technische universität dortmund

TE connectivity

Study and Implementation of Perpendicular Magnetic Recorder for Automatic Magnetization of Pole tab

01.09.2015

Bijna Balan

Master Thesis – Final Presentation

Embedded Sensing Technologies

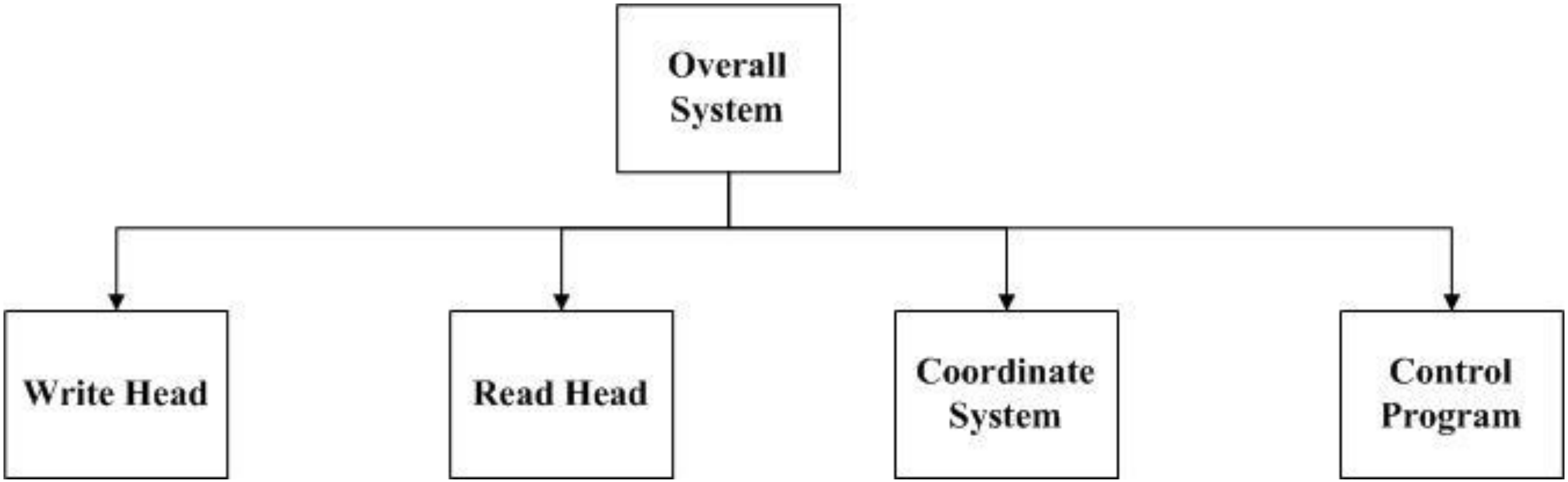
Overview

- Motivation
- Overall System Design
- Signal Processing and Analysis
- Experiments and Results
- Conclusion
- Future Improvements

Motivation

- Conducting an extensive study on Perpendicular Magnetic recorder with emphasis on:
  - Experimental study of magnetization principles to develop an optimal write head design.
  - Design and construction of a system for automatic magnetization of magnetic tapes
  - Implementation of read process by incorporating different sensors.
  - Introduction of error correction method for the write and read process.
  - Enable automatic writing and reading operation on pole tab.

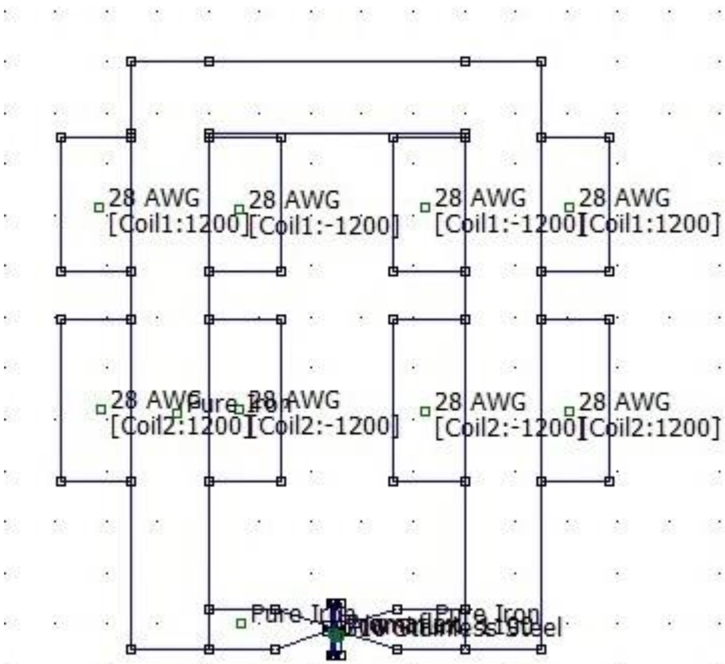
System Design



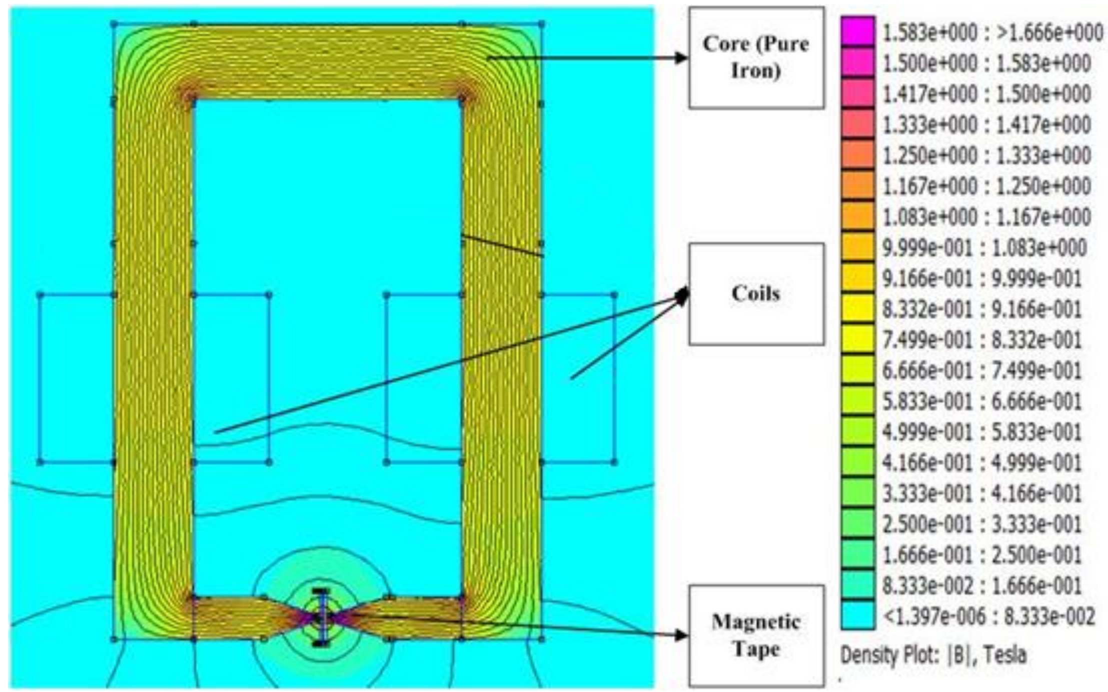
Write Head

- **Requirements**
  - Primary
    - Guided flux design
    - Less current
    - Less heat dissipation
    - Reduce stray field
    - Material selection
  - Secondary
    - Mechanical strength
    - Minimum parts
    - Minimum Cost
    - Optimal air gap adjustment
- **Proposed designs**
  - G-Head
  - M-Head
- **Steps involved**
  - Magnetic field simulation study using FEMM
  - 3D modelling using Solidworks
  - Prototype construction

G-Head (FEMM Simulation)



(a) Geometry design of G-Head

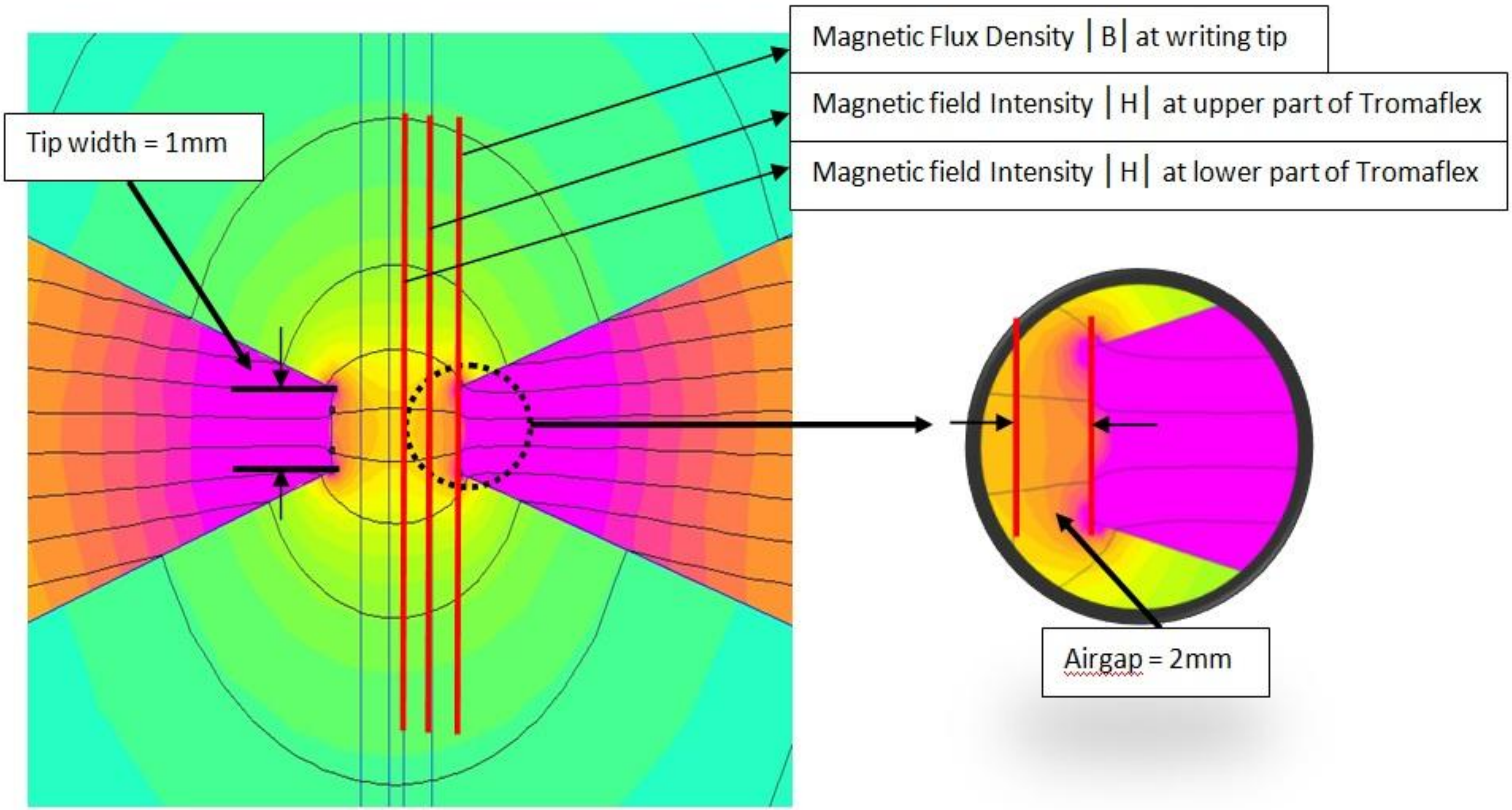


(b) Magnetic simulation result of G-Head

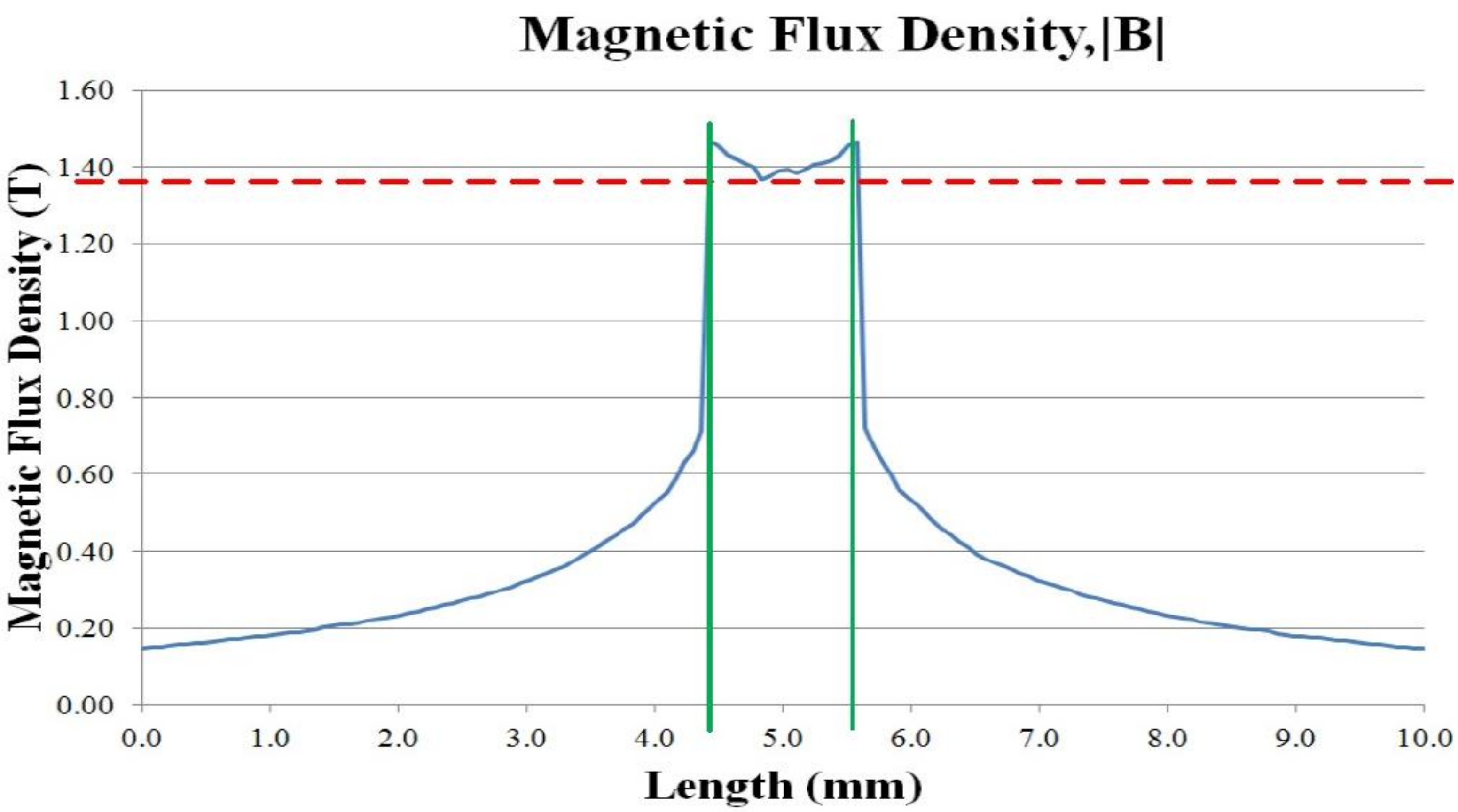
Simulation Results

- Magnetic tape – Tromaflex TX928 (Hc = 170kA/m)
- Material Selected – Pure iron (Bs = 2.3 T)
- Number of windings per coil – 1200 (2 coils used)
- Current supply – 3.0A
- Air gap – 2mm

G-Head (Write tip analysis)

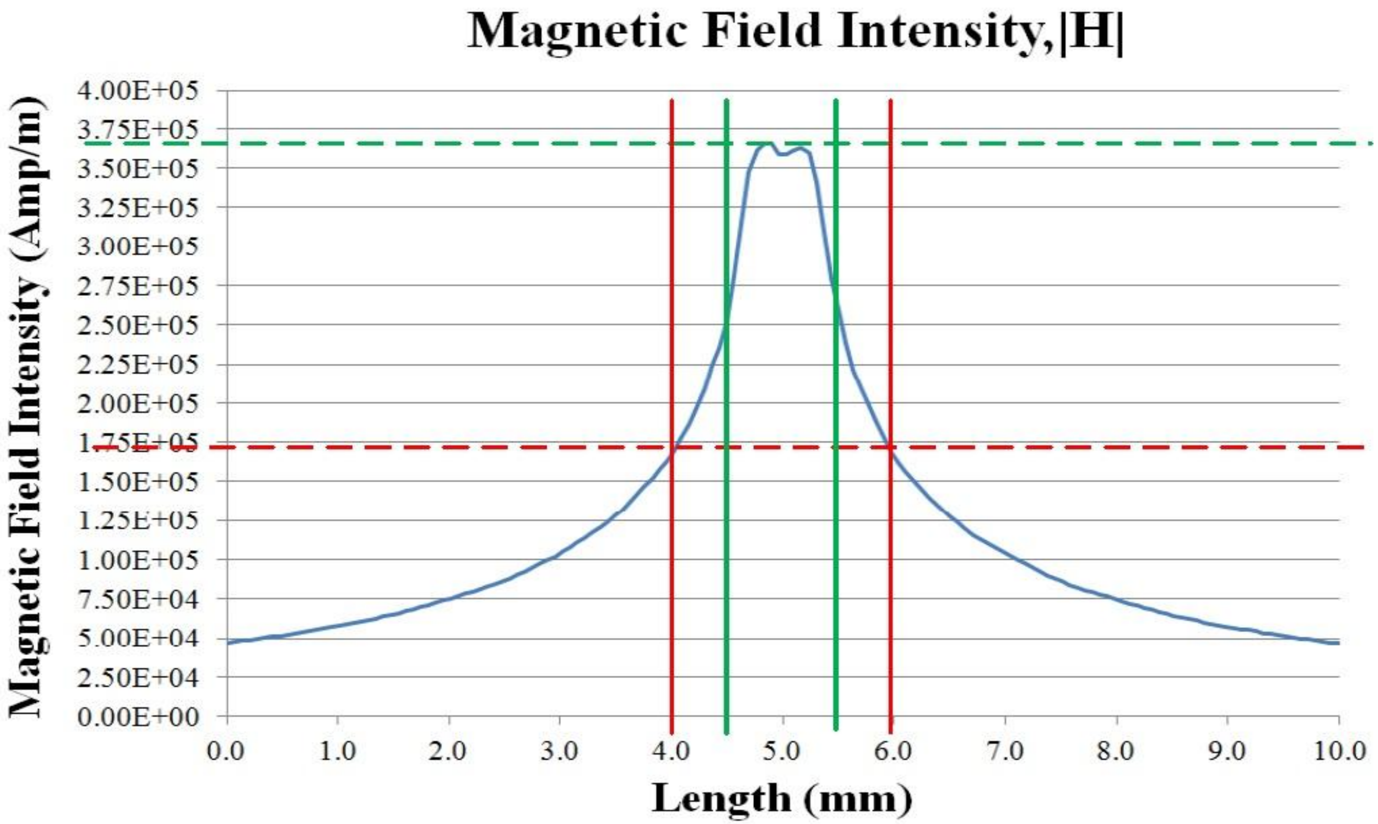


Magnetic flux density, |B| at write tip of G-Head



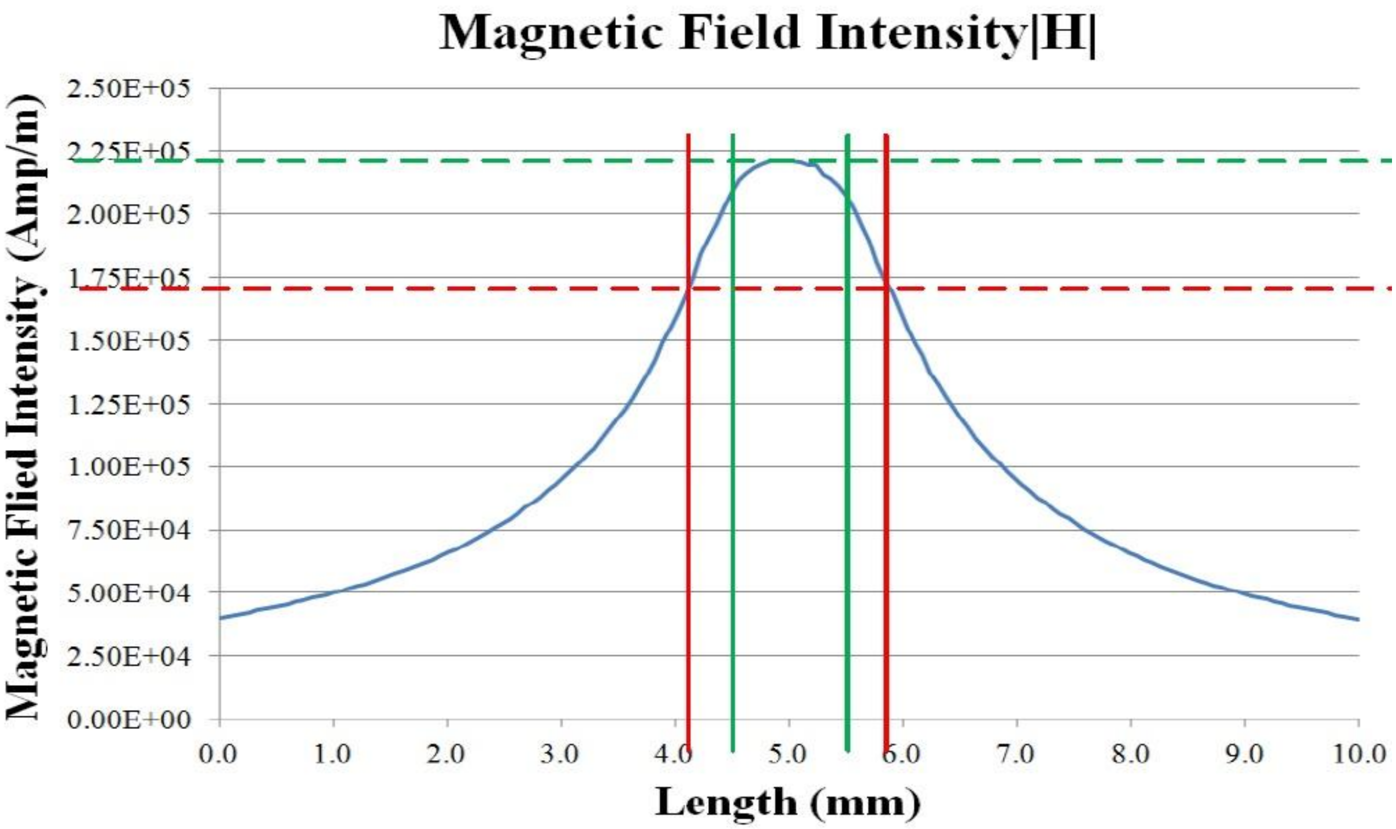
- ➢Red dotted lines – Upper limit of magnetic flux density (1.38 T)
- ➢Green vertical lines – Width of the write tip

Magnetic field intensity, |H| at upper layer of tape



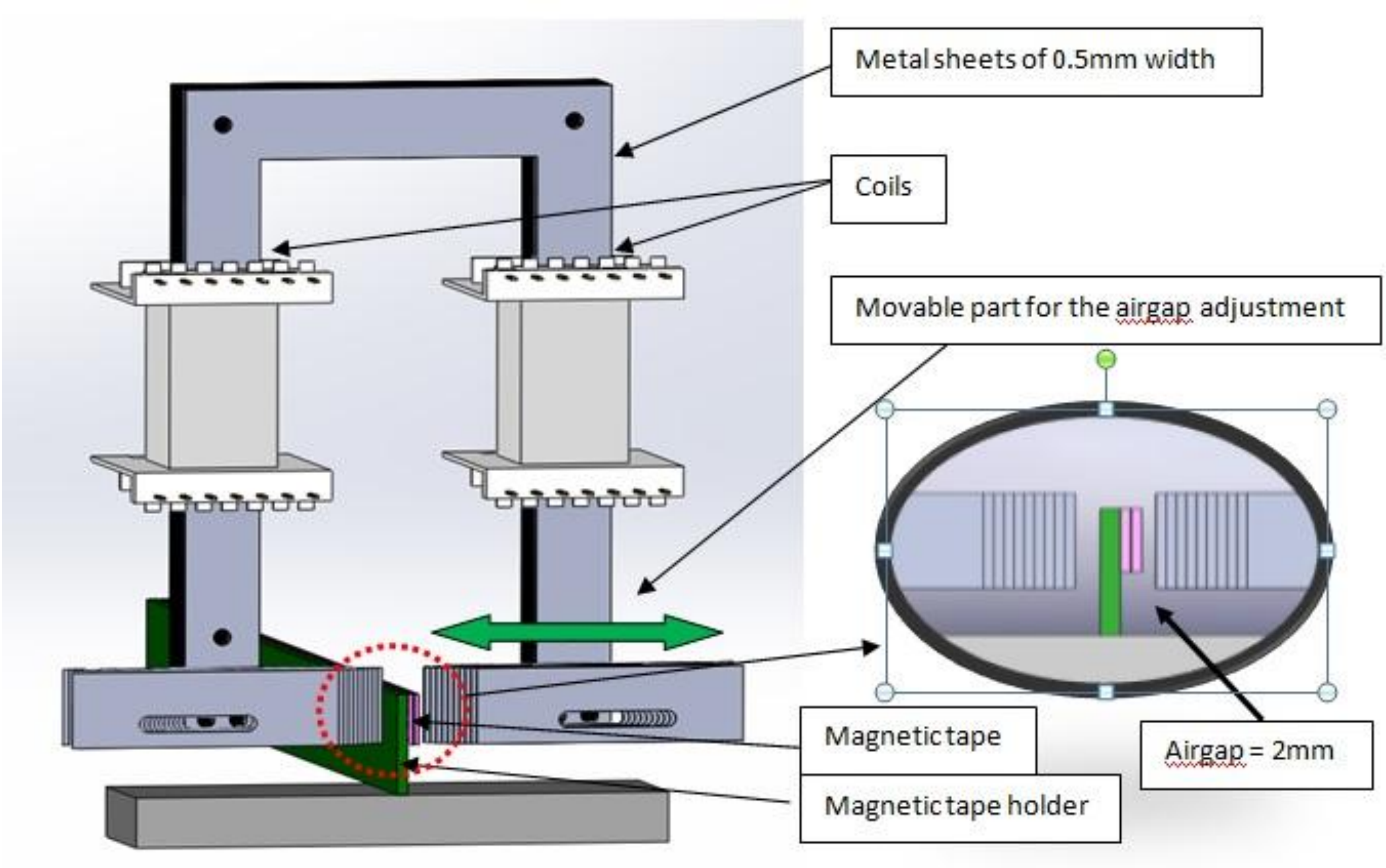
- ➢Green dotted lines – Upper limit of magnetic field intensity (365 kA/m)
- ➢Red dotted lines – Coercivity of Tromaflex TX928 (170 kA/m)
- ➢Green vertical lines – Width of the write tip
- ➢Green vertical lines – Effect of stray field on either sides of the write tip

Magnetic field intensity, |H| at lower layer of tape

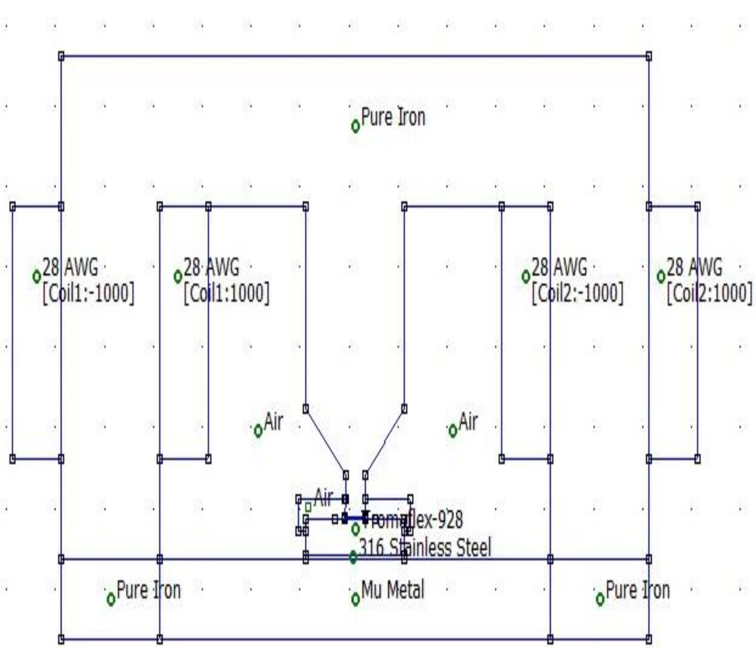


- ➢Green dotted lines – Upper limit of magnetic field intensity (286 kA/m)
- ➢Red dotted lines – Coercivity of Tromaflex TX928 (170 kA/m)
- ➢Green vertical lines – Width of the write tip
- ➢Green vertical lines – Effect of stray field on either sides of the write tip

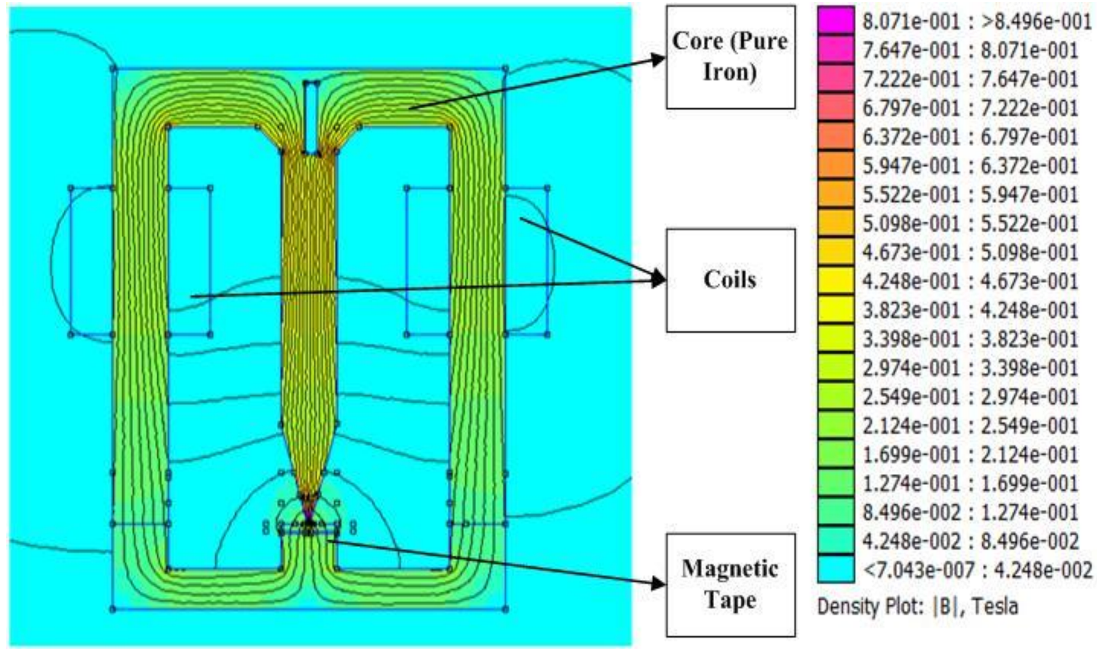
G-Head (3D model)



M-Head (FEMM Simulation)



(a) Geometry design of M-Head

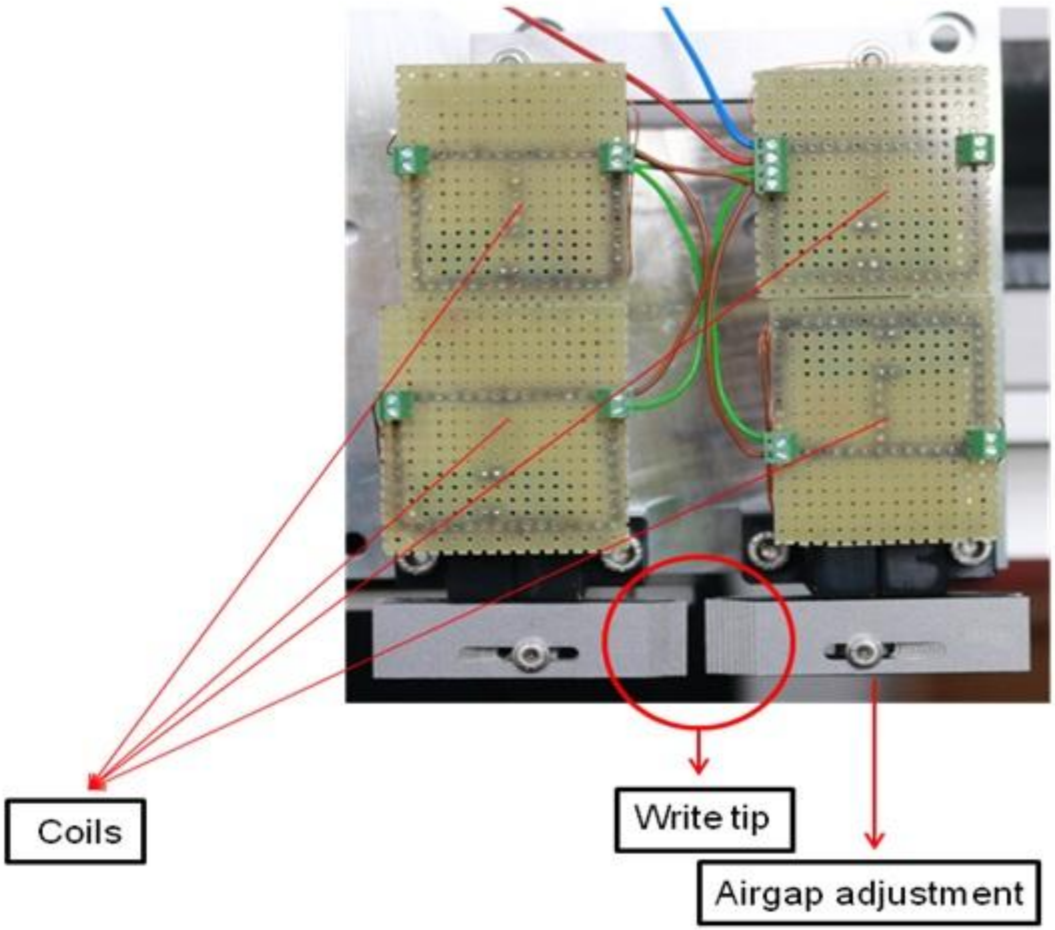


(b) Magnetic simulation result of M-Head

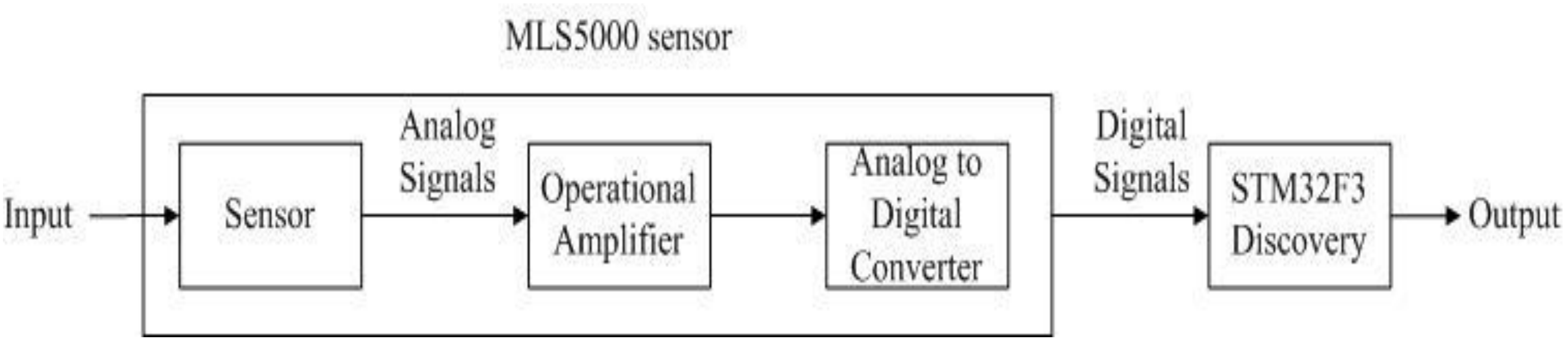
Simulation Results

- Magnetic tape – Tromaflex TX928 (Hc = 170kA/m)
- Material Selected – Pure iron (Bs = 2.3 T)
- Number of windings per coil – 1200 (2 coils used)
- Current supply – 3.0A
- Air gap – 2mm

G-Head (Prototype)

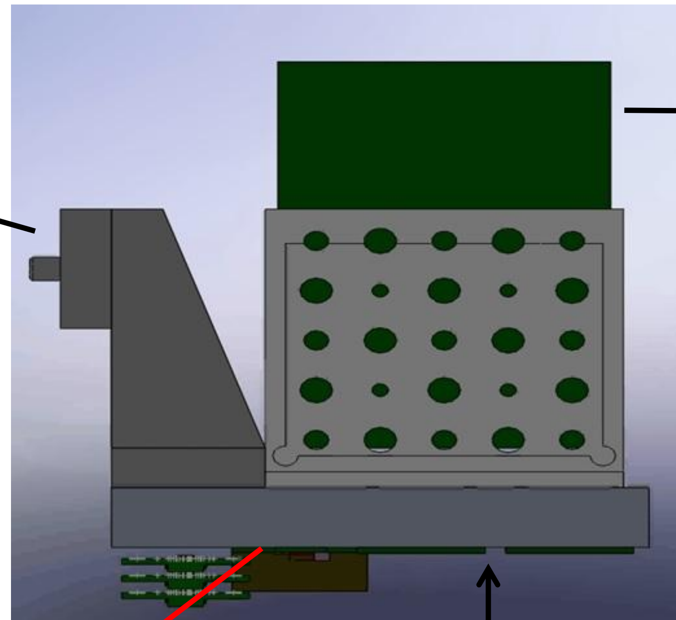


Read Head


MLS5000 sensor
Input
Sensor
Analog
Signals
Operational
Amplifier
Analog to
Digital
Converter
Digital
Signals
STM32F3
Discovery
Output

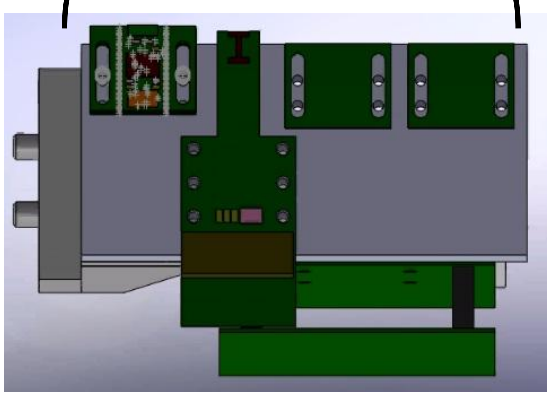
Read Head (3D model)

Holder to connect to the translational stage



STM32F3 Discovery board

Sensors

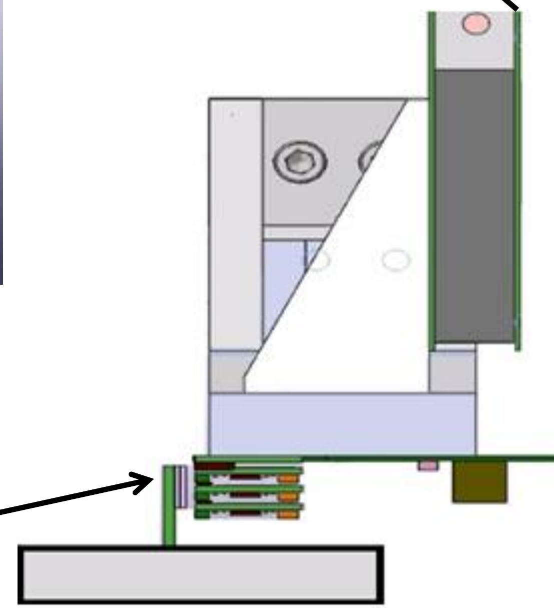


Bottom view

Side view

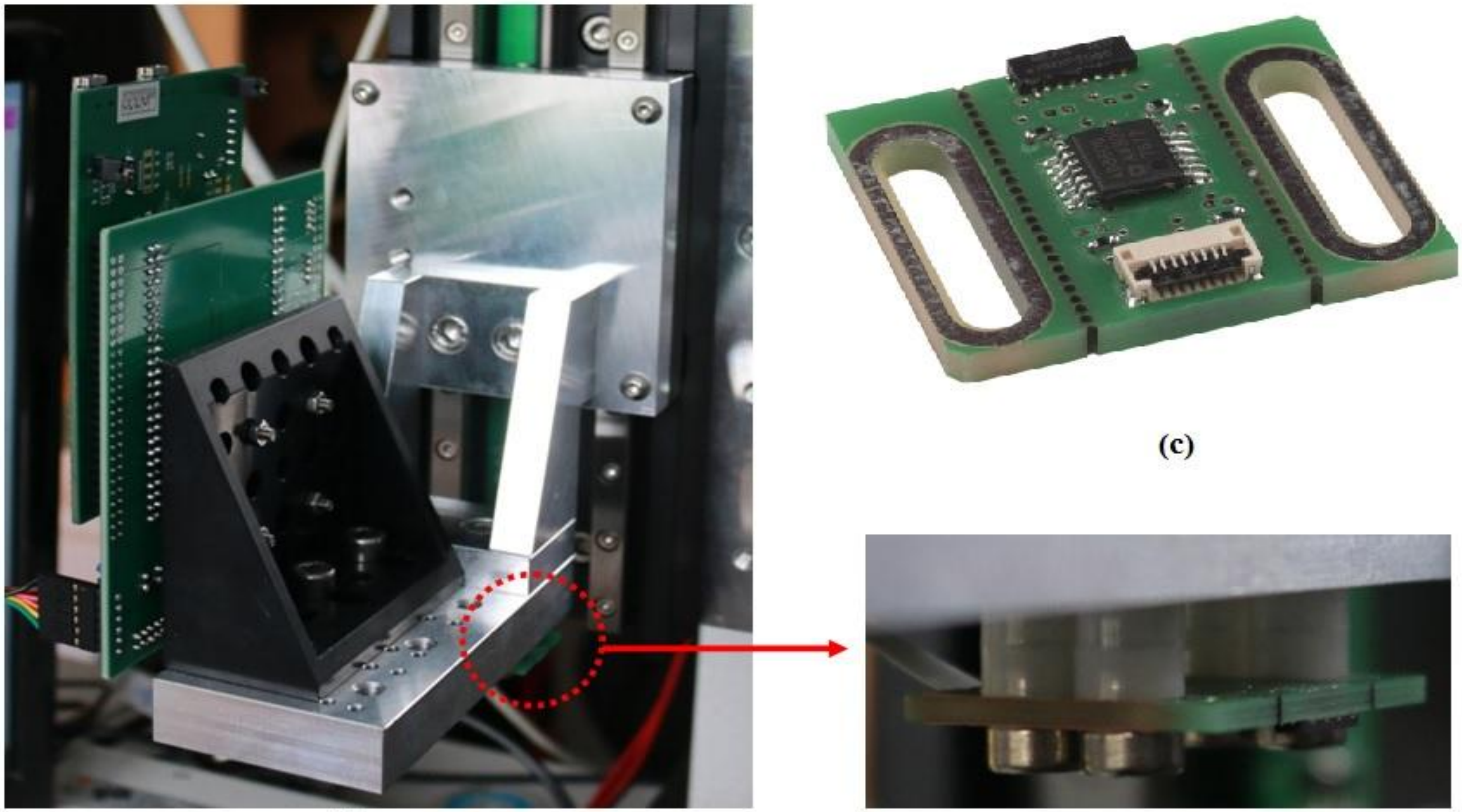
Holder for sensors

Magnetic tape and holder



Front view

Read Head (Prototype)



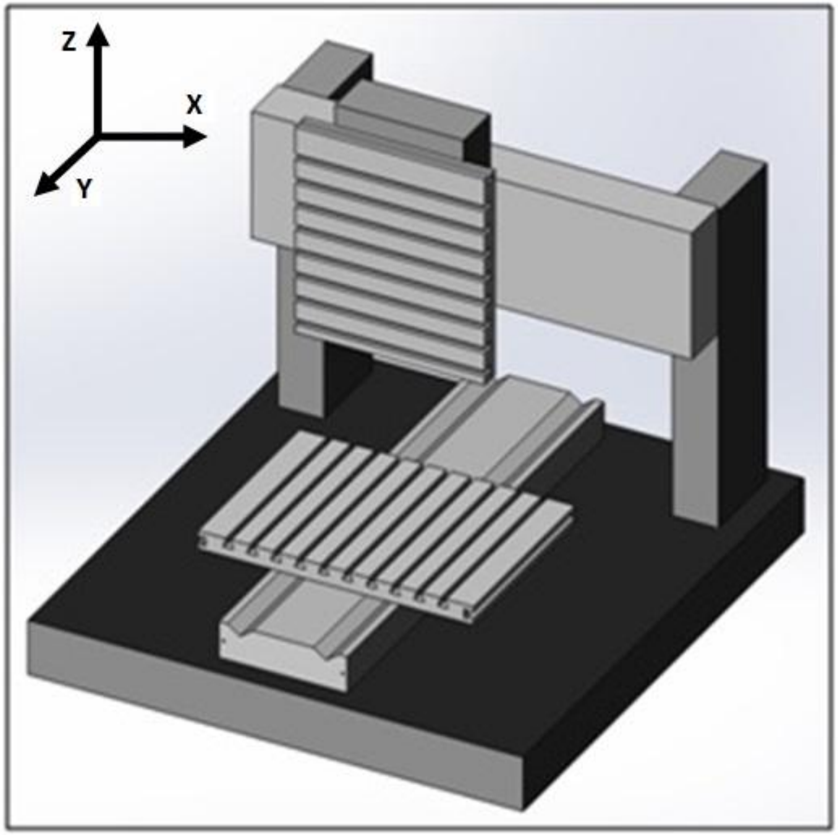
(c)

(a)

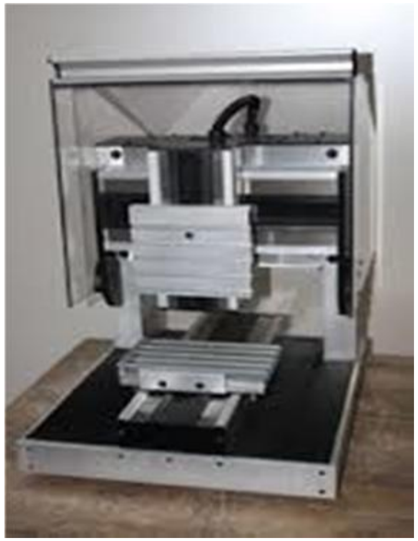
(b)

(a) Read Head Assembly (b) Arrangement of MLS5000 sensor on read head (c) MLS5000 sensor

KOSY3(Koordinatentisch-System)

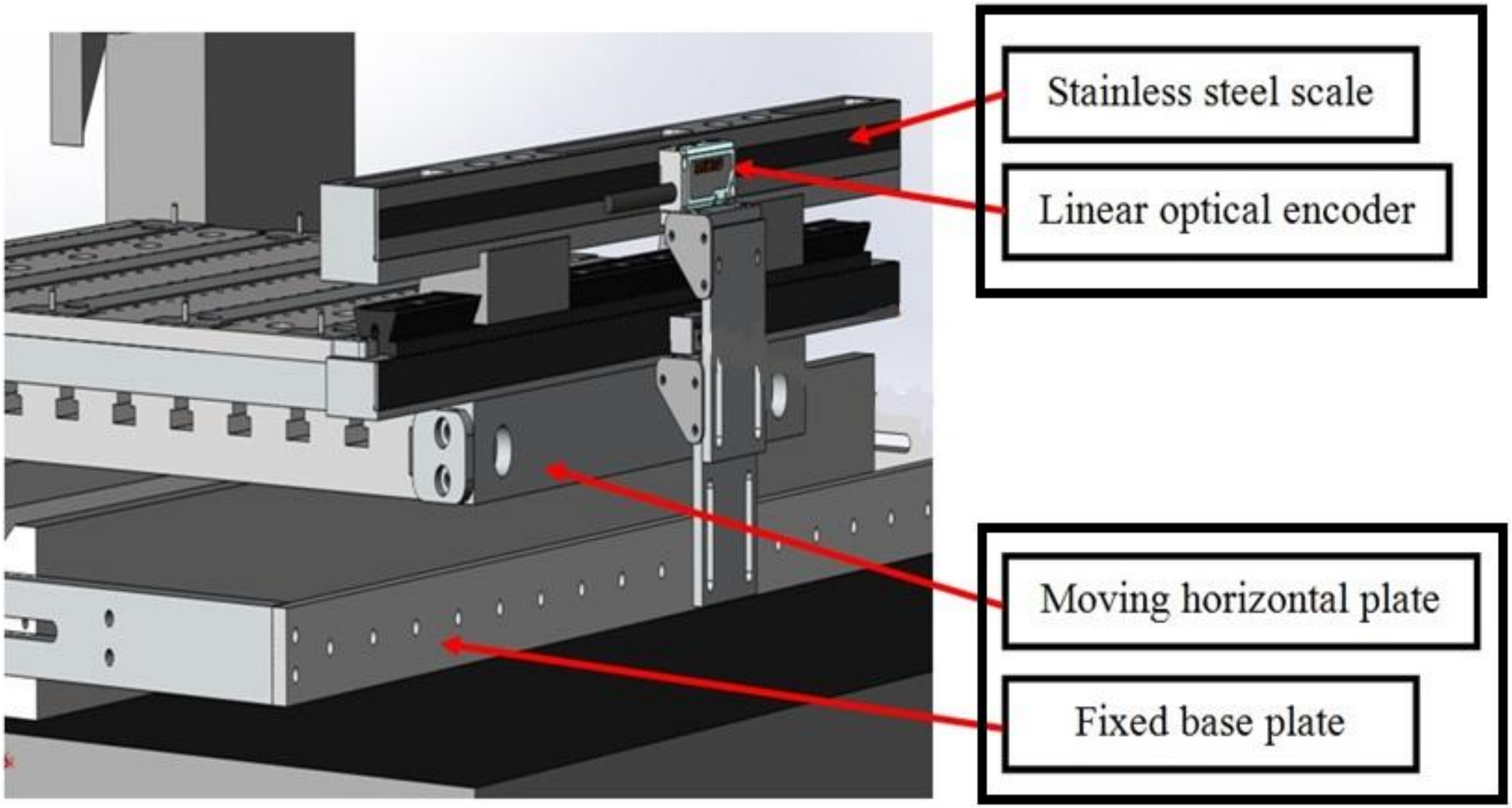


(a) 3D model of KOSY3 platform

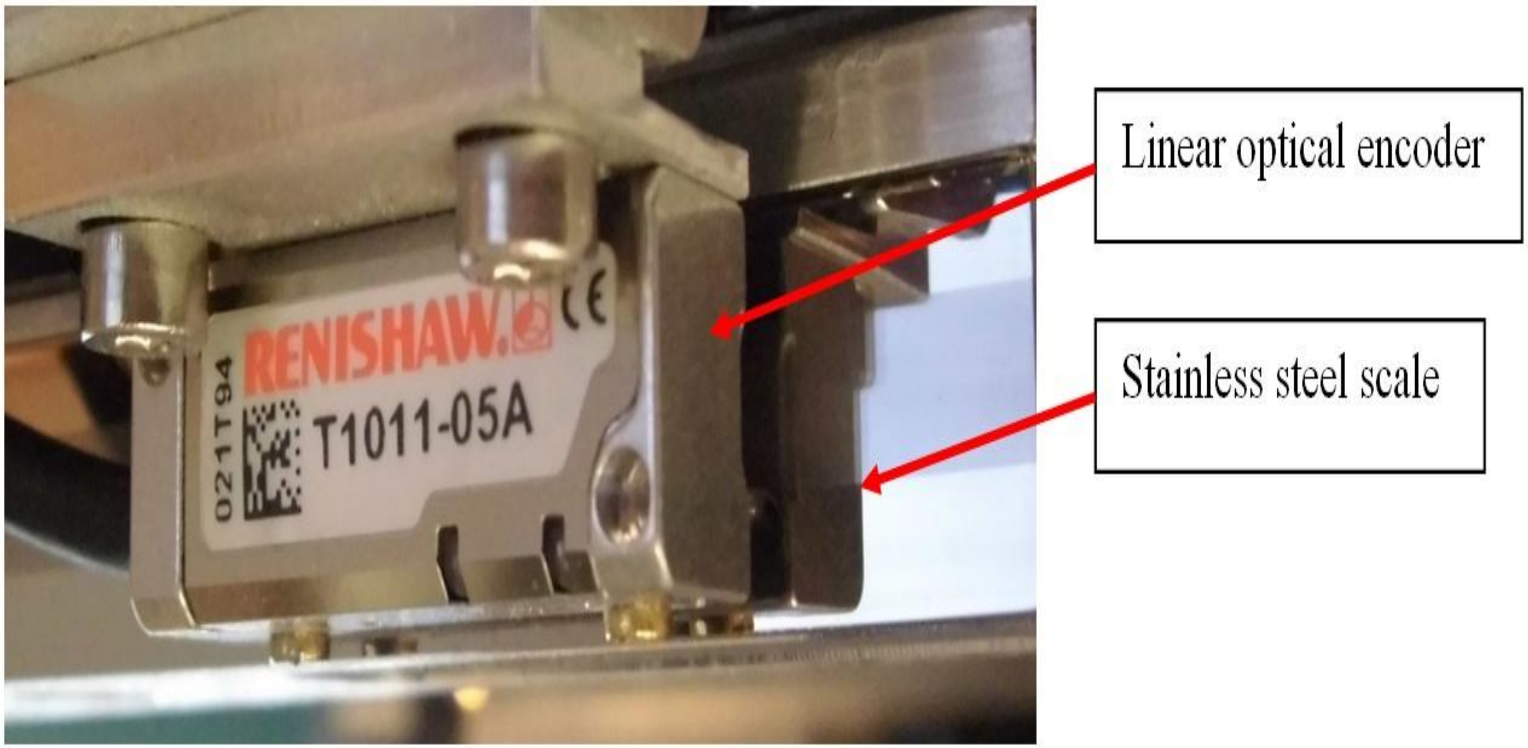


(b) KOSY3 platform

Position Reference Measurement System

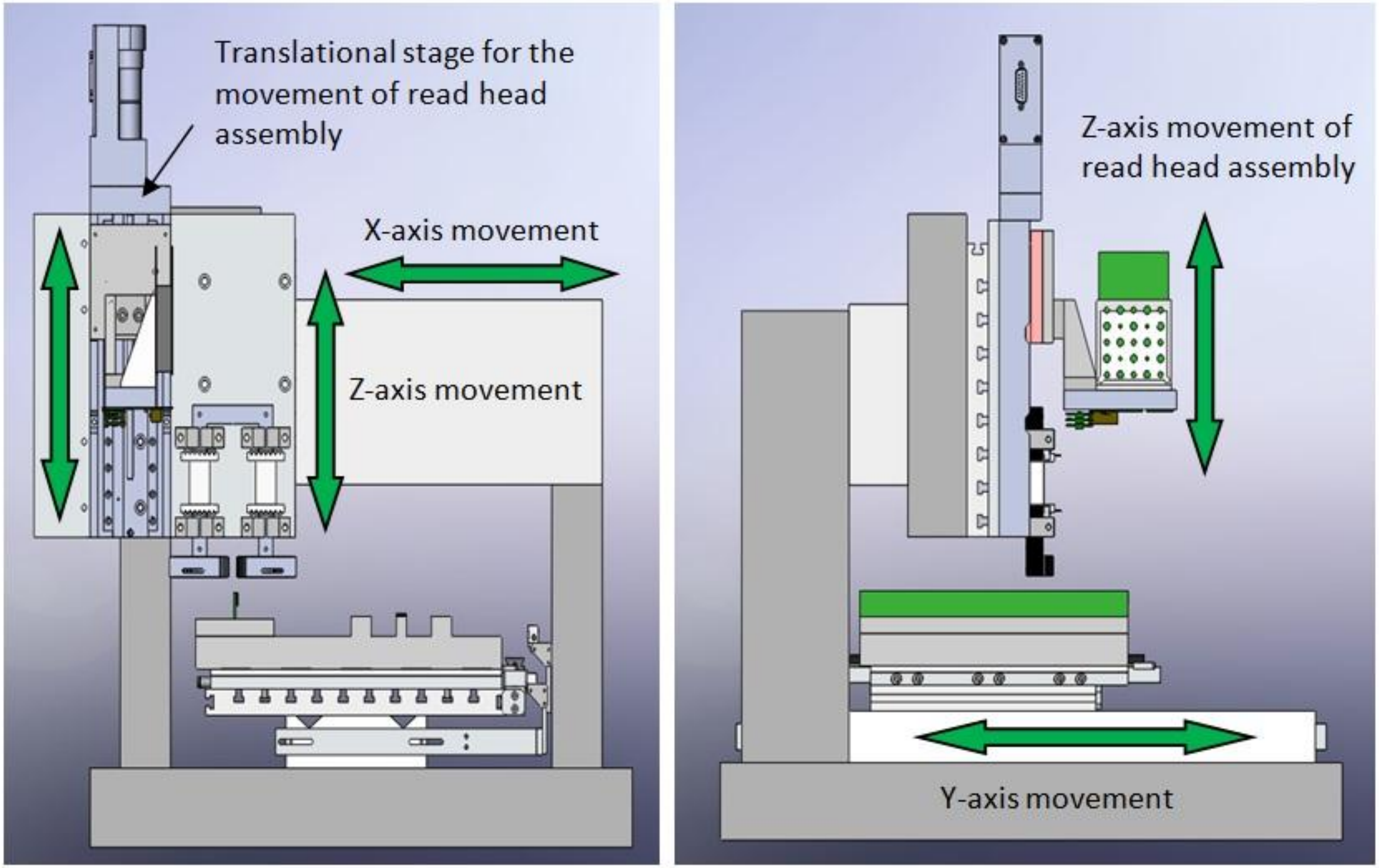


Linear Encoders

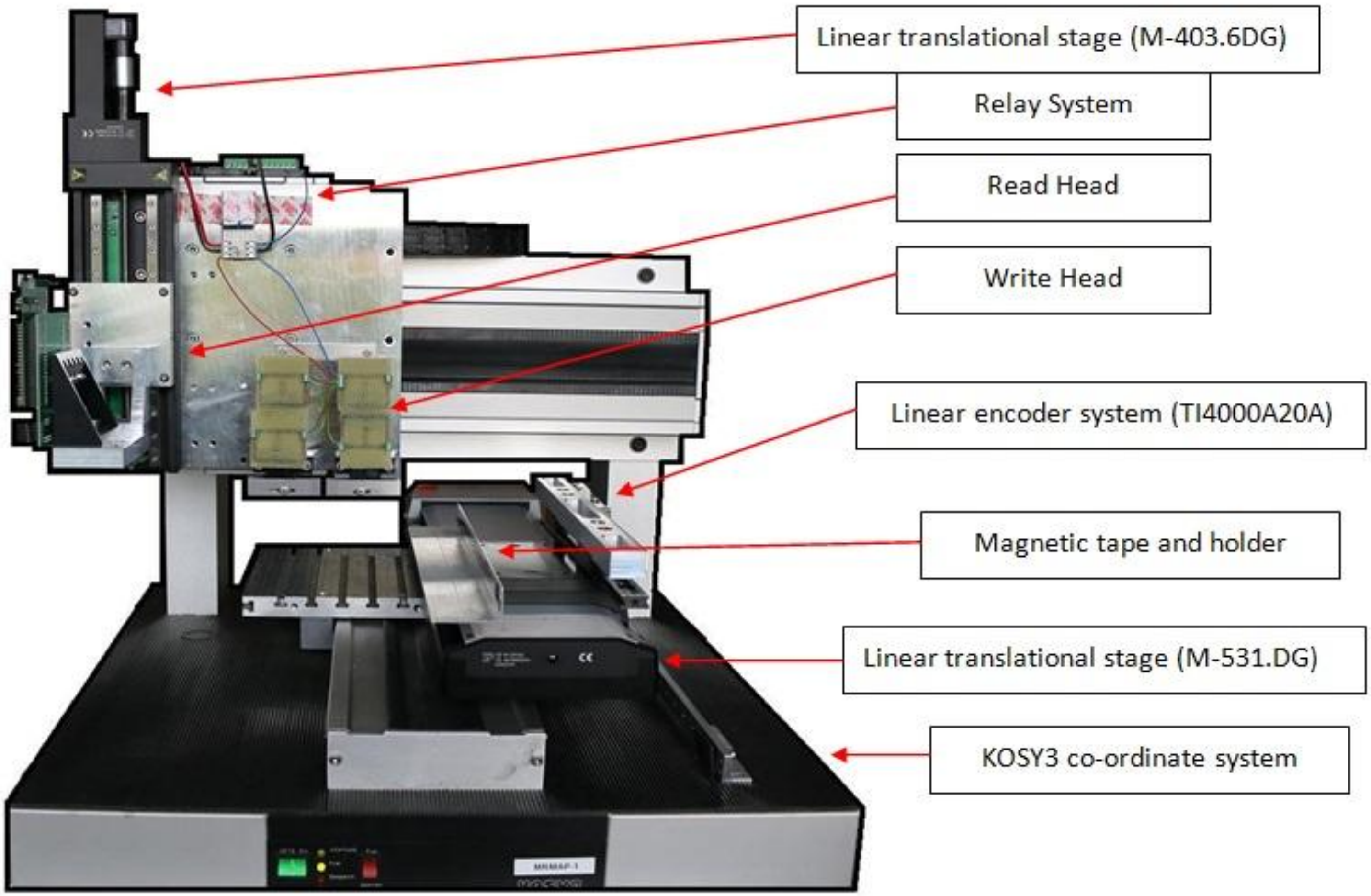


Linear optical encoder with stainless steel scale

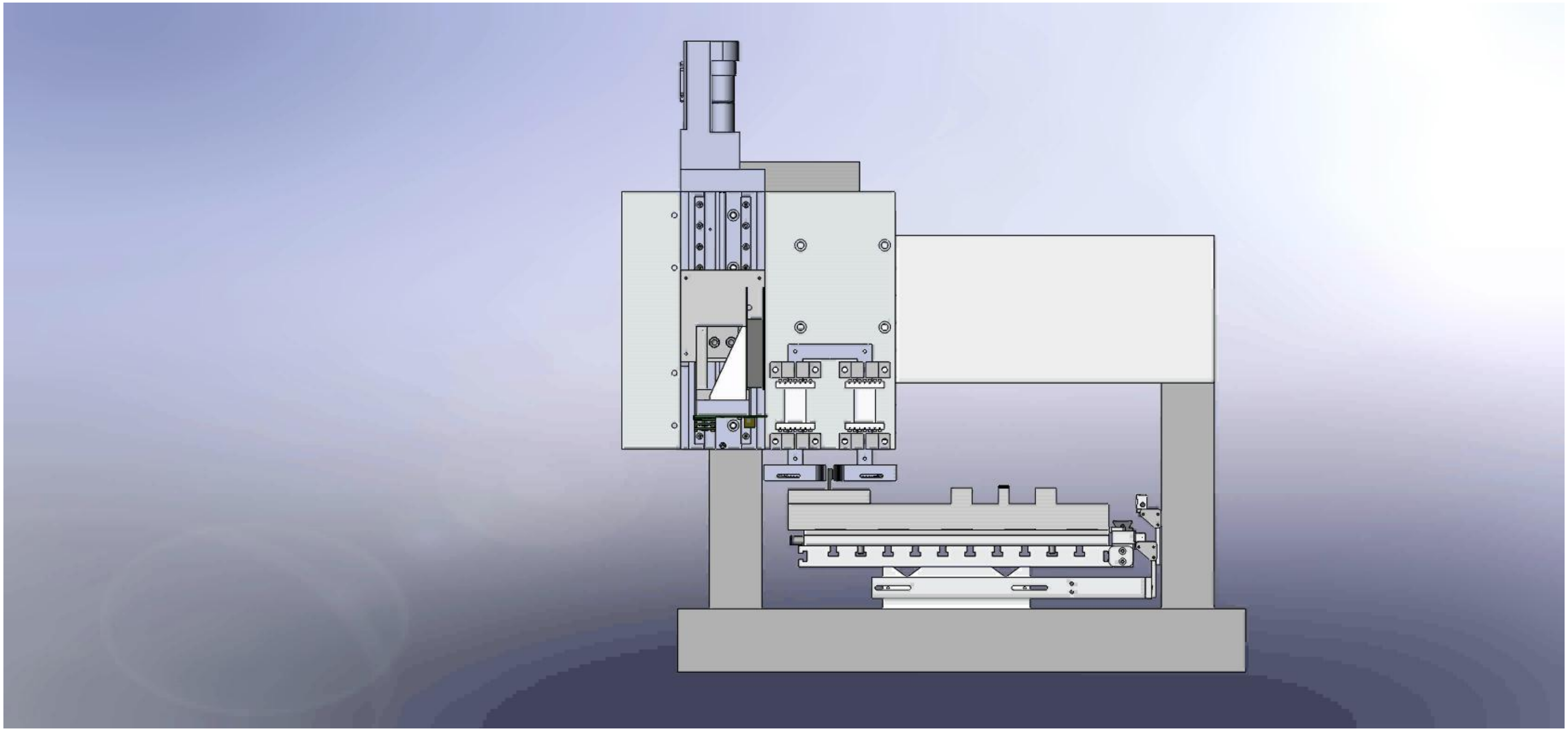
Complete System (3D model)



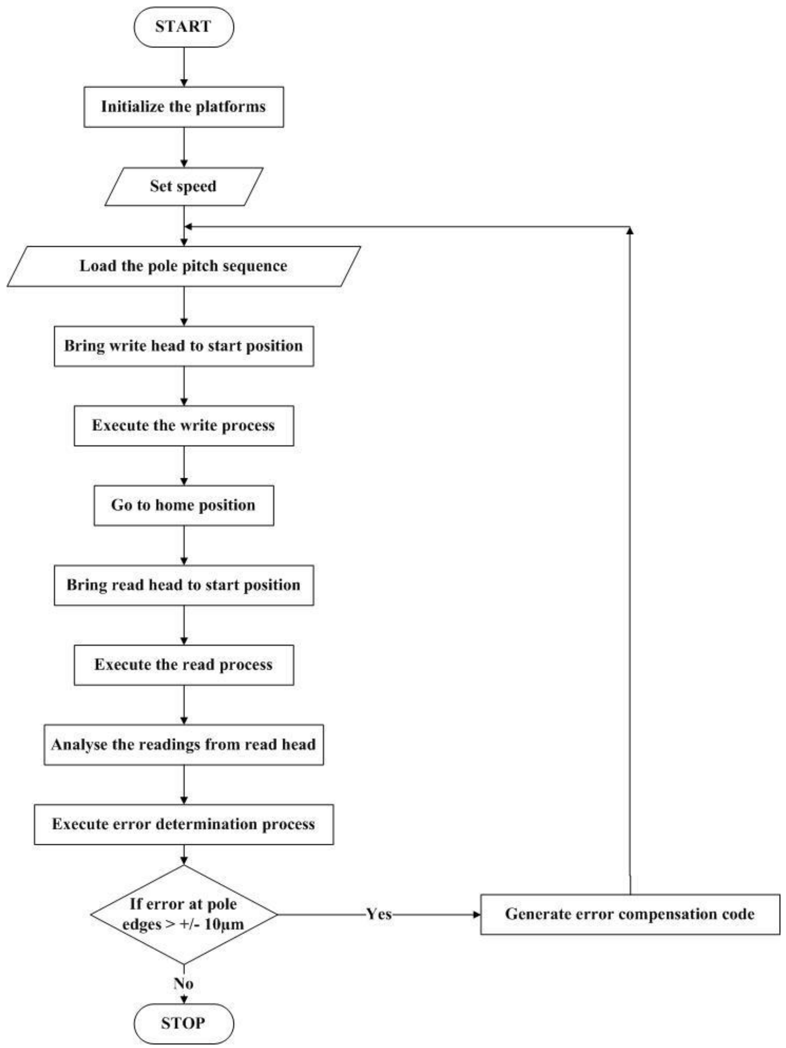
Complete System (Prototype)



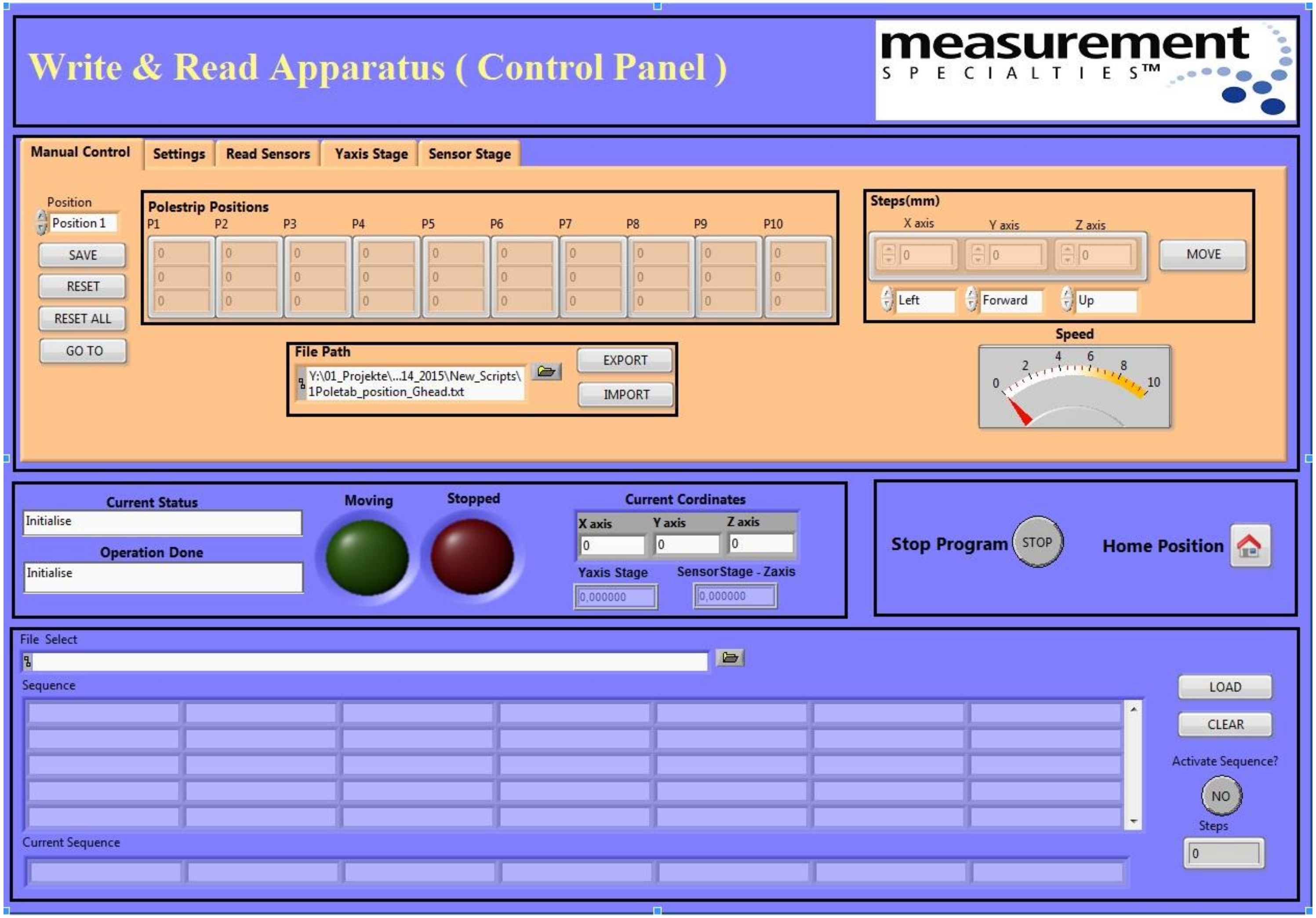
Complete System (3D model demo)



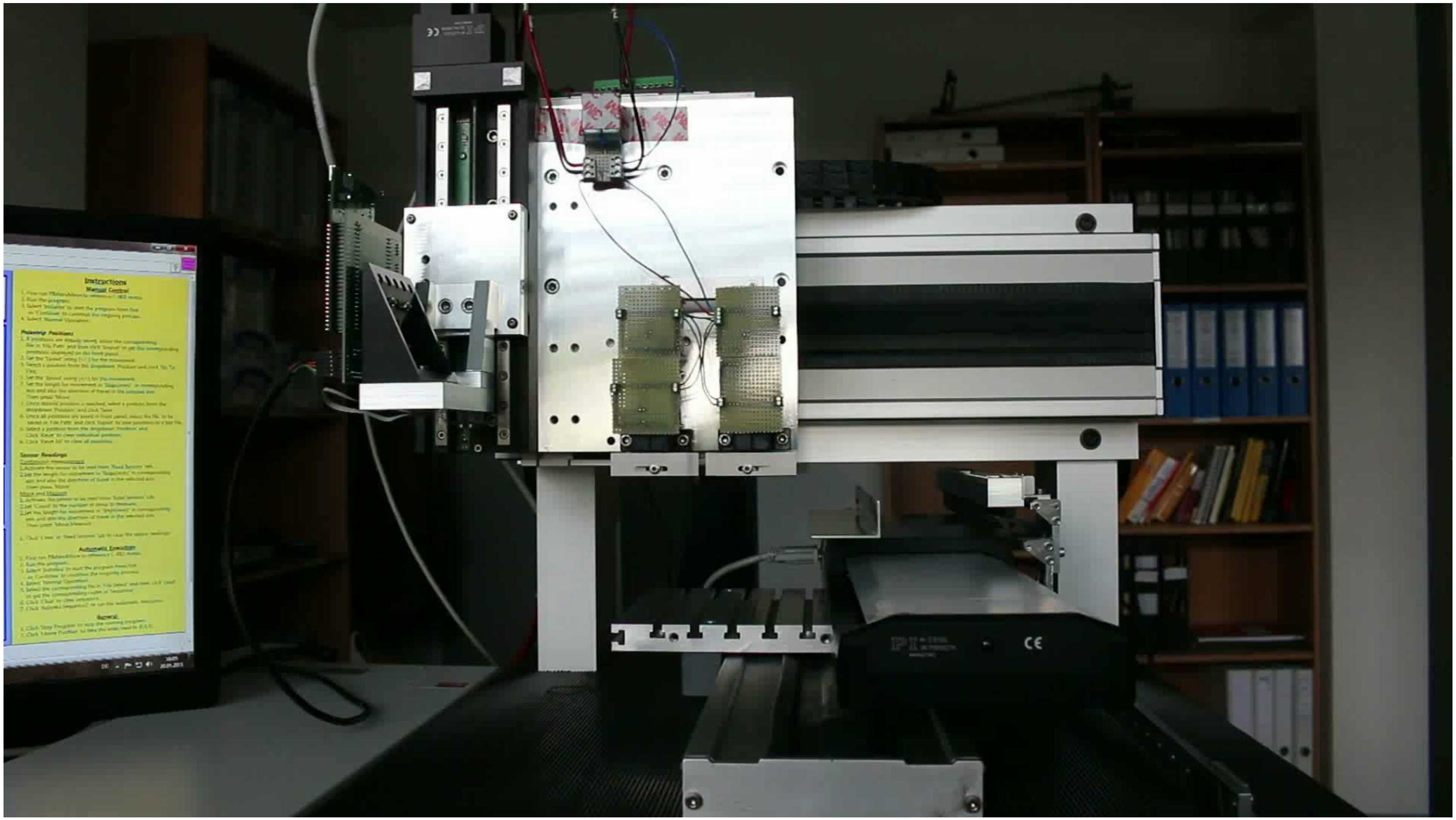
Control Program (Flow chart)



Control Program (LabVIEW)



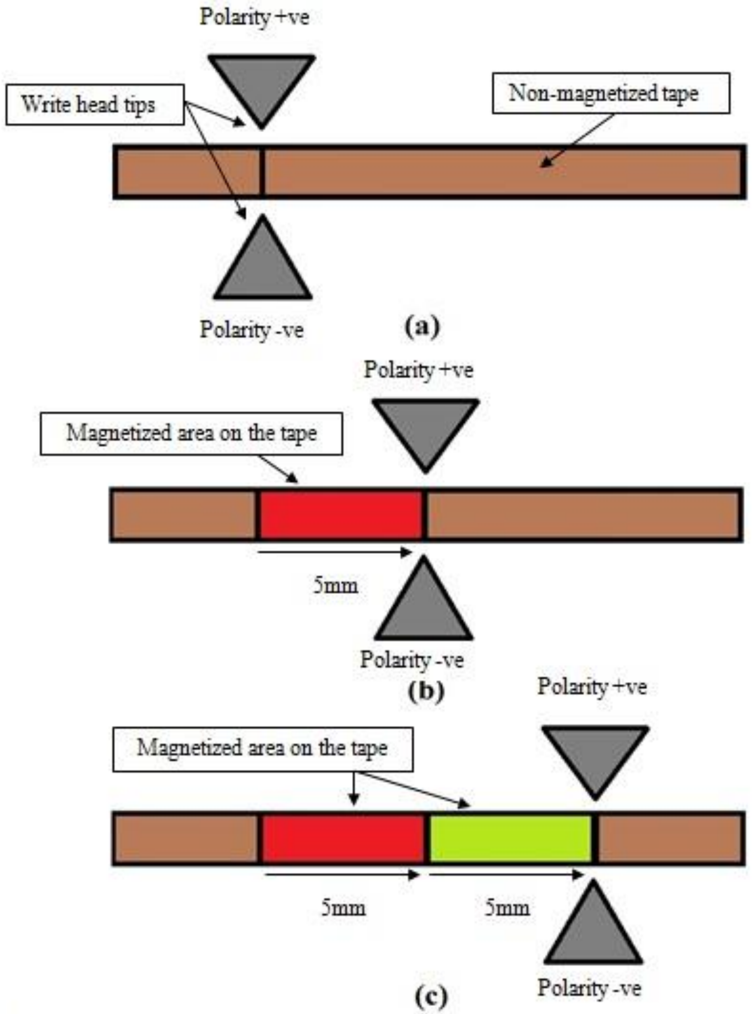
System Execution



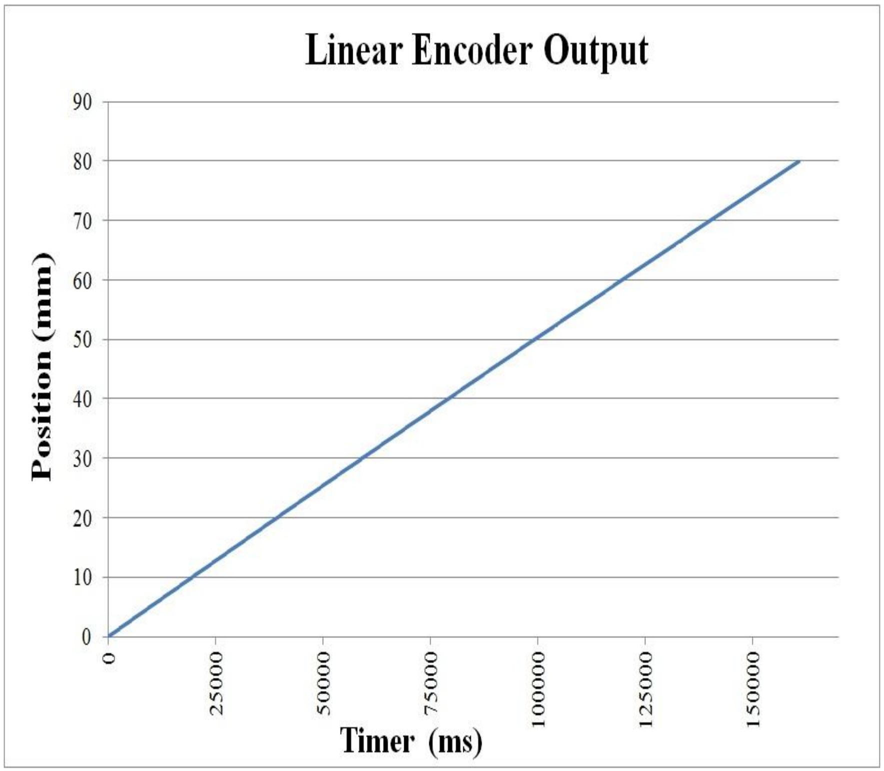
Signal Processing and Analysis

- Write Process
  - Magnetic tape (Tromaflex TX928)
  - Perpendicular magnetic recording
- Read Process
  - Raw values from
    - Linear encoder
    - Magnetic sensor (MLS5000)
  - Processing raw values
  - Pole length determination
  - Determination of error in each pole pitch

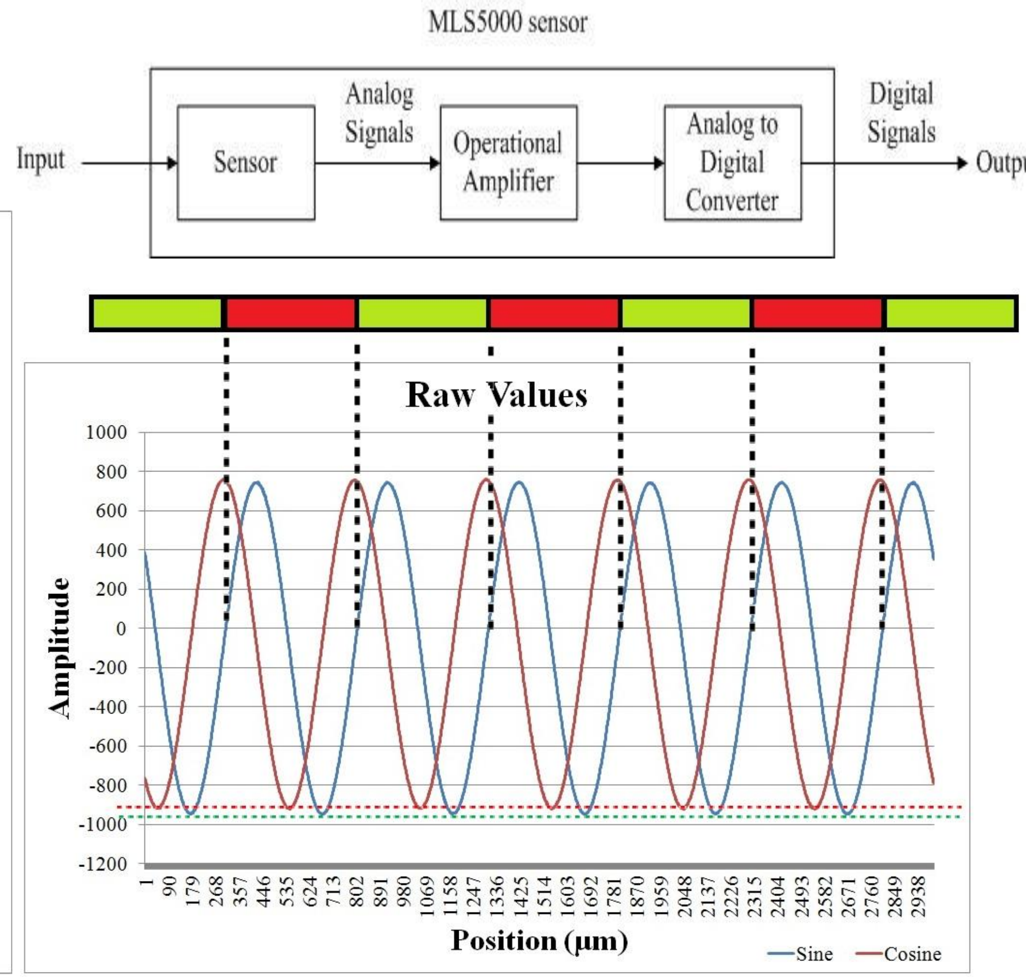
Write Process



Measured Inputs

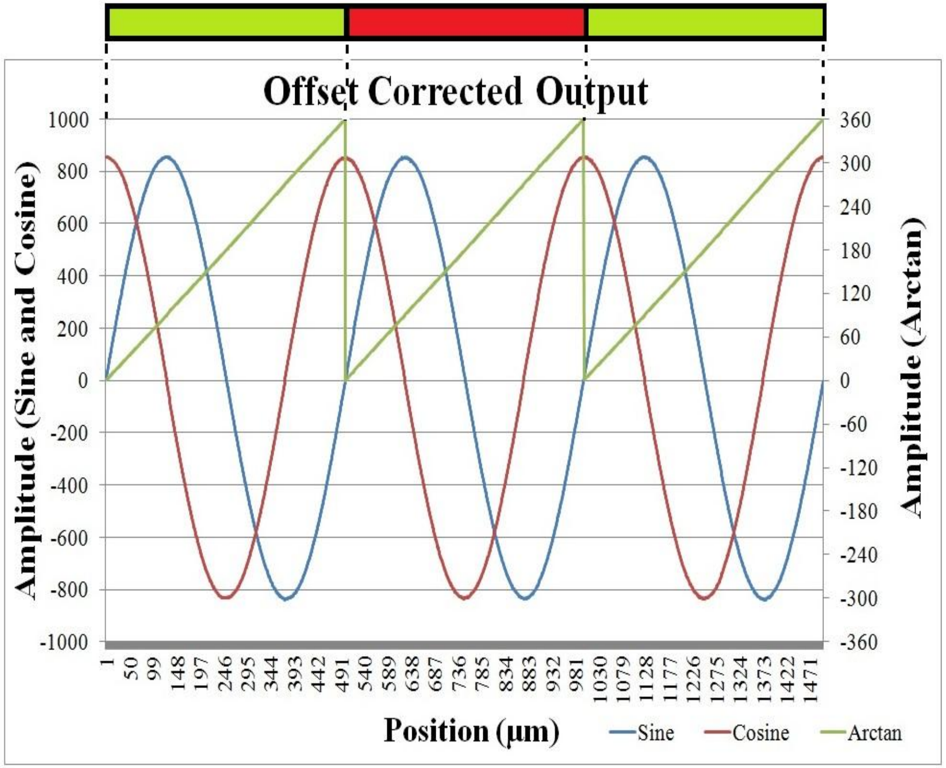


(a) Linear encoder output

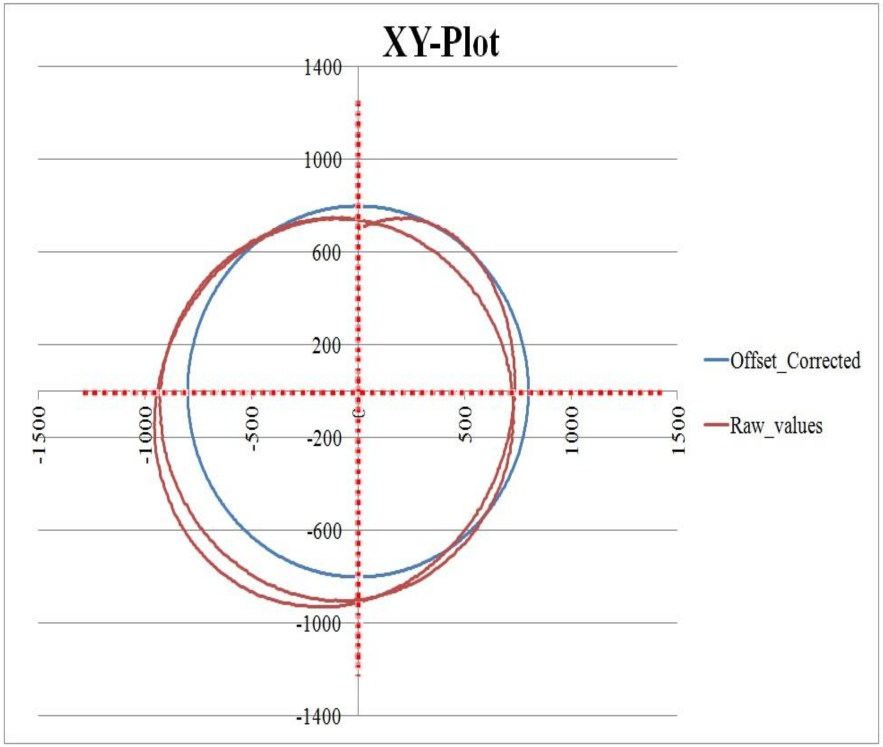


(b) Sensor head output

Offset Correction

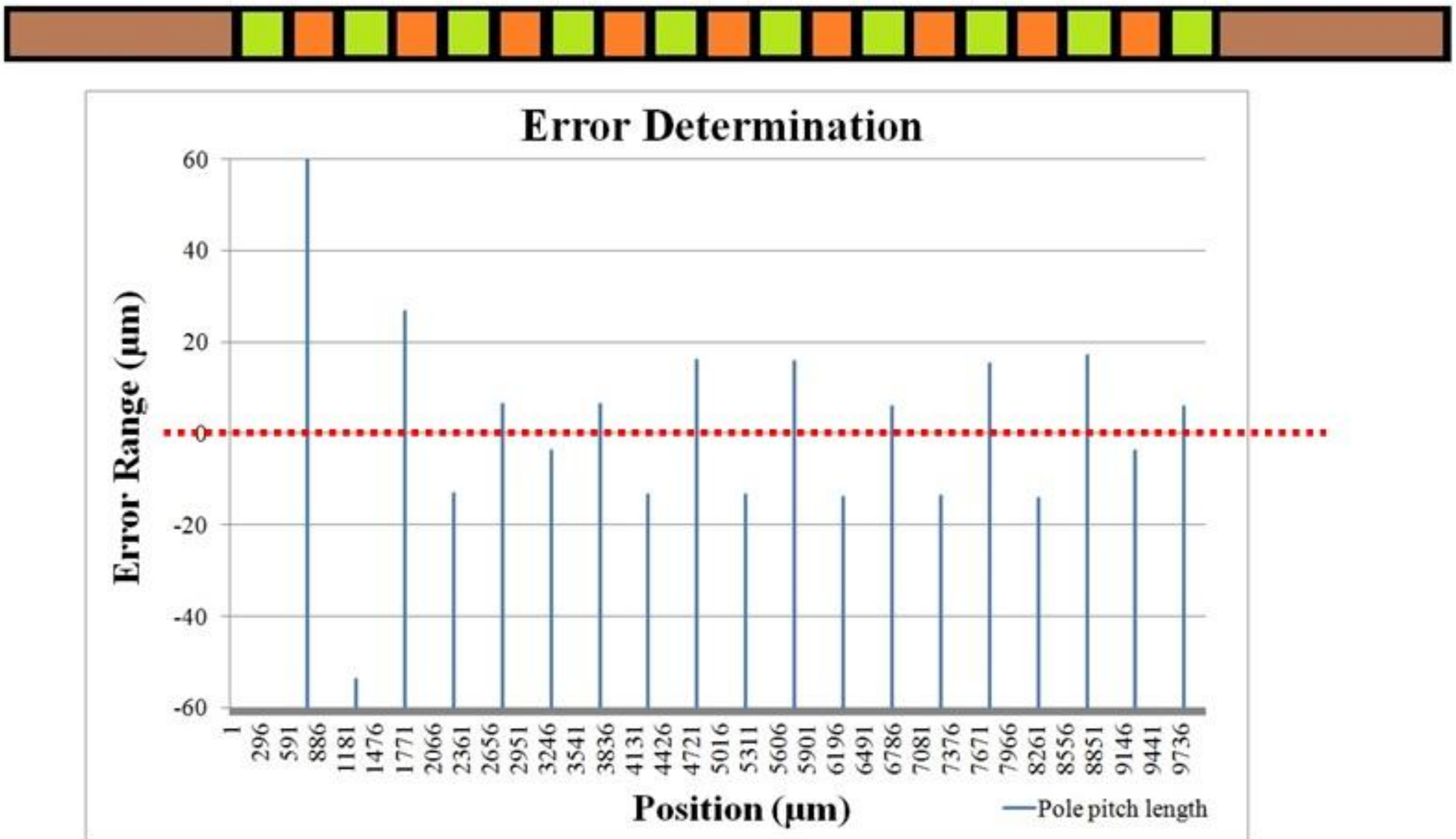


(a) Offset corrected sine and cosine values



(b) Lissajous figure of sine and cosine values technische universität dortmund

Error Determination



Experiments and Analysis

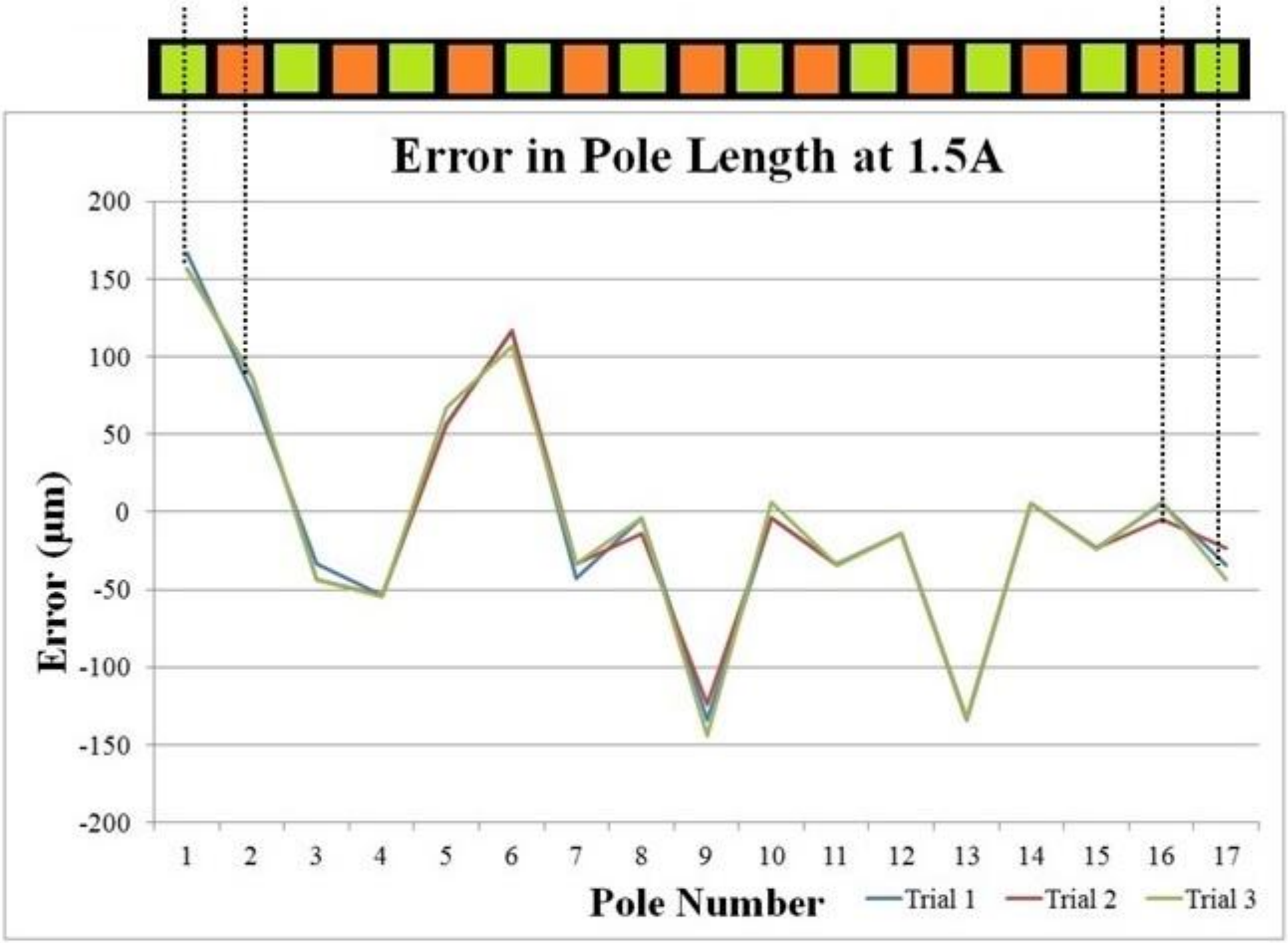
- Effect of electric current on magnetization
- Effect of air gap on magnetization
- Analysis of magnetization effect on 5mm pole pitch
  - Effect of positioning error by KOSY3 platform
  - Effect of positioning error by PI stage
- Analysis of error correction on 5mm pole pitch
- Fourier analysis on signals

Effect of electric current on magnetization

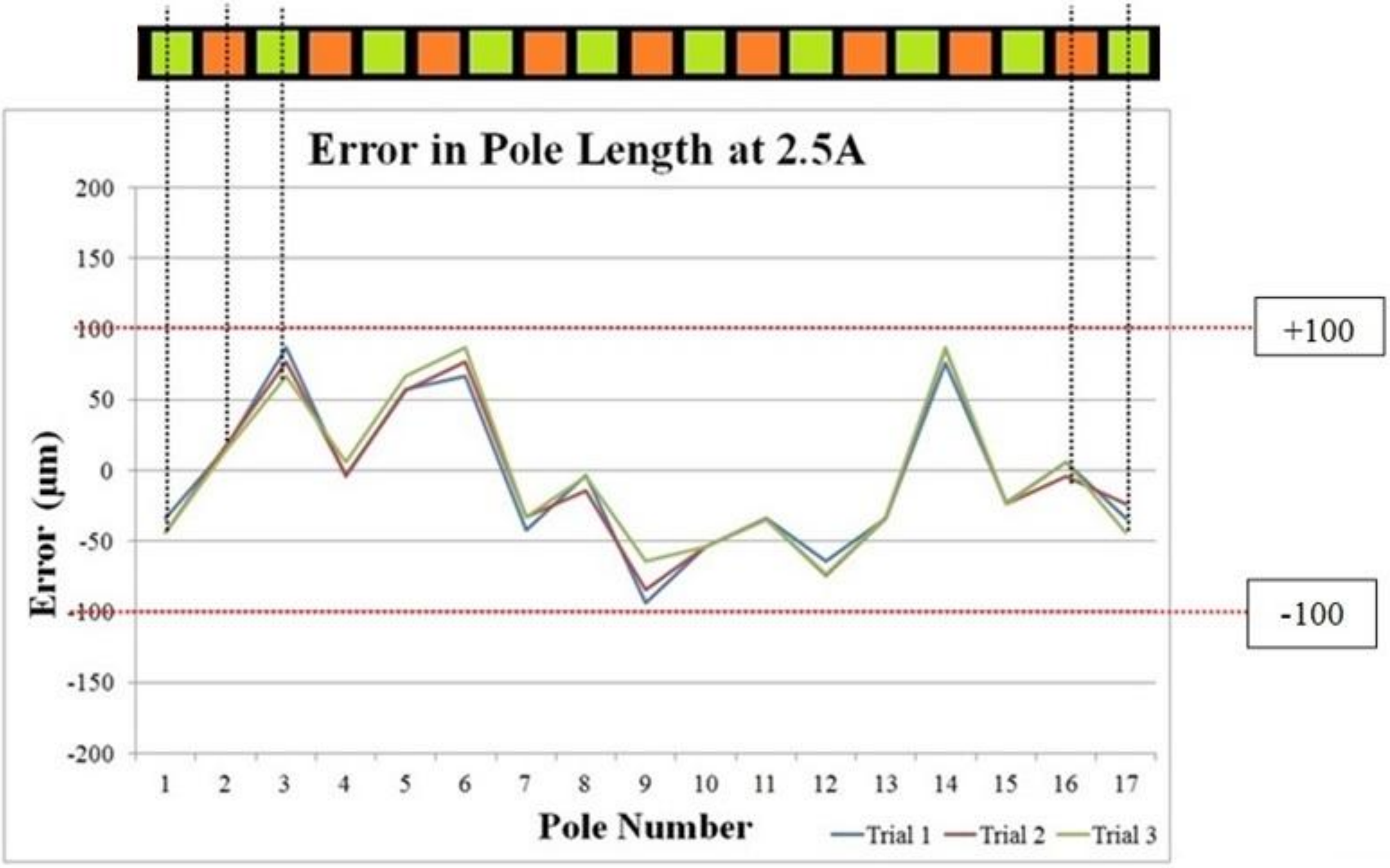
- Effect of electric current on magnetic field intensity measured by a gauss meter

Current Range (A)	Magnetic Field Intensity (kA/m)
0.5 – 1.5	90 - 120
1.5 – 2.5	120 - 160
2.5 – 3.5	160 - 350

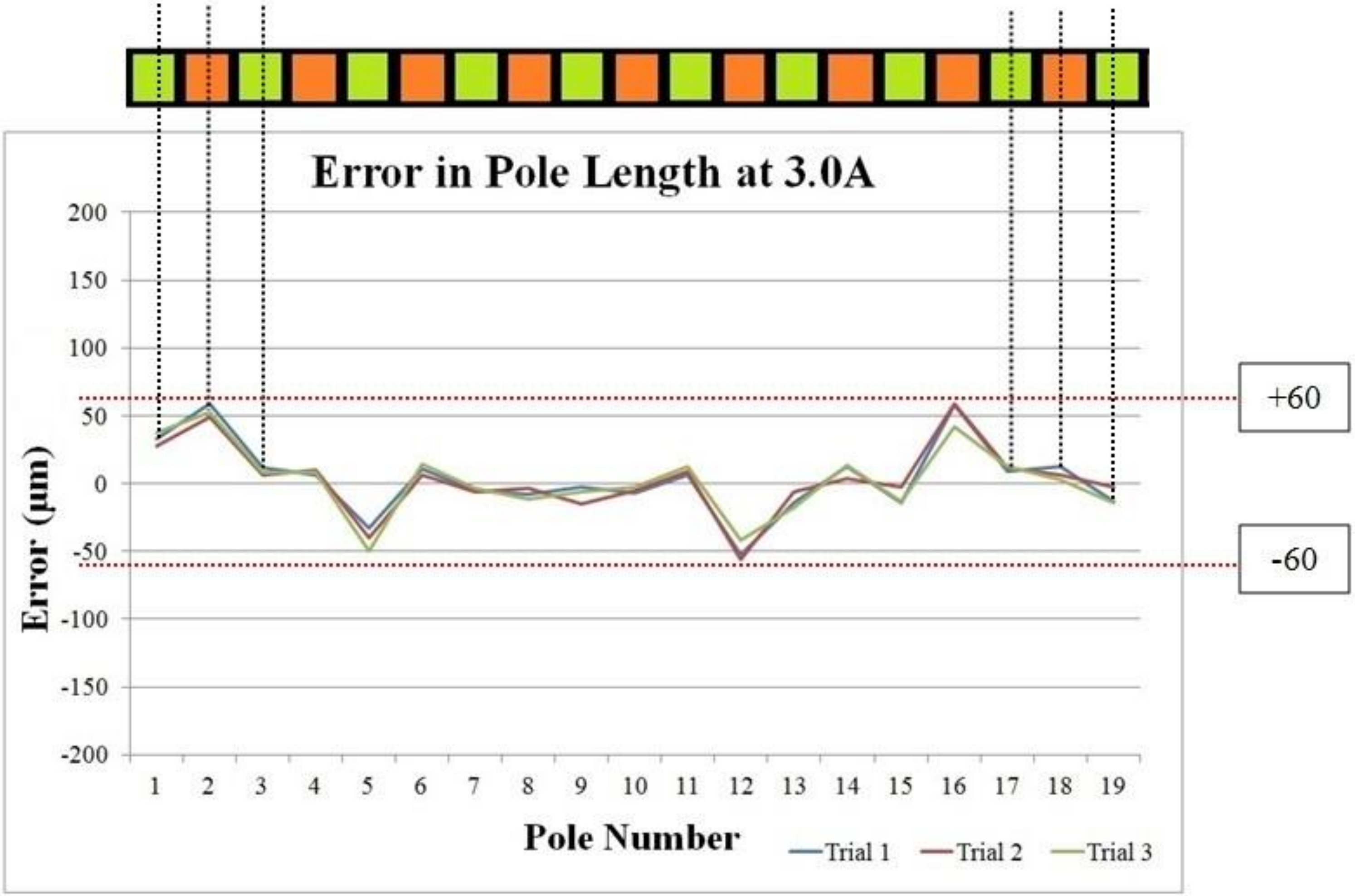
Error in pole length at 1.5A



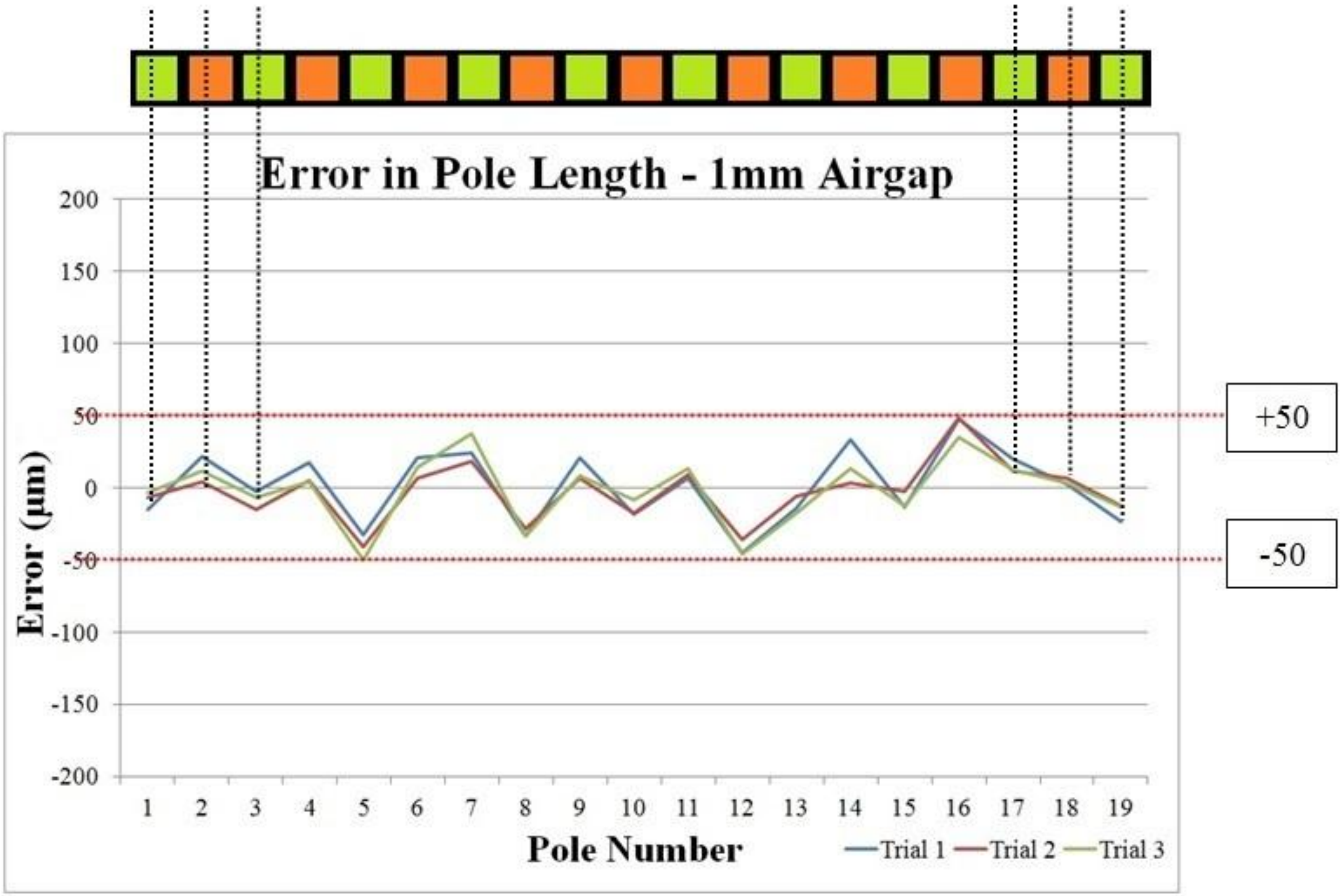
Error in pole length at 2.5A



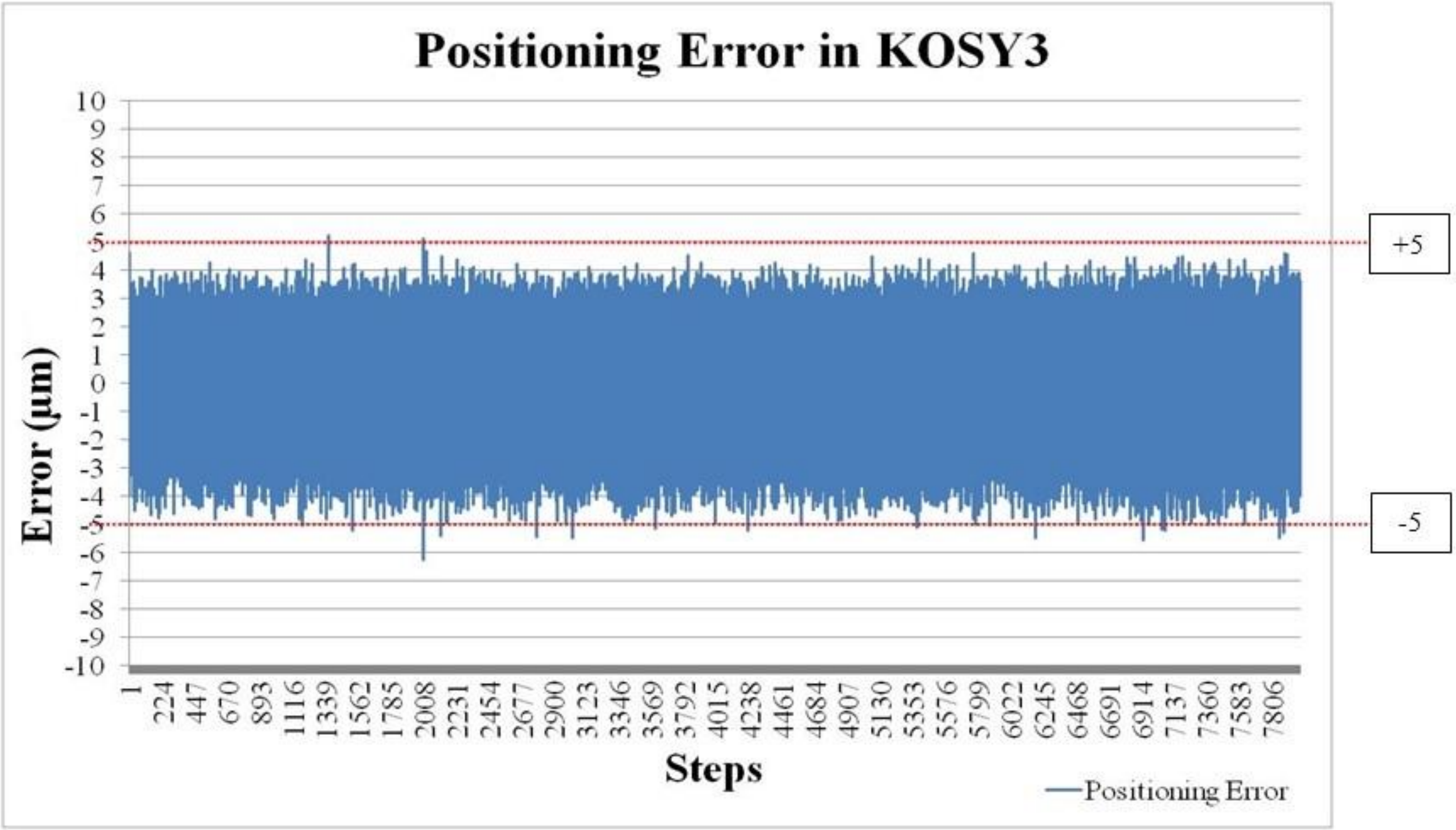
Error in pole length at 3.0A



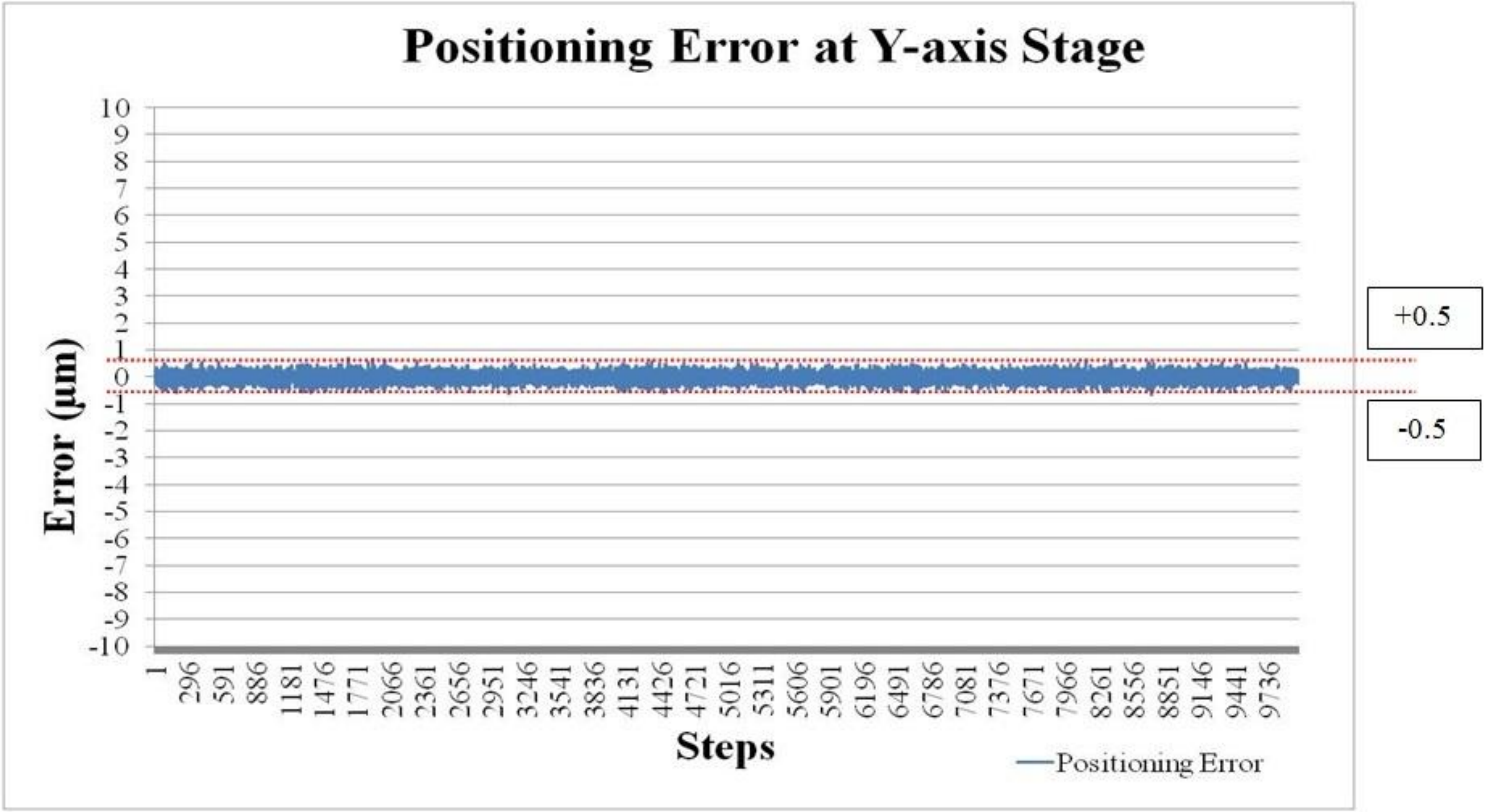
Effect of air gap on magnetization



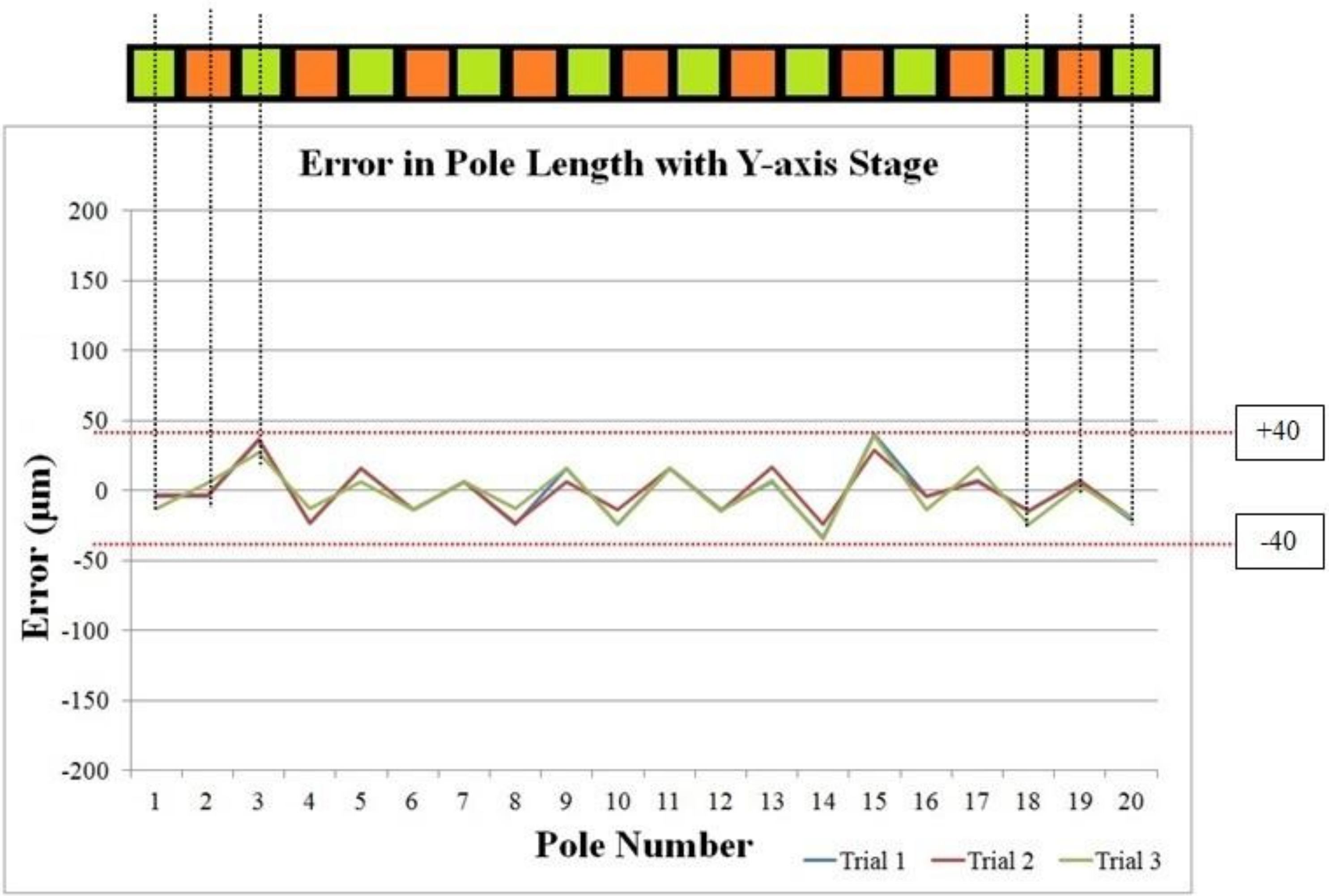
Effect of positioning error by KOSY3 platform



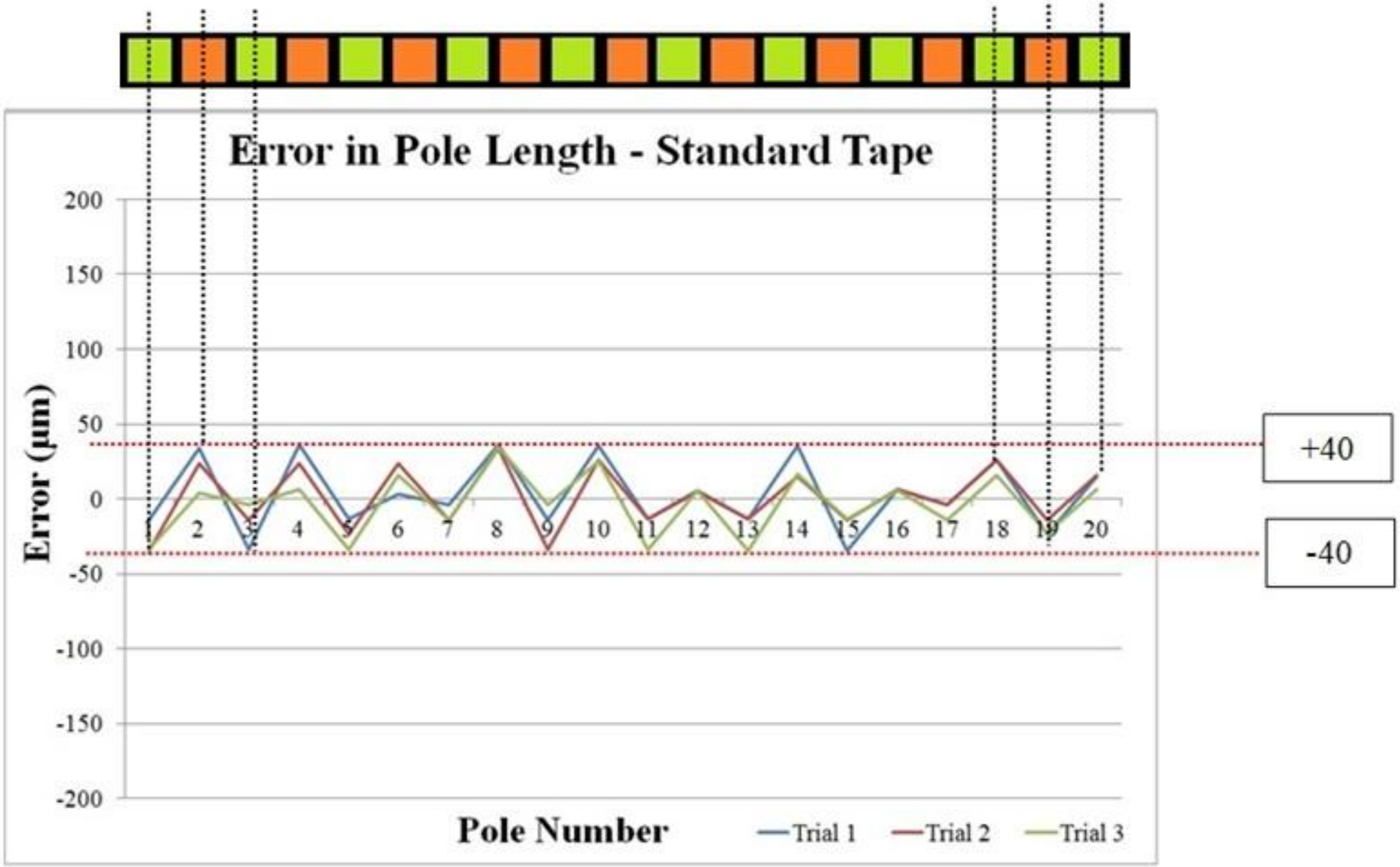
Effect of positioning error by PI stage



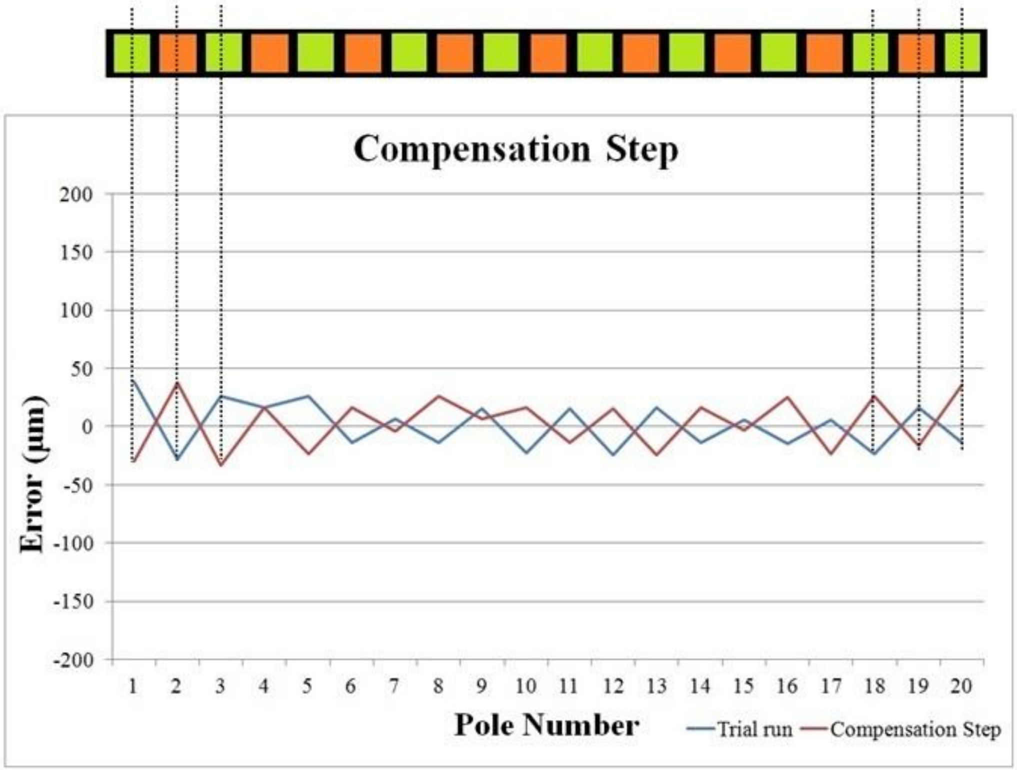
Error in pole length with PI stage in Y-axis



Error in pole length – Standard tape

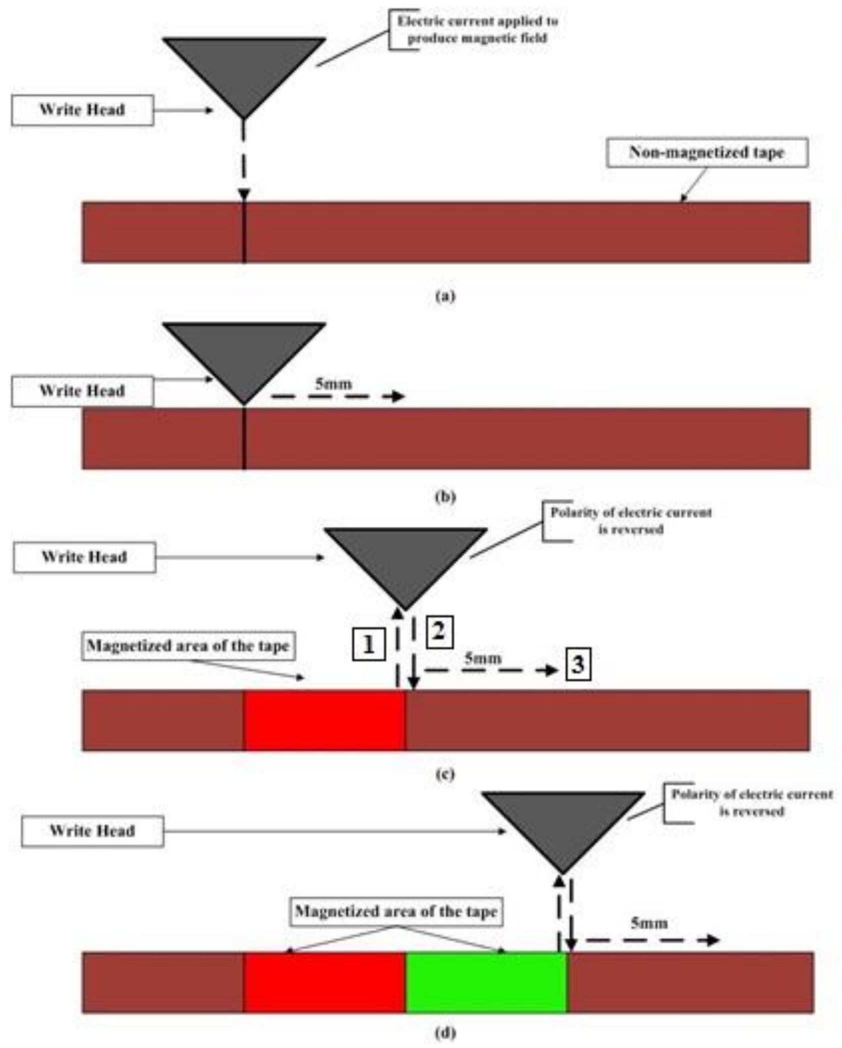


Error Compensation Step



First pole pitch sequence	Measured pole pitch	New pole pitch sequence
5	4.95	5.05
5	5.06	4.94
5	4.98	5.02
5	5.05	4.95
5	5	5

Error Correction Step



Error correction step – middle poles

Fourier Analysis

- Procedure
  - Determine the FFT complex
  - Determine the FFT magnitude
  - Number of Sample = 4096 (2^10)
  - Sampling frequency = No. Of Samples/(Last position – First Position)

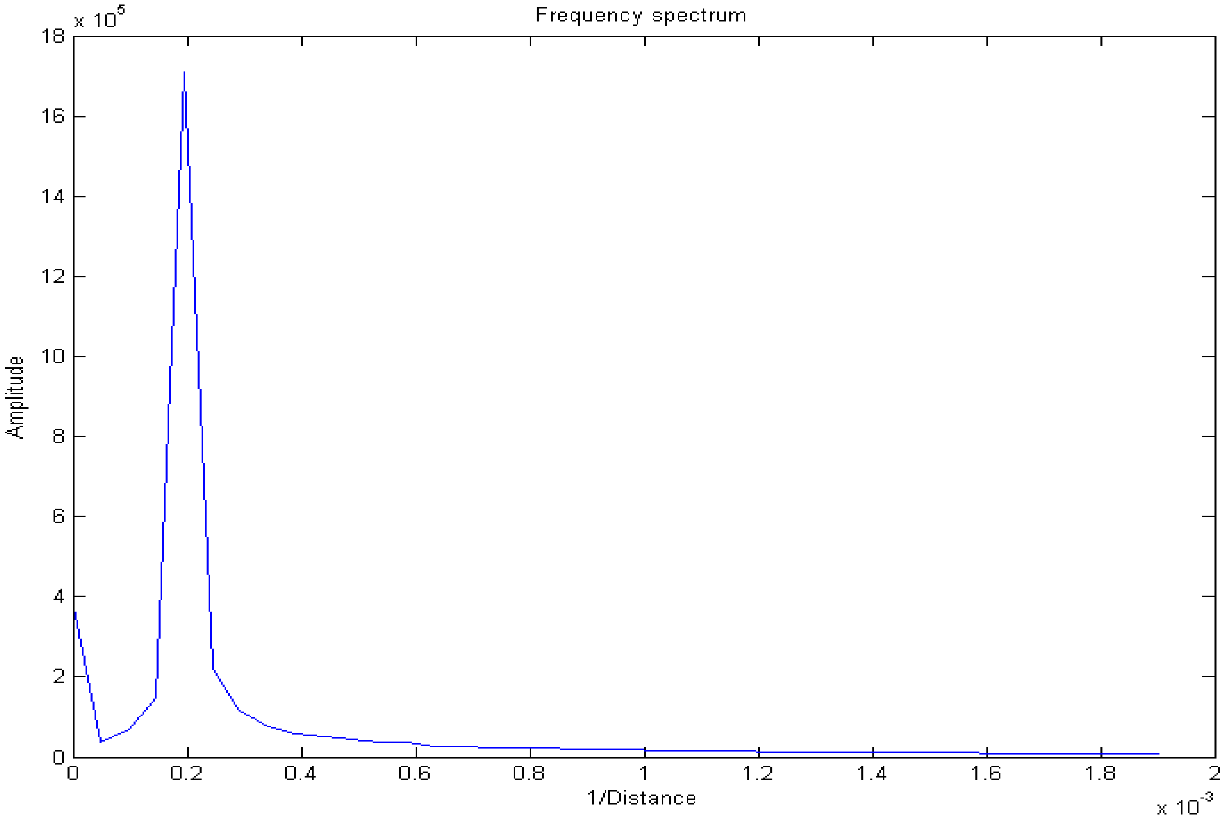
    = 4096/ 20500.66

    = 0.199798446
  - Step value = Sampling frequency / No. Of Samples

    = 4.8779E-05
  - Determine the dominant frequency = 0.000195116
  - Period = 1/Dominant frequency

    = 5125.165
  - Disadvantage –
    - Samples always an integer multiple of 2^n
    - Cannot determine frequencies that are not integer multiple of fundamental frequency

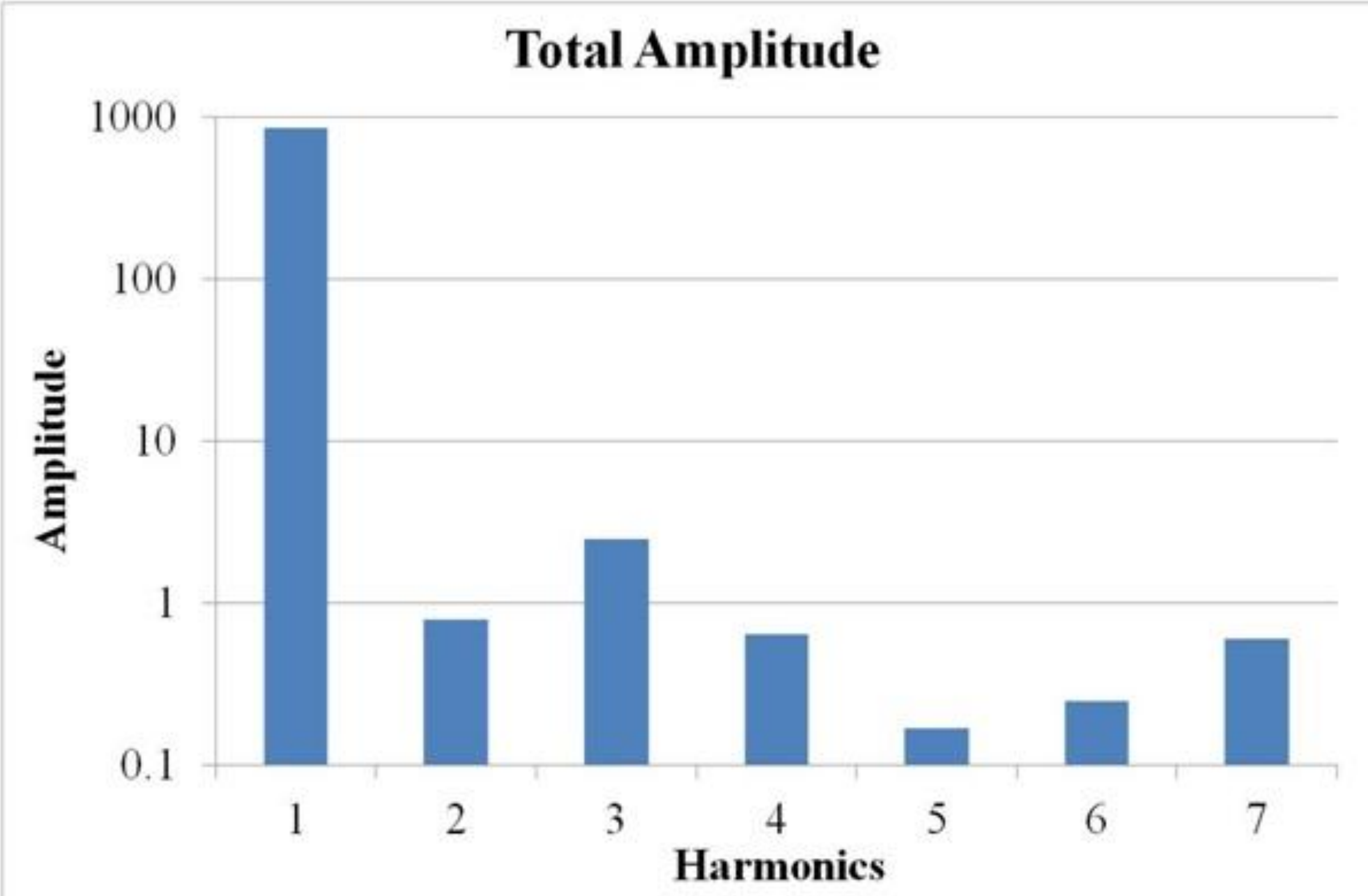
Fourier Analysis – Results (Matlab)



Dominant Frequency = 1.9512e-04

Period = 5125.165

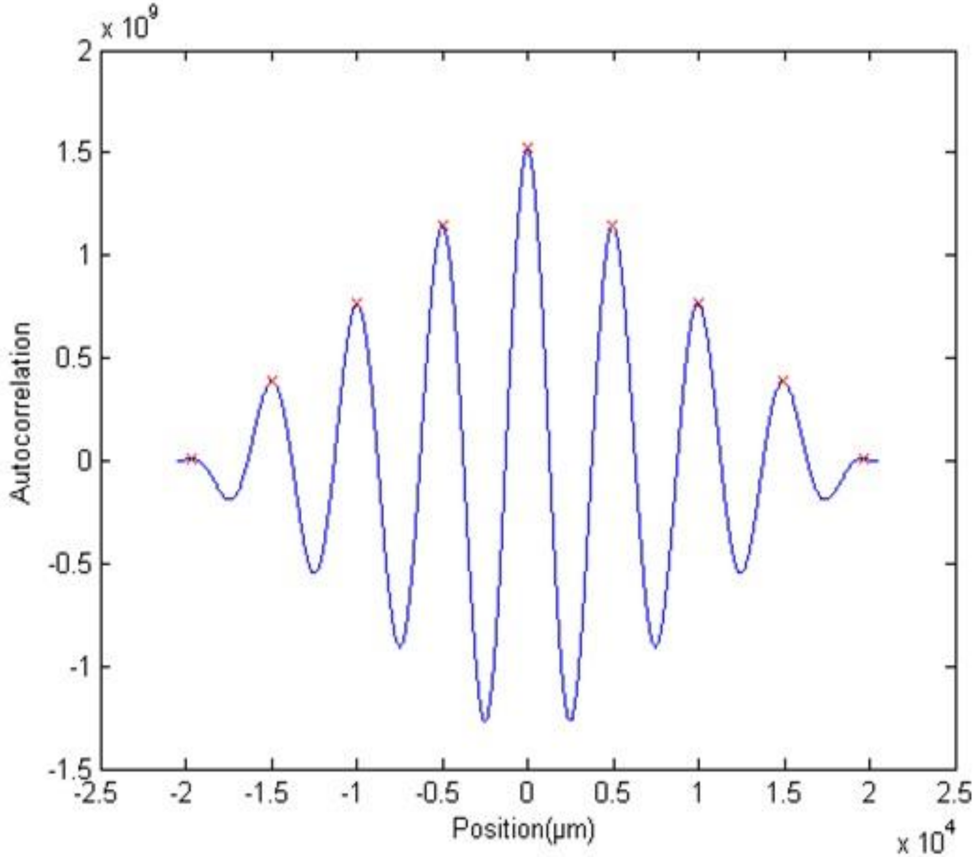
Fourier Analysis – Results (Excel)



Autocorrelation

- Cross correlation of a signal with itself at different points in time
- Autocorrelation sequence of a periodic signal has the same cyclic characteristics as the signal itself.
- Hence, autocorrelation can help verify the presence of cycles and determine their durations.

Autocorrelation – Results (Matlab)



Difference between two peaks (µm)	Error (µm)
5019	19
4986	-14
4985	-15
4980	-20
5013	13
4985	-15
4995	-5
5005	5

Conclusion

- Design and construction of an apparatus to produce magnetic scales with perpendicular magnetic recording
  - Conducted magnetic simulation study according to the requirements
  - 3D modelling of the prototype
  - Prototype construction
  - Control program in LabVIEW
- Write Process (magnetization of tape in incremental manner with 5mm pole pitch)
- Evaluation of the efficiency of the process of magnetization
  - Read process (MLS5000 sensor)
  - Processing raw values
  - Pole length determination
- Analysis of effect of various parameters on magnetization
  - Electric current
  - Air gap
  - Positioning error
- Error correction step

Future Work

- Magnetization with different pole pitches (2mm, 1mm)
- Absolute magnetization
- Improvement in current design
  - Analysis of effects of reduction in write tip width
  - Effect of magnetic history
  - Incorporating a 3D hall sensor
- Prototype construction of M-Head and real time comparison with G-Head
- Possibility of further reduction in error range
  - Requires more sophisticated and precise hardware setup
  - Controlled environment


Questions

Thank you!!!