ALBA Close gap measurement bench

Hall probe bench prototype for In-vacuum Insertion devices magnetic characterization

Carles COLLDELRAM
Lluis MIRALLES
Llibert RIBÓ
Engineering division
CELLS

Outline

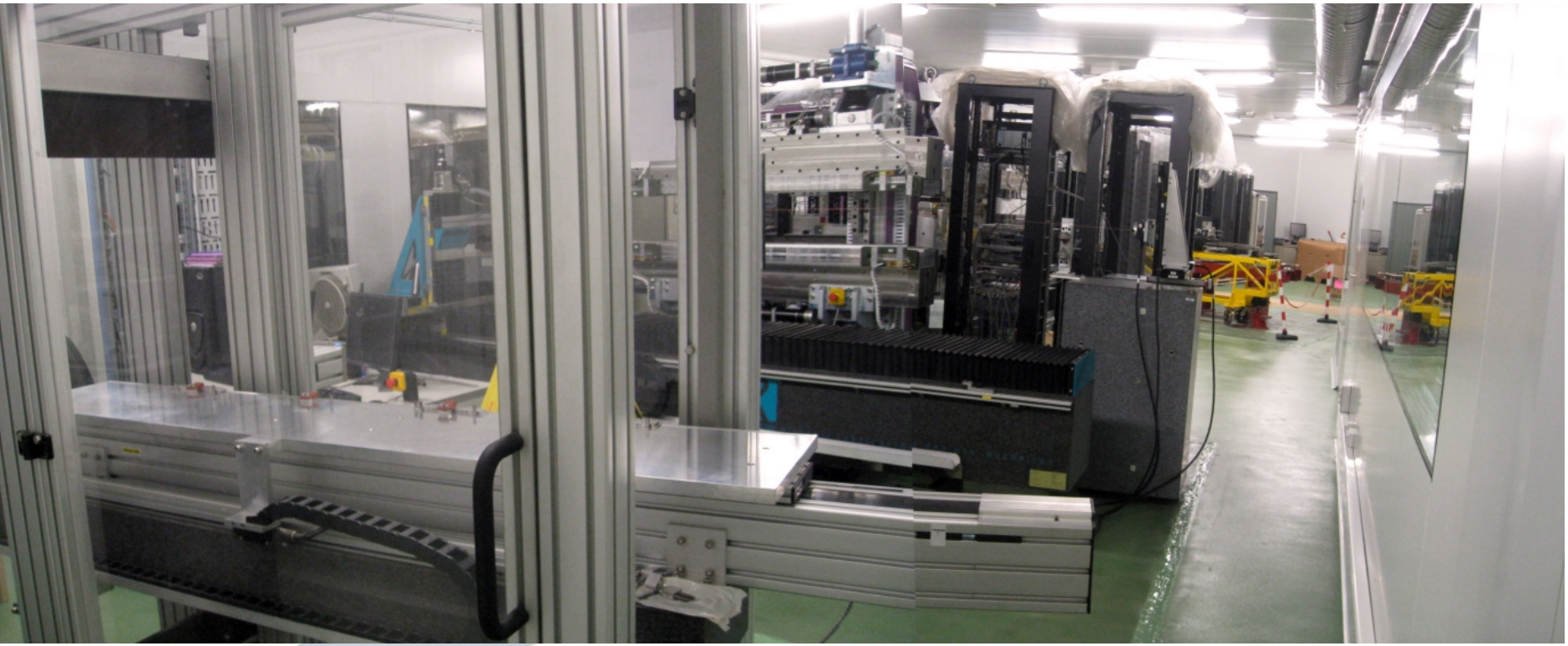
1. Insertion device status: New test bench required
2. Conceptual design
3. Prototype
4. Tests, Results
5. Next steps

ALBA Facility

- Spanish Synchrotron, near Barcelona
- 3-GeV low emittance storage ring
- Seven Beam lines:

Core Level Absorption & Emission MPW80 Spectroscopy Beamline. CLÆSS.	MPW80
Materials Science and Powder Diffraction Beam Line. MSPD.	SCW30
Macromolecular Crystallography beamline. XALOC.	IVU21
Non Crystalline Diffraction beam line . NCD.	IVU 21
Photoemission Spectroscopy and Microscopy . CIRCE.	EU62
Beamline for Resonant Absorption and Scattering. BOREAS.	EU71
Soft X-ray microscope beamline. MISTRAL.	BM

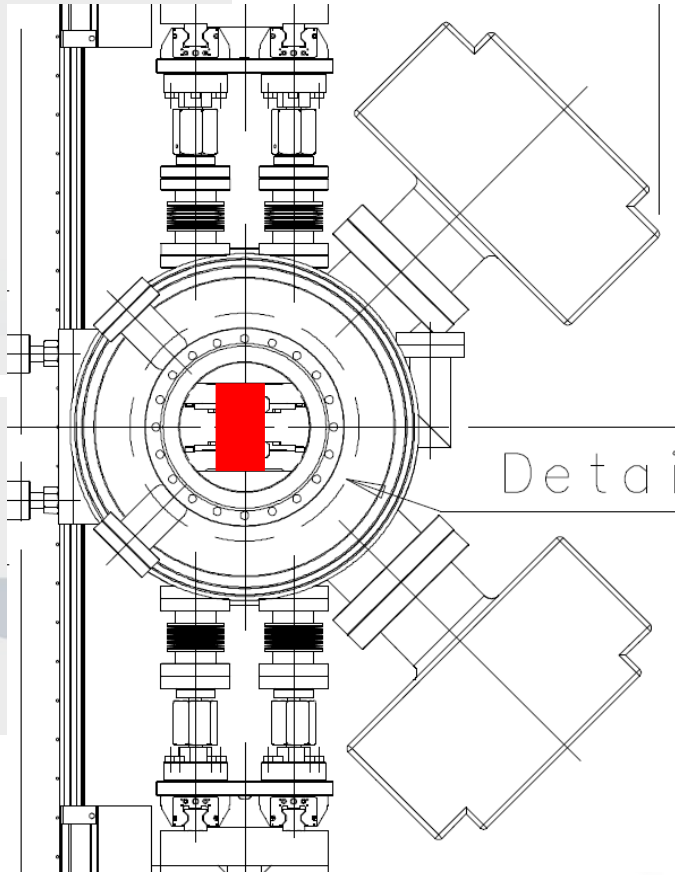
Insertion Device laboratory



- 3m long Hall probe bench
- Fixed stretched wire
- Flipping coil
- Rotating coil
- Helmholtz coil
- Second slab for future laboratory upgrades

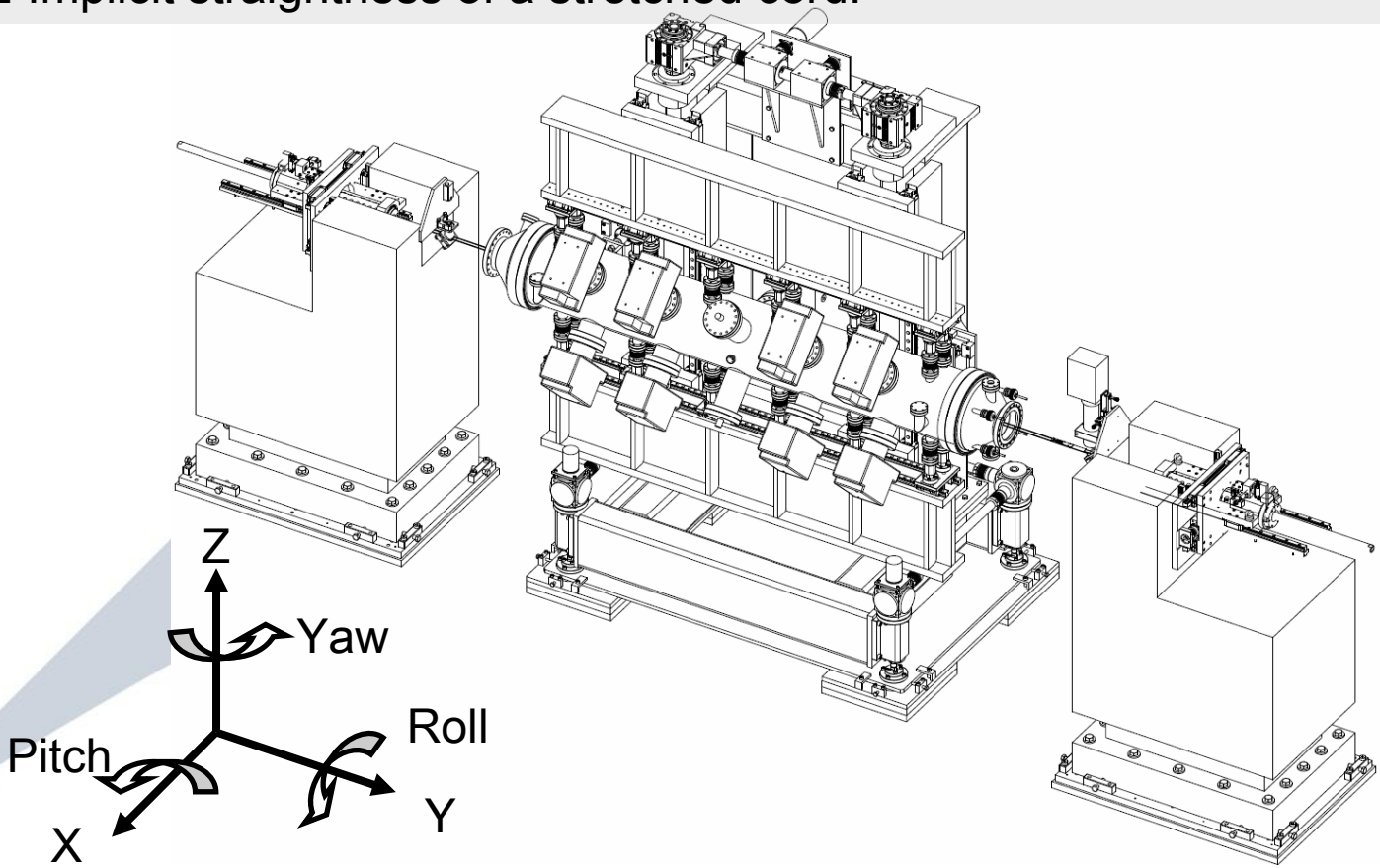
New bench: Hall probe bench to measure In-vacuum ID's

- Specifications
  - Measuring range: 3m.
  - Positioning accuracy, Y: ± 50μm.
  - Positioning measurement accuracy, Y: ± 10μm
  - Transversal guidance accuracy, X,Z: ± 25μm
  - Pitch, Roll & Yaw guidance errors:
    - 50μrad, 100μrad, 50μrad.
- Additional constrains
  - Accessibility.
  - Measurement under vacuum
  - Tight cross section: 5mm x 25 mm rectangular



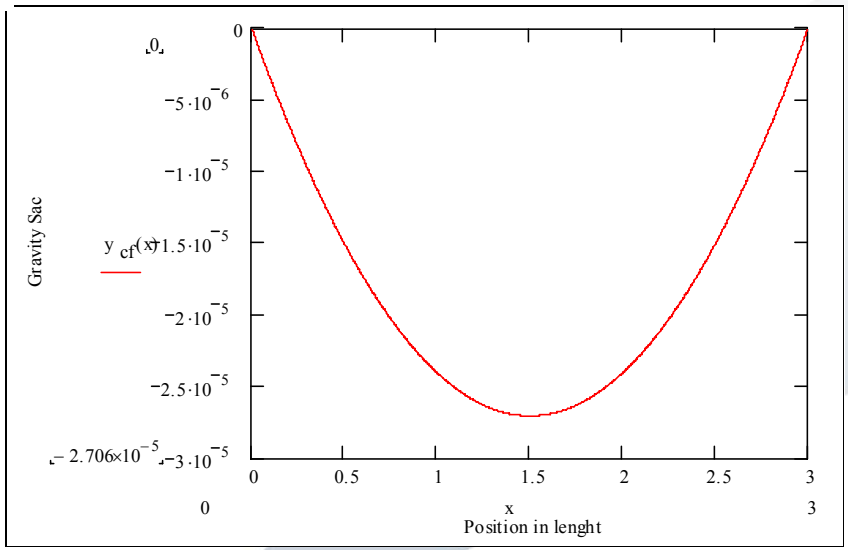
Conceptual design proposal

- Guidance and support: Stretched carbon fiber cords.
  - Sag minimization:
  - Implicit straightness of a stretched cord.



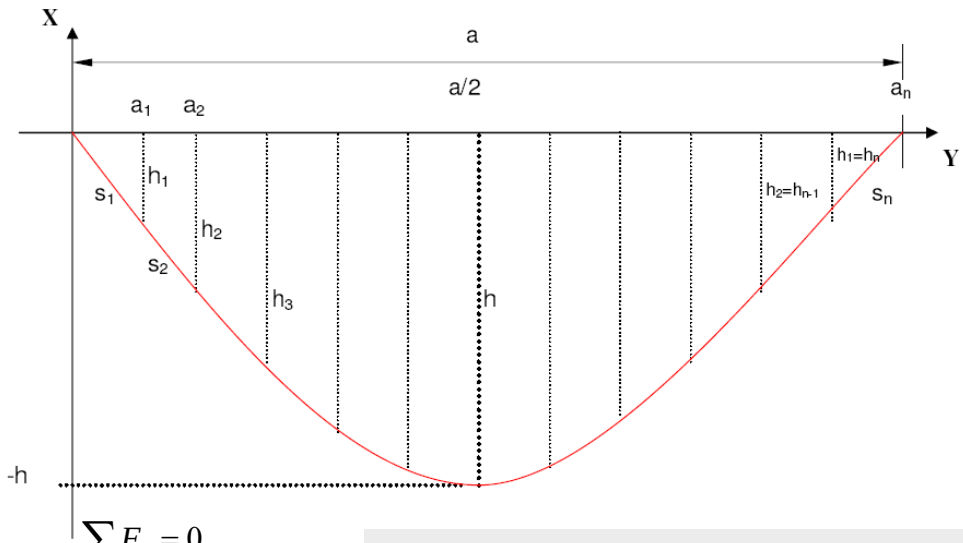
Conceptual design proposal: validation

- Guidance: Stretched carbon fiber cords.
  - Sag minimization:
    - Catenary calculation: Carriage weight: 10g.



$$y_{cf}(x) := \frac{T_0}{g \cdot \rho_{1cf}} \left[\cosh\left[\rho_{1cf} \frac{g}{2 T_0} (2x - a) \right] - \cosh\left(\rho_{1cf} \frac{g\, a}{2 T_0} \right) \right]$$

- Sag: 25µm.
- σ = 1,1 GPa
- T_0=3500N.



$$\sum F_x = 0$$

$$\sum F_y = 0$$

$$\sum M_n = 0$$

$$S_n^{\,2} = a_n^{\,2} + (h_n - h_{n-1})^2$$

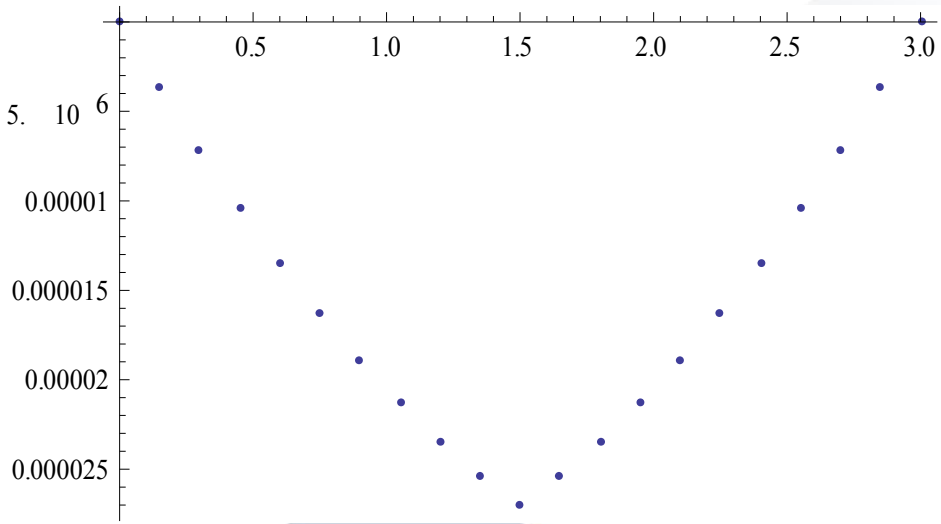
$$a_1 = a_2 = \ldots = a_n = a/n$$

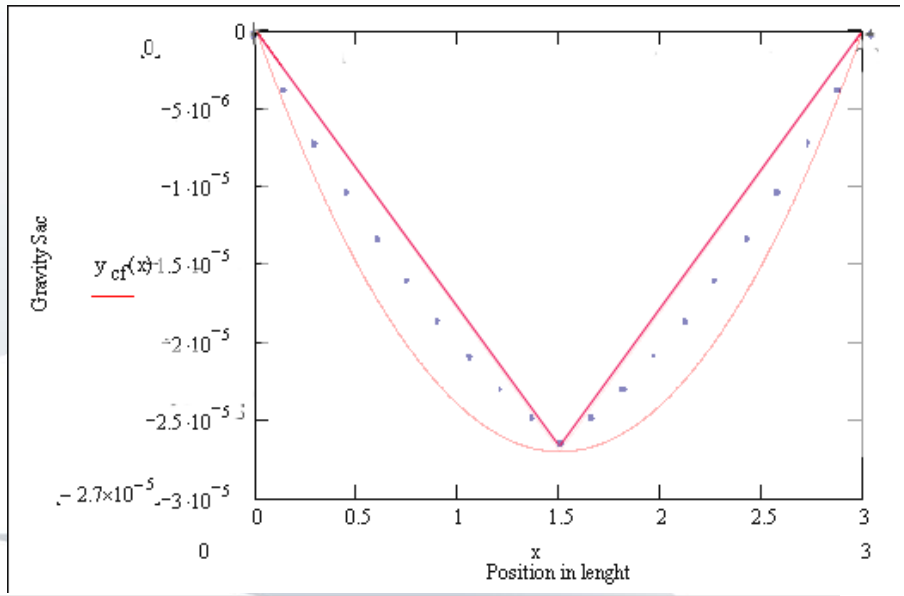
Second order equation system, can be linearized:

$$\underset{h \to 0}{Lim} S_n = a/n = a_n$$

Conceptual design proposal: validation

- Guidance: Stretched carbon fiber cords.
  - Sag minimization:
    - Catenary calculation: Carriage weight: 10g.





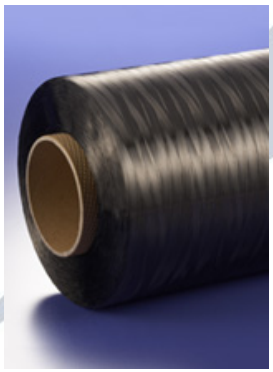
- Sag: 25µm.
- σ = 1,712 GPa
- T0=5138N

- Comparison:
  - Numerical calculation allows simulate carriage weight at conservative side.

Conceptual design proposal: Validation

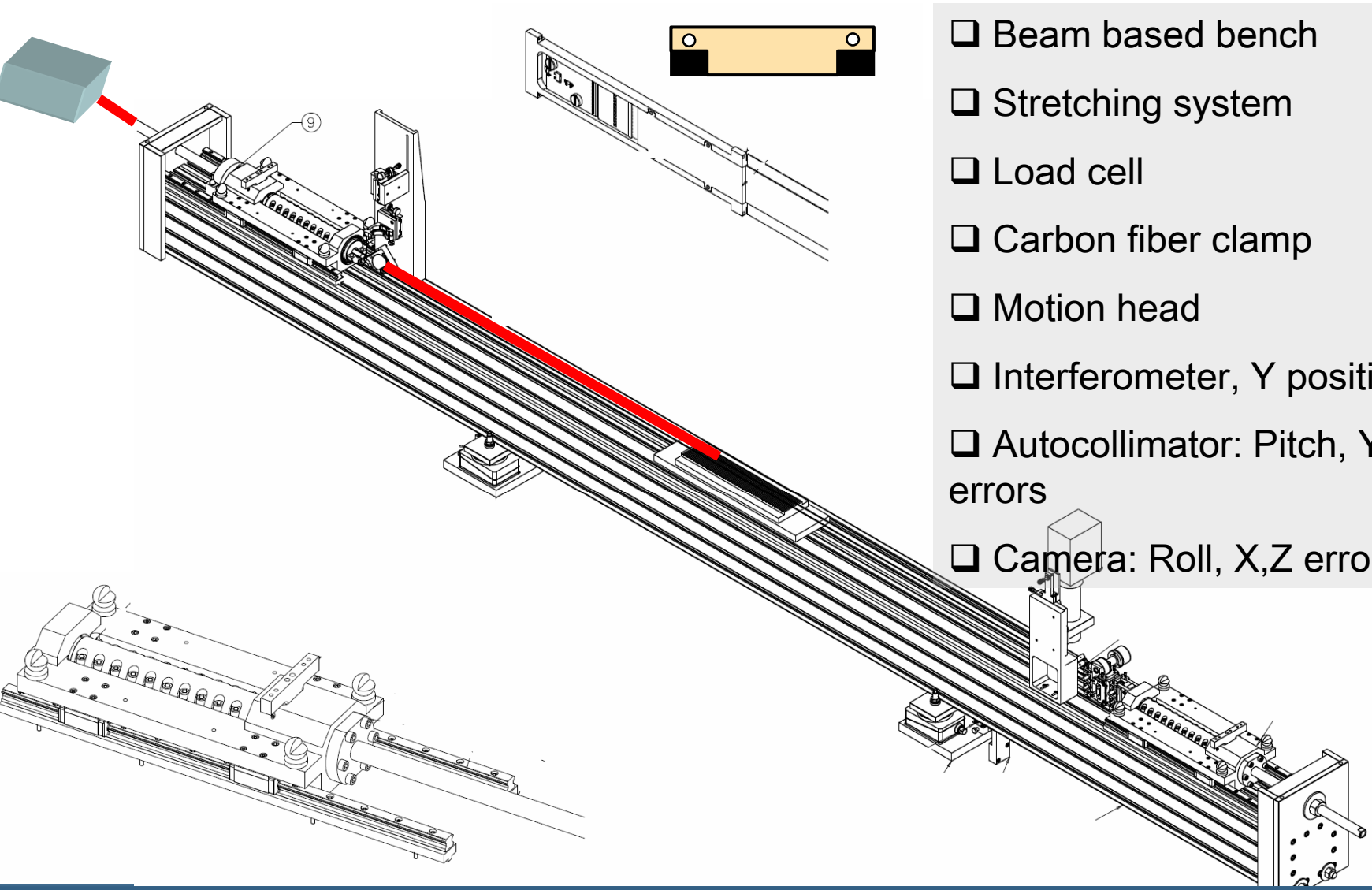
- Guidance: Stretched carbon fiber cords.
  - Carbon fiber selection: 3000 MPa tensile strength standard flat tape.
  - Manufacturing process.

- Tensile strength: 4 GPa – 6 GPa
- Composition:
  - 60% - 70% fiber
  - 40% - 30% epoxy
- Composites: tensile strength: 2 – 3 GPa



- Manufacturing:
  - Pultruded:
    - Standard dimensions: Does no fit
    - Customized: minimum order not afordable
    - Modify standard: Microfissuring, from flat tape
  - In-house manufacturing:
    - Needs mold, very complex.

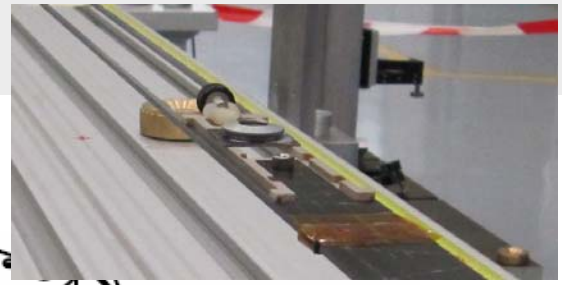
Design: Prototype development

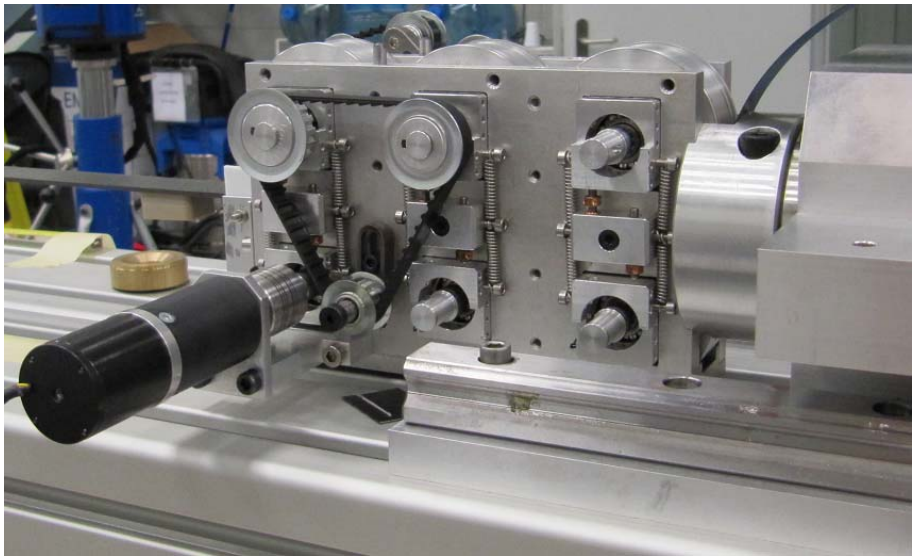


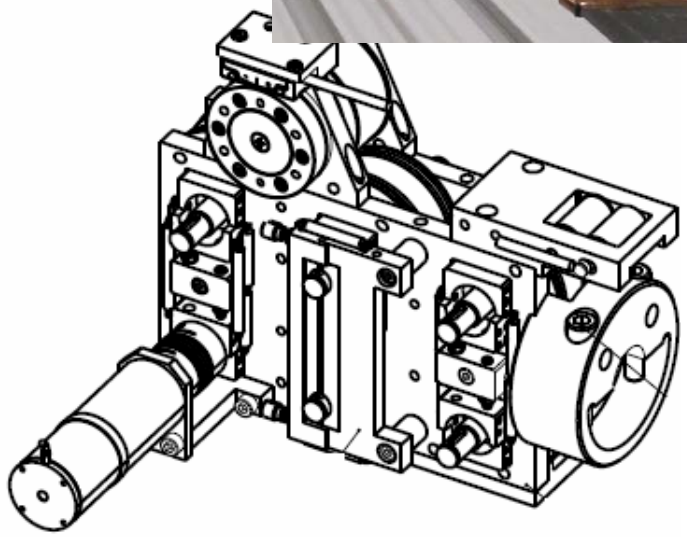
- Beam based bench
- Stretching system
- Load cell
- Carbon fiber clamp
- Motion head
- Interferometer, Y positioning
- Autocollimator: Pitch, Yaw errors
- Camera: Roll, X,Z errors

Design development: Motion head

- Motion head
  - Euler friction equation based roller mechanism
  - Integrated rotary encoder as ancillary measuring system.
  - Pushing, puller tape: Carbon fiber 0,3 x 24 mm tape
    - Handmade manufactured.







Manufacturing issues

- Special features: Guiding Carbon fiber
  - Modification of standard tape
    - 3 GPa tensile strength
    - 20 μm thickness tolerance
  - Water cutting with mm's of excess
    - Special fixing tooling.
  - Fine machining, Grinding/Milling, requires special tooling.

- Special features: Motion tape carbon fiber
  - Handmade
  - 45º filaments net
  - Epoxy matrix, cured with autoclave
  - Hand polished

Assembly

Interferometer

Motion head

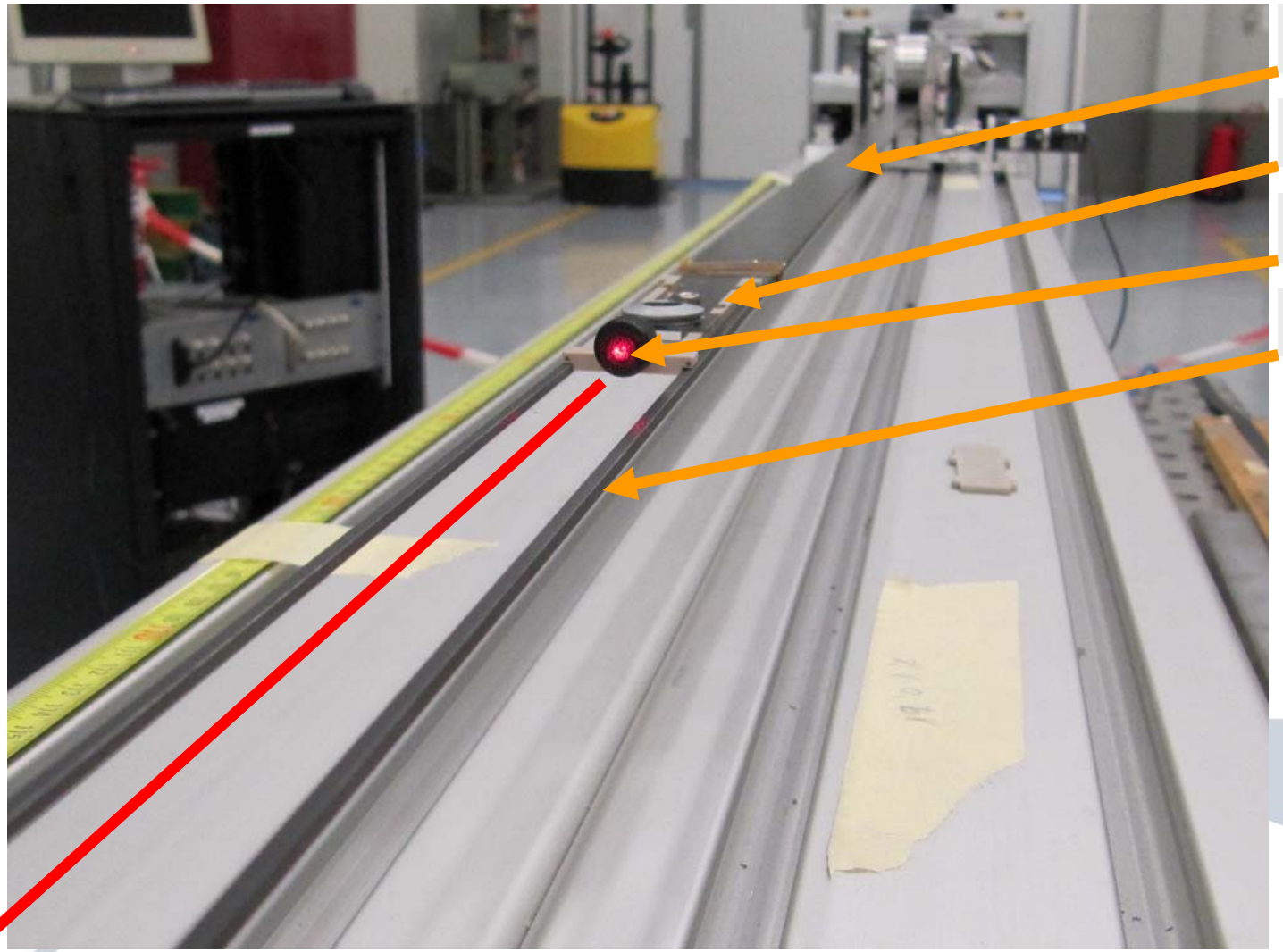
Stretching system

Clamp

Carbon fiber

Load cell

Assembly

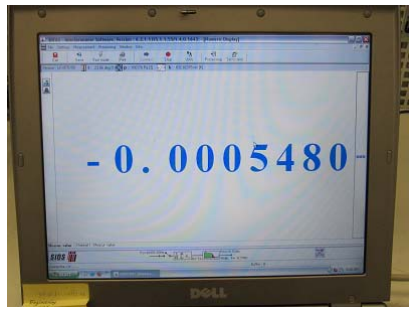


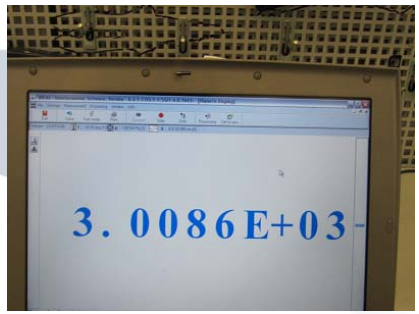
Motion tape

Hall probe carriage

Cateye

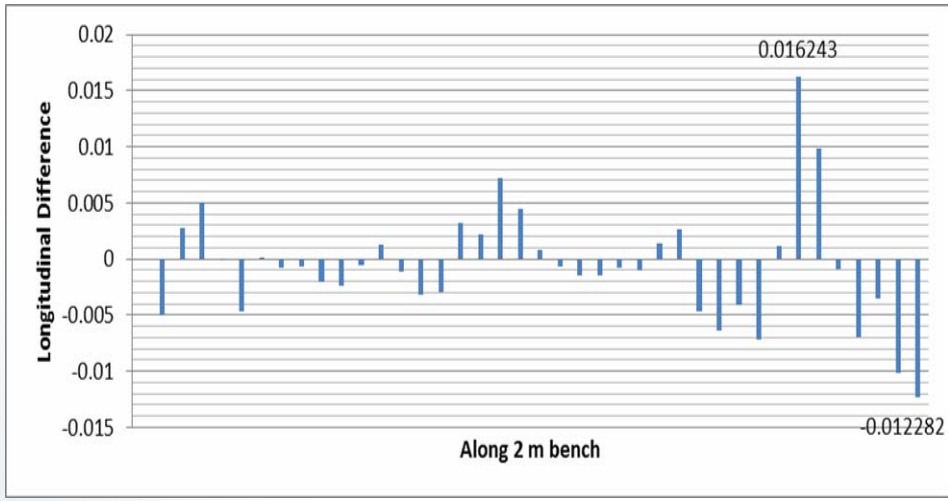
Carbon fiber guide



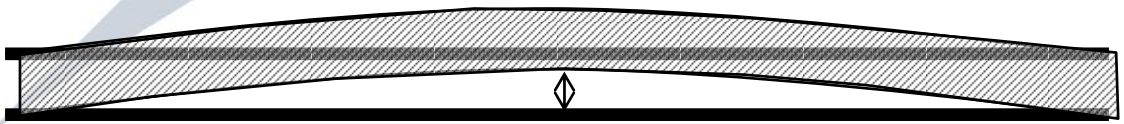


Assembly, Adjustment and TEST

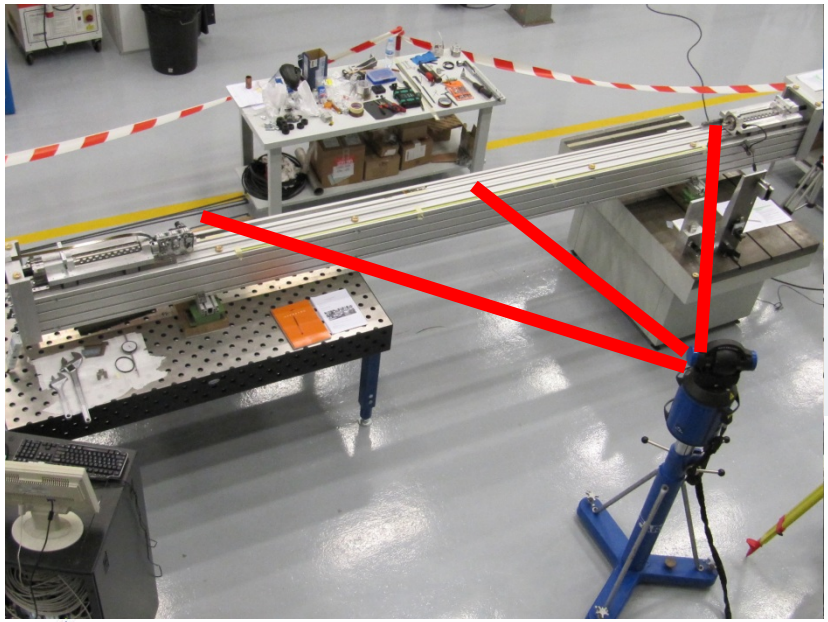
- Stretching the fiber
  - Sag vs stretching force measured with optical level. See attached table.
- Interferometer reading up to 3 m. Manually. Accuracy: 20µm
- Motion system works up to 2,3 m
  - Lateral bending: guidance lost.
- Manufacturing problems
  - Gap between fiber 0,4 mm straightness error
  - Carbon fiber width: 0,4 mm error
- Motion tape: 5 mm transversal bending



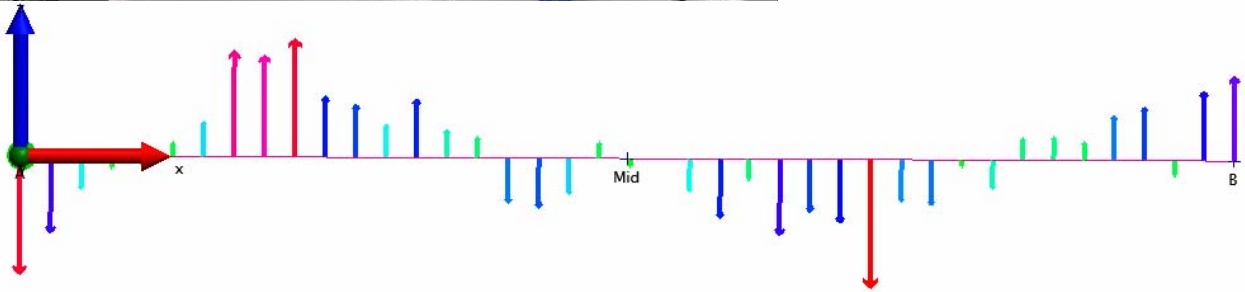
TENSION	SAG
N	mm
0	5.715
49	4.26
1000	0.145
2000	0.09
3000	0.065
4000	0.045
5000	-0.005
6000	-0.005

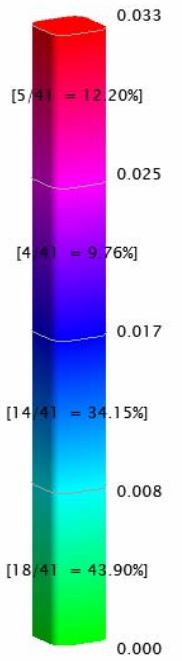


TESTS

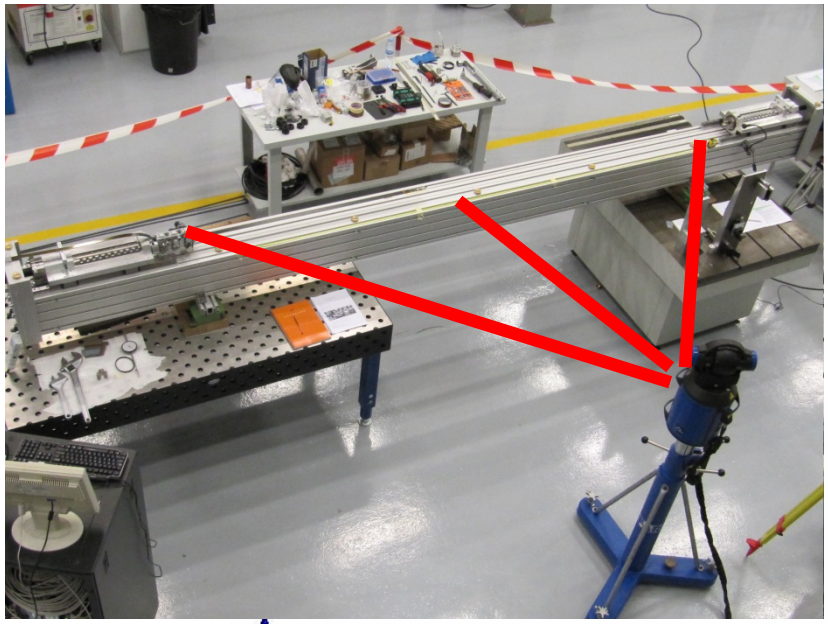


- Guidance (over 2m): with Laser Tracker
  - Vertical, Z: ±30µm peak to valley



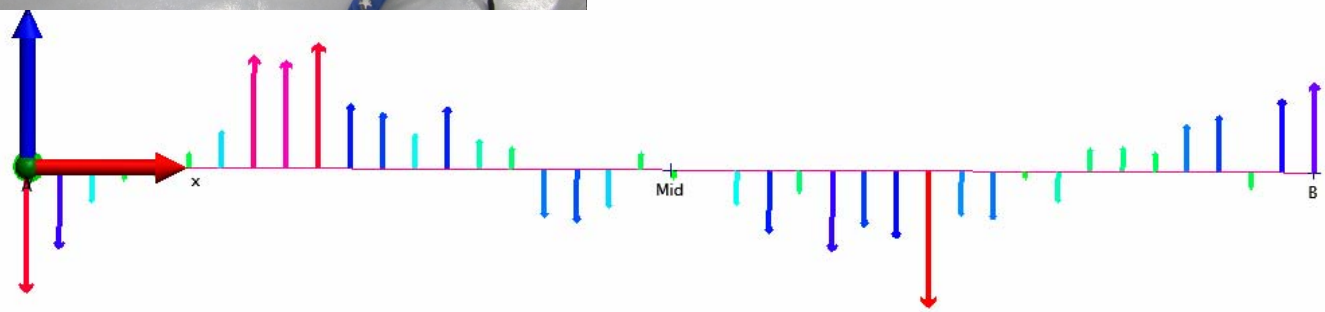


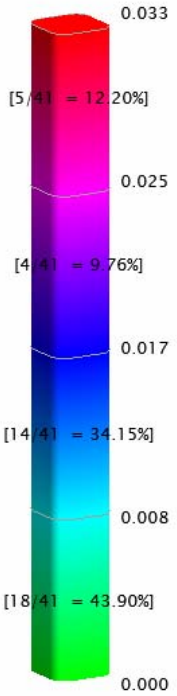
TESTS



- Guidance (over 2m): with Laser Tracker
  - Transversal, X: ±120µm peak to valley

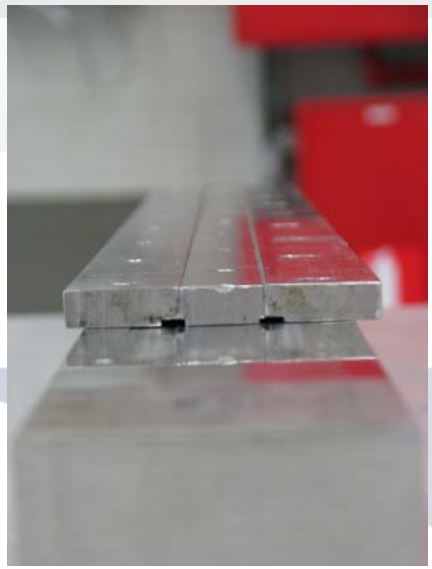
Statistic	dX	dZ	Mag
Min	-0.091	-0.033	0.003
Max	0.148	0.031	0.15
RMS	0.07	0.015	0.072

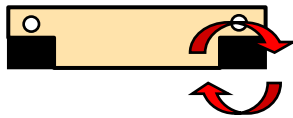




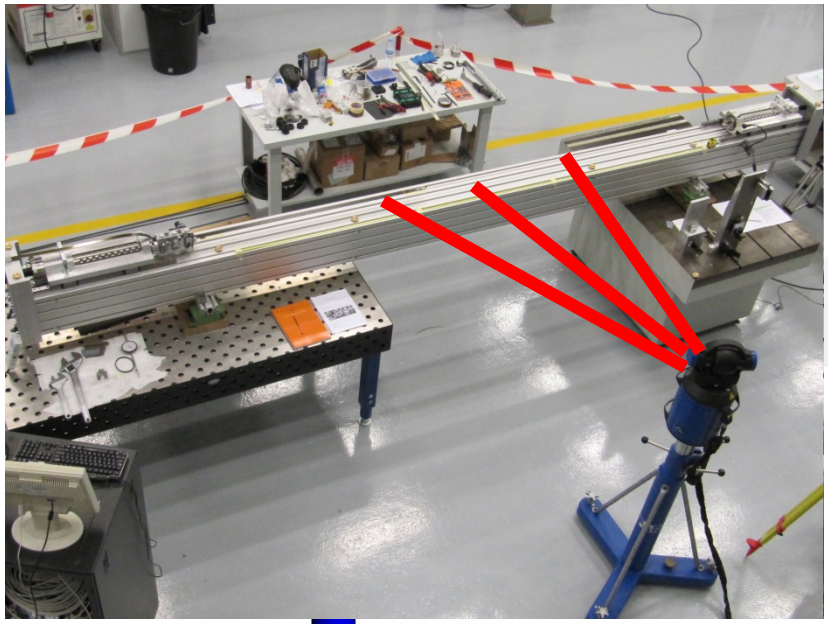
Improvements

- ❑ The transversal errors are induced by the manufacturing errors of the carbon fiber guide.
- ❑ Those errors are originated by the grinding tooling supporting the fiber, the fixation was not good enough and it allowed displacements of the fiber during machining.
- ❑ New tooling prototype was manufactured for a 700 mm range fiber machining.
- ❑ The straightness is better than 10 µm

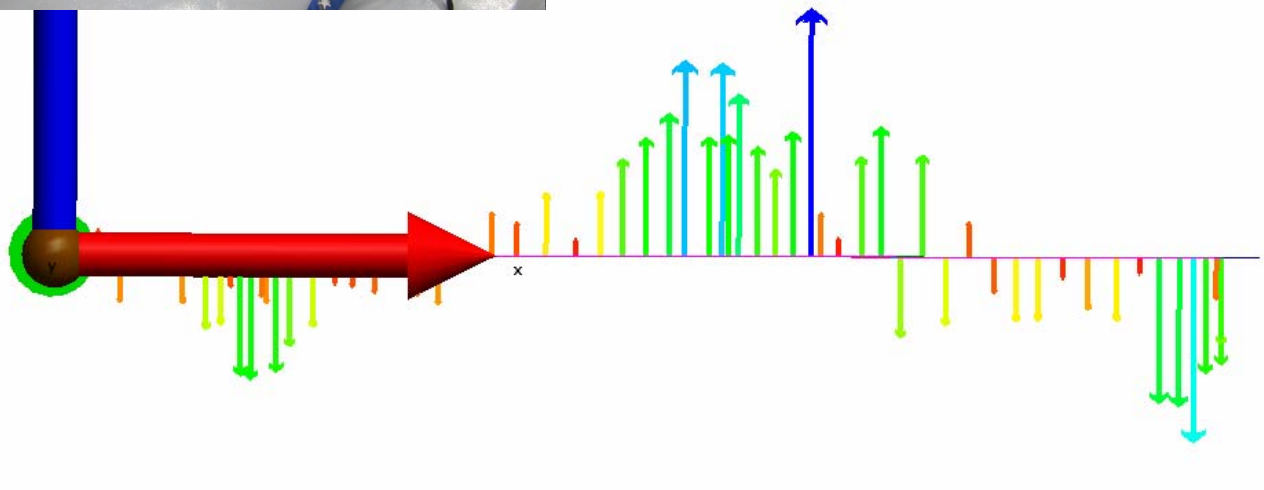




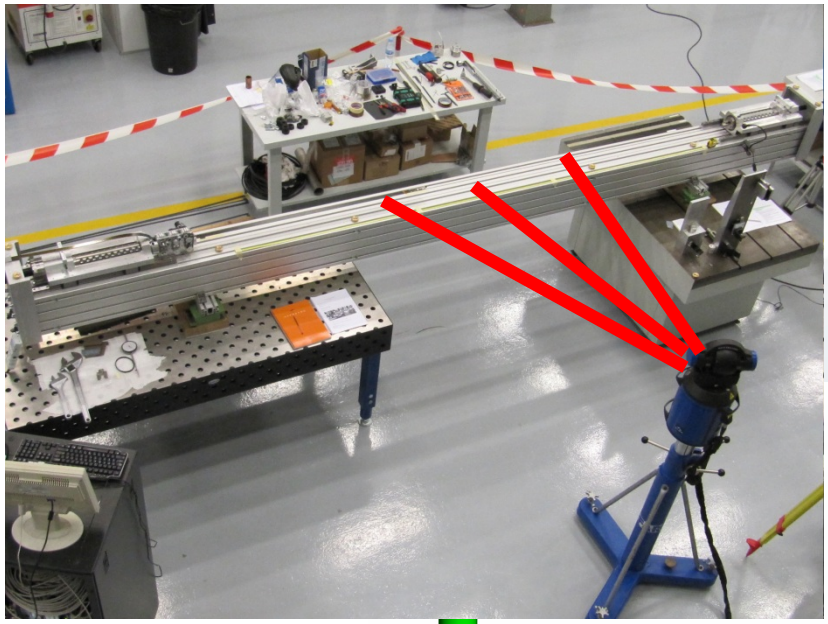
TESTS



- Guidance (over 700mm): with Laser Tracker
  - Vertical, Z: ±19µm peak to valley

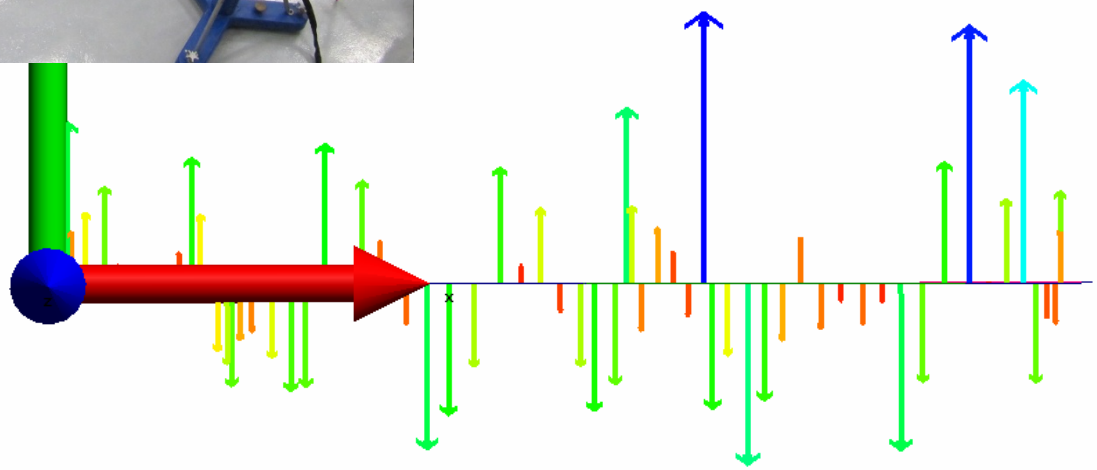


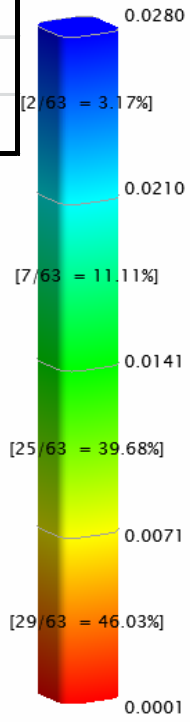
TESTS



- Guidance (over 700mm): with Laser Tracker
  - Transversal, X: ± 23µm peak to valley

Statistic	dX	dZ	Mag
Min	-0.0187	-0.0164	0.0007
Max	0.028	0.0221	0.0357
RMS	0.0104	0.0083	0.0133



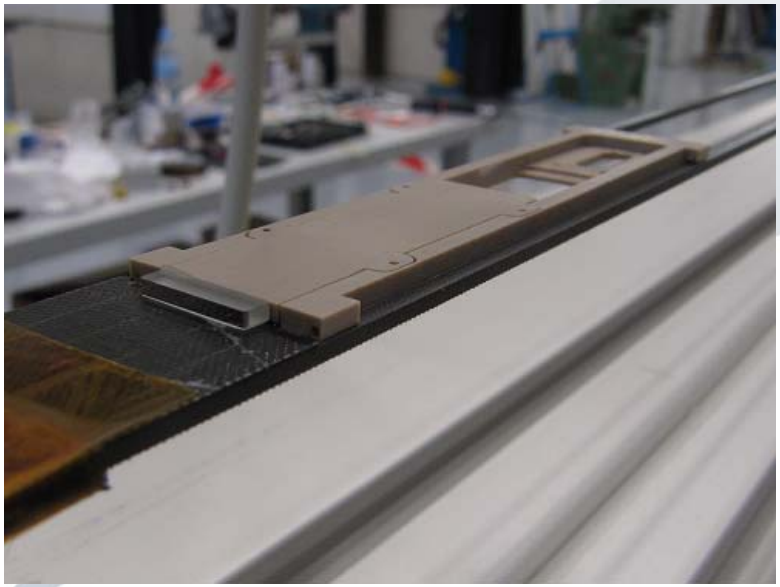


Next steps

- Next steps
  - Manufacture new tooling for 3 m functional range fiber
  - Measure the new fiber guidance.
  - Design a prototype for the tube.

On going tests

- Autocollimator Yaw, Pitch, Roll errors guidance
  - Small mirrors, difficult to align
  - Working to get it



Conclusions

- The main principle works
  - It is possible to minimize the catenary errors by stretching carbon fiber guide cords.
  - It is possible to have a good guidance with this carbon fiber cords
  - It is possible to accurately read the carriage position with a interferometer with a very small cateye (<1mm)
  - After implementation and crosscheck of the vacuum pipe the accomplishment of the vacuum measurement requirement will be set.

Anowkledgements

J. Ferrer workshop group leader
F. Rey Alignment group leader
JC. Martinez metrology lab.
Dr. Josep Campmany Insertion device section Head

THANKS' FOR YOUR ATTENTION