Commercial Scanners and Science
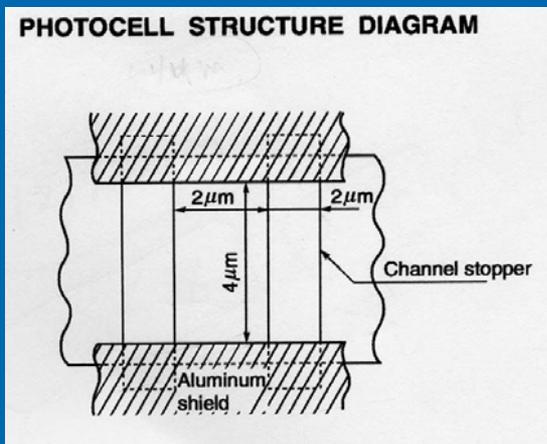
Specs vs Reality

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Starting with Pixels

➤ Photosensitive area on the CCD chip

PHOTOCELL STRUCTURE DIAGRAM

2um x 4um
Photosensitive
Area (8 sq um)

This pixel would often be called a 4um pixel even though the sensitive area is 2um x 4 um

The fill factor (sensitive area %)would be 50%

Some chips have microlenses over the pixel area to focus light onto the sensitive area to try to achieve 100% fill factor
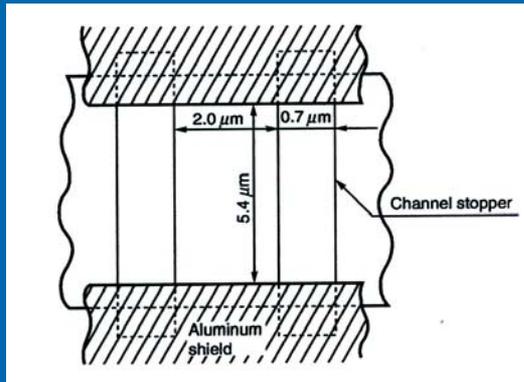
Optics blow up the chip pixel to the size needed at the platen

(1200dpi over 8.5' = 10, 200 pixels)

10,200 pixels over 8.5" => 21.16um pixels at platen   5.29X optics needed.

Pixels vs Marketing

➢ NEC /Epson? Pixels

This 2.7um x 5.4 um pixel (with micro-lens) seems to be in common use in NEC chips and I believe in Epson scanners like the V750

Notice that the pixel is not square! But has a 1:2 ratio between the X and Y directions. (greater dynamic range)

The CCD in the Epson V750 has 6 lines of 20,400 pixels (dual lines for each of the RGB colors)
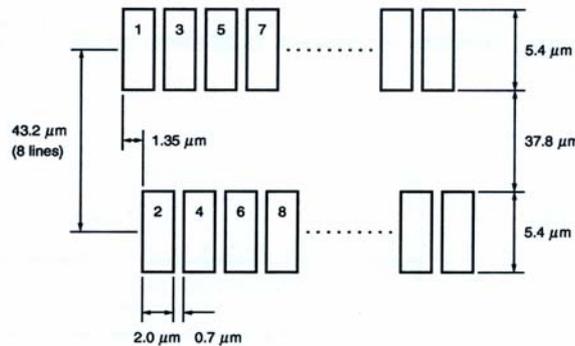
At the platen these pixels are really

(10.58um x 21.2um -2400 dpi x 1200 dpi)

Epson has two modes 2400 dpi over 8.5" and 3200 dpi over 5.9" by using two lenses (which also focus at different places)

➢ Marketing resolution with small Die

PHOTOCELL ARRAY STRUCTURE DIAGRAM-2 (Odd-even pixel)

6 Line CCD – each color consists of two rows of pixels offset by ½ pixel. Claimed resolution is the sum of the pixel count. (e.g. a 4800 dpi scanner will have two rows of 2400 dpi pixels and note that in the Y direction – the pixels are really 1200 dpi size)

Making Sub-pixels

In X direction take ½ of the value of the overlapping top pixel and ½ of the value of the overlapping bottom pixel to create an "non-optical" pixel of "higher" resolution.

In Y direction use the stepper motor/ mechanical system capability as the resolution
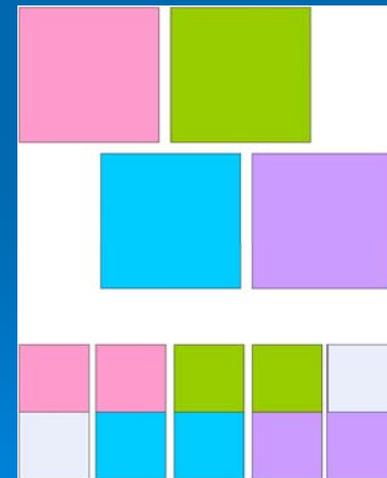
➢ The Epson scanner uses a six line (overlapped) tri-color CCD chip that has 6 – 20,400 pixel lines and has an active line length of ~55mm

➢ The Nikon scanner has a 3 line scanner that does not have color filters, but instead is used to increase the scanning speed (for B/W). For color work they have different color LEDs. The line length is 10,300 pixels.

The pixel size for 4000 dpi is 6.35 um. We do not know what the actual silicon pixel sizes are. They also seem to be asymmetric from looking at the MTF.

Unfortunately the long scan direction is also the long pixel direction.

Dmax– A/D conversion & Noise

- Scanners often use the A/D conversion range to claim Dmax   This has little relationship to the real transmission density that can be captured from a film with these scanners and is very misleading

- The CCD chips typically have a saturation voltage of 2.5-2.7 volts. The A/D may assign 16 bits to that range hence claims of Dmax=4+

- But random noise is typically ~1.2mv and dark current variation is typically allowed to vary 2.0mv

- Allowing random noise and the dark current to be ~ ½ bit of full range then the actual range of the CCD is about 9 bits

- This means that the true D max is about 2.5D

- Interestingly, this is often identical to what many have found is the true dynamic range of film

- However as we will see the MTF can significantly degrade even this lower Dmax for small features

Sampling theory

➢ The Nyquist theorem states that a signal must be sampled at a rate *greater than twice the highest frequency component of the signal* to accurately reconstruct the waveform; otherwise, the high-frequency content will alias at a frequency inside the spectrum of interest (passband). An alias is a false lower frequency component that appears in sampled data acquired at too low a sampling rate. The following figure shows a 5 MHz sine wave digitized by a 6 MS/s ADC. The dotted line indicates the aliased signal recorded by the ADC and is sampled as a 1 MHz signal instead of a 5 MHz signal.
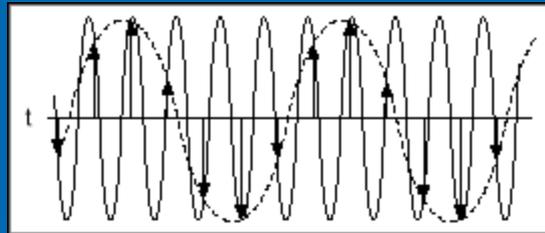
Sine Wave Demonstrating the Nyquist Frequency

➢ **To account for phase shifts a safer criteria is to *sample at 3x* the highest frequency component**

➤ Aliasing
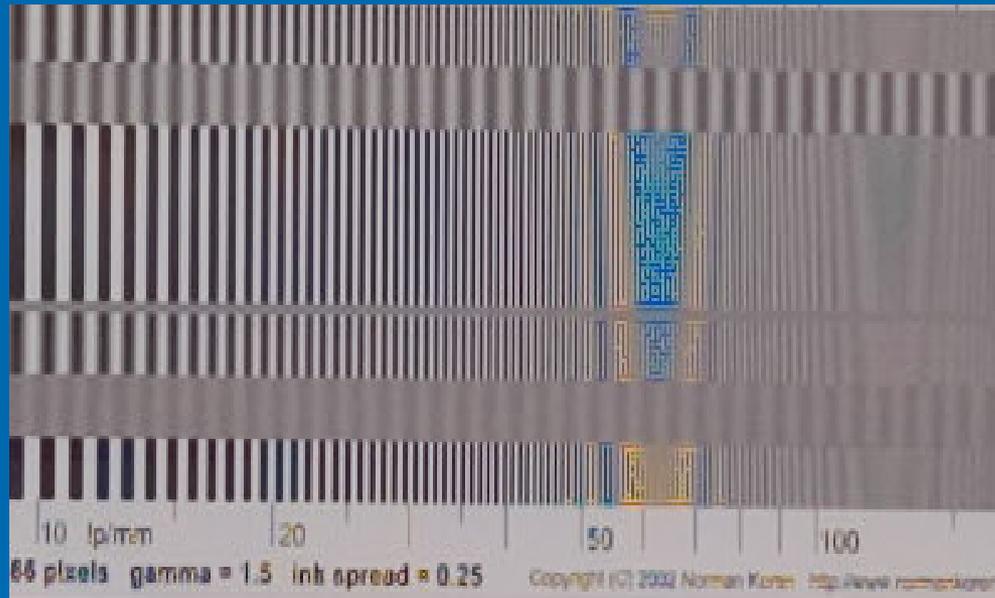
Courtesy of Norman Koren/Imatest

If the optical MTF is high in the frequency range beyond the sensor Nyquist and the data also has high frequency components there can be interactions that create false images.

Understanding MTF

➢ Modulation Transfer function - How well contrast is preserved

f50 = 45 lp/mm; fboost = 13 lp/mm; flens = 61 lp/mm; lord = 2; ksharp = 0.4

Sine pattern: Original
Sine pattern: Film & lens
Bar pattern: Original
Bar pattern: Film & lens

Bar pattern (bottom); Sine pattern (top)

MTF %, amplitude

Line pairs per mm; MTF = 50%,10% @ 36.8, 68.6/mm; Max MTF = 1.2
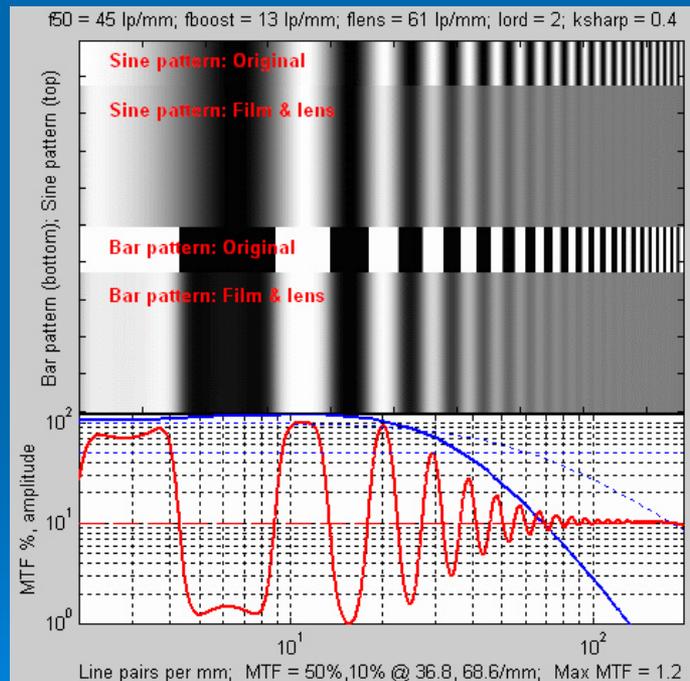
Courtesy of Norman Koren/Imatest

MTF is the multiplicative combination of all of the parts of the system that can affect MTF (contrast)

* Film

* Optical system of Camera

Scanner

* Mirrors and Lenses

* Sensors

100%
50%
10%
5%
2%
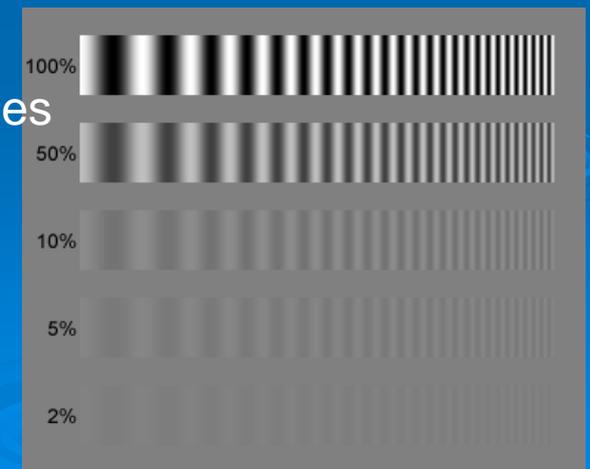
Three Different Scanners
Two commercial, one custom

➤ Epson V750 Flatbed scanner ~$700

2400/4800 over 8.5 x 11.7 inch

3200/6400 over 5.9 x 9.7 inch for film holders

➤ Nikon CS 9000 Film scanner ~ $2000

4000 dpi

2.24 x 3.3 inch max film size

➤ DASCH – custom digitizer – 4k x 4k CCD ~ $250k

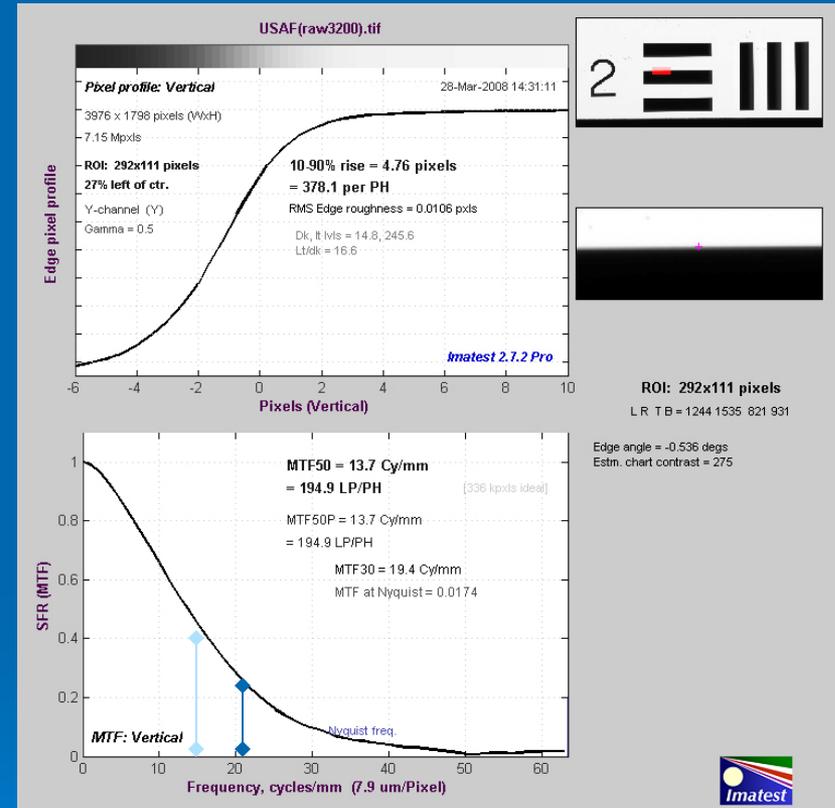2300 dpi over 13.5 x 16.5 inches (14" x 17")

Epson V750 optics

Light

Epson Folded
Light Path

First surface mirrors

LENS (2 -1 selected)

CCD
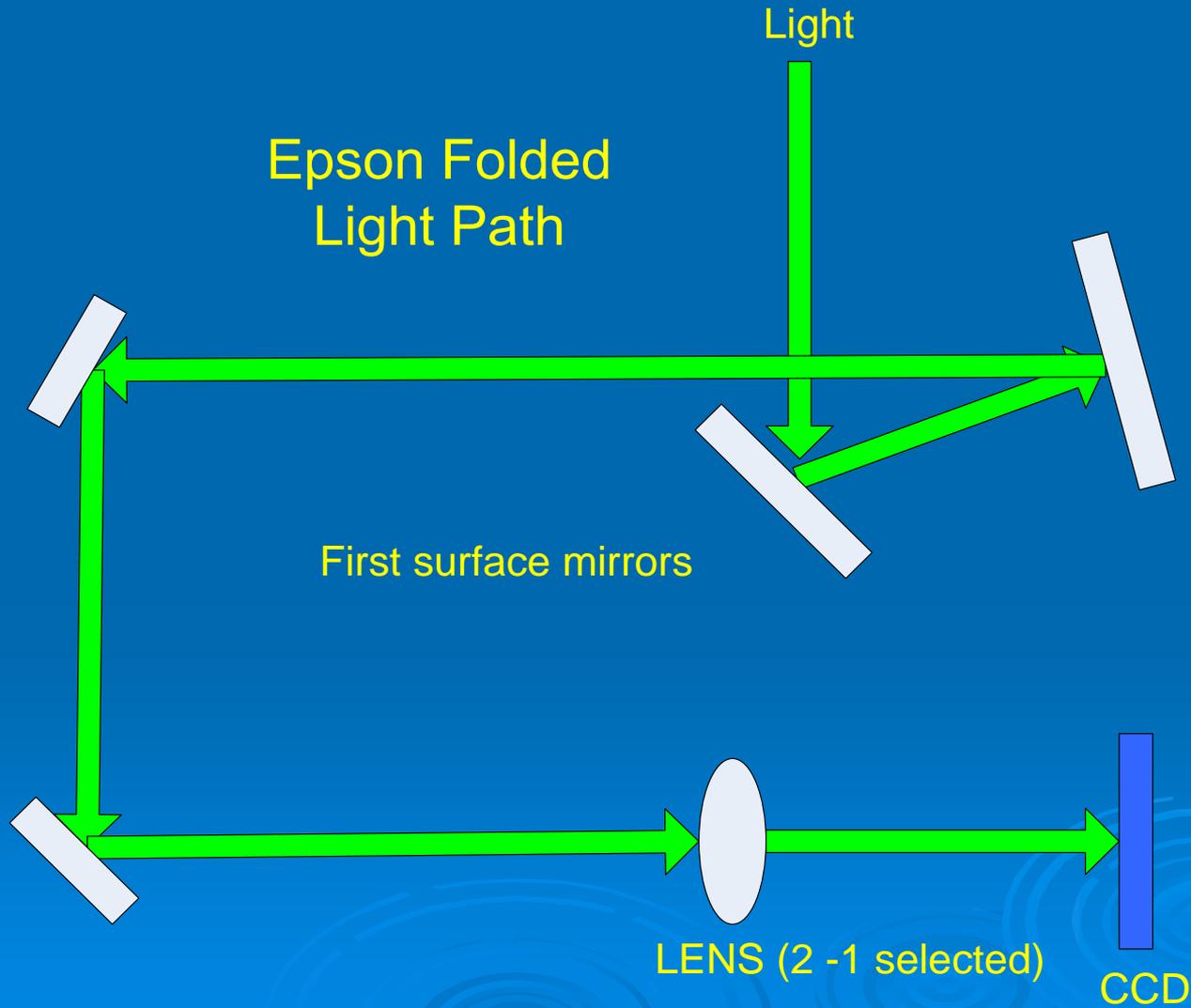
Epson V750 2400dpi mode
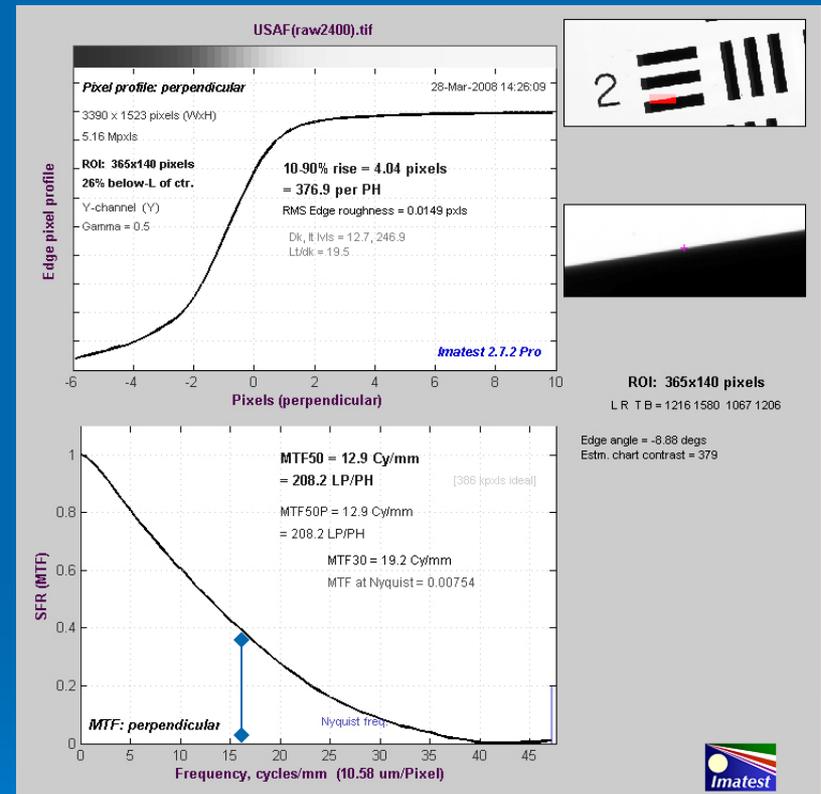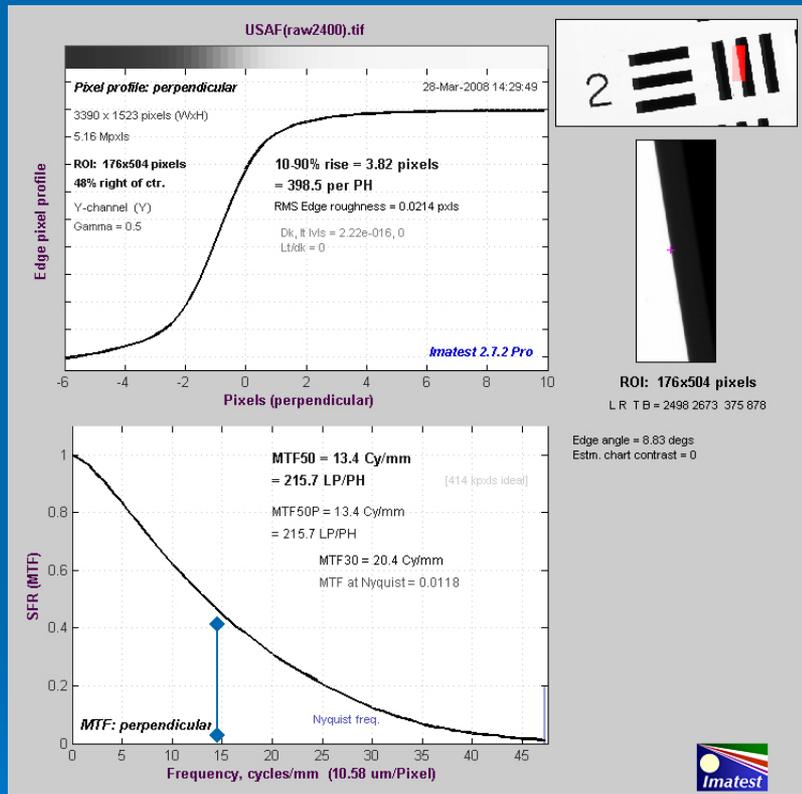
3 x - 10.58 um = 31.7um lines and spaces ~ 16 lp/mm

Epson V750 3200dpi mode
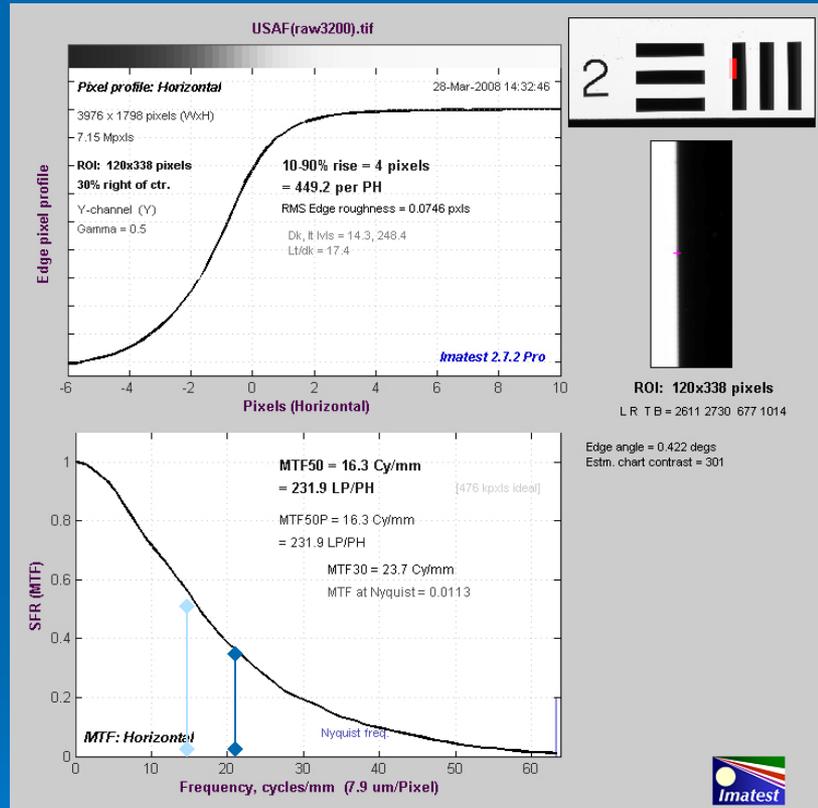
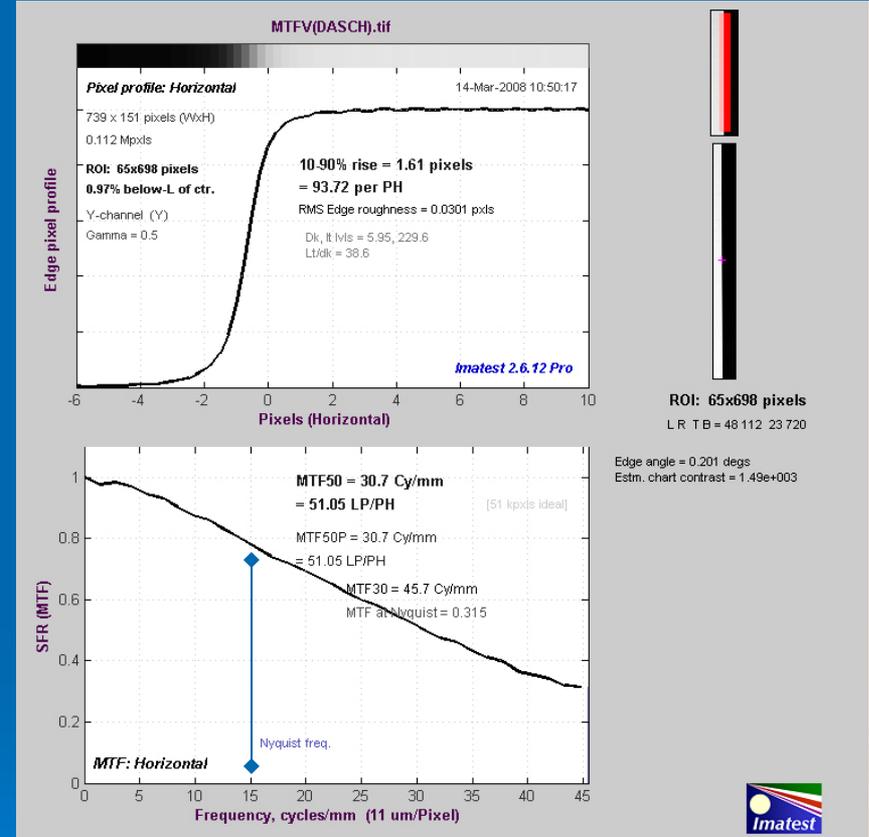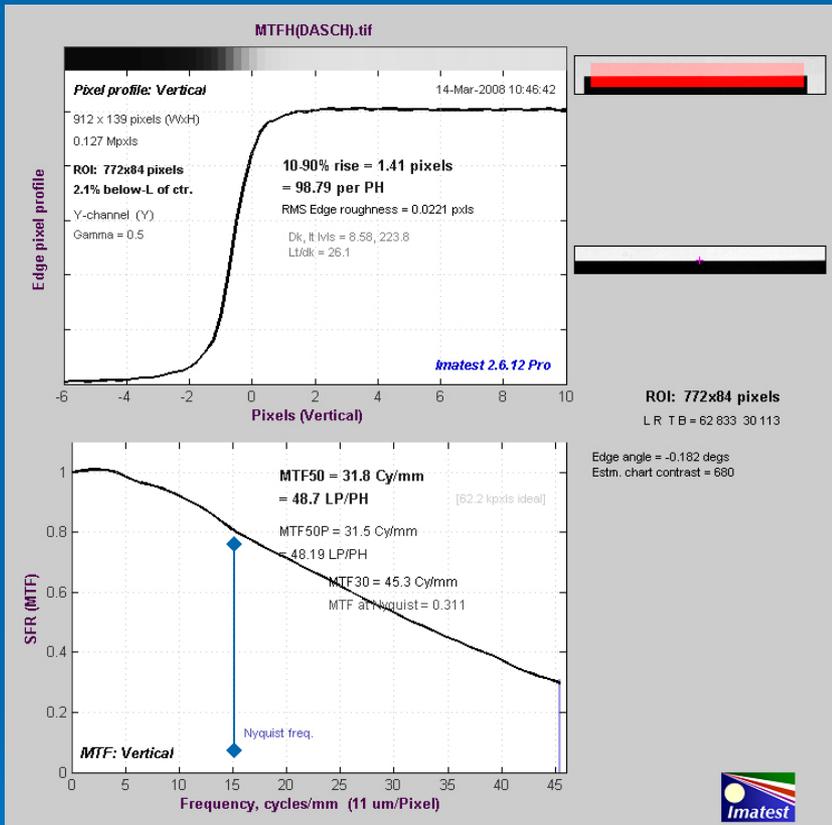3 x - 7.9 um = 23.7um lines and spaces ~ 21 lp/mm

MTF falloff is such that the 2400 dpi
and the 3200 dpi scans will show little difference

Nikon CS9000 4000 dpi
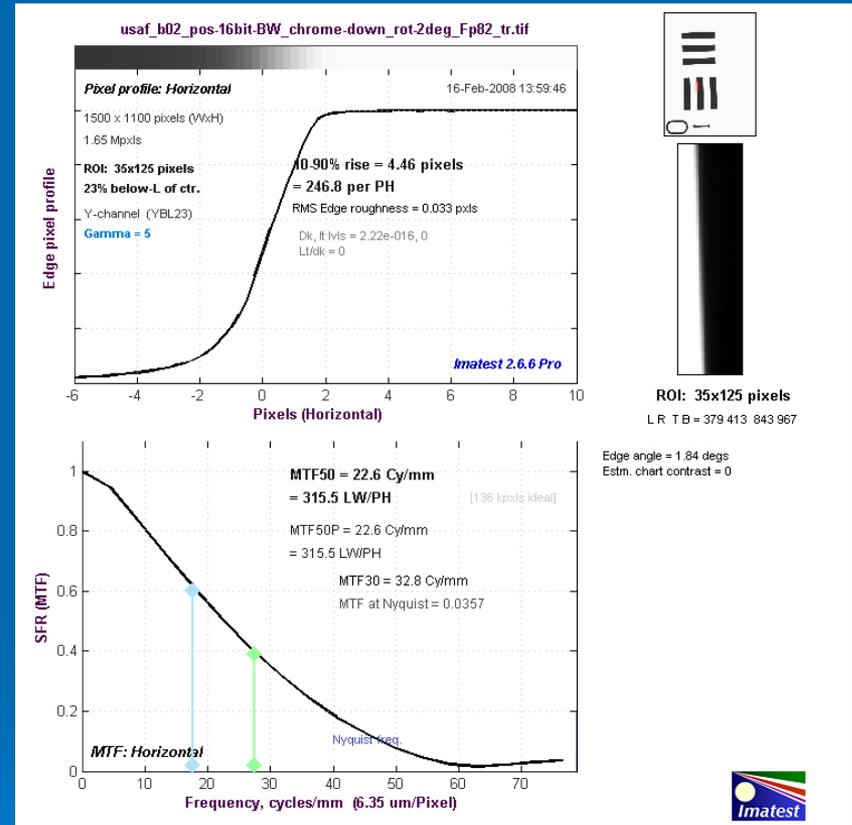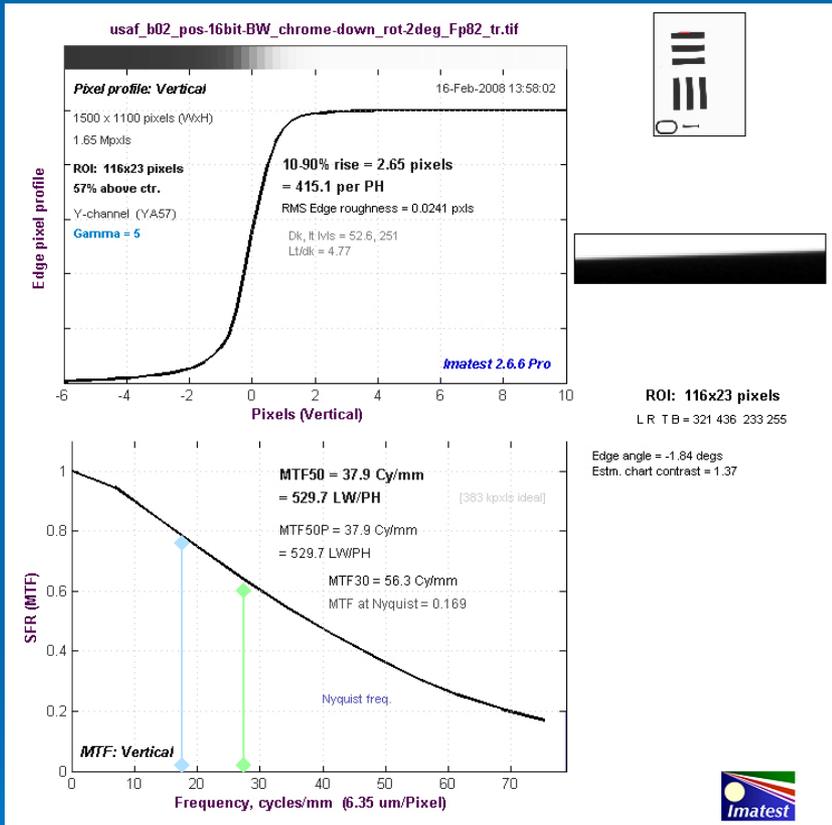
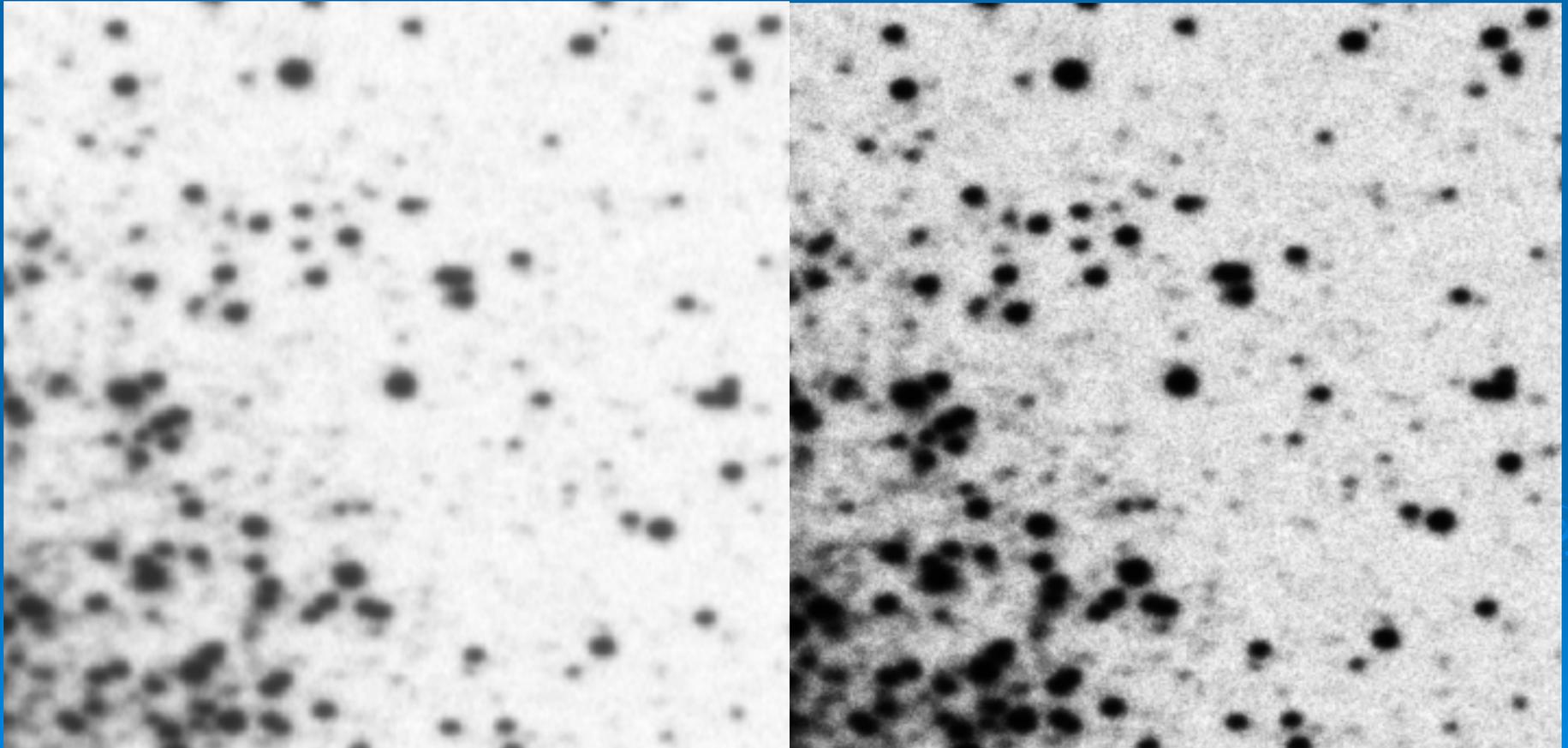3 x - 6.35 um = 19um lines and spaces ~ 25 lp/mm

DASCH Digitizer 2311 dpi

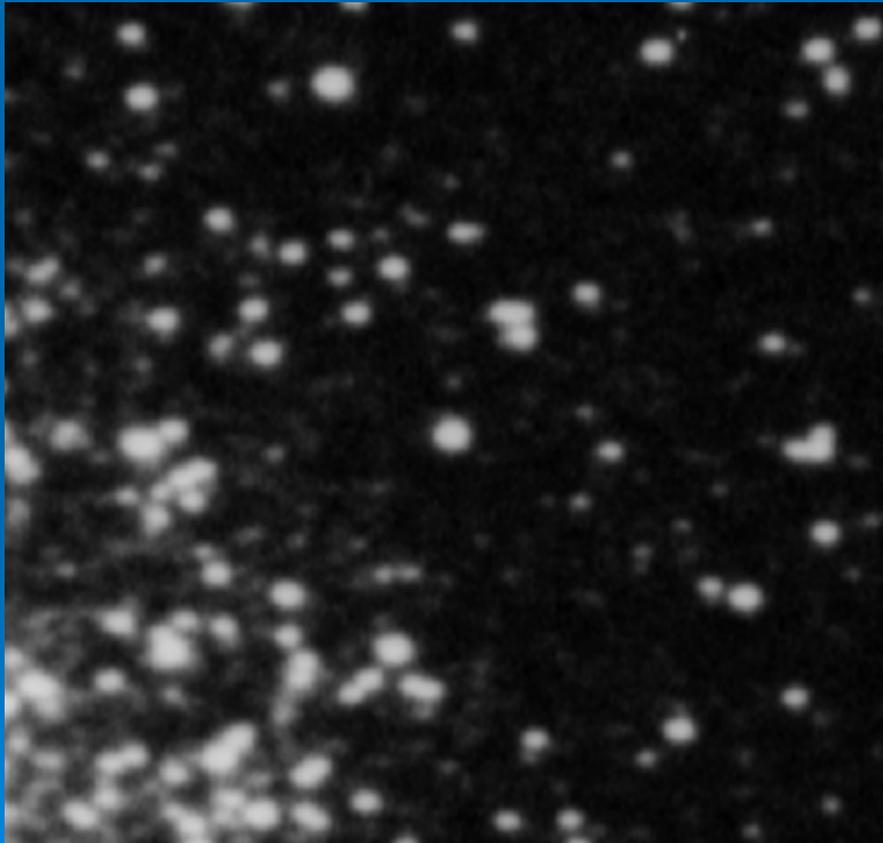3 x - 11 um = 33um lines and spaces ~ 15 lp/mm

Wide field plate
LC5820

Epson @2400 dpi ~ 40% contrast
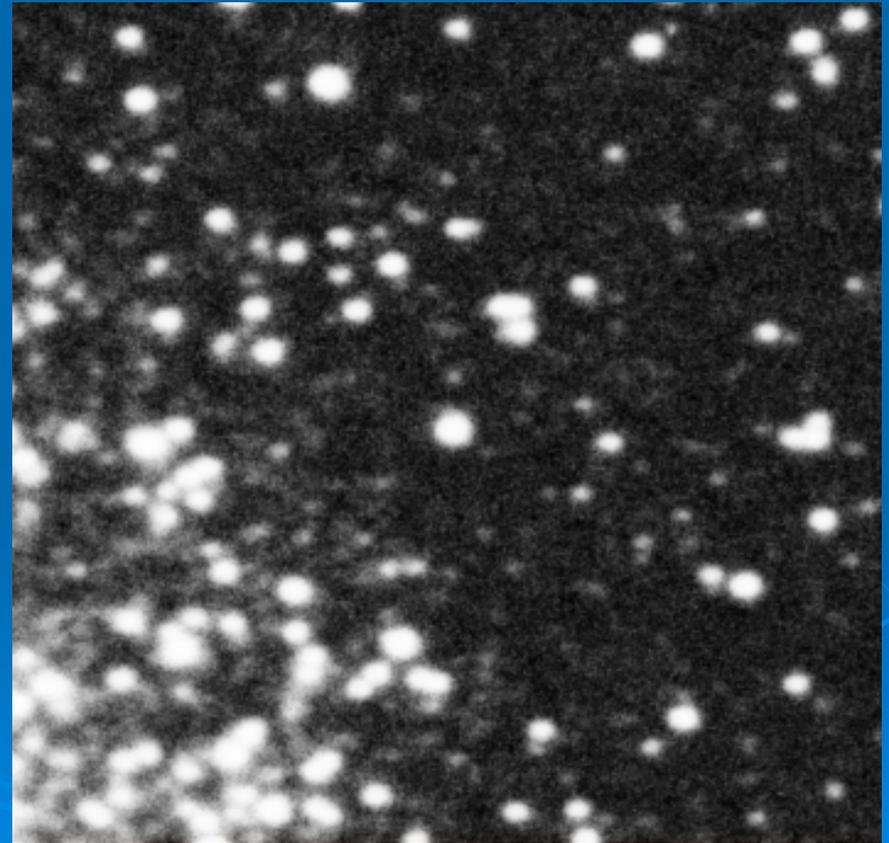
DASCH @ 2311 dpi ~ 80% contrast

Wide field plate
LC5820
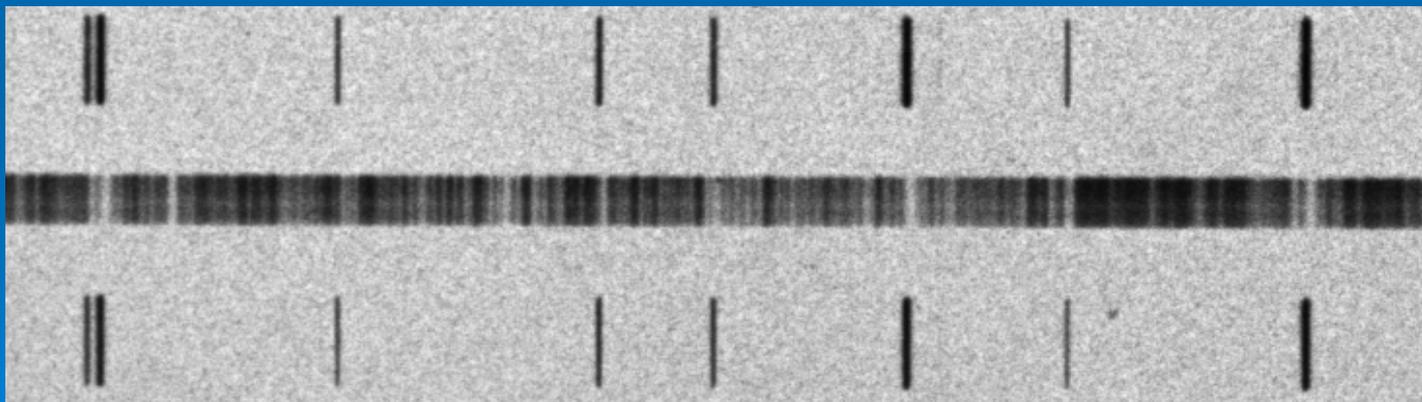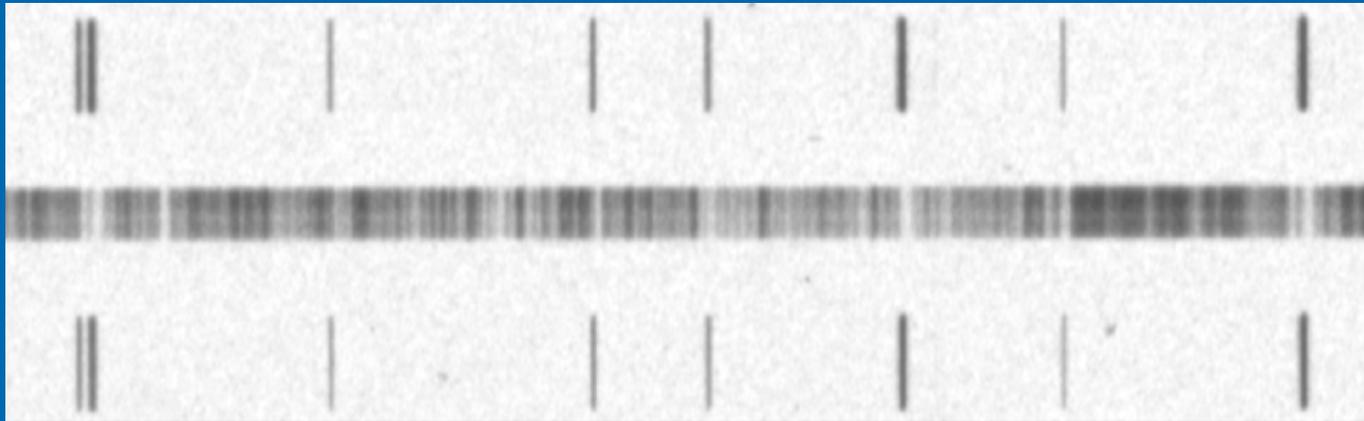
Epson @2400 dpi ~ 40% contrast

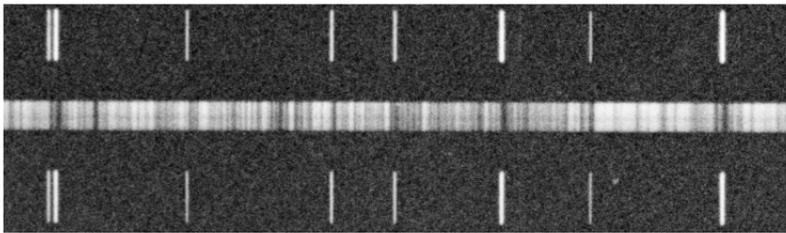DASCH @ 2311 dpi ~ 80% contrast

Area on Spectra plate
46848

Epson @2400 dpi ~ 40% contrast

DASCH @ 2311 dpi ~ 80% contrast

Both inverted in DS9

Dasch

Epson
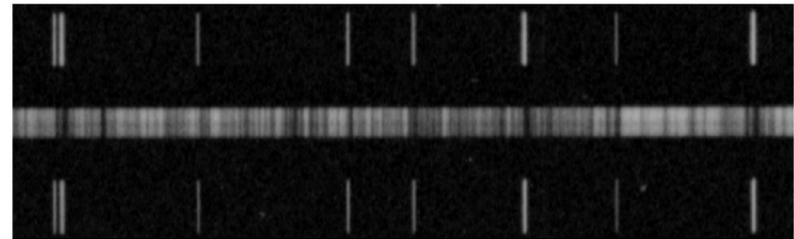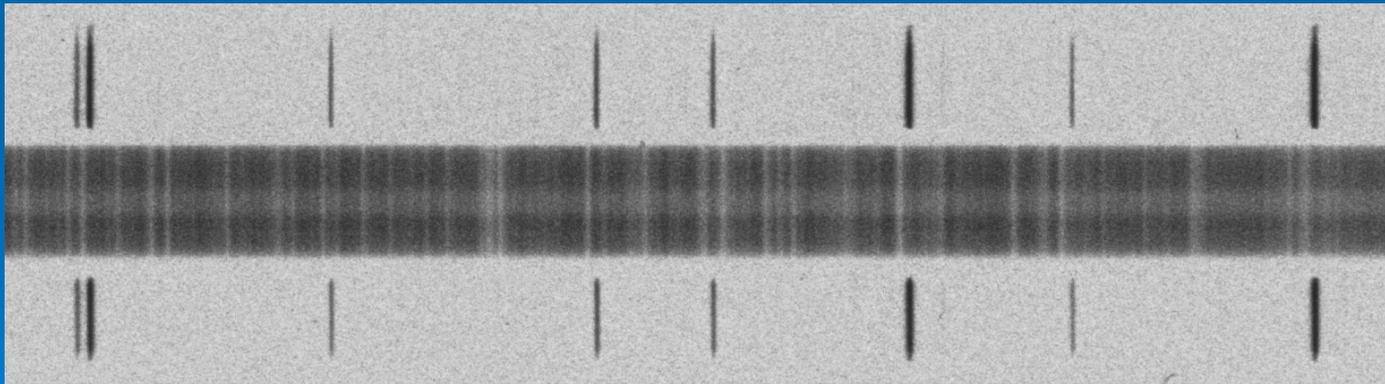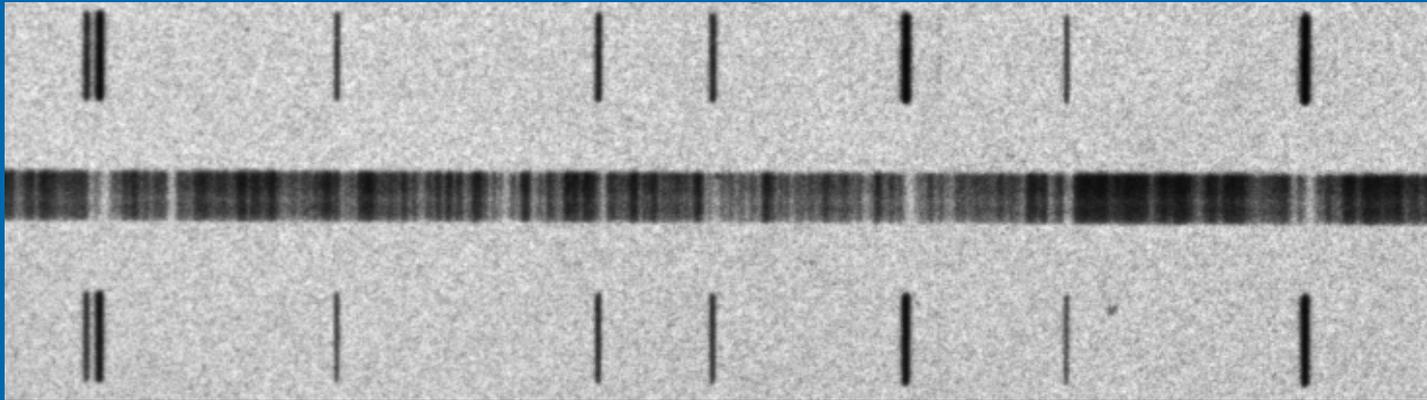
Dash(2311) and Nikon(4000)
(different spectra but similar lines)

Evaluations Underway

- Can either or both commercial scanners give results equivalent to a PDS ?
  - Ian is evaluating this and preliminary indications are that the Nikon has the potential to be OK for science
  - A problem with the Nikon is that it has a limited scan range and Spectra need to be scanned in two or more sections.
- Can the Epson be used for wide field plates?
  - MTF fall off means that the Epson scanner will not capture the photometric limits of the plates
  - Work is starting with Imants Platais to understand the astrometric limitations

Evaluations Underway

➢ The next few months will bring more quantitative results on the scientific usefulness of digitized data of the different scanners

➢ With MTF analysis we have a way to evaluate scanners in a quantitative way.   Evaluations of scanners on photographically oriented web sites do not generally provide good insight.

Thanks for your attention!

Questions?
Discussion?