

4k-HDR-Imagers

Dr Peter Centen
VP R&D Cameras

 FUTURE-READY



grass valley

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Agenda

❏ Imagers

- Enabler of HDR, MTF, HFR

❏ 4k and aliasing

❏ HDR

- Life is so much easier for the shader with PQ and it is reversible
- Knee and 709 is set per situation and often not reversible
- Zurich 2014 European Athletics Championships 12-17aug
 - How long do you need for post?.....after the event we are done it is live

❏ Colorgamut

- “Wider” colorgamut is already there, just a matter of another matrix

Sensitivity and signal levels

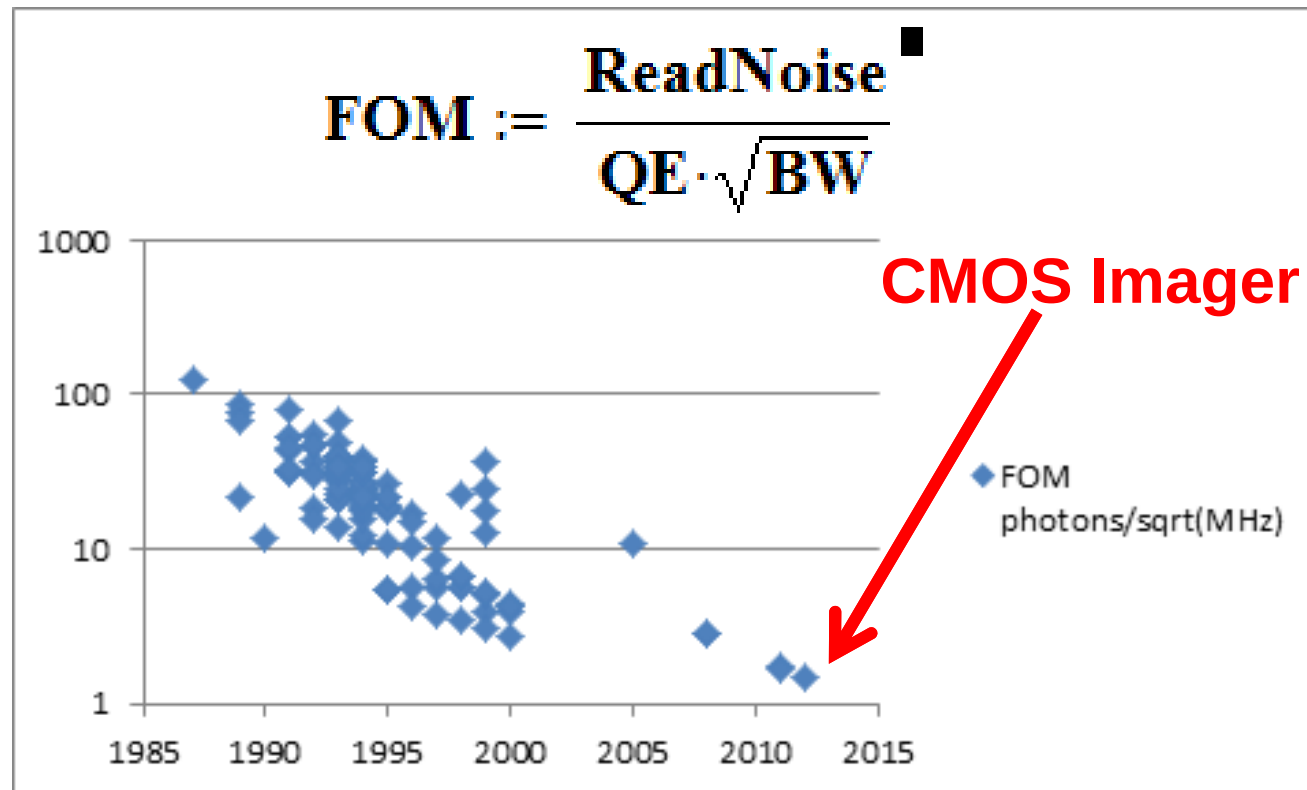
- ❖ 2000 lux; 89.9 %; 3200K, f/11
- ❖ Blackbody radiator 3200K: 6000 photons/lux.sec/um²@BW+IR
 - A 5um pixel collects in 16.67ms

Mastergain	Red	Green	Blue
0dB	3206 photons	3029 photons	1114 photons
0dB	1924 electrons	1818 electrons	668 electrons
+12dB	481 electrons	454 electrons	167 electrons

How many bits are enough

- ❖ *In a pixel electrons are generated and the number of electrons is proportional to the number of photons hitting the pixel.*
- ❖ *There are only 'whole' electrons, the pixel-output signal is quantized in steps of 1-electron. Eg 1,2,3,....,1000,...,12021*
- ❖ *The maximum number of bits needed to represent a signal from an imager including shotnoise may always be limited to $^2\log(Q_{\max})$.*
 - $Q_{\max}$ is the maximum number of electrons a pixel can store.
 - A 5um pixel a $Q_{\max}=15\text{ke}$, so 14 bits is enough
 - More bits will only represent the read-noise more precise!

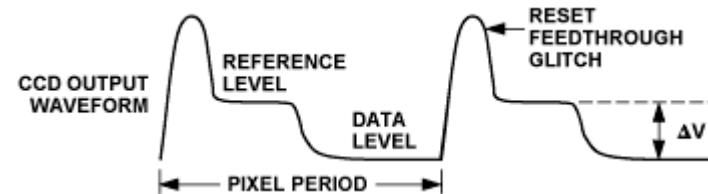
Noise and sensitivity improvements



HFR, HDR

- ❖ Output section CCD or CMOS
- ❖ Eg 1920x1080p60 HDTV imager

- Swing of 1 Volt
- CCD a 1-2 analog output, pixels are processed on a 7-14 ns scale
- CMOS imager each pixel is processed on the column on a 16us scale, that is why
 - High frame rate is much easier with CMOS imager
 - The readnoise can be intrinsically lower (16us to average the noise)
 - Sharpness is much better (
 - HDR can be done too, but that is in the pixel.



4k

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Why 4k in 2/3"

- ❖ Sports, motion
- ❖ B4 mount
- ❖ 100x zoom lenses can still be used....
- ❖ Same sensitivity, F-number, DOF
- ❖ Chromatic aberration corrections
- ❖ Intended for sports and not drama: choose
- ❖ Uses 5um optimized pixel enabling HDR, HFR
- ❖ Camera in HD mode has 4:2:2, in 4k mode uses 4:4:4 and does the same thing the single-imager camera does!

Resolution = MTF and Aliasing

- ❖ MTF: is defined by the pixel aperture (Pixel width)
 - And lens and OLP
- ❖ Aliasing: is defined by the pixel/sample grid (Pixel pitch)
- ❖ Half pixel offset does not change the MTF in it self,
 - it reduces aliasing and because of that one can electronically enhance MTF without enhancing aliasing. It double the sample frequency.

How to suppress Aliasing

- ❖ There is no such thing as

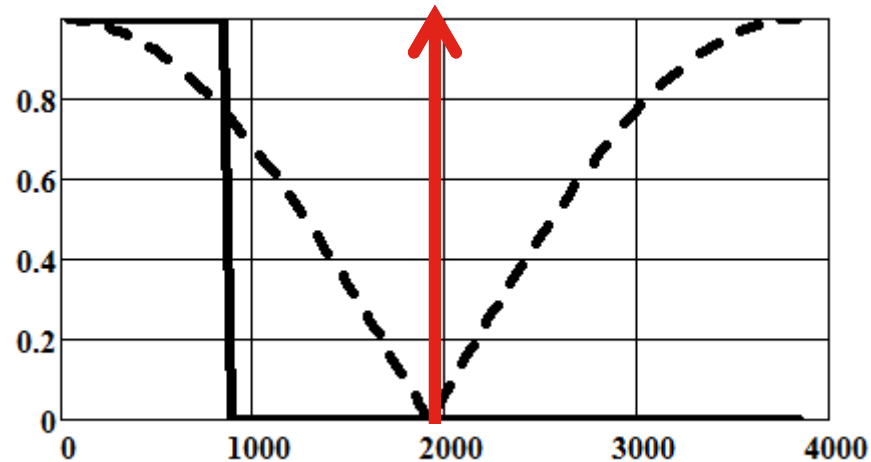
- As an engineer

- ❖ Nyquist will

- ❖ Low frequency

- ❖ The closest frequency

- Or have aliasing cancel out: half pixel offset



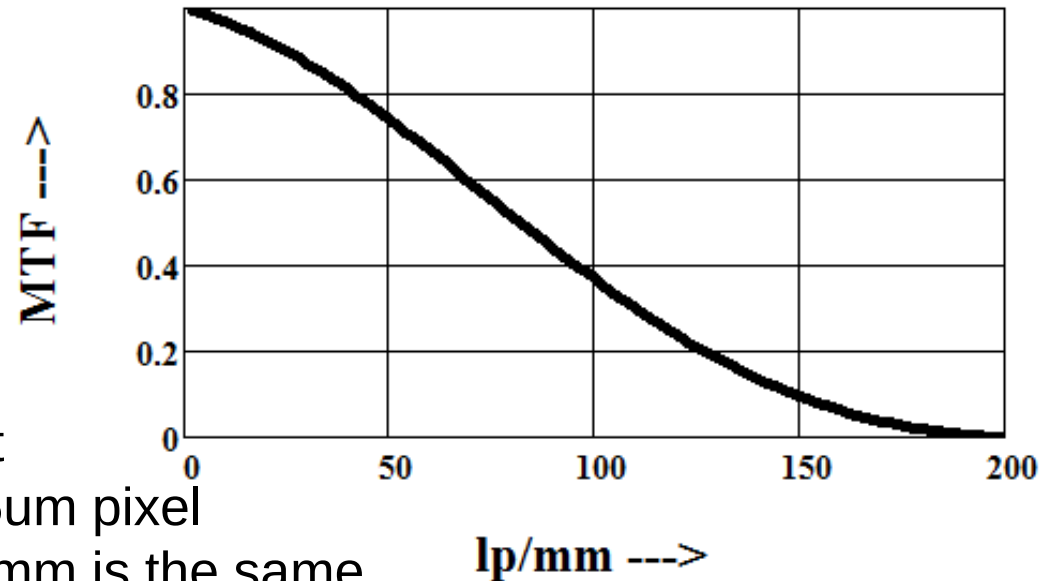
|, there is no

,

e sample

MTF determined by aperture

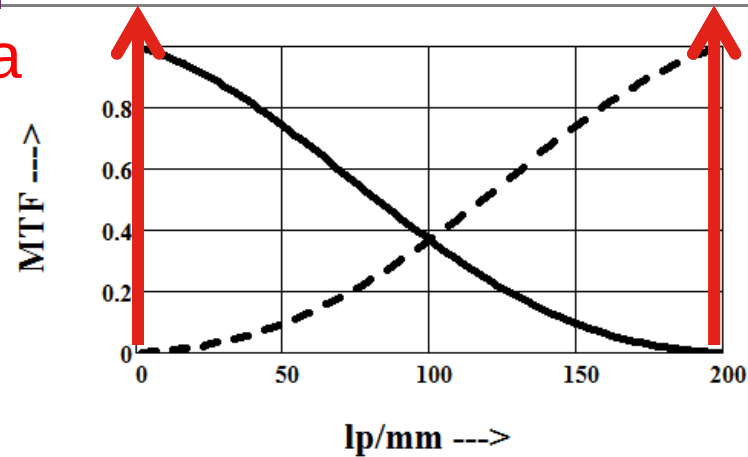
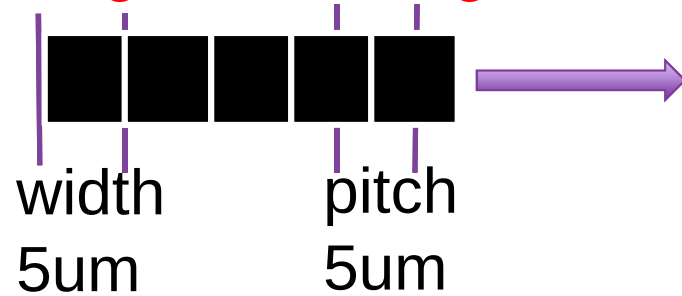
Lens at f//4, OLP at 200lp/mm, pixel aperture 5um



Both single imager large format
and 3 imager 2/3" have about 5um pixel
So the MTF as a function of lp/mm is the same

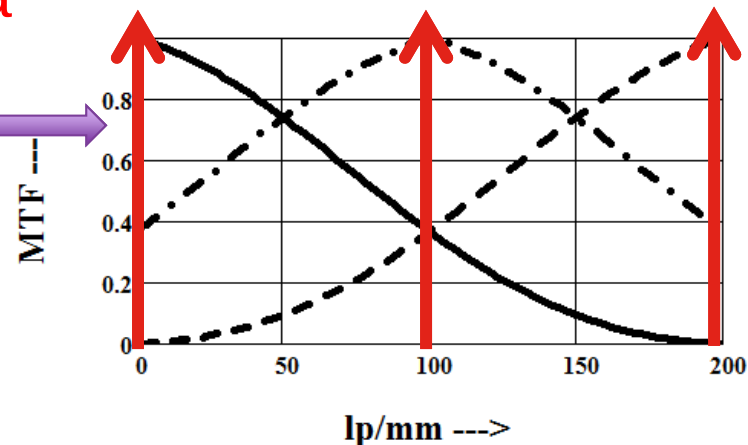
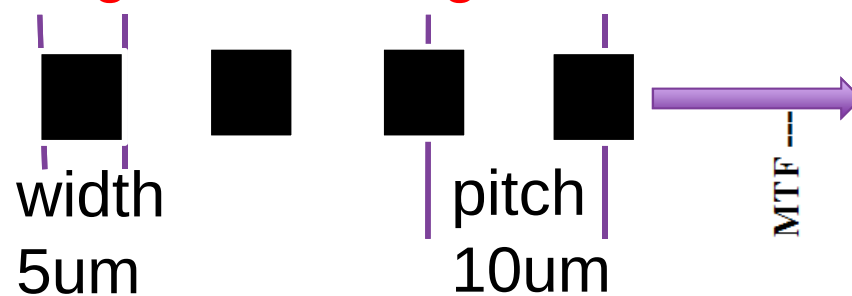
Imager a spatial sampler

Pixelgrid in 3 imager camera



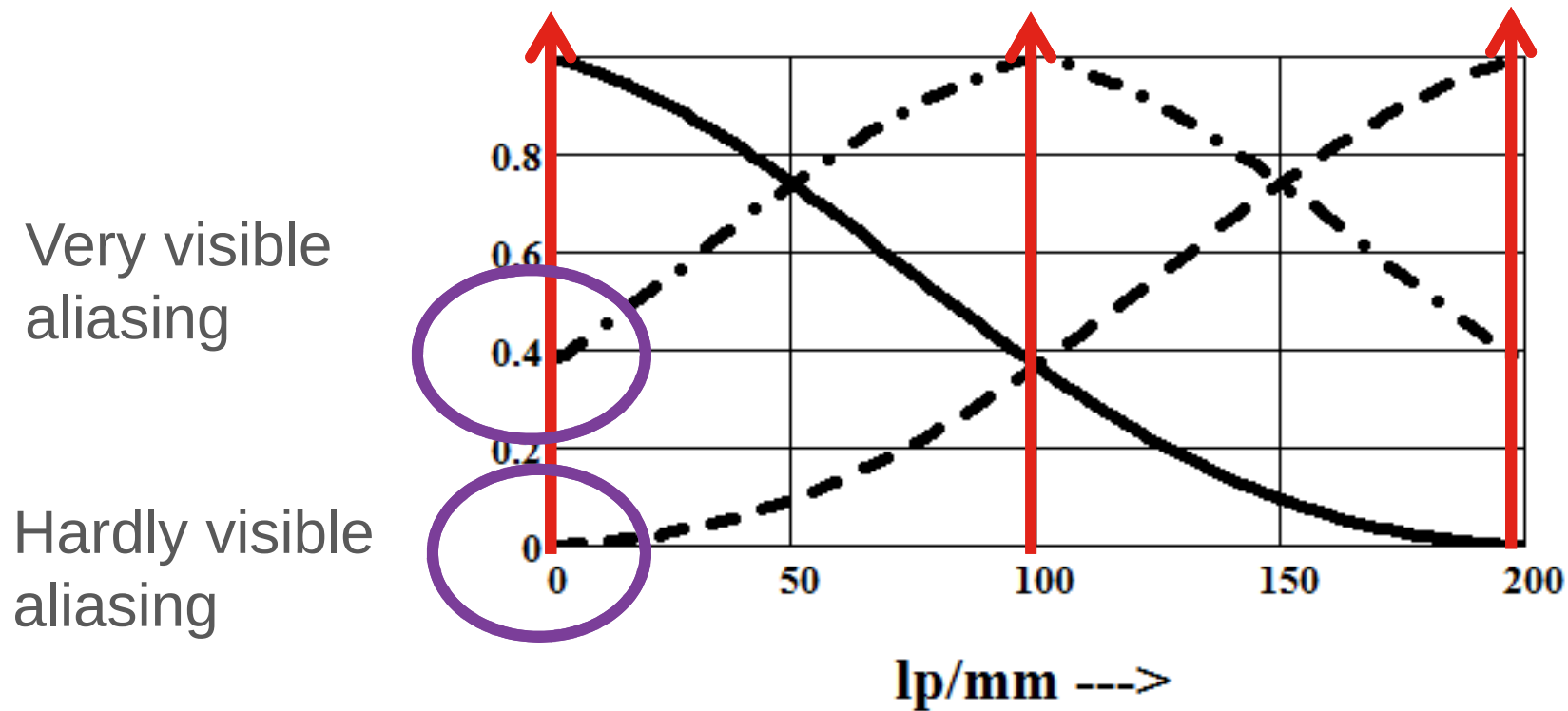
F_{sample}
200lp/mm

Pixelgrid in 1 imager camera



F_{sample}
100lp/mm

Imager a spatial sampler

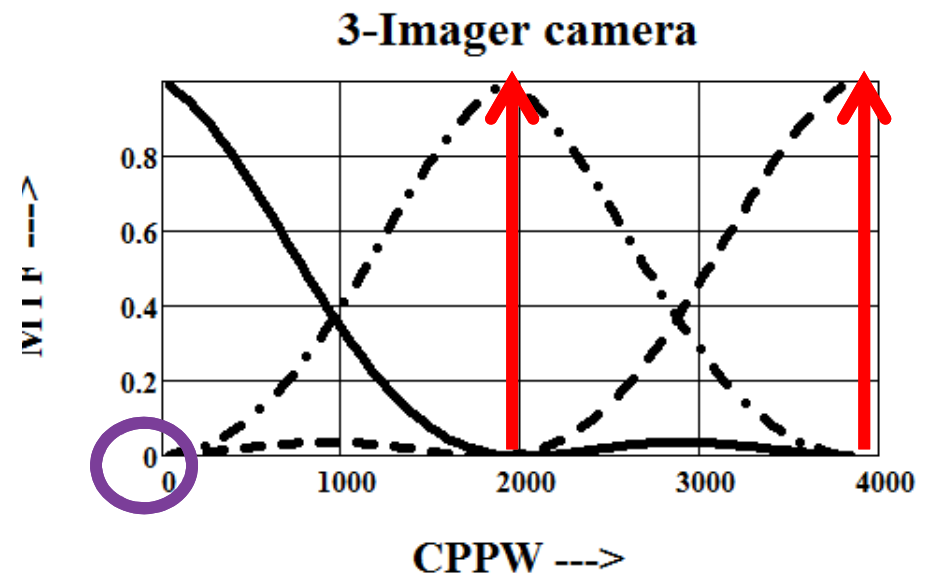
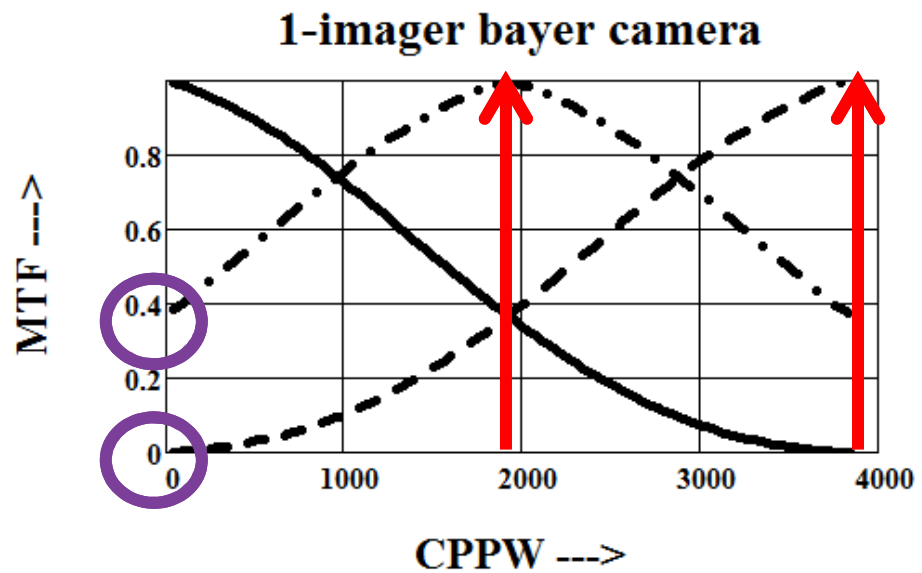


From lp/mm to Cycles-per-picture-width

❏ From 200lp/mm to CPPW

- in 2/3" with 3 imagers is equivalent with 1920 CPPW
 - 5um pixels, 1920 pixels on a row, 1920 co-sited pixels, pixel pitch 5um
- in large imager with bayer is equivalent with 3840 CPPW
 - 5um pixels, 3940 pixels on a row of 1920 pixels per color, pixel pitch 10um

Aliased spectrum

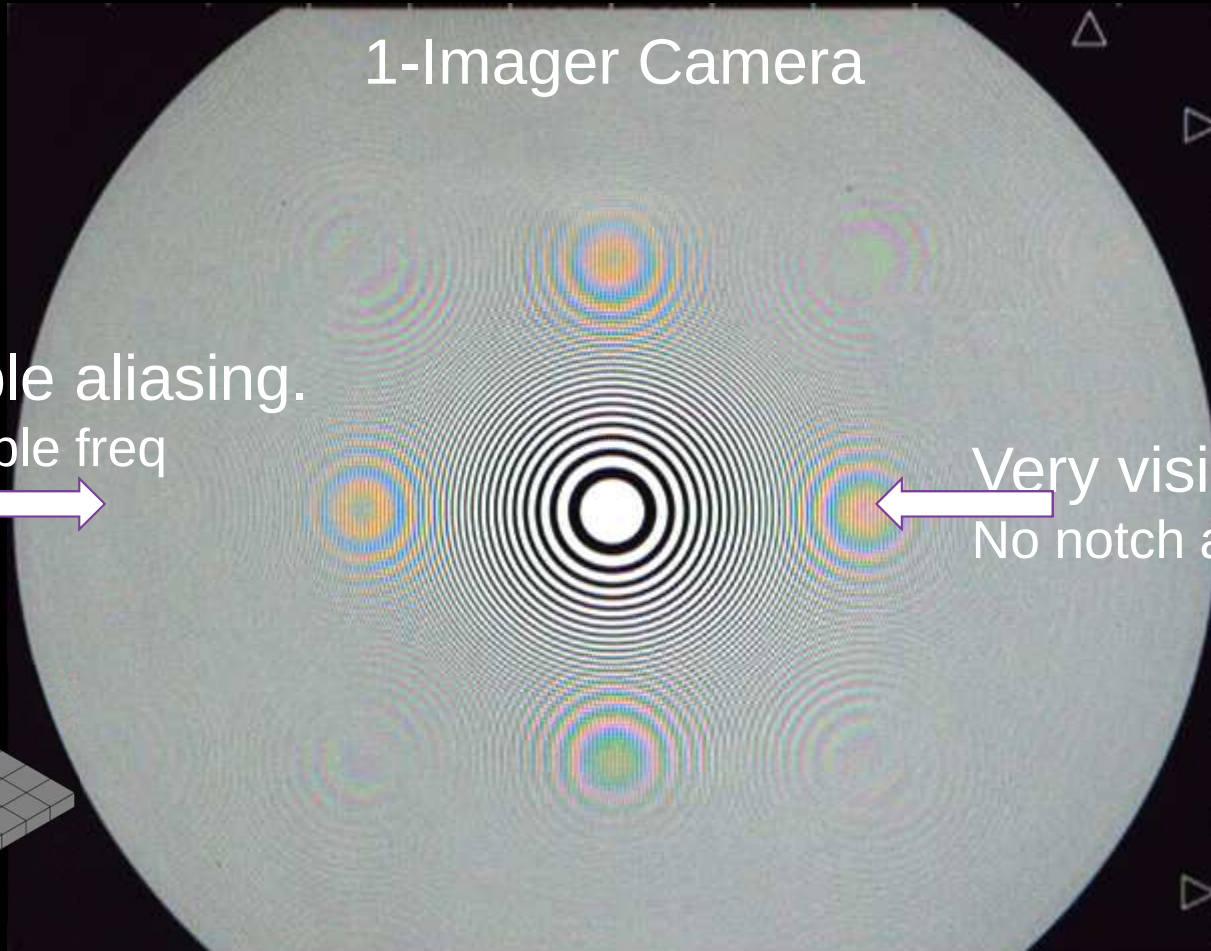
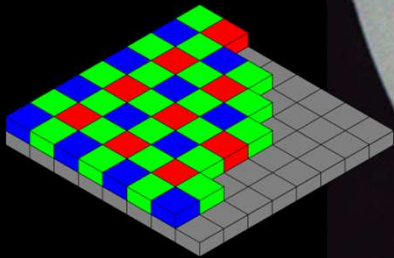
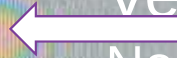


1-Imager Camera

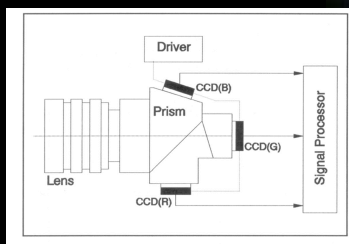
Hardly visible aliasing.
Notch at sample freq



Very visible aliasing.
No notch at sample freq



3-Imager Camera



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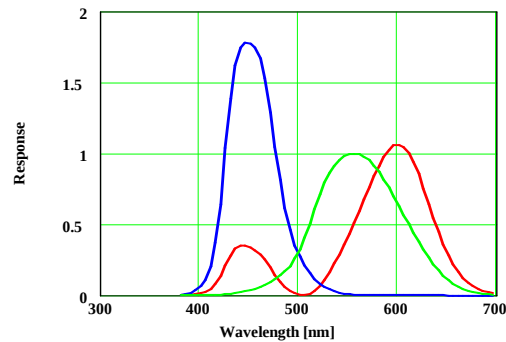
How Wide Gamut Is A Broadcast Camera

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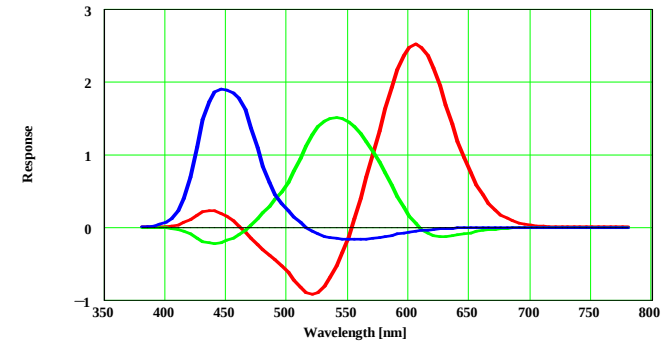


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XYZ-Human Observer Functions

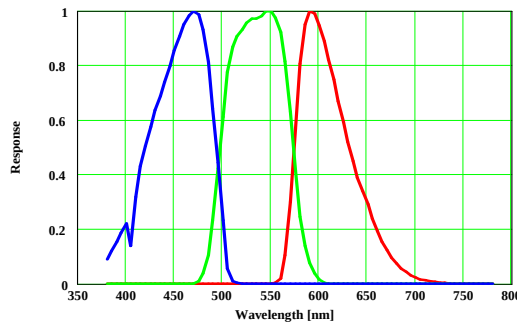


Rec.-709
Primaries



XYZ

CMF709



Matrix for matching
to Rec.-709

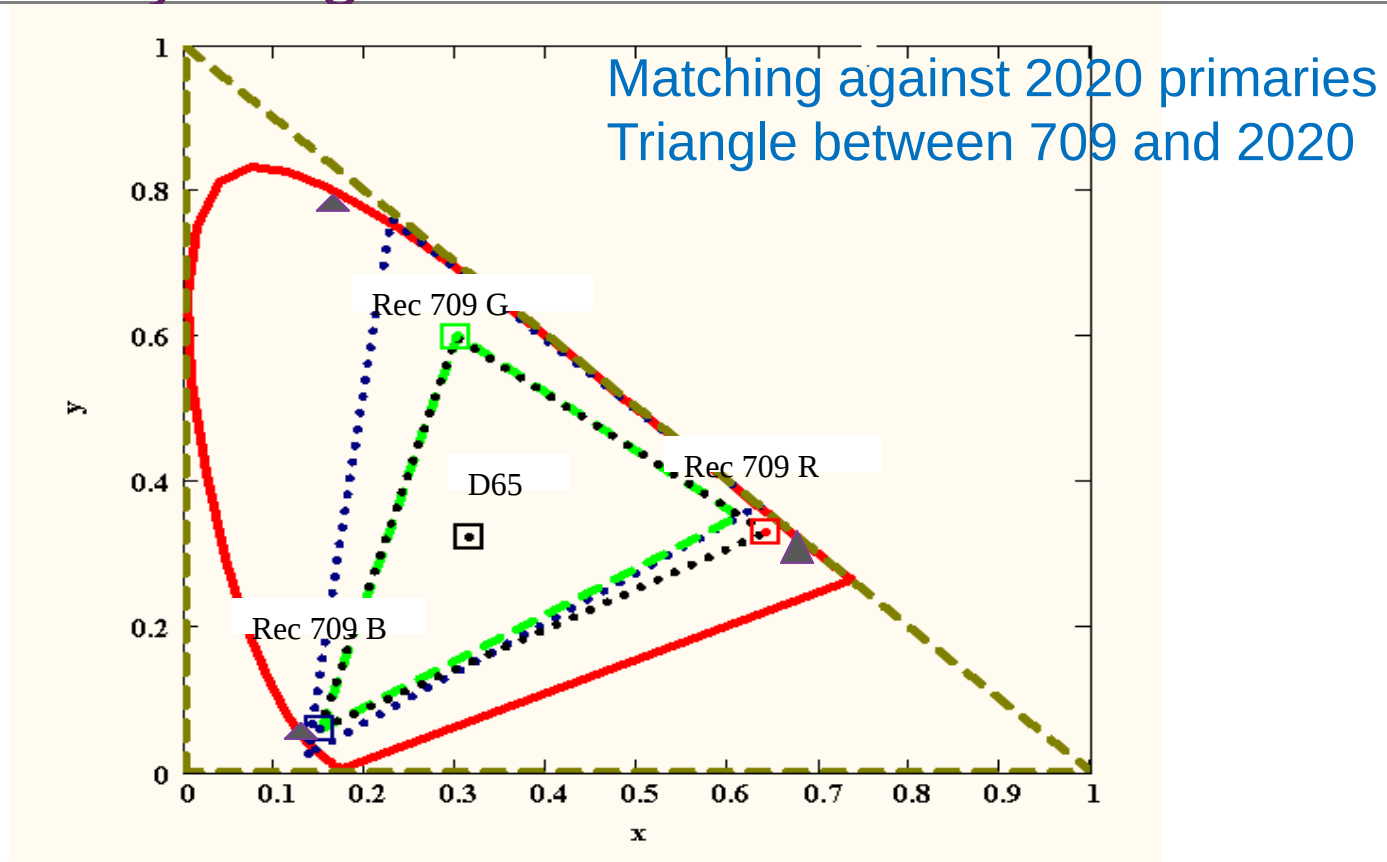


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Chromaticity diagram





HDR

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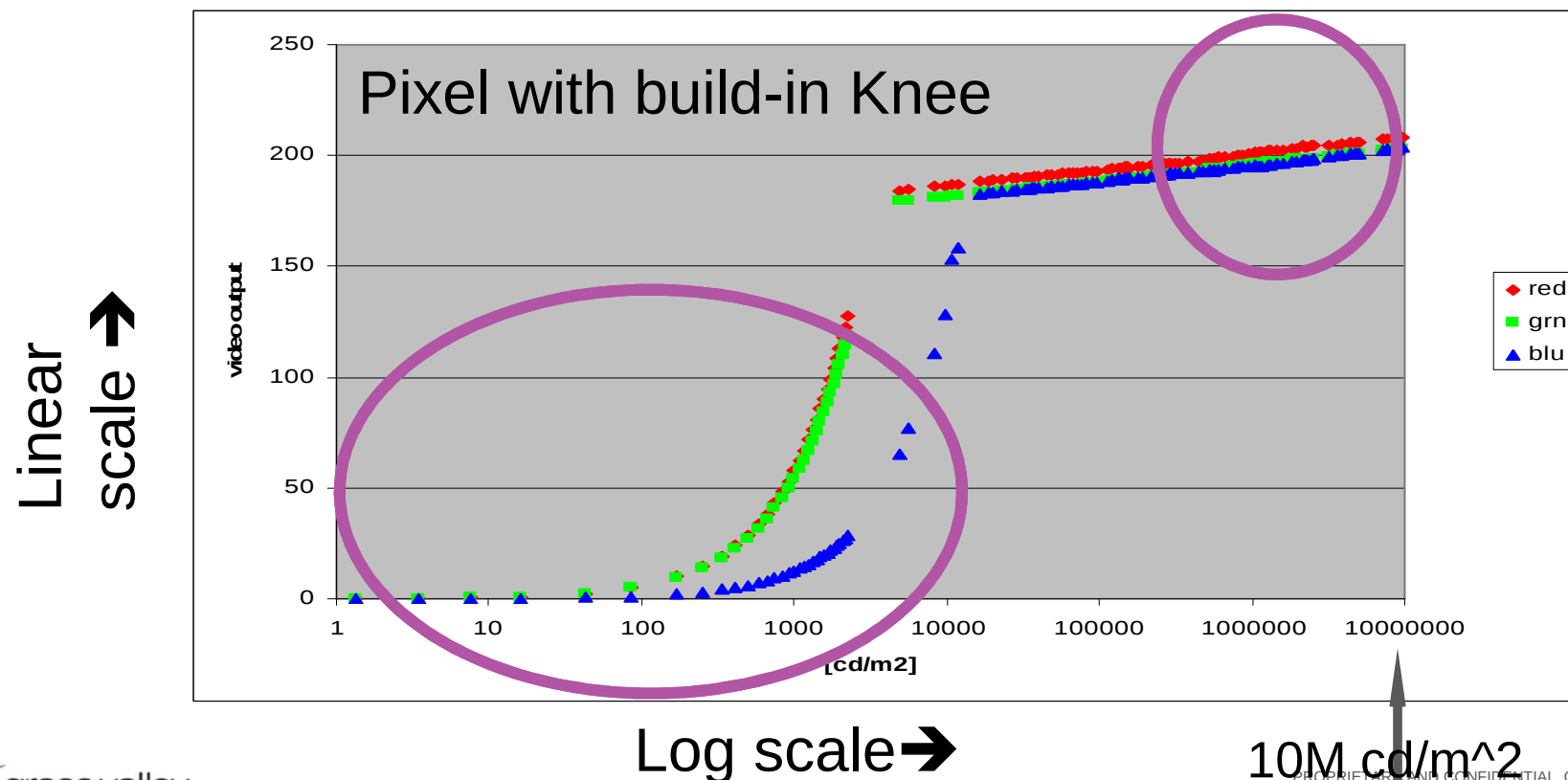
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If only it was black and white!



Jeroen Rotte

HDR-Transfercurve at 3200K



Weber-Fechner

- ❖ Poynton's teachings showed us that for 1% steps: 70 levels per f-stop would be ok.
 - This is about 12 levels/dB
- ❖ From the graph one can derive that the HDR part of the pixel is 6 LSB/dB which means steps of 2%
- ❖ Biggest hurdle is the inflection point from lin to log
 - Maintain eg 3200K white point also in the HDR part

Normal Exp.

HDR

SDR.

Jeroen Rotte

VF

Wide open lens

HDR



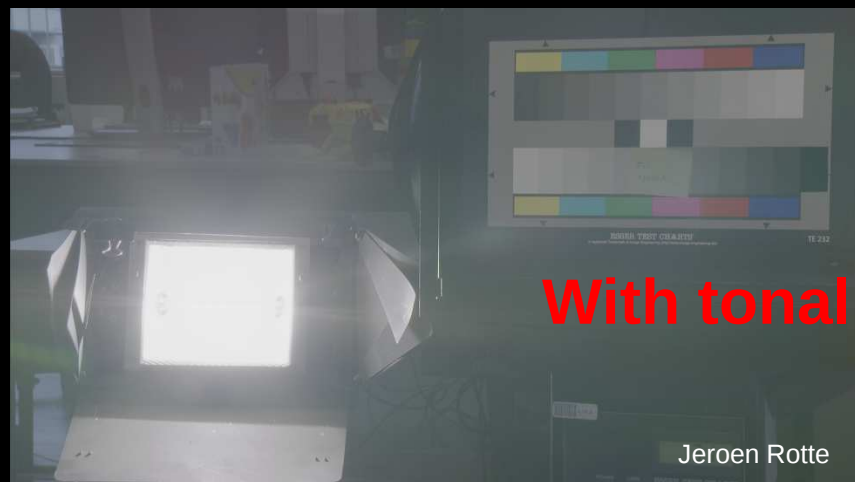
SDR



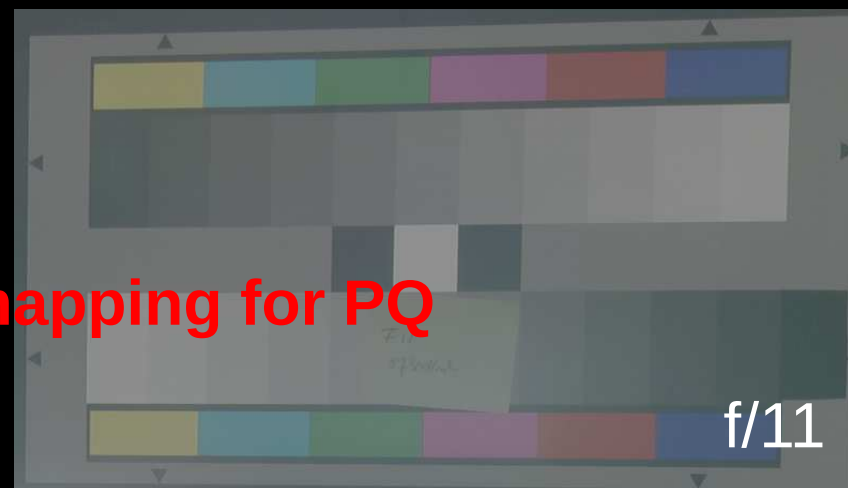
VF

HDR in 10 bits

- ❖ The HDR of the imager is huge 120dB – 160dB
- ❖ Mapping in 10 bit SDI with 12 levels/dB=>85dB,
 - at 2% steps would accommodate 170dB,
 - Dolby's PQ showed that with 10-bit you still make good HDR images
 - With LDX mapped up to 20x and stayed in the linear part preventing the white point shift



With tonal mapping for PQ



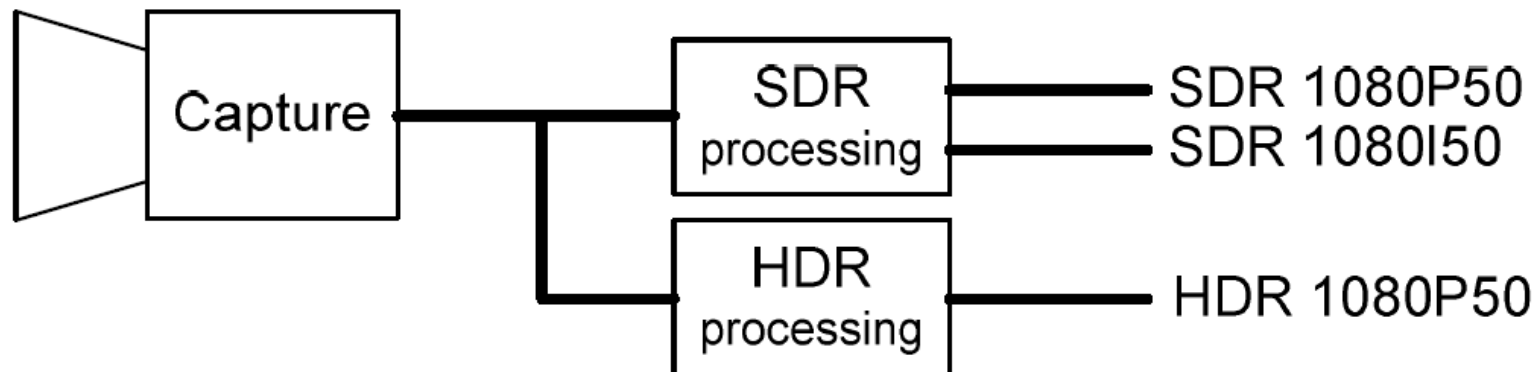
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HDR-trials

- ❖ Zurich 2014 European Athletics Championships 12-17aug
 - How much time do you need for post?.....after the event we are done it is live!
- ❖ Motogp in Valencia
 - Test under difficult circumstances: low sun; shades, darks
- ❖ The setup: camera system with SDR and simultaneous HDR output
 - Life is so much easier for the shader with “PQ” and it is reversible
 - Knee and 709 is set per situation and often not reversible
 - Dolby supplied the monitors during the trials and for debugging

HDR-trials camera system

- ❖ SDR processing: Matrix, Gamma, Knee same as LDX.
- ❖ HDR processing: the full imager dynamic range is preserved, and knee and gamma functions are replaced by a mapping to accommodate Dolby's SMPTE 2084 formatted monitor



Motogp valencia



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SHADER HDR

SHADER SDR

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HDR-live

- ❖ Define 100% as code level 512 (100nits)
- ❖ Black level: trial and error
 - differential gain for low exposures can get large. eg 50x and more
- ❖ There is already legacy to transport 3D in a studio
 - left eye and right eye.
 - Use it for HDR and SDR feeds, one only has to shade the SDR and HDR is usable as is.

Conclusion

- ❖ In a single imager 4k camera there is additional colored aliasing at 2k.
- ❖ With a proper matrix one can reach a chromaticity triangle between 709 and 2020.
- ❖ The SDR channel with gamma+knee can give situations where there is no inverse transform possible because of washed out colors.
- ❖ With mapping for SMPTE 2084 one can always derive an SDR feed afterwards
- ❖ The first live trials with a dual output: one for SDR one for HDR worked very well. And a dynamic range of 20x linear was established.
 - The quality of the images which are tonal mapped for SMPTE 2084 are rather insensitive for f-number setting.
 - The shader can handle many cameras under difficult situations with ease.
- ❖ See Dolby in the exhibition next door
- ❖