StaFF Progress Report

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Cast

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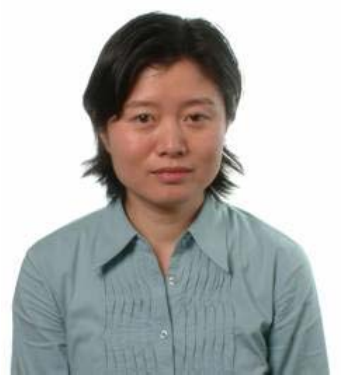


Stephanie Yang
(mechanical engineering)

Tony Handford
(workshop)

Roy Wastie
(electrical engineering)

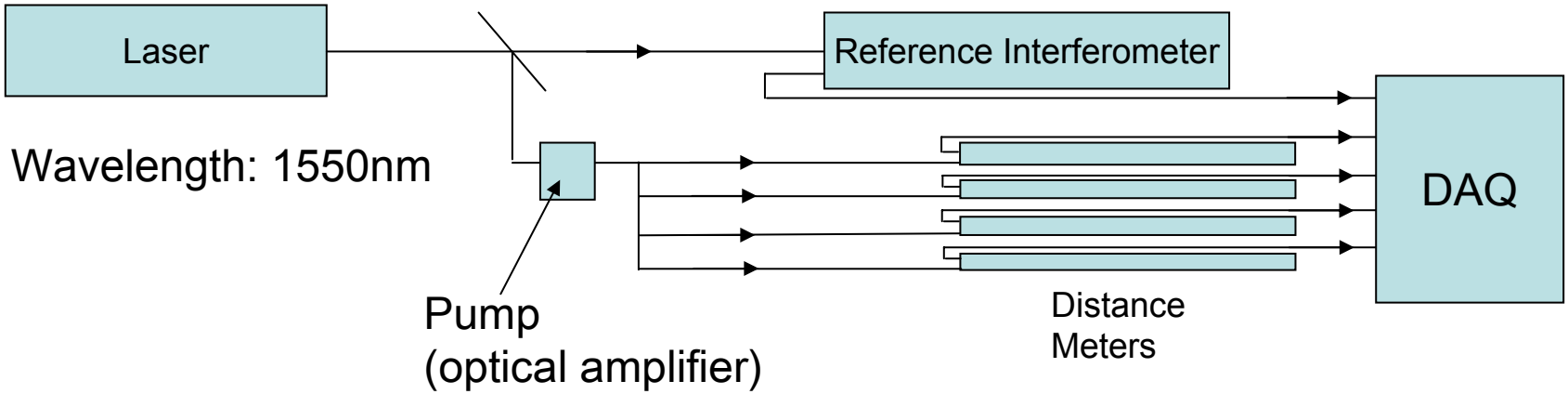
Measuring Motion

- At the ILC beam delivery system many magnets have to be stable with respect to each other to achieve high luminosities.
  - Final focus doublet
  - Critical magnets in BDS
  - Position monitoring of BPM's in energy chicane.
- Often no direct line of sight:
  - Correlate position information of magnet to stable platform (e.g. anchored in ground) interferometrically.
  - Can be coupled with very large accelerometer performing better at small frequencies.
  - Correlate the stable platforms interferometrically.

Generic Tools

- Straightness monitor
- Distance meter (build first)

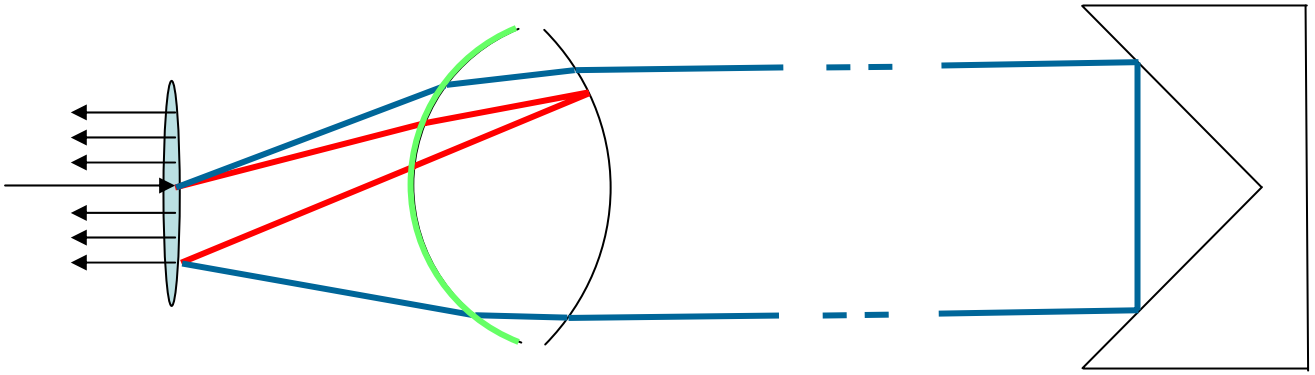
Distance Meter: Method of Measurement



- Distance meter 2 modes:
  - Interferometer mode:
    - fast,
    - relative distances
    - resolution nm
  - FSI mode:
    - slow
    - Absolute distances
    - Precision 1μm.

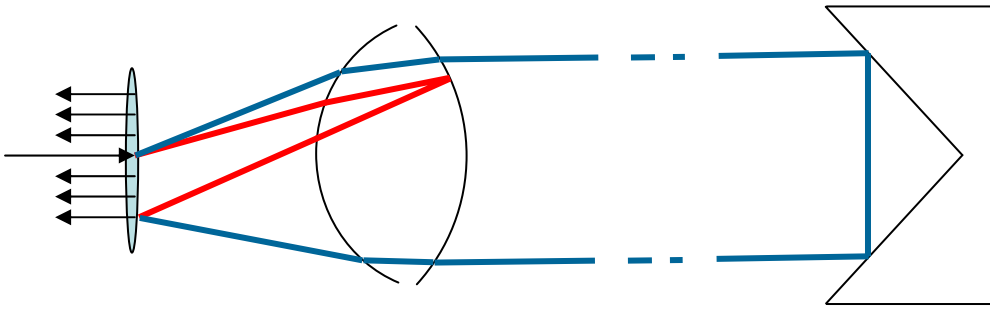
Design costs down 2 for distance meters so that overall cost scale favourably.

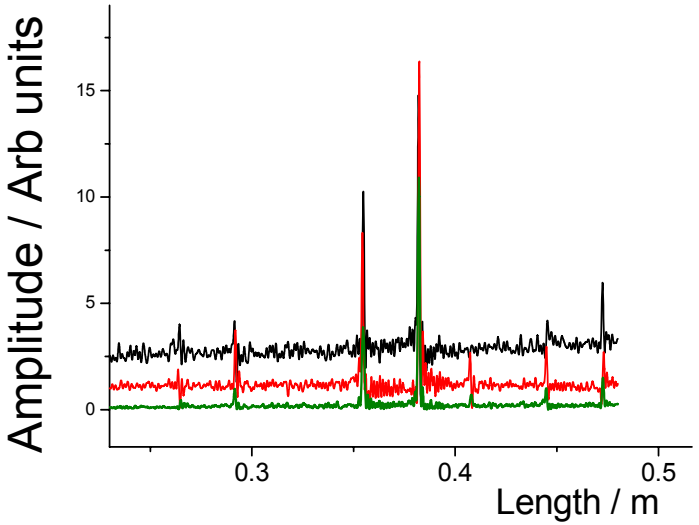
The Distance Meter: FSI Mode



- Blue (long) arm reflected at Retro-reflector returning light at same angle
  - Slightly defocus lens → returning light is spread to ~1mm circle at launch plane.
- Red (short arm) reflected at far end of lens
  - Both arms cross same amount of material (1. order)
  - Close end of lens has to be anti-reflection coated.
  - Chose lens: short arm is reflected into small region.
- Red (short arm) and blue (long arm) interfere.
- FSI: Needs only one return line.
- Tune laser from 1530-1560 nm.
  - #wavelength-#wavelength changes
  - For constant tuning speed: constant FSI frequency.

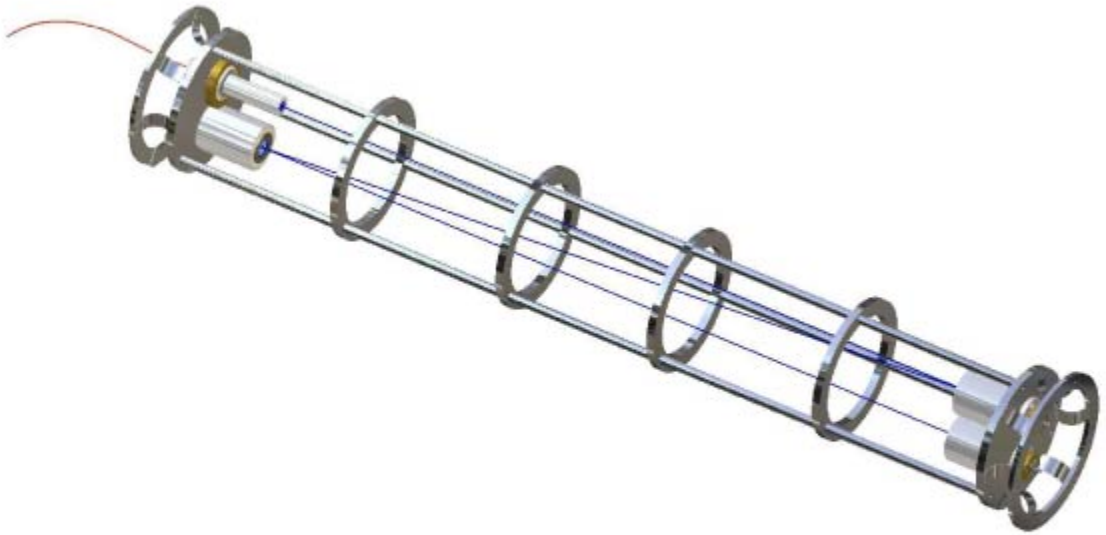
The Distance Meter: FSI Mode

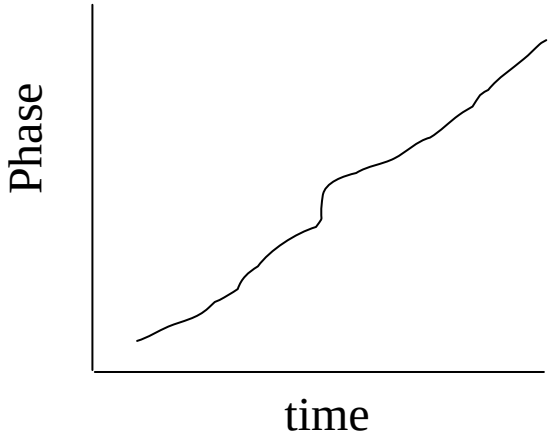




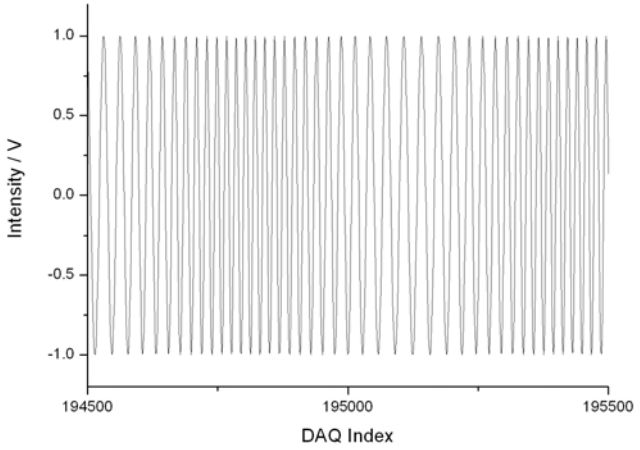
- Measure fringe frequency using fast Fourier transformation.
  - #fringes * frequency → total phase advance.
  - Known effective length of reference → effective length of distance meter.
  - Fourier spectrum measures all frequencies → all interferences at all distances!

FSI: Reference Interferometer

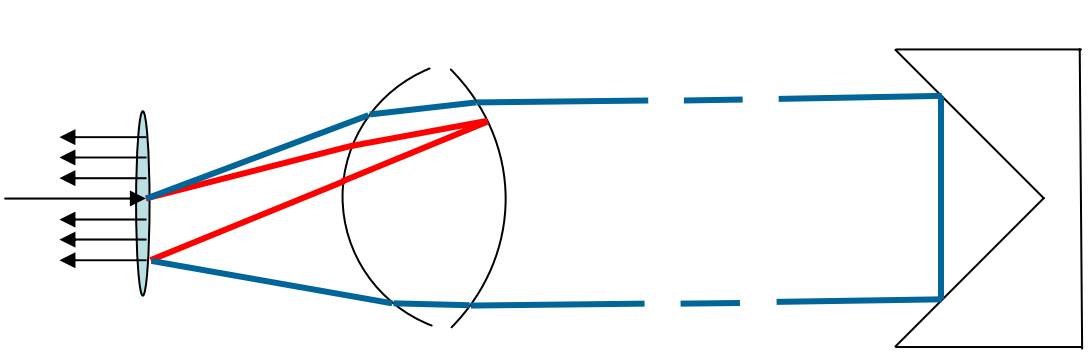


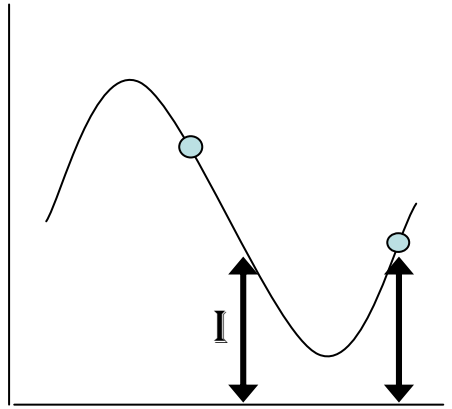


- Laser: Constant tuning spee[illegible]
  - Unfortunately no.
- Reference interferometer de[illegible]
- Use Reference interferomet[illegible]
- Then correct phase informa[illegible]



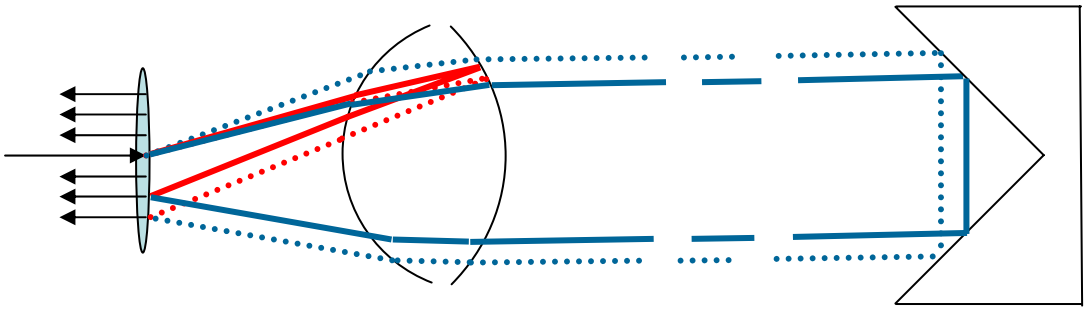
The Distance Meter: Michelson mode



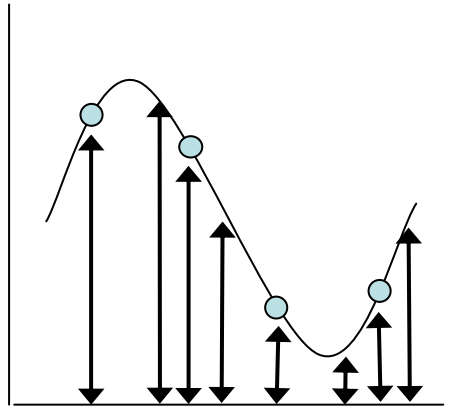


- Length motion leads to change in interference pattern
  - Measure intensity I.

The Distance Meter: Michelson mode

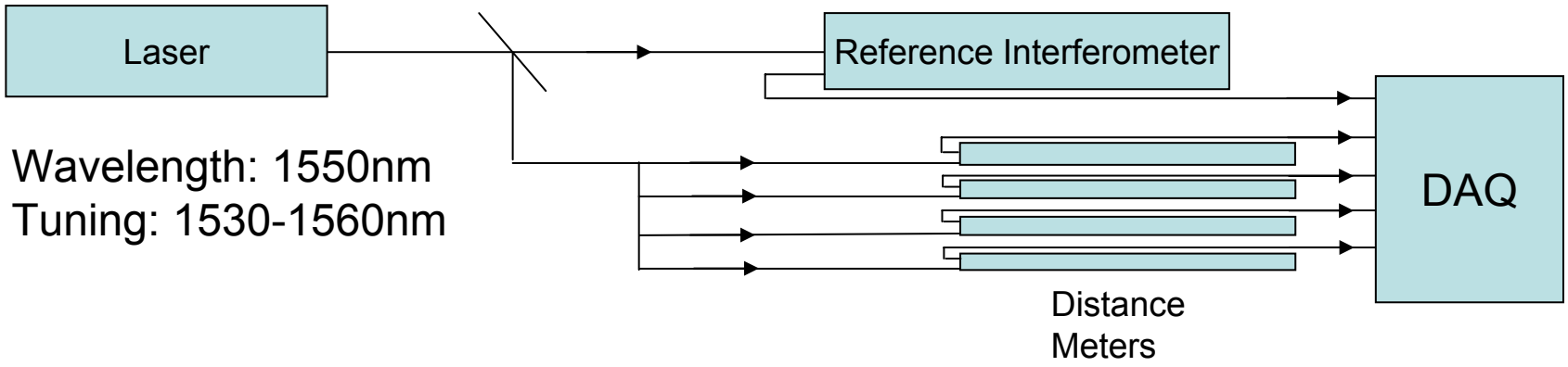


Fixed Laser Frequency



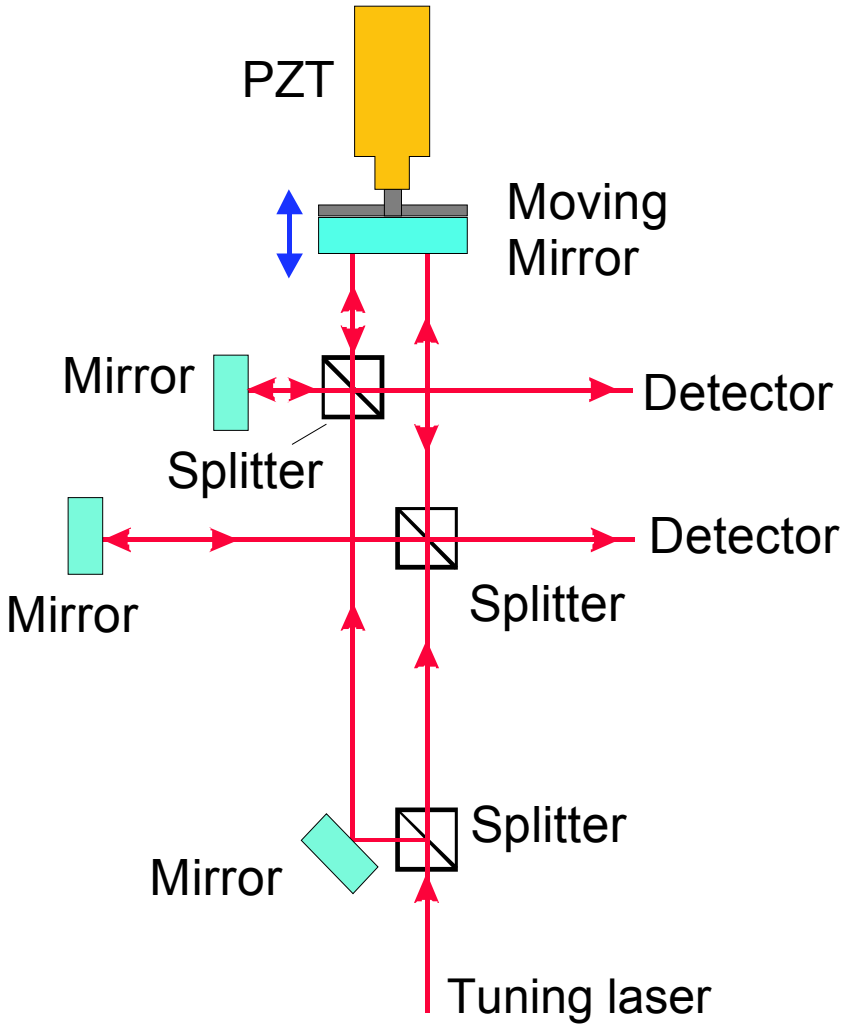
- Length motion leads to change in interference pattern
  - Measure intensity I.
- Add more lines
  - Each line will have another path length difference.
  - 4 lines enough to calculate exact motion.

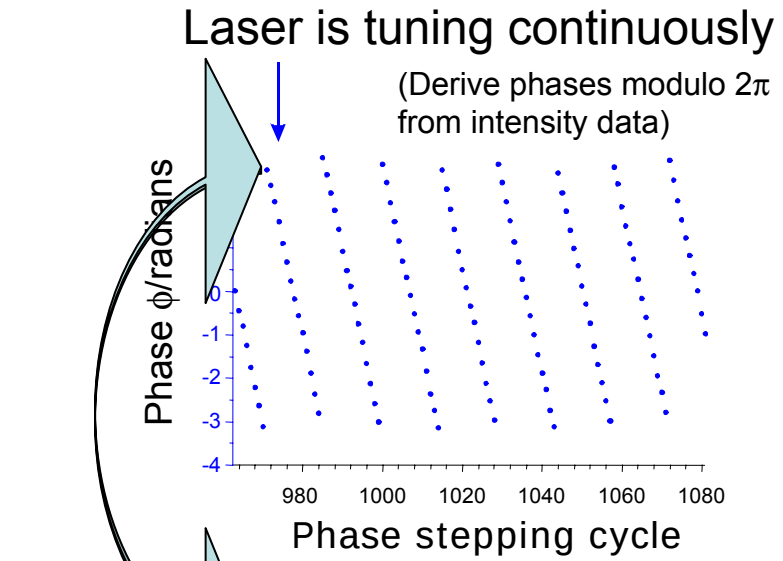
Pay Attention to Systematic Effects

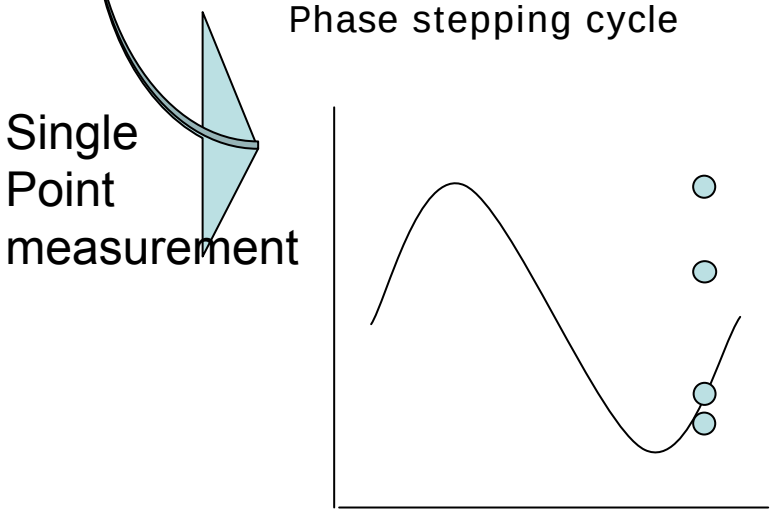


- Understanding the behaviour of laser is key!
- FSI mode:
  - Can we get better handle on tuning speed?

Piezzo Driven Monitor

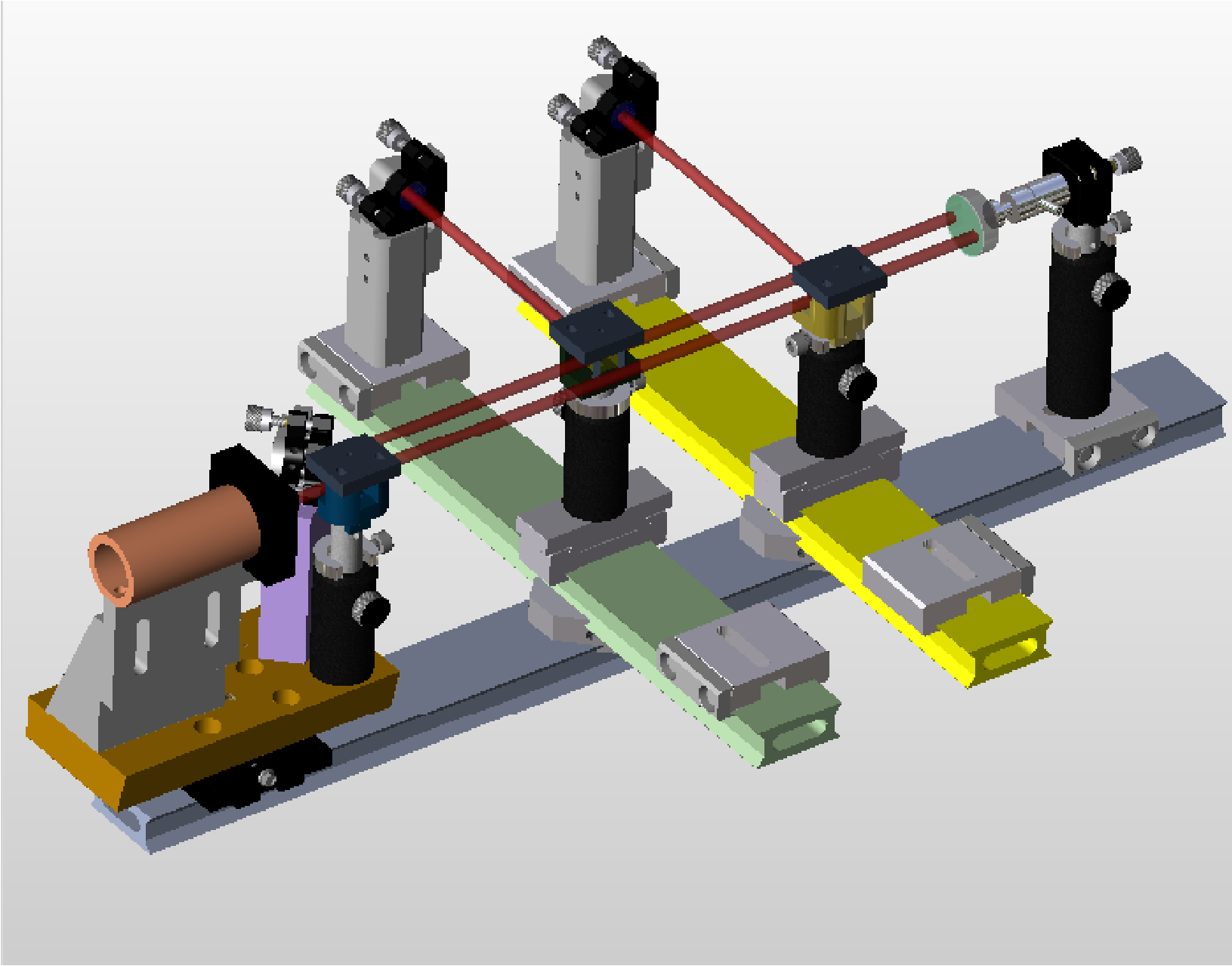




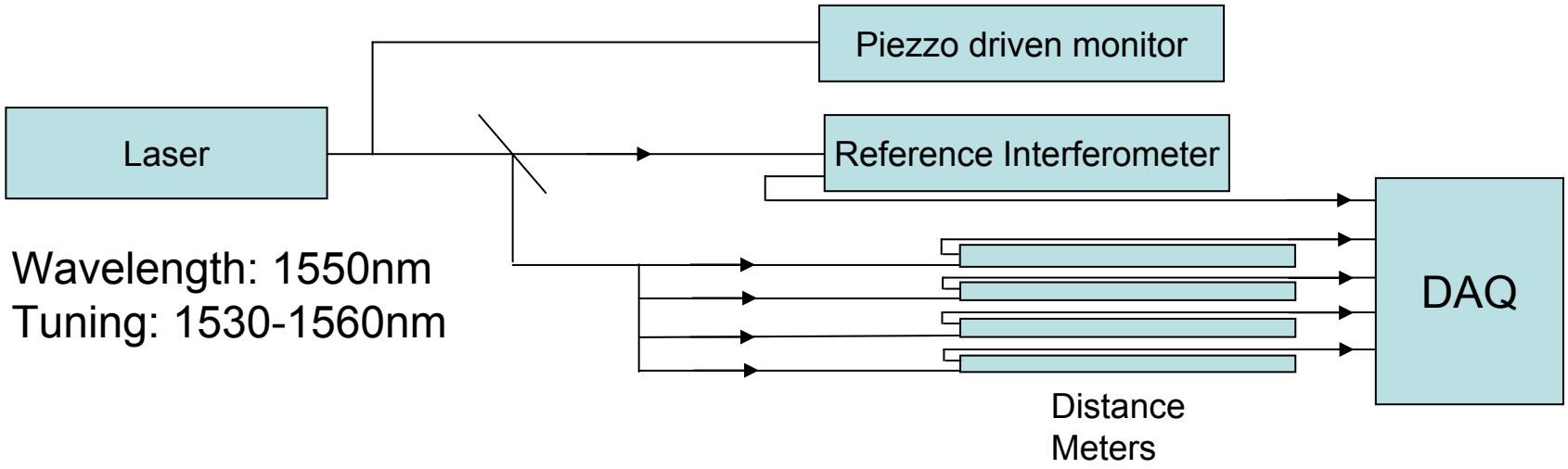


Moving mirror: Measure Intensity pattern

3–D mechanical model, detector side removed for clarity



Systematic Effects: Laser



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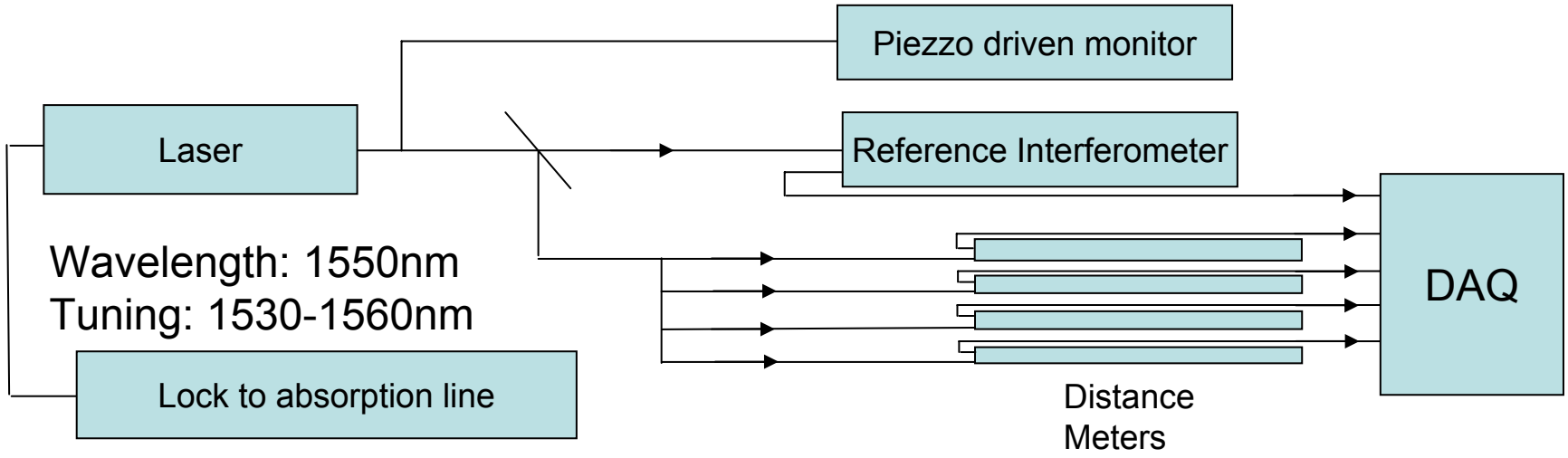
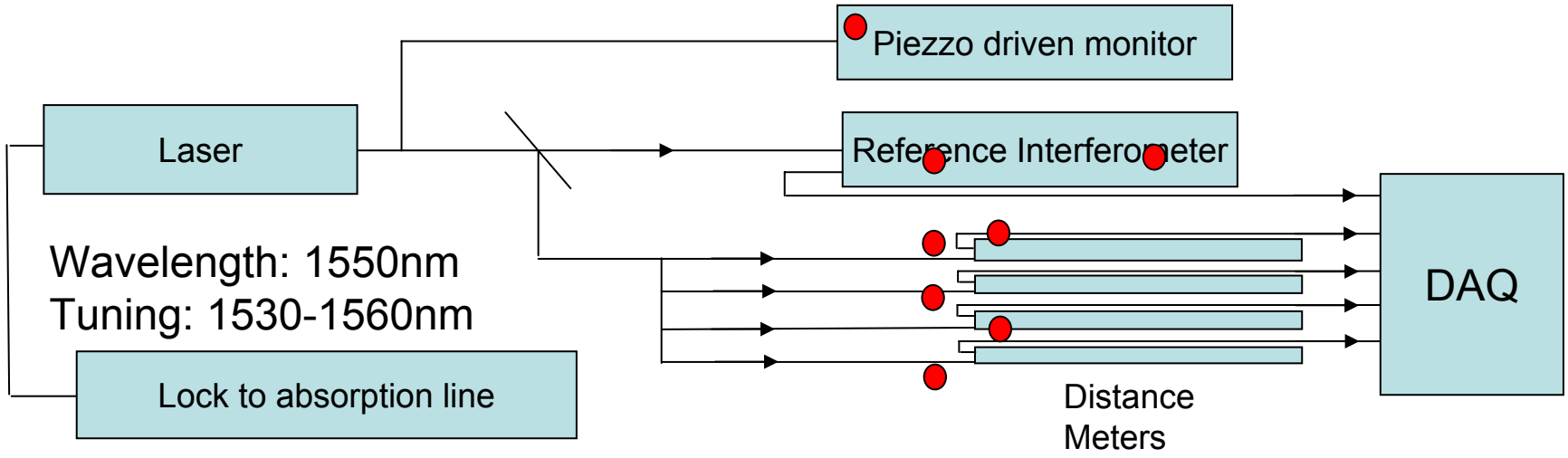
- FSI mode:
  - Can we get better handle on tuning speed?

Systematic Effects: Laser



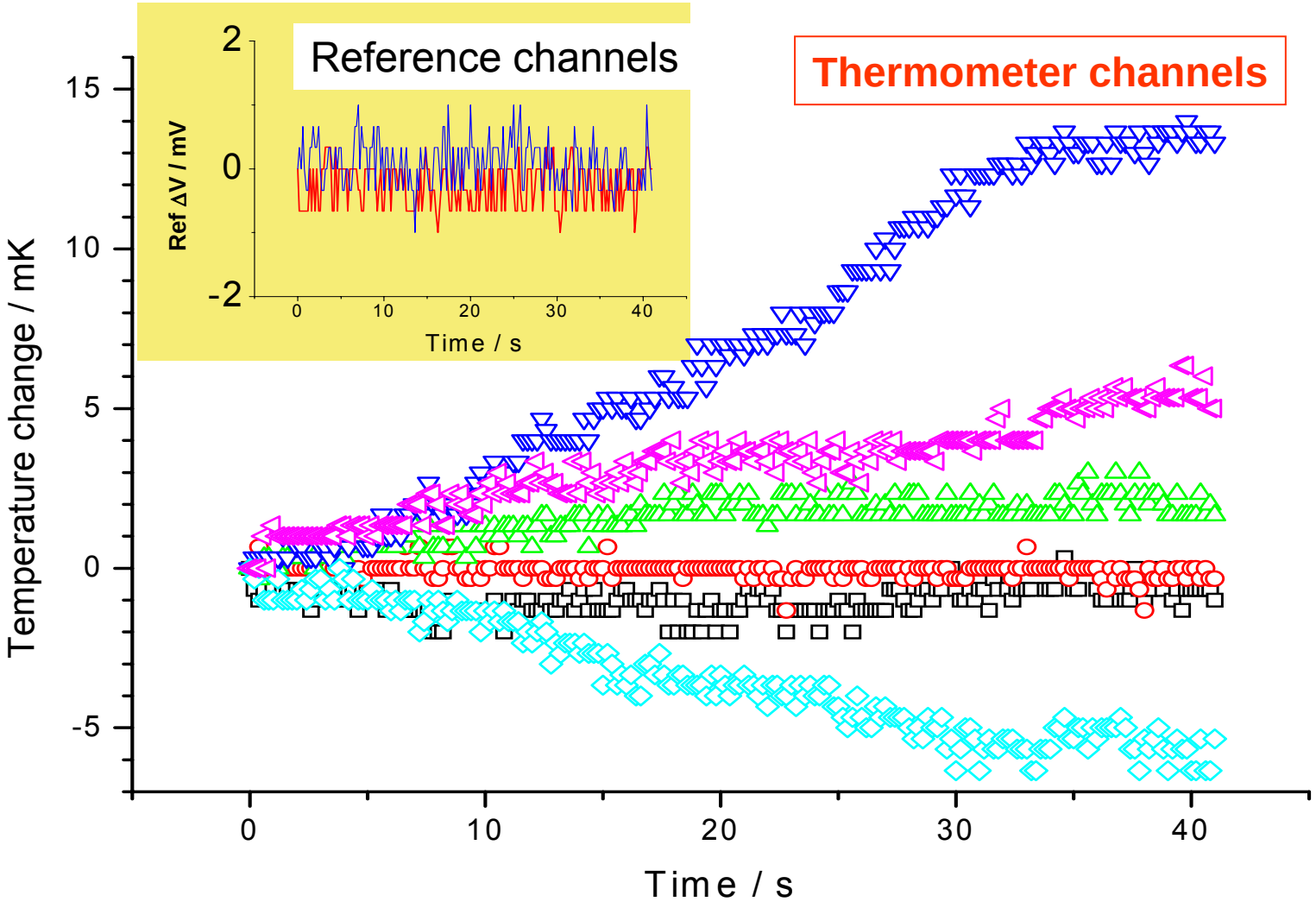
- Understanding the behaviour of laser is key!
- Michelson mode:
  - Stable frequency needed (unbalanced arm length) at level ~30kHz!
    - Lock Laser to absorption line (very hard at 1550nm).
    - Equip reference with Michelson Mode readout. → Change of reference interferometer information measures frequency change (assuming length is stable).

Other Systematic Effects



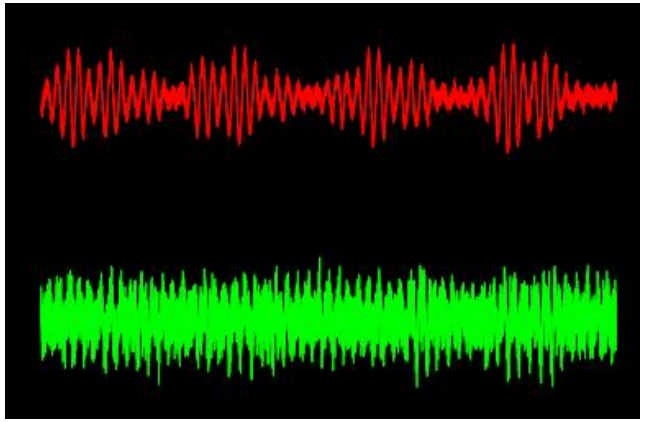
- FSI mode:
  - Length change of distance meter during tuning (1nm → ~40nm error).
    - Scan rapidly → Piezzo driven monitor will not work!
    - Use Michelson information of distance meter to track length change.
    - Use both methods.
- Vacuum enclosure of distance meters needed.
- Temperature effects.

First Temperature Measurements

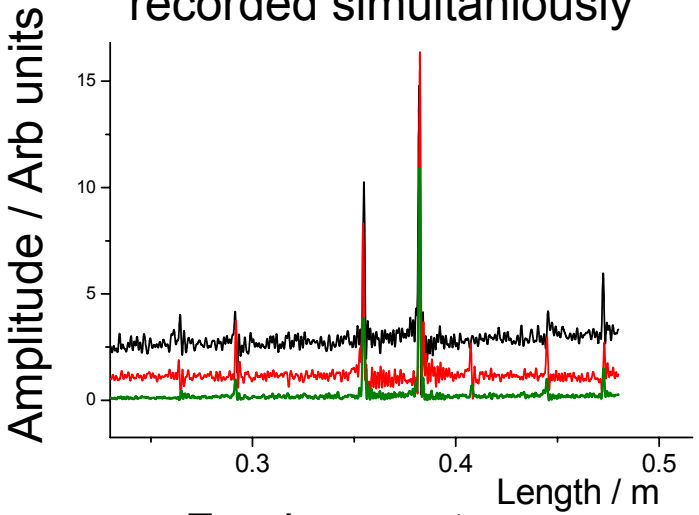


Status of Distance Meter Development

- Double peak found in two different prototypes.
- Ruled out possibility of analysis artefact.
- No obvious reflective surfaces
- Software in place now to analyse data within minutes after data taking should enable us to trace the problem



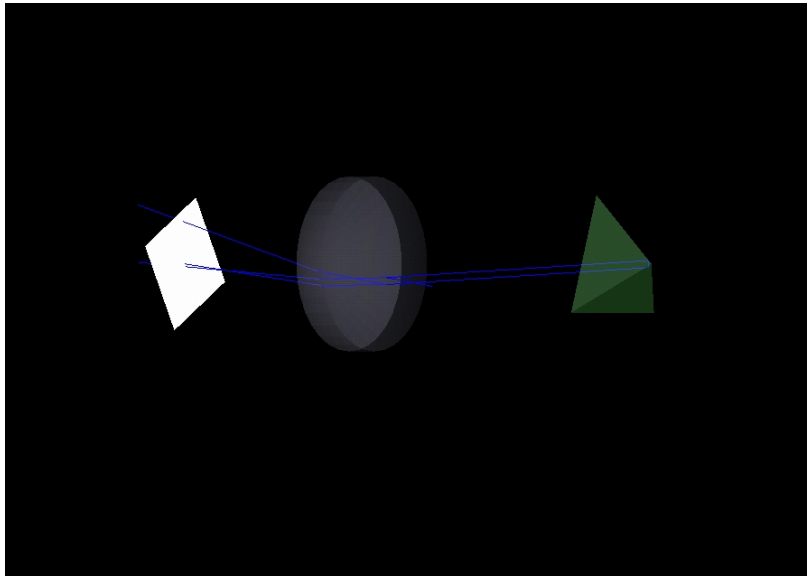
Raw data of 2 channels recorded simultaniously



Fourier spectrum

Distance meter simulation

- Simulation done with Zemax
- Use non-sequential mode
  - Take into account polarisation → correct interference pattern
  - Allows stray light analysis
- Allow analysis of chromatic aberrations



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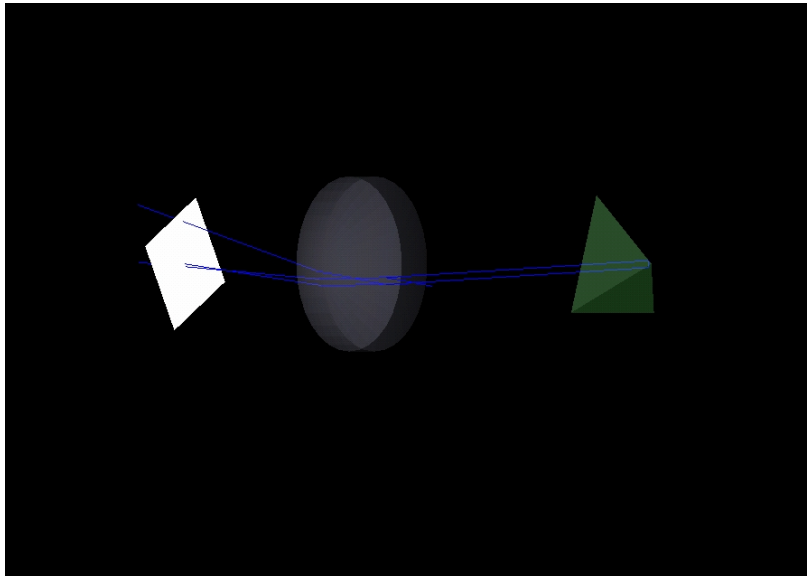
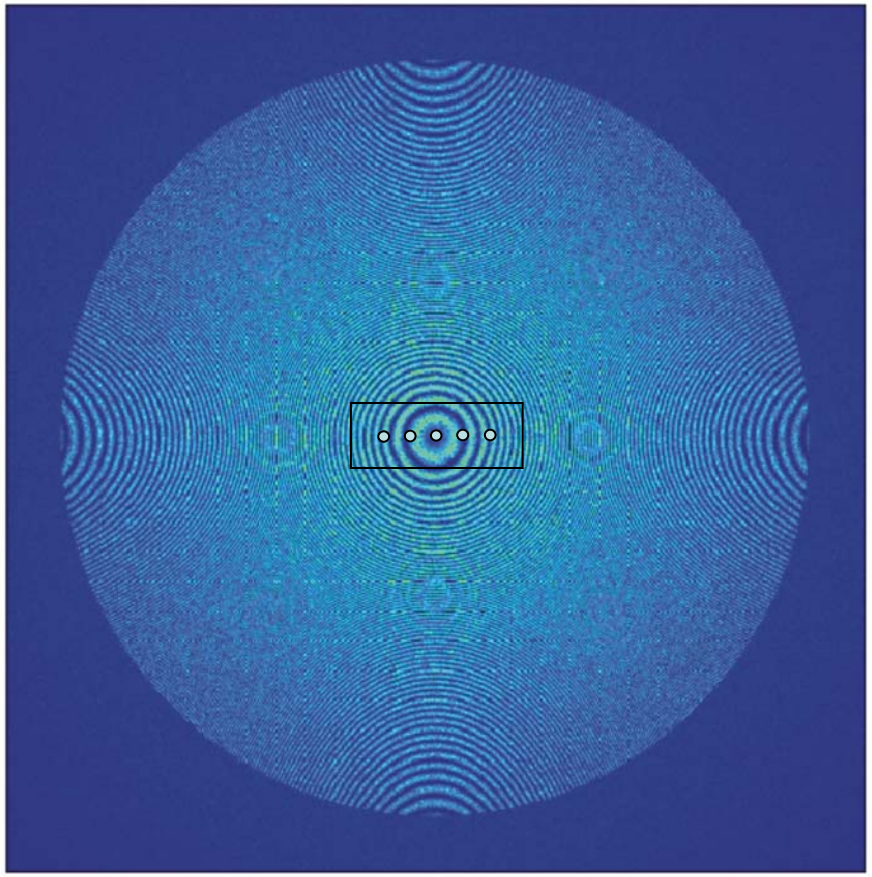
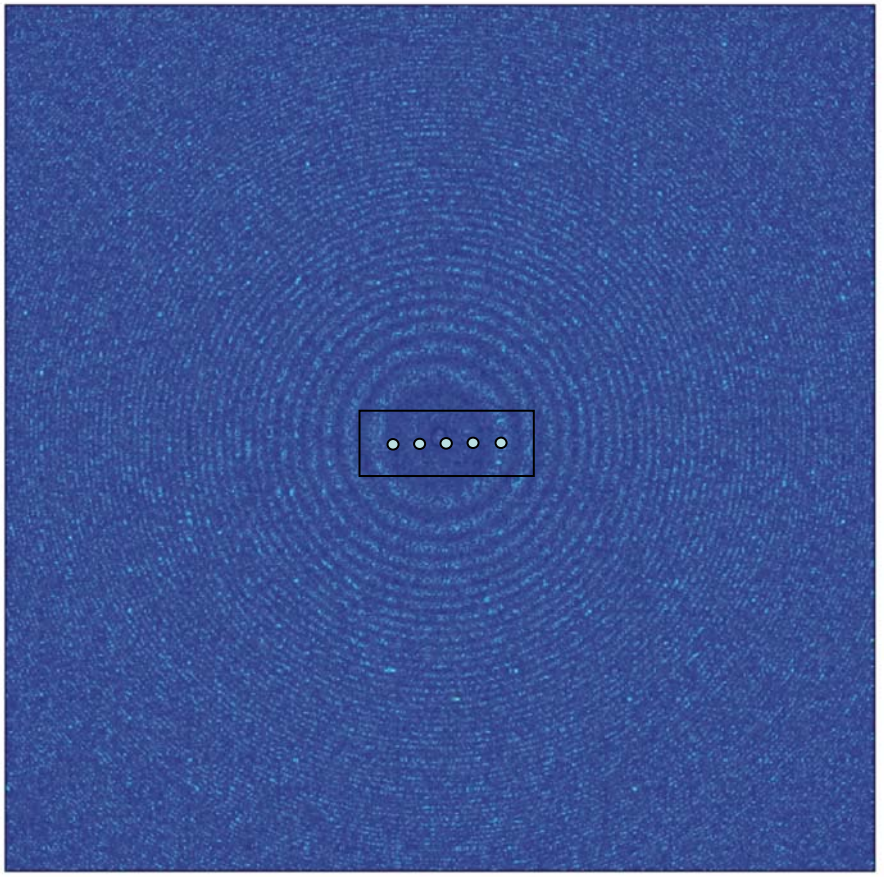
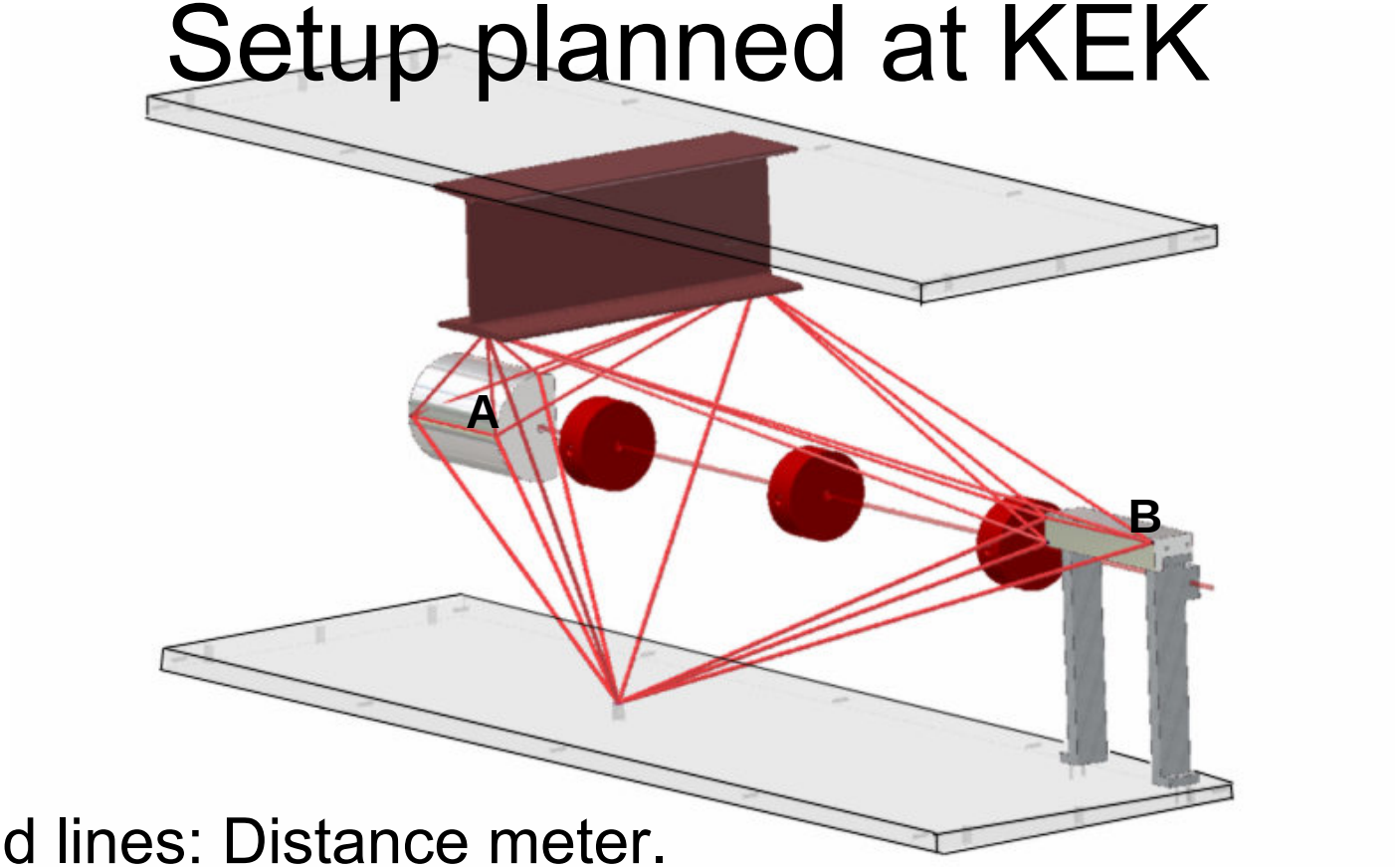


Simulated Interference Patters



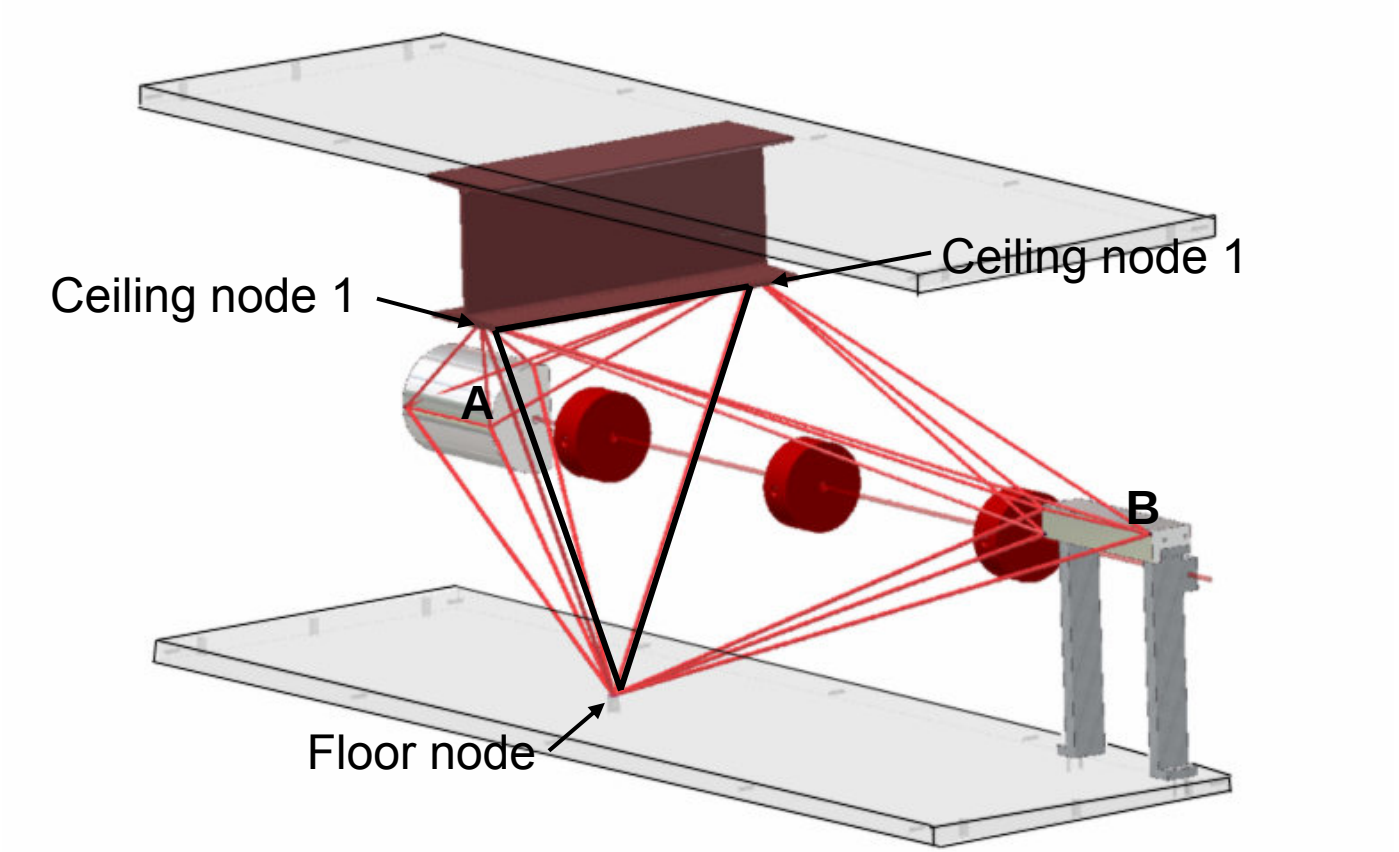


A Straightness Monitor Made from Distance Meters
Setup planned at KEK



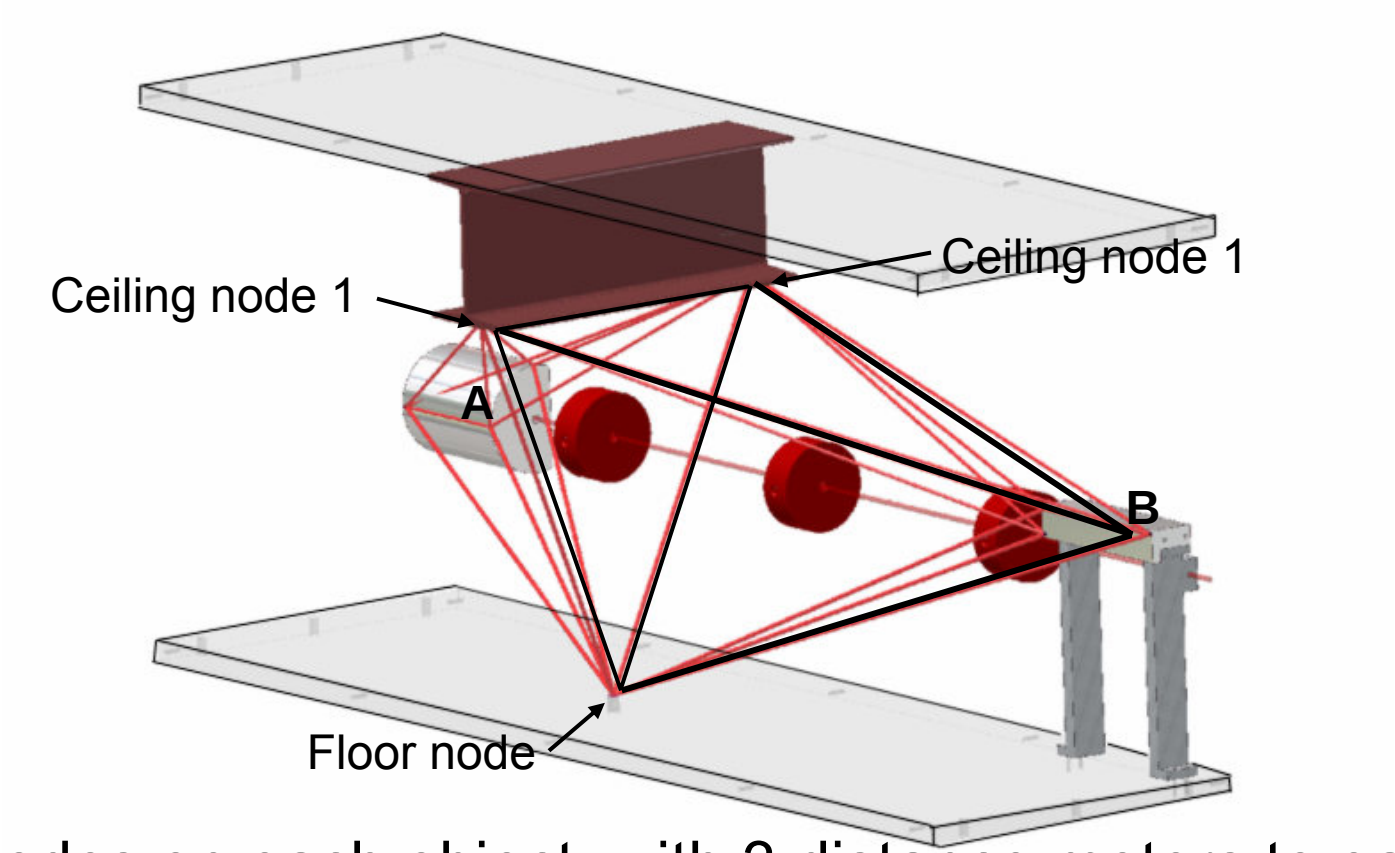
- Red lines: Distance meter.
- Multilateration measure 6D coord. of A with respect to B.

A Straightness Monitor Made from Distance Meters



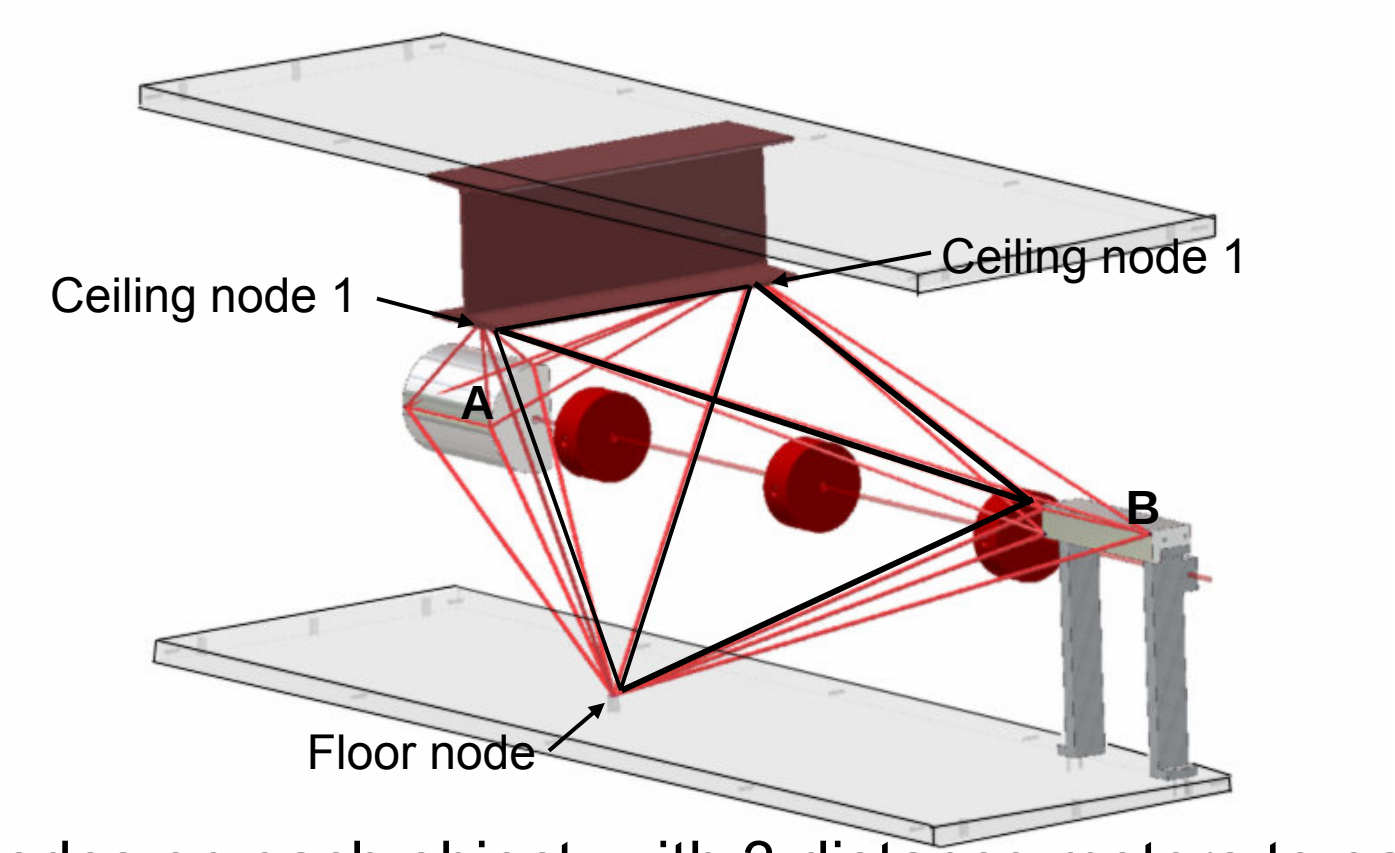
- Information related via central triangle

A Straightness Monitor Made from Distance Meters



- 3 nodes on each object, with 3 distance meters to each triangle node

A Straightness Monitor Made from Distance Meters



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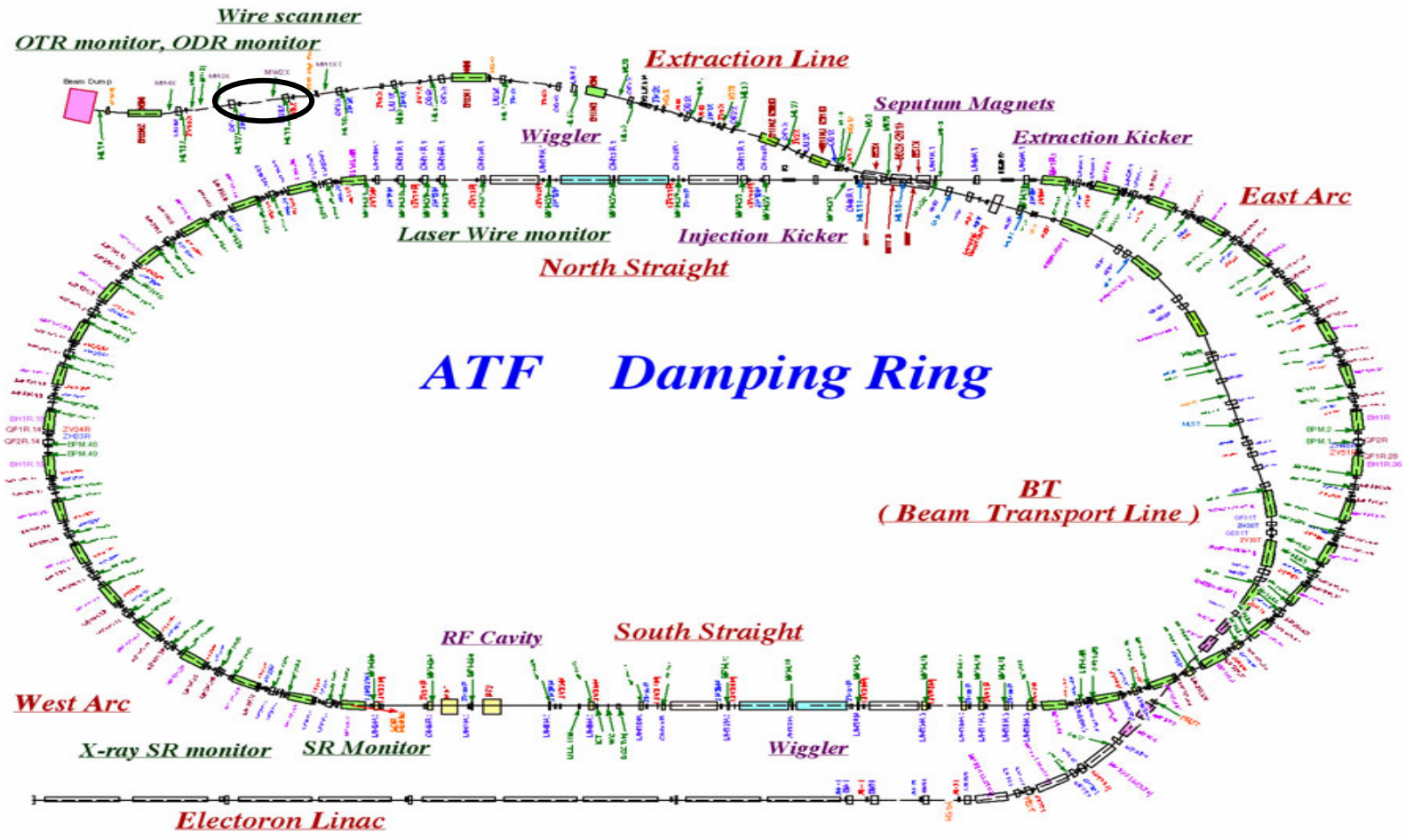
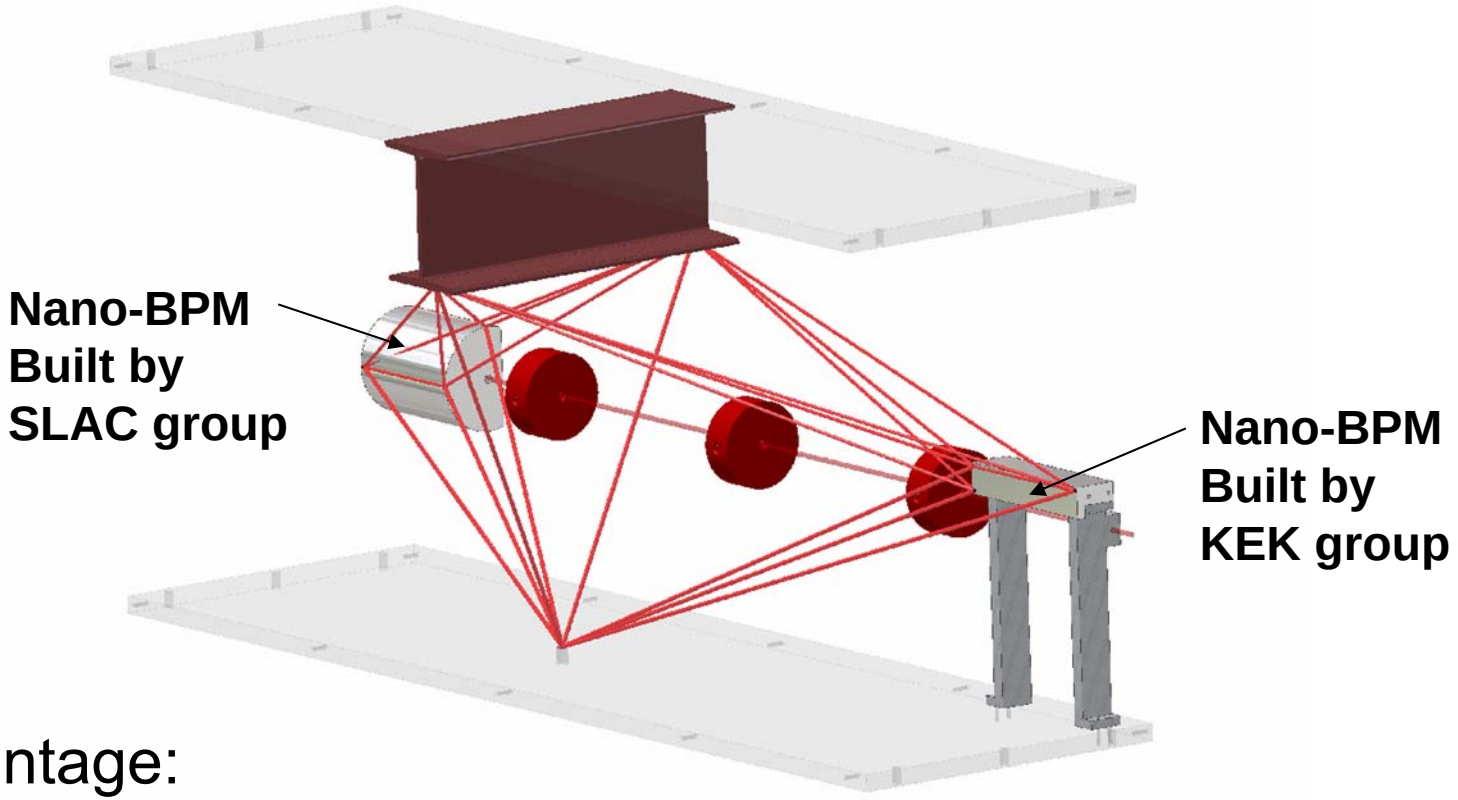
ATF at KEK

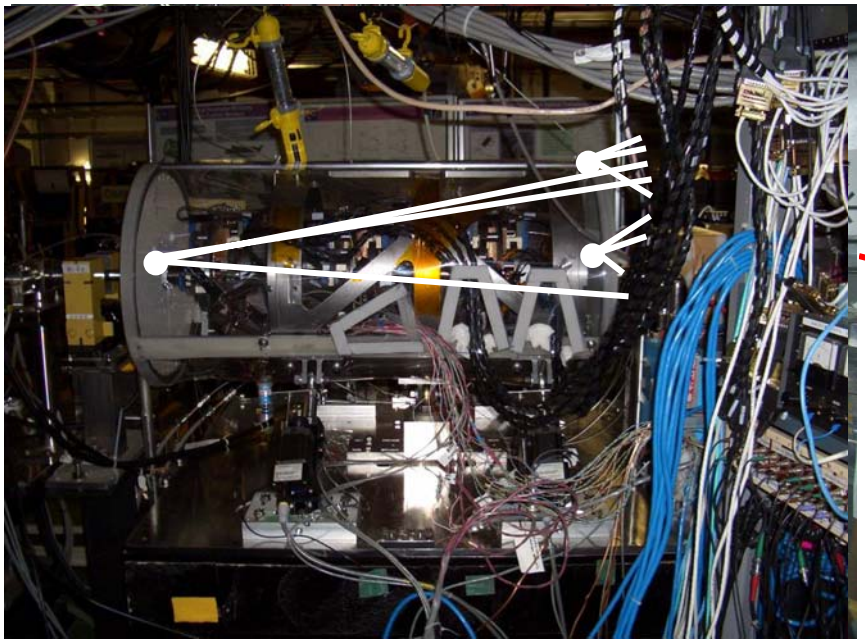

Wire scanner
OTR monitor, ODR monitor
Extraction Line
Seputum Magnets
Wiggler
Extraction Kicker
East Arc
Laser Wire monitor
Injection Kicker
North Straight
ATF Damping Ring
BT
(Beam Transport Line)
RF Cavity
South Straight
West Arc
X-ray SR monitor
SR Monitor
Wiggler
Electoron Linac

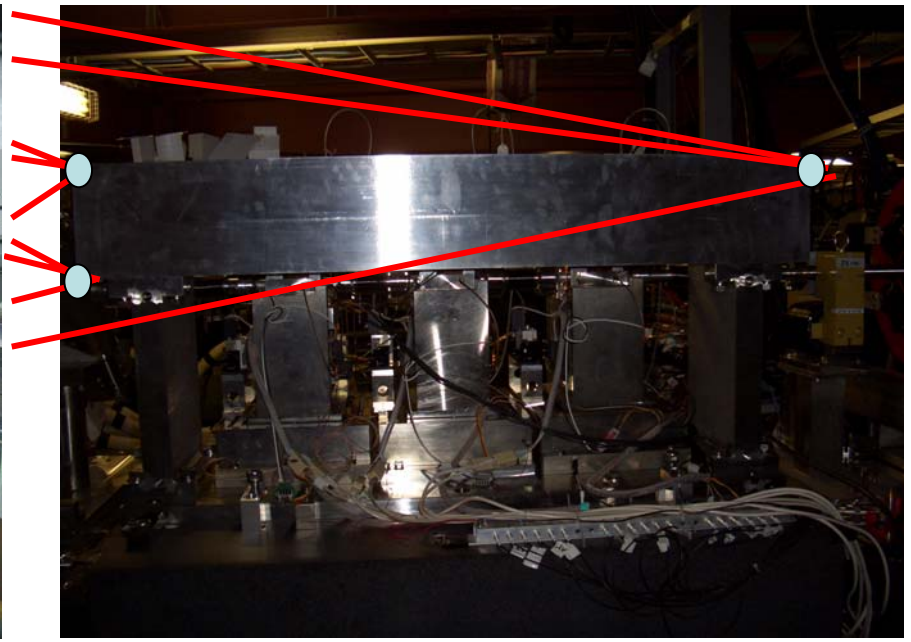
Implement system at ATF/KEK relating positions of nano-BPM's



- Advantage:
  - Nano-BPM have 5-100 nm resolution: cross check of results
  - Test of distance meter in accelerator environment

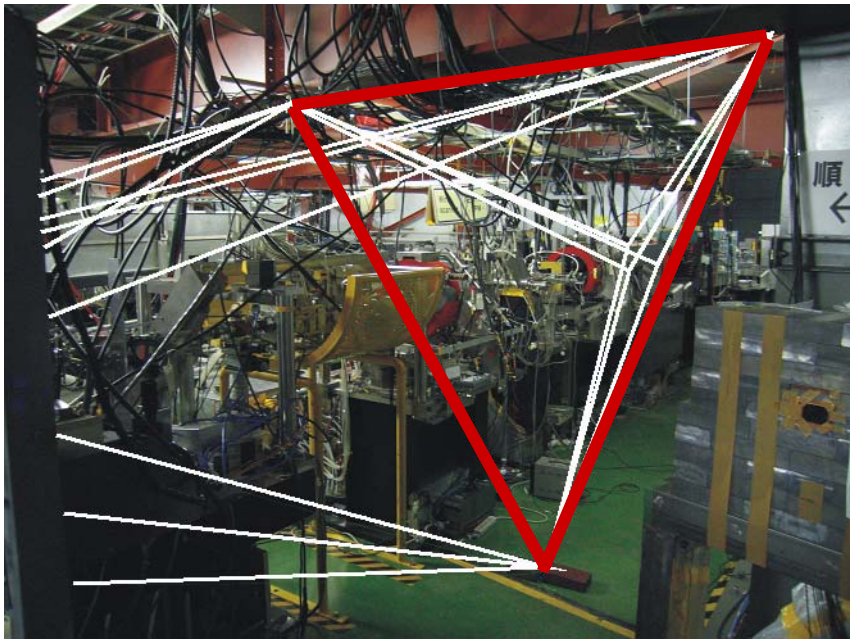
Spider web Design with Opto-Geometrical Simulation: Simulgeo





Spider web Design with Opto-Geometrical Simulation: Simulgeo

- Allows objects to be placed (6D) in hierarchal structure
  - Reference placements.
  - Fixed placements (with error).
  - Variable placements (the objects to measure).
- Objects can be points, mirrors, distance meters…
  - Distance meter assume measurement between points with error.
- Big matrix inversion takes into account all errors and constrains 6D position of all points.



Spider web Design with Opto-Geometrical Simulation: Simulgeo

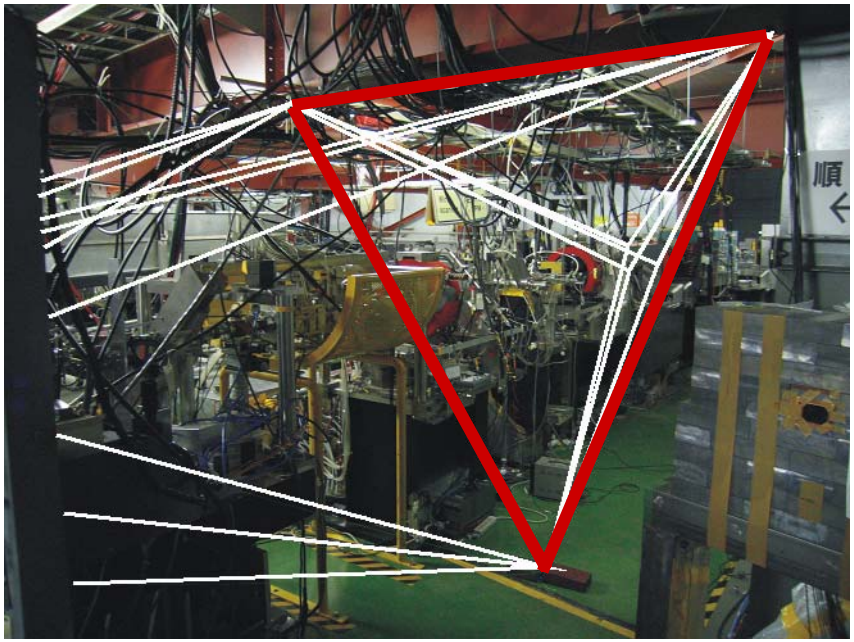
- Resolution of distancemeter: 1nm
- Mount precision of distancemeter: 1nm
- Angle precision of distancemeter holder: 10 μrad.

SLAC BPM: reference

KEK BPM variable (6D):

Position: x:32 y:19 z:2 nm

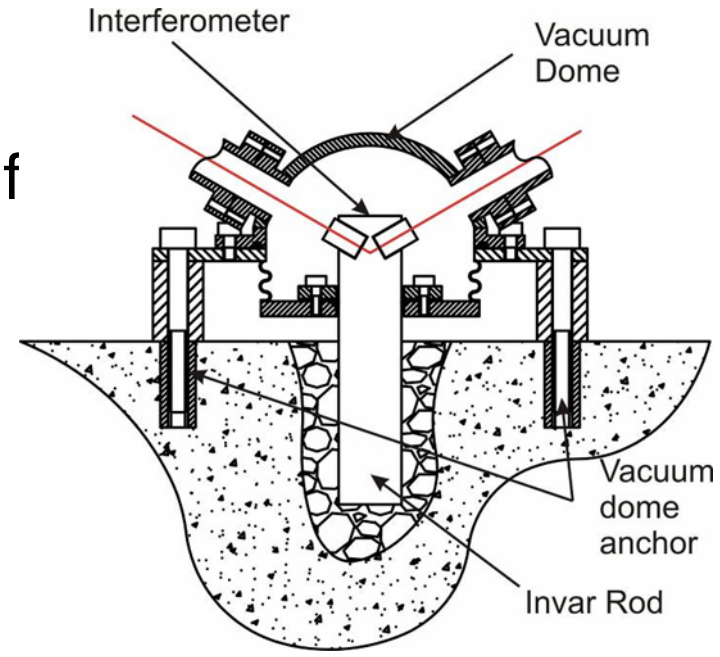
Angle: x:0.01 y:0.01 z:0.1 μrad



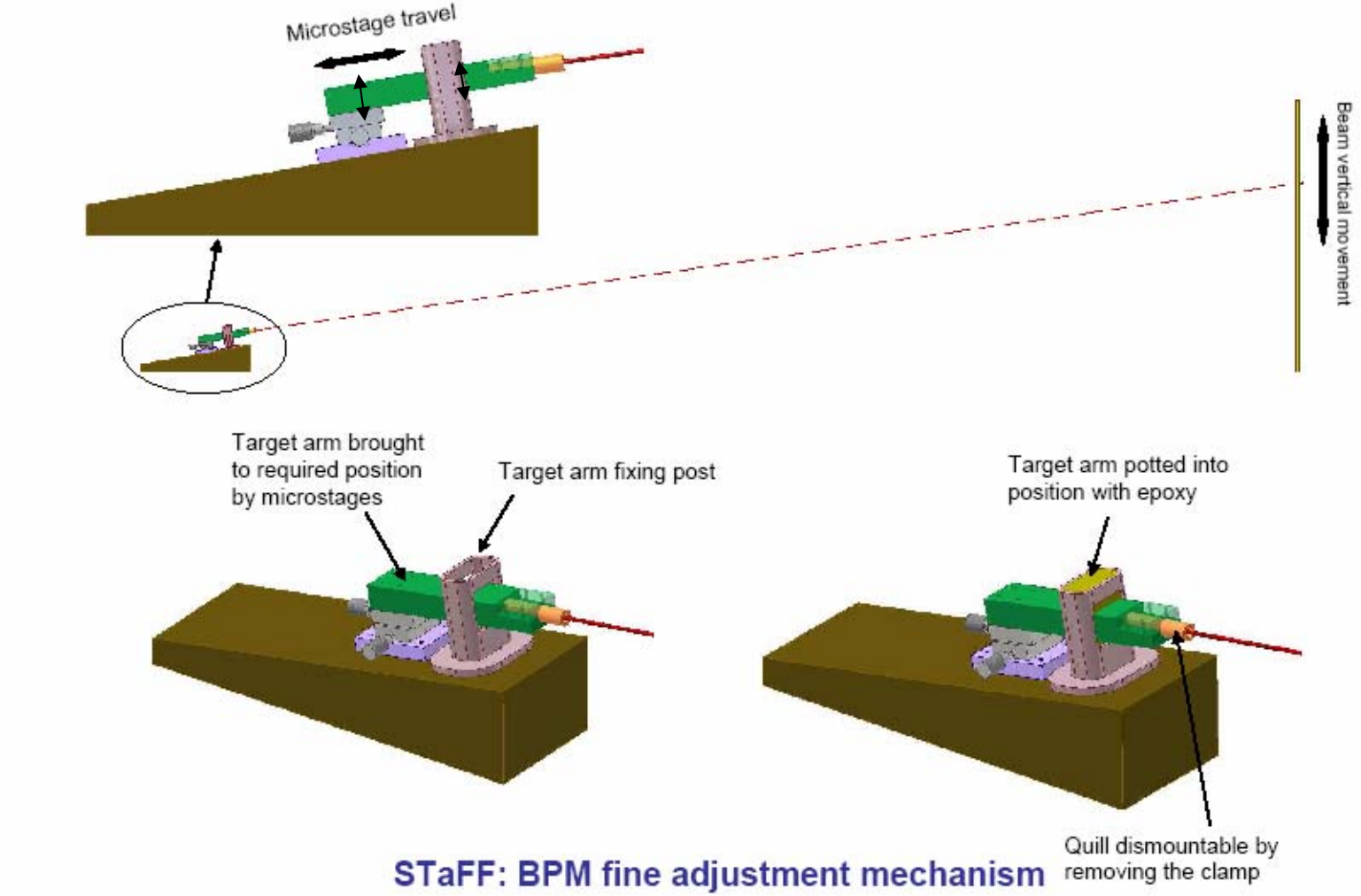
~1μm absolute distance resolution needed to determine constants required to solve geometry.

Triangle Nodes

- Distance meter heads located in triangle nodes.
- Floor node
  - Overall resolution improves if firmly anchored.
  - Dome anchored separately from interferometers.
- Ceiling nodes: position stability unimportant.



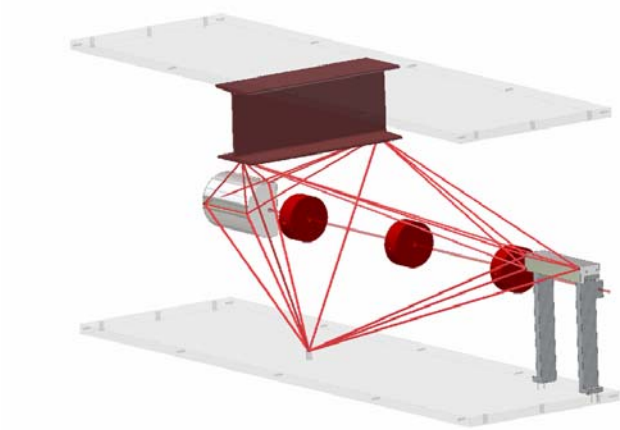
First Concept on how to Align Distance Meters in Network

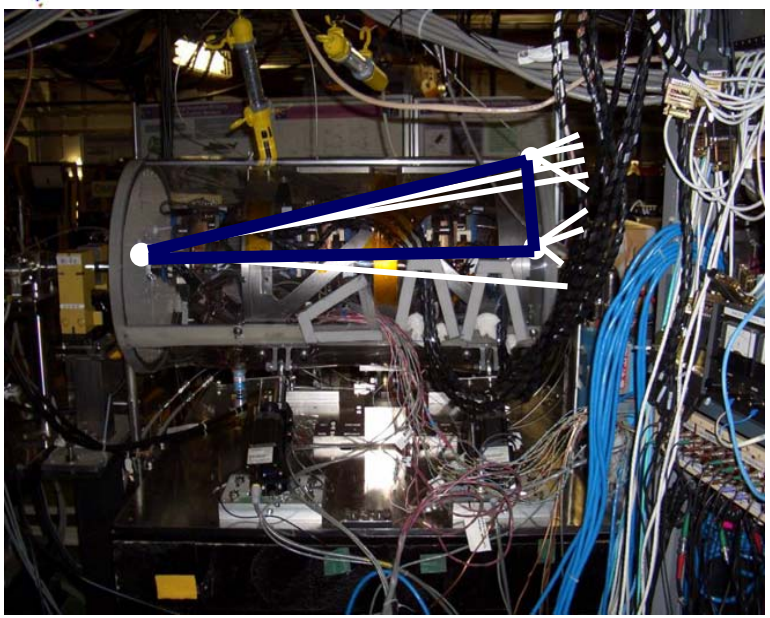


STaFF: BPM fine adjustment mechanism

BPM Nodes

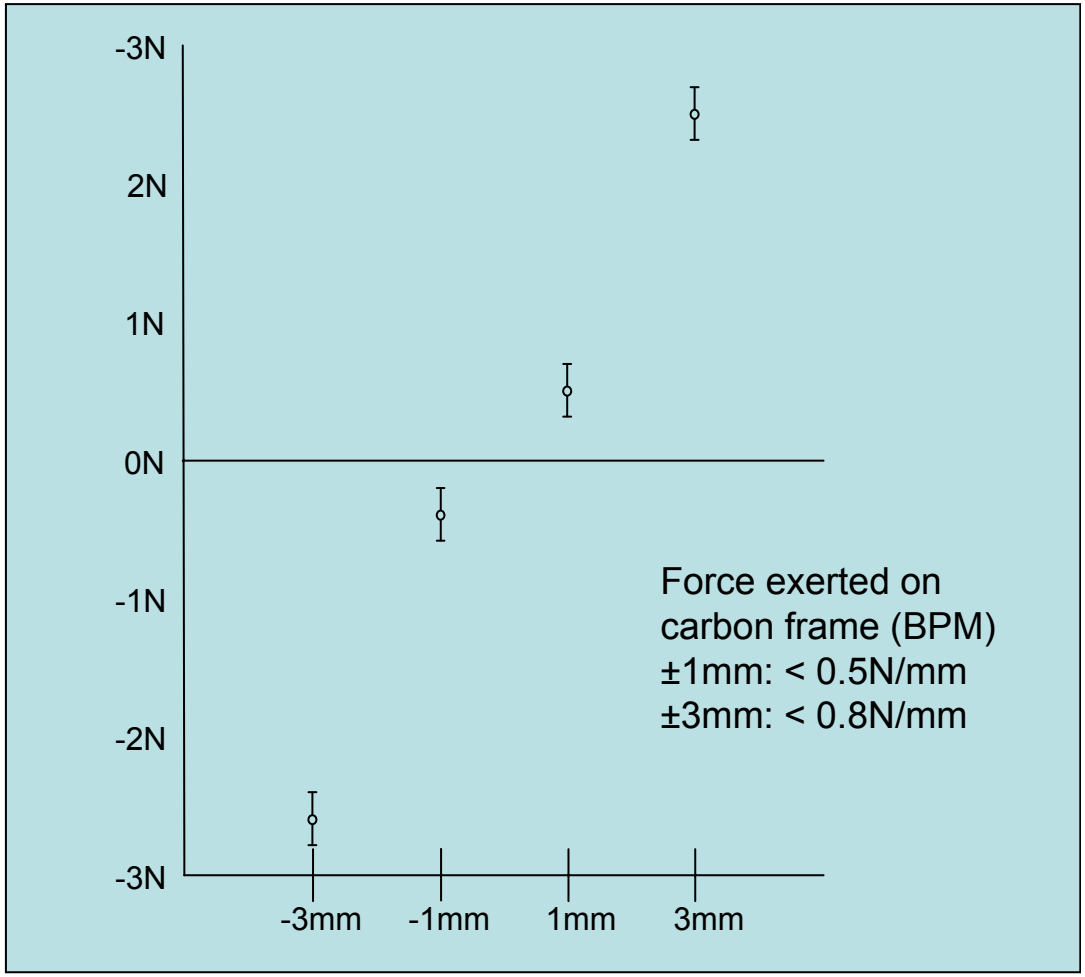
- One wide angle retro-reflector (cateye) for each node
- Challenges:
  - Relative position between retro-reflector needs to be known to 1nm
    - Requires measurement between 3 nodes on each nano-BPM.(blue lines).
  - Attachment of vacuum lines to BPM's
    - Requires zero-force design.





Force Free Mount

- Needs bellow to allow motion of BPM
  - Vacuum causes a force order of 100N!
- Develop small force vacuum mount using double bellow system.
- Allows small motion (~1 mm) of BPM-system
- Test stand to measure remaining (perpendicular) force on BPM frame.



Force exerted by perpendicular motion

Concluding Remarks

- Developing
  - Software to understand distance meter.
  - Hardware to characterize laser.
  - Temperature sensing system.
- First optical simulation in place.
- Force Free mount system seems to work.
- Starting work on Mount/Alignment system for distance meter setup at KEK
- Still much to do
  - but things start to fall into place