Motional Stark Effect Imaging on ASDEX Upgrade:

First results - January 2013

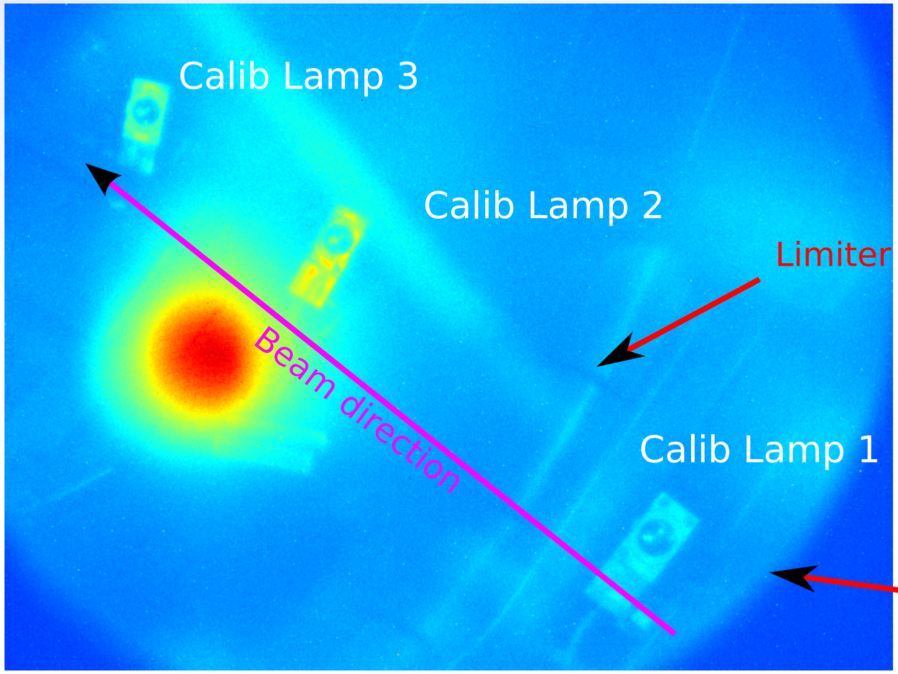
O. P. Ford,[1] J. Howard,[2] R. Wolf,[1] M.Reich [1]

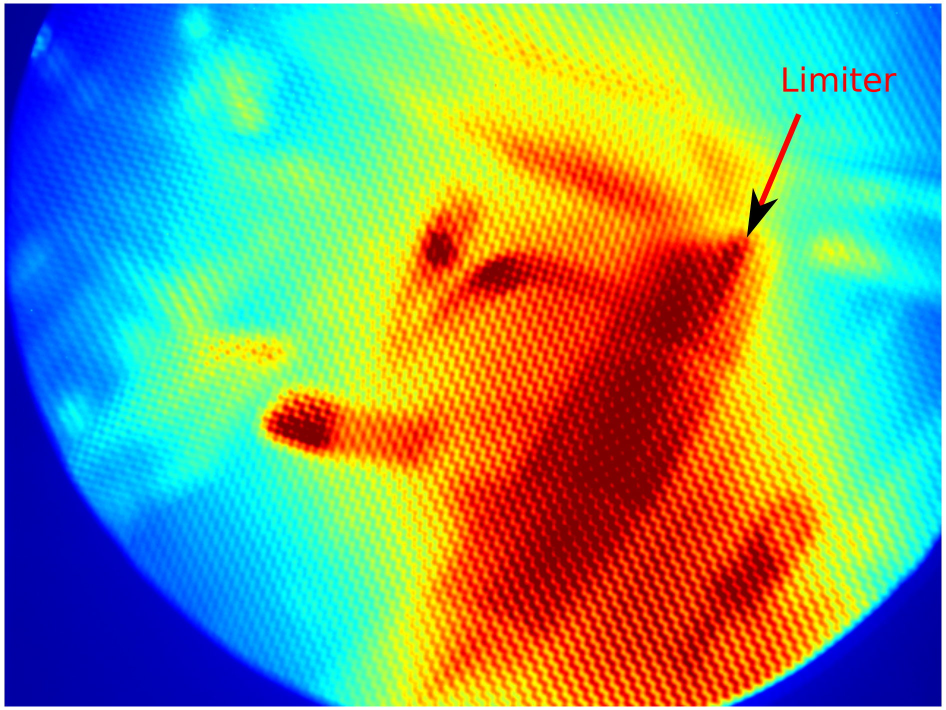
1: Max-Planck Institut für Plasmaphysik, Greifswald/Garching, Germany
2: Plasma Research Laboratory, Australian National University, Canberra

Oliver Ford
IPP Greifswald
gmds/AUG/75-97

Very very early results.

Wednesday night, fitting camera.
No filter, big lamps in torus:





First image of beam emission.
Thursday 24th Jan 2013, 08:55:06

Guessed at 50ms expsoure, which was too much.

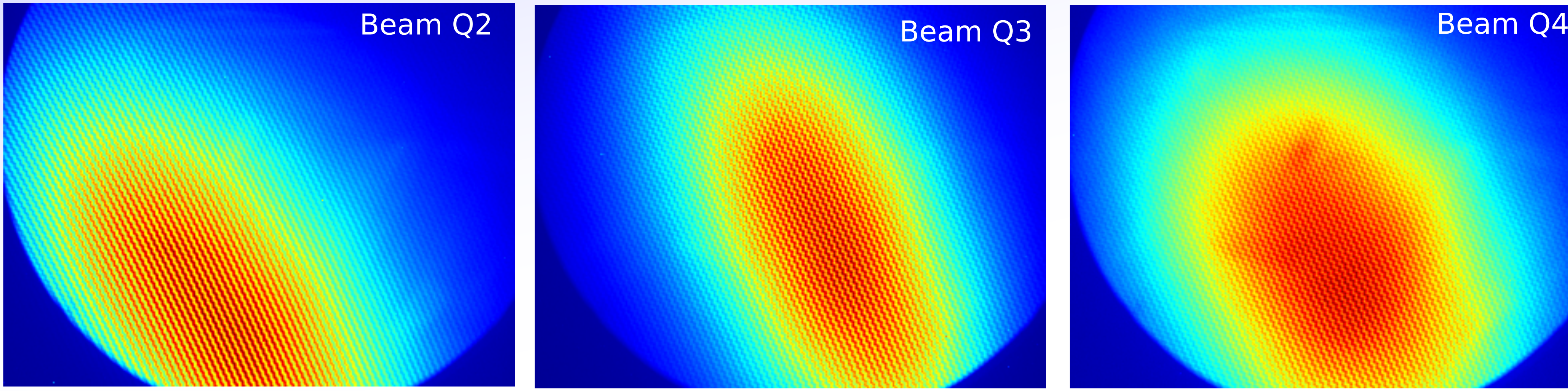
For 2.5MW beam source 3, require 2-10ms exposure.

Up to 30ms in low-density, lower power/voltage.

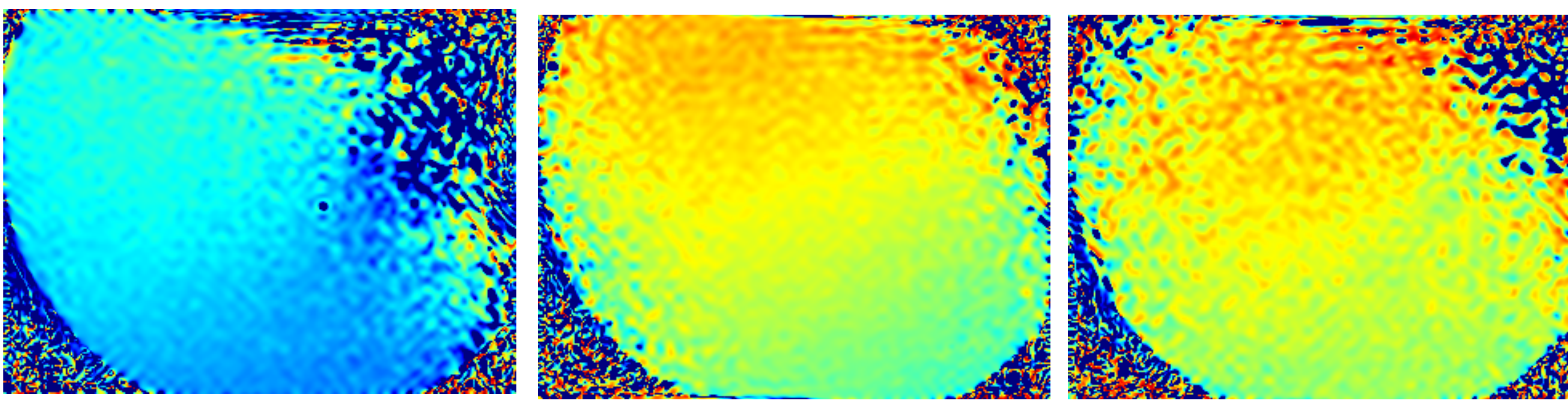
Very very early results (Today)

Oliver Ford
IPP Greifswald
gmds/AUG/75-97

Different beams, all seem to work, but give different angles (as expected).



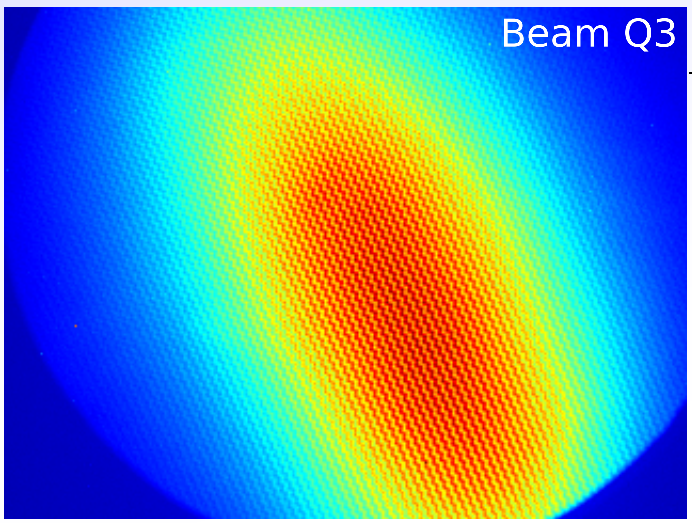
~Polarisation angle:

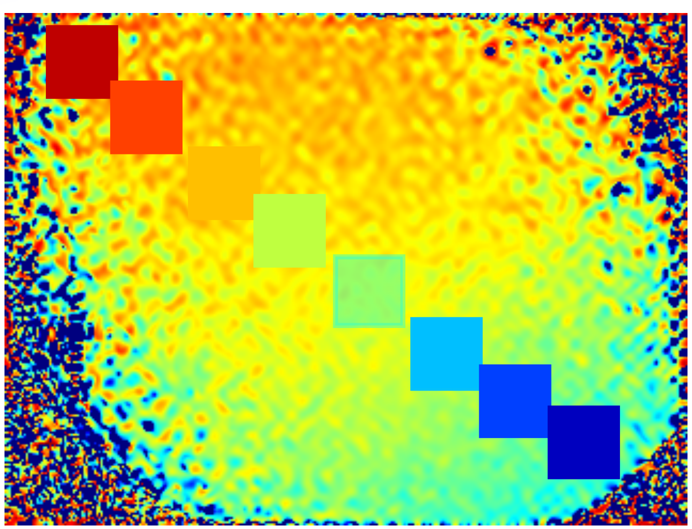


Early current ramp results

Oliver Ford
IPP Greifswald
gmds/AUG/29317

Q2 (beam source 2) and mostly Q3 fired during current ramp, and H-mode on first plasma day.
Looks interesting, but I haven't begun to think whether it's sensible or not.





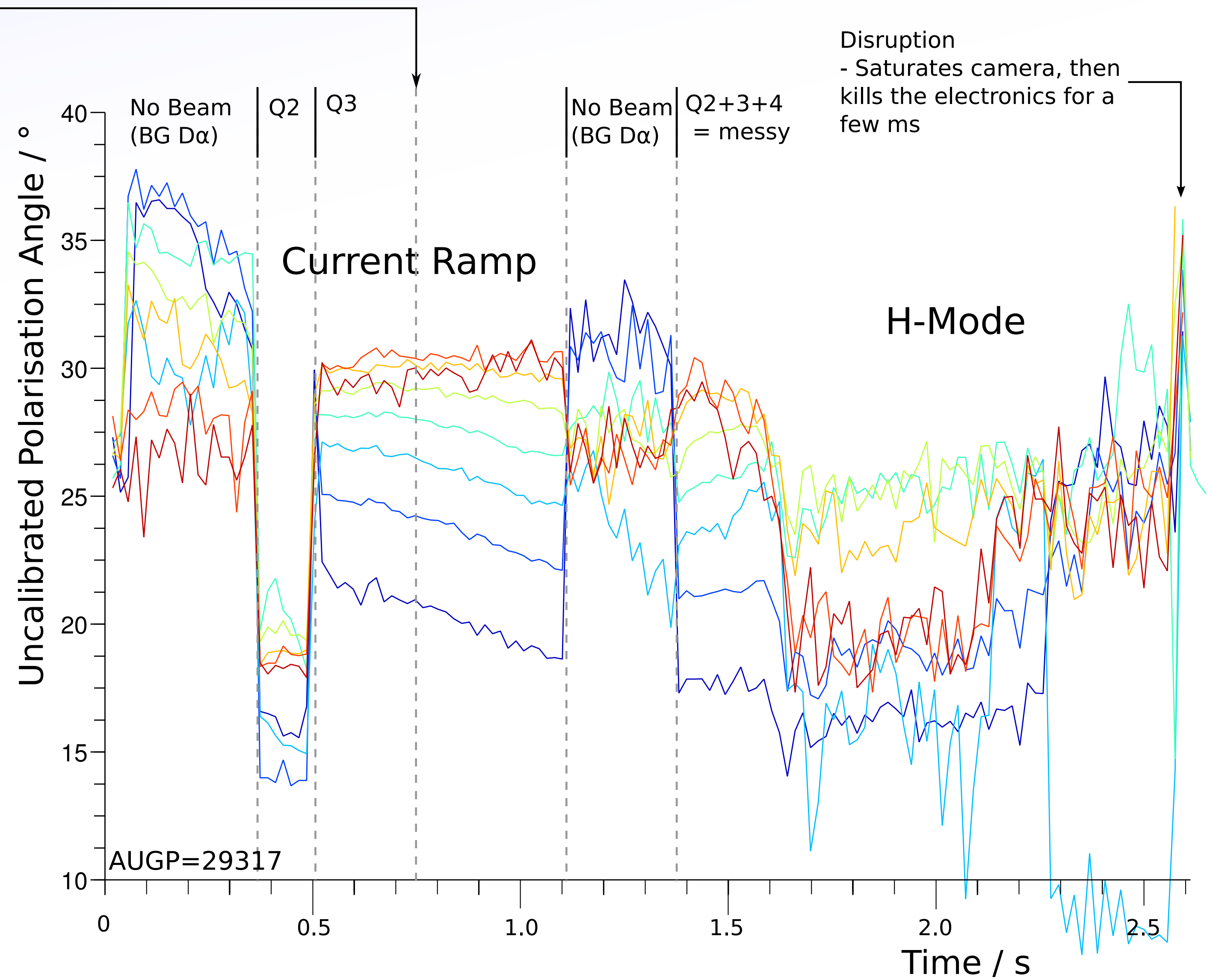
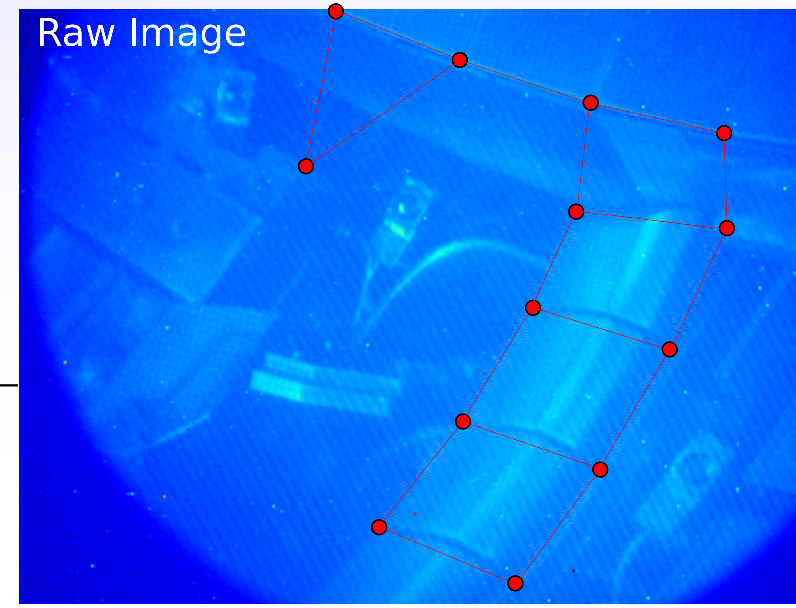


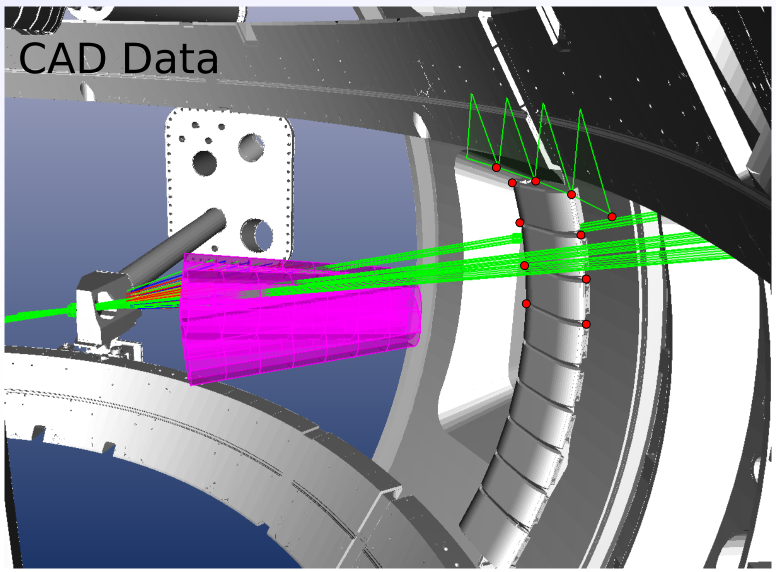
Image Transform

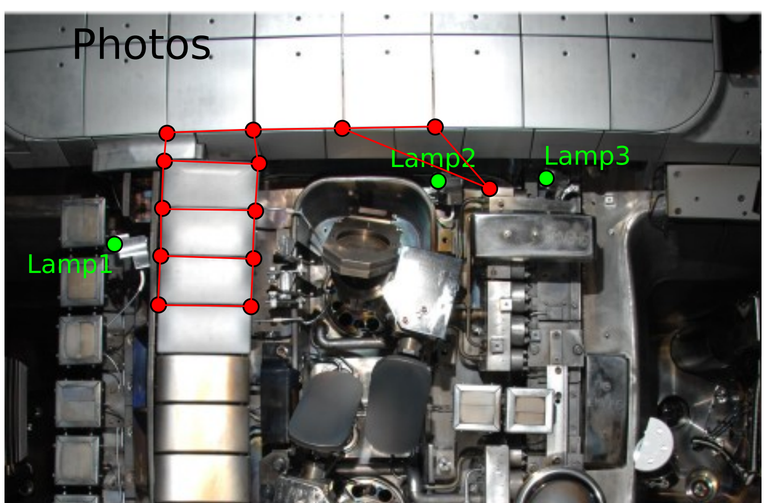
Oliver Ford
IPP Greifswald
gmds/AUG/29317

To convert image coordinates to plasma relevant (R,Z) coordinates:

1) Use background and locate the related points in 3D from CAD data.
2) Take (R,Z) of point at closest approach to beam axis on line from camera to object.
3) Fit Affine/Cubic transform to points.







Project in (R,Z)

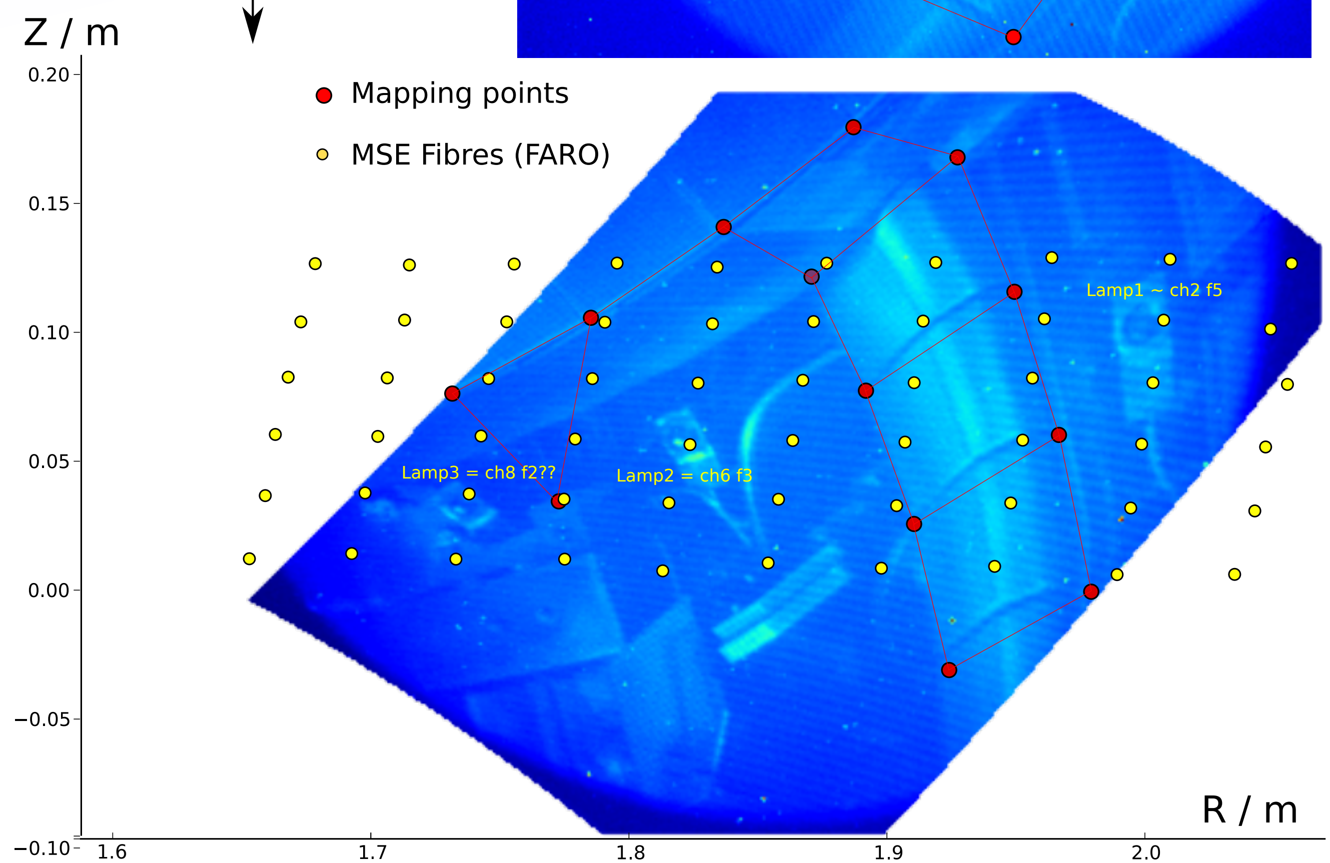
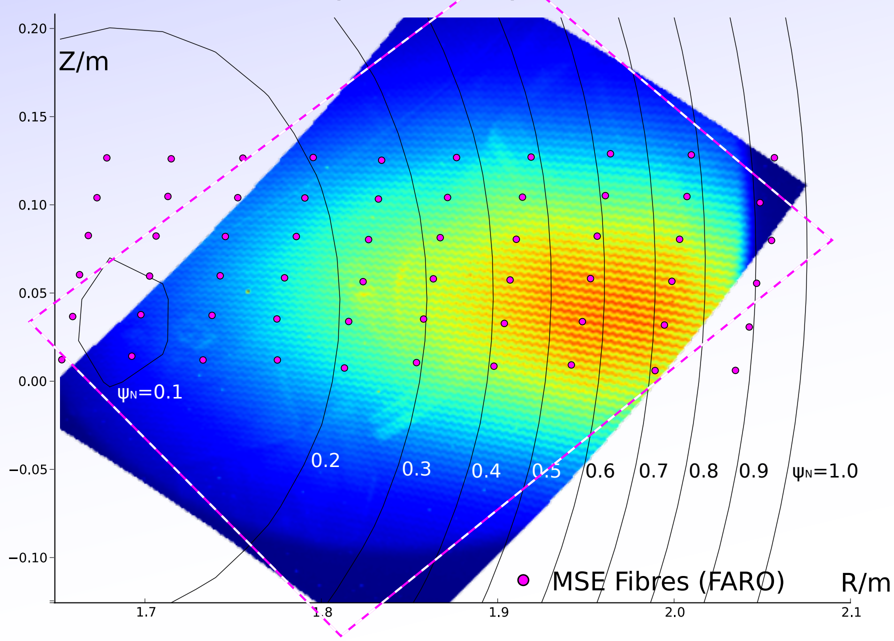


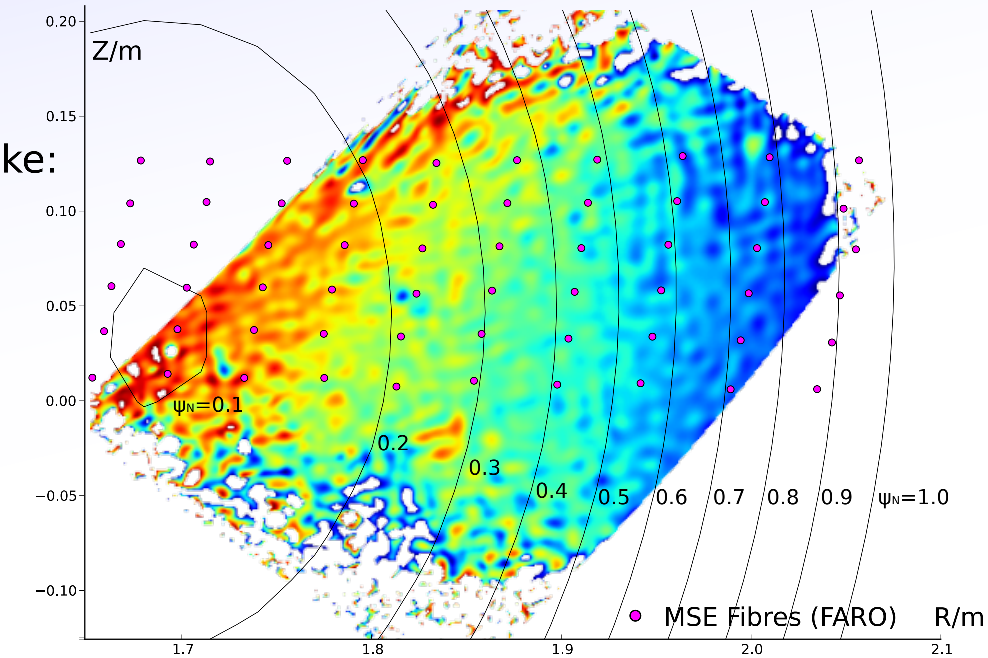
Image Transform 2

Oliver Ford
IPP Greifswald
gmds/AUG/29317

With MSE beam (source 3) and flux surfaces:

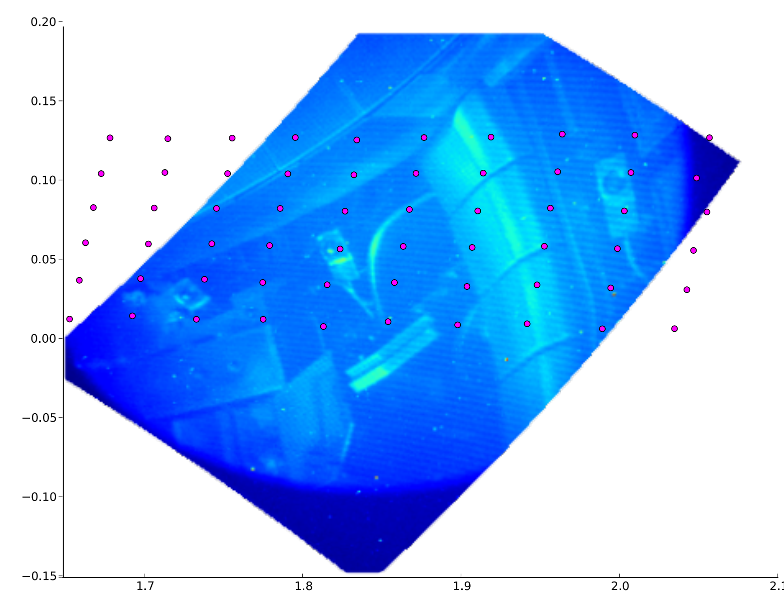


Transformed polaristion angle looks like:



*April2013: Rotated and moved camera to get better view of core and edge.

Ideally would rotate camera ~22° clockwise, but can only get 10° due to physical restrictions.

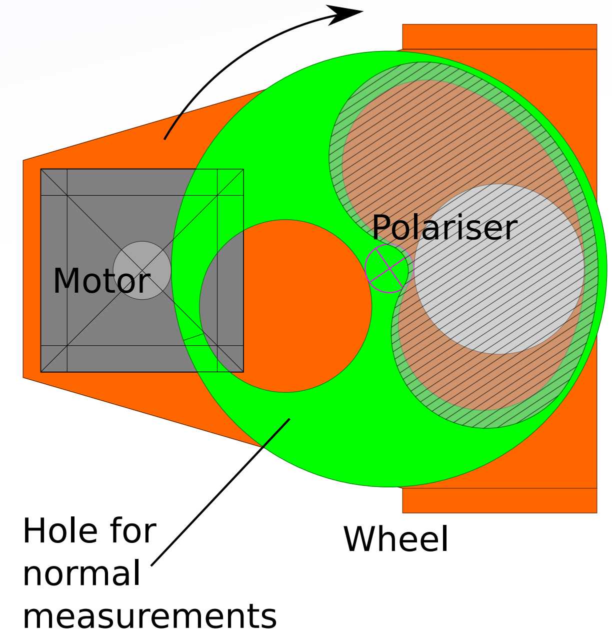


Intrinsic Contrast Calibration

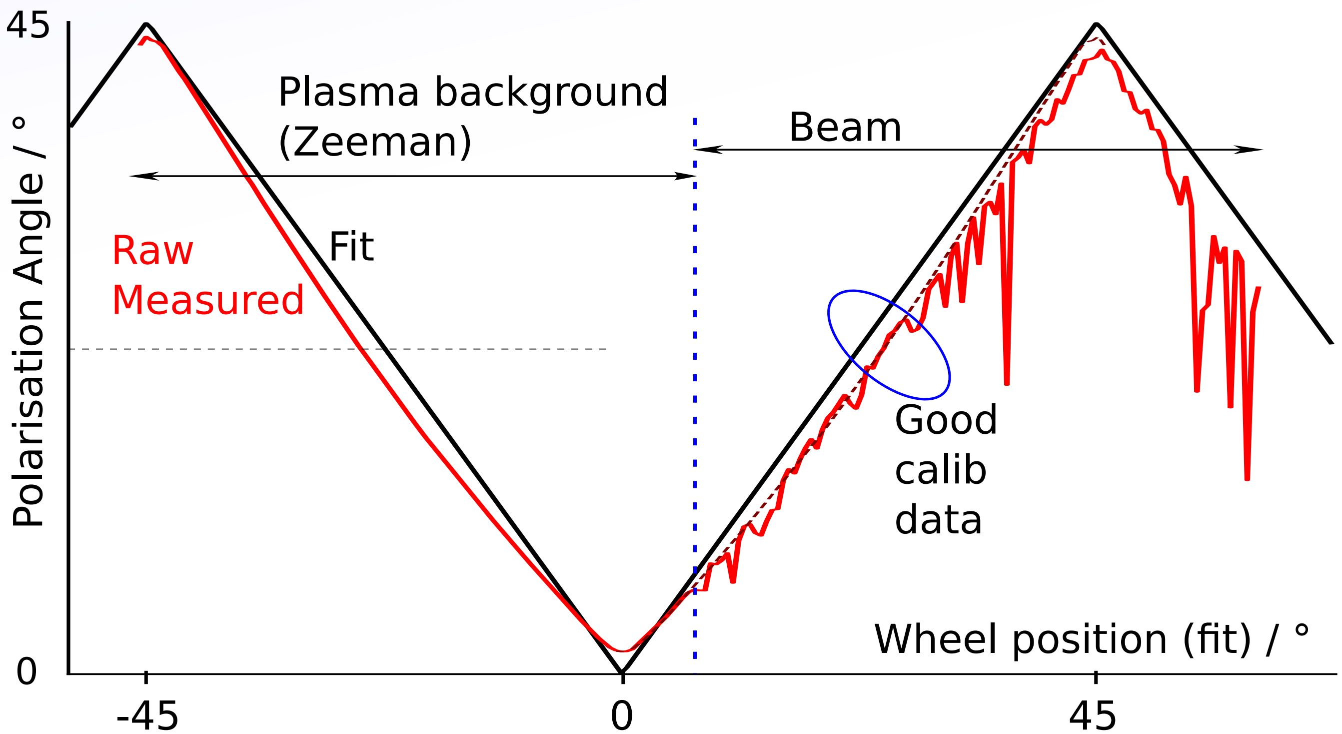
Oliver Ford
IPP Greifswald
gmds/AUG/29317

To first order, the system shouldn't require calibration. However, there is a ~3° non-linearity due to intrinsic constrast of the Savart plate. It varies with polarisation, across the image, and with input light cone.

System has a built in polariser on a wheel to provide the calibration for this. Best is a ~100° scan of polarisation angle using full spectrum of beam light but sometimes motor didn't run during pulse.



1) Full rotation with any light source needed to calibrate stepper motor positions against absolute measured angle:



*April2013: Doubled motor voltage and can now run full scan during all pulses.
Primary calibration for Friday 19th missed due to water leak.

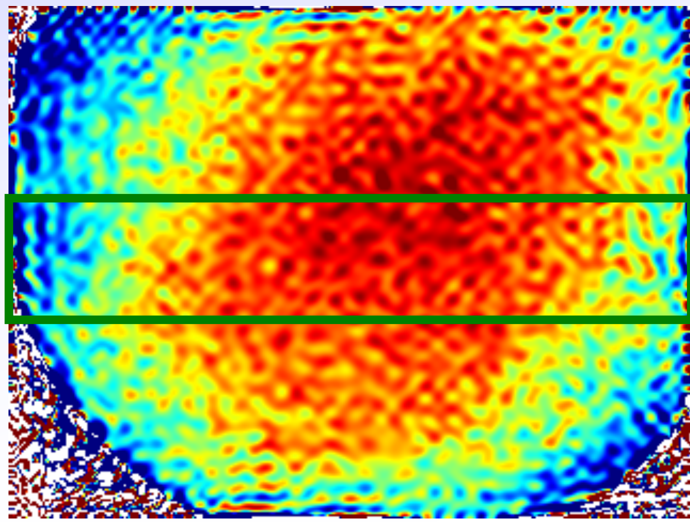
2) Record images with beam light at known absolute angle (near 22.5° is best).
In some cases this was a complete scan as above, in other cases a whole pulse at a fixed angle.

Intrinsic Contrast Calibration

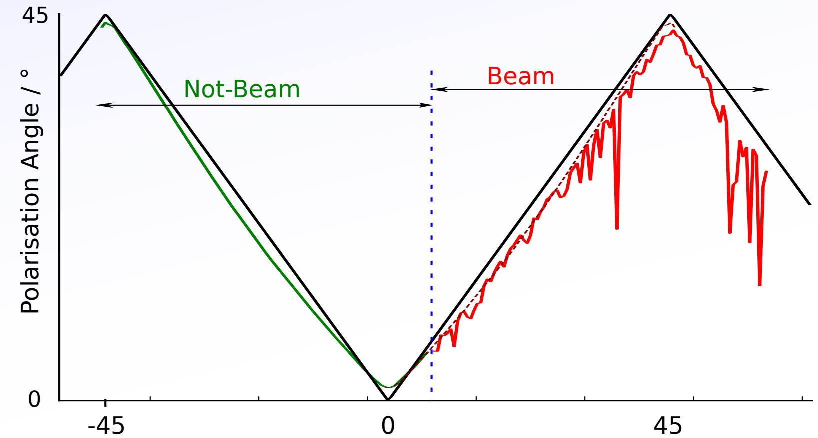
Oliver Ford
IPP Greifswald
gmds/AUG/29317

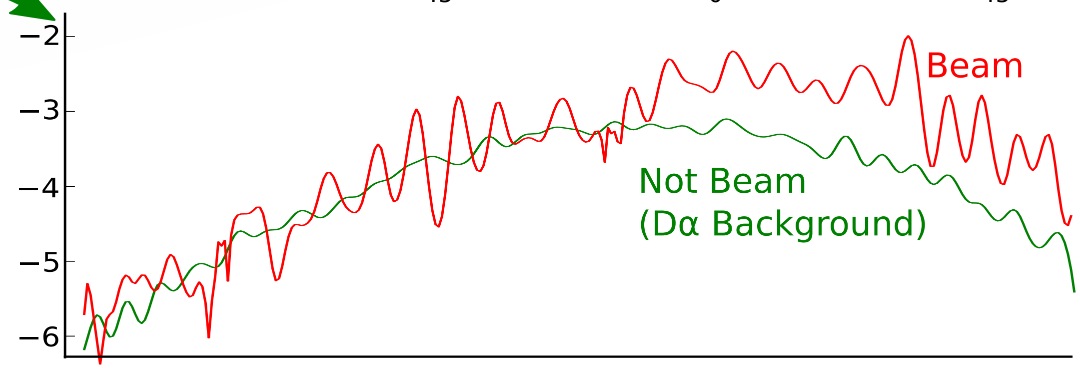
Recorded image gives correction maps:

Not-Beam

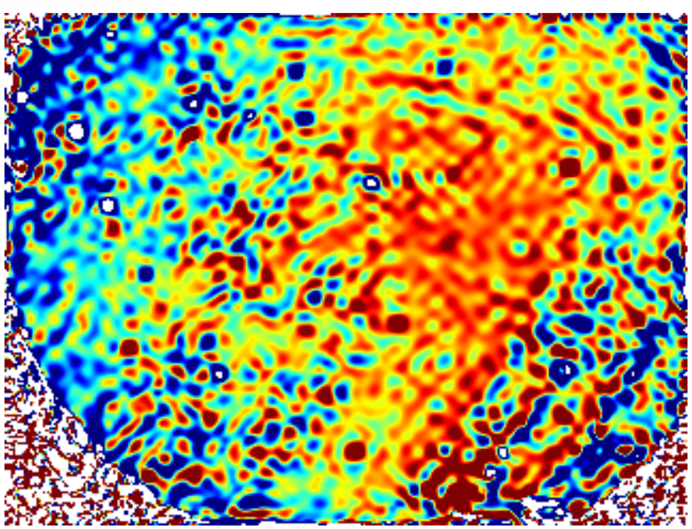


Not-Beam gives much cleaner image, but not necessarily exactly the same as the beam calibration, since light source is at a slightly different focus (distance from lens).

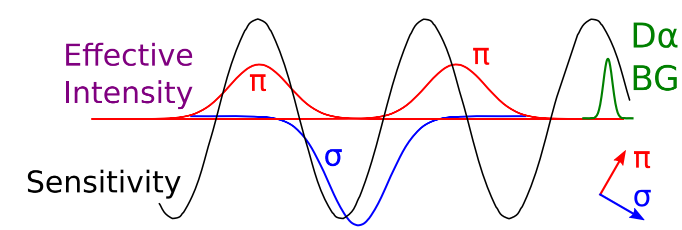




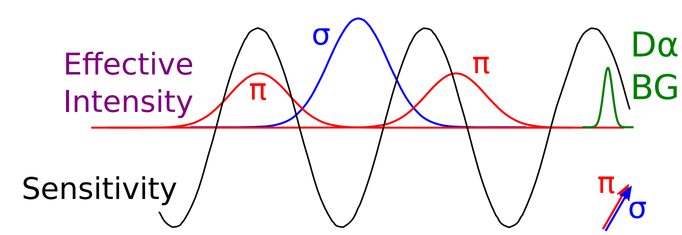
Beam



Beam image has very low contrast, and almost 0 in some areas, because the system delay is set so that contrast adds when σ and π are 90° apart:



With the polariser, σ and π now 0° apart, so system delay makes them subtract while background remains strong.

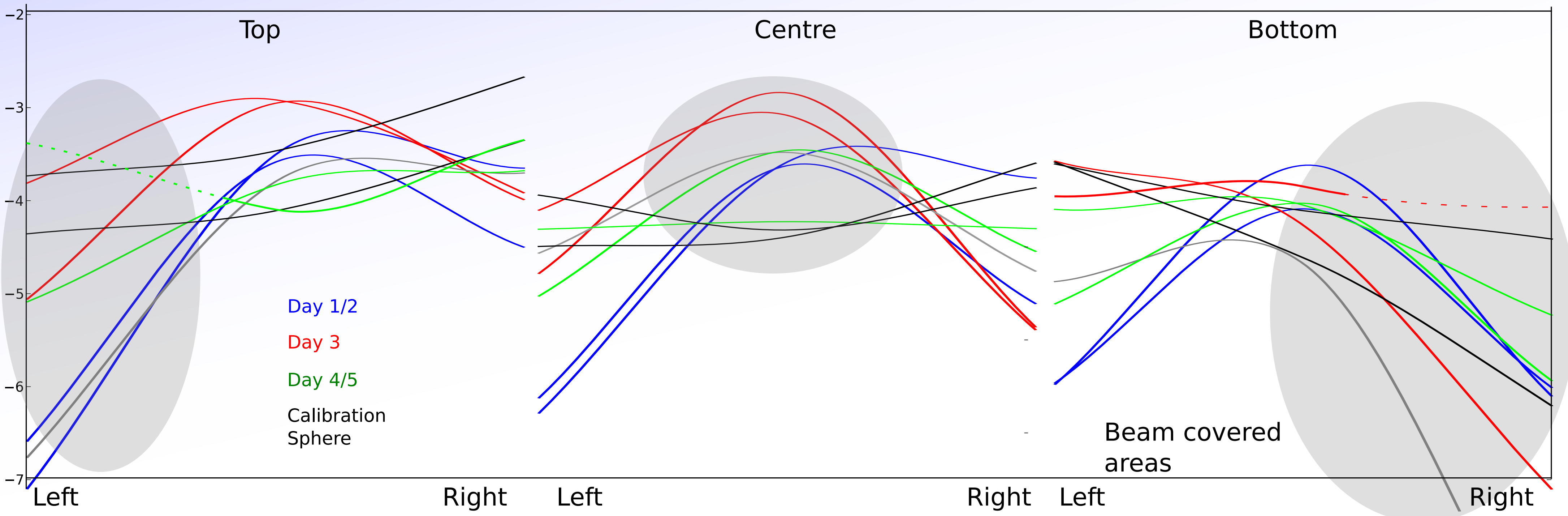


This can be partially mitigated by aligning the polariser to preferentially select σ or π.

Intrinsic Contrast Calibration

Oliver Ford
IPP Greifswald

Fitting 3x3 cubic to good parts of image gives calibration images.



- Variation between days is expected, since the camera and cell were refitted inbetween.
- Calibration sphere is expected to show a different curve, since acceptance angle for image edges is very different to the vignetted beam light.
- ±0.2° of offset is expected due to uncertainty in calibration wheel position (Improved for April experiments).
- Systematic error here is unacceptably large, so calibration needs improvment.

The biggest problem, particularly in the lower right of the image (plasma edge), is that the calibration is almost entirely dominated by reflections since the plasma light is optimised away by the delay plate.

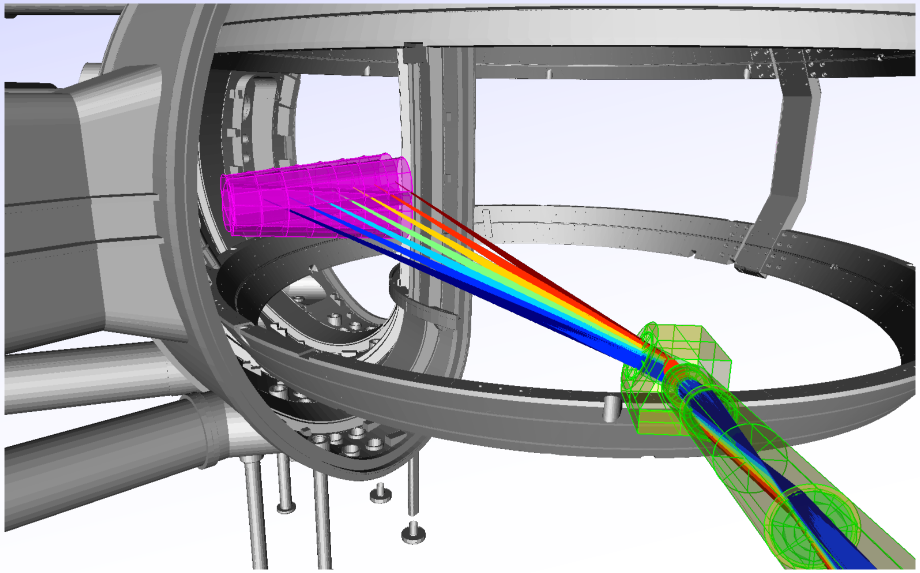
So, for April:

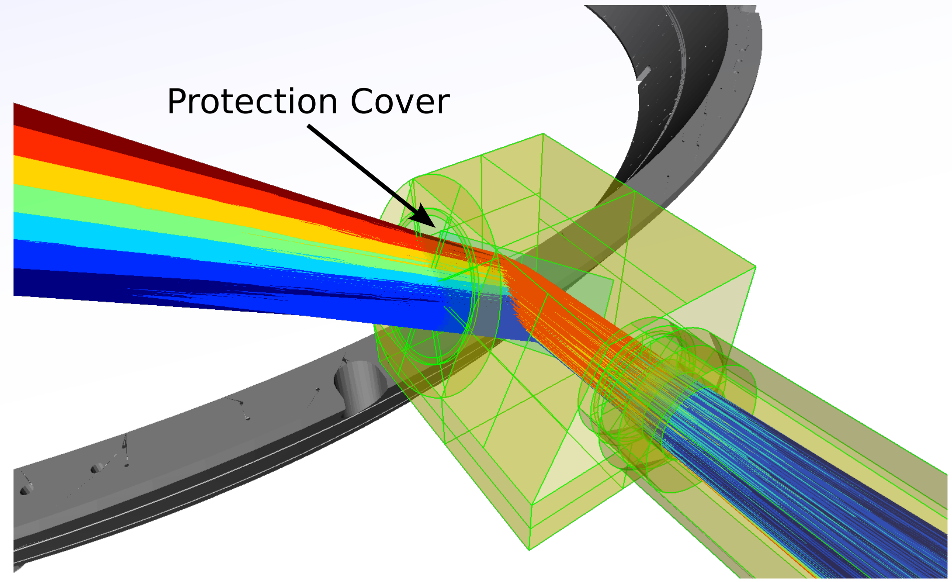
1) Improve calibration wheel reproducibility or knowledge of position (mouse sensor). Done
2) Better filter to reduce Dα background. Arriving now (10am Monday)
3) Several positions over 90° range to preferentially select σ and/or π. Try tomorrow.

Faraday Rotation

Oliver Ford
IPP Greifswald

Faraday rotation in the forward optics significant, particularly in the 3.5mm Fused Silica protection cover.





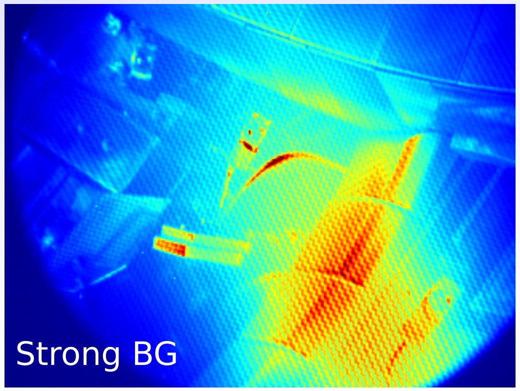
Cover is roughly perpendicular to toroidal field.
Rays vary in angle through glass and to toroidal field dramatically with source/image position but also slightly with position across glass (i.e. the collection cone angle).

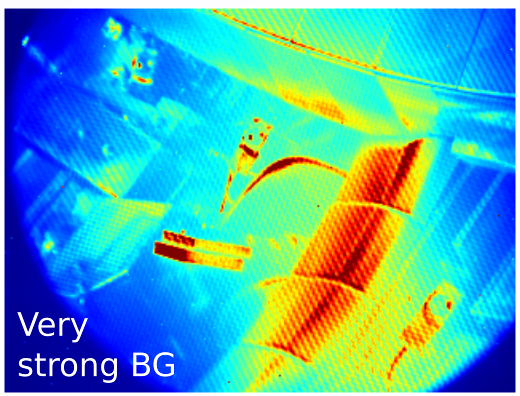
Reflections - Background Dα

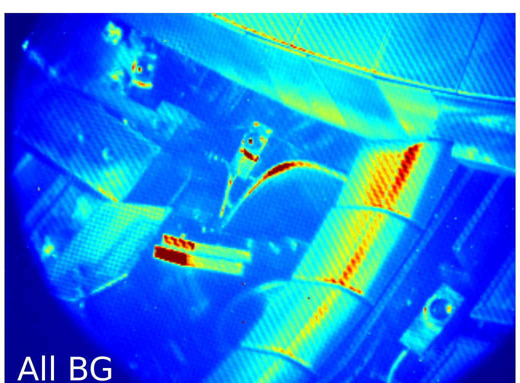
Oliver Ford
IPP Greifswald
gmds/AUG/29317

During H-Mode / high density operation, background light reflecting from limiter etc significantly contaminates the signal:

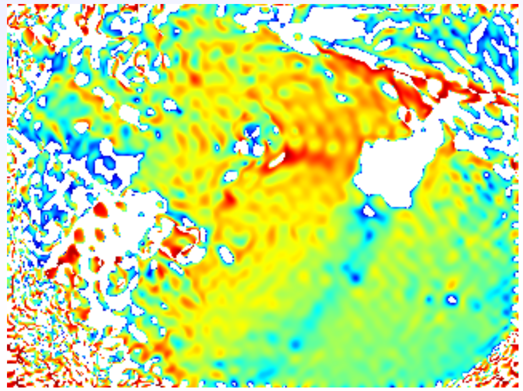
Image

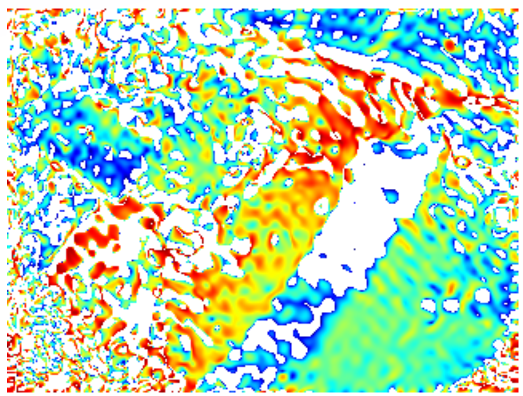


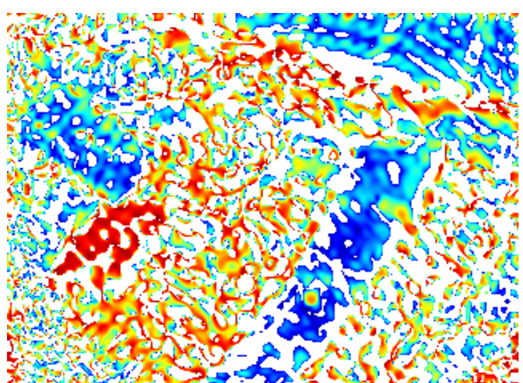




Polarisation:

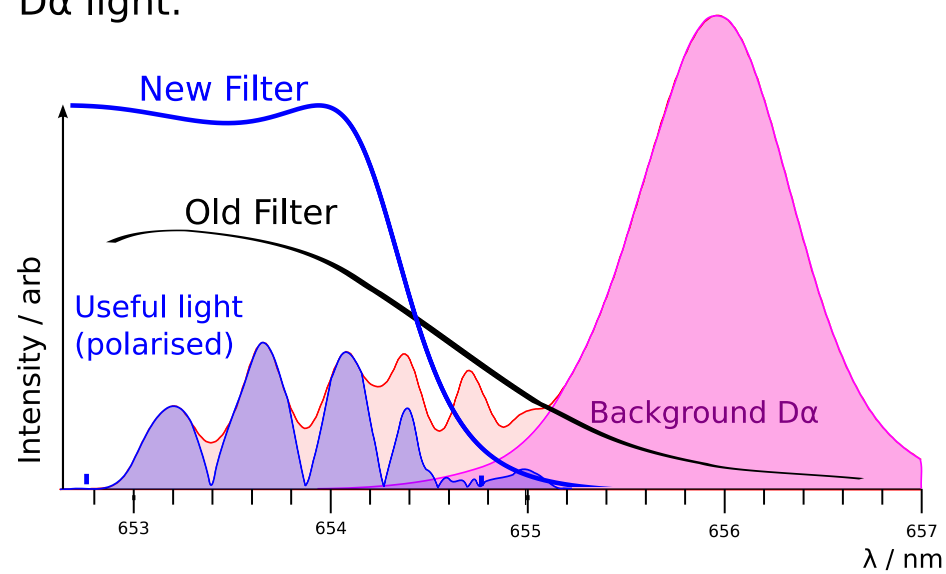






(This is a particularly bad case during a detachment experiment)

This is suspected to be because the filter used is too wide and catches the abundant edge Dα light:

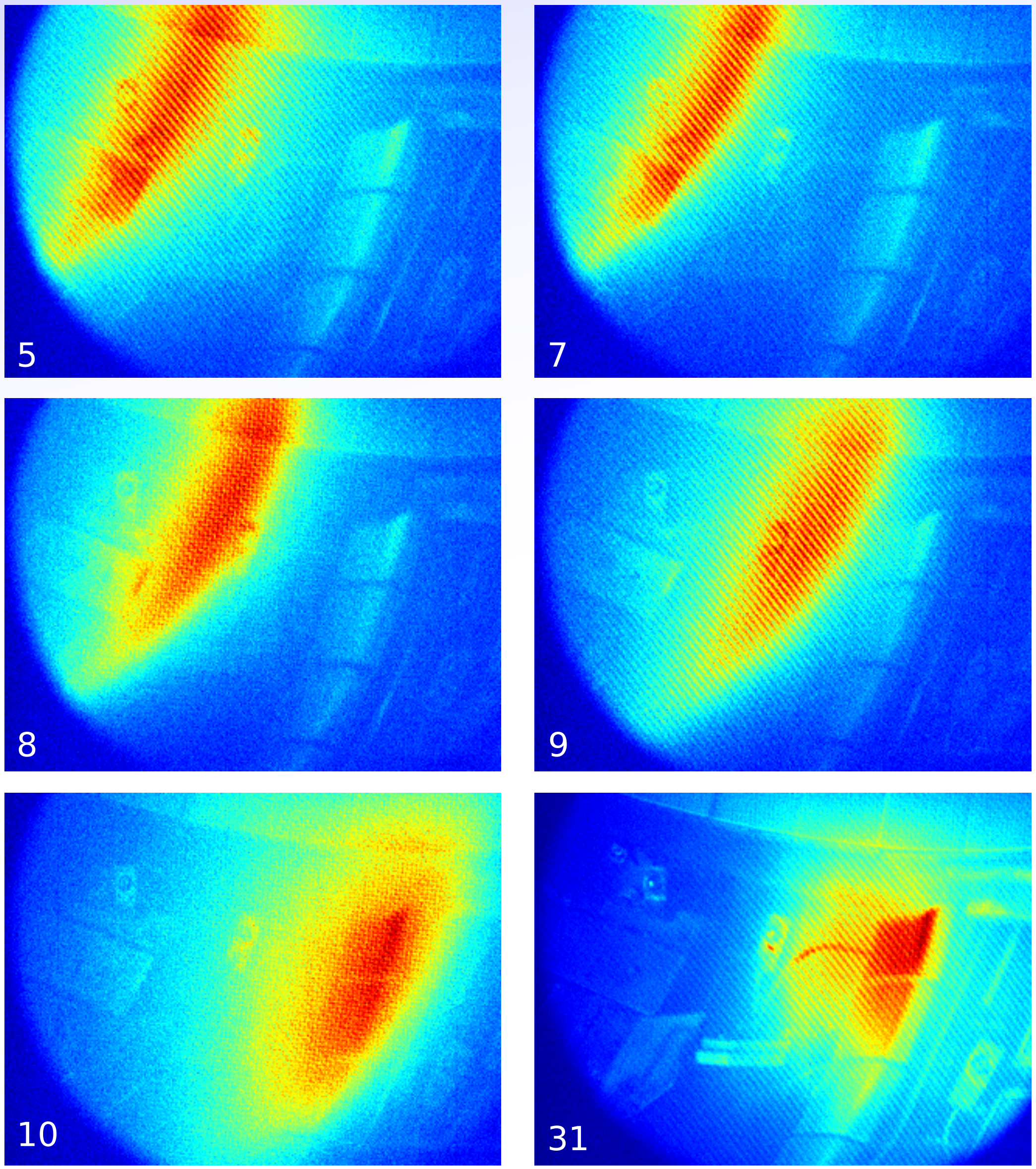


Meanwhile, Dα reflections could be used to track drifts in forward optics, if reflections from limiter maintain polarisation direction.

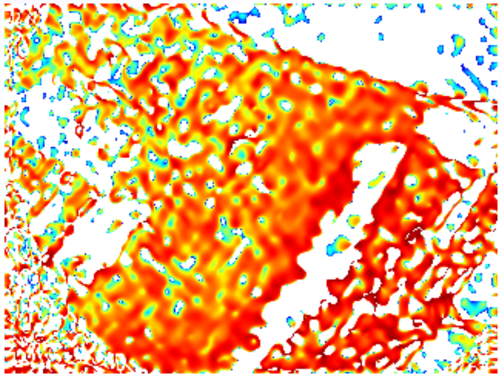
Oliver Ford
IPP Greifswald
gmds/AUG/29317

Other background - Zeeman split Dα??

During plasma startup (no beam), background plasma light is polarised (shows fringes).



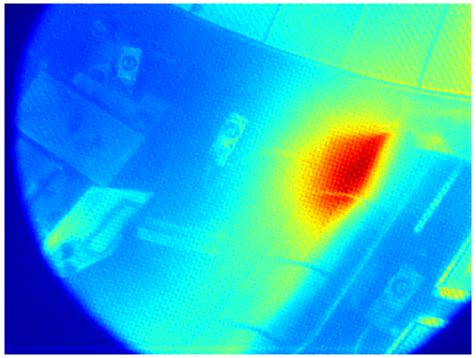
Emission starts near centre and migrates out.
Eventually it comes brightest from plasma immediately in front of limiter.
Finally it almost disappears at separatrix formation.



Polarisation very elliptical, with a direction that changes as the current ramps up.

It seems to be consistent with Zeeman splitting of Dα peak from recycling neutrals.

To check, used a Dα filter on Thursday (no beam day) and signal is still present:



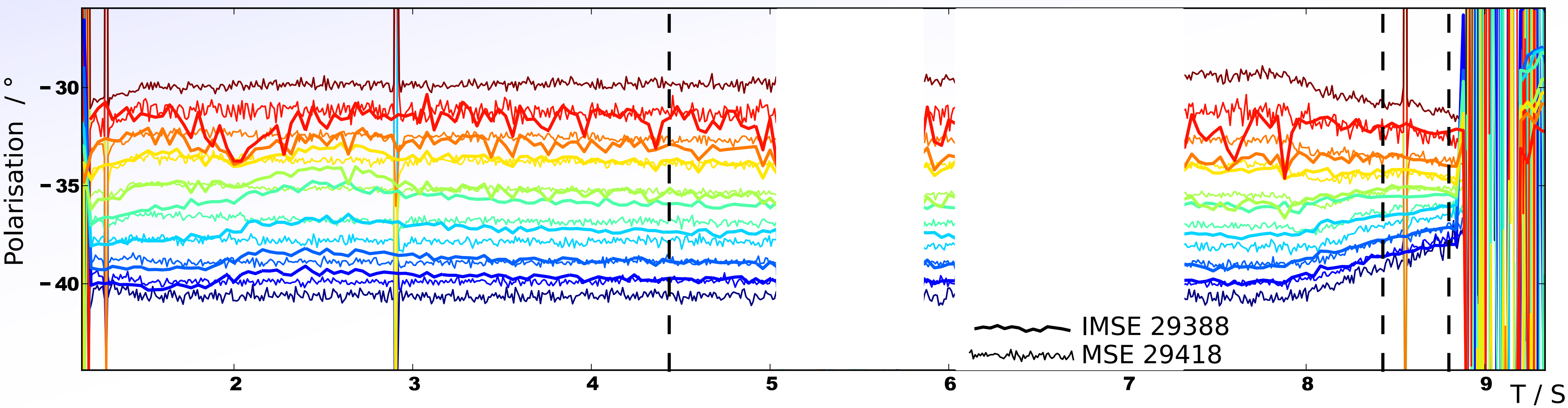
As field direction during startup, and in front of limiter are both well known, it could be used as cross-check or calibration of diagnostic.

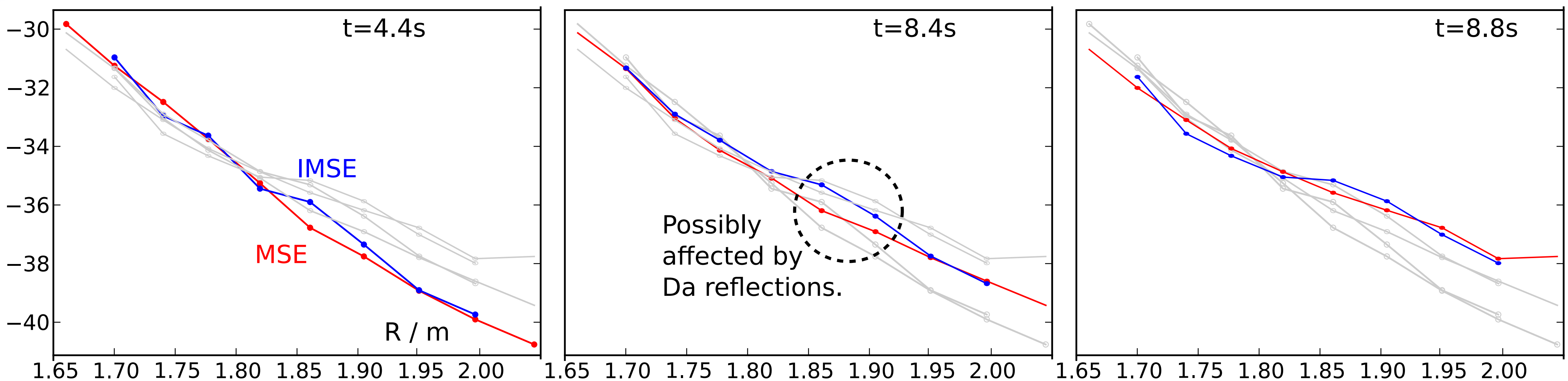
We're also considering what can be measured with a system designed specifically to see it.

Direct MSE - IMSE comparison

Oliver Ford
IPP Greifswald
gmds/AUG/29317

To compare the IMSE/MSE systems directly the same pulse was run the following week with the MSE system back in place. There is a polarising wheel in the MSE forward optics which can be used as a common zero reference between the two systems, so the offset *should* also be correct (however, 1.1° is added here)





So far, temporal evolution agreement is very good, spatial agreement is reasonable and should be improved by changes in April. An unidentified offset of 1.1° is still required.

Edge fields.

Preliminary (very) results from the IMSE system on K-STAR show some interesting extreme effect at edge [John Howard]:

+20°!!!

L-Mode: L-H Transition H-Mode

Clearly see:
- No edge freatre in L-Mode.
- Small pedestal ridge in H-Mode.
- Extreme ridge in during L-H transition.

So, if we see something, it's either;
- Effect of radial electric field (which we can cross-check)
- Extremely large anti-parallel pedestal currents.

To do this we would need to move the MSE mirror on Thursday and run an H-mode pulse with one beam during L-H transition and as much pedestal current as possible.