Monitor Schemes for Angle and Position Tuning of the European XFEL Beamline Mirrors

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European XFEL WP-74

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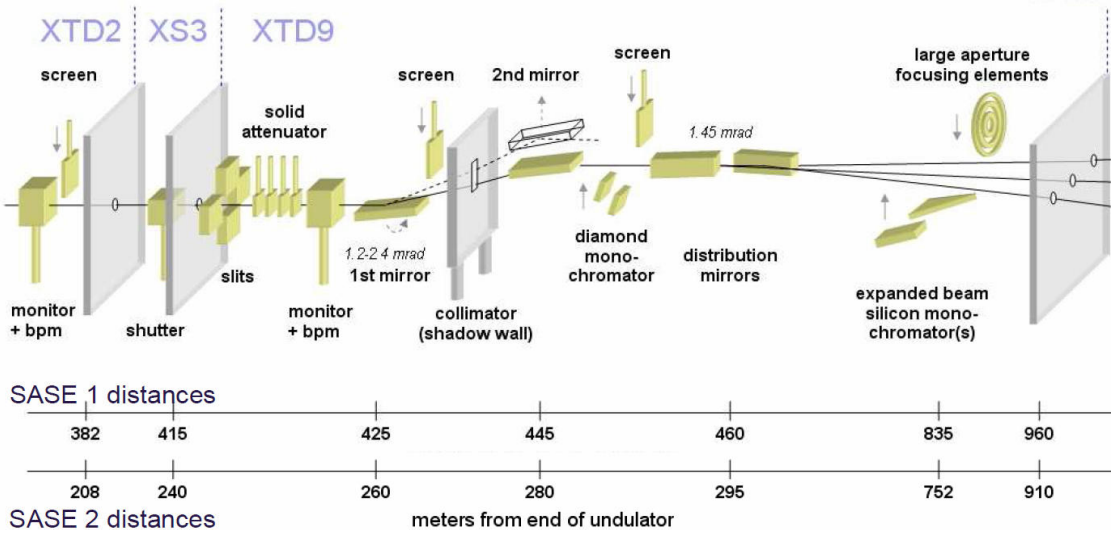
European XFEL

- Operational by 2015
- Electron energy 17.5 GeV
- SASE 1 photon energy 12.4 keV, equivalent to 0.1nm
- Up to 27000 flashes per second
- Applications:
  - Structure of biomolecules
  - Nanoparticles
  - Filming chemical reactions
  - Extreme states of matter
  - And many more!

Photon Diagnostics



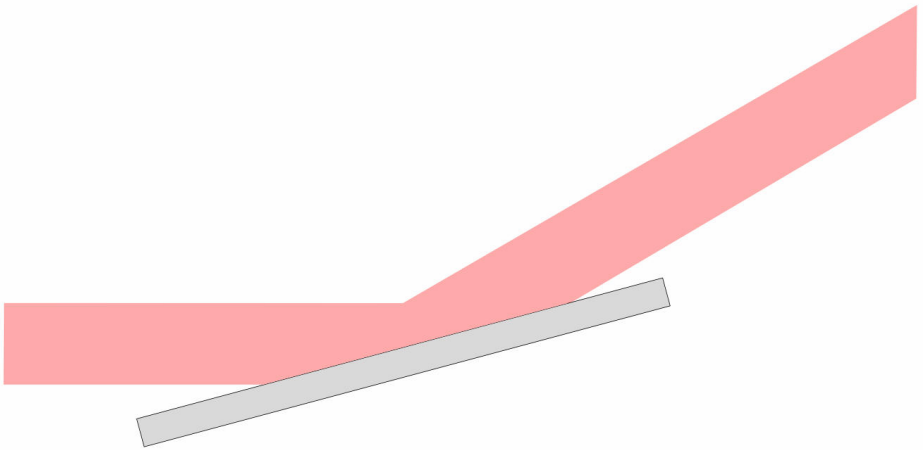
- Monitors ensure correct alignment
- Resolution < 10 µrad (100µm at 10m)
- Mirrors:
  - Tuning range 1-3 mrad
  - ~ 1m long
  - Flat to nm scale

- Optical elements:
  - Slits
  - Mirrors
  - Monochromators
  - Attenuators

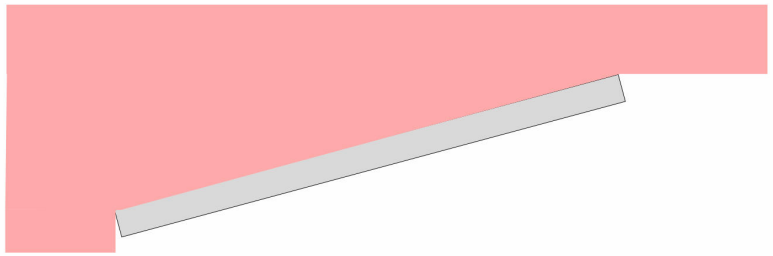
Diagram: H. Sinn, European XFEL WP-73 Presentation, 2010

Monitor Schemes

- Studied two possible solutions:
  - ‘Pencil beam’ setup
    - ➔ Small beam on mirror
    - ➔ Reflected onto photodiode
    - ➔ Diode signal gives angle

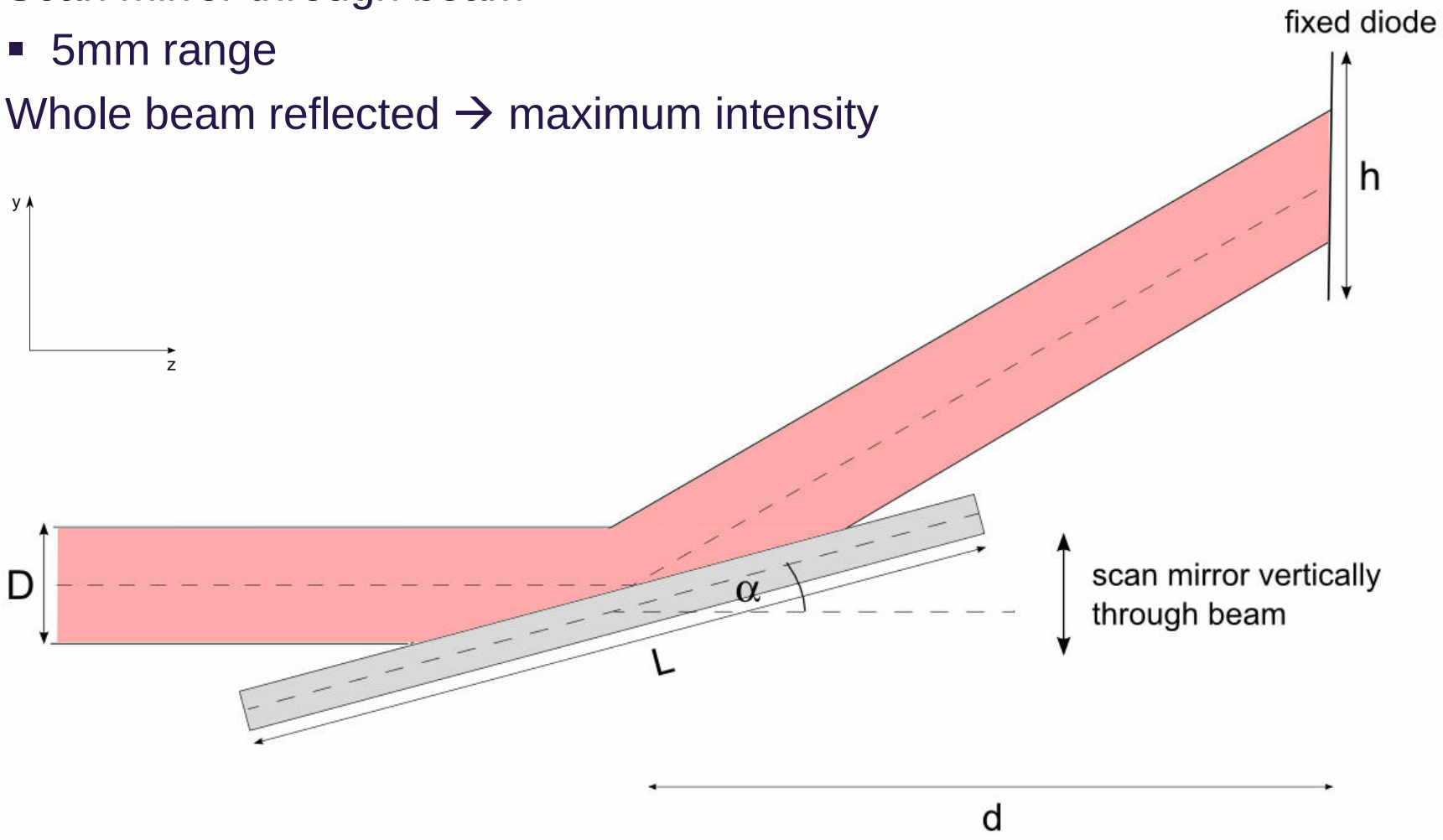


  - ‘Immersion’ setup
    - ➔ Large beam over mirror
    - ➔ View reflected and unreflected images on screen
    - ➔ Distance between images gives angle



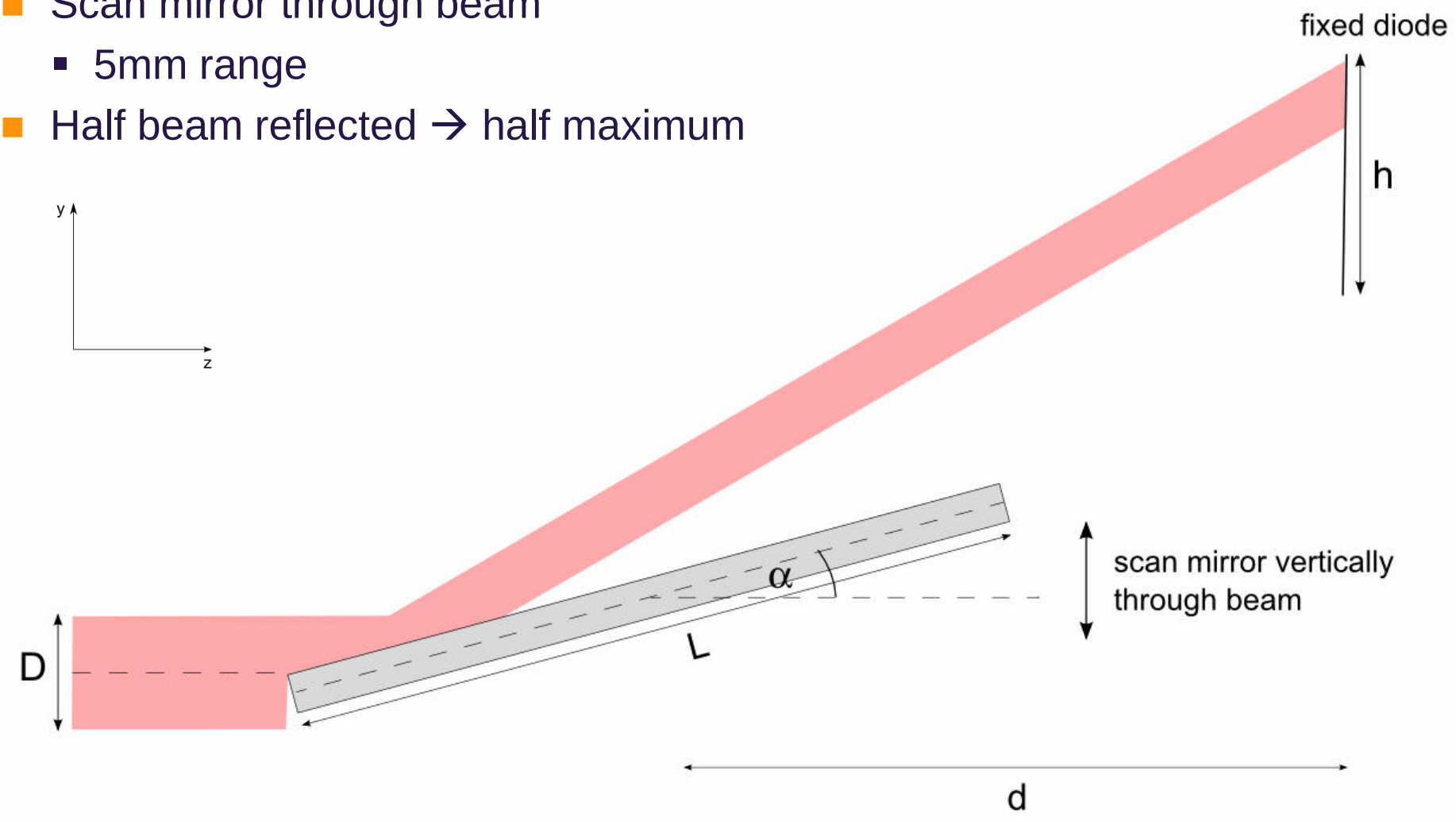
Pencil beam setup - geometry

- Scan mirror through beam
  - 5mm range
- Whole beam reflected → maximum intensity



Pencil beam setup - geometry

- Scan mirror through beam
  - 5mm range
- Half beam reflected → half maximum



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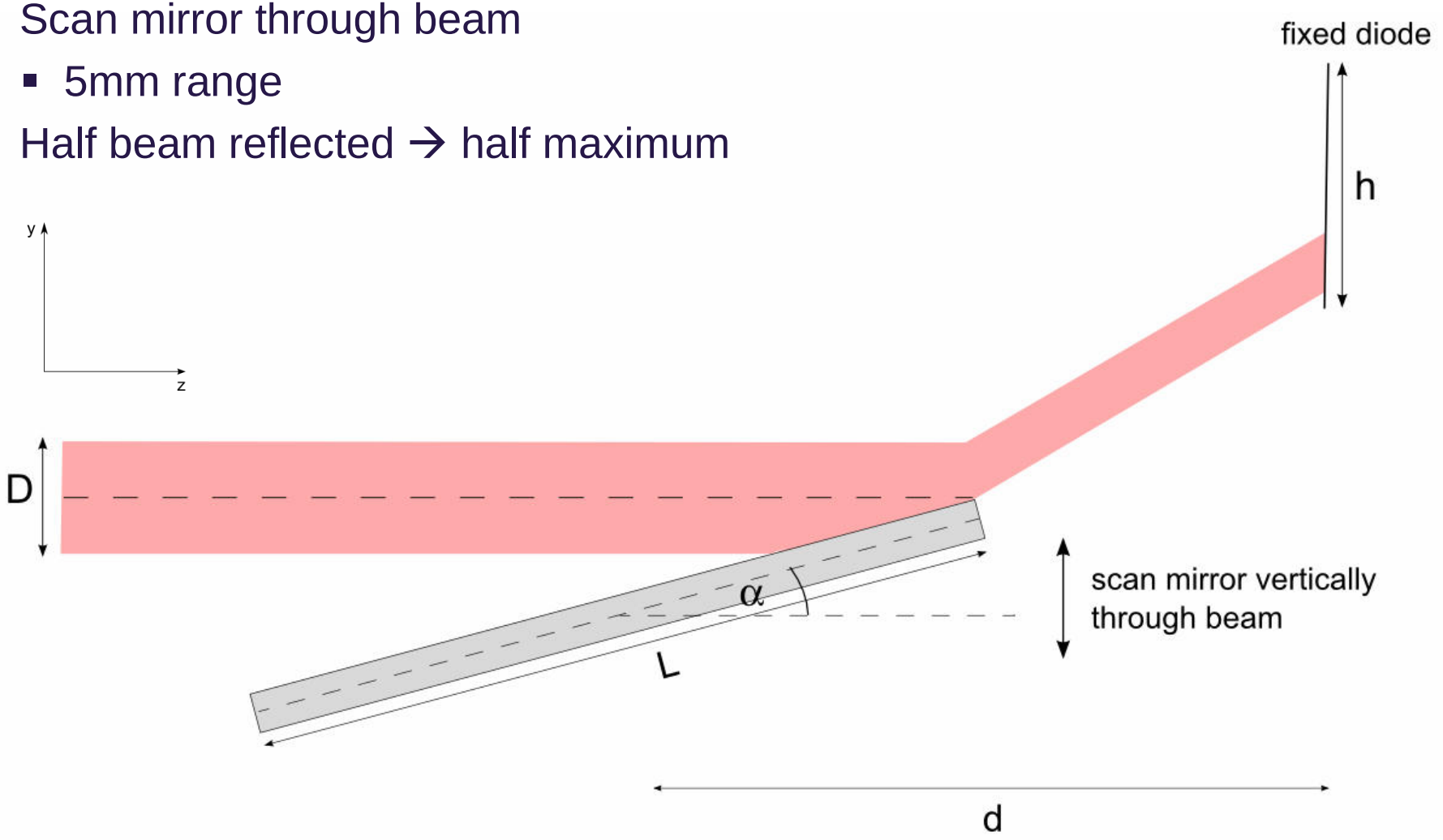
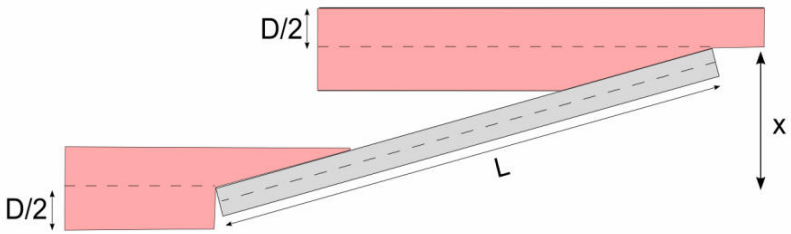
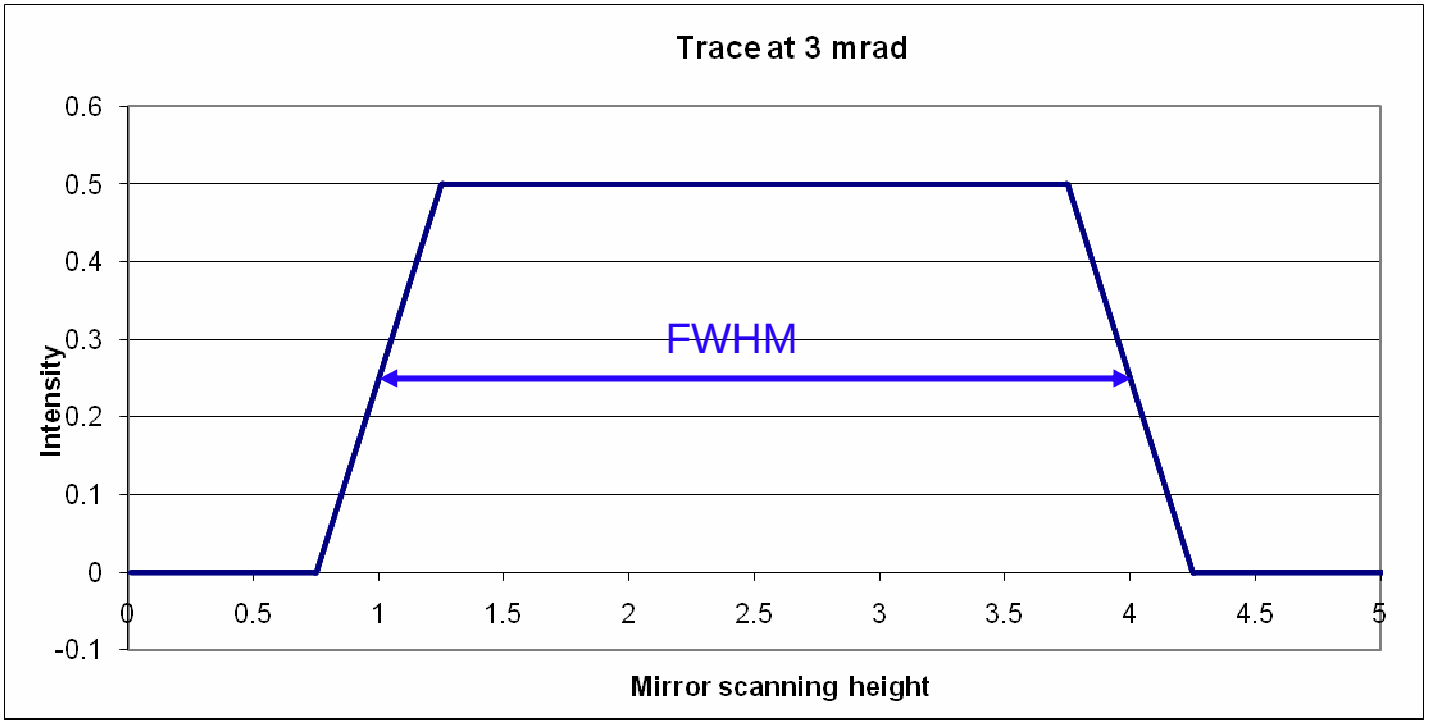


Pencil beam setup - trace

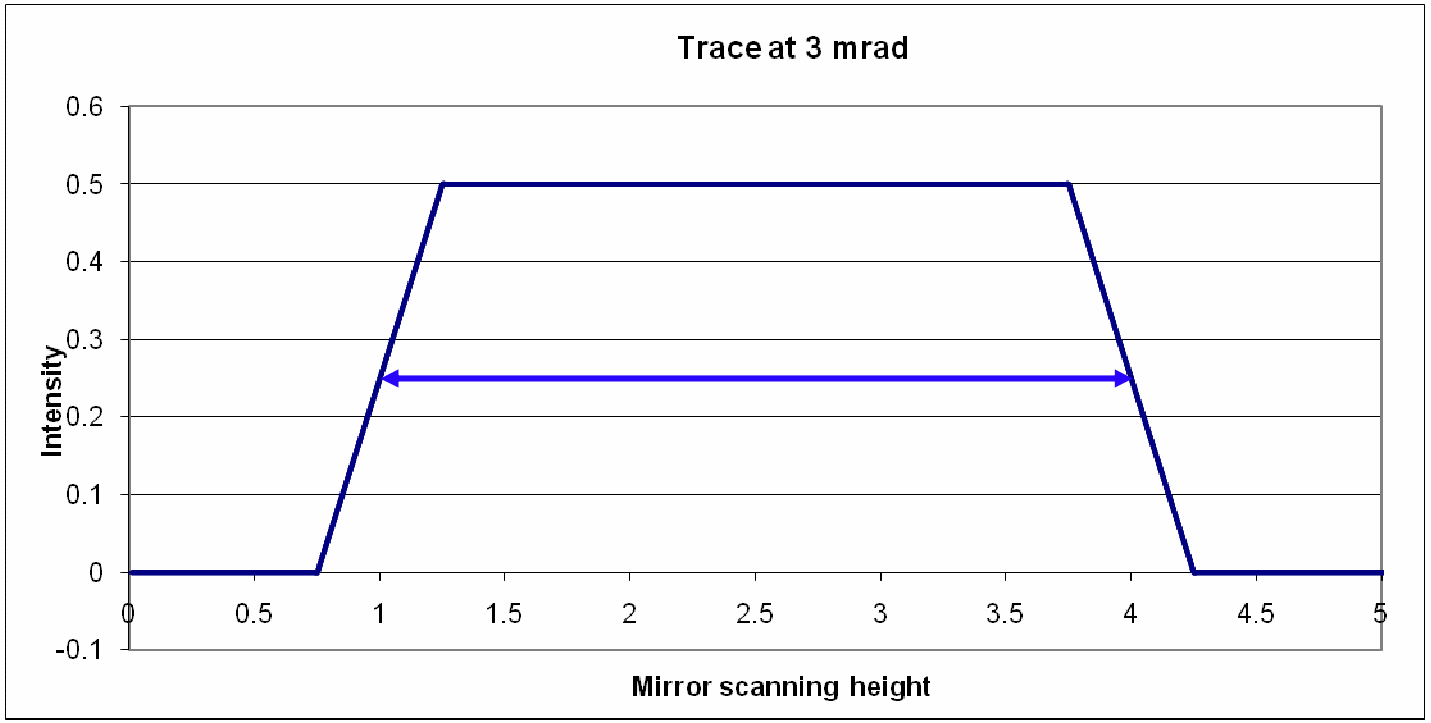
- Scan mirror through beam
  - 5mm range
- Trace taken by photodiode
- FWHM = L sin α





Pencil beam setup - limitations

- $D > L \sin \alpha$
  - beam too large → FWHM = beam diameter
- $h > L \tan 2\alpha \cos \alpha$
  - diode too small → FWHM falsely small



Nominal trace

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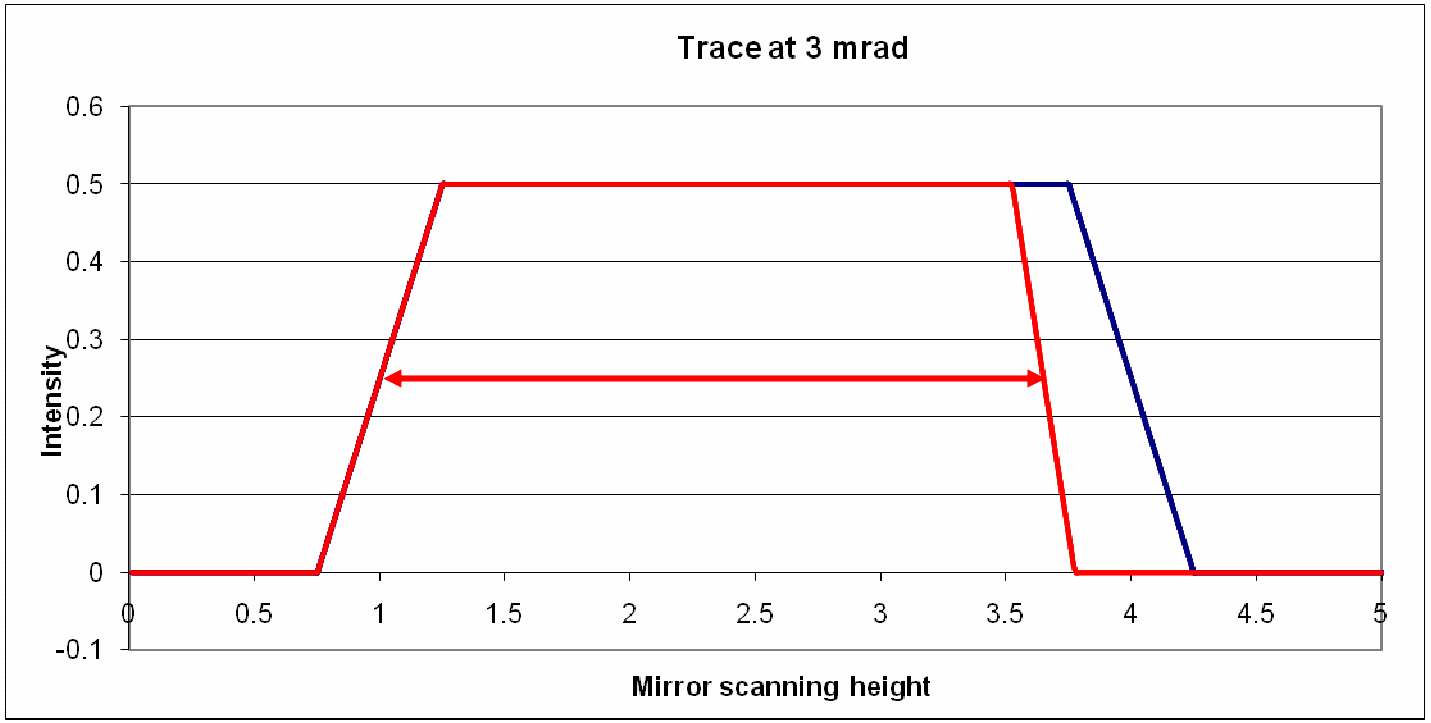

Nominal trace

Misaligned

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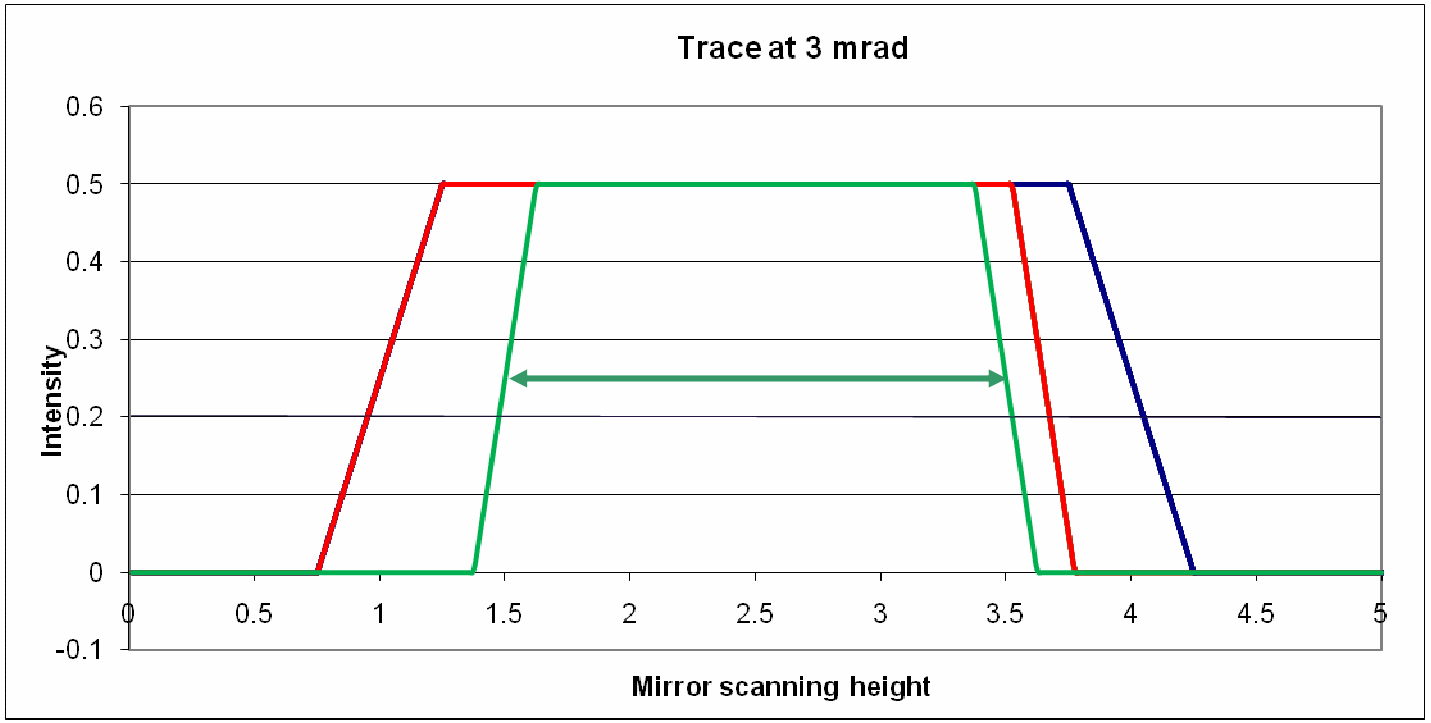
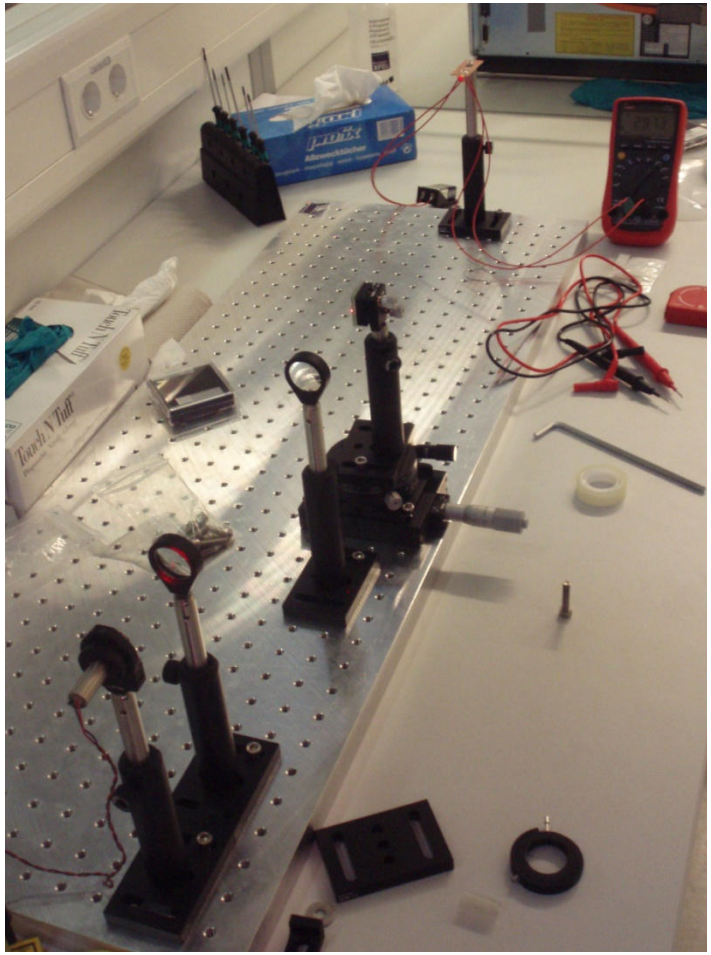


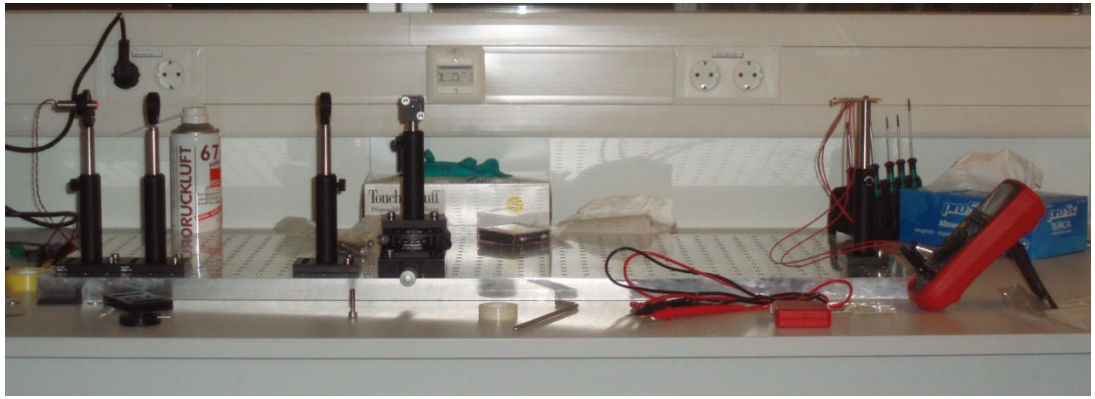
Nominal trace

Misaligned

Diode too small

Pencil beam setup - demonstration

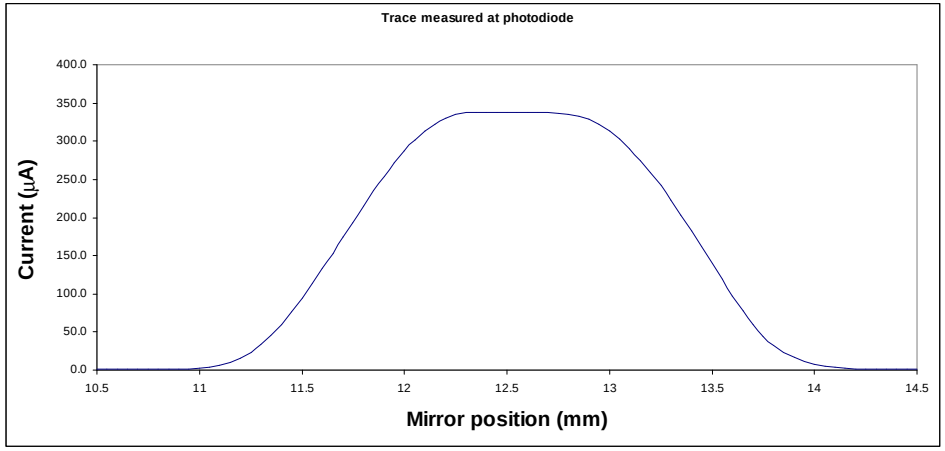




What's different?

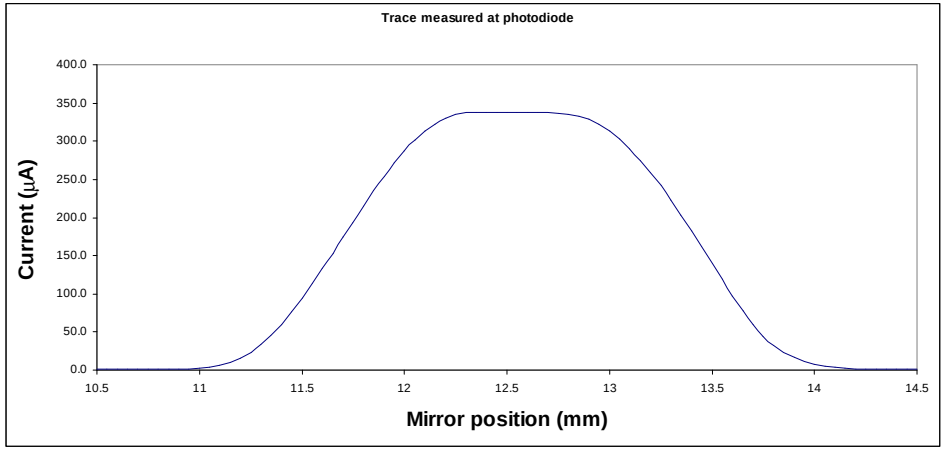
- Optical light
- Small, collimated beam
- Shorter mirror on linear + angular stage
- Operating range 3 – 4.2°

Pencil beam setup - discussion



- Measured angle = 4.33°
- Angle calculated from FWHM = 4.00°
- Diode too small

Pencil beam setup - discussion



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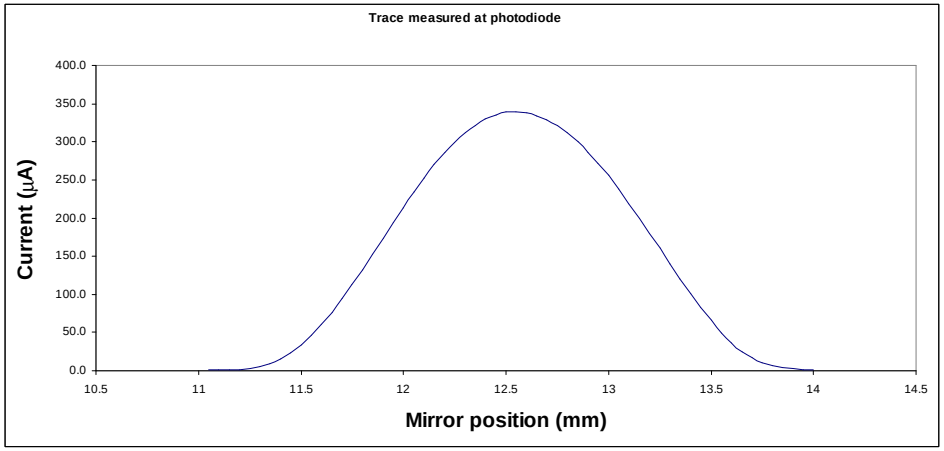
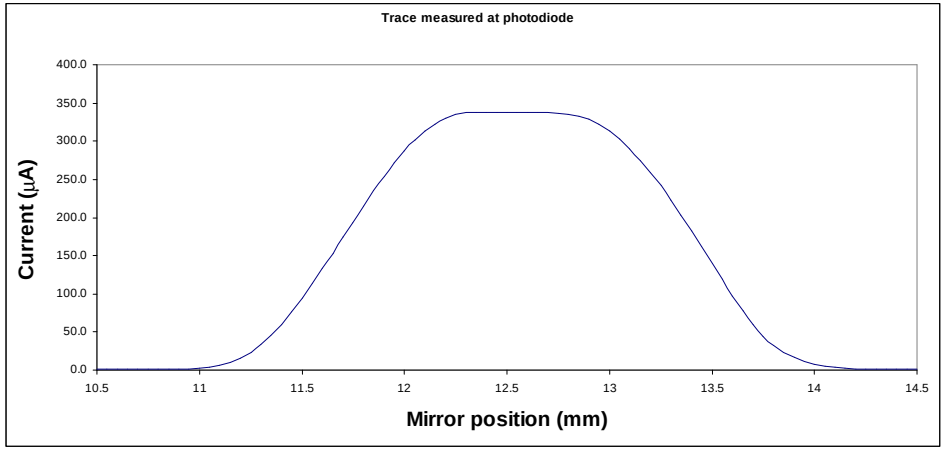


- Measured angle = 3.13°
- Angle calculated from FWHM = 3.06°
- Close to $D > L \sin \alpha$ limit.

Pencil beam setup - discussion



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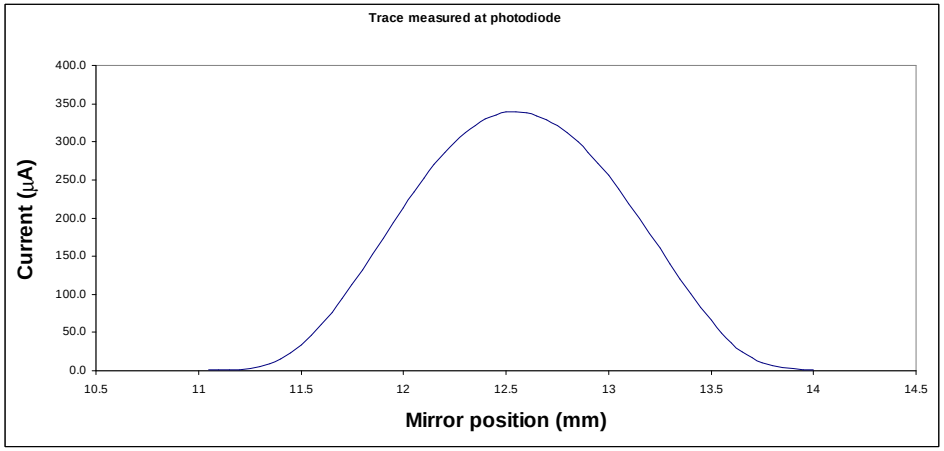
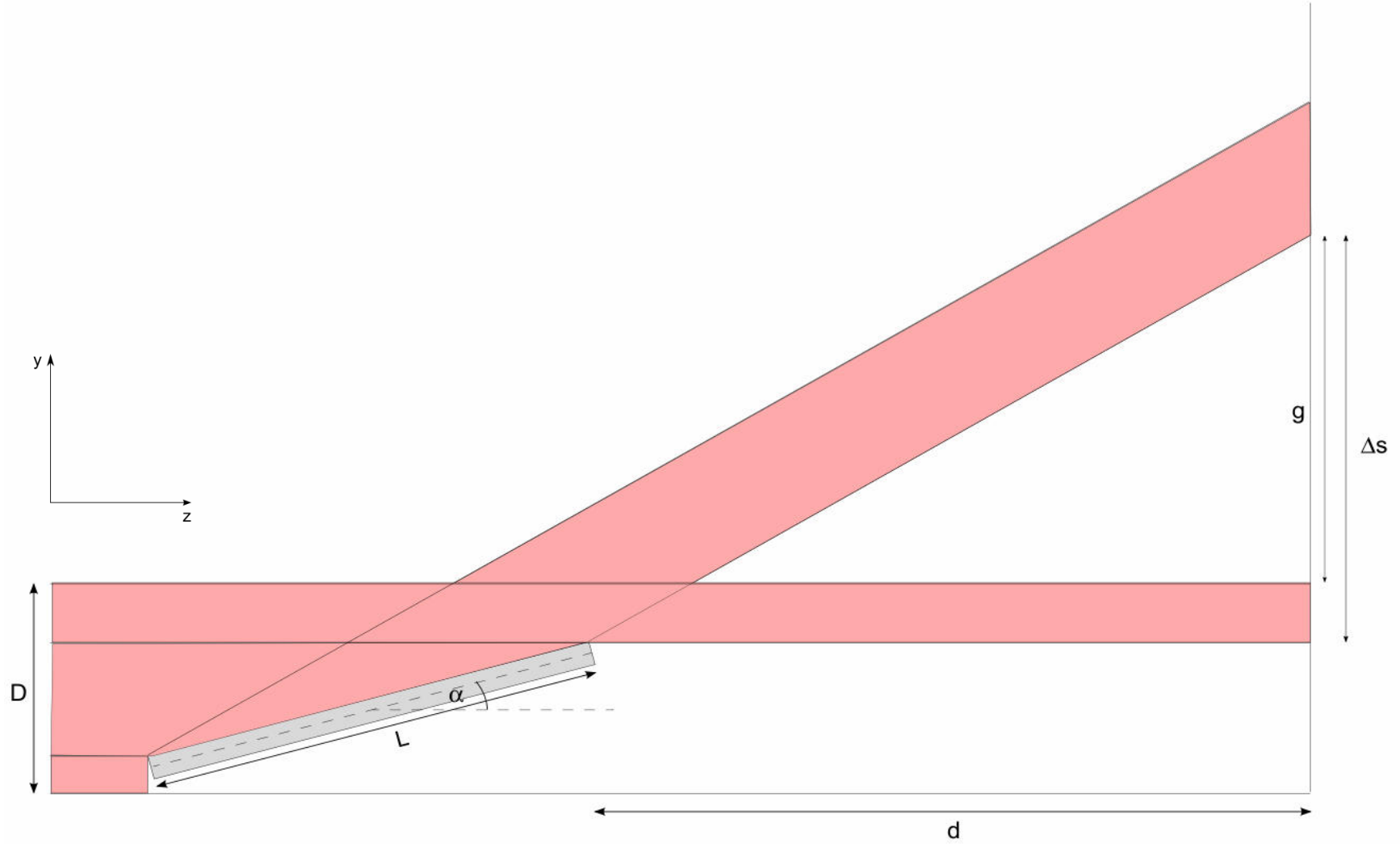


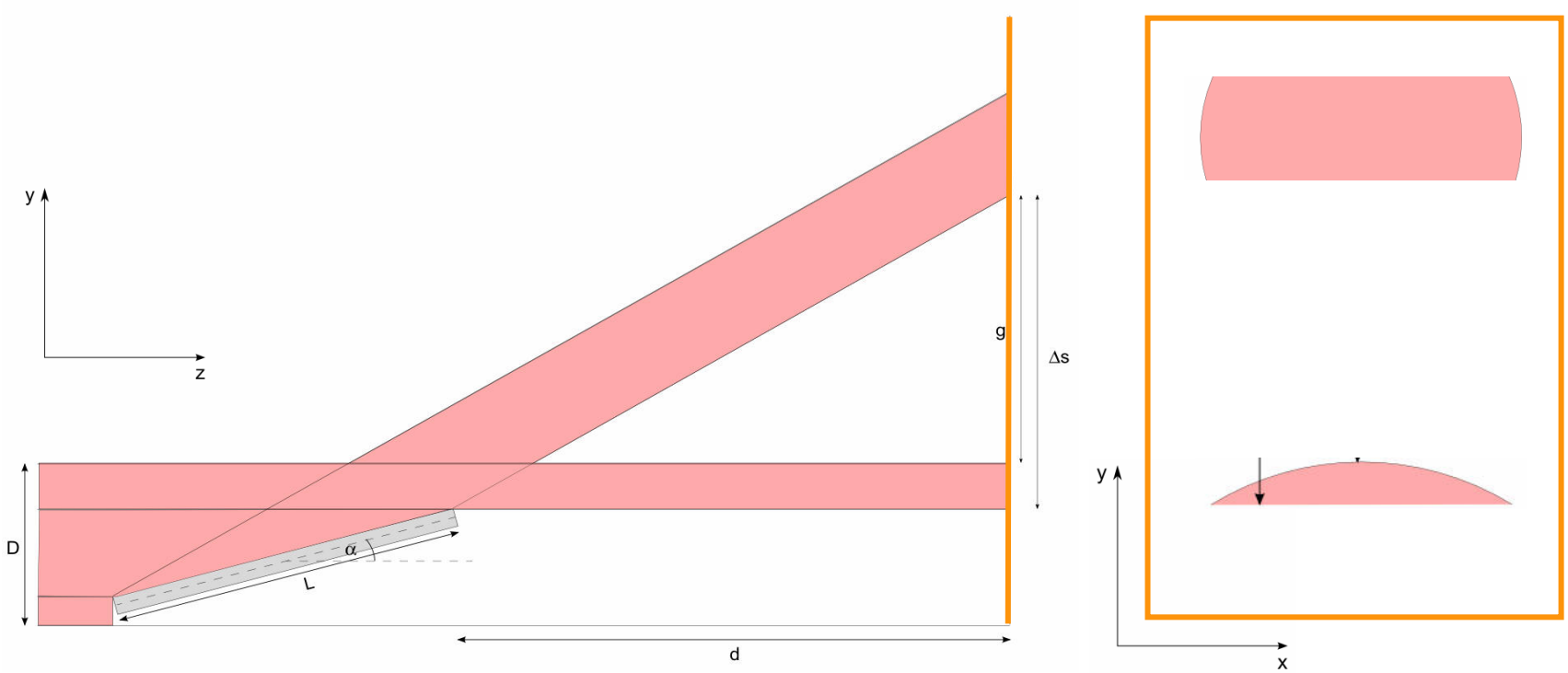
- Measured angle = 3.13°
- Angle calculated from FWHM = 3.06°
- Close to $D > L \sin \alpha$ limit.

- At the XFEL
  - 10mm diode can cover whole angular range
  - Need only 2 degrees of freedom
    - Mirror y-motion
    - Mirror angular motion

Immersion setup - geometry

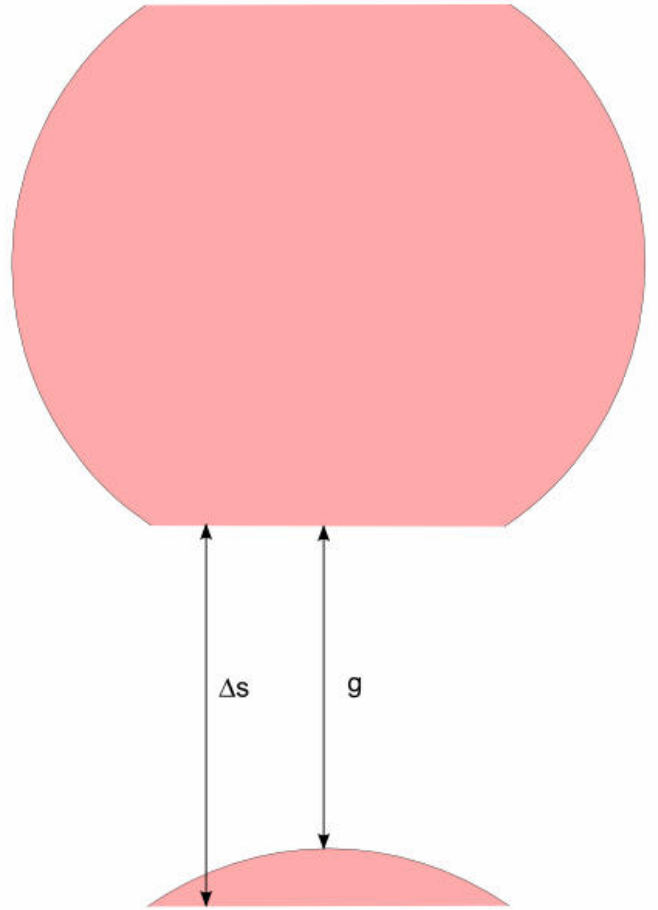


Immersion setup - geometry

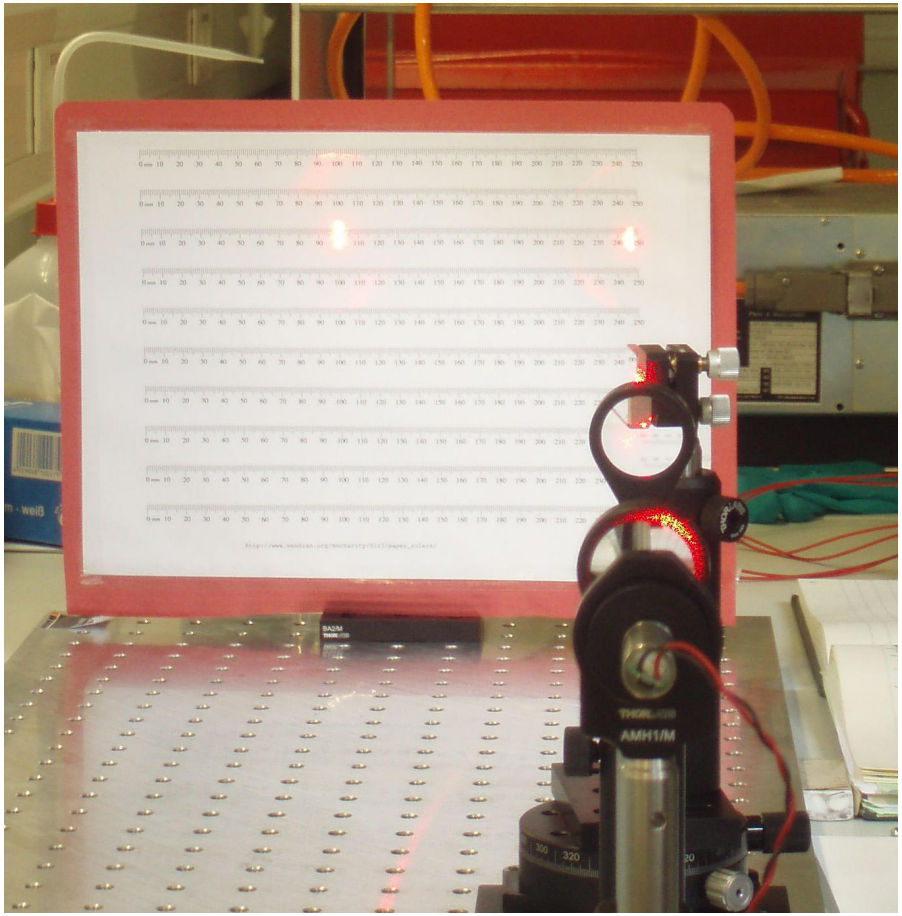


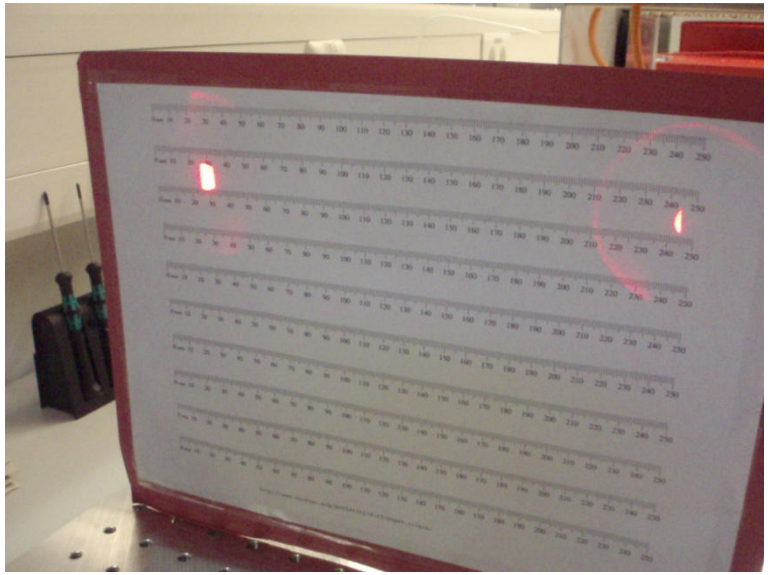
Immersion setup - geometry

- Immerse mirror in wide beam
- Two areas on screen
- Compare reflected/unreflected areas
  - $\tan 2\alpha = \frac{\Delta s}{d}$
  - g can determine offset



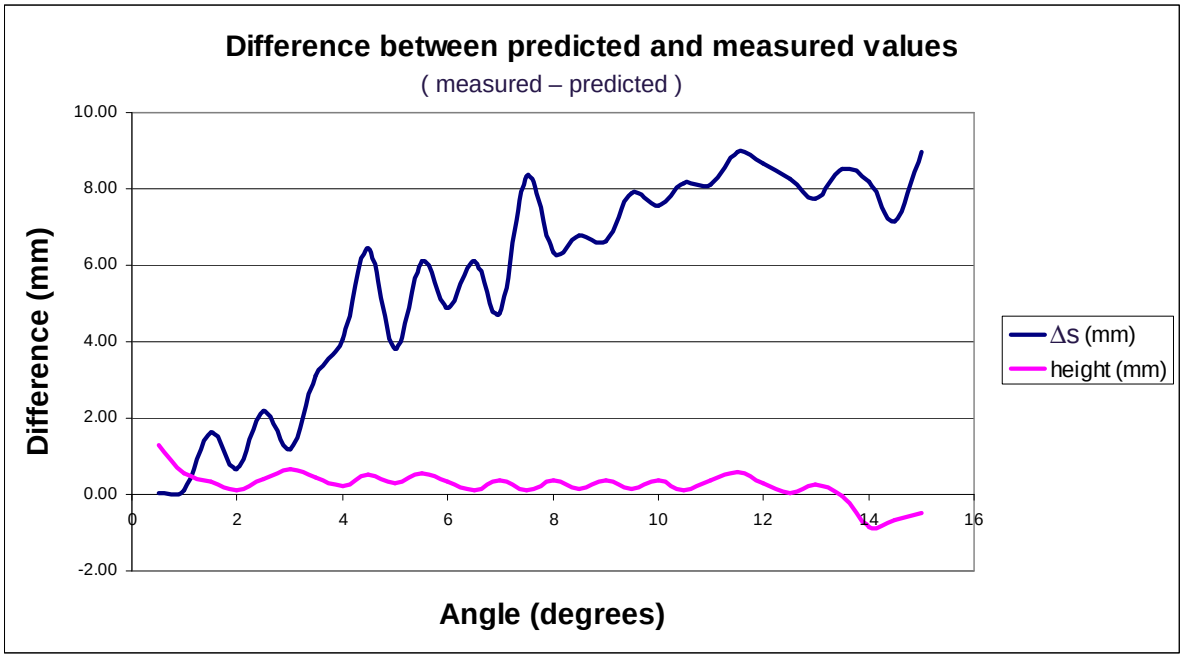
Immersion setup - demonstration





- Limitations:
  - Alignment of mirror surface to rotation axis
  - Fuzzy images
  - Screen not perfectly flat

Immersion setup - discussion

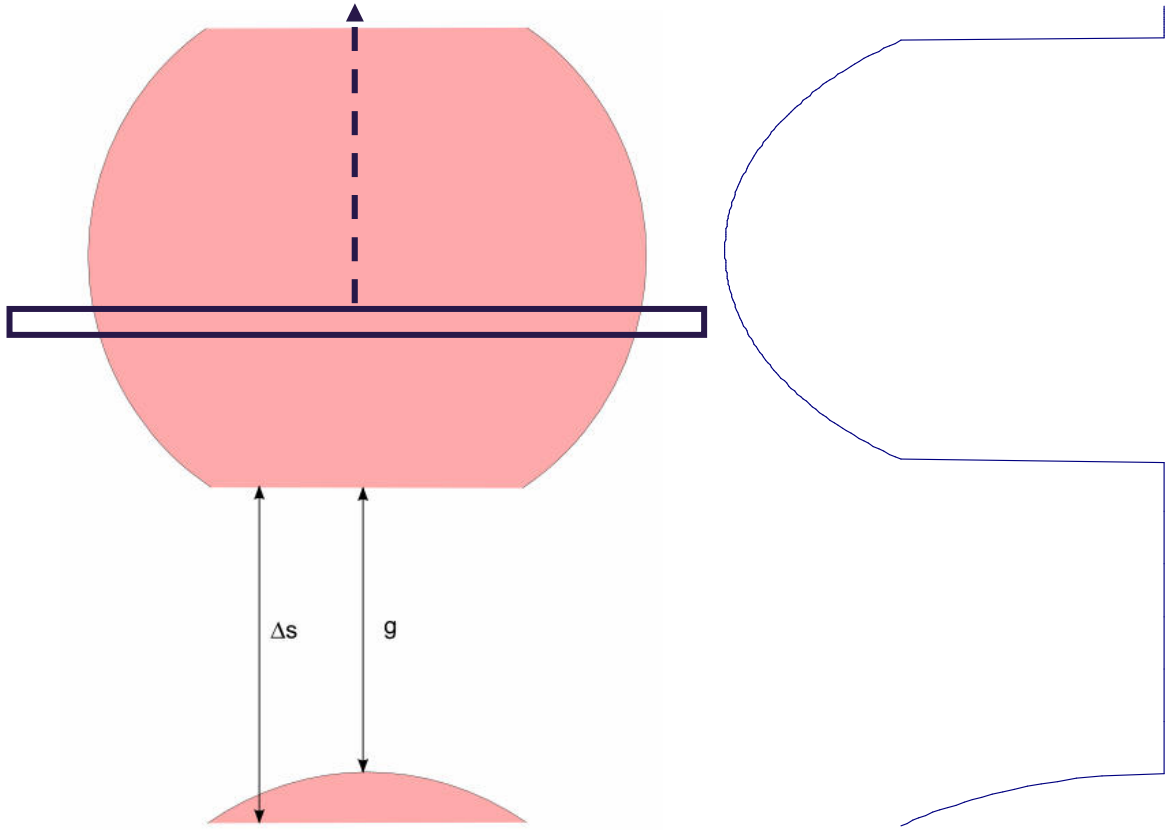


- Δs diverges from prediction, increases with angle:
  - Alignment error?
  - Why does height not diverge?

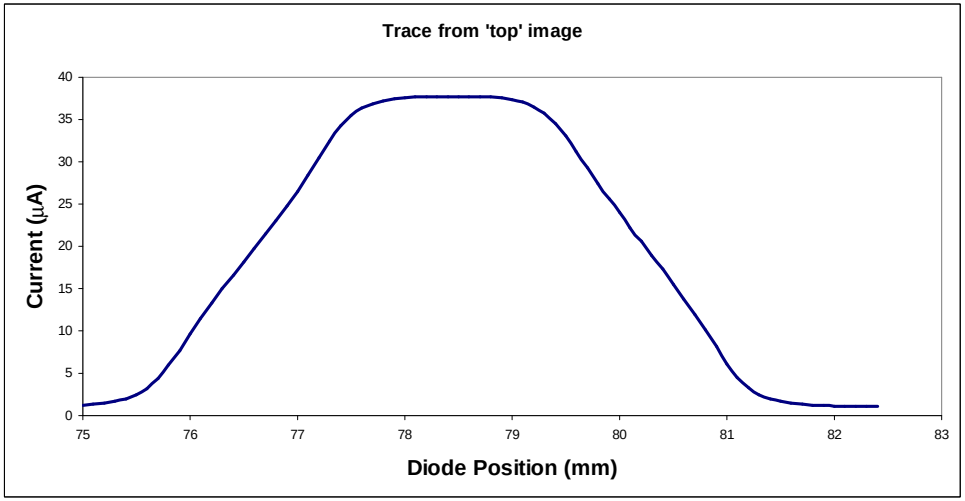
- Screen:
  - \+ Easy to read
  - \- Need camera
  - \- Hard to achieve resolution (40µm required)
- Another solution?

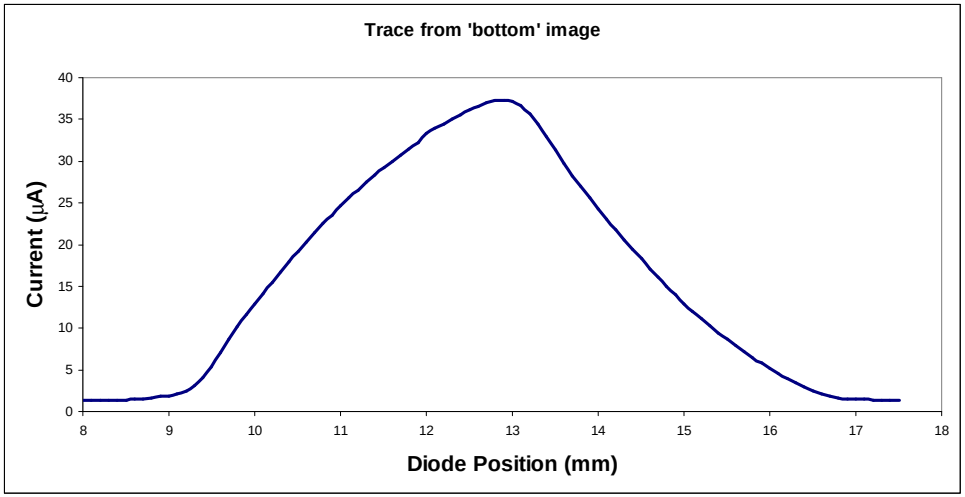
Immersion setup with diode

- Use a thin, wide diode
  - Scan across image plane
  - Determine Δs and g from trace



Immersion setup with diode - demonstration





No slit used:

- Not enough intensity
- Mounting and alignment problems

Inaccurate:

- Circular beam
- Small range of stage
- Easily misaligned when readjusted
- Δs error = 5mm
- Equivalent to 0.5°

However, should work better at XFEL

- Thinner diode = easier to read

Comparison

	Pencil beam	Immersion + screen	Immersion + diode
Degrees of freedom	2 fine + in/out	2 fine + in/out	3 fine
Ease of installation	Full range with 10mm diode.	20mm screen at 2m. Camera in vacuum chamber.	20mm diode range at 2m.
Required accuracy	<5μm over 5mm range. Achieved at FLASH.	<40μm in Δs -> 20μm at 2m.	~10μm for 10μm high diode.
Ease of use	Easy to find FWHM.	Easy to read from screen.	Easy to find edges with small diode.
Conclusion	Easy to install. Easy to read. Good resolution.	Too much equipment. Uncertain resolution.	Good resolution. Untested. Extra degree of freedom.