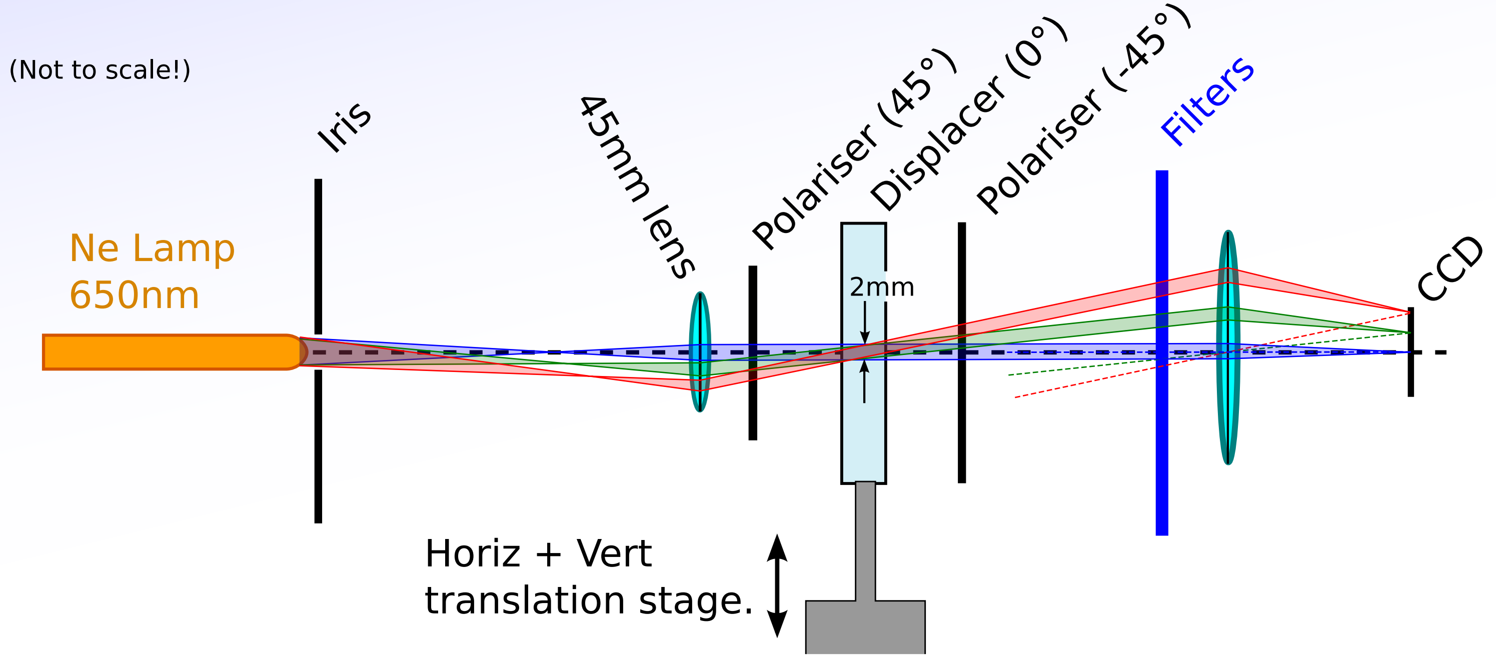
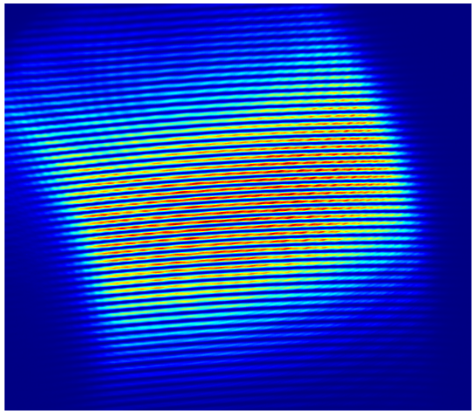
Interference imaging within a 2mm dot.

Oliver Ford
IPP Greifswald
gmds/SPECLAB/408,409

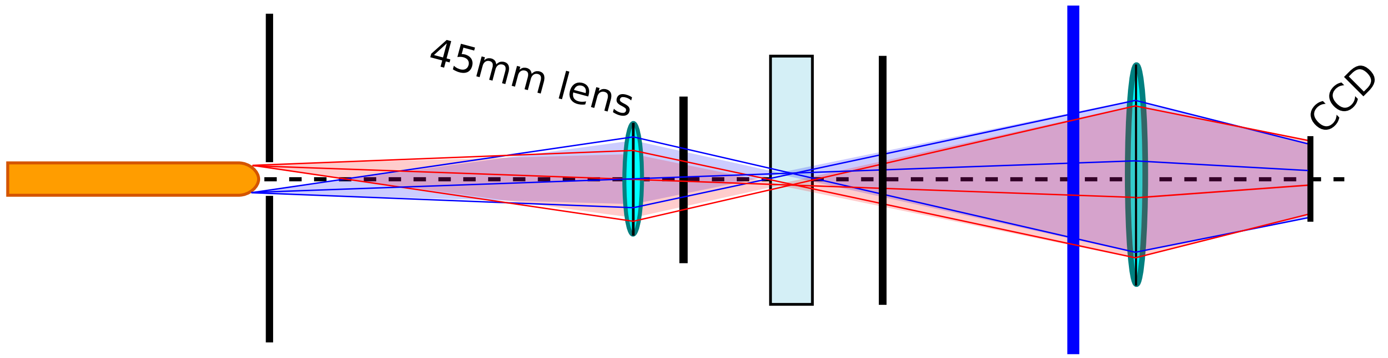
The optical system is setup with the camera lens focused at infinity onto CCD.
Each CCD position corresponds to particular AOI through the plates.
The phase shift in the displacer changes with AOI and creates an interference pattern on the CCD.



CCD Image:



The Ne lamp is focused by the first lens onto a small point on the crystal. This is NOT focused onto the CCD.

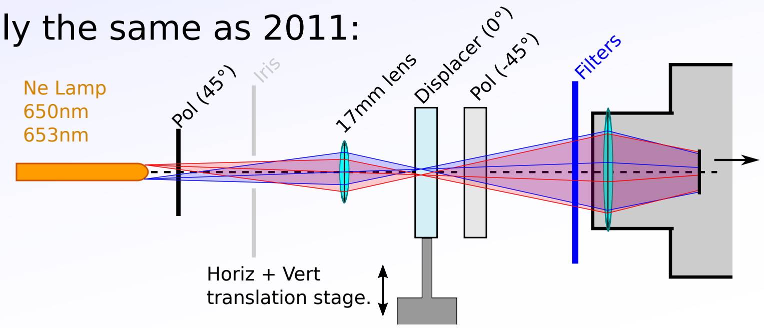


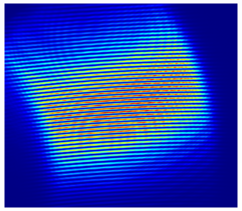
Surface Scans of phase

Oliver Ford
IPP Greifswald
gmds/SPECLAB/408,409

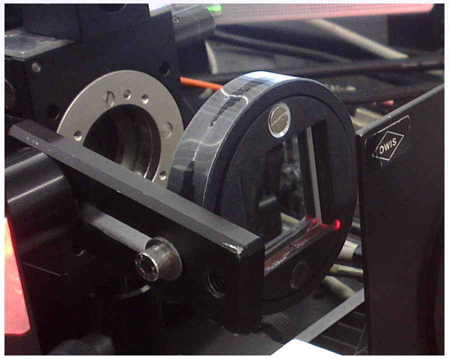
Measurements of surface scans of all crystals, 2015. Setup roughly the same as 2011:

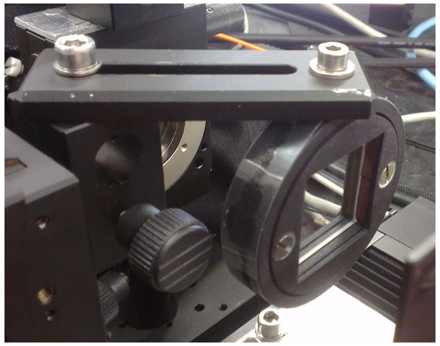
Focus the image of the Ne calibration lamp end onto a very small (~2mm) area of Savart front surface with enough angular variation to light some of CCD image (CCD image is focused at infinity, not on lamp). Then translate plate and measure phase somewhere on the image as a function of surface position. Measure at different rotations of the crystal to check consistency.

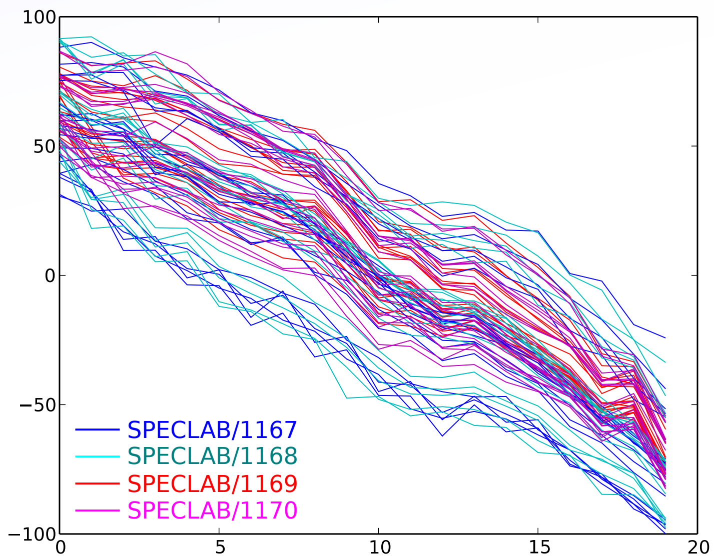


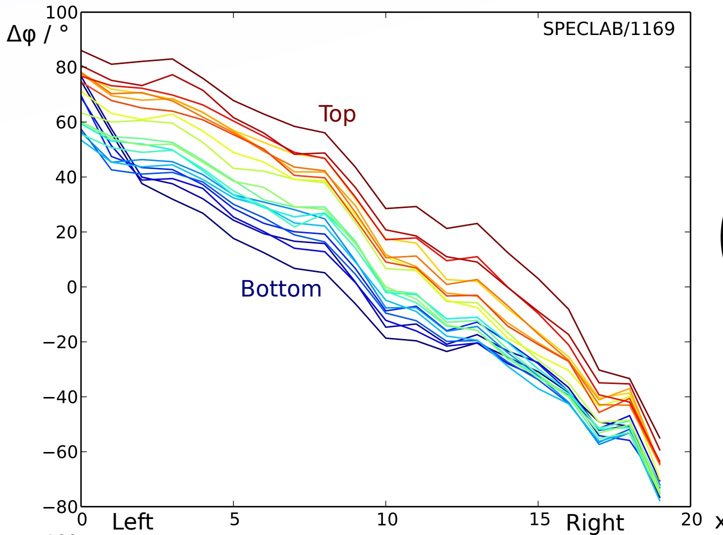


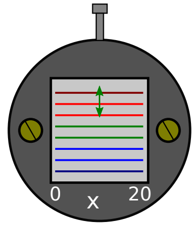
1) Dorothea's 40 x 40 x 5.4mm Displacer from United Crystals.

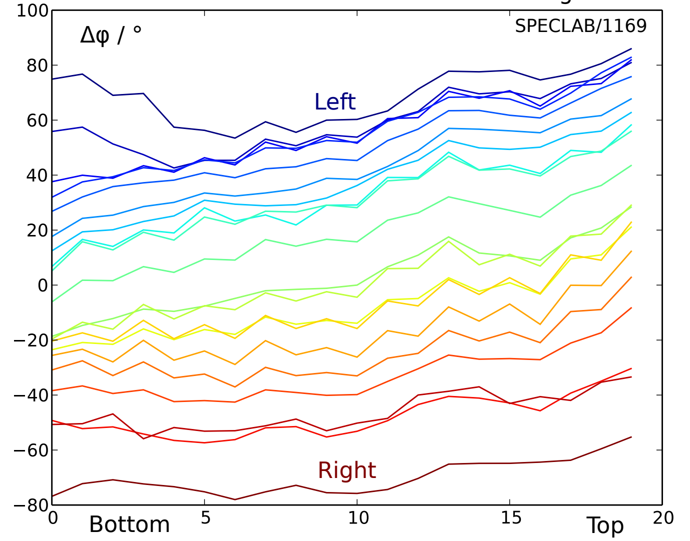


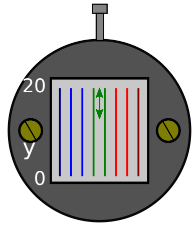




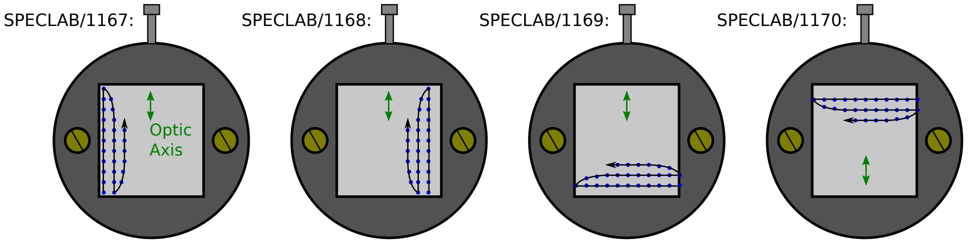








Orientations:

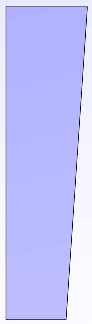


Surface Scans of phase

Oliver Ford
IPP Greifswald
~gmds/SPECLAB/1170

Change is consistently measurable despite long time and significant equipment rearrangement inbetween runs.
There is a real ~120° phase across 40mm of surface in the direction orthogonal to the optic axis plane. Why?

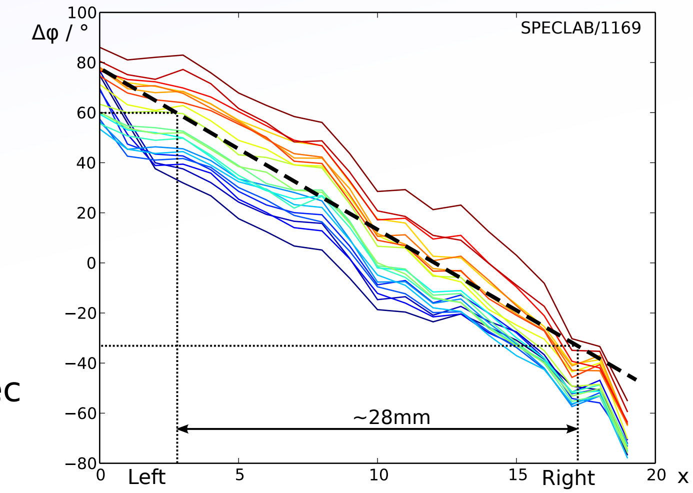
Wedge/Parallelism:



Specs from United Crystals says ±6" within 70% area.
70% * 40mm = 28mm (or would be 33mm for 70% of 1600mm²)
Experimentally, Δφ ~ 90° over the central 28mm L/R

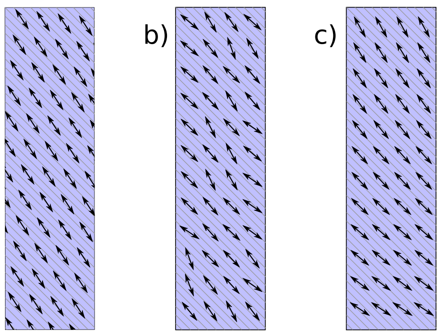
6" x 28mm = 0.8μm

$\Delta\varphi = 360\,(n_o - n_e)\,\Delta L / \lambda = 50°$
So, what we measure is quite a bit (but not orders) worse than spec (if parallelism is the cause)



Angular variation:

a) b) c)



Specs from United Crystals don't give this, but other companies are ~ ±0.25 - 0.5°.
We don't currently know what that means. I can think of 3 things it might mean. (see left).

For the worst case (c), if United Crystals has an axis variation of only θ = 45±0.2°, this gives a theoretical possible phase difference of ±2000°

To get the observed 120° of change, the axis must vary gradually only by 0.02°

a) Crystal cut not aligned with optic axis, but axis is homogeneous.
No problem at all.

Axis angle varies over small scales randomly but average remains constant.
Reduces contrast but not a serious problem.

Slow variation of axis angle across plate surface.

Really bad - gives surface dependent phase and aperture dependent contrast.

....or maybe also ....

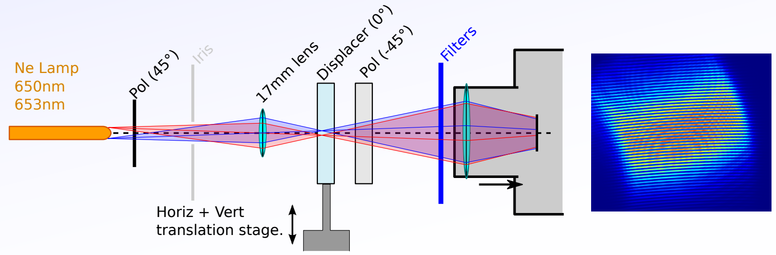
3.8mm Displacer A (Stress)

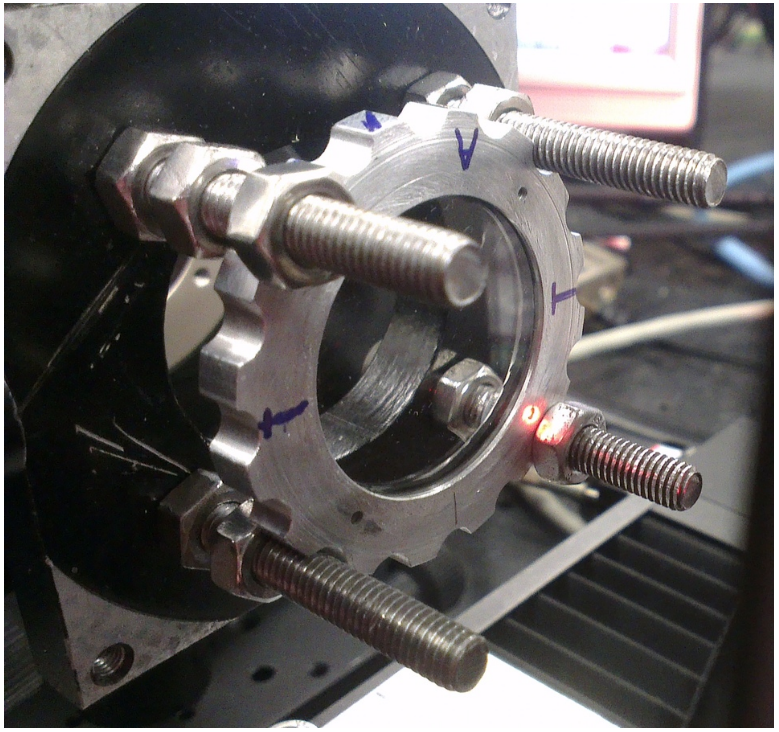
Oliver Ford
IPP Greifswald
~gmds/SPECLAB/1170

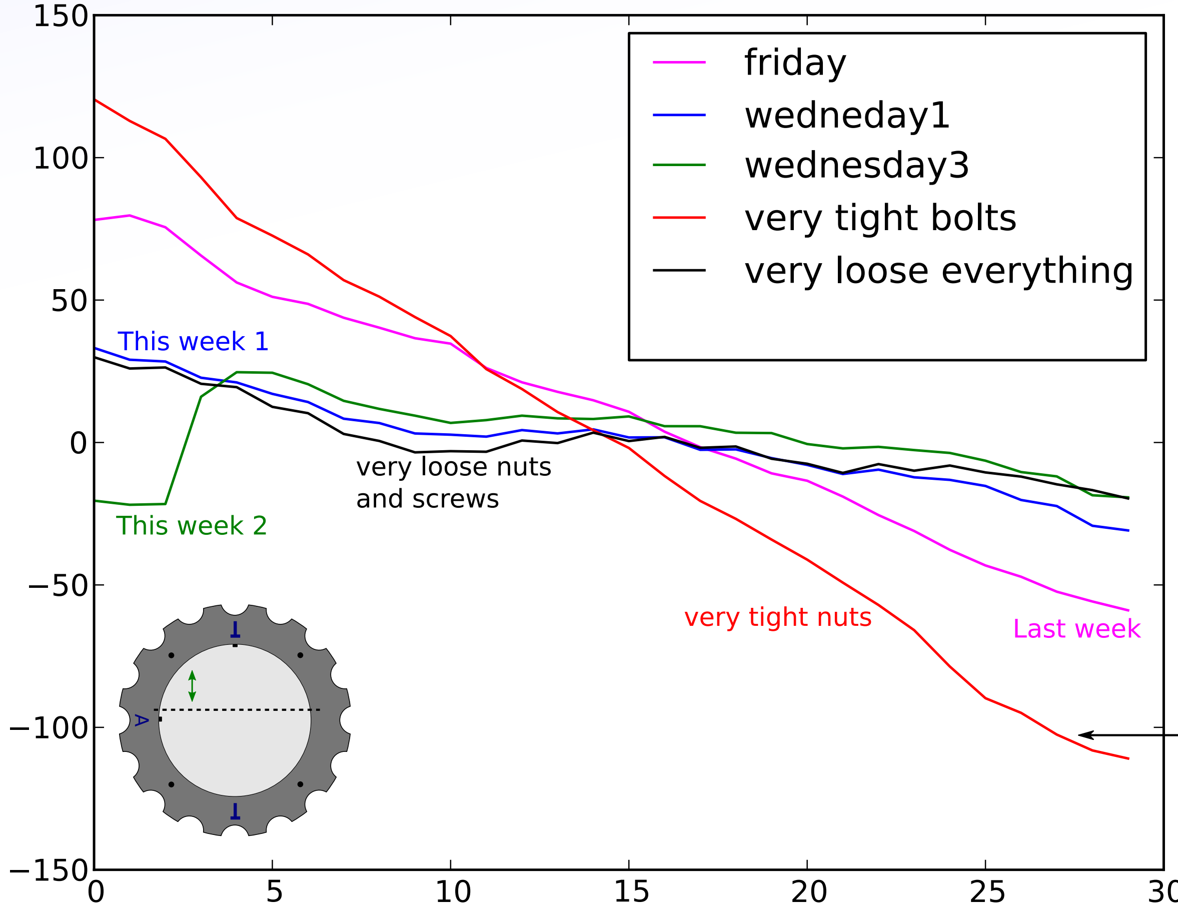
Again, for the first 3.8mm αBBO displacer for the AUG permIMSE (Plate 'A').

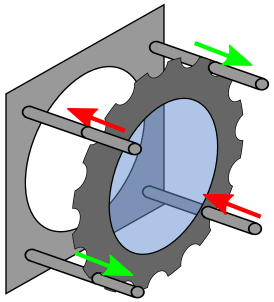
Made 1 set of measurements which were not perfectly consistent. Repeated after weekend and measured a much weaker variation.

Repeated with 4x mounting nuts, to put some pressure towards non-planar on the holder. Repeated again with only just touching nuts and loosened screws holding the crystal into the holder. Meachnical stress on the crystal by/via the holder seems to cause the large (>= 150°) variation. Some (50°) remains but this could be still the holder lid that holds the crystal in.



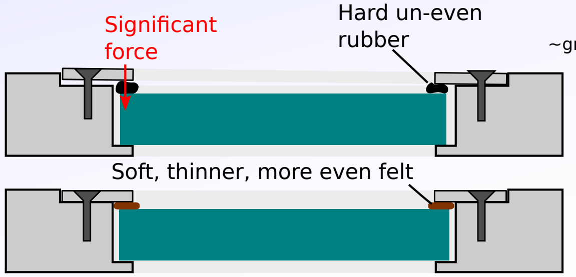






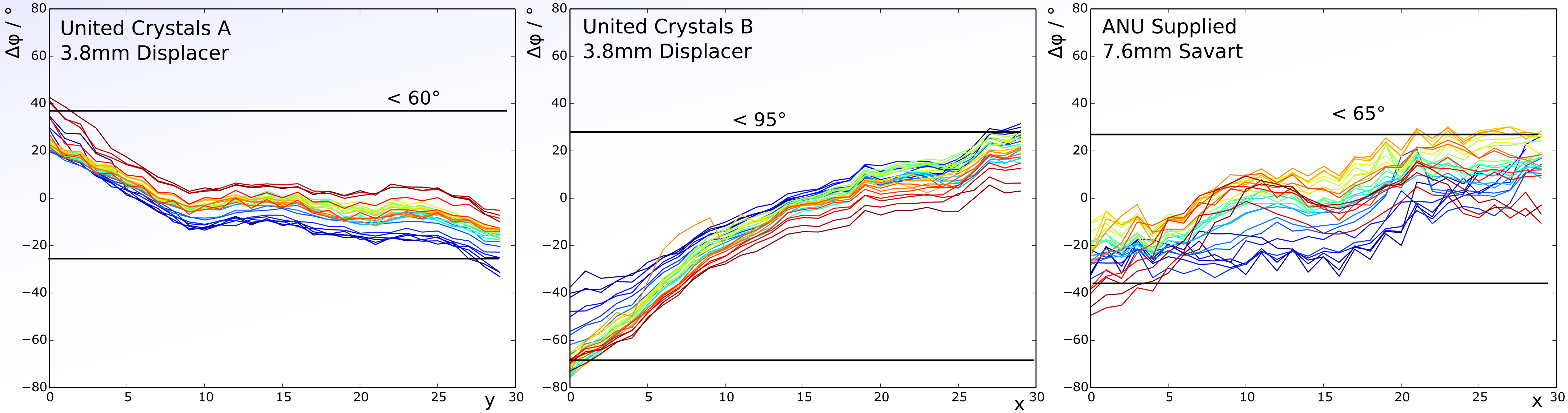
Remounting

Oliver Ford
IPP Greifswald
~gmds/SPECLAB/1180



The 2 new crystals were mounted using hard rubber under the retaining cover. Now redone with thinner soft felt.

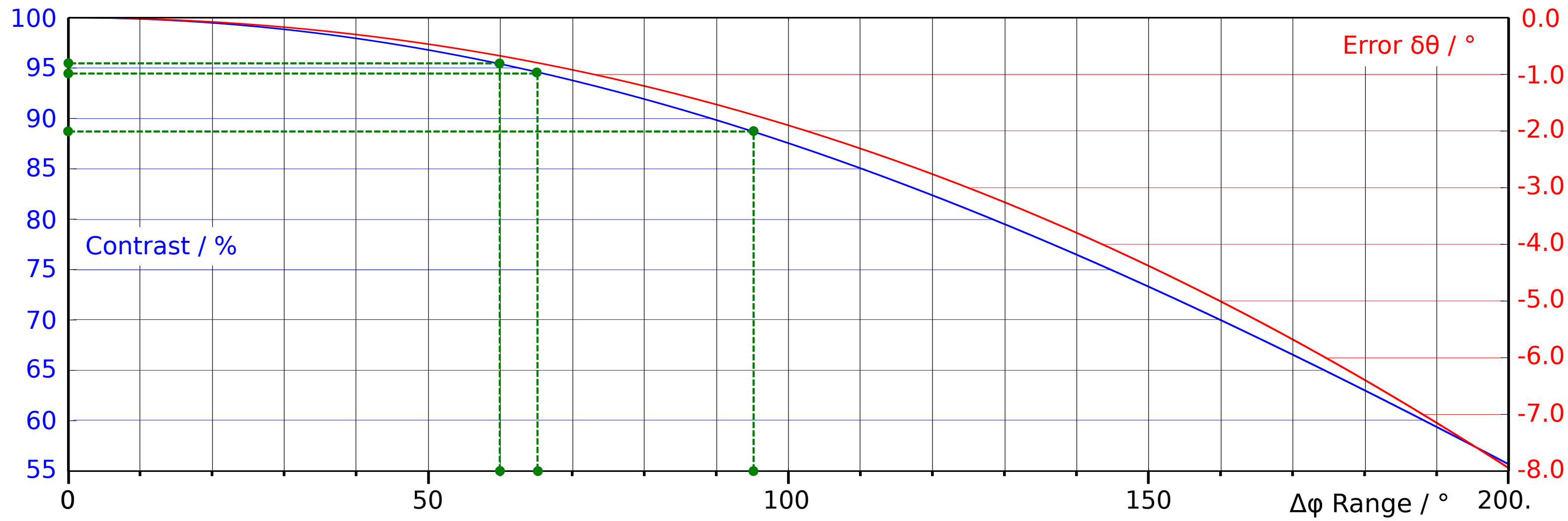
Could do this with more than 4 screws to make pressure on crystal more even.



Reducing the stress has certainly helped. Remouting again doesn't change the result any more so what we have now is probably intrinsic.

We can theoretically calculate what integrating over a linear gradient of Δφ does to the contrast (and hence to the IMSE θ).

Even for the worst case of completely illuminating a sweep of 95° we would only expect the contrast to be ~87%, not 70%.

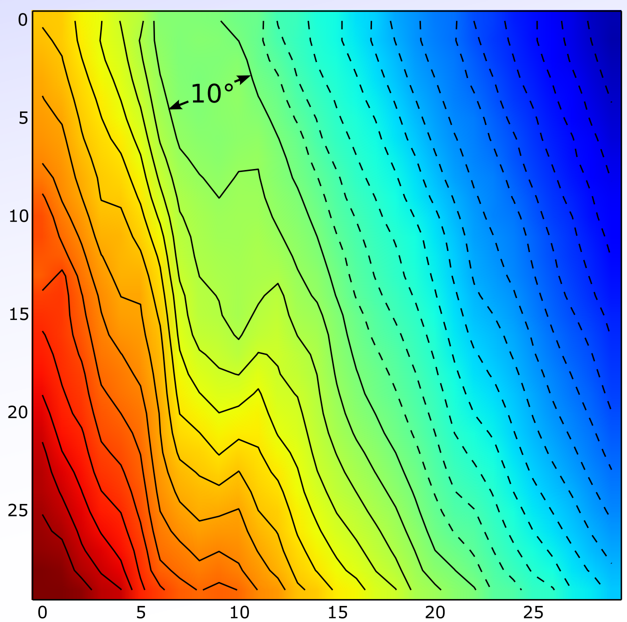


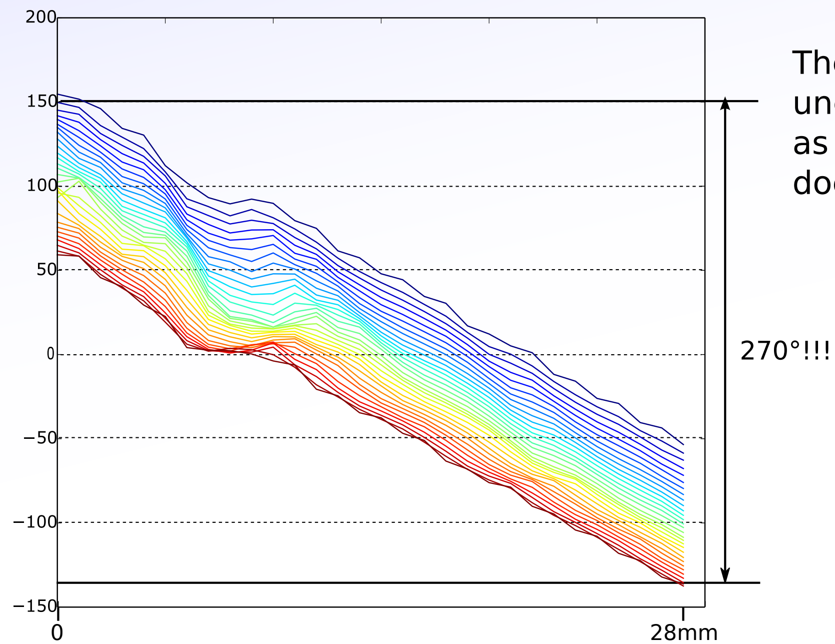
40x40x10mm Plates

Oliver Ford
IPP Greifswald
~gmds/SPECLAB/1180

We ordered two 40x40x10mm delay plates:

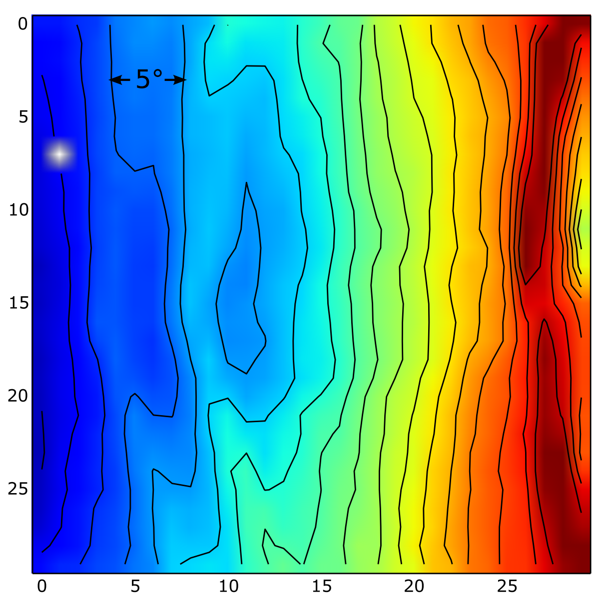
United Crystals:

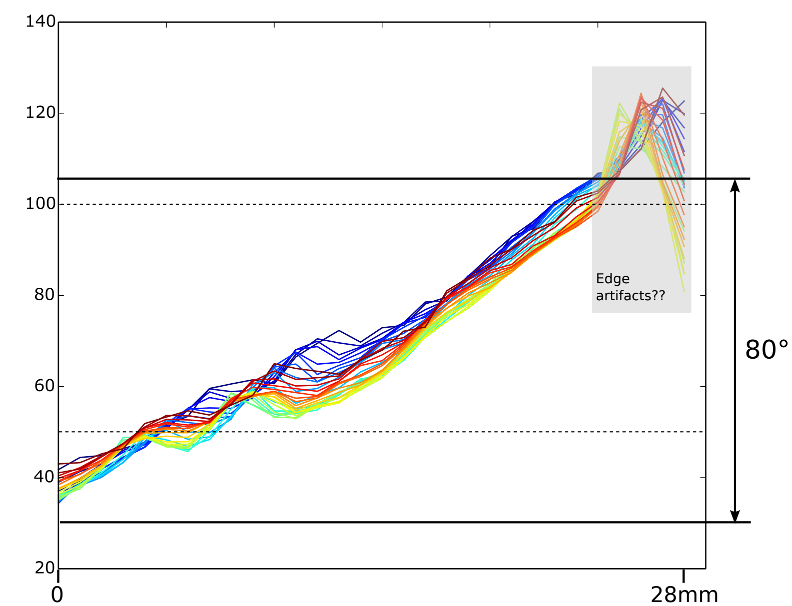




The united crystals plate is particularly uneven. We tried remounting this with as loose as possible screws but it doesn't change the result.

Bluebean optical:



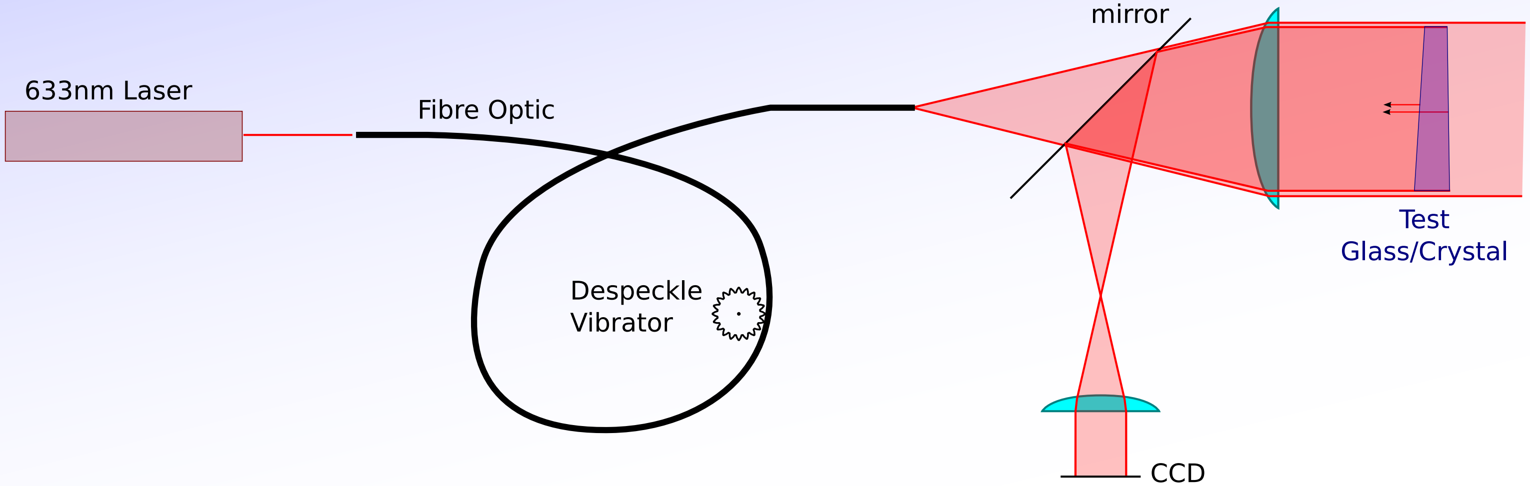


The Bluebean optical delay plate is 3x better and half the price, but still isn't really as good as we need.

Surface Inteference

Oliver Ford
IPP Greifswald
~gmds/SPECLAB/1245

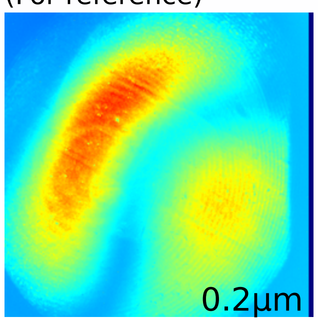
Built a Fizeau interferometer:



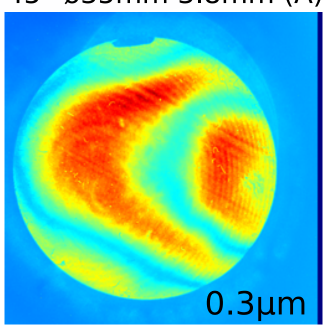
1 fringe = λ/2 wave change in thickness.
(ne + no)/2 = 1.6
λ_0 = 633nm
λ in crystal = 394nm

1 fringe ~ 200nm

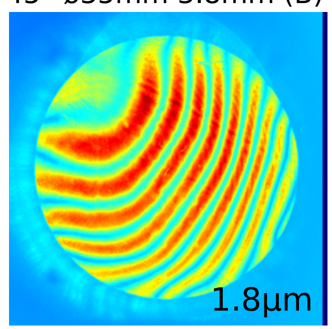
"λ/10" Glass substrate (For reference)



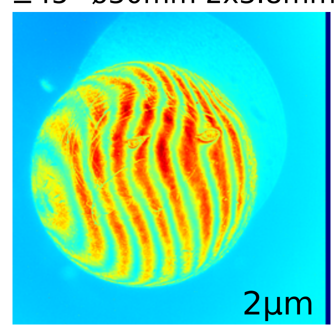
United Crystals 45° ø35mm 3.8mm (A)



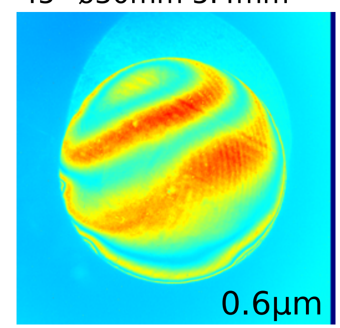
United Crystals 45° ø35mm 3.8mm (B)



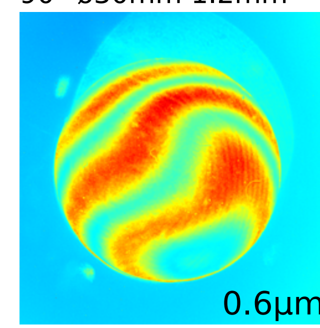
(CLaser?) Savart ±45° ø30mm 2x3.8mm



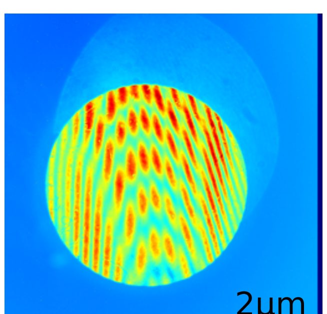
(CLaser?) Displacer 45° ø30mm 5.4mm



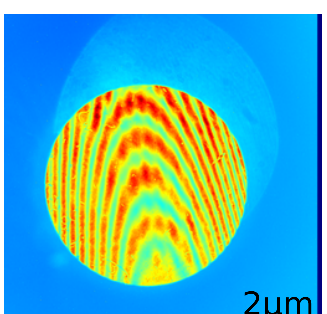
(CLaser?) Delay 90° ø30mm 1.2mm



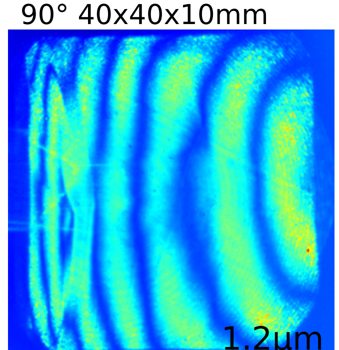
FLC (off)



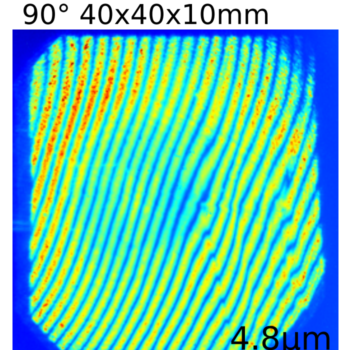
FLC (on)



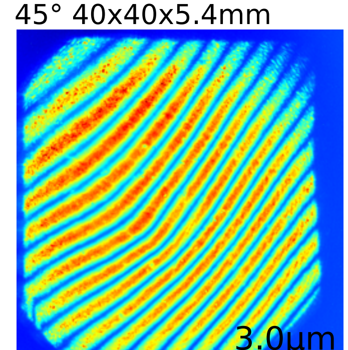
Bluebean 90° 40x40x10mm



United Crystals 90° 40x40x10mm



United Crystals 45° 40x40x5.4mm



Interferometric vs Birefringence

Oliver Ford
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~gmds/SPECLAB/1245

Compare the birefringent phase-based measurements with those of the Fizeau interferometer.
From the birefringent phase difference, calculate a thickness difference:

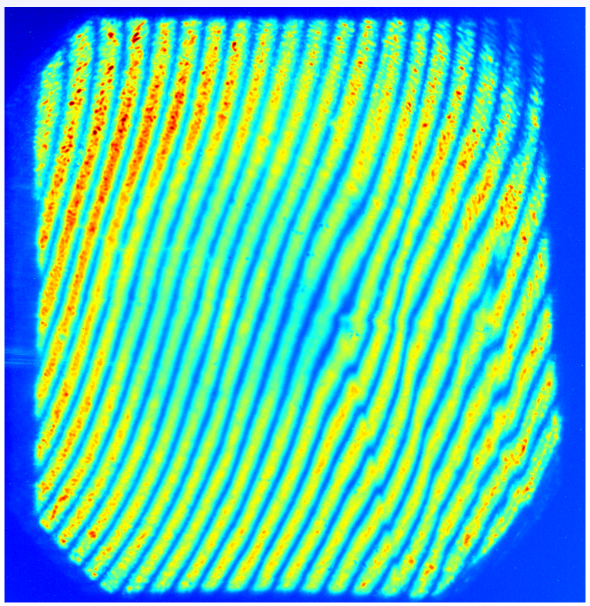
$\Delta L = \Delta\varphi / 2\pi * 653nm / (ne - no)$

and then convert to a number of waves at 633nm

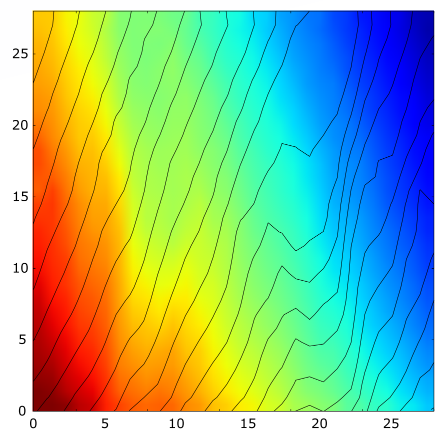
$f = \Delta L * 2 \text{ passes} * (ne+no)/2 / 633nm$

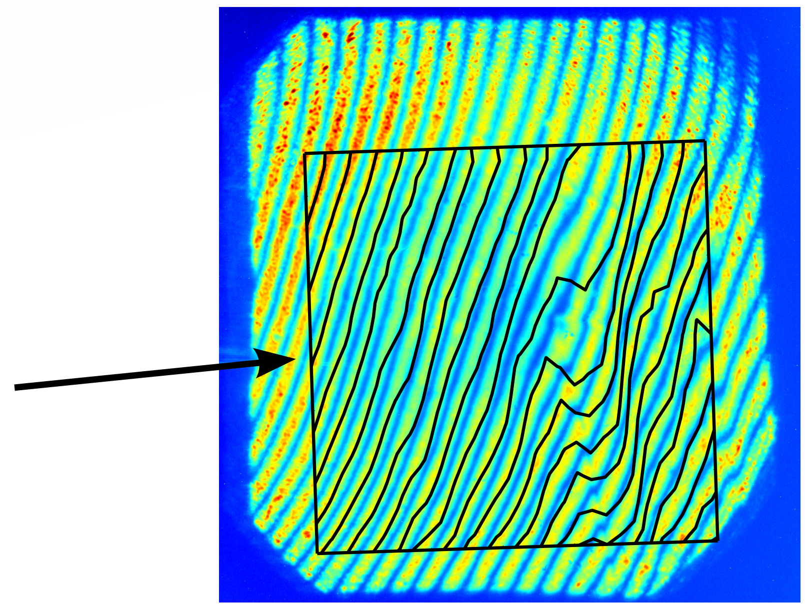
United Crystals
90° 40x40x10mm

Fizeau fringes:



Birefringent phase





The agreement is very good, so the problem results from the path length, not from any effect of the optic axis. Polarisation has no effect on the Fizeau fringe frequency, so proves this.

There are now two possibilities: Parallelism / Surface deformation, or refractive index inhomogeniety. The former is much more likely.

Over the cental 28mm (70%), this crystal has 3.3µm of thickness variation.
That is 24 arcseconds, 4x worse then the specified 6", but just within the 30" given by all other companies.

Surface Inteference

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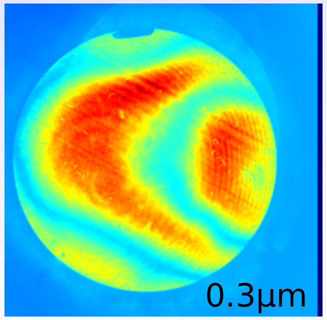
~gmds/SPECLAB/1245

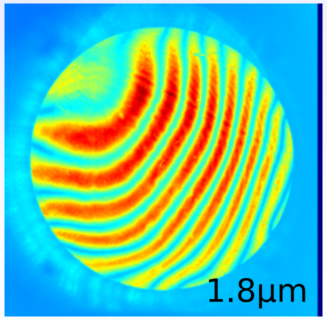
More Fizeau measurements...
UC Crystals from before:

Bluebean Octagon Crystals

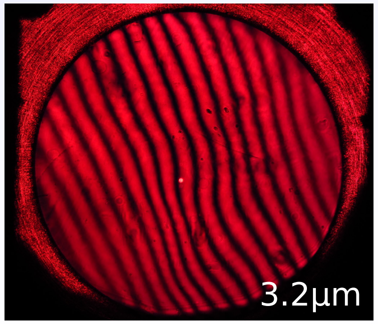
United Crystals
45° ø35mm 3.8mm (A)



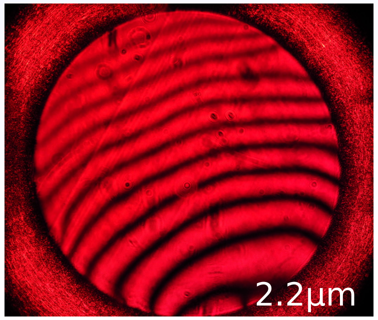
United Crystals
45° ø35mm 3.8mm (B)



Bluebean Octagon
45° ø35mm 3.8mm (C)



Bluebean Octagon
45° ø35mm 3.8mm (D)

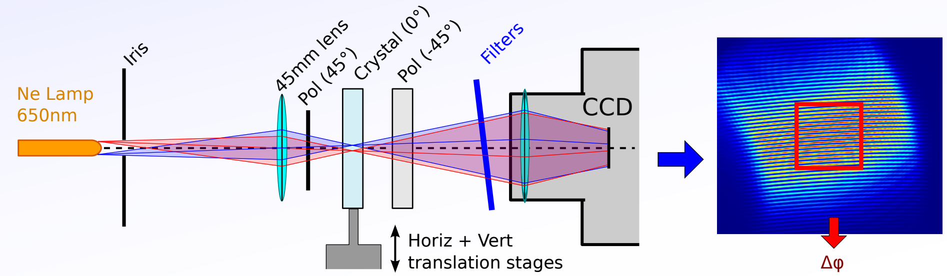


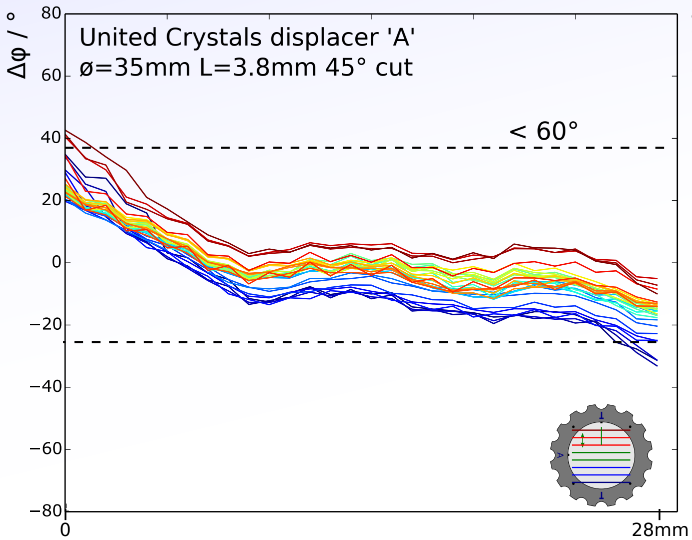
The bluebean ones are much worse, so I'll send them both to Dresen Uni to get Ion Beam polished.

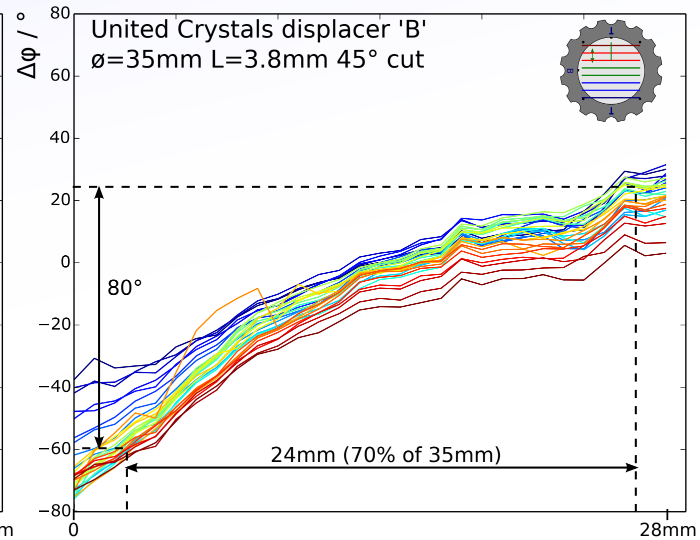
Birefringence change over surface.

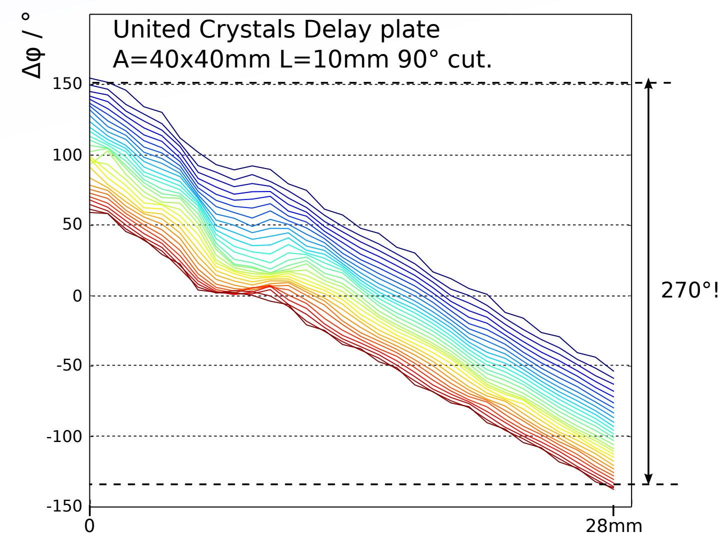
Oliver Ford
IPP Greifswald
~gmds/SPECLAB/1180

We measure the birefringent phase difference between ordinary and extraordinary components over a ~2mm area scanned across the surface of the crystal. Measurements are very reproducible.
Delay plates (90° cut) are measured with a fixed displacer after the first polariser. Displacer plates (45° cut) are measured alone.

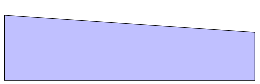








We are not entirely sure what property of the plate causes this. Primary suspects:



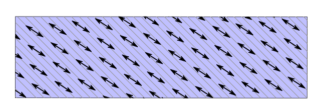
Parallelism

Specs from United Crystals say "±6 arcsecs within 70% area". 70% of 35mm is 24mm or would be 29mm for 70% of the 'area' (1225mm²). 6 arcsecs over 24mm would give a 0.7μm thickness difference.

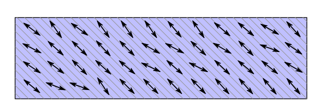
$\Delta\varphi = 360\,(n_o - n_e)\,\Delta L / \lambda = 45°$
Plate A is better than this, plate B is 2x worse.
The 40x40x10mm plate is much worse.

Optic axis Angle:

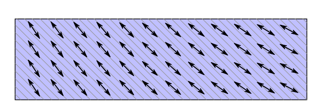
Not specified by United Crystals, but typically ±0.25° elsewhere.
What does this mean? I can think of:



a) Crystal cut not aligned with optic axis, but axis is homogeneous: No problem at all.



Axis angle varies over small scales randomly but average remains constant: Not a serious problem.



Slow variation of axis angle across plate surface: Really bad - gives surface dependent phase. 0.2° change would give 2000° of phase variation!