



# The Fastjack

## A robust, UHV compatible and high performance linear actuator

SIG Meeting: Precision Motion Systems & Control

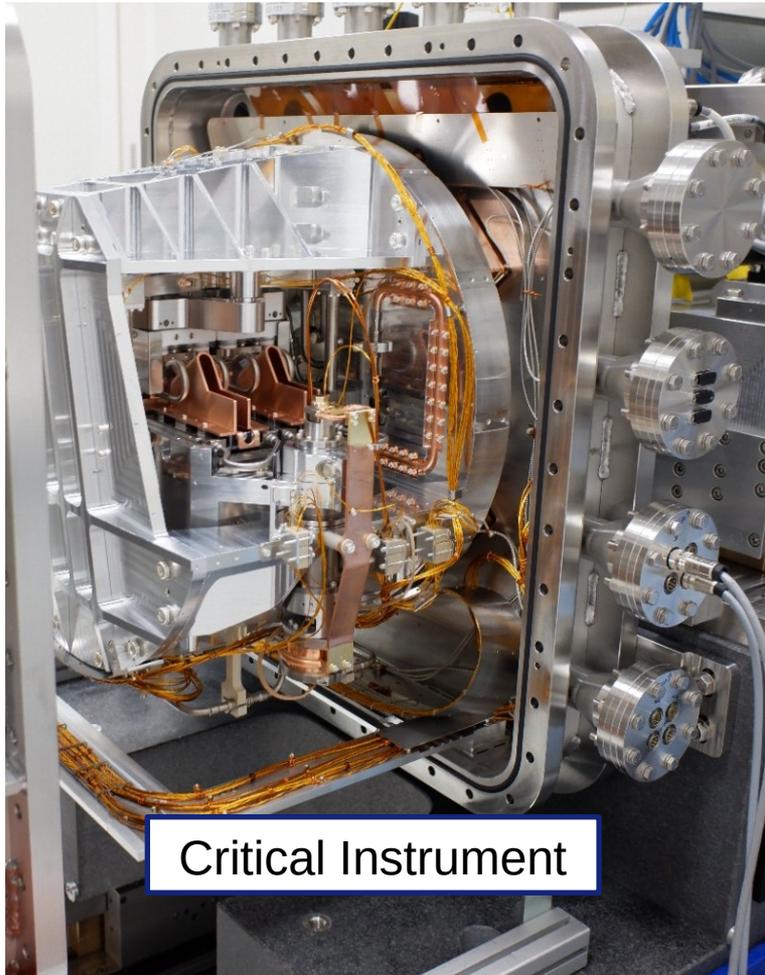
Thomas Dehaeze <sup>(1,2,\*)</sup>, Ludovic Ducotté <sup>(1)</sup>

(1) *ESRF – The European Synchrotron, Grenoble, France*

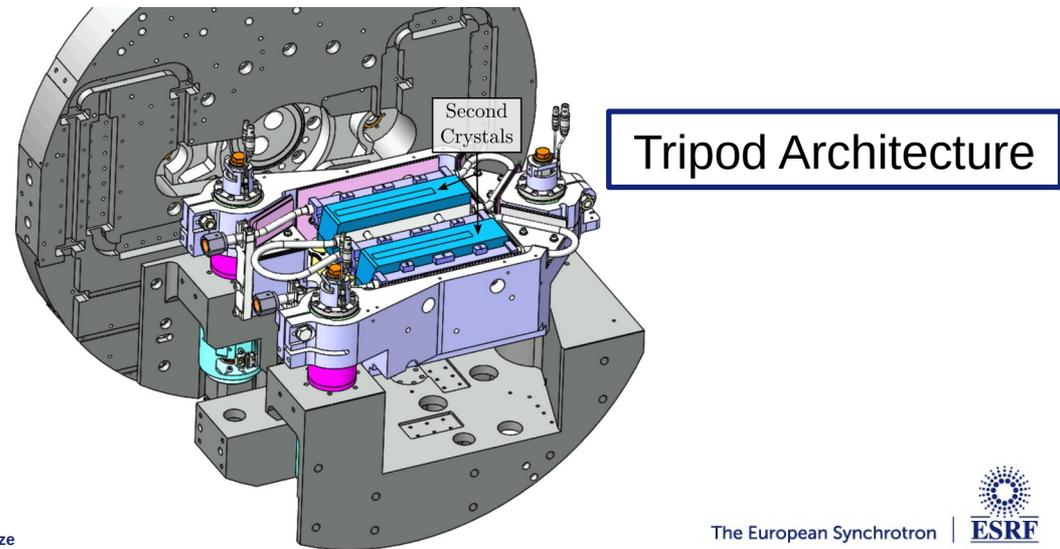
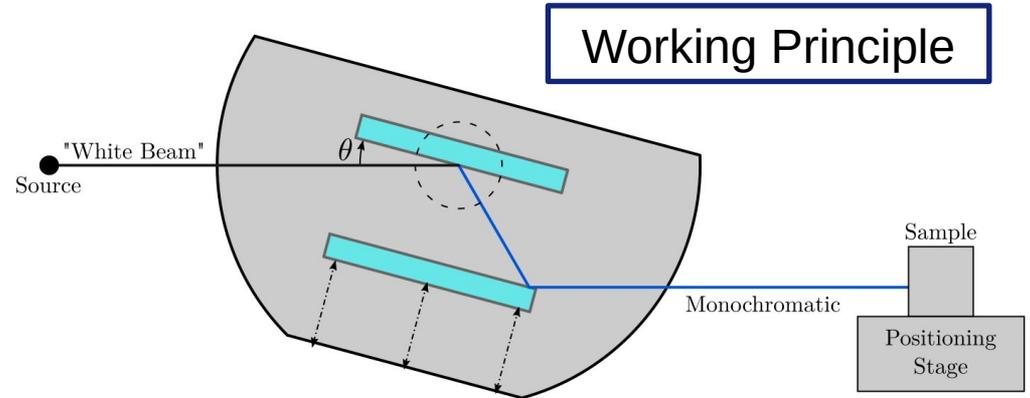
(2) *PML – Precision Mechatronics Laboratory, Liege, Belgium*

(\*) *thomas.dehaeze@esrf.fr*

# THE ESRF DOUBLE CRYSTAL MONOCHROMATOR (DCM)



Critical Instrument



Tripod Architecture

# THE FASTJACK – REQUIREMENTS AND DESIGN CHOICES

## Specifications

**Robustness:** 10 million cycles without maintenance. Open loop capable with 5 $\mu$ m accuracy.

**Performance:** Closed loop 5nm accuracy.

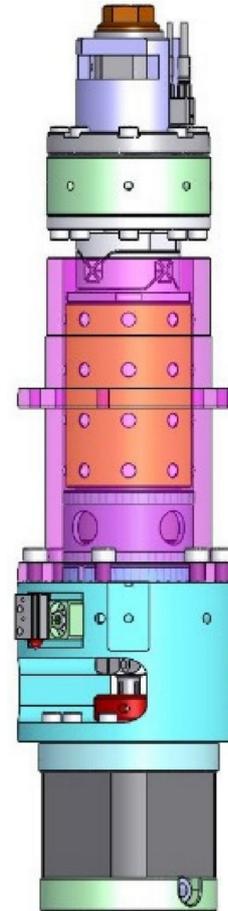
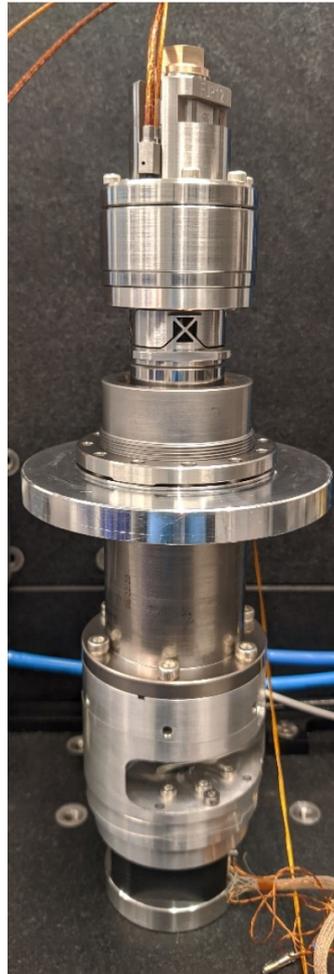
UHV & radiation compatible

Stroke	30 mm
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Velocity	1 mm/s
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Stiffness	> 10 N/ $\mu$ m
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Payload	10 kg
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Piezoelectric Stack  
(15 $\mu$ m stroke)

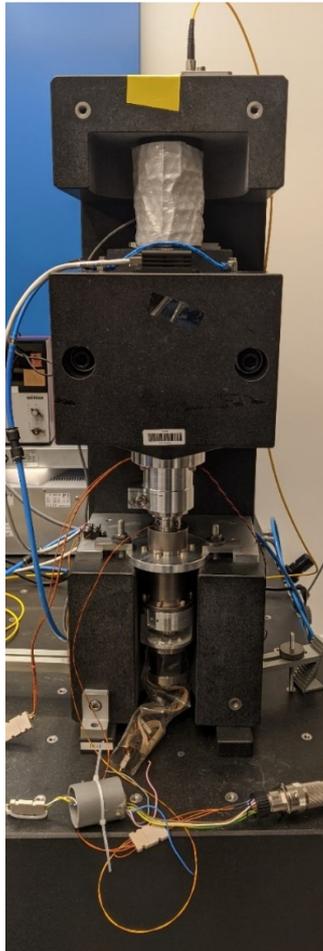
Flexible Joint

Satellite roller screw  
(1mm pitch)

Ball bearing guide

Hybrid Stepper Motor  
(200 steps/turn)

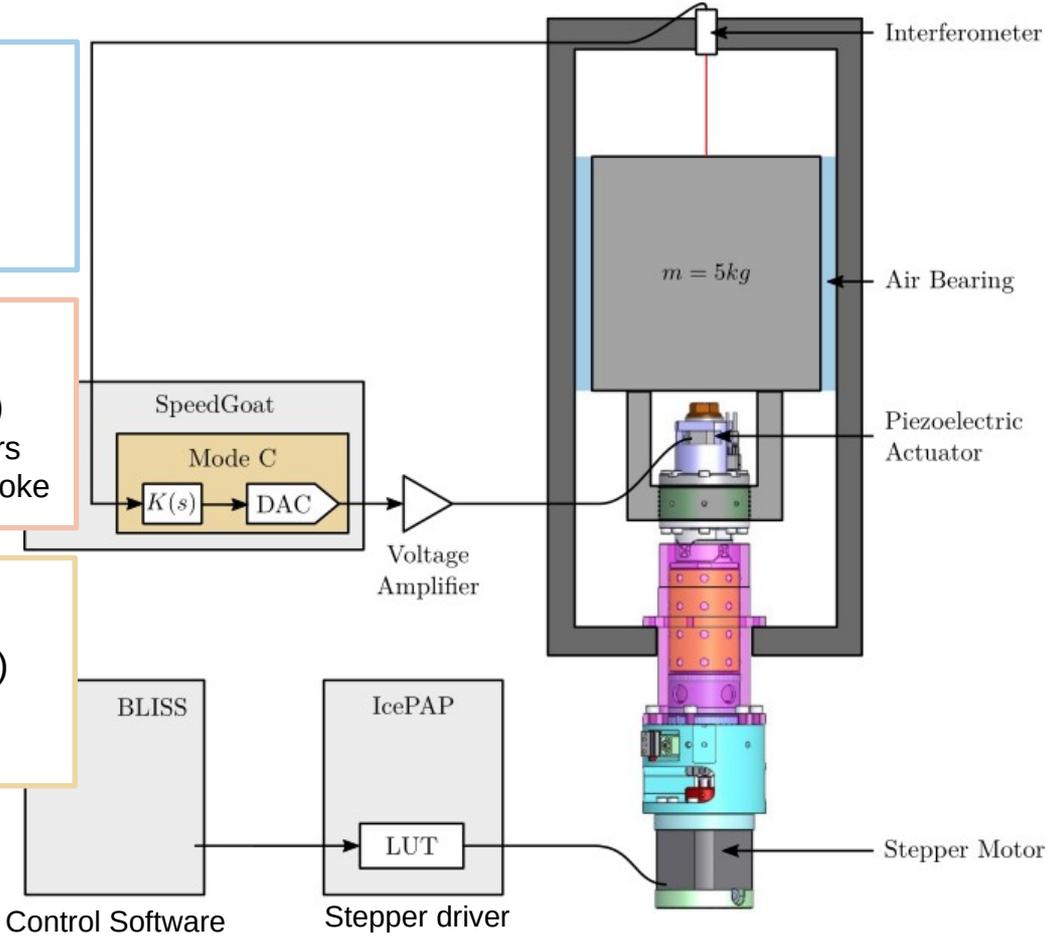
# TEST BENCH AND WORKING MODES



**Mode A**  
(Open Loop)  
Degraded mode  
Used as a backup

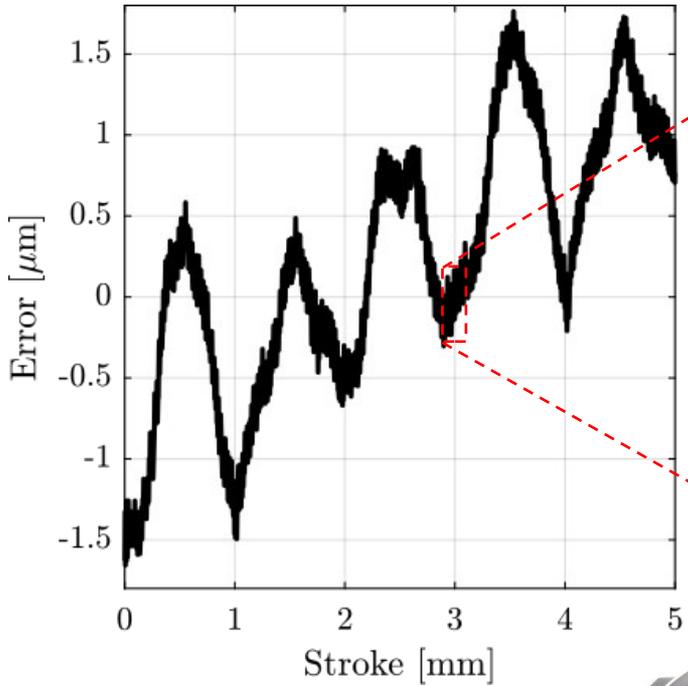
**Mode B**  
(Calibrated Steppers)  
Decrease repeatable errors  
Decrease required Piezo stroke

**Mode C**  
(Real Time Feedback)  
Best performance  
Normal working mode

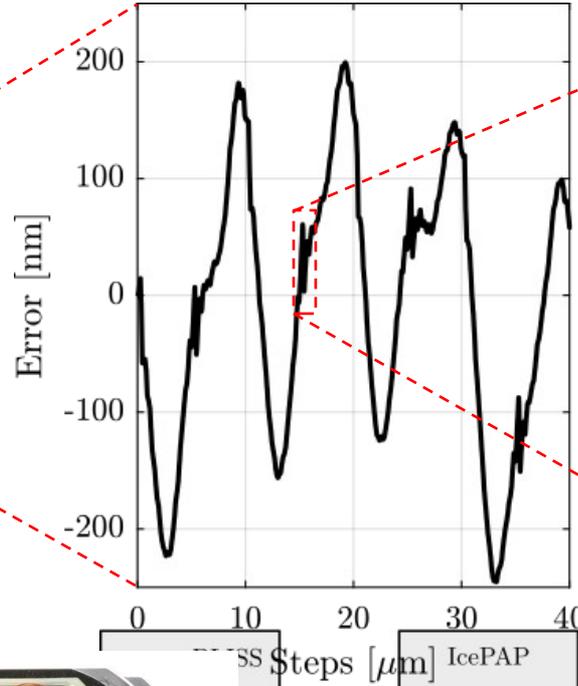


# OPEN LOOP ERROR ANALYSIS (MODE A)

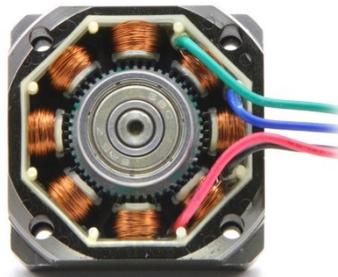
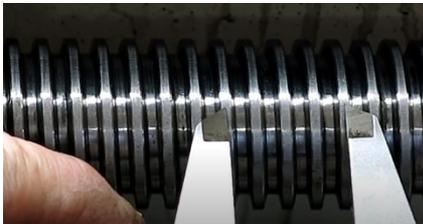
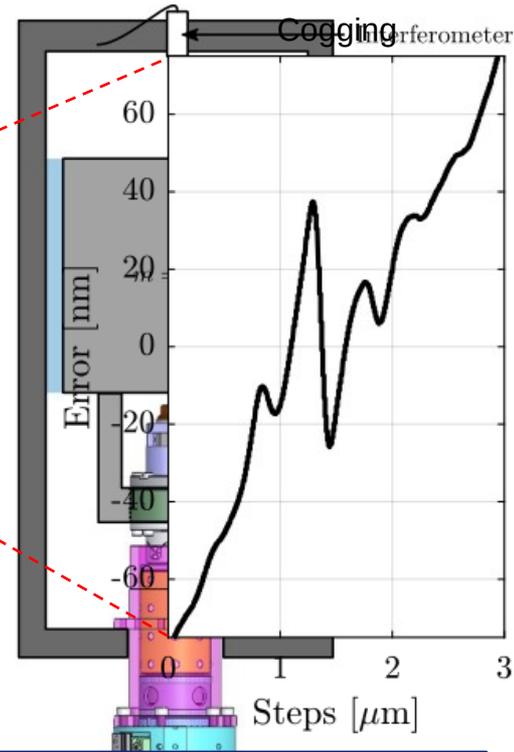
Lead Screw Errors



Microstepping Errors

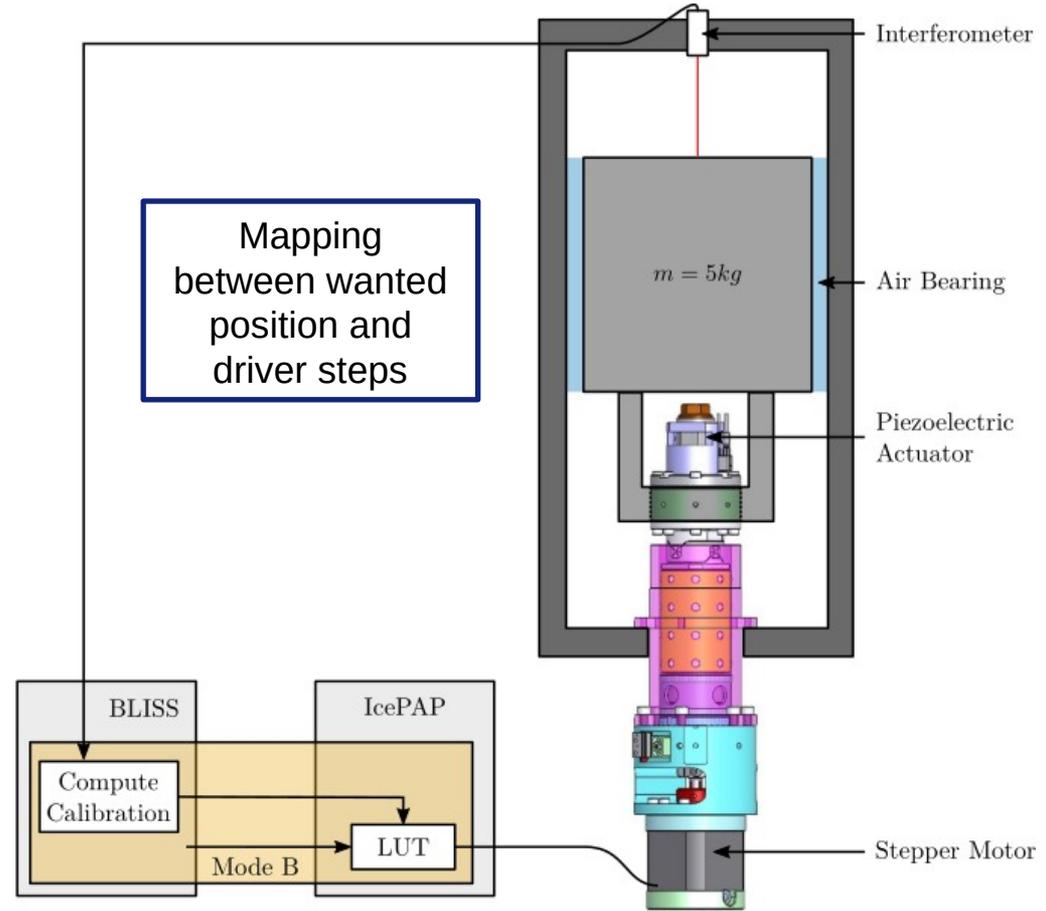
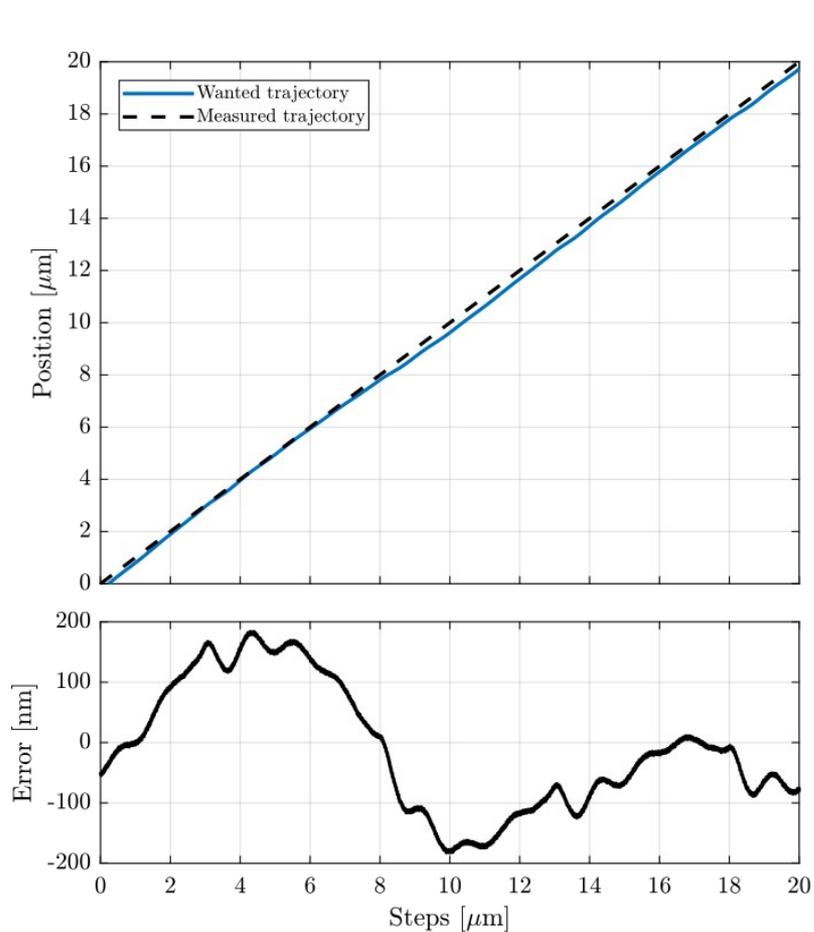


Cogging Interferometer

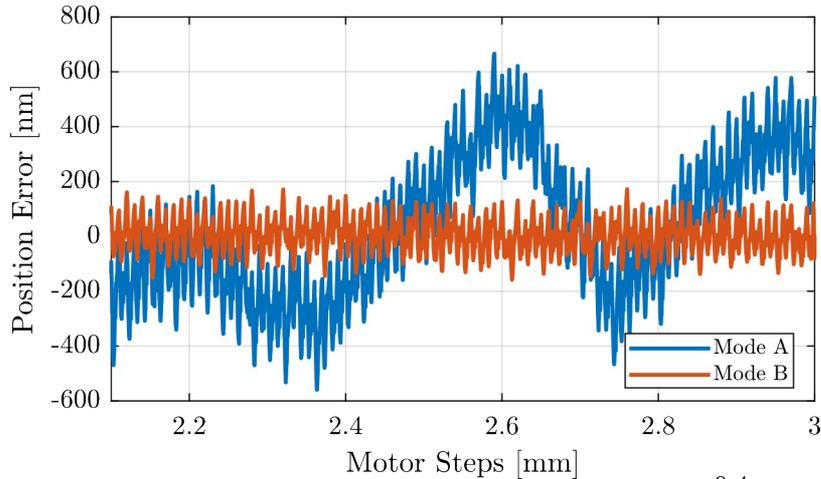


These errors are linked to spatial effects.  
Their frequency are proportional to velocity.

# CALIBRATION OF REPEATABLE ERRORS



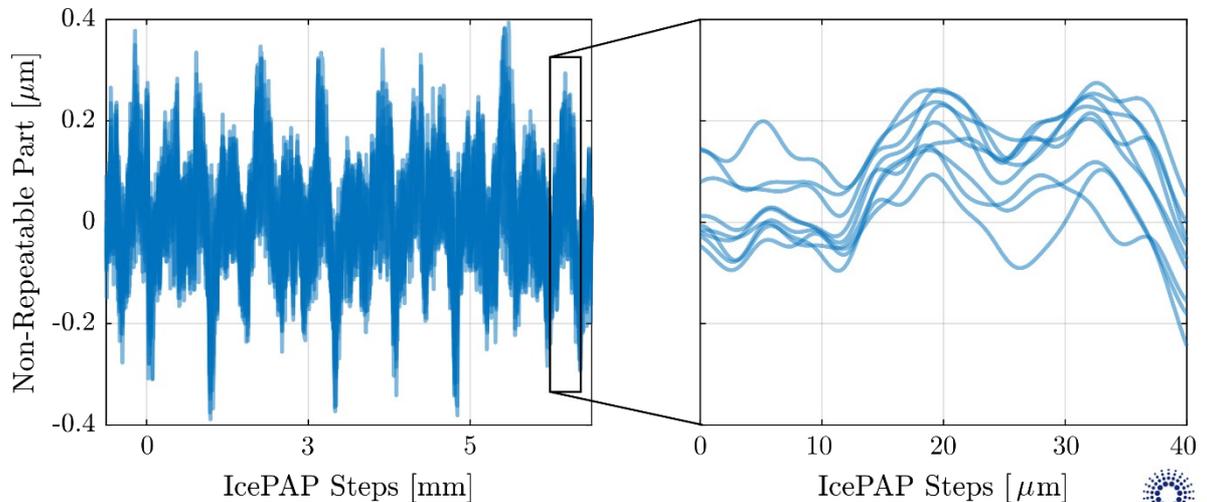
# ERRORS OF THE CALIBRATED FASTJACK (MODE B)



Lead screw errors can be well calibrated ...

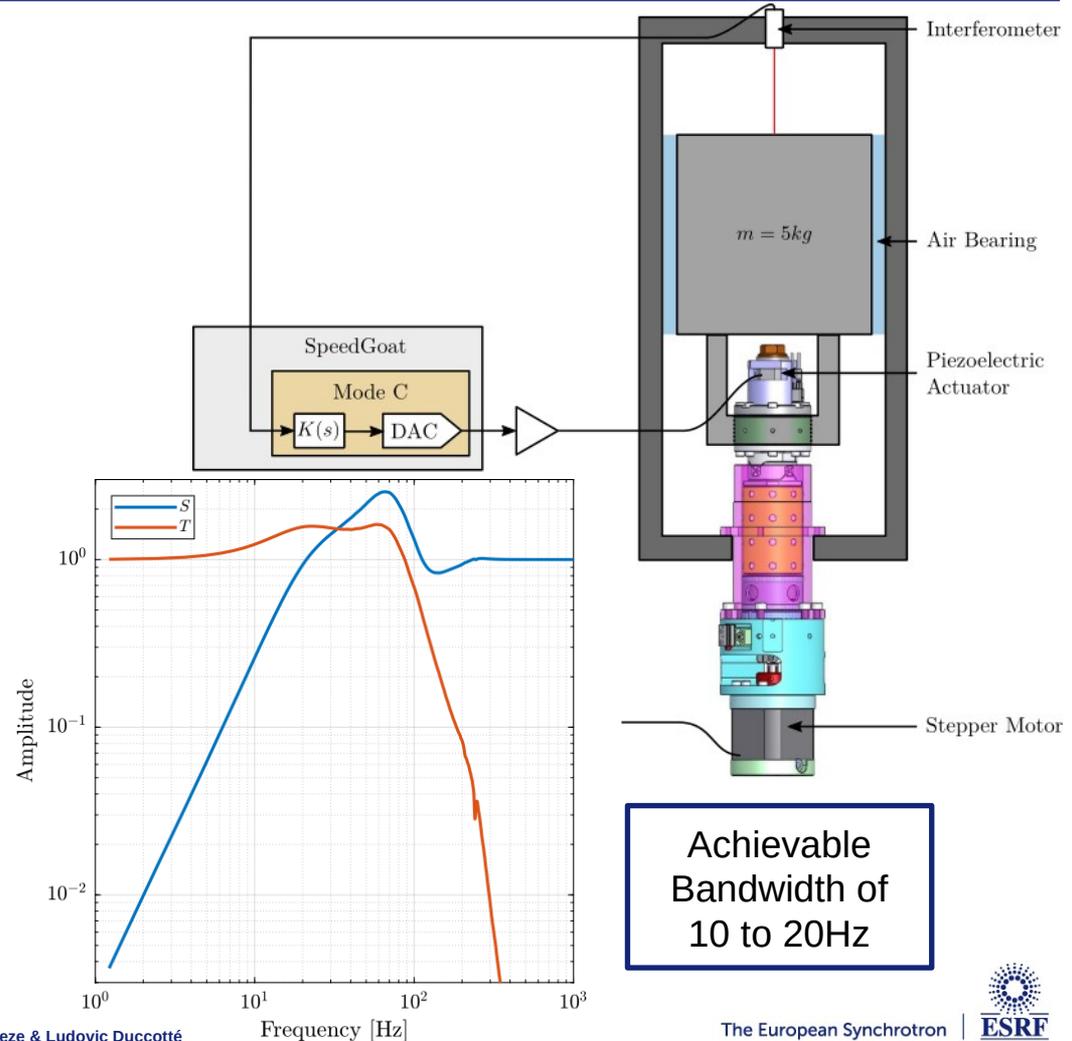
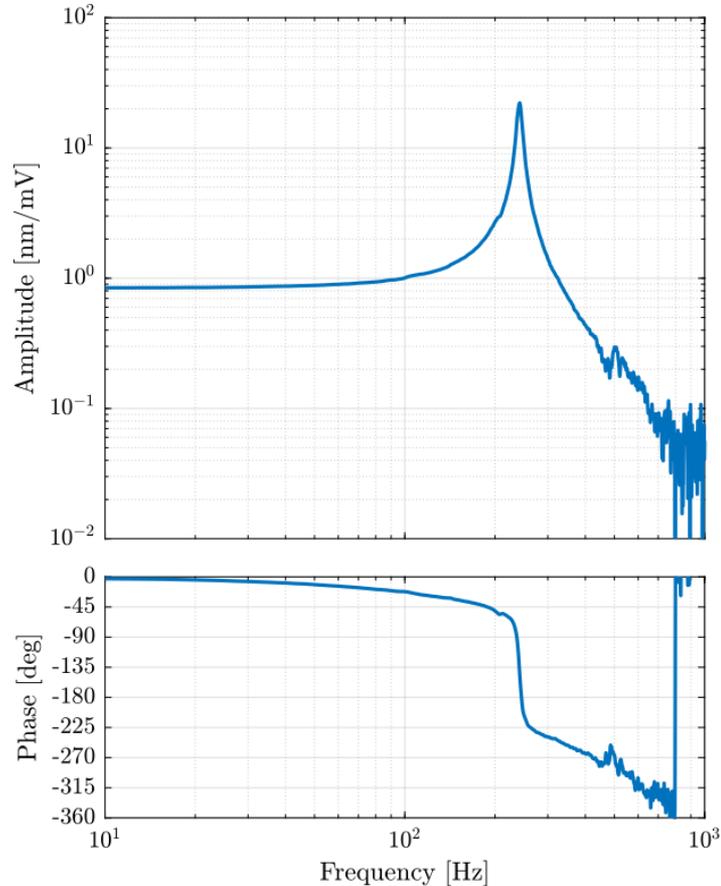
... but micro-stepping errors are not repeatable.

Physical reason yet to be investigated

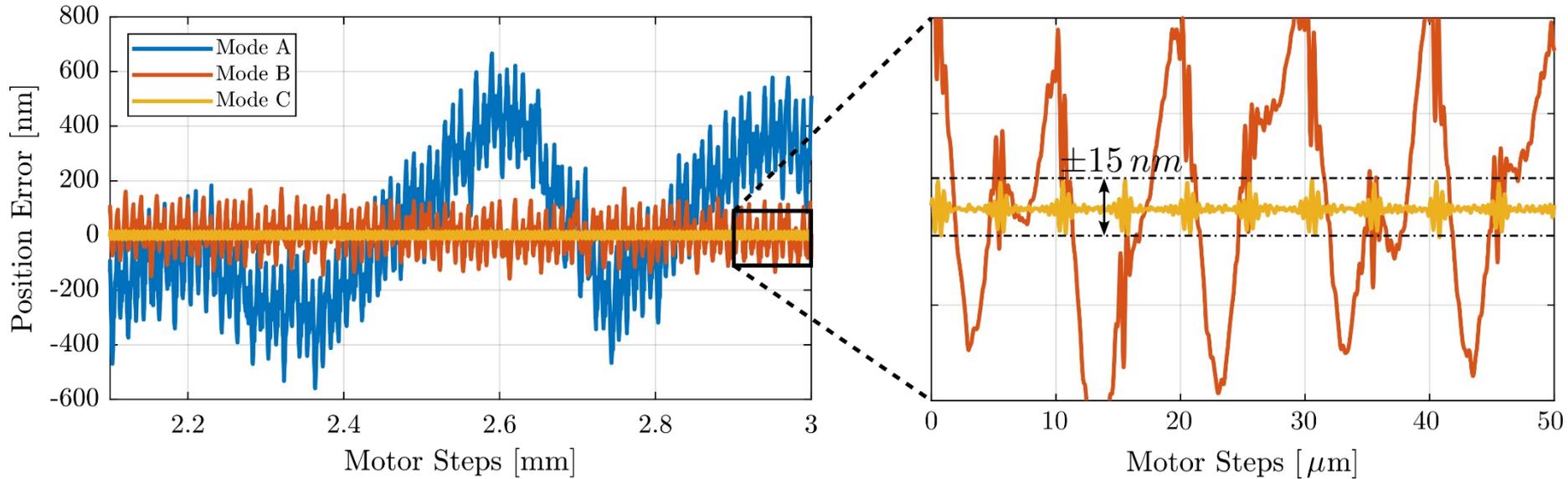


# FEEDBACK CONTROL (MODE C)

Bode Plot – Piezo voltage to Interferometer



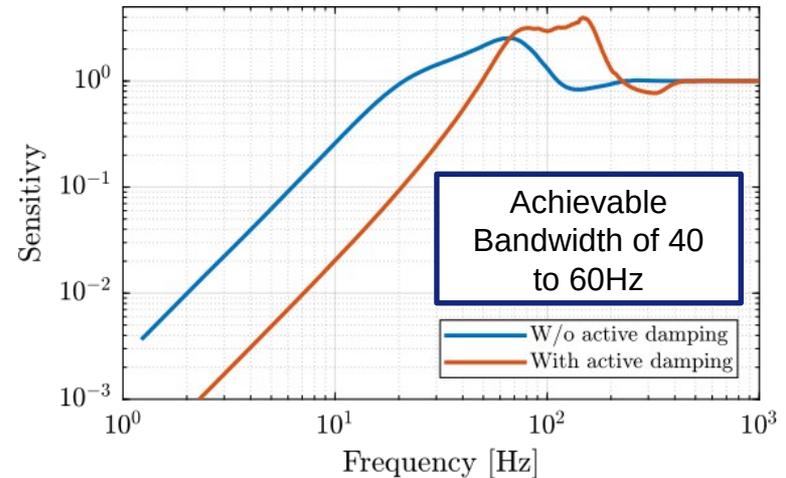
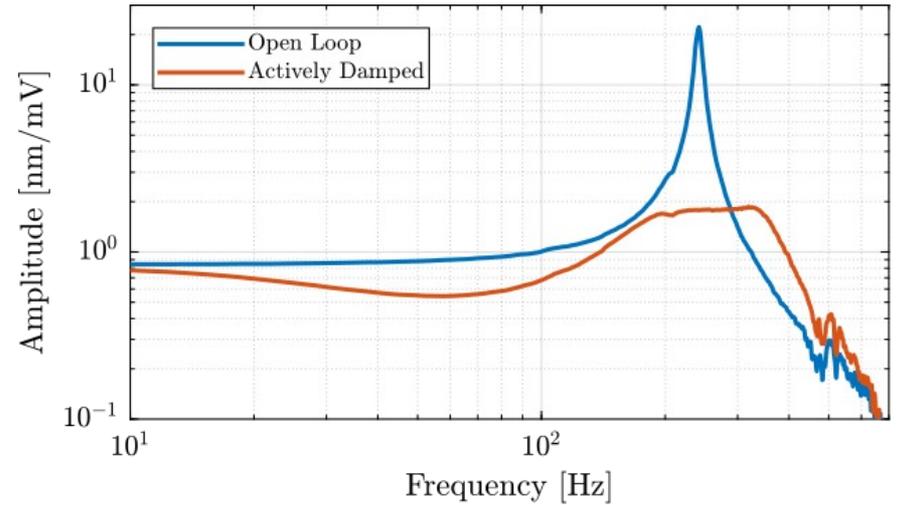
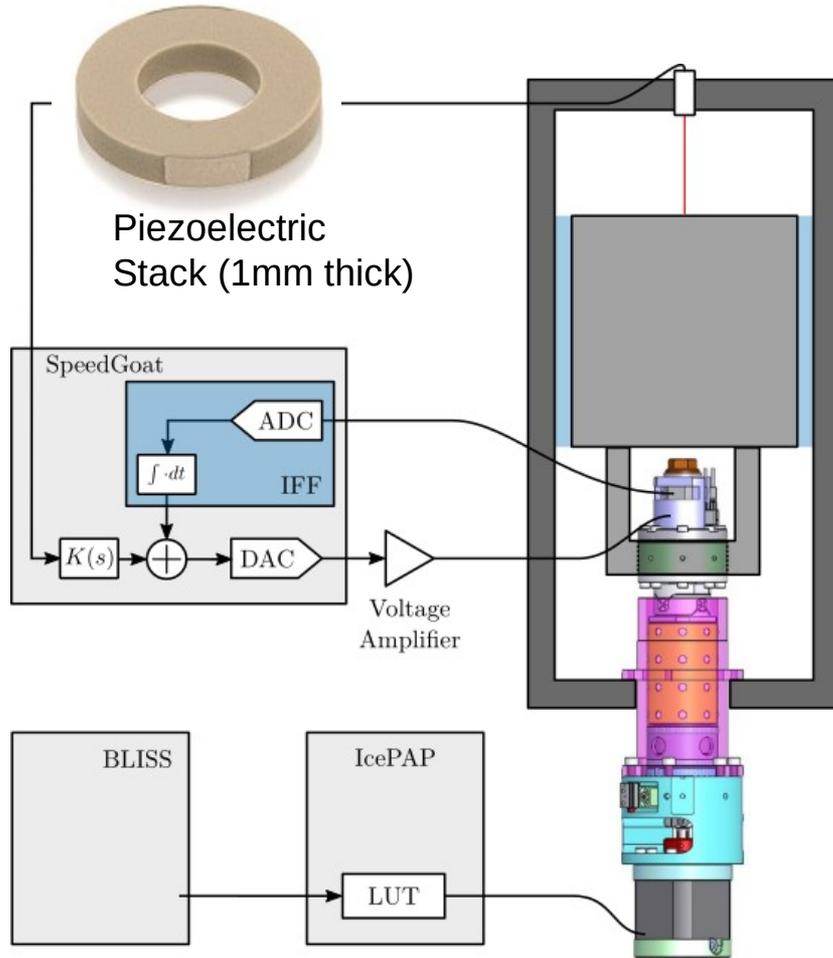
# FEEDBACK CONTROL (MODE C) - PERFORMANCES



Error	Period	$v=10\mu\text{m/s}$	$v=1\text{mm/s}$
Screw	1 mm	0.01 Hz	1 Hz
Microstep	5 $\mu\text{m}$	2.5 Hz	200 Hz
Cogging	0.3 $\mu\text{m}$	33 Hz	3.3 kHz

**Main objective:**  
 Improve the performances  
 at high velocity

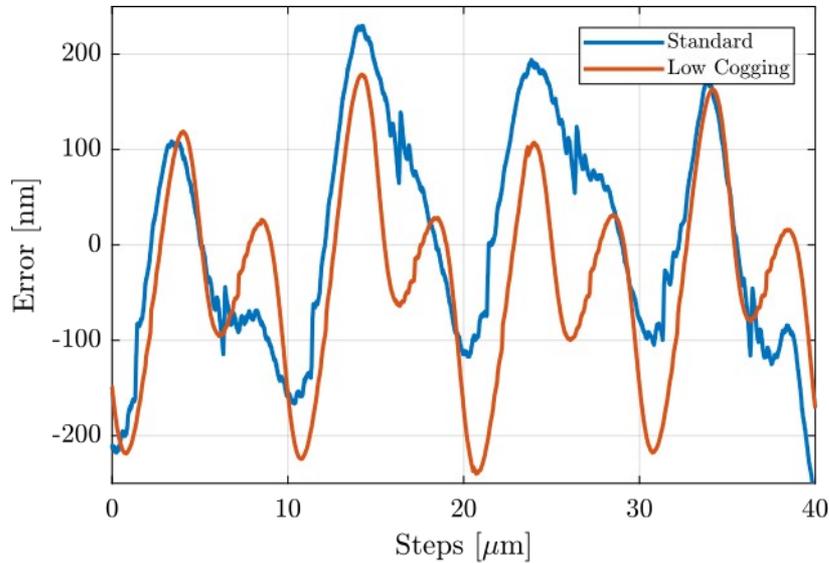
# INCREASING THE CONTROL BANDWIDTH WITH ACTIVE DAMPING



# FURTHER IMPROVEMENTS – CHANGE OF MOTOR

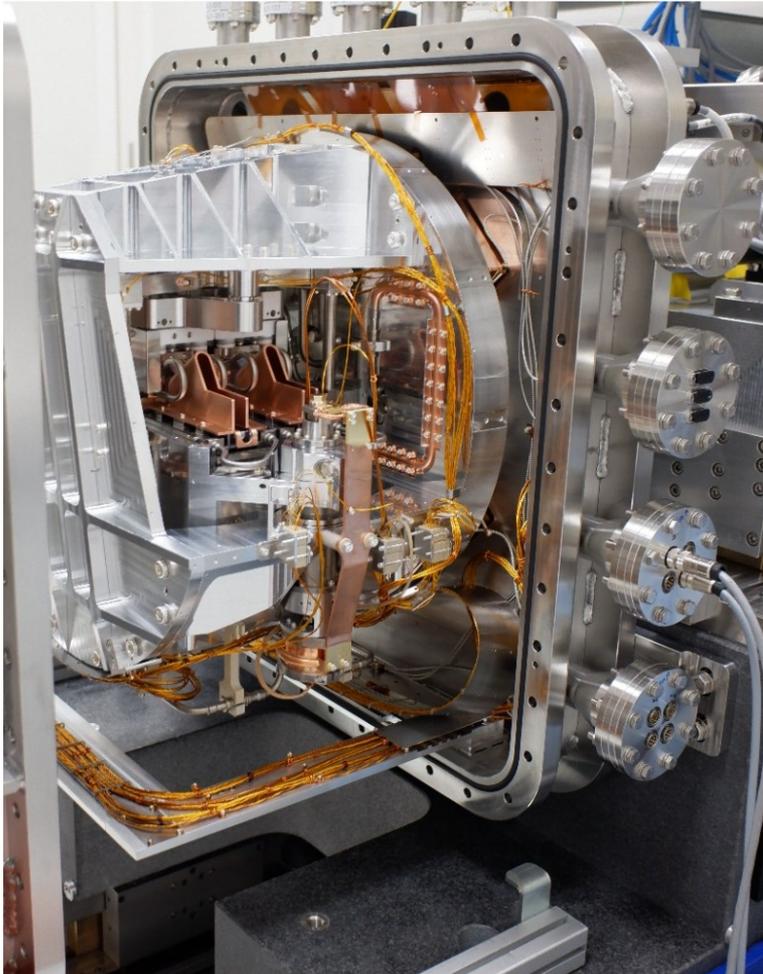


“Low Cogging”  
Stepper motor



Investigation of alternatives without  
sacrificing the required robustness.

## CONCLUSION



*Paper from 2002:*

*“ At the start of the European Synchrotron, [...] stepper motorizations were considered capable of satisfying all positioning requirements. ”*

This is no longer the case.

Fastjack performances are great except for high velocity scans, where the limitation is coming from the stepper motors.

Alternatives are being investigated for the future most demanding applications.