Ultra-Precision Mechanics for Fourth-Generation Sources

Concepts for Ultra-Precision at PETRA IV

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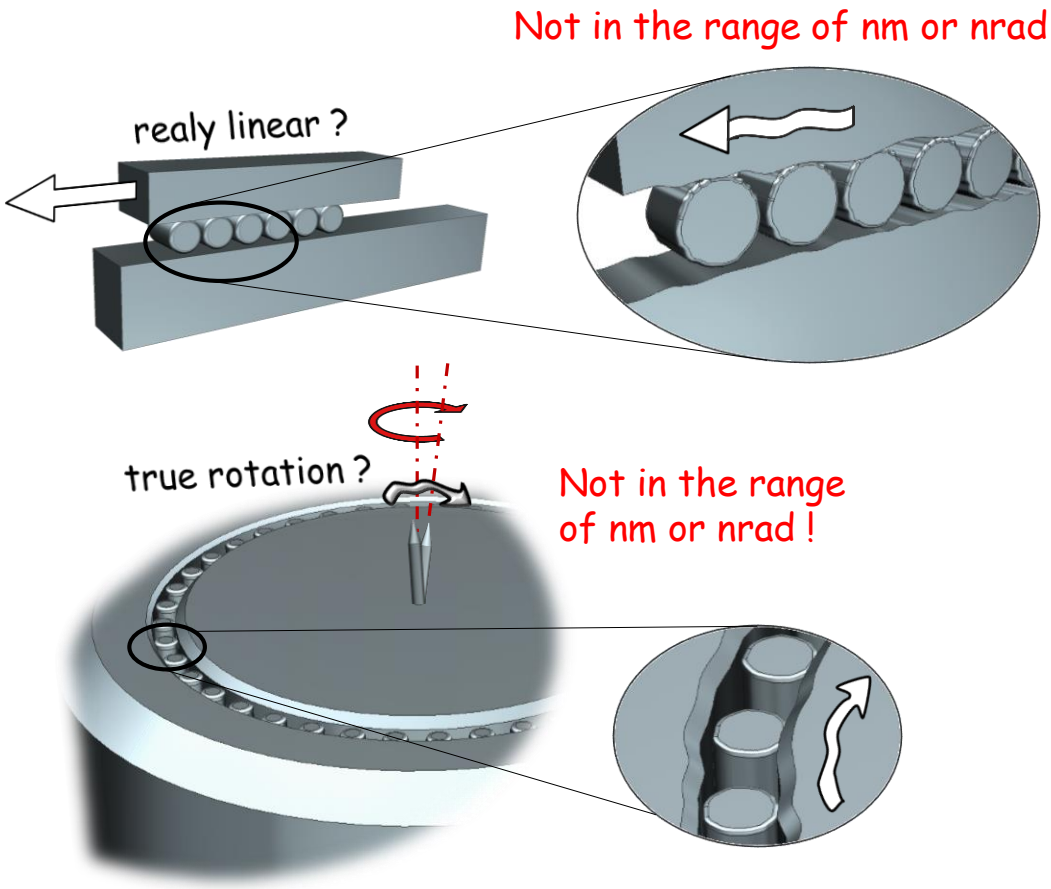
HELMHOLTZ RESEARCH FOR GRAND CHALLENGES

DESY.

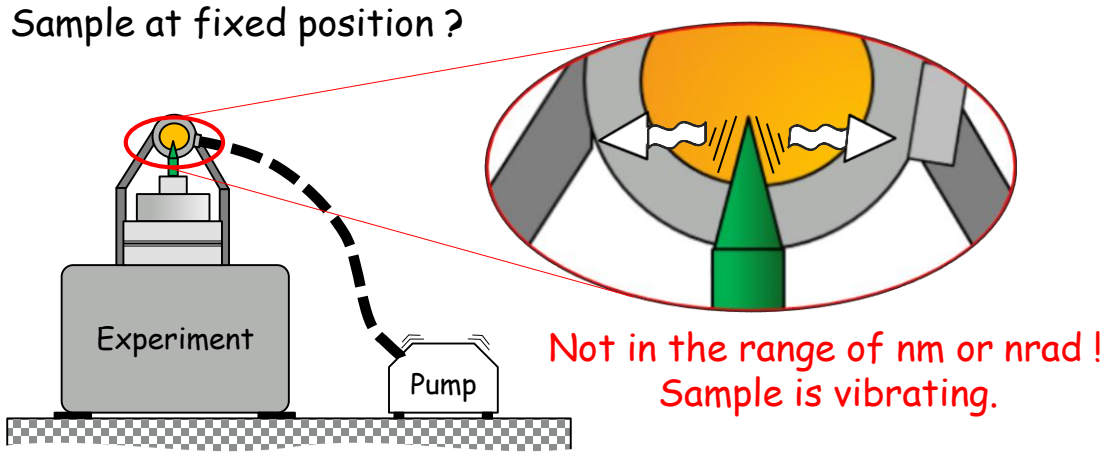
General considerations on Ultra Precision Mechanics

Some basic consideration

Precision and accuracy



Stability → Rigid and positionally stable

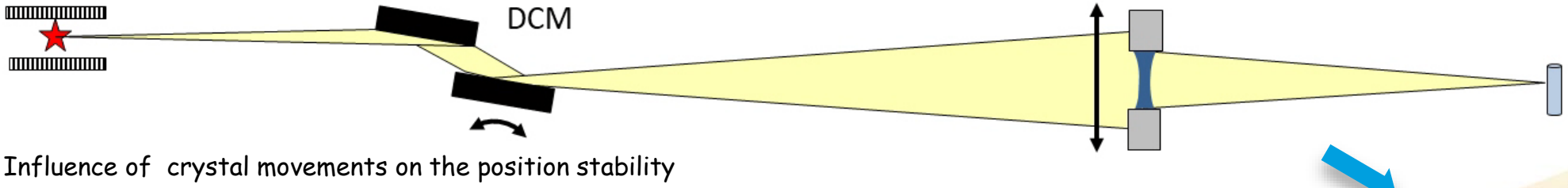


Stability and precision are only defined by the way you look at things.

General considerations on required stability

Some Examples

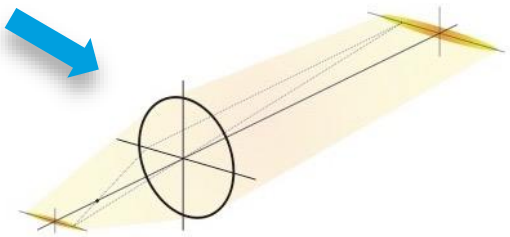
Example 1: DCM Vibration 3rd generation Source



Influence of crystal movements on the position stability

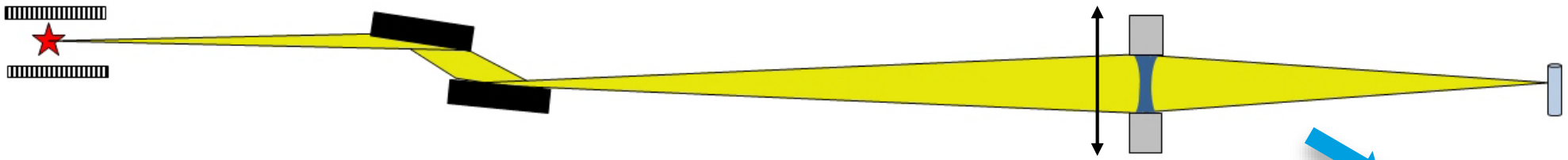
PETRA III

source size:
140 µm x 6 µm



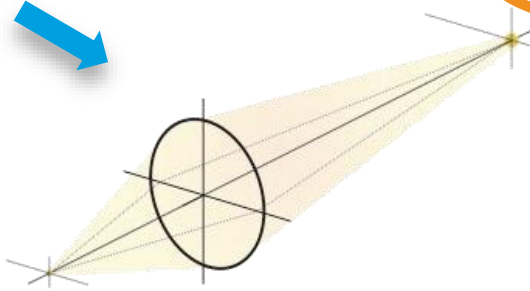
asymmetrical
x-ray beam

Example 2: DCM Vibration 4th generation Source



PETRA IV

source size:
6 µm x 6 µm



round
x-ray beam

Problem → Much more sensitive for vibrations

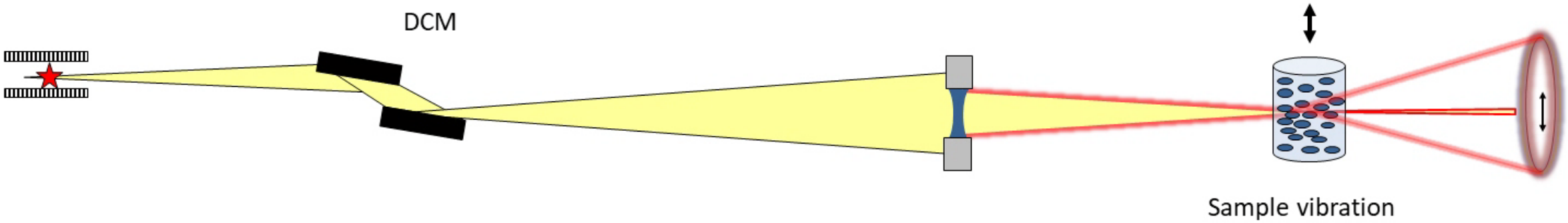
Movements can generate intensity fluctuations

nanometer
focusing

General considerations on stability

Some Examples

Example 3: Sample drifts and vibrations



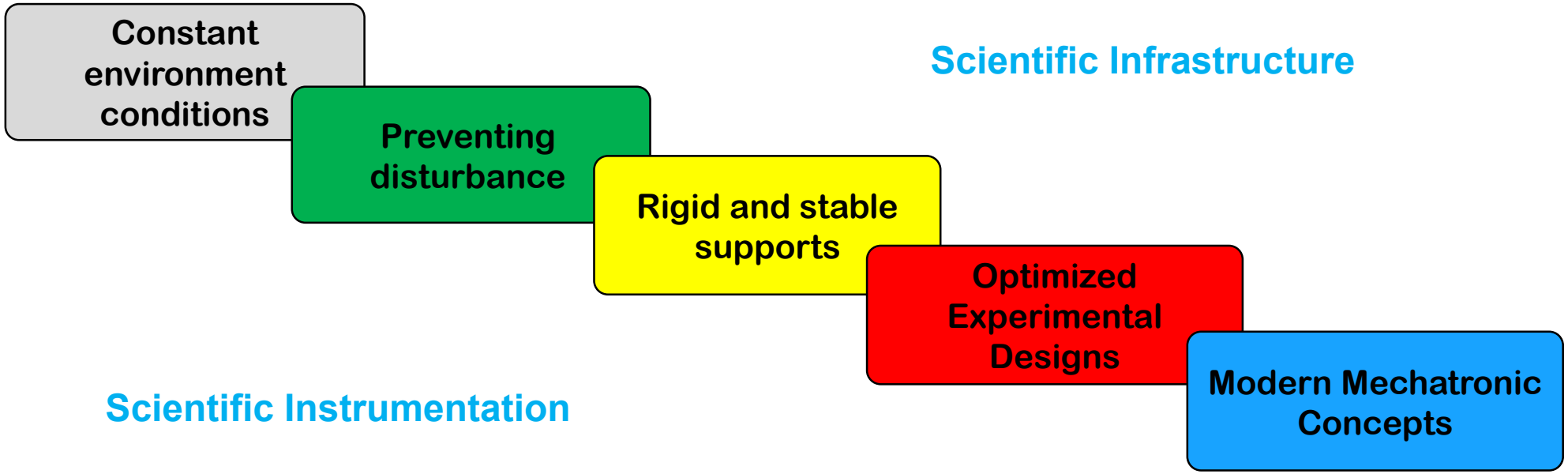
Conclusion

- **Precision in the mechanics is one important factor to perform good measurements**
- **Many other factors have also influence on the conditions**

Motivation and Outlook

- Good concepts are needed to meet the extreme requirements of PETRA IV.

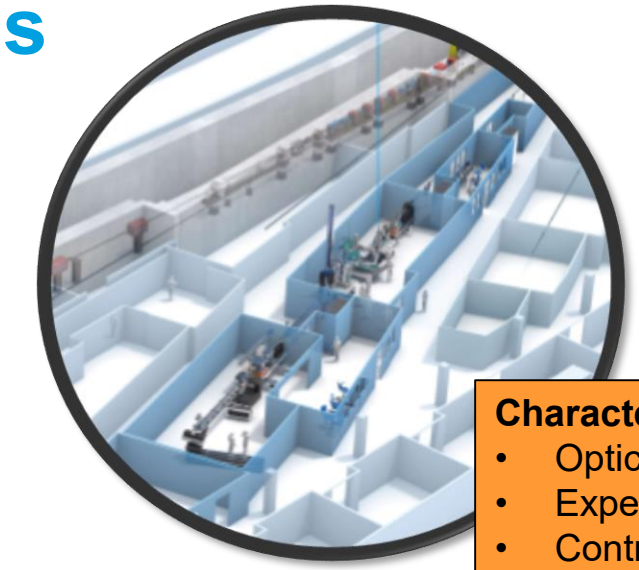
- Considering five basic points using the full range of systems engineering in order to meet the strong requirements of PETRA IV



Concepts for Stable Systems

Scientific infrastructure

Controlled environment



To be considered

- Temperature and humidity
- Clean and dust -free

Characteristic Beamline layout
- Optics hutch
- Experimental hutch
- Control hutch

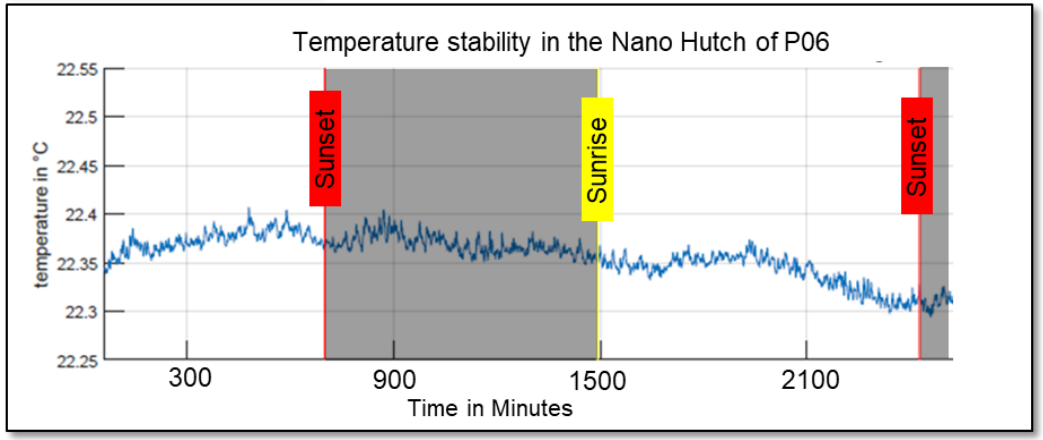
Scientific Infrastructure

options for improvements

- Very good climate-control systems
- Using climate locks
- Avoidance of disturbing influences

Example:

Temperature stability of experimental Hutch at P06



→ Short term stability (1-2h) ±0.02K
→ Long term stability (1-2 d) ±0.05K

Concepts for Stable Systems

Scientific infrastructure

Controlled environment

Monitoring

- Floor vibration
- Background noise

Preventing disturbance

Damping

- Pumps, generators
- Valves, shutter, absorber.
- Air conditioning units.

Decoupling from experiment

- Any vibrating beamline equipment.
- Media supply lines (Water, LN2)
- Air conditioning equipment.

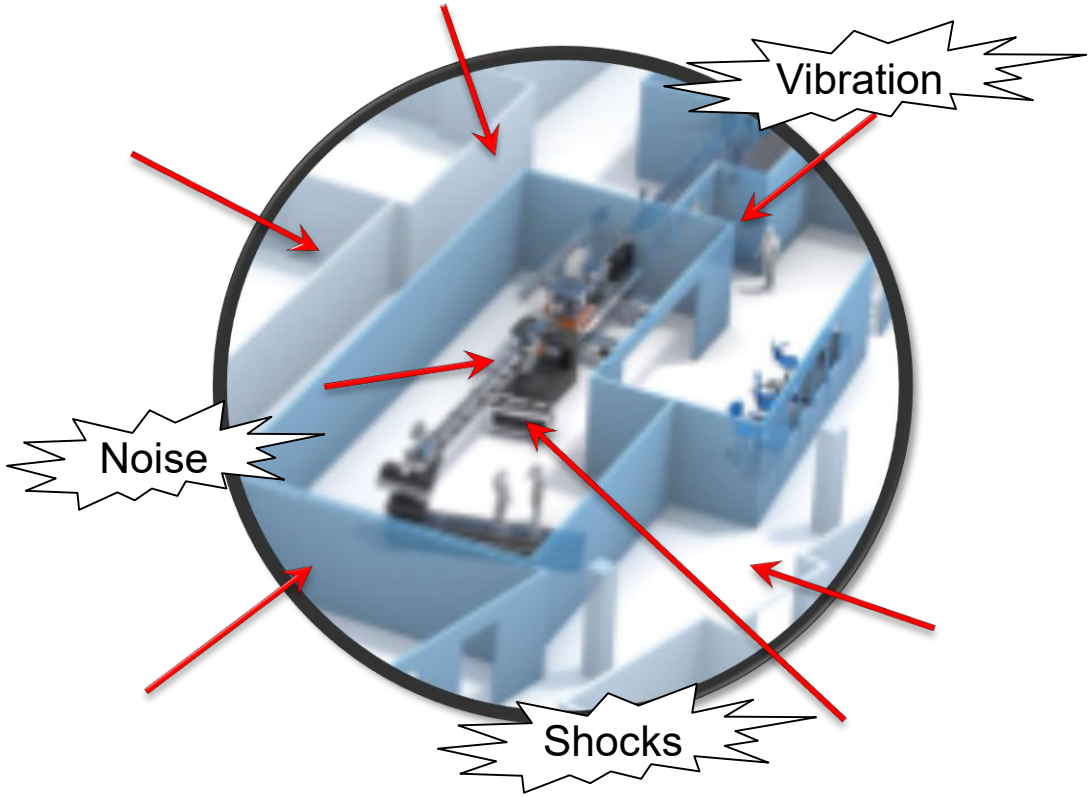
Optimizing problematic components

- Moving conditions of valves, shutter, absorbers.
- Design of experimental hutches
- Media pipes

To be considered

- Sources of vibration
- Shocks and impacts
- Acoustic noise

Options to improve



Concepts for Stable Systems

Scientific infrastructure potential for Improvement

Controlled environment

Preventing disturbance

- **Monitoring**
  - Floor vibration
  - Background noise
- **Damping**
  - Pumps, generators
  - Valves, shutter, absorber.
  - Air conditioning units.
- **Decoupling from experiment**
  - Any vibrating beamline equipment.
  - Media supply lines (Water, LN2)
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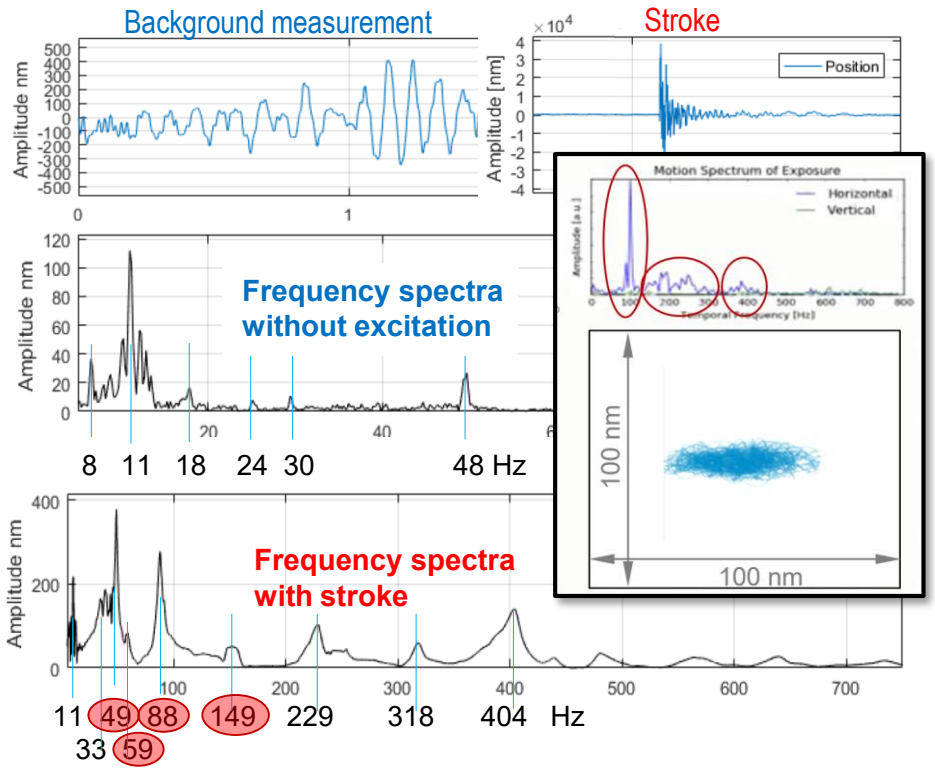
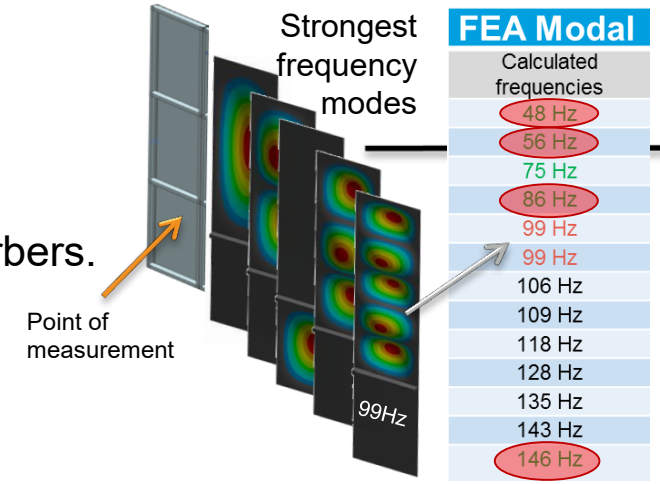
- **Optimizing problematic components**
  - Moving conditions of valves, shutter, absorbers.
  - Design of experimental hutches
  - Media pipes

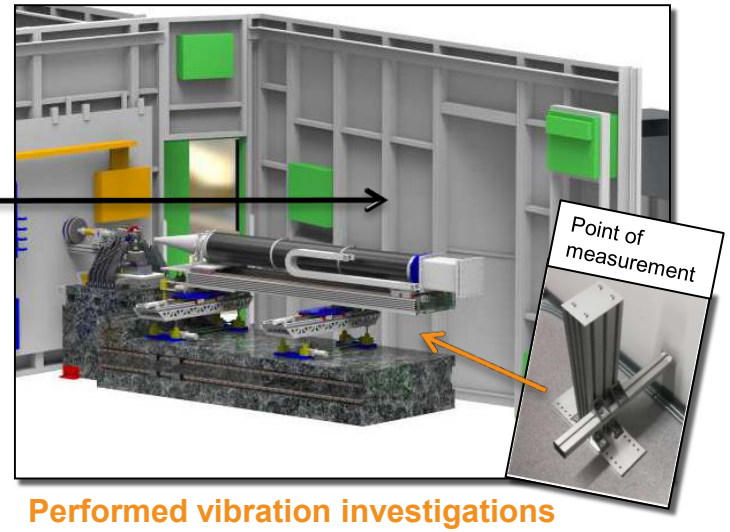
Example

Vibration behavior of an Experimental -Hutch



Modal analysis of the structure

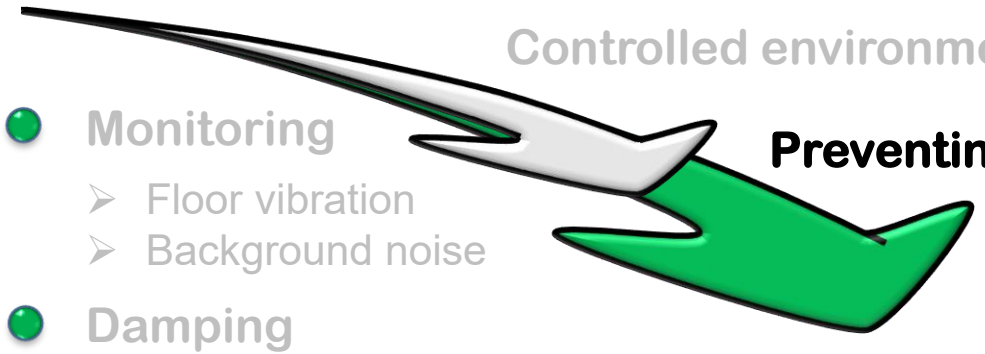




Performed vibration investigations
(Bachelor thesis Torben Reuß)

Concepts for Stable Systems

Scientific infrastructure potential for Improvement



- **Monitoring**
  - Floor vibration
  - Background noise
- **Damping**
  - Pumps, generators
  - Valves, shutter, absorber.
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- **Decoupling from experiment**
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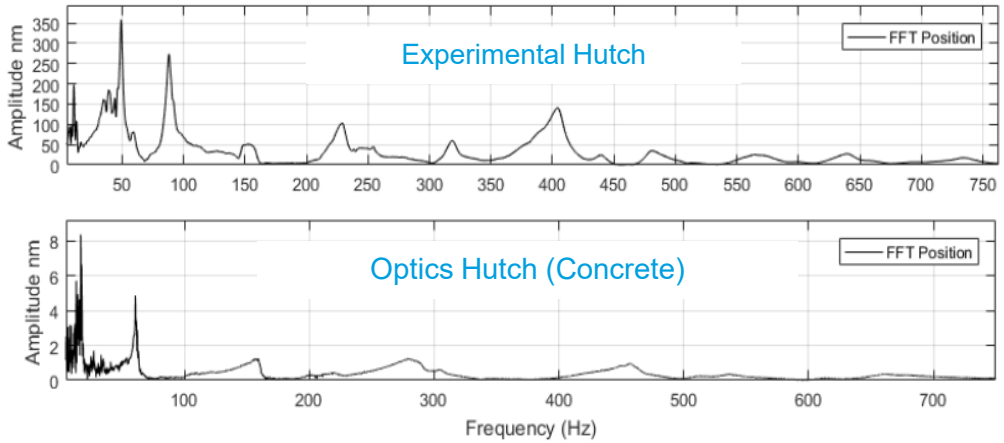


Positon	Eigen frequencies / Amplitudes						
Exp. Hutch	11 Hz	49 Hz	88 Hz	153 Hz	229 Hz	318 Hz	404 Hz
	92 nm	213 nm	162 nm	30 nm	61 nm	35 nm	84 nm
Optics Hutch	17 Hz	61 Hz	_	158 Hz	_	280 Hz	458 Hz
	8,2 nm	3,7 nm	_	1,2 nm	_	1,2 nm	0,9 nm

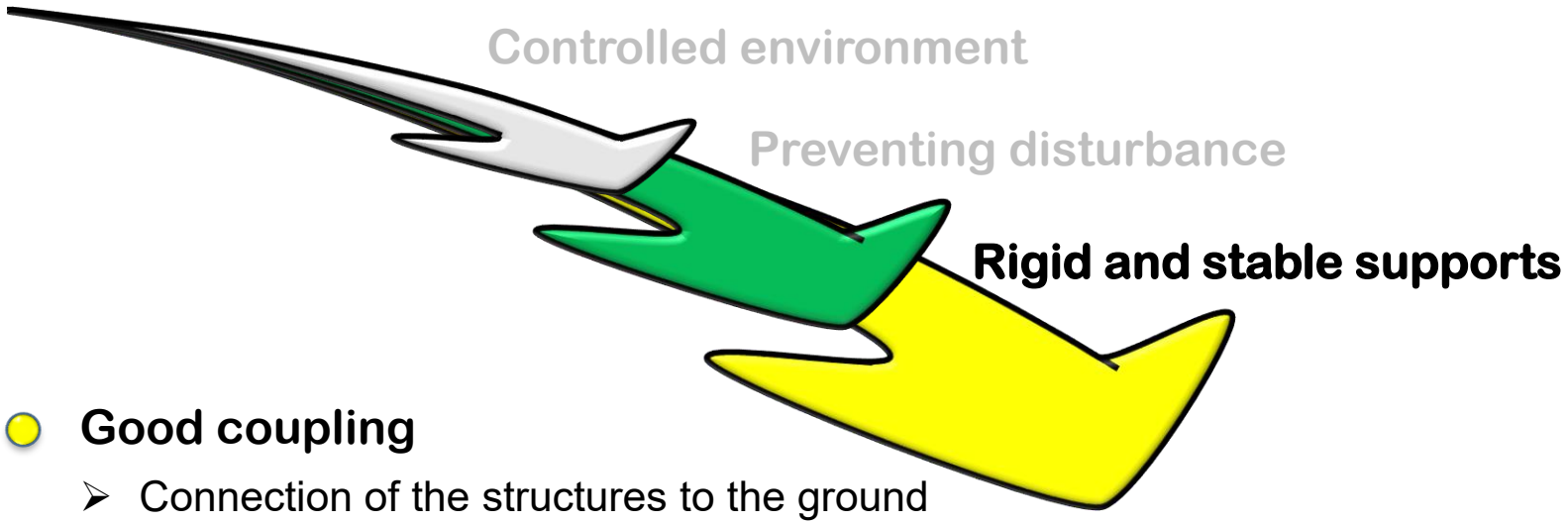
Potential for Improvement

Considering new concepts for experimental hutches.

- **Optimizing problematic components**
  - Moving conditions of valves, shutter, absorbers.
  - Design of experimental hutches
  - Media pipes

Concepts for Stable Systems

To achieve the best measurement conditions



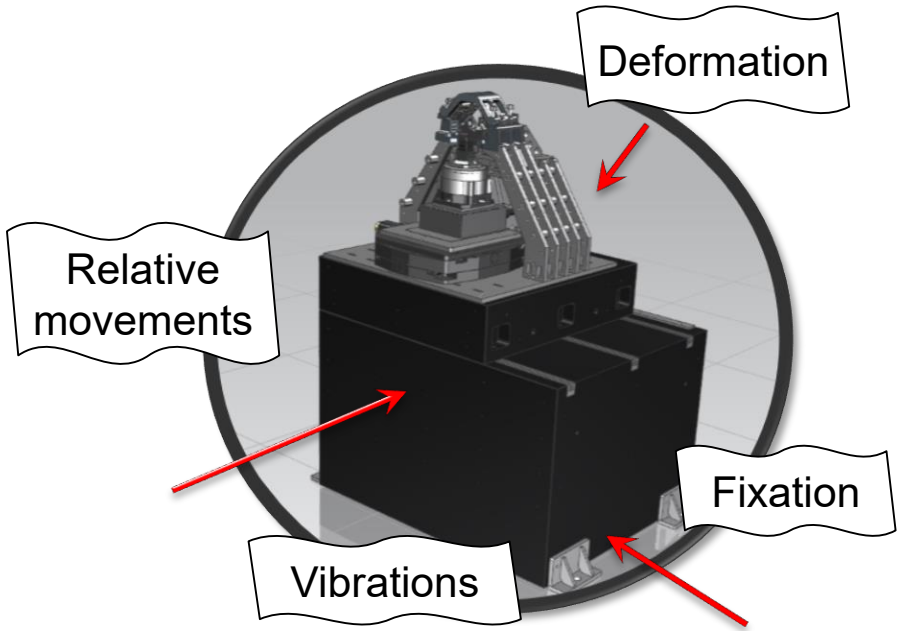
- **Good coupling**
  - Connection of the structures to the ground
  - Fixation of the structural components
- **Stiff construction**
- **Closed structures**
- **Optimize to high eigenfrequencies and vibration behavior**

→ Biologically Inspired Petra IV Girder Design
Talk by Simone Andresen

Options to improve

To be considered

- Installation and fixation
- Deformation and drifts
- Relative movements
- Eigenfrequencies



Concepts for Stable Systems

To achieve the best measurement conditions

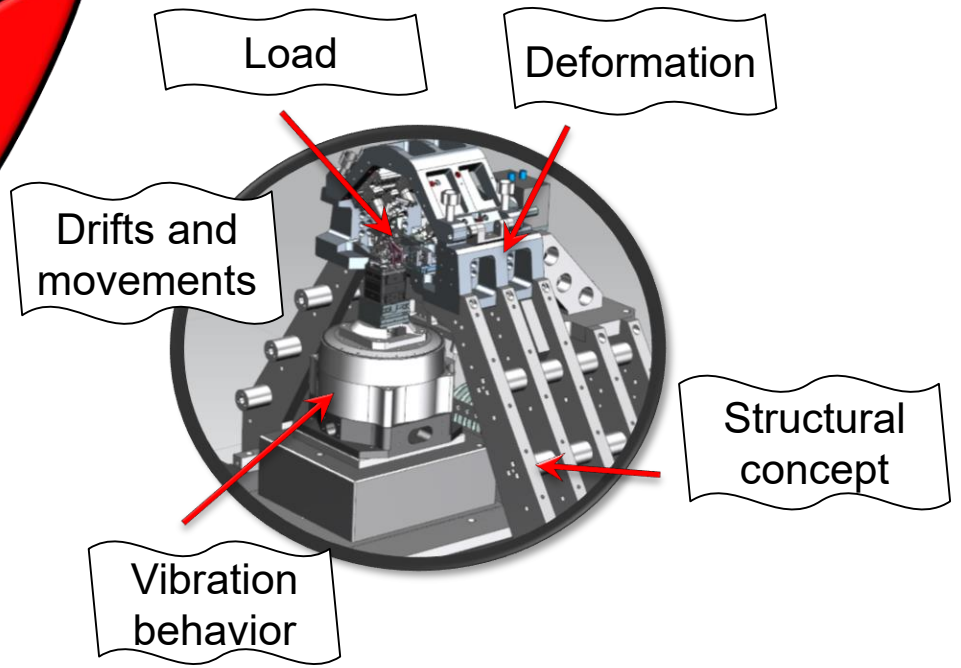
Controlled environment

Preventing disturbance

Rigid and stable supports

Optimized experimental designs

- **Detailed system analysis**
  - Minimizing vibration excitation
  - Identification of critical components
  - Minimizing levels of freedom
- **Structural Optimization**
  - Shape and design i.e. realizing optimized structures (Bionic design)
  - Mass, material, weight
  - Deformation and vibration behavior
- **Optimized experimental setups:**
  - Prevent for free swinging components attached
  - Temperature drifts
  - Fixation of components



Concepts for Stable Systems

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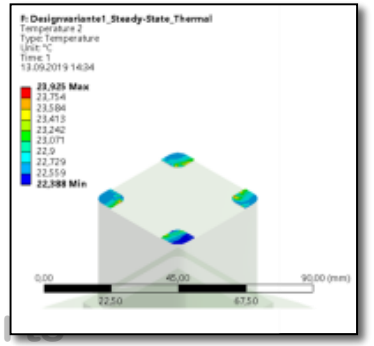
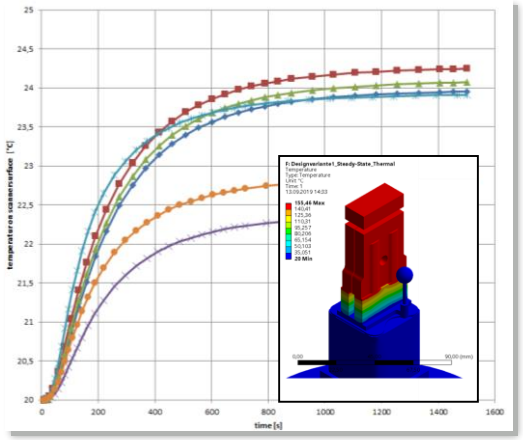
  - ➢ Temperature drifts
  - ➢ Fixation of components

Optimized experimental designs

Examples

Thermal analysis and optimization of a heating cell for drifts and heat transfer (ANSYS)

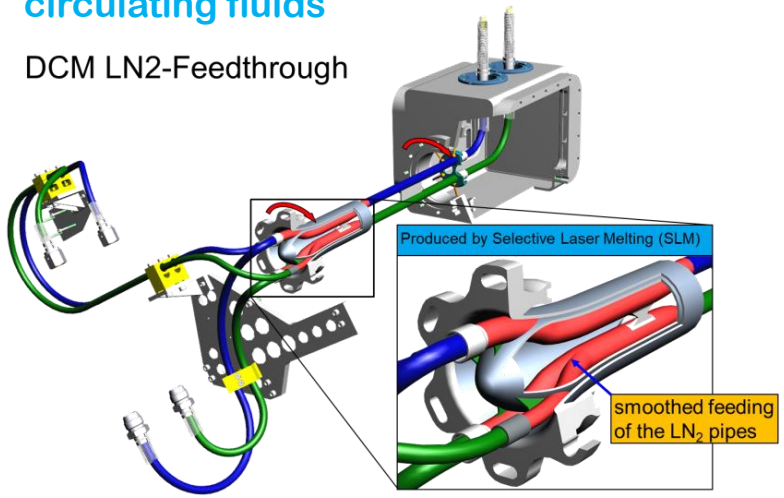




M. Landmann (DESY)

Minimizing vibration excitation from circulating fluids

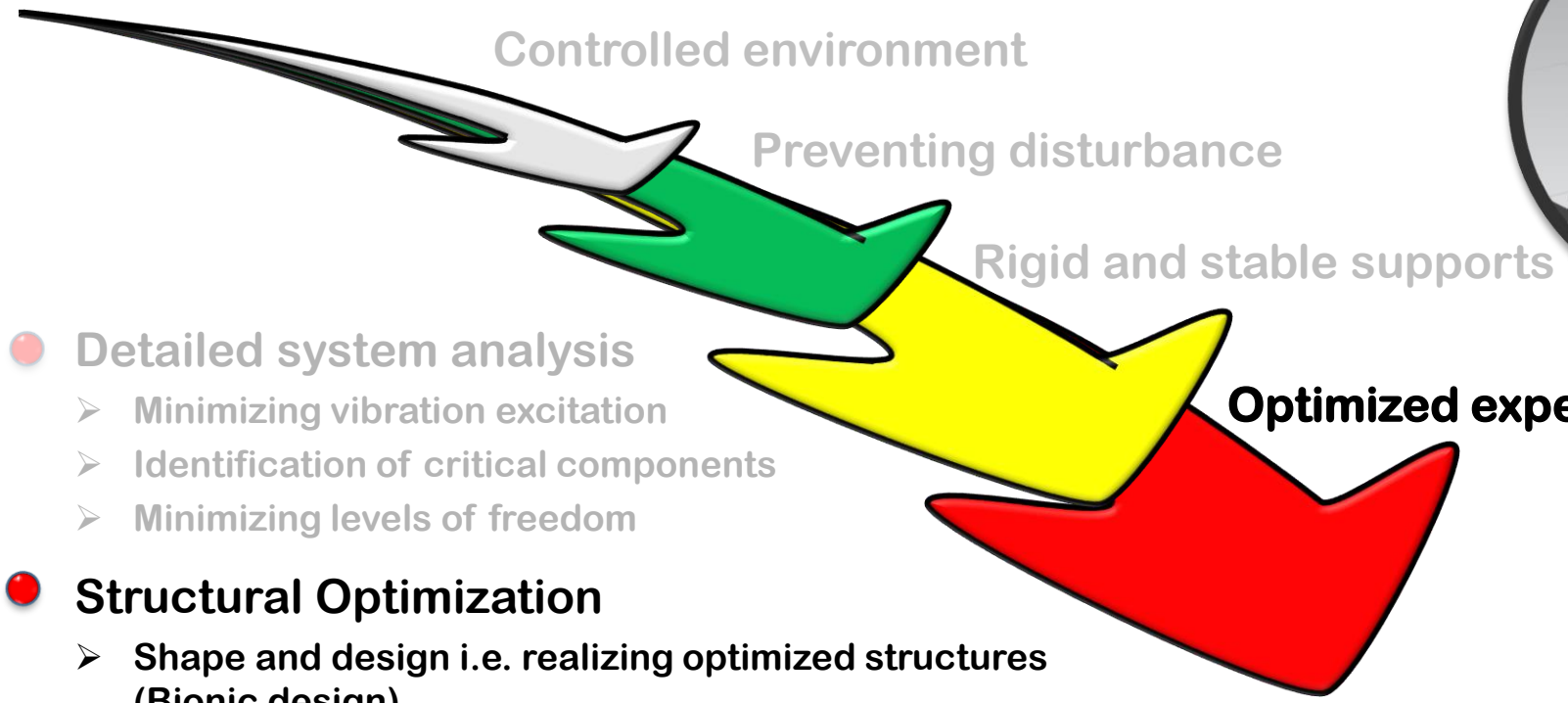
DCM LN2-Feedthrough



- ➢ Realizing smoothed feeding of LN2
- ➢ Optimized stiffness and heat transfer
- ➢ Simple and easy production using SLM

Concepts for Stable Systems

To achieve the best measurement conditions



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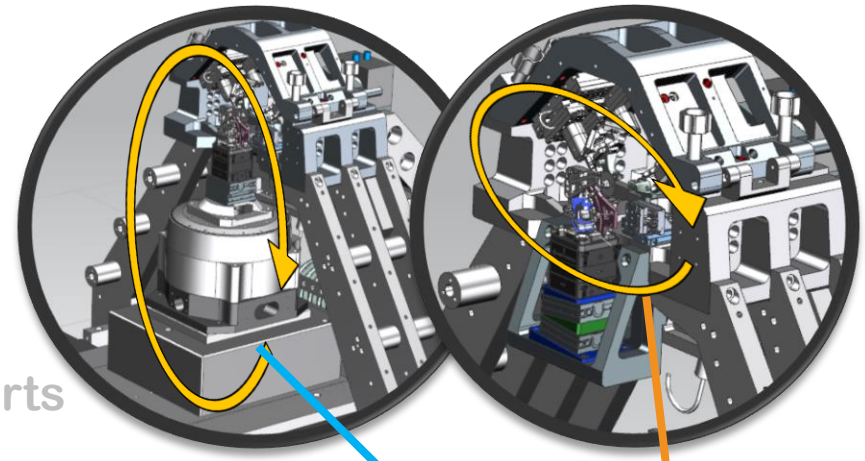
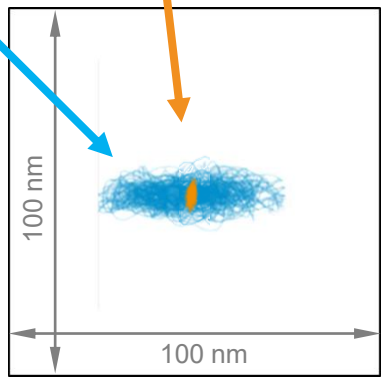
Examples



Closed Structure
Including positioning and precise position measurement in a closed loop



Concepts for Stable Systems

To achieve the best measurement conditions

Controlled environment

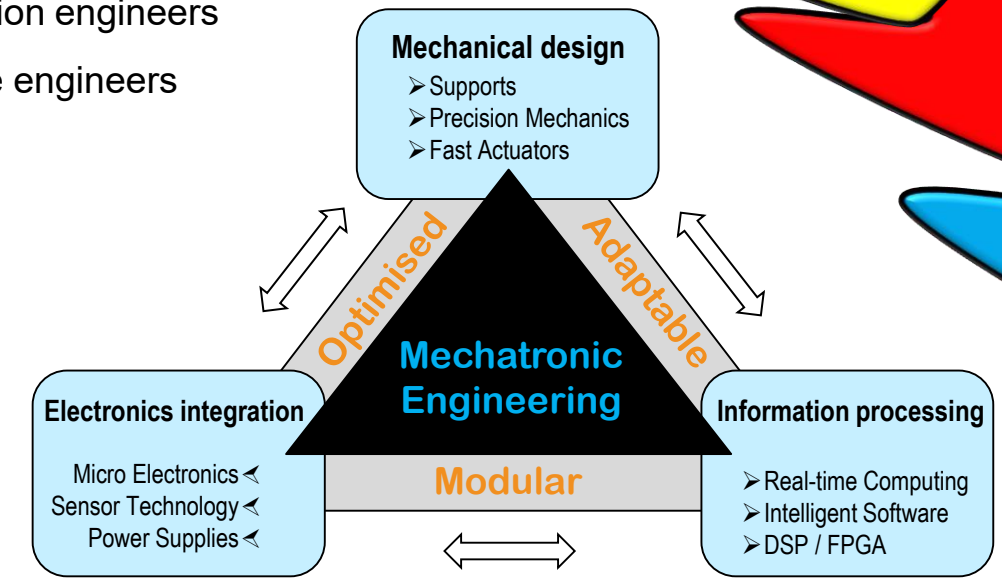
Preventing disturbance

Rigid and stable supports

Optimized experimental designs

Modern mechatronic concepts

- **Make use of System-Engineering for developing components**
  - ➢ Mechanical design engineers
  - ➢ Automation engineers
  - ➢ Software engineers

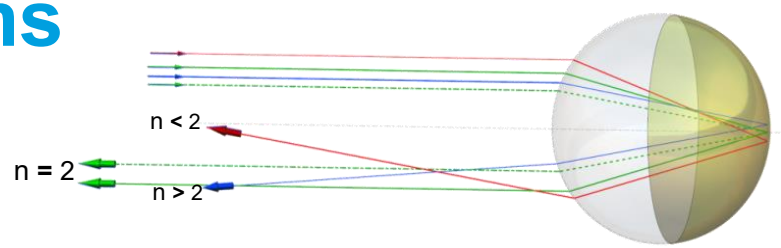


To be considered

- Systems becoming more and more complex
- Requirements will increase

Concepts for Stable Systems

To achieve the best measurement conditions



Ball Lens as a retroreflector
- works also during rotation

Controlled environment

Preventing disturbance

- Make use of System-Engineering for developing components

Rigid and stable supports

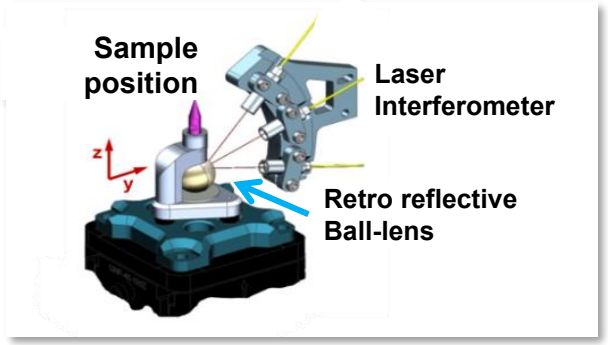
- **Integration of fast feedback systems**
  - ➢ Precise position detection
  - ➢ Fast and accurate actuators
  - ➢ Fast control loops

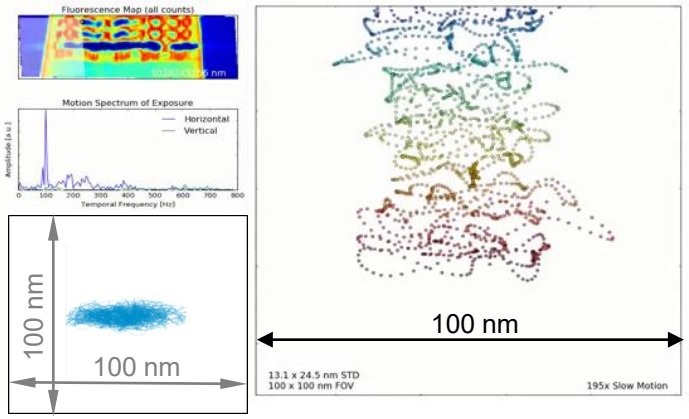
Optimized experimental designs

Modern mechatronic concepts

Example

Position detection using Laser Interferometer





Position fluctuation of the sample at a continuous scan.
Measured with a set of laser interferometer
DESY P06 PtyNAMi Beamline

Concepts for Stable Systems

To achieve the best measurement conditions

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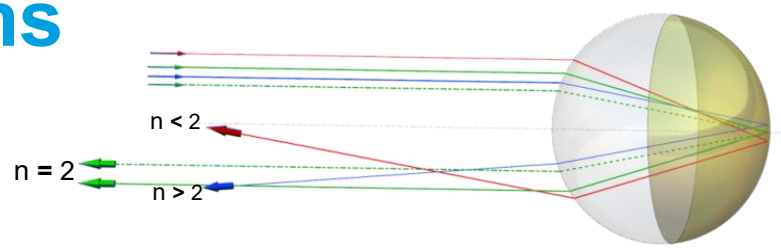
Optimized experimental designs

Modern mechatronic concepts

- Make use of System-Engineering for developing components

- **Integration of fast feedback systems**
  - Precise position detection
  - Fast and accurate actuators
  - Fast control loops

- **Suppressing disturbing interferences**
  - Investigating active damping
  - Anti- sound technics



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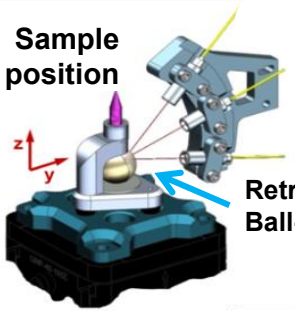
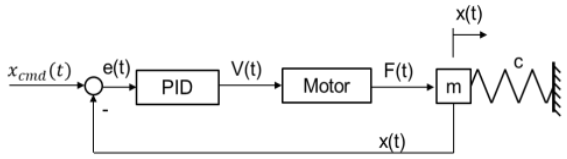
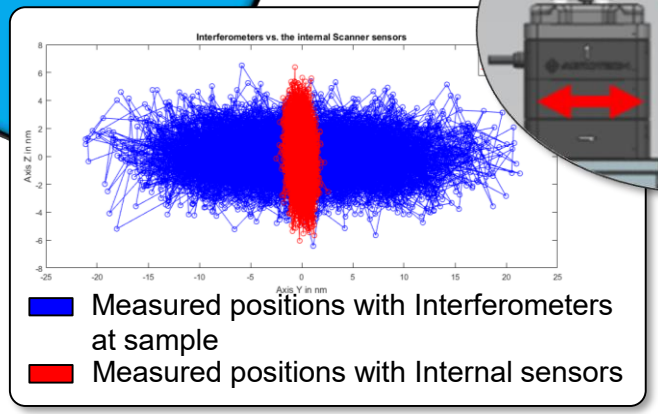


Example

Position correction using Laser Interferometer

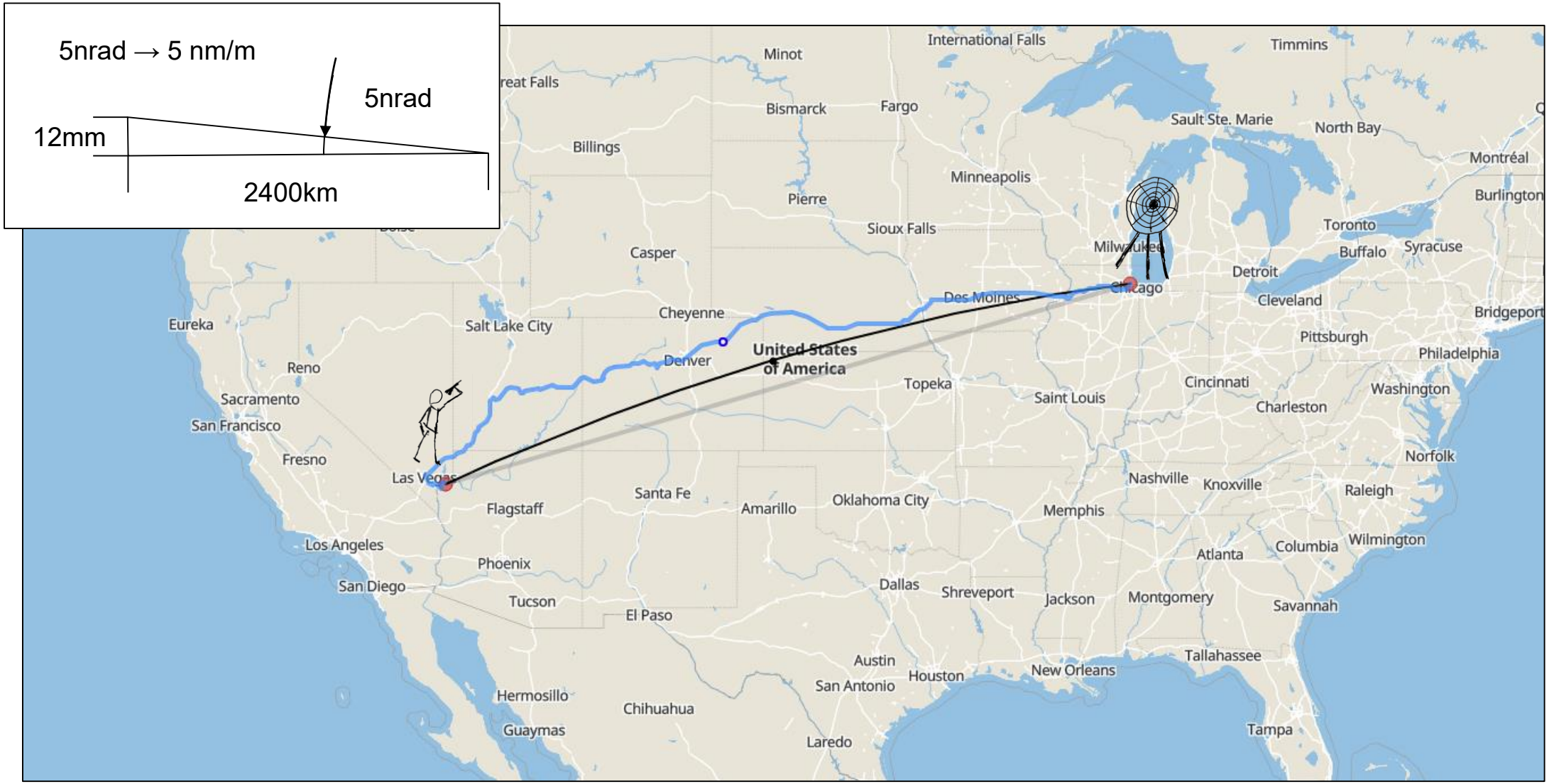




Conclusion an Outlook

- UPM alone is not able to fulfill all the requirements in stability and accuracy
- Using the full range of systems engineering to optimize the five basic points for good experimentation conditions
- All disturbing influences must be eliminated
- The environmental conditions must be created in the best possible way
- Development of highly specialized setups are in progress
  - → To study the optimization of sample environments
  - → New feedback control systems
  - → Scanning strategies

Precision requirements transferred to macroscopic scale



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- **FS-PETRA Engineering Students**

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  Torben Reuß
  Jan Horstmann

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- **FS-PETRA Staff**
- **P06 Staff**
- **DESY Central Construction**

Thank you for your Attention !