Monitoring Alignment & Stabilisation with high Accuracy

MONALISA

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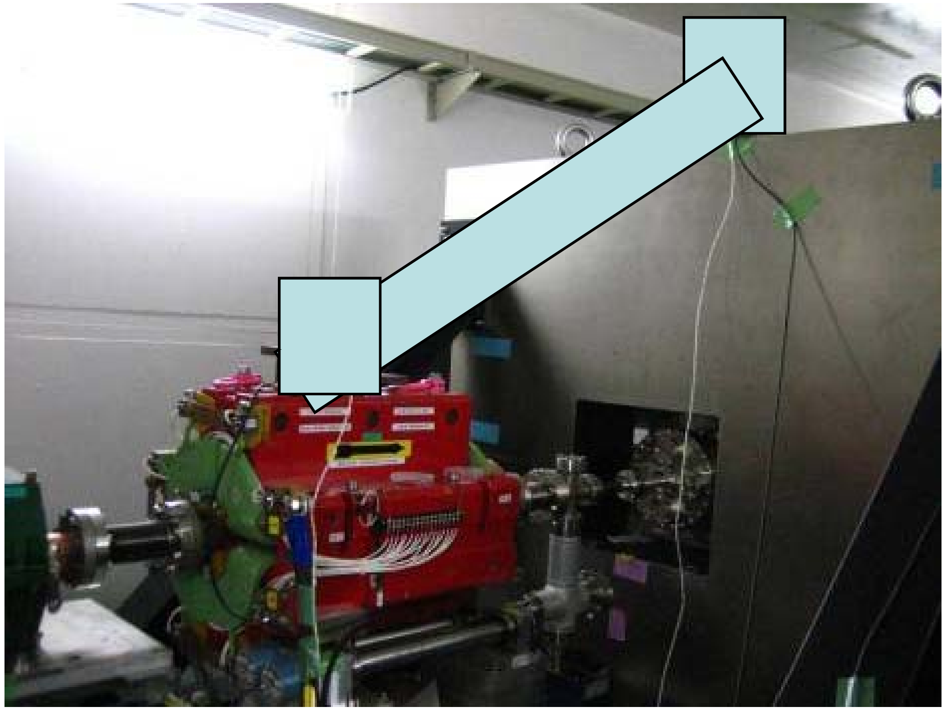
MONALISA

- Is an interferometric metrology system for continuous monitoring of position critical accelerator components
- Consists of a network of evacuated interferometric distance meters

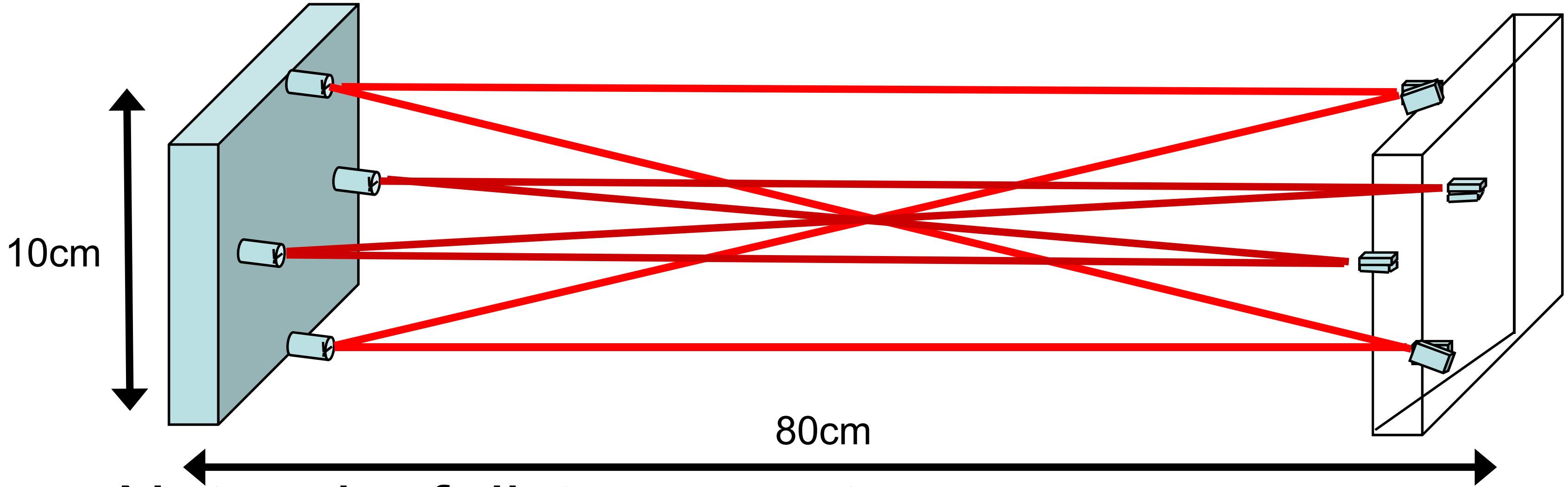


Features

- Permanently installed monitoring system
- Long and short timescales with one instrument
- Relative
  - position
  - and orientation

- Evacuated lines of sight required for highest accuracy

Operation



- Network of distance metres
- Measurement end points fixed
- Gives overconstrained geometric system
- Allows us to reconstruct full 6 degrees of freedom from distance measurements

- Development status of
  - **Interferometric Position Monitor**
  - Data Acquisition Hardware
  - Vacuum Enclosure

Understanding FFI Uncertainties

- Electronics noise
- Electronics stability
- Laser frequency fluctuations
- Movement of launch head components
- Polarisation dependence
- Laser power fluctuations
- Beam walk
- Ellipse fit calibration error

To perform precise, reliable measurements we must have a very good understanding of the sources of measurement uncertainty

Understanding FFI Uncertainties

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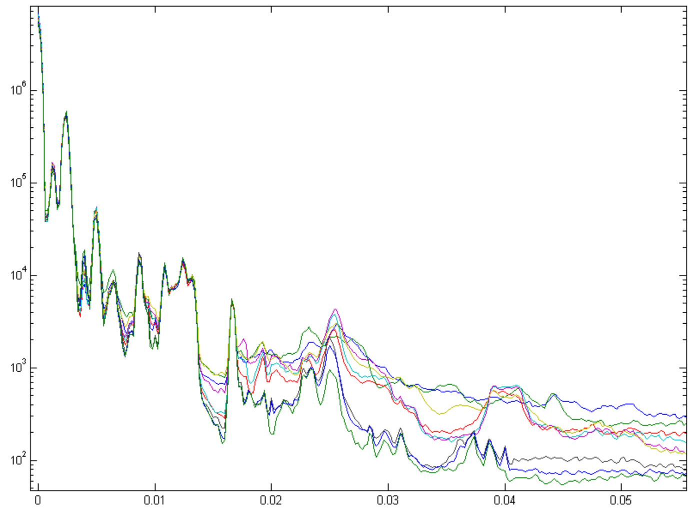
White noise limit from Thermal (Johnson) noise

SNR linearly with laser power

At high power, as low as 1pm/√Hz



Understanding FFI Uncertainties

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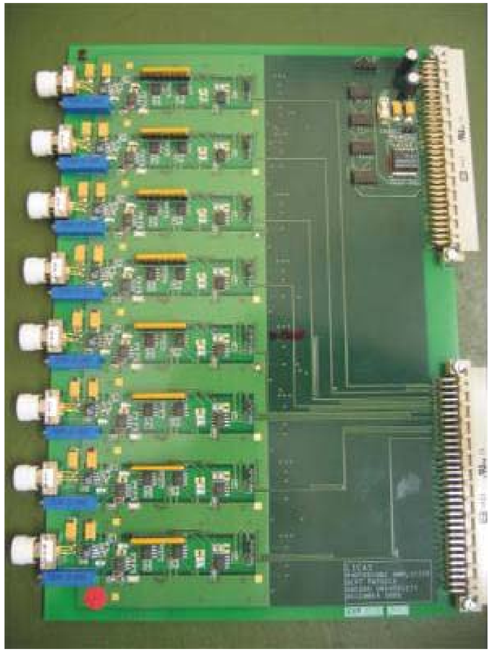
Chosen amplifier components to be insensitive to thermal changes.



Understanding FFI Uncertainties

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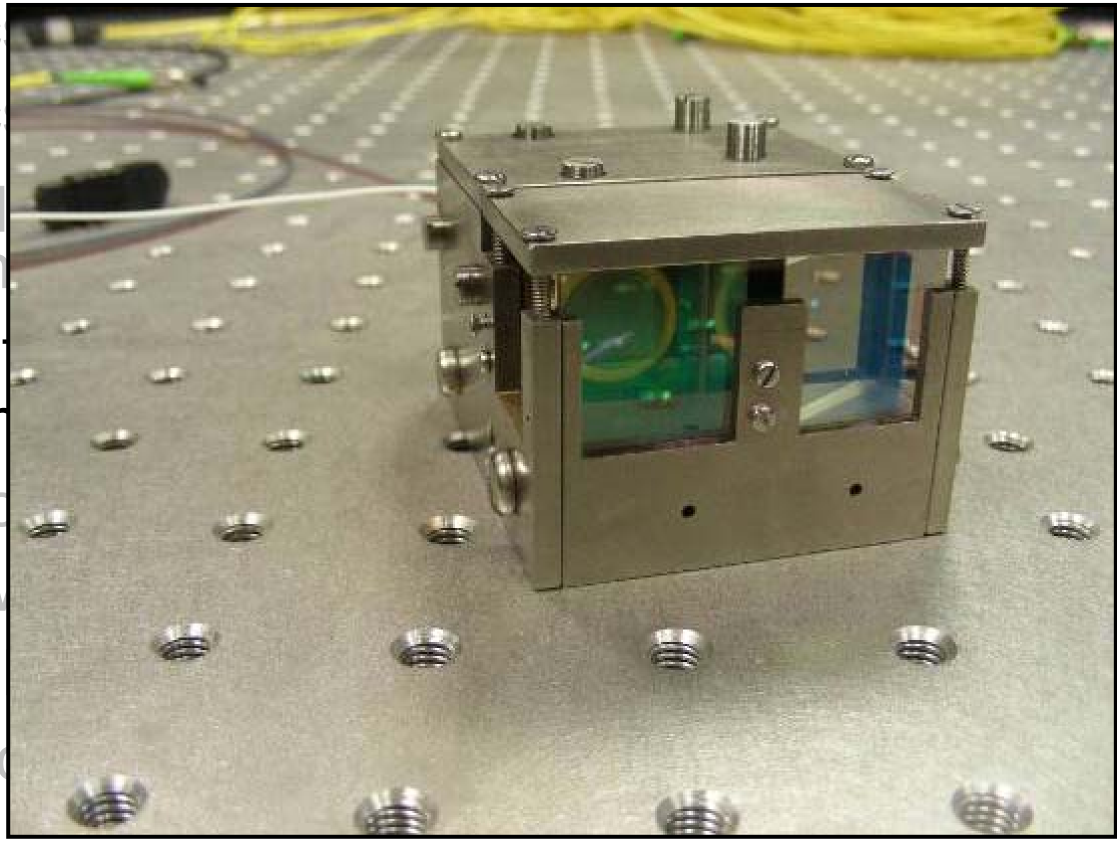

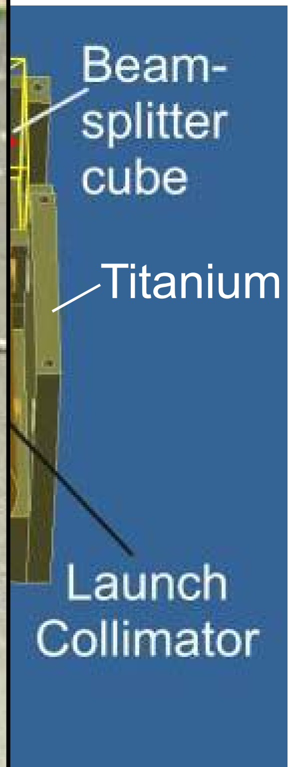

Understanding FFI Uncertainties

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Stress in optical fibres changes the polarisation state of the output light.

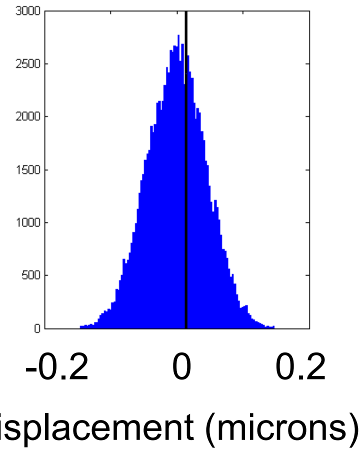
Have found small polarisation dependence in our system.

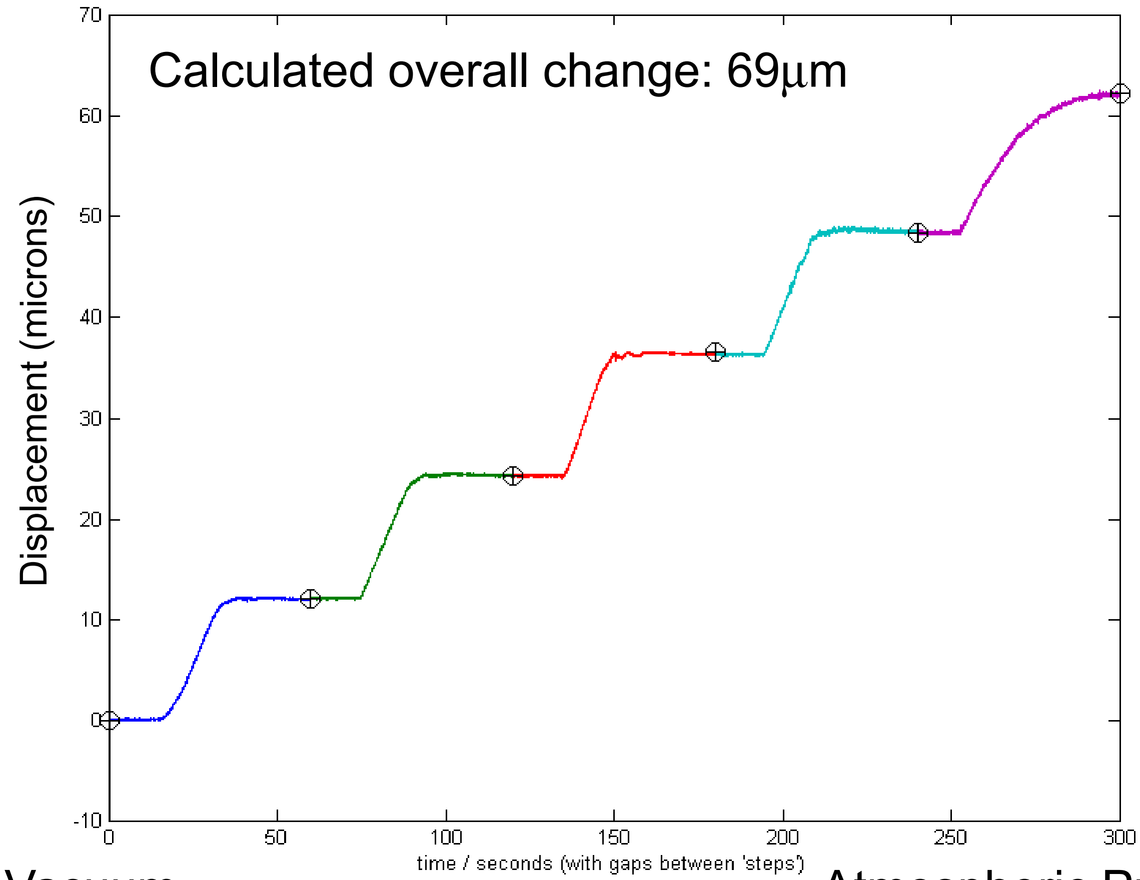
Tests show errors below 1nm

Polarisation maintaining fibre an option, if required.

Verification: FSI / FFI Comparison

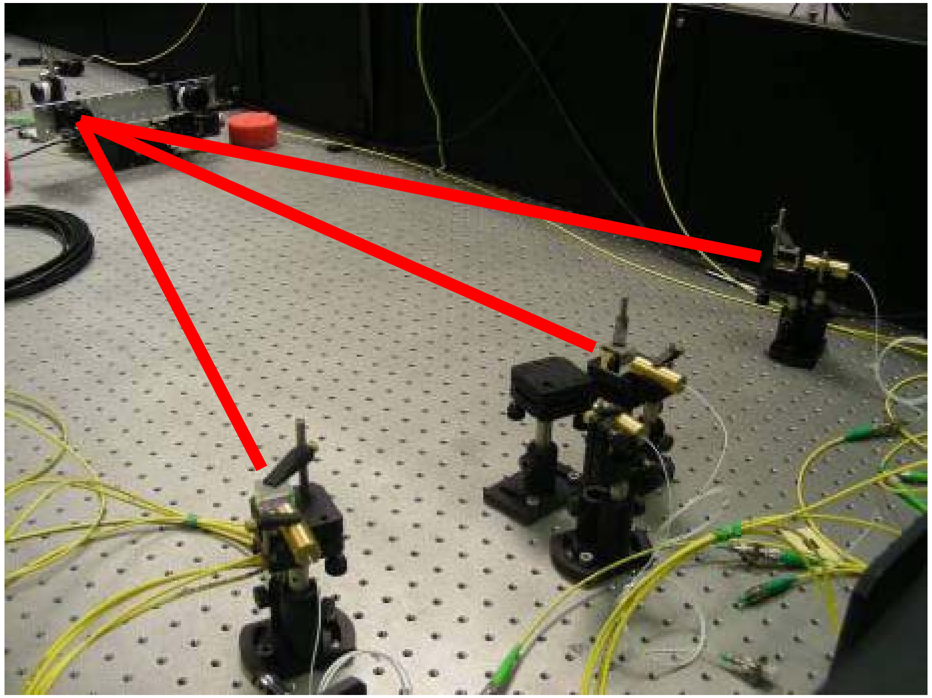
The two different measurement modes show good agreement





Interferometer grid

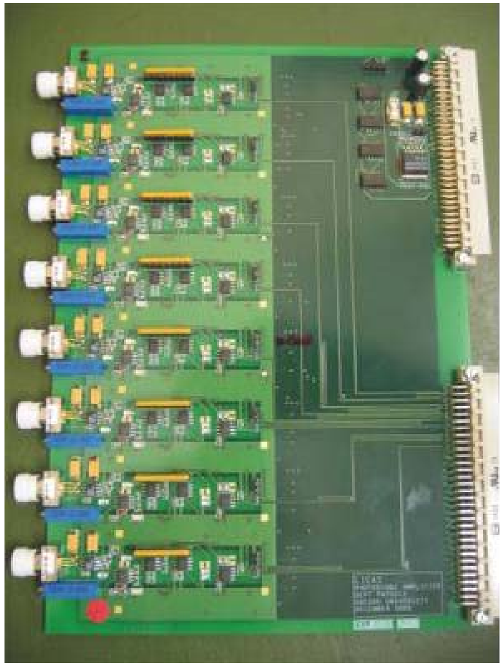
- Simulations performed by summer student
- Now working with simplified setups in the lab
- Building understanding as we move toward the final system

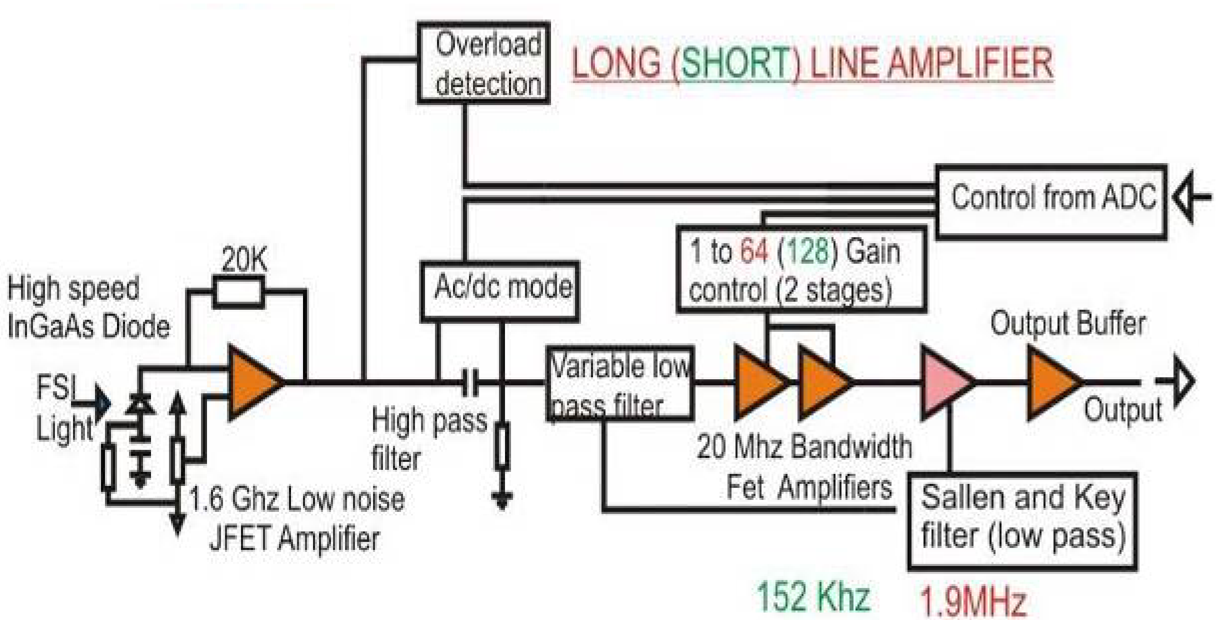


- Development status of
  - Interferometric Position Monitor
  - **Data Acquisition Hardware**
  - Vacuum Enclosure

Photo Amplifiers adapted from LiCAS

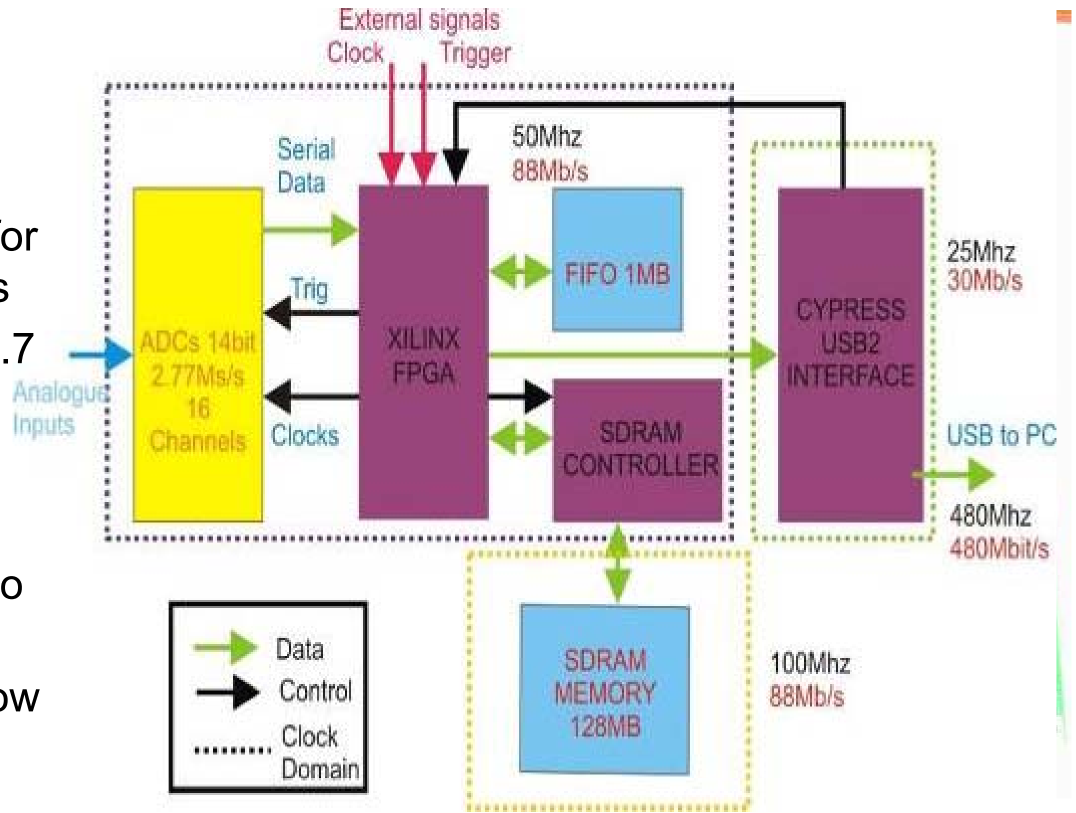
- Switchable between AC (for FSI), DC (for FFI)
- Improved components, for temperature insensitivity
- Artwork and design close to be ready to be sent out





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
- 128 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.

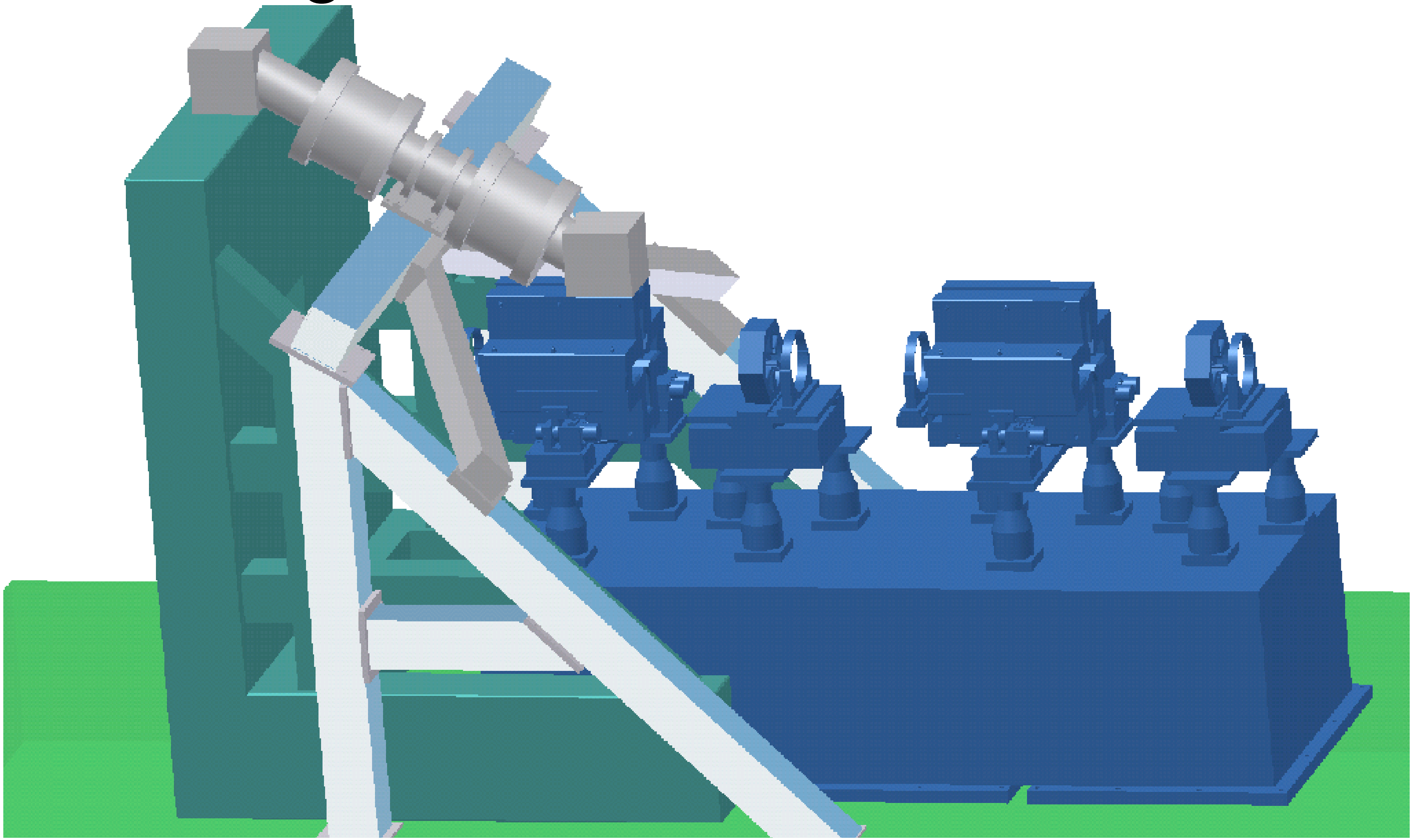


- Development status of
  - Interferometric Position Monitor
  - Data Acquisition Hardware
  - **Vacuum Enclosure**

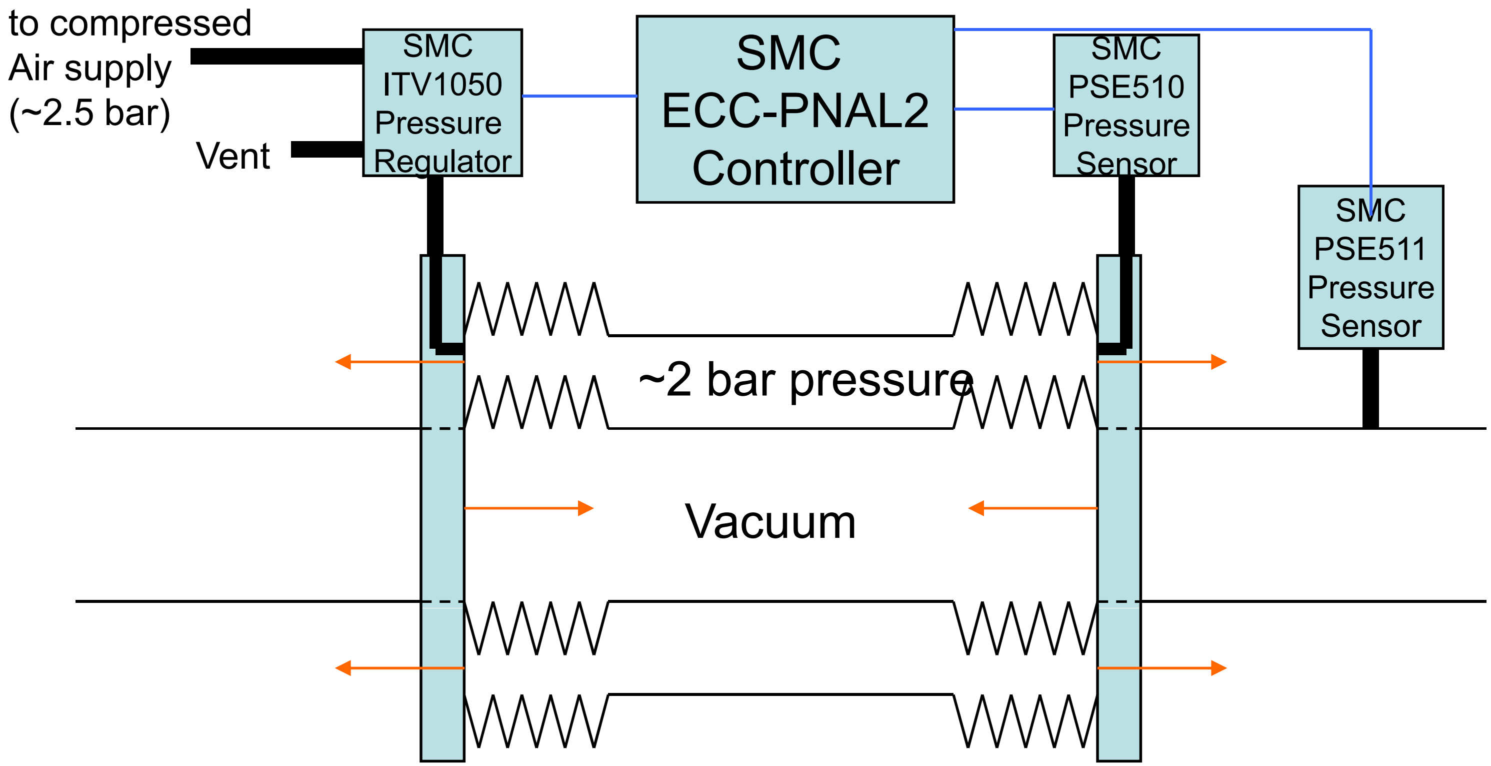
Passive Double Bellow System

Requires large structure to fasten all aspects of system. Therfore we need support-scaffold!

Model of MONALISA installation using two active double bellows



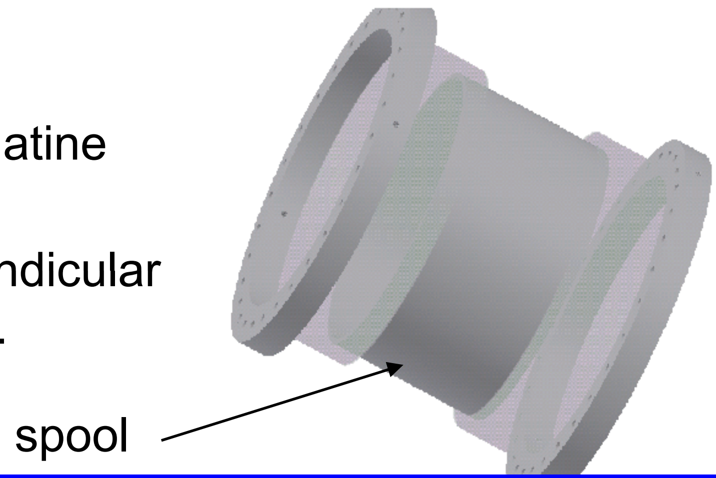
Active Double Bellow Principle



- Idea: Generated Force is proportional to sum of pressure in inner and outer bellow system.
  - Find Point where force is zero
- Commercial control system has been delivered to Oxford.

Active Double Bellow Development

- Large bellow:
  - Pay attention to spring rate.
  - Develop with Palatine Precision system with minimal spring rate.
  - Prototype system showed that a total perpendicular rate of 3N/mm is possible
    - This includes stiffening effects from vacuum and overpressured sections
- Over-pressured bellow:
  - Tend to buckle (in general).
  - Second prototype system build by Palatine tested ok up to 4 bar over-pressure
  - Spool piece will maintain same perpendicular spring rate but is less prone to buckle.



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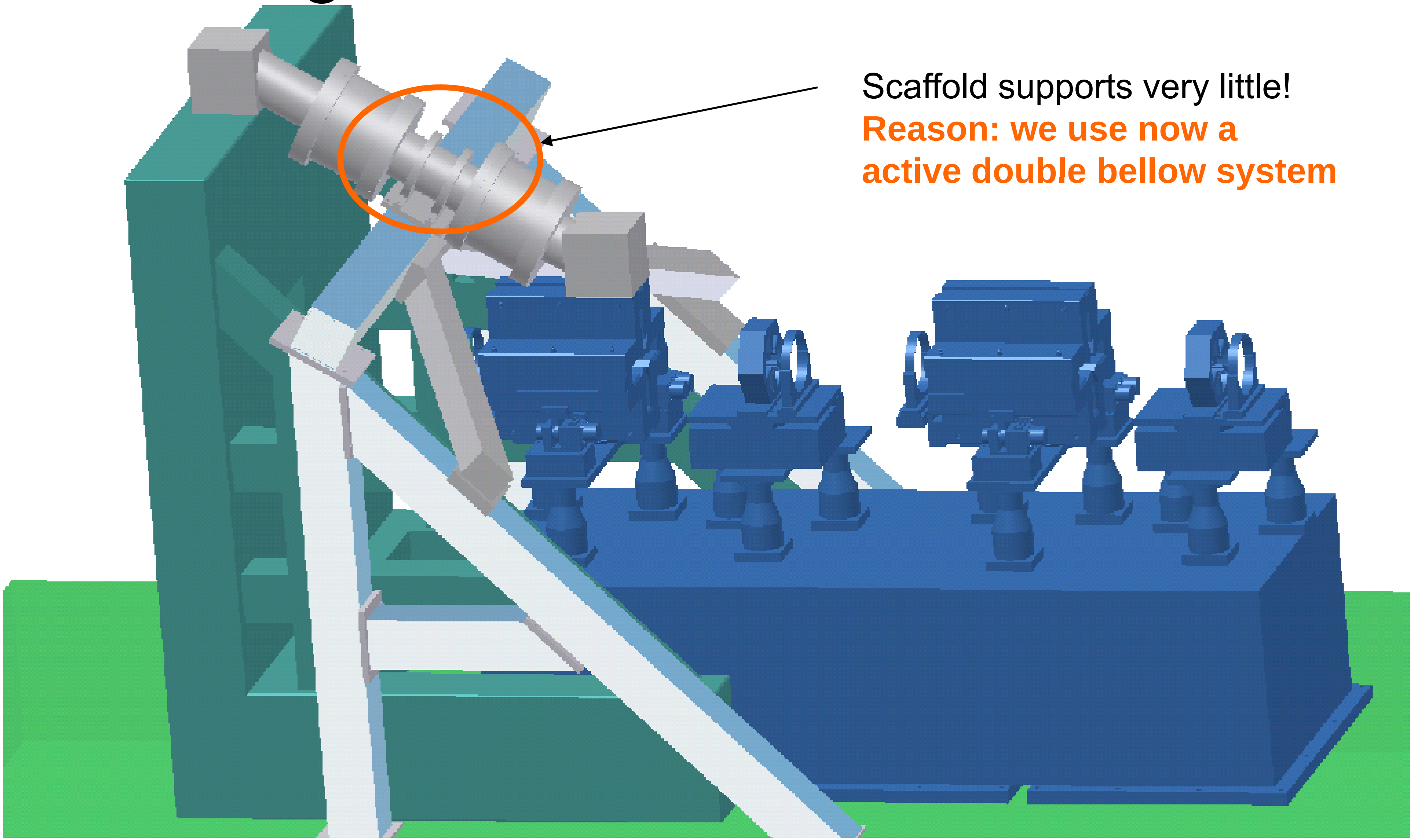
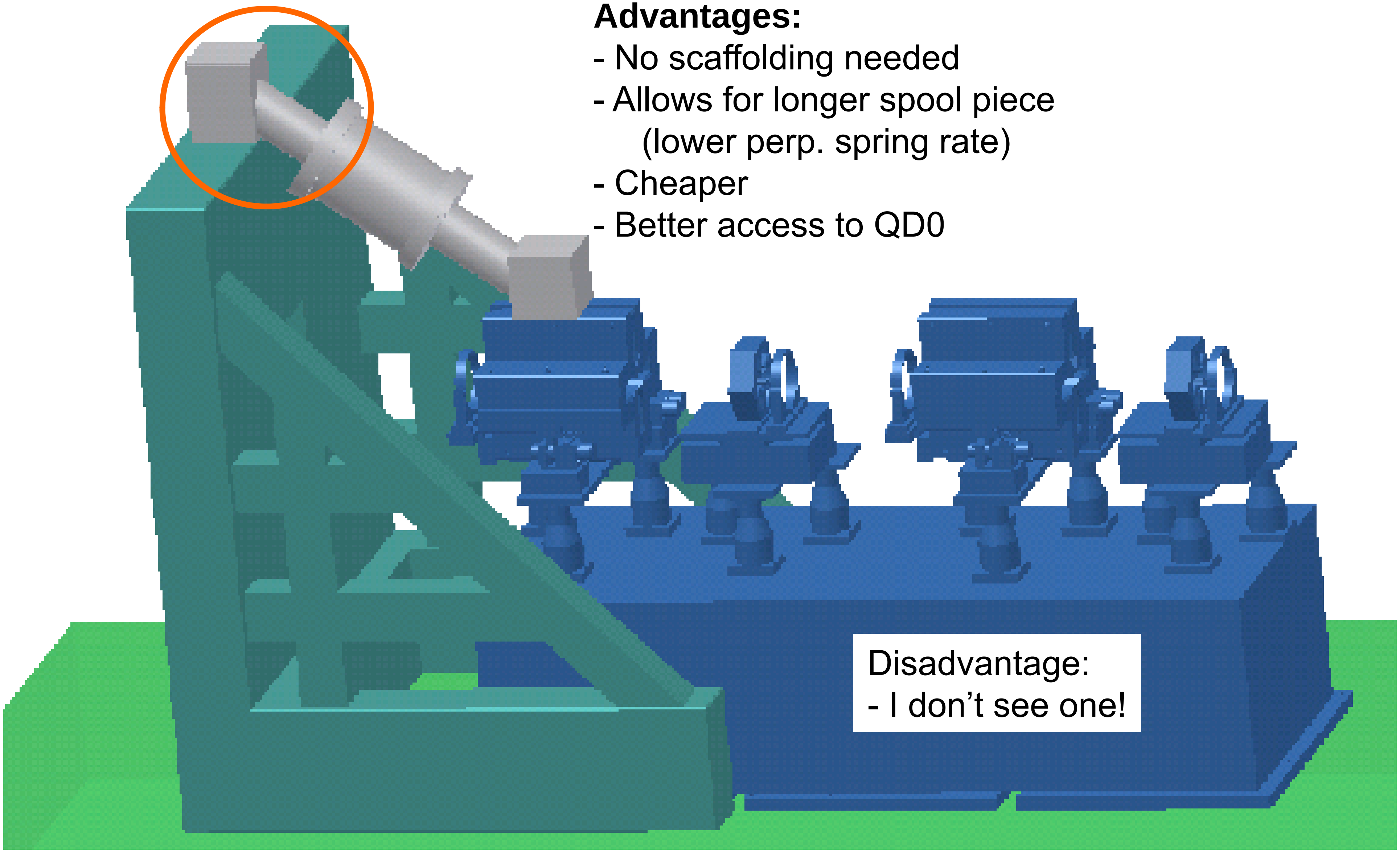


Scaffold supports very little!

Reason: we use now a active double bellow system

One active double bellow system

Advantages:
- No scaffolding needed
- Allows for longer spool piece
  (lower perp. spring rate)
- Cheaper
- Better access to QD0



Disadvantage:
- I don’t see one!

One active double bellow system

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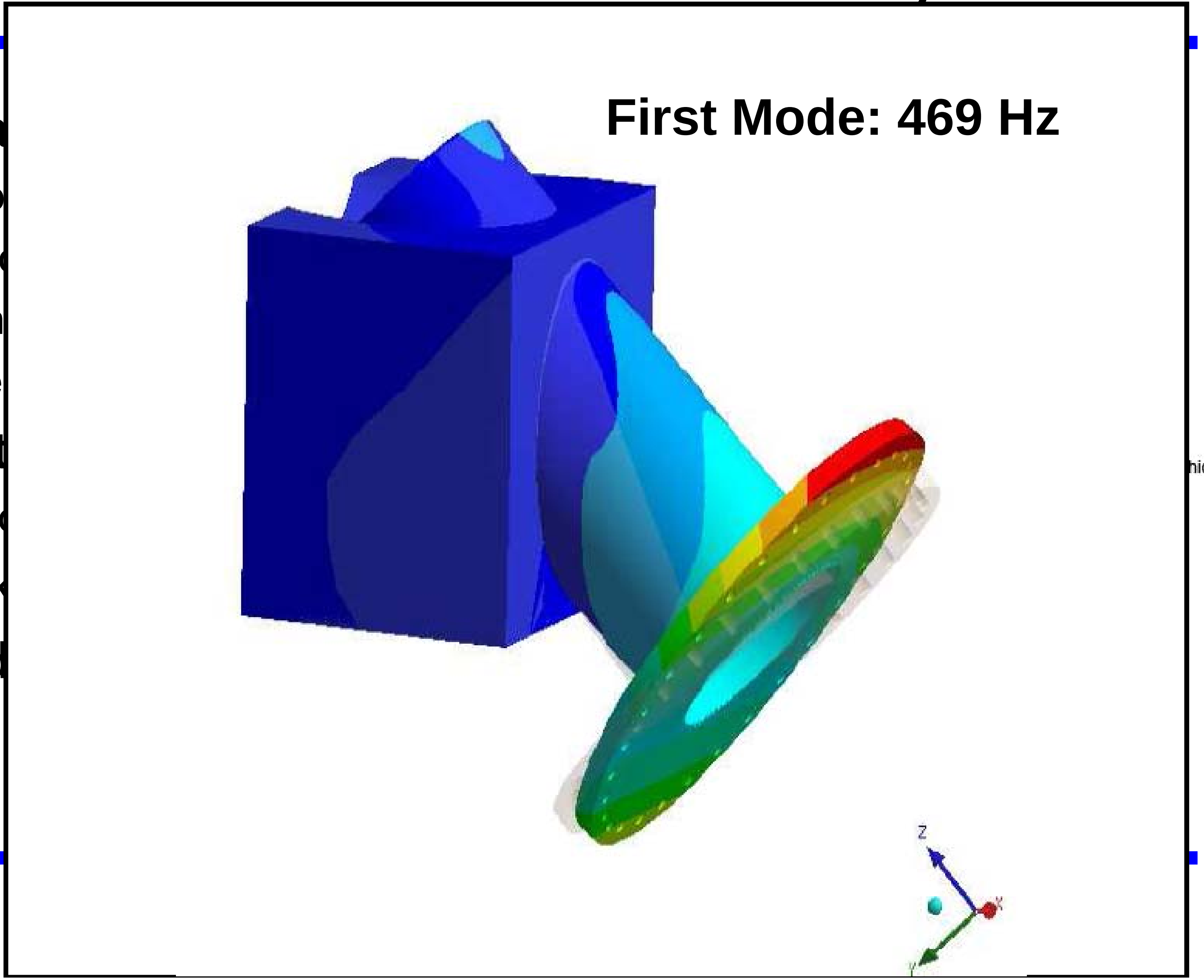
  - I d
- Quick
  to ind



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Transport to KEK

- Plan to import our equipment permanently
  - Vacuum system (metal value)
  - 2 lasers (~£12000 each)
  - Optics (~£5000 total)
  - Misc (~£5000)
- Help from KEK with paperwork would be appreciated
  - We are happy to pay for duty… (discuss)

Summary

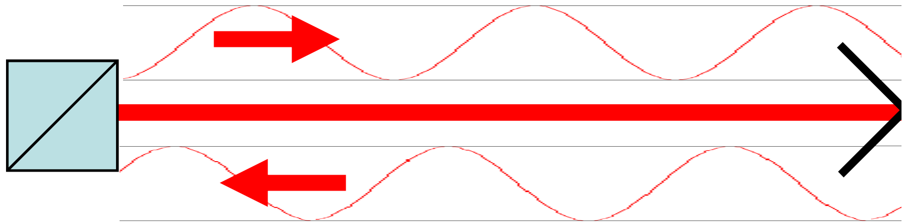
- Straightness Monitor
  - Distance Metre operation understood
  - Analysis algorithms and software in place
  - Continue investigating interferometer grids experimentally
  - Construct final system
- Data acquisition hardware
  - Built, working on DAQ software
- Vacuum Enclosure
  - Tests of bellows system performed satisfactorily
  - Verify force compensation system
  - Construction for installation at ATF2 (summer 09 / Jan 10)

Operation

Large range of measurement timescales achieved by using two modes of interferometer operation

Fixed Frequency	Relative	High Precision ~nm	Rapid readout >10kHz
Frequency Scanning	Absolute	Moderate Precision ~100nm	Slow readout ~1 per second

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

FFI Phase Calculation Method