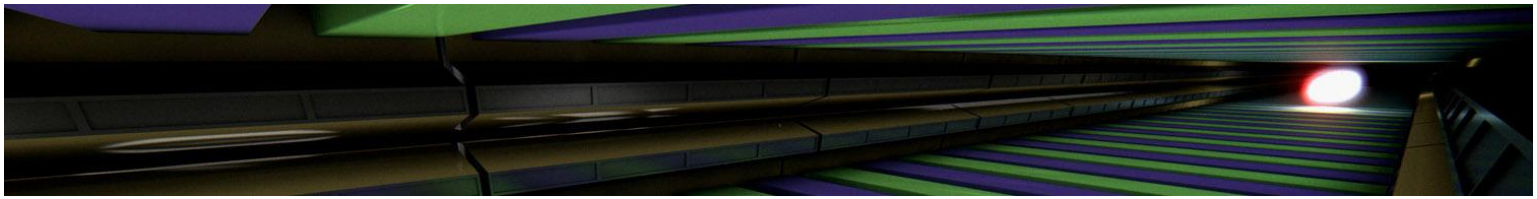


# Comparative Study between mechanic and magnetic Measurements of Gap Dependent Hysteresis on XFEL-Undulator Prototypes

A. Liebram; U. Englisch; J. Pflüger

European XFEL GmbH; Germany

# Overview



- Comparison of the built-in linear encoder system with a external reference gauge

  (U48 prototype and U40 pre-series model)

- Hall-Probe measurements as a function of gap and direction of movement

- Conclusion

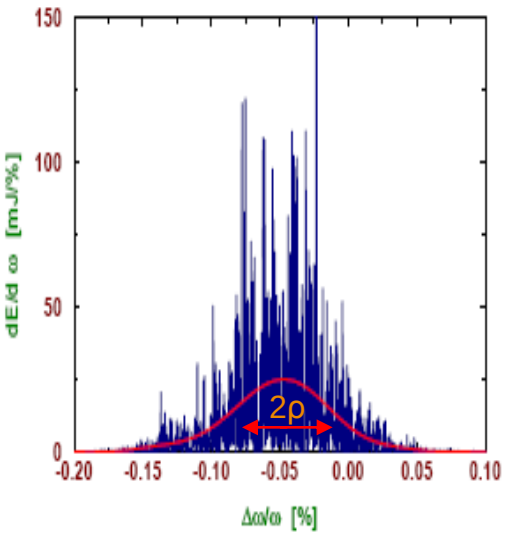
# Motivation



Resonance condition:

$$\lambda_s = \frac{\lambda_u}{2\gamma^2}(1+K^2) \Rightarrow \frac{\Delta\lambda_s}{\lambda_s} = \frac{2K\cdot\Delta K}{1+K^2} \approx \frac{2\Delta K}{K} < \rho$$

SASE FEL bandwidth




If this criterion is fulfilled no gain degradation is expected!

$$\Delta K = \frac{e}{2\pi\cdot m\cdot c}\cdot\lambda\cdot\frac{\partial B}{\partial g}\cdot\Delta g$$

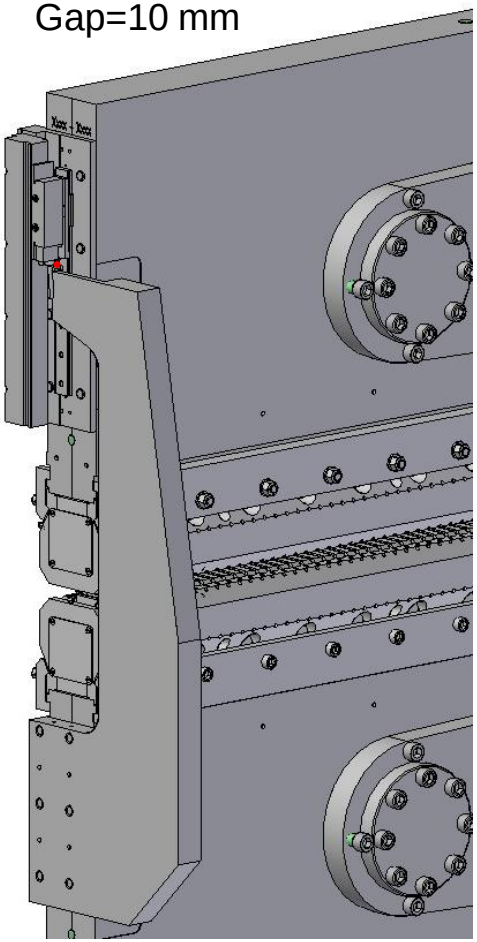
$\rho \approx 10^{-4}$ for XFEL

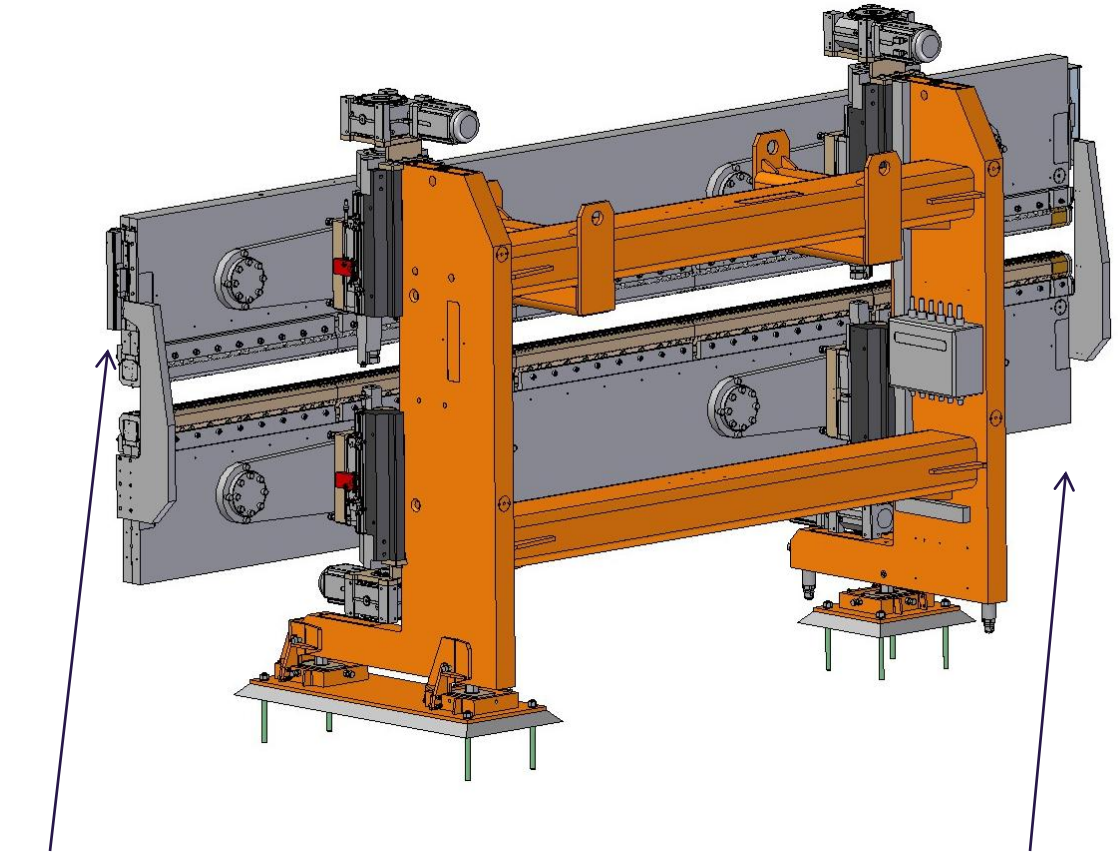
$\Delta g \approx 1$ µm max. ➡ Very stringent requirement on gap precision

# Planar Undulator; Overview



Gap=10 mm



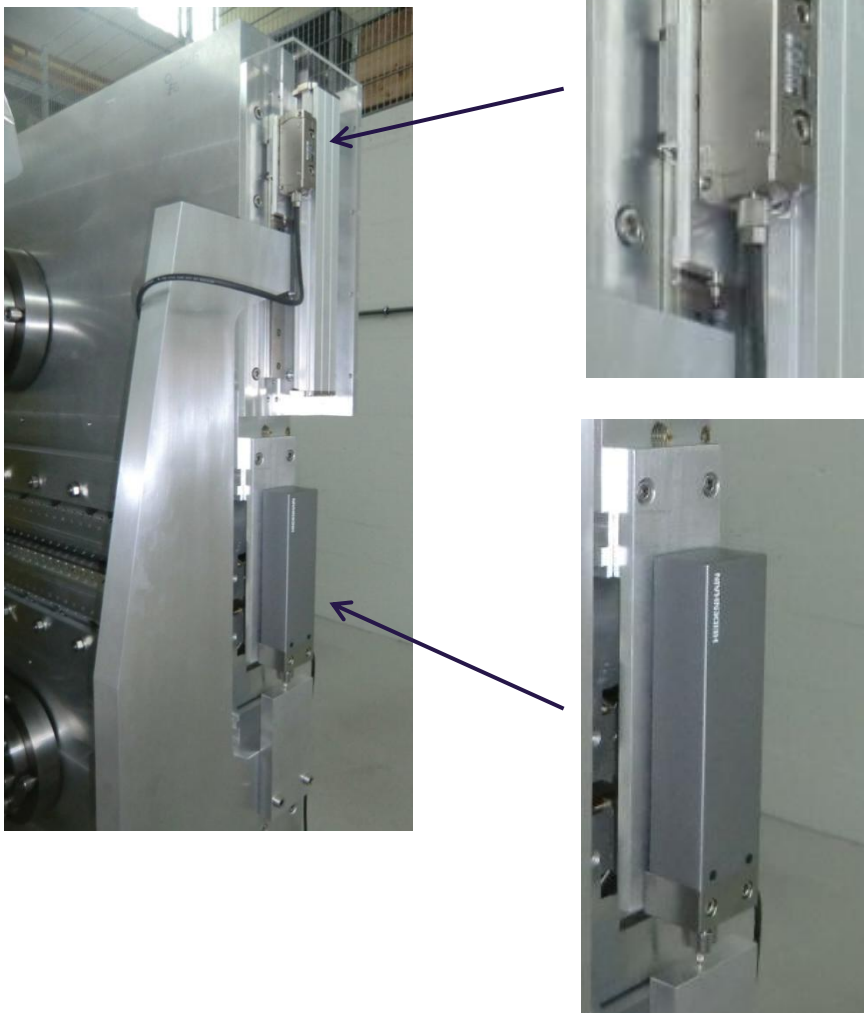


Linear Encoder No.1

Linear Encoder No. 2

# Comparison of the built-in Linear Encoder System with a Reference Gauge





LC183:

Position error of individual build-in encoders < +/- 0.72 µm

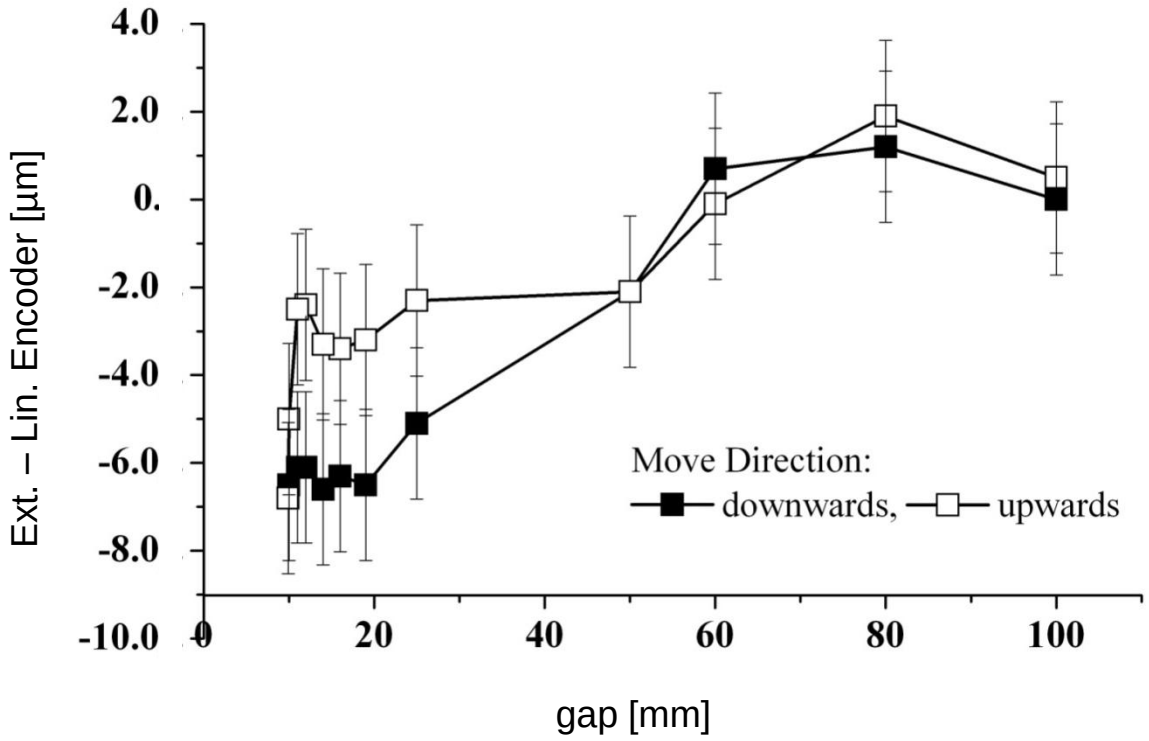
MT101:

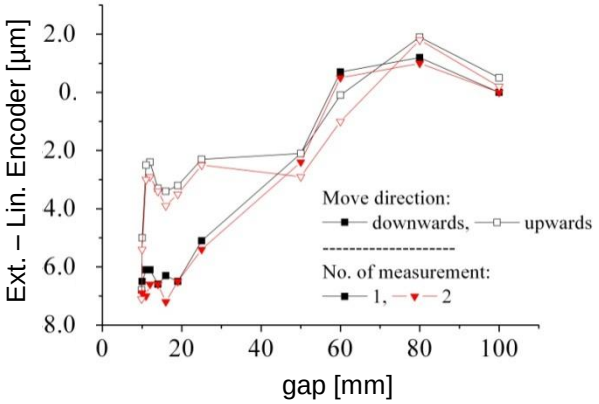
Specified system accuracy : +/- 1µm

# Comparison of the built-in Linear Encoder System with a Reference Gauge ; U48 Prototype



Difference between external reference gauge and build-in encoder No.1



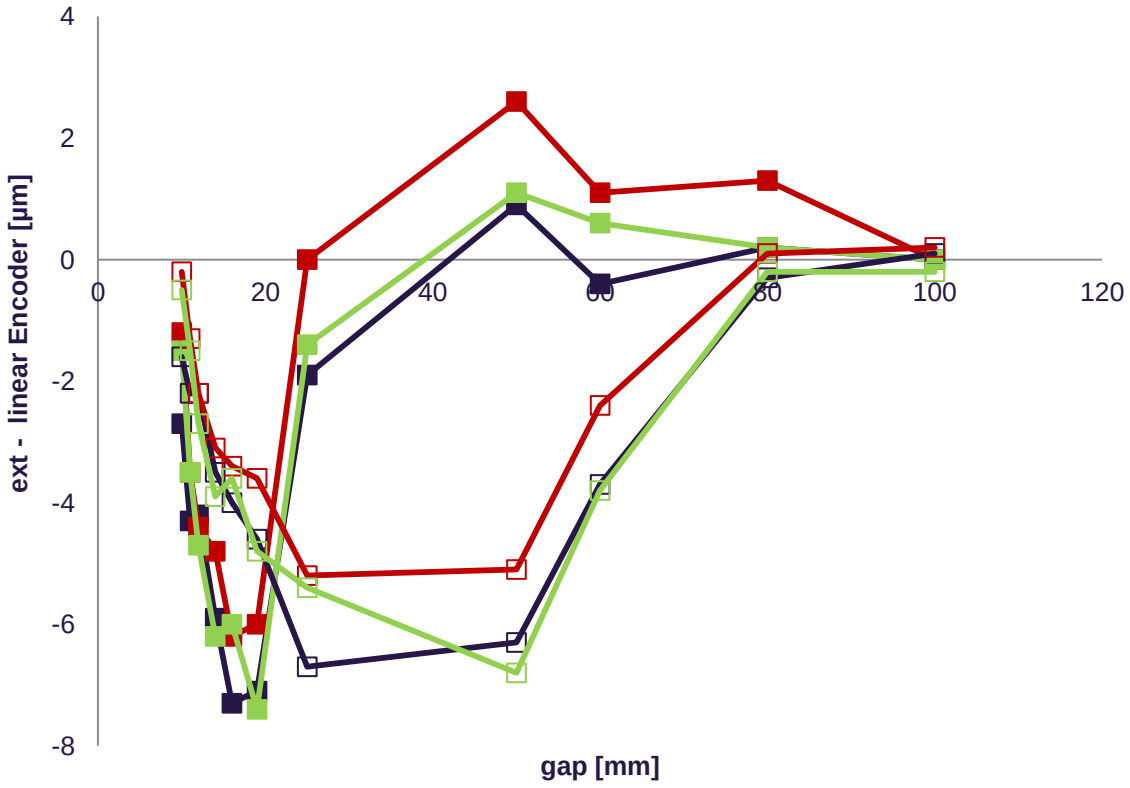




Encoder No. 1:
Max. mechanical hysteresis
ca. +/- 2µm

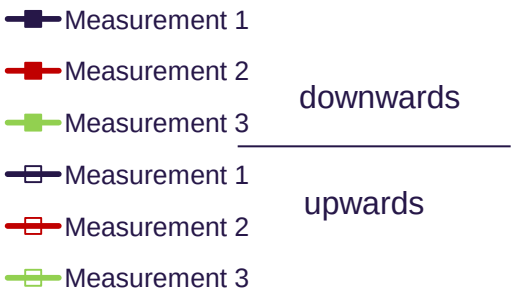
# Comparison of the built-in Linear Encoder System with a Reference Gauge ; U48 Prototype



Difference between reference gauge and build-in encoder No.2



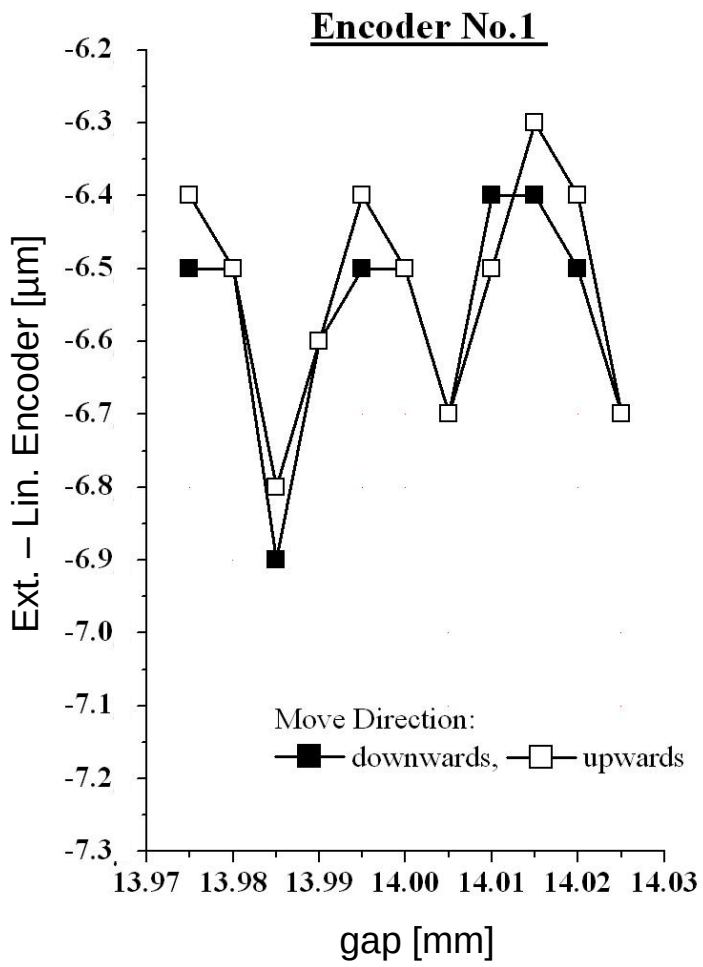

Encoder No. 2:
Max. mechanical hysteresis
ca. +/- 4 µm
(+/- 2 µm for gap < 20mm)

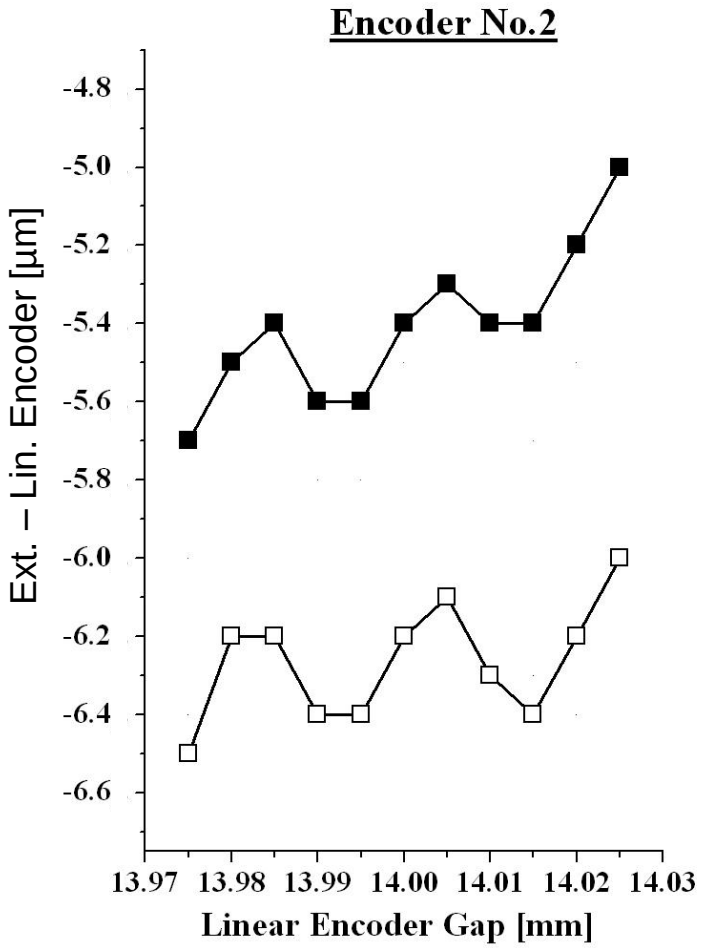


# Comparison of the built-in Linear Encoder System with a Reference Gauge ; U48 Prototype



Small drive cycle; Difference between reference gauge and build-in encoders



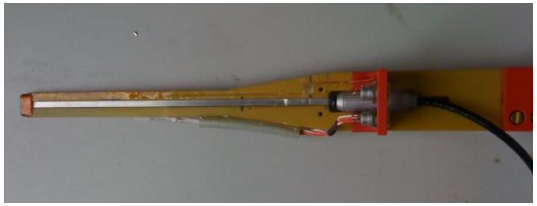




Both encoders:
Max. mechanical hysteresis :
ca. +/- 0.5 µm
for small changes

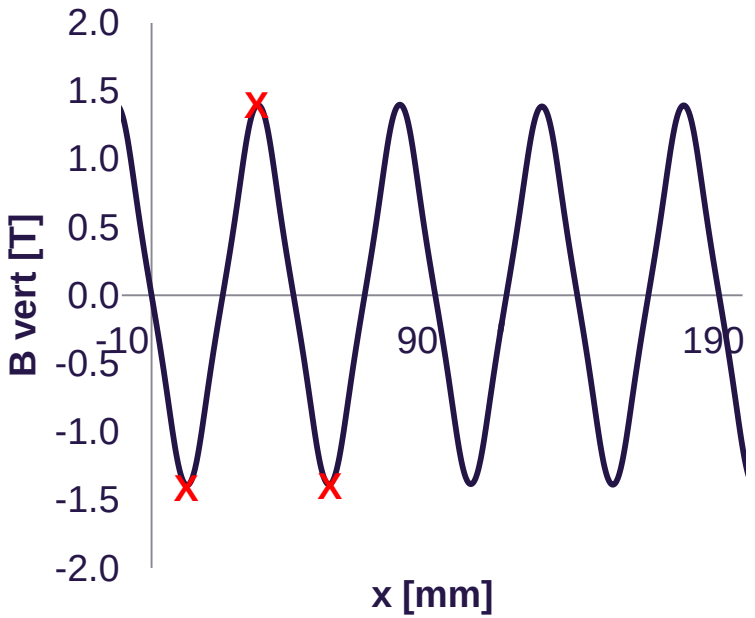
# Set-up for Magnetic Measurements



XFELs Magnetic Measurement Bench
equipped with hybrid sensor
(presented in previous talk by Uwe Englisch)



Vertical magnetic field
measured with hall probe




Data analysis:

- Peakfield calculation via parabolic fit,
- rms calculation along beam axis

# Hysteresis in Magnetic Measurements; U48 Prototype



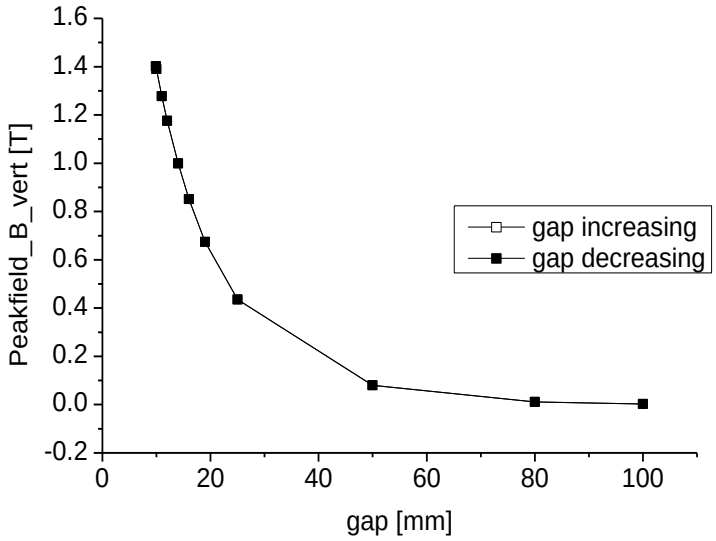
Hall-Probe measurements:

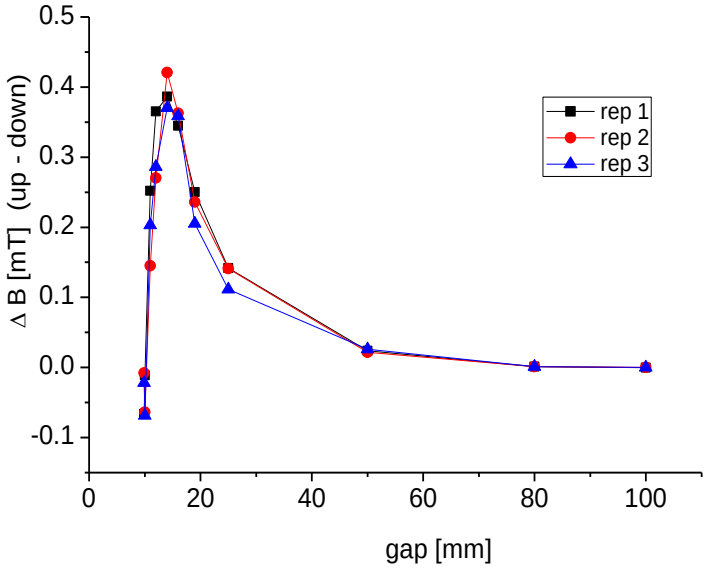
Gap increasing: 10mm->...-> 80mm -> 100mm

Gap decreasing: 100mm -> 80mm->... -> 10mm

Max. hysteresis

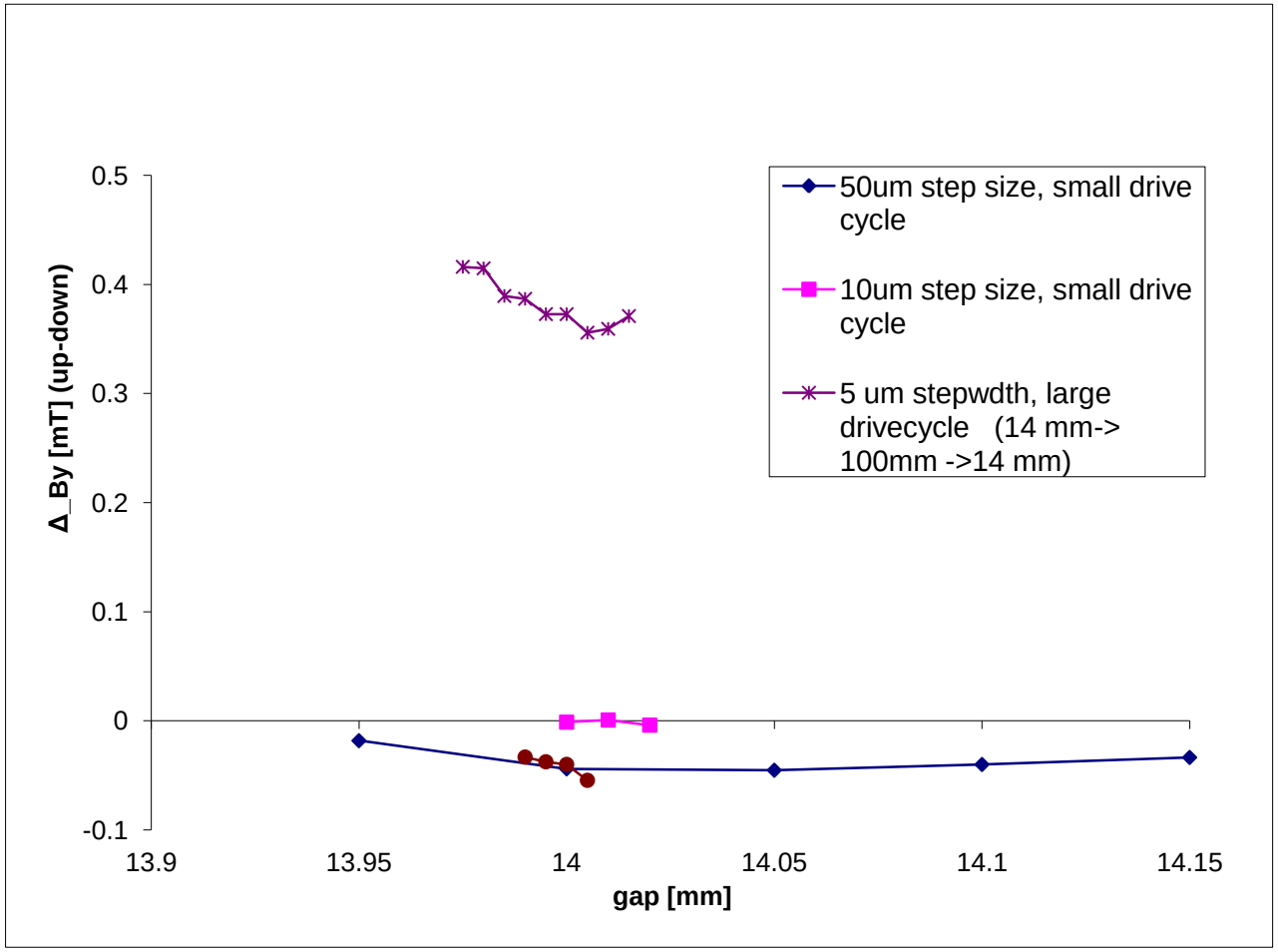
Ca. 400 µT (equals ca. 4µm Δg)



# Hysteresis against Step Size and Drive Cycle; U48



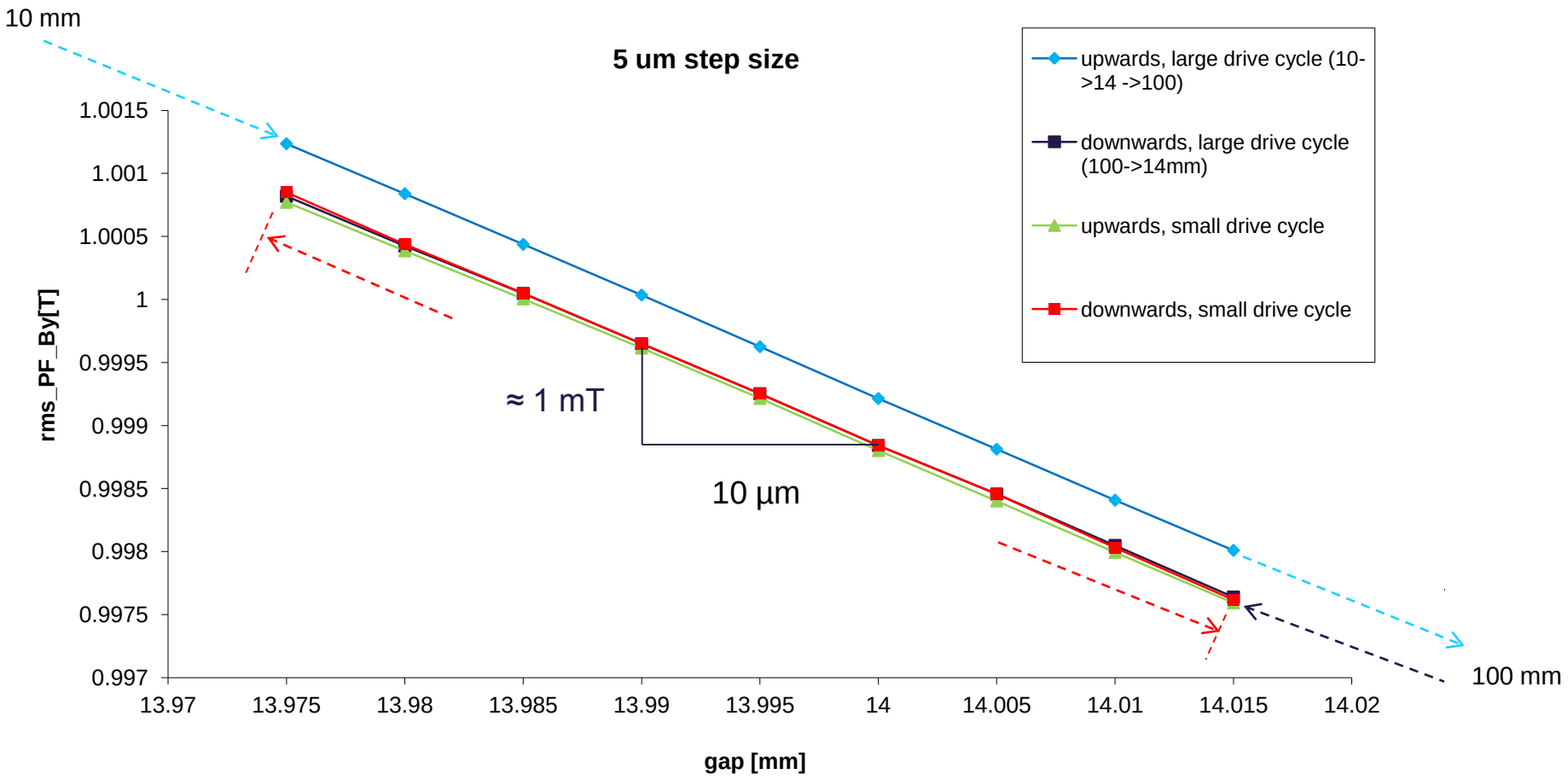



Hysteresis:

- Independent from step size
- Dependent from drive cycle

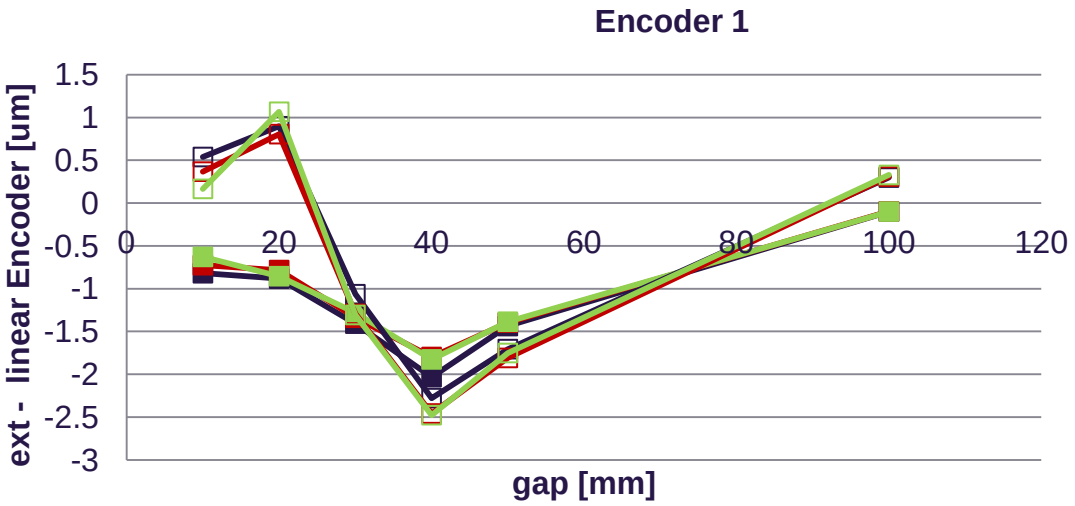
# Hysteresis in Magnetic Measurements; U48 Prototype

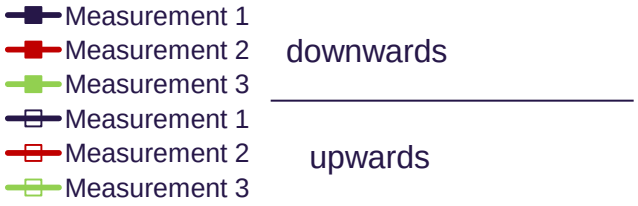




# Comparison of the built-in Linear Encoder System with a Reference Gauge; U40 Pre-Series Model

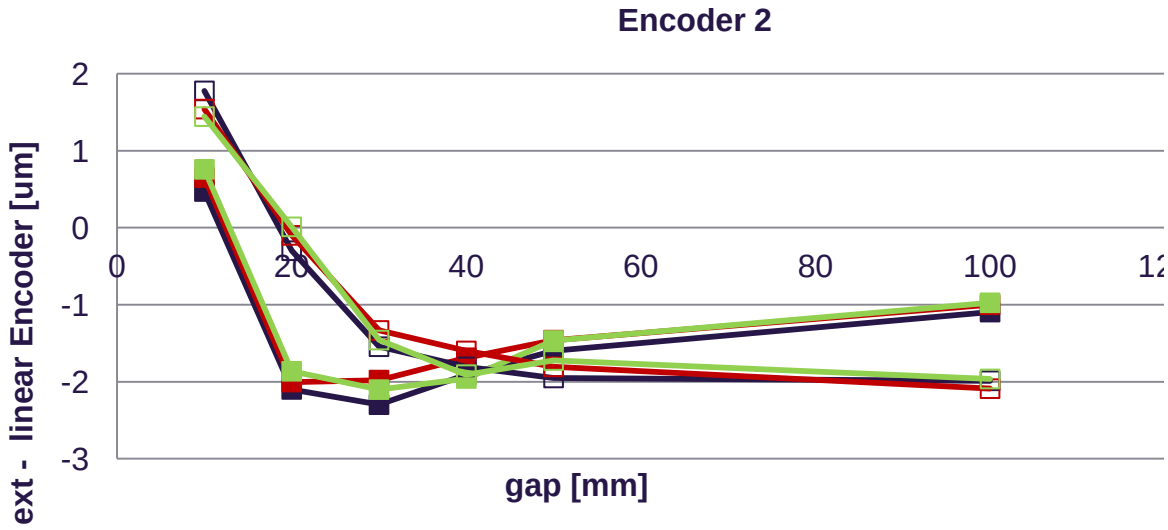





downwards

upwards




Both Encoders :

Max. mechanical hysteresis

< +/- 1µm

Suren Karabekyan; 05.Sept.2011

# Hysteresis in Magnetic Measurements; U40 Pre-series Model



Hall-Probe measurements:

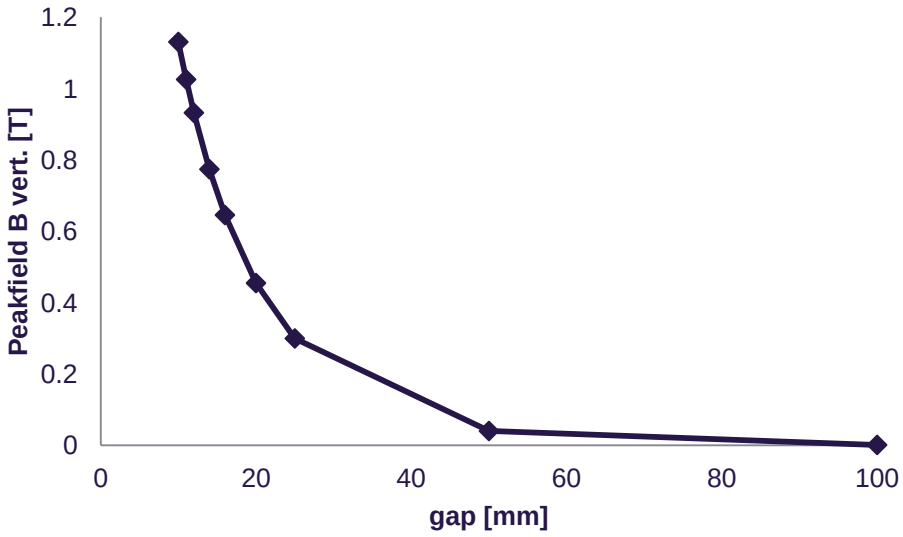
Gap increasing: 10mm->...-> 80mm -> 100mm

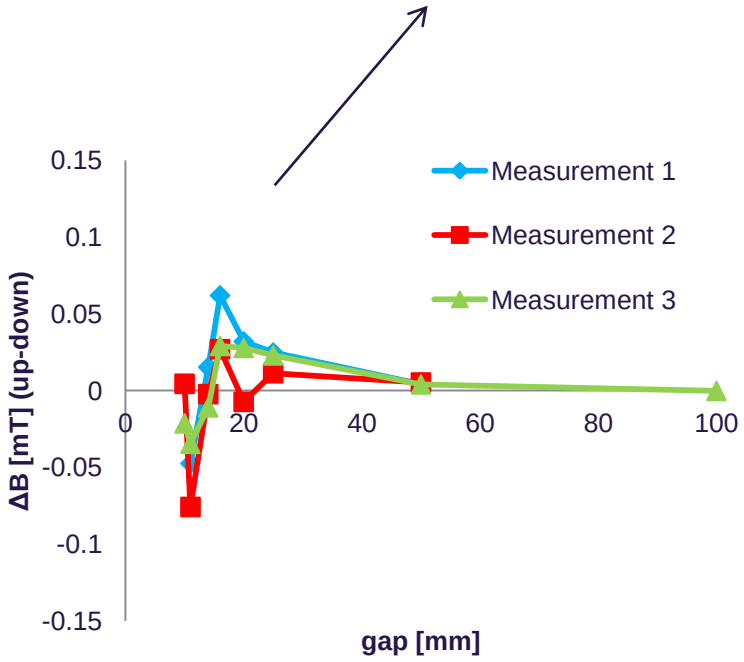
Gap decreasing: 100mm -> 80mm->... -> 10mm

Max. hysteresis U40

< 80 µT

(equals < 1µm Δg for g < 20 mm)



# Summary

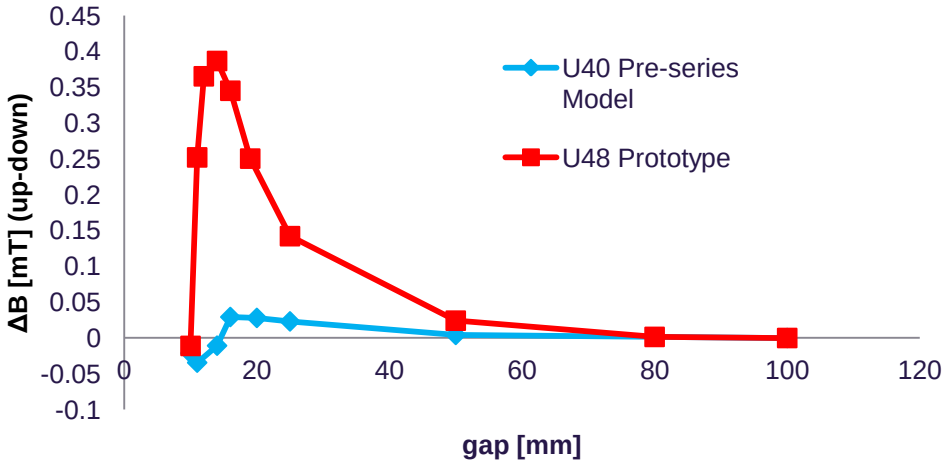


Mechanical hysteresis:

U48 prototype: ≤ +/- 2µm (gap < 20 mm); ≤ +/- 4 µm gap < 100 mm

U40 pre-series model: ≤ +/- 1 µm

Hysteresis in magnetic measurements;




U48 prototype:
Max. hysteresis ≈ 400 µT
equals ≤ 4 µm (gap < 20 mm)

U40 pre-series model:
Max. hysteresis ≈ 80 µT
equals ≤ 1 µm (gap < 20 mm)

# Conclusion



- Observed hysteresis in magnetic measurements can be explained by mechanical hysteresis
- Obtainable gap accuracy near to required accuracy
  - U48-prototype:
    - Required accuracy not fully achieved
    - Precise adjustment of field strength by gap movement requires beside gap measurement a well-known previous history
  - U40-pre-series Model:
    - accuracy sufficient
    - Influence of gap history is negligible