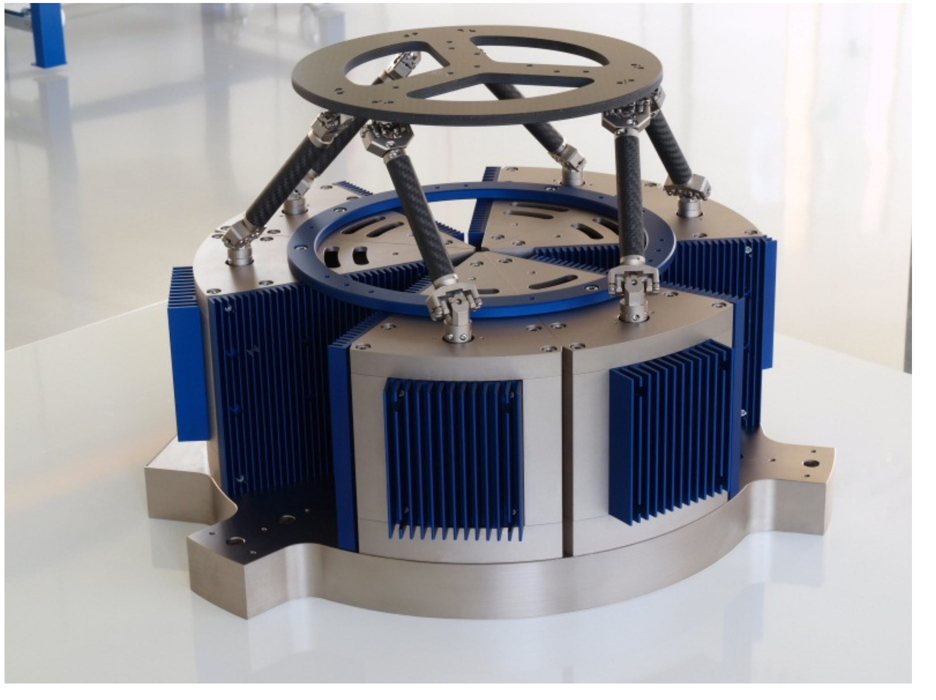
Physik Instrumente

Hexapoden für hochdynamische, präzise Bewegungssimulationen in sechs Achsen

Outline

- Motivation
- Mechanical Design H-860KMAG
- Results



Motivation

- Shaking Applications for Image Stabilization Routines
  - Simulating external influences on the mobile camera device require high velocities:

    > 150 mm/s while being seated in a moving car

    > 500 mm/s while walking

- High Precision Trajectories

- Further requirements:
  - No backlash
  - No disturbing noises
  - High eigenfrequencies
  - Light weighted design

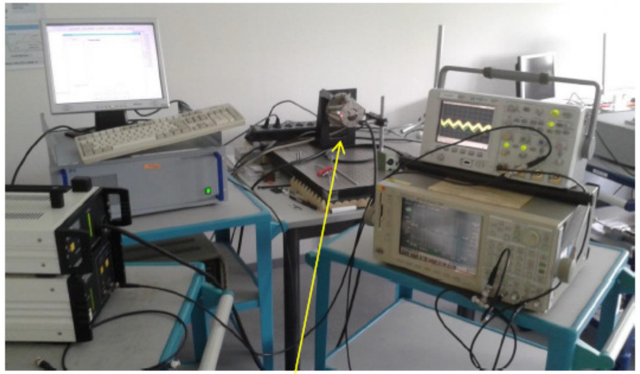
Existing Hexapod System H-811.S2

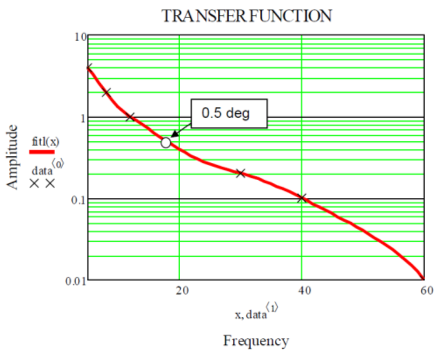
Useful for highly dynamic applications?

- CIPA certified
  - Camera & Imaging Products Association
  - http://www.cipa.jp/image-stabilization/contents_e/list_e.html

- H-811.S2
  - Payload (dynamic) m = 1 kg
  - Velocity v = 20 mm/s, max. 25mm/s
  - Actuator resolution < 40 nm
  - 1st Eigenfrequency > 100 Hz
  - Acceleration < 0.2 g
  - Ball Screw Drive
  - Ball Bearings

H-811.S2 – Dynamic Performance





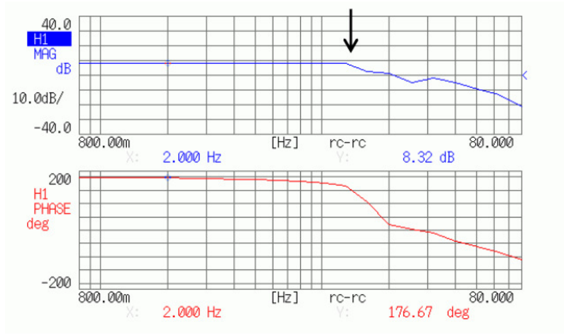
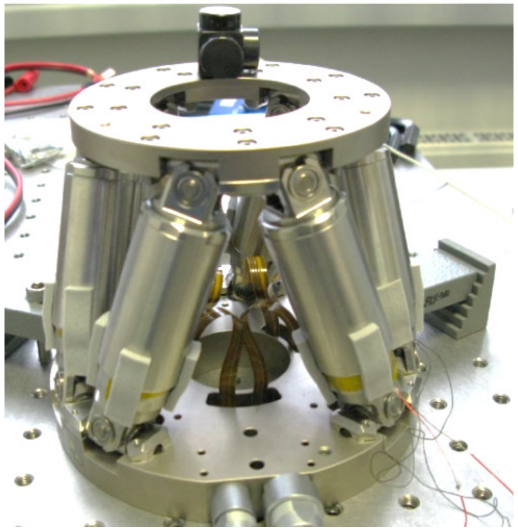
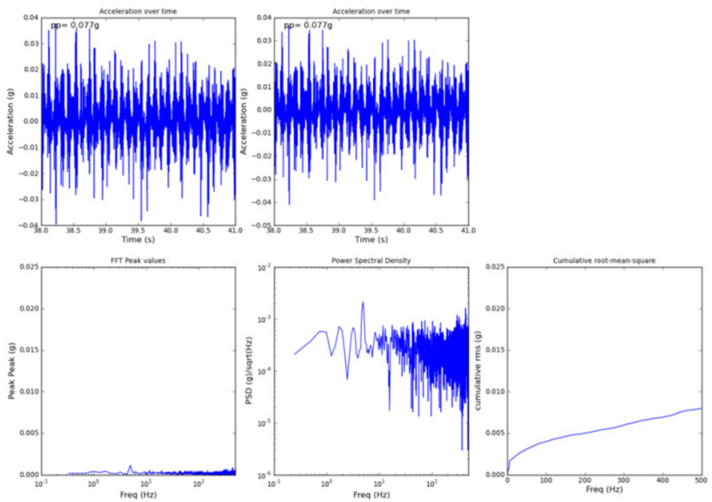


Fig.4: V-motion (rot Y), amplitude= 1deg pp, linearity up to 12Hz





Requirements for New System

H-811.S2

- Payload m = 1 kg (dynamic)
- Velocity v < 25 mm/s
- Actuator resolution < 40 nm
- 1st Eigenfrequency > 100 Hz
- Acceleration < 0.2 g
- Ball Screw
- Ball Bearings
- BLDC Motor

H-860KMAG

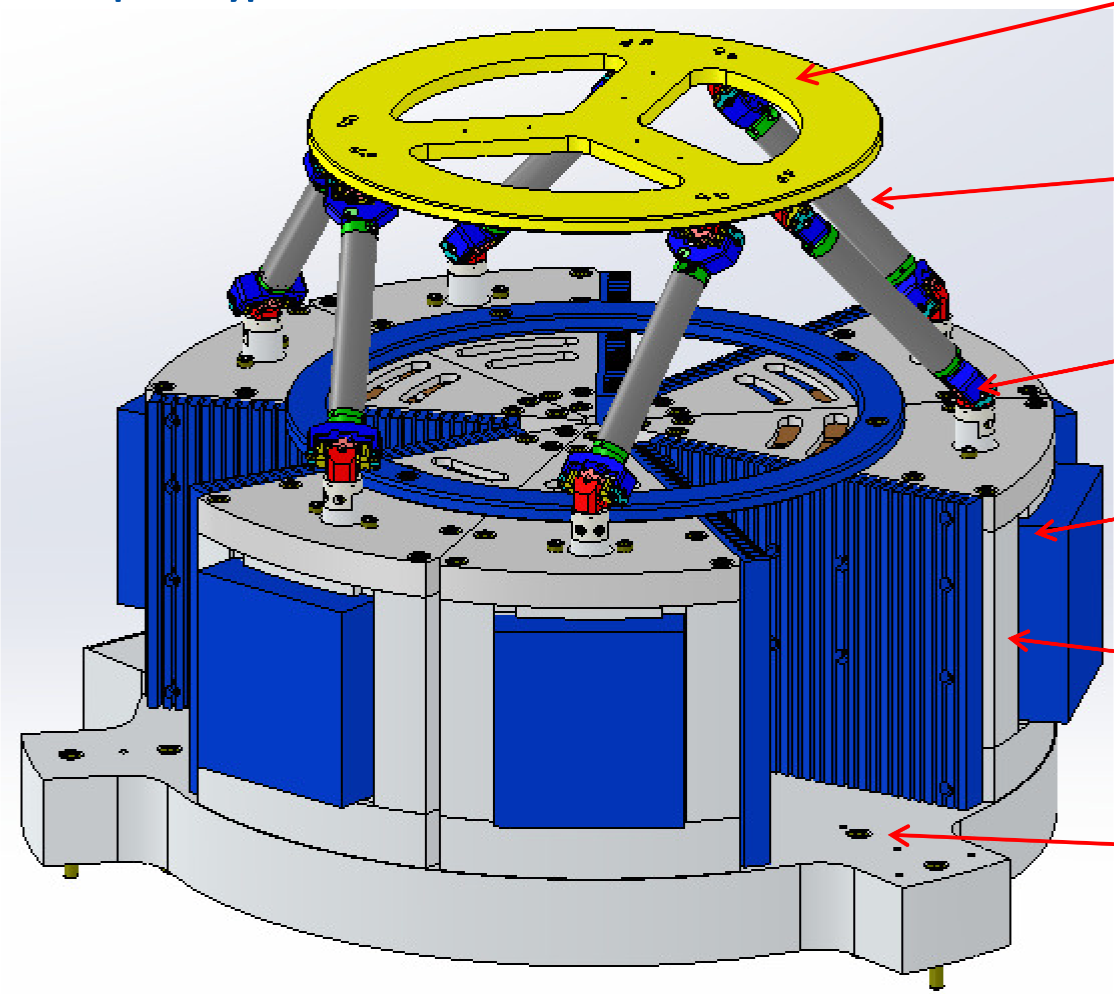
- m = 1 kg (dynamic)
- v > 250 mm/s
- < 20 nm
- > 200 Hz
- > 4 g
- No rolling elements

→ Flexures

- Voice Coil Drive

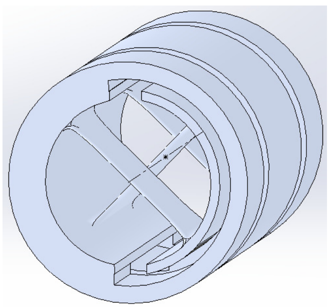
Mechanical Set-up

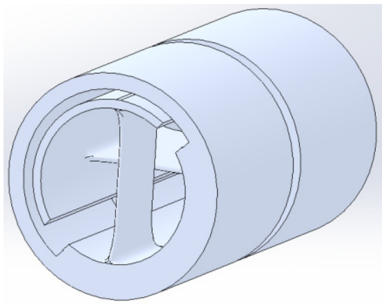
1st prototype



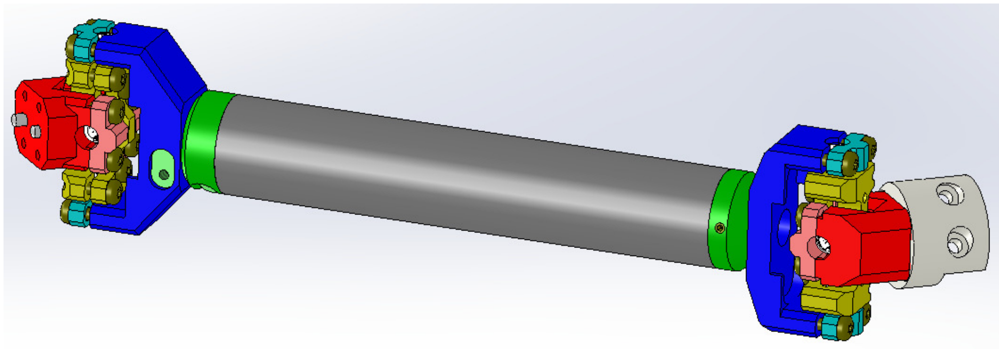
Struts

- Passive structure → constant leg length
- Flexural joints
- Strut material CFC

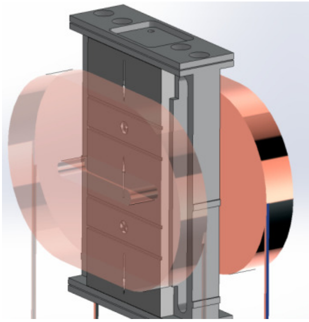


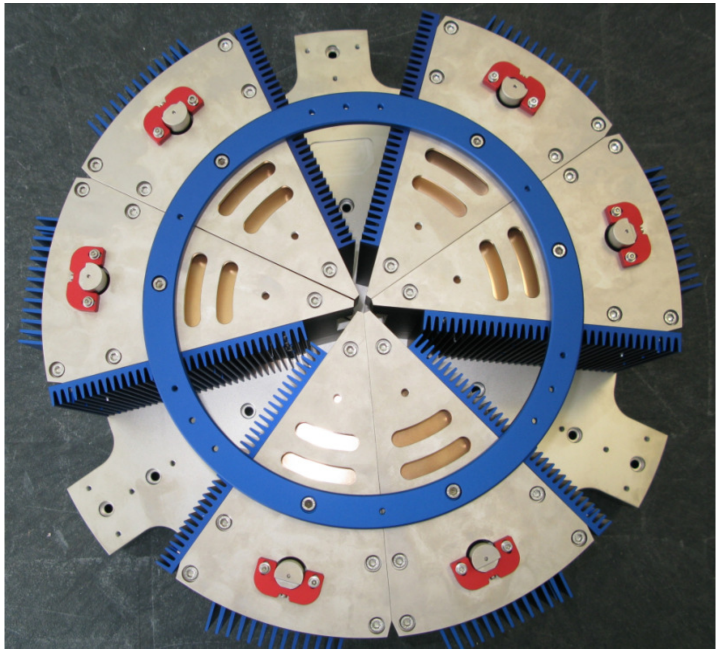


- Strut:
  - Total weight < 60 g
  - Length approx. 125 mm
  - Non-magnetic

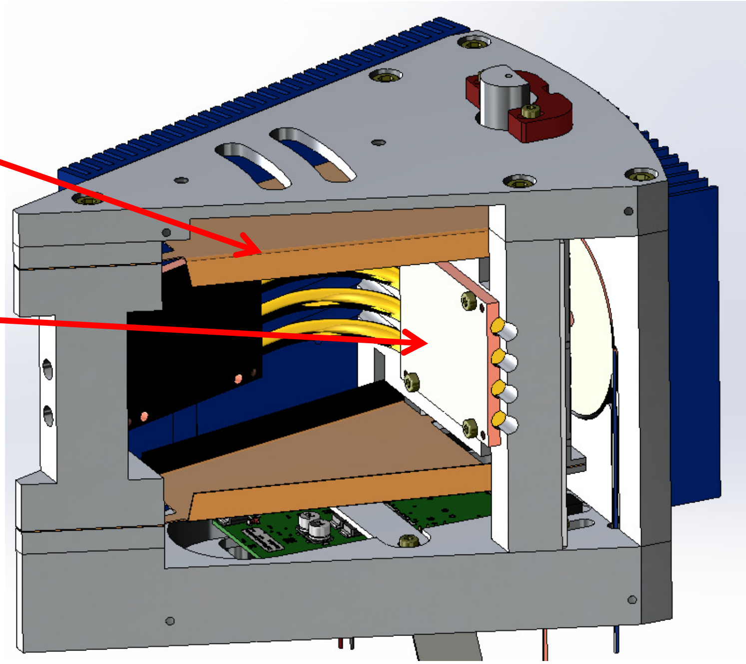


Single Actuator



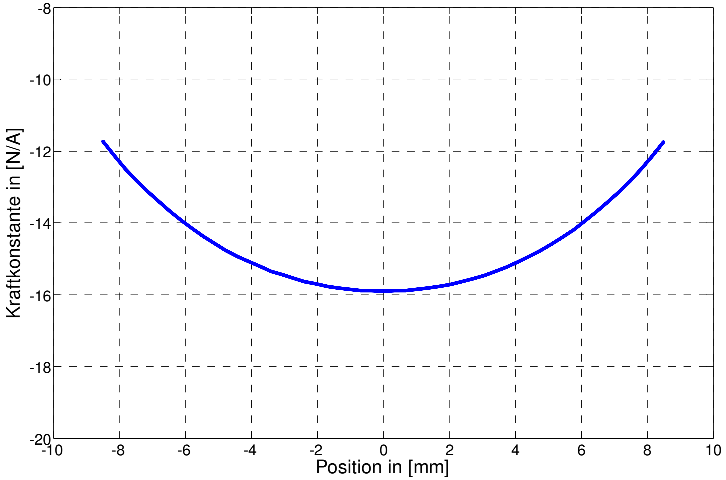


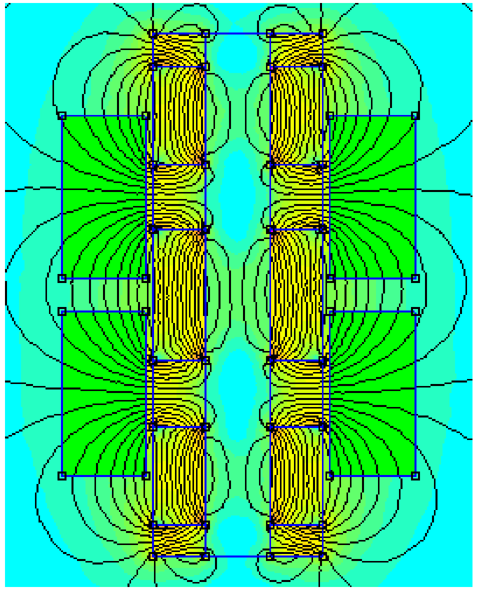
- Voice Coil setup comprising
  - Halbach Arrays
  - Two Coils
- Flexural guiding
  - Leaf springs
- Thermal Management consisting of
  - Coupling Elements
  - Heatpipe Array
  - Cooling Elements

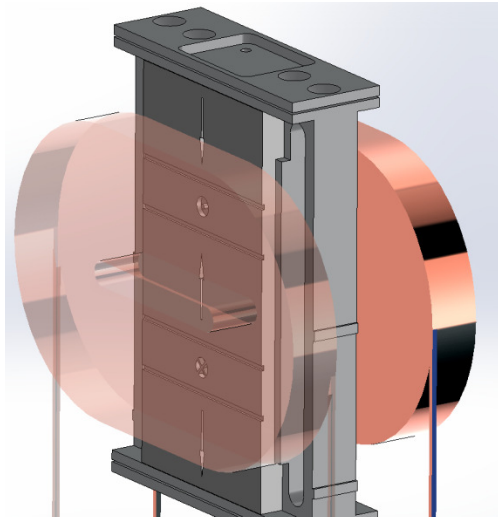


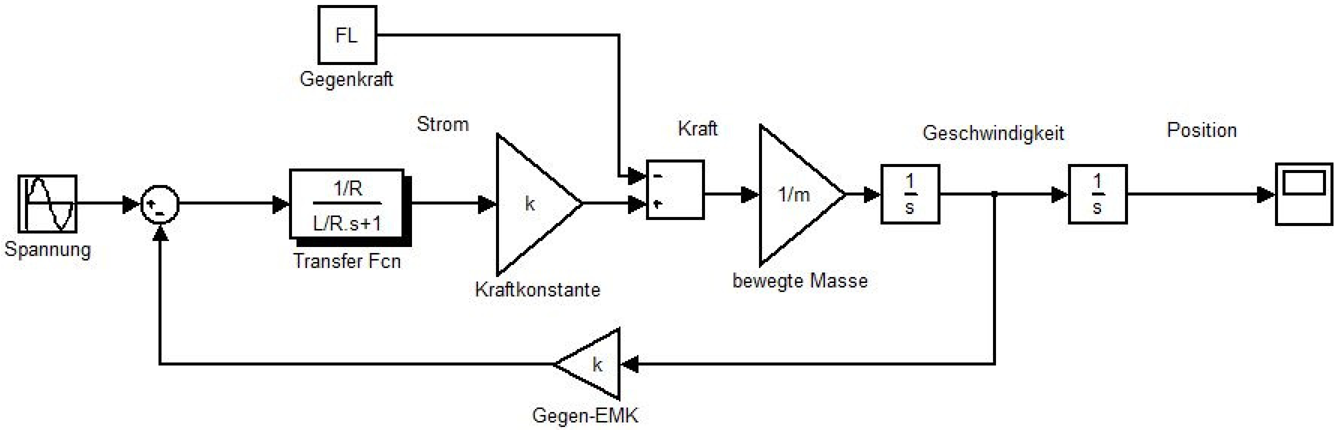
Linear Actuator Simulation

- R = 2 * 2.6 Ohm
- L = 2 * 9.8 mH
- k = f(z)
- k_max ~ 16N/A
- m = 0.31kg









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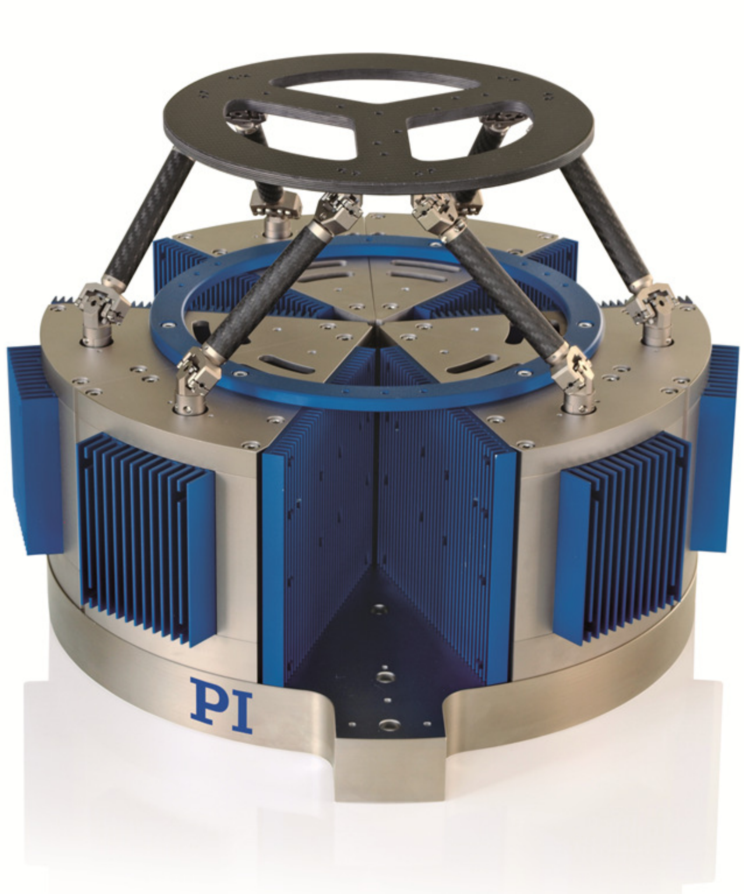
Voice Coil Driven Hexapod – Completely Flexural Design

H-860KMAG



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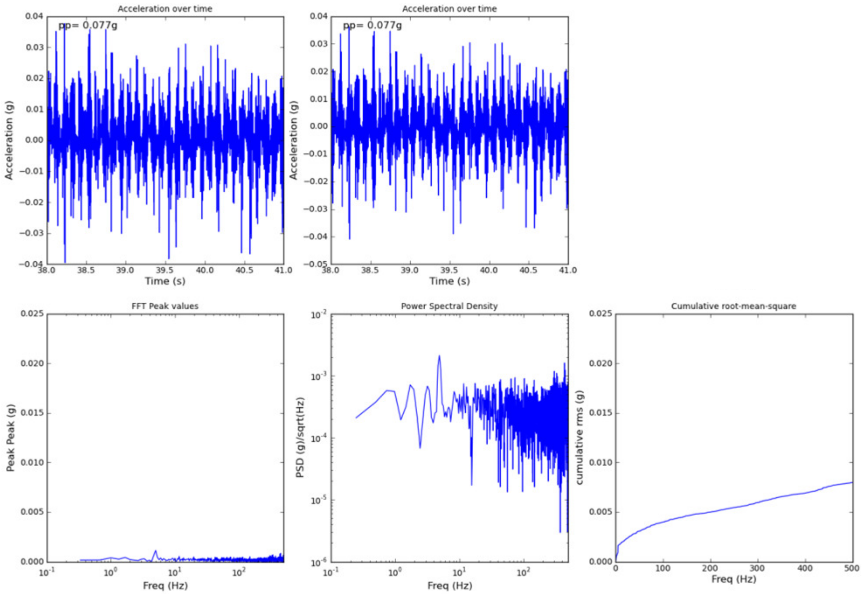
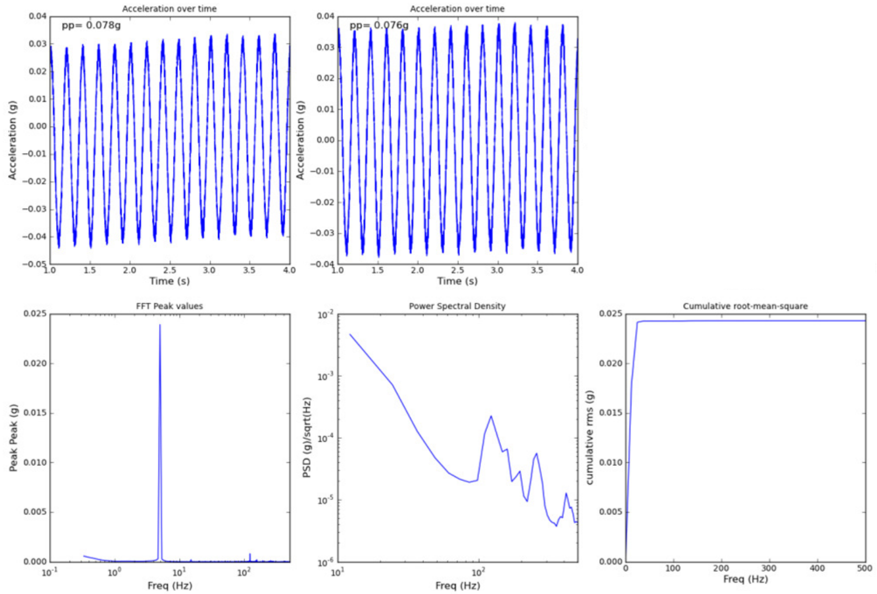
Dynamic Performance

Oscillation about V (rot Y): 0.5° pp @ 5 Hz



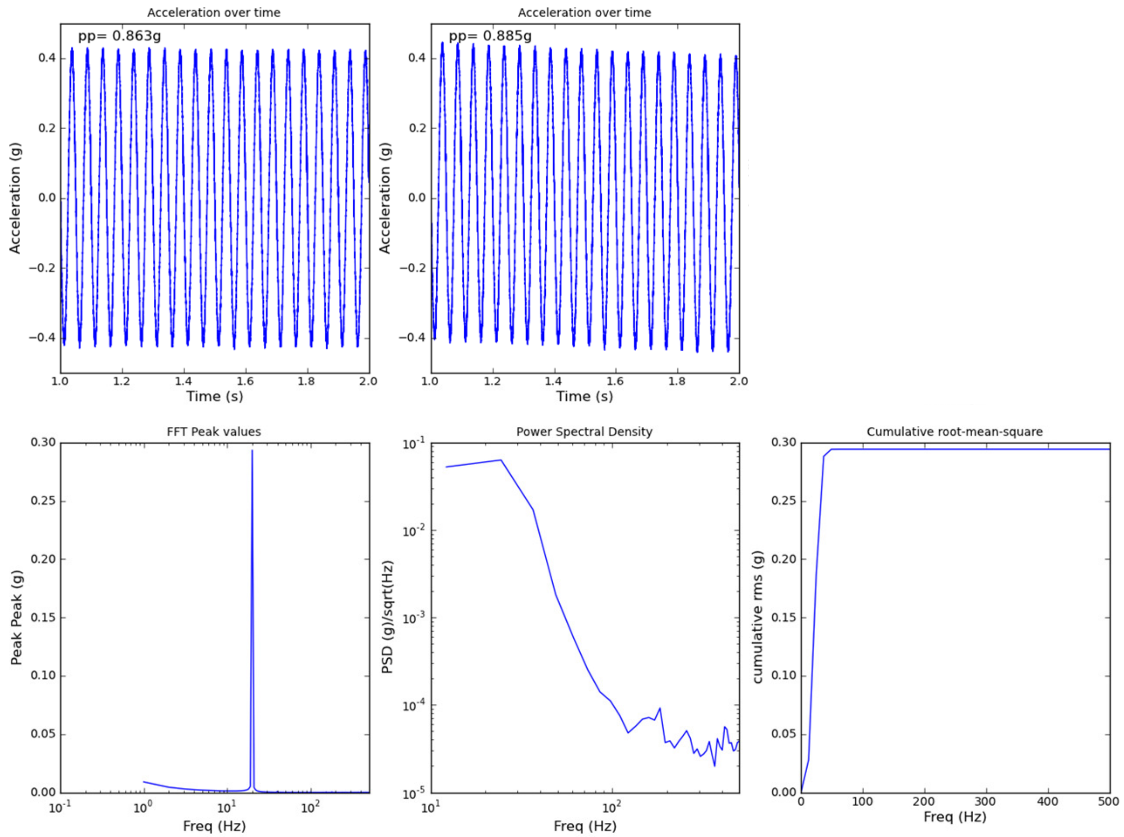
H-811



H-860

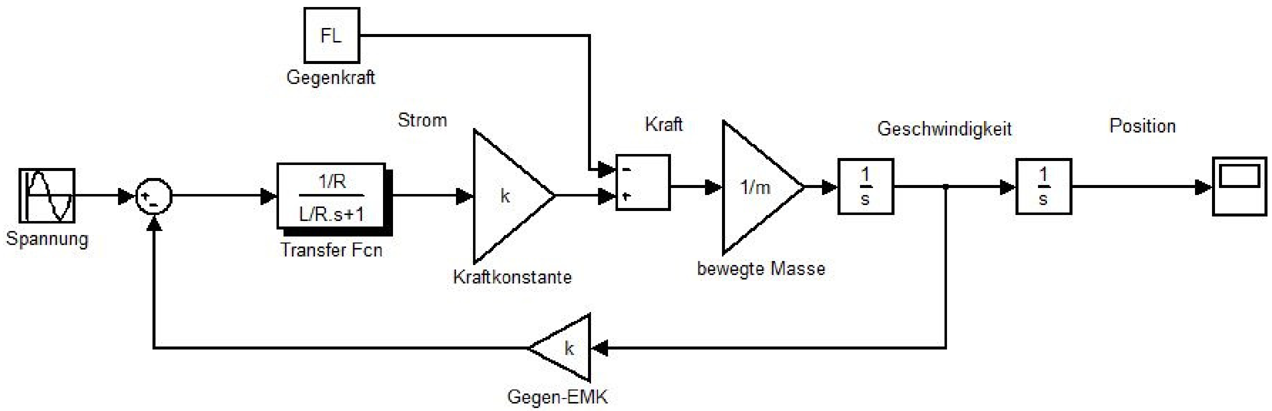
Dynamic Performance

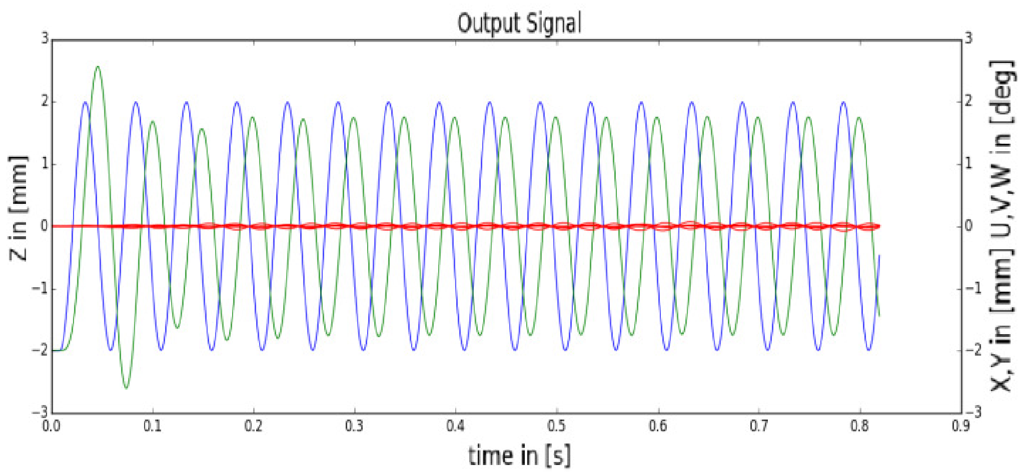
H-860KMAG: Oscillation about U (rot X): 0.25° pp @ 20 Hz



Improvement of Control Loop Design

Starting from





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Extended Control Scheme

System Transfer Function:

$$G_{sys}(s) = G_E G_M G_L = \frac{k}{(L_0 s + R)(T_M s + 1)(ms^2 + c_F)}$$

- Increasing bandwidth and reducing phase shift

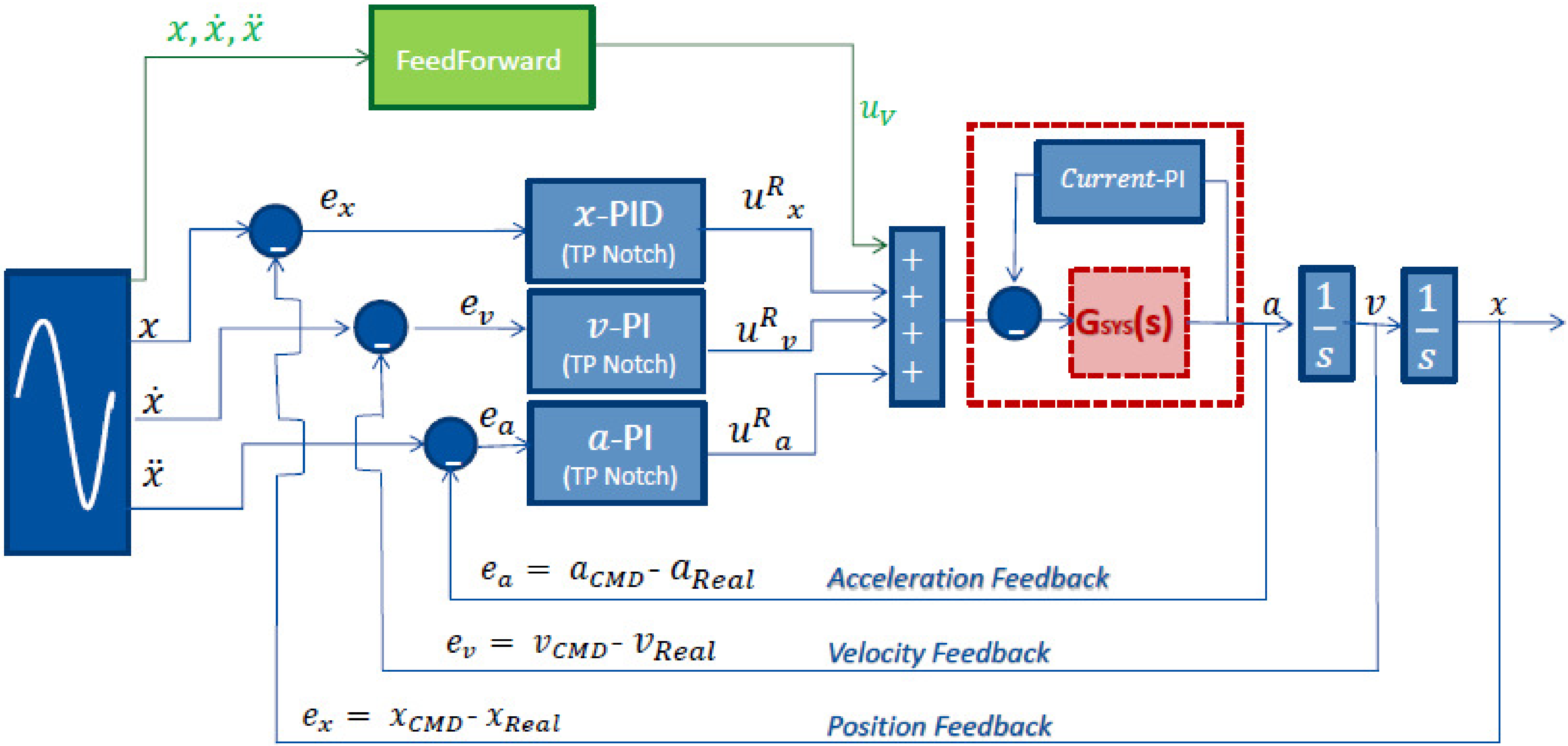
→ Adding FeedForward path

- Consideration of closed-loop poles

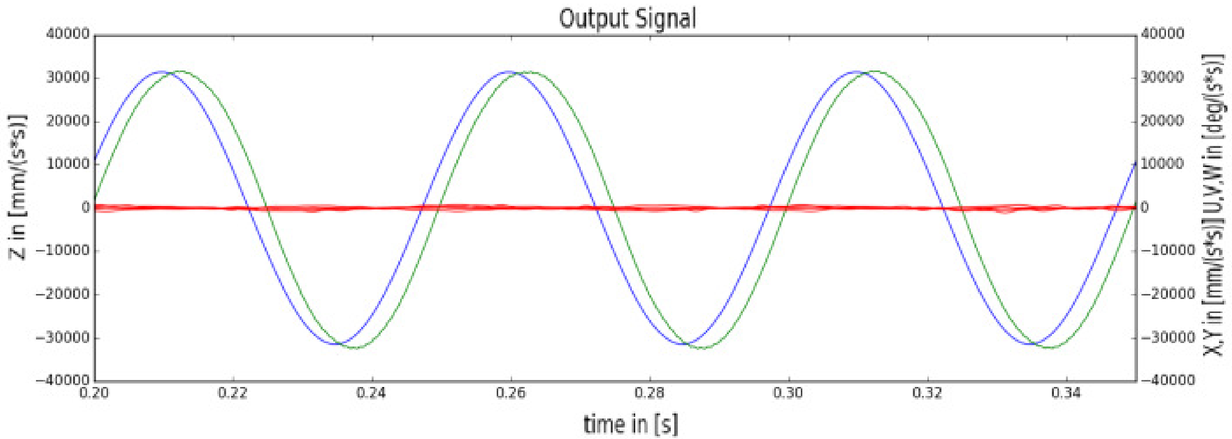
→ Implementation of additional current controller

→ velocity + acceleration feedback

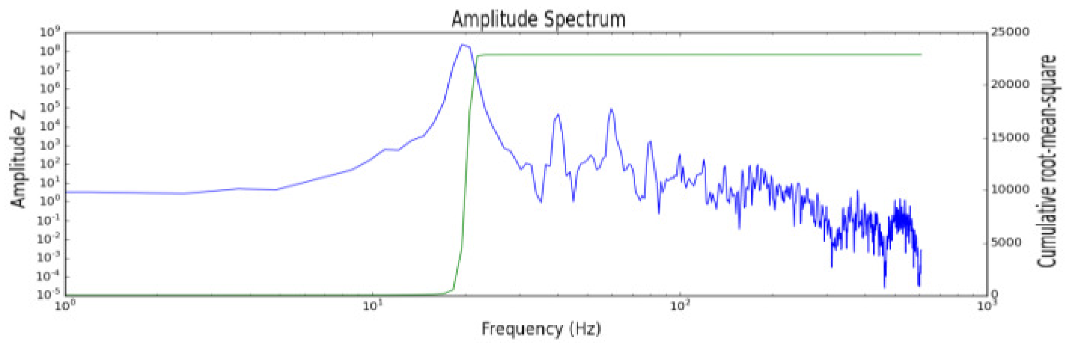
Extended Control Scheme



Results – acceleration measurements



- Accelerations up to 6g
- Velocity up to 750 mm/s
- → 20 Hz at 2 mm amplitude with tracking error < 15 µm



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Summary and Outlook

- Summary
  - Voice Coil driven hexapod with flexural guidings
  - Control structure
  - Dynamic Performance

- Outlook
  - Further increase of system stiffness
  - Optimization of power management
  - Optimization of control structure

Physik Instrumente

Physik Instrumente (PI) GmbH & Co. KG
Auf der Roemerstrasse 1
76228 Karlsruhe
Germany

Phone +49 721 4846-0
E-Mail info@pi.ws

Visit us: www.pi.ws