Glare Measurement
with
HDR Photography

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11th International Radiance Workshop, Copenhagen, September 2012

Structure

- Intro
- Spatial Calibration
- Captured Range
- Lamp Flicker
- Vignetting
- RAW vs JPG
- White Balance

Introduction

Background

- Uni of Westminster: Identical IT labs, fitted with fluorescent, LED luminaires
- Q: Does one or the other type of fitting cause more glare?

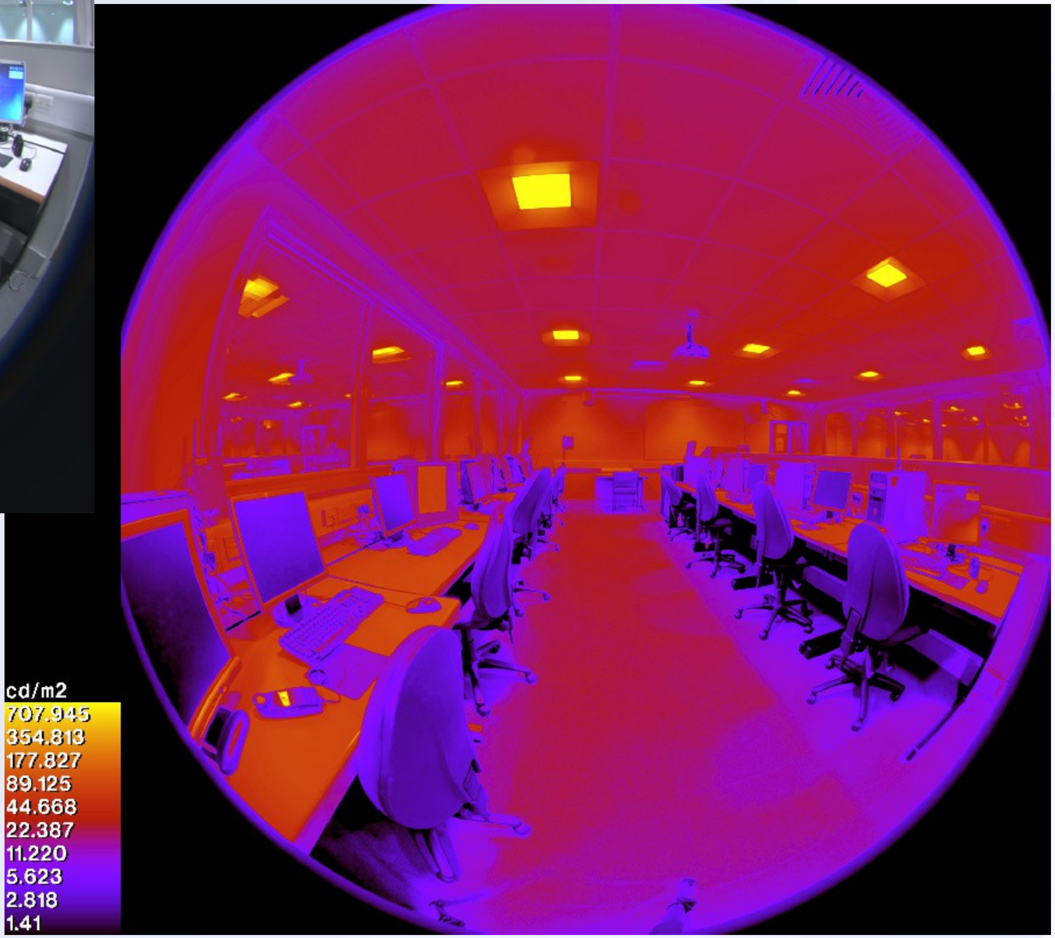
Methodology

- HDR photographs with Nikon D200 and Sigma 4.5mm fisheye lens
- Same view points, camera positions in both IT labs
- Also measured: vertical illuminance at lens, luminance of test patch

Steps

- HDR sequence (tripod, AEB, tether)
- Pre-crop with ImageMagick
- *hdrgen* (exposure merge JPGs into HDR)
- *hdrexpo.pl* (apply calibration factor)
- *pcomb* (mask off circular image)
- *findglare*, *glarendx* (glare metrics)
- *falsecolor*, *xglaresrc* (images for report)

10441
3214
464
3911
915
2146
1709
3863
2685
2740
245 lux
UGR 20



cd/m2
707.945
354.813
177.827
89.125
44.668
22.387
11.220
5.623
2.818
1.41

Calibration Factor

#Location	ID	Lumi_meas	Illu_meas	Lumi_HDR	Illu_HDR	CF_lumi	CF_illu
LG45_1A	01	35.8	67.4	27.4	48	1.307	1.404
LG45_1B	02	31.1	108.9	23.8	71	1.307	1.534
LG45_2A	03	75.4	110	56.3	77	1.339	1.429
LG45_2B	04	23.2	125	18.5	106	1.254	1.179
LG45_3A	05	25.2	83	19.6	62	1.286	1.339
T5					*average*	***1.298***	***1.377***
					std dev	***0.031***	***0.131***
LG43_1A	06	43.2	108	30.5	70	1.416	1.543
LG43_1B	07	72.8	260	47.7	135	1.526	1.926
LG43_2A	08	41	171	27.3	84	1.502	2.036
LG43_2B	09	35.9	166	23.8	106	1.508	1.566
LG43_3A	10	51.2	166	34	79	1.506	2.101
LED					*average*	***1.492***	***1.834***
					std dev	***0.043***	***0.263***

But wait...

How good are those UGR values?
How accurate are HDRs?

The following pages show some of the results obtained from experiments involving 4000 JPG photographs, 2500 RAW photographs over the course of many months.
This is work in progress.
The images currently amount to 70 GB of data.

Spatial Calibration

Spatial Calibration

Solid angle

$$UGR = 8\log\left[\frac{0.25}{L_b}\sum\frac{L^2\omega}{p^2}\right]$$

Guth position index

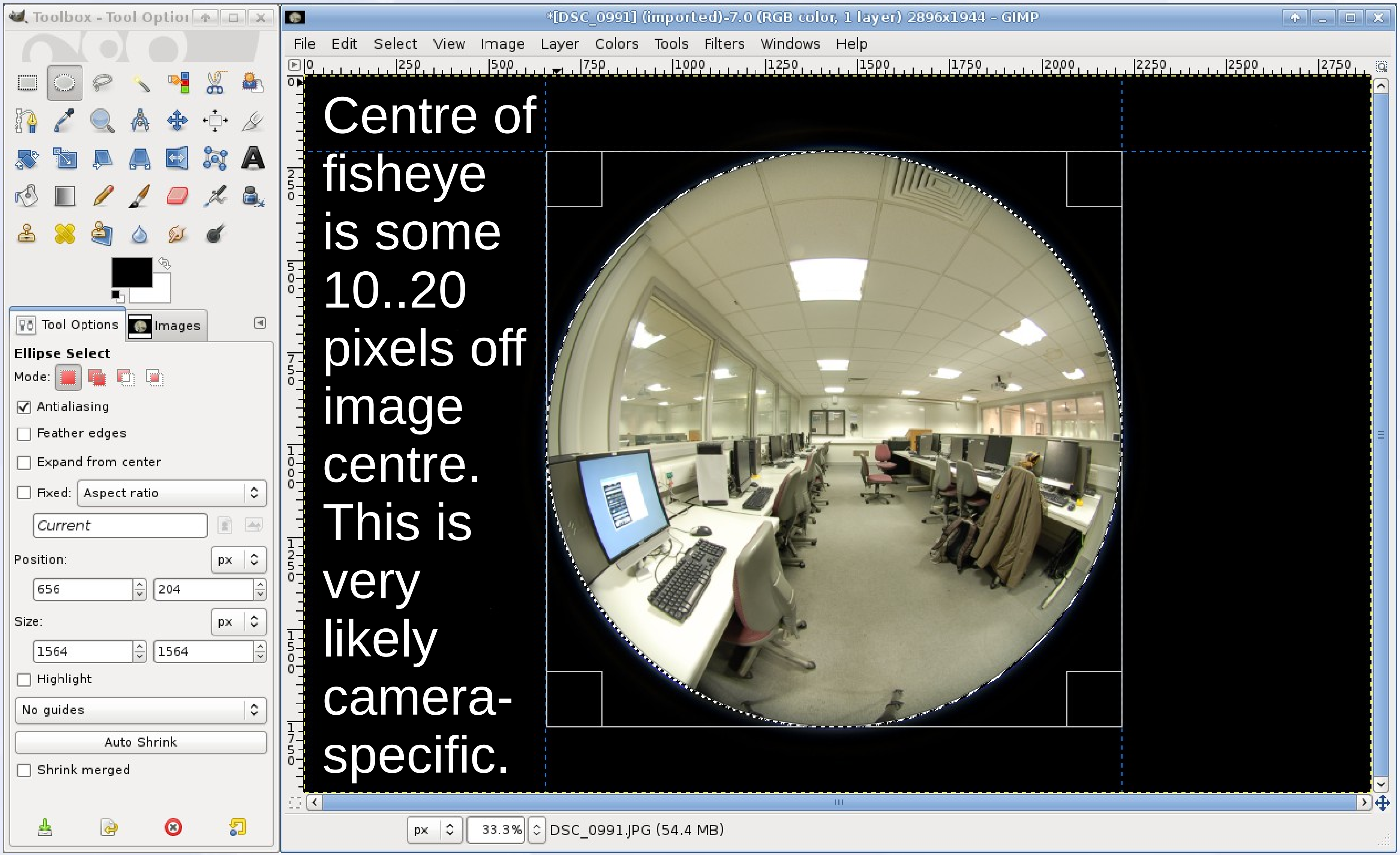
Nodal Point

- Nodal point must be centre of camera rotation in later experiments
- Align two vertical objects or edges
- Nearby, faraway objects must not move relative to one another
- Move camera back, forward until good result
- Needed: tripod and sliding camera mount (mine was not very good)

Nodal Point

NP is somewhere between front of lens and front of barrel

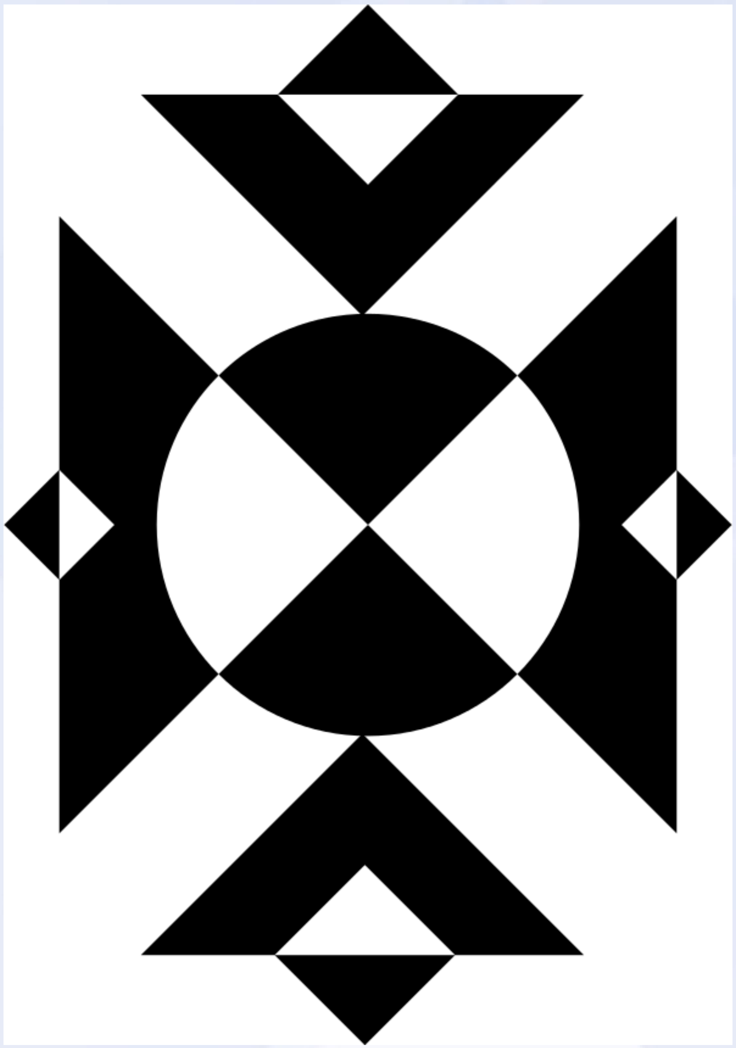
Image Centre

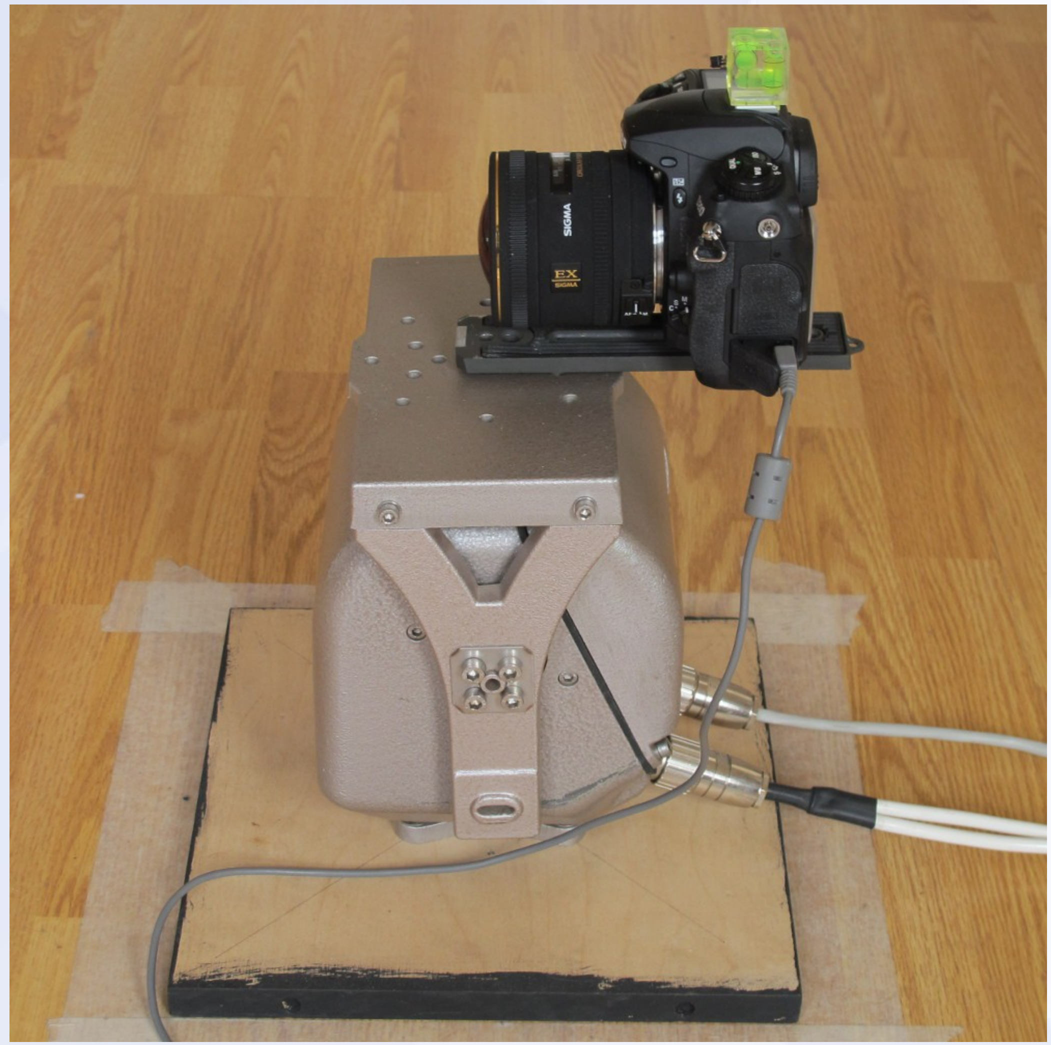


Projection

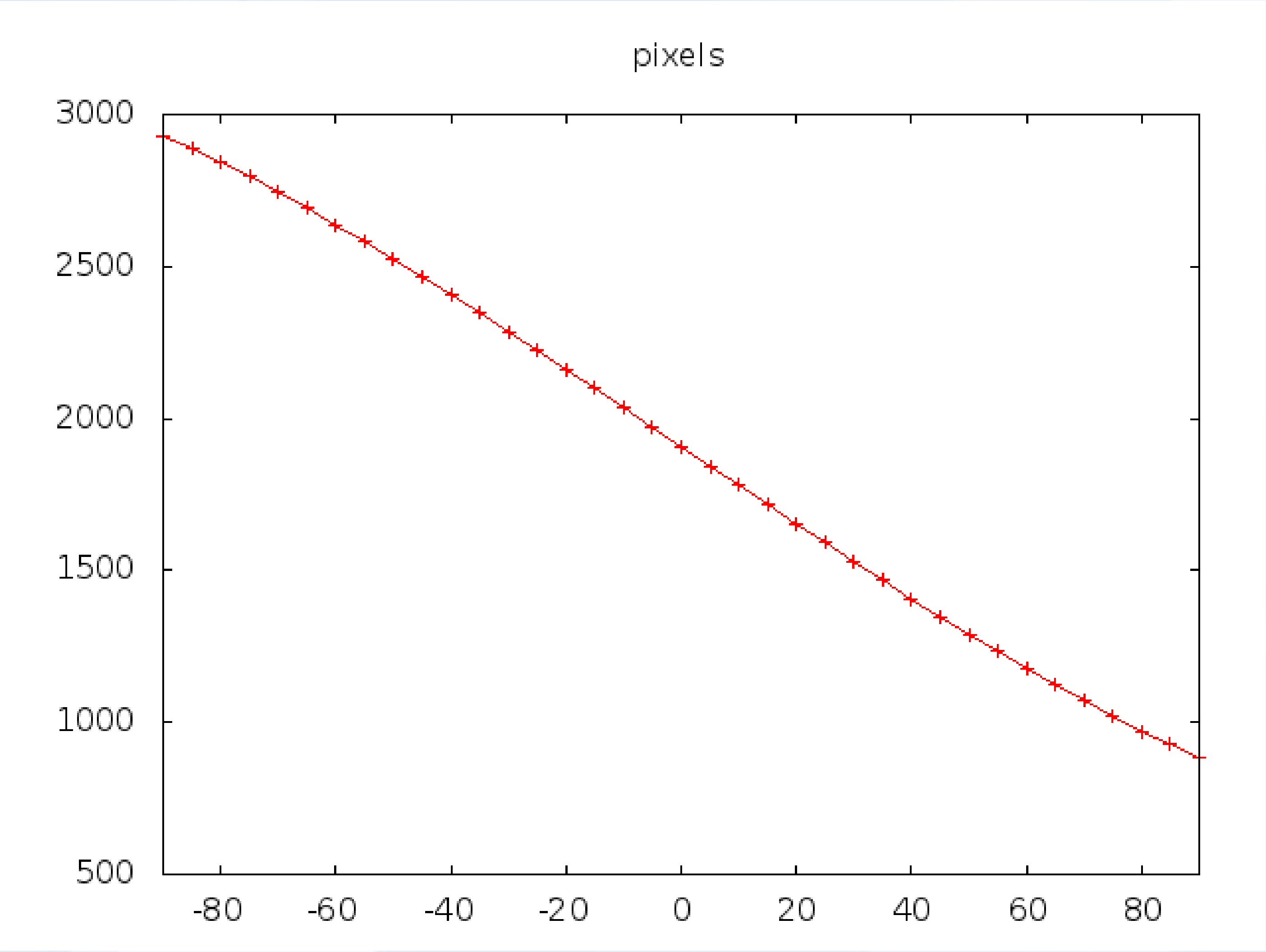
- Sigma claim their 4.5mm lens has an equi-solidangle projection
- But does it?
- Test:
  - Mount camera on motorised head with stepper motors (just over 16,000 steps per 360deg)
  - Rotate camera around nodal point
  - Take photograph of target every 5 degrees
  - Compare against known projections

Projection



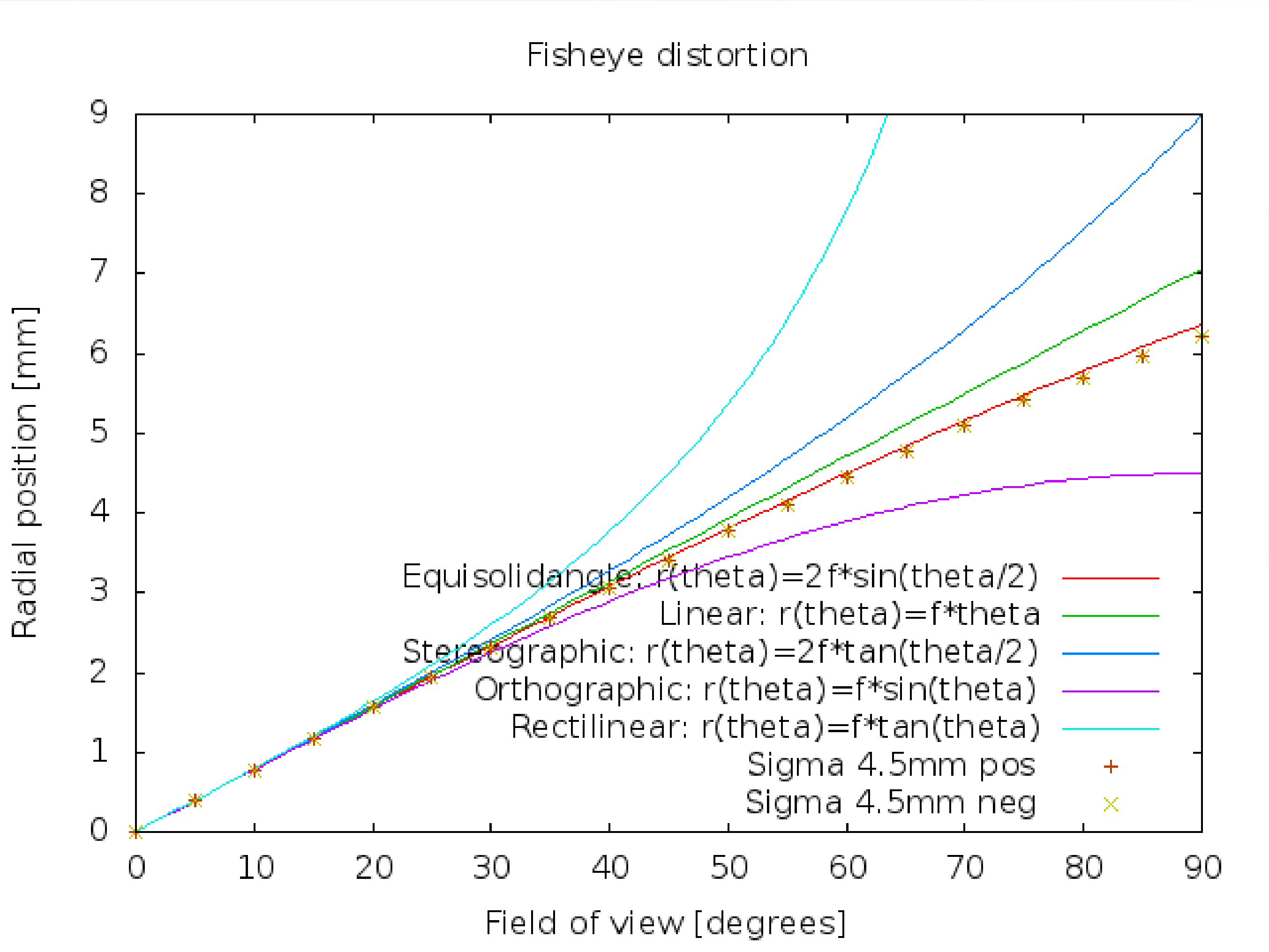


Projection



Projection

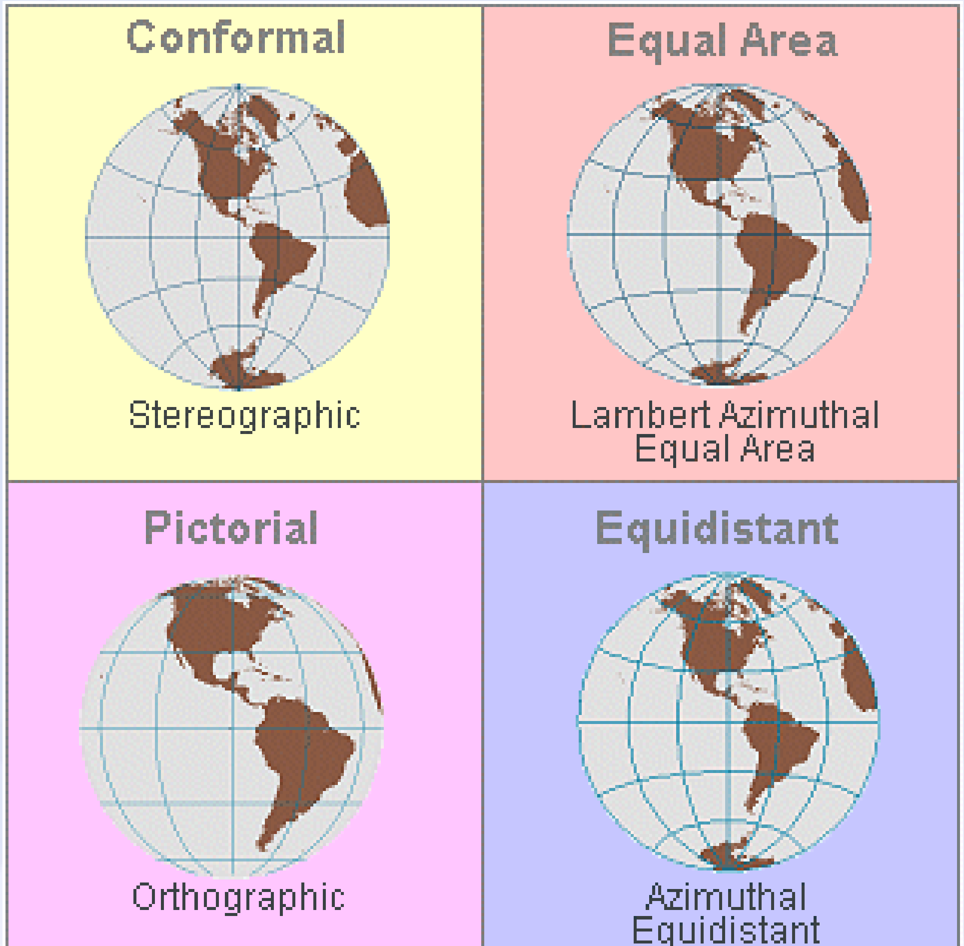
- Lens projection is equi-solidangle
- Field of view is larger than 180deg



Projection

planisphere
-vts

equi-solidangle
-vt?



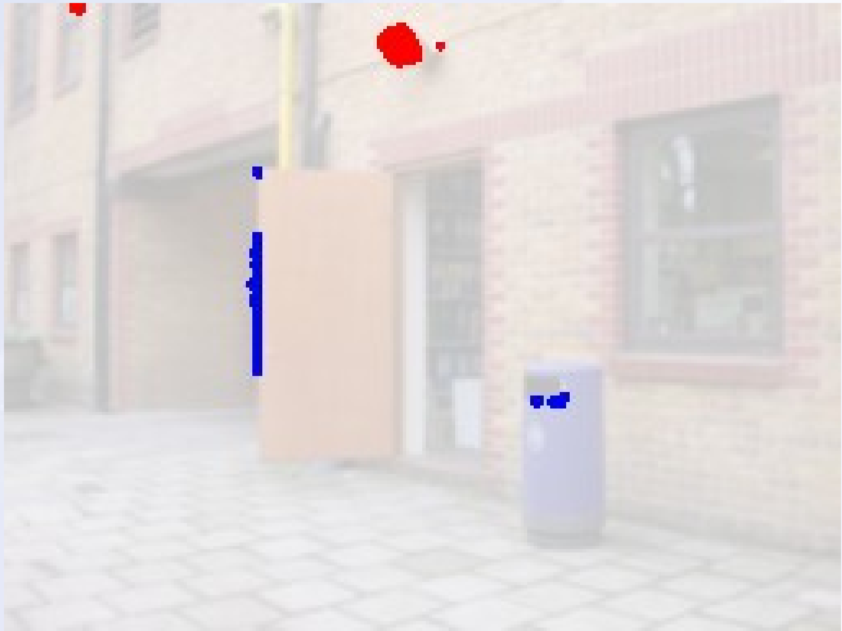
-vth
hemispherical

-vta
equi-angular

http://www.geo.hunter.cuny.edu/~jochen

Captured Range

Captured Range



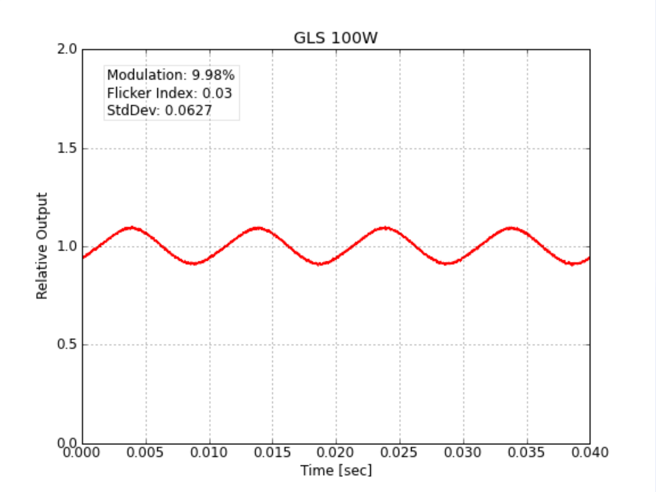
When deriving glare metrics from HDRs, the results are extremely sensitive to the accuracy of the highlights in the image.
Make sure light sources are captured with sufficient EB range.
WebHDR's heatmap shows regions in the image that are not accurately represented in the HDR.
If there are any red pixels, re-shoot sequence with shorter exposure times.

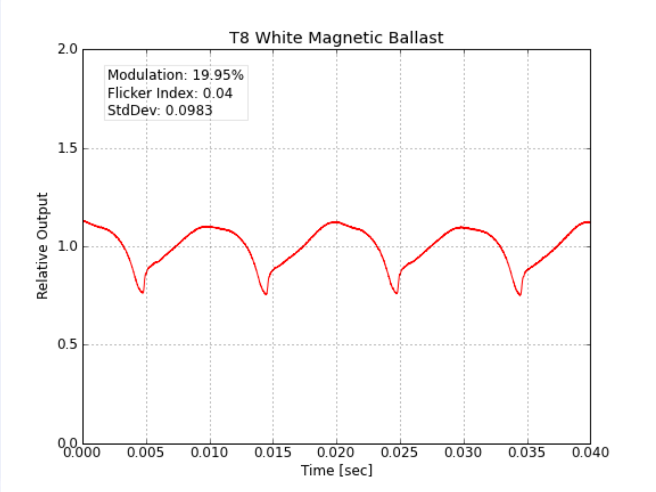
WebHDR Tools

- Collection of Perl scripts for working with HDRs and EB JPG sequences
- Tidy up spaghetti code of WebHDR
- Soon to be released on JALOXA (only some web pages are missing)
- hdrcalib, jpgheatmap, jpgsep, rspplot, jpgfixexif, jpginfo, rspavrg

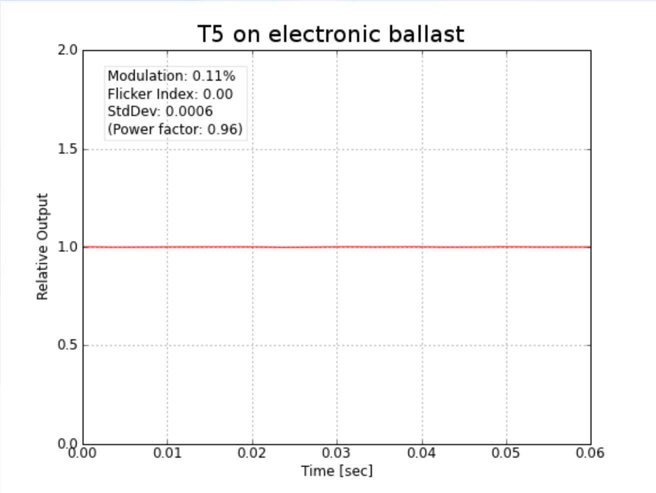
Lamp Flicker

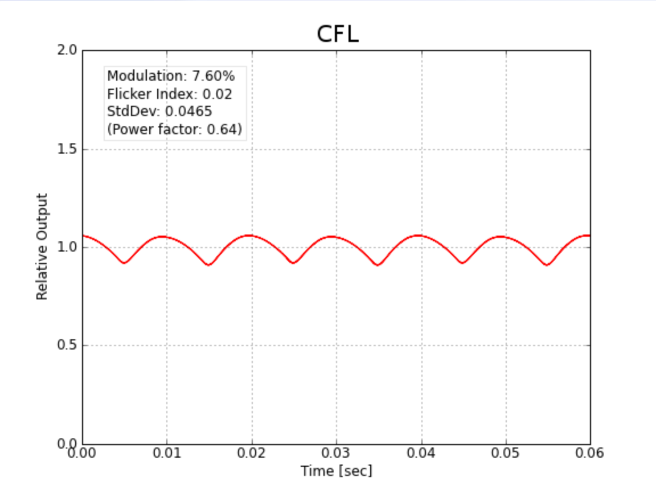
Conventional Lamps



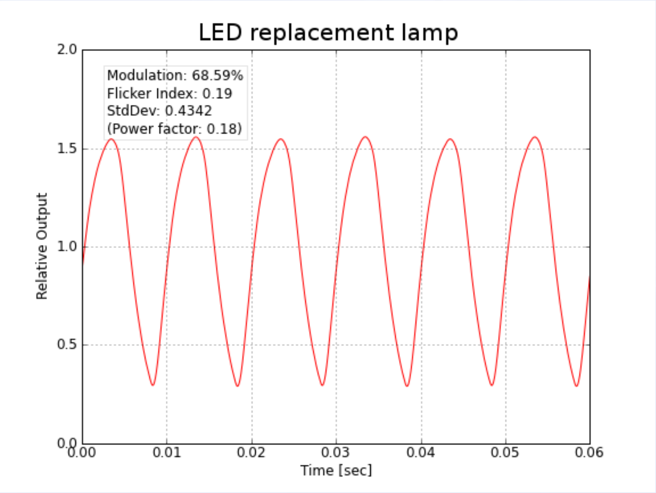


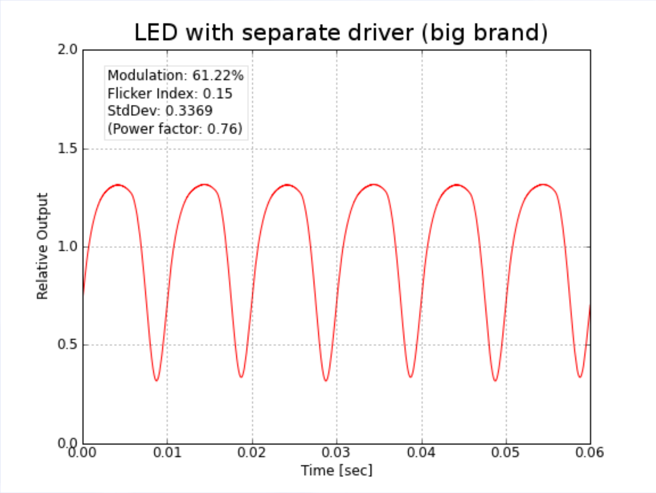
Lamp technology 1: From Tungsten to CFL



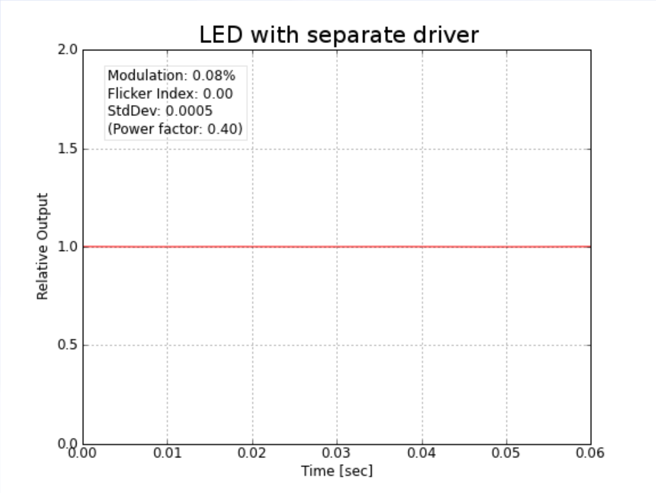


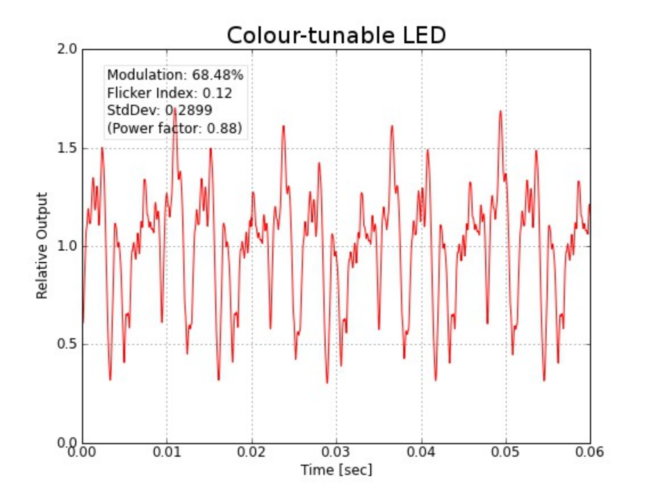
LED Lamps



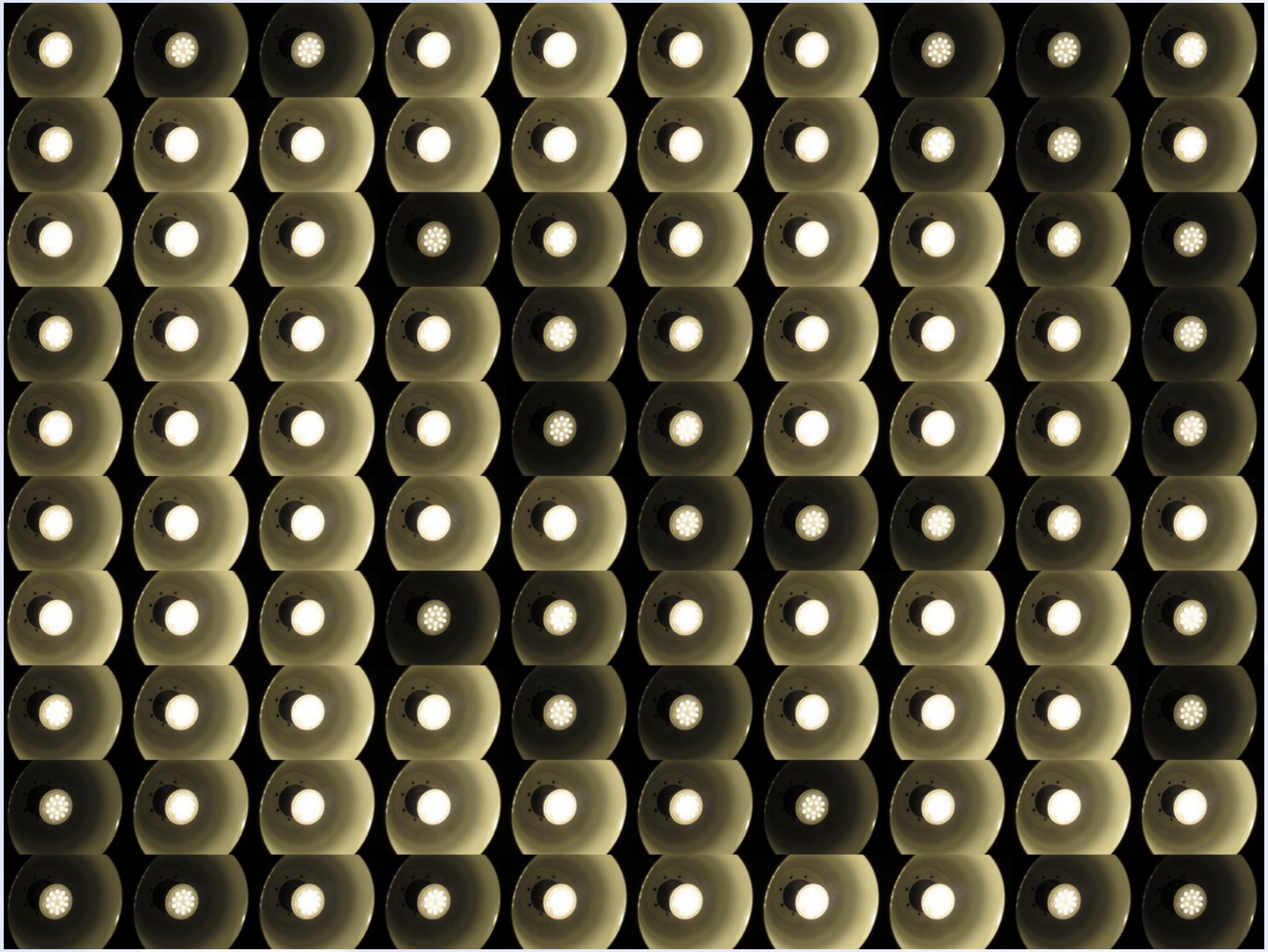


Lamp technology 2: Modern LED lamps



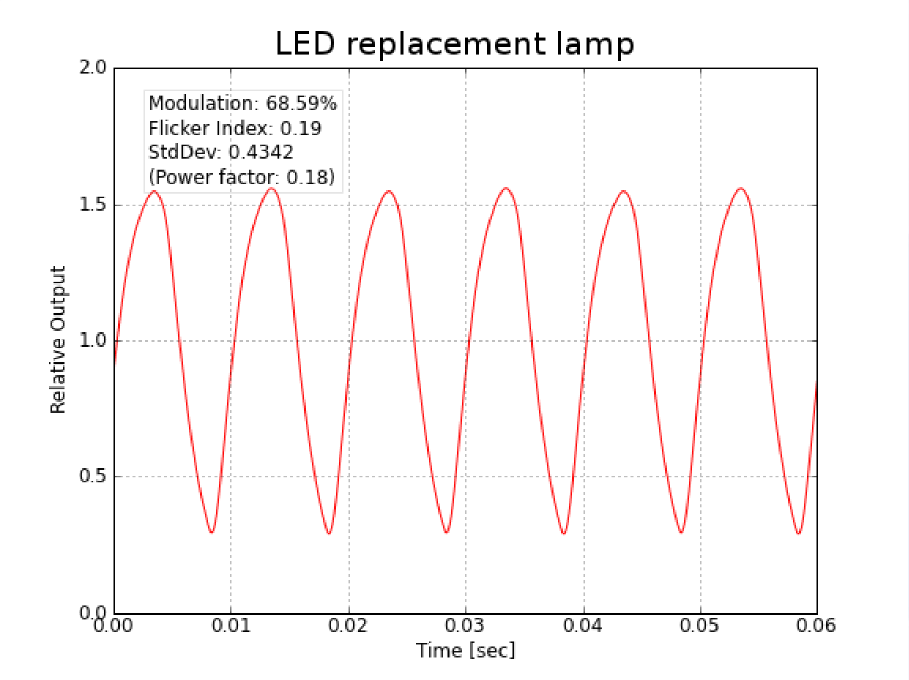


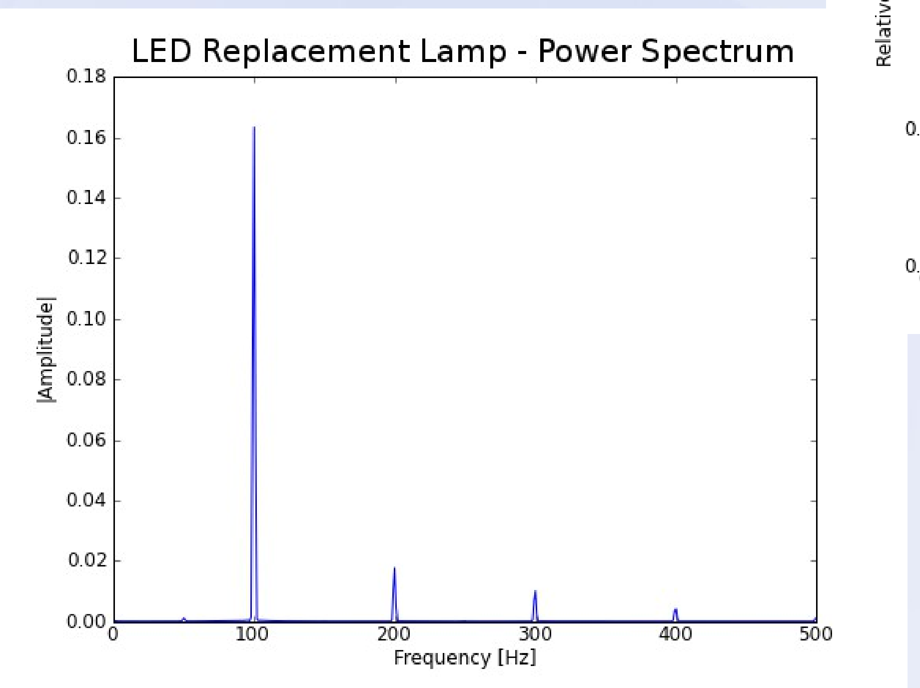
Compact Digital Camera



100 photographs at 1/500 sec, taken with a Canon G12

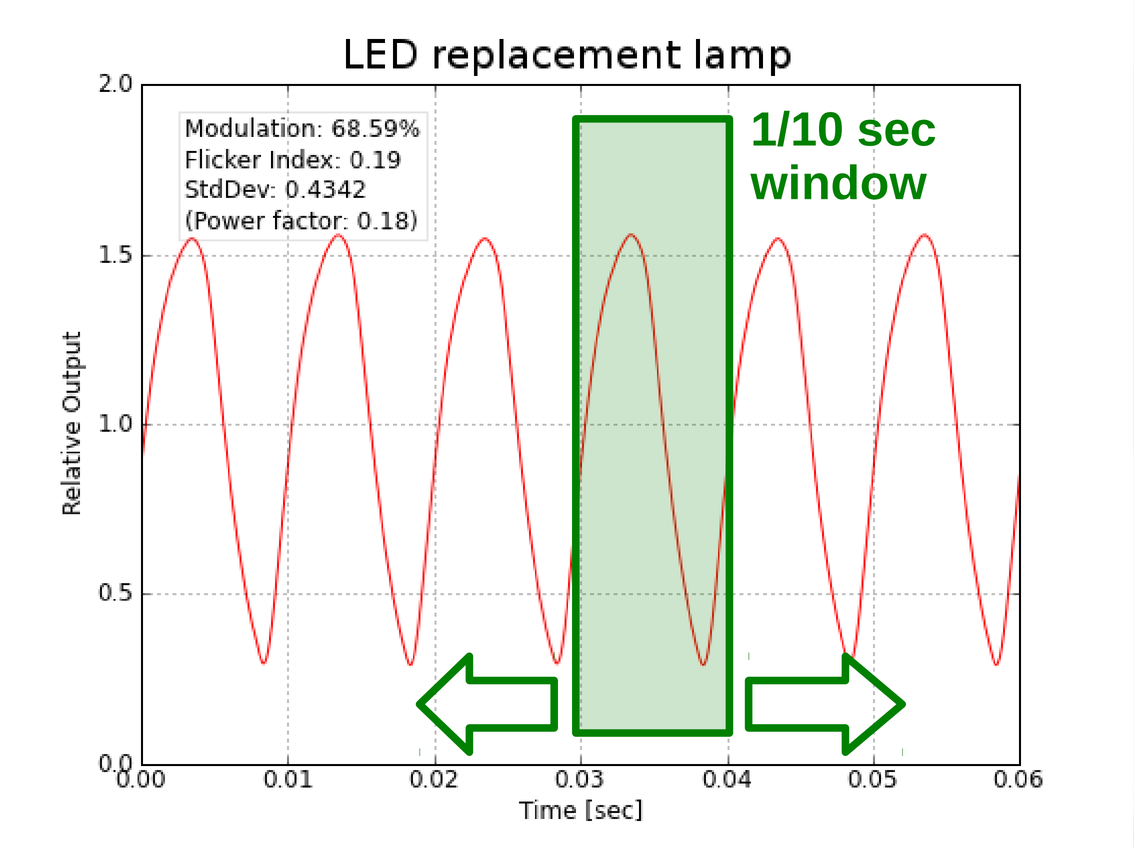
Our Test Lamp



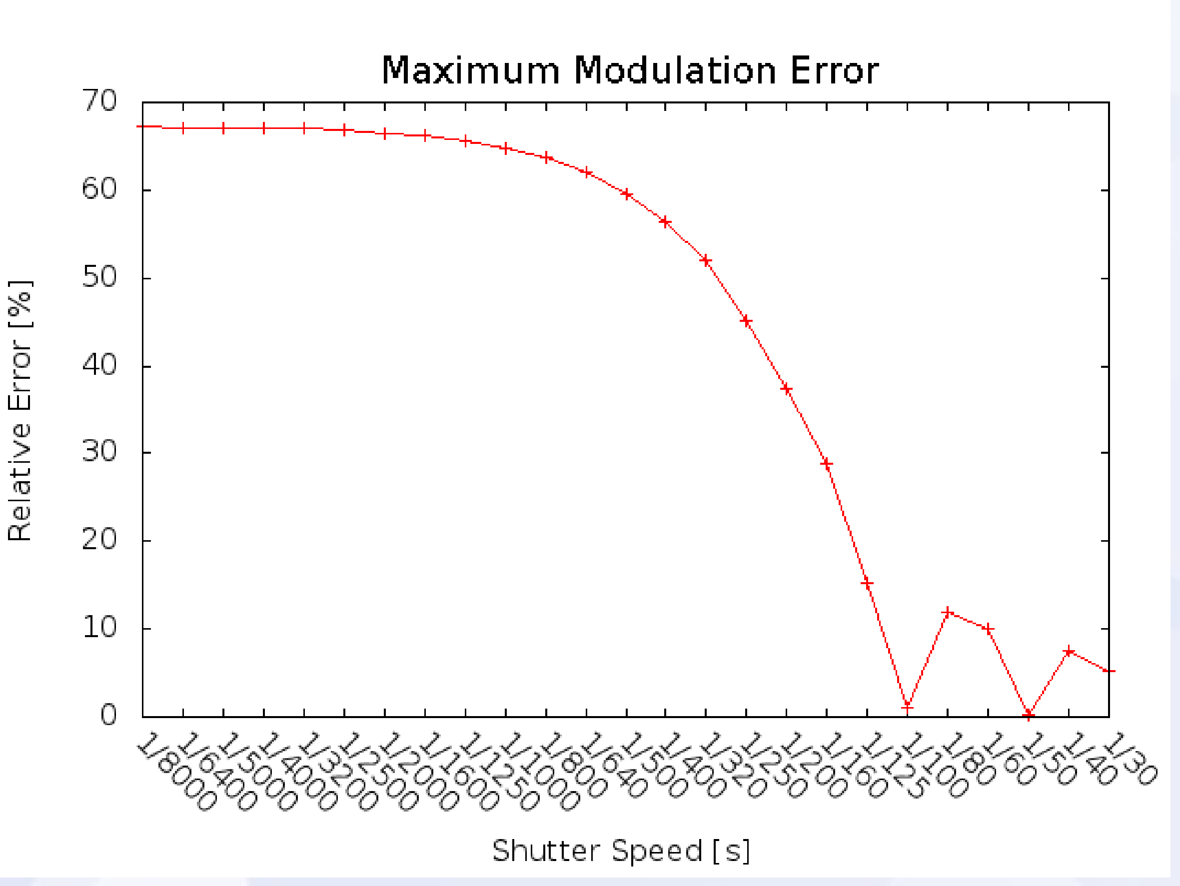


Sliding Window

- Move sliding window over measured waveform (1 second)
- Window width = shutter speed
- Take average over window
- Plot maximum error

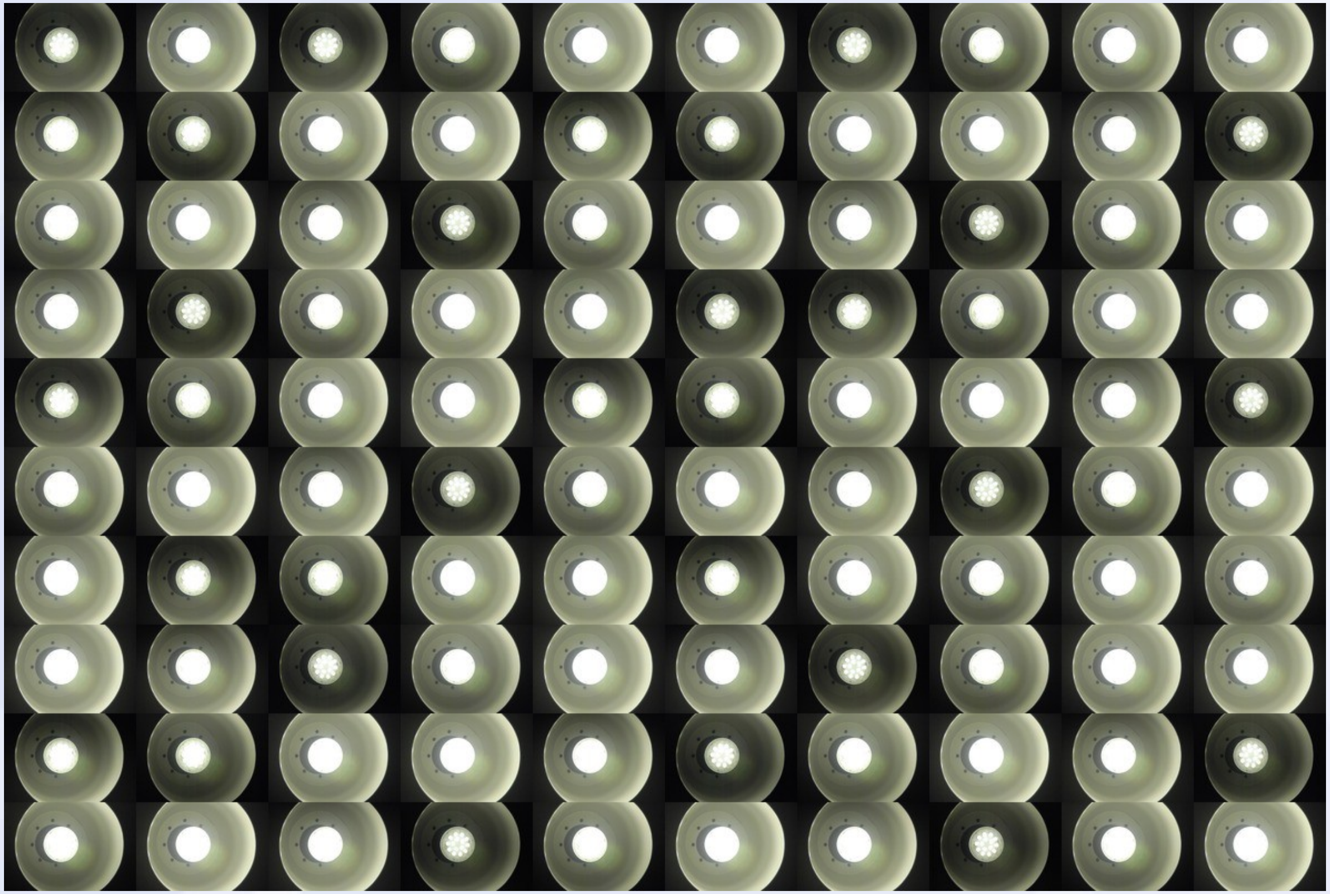


Modulation Error



Maximum modulation error is roughly the same as the modulation of the light source. BUT only for compact digital cameras!

DSLR



Contact sheet 1/500, taken with D200 DSLR.
Due to the sliding mechanical shutter, flicker response is even less predictable than with a digital compact camera

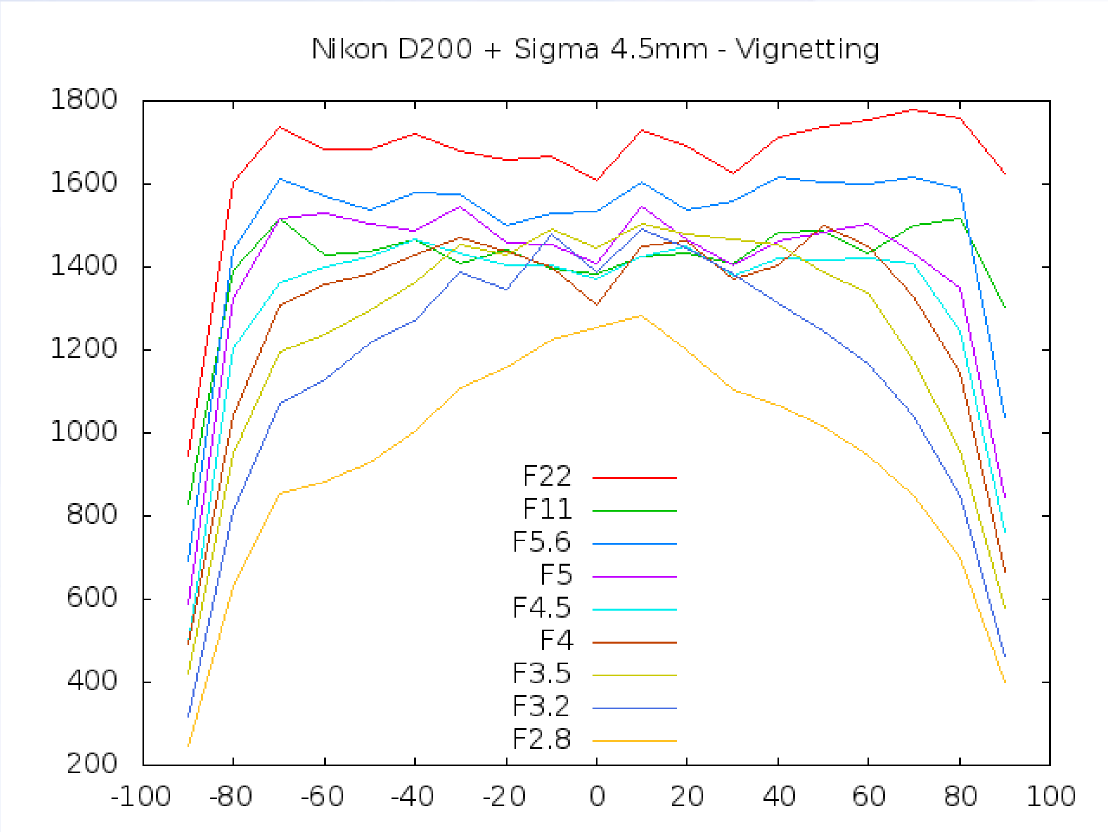
Flicker is Evil!

- If you specify LED lighting, do look into flicker
- Some references:
  - Poplawski: CALiPER Exploratory Study Highlights: Flicker & Dimming (PDF)
  - Wilkins, A.J., Nimmo-Smith, I.M., Slater, A. and Bedocs, L. (1989) Fluorescent lighting, headaches and eye-strain. Lighting Research and Technology, 21(1), 11-18. (PDF)
  - IEEE PAR1789: "Recommending practices for modulating current in High Brightness LEDs for mitigating health risks to viewers" (Web site)

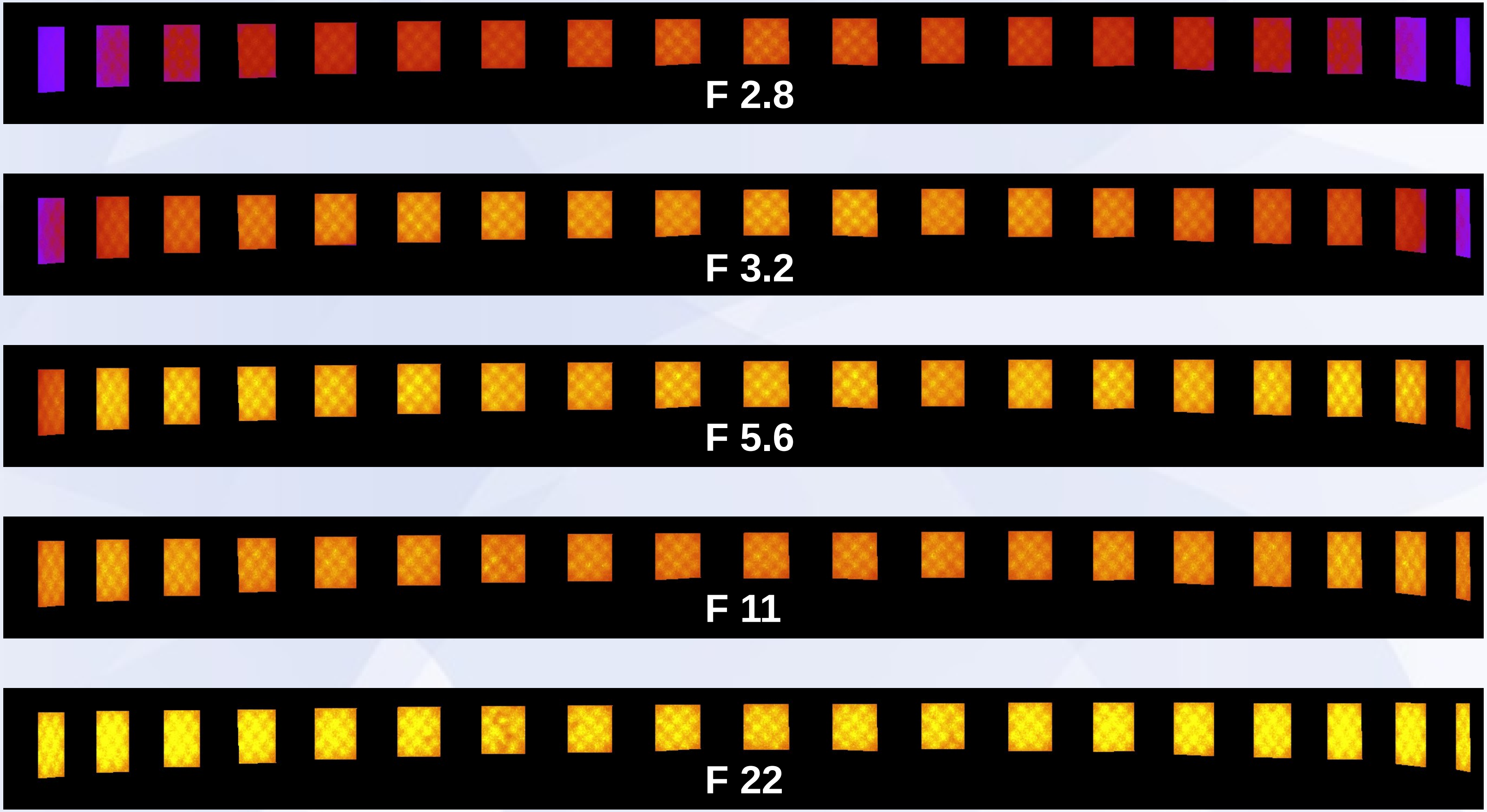
Vignetting

Vignetting

- HDRs from RAW
- 10 deg steps
- Light source masked and extracted
- Quality not very good (light source not uniform, not properly centred, no temperature stabilisation, no dark room)
- We can still get some valuable clues from these measurements

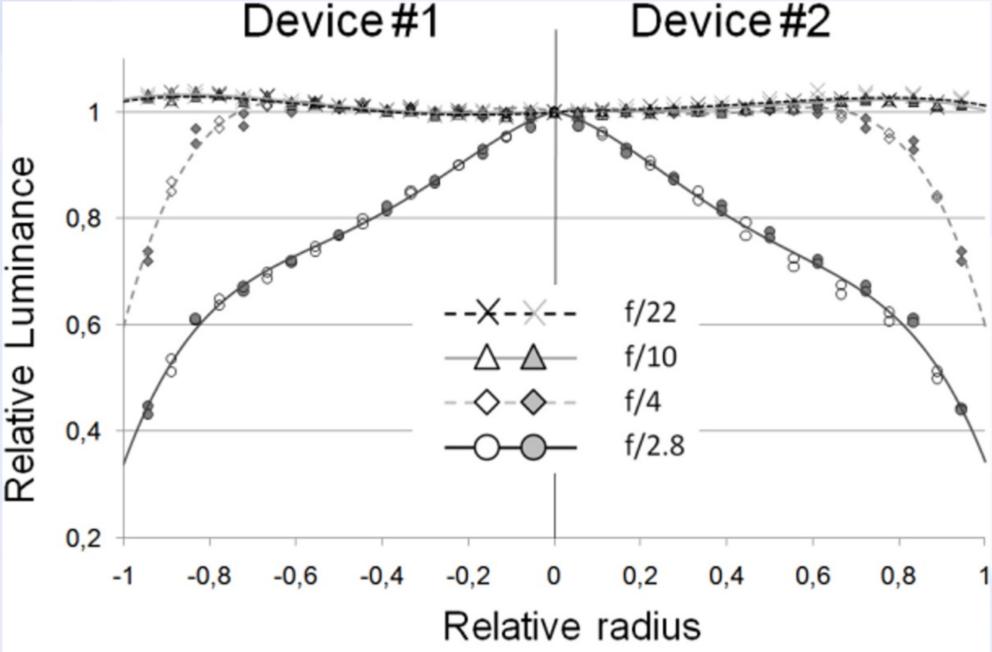


False Colour Patches



Vignetting

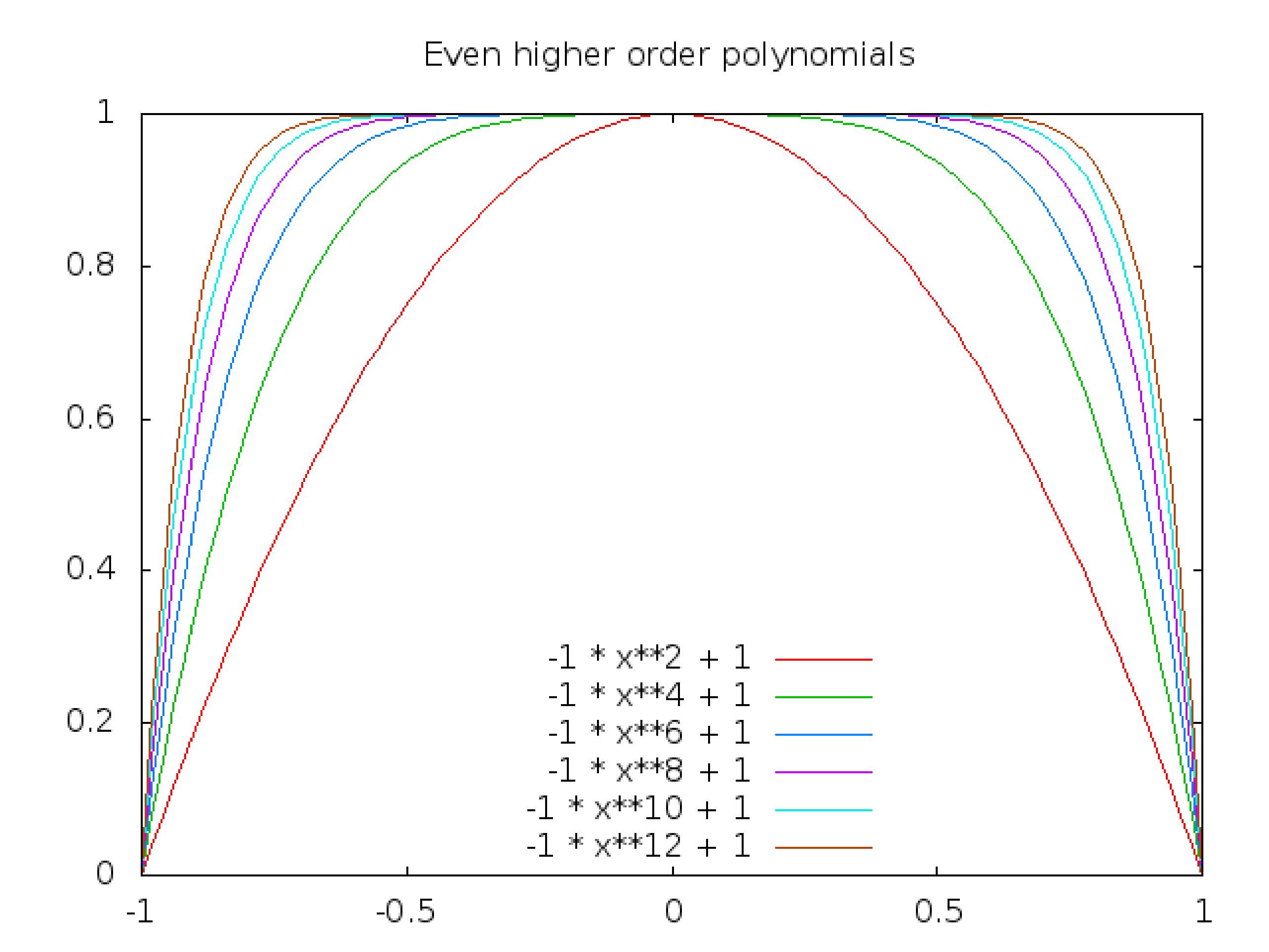
- Raw measurements show a fairly good match with Cauwerts C., Deneyer A., Bodart M., *Vignetting effect of two identical fisheye lenses*; Proceedings of the 2nd CIE Expert Symposium on Appearance "When appearance meets Lightning…" p. 97-99 (2010) ([PDF](PDF))



Polynomial Approximation

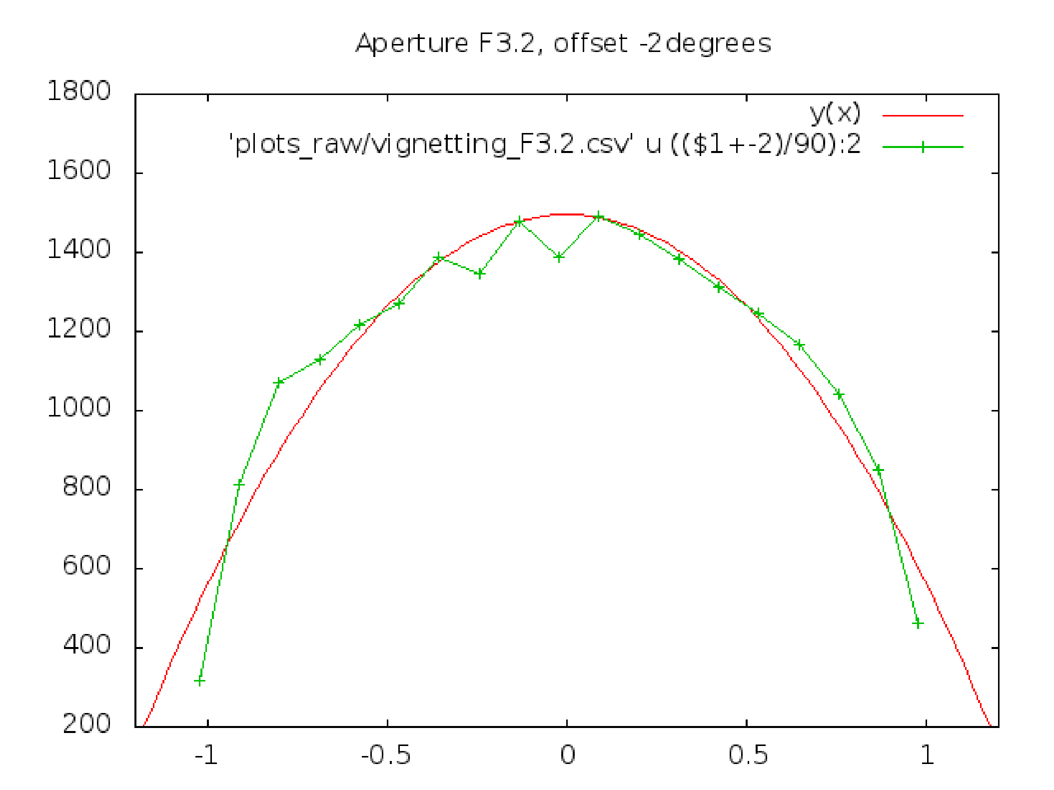
- Vignetting is commonly described with a higher-order polynomial; even orders only to achieve symmetry
- A polynomial representation is also handy for correcting vignetting in Radiance
- Cauwerts et al did not carry out a polynomial fit
- There are lens databases (both free and commercial) that include vignetting data for specific photographic lenses in polynomial form
- Sigma 4.5mm lens vignetting is fairly flat for apertures F 5.6 or higher but shows a sharp drop-off above 80 degrees.
- Polynomial >6th order is needed.

Even Order Polynomials



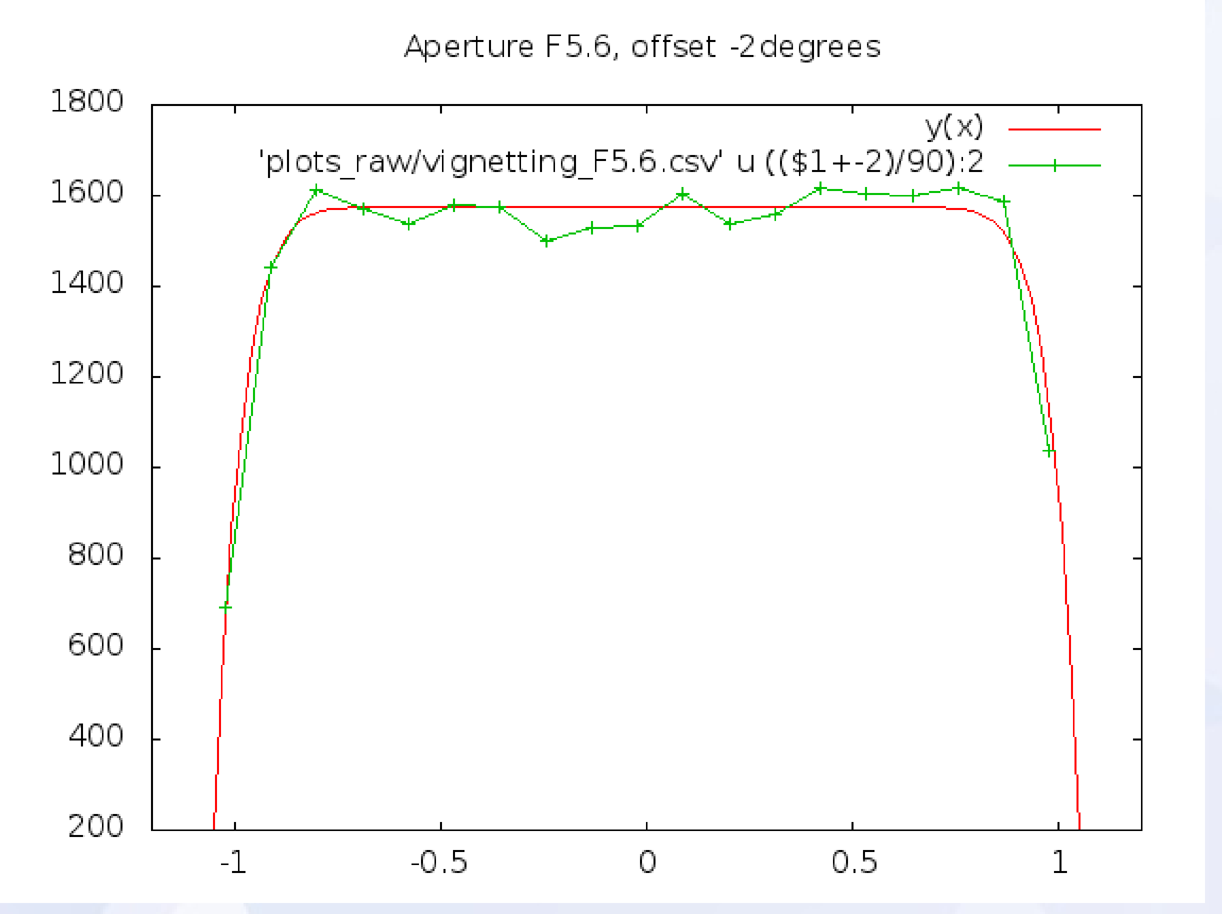
y(x) = a + bx^2 + cx^4 + dx^6 + ex^8 + fx^10 + gx^12 + hx^14 + ...

Vignetting



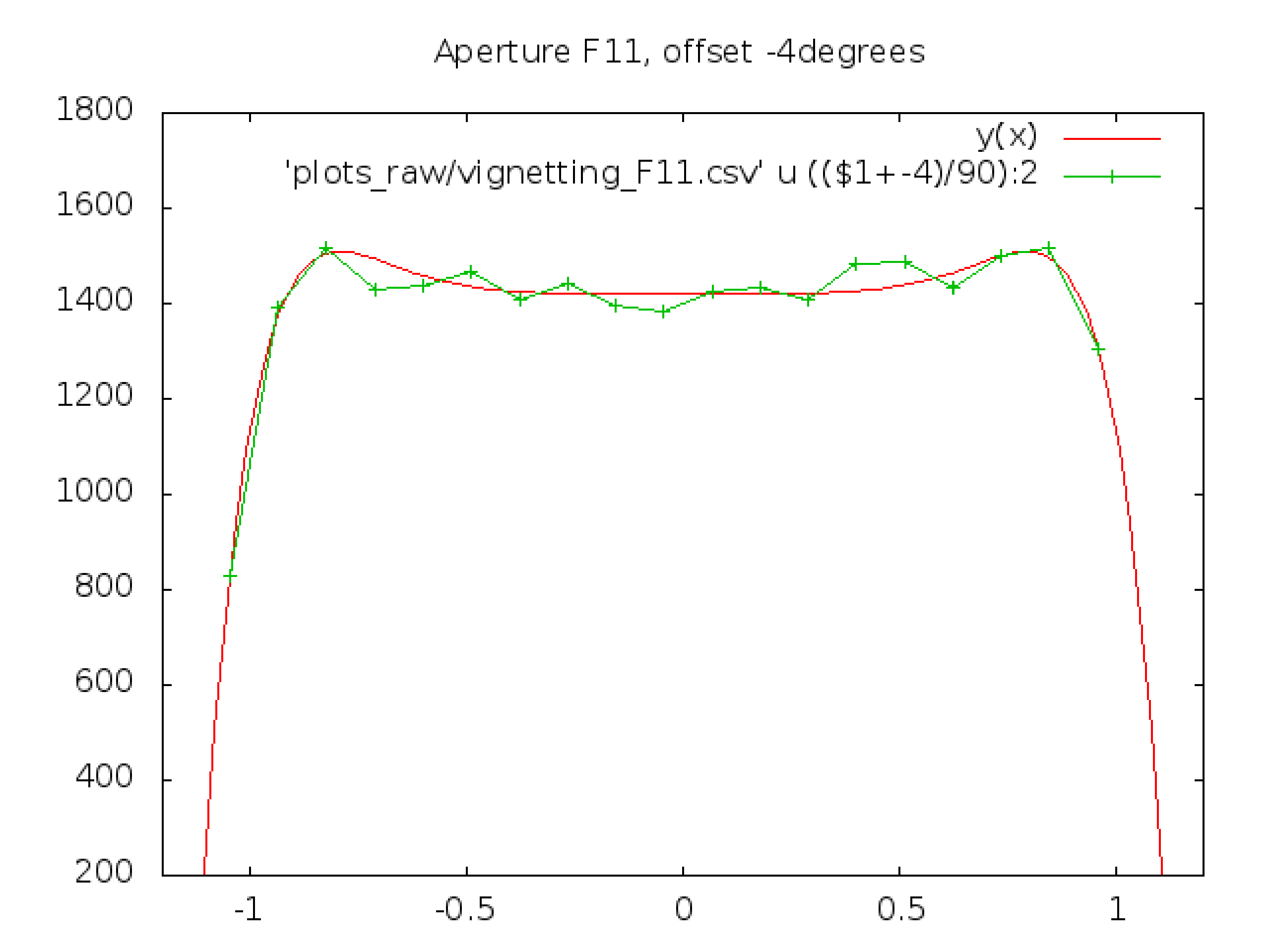
For F3.2, a second order seems to work well: y = a + b x^2
To be useful with Radiance, this should be normalised so that y(0) = 1.
This would remove the constant 'a' from the polynomial equation.
This is not done on this plot and the following ones.

Vignetting



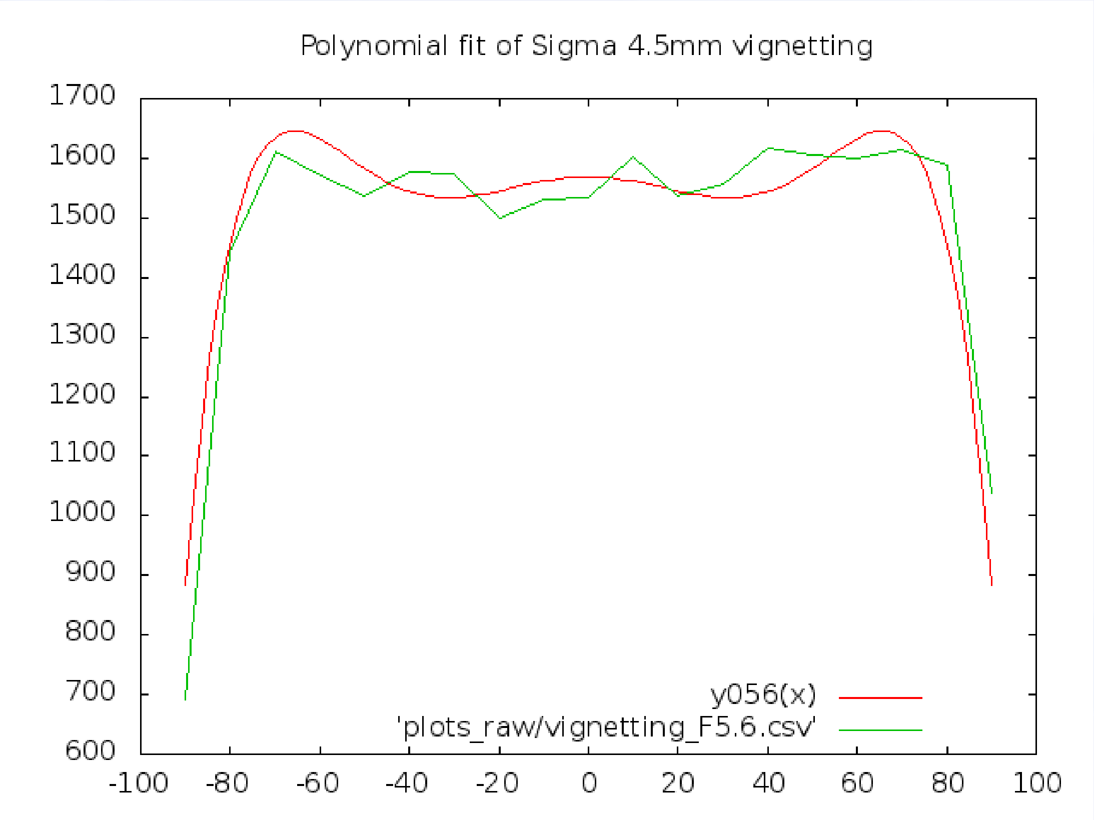
The quality of the raw data does not allow to say with certainty whether the 'wings' at about 80 degrees are a real phenomenon. If they are not, we can try a polynomial with a single higher order coefficient: y(x) = a + fx^10

Vignetting



… but if the 'wings' are real, two higher orders will work better e.g.
y(x) = a + dx^6 + ex^8   or possibly   y(x) = a + cx^4 + ex^8

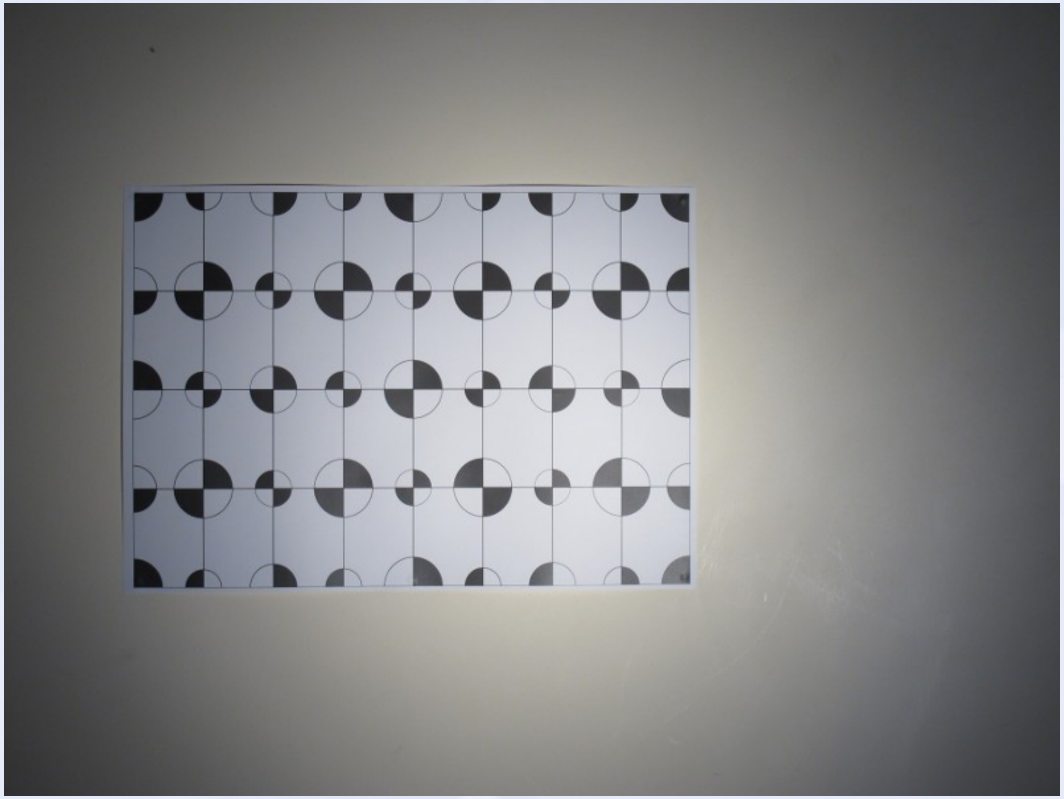
Vignetting

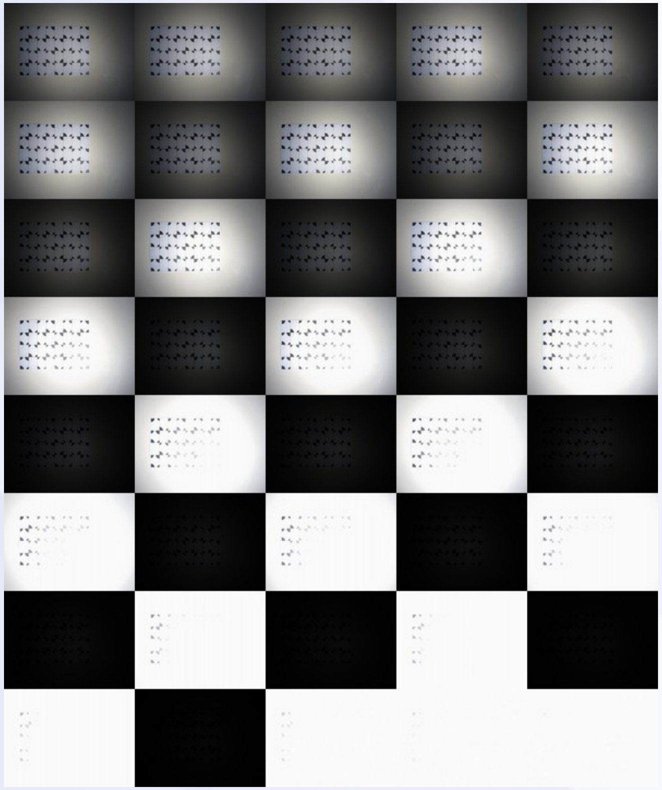


If all (even) orders are used in the regression analysis, we might end up with some 'wobbles' that are probably not very correct, either. Again, this largely depends on the quality of the raw data, which is not particularly good here. Maybe a regression analysis on good quality data does not require so much tinkering and guesswork.

RAW vs JPG

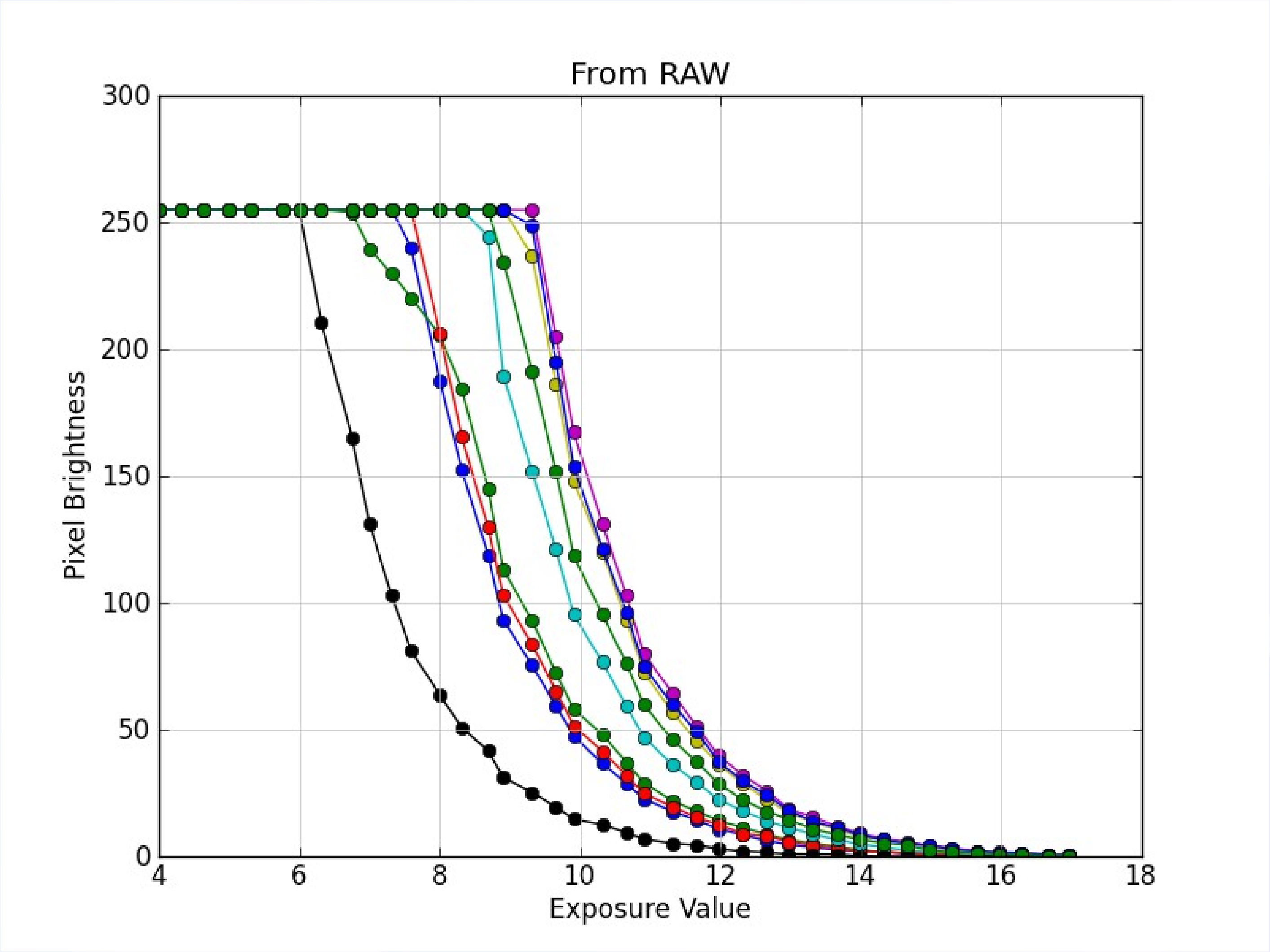
RAW vs JPG





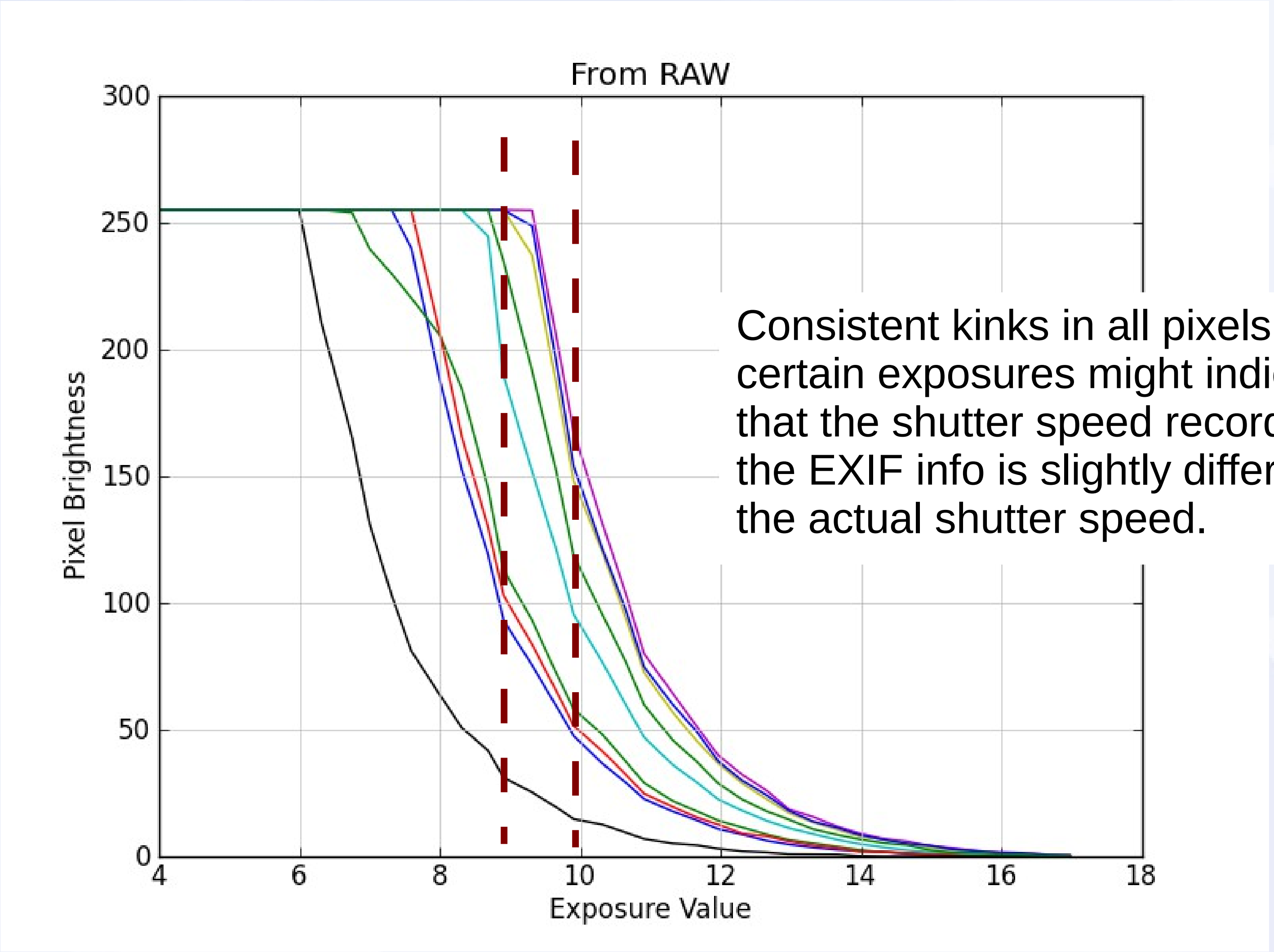
- EB sequence in RAW and JPG with 1/3 EV steps (G12)
- Extract values of 10 pseudo-randomly sampled points

RAW vs JPG



From RAW
Pixel Brightness
Exposure Value
300
250
200
150
100
50
0
4
6
8
10
12
14
16
18

RAW vs JPG



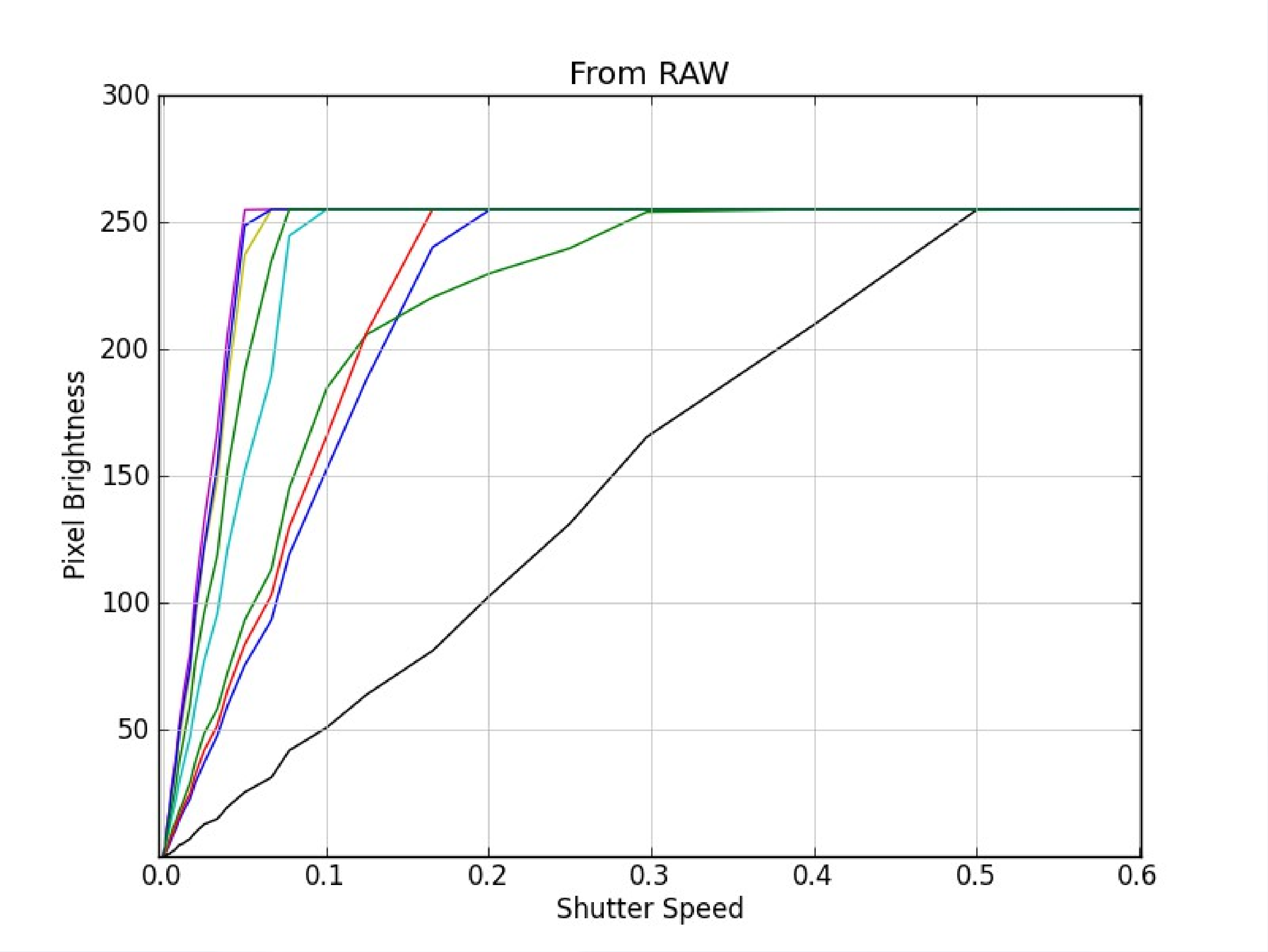
Consistent kinks in all pixels for certain exposures might indicate that the shutter speed recorded in the EXIF info is slightly different to the actual shutter speed.

RAW vs JPG

$$EV = log_2(\frac{Aperture^2}{ShutterSpeed} \times \frac{ISO}{100})$$

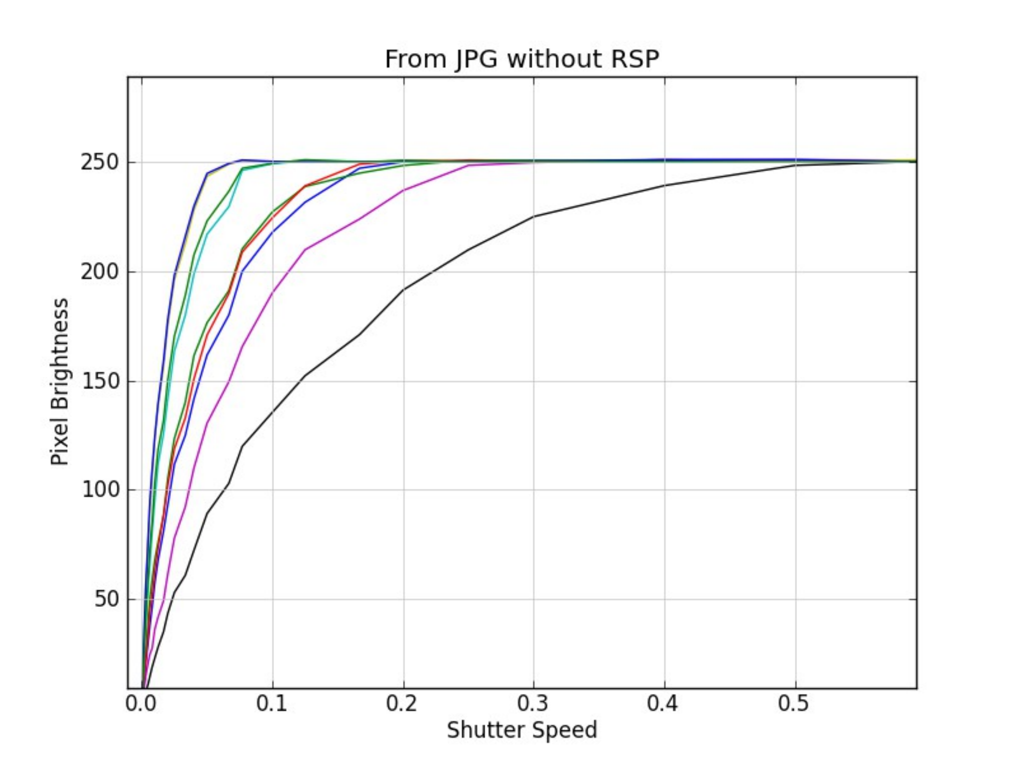
Exposure value is a log2 function.
Let's plot against ShutterSpeed...

RAW vs JPG



Nice and linear pixel response. Results can be a bit weird near saturation point. Pixel values were averaged over 10x10 area to cut down on noise.

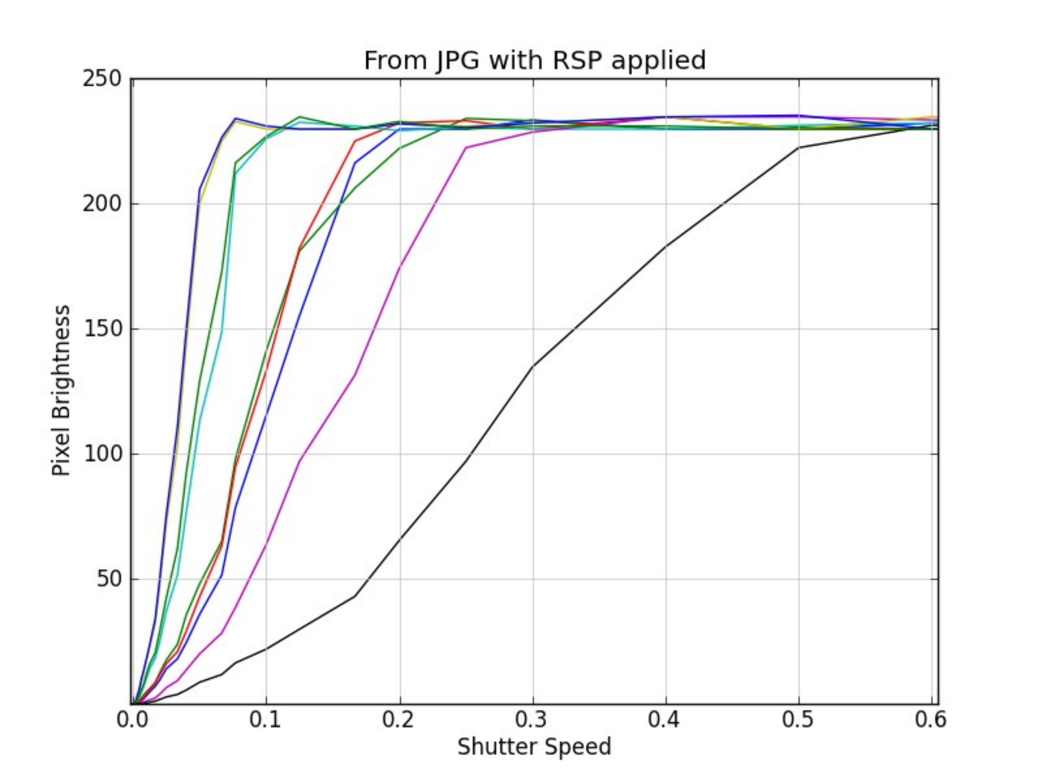
RAW vs JPG



Same plot, same pixels from JPG (G12). Notice two things:

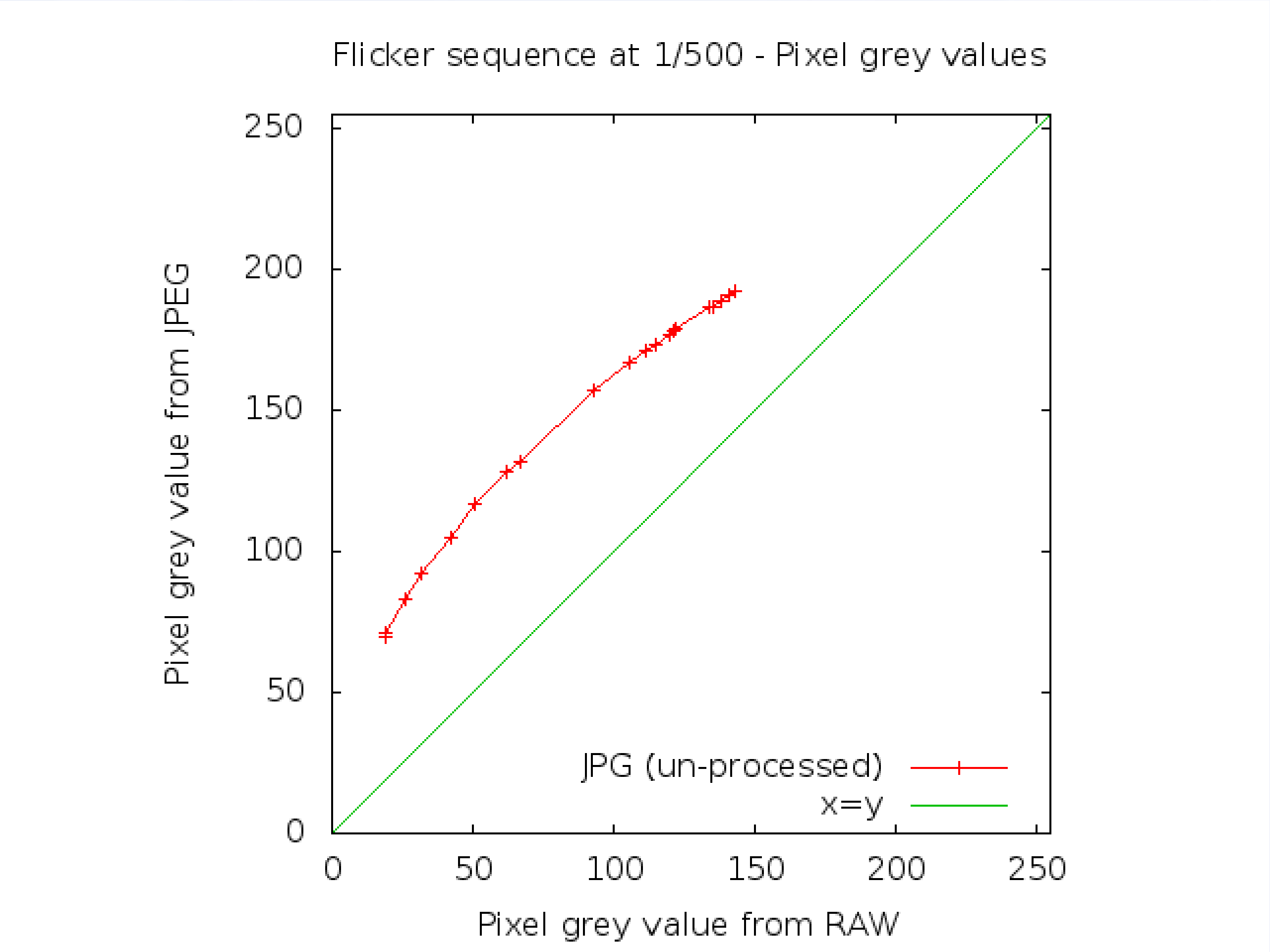
- non-linear response
- bug in camera firmware or processor means that no pixel is brighter than 251 (should be 255)

RAW vs JPG



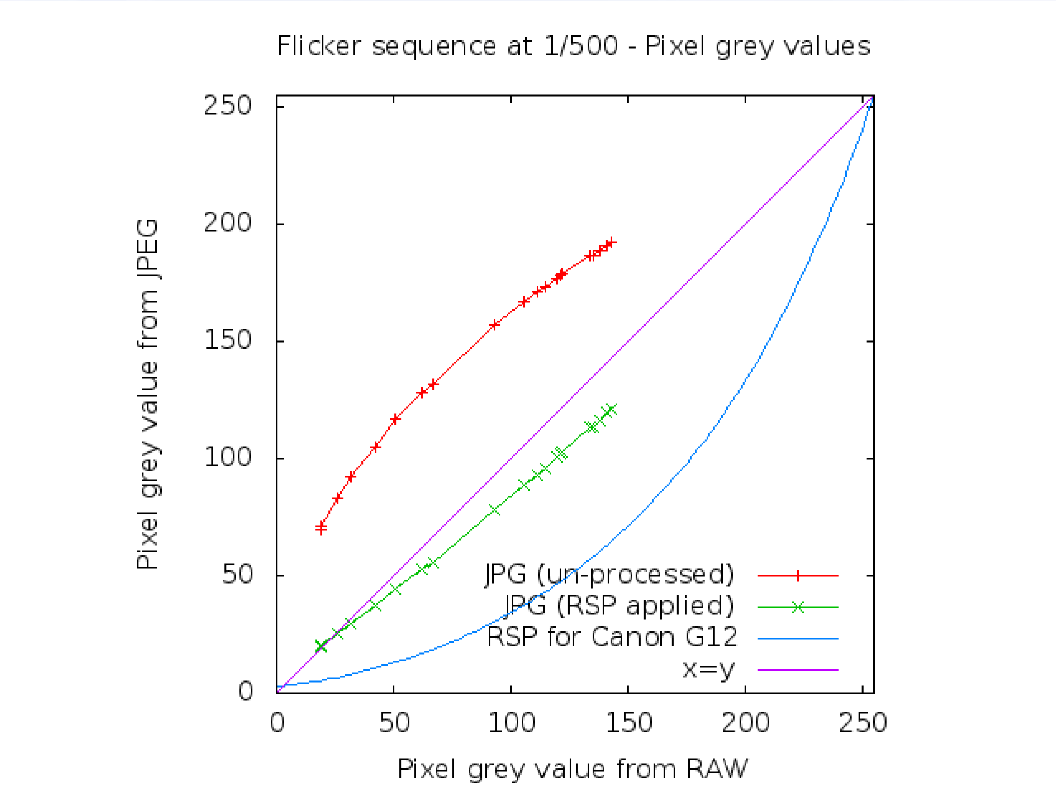
Same JPGs, same pixels, this time with RSP applied.
Curves are much straighter, but not as good as from RAW.
G12 bug shows up again.
Q: Just how good is the RSP?

RAW vs JPG



If we use RAW as baseline, we can plot an X/Y diagram with the pixel grey values.

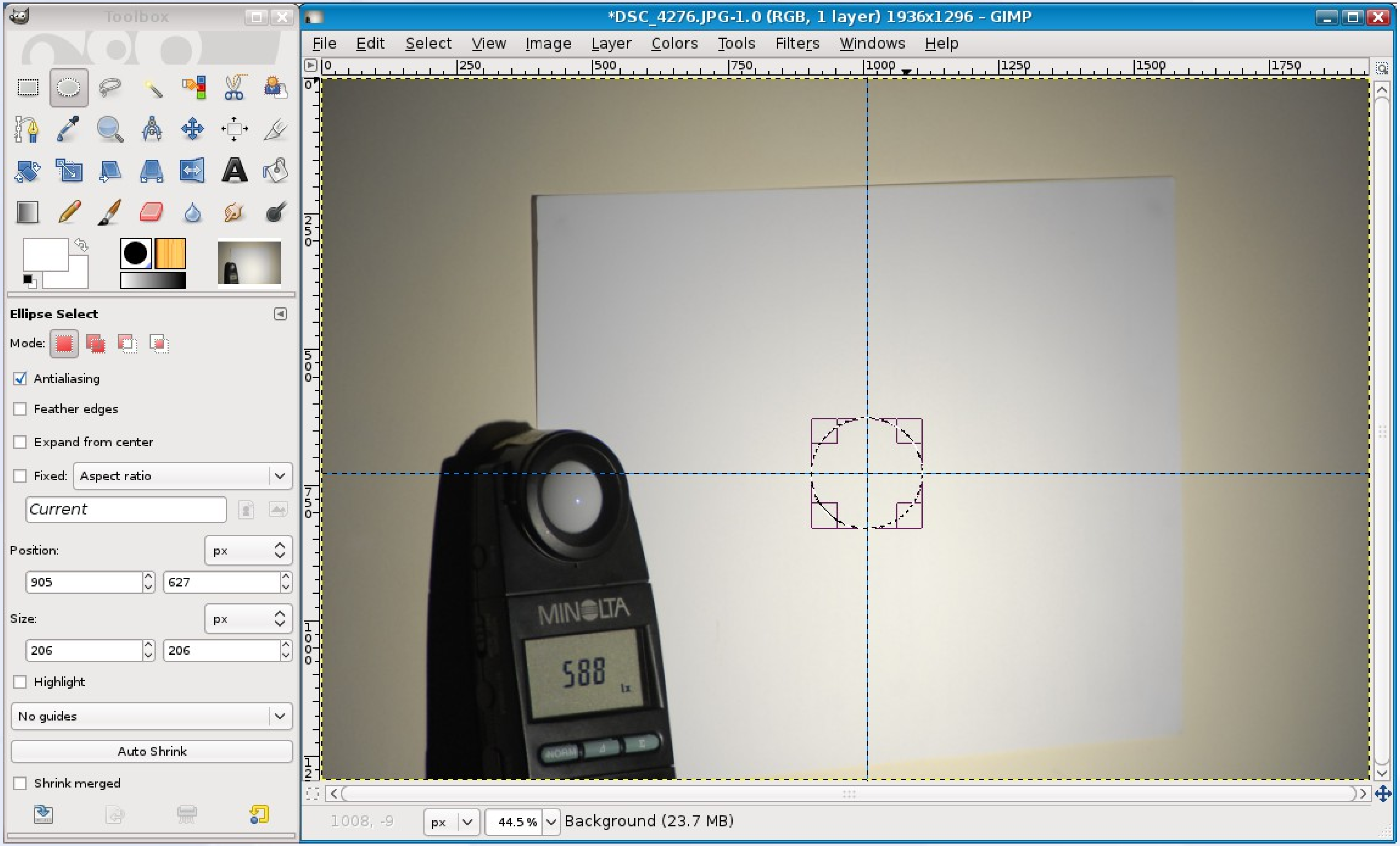
RAW vs JPG



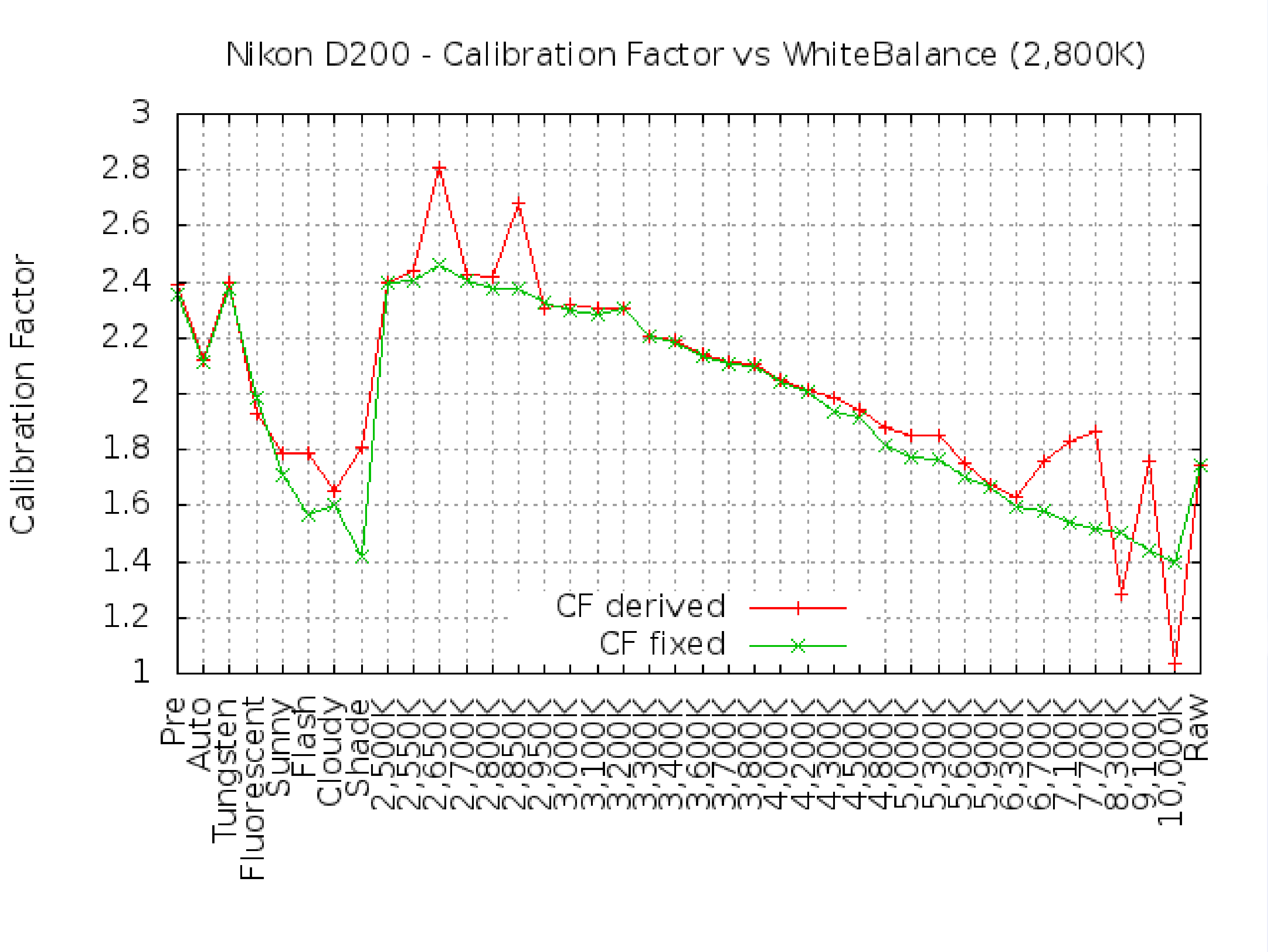
Now apply RSP to JPG. X/Y chart should show a perfectly straight line.
This particular RSP over-compensates for the unknown camera transformations.
There appears to be no reliable way of knowing whether an RSP is good.
Use RAW for most accurate results.

Whitebalance

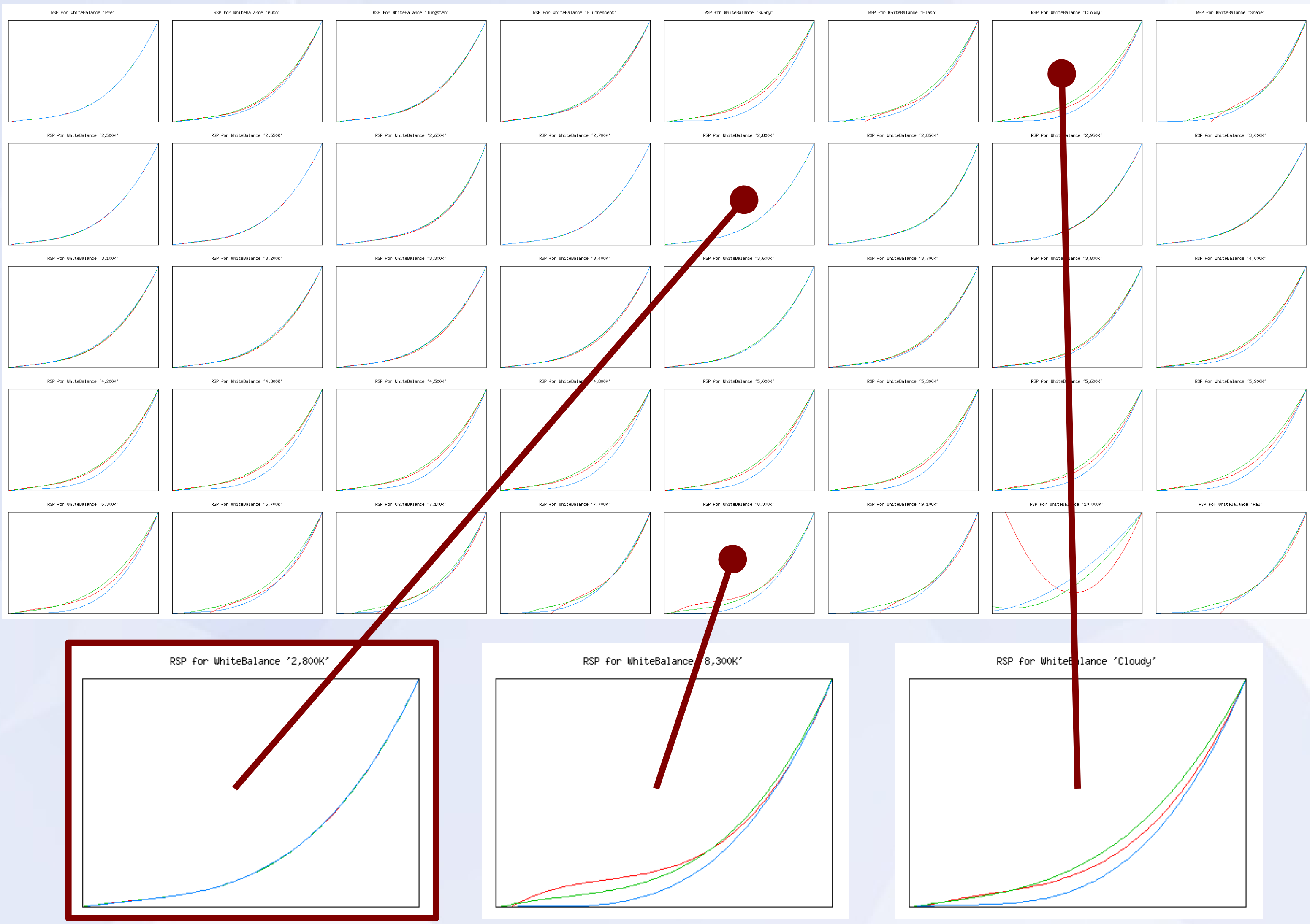
Area of Interest



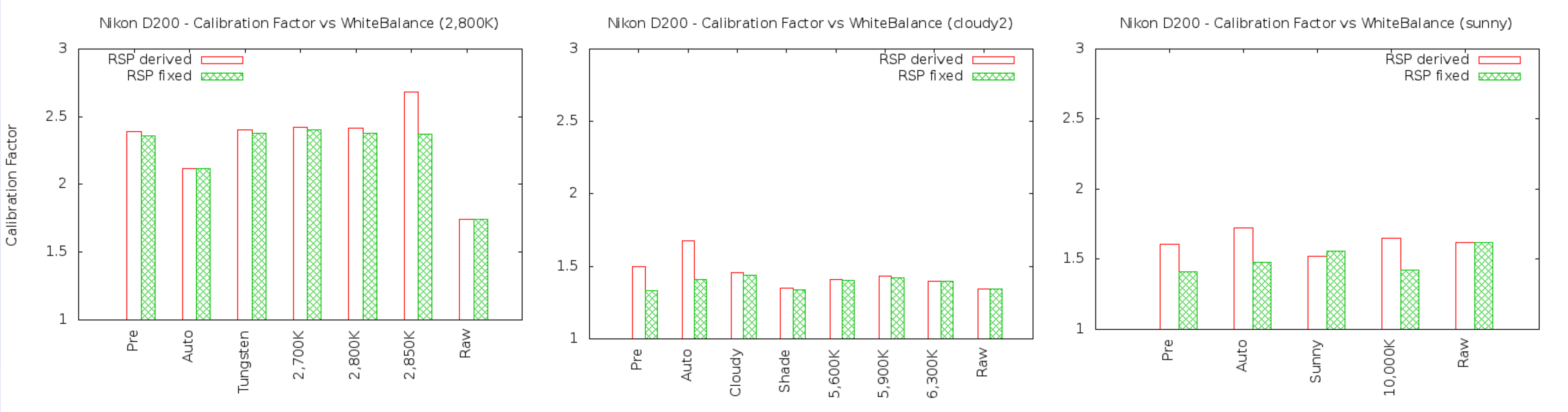
Calibration Factors



RSP Polynomials



CCT



Results suggest that RSP is not only dependent on camera's WB setting, but also on the predominant light source.

This is bad news because it leads to many different combinations of WB and CCT that need to be looked at.

Whitebalance

- Creating a good RSP requires a non-chromatic scene with smooth gradients, as well as a fixed camera WB. This is old news.
- It is not clear how a good RSP can be created reliably.
- A good way of testing an RSP seems to be to compare pixel values against RAW data. This is a little awkward since were are trying to avoid capturing RAW (very large files sizes)
- A JPG vs RAW X/Y plot can show the fitness of an RSP. It could also be used to create an accurate RSP.
- CF is often used as the only means of calibration when some of the photometric inaccuracy actually lies with an improper RSP.

Conclusions

Conclusions

- Some variables that impact upon the accuracy of HDR images created from EB sequences have been presented
- Those variables fall into one of three categories:
  - Those that can be determined accurately and compensated for (vignetting)
  - Those that can be measured but not corrected (flicker modulation error)
  - Those that cannot be fully known (whitebalance)

Conclusions

- A motorised head is very handy to have.
- Not all of the equipment was up to scratch, e.g. the 'pano head' and the light source.
- Nevertheless, the experiments still give us a good idea about some (but not all) of the variables that affect the accuracy of HDR photographs.
- This is work-in-progress. More work (and thinking) is required...

Acknowledgements

- XAL for the flat panel light source used in the vignetting tests
- Mike Wilson and Joe Copland of University of Westminster, London for getting me involved in the IT lab glare project
- Peter Hiscocks of Ryerson Polytechnical University, Toronto for the inspiration and encouragement he has given, as well as for his advice on electronics, and his efforts to design a portable flicker meter
- Udo Krueger of Technoteam Ilmenau for the interesting discussion we had the Light+Building in Frankfurt this year