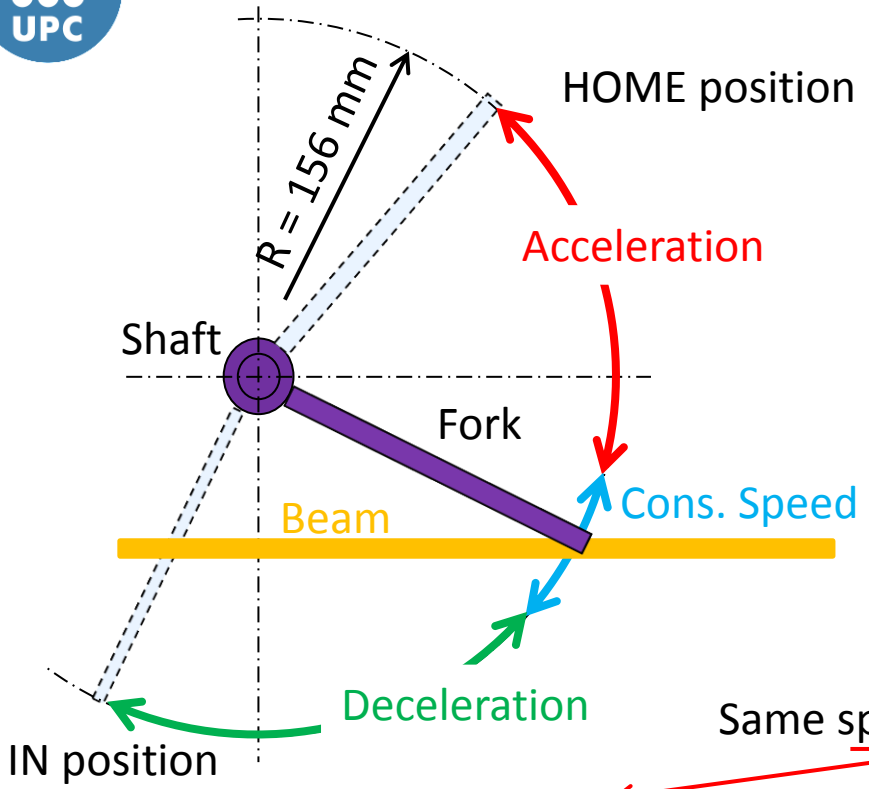
Review of the New CERN Fast Wirescanner

Mechanical aspects important for determining the final wire position accuracy

Juan Herranz

- Wire Scanner general considerations
- Sources of uncertainty
- Strategy to minimize uncertainties
- Summary
- Conclusions

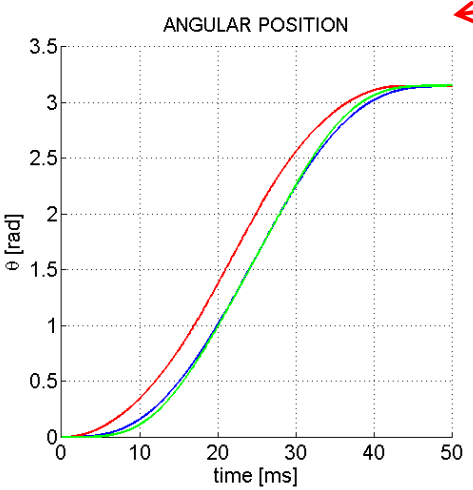
General considerations

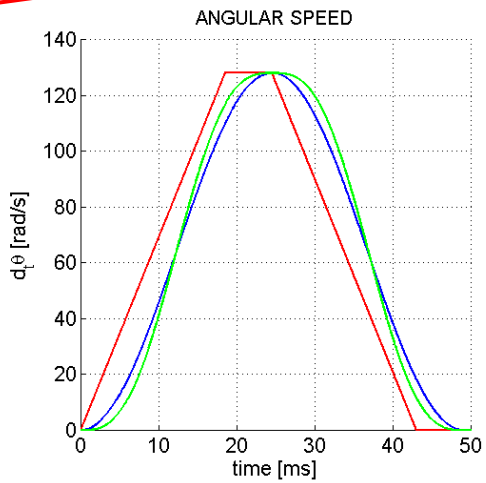


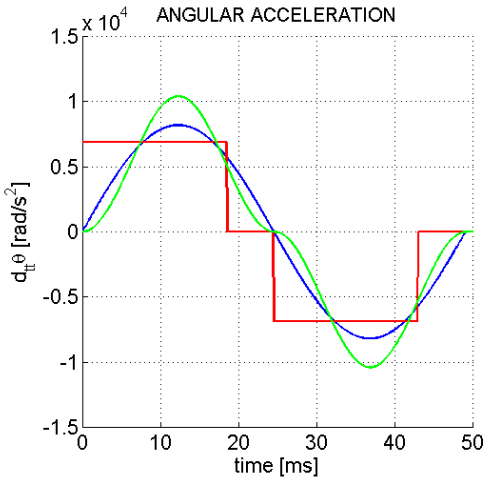
SPS configuration

Peak lin. speed	20 m/s
Fork length	156 mm
Peak ang. speed	128.20 rad/s
Peak ang. acceleration	6700 - 10000 rad/s^2
Tang. acceleration	**95 – 159 g**
Normal acceleration	260 g

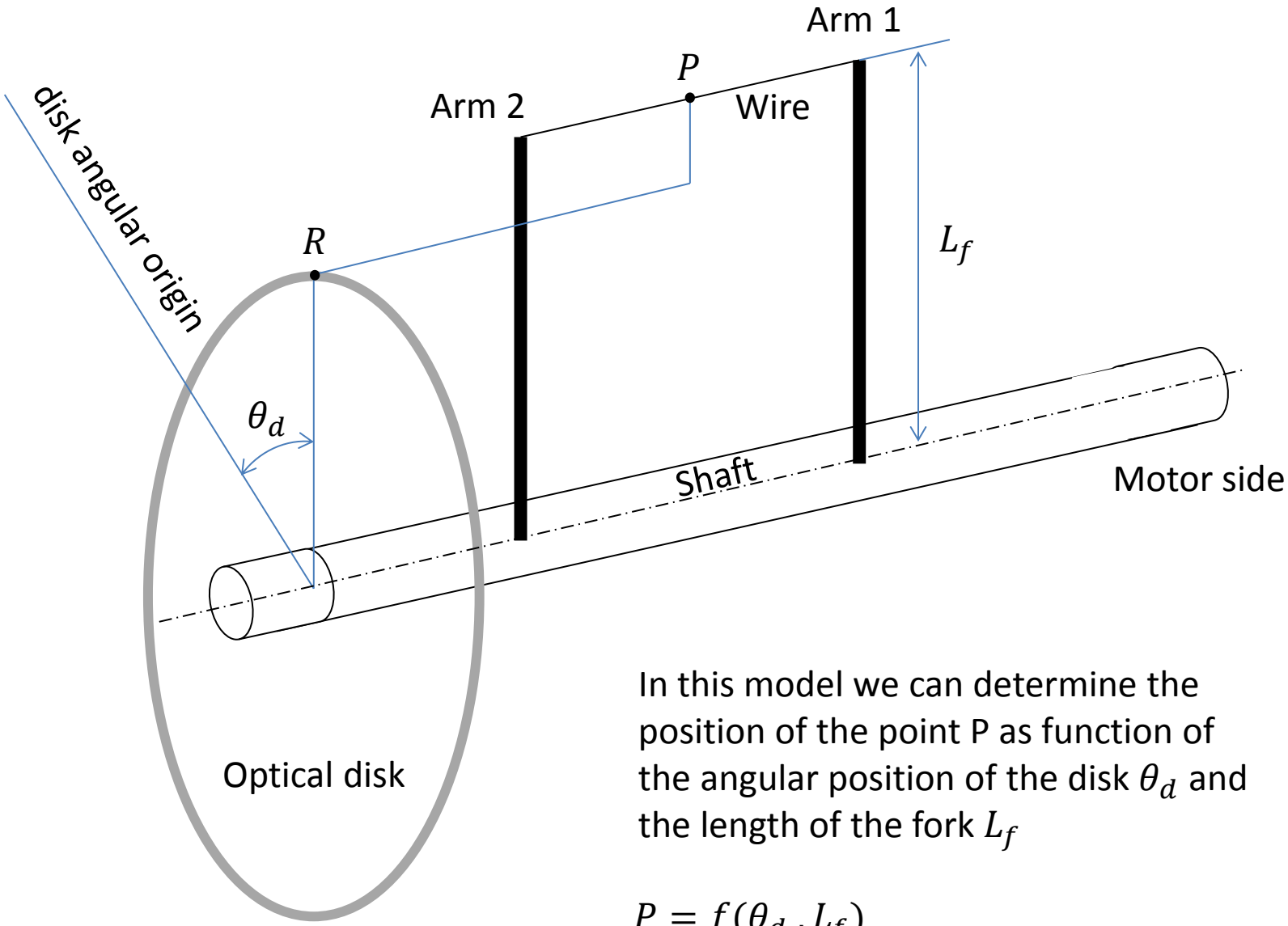
Same speed and position but different pick acceleration







General considerations

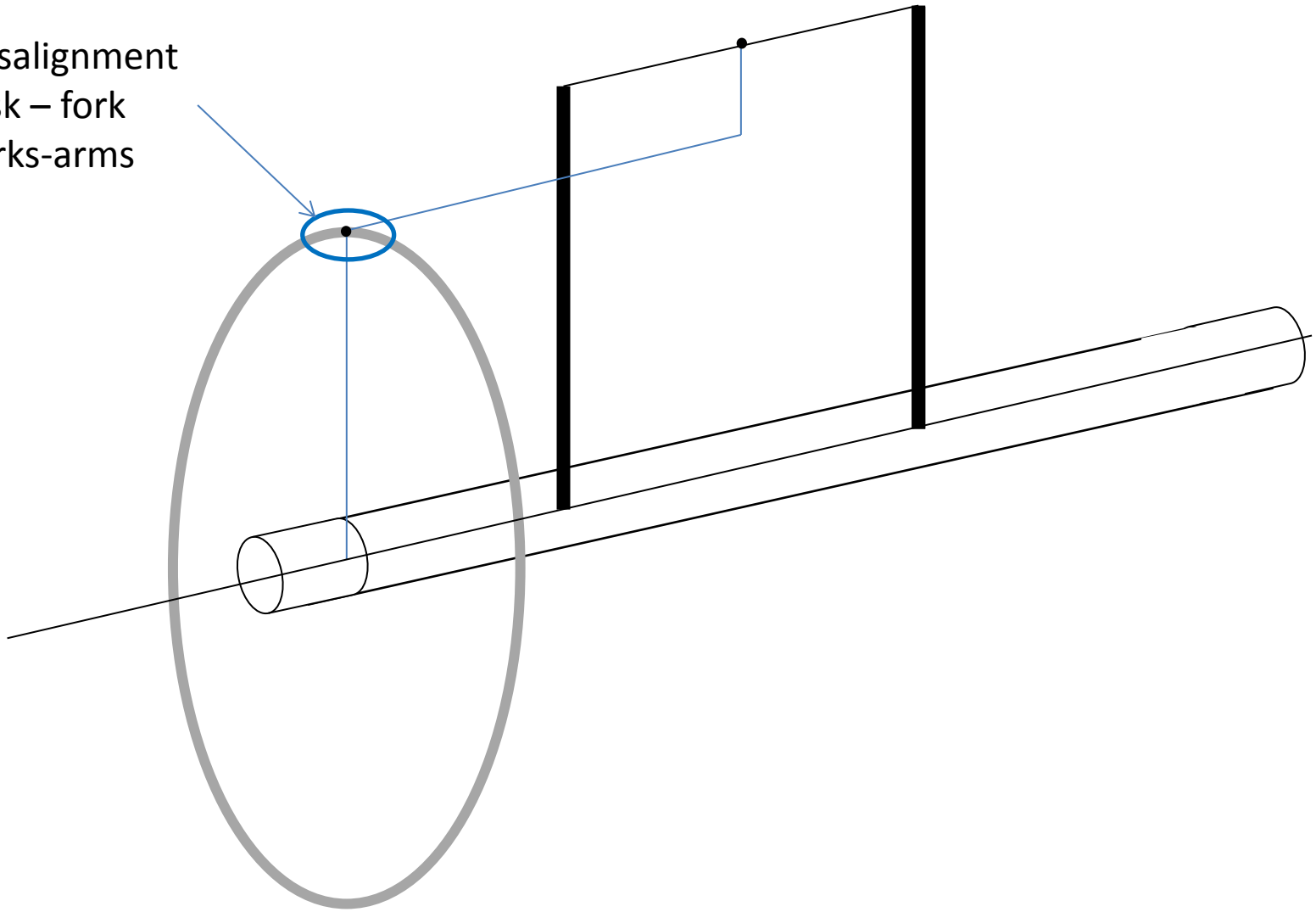


In this model we can determine the position of the point P as function of the angular position of the disk θ_d and the length of the fork L_f

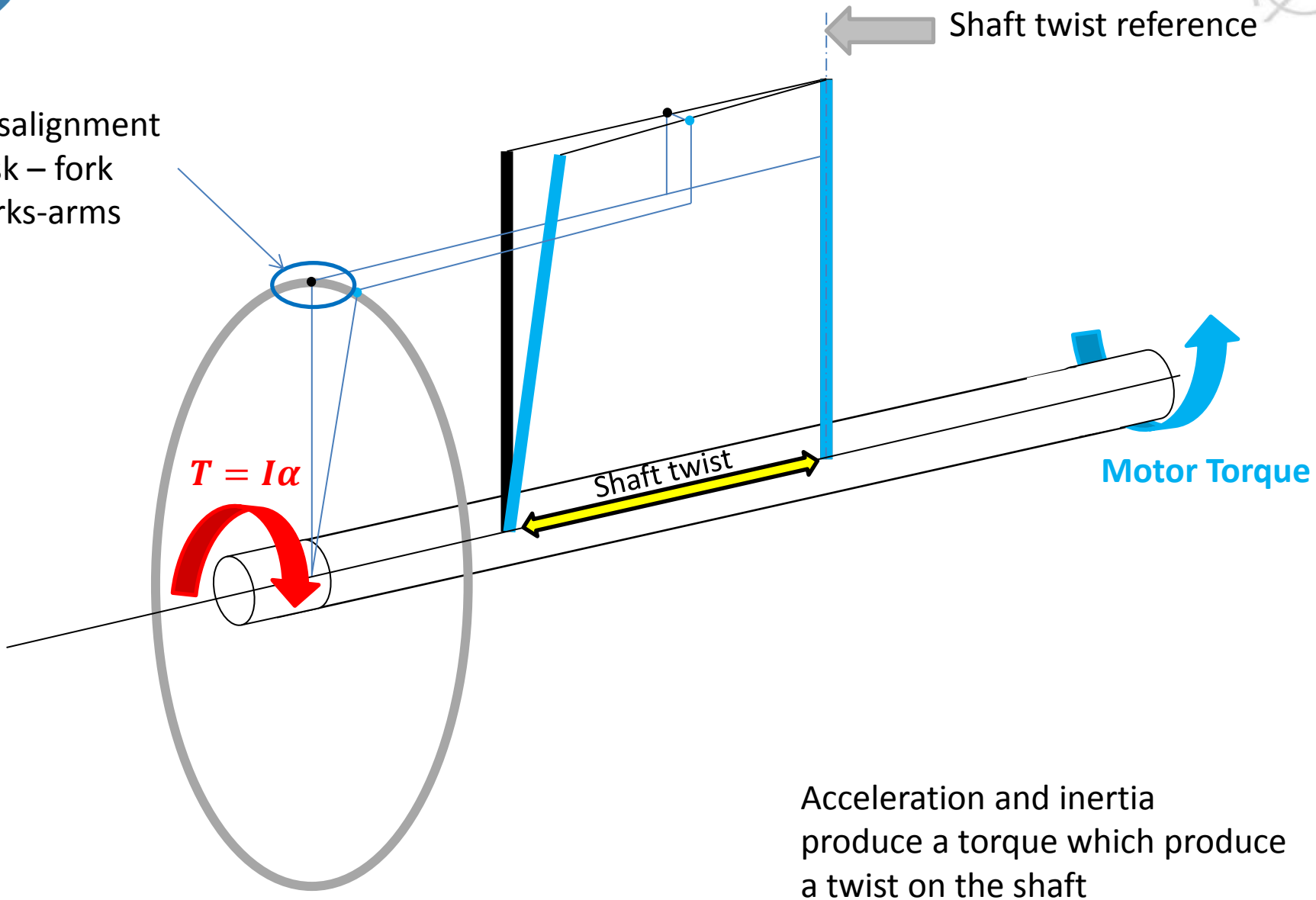
$$P = f(\theta_d , L_f)$$

Sources of uncertainty

Misalignment
Disk – fork
Forks-arms

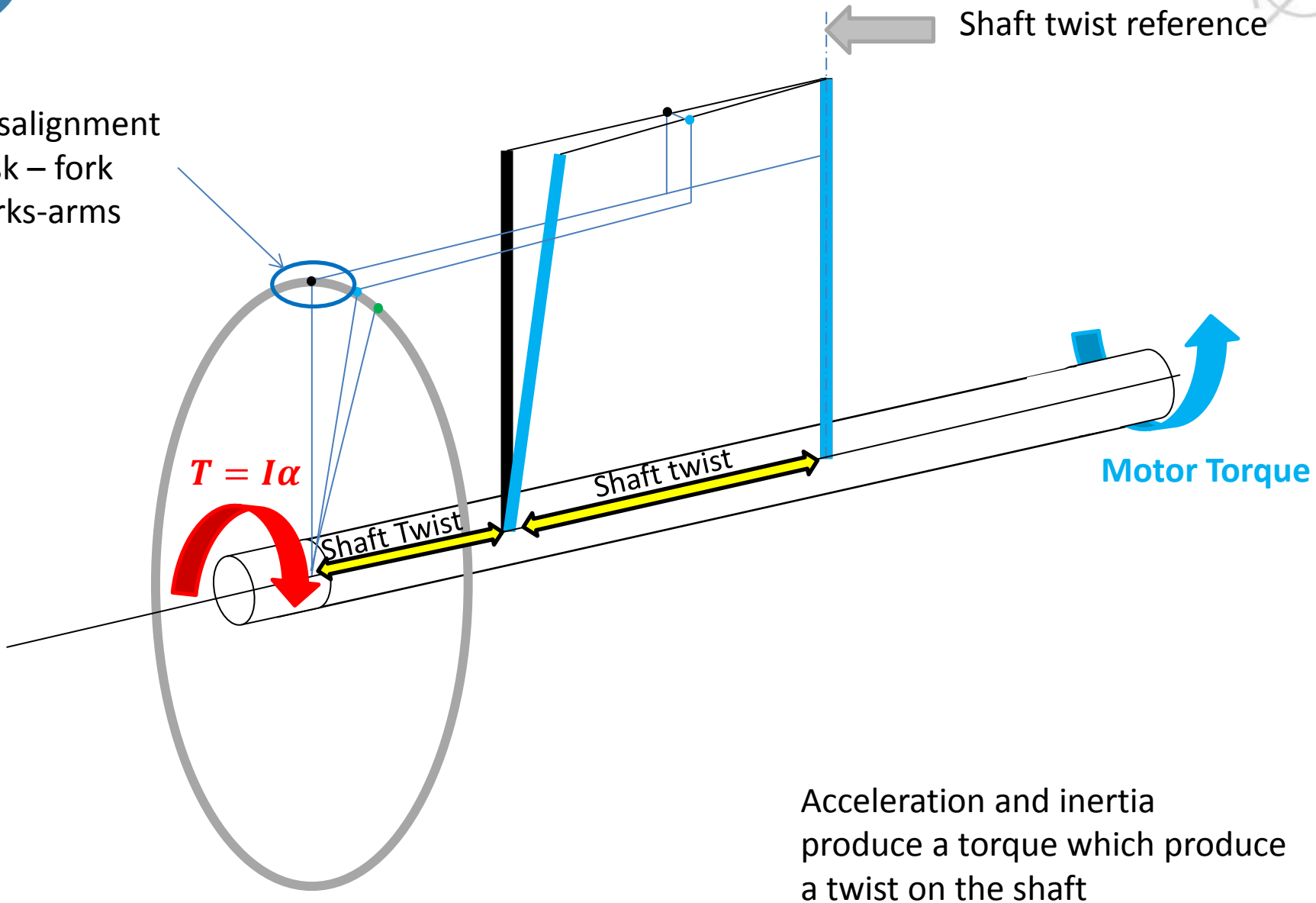


Sources of uncertainty



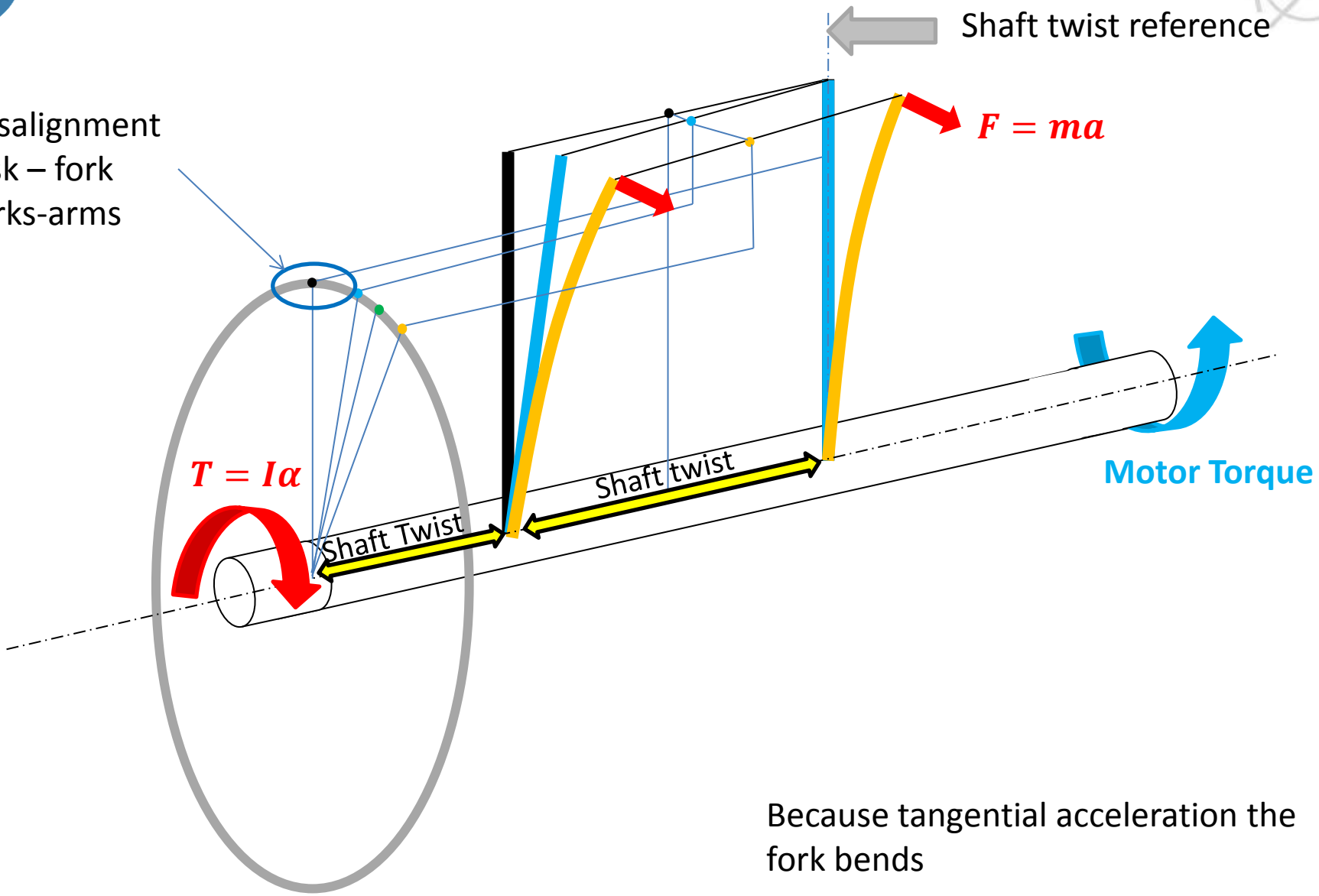
Acceleration and inertia produce a torque which produce a twist on the shaft

Sources of uncertainty



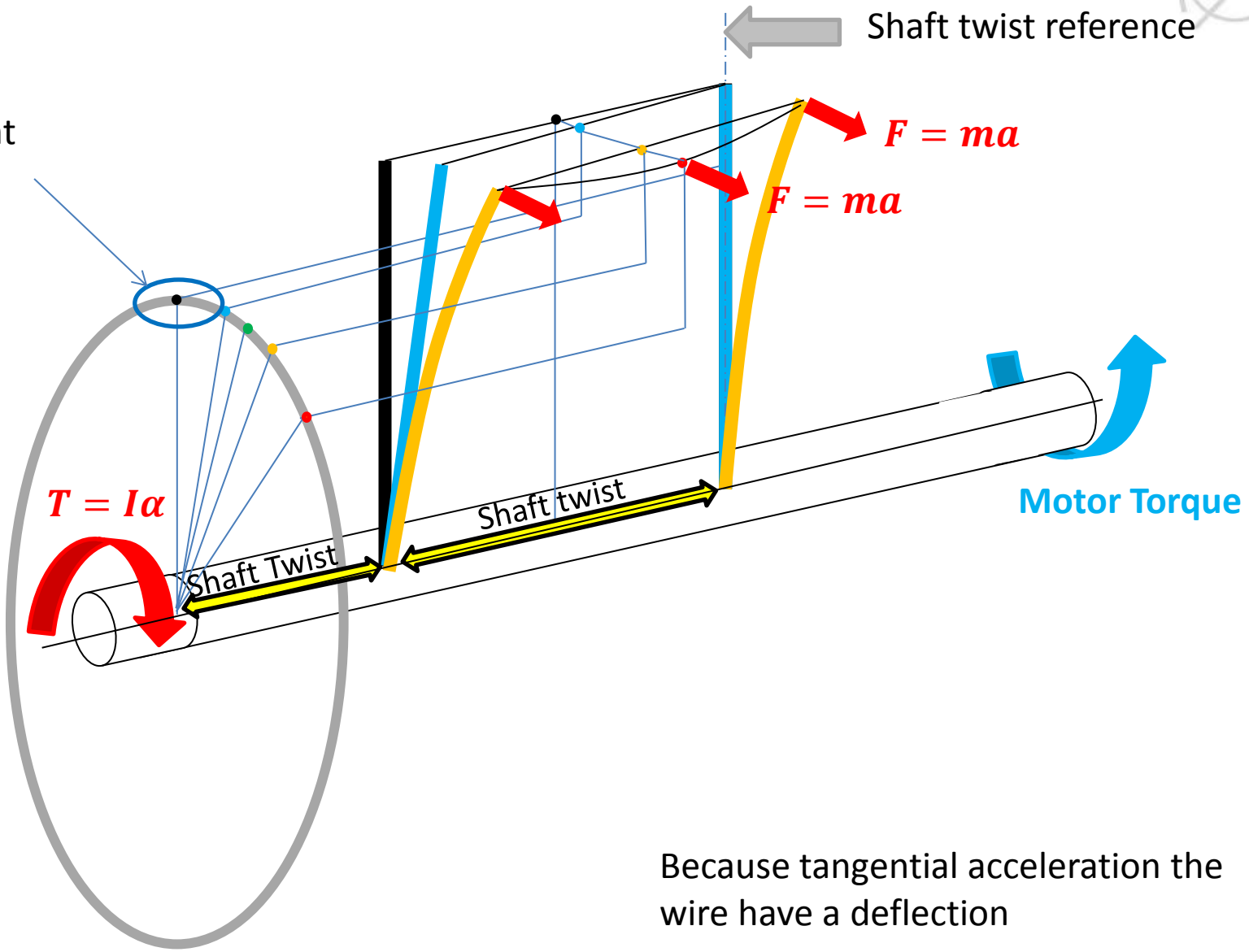
Acceleration and inertia produce a torque which produce a twist on the shaft

Sources of uncertainty



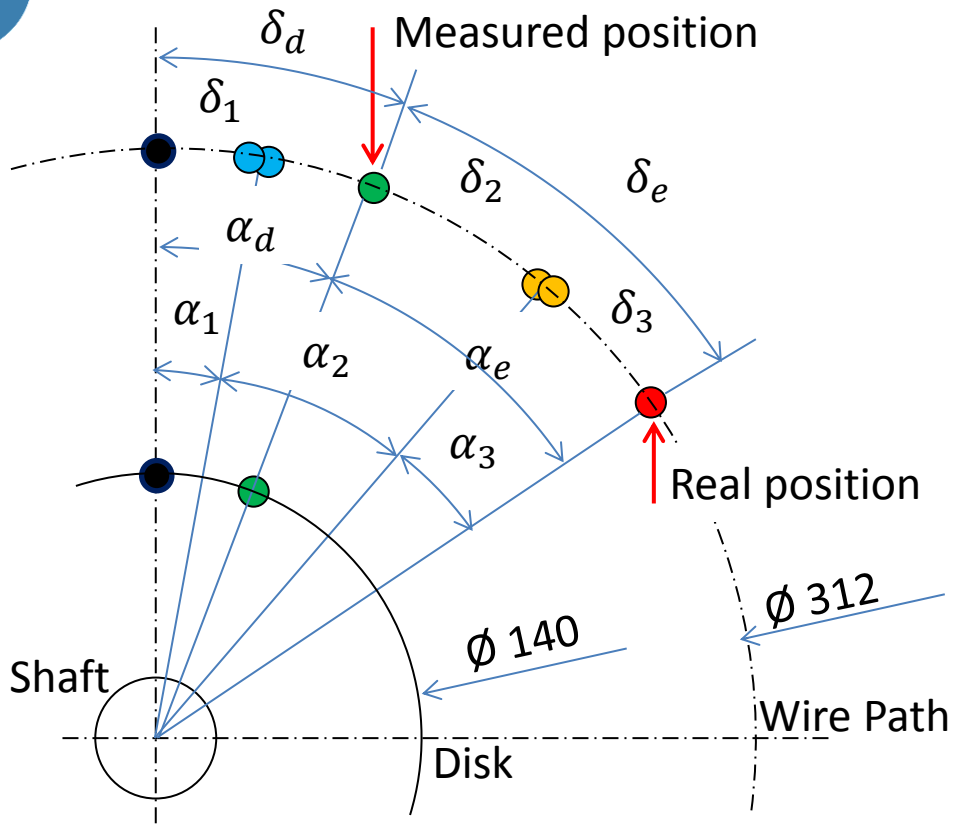
Because tangential acceleration the fork bends

Sources of uncertainty



Because tangential acceleration the wire have a deflection

Sources of uncertainty



$$\alpha_e = \alpha_1 + \alpha_2 + \alpha_3 - \alpha_d$$

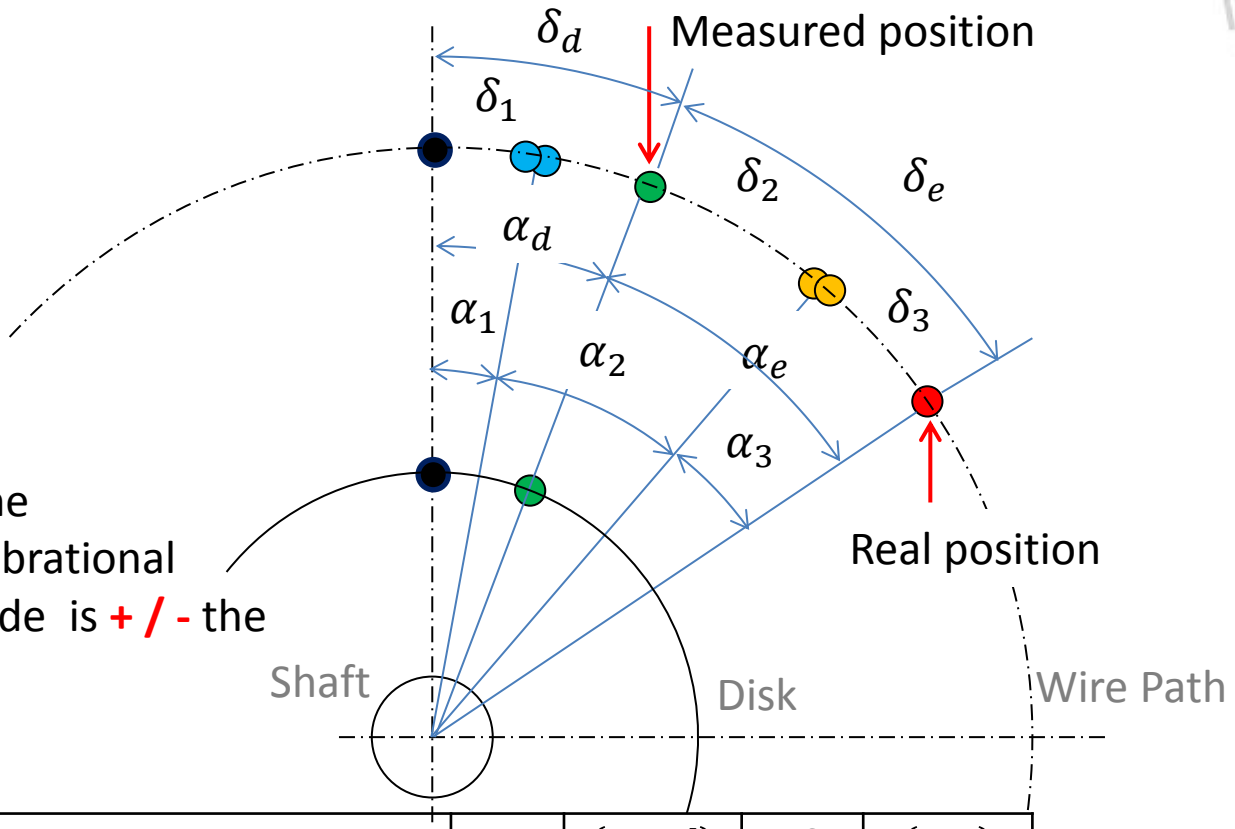
$$\delta_e = \delta_1 + \delta_2 + \delta_3 - \delta_d$$

"Deterministic" displacement due to the peak acceleration and the inertia of the system

Pick accel. 6700 rad/s^2
Optical disk, 3 mm thickness
Wire, 12 strands of 7um

	$\boldsymbol{\alpha}$	(μrad)	$\boldsymbol{\delta}$	(μm)	
Twist of the shaft (fork)	1	*50*	1	*7.8*	FEA estimation
Fork bending	2	*256*	2	*40*	FEA estimation
Wire deflection	3	*128*	3	*20*	Analytical estimation
Twist of the shaft (disk)	d	*112.0*	d	*17.5*	FEA estimation
Total deformation	e	***547***	e	***85.3***	

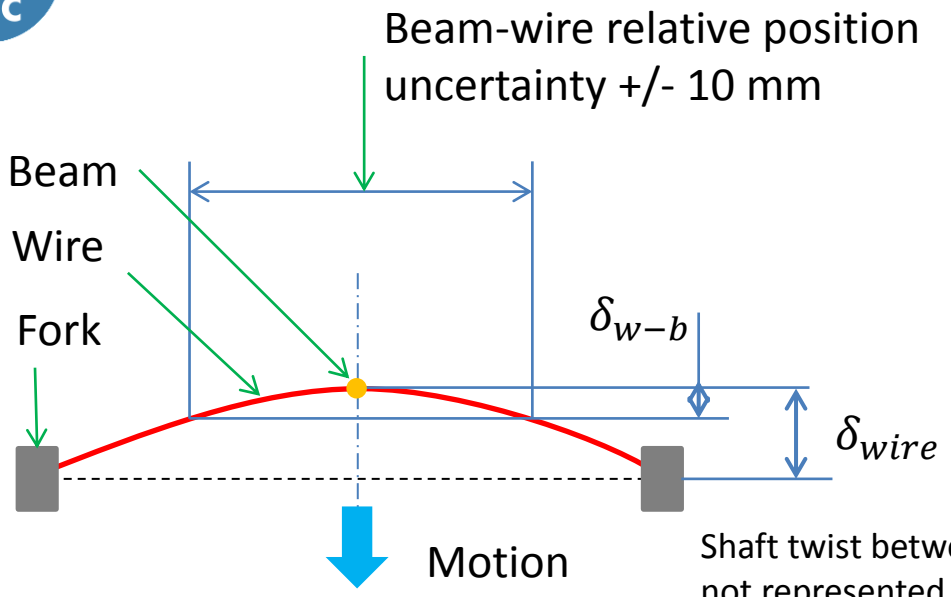
Sources of uncertainty



Due to the variation of the acceleration we have a vibrational behaviour which amplitude is **+ / -** the value of the deformation

	$\boldsymbol{\alpha}$	(μrad)	$\boldsymbol{\delta}$	(μm)
Twist of the shaft (fork)	1	*± 50*	1	*± 7.8*
Fork bending	2	*± 256*	2	*± 40*
Wire deflection	3	*± 128*	3	*± 20*
Twist of the shaft (disk)	d	*± 112.0*	d	*± 17.5*
Vibration amplitude	e	***± 547***	e	***± 85.3***

Sources of uncertainty



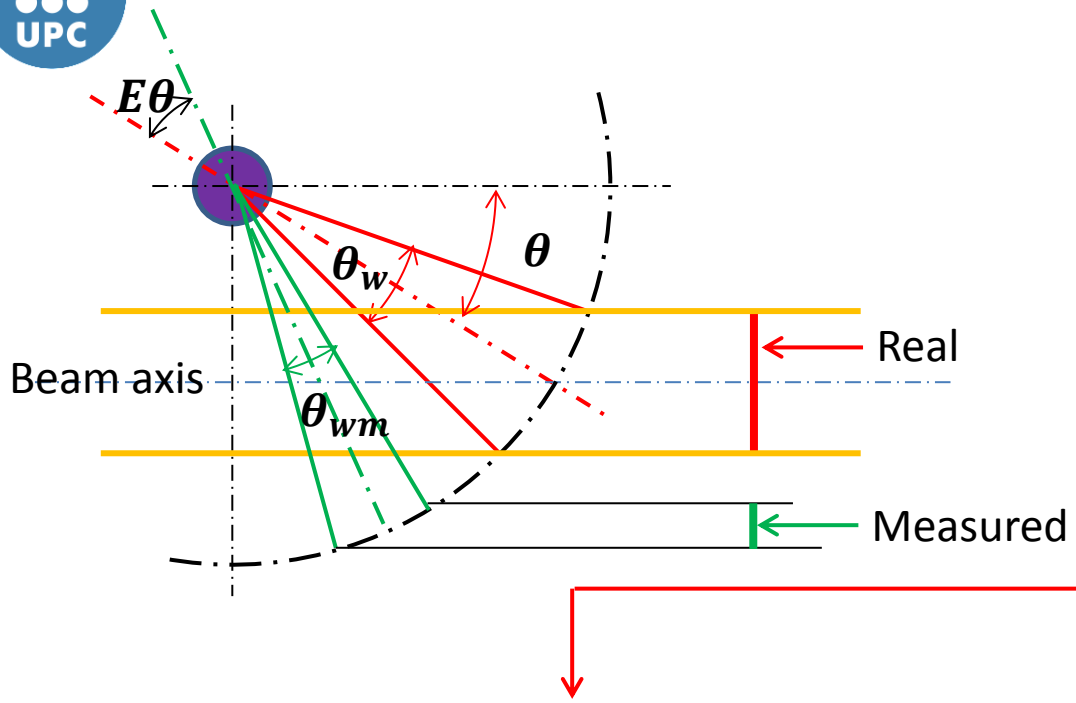
For a wire deflection (δ_{wire}) of 20 µm and a beam-wire relative position of +/- 10 mm

$\delta_{w-b} = 5\ (\mu m)$

APROXIMATIVE VALUES

	Systematic		*Statistical*		***Total***	
	(μrad)	(μm)	(μrad)	(μm)	(μrad)	(μm)
Misalignment	*± 160*	*± 25*			*± 160*	*± 25*
Pure deformations						
Vibrations			*± 547*	*± 85.3*	*± 547*	*± 85.3*
Rel. Beam-Wire pos.			*± 32*	*± 5*	*± 32*	*± 5*
Total	*± 160*	*± 25*	*± 579*	*± 90.3*	***± 739***	***± 115.3***

Sources of uncertainty



Error in position: $E\theta$

Error in width: $E\theta_w = E\theta_w - E\theta_{wm}$

Relative error in the projection:

$$\frac{P_{error}}{P} = \left|\frac{E\theta_w}{\theta_w}\right| + |\tan(\theta) E\theta|$$

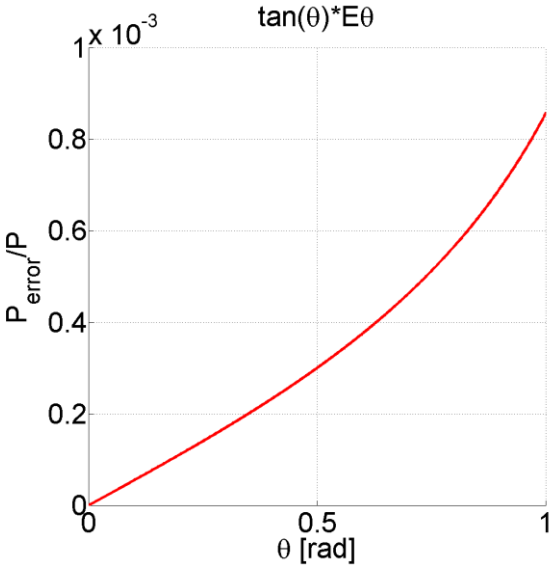
Width error — Position error

$$|\tan(30°)\, 739x10^{-6}| = 4.7x10^{-3}$$

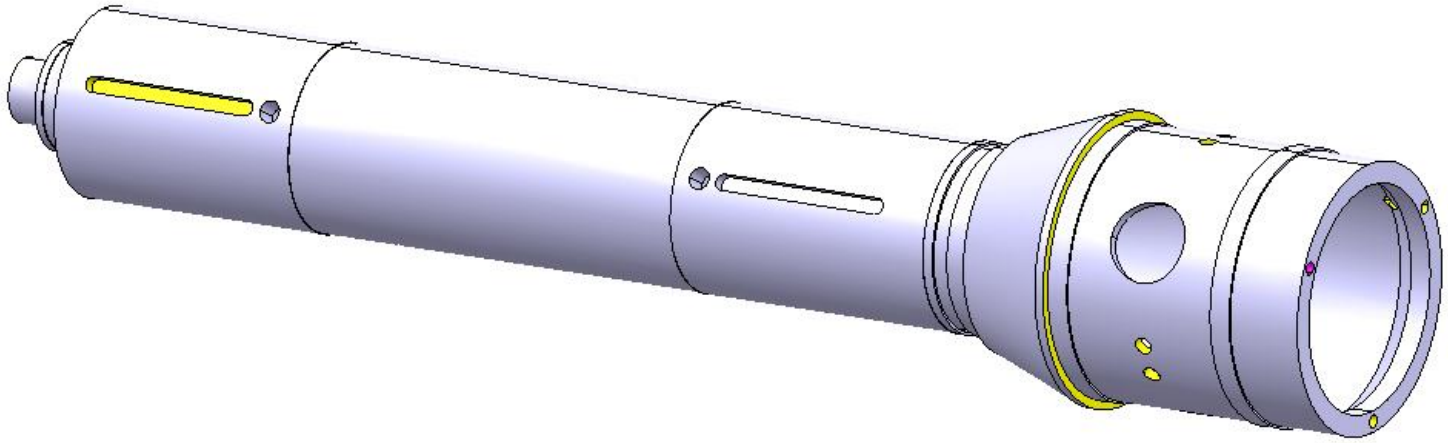
At 20m/s the wire needs 15µs to travel 300 µm

In 15µs an oscillation of 170 µm amplitude and 1kHz can travel 8.5 µm

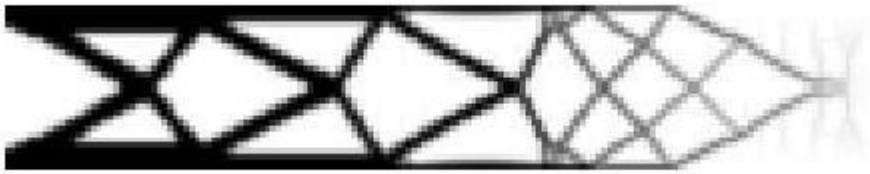
That represents a relative error 2.8%

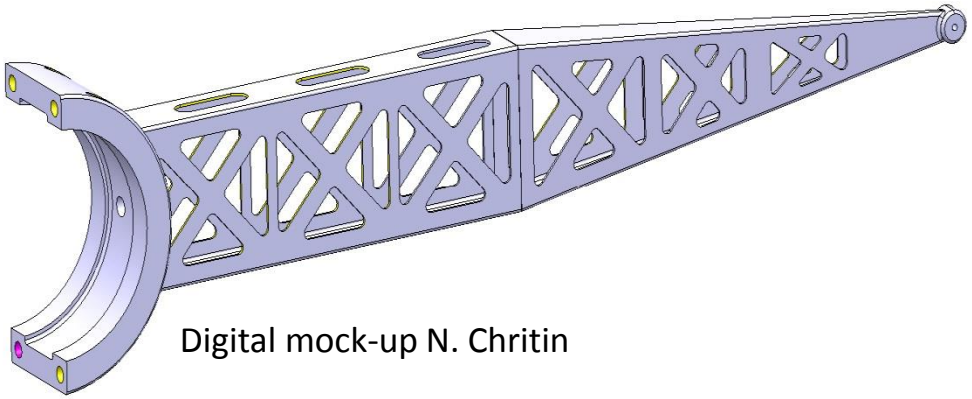


Minimization strategies - Design



Digital mock-up N. Chritin



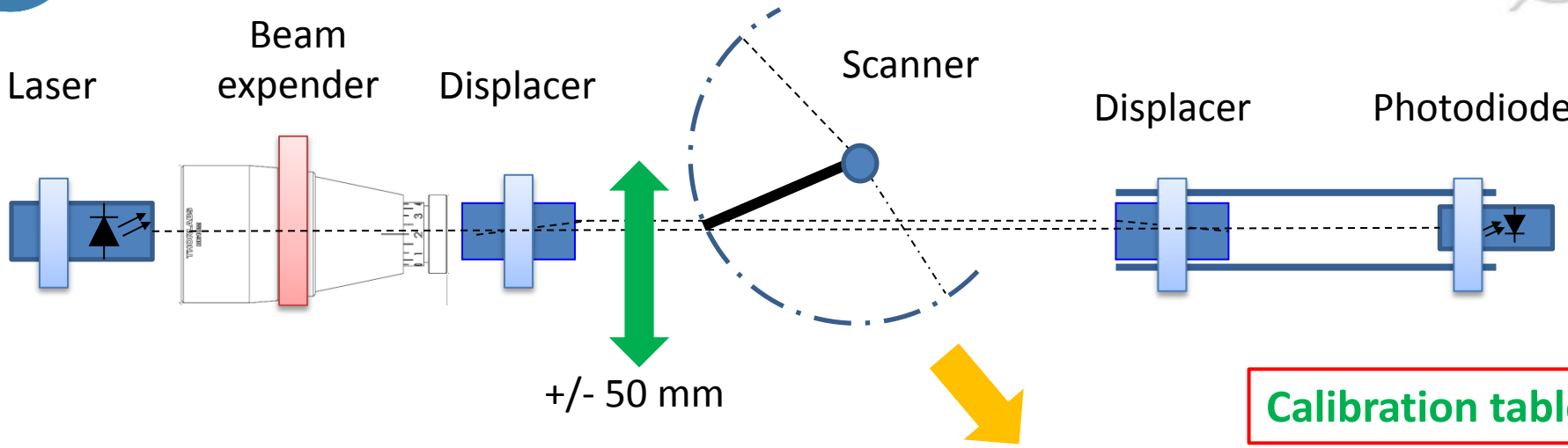


Digital mock-up N. Chritin

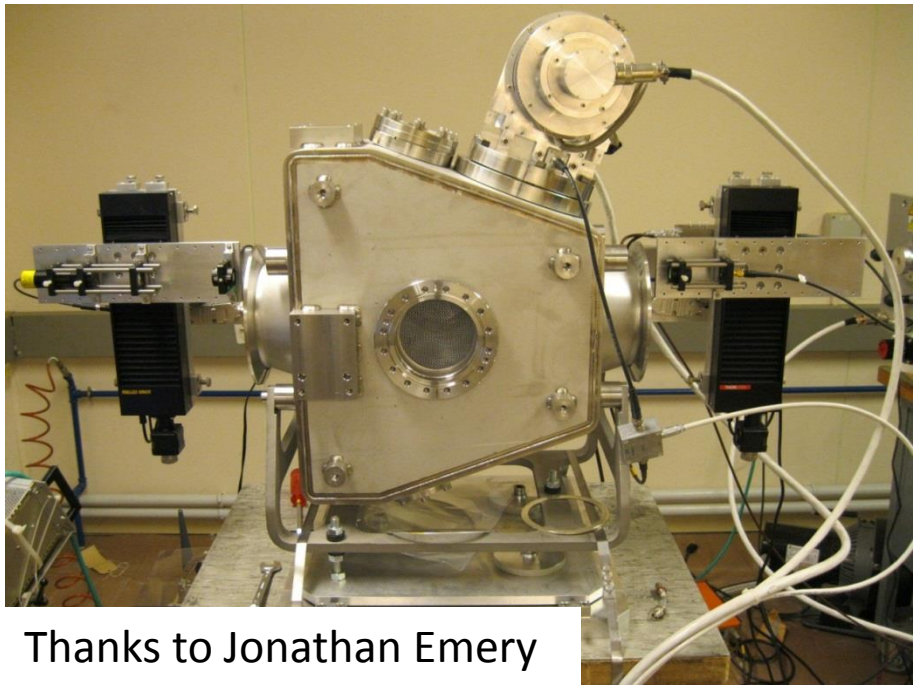
Optimization of stiffness and inertia to minimize deformations

See Sebastian's presentation

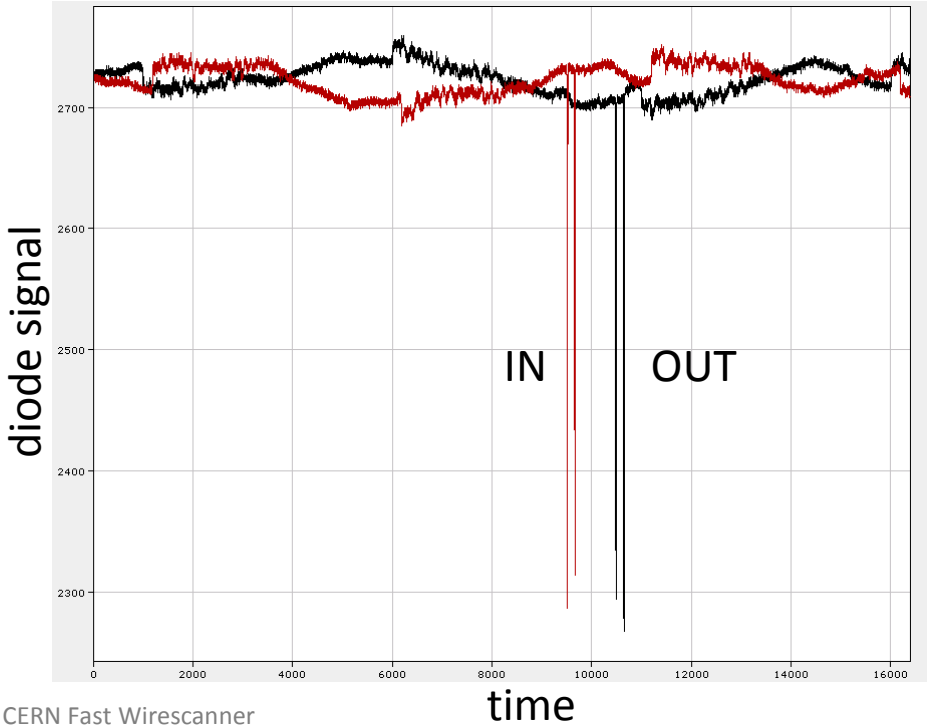
Minimization strategies - Calibration



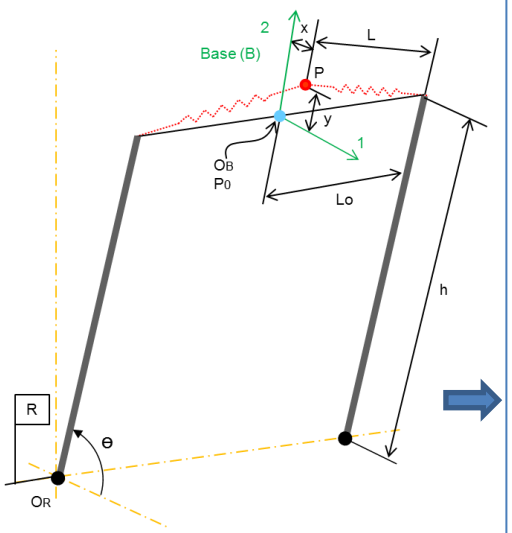
Calibration table



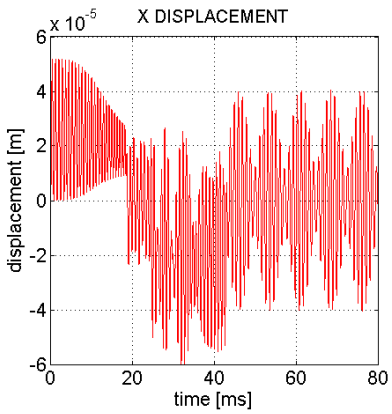
Thanks to Jonathan Emery

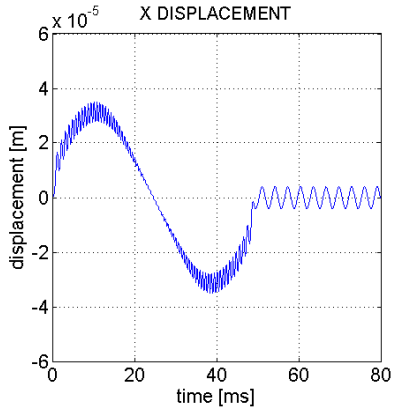


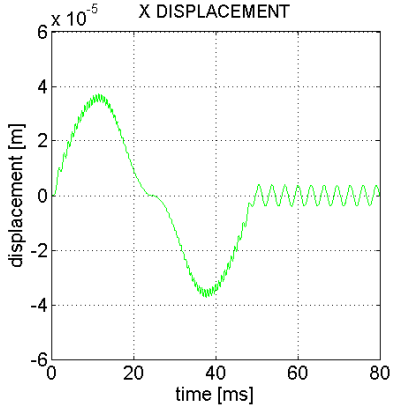
Minimization strategies – Motion pattern

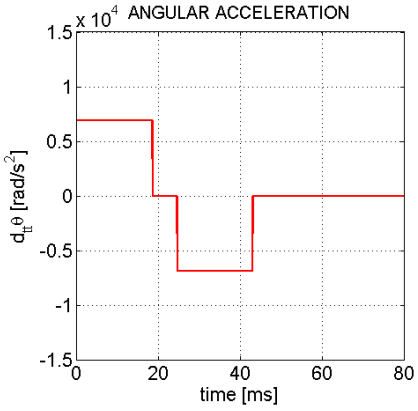


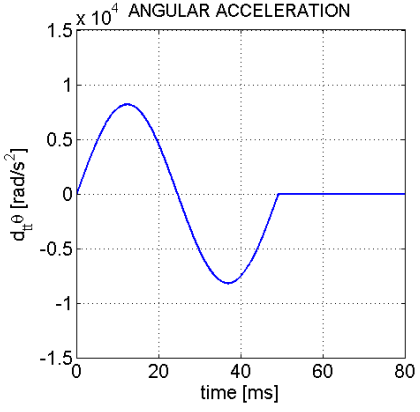
Wire fork simplified model

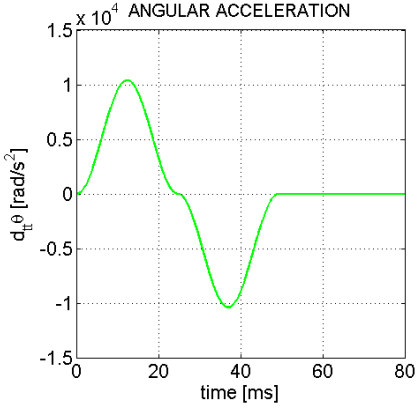








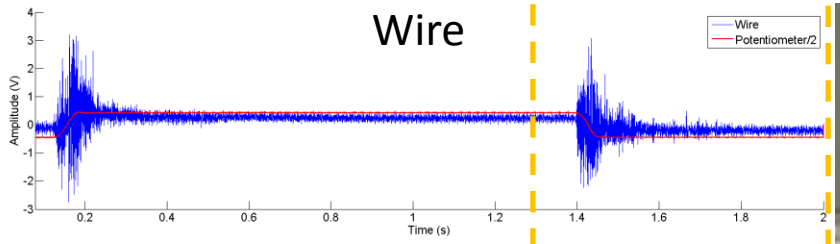


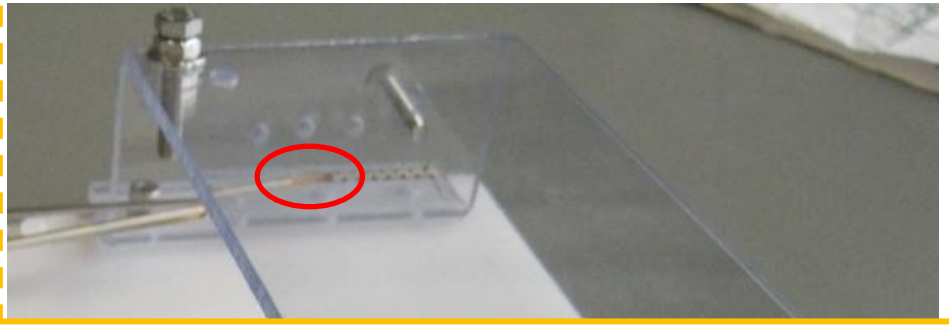


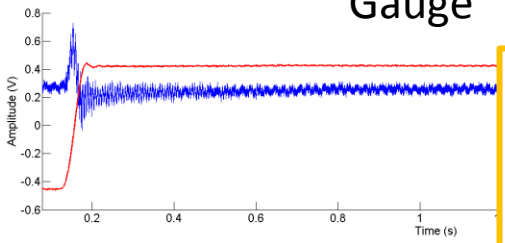
Displacement	25 µm	30 µm	35 µm
Vibration amplitude	50 µm	8 µm	3.5 µm
Factor	1	0.16	0.07

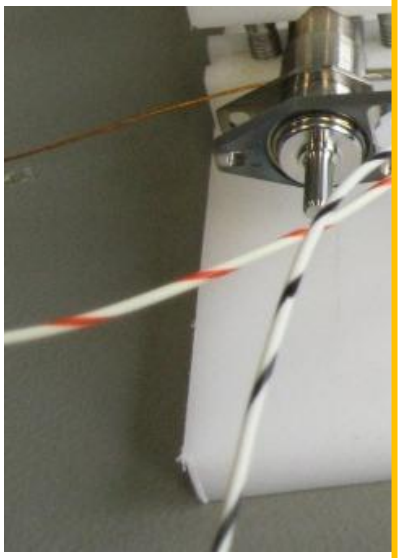
Pattern optimization can provide large improvements in the residual vibrations minimization

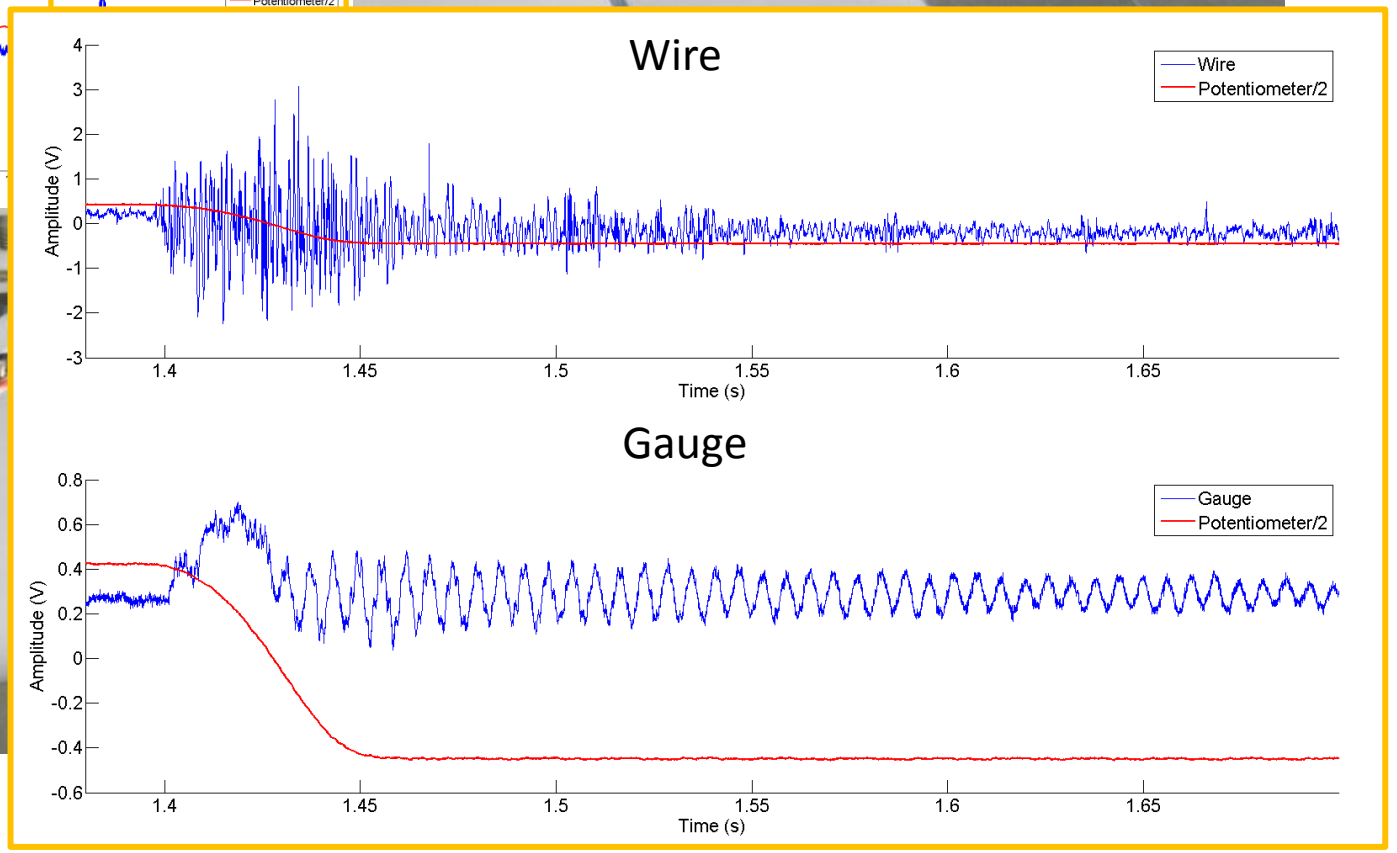
Minimization strategies – Vibration measurements

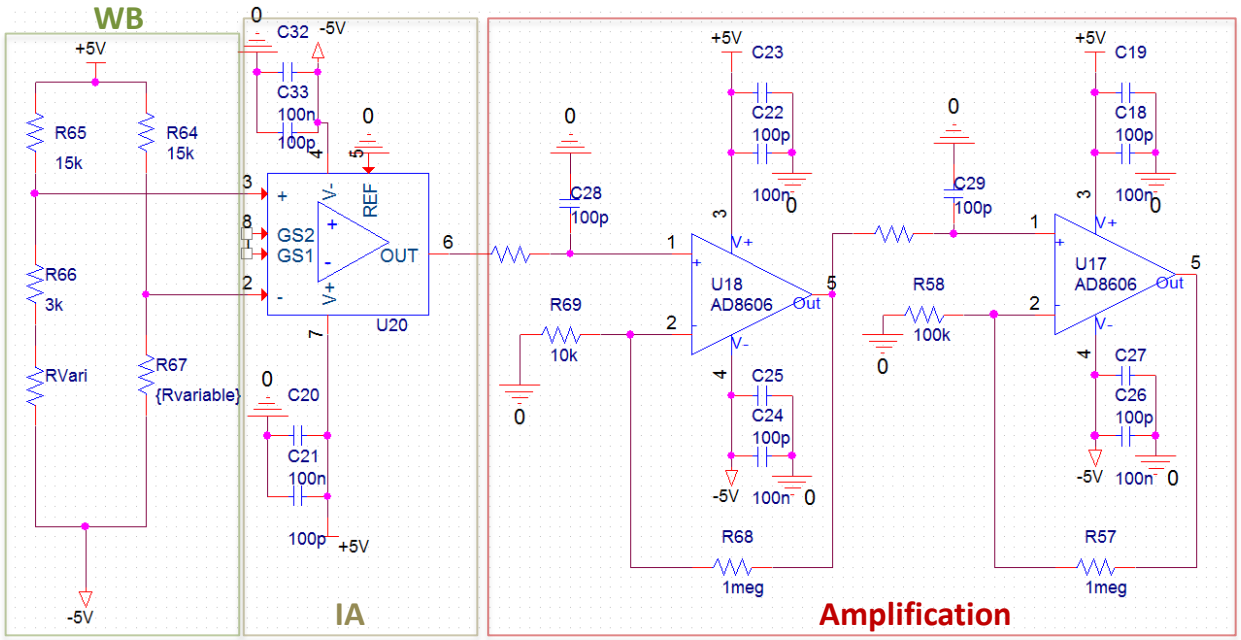






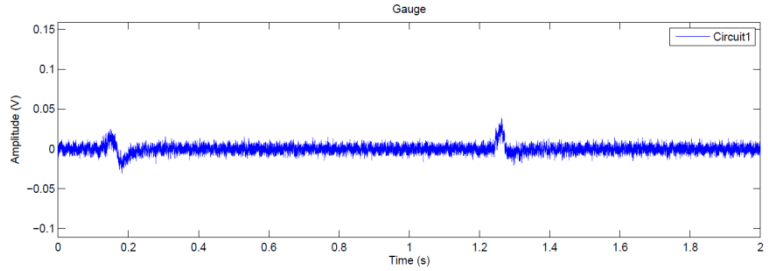




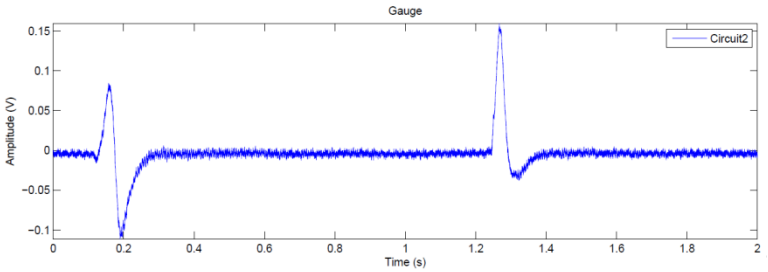


Strain Gauge (GF = 2.1)

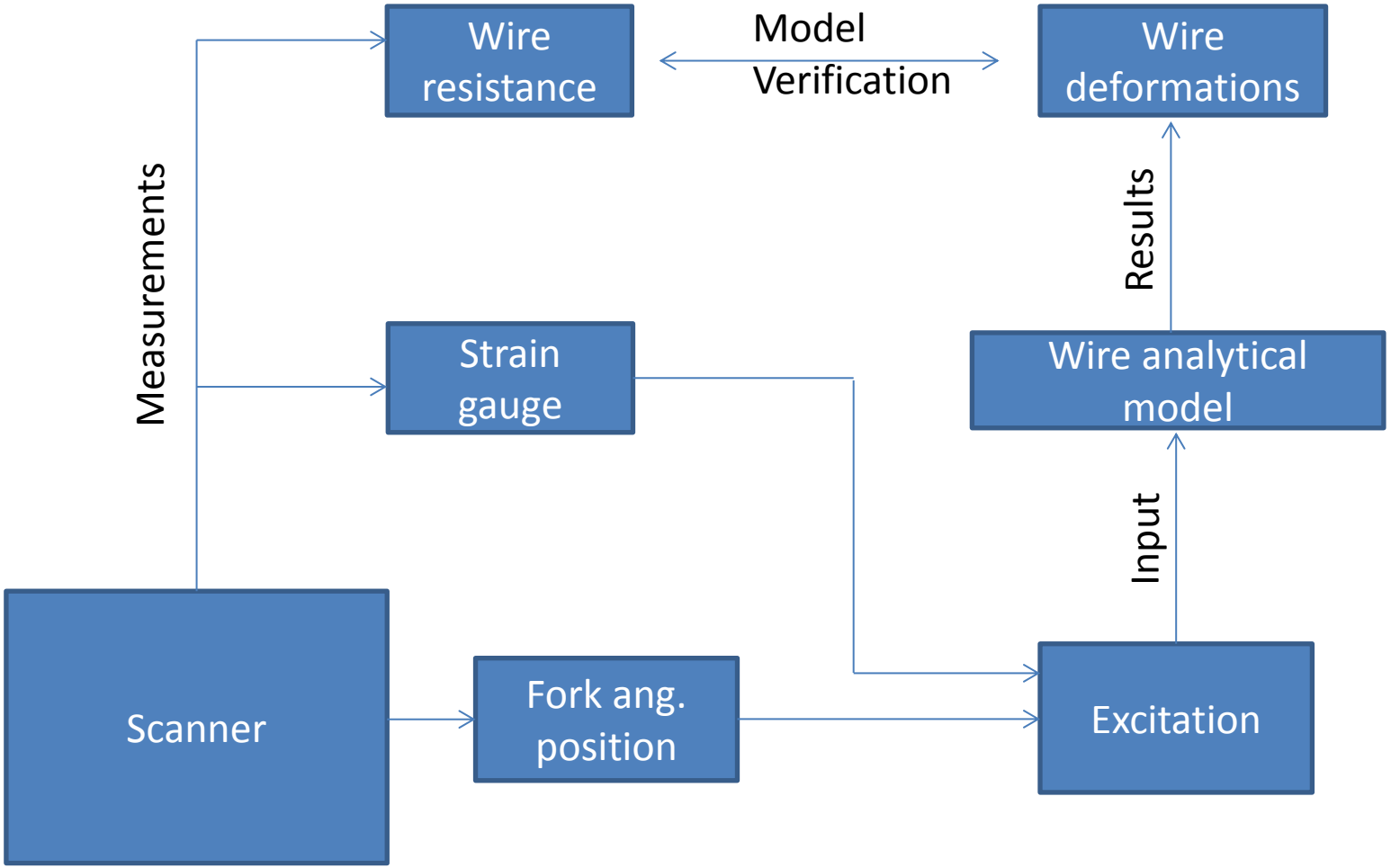
- G = 1000
- BS = ± 5V
- 3 kHz LP filter
- Fork speed: 10 m/s



- G = 1000
- BS = ± 1V
- 3 kHz LP filter
- Fork speed: 10 m/s
- R_{64} and R_{65} = 1kΩ



Minimization strategies - Wire dynamic model



Dynamic model intended to provide quantitative experimental information about Residual vibration of the scanner

Summary

Uncertainty	***Minimization strategy***		
	Design	***Calibration***	***Motion pattern***
Misalignment	*No play in the system*	*Correction by calibration tables*	
Pure deformations	*Optimization stiffness and inertia*	*Correction by calibration tables*	*Smother profiles have more deterministic behaviour*
Residual Vibrations	*Optimization stiffness and inertia*		*Minimizing residual vibrations*
Rel. Beam-Wire pos.			*Smother -> deterministic behaviour*

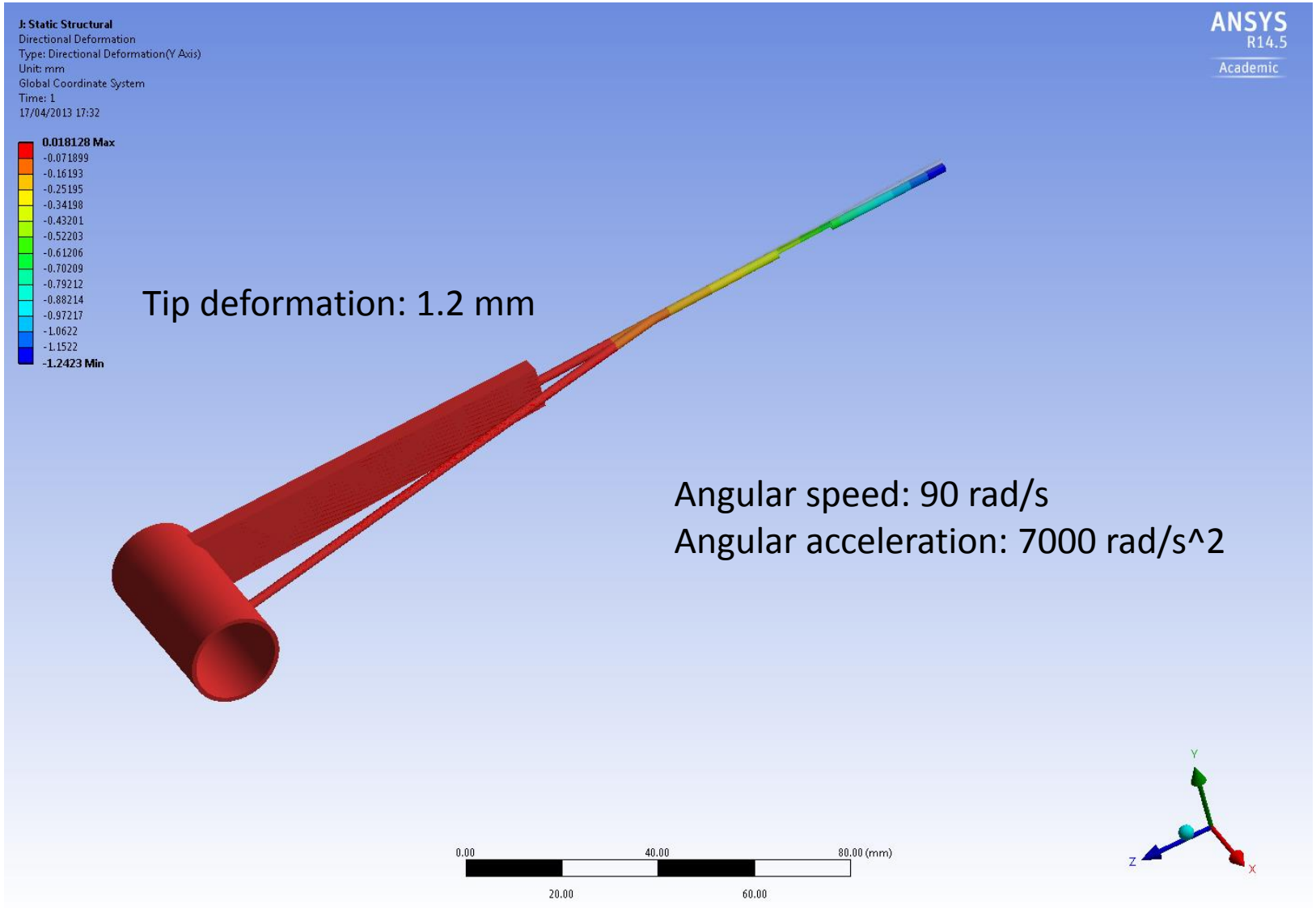
Expected **approximate** values after uncertainties minimization:
(the expectation is to attend values of the **same order of magnitude**)

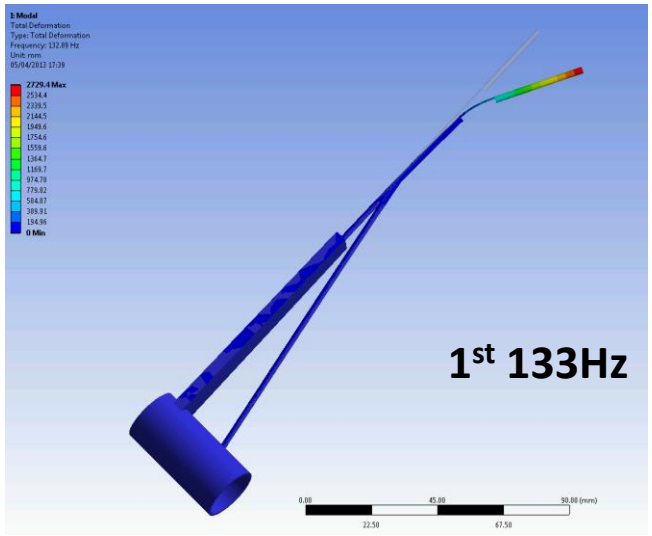
	(μrad)	(μm)
Misalignment	$\pm$ *32*	$\pm$ *5*
Pure deformations	$\pm$ *32*	$\pm$ *5*
Vibrations	$\pm$ *12*	$\pm$ *2*
Rel. Beam-Wire pos.	$\pm$ *32*	$\pm$ *5*
Total	$\pm$ ***109***	$\pm$ ***17***

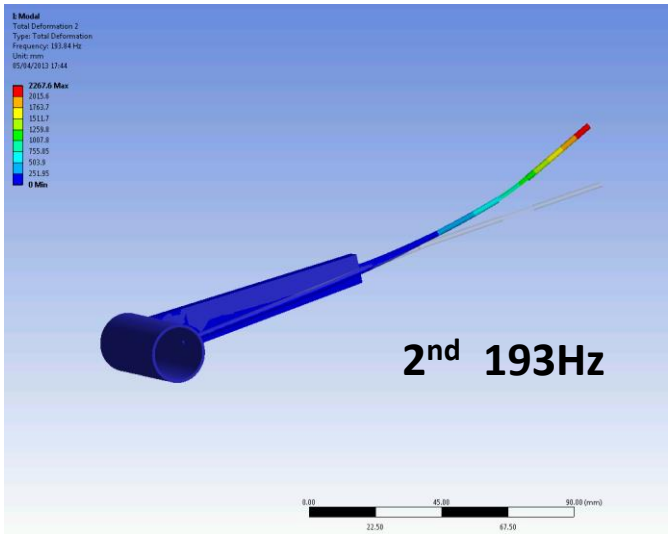
Conclusions

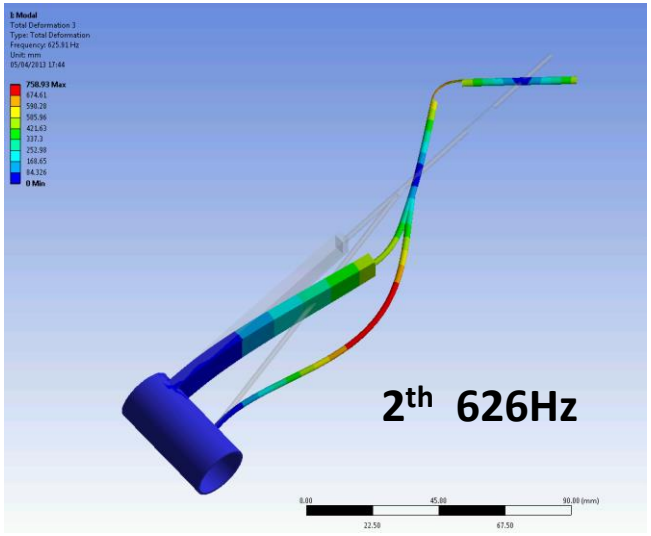
- The main sources of uncertainty for determining the wire position has been identified
- Actions to minimize this uncertainties has been take and integrated in the design
- Studies to minimize the influence of the motion pattern are ongoing
- Vibration measurement and quantification system are in phase of test and development using the exiting calibration test bench for PS and PSB scanners and this systems are going to be integrated in the first prototype

Many thanks !


J: Static Structural
Directional Deformation
Type: Directional Deformation(Y Axis)
Unit: mm
Global Coordinate System
Time: 1
17/04/2013 17:32
0.018128 Max
-0.071899
-0.16193
-0.25195
-0.34198
-0.43201
-0.52203
-0.61206
-0.70209
-0.79212
-0.88214
-0.97217
-1.0622
-1.1522
-1.2423 Min
ANSYS
R14.5
Academic
Tip deformation: 1.2 mm
Angular speed: 90 rad/s
Angular acceleration: 7000 rad/s^2
0.00
40.00
80.00 (mm)
20.00
60.00
Y
Z
X


1st 133Hz


2nd 193Hz


2th 626Hz

Uncertainty	Minimization strategy		
	Design	***Calibration***	***Motion pattern***
Misalignment	*No play in the system*	*Correction by calibration tables*	
Pure deformations	*Optimization stiffness and inertia*	*Correction by calibration tables*	*Smother profiles have more deterministic behaviour*
Residual Vibrations	*Optimization stiffness and inertia*		*Minimizing residual vibrations*
Rel. Beam-Wire pos.	*= minimize deformations*		

	Total	
	(μrad)	(μm)
Misalignment	*± 32*	*± 5*
Pure deformations	*± 32*	*± 5*
Vibrations	*± 12*	*± 2*
Rel. Beam-Wire pos.	*± 32*	*± 5*
Total	*± 109*	*± 17*

$$\frac{P_{error}}{P} = \left|\frac{E\theta_w}{\theta_w}\right| + |\tan(\theta)E\theta|$$

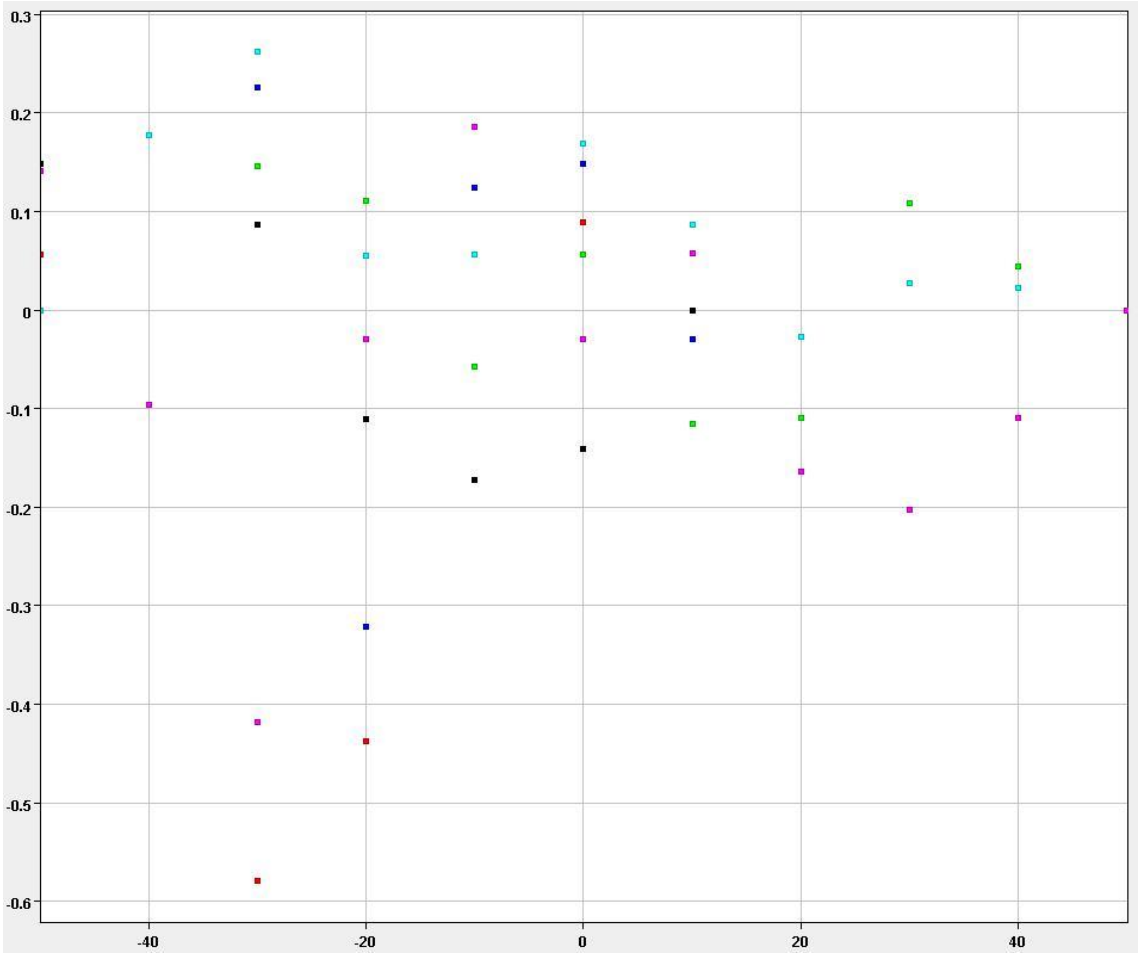
$$\tan(30°)\,17x10^{-6} = 9.8x10^{-6}$$

$$\frac{E\theta_w}{\theta_w} = 6.28\,x10^{-4}$$

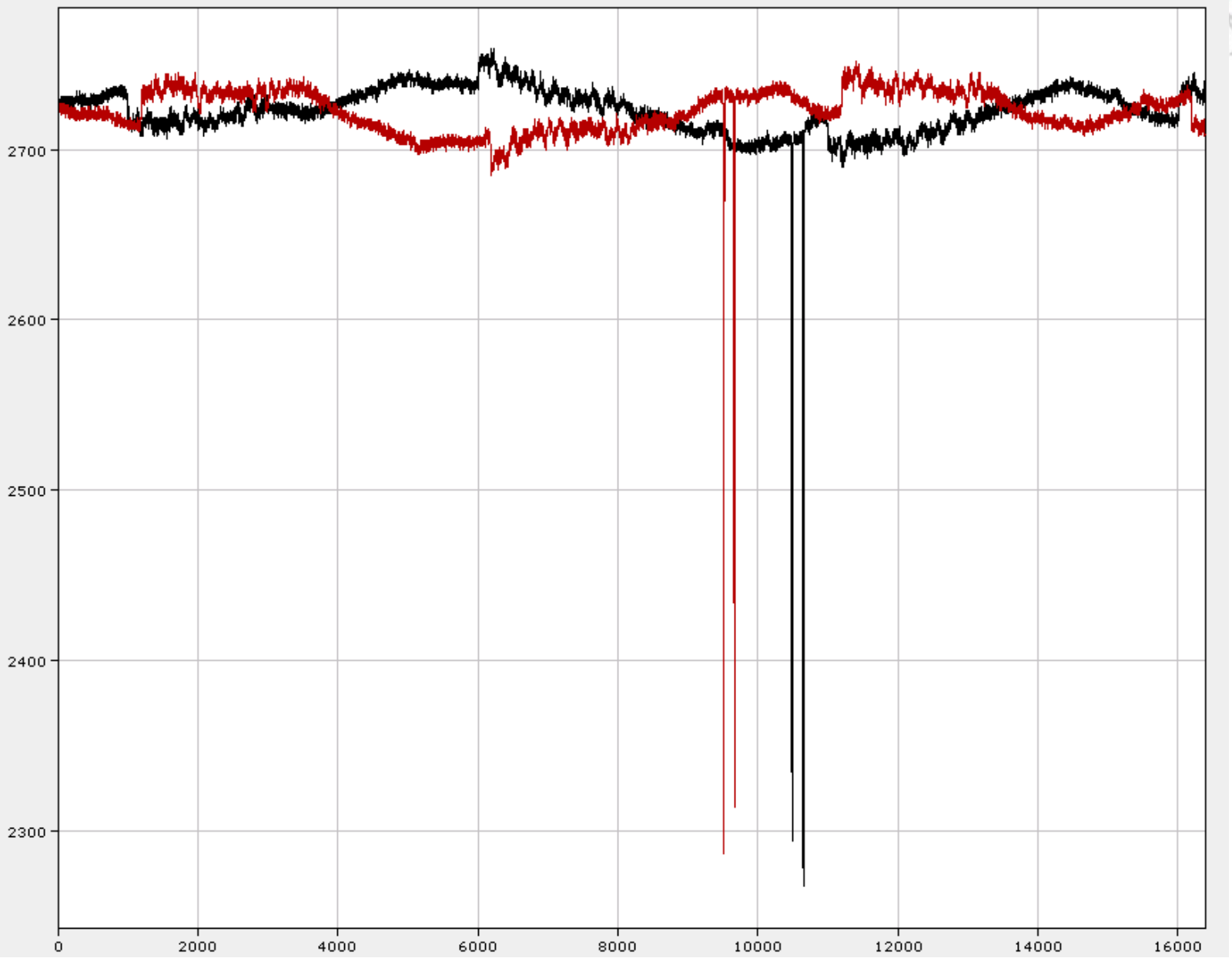
$$P_{error} = \mathbf{300}x6.38x10^{-4} = \mathbf{0.2}$$

15 m/sec check

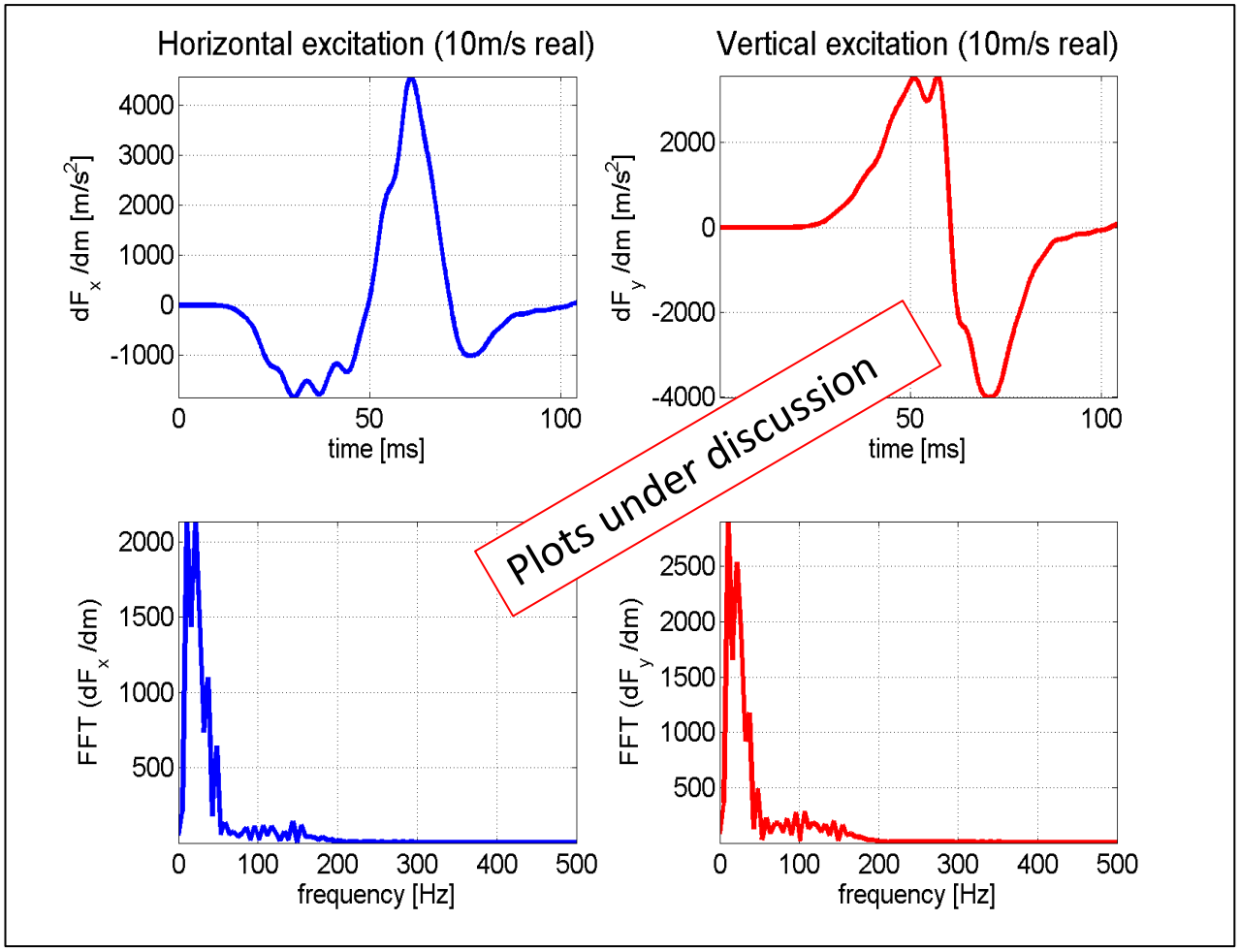
Typical results after calibration for PS scanner

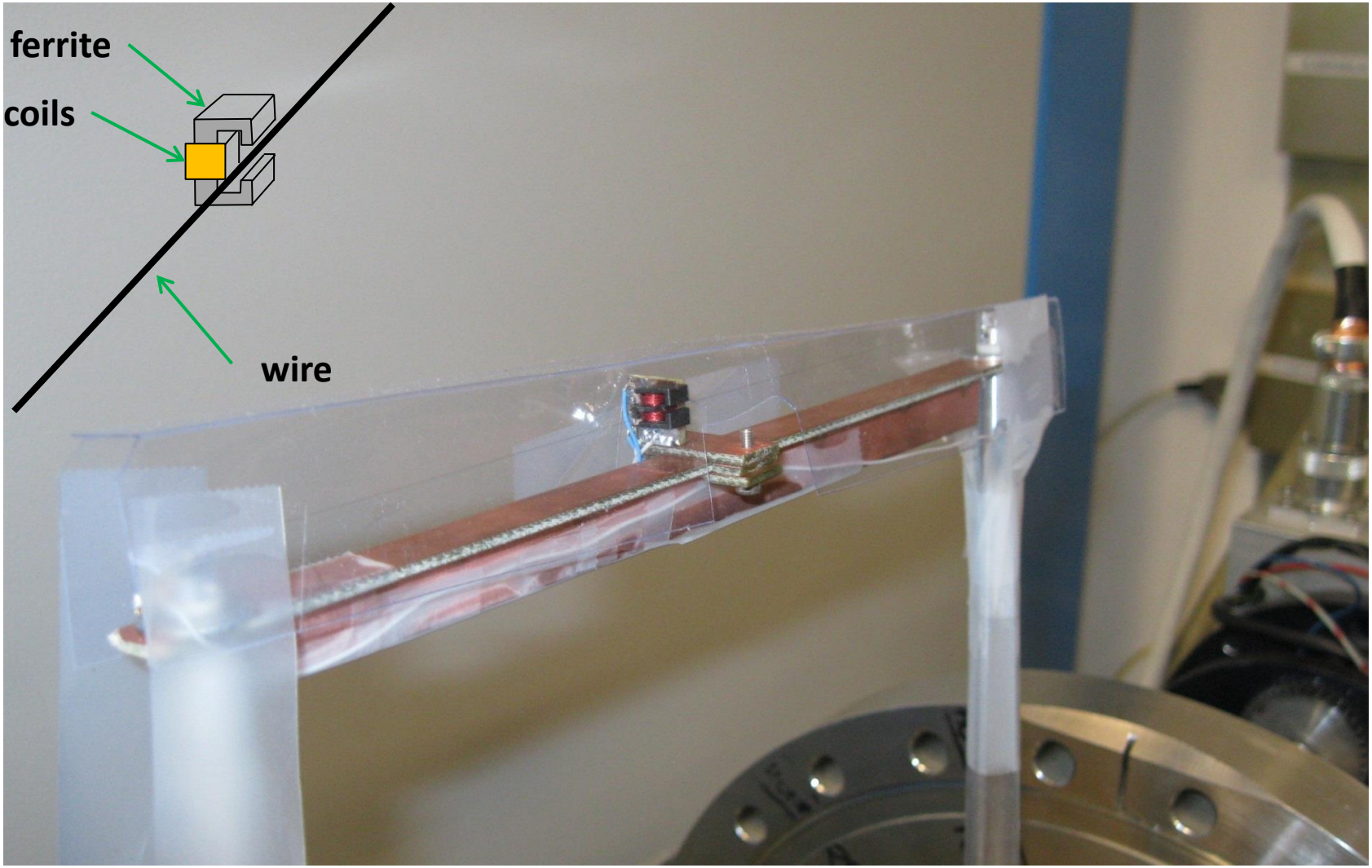


Jonathan Emery



Jonathan Emery


Horizontal excitation (10m/s real)
Vertical excitation (10m/s real)
dF_x /dm [m/s^2]
dF_y /dm [m/s^2]
time [ms]
time [ms]
Plots under discussion
FFT (dF_x /dm)
FFT (dF_y /dm)
frequency [Hz]
frequency [Hz]


ferrite
coils
wire