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Resolution bottlenecks in digital image capturing

photokina, Germany
27 september 2002

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What is resolution?

- **Sensor size, number of pixels**
- **File Size**
- **Lines per image height**
- **MTF of the lens**
- **Compression**
- **xxxxxxxx**
- **.....**

All of this is not resolution!

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Resolution is …

… what you get in the end!

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Resolution is an overall result of:

- sampling rate, sensor size, number of pixels
- MTF of:
    - lens
    - sensor
    - microlenses
    - low pass filter
    - signal processing
- sharpening, signal processing, interpolation, noise reduction
- aperture, diffraction
- lossy compression
- assembling accuracy, optical centering, damages
- costs **etc …**

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Typical tradeoffs

sensor size & good marketing specs	<->	oversampling / low data efficiency
popular 35 mm - SLR - lenses	<->	limitation by the “non-digital” design
compact lens design	<->	lens quality & resolution & useful aperture ranges
small sensor size	<->	diffraction & bad S/N-ratio
sharp & brilliant look	<->	noise & artefacts & bad postprocessing
sophisticated signal processing	<->	processing time & battery load
noise and dust compensation	<->	loss of resolution
compression	<->	loss of information
assembling accuracy & quality management	<->	production costs

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Detection of bottlenecks and weak points

R&D quality tests mostly take place in the sophisticated examination of components or the interaction between a few of them. But the consumer always “tests” the whole system. The quality he gets, is the result of all aspects and tradeoffs mentioned before.

Based on the approach from the user’s point of view, the test environment DCTau® uses the black-box-principle. From a set of test images, a sophisticated classification extracts individual marks to discriminate and evaluate the components’ capabilities and weak points.

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First bottleneck: digital adaptation of „analog“ designs

A popular (but wrong !)assumption:
“Silver halide film is equivalent to about 15 - 30 megapixel”

→ Well, a 20 MP-sensor in a 35 - mm - body should be our goal!

Silver halide film works over a broad range of angle of incidence. This allows various designs of “analog lenses”.

Electronic sensors do have significant problems with slanted beampencils of light. The best solution are parallel beampencils. Using microlens-shifting, a sensor can be optimized to a certain distribution of angle of incidence. Unfortunately existing sets of 35 mm - lenses do not share the same distribution.

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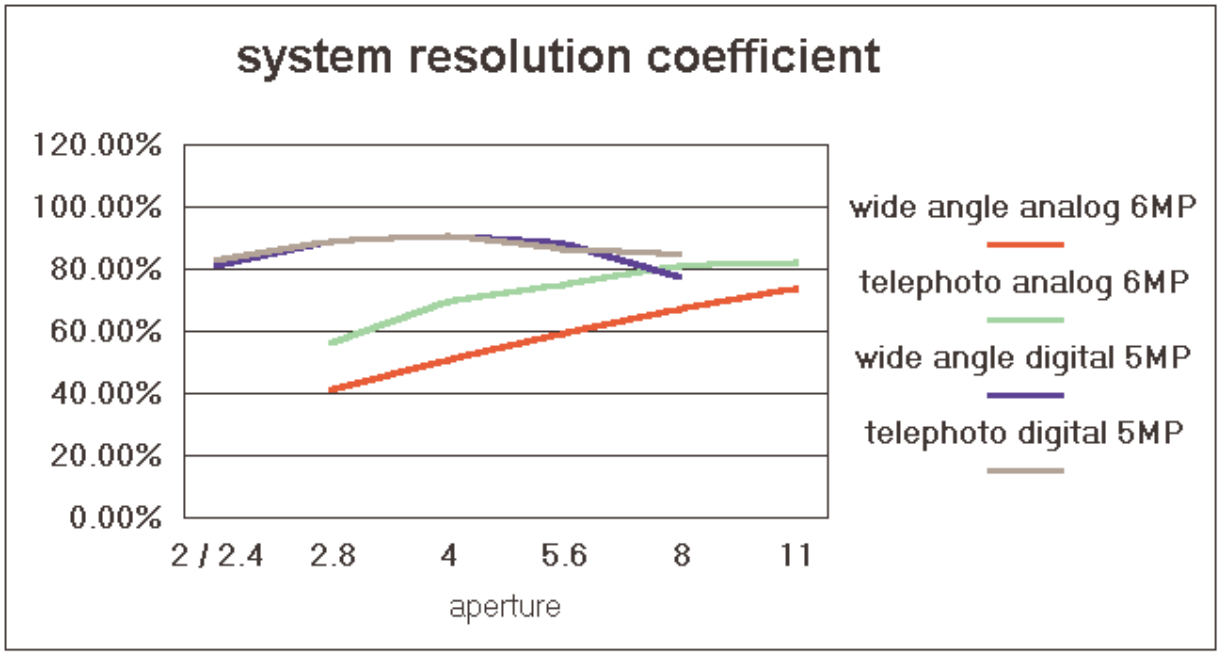
Comparison of two 6 megapixel - models using 35 mm - lenses and a 5 megapixel - camera with a digital designed lens. The **system resolution coefficient** in DCTau® describes the system‘s efficiency and trim at various aperture setting.



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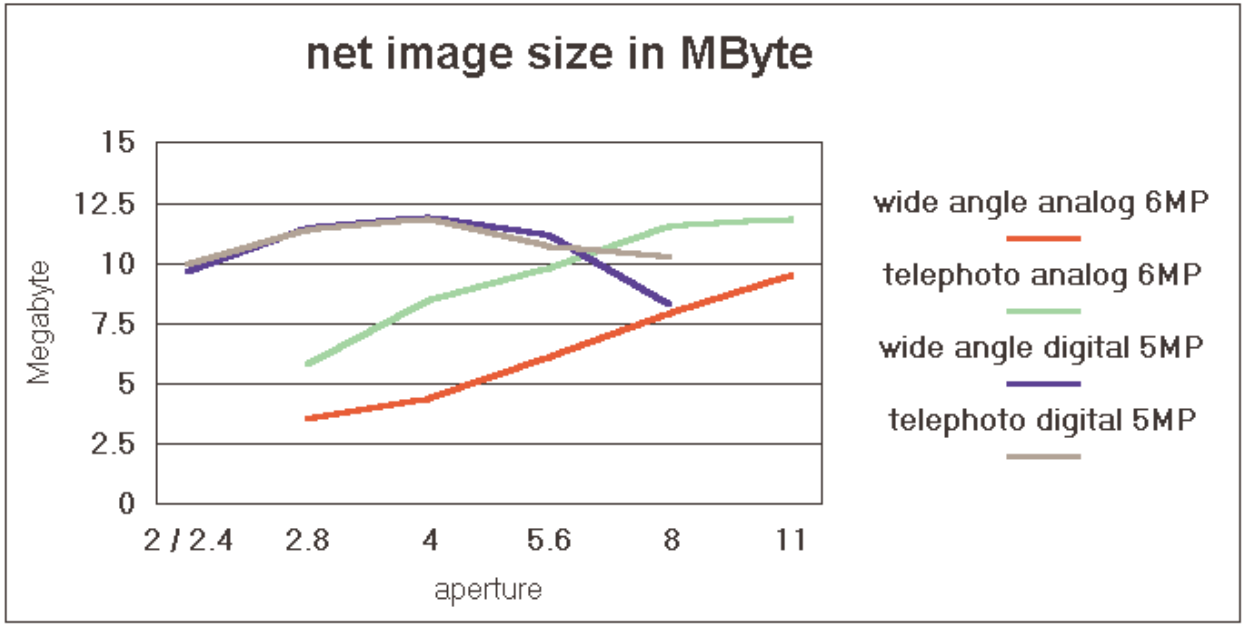
The **net image size** shows the usable image file content, without unsharpness or data redundancy. Here, the smaller sensor even gains more information from his optimized system.



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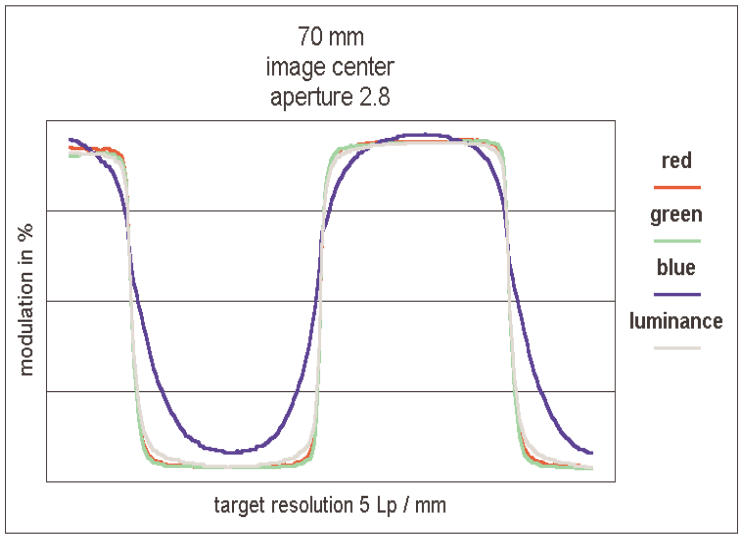
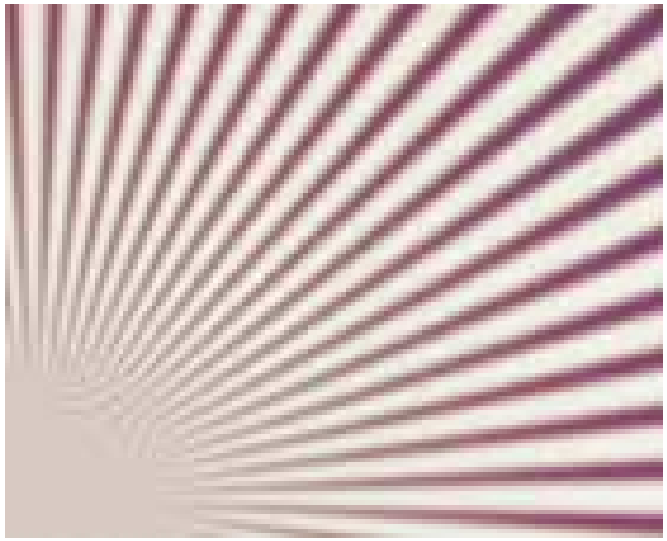
The focal length difference of blue light interferes with the pixel size. At maximum aperture occurs a strong blue flare, reducing contrast and resolution.





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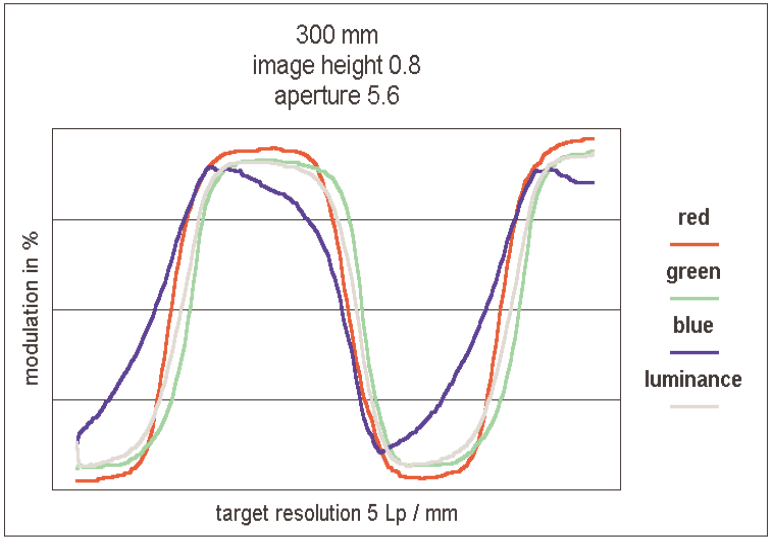
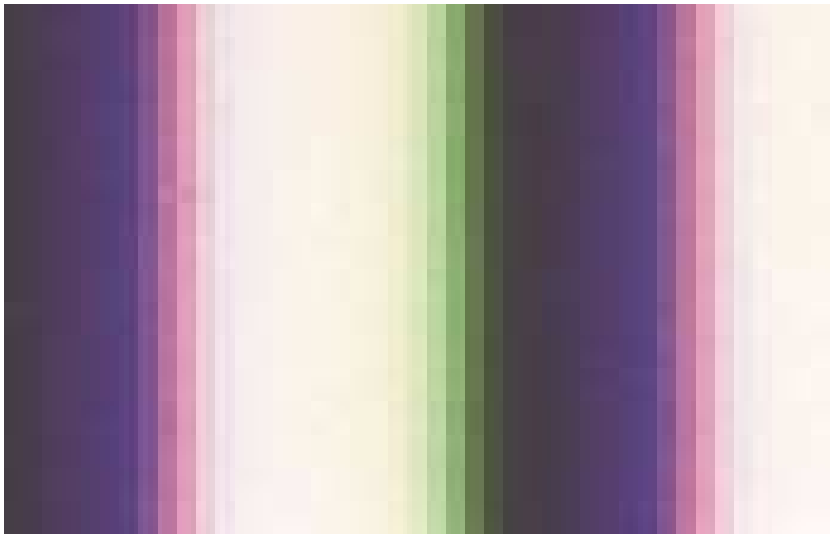
Chromatic aberration is capable to interfere with the pixel matrix or the mosaic color filter. Strong aberrations is capable to produce a serious loss of quality.





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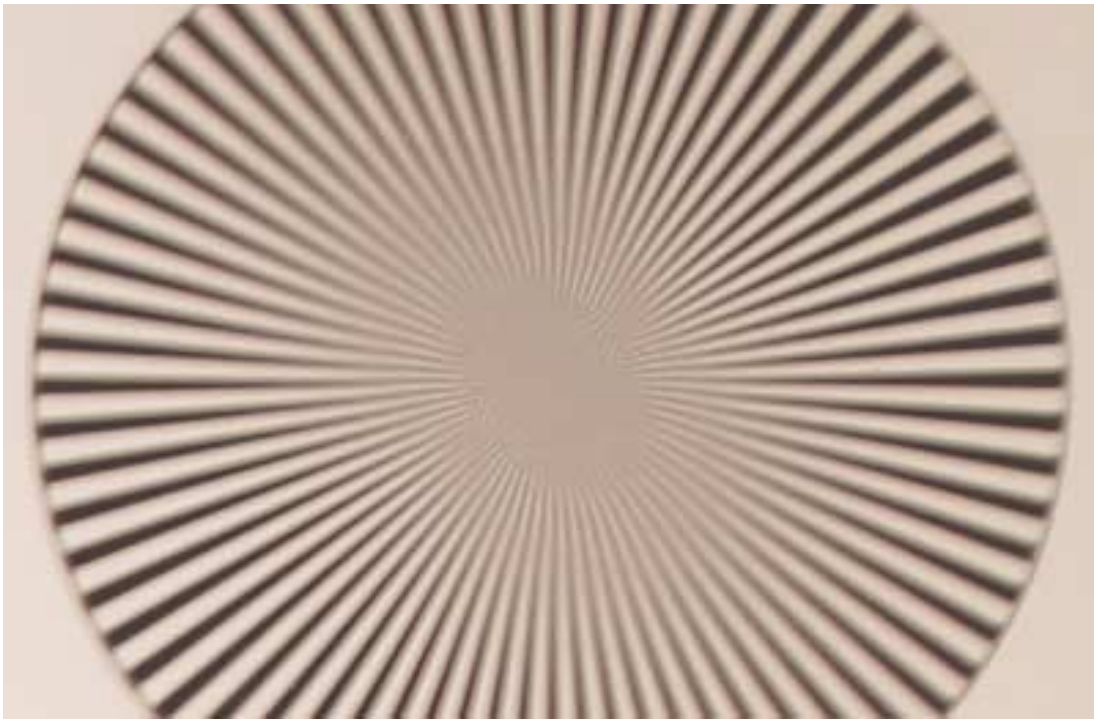
Defect caused by a combination of astigmatism and the petzval surface.



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Second bottleneck: assembling accuracy

“During an editorial test of digital cameras of 2 megapixel and 3 megapixel, in june 2002, six of nine cameras showed visible to critical defects. All of them were dedicated test samples, provided by the manufacturer.”

- About 40 % of digital the cameras tested in the past, show visible restrictions
- About 20 % show critical defects
- The defects occur over the whole quality and resolution range and with almost every manufacturer.
- A German survey result: Manufacturers do not possess appropriate testing or quality assurance systems nor at the production neither at the service resorts.

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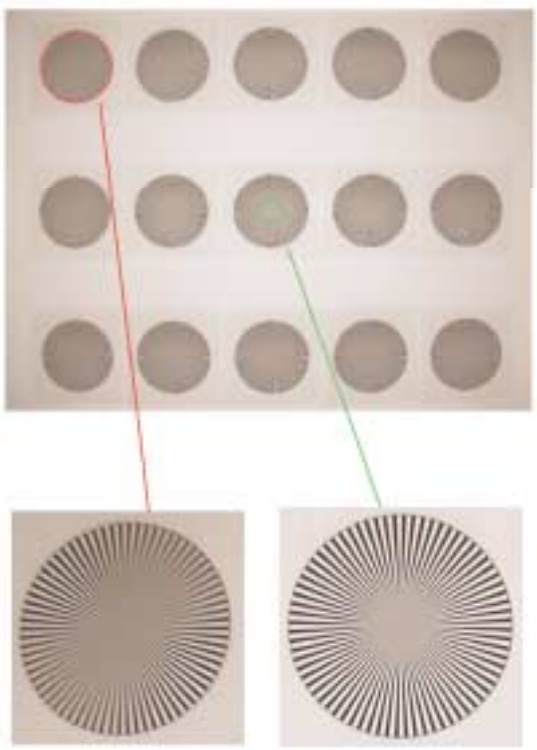
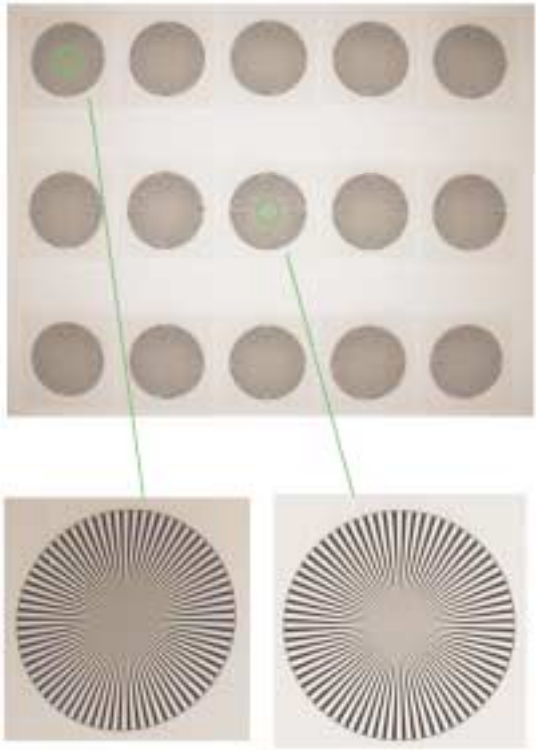
Two samples of one model, showing critical and good results:





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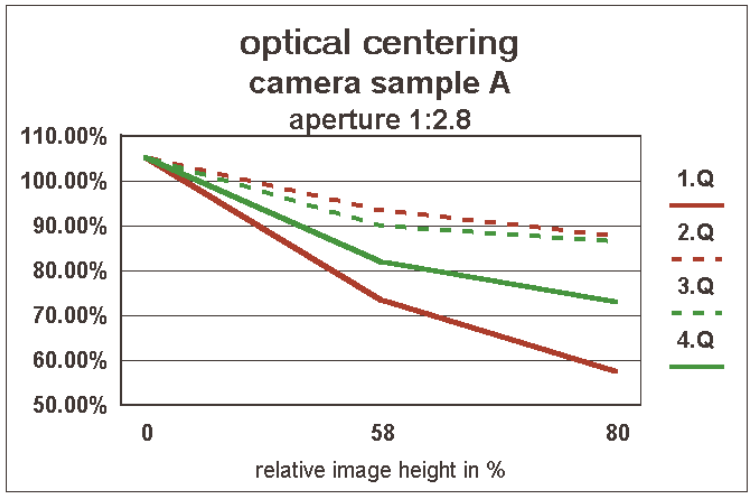
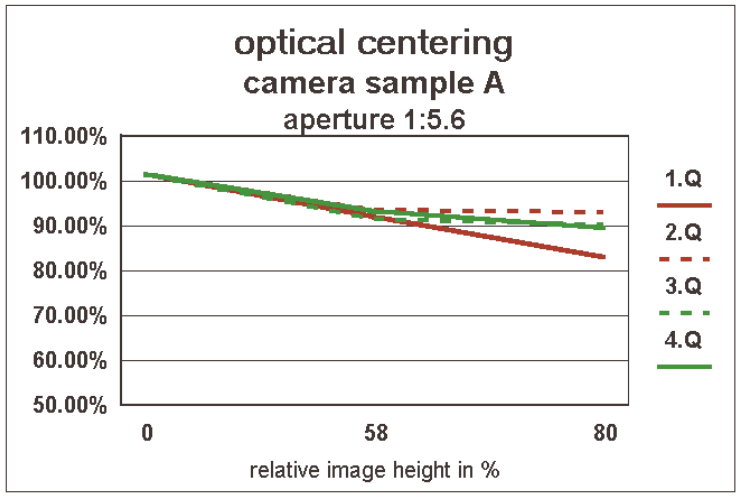
Centering defects must be evaluated at open aperture:





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There is a relevant need for suitable tests and quality assurance & management systems to gain various benefits:

- Better tools for the R&D
- Higher reliability during the assembling process
- Less complaint by sophisticated consumers and a better reputation
- More efficiency at service & repair
- Elimination of unreliable samples for editorial tests (for further details, please see the report of *C. Loebich, A. Uschold*)

A dedicated version of DCTau® for R&D, production and service facilities is under progress. For further information, please contact us.

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Third bottleneck: image processing

Image processing is capable to affect resolution in different ways:

- The character of fine structures variies from moderate to aggressive: This results in restrictions or benefits to the most important consumer-groups: “shoot-to-print” and “sophisticated dtp”
- Image processing is capable to induce orientation - specific artefacts. They can vary in chroma and luminance aspects

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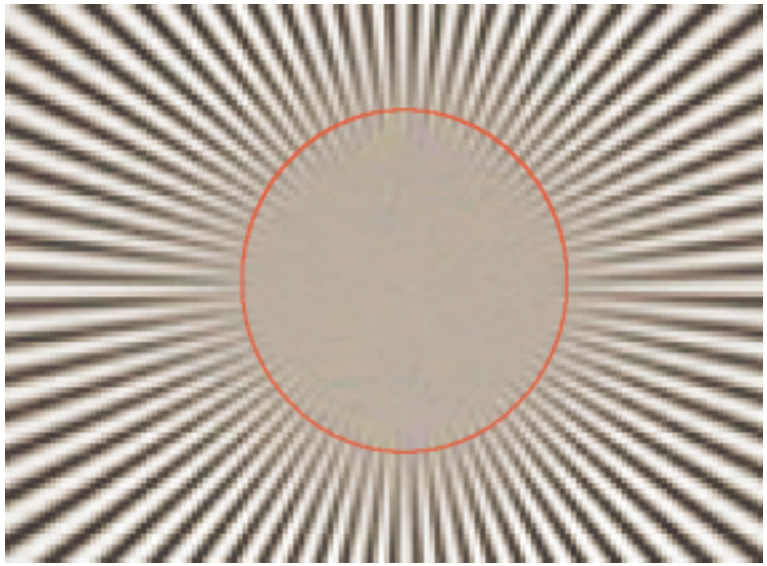
From moderate to aggressive sharpening. The latter does not produce a higher resolution but problems for sophisticated dtp:



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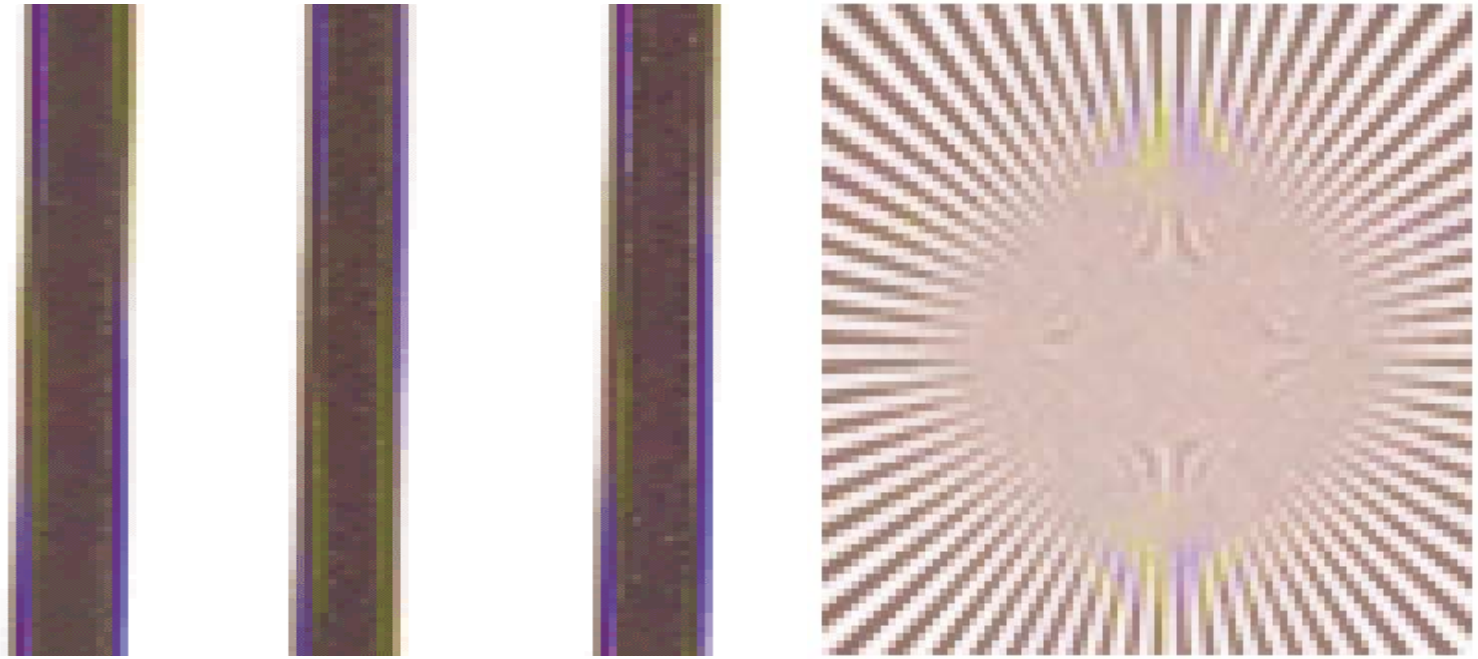
„Software-based“ chromatic artefacts at structures from 70 – 110 degree:



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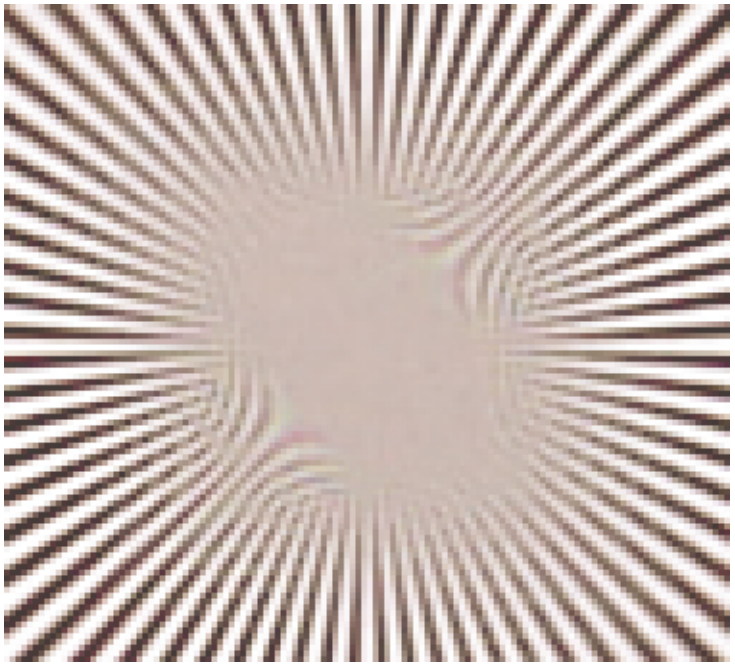
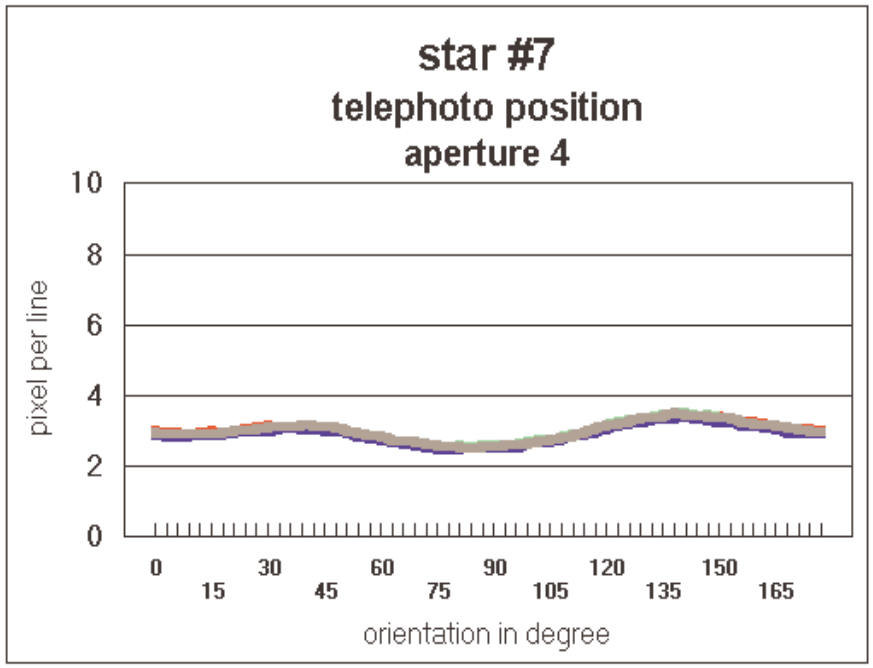
Extreme resolution - orientation - dependency and significant artefacts, typical orthogonal CCD. This mark is not evaluable using the ISO slanted edge method:





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Fazit

Resolution is a very complex topic. It is a result of many interfering aspects and technologies. Due to inherent tradeoffs and different needs of several consumer groups, nor the optimal resolution neither the perfect camera can be created. Three examples tried to give a first impression about the complexity.

To avoid bottlenecks and weak points it is recommendable to improve test standards regarding the whole system, not only parts of it. On the other hand collaboration between all technical groups like semiconductor, optical, software **and** independent external experts is advisable.

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Information about the expert

Anders Uschold studied computer science at the Technical University of Munich, with scientific photography and digital image analysis as major subjects. He teaches as assistent professor for digital imaging and digital photography at the Institute of Computer Science, Department of Digital Image Analysis, Technical University of Munich, Germany.

He is an expert, publicly certified by the chamber of industry and commerce and member of the DIN / ISO - committee phoki 2.2 / TC 42 WG18 , „Photography“.

Since 1995 he is working as a journalist for several german magazines.

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