MONALISA

Laser based alignment and stability monitoring

09:40 – 10:00 (JST)
Wed 5 Mar 2008

The Oxford MONALISA Group

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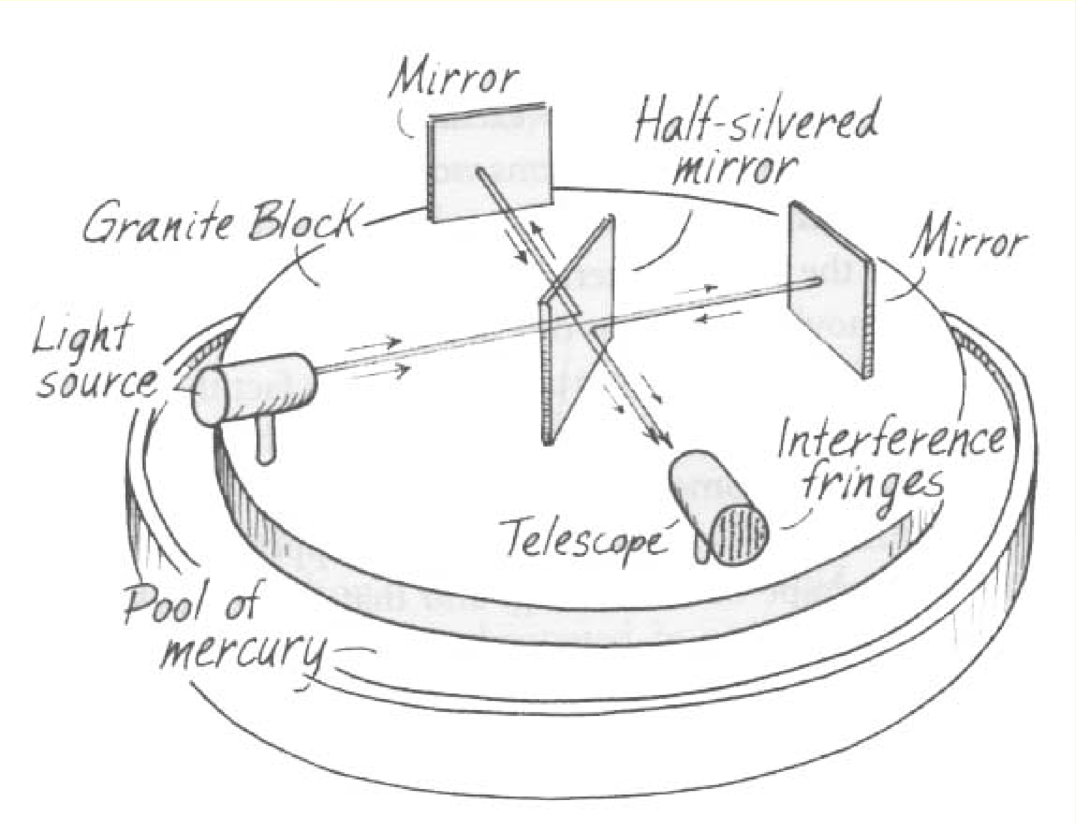
- Interferometer experience at Oxford
  - built up since mid 1990s
- Interferometer based alignment is "coming of age"
  - Key results imminent from 3 interferometer groups
  - IWAA 08 presentations http://www-conf.kek.jp/iwaa08/

Interferometers: Best of old & new

High precision in fundamental physics since 1887



- In 2008 we have
  - laser sources
  - fibre amplifiers
  - fibre coupling
- Enabling
  - radiation tolerance
  - cost effective
  - scaleable
  - rapid read out

Why 2008 is so exciting for us

- MONALISA enjoying fruitful collaboration in Oxford:
  - LiCAS
    - Prototype rapid survey system (tests in DESY)
  - ATLAS: SCT optical alignment
    - being completed at CERN

- The whole is greater than the sum of the parts

Beam based feedback

- Is essential for ILC, CLIC
- Requires an operational beam
  - prerequisite initial alignment
  - components move after survey

- Working alignment needs to be maintained / restored
  - between trains
    - 200 ms is long enough for several 100 nm movement
  - after push-pull events:
    - IR hall floor <u>will move</u> after rolling two heavy detectors
  - after shutdown periods

Component Alignment Challenge

- relative mechanical DoF between many neighbouring components
  - choose important rotations / displacements
- in-situ
  - hostile radiation environment
  - cramped spaces
- ILC, CLIC require large dynamic range
  - (sub) nm precision over range of metres
  - micron precision over many 10s of metres

MONALISA: Benefits 1

Monitoring fiducial locations on key components

- after interruption of beam
  - independently follows changes in alignment
- during commissioning / start up
  - improves understanding of machine behaviour
- before accelerator operation
  - speeds up initial convergence of machine

MONALISA: Benefits 2

Return detector / QDzero position after push-pull

- expect to get micron repeatability
  - for return of magnet positions
- get machine within beam based capture range
  - improves switchover time
- more reliable accelerator operation
  - lower chance of damage
  - luminosity can only win

MONALISA : Requirements

- The ideal for any survey/monitor system
  - measure distances along clear lines of sight
  - use evacuated narrow tubes
- MDI issues for detector LoI
  - issues broadly as discussed here at SENDAI in Tuesday MDI session
  - e.g. push pull vacuum connections

Personal comments to add to Sendai meeting MDI discussion

- QD zero in tunnel scenario very exciting
  - MONALISA (as other systems)
    - much simpler / cheaper
    - much easier to achieve target performance
  - Personal plea to consider it favourably
  - IMHO:
    - Achievable luminosity probably greater with simpler ILC

MONALISA illustration

- Returning to buried QDzero scenario

- following sequence shows an ILC study

  – simulated example geometry

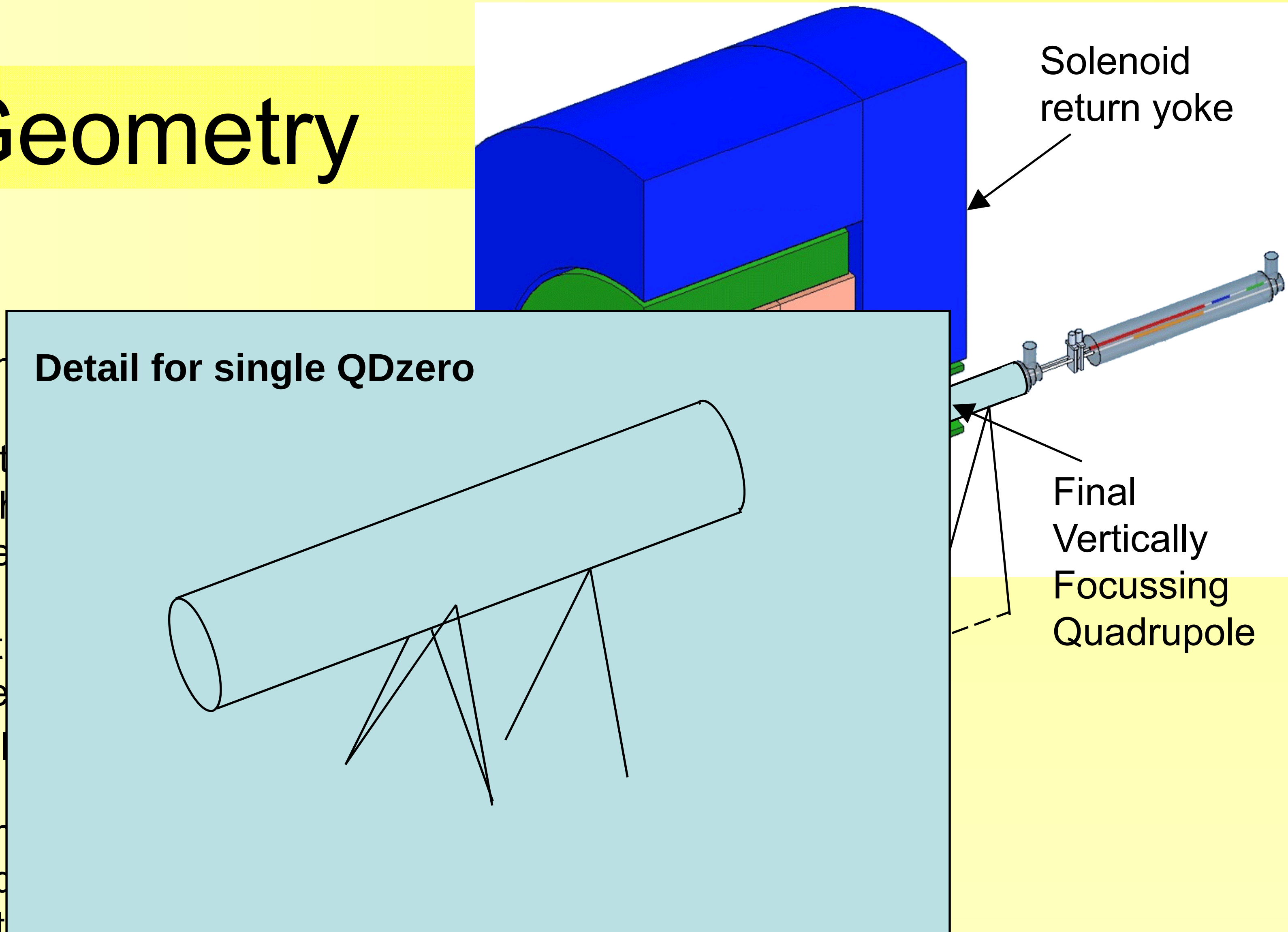
  – compact straightness monitor (CSM)
    - concept arises from necessity

Geometry

Measure m
QD0s with
some point
outwards th
detector fie

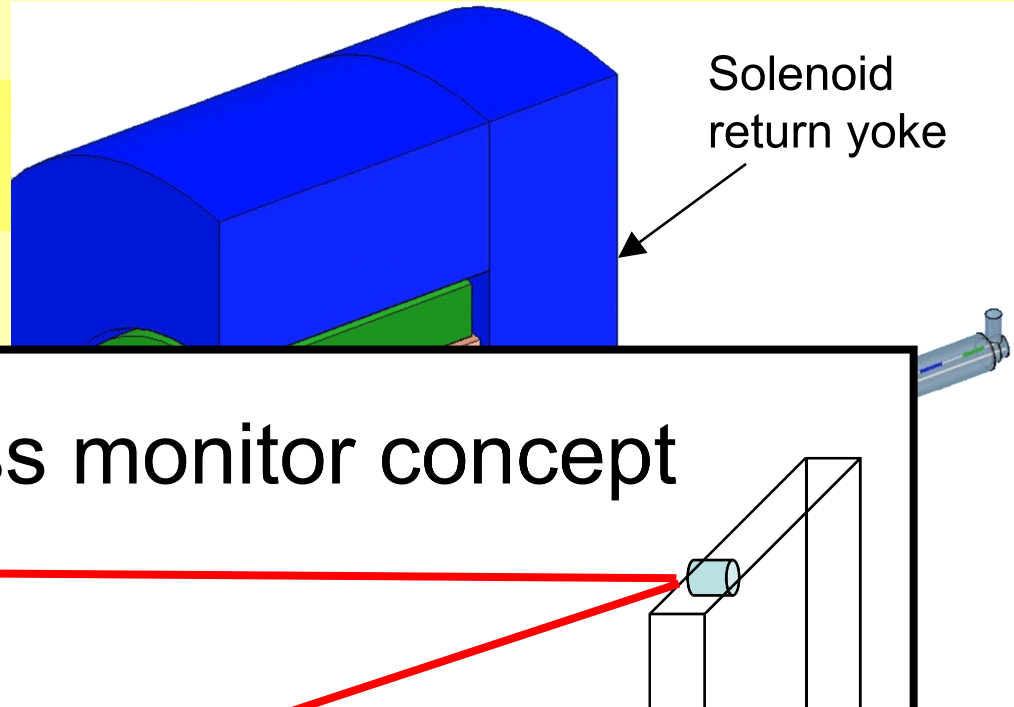
Then must
the relative
these end p

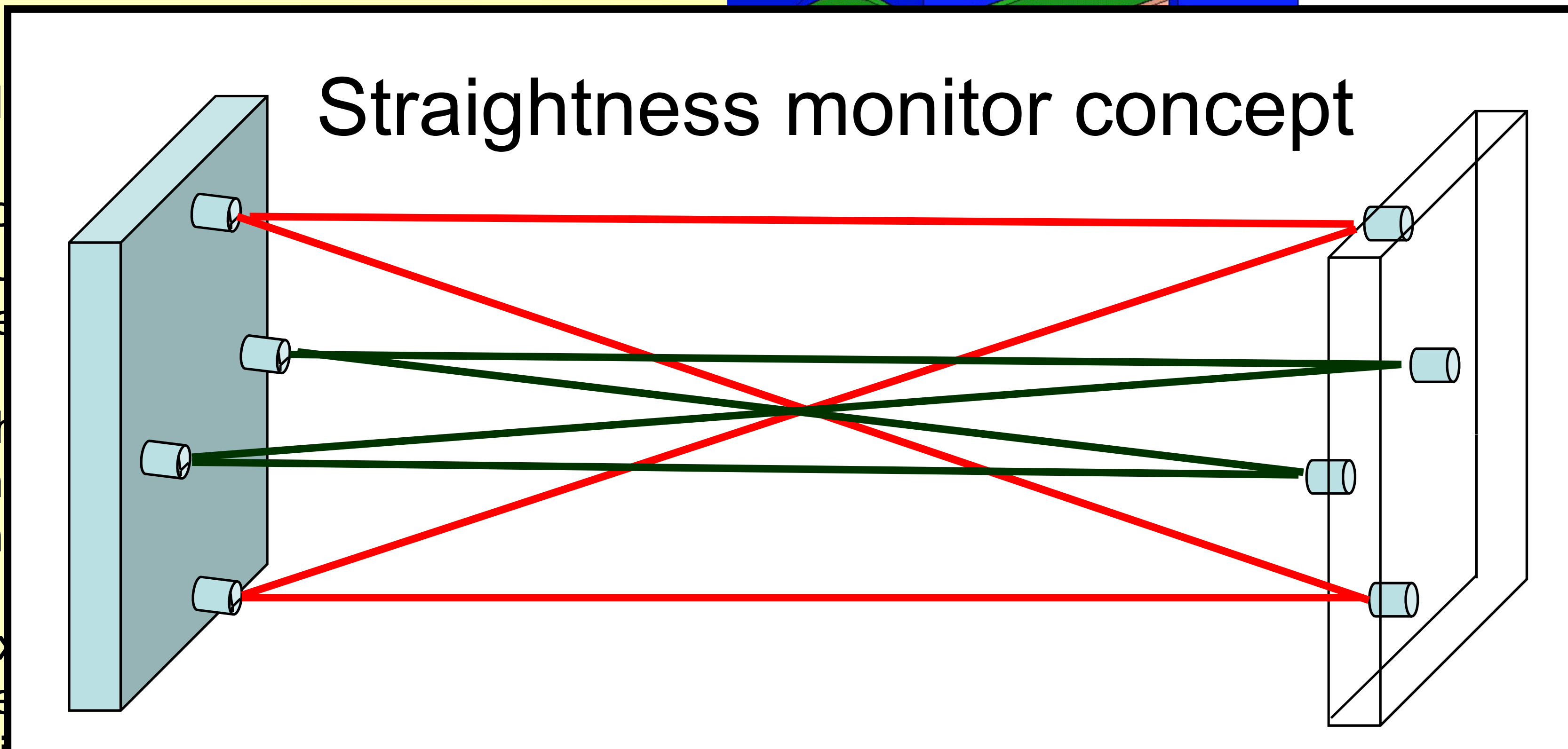
Exact geon
determined
with detector design



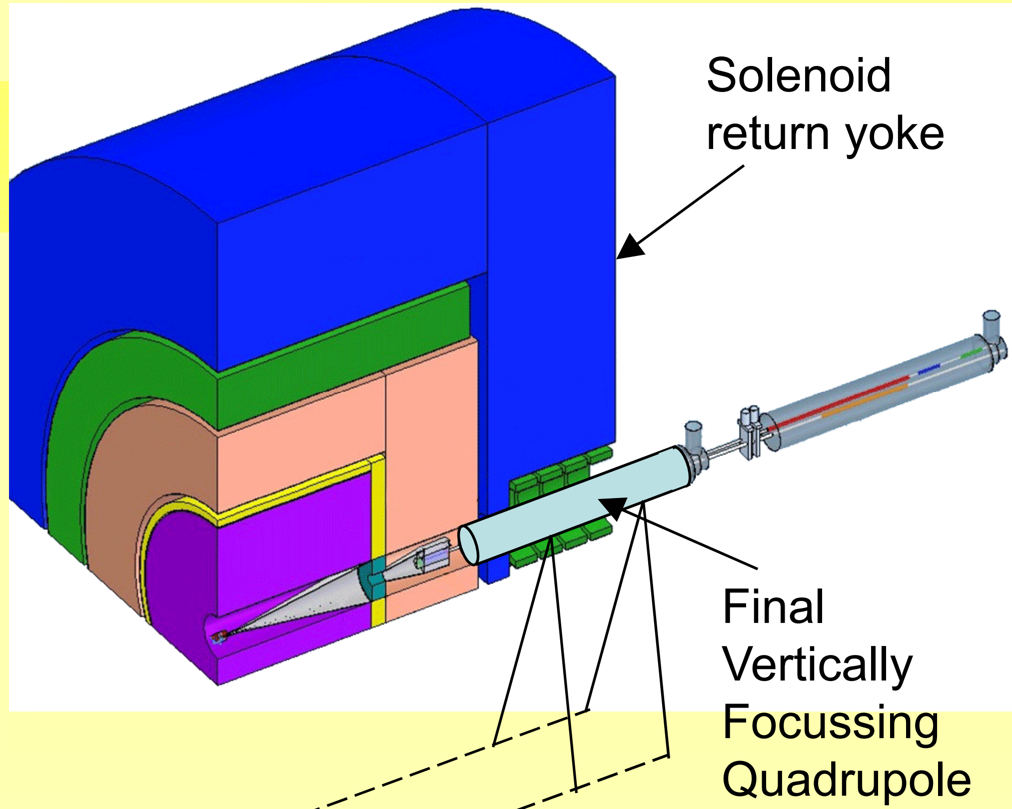
– – – – – – Straightness Monitor

Geometry

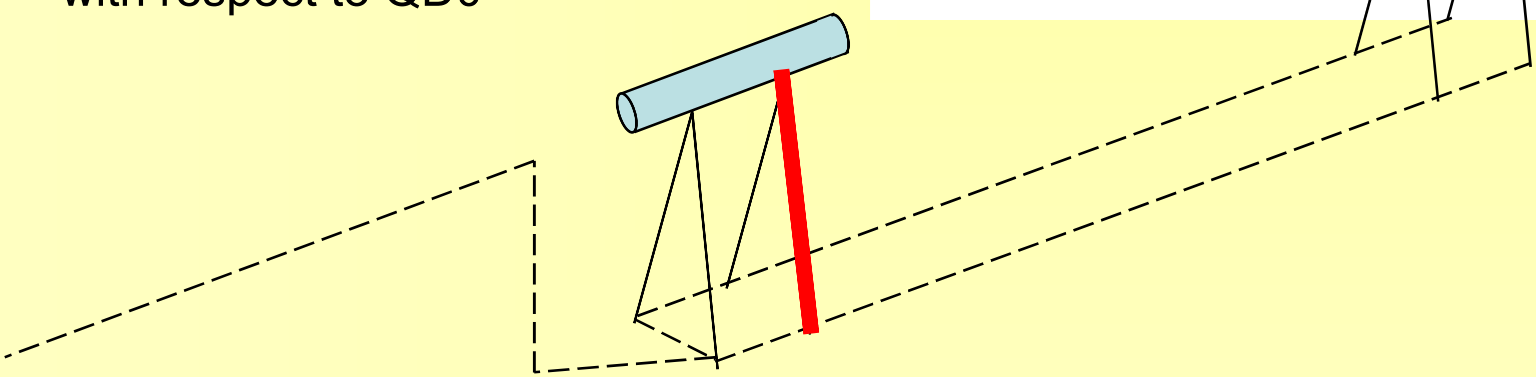




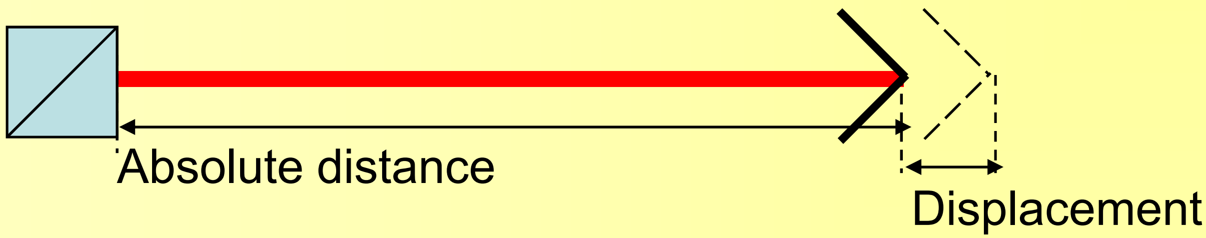
Geometry



Extension into tunnels possible. Allows monitoring of other magnets positions with respect to QD0



Measurement lines

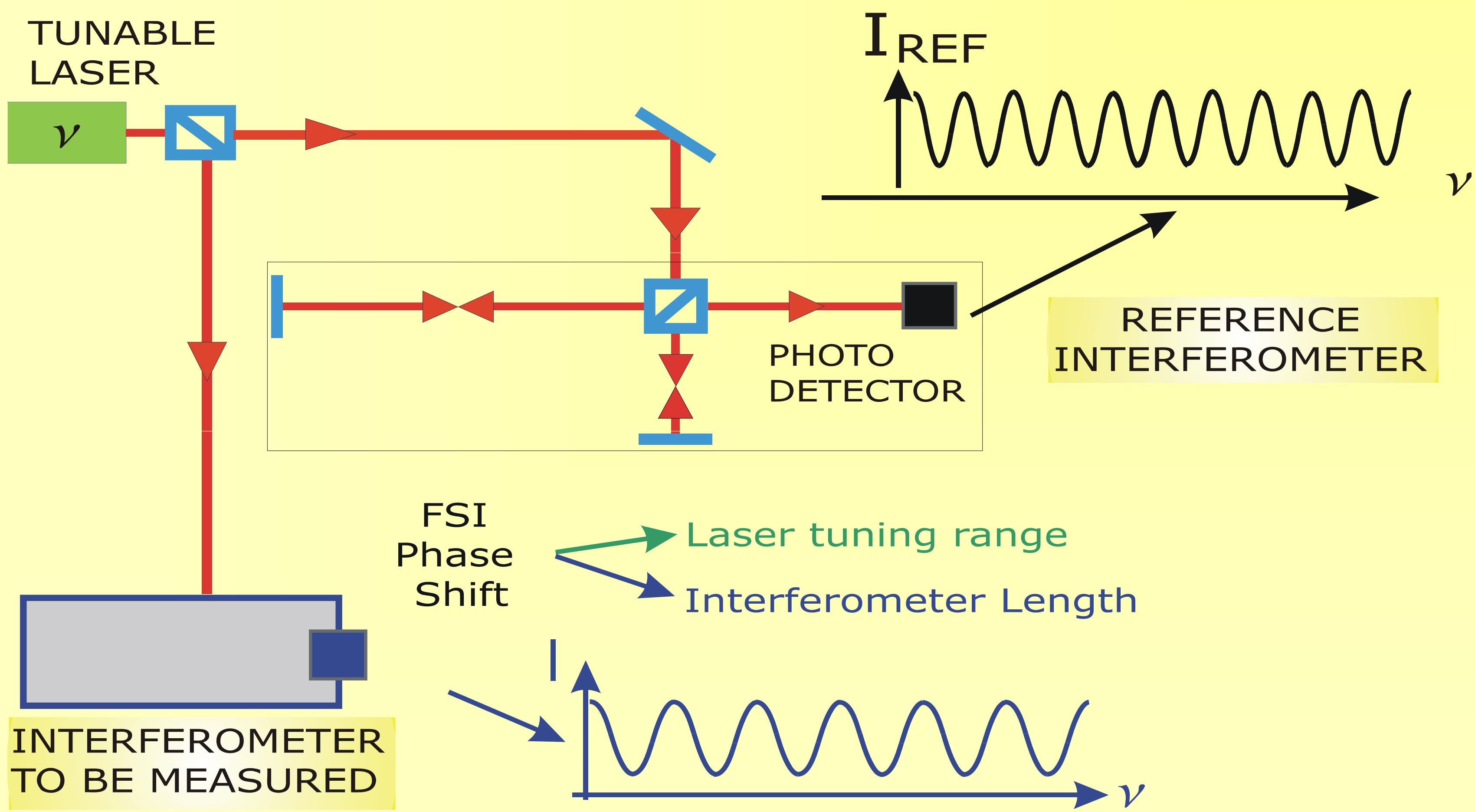


We measure distances along measurement lines using two techniques:

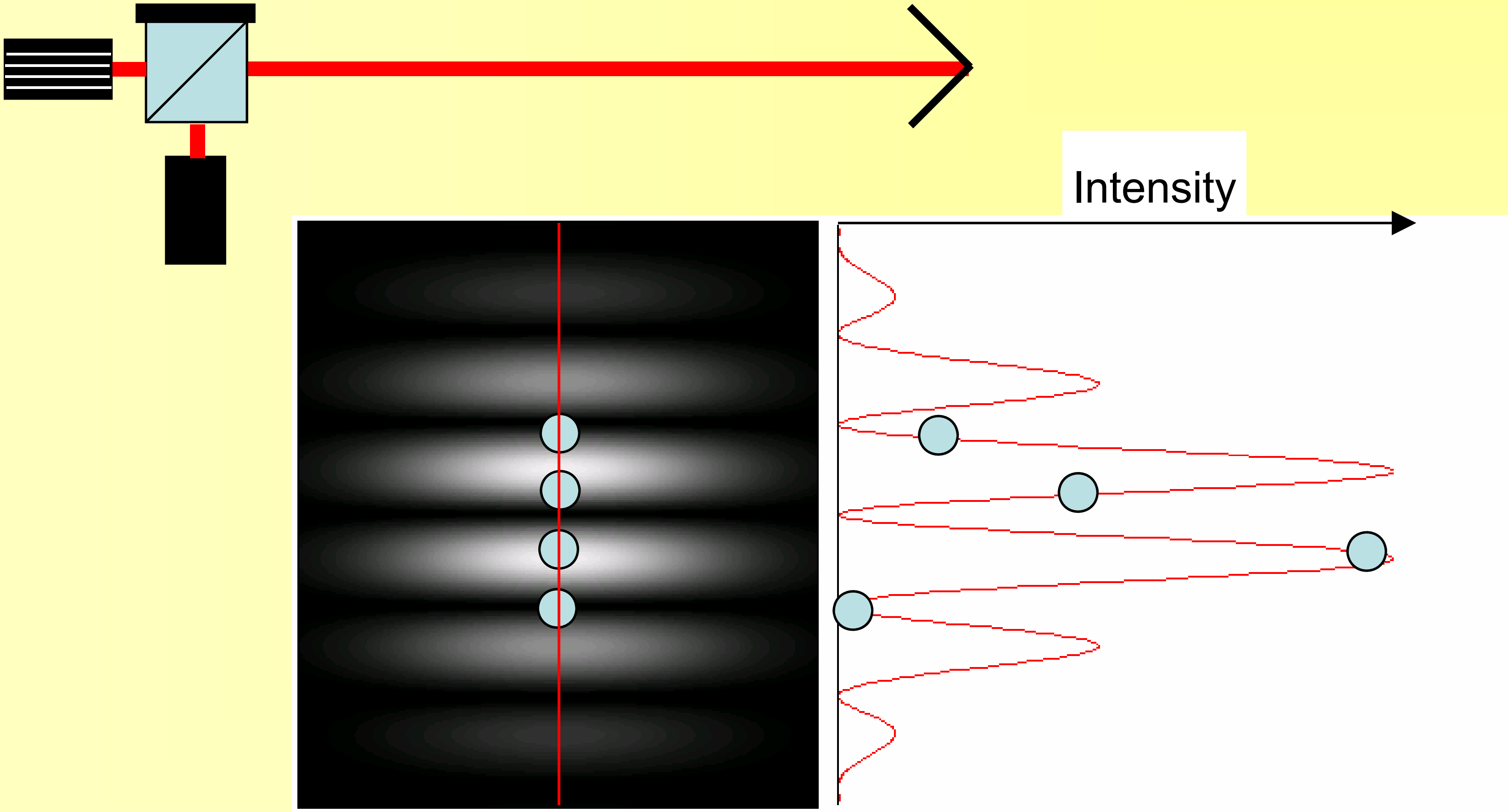
- Absolute distance interferometry
- Displacement interferometry

Each line is the same, and is capable of performing both types of measurement.

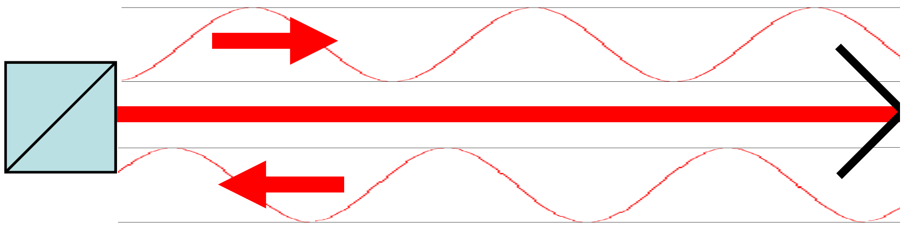
FSI: Frequency scanning Interferometry



Interferometer operation



Interferometer operation



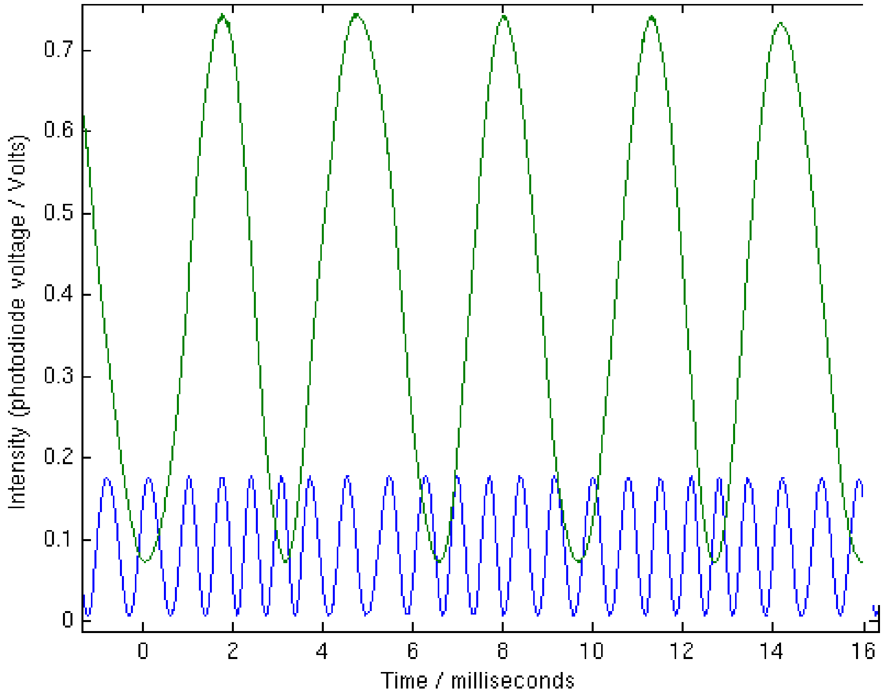
Phase = 2π (Optical Path Distance) / Wavelength

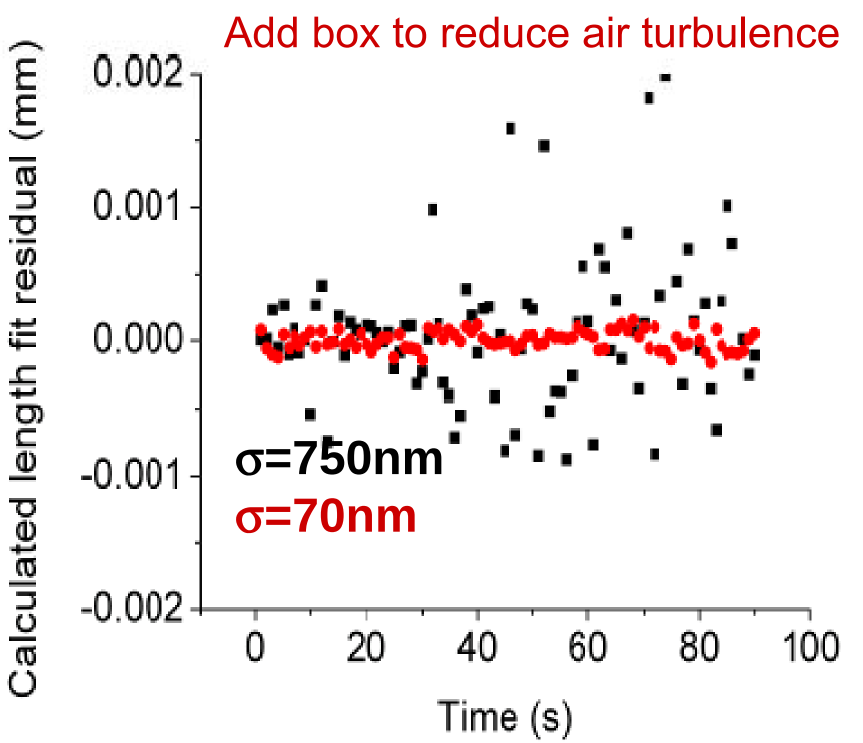
$$\Phi = 2\pi D / \lambda$$
$$= 2\pi D (v / c)$$

Fixed Frequency Interferometry	Frequency Scanning Interferometry
$\Delta D = (c/2\pi v)\, \Delta\Phi$	$D = (c/ 2\pi)\,(\Delta\Phi/\Delta nu)$, $R = (c/ 2\pi)\,(\Delta\theta/\Delta nu)$ → $D = R\,(\Delta\Phi/\Delta\theta)$

FSI: recent results in air

MHz raw signal

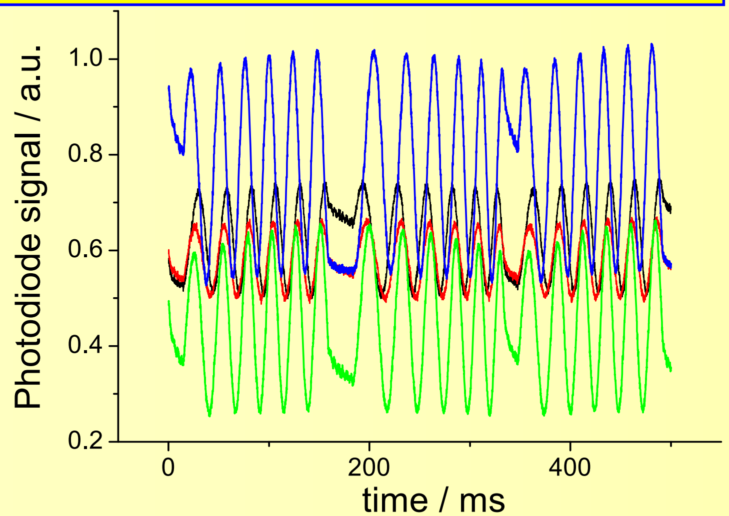




Distance RMS < 1μm

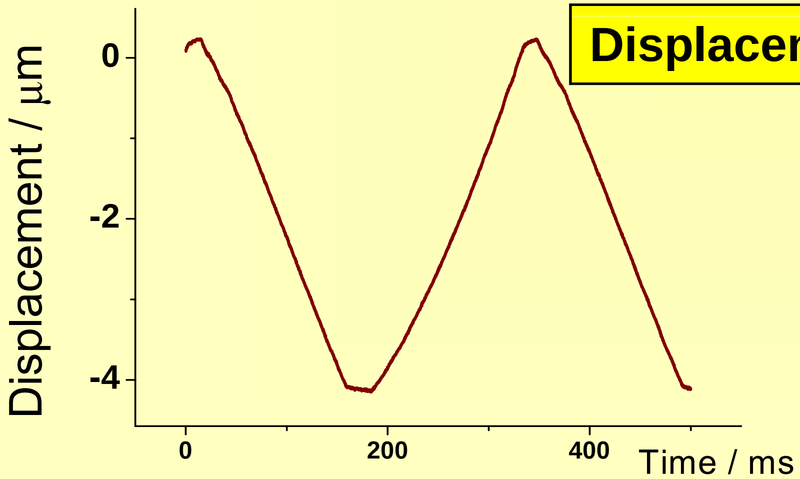
FFI: recent results in air

Following displacements

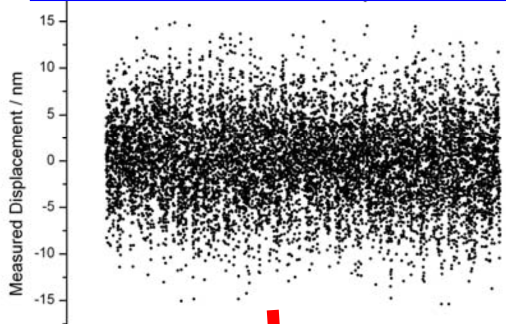


Four fibres' raw signal

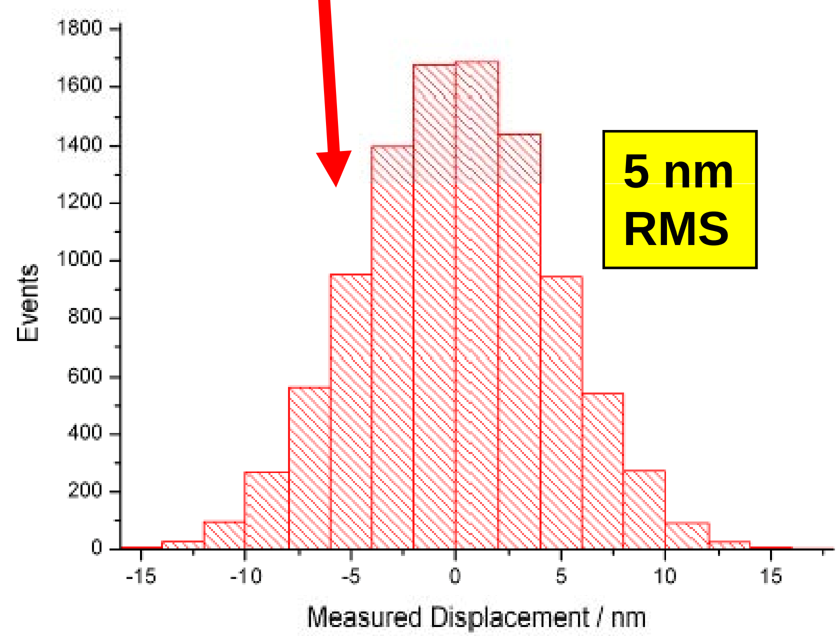
Displacement



Static resolution estimate



MHz raw signal



5 nm RMS

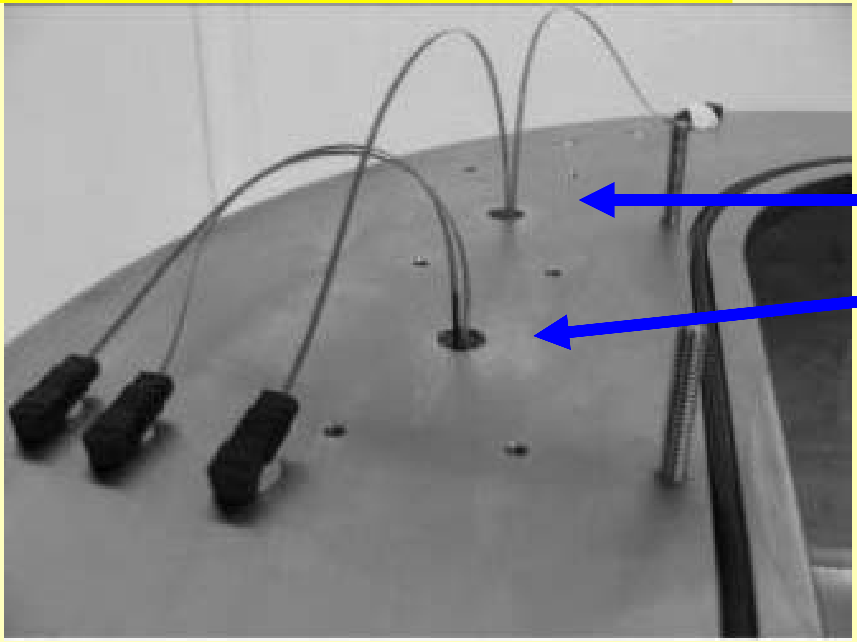
Up coming work at Oxford

- Have vacuum vessel ready for testing interferometers down to below 1 mbar

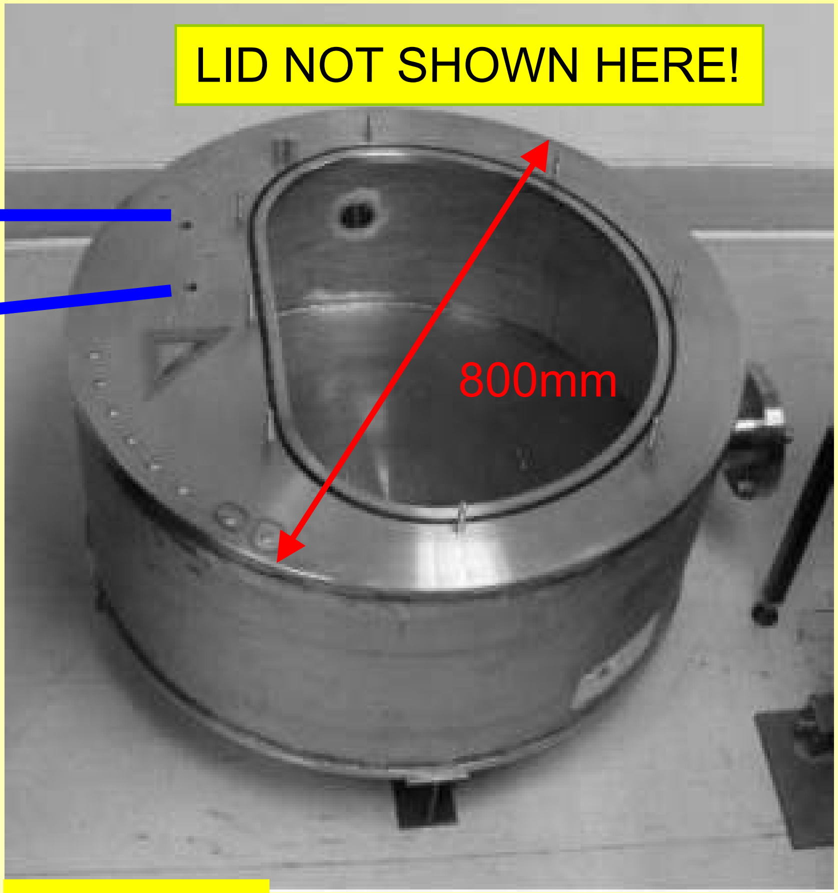
- Frequency stabilised ultra-narrow linewidth laser will improve reliability of FFI displacement measurements

Vacuum Vessel (0.1-1mbar)

Equipped with 4 x 8 way fibre



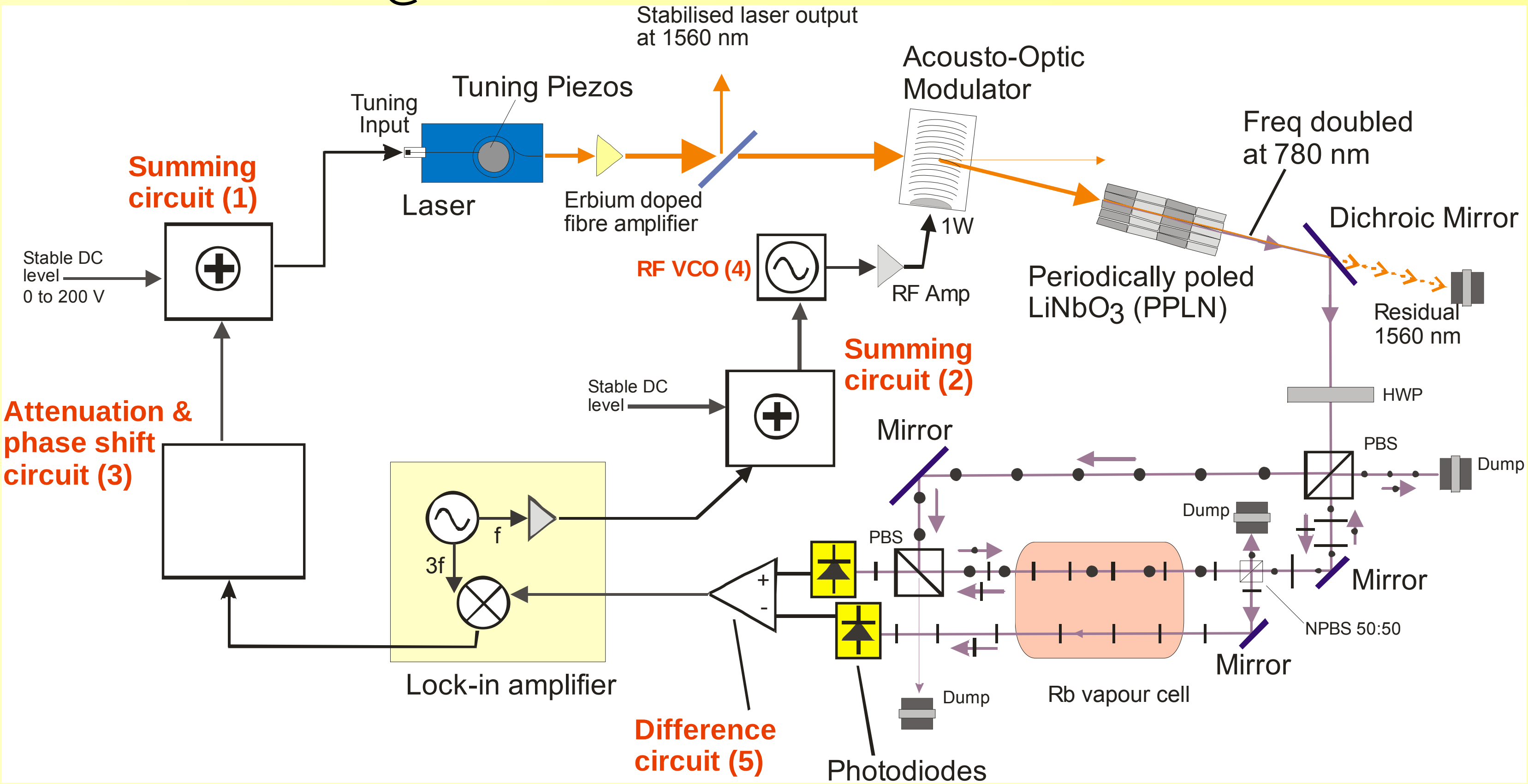
AFTER



BEFORE

Rb-87 frequency reference (FFI)

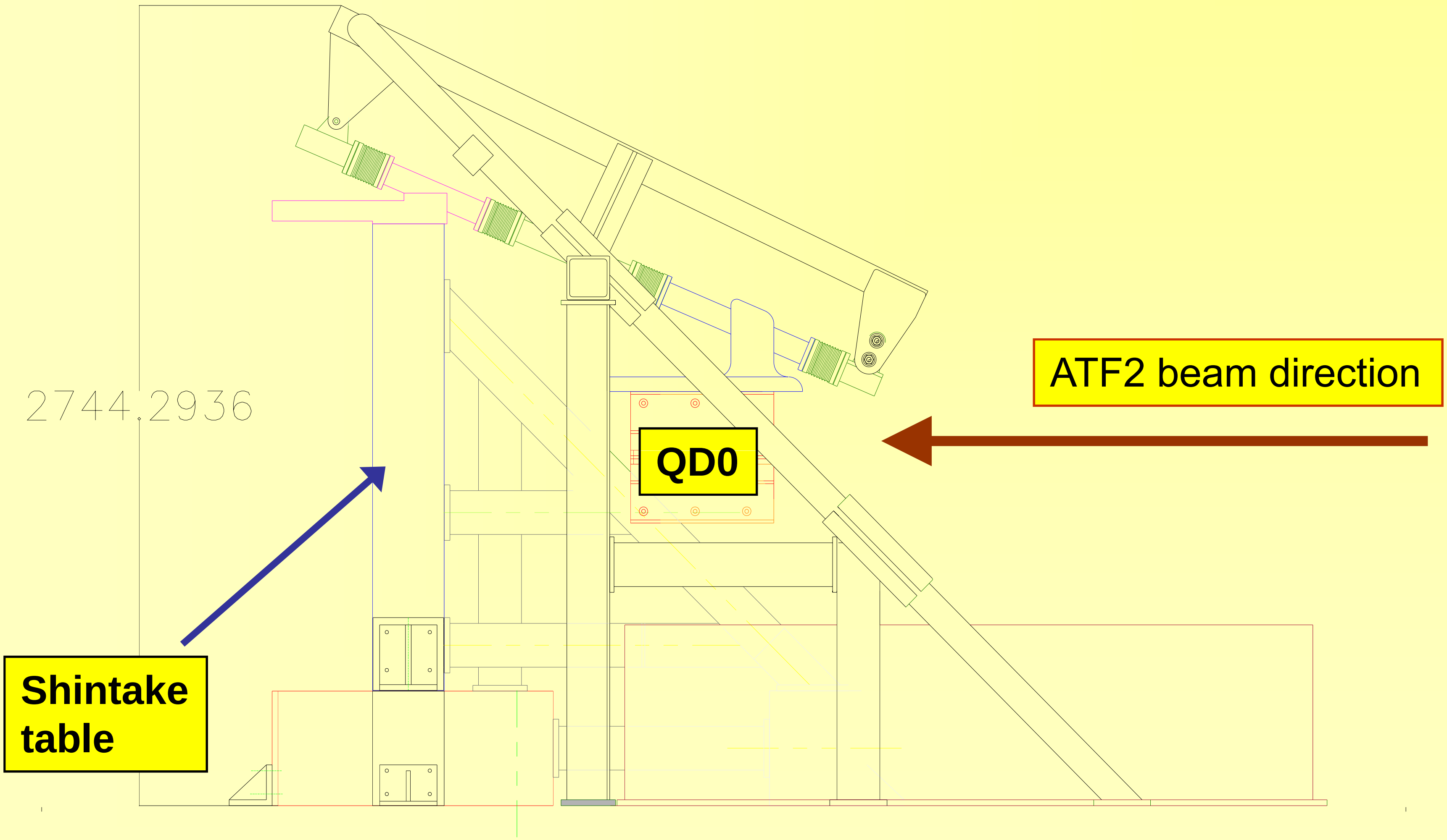
- **Target ~3 khz linewidth**
- **Need 19 kHz for 1nm @ 10m**



Almost all equipment has been ordered or purchased : setting up from March on

ATF2 extraction line: 08 Feb 2008

ATF2: Monitor relative vertical motion



Summary

- MONALISA will be a boon to ILC
  - QDzero nanometre vertical alignment
  - Repositioning after push-pull to microns
- Needs to be included in MDI engineering and detector layout
  - push to get MONALISA concepts into detector
  - greatly encouraged by creative thinking at TILC08
- Performance demonstrations on going
  - Oxford: Vacuum and frequency reference systems
  - ATF2: Final focus monitoring system to be installed