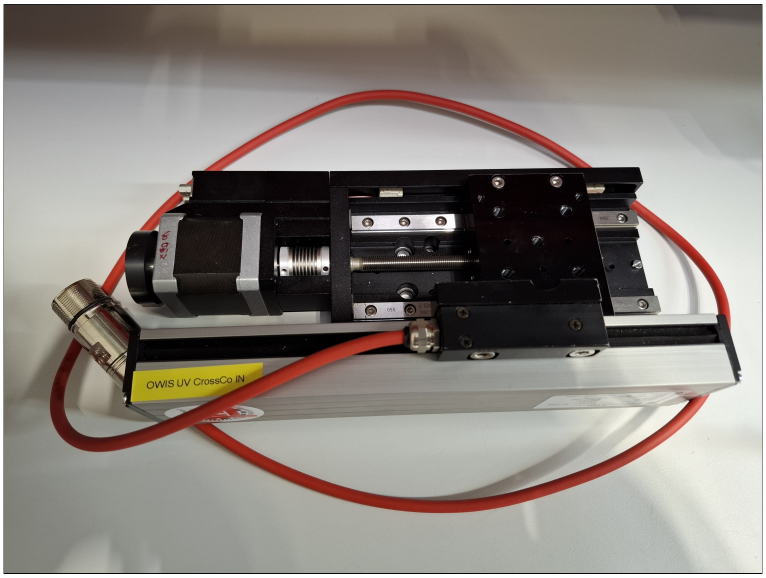
PSI	Project
Title **Linear Stage Characterization Report**	Document Identification Linear_Stage_Characterization_Working_Draft.pdf
Author Henrique	Review Index **0.1**

Overall stage image



Test type	Characterization
Stage identifier	0004
Main Facility	SwissFEL
Repository	https://gitea.psi.ch/AIK-FAT/FAT_OwisStageTREncoder_0004
Encoder	TR-Electronic GmbH; LT140-S
Motor	2-phase/5-phase stepping motor; Oriental Motor Co., Ltd.; PK245M-02B-C2
Drive	ED7062 CSP; ED7062 CSV; EL7041
Dates	2026-08-27; 2026-09-07; 2026-09-08
Applicable standards	ISO 230-2:2014; ISO 230-2:1997

Test Checklists

Pre-Test Safety

Item	Checklist Item	Yes	No	Remarks
2.1	Risk assessment conducted			NA
2.2	Safety barriers in place			NA
2.3	E-stop functional			NA
2.4	Equipment grounded			
2.5	Personnel briefed	✓		
2.6	Cable routing safe	✓		
2.7	Environmental conditions OK	✓		

Equipment Verification

Item	Checklist Item	Yes	No	Remarks
3.1	Stage model verified		✓	
3.2	Encoder model verified		✓	
3.3	Motor model verified	✓		
3.4	Drive model verified			NA
3.5	Encoder interface verified		✓	
3.6	Measurement system calibrated	✓		
3.7	Documentation available			NA
3.8	Calibration certificates valid			NA

Mechanical and Electrical Checks

Item	Checklist Item	Yes	No	Remarks
4.1	Mounting interfaces verified			NA
4.2	Travel unobstructed	✓		
4.3	End stops functional	✓		
4.4	Cable carrier movement OK	✓		
4.5	Encoder alignment checked	✓		
4.6	Motor coupling secure	✓		
4.7	Supply voltage verified	✓		
4.8	Signal connections verified	✓		
4.9	Ground continuity checked	✓		
4.10	No abnormal noise or vibration	✓		

Control System Verification

Item	Checklist Item	Yes	No	Remarks
5.1	Communication established	✓		

Item	Checklist Item	Yes	No	Remarks
5.2	Drive parameters verified	✓		
5.3	Encoder scaling verified	✓		
5.4	Current or force limit verified	✓		
5.5	Homing or referencing functional			NA
5.6	Software limits configured	✓		
5.7	E-stop response verified			NA
5.8	Motion profile verified	✓		
5.9	Closed-loop stability verified	✓		
5.10	Following error acceptable			NA

Test Execution

Item	Checklist Item	Yes	No	Remarks
6.1	Measurement system aligned	✓		
6.2	Environmental compensation set	✓		
6.3	Test parameters recorded	✓		
6.4	Required cycles completed	✓		
6.5	Raw data saved	✓		
6.6	Analysis files generated	✓		
6.7	Environmental data logged	✓		
6.8	All configurations tested	✓		

Hardware and Configuration

Coordinate Convention

Quantity	Project convention
Linear travel	Z axis
Vertical direction	Y axis, perpendicular to Z
Horizontal direction	X axis, perpendicular to Y and Z
Roll	Rotation around Z (travel)
Yaw	Rotation around Y (vertical)
Pitch	Rotation around Y (horizontal)
Positive rotational direction	Right-hand rule

Component	Verified specification
Stage	Owis TR Electronics
Stage identifier	0004
Travel	96 mm configured software-limit span (–1 mm to 95 mm)
Encoder	TR-Electronic GmbH; LT140-S
Encoder protocol	SSI/24-bit binary
Encoder resolution	0.1 µm
Motor or actuator	Oriental Motor Co., Ltd.; PK245M-02B-C2
Motor type and steps	2-phase/5-phase stepping motor; 400 steps/rev
Motor resistance	7.5 Ω
Drive	ED7062 CSP; ED7062 CSV; EL7041

Measurement System

Measurement-system parameter	Documented value
Manufacturer	Keysight Technologies
System family / model	5530 Laser Calibration System
Laser-head model	5519A/B HeNe laser system
Laser type	Helium-neon, automatically tuned Zeeman-split two-frequency output
Vacuum wavelength	632.991354 nm
Wavelength accuracy	±0.1 ppm; ±0.02 ppm with factory-calibration option
Wavelength stability	±0.002 ppm short term (1 h); ±0.02 ppm lifetime
Linear measurement range	Up to 40 m with linear optics; up to 80 m with long-range option
Straightness range / resolution	10774A: up to 3 m, 0.01 µm; 10775A: up to 30 m, 0.1 µm
Environmental compensation	E1738A air sensor: automatic temperature, pressure, humidity, and wavelength-in-air compensation
Air-sensor accuracy	Temperature ±0.1 °C; relative humidity ±5 %; absolute pressure ±80 Pa

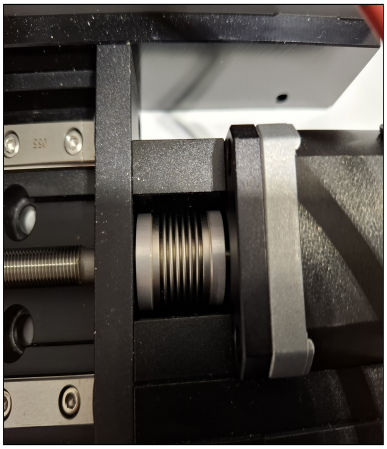
Evidence Images



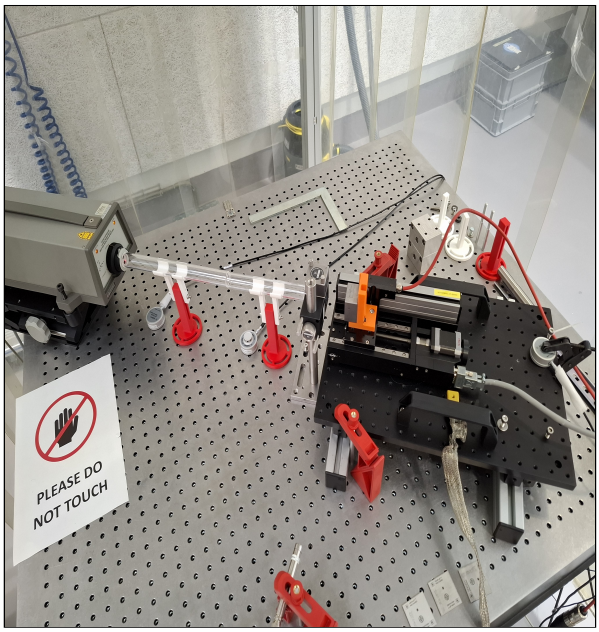
Encoder



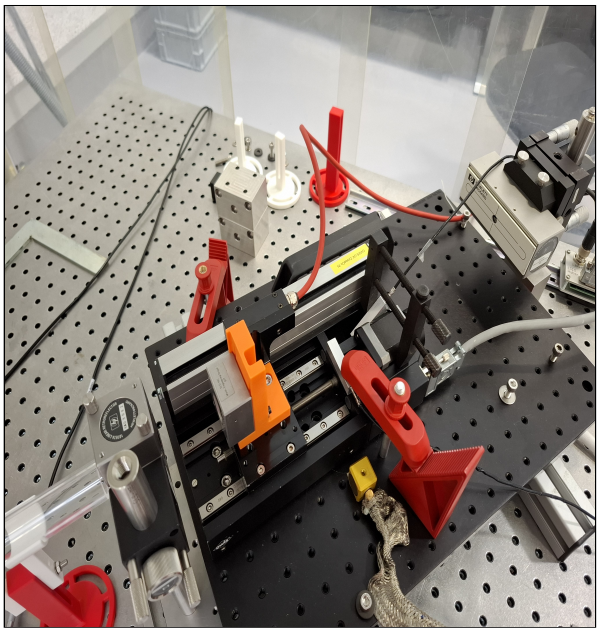
Motor



Coupling



Measurement setup



Measurement setup 2

Test Description

Applicable standard(s), edition(s), and clause(s): ISO 230-2:2014; ISO 230-2:1997

Measurement-system operating procedure and revision:

OWIS stageTR Electronics FAT ISO230 Stepper ED7062 CSP EL5042 DC ClosedLoop SCurve gap

Evidence file: OWIS_stageTR_Electronics_FAT_ISO230_Stepper_ED7062_CSP_EL5042_DC_ClosedLoop_SCurve_gap.pdf

Parameter	Characterization setup
Measured positions	10 positions from 1.0000 mm to 90.0000 mm; 0.2000 mm approach offset
Speed	2 mm/s
Acceleration	3 mm/s²; deceleration 3 mm/s²
PID settings	Kp = 0.06; Ki = 0.04; Kd = 0.01; Kff = 1

Environmental Conditions (min / mean / max)

Temperature	Pressure	Humidity
22.03 / 22.05 / 22.06 °C (min / mean / max)	738.1 / 738.2 / 738.2 mmHg (min / mean / max)	53 / 54 / 54 %RH (min / mean / max)
Accuracy	**Repeatability**	**Reversal error**
A = 8.7 µm	R = 2.7 µm	B = 0.8 µm

OWIS stageTR Electronics FAT ISO230 Stepper ED7062 CSV EL5042 DC ClosedLoop SCurve gap

Evidence file: OWIS_stageTR_Electronics_FAT_ISO230_Stepper_ED7062_CSV_EL5042_DC_ClosedLoop_SCurve_gap.pdf

Parameter	Characterization setup
Measured positions	10 positions from 1.0000 mm to 90.0000 mm; 0.2000 mm approach offset
Speed	2 mm/s
Acceleration	3 mm/s²; deceleration 3 mm/s²
PID settings	Kp = 0.06; Ki = 0.04; Kd = 0.01; Kff = 1

Environmental Conditions (min / mean / max)

Temperature	Pressure	Humidity
21.86 / 21.87 / 21.88 °C (min / mean / max)	738.3 / 738.6 / 738.7 mmHg (min / mean / max)	53 / 53 / 53 %RH (min / mean / max)
Accuracy	**Repeatability**	**Reversal error**
A = 9.2 µm	R = 3.7 µm	B = 0.8 µm

OWIS stageTR Electronics FAT ISO230 Stepper EL7041 EL5042

Evidence file: OWIS_stageTR_Electronics_FAT_ISO230_Stepper_EL7041_EL5042.pdf

Parameter	Characterization setup
Measured positions	10 positions from 1.0000 mm to 90.0000 mm; 0.2000 mm approach offset
Speed	2 mm/s
Acceleration	3 mm/s²; deceleration 3 mm/s²

Parameter	Characterization setup
PID settings	Kp = 0.06; Ki = 0.04; Kd = 0.01; Kff = 1

Environmental Conditions (min / mean / max)

Temperature	Pressure	Humidity
22.14 / 22.14 / 22.14 °C (min / mean / max)	734.4 / 734.4 / 734.4 mmHg (min / mean / max)	33 / 33 / 33 %RH (min / mean / max)
Accuracy	**Repeatability**	**Reversal error**
A = 12.9 µm	R = 6.0 µm	B = 1.6 µm

OWIS stageTR Electronics FAT Straightness Horizontal XZ

Evidence file: OWIS_stageTR_Electronics_FAT_Straightness_Horizontal_XZ.pdf

Parameter	Characterization setup
Measured positions	20 positions from 1.0000 mm to 86.0000 mm in 5.0000 mm increments; endpoints duplicated
Speed	3 mm/s
Acceleration	2 mm/s²; deceleration 2 mm/s²
PID settings	Kp = 0.06; Ki = 0.04; Kd = 0.01; Kff = 1

Environmental Conditions (min / mean / max)

Temperature	Pressure	Humidity
22.06 / 22.10 / 22.14 °C (min / mean / max)	732.2 / 732.4 / 732.5 mmHg (min / mean / max)	57 / 58 / 58 %RH (min / mean / max)
Accuracy	**Repeatability**	**Reversal error**
A = 10.3 µm	R = 9.6 µm	B = 2.0 µm

OWIS stageTR Electronics FAT Straightness Vertical YZ

Evidence file: OWIS_stageTR_Electronics_FAT_Straightness_Vertical_YZ.pdf

Parameter	Characterization setup
Measured positions	20 positions from 1.0000 mm to 86.0000 mm in 5.0000 mm increments; endpoints duplicated
Speed	3 mm/s
Acceleration	2 mm/s²; deceleration 2 mm/s²
PID settings	Kp = 0.06; Ki = 0.04; Kd = 0.01; Kff = 1

Environmental Conditions (min / mean / max)

Temperature	Pressure	Humidity
22.45 / 22.48 / 22.52 °C (min / mean / max)	730.0 / 730.4 / 730.7 mmHg (min / mean / max)	55 / 55 / 55 %RH (min / mean / max)
Accuracy	**Repeatability**	**Reversal error**
A = 4.8 µm	R = 4.4 µm	B = 0.5 µm

Test Files and Data

The following exact evidence basenames identify the delivered raw and analysis files.

Raw Files

Analysis Files

• OWIS_stageTR_Electronics_FAT_ISO230_Stepper_ED7062_CSP_EL5042_DC_ClosedLoop_SCurve_gap.pdf

• OWIS_stageTR_Electronics_FAT_ISO230_Stepper_ED7062_CSV_EL5042_DC_ClosedLoop_SCurve_gap.pdf

• OWIS_stageTR_Electronics_FAT_ISO230_Stepper_EL7041_EL5042.pdf

• OWIS_stageTR_Electronics_FAT_Straightness_Horizontal_XZ.pdf

• OWIS_stageTR_Electronics_FAT_Straightness_Vertical_YZ.pdf

Characterization Results

Test	Accuracy	Repeatability	Reversal error
OWIS stageTR Electronics FAT ISO230 Stepper ED7062 CSP EL5042 DC ClosedLoop SCurve gap	A = 8.7 µm	R = 2.7 µm	B = 0.8 µm
OWIS stageTR Electronics FAT ISO230 Stepper ED7062 CSV EL5042 DC ClosedLoop SCurve gap	A = 9.2 µm	R = 3.7 µm	B = 0.8 µm
OWIS stageTR Electronics FAT ISO230 Stepper EL7041 EL5042	A = 12.9 µm	R = 6.0 µm	B = 1.6 µm
OWIS stageTR Electronics FAT Straightness Horizontal XZ	A = 10.3 µm	R = 9.6 µm	B = 2.0 µm
OWIS stageTR Electronics FAT Straightness Vertical YZ	A = 4.8 µm	R = 4.4 µm	B = 0.5 µm

References

Stage manufacturer document, number, and revision:

Encoder, motor, and drive documents and revisions:

Standards and procedures: ISO 230-2:2014; ISO 230-2:1997

Calibration certificates:

Document History

Date	Version	Description
2026-11-15	0.1	Initial project-specific report generated by direct Python build

Appendix: Measurement Analysis Files

The following measurement analysis documents are attached in the listed order.

• OWIS_stageTR_Electronics_FAT_ISO230_Stepper_ED7062_CSP_EL5042_DC_ClosedLoop_SCurve_gap.pdf

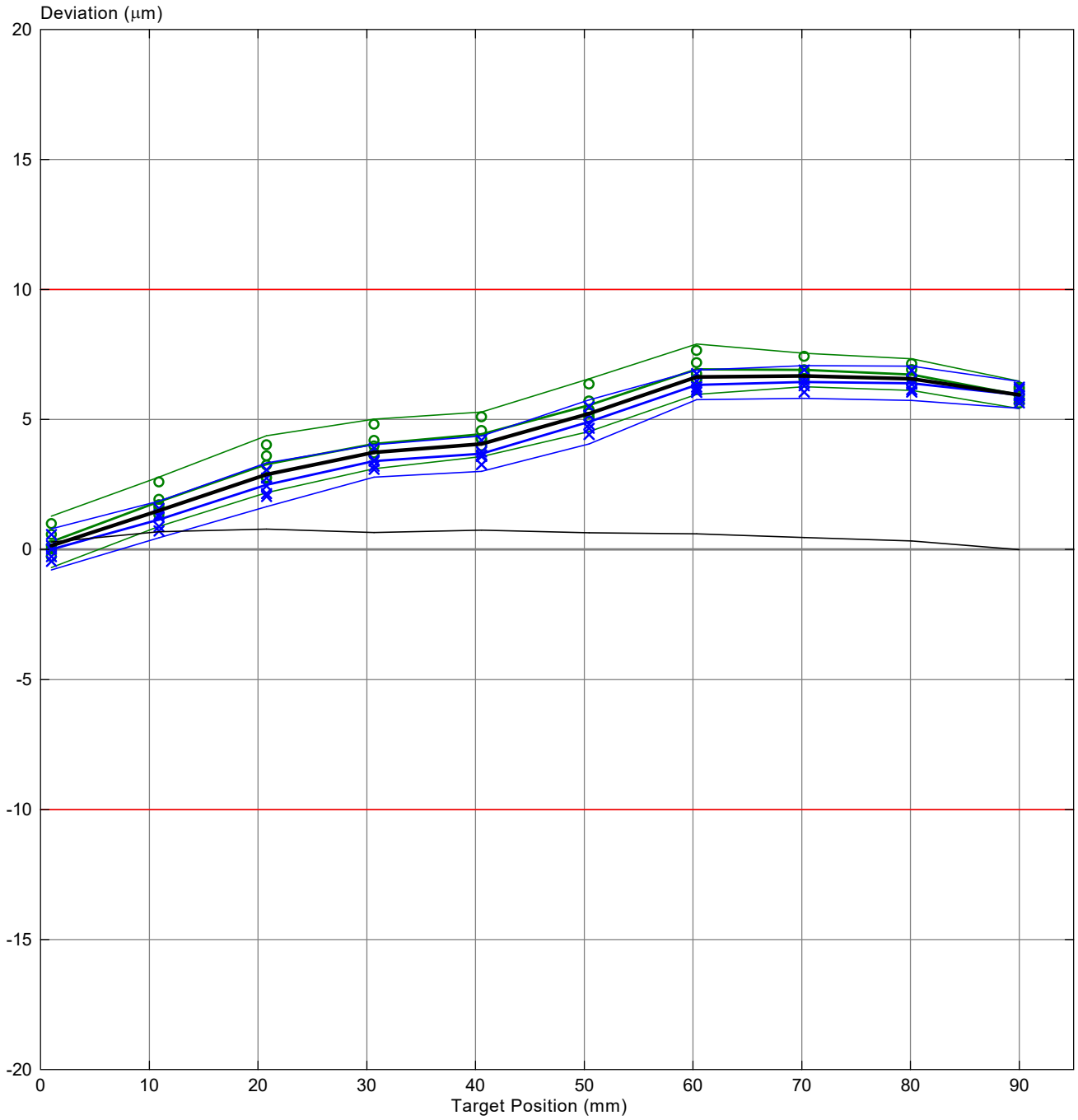
• OWIS_stageTR_Electronics_FAT_ISO230_Stepper_ED7062_CSV_EL5042_DC_ClosedLoop_SCurve_gap.pdf

• OWIS_stageTR_Electronics_FAT_ISO230_Stepper_EL7041_EL5042.pdf

• OWIS_stageTR_Electronics_FAT_Straightness_Horizontal_XZ.pdf

• OWIS_stageTR_Electronics_FAT_Straightness_Vertical_YZ.pdf

Linear - Measurement Axis: Z



Forward Data Runs — Forward Mean — Forward +/-n sigma — Reverse Data Runs
Reverse Mean — Reverse +/-n sigma — Combined Mean — Limit Lines
Backlash / pt.

Numerical Analysis

Standards:	ISO 230-2 2014 (Modified)
Error Sign Convention:	Algebraic
Coverage Factor (Sigma):	2
Accuracy:	A = 8.7 µm
	A↑= 8.6 µm
	A↓= 7.9 µm
Sys. Dev. Pos.:	E = 6.9 µm
	E↑= 6.6 µm
	E↓= 6.4 µm
Mean Bidir. Pos. Dev.:	M = 6.5 µm
Repeatability:	R = 2.7 µm
	R↑= 2.2 µm
	R↓= 1.7 µm
Max Reversal Error:	B = 0.8 µm
Mean Reversal Error:	$\overline{B}$ = 0.5 µm

Machine Information

Name of Inspector:	Henrique
Machine Name:	Test setup
Machine Serial No.:	
Location:	Mechatronics Lab
Date of Test:	07.09.2026 11:32:19
Current Date:	20.10.2026 13:01:45
Filename:	OWIS_stageTR_Electronics...
Comments:	

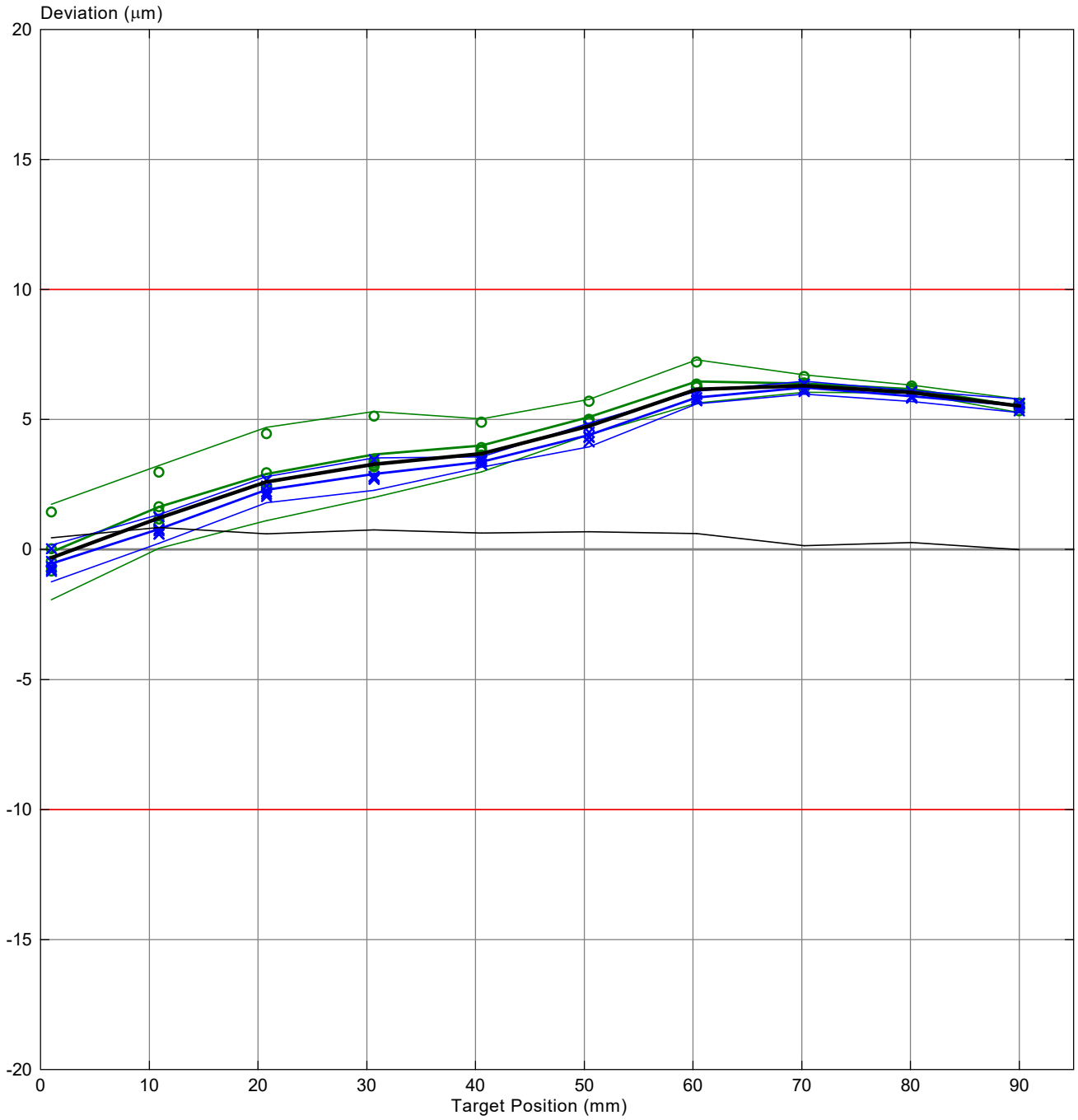
TR-Electronics
EL5042_DC
ED7062_CSP
ClosedLoop
S-Curve
100 microns step before position

Environmental Data

	Max	Min	Mean
AT (°C)	22.06	22.03	22.05
AP (mmHg)	738.2	738.1	738.2
RH (%)	54	53	54
MT1 (°C)	22.28	22.25	22.26
MT2 (°C)	22.07	22.05	22.06
MT3 (°C)			

Expans. Coeff.: 11.7 ppm/°C

Linear - Measurement Axis: Z



Forward Data Runs — Forward Mean — Forward +/-n sigma — Reverse Data Runs
Reverse Mean — Reverse +/-n sigma — Combined Mean — Limit Lines
Backlash / pt.

Numerical Analysis

Standards:	ISO 230-2 2014 (Modified)
Error Sign Convention:	Algebraic
Coverage Factor (Sigma):	2
Accuracy:	A = 9.2 µm
	A↑= 9.2 µm
	A↓= 7.7 µm
Sys. Dev. Pos.:	E = 7.0 µm
	E↑= 6.6 µm
	E↓= 6.8 µm
Mean Bidir. Pos. Dev.:	M = 6.6 µm
Repeatability:	R = 3.7 µm
	R↑= 3.7 µm
	R↓= 1.4 µm
Max Reversal Error:	B = 0.8 µm
Mean Reversal Error:	$\overline{B}$ = 0.5 µm

Machine Information

Name of Inspector:	Henrique
Machine Name:	Test setup
Machine Serial No.:	
Location:	Mechatronics Lab
Date of Test:	07.09.2026 10:02:27
Current Date:	20.10.2026 13:02:54
Filename:	OWIS_stageTR_Electronics...
Comments:	

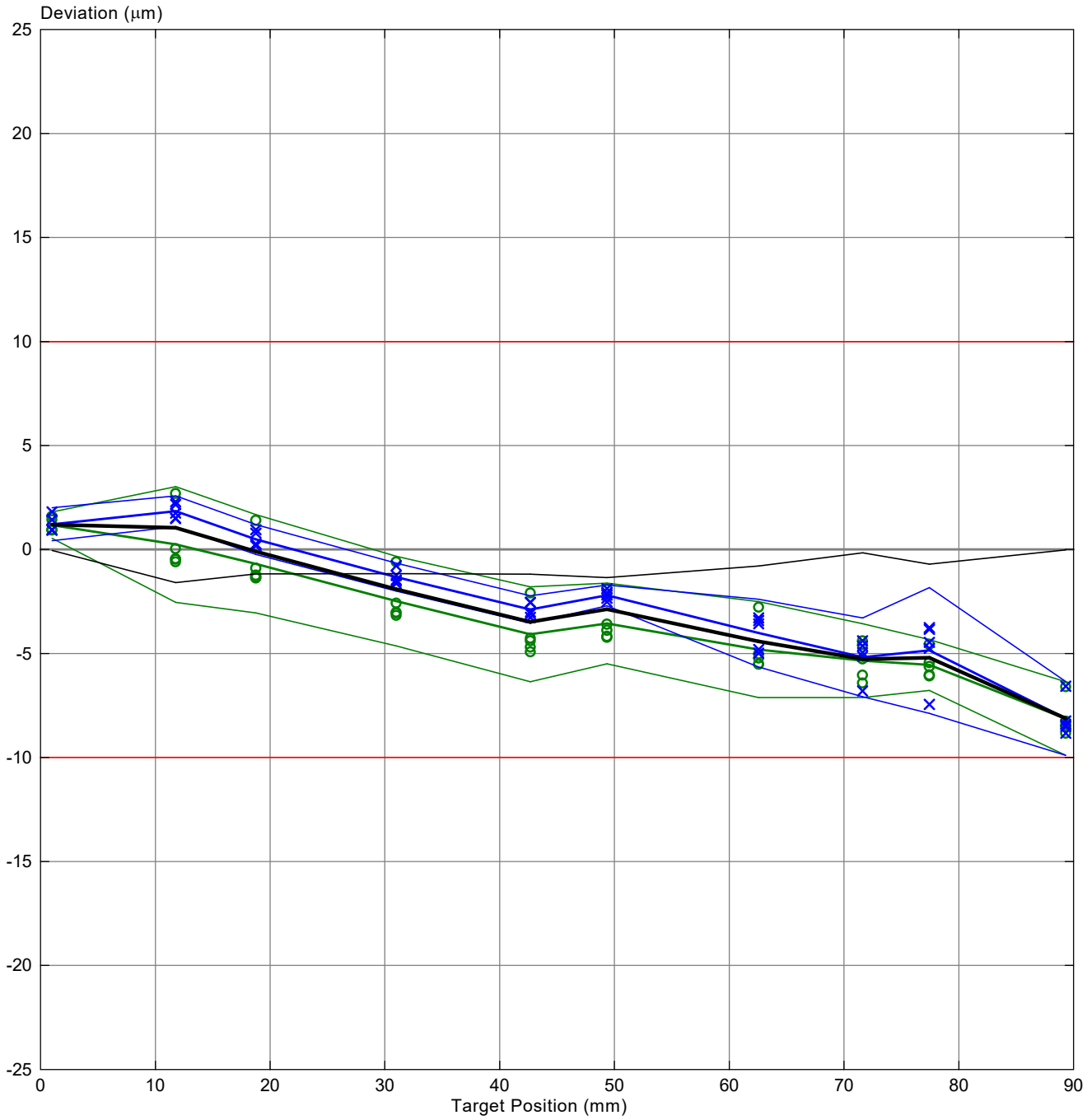
TR-Electronics
EL5042_DC
ED7062_CSV
ClosedLoop
S-Curve
100 microns step before position

Environmental Data

	Max	Min	Mean
AT (°C)	21.88	21.86	21.87
AP (mmHg)	738.7	738.3	738.6
RH (%)	53	53	53
MT1 (°C)	22.13	22.11	22.12
MT2 (°C)	21.87	21.84	21.86
MT3 (°C)			

Expans. Coeff.: 11.7 ppm/°C

Linear - Measurement Axis: Z



Forward Data Runs — Forward Mean — Forward +/-n sigma — Reverse Data Runs
Reverse Mean — Reverse +/-n sigma — Combined Mean — Limit Lines
Backlash / pt.

Numerical Analysis

Standards:	ISO 230-2 2014 (Modified)
Error Sign Convention:	Algebraic
Coverage Factor (Sigma):	2
Accuracy:	A = 12.9 µm
	A↑= 12.9 µm
	A↓= 12.5 µm
Sys. Dev. Pos.:	E = 10.0 µm
	E↑= 9.3 µm
	E↓= 10.0 µm
Mean Bidir. Pos. Dev.:	M = 9.3 µm
Repeatability:	R = 6.0 µm
	R↑= 5.6 µm
	R↓= 6.0 µm
Max Reversal Error:	B = 1.6 µm
Mean Reversal Error:	$\overline{B}$ = -0.8 µm

Machine Information

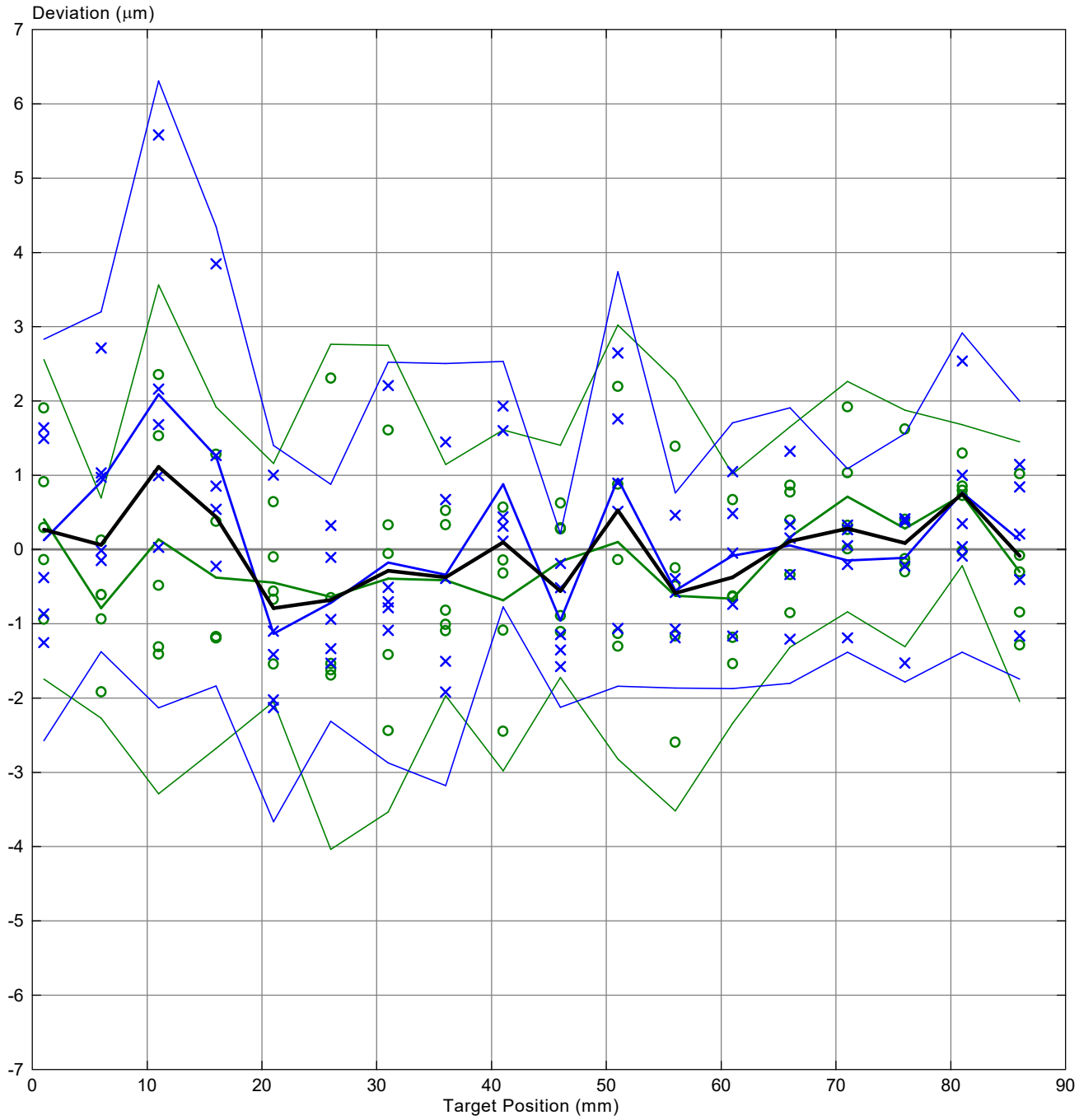
Name of Inspector:	Henrique
Machine Name:	Test setup
Machine Serial No.:	
Location:	Mechatronics Lab
Date of Test:	27.08.2026 10:54:19
Current Date:	20.10.2026 13:03:54
Filename:	OWIS_stageTR_Electronics...
Comments:	
TR-Electronics	
EL5042	
EL7041	
closedLoop	
S-Curve	

Environmental Data

	Max	Min	Mean
AT (°C)	22.14	22.14	22.14
AP (mmHg)	734.4	734.4	734.4
RH (%)	33	33	33
MT1 (°C)	22.74	22.74	22.74
MT2 (°C)	23.11	23.11	23.11
MT3 (°C)			

Expans. Coeff.: 11.7 ppm/°C

Straightness - Measurement Axis: Z



Forward Data Runs — Forward Mean — Forward +/-n sigma — Reverse Data Runs

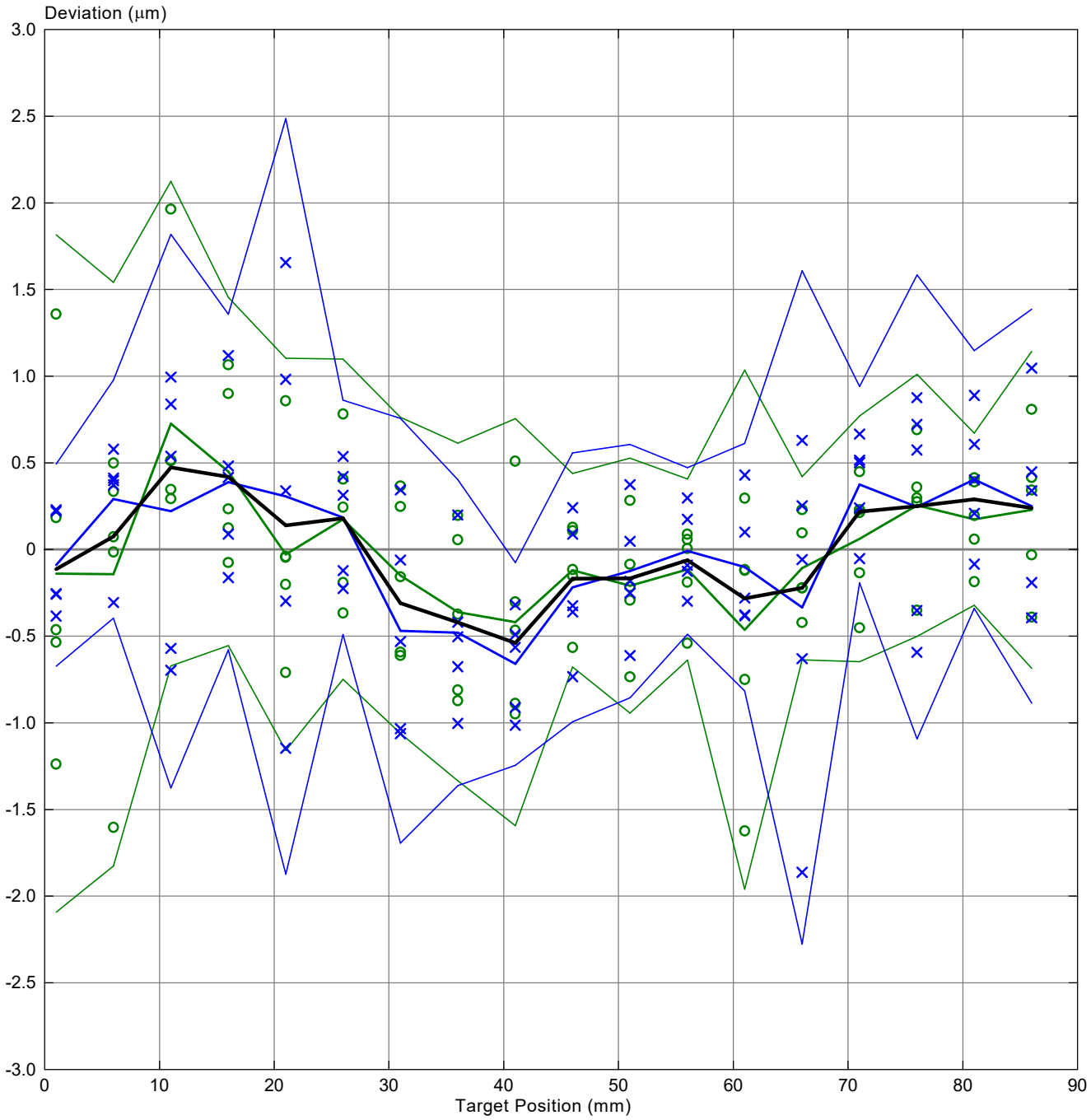
Reverse Mean — Reverse +/-n sigma — Combined Mean

Numerical Analysis	
Standards:	ISO 230-2 1997
Coverage Factor (Sigma):	2
Accuracy:	A = 10.3 µm
	A↑= 7.6 µm
	A↓= 10.0 µm
Sys. Dev. Pos.:	E = 3.2 µm
	E↑= 1.5 µm
	E↓= 3.2 µm
Mean Bidir. Pos. Dev.:	M = 1.9 µm
Repeatability:	R = 9.6 µm
	R↑= 6.9 µm
	R↓= 8.4 µm
Max Reversal Error:	B = 2.0 µm
Mean Reversal Error:	$\overline{B}$ = -0.3 µm

Machine Information	
Name of Inspector:	Henrique
Machine Name:	Owis Stage
Machine Serial No.:	
Location:	Mechatronics Lab
Date of Test:	08.09.2026 11:12:37
Current Date:	20.10.2026 13:15:38
Filename:	OWIS_stageTR_Electronics...
Comments:	
TR-Electronics Encoder	
EL5042_DC	
ED7062_CSP	
Horizontal XZ plane	

Environmental Data	Max	Min	Mean
AT (°C)	22.14	22.06	22.10
AP (mmHg)	732.5	732.2	732.4
RH (%)	58	57	58
MT1 (°C)	22.36	22.29	22.32
MT2 (°C)	22.13	22.02	22.08
MT3 (°C)			

Straightness - Measurement Axis: Z



Forward Data Runs — Forward Mean — Forward +/-n sigma — Reverse Data Runs

Reverse Mean — Reverse +/-n sigma — Combined Mean

Numerical Analysis	
Standards:	ISO 230-2 1997
Coverage Factor (Sigma):	2
Accuracy:	A = 4.8 µm
	A↑= 4.2 µm
	A↓= 4.8 µm
Sys. Dev. Pos.:	E = 1.4 µm
	E↑= 1.2 µm
	E↓= 1.1 µm
Mean Bidir. Pos. Dev.:	M = 1.0 µm
Repeatability:	R = 4.4 µm
	R↑= 3.9 µm
	R↓= 4.4 µm
Max Reversal Error:	B = 0.5 µm
Mean Reversal Error:	$\overline{B}$ = 0.0 µm

Machine Information	
Name of Inspector:	Henrique
Machine Name:	Owis Stage
Machine Serial No.:	
Location:	Mechatronics Lab
Date of Test:	08.09.2026 13:49:48
Current Date:	20.10.2026 13:16:05
Filename:	OWIS_stageTR_Electronics...
Comments:	
TR-Electronics Encoder	
EL5042_DC	
ED7062_CSP	
Vertical YZ plane	

Environmental Data	Max	Min	Mean
AT (°C)	22.52	22.45	22.48
AP (mmHg)	730.7	730.0	730.4
RH (%)	55	55	55
MT1 (°C)	22.72	22.65	22.68
MT2 (°C)	22.44	22.37	22.41
MT3 (°C)			