

Integrating Magnetic Field Mapping Crack Detection and Coordinate Measurement

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Magnetics 2016
January 21 & 22, 2016
Jacksonville FL, USA



State-of-the-art Hall-based Magnetic Field Mapper

- 4 Axis capability: X,Y, Z and θ
- Scanning volume: up to 500mm cubical volume
- Scanning speed: up to 100mm/s
- Probe positioning resolution: $\pm 2\mu\text{m}$ (X,Y,Z) / $\pm 0.02^\circ$ (θ)
- Standard magnetic resolution: $< 10\mu\text{T}$ (rms)
- Measurement accuracy: 0.1% of measurement range
- Angular error (calibrated): 0.1°
- Measuring sensitive volume: $< 150 \times 10 \times 150 \mu\text{m}$
- Magnetic field range: selectable $\pm 100\mu\text{T}$ to $\pm 2\text{T}$
- Magnetic field bandwidth: DC to 25 kHz (-3 db)

Increasing requirements for Magnetic Field Mapper

- Measurement of all three components of the magnetic field at the same spot
- Small overall dimensions of the probe
- Well calibrated mechanics (Cartesian Moving platform)
- Accurate positioning of the probe with respect to a coordinate system of the mapper
- Accurate positioning of objects under test
- Cracks and material inhomogeneity detection
- Specialized measurements (e.g. rotor mapping)
- Performance - Price - Ratio



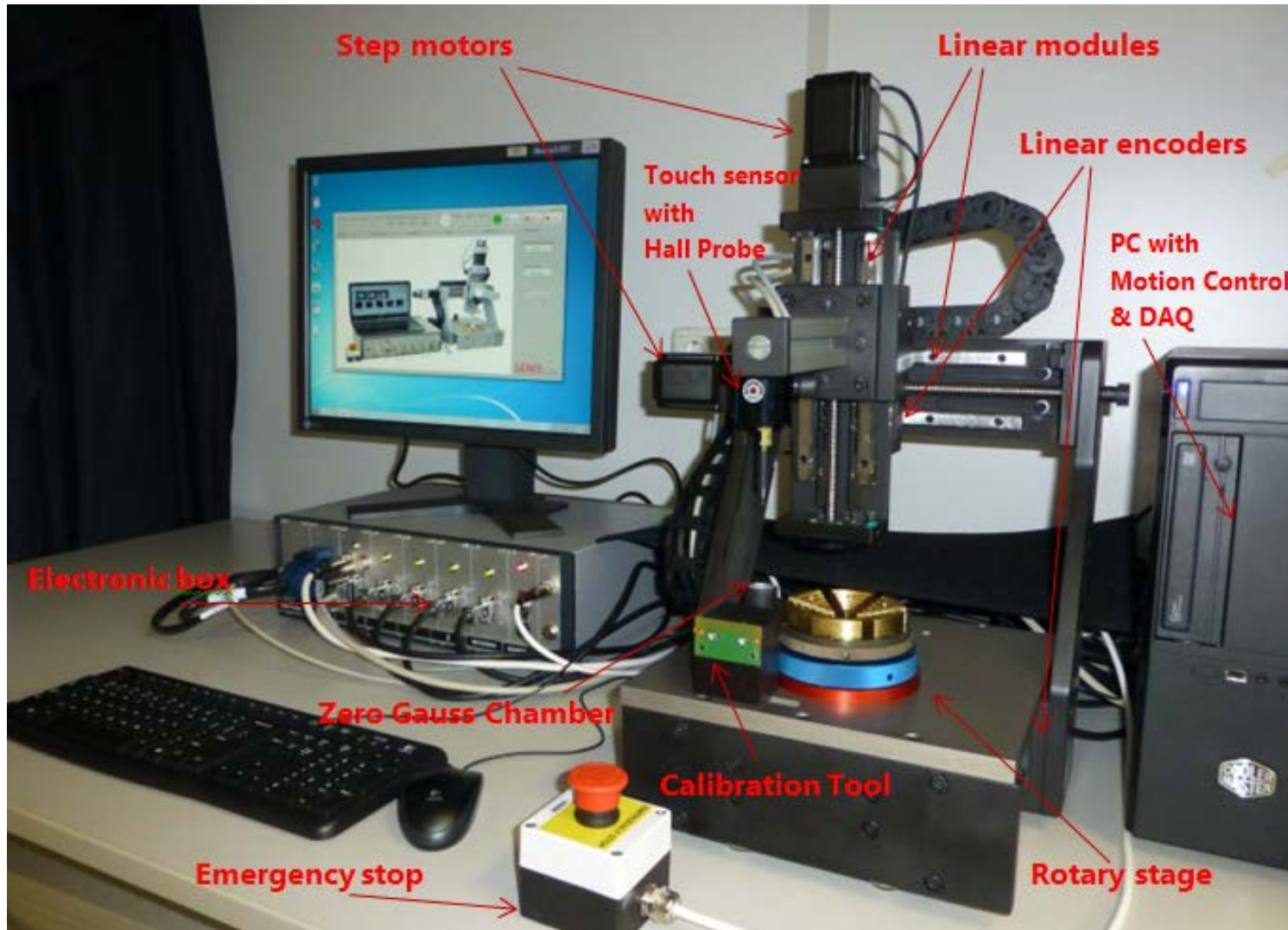
Increasing Requirements for Magnetic Field Mapper



All-in-One Magnetic Field Mapper

SENIS
magnetic & current measurement

GMW Associates



1/12/2016

I. J. Walker, S. Spasic



Mapper Size

- Standard: scanning volume 135mm x 135mm x 135mm
- Extended: scanning volume 500mm x 500mm x 500mm



Applications of Mappers

- DC and AC magnetic flux densities (25kHz and higher)
- Homogeneous and highly inhomogeneous fields
- Permanent magnet mapping (disc, ring, block, segment)
- Magnetic moment, polarization angle determination
- Mapping of Rotors and Stators (small motors, turbines)
- Mapping of quadrupoles
- Cracks and inhomogeneity detection (also non-magnetic)
- Mapping of micro structures (encoders, code-plates, etc.)
- Smartphones & PCB mapping
- Quality Control, Development, Testing
- Automotive, Energy, Consumer Industry
- Research Laboratories, Accelerators, Light Sources, Synchrotron Radiations...

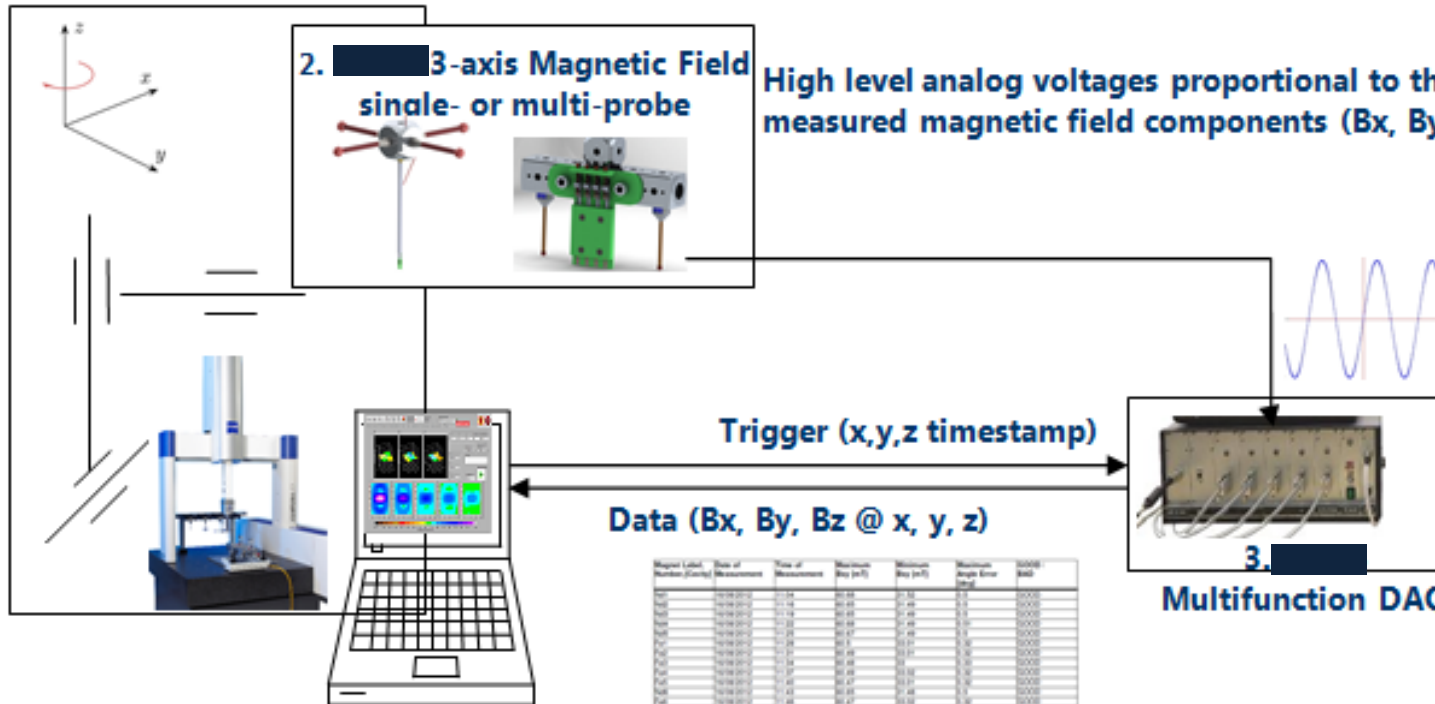


Mapper Integration in Zeiss CMM

1. Coordinate Measuring Machine with integrated ██████ Hall probe

2. ██████ 3-axis Magnetic Field single- or multi-probe

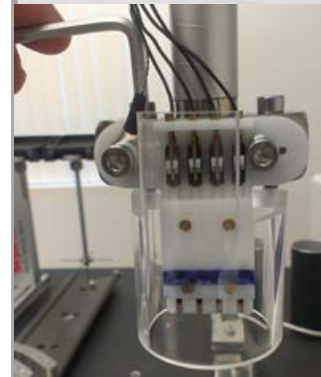
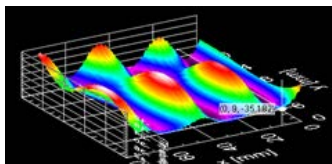
High level analog voltages proportional to the measured magnetic field components (B_x , B_y , B_z)



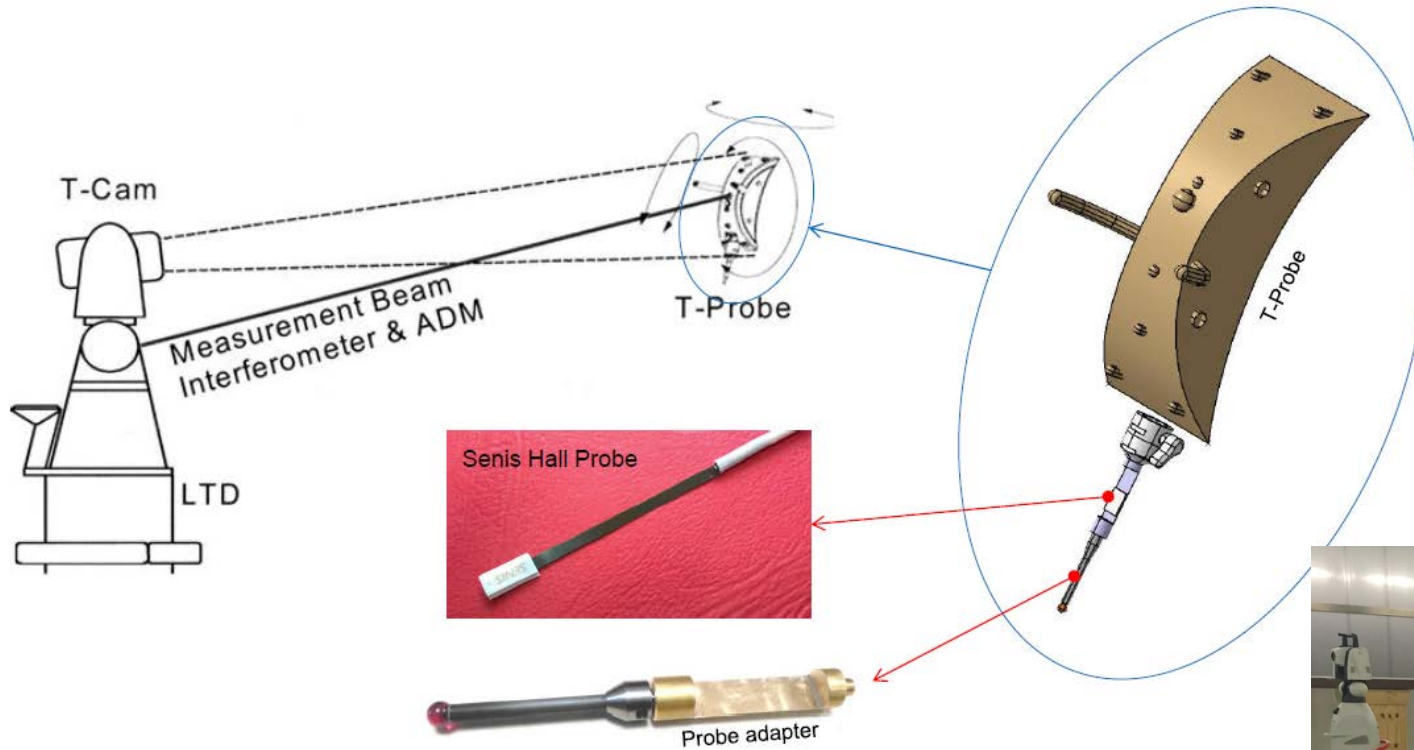
4. PC for CMM control, data acquisition & visualization, setup and report generation

Magnet Label	Date of Measurement	Time of Measurement	Maximum Bx (nT)	Minimum Bx (nT)	Maximum By (nT)	Minimum By (nT)	Maximum Bz (nT)	Minimum Bz (nT)	SD/0.01 (nT)
Mag1	12-12-2016	12:14	20.14	-20.14	20.14	-20.14	20.14	-20.14	0.001
Mag2	12-12-2016	12:14	20.14	-20.14	20.14	-20.14	20.14	-20.14	0.001
Mag3	12-12-2016	12:14	20.14	-20.14	20.14	-20.14	20.14	-20.14	0.001
Mag4	12-12-2016	12:14	20.14	-20.14	20.14	-20.14	20.14	-20.14	0.001
Mag5	12-12-2016	12:14	20.14	-20.14	20.14	-20.14	20.14	-20.14	0.001
Mag6	12-12-2016	12:14	20.14	-20.14	20.14	-20.14	20.14	-20.14	0.001
Mag7	12-12-2016	12:14	20.14	-20.14	20.14	-20.14	20.14	-20.14	0.001
Mag8	12-12-2016	12:14	20.14	-20.14	20.14	-20.14	20.14	-20.14	0.001
Mag9	12-12-2016	12:14	20.14	-20.14	20.14	-20.14	20.14	-20.14	0.001
Mag10	12-12-2016	12:14	20.14	-20.14	20.14	-20.14	20.14	-20.14	0.001
Mag11	12-12-2016	12:14	20.14	-20.14	20.14	-20.14	20.14	-20.14	0.001
Mag12	12-12-2016	12:14	20.14	-20.14	20.14	-20.14	20.14	-20.14	0.001
Mag13	12-12-2016	12:14	20.14	-20.14	20.14	-20.14	20.14	-20.14	0.001
Mag14	12-12-2016	12:14	20.14	-20.14	20.14	-20.14	20.14	-20.14	0.001
Mag15	12-12-2016	12:14	20.14	-20.14	20.14	-20.14	20.14	-20.14	0.001
Mag16	12-12-2016	12:14	20.14	-20.14	20.14	-20.14	20.14	-20.14	0.001
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Mag18	12-12-2016	12:14	20.14	-20.14	20.14	-20.14	20.14	-20.14	0.001
Mag19	12-12-2016	12:14	20.14	-20.14	20.14	-20.14	20.14	-20.14	0.001
Mag20	12-12-2016	12:14	20.14	-20.14	20.14	-20.14	20.14	-20.14	0.001
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Mag22	12-12-2016	12:14	20.14	-20.14	20.14	-20.14	20.14	-20.14	0.001
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Mag28	12-12-2016	12:14	20.14	-20.14	20.14	-20.14	20.14	-20.14	0.001
Mag29	12-12-2016	12:14	20.14	-20.14	20.14	-20.14	20.14	-20.14	0.001
Mag30	12-12-2016	12:14	20.14	-20.14	20.14	-20.14	20.14	-20.14	0.001

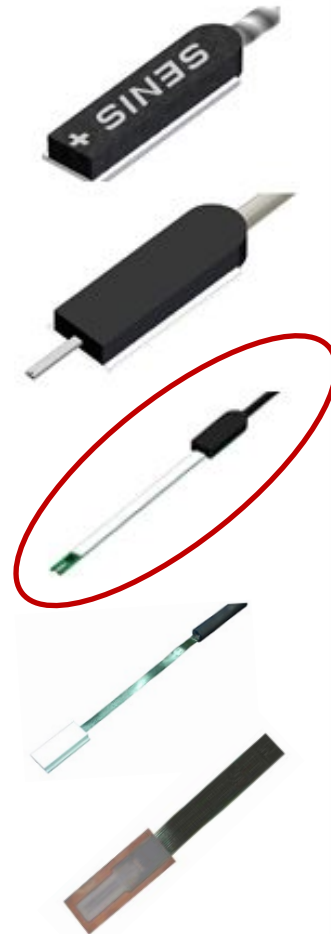
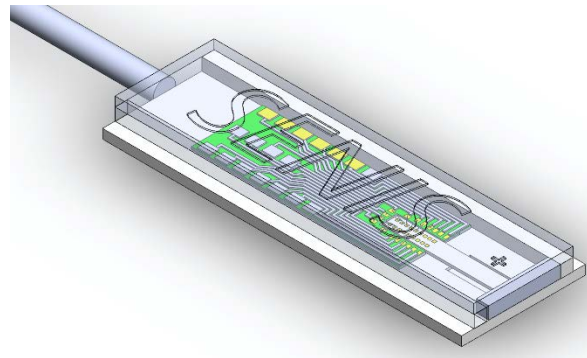
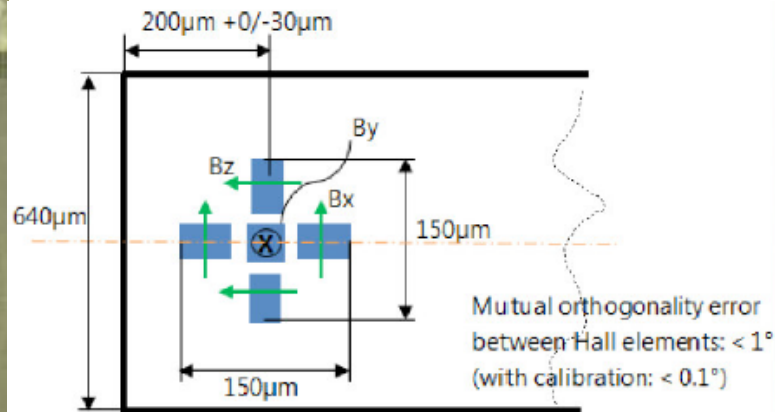
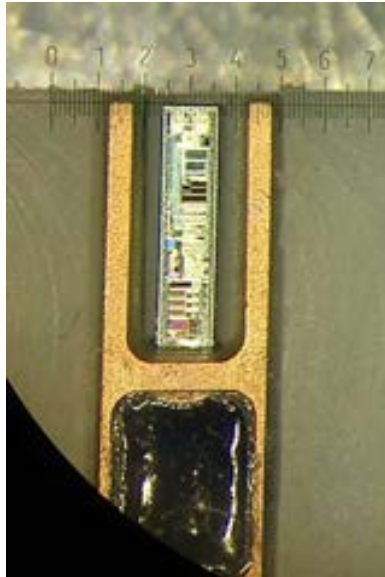
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Supervisor: Supervisor
Date & Time: Thu, 12/12/2016 at 11:47



Leica Laser Tracker Integration



3-axis Hall Probe

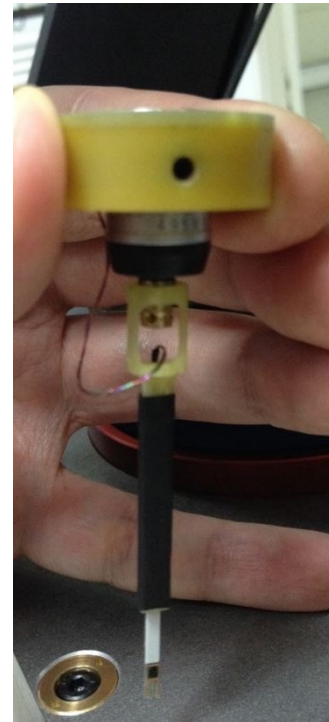
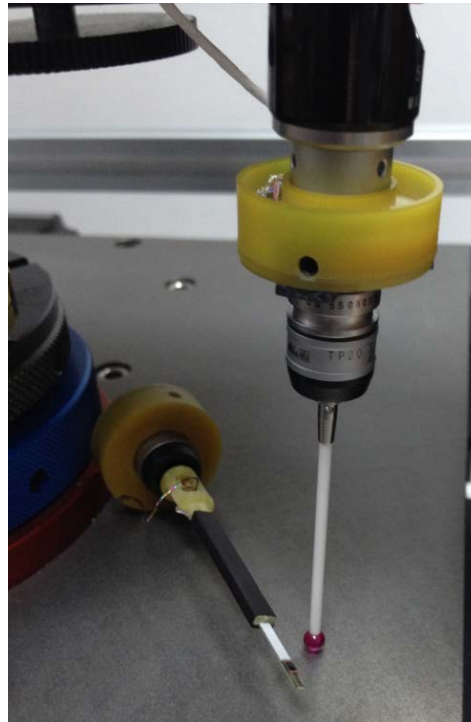
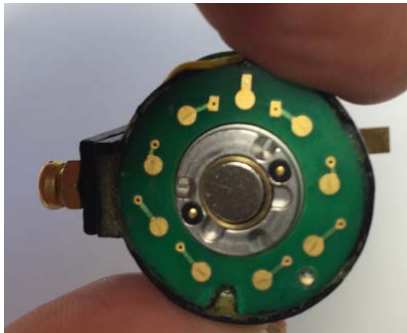
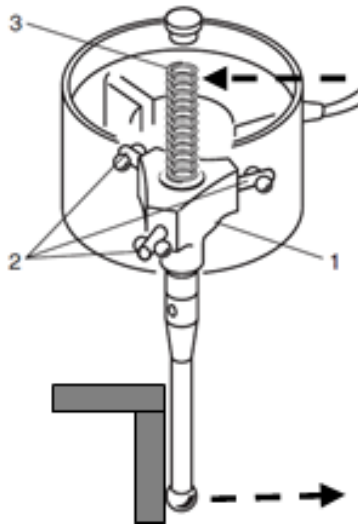


Standard dimensions of the mapper probe:
(LxWxH in mm): 42.0 x 2.0 x 0.5



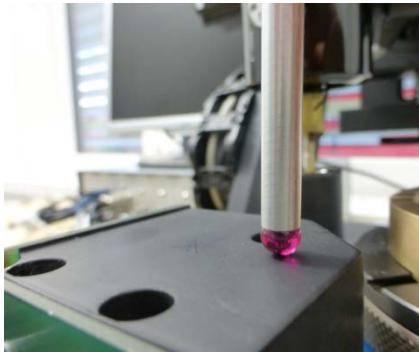
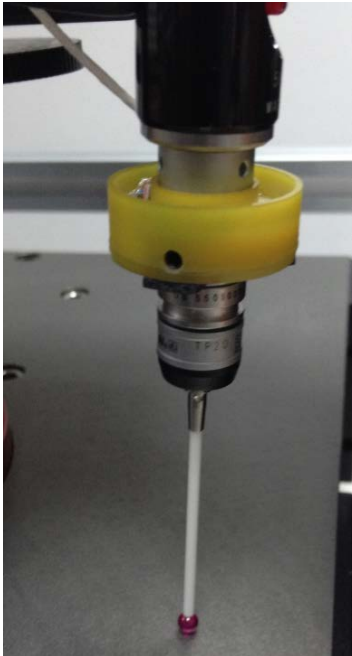
Touch Sensor Integration

- Touch-trigger sensor and stylus

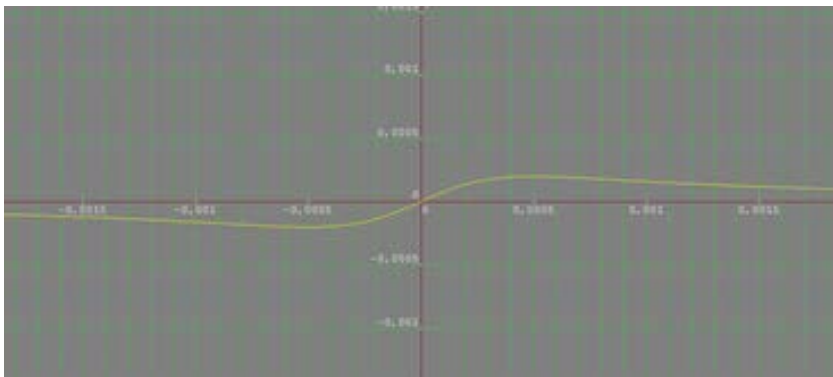
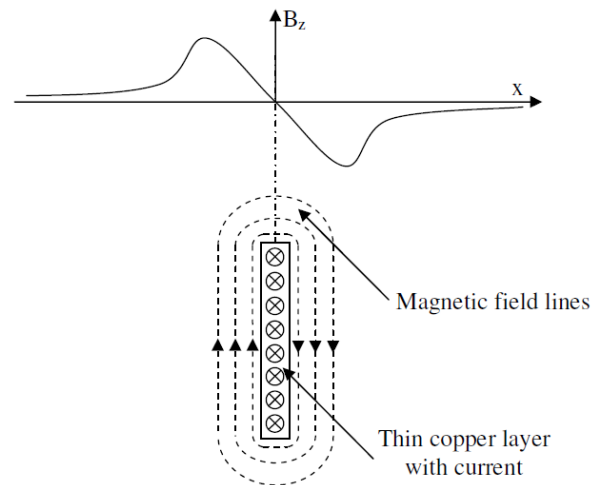
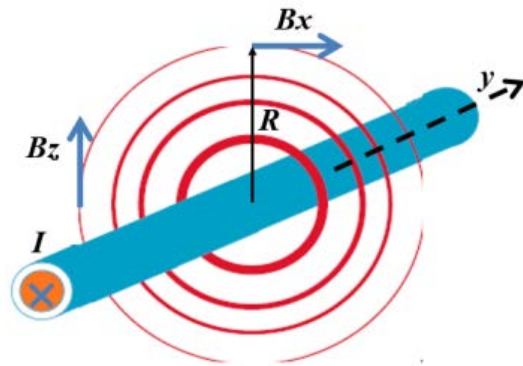


Dimensional Measurement

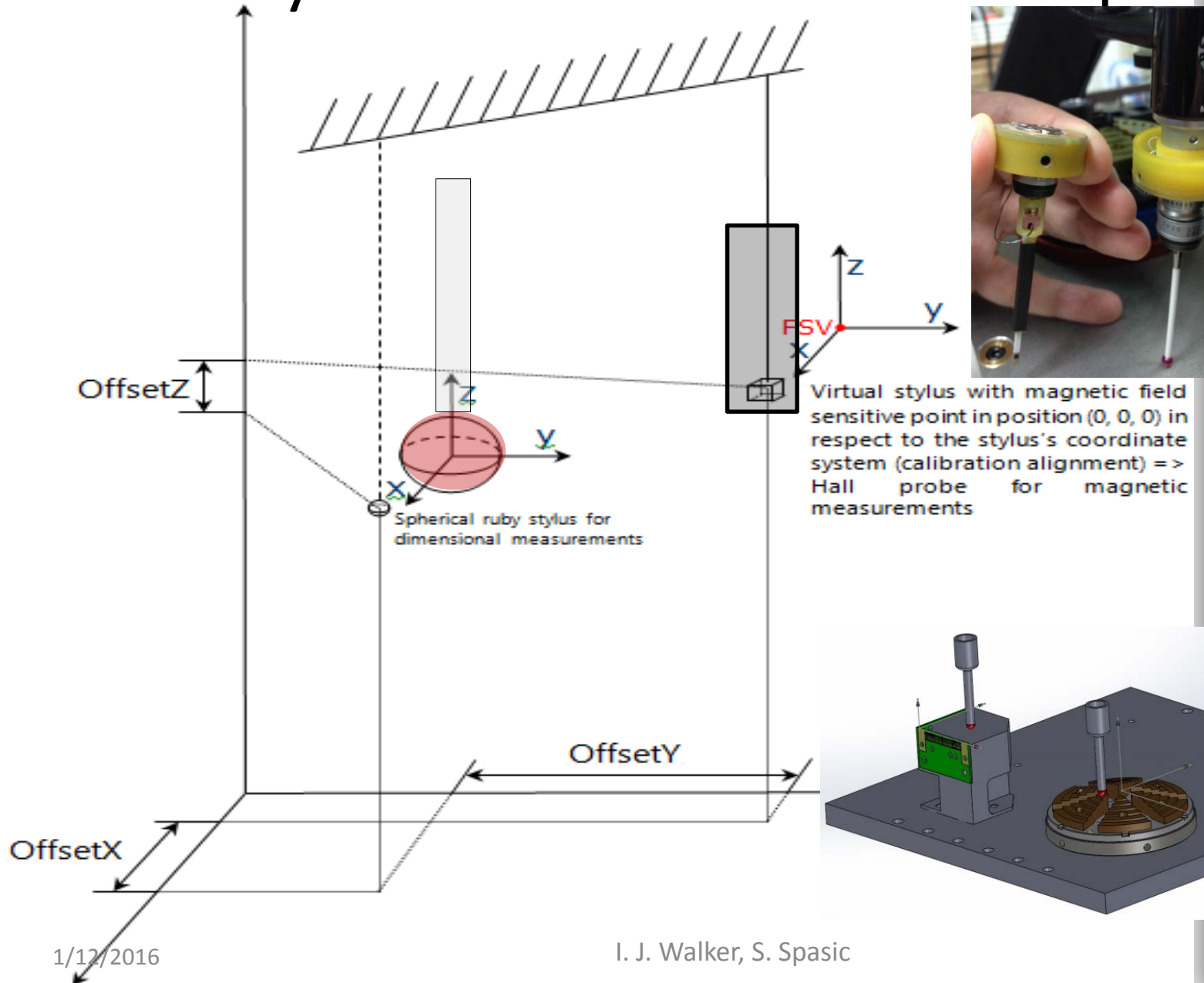
- Simple dimensional measurement
- Absolute magnet positioning
- Measurement distance definition
- Mapper calibration



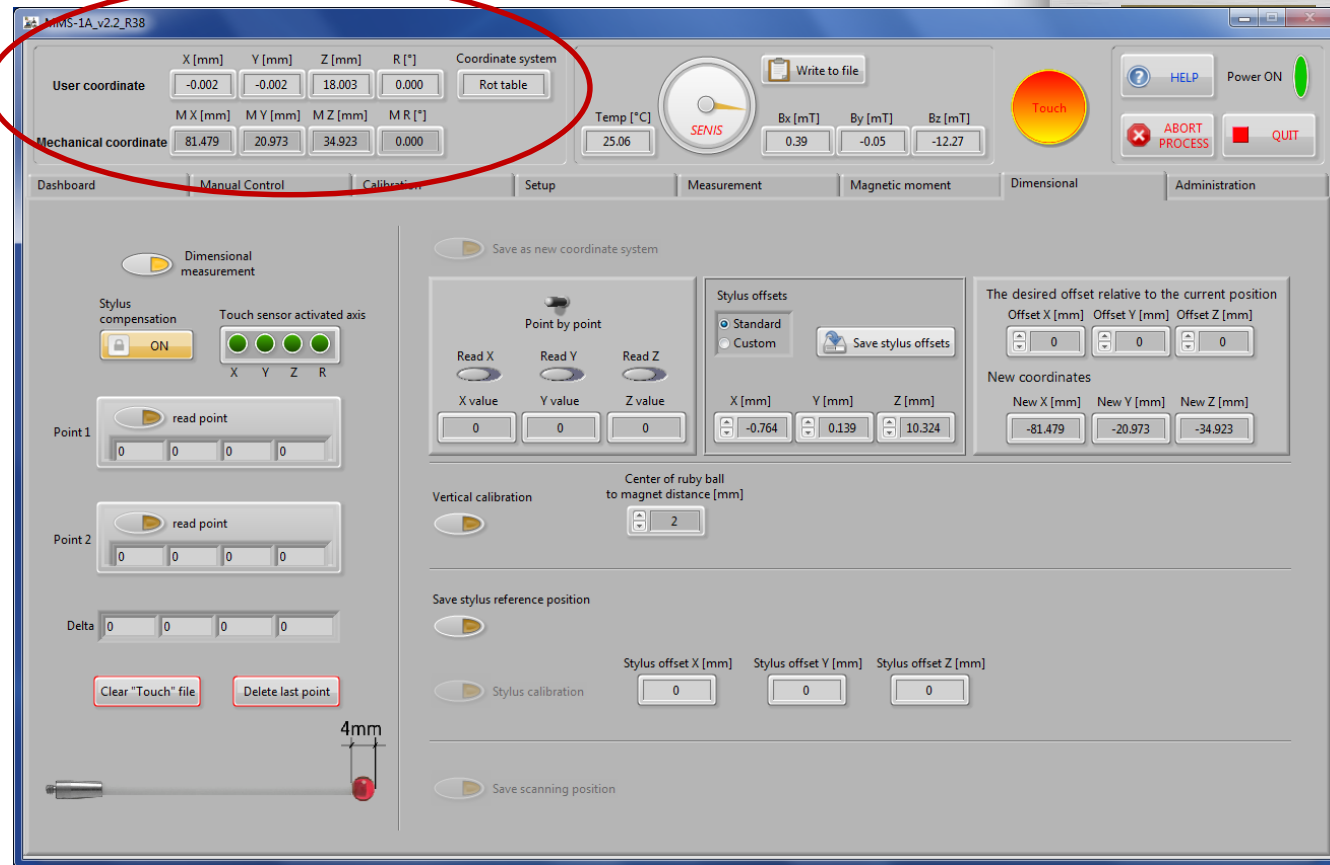
Determination of probe's Magnetic Field Sensitive Volume



Touch-Stylus $\leftrightarrow$ Probe's Sensitive Spot



Dimensional Measurement



Dimensional measurement

Delta 17.242 1.603 5.557 0.044

Point 1 read point
-17.242 1.603 5.557 0.044

Point 2 read point
0 0 0 0

Dimensional measurement

Delta 29.32 2.065 3.282 0

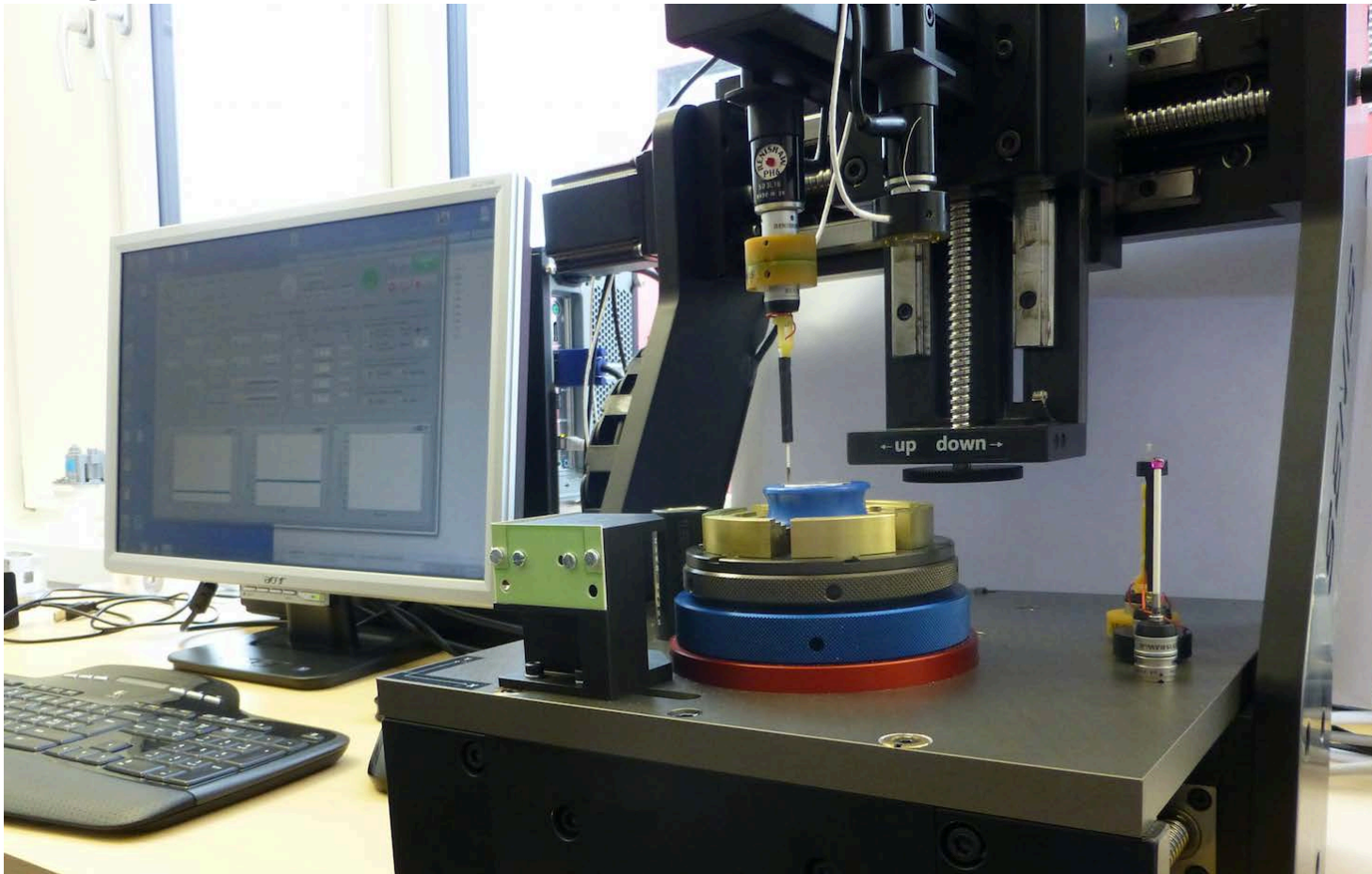
Point 1 read point
-17.242 1.603 5.557 0.044

Point 2 read point
12.078 3.668 8.839 0.044

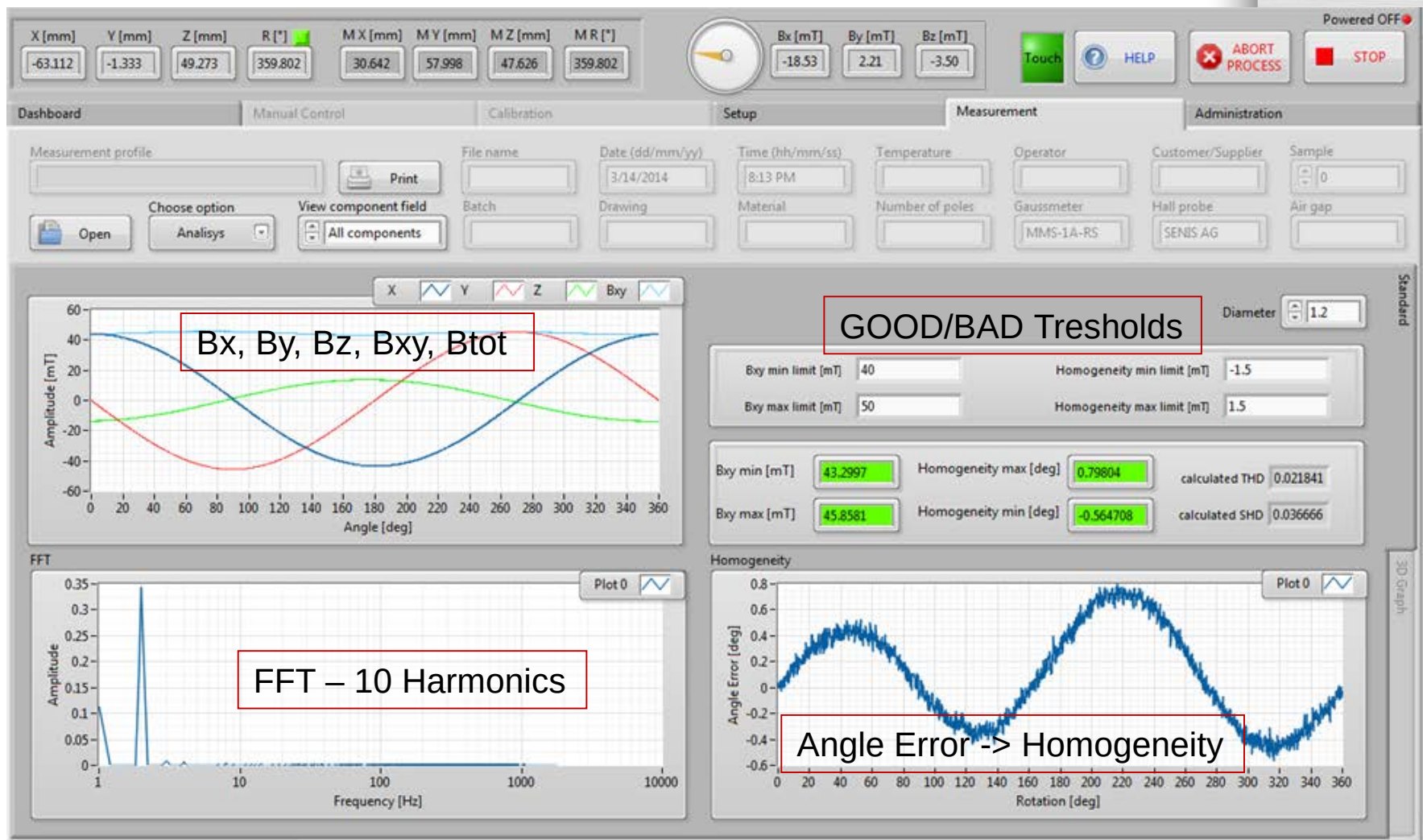
$$\Delta(x,y,z) = P2_{(x2,y2,z2)} - P1_{(x1,y1,z1)}$$

Magnetic Field Mapping

- Measurement (mapping) of the DC/AC 3-axis magnetic field around permanent magnets of all materials and geometries (ring, disc, block, etc.).

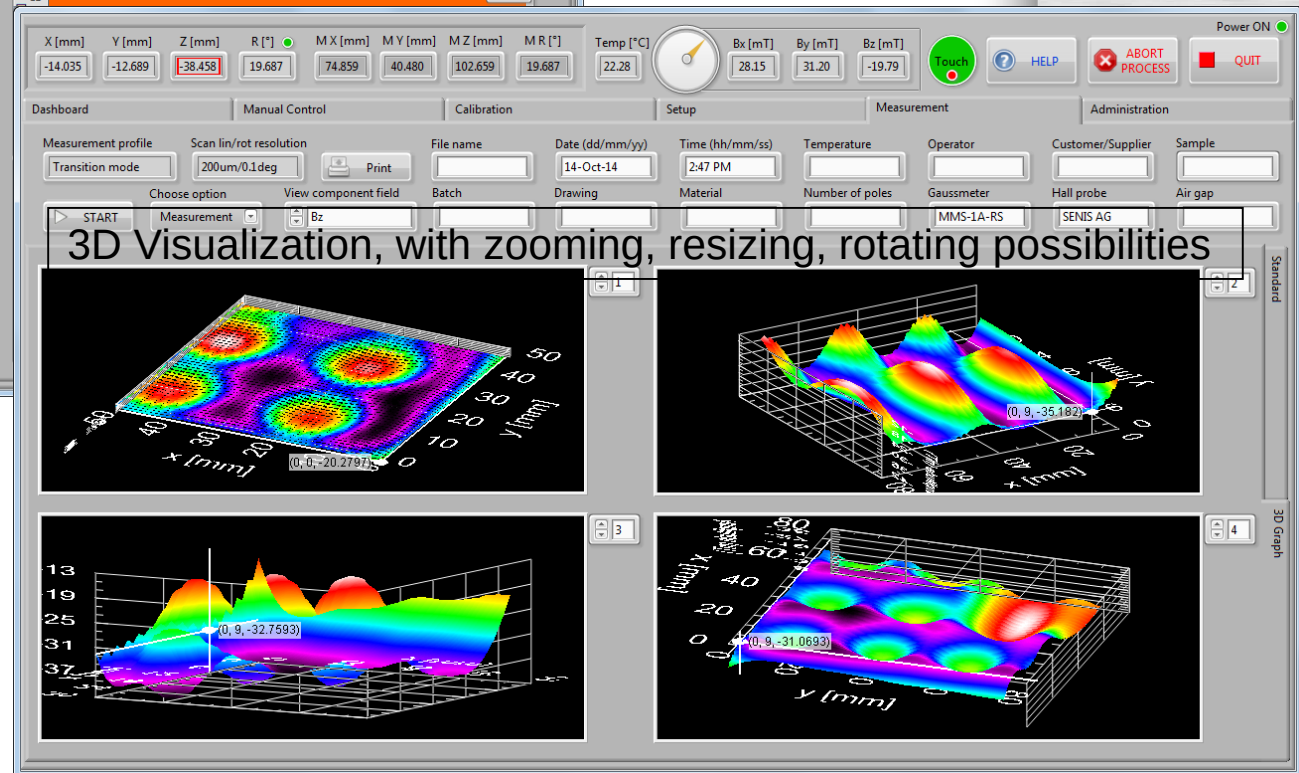
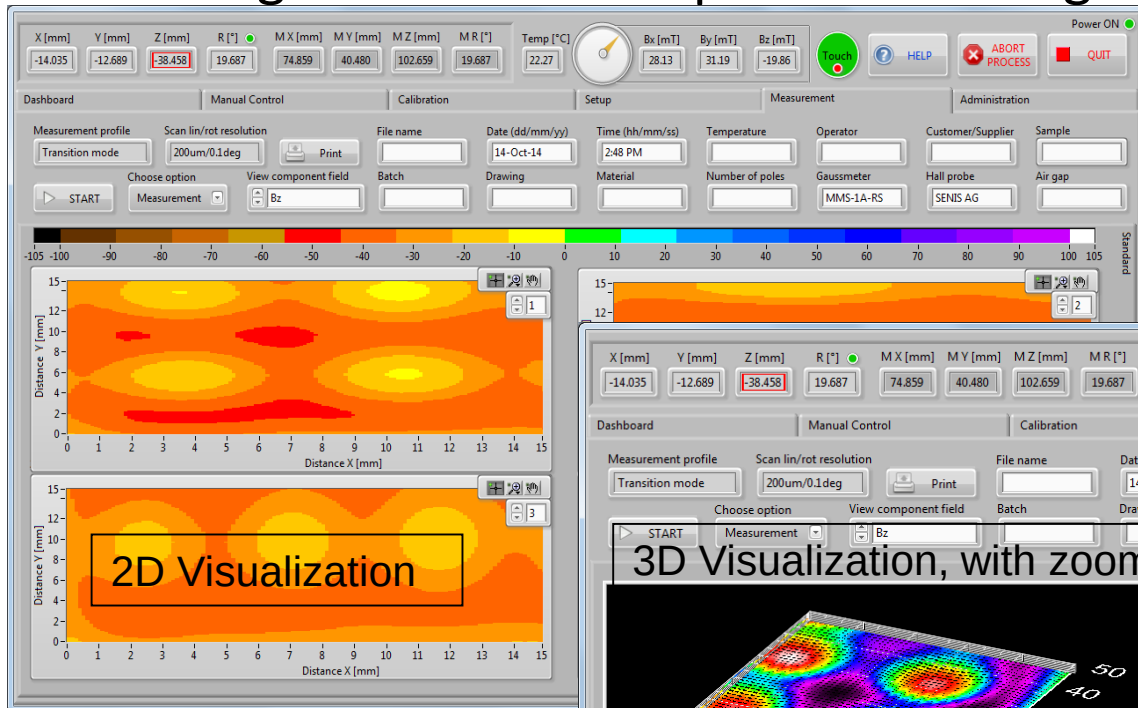


Magnetic Field Mapping



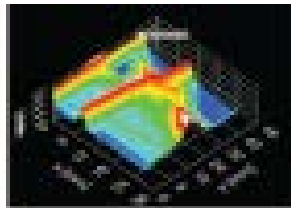
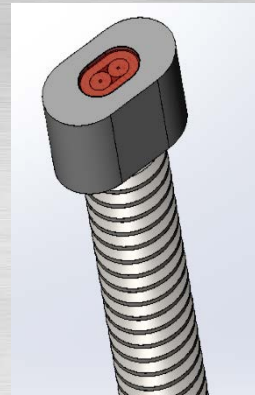
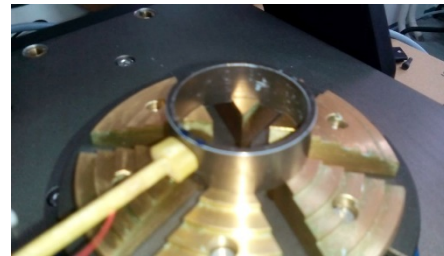
Magnetic Field Mapping

- Scanning an area around permanent magnets (disc, block)



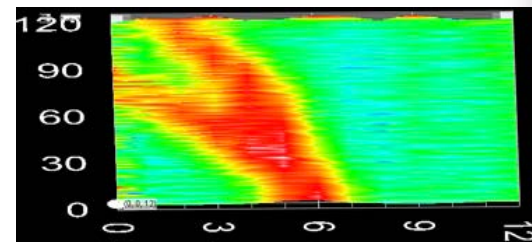
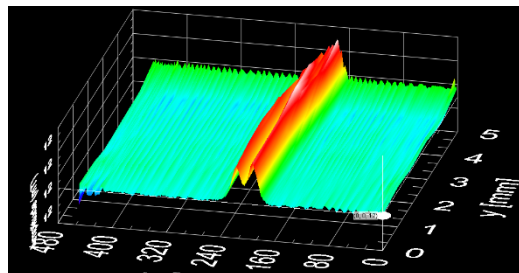
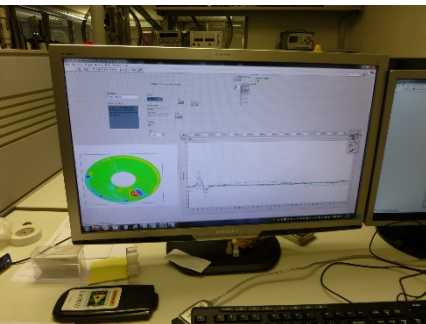
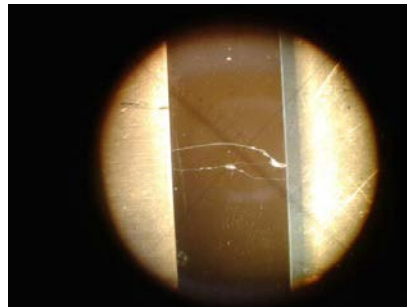
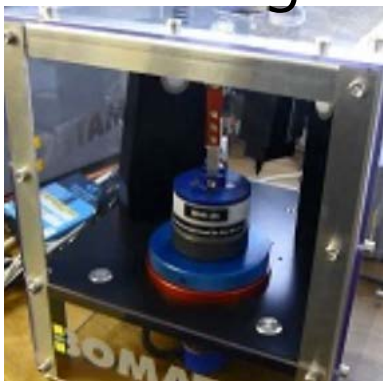
Crack & Inhomogeneity Detection

- Eddy-Current probe for cracks and inhomogeneity detection in magnetic materials and in non-magnetized parts.

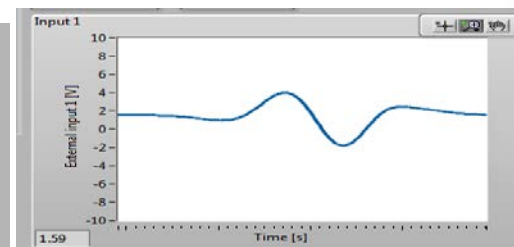
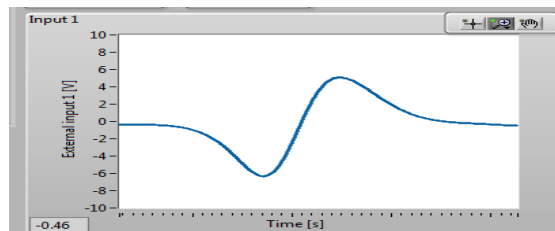
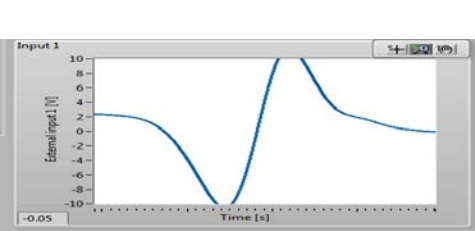


Crack & Inhomogeneity Detection

- Visible and invisible cracks (inside material or under coating)
- Inhomogeneity inside material (prior to magnetizing)



**2D & 3D
Visualization**



**Diff.-Voltage
Visualization**

Defectoscope for Crack Detection



SCANNING

Sequence started at:

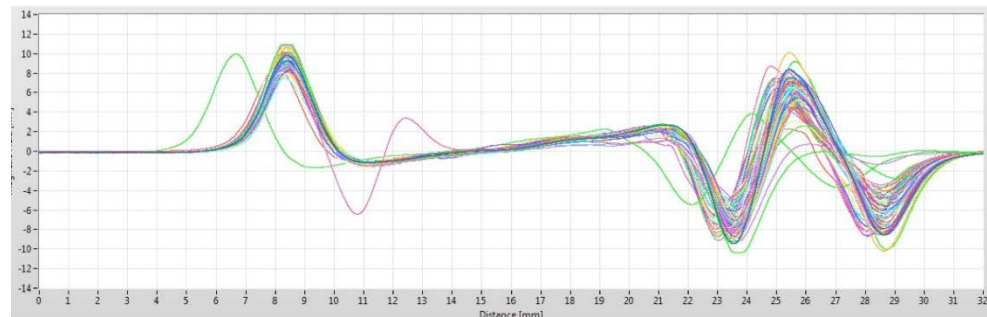
Sequence ended at:

Green Yellow Red

Good Error Bad

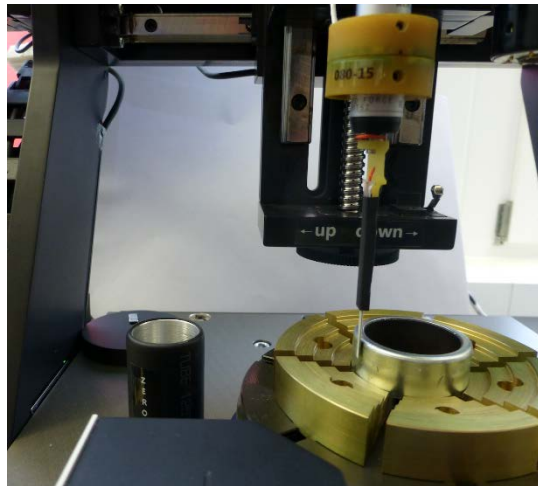
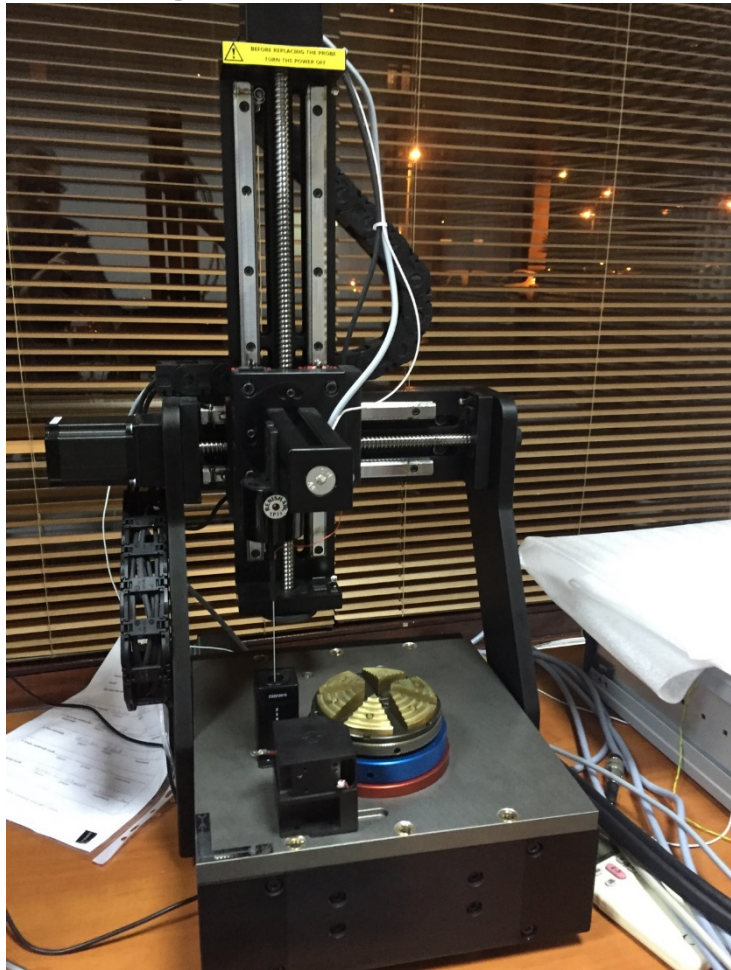
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Error Description:

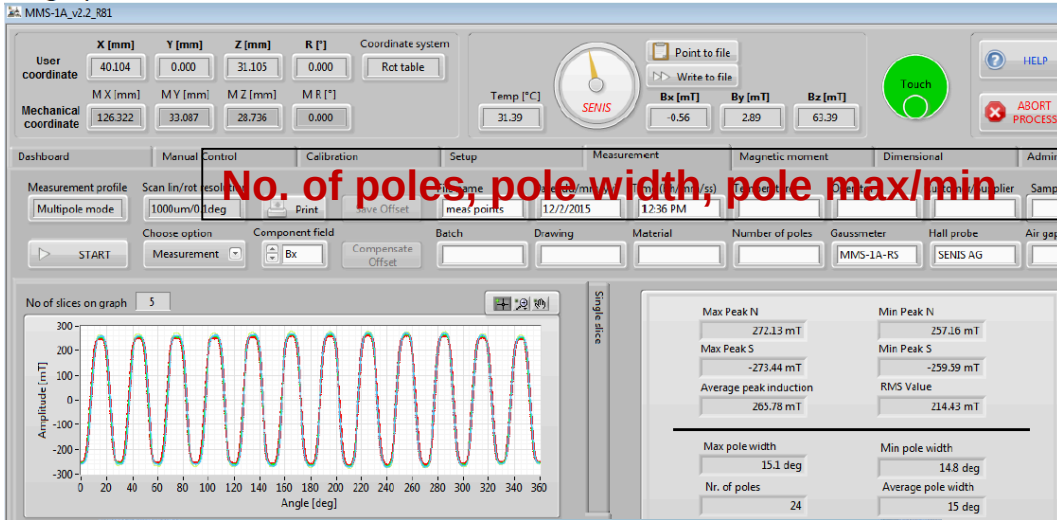


Rotor Measurements

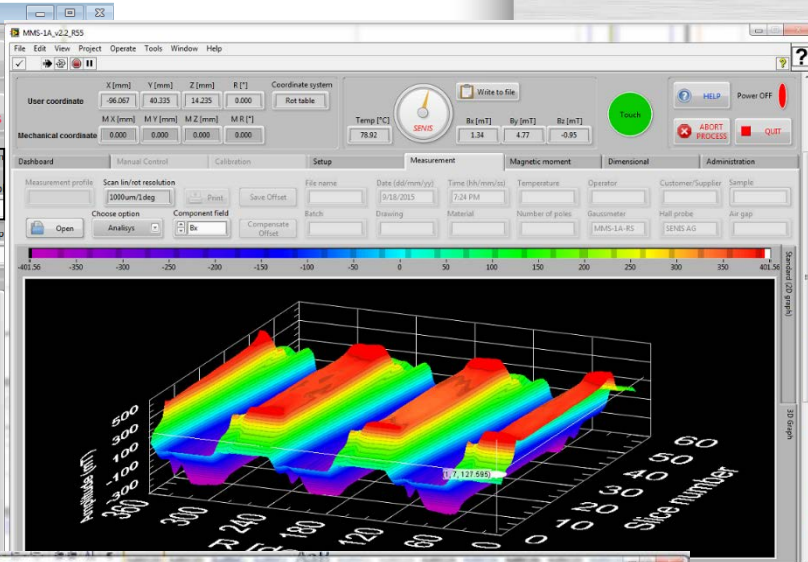
- Specialized probes with a “knee” for higher rotors or very long (90mm) and thin for air gaps of large rotors-stators



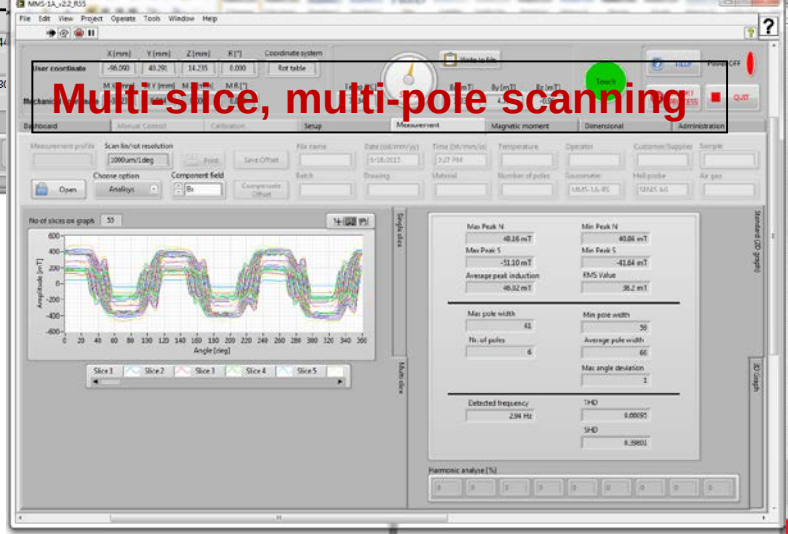
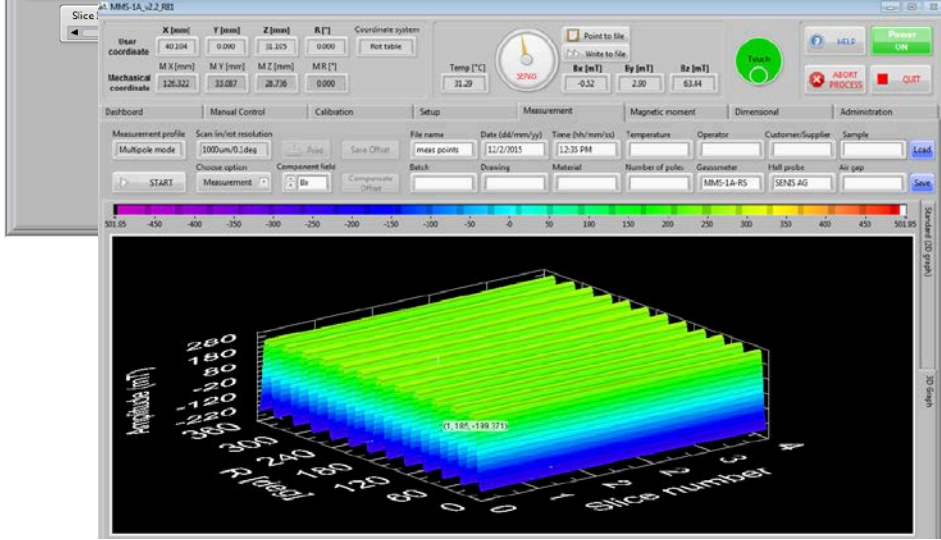
Rotor Measurements



No. of poles, pole width, pole max/min

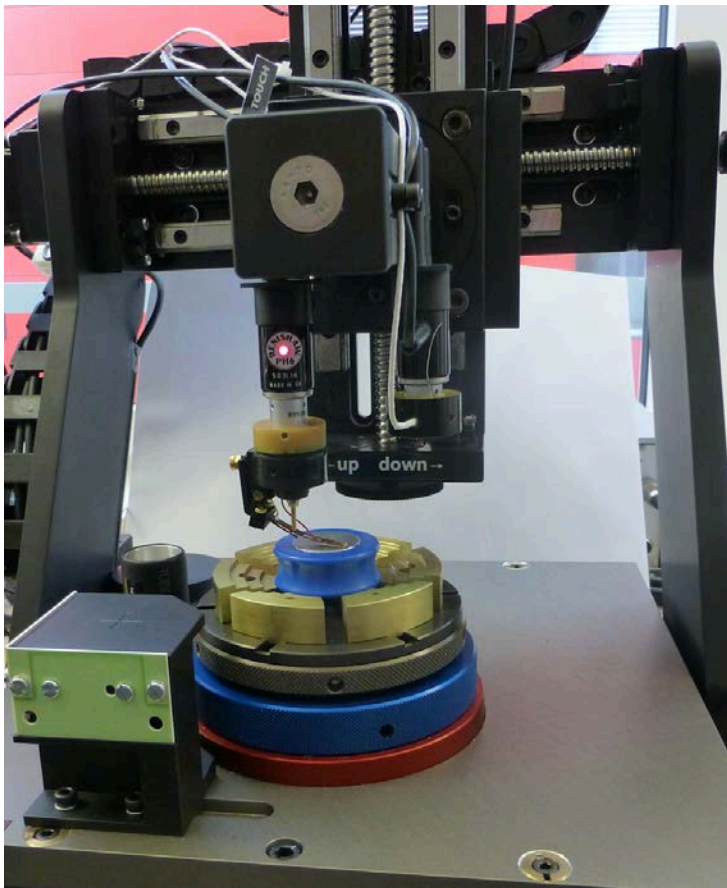


Multi-slice, multi-pole scanning

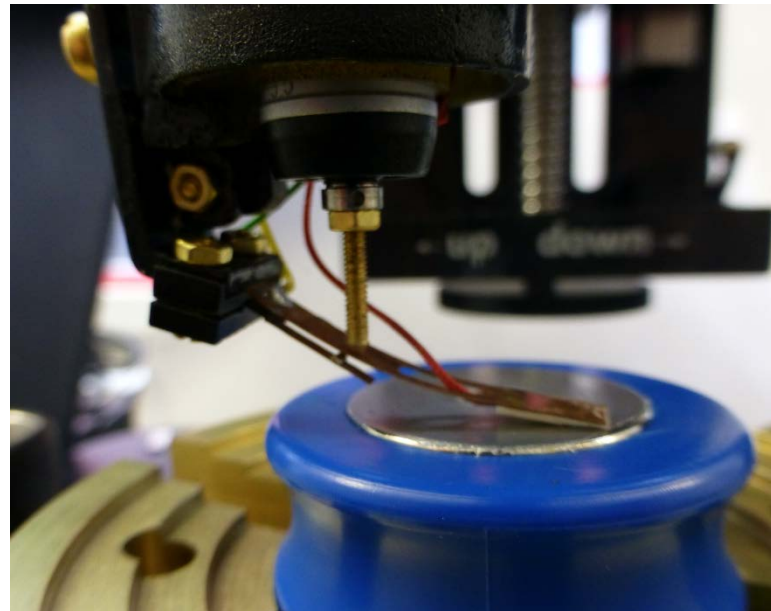


In-Contact Measurement

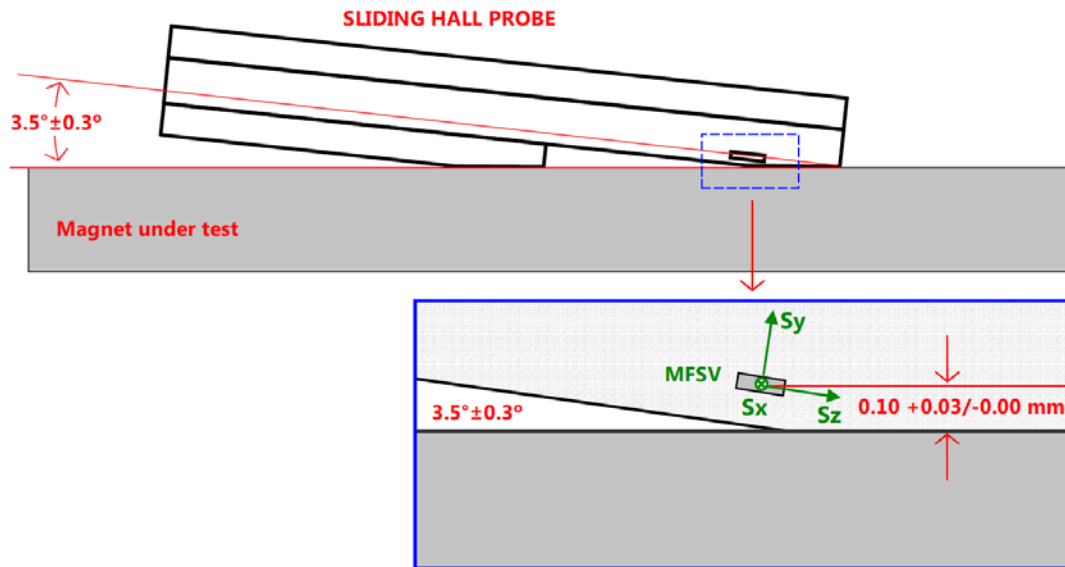
- Sliding Probe for In-Contact Measurement



1/12/2016

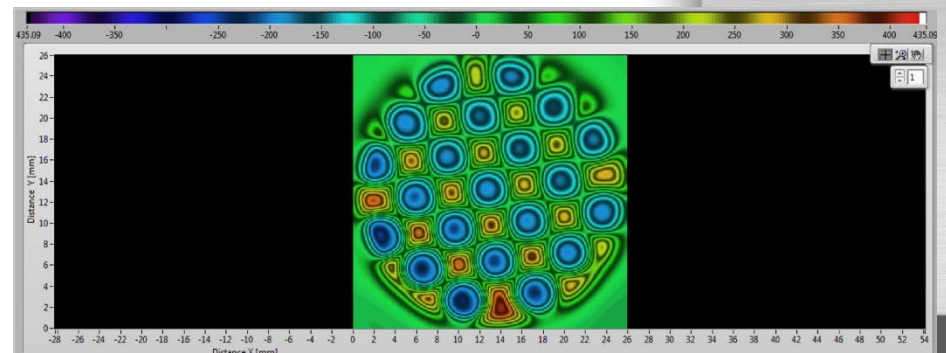
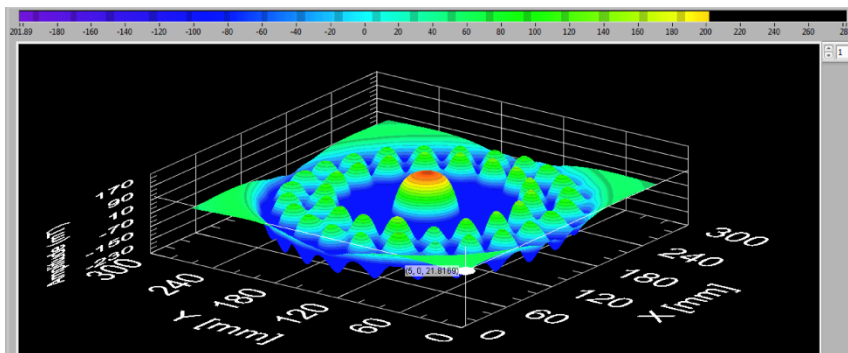
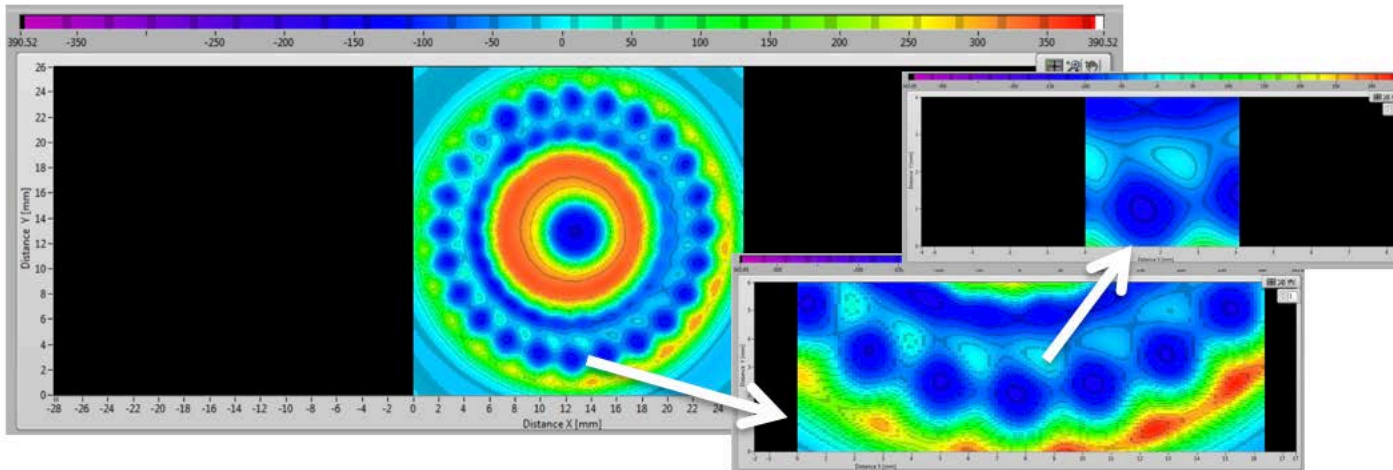


In-Contact Measurement



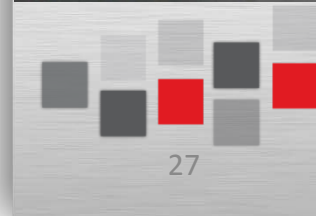
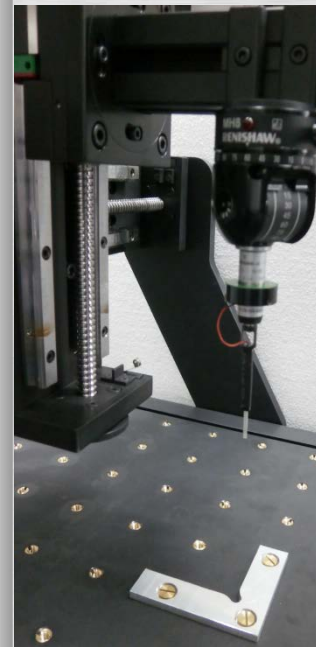
In-Contact Measurement

- Scanning of magnetic microstructures with the sliding probe



Further Developments

- RFID for automatic identification of the connected probe has already been implemented
- The mapper option “additional analog/digital inputs” allows integrating of customers own probes, such as Hall probes for comparative measurements
- Magneto-optical sensors can be integrated for quick tests and mapper for the detailed magnetic field measurement
- Magnetic arrays and cameras (probe matrix) for specialized measurements
- Integration of the manually indexing touch sensor for positioning the probe in any angle between 0° and 90° in respect to the mapper table (has been implemented)



▶▶▶ Our World Records:

the only fully integrated 3-axis Hall Probe on the market

the smallest and thinnest 3-axis Hall Probe

magnetic field transducer & teslameter

with the highest resolution

and the highest frequency bandwidth

magnetic field measurements with the highest accuracy

Thank you!

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