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Sub-micron accuracy target alignment on the Astra-Gemini facility

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- The target positioning problem
- 3-colour interferometry
- Rear surface imaging
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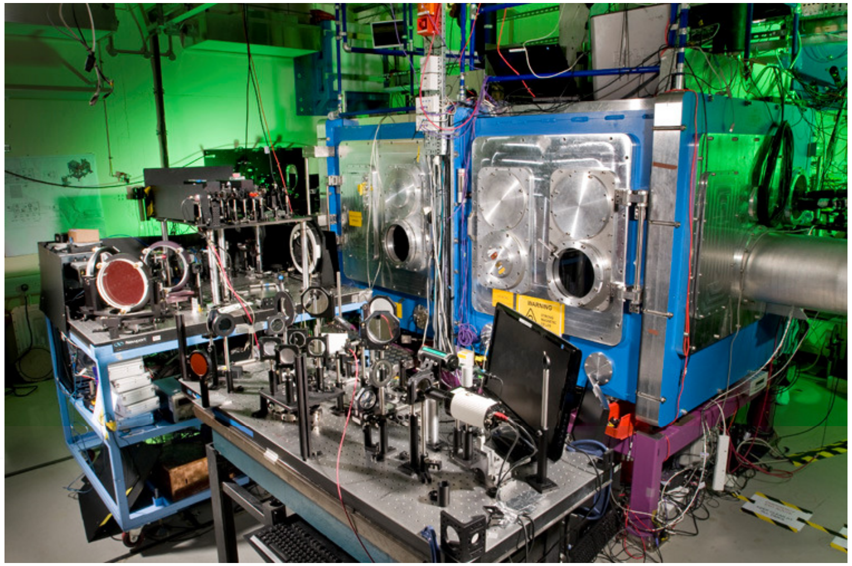
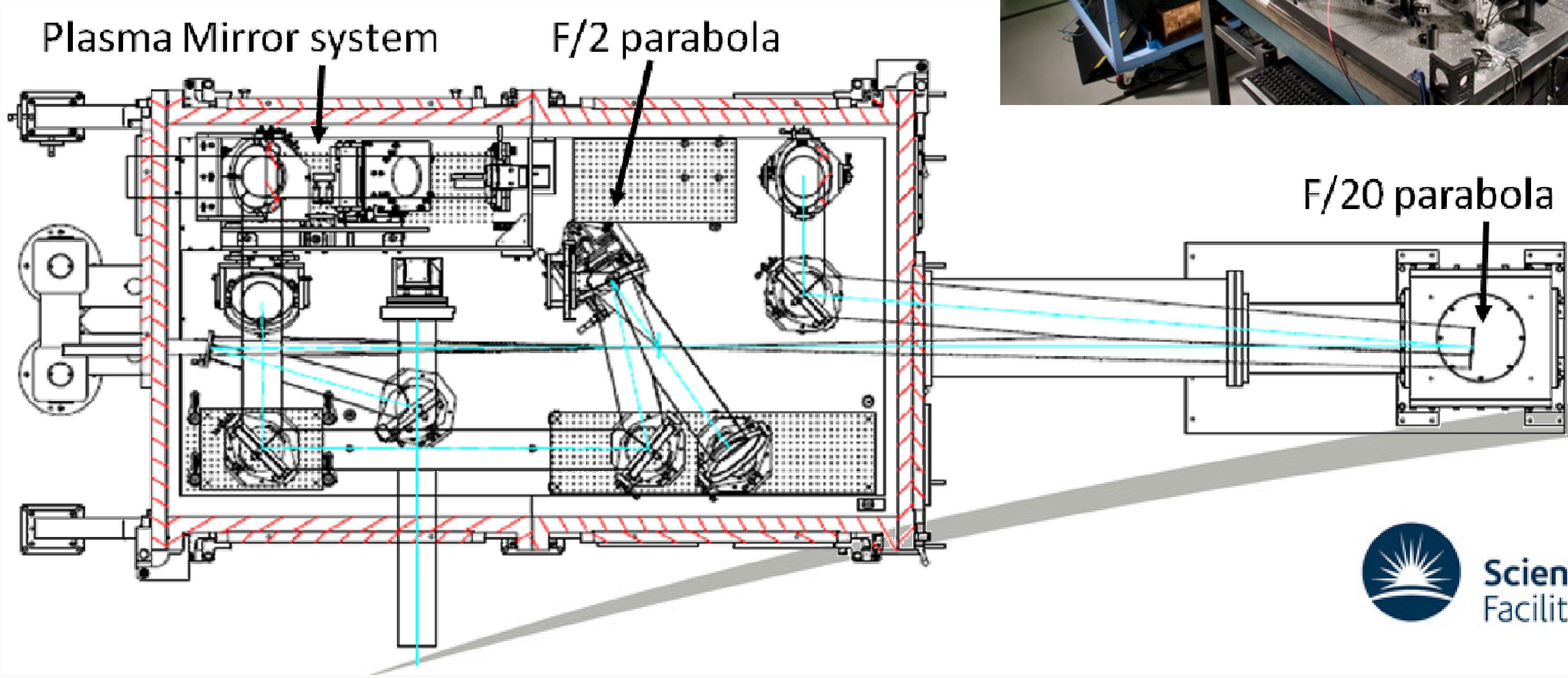
The Astra-Gemini facility

- Dual beam facility
- Up to 0.5 PW in each beam
- Double plasma mirror system
- Adaptive optics
- Gas and solid target experiments

Experiments on Gemini

Very flexible system – can accommodate variety of experimental layouts





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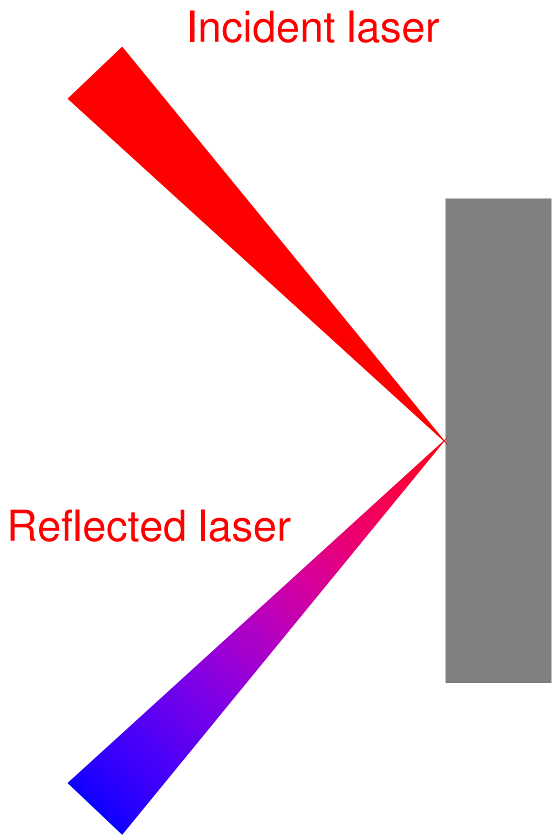
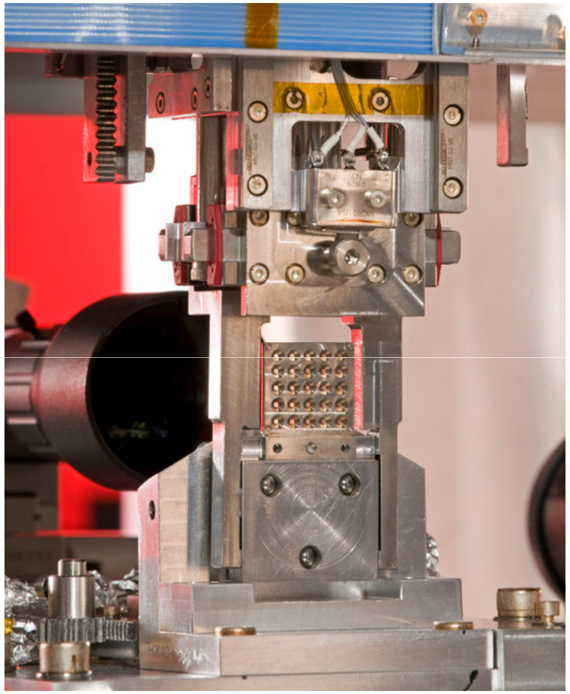
Highest intensities required for solid target interactions



- Targets typically an array of foils ~25mm square
- Thickness from 5nm to few microns
- Repetition rate is limited by **targets**



- Tight focus parabola for 2mm spot
- Target is opaque to the laser
- Intensity approaching 10^{22} Wcm^{-2}

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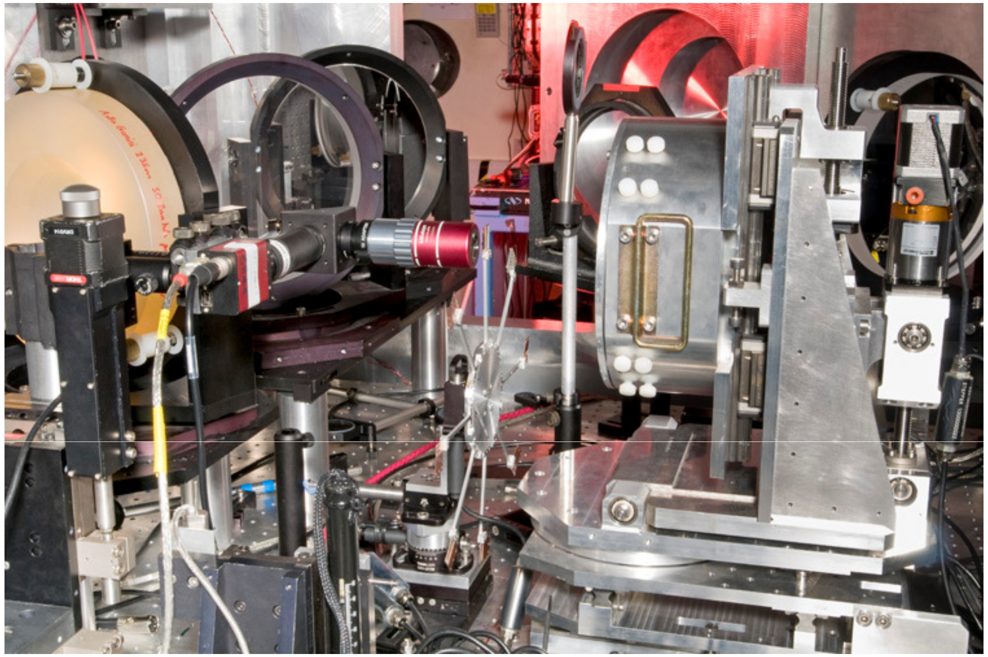
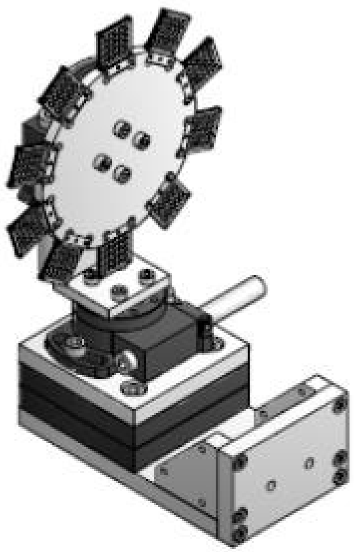
The target positioning problem

- Typical time to align a target > 10 mins
- Short focal length optics have Rayleigh ranges < 8microns





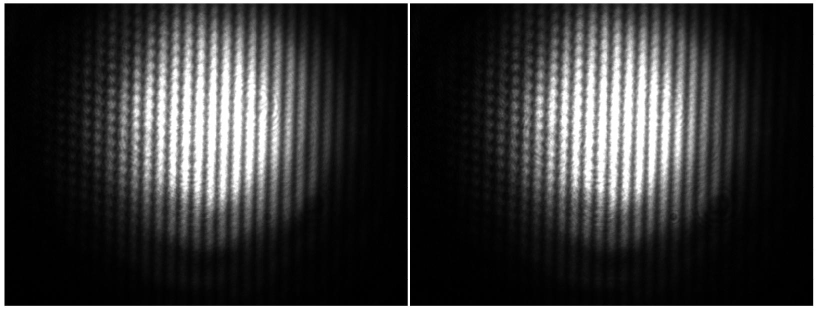
To access the highest intensities available and for accurate interpretation of data, position of targets must be known to micron accuracy

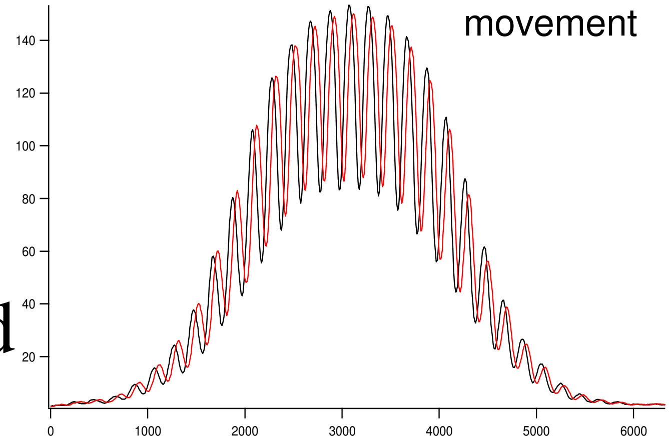
Current methods of target positioning

- Target positioning done in a variety of ways
  - Long working distance microscopes
  - Retro-reflection
  - Interferometry
  - White light illumination of the front surface
- None of these methods have the required accuracy for Gemini f#/2

Interferometry for target positioning

- Single colour interferometry accurate to $\lambda/2$
- However, impossible to determine which fringe you are looking at
- Ideal would be white light
  - Would require high bandwidth and very high brightness
- Use three combined wavelengths in fibre output





Three colour interferometry

- Using three wavelengths
  - 532nm, 635nm, 658nm
- All fibre coupled and combined with a wavelength division multiplexer
- Three colours gives a distinct output pattern allowing us to distinguish between fringes
- Will give us sub-micron accuracy in positioning

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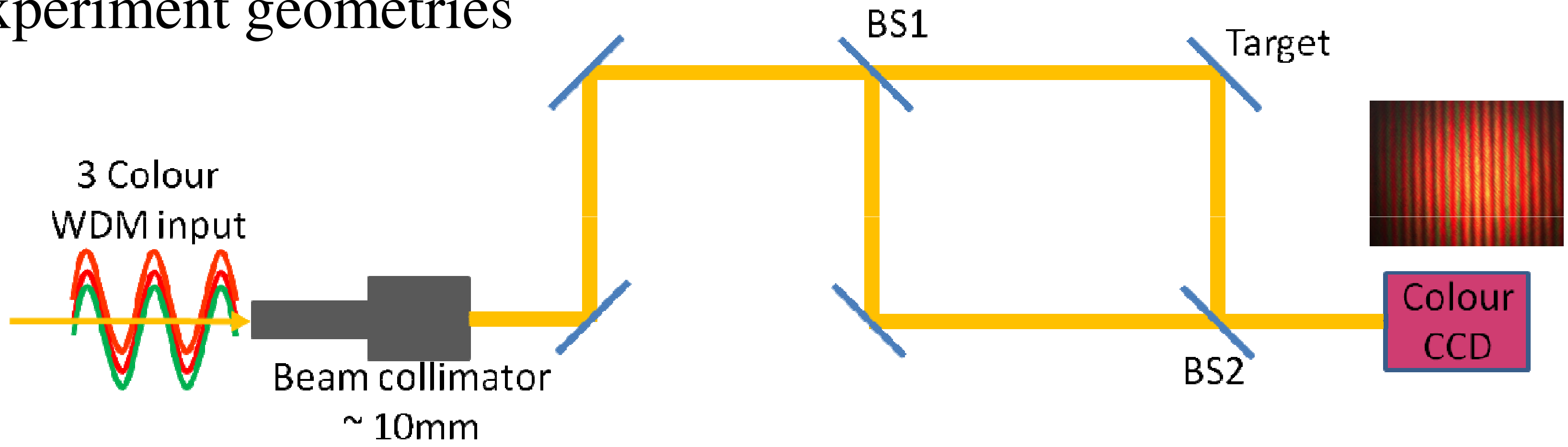
The Mach-Zehnder interferometer

Mach Zehnder allows greatest flexibility for different experiment geometries

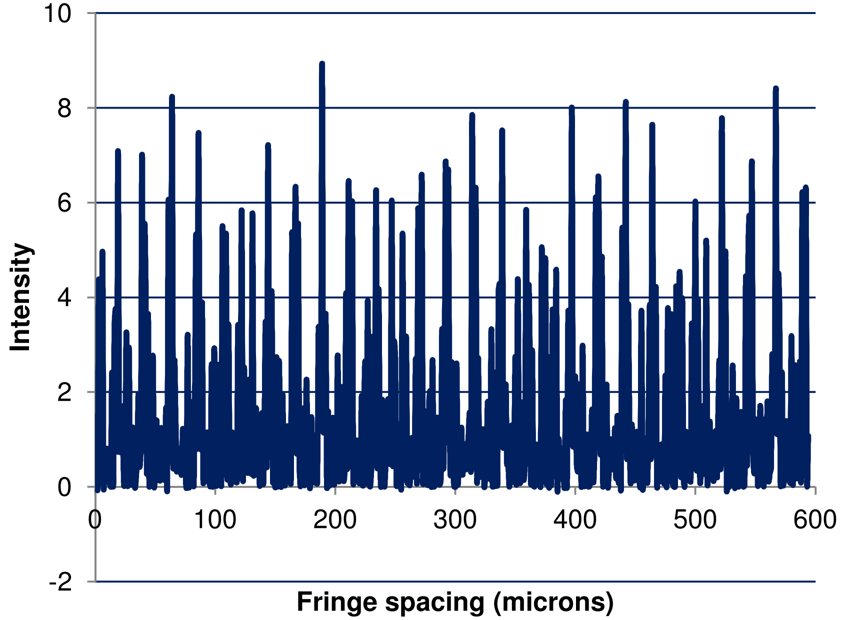


Beam currently collimated at 10mm

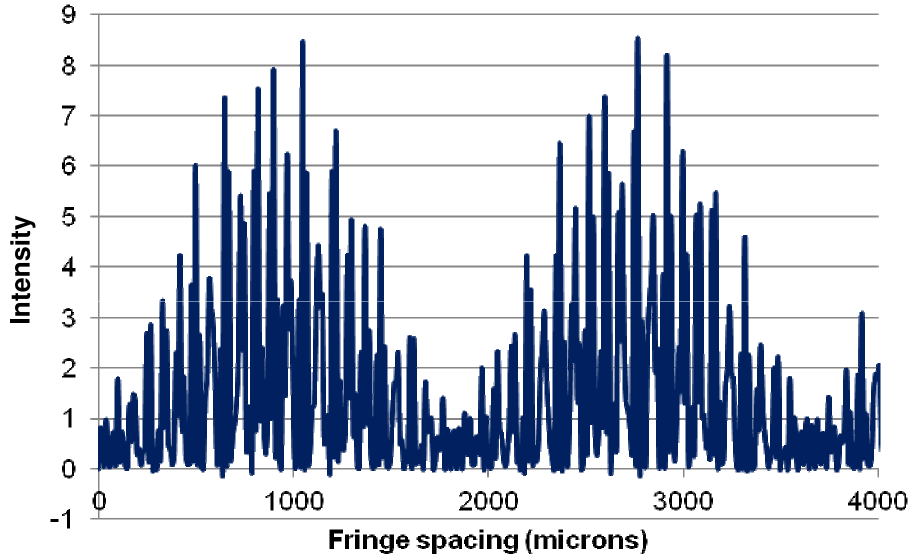
Target positioned at one arm

Theoretical interference patterns

1 micron move



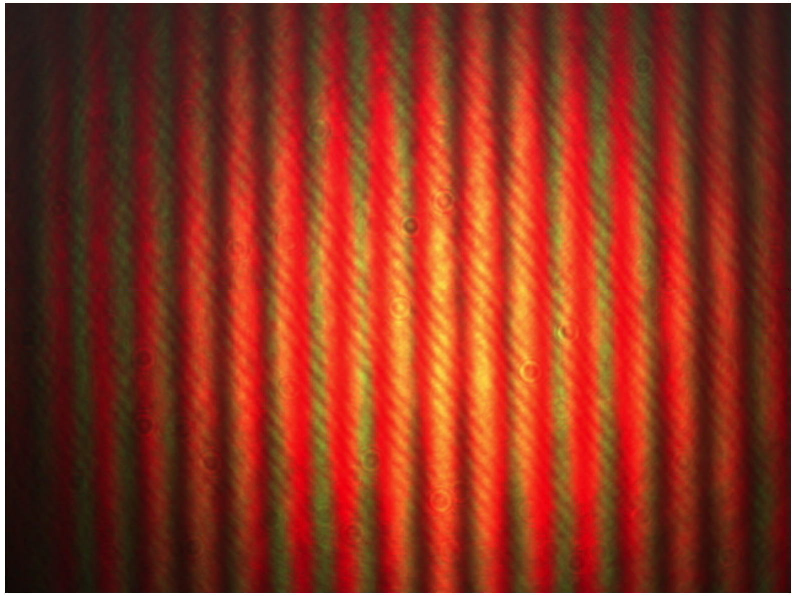
10 micron move

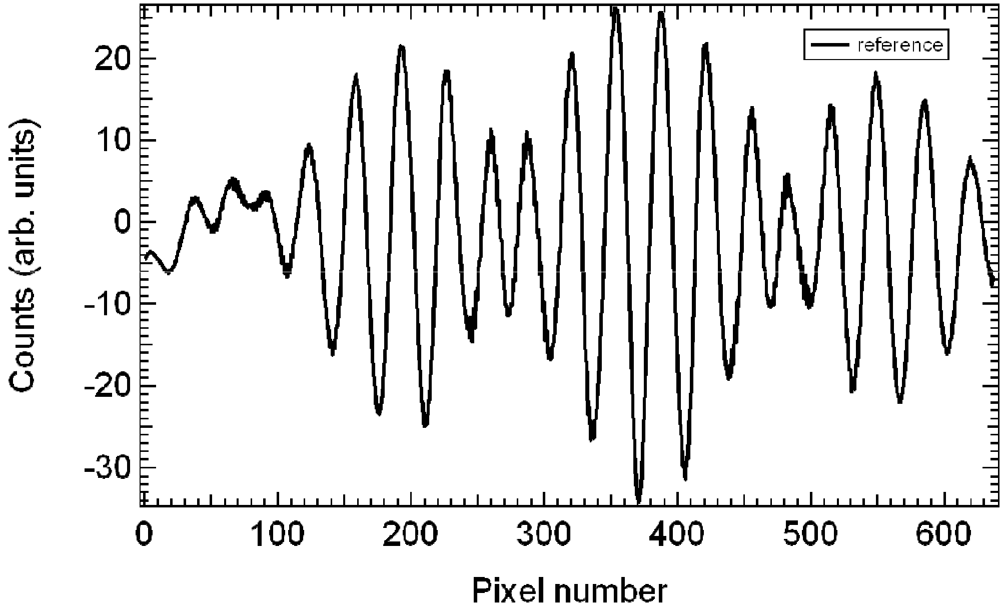


Can see a large change in the interference patterns when moving between 1 and 10 microns from the ideal

Reference images

Start from a reference pattern when properly aligned





Differences in the interference pattern are more obviously noticeable than in the case of the monochromatic interferometer

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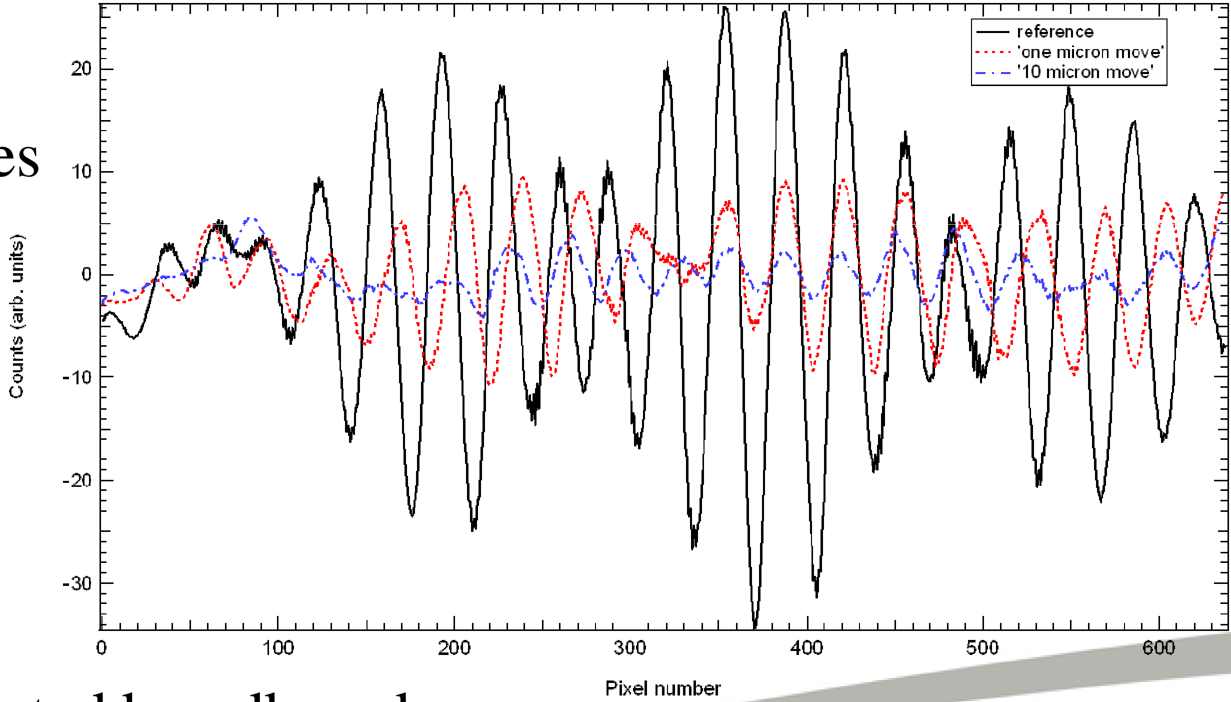
Distance movements on the target

Movements from the reference position by 1 and 10 microns shows significant changes in the interference patterns

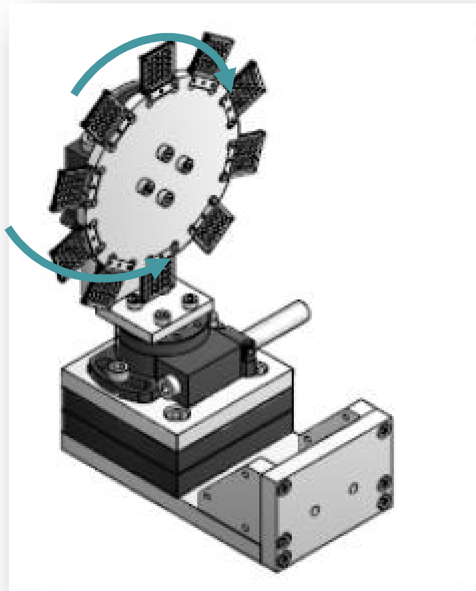
Changes in the intensity of the fringes apparent – as seen in the theoretical case also



As this is not under vacuum or on an isolated breadboard, some vibrations/air currents may be involved

Vertical and horizontal rotations

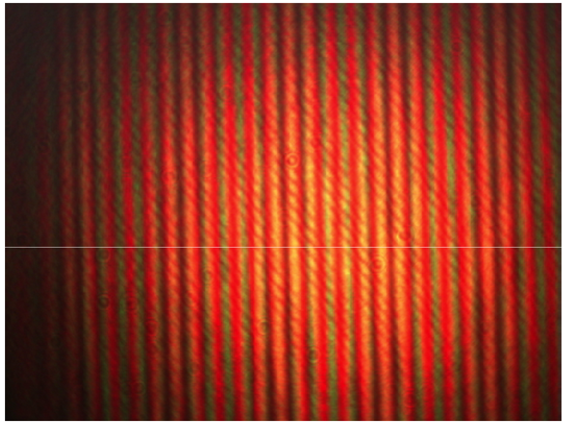
Vertical and horizontal tips and tilts also have a serious impact on target positioning



a.

Vertical

b.



Horizontal

Vertical – fringe rotation

Horizontal – fringe spacing changes

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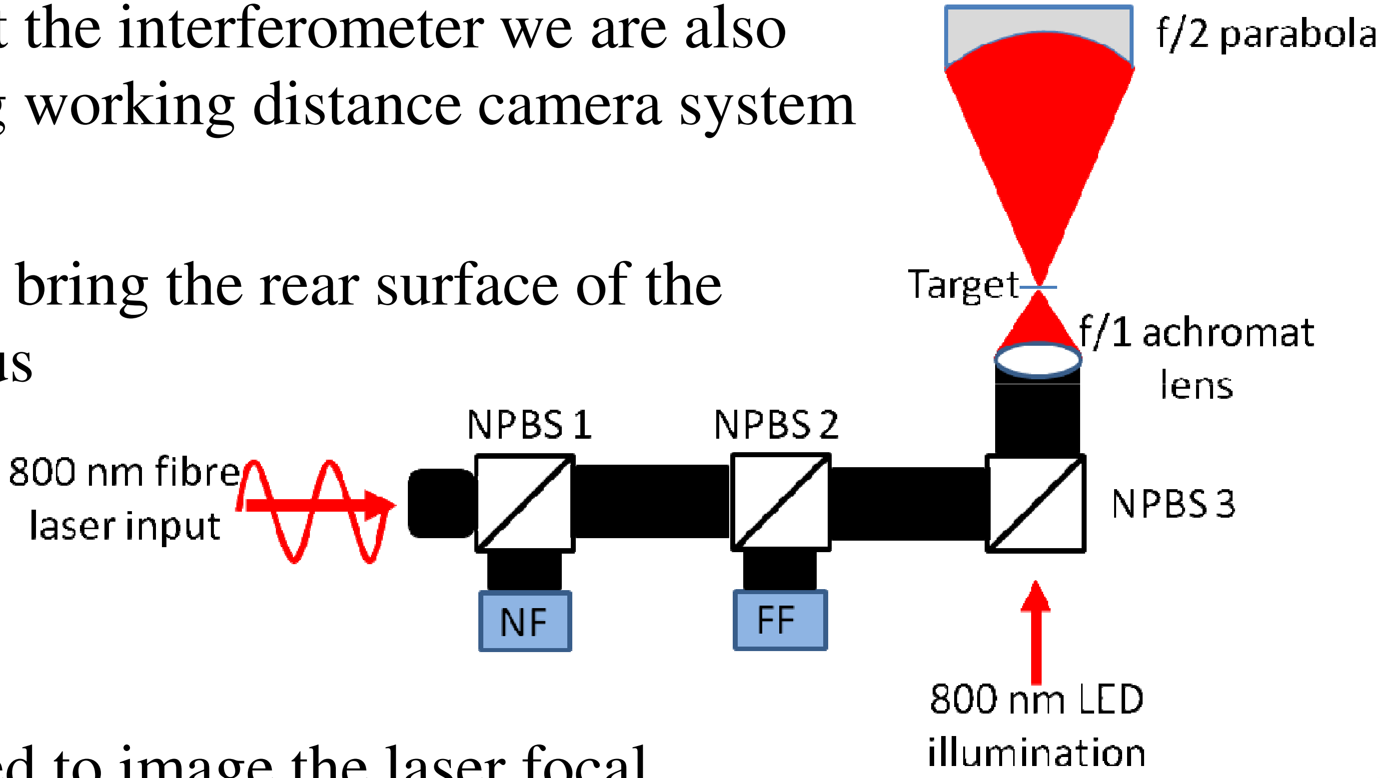
Rear surface imaging

To compliment the interferometer we are also building a long working distance camera system

Can be used to bring the rear surface of the target into focus



Can also be used to image the laser focal spot

LED illumination of the target

Illuminating the rear of the target with an 800nm LED

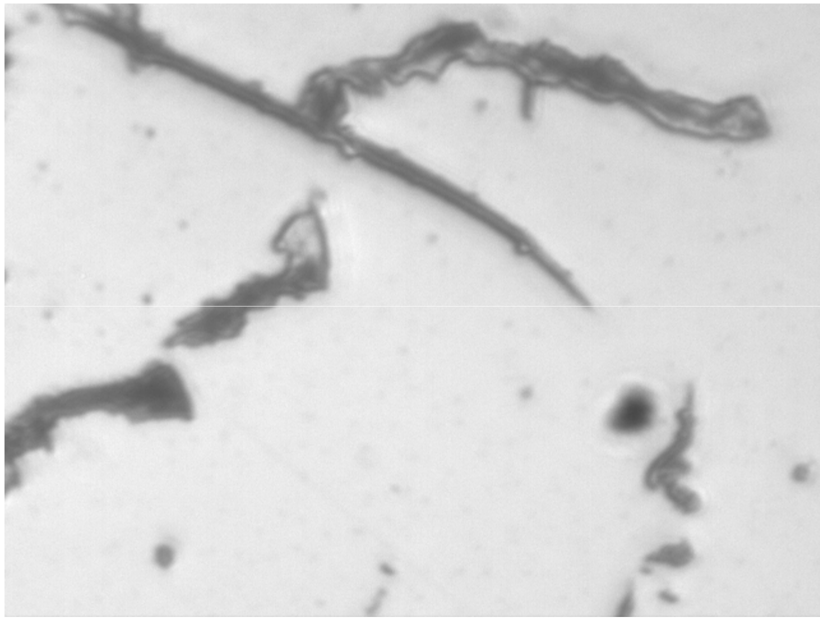


Image features on the rear of the target to bring it into focus

Current resolution approximately 1-2 μm

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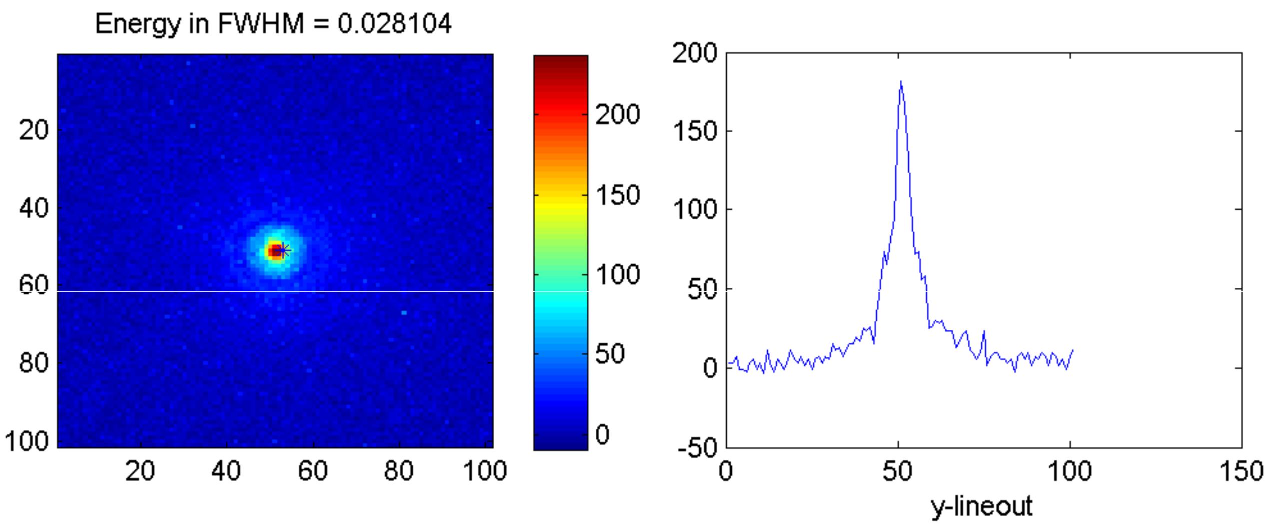
Fibre laser focussing

Collimated 800nm fibre laser input – no chromatic offsets required



To be imaged with both the near- and far- field cameras

Will also give information on angular positioning of the target to compliment the interferometer

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Future work

- Integrate both systems on a real target
- Isolated breadboard
- Automate
- Commissioning on next solid target run – April 2014

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Conclusions

- Target positioning is a real problem for high intensity experiments
  - Direct affect on data interpretation
- CLF tackling this on two fronts
  - 3 colour interferometer
  - Rear surface imaging
- Will allow positioning to sub-micron accuracy giving access to ultra-high intensities ($> 10^{21}$ Wcm^{-2}) available on Gemini

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Target interaction challenges and developments workshop

Abingdon, UK: 28th and 29th April 2014

Covering:

- Target positioning and alignment systems
- High repetition rate targetry
  - Target quality and surface finish
- Plasma absorption and characterisation

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Laserlab Europe

The "**Integrated Initiative**" of European Laser Infrastructures
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