Development of an In-Vacuum Field Measurement System and Results for the Cryoundulator Prototype

Takashi Tanaka
On behalf of SPring-8 Insertion Device Group

- Cryogenic Undulator (Cryoundulator)
  - Concept and Principle
  - Construction of Prototype
- In-Vacuum Field Measurement System
  - Principle
  - System Overview
  - Measurement Accuracy
- Measurement of the Cryoundulator Prototype
  - Peak Field Enhancement
  - Error Field Variation
  - Stability
- Summary

Cryoundulator Concept

- PMs for Undulators Should Have:
  - –high remanence: magnetic field
  - –high coercivity: resistance against demagnetization

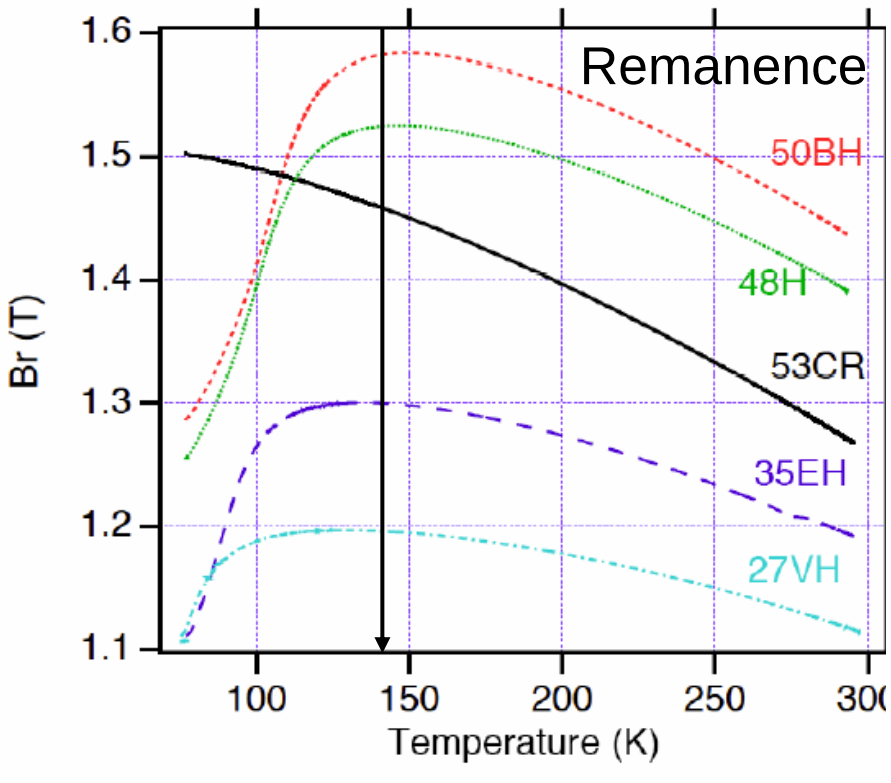
    However, Br x iHc ~ constant: low Br and high iHc
- Temperature Coefficient of PM Material
  - –remanence： -0.1%/K@300K
  - –coercivity： -0.6%/K@300K

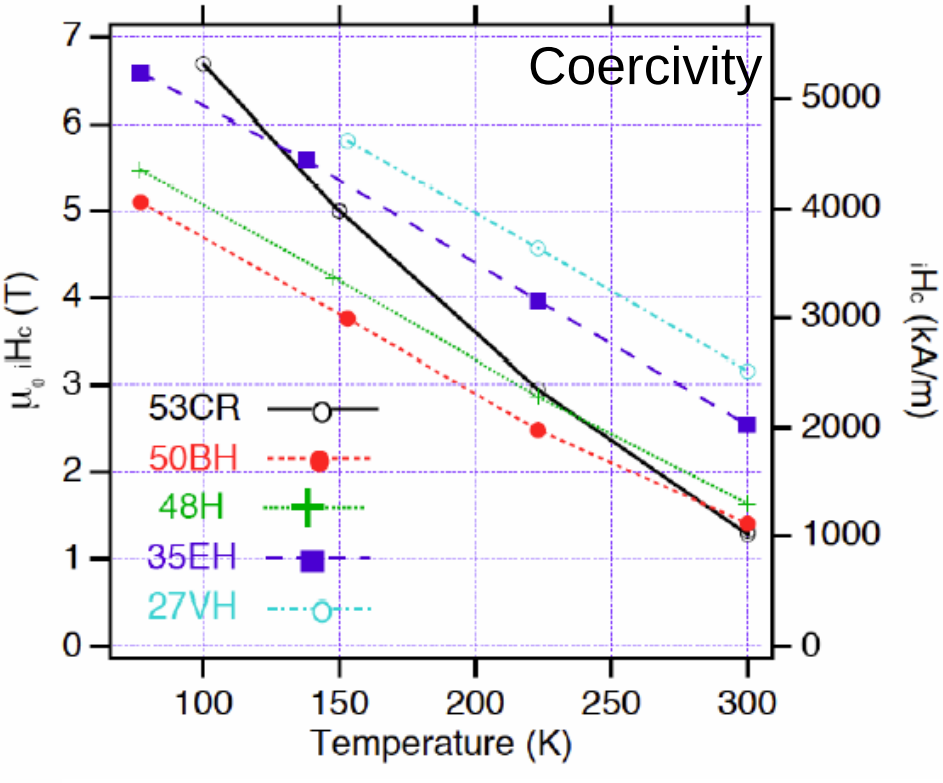
PMs at Cryogenic Temperature for Better Magnetic Performance

Cryogenic Undulator Concept

T. Hara T. Tanaka H. Kitamura T. Bizen T. Seike T. Kohda & Y. Matsuura Phys. Rev. ST-AB, 7 (2004) 050702.

Temperature Dependence of PMs

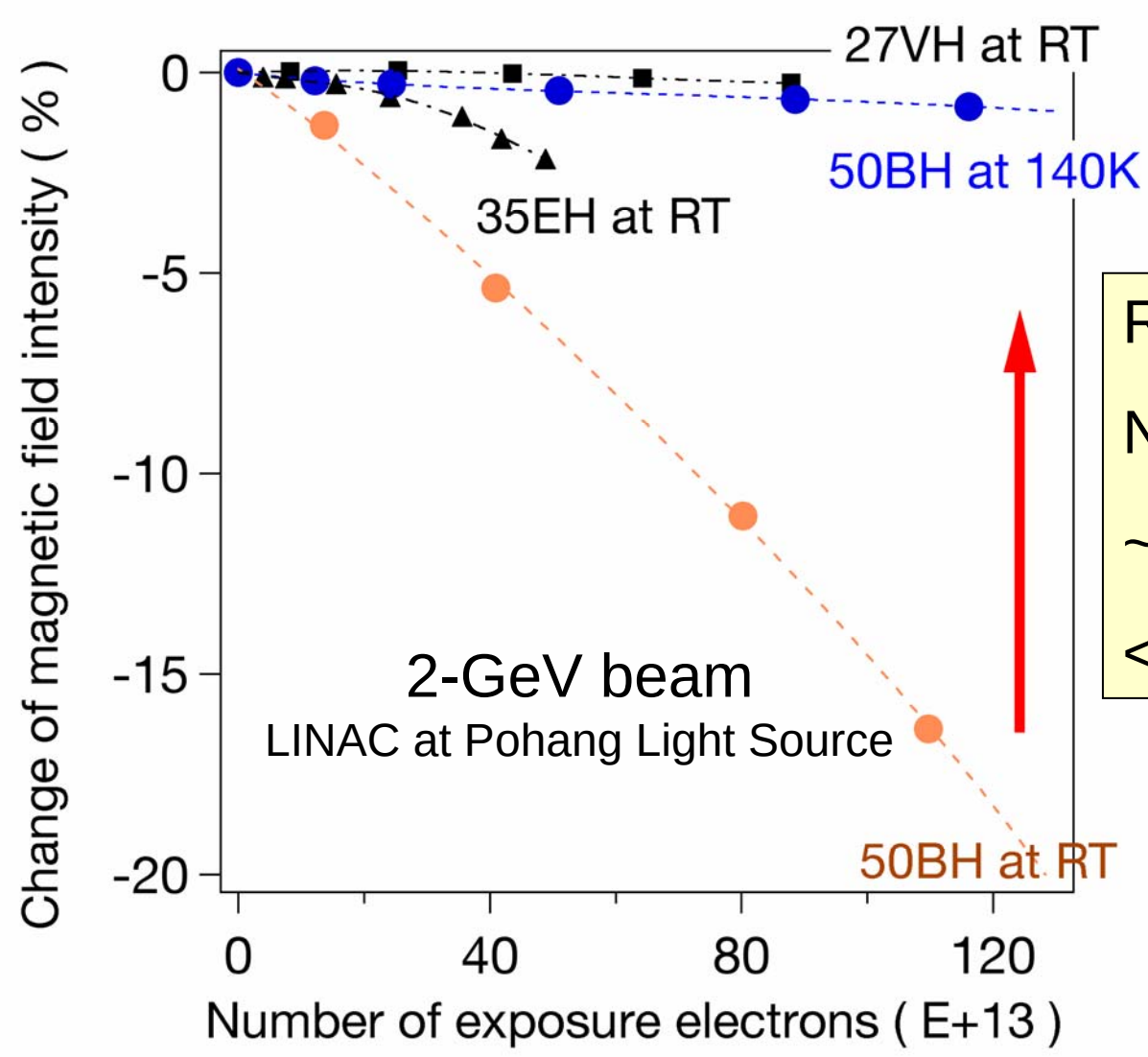




Operation of NEOMAX50BH around 140K is reasonable

- Maximum remanence
- Low sensitivity to temperature variation

Resistance against Radiation Damage



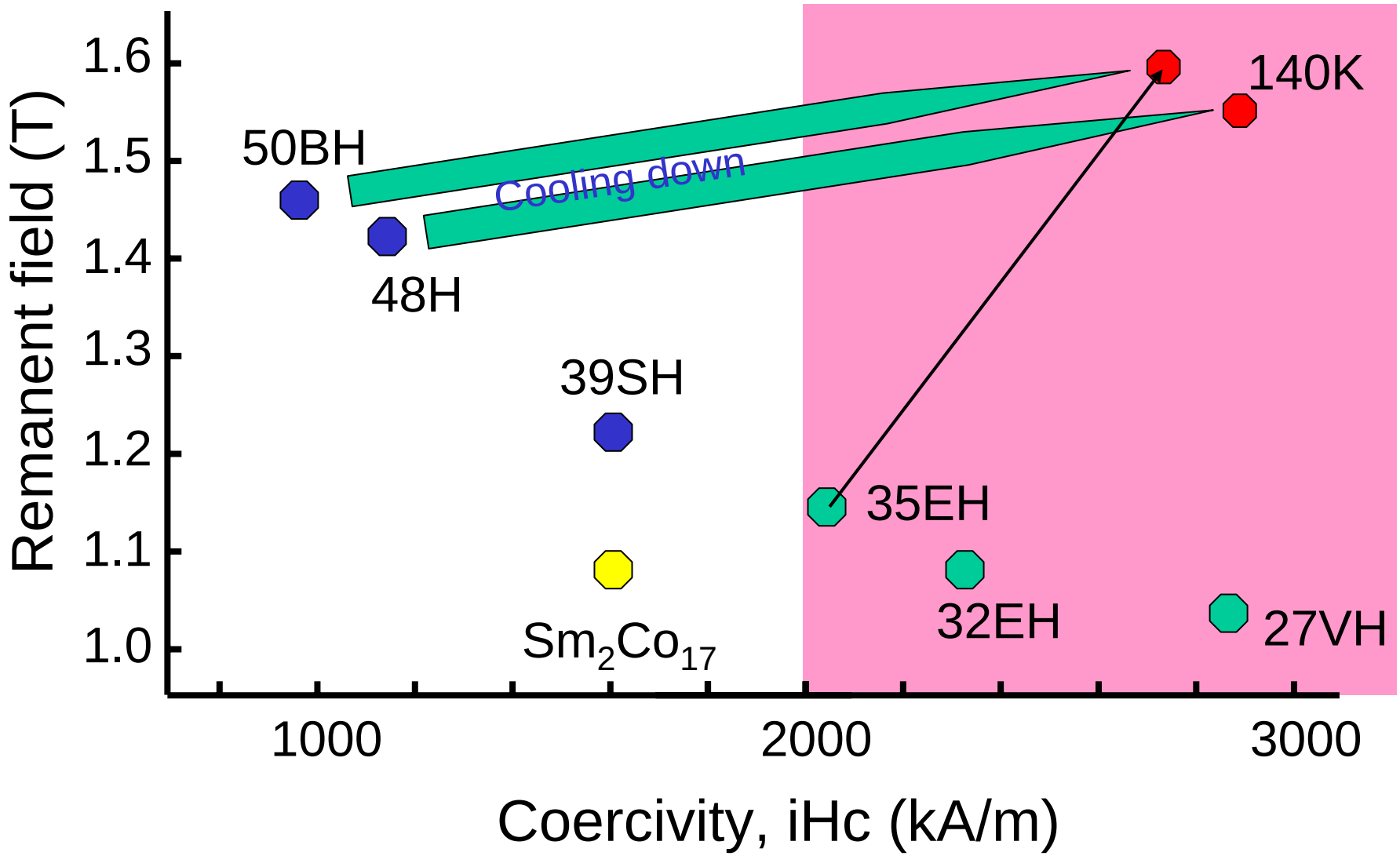
Radiation Damage:

NEOMAX50BH@140K

~ NEOMAX27VH@RT

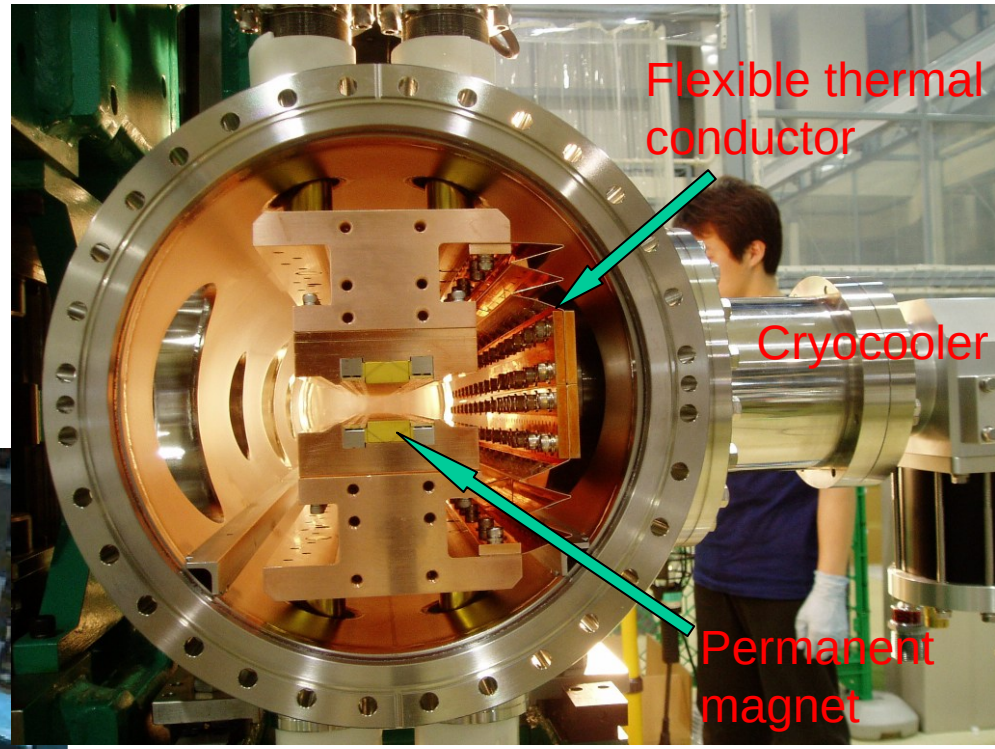
< NEOMAX35EH@RT

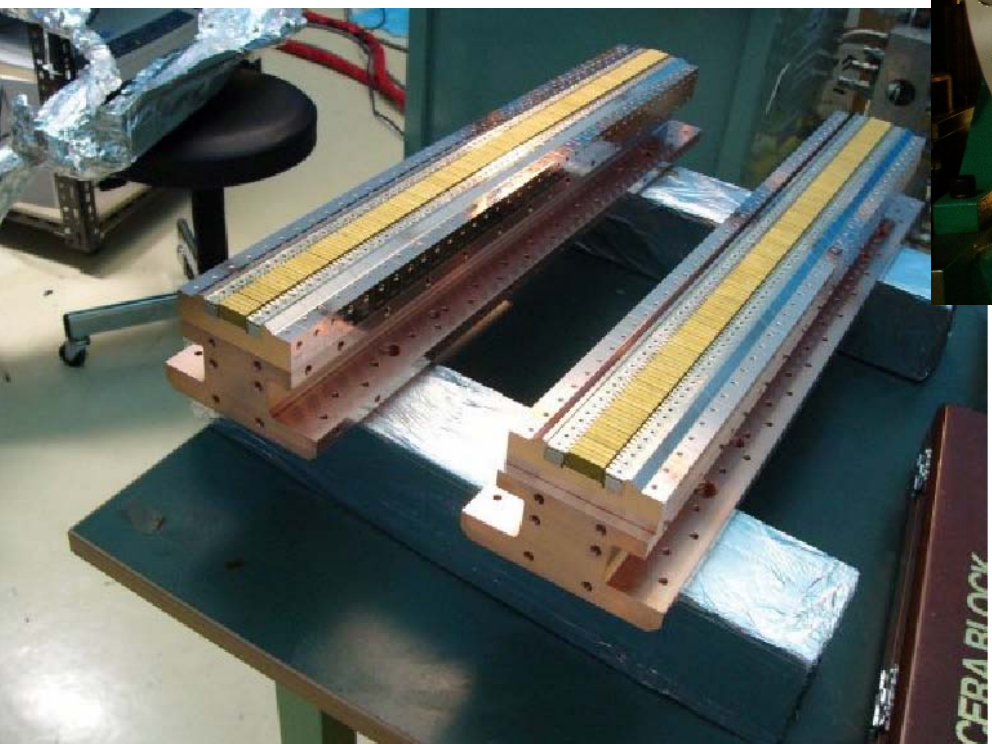
Performance of Cryoundulator



Cryoundulator Prototype

Cryoundulator Prototype
PM Material: NEOMAX50BH
λ_u=15mm,L=0.6m





Temperature Control
GM-cycle Cryocooler &
Sheath Heater

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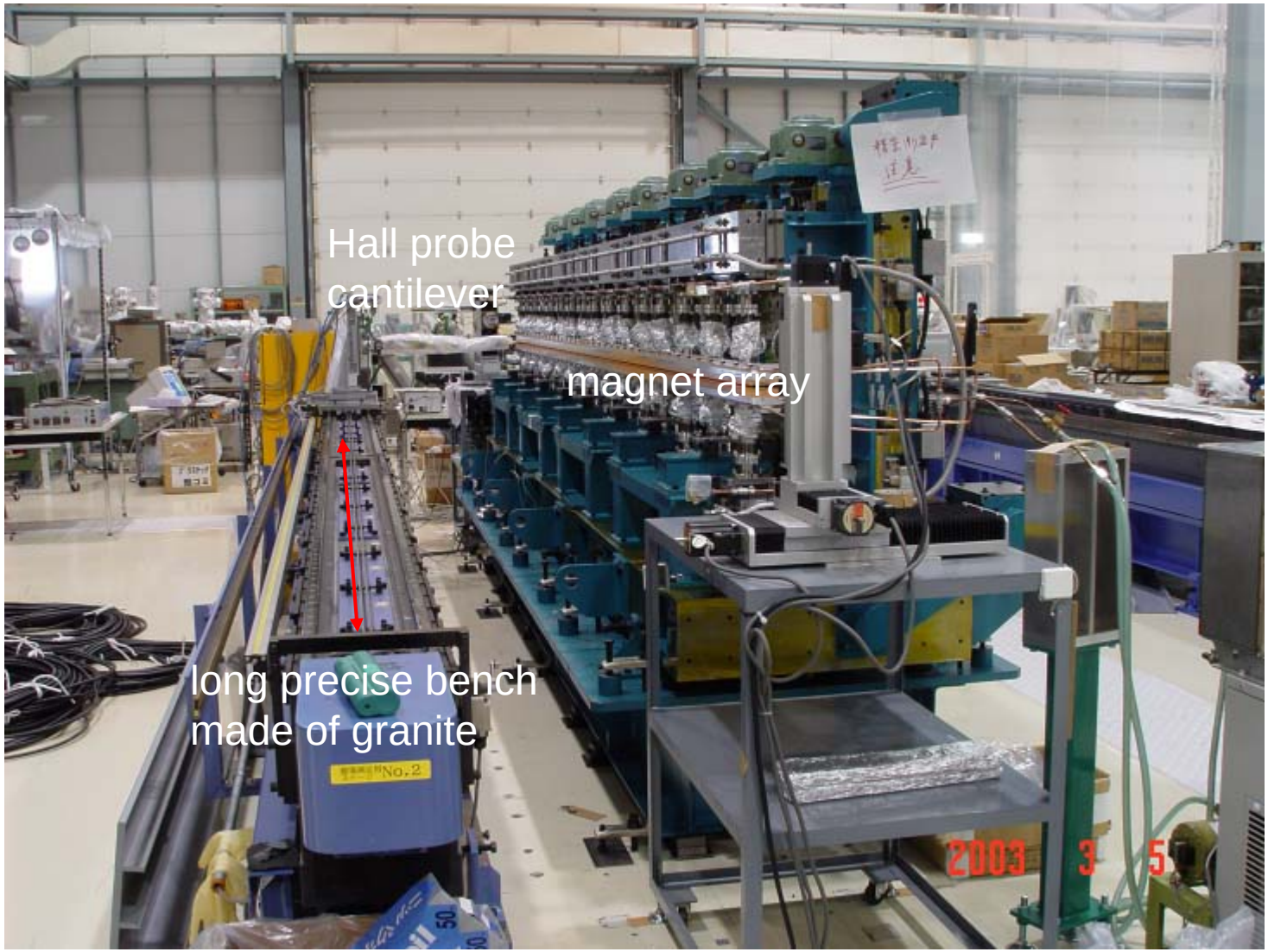
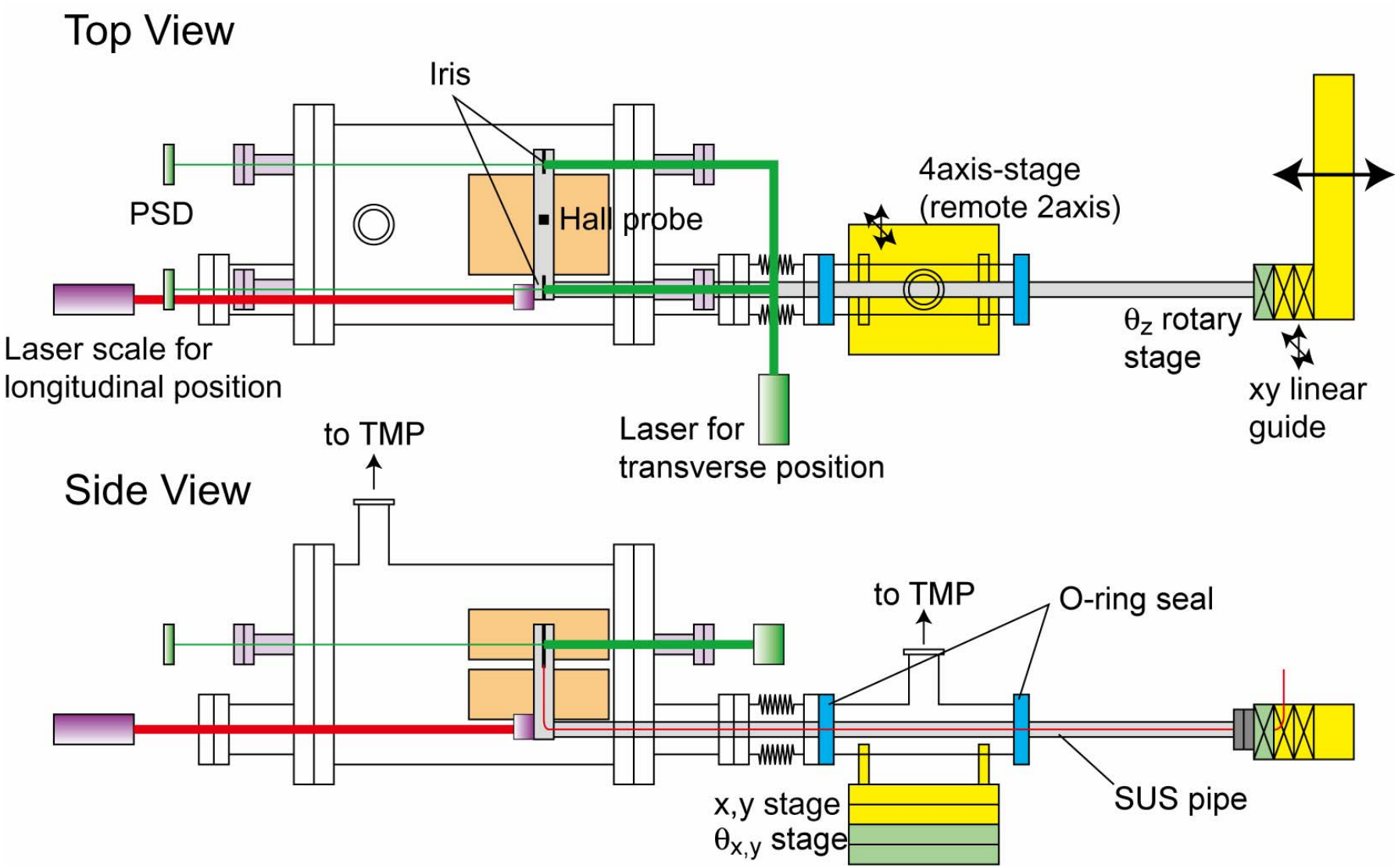
In-Vacuum Field Measurement System

- Cryoundulator Needs Cryogenic Environment
  - magnet arrays installed in vacuum
  - field measurement under vacuum
- Requirements
  - actuation of a Hall probe in vacuum
  - positional fluctuation due to pitching, rolling and yawing of the actuator should be low enough
- Candidates
  - install a rigid linear guide with high mechanical precision in vacuum
  - measure the Hall-probe position and feedback

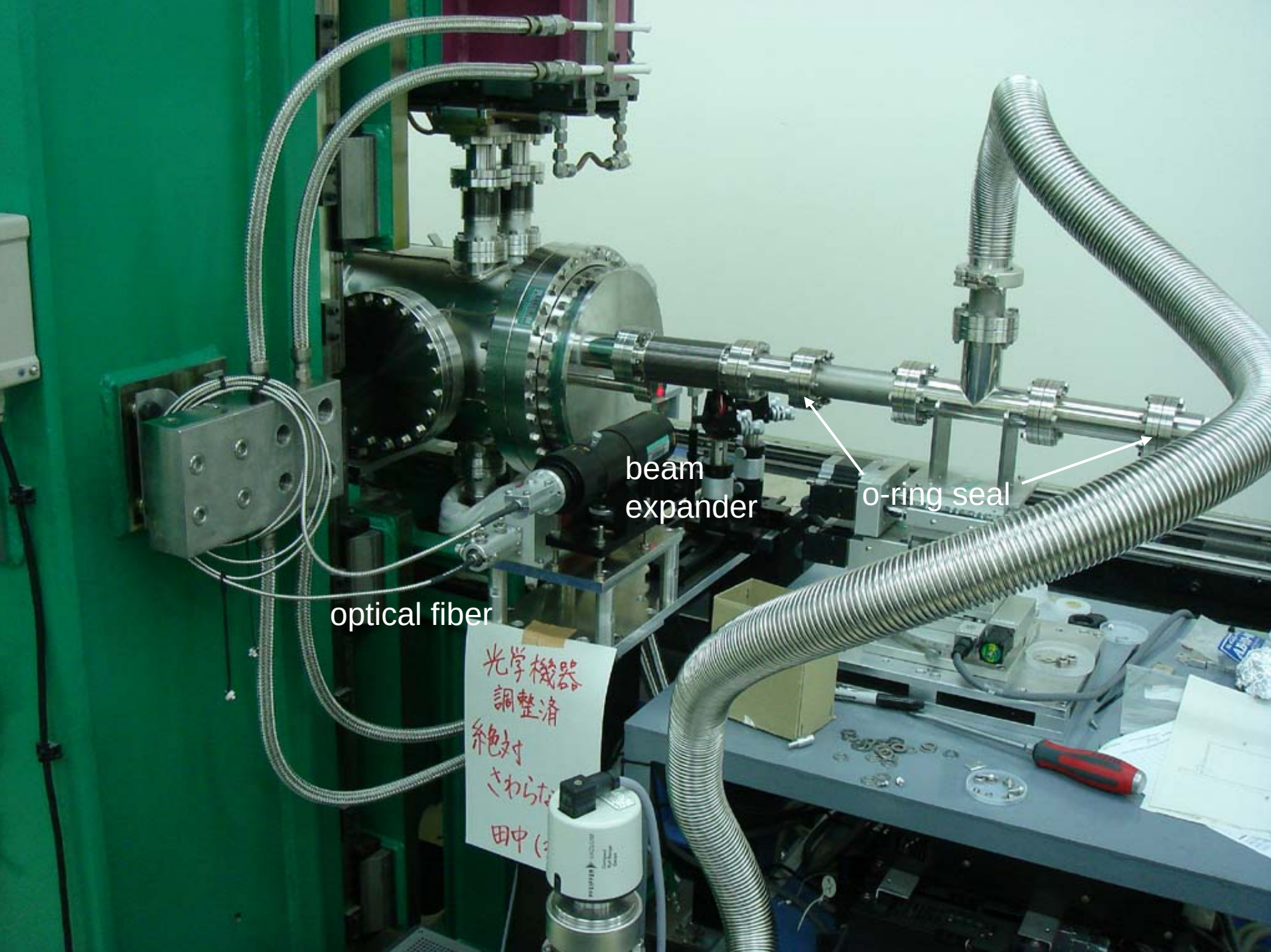
Conventional Measurement System

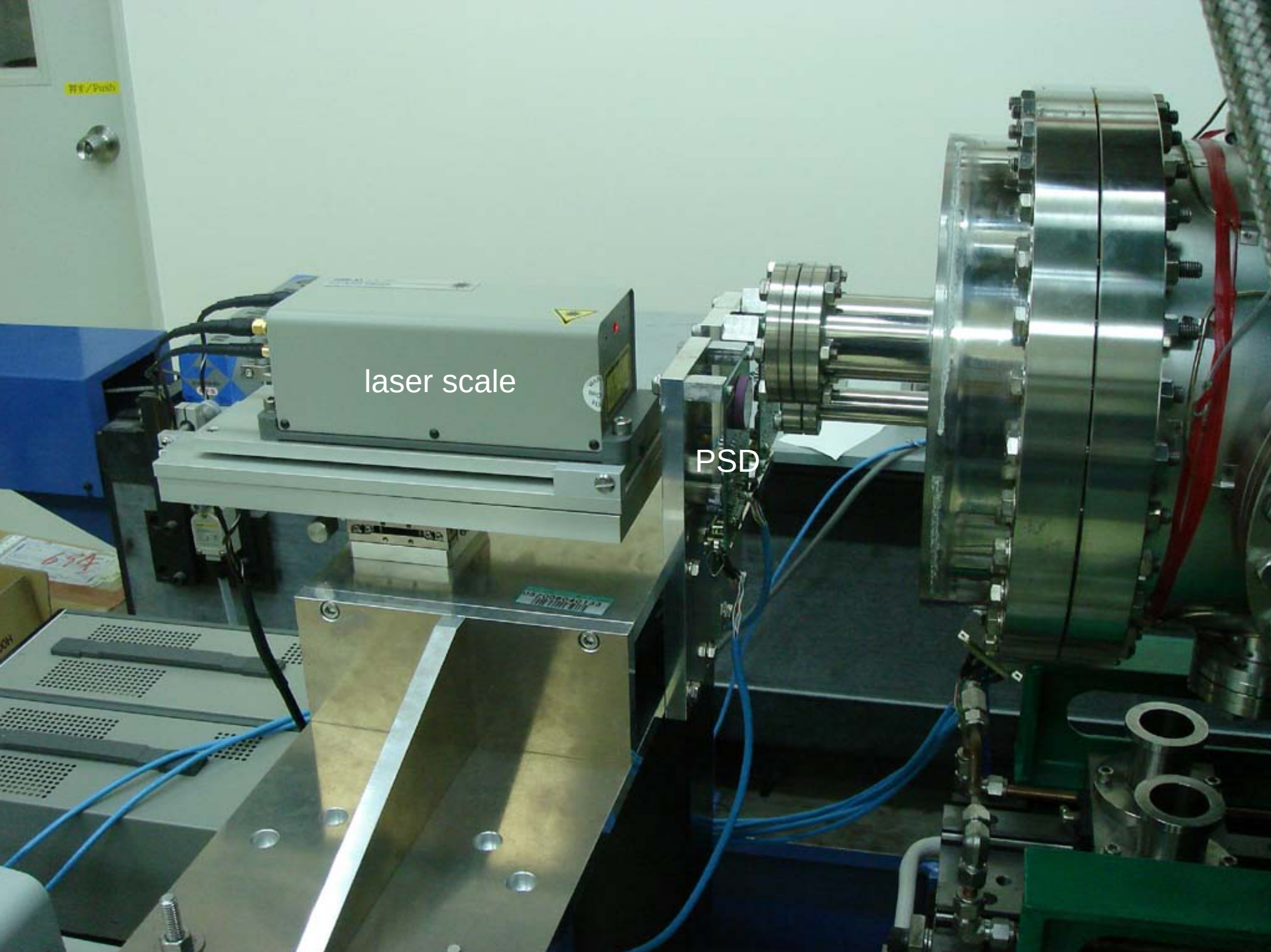


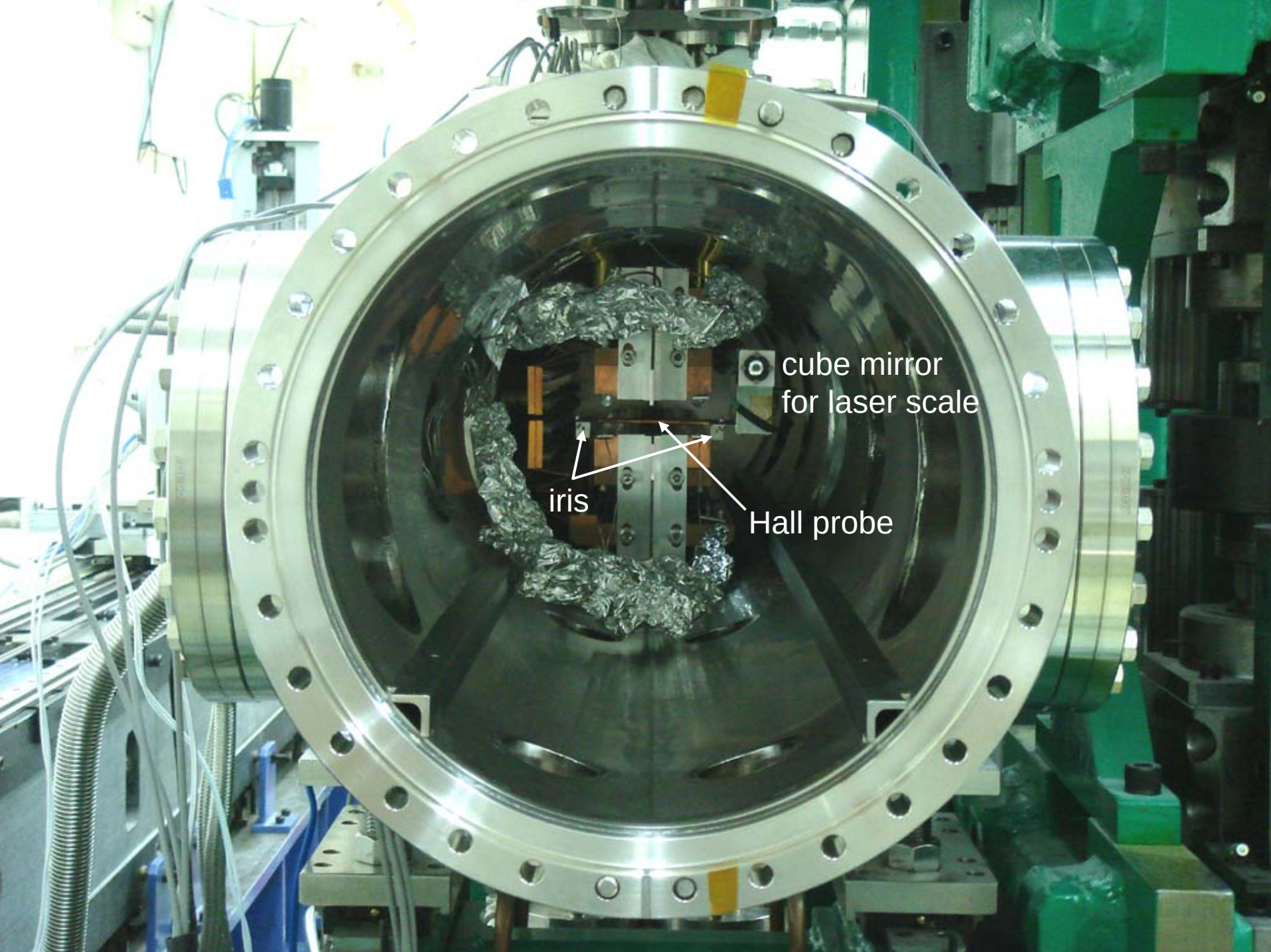
Development of IVFM System




laser
diode
mirror
beam
splitter
4-axis stage

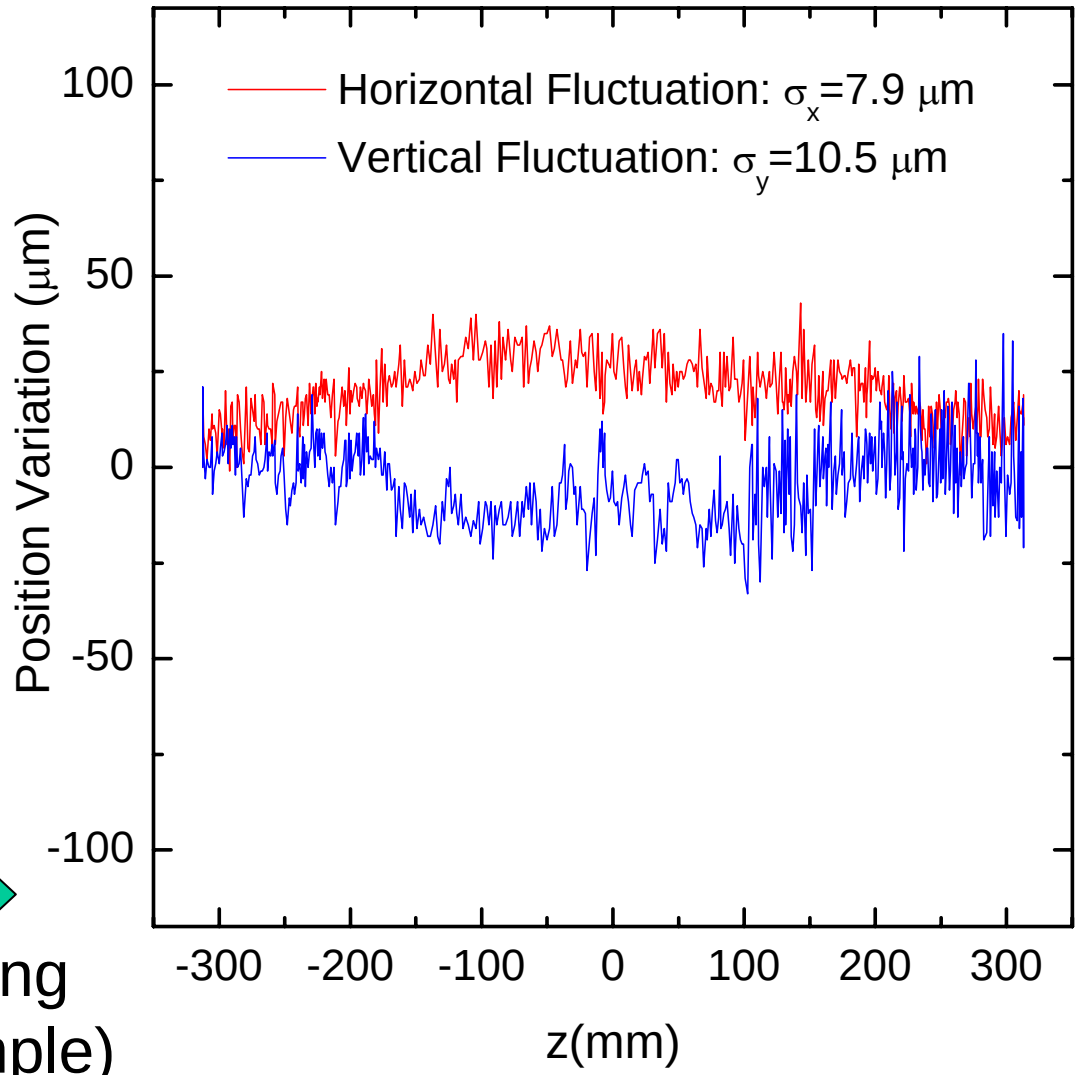

beam
expander
o-ring seal
optical fiber
光学機器
調整済
絶対
さわらな
田中


laser scale
PSD


cube mirror
for laser scale
iris
Hall probe

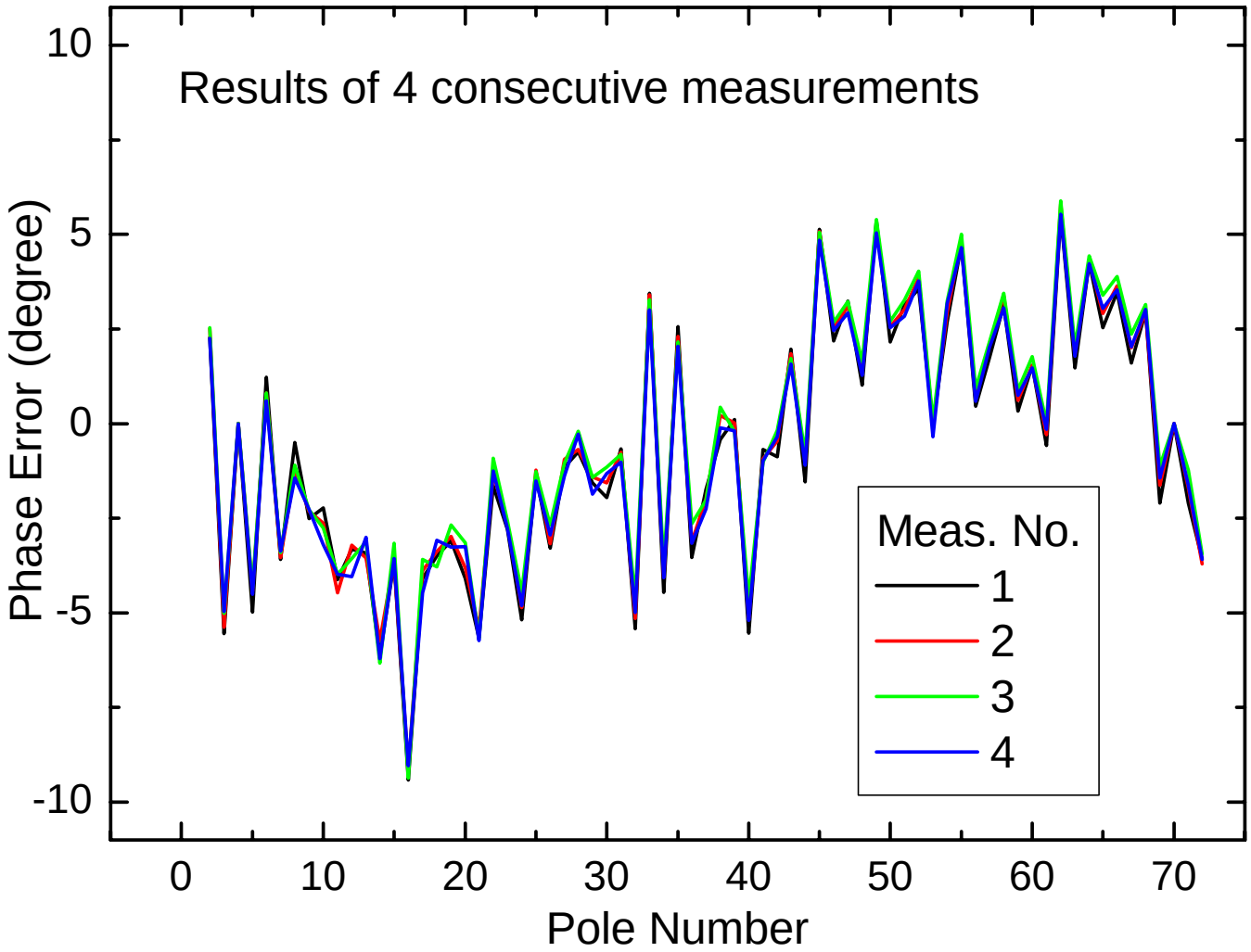
Position Feedback

- Hall Probe Position
  - Measure the Laser Spot Position with PSD
- Feedback
  - y direction
    - swivel (θ_x) stage
  - x direction
    - linear (x) stage



Positional fluctuation during field measurement (example)

Field Measurement Reproducibility



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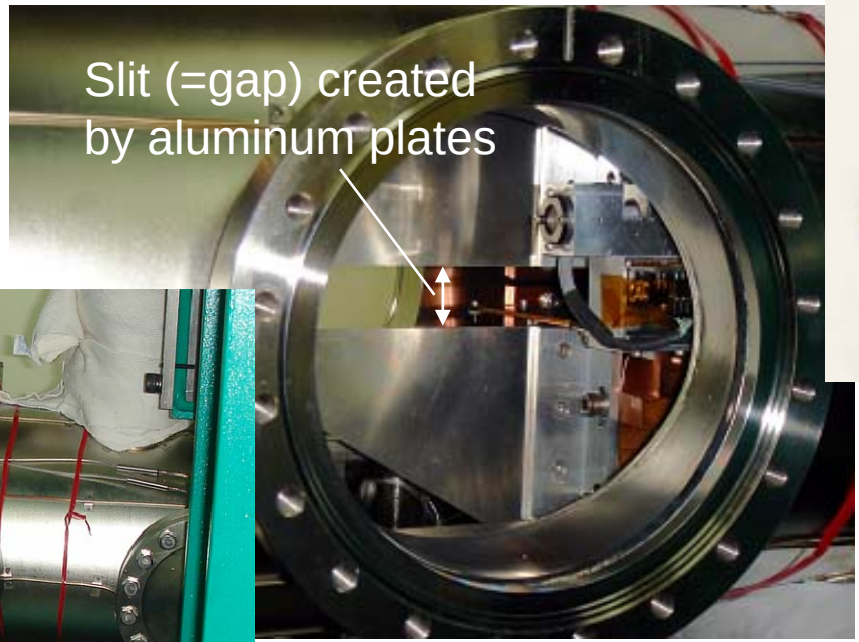
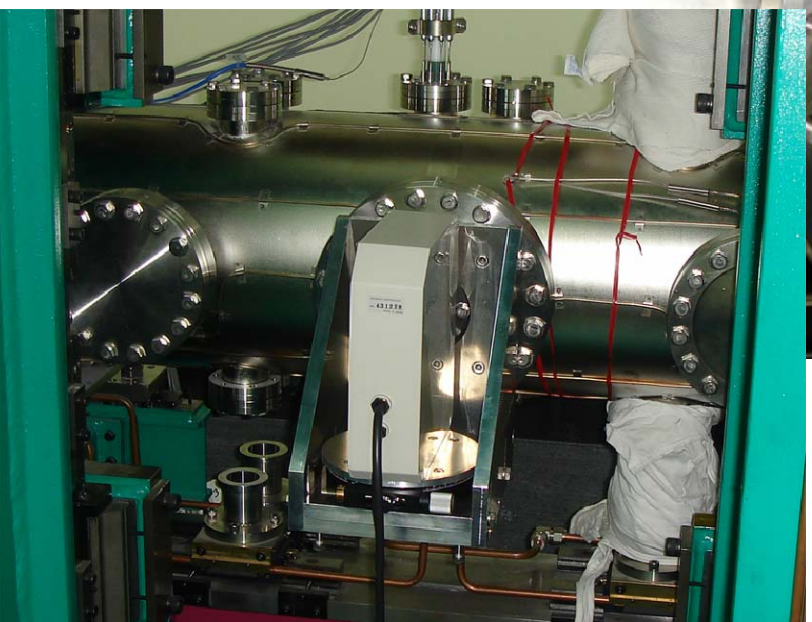
Field Measurement of the Prototype

- Measure the Field Distribution at Different Temperatures:
  1. Field enhancement by cooling the PM array
     - Nominal operating temperature
  2. Phase-error variation due to temperature change
- Check the Magnetic Stability at the Nominal Operating Temperature:
  1. During the steady state
  2. Between cooling cycles

Gap Monitoring and Compensation

- Variation during Cooling due to Thermal Shrink
- Monitor the Gap with an Optical Gauge

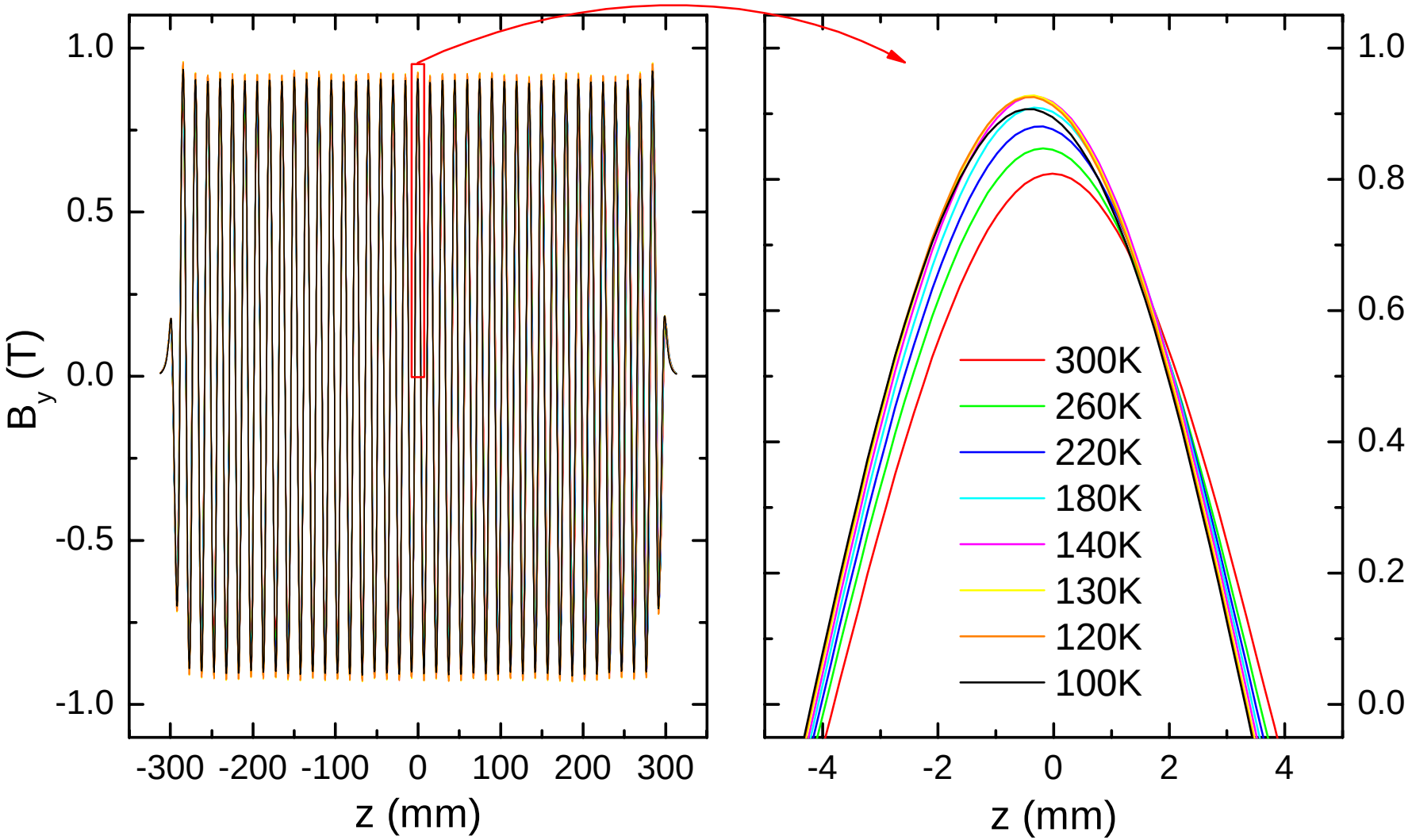




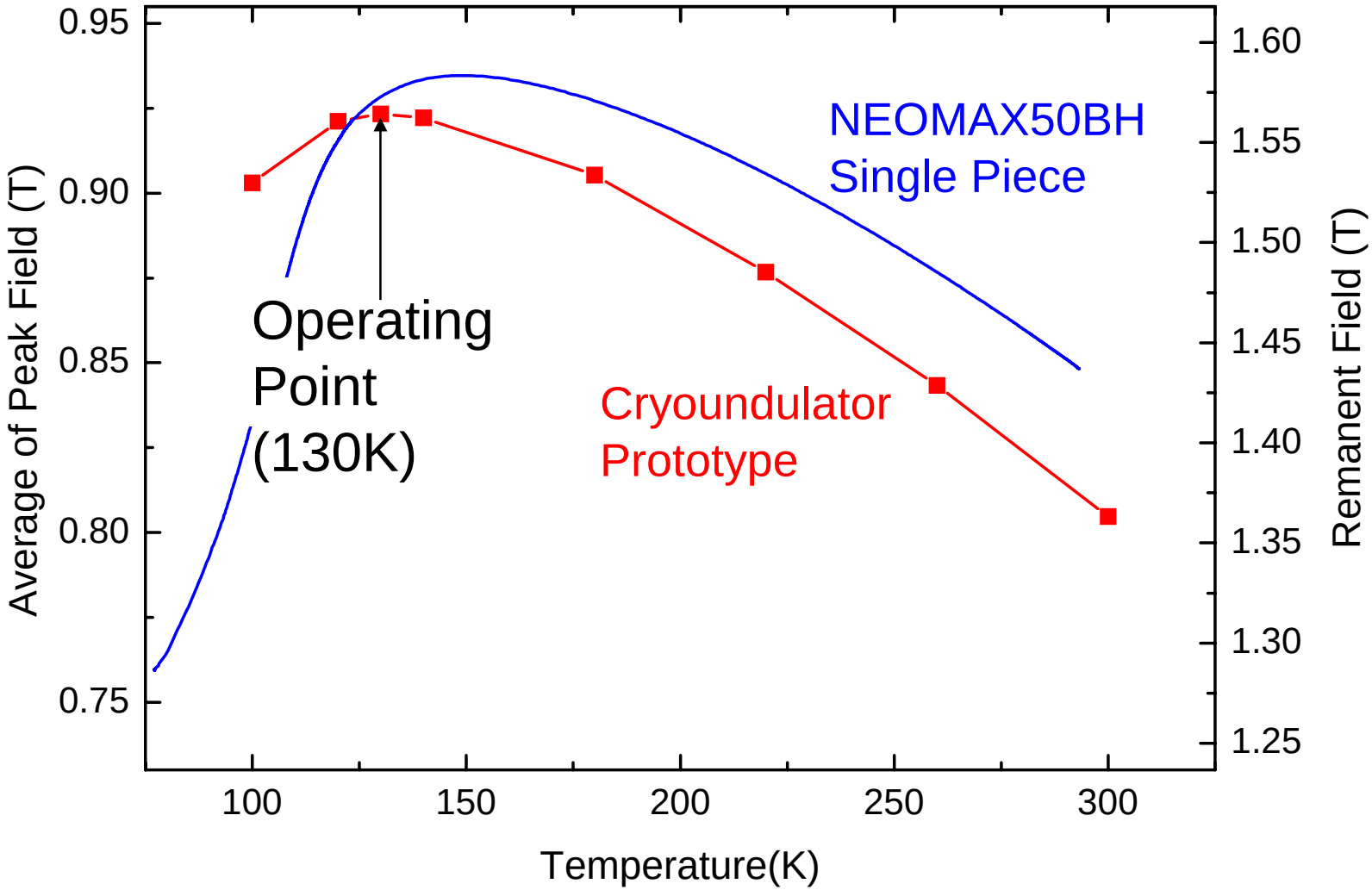
Keyence LS-7000

Field measurement was done at the gap of 5 mm

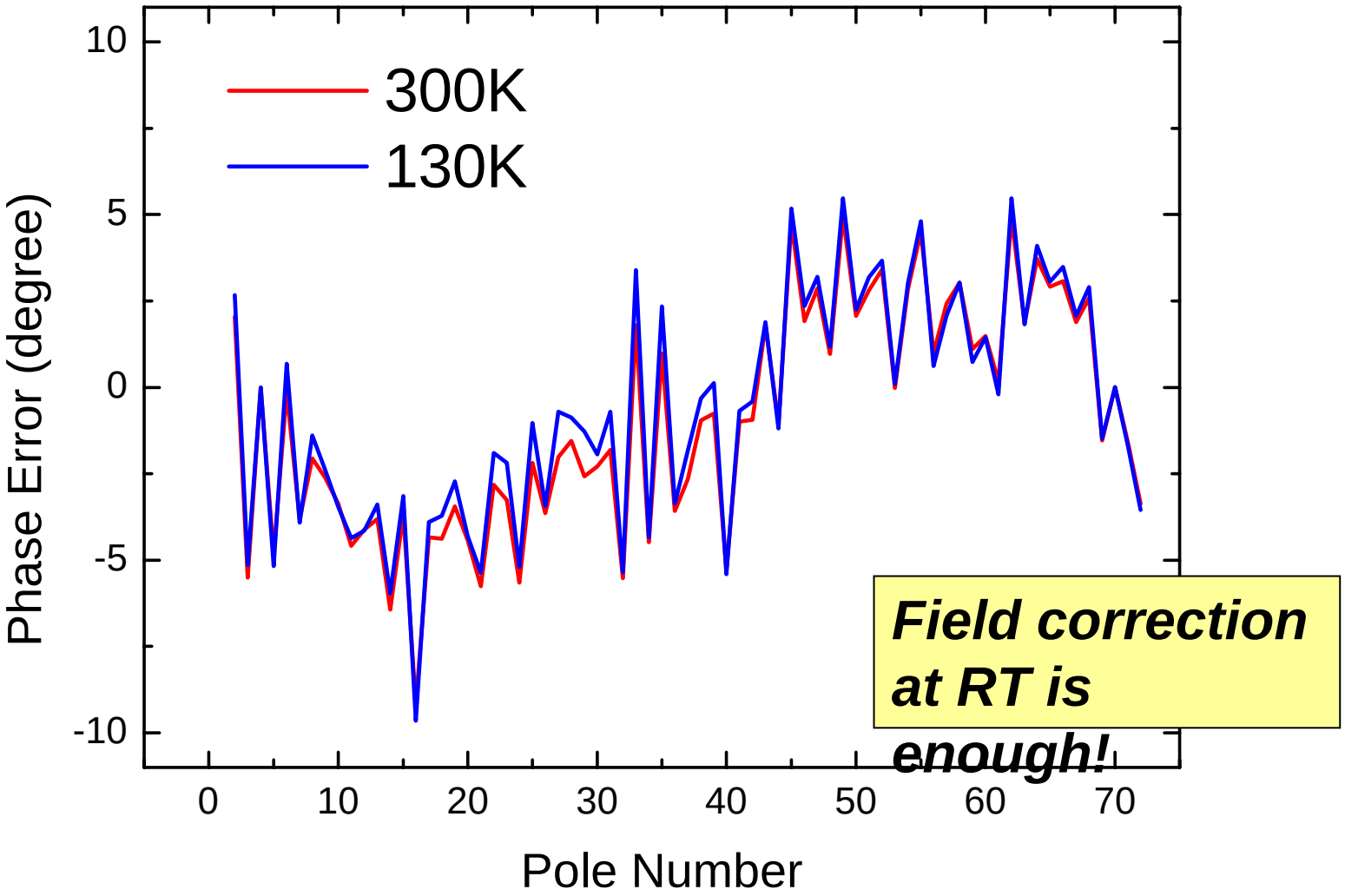
Field Distribution at Different Temp.



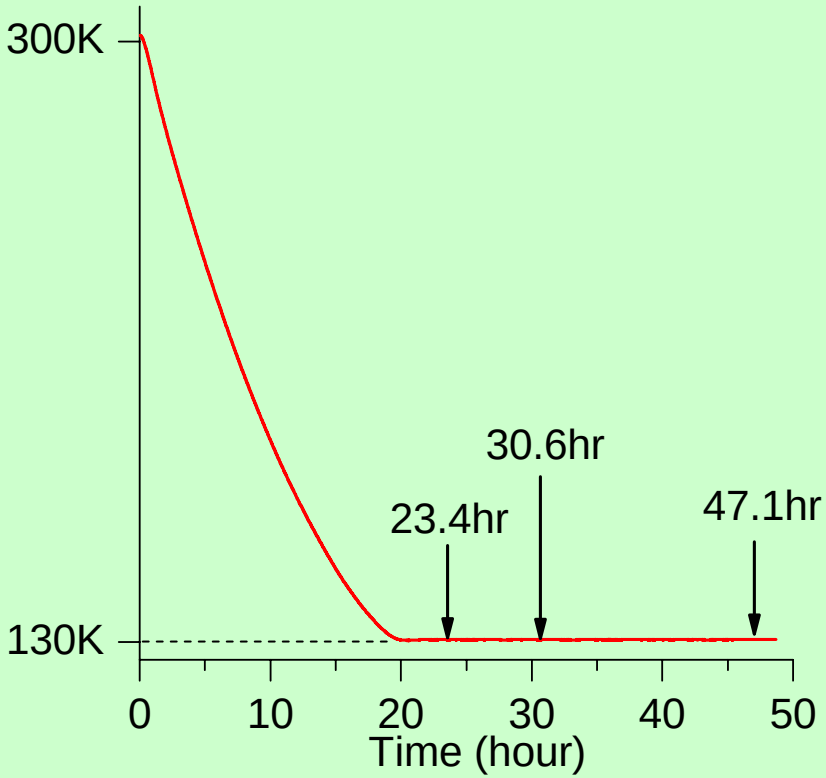
Peak Field vs. Temperature



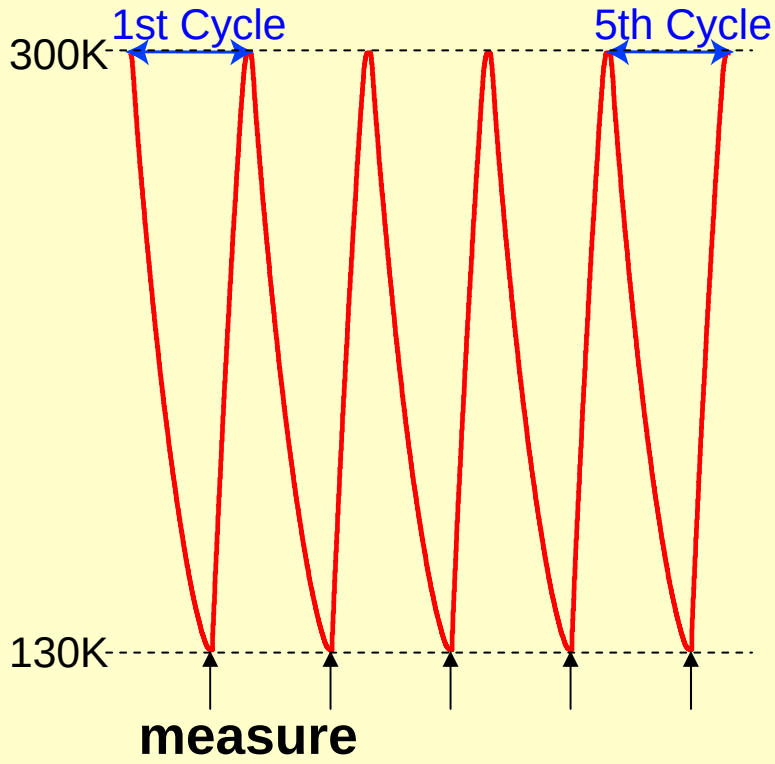
Phase Error Variation



Magnetic Stability at 130 K

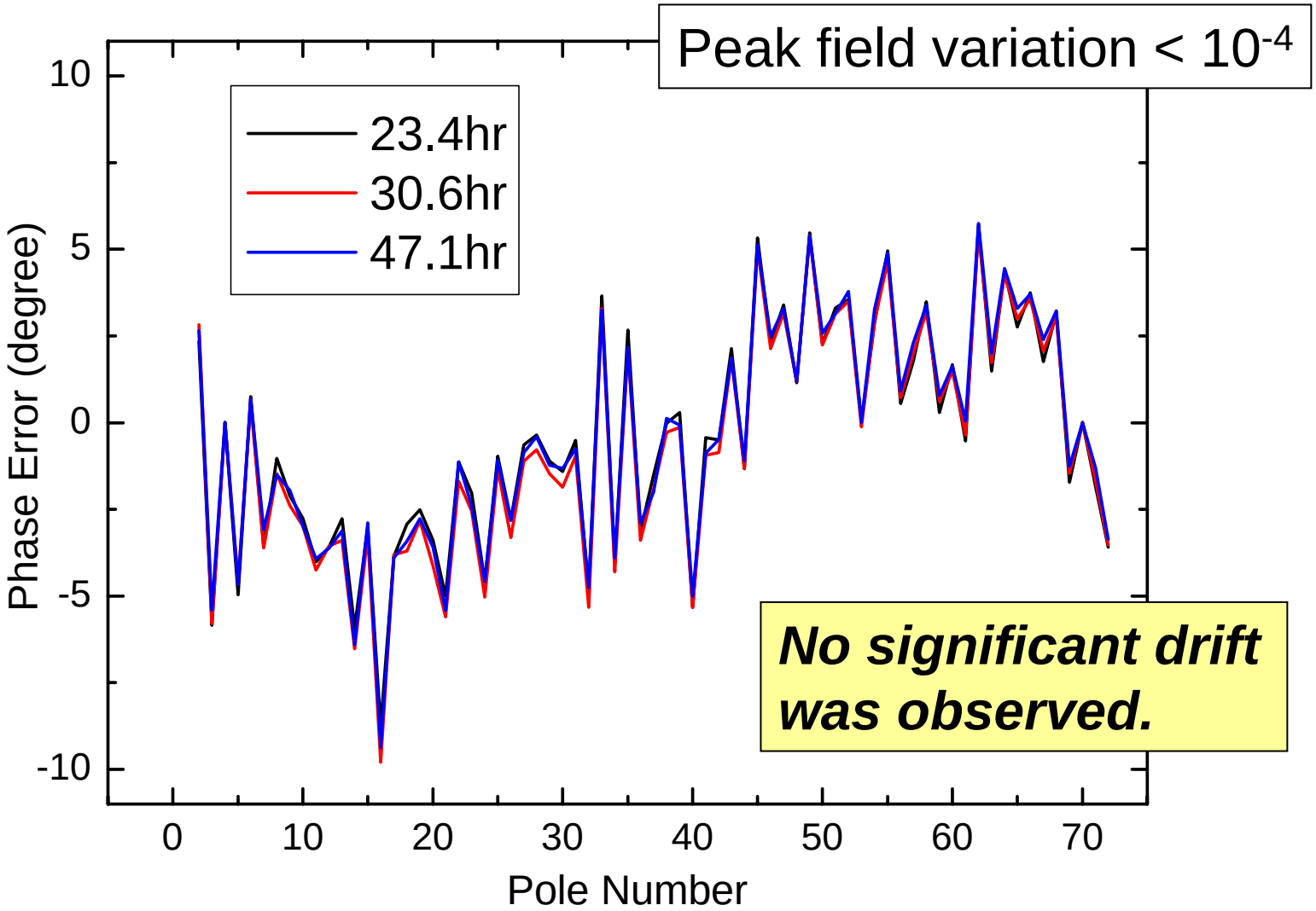


Drift after Reaching the Steady State

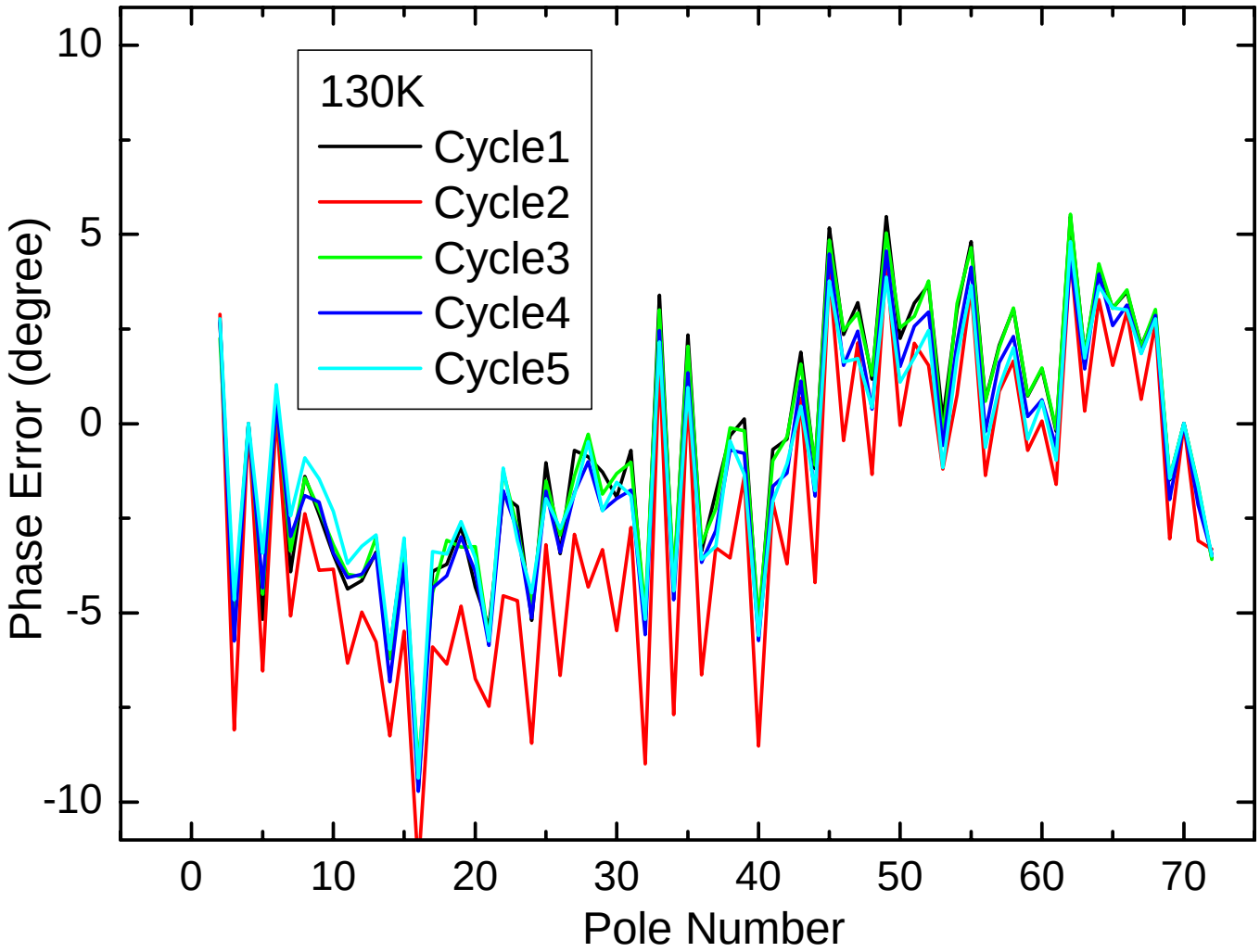


Reproducibility between Cycles

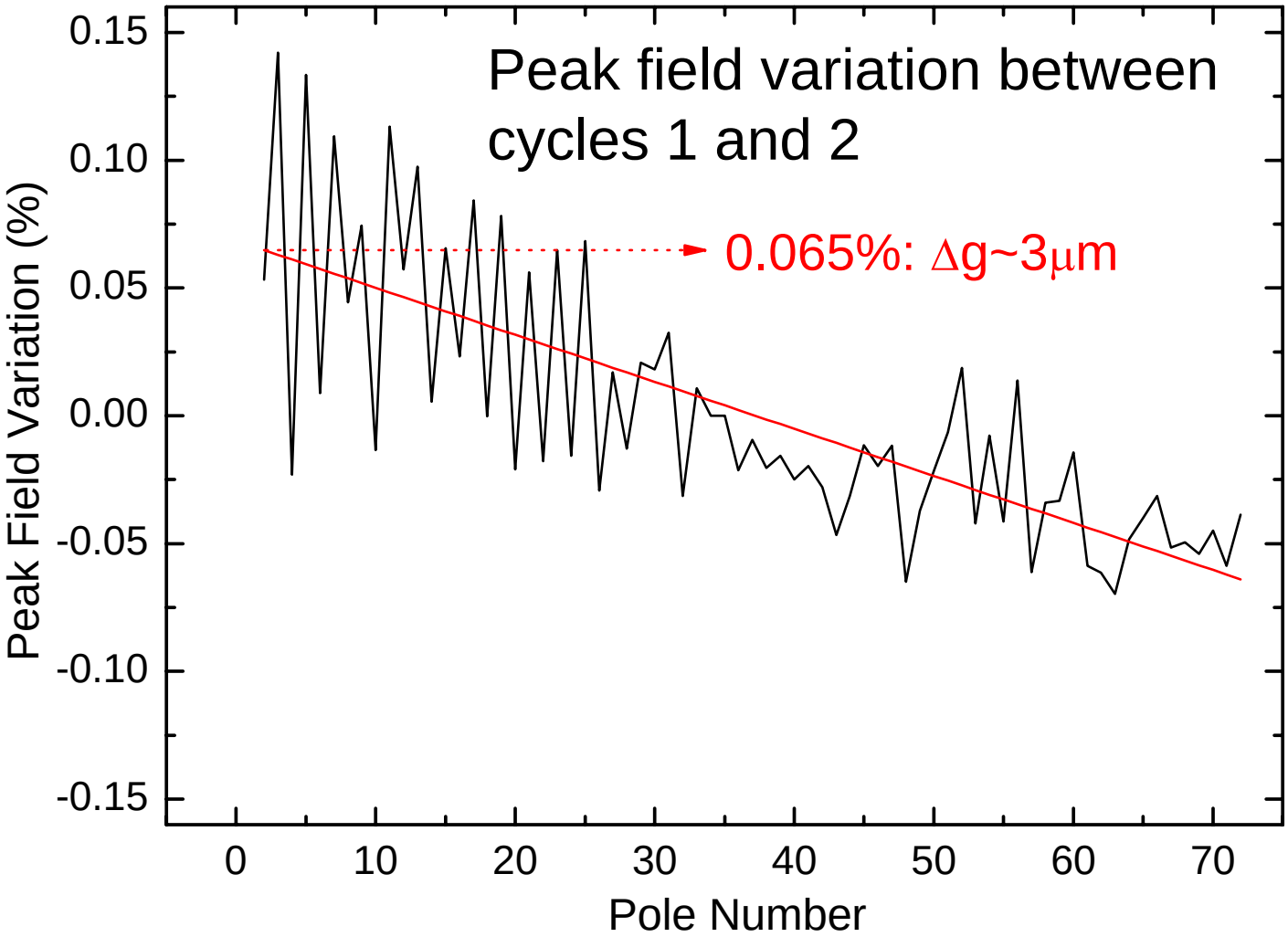
Drift after Reaching Steady State



Reproducibility between Cycles



Reason for the 2nd Cycle Deviation



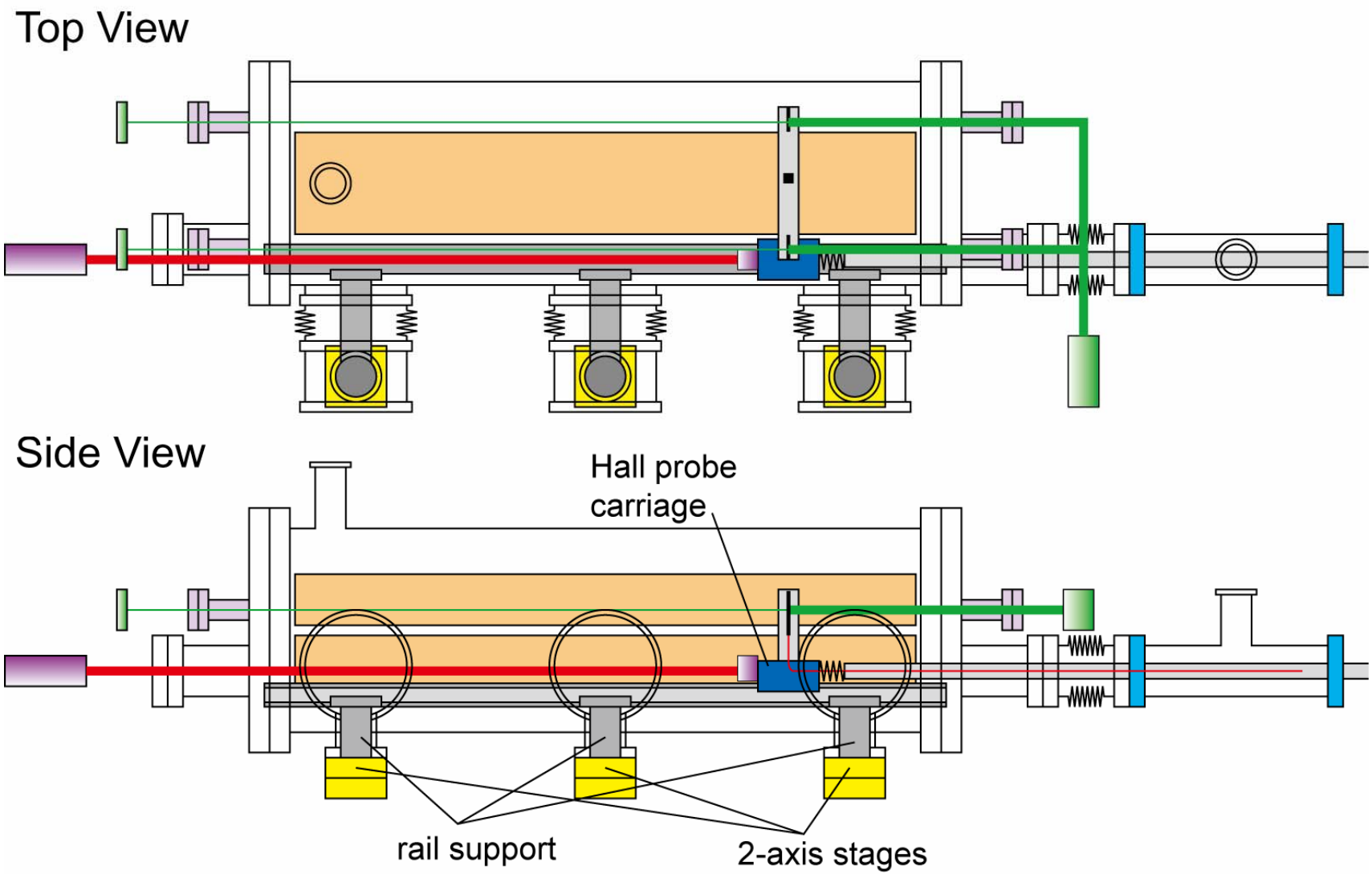
Measurement Summary

- Peak Field Enhancement Curve
  - 130K for the nominal operating temperature
  - slightly different from that of the single piece
- Phase Error Variation Negligible
  - field correction can be applied at room temperature
    - **Conventional schemes can be applied!**
- Reproducibility
  - after reaching the steady state: OK
  - between cycles: small deviation due to gap tapering

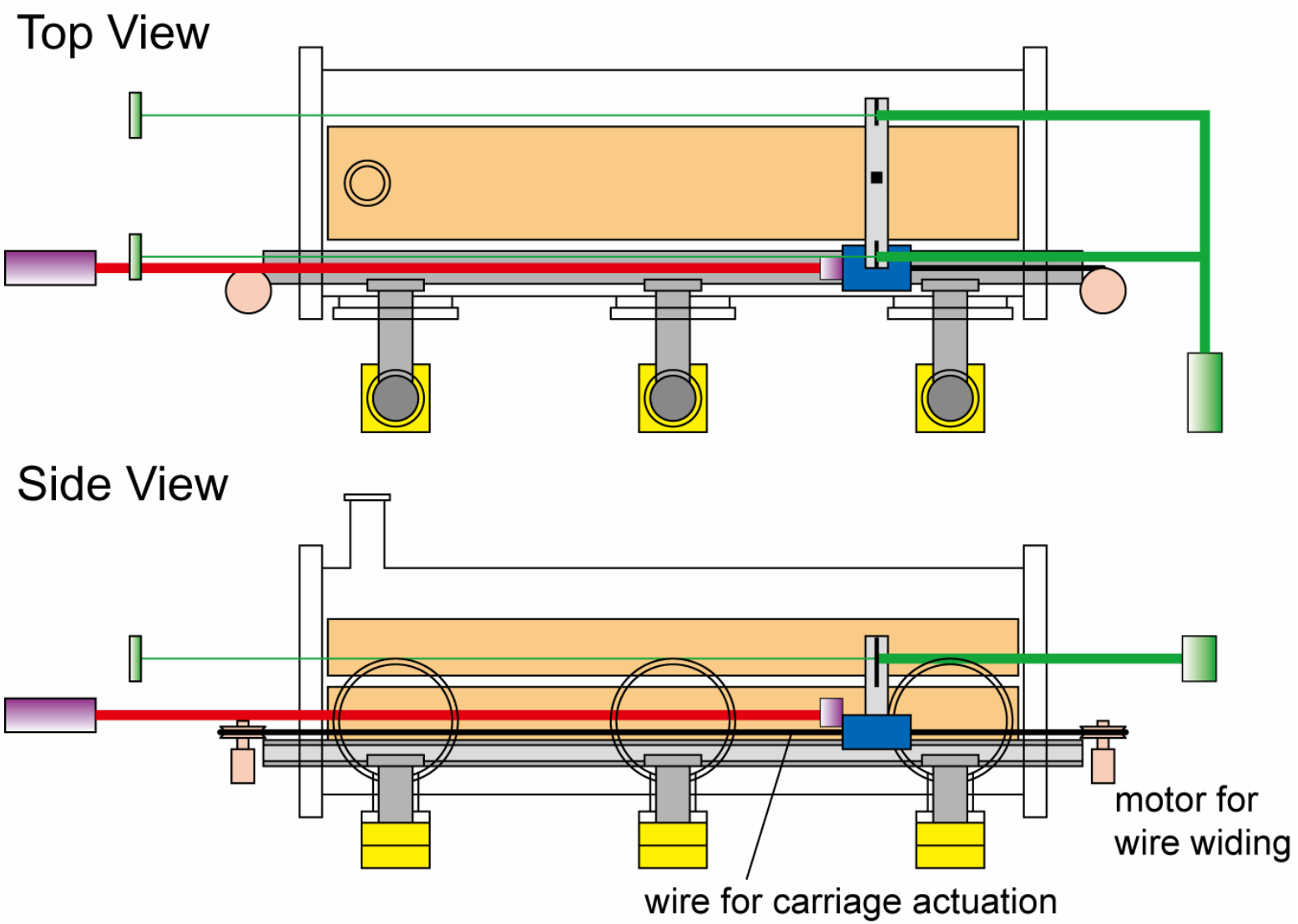
Outlook

- Vacuum Test of Prototype
  - Bakeout at high temperature is not allowed for NEOMAX50BH
  - Check the achievable vacuum without bakeout at 130K
- Field Measurement with Longer Device
  - Installation of 2nd O-ring seal at the downstream
  - Installation of a “rail” and “carriage” for Hall probe scanning
  - Application to in-vacuum undulator (final performance check after assembly)

Modification for Longer Device



Application to IVU



Thank you for attention!