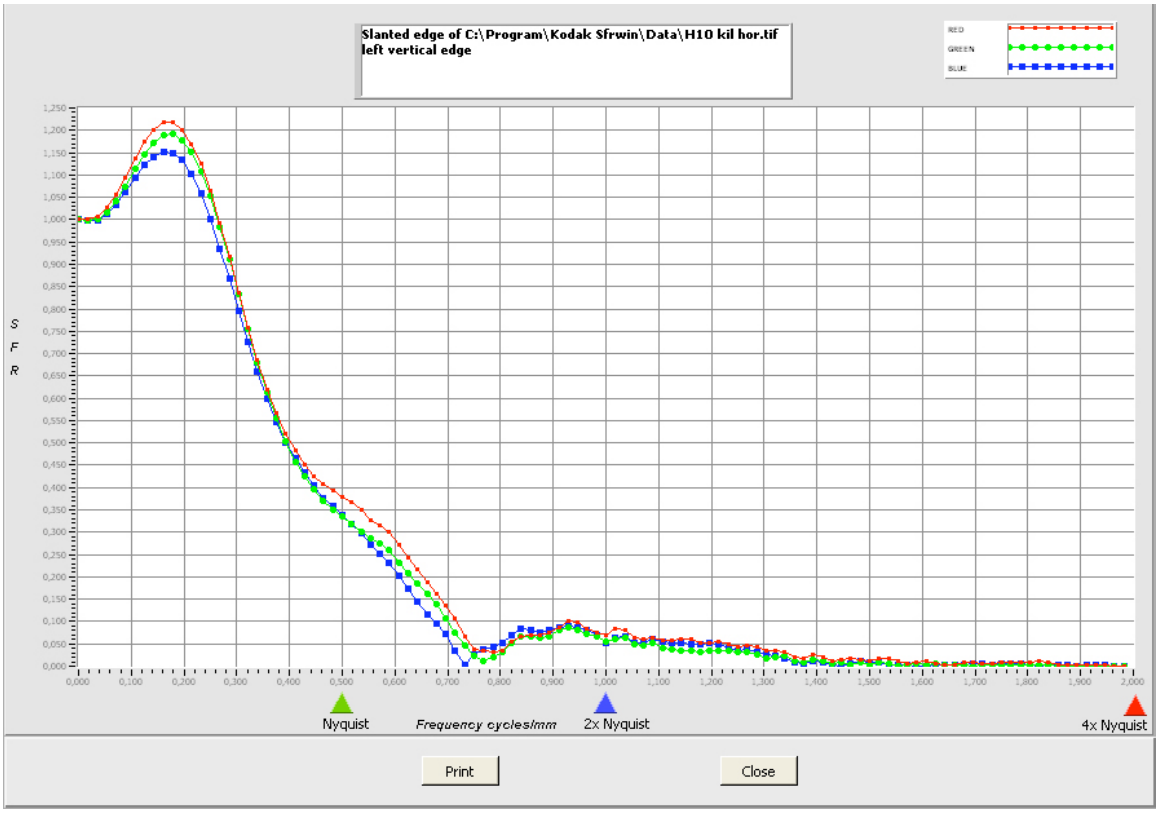
Another problem using the TU170 testchart is that it is designed to test digital cameras of about 2-3 MP resolution. The cameras tested here have more than double the resolution, so we doubled the distance of the testchart to the camera. When doing so we couldn't test the uniformity of the lens (lenses normally perform poorer at the edges than in the center), since the TU 170 testchart now didn't fill the viewfinder. But the main purpose whas to test the sensor and the processing software, not the lenses.

In the following we show the SFR results, cameraback by cameraback, continuing with the Leaf cameraback (the Kodak Proback is shown abow).

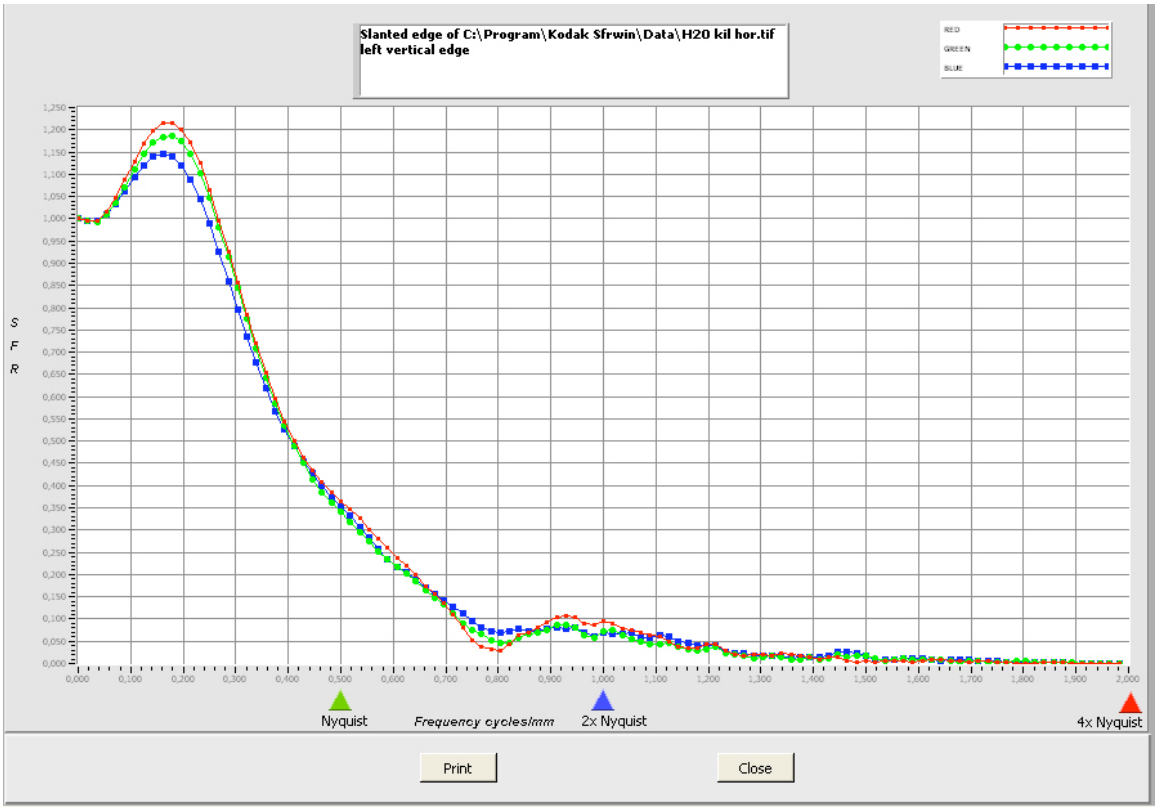
You can do an analysis of the SFR value for both horisontal pixel orientation and the vertical direction, but the differences weren't that great. We therefor only show the SFR diagrams for the horisonal pixel axis.



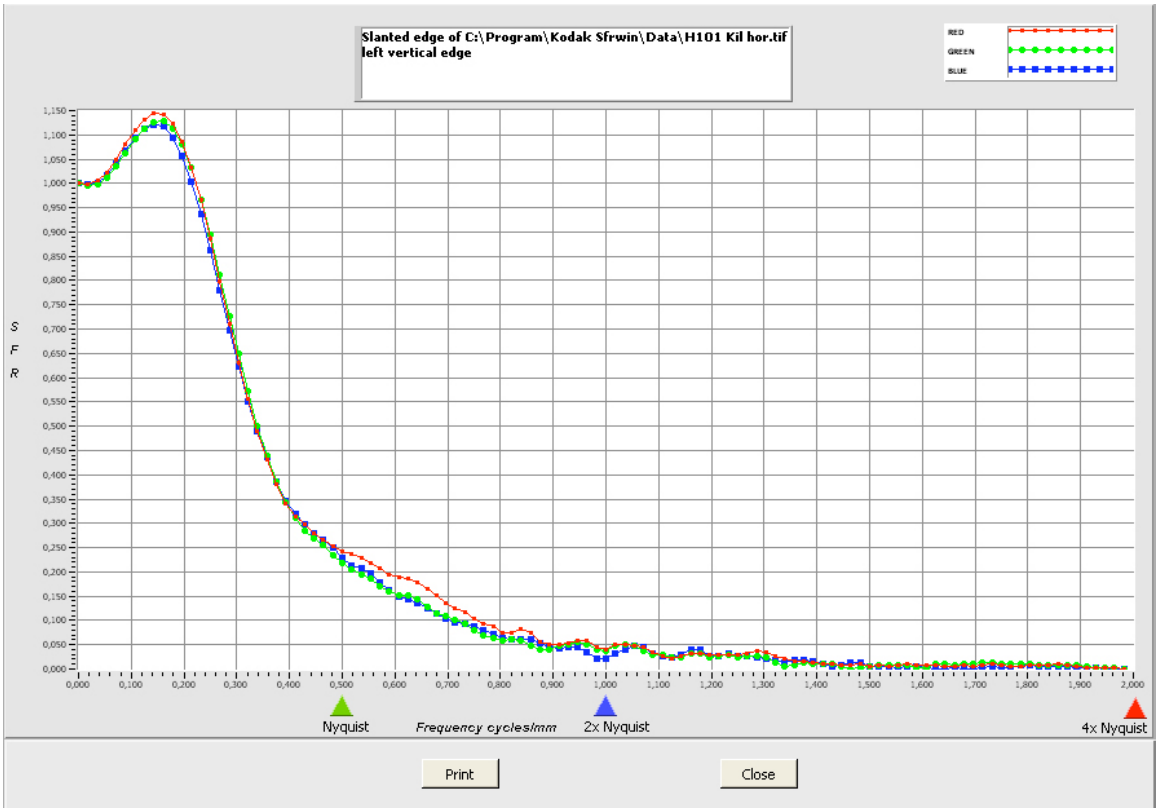
SFR Analysis; Leaf Volare 11. The curves keep close together and are well abow 0.1 at the Nykvist value (green triangle).



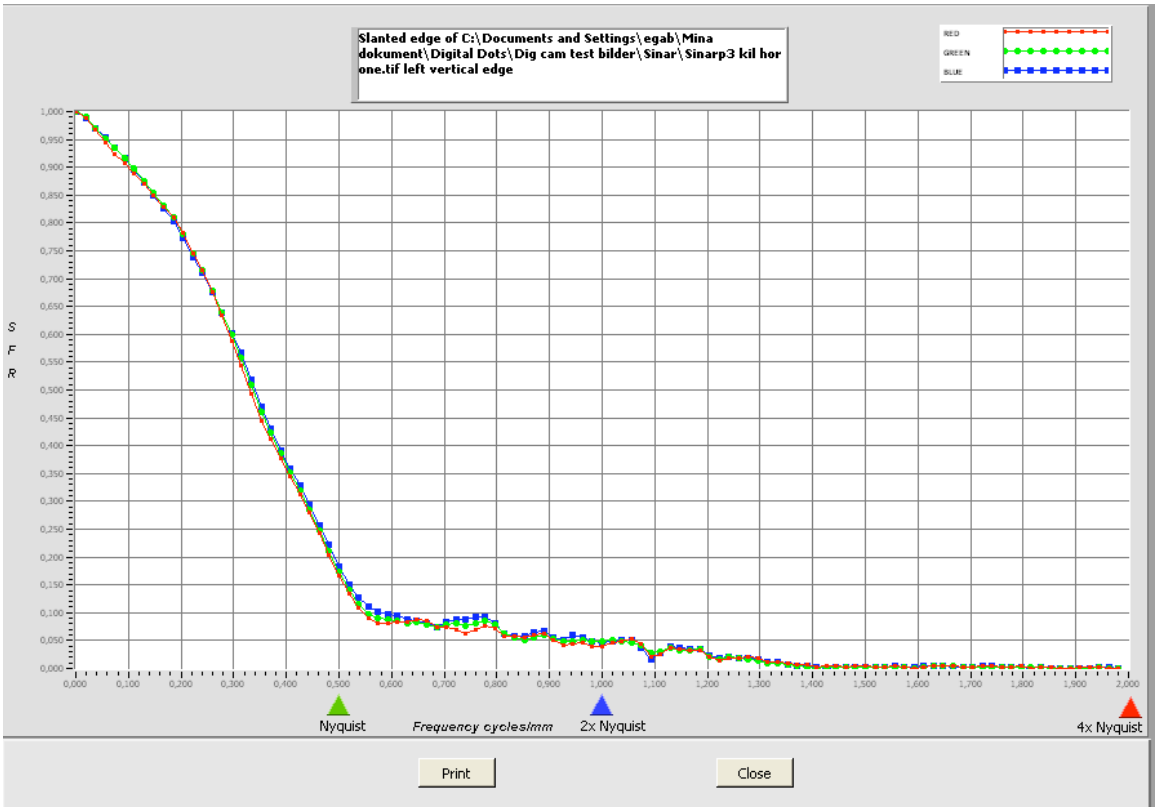
SFR Analysis; Phase One H10. The curves keep resonably close together and are well abow 0.1 at the Nykvist value (green triangle).



SFR Analysis; Phase One H20. The curves keep resonably close together and are well abow 0.1 at the Nykvist value (green triangle).

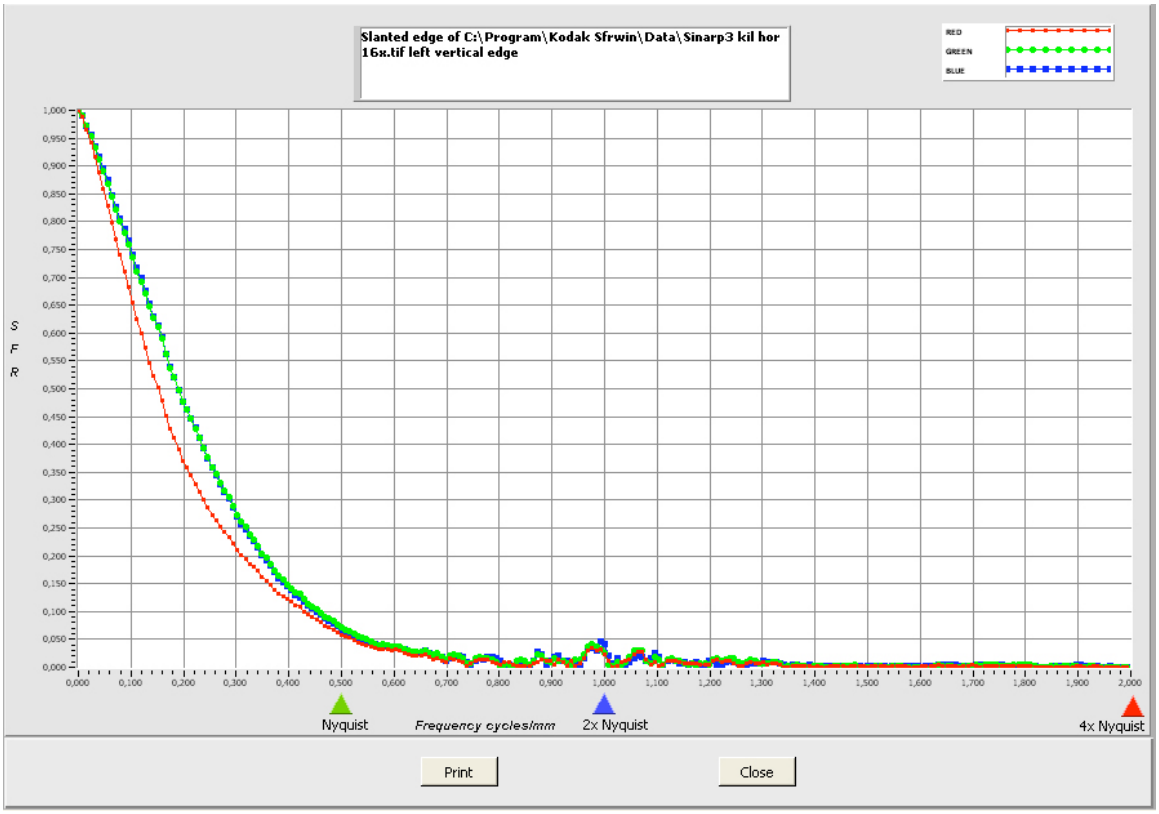


SFR Analysis; Phase One H101. The curves keep resonably close together and are well abow 0.1 at the Nykvist value (green triangle).



SFR Analysis; Sinarback 54H – one shot . The curves keep extremely close together and are well abow 0.1 at the Nykvist value (green triangle).

SFR Analysis; Sinarback 54H – 4-shot . The curves keep close together and are well abow 0.1 at the Nykvist value (green triangle).



SFR Analysis; Sinarback 54H – 16-shot . The curves keep fairly close together but are not abow 0.1 at the Nykvist value (green triangle).Since the resolution is so much higher here – crop from a 260 MB file in comparison to for example the Kodak 48 MB file, the low SFR value (low contrast) is somewhat misleading.

Paul Lindström conclusions and comments

Before starting the tests we pondered on what should happen next if there were no significant difference between the camera systems tested. As it turned out we didn't need to worry about that – there are many differences, both in the camera systems' workflow designs, the control softwares' functionalities, and not the least resolution and colour quality achieved. Generally spoken digital photography is now at a very high lever both regarding image resolution and image quality.

The differences in the workflow may seem subtle but still noticeable. With the risk of oversimplifying one could say that Phase One tend to process the images quite "hard" with the default settings, to make most of the images ready to use directly without any manual intervention by the photographer. In contrast to this Leaf tend to process the images quite "soft" with the default settings, leaving the post processing to be made when the final usage is known. Obviously this is a kind of "political" choice to make by the vendors, in guessing what the typical workflow look like for their costumers. One way to argue is that images should go into some kind of image archive before final use, and therefore have little production processing applied onto them in this first stage. If for example very hard sharpness is applied on an image this can never be entirely reversed later, the image is "ruined". On the other hand time is money, and another approach to take is that the images should come out of the processing software with a "pleasing look", which often mean quite sharp and with an enhanced colour saturation. We have mentioned Phase One and Leaf as examples of how you can take different approaches in this matter.

Looking at the Sinar processing software they operate more or less in a division of their own. The possibilities and features seem to be endless, especially when it comes to colour management. There is a feeling of heavy duty ingeneering over the software which attracts some user obviously, but may defer some. In contrast to this the Kodak software is in the other end of the scale – fast and easy to use. Almost too easy – the advanced user may not find all the function wanted. And when it comes to speed the Kodak software may be too fast as well. Processing a raw data file in the Kodak software is twice as fast as for example the same file size processed by Phase One (44 seconds processing the file from Proback 645H in the Kodak software in comparison to 104 seconds processing the Phase One

H20 file in the Capture One software). However the prize for this higher seem to be inferior image quality in the Kodak image. The Phase One image seem to have higher optical resolution and less tendency of moiré than the Kodak image. And this is from camera backs that use the same type of sensor, the Kodak 16 MP CCD. We can't know for sure, but possibly Kodak would reach a better result, more similar to the one Phase One show, if they Kodak allowed the user to choose a slower but more accurate processing of the images.

Our questions weather the 16 shot mode really achieved a higher resolution than the normal 4 shot mode were fully answered. It does. The pictures taken with the Sinar camera p3 using the Sinaron "digital" lens offers an amazingly high resolution. Looking at those images we discovered that some dust had fallen onto the surface of the coffe in the coffecup! That there is a big difference between shooting in one-shot mode and 4-shot mode we knew already, and this was again confirmed in this test.

The general conclusion to make is that the camera backs of today have a high dynamic range and can capture more or less all colours thinkable. The number of f-stops available when shooting digitally are simply more than shooting with analogue film. Using good lightning equipment in a proper way and controlling the exposure settings carefully your get the most out of the sensor. Proper composition and setting of the light is still fundamental in photography. Shooting digitally doesn't change this. Choose camera according to the type of work you do – there are differences even at this professional level reflected in this test.

Conclusions and comments – Thomas Wilke

It's interesting to note how the vendors more or less on purpose have focused on different segments of the market. This revealed in the way the software is designed and how the default workflow is set up. Regarding Kodak their solutions clearly are aimed at portable photography, typically outdoor shooting of live and moving objects. The images are stored in the camera and the software process the raw data files fast.

For Leaf the situation it quite tuff. From having been the market leader they for example at the moment doesn't have a appointed distributor in Sweden. They

seem to fall somewhere between Kodak and Phase One in the market. But their solution for portability are nice, and I very much like the software module for removing moiré already on the raw data 16 bit image files. To me the software development at Leaf seem a little slow – I would like to have the possibility to process the raw data image files directly in Oxygen, but this isn't yet possible.

Phase One is able to reach several types of users with their broad range of products. It looks like they have a little "non-technical" approach in their marketing, to keep the link to traditional analogue photography. An example is that they have chosen not to show the exposure meter or gradation curve tool in the base window of the image processing function. This may be because they want to steer the photographer away from adjusting the image here, in the software, rather than spend more time earlier on making sure to get the correct exposure settings.

I think that the images produced by Phase One is of a better quality and with less the tendency of moiré than some of the competitors. If this is thanks to longer processing times or better algorithms I don't know, but it looks good. I'm not sure that the default setting of for example unsharp masking should be that high, but probably many photographers like the images to be "ready for use" directly after processing to 8 bit rgb. And there is always the possibility to change the default values if you prefer "softer" images as a standard.

Sinar offers the highest quality possible; there is no question about it. But it's at the same time a more demanding system, technically. At least I think that this is the view of many photographers. If you have experience from scanning beforehand, I'm sure there should be no problem, even with the advanced and somewhat complex software modules. Using the multi shot features gives you impressive resolution and image details. However I'm not sure it's actually needed in that many applications.

My favourites therefore are Phase One and Sinar, depending on application.

Conclusions and comments – Andreas Bohlin

It's easy to fall into gargon when discussing digital photography. What has been said over the years about for example "what colour space is the best to use" or "how to calibrate the camera" is often irrelevant if not plainly wrong. What is

more, those discussions often miss the really important issues. The fundamentals in photography, which are the light, the optics, and correct exposure/smooth tonal rendering.

A photographer may have to wait hours for the perfect light, this we know. Some photographers will wait for weeks. When working in a studio the composition of the light is as important as ever. The most important thing when testing different exposure settings is to capture all the tonal values you want reproduced in the image. Just when using analogue film. The different choices of colour space are a secondary question. Yes, you need to understand at least the basic technology behind digital photography, but the links to traditional analogue photography is very strong. Unfortunately I've seen too many digital photographers trying to adjust an image using the gradation tools, instead of using the correct aperture setting in the first place.

Technologywise we have come a long way, the sensors are big, there seem to be few problems with moiré. I would say that we don't need more pixels at the moment, but better algorithms in the softwares. There is definitely room for improvement here. As most of us have realised, it's the same make of sensor in many of the camera backs. When the sensor is the same, but the image quality differs, the difference obviously is in the software. From a quality viewpoint therefore the software is equally important to judge, as the choice of sensor, filter type, lenses and light system.

There are two types of image processing that I believe could be made better. First it's the extrapolation of missing image data in one-shot mode. The other is the sampling of the raw data from the sensor and filters. This raw data is actually quite poor. Both of those calculations are of course crucial in one-shot mode. If the extrapolation is made poorly from poorly sampled data of course the final image will be of poor quality. In multiple shot mode there is no need for extrapolation – the pixel information is there. But good processing of the sampled pixels is still important.

There is an important break trough when it comes to processing the raw data. Just a year or so ago it was more or less impossible to find a camera vendor that suggested the costumer to use the software from a competitor to process the files. But today several vendors, among them Canon and Nikon, have made the file format of their raw data image files open to the best processing software on the market, at least for one shot mode. I mean the Capture One from Phase One. The

camera manufacturers seem to have found their niche, and are prepared, at least in some cases, to point to other softwares than their own, for best processing of the images.

Among the tested camera backs here I personally think that the quadrelatural format of the sensor in the Kodak Proback and the Phase One H20 is a bad solution. Most images used are rectangular, landscape or portrait mode. It's a lot of expensive pixels that get thrown away. And finally I think it's a shame that Kodak isn't capable of processing their image files in a better way – they do a lot of other things so well! I don't think that slowing down the process will help – they need better algorithms.

It's good to see that Leaf has got things going again. I like the software and their solutions regarding portability. And the images are of high quality.

It looks like Phase One has some really good programmers that they should hold on to tightly. The software is really good – both because of the image quality achieved and because of the user interface that I as an amateur photographer really like. It seem a little stupid to me though that you can't export to any profile of your choice, you have to use the Phase One "boosted" profiles. There is of course a workaround – you can switch the colour management off and work directly to a calibrated monitor of high quality. But in this area there is room for improvement.

Sinar have established themselves at a high quality level among photographers, and are well respected worldwide. The multiple shot mode offers incredible high resolution – higher than can be reach using analogue film and scanning the images on a drum scanner! The one shot mode I think can be improved, even if the result at the moment is satisfactory.

Thanks to

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Special CDs

This is a report by Digital Dots (www.digitaldots.org). To properly evaluate a digital camera back it is particulary important to view the high-resolution images on screen. This report and all the evaluated images in high resolution is available on a special CD for E150. Orders can be made at the web site.