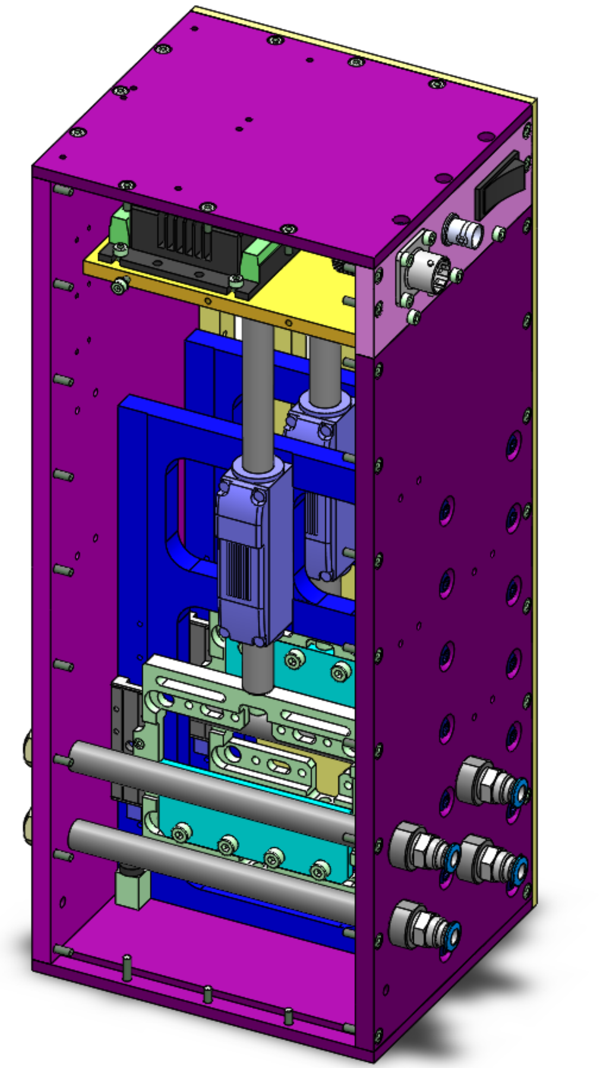

Development of a Linear Fast Shutter for BM05 and BEATS

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CONTENTS

Why a fast shutter?

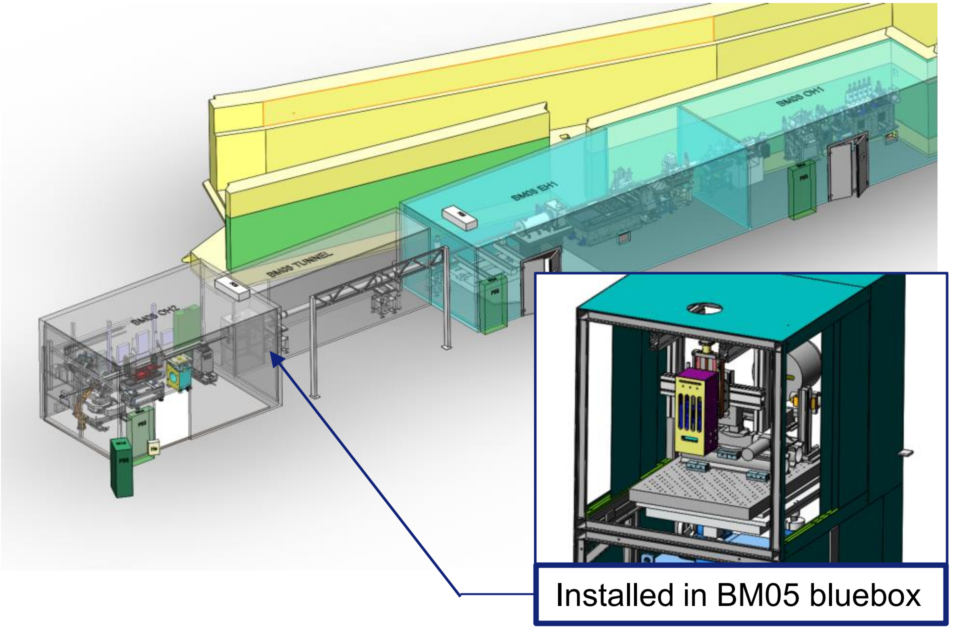
White beam tomography: protect samples from long radiation exposure and allows sample rotation when the shutter is closed

Diffraction topography: protect the CCD detector from radiation during data readout

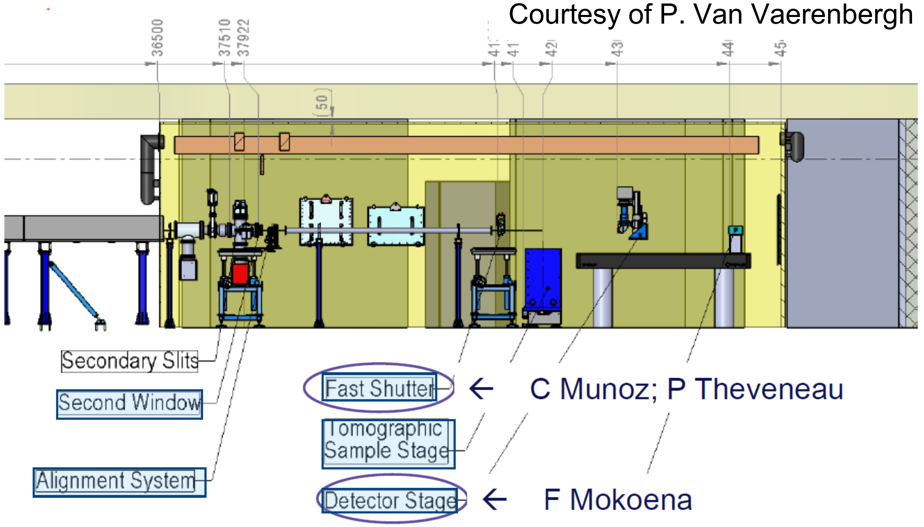
Two units to be produced:

One to be installed at tunnel before OH2 in BM05-ESRF

One to be installed at experimental station at BEATS-SESAME

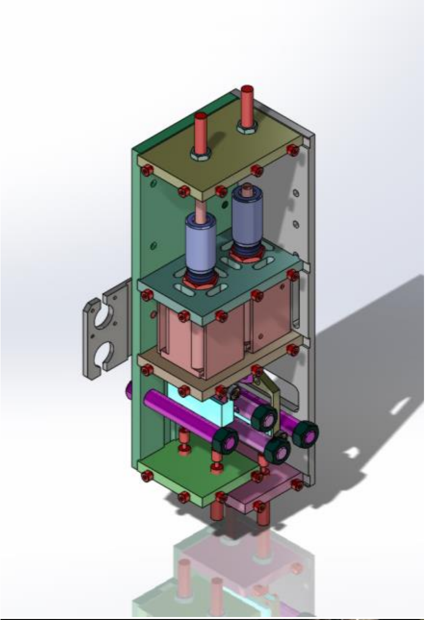


Courtesy of P. Van Vaerenbergh



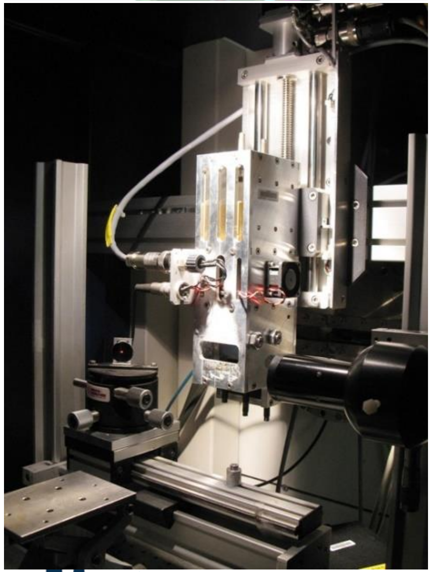
Old fast shutter (ID19 design) installed in BM05

- Motion through two electromagnets
- Spring shock absorbers to stop the blades



Problems:

- Shock causing slides to wear and huge vibrations
- Fluorescence phenomena in the stainless steel blades
- Control system is now obsolete



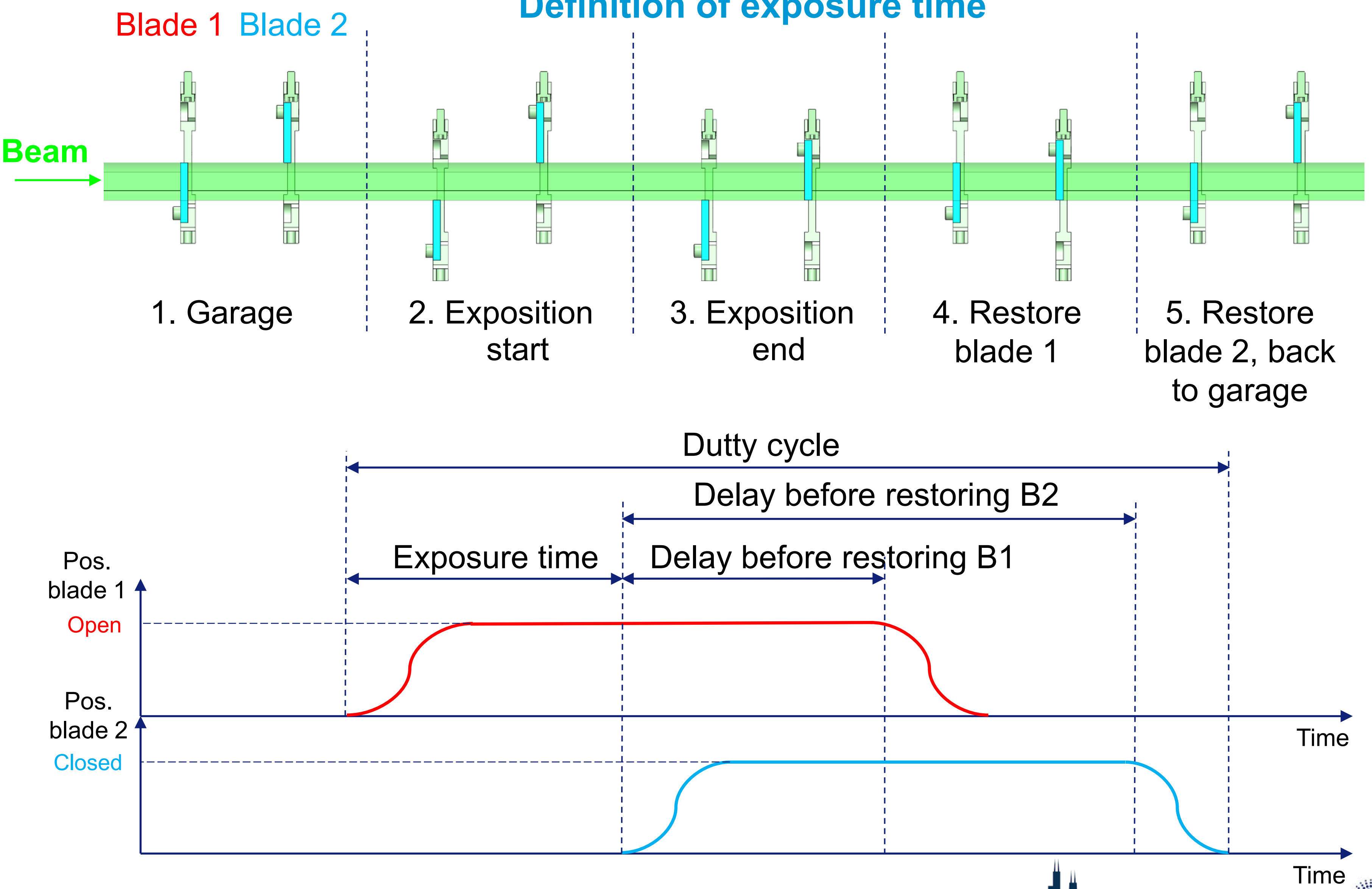
New specifications:

- Bigger window size: H 80 mm x V 20 mm
- Blades: tantalum, 4 mm thickness
- Exposure time: 100 ms - 60 s
- Time between exposure cycles: 1 s (repetition rate 1 Hz)

Objective:

- To achieve the desired exposure time and repetition rate
- To obtain a repeatable and uniform exposure time

Definition of exposure time



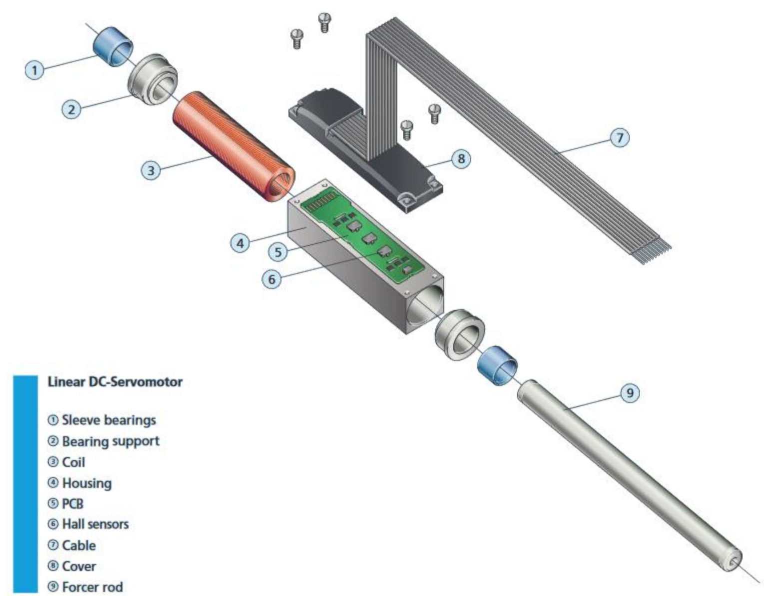
Faulhaber linear brushless DC motors:

- Solid stator housing with a coil assembly and a multi-pole magnetic rod
- High dynamics and precision: **accuracy 200 µm** and **repeatability 60 µm**
- Compact and easy to install, but careful design to respect distance to magnetized rods

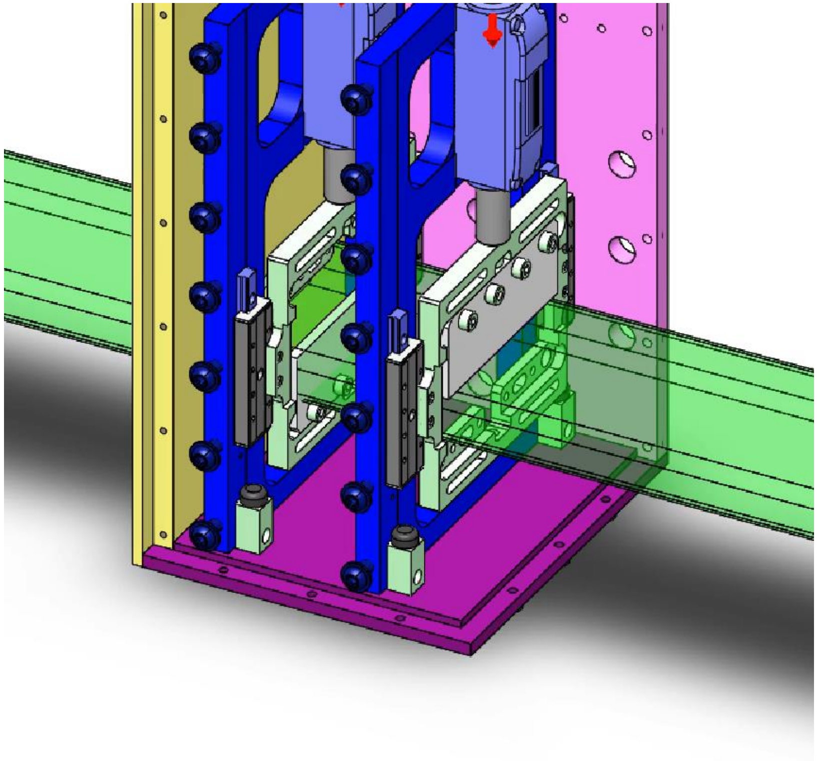
LM2080-080-11 parameters	
Continuous force [N]	9.2
Peak force [N]	27.0
Continuum current [A]	0.8
Peak current [A]	2.4
Stroke [mm]	80
Acceleration [m/s2]	61.3
Velocity [m/s]	2.2

Electronics and control:

- Controller for brushless DC motors with interface RS232
- Interface Faulhaber to program the sequences
- Each motor controlled **independently**
- Sequence produced with **TTL control signal**



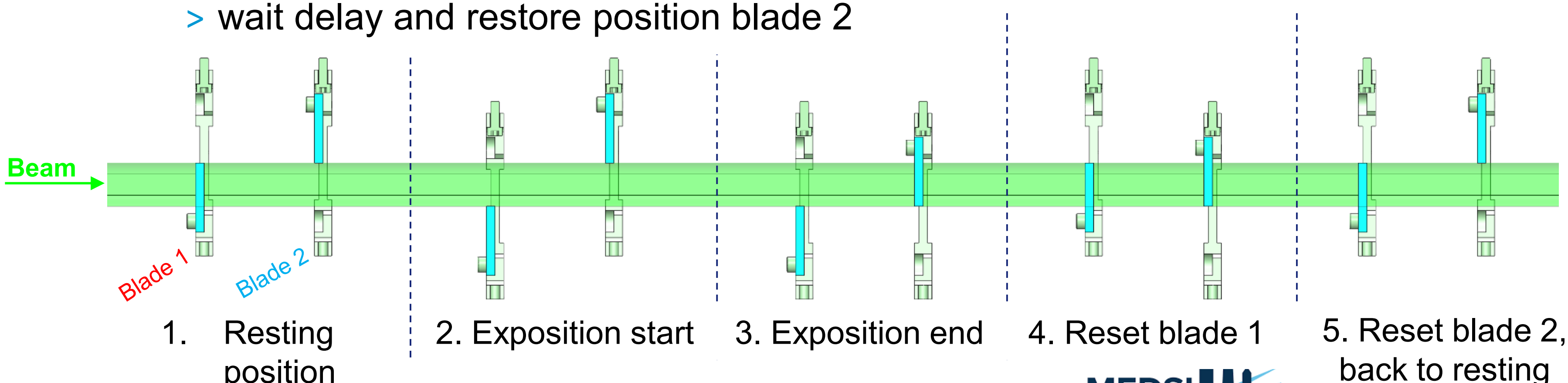
Exposure sequence:



Triangular profile of velocities with maximum acceleration

Control through **square wave with pulse width equal the exposure time**:

- Power ON: blades go to garage position
- Control signal from 0 to 1: move blade 1 to OPEN
- Control signal from 1 to 0:
  - move blade 2 to CLOSED
  - wait delay and restore position blade 1
  - wait delay and restore position blade 2



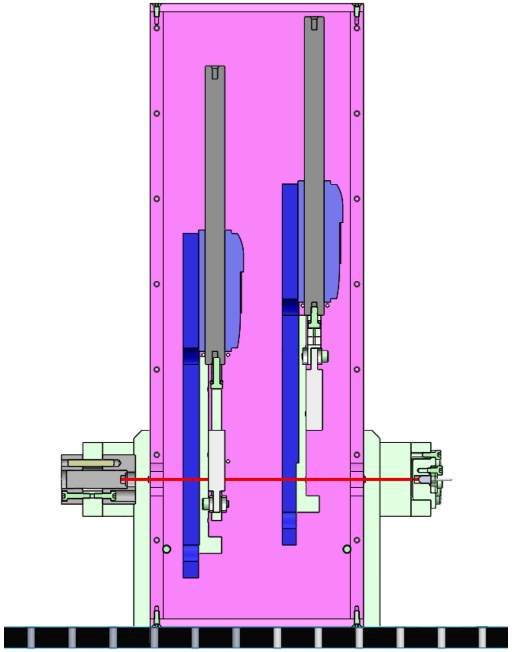
Construction of test bench to prove this concept

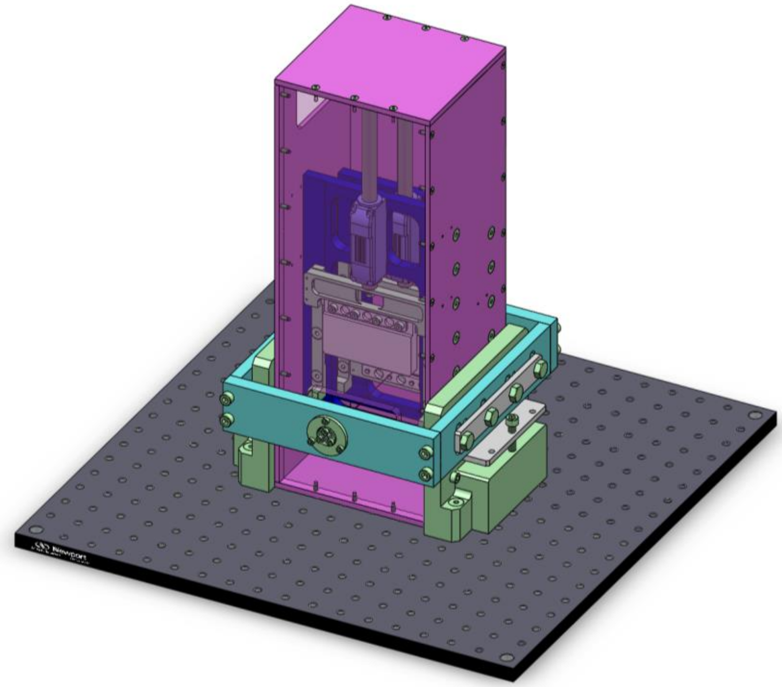
Shutter cage, motor frames and mock-up blades

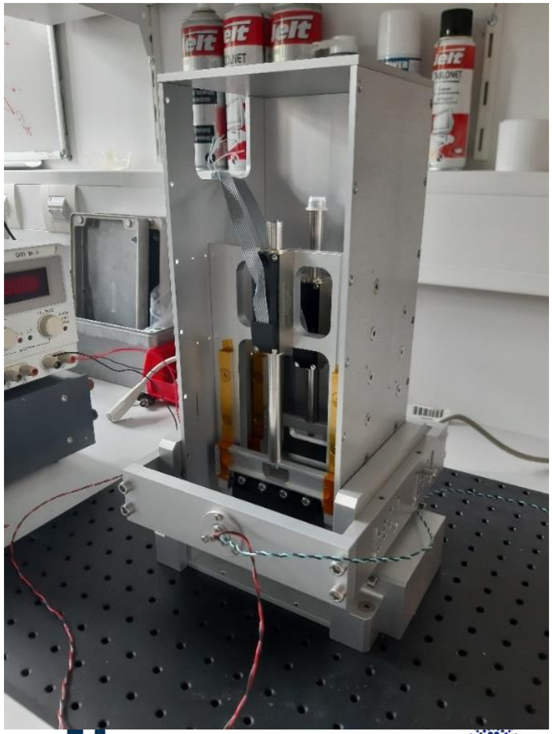
Mobile frame with laser and photodiode in Z

Measurements at different heights of the window

No guiding included – aluminium guide with kapton layer to prevent rotation







Measurements

- 40 open/close cycles for each position z, exposition time fixed to 100 ms
- 6 positions for different heights z

$\Delta t_1(z)$: time elapsed between the order to open blade 1 – see beam on the oscilloscope

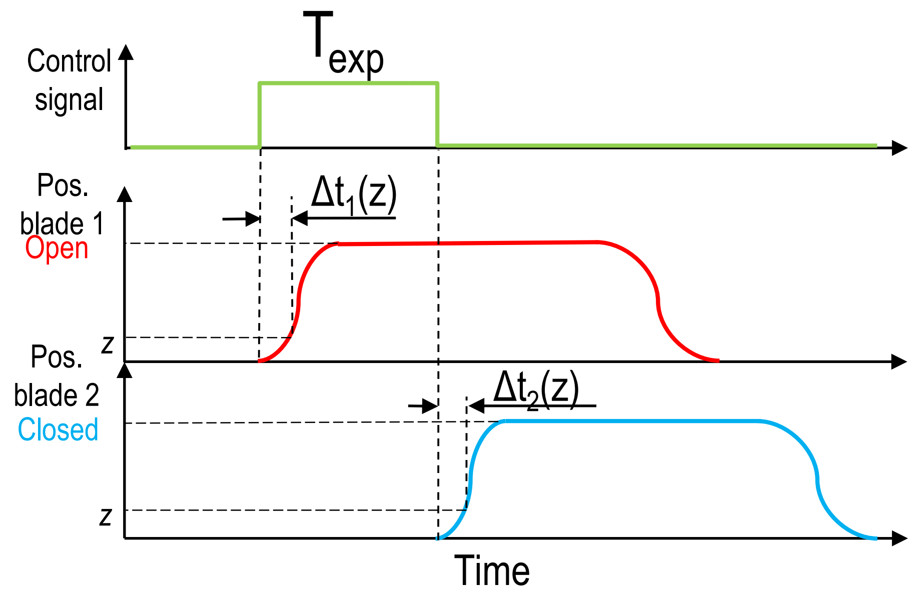
$\Delta t_2(z)$: time elapsed between the order to close blade 2 – no longer see beam on the oscilloscope

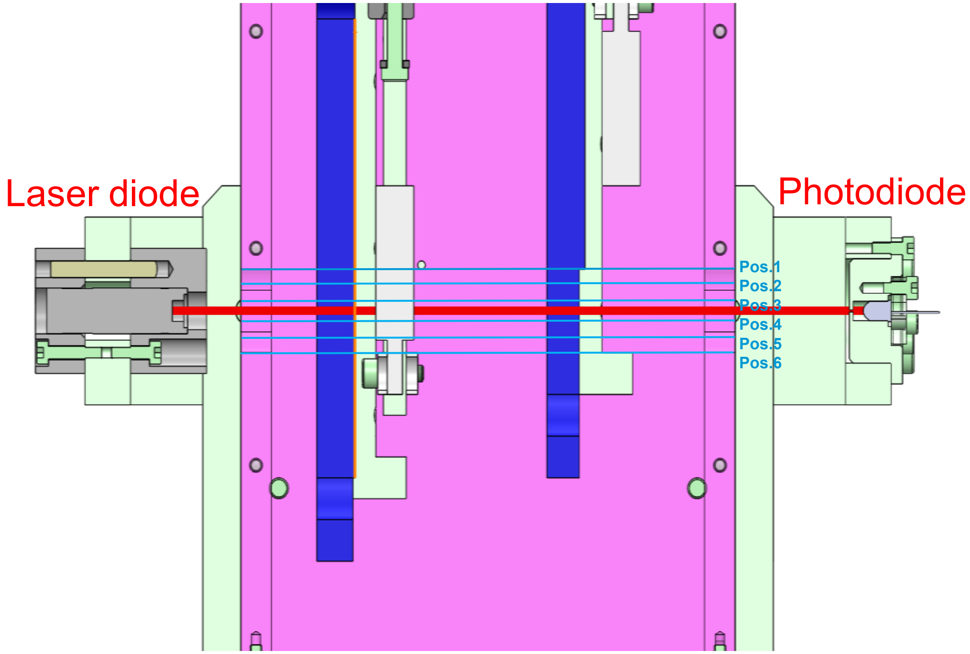
$$t_{exp}(z) = T_{exp} + \Delta t_2\,(z) - \Delta t_1(z)$$

- To have a uniform exposure:

$$\Delta t_1(z) = \Delta t_2\,(z)$$

i.e. identical closing/opening curves for the blades



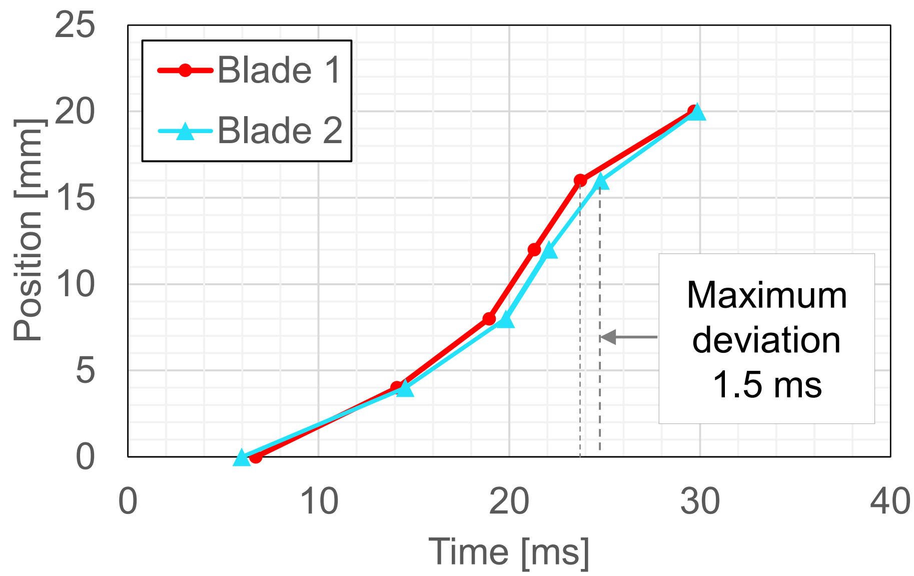


Blades trajectories

- The difference between the curves:

$$\left| \Delta t_1(z) - \Delta t_2(z) \right| \leq 1.5 \text{ ms}$$

- **Reaction time** between control signal and response of blades around **6-7 ms**
- **Opening time** of the blade **30 ms**
- **Limit in acceleration 32.5 m/s²**
- **Minimum exposure time < 100 ms**
- Lower exposure times can be achieved, but with error of 1.5 ms
- Other window sizes and blade materials can be studied, but an optimization of the parameters is required



Characterization of repetition rate for exposure 100 ms

Reset times [ms]	
Blade 1	62.2
Blade 2	70.4
Theoretical	79.0

Dutty cycle: 300 ms→ rep. rate 3 Hz

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Main characteristics

Cage 36 x 15 x 15 cm to be mounted on vertical stage

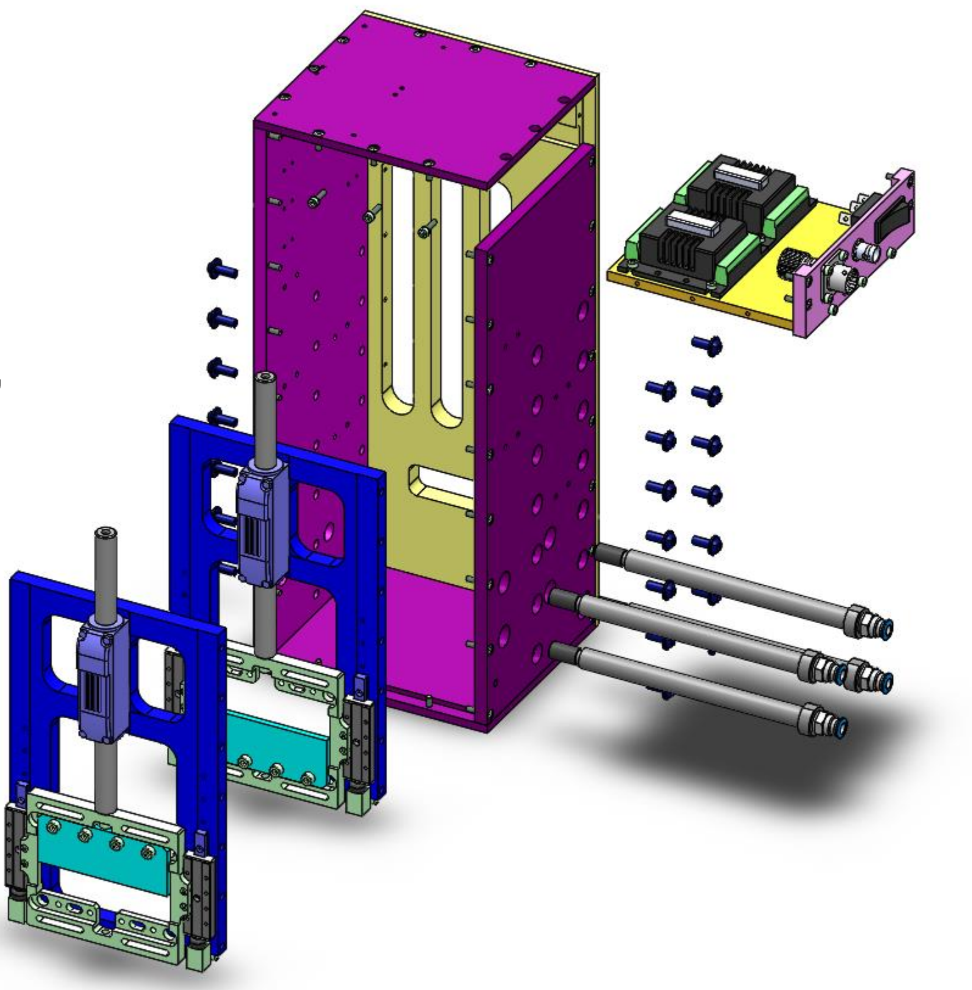
Weight: roughly 10 kg

Identical assemblies for both blades, identical masses of the frames

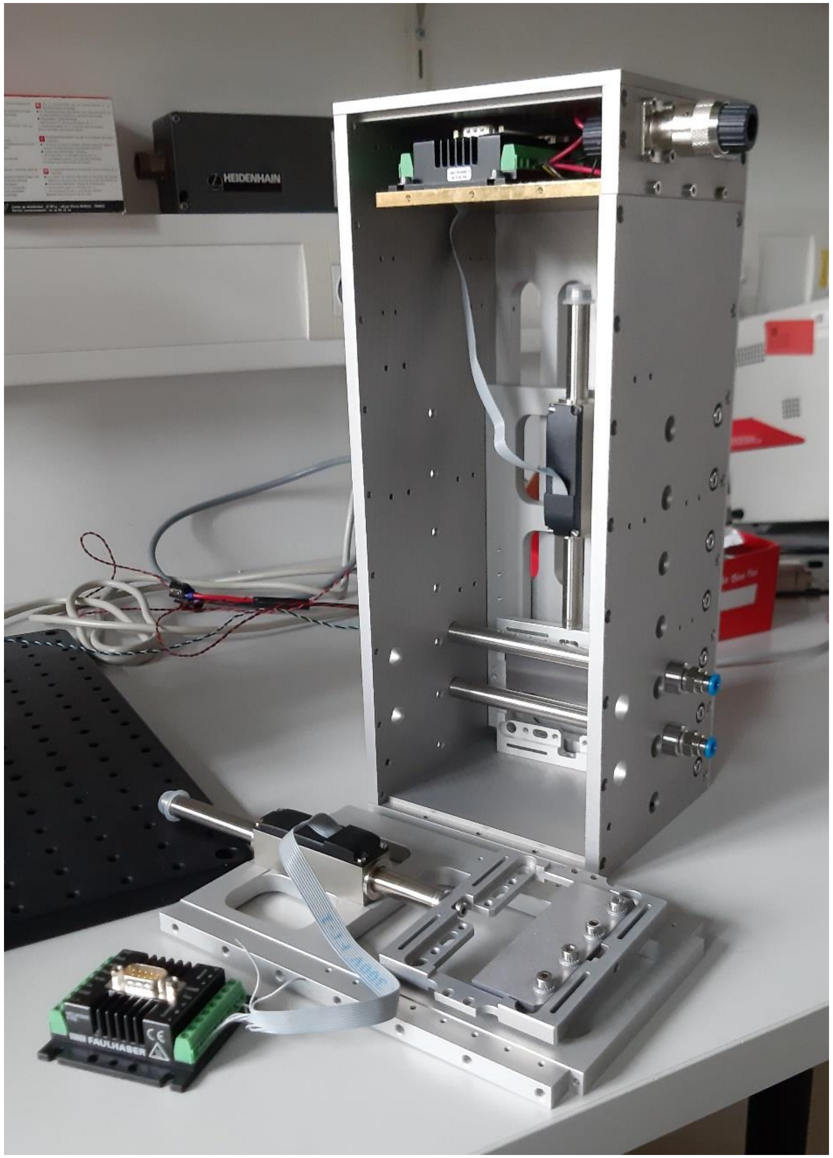
- Easier to program control sequence
- Easier for assembly

Optimized geometry of frames to withstand thermal load and stresses

Controllers and electronics included in a brass drawer for shielding



4. FINAL PROTOTYPE DESIGN



Modular: the motors and blades can be assembled in their frames, then onto the cage

Nordlock fasteners: washers with wedges to avoid loosening under vibrations

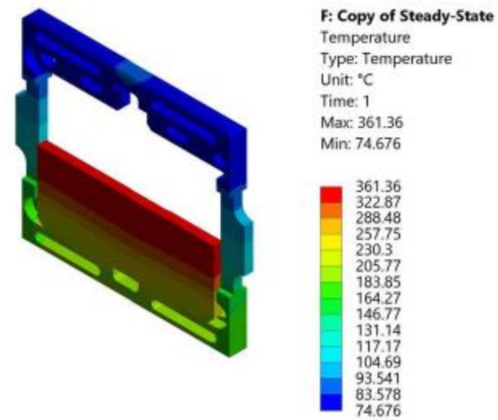
Guiding included: Schneeberger MSQ7-50.36 ball bearing slide

- Resists temperatures up to 150 ºC and accelerations up to 300 m/s^2
- Smallest guide coping with velocities > 1 m/s

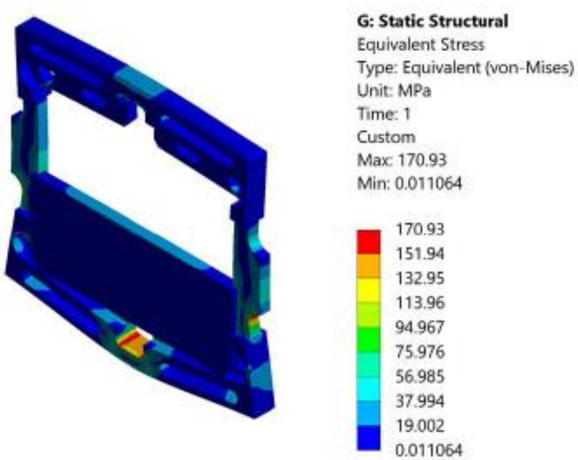
Nitrogen buffers for cooling in stainless steel 316L with apertures D4 mm

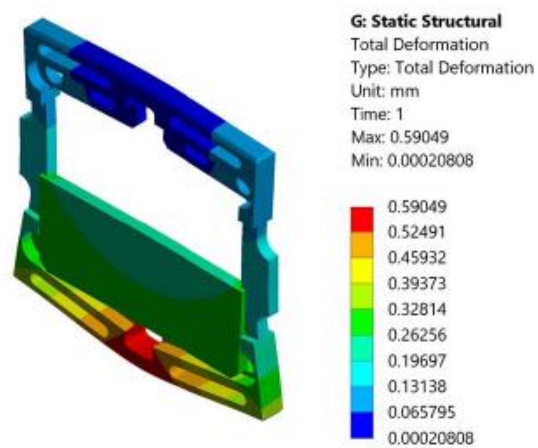
Thermal analysis:

- Thermal contact conductance tantalum/aluminium estimated at 4000 W/m2K (theoretical correlation Mikic)
- Optimized for a maximum power of 380 W
- Convection coefficient estimated at 300 W/m2/ºC (correlation for impinging jet Incropera)



Max. blade temp. 360 ºC
Max. frame temp. 220 ºC





Max. Von-Mises stress 170 MPa on frame
Max. blade def. 0.3 mm

Mechanical analysis:

- Frame fixed on top and in contact with guideway
- Design of the frames optimized to avoid stress concentrators
- Fatigue has not been considered for this study

6. CONCLUSIONS AND FUTURE WORK

Main conclusions to draw from the tests:

Faulhaber motors can be driven with their controller through the software interface

Desired exposure sequence can be obtained through TTL signals

Repeatable exposure and reaction times within specifications

Much smoother dynamics and improved stability

Test bench can be used to characterize future prototypes

Where are we at now?

Awaiting delivery of ball bearing guides to finish final prototype

What's next?

Assembly and testing in BM05: exposure sequence with guides

Check thermal behavior under beam and analyze if fatigue is critical

Other prototypes on request?

Thank you for your attention!

Questions?

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