MONALISA
LiCAS

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Uppsala 28 Aug. 2008

Science & Technology Facilities Council

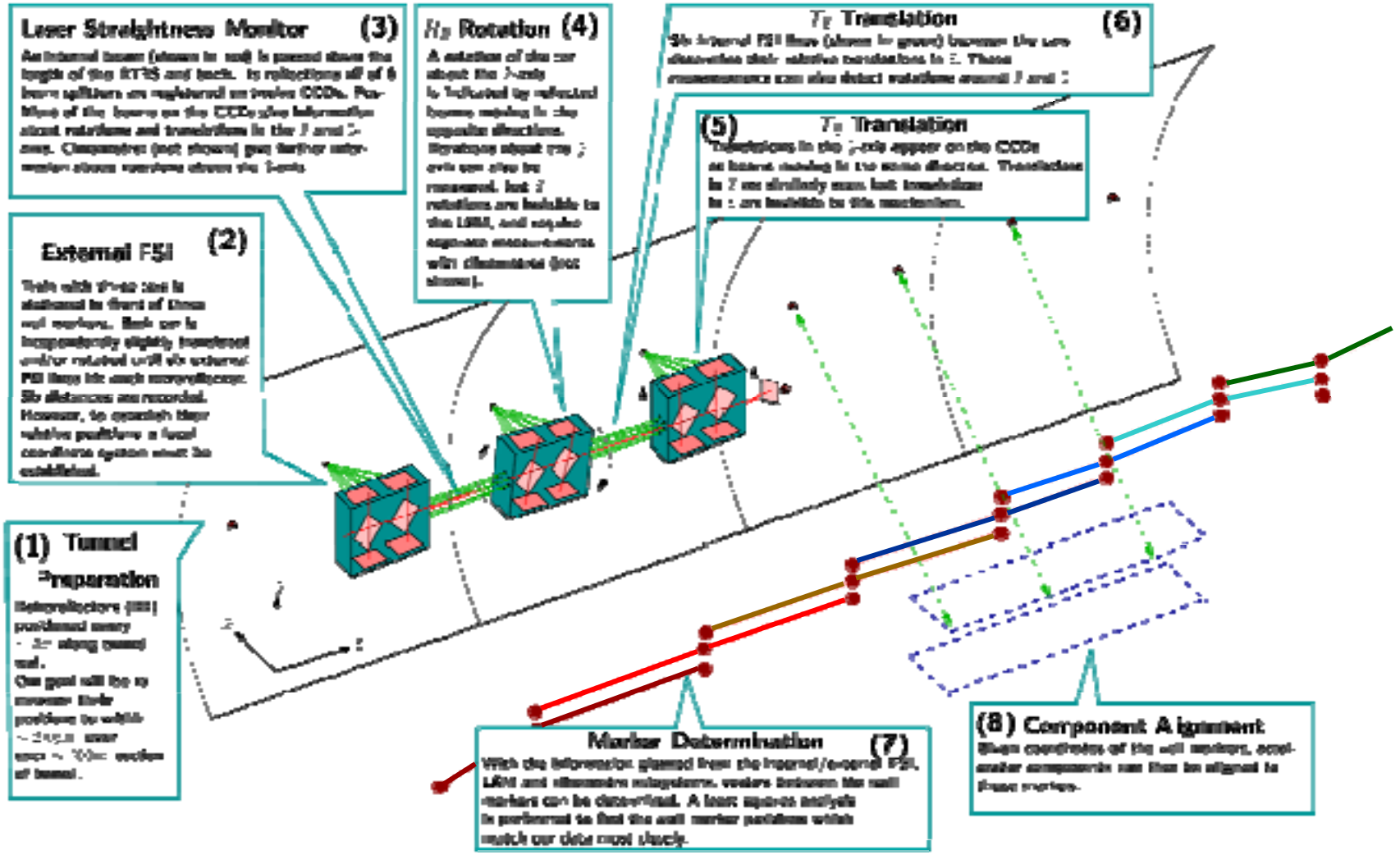
LiCAS

- Linear colliders will operate at ultra-low emittance:
  - Very tight alignment tolerances
  - Long tunnels-> slow and expensive survey if done by hand
- Solution: LiCAS[1]
  - Use high resolution of interferometer
  - Fast: Build fully automated robot train RTRS[2]
  - Cheap:
    - Single “expensive” production of light,
    - multiple inexpensive readout

[1] Linear Collider And Survey

[2] Rapid Tunnel Reference Surveyor

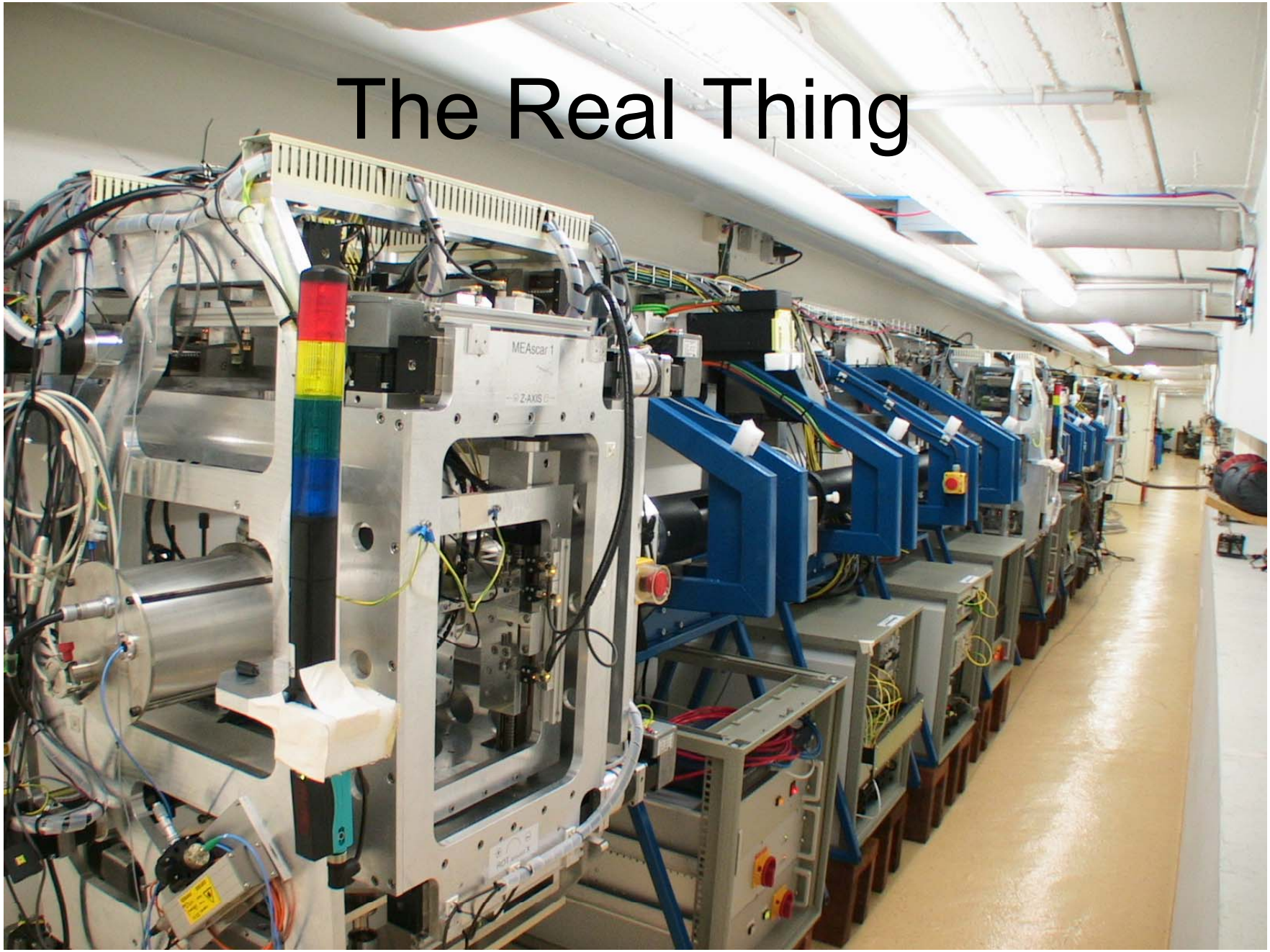
Principle of Overlapping Measurements



LiCAS Measurement Unit Assembly

- Assembly = VERY hard work for very long time under clean room conditions
- Oxford workshop and students essential (overtime, weekends, long hours, fast turnaround)

The Real Thing



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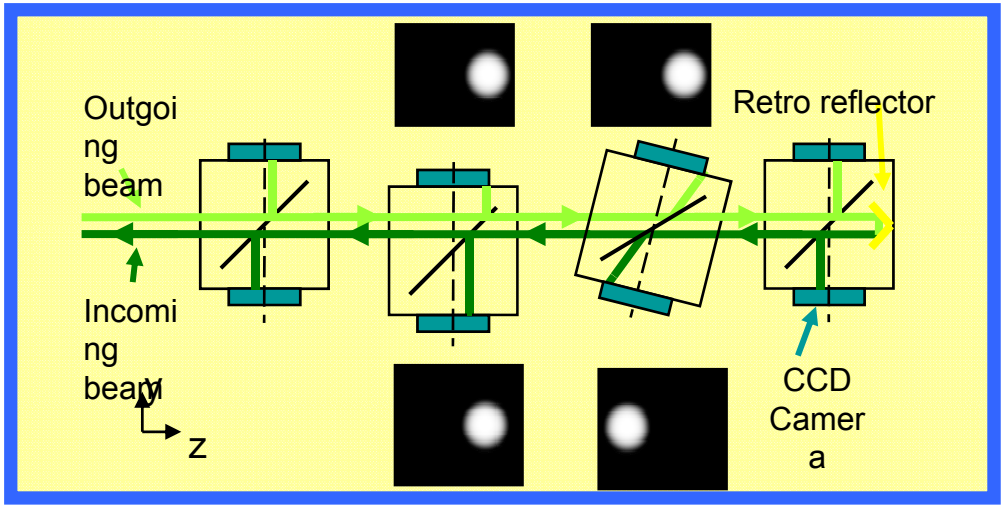
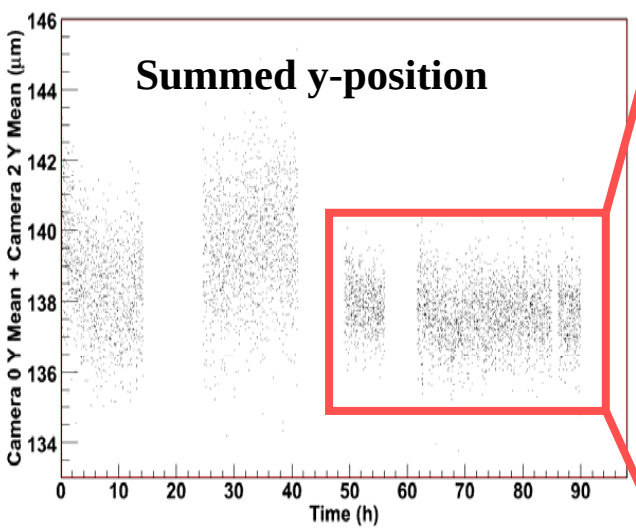
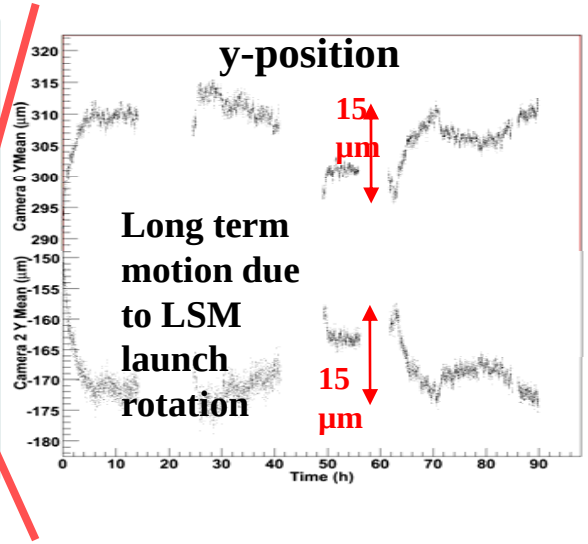
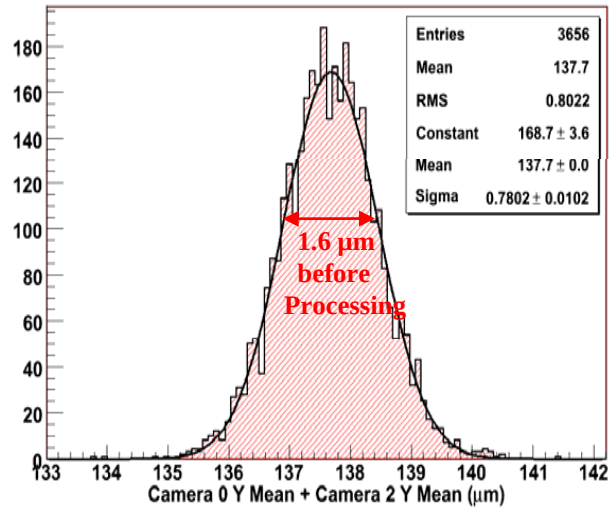
LSM

- Extraction of the y-position
- Limited by electronics feed-trough
  - Use averaging improves resolution by factor 5
  - Solve hardware problem

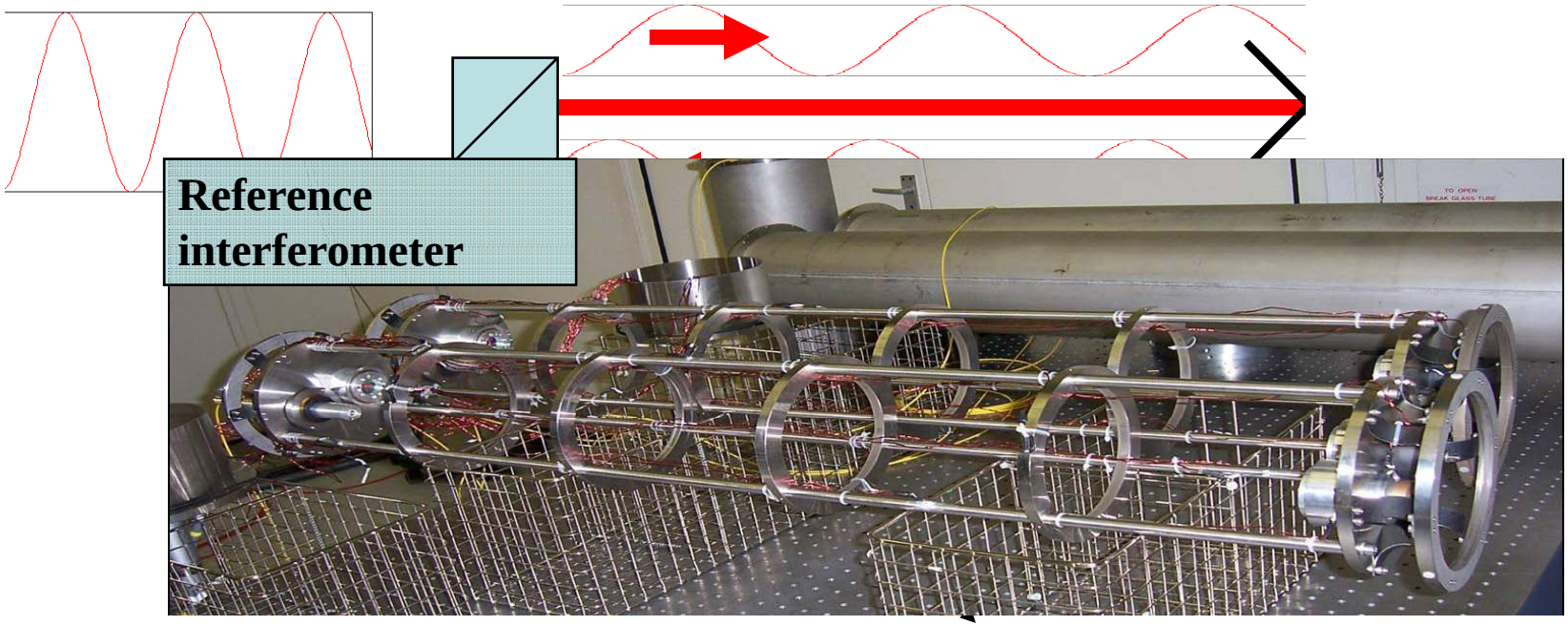








FSI



$D = (c/2\pi)(\Delta\Phi/\Delta nu)$

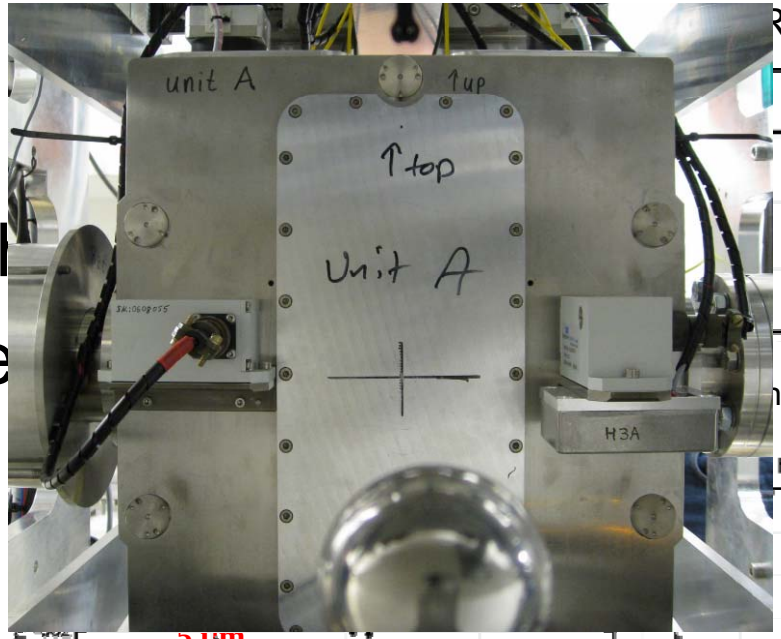
$R = (c/2\pi)(\Delta\theta/\Delta nu)$

$D = R(\Delta\Phi/\Delta\theta)$

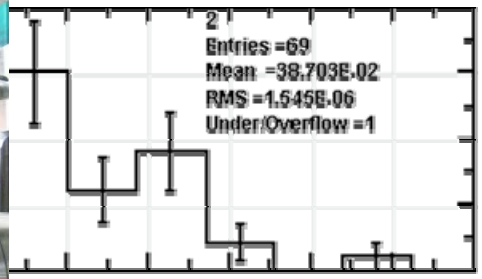
Frequency Scanning Interferometry

External FSI

- Stability
  - Data: 14h
  - Micron le

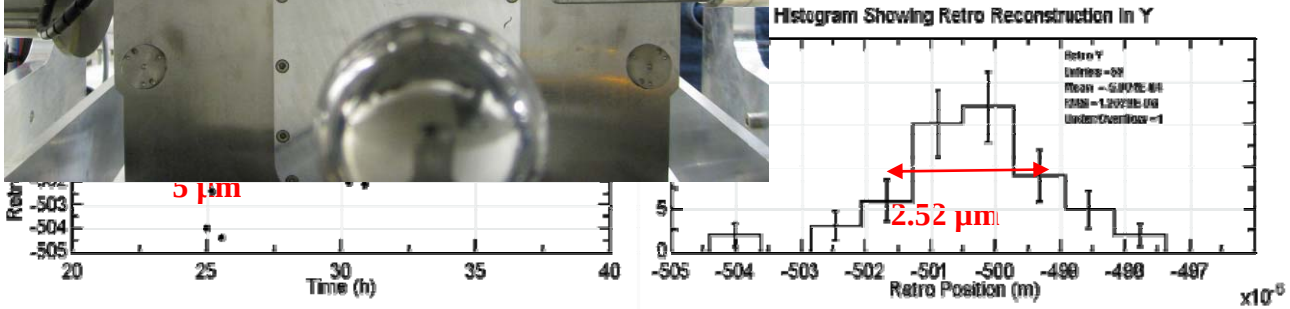


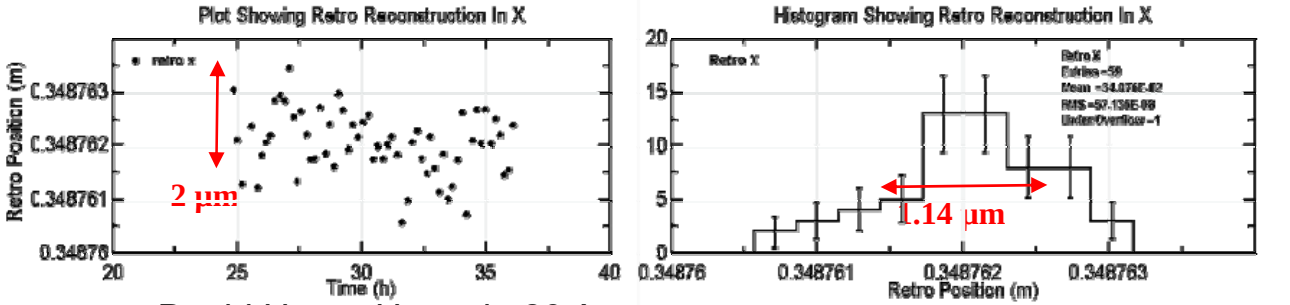
Resolution between 0.8-1.7 μm



0.387031 0.387036

ngth distribution





Other important efforts

- Internal FSI: Measure Distance along train and cross check LSM
- Simulation of entire train
- Calibration of all measurements with respect to each other using Least Squares Method
- Thousands of details

Outlook

- Much of Data still under analysis
  - Gregg Moss and John Dale finishing their thesis.
- Funding situation means no immediate development from Lab-instrument into surveyor-instrument
- Goal:
  - Publish method and results
  - Ready to take out of drawer, if need arises.

MONALISA

- Is an interferometric metrology system for continuous monitoring of position critical accelerator components
- Consists of a fixed network of evacuated interferometric distance meters
- Requires:
  - Nanometre type resolutions over O(10m)
  - Scalable to large numbers of components

Beam based feedback

- Survey and initial alignment required.
- Working alignment needs to be maintained / restored.
  - between trains
    - 200 ms is long enough for several 100 nm movement
  - Take into account long term drifts
  - after push-pull events:
    - IR hall floor will move after rolling two heavy detectors
  - after shutdown periods
- A cheap position monitoring system of critical elements is your friend.

MONALISA: Benefits

Monitoring fiducial locations on key components

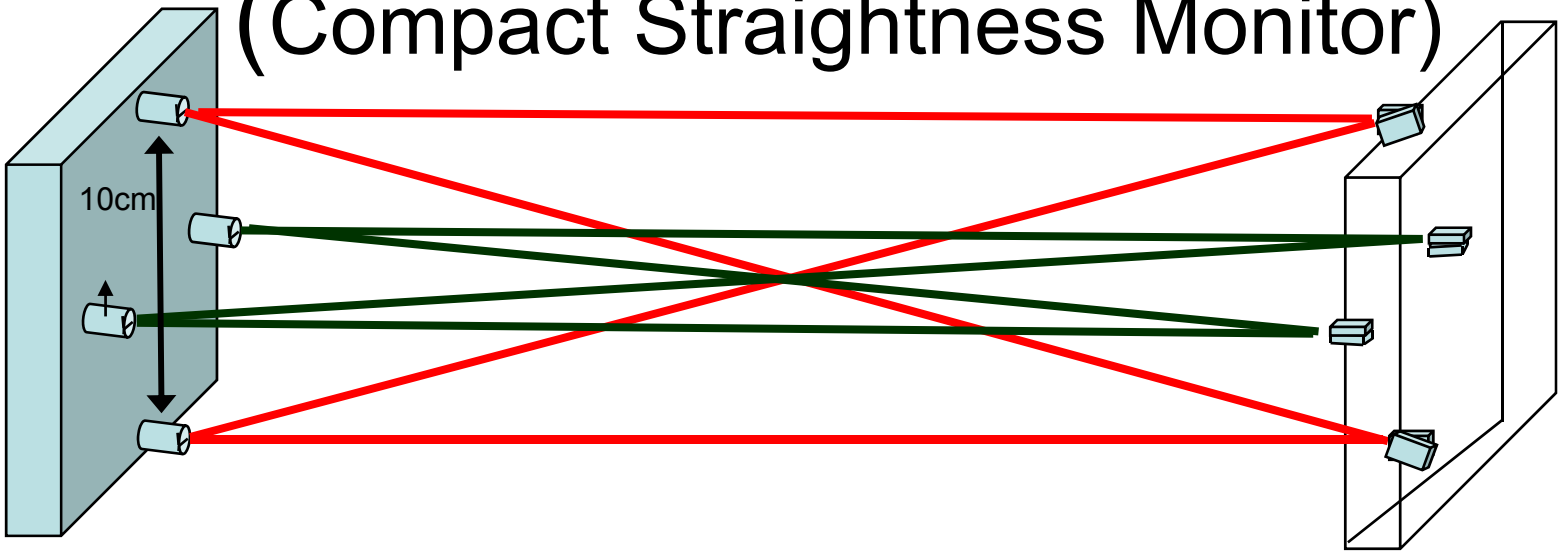
- after interruption of beam
  - independently follows changes in alignment
- during commissioning / start up
  - improves understanding of machine behaviour
- before accelerator operation
  - speeds up initial convergence of machine
- more reliable accelerator operation
  - lower chance of damage
  - luminosity can only win

Return detector / QDzero position after push-pull at ILC

- expect to get micron repeatability
  - for return of magnet positions
  - but compared to which location?
- get machine within beam based capture range
  - improves switchover time

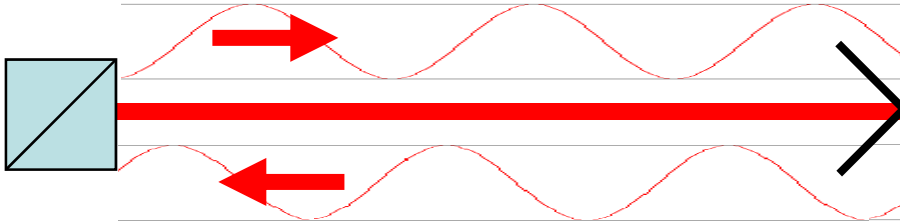
In discussion with detector collaborations about including system in into design

Main Component: CSM (Compact Straightness Monitor)



- 6D position transferred from left to right
  - Integral use of sturdy endplates required.
- Preliminary simulation results of CSM Resolution:
  - σ_y:10nm
  - distance meter resolution: 1nm = Resolution in z-direction
  - Positional change of optics components with respect to each other: 1nm.
  - Using Least Chisquare Method employed by LiCAS:
    - Calibration of unknown positions of launch heads by multiple measurements
    - Preliminary studies indicate that results within a factor of 2 are achievable.

Interferometer operation



Phase = 2π (Optical Path Distance) / Wavelength

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

frequeny scanning

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

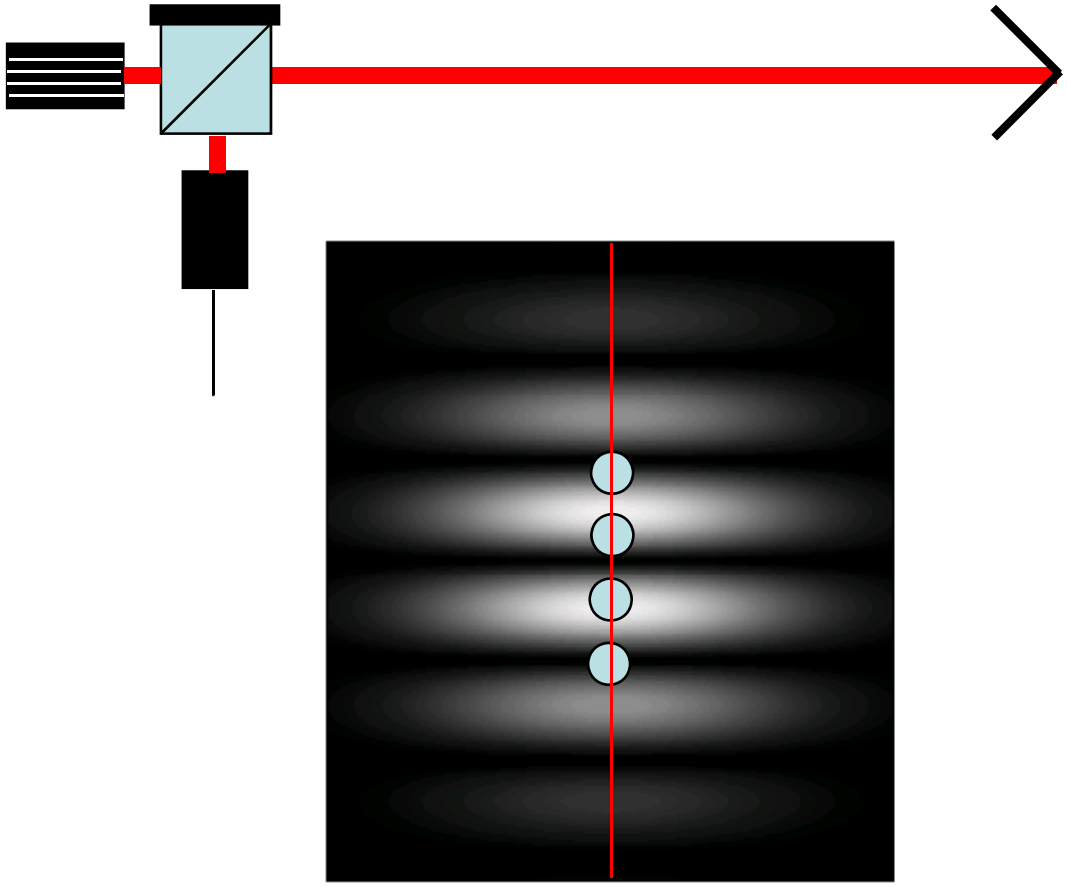
Fixed Frequency Interferometry

$$D = (c/2\pi)(\Delta\Phi/\Delta nu)$$
$$R = (c/2\pi)(\Delta\theta/\Delta nu)$$
$$D = R\,(\Delta\Phi/\Delta\theta)$$

Frequency Scanning Interferometry

David Urner, Uppsala 28 Aug 2008

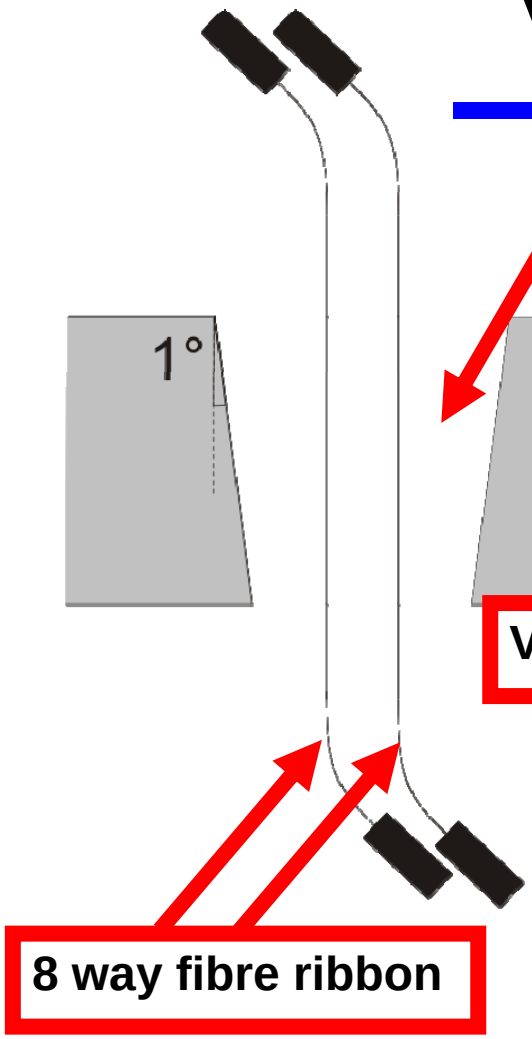
Interferometer operation

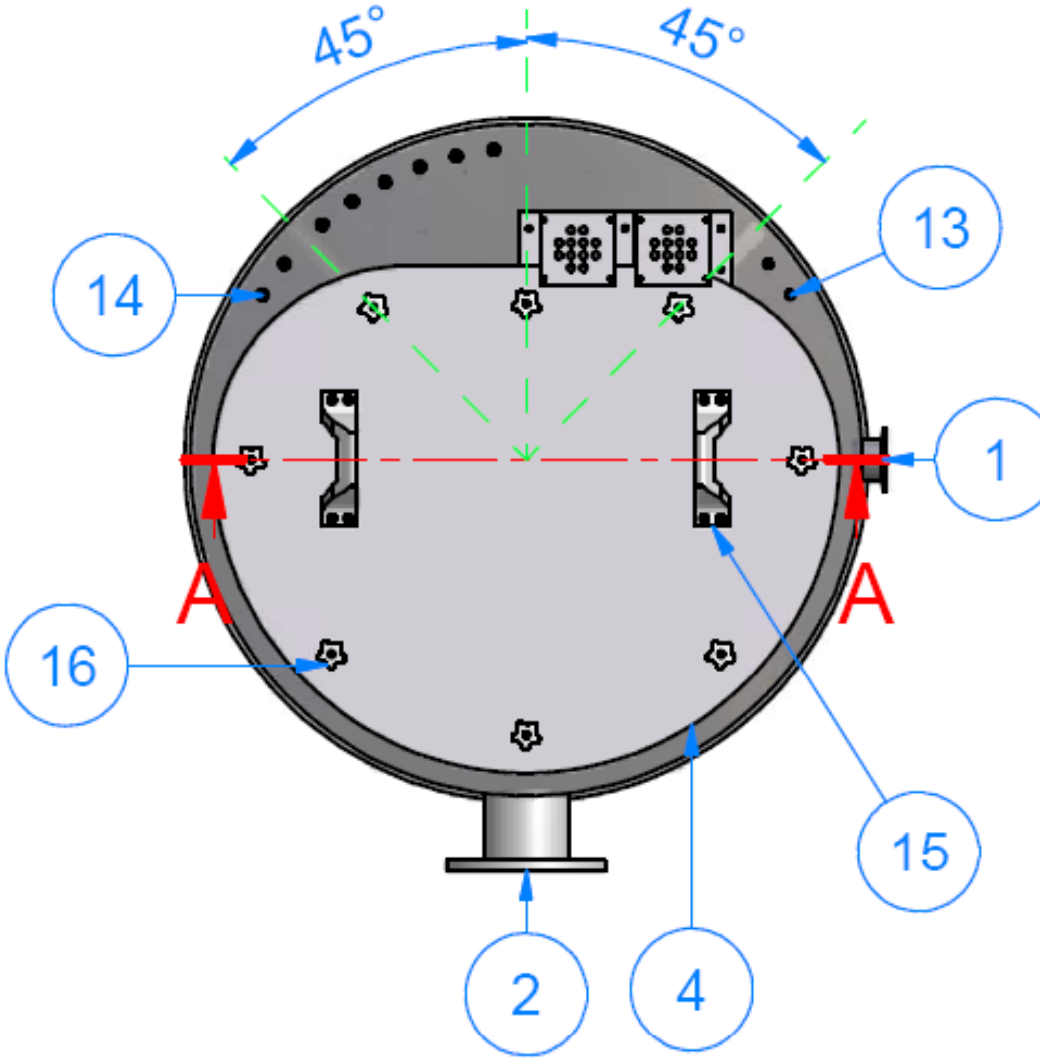


Distance meter

- Measurement Frequencies:
  - FFI: up to 10kHz
  - FSI: up to 1Hz
- Long term stability determines low frequency behaviour
  - Minutes possible
  - Lot of work needed to extend to hours or days.
- Advantage of interferometric measurement system is fairly low cost per line.
  - Use of telecom frequency allows use of cheap commercial hardware
  - Cheap amplification of light
  - Current estimate: as low as £800 per distance metre
    - Not including the main setup

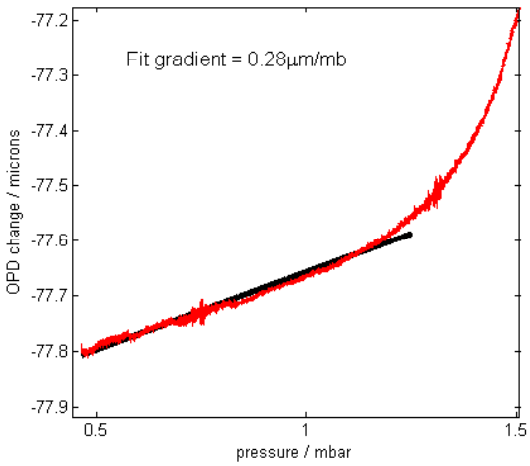
Vacuum System





Changing Pressure

- Good agreement between FSI and FFI
- Decent correlation between pressure and measured OPD



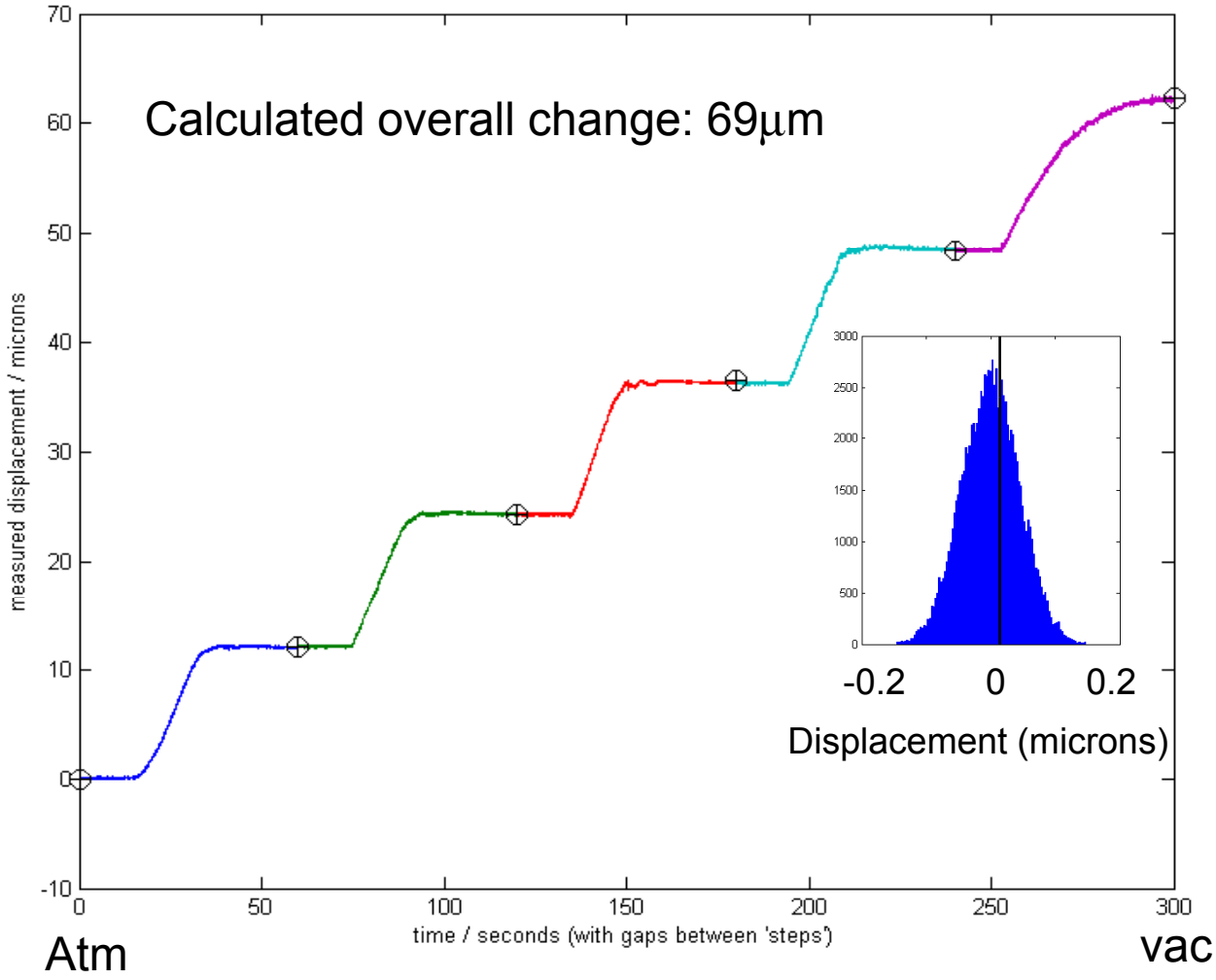
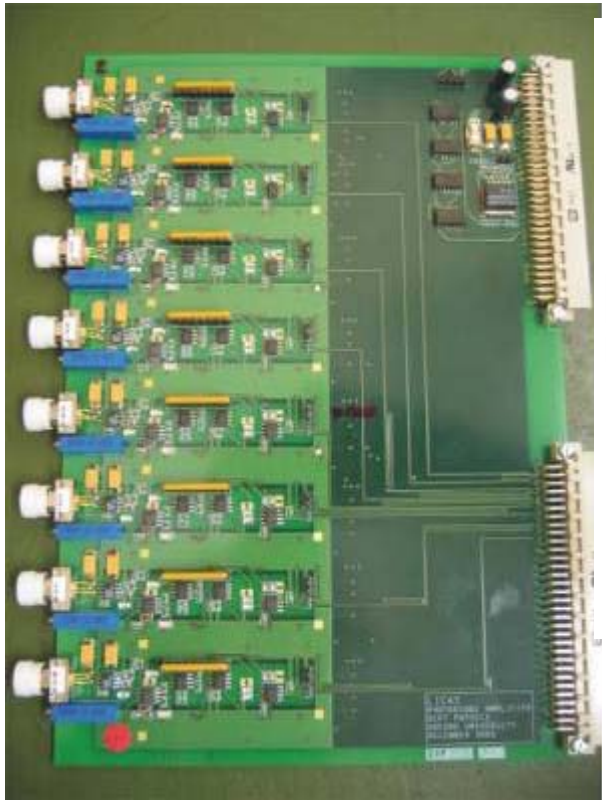
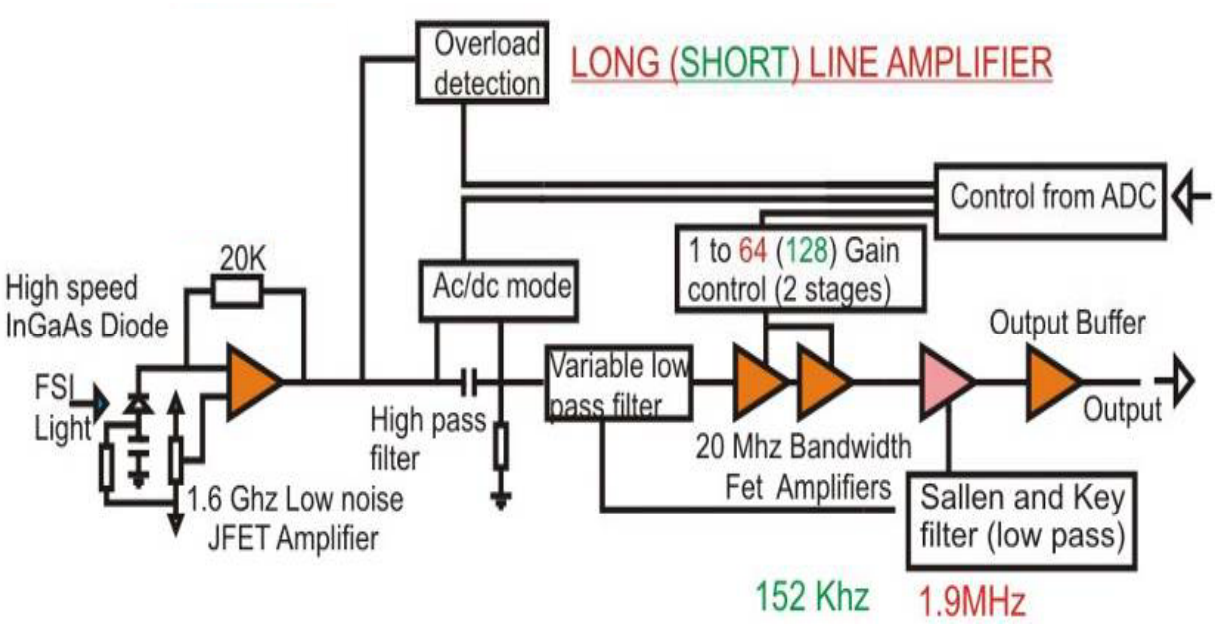


Photo Amplifiers adapted from LiCAS

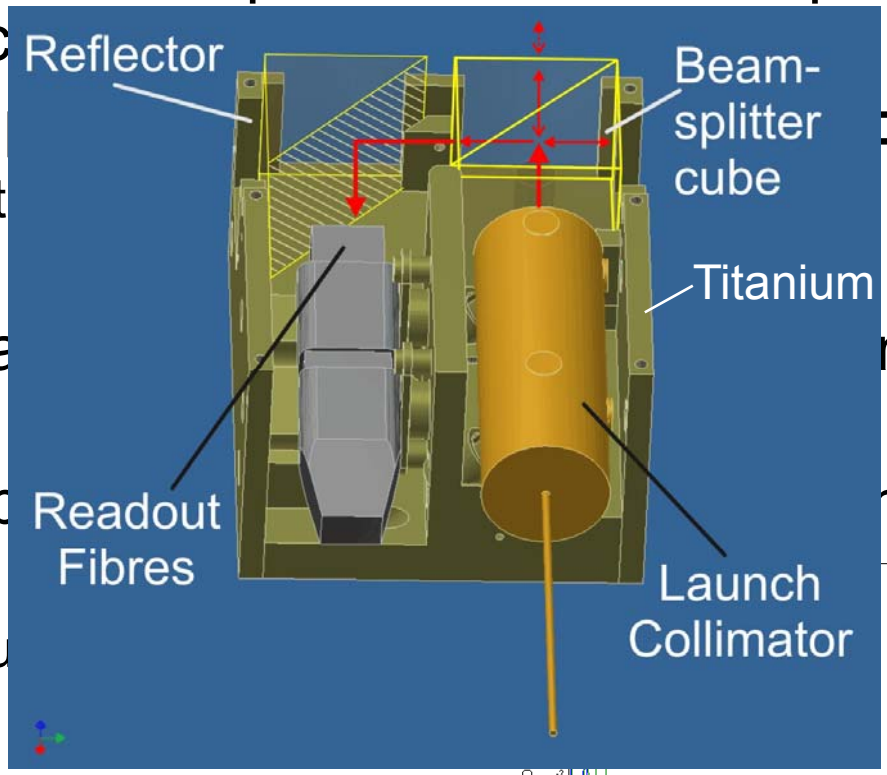
- Switchable between AC (for FSI), DC (for FFI)
- Improved components, for temperature insensitivity
- Artwork and design close to be ready to be sent out

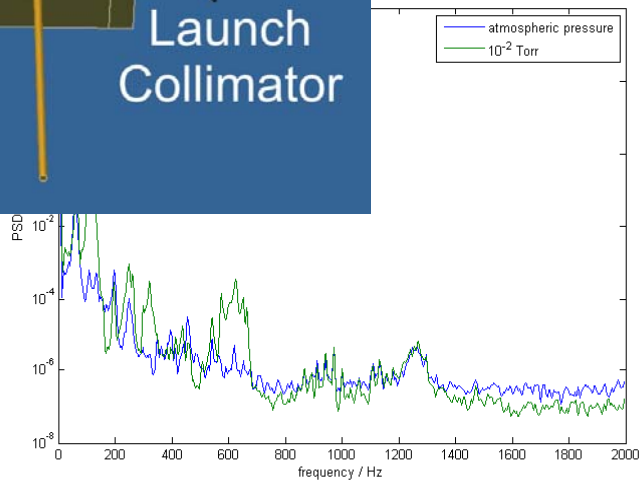




Fixed Frequency Interferometry

- Improvement of amplifier to reduce temperature dependenc
- Test of Am
  - Linear wit
  - With high
- Spectrum a noise dominated
- Spectrum b minated
  - Vibration
  - Stable lau
- Eventually
  - Air turbulences
  - Laser frequency instabilities

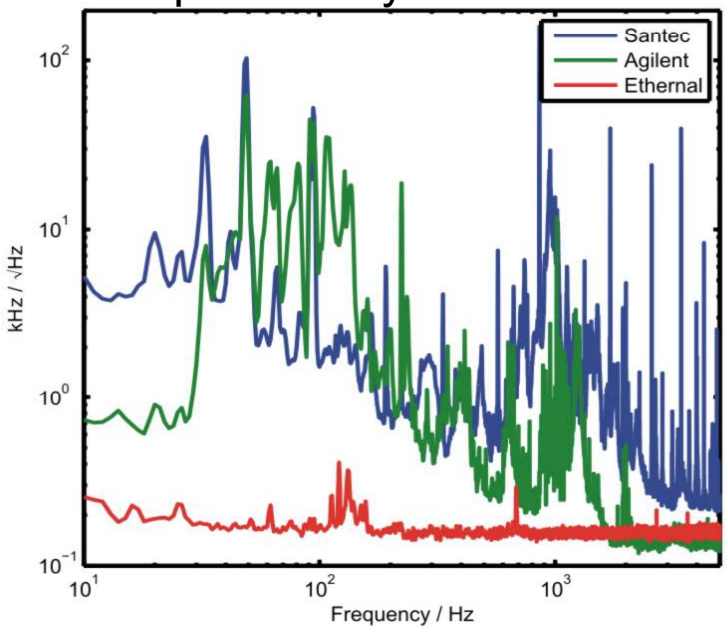




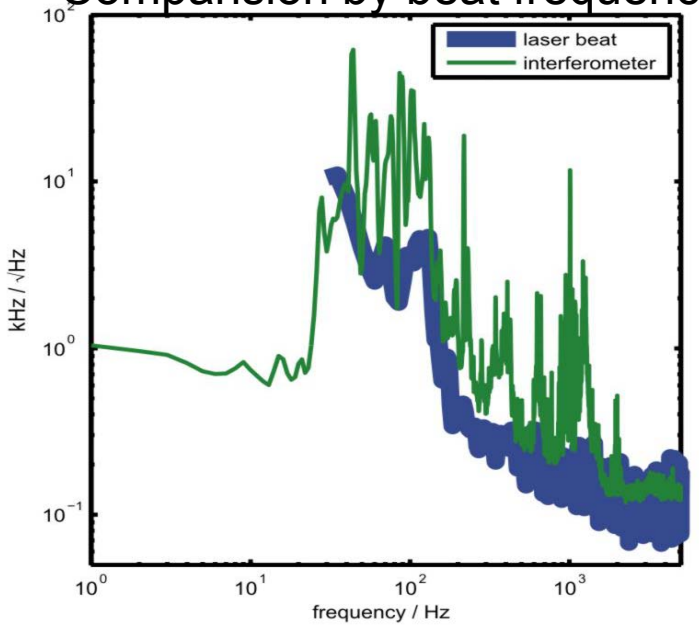
Laser Stability

- Eurotev note 2008-031
  - Describes frequency characterization of our lasers

Frequency fluctuation spectra
Comparision by distance metre

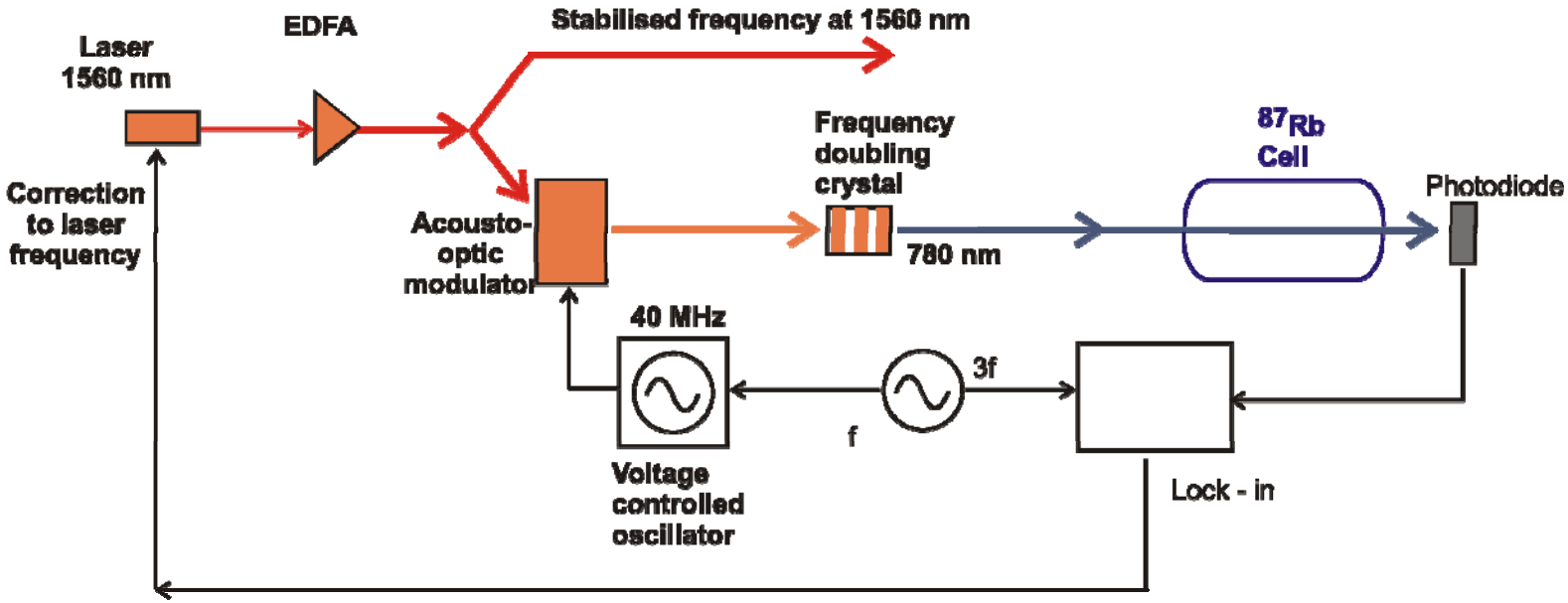


Frequency fluctuation spectra
Comparision by beat frequency



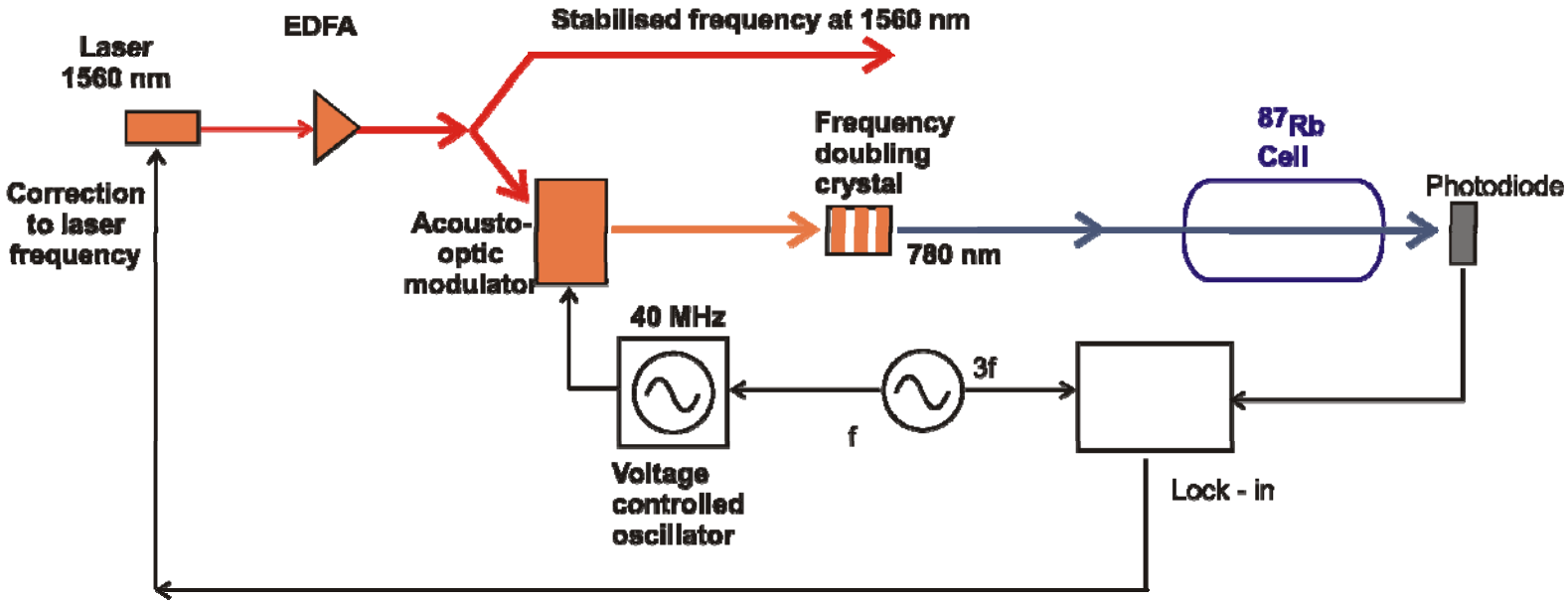
Frequency Stabilisation

- Lock laser to spectral feature of rubidium
- Use a frequency doubling crystal to reach this frequency



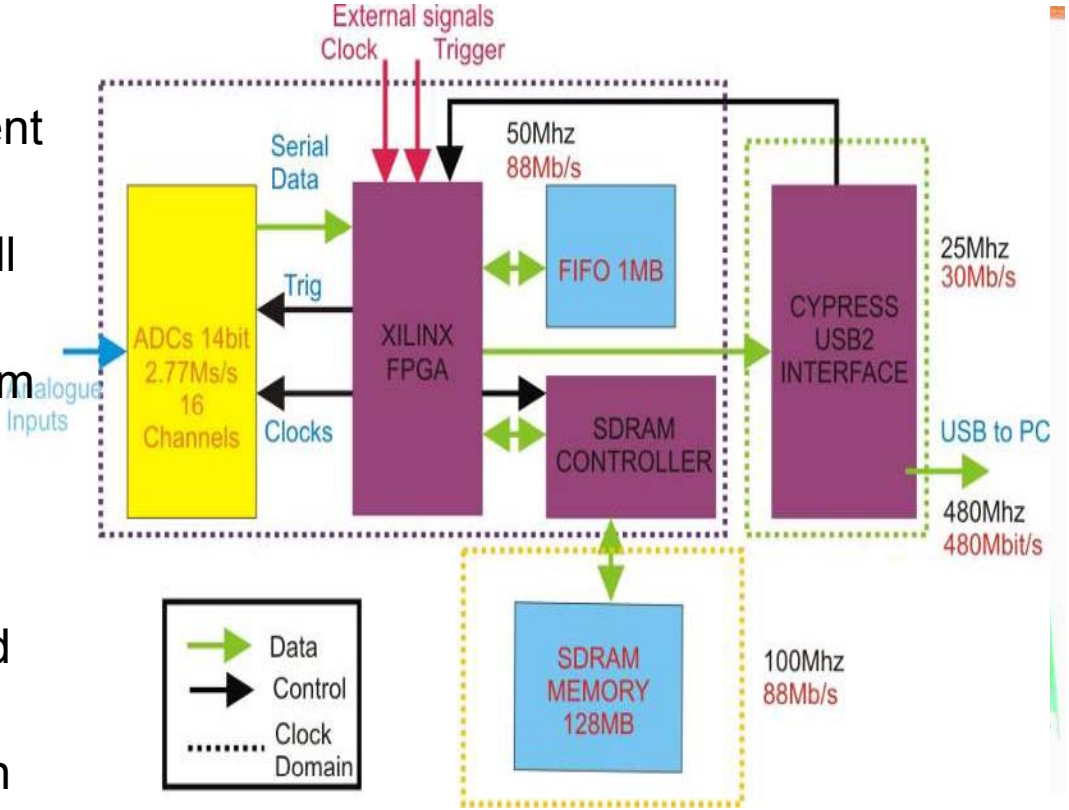
Frequency Stabilisation

- All parts are at Oxford
- Mechanical assembly in progress



USB readable ADC adapted from LiCAS

- 2.7 MHz readout
- Store all 16 channels worth of FSI Data for single measurement
- Switch to continual readout mode for FFI at 2.7MHz/8 for all 16 channels
- Down-sampling (averaging) from 2.7 MHz to as low as 50Hz.
- Data throughput ~ 25 MHz
- 80 channels built
- DLL for USB readout integrated into Labview
- Data finally stored together with slow data such as temperature or pressure and META-data in GIACONDE binary format.



Data Analysis

- Data can be analysed in several layers
  - Directly by Labview
    - Simple but quick
    - Check quality at data acquisition
  - By Java structure developed together with LiCAS
    - able to deal with large data files
    - Apply established procedures and calibrations
    - Assemble different data stream and store in Giaconde
    - Store selected data in ASCII readable by MATLAB
  - Experimental and Flexible data analysis in MATLAB

Outlook

- Deployment at ATF2 at KEK to monitor relative positions of QD0 and IP measuring device
- Further development of system in framework of FP7 at CTF3
  - Monitoring of CLIC qudrupole magnet on CLIC girder
  - Stabilization test facility
    - improve our ultimate resolution as needed for CLIC final focus
    - Compare interferometric with seismic sensors