Hotspin 2

Implementation and testing of a new high temperature spinner magnetometer

Michael Wack

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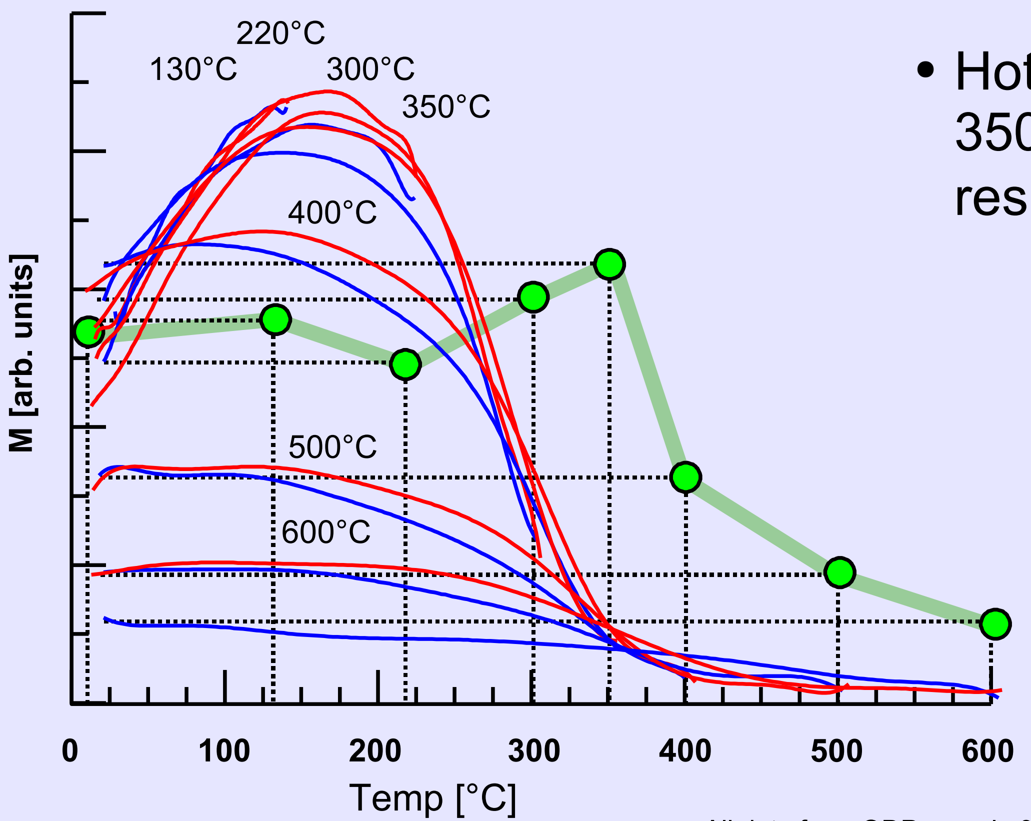
GEO LMU
Ludwig Maximilians University Munich

MichaelWack@gmx.net

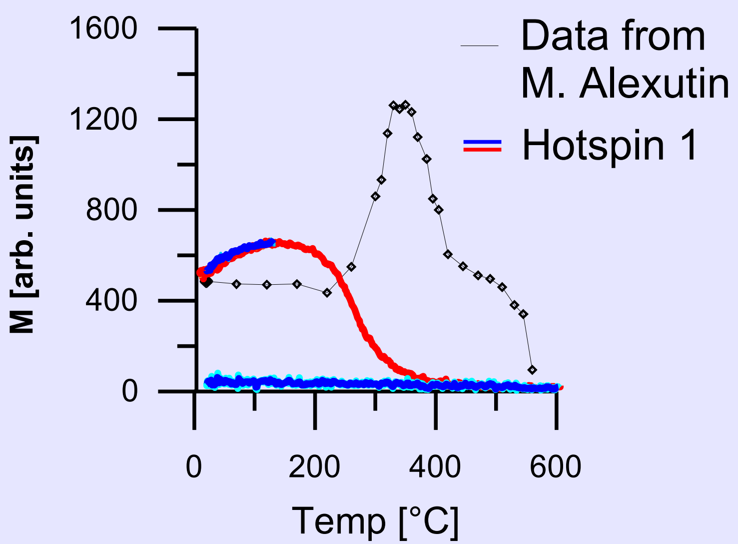
Motivation

- Most paleomagnetic data by stepwise thermal demagnetization

Heating Cooling



- Unnoticed effects in stepwise demagnetization due to alteration of magnetic minerals
- Classic interpretation: 3 components including one with magnetite
- Hotspin shows mineral unblocking at 350°C ⇒ titano-maghemite and P- resp. N-type (Neel) behavior



All data from ODP sample 9-0079-017R-01w 102-106

MichaelWack@gmx.net

Planned Features

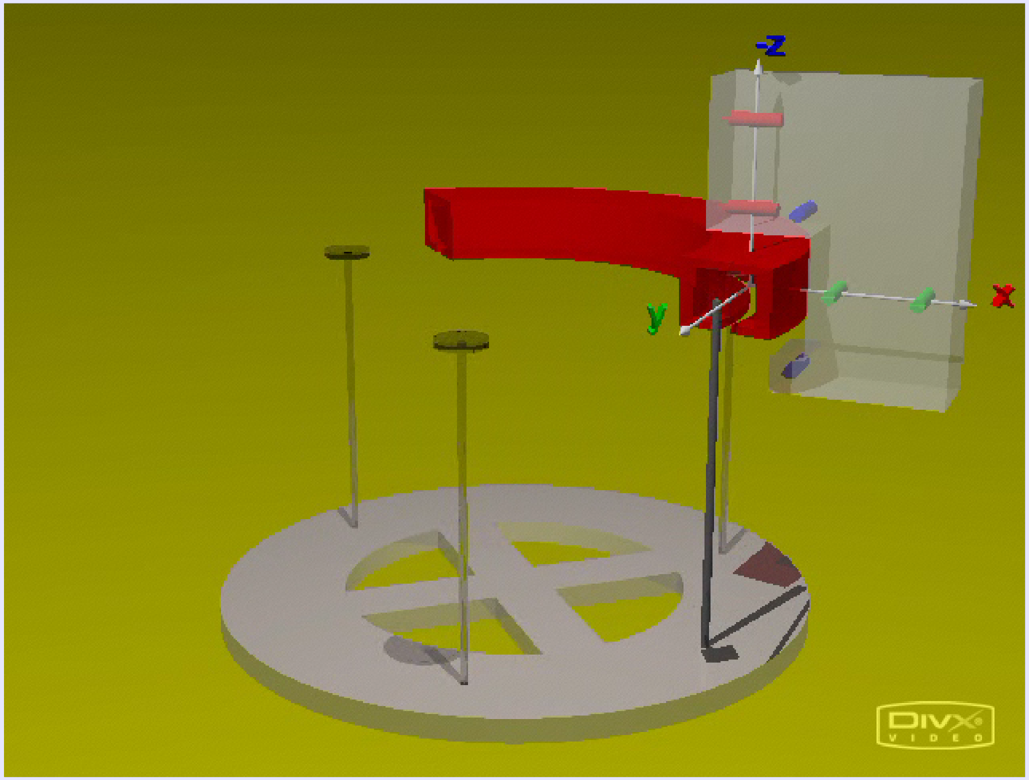
- Temperatures up to 600°C
- Full 3D vector of magnetization *
- Several specimen at once *
- Sensitivity approx. 50 mA/m
- Rotation around z-Axis
- Possibility to apply magnetic field in z-direction for experiments (TRM, palaeointensities) *
- Inch cores *
- User friendly software, sophisticated analysis functions *

* Improvement over Hotspin 1

MichaelWack@gmx.net

Principles of Operation

- Off-axis spinner magnetometer
- Specimens and temperature sensor moving on circular (R=15cm) path
- Oven is also circular
- Fluxgate sensors (2 for each direction in space – differential measurement eliminates errors due to background fields)
- External field compensated by Helmholtz coils



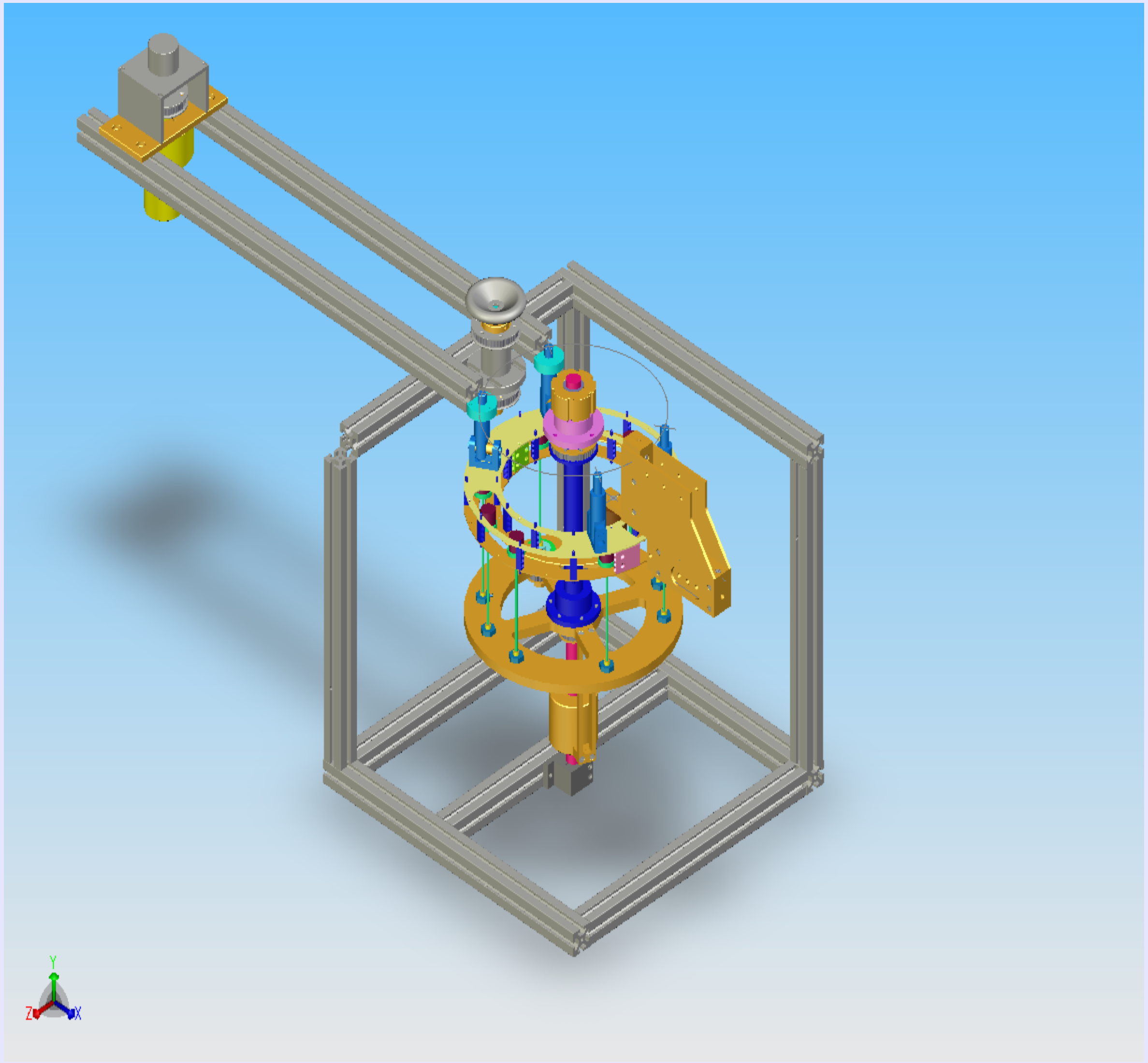
Off-axis vs. normal spinner magnetometer

	Normal spinner	**Off-axis spinner**
Expected signals at sensor	Sinusoidal	Similar to those measured over magnetic anomalies in the subsurface
Data interpretation	Phase and amplitude correspond to the direction and the intensity of the magnetic moment.	Functions calculated from the dipole formula (see later) must be fitted to the measured curves. The determined coefficients are the sought-after components of the magnetic moment.

MichaelWack@gmx.net

Setup

- Built of non-magnetic materials
- All electrical powered stuff away from samples and sensors
- Heating by hot air (details later)
- Fluxgate sensors (geometrical details later)
- Low pass filter to reduce 50Hz and tram noise



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Heat Gun

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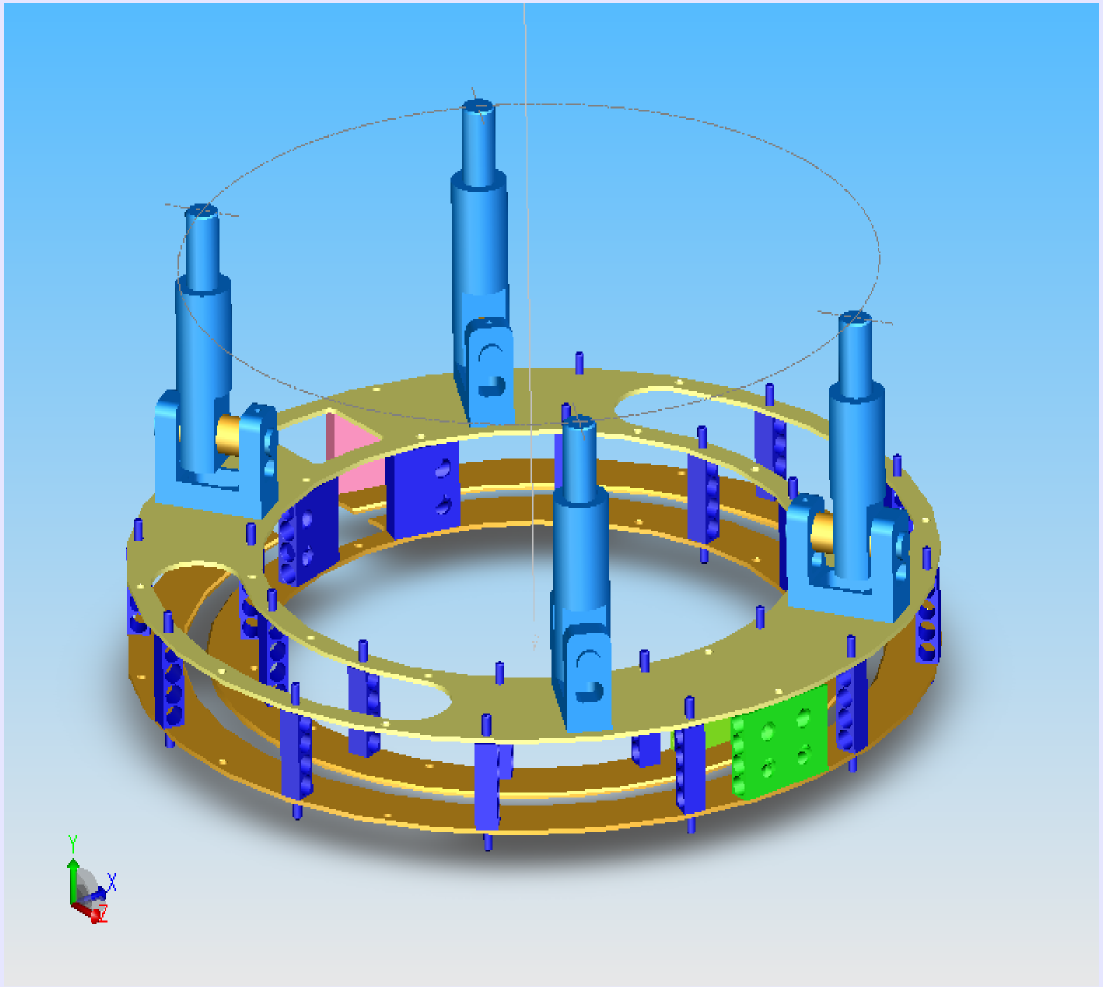
Heating Ring

- Hot air runs through copper pipes on the in- and outside of the ring
- Samples are primarily heated through radiation
- Good temperature dispersion (copper is a good conductor of heat)
- No magnetic effects
- No dangerous voltage



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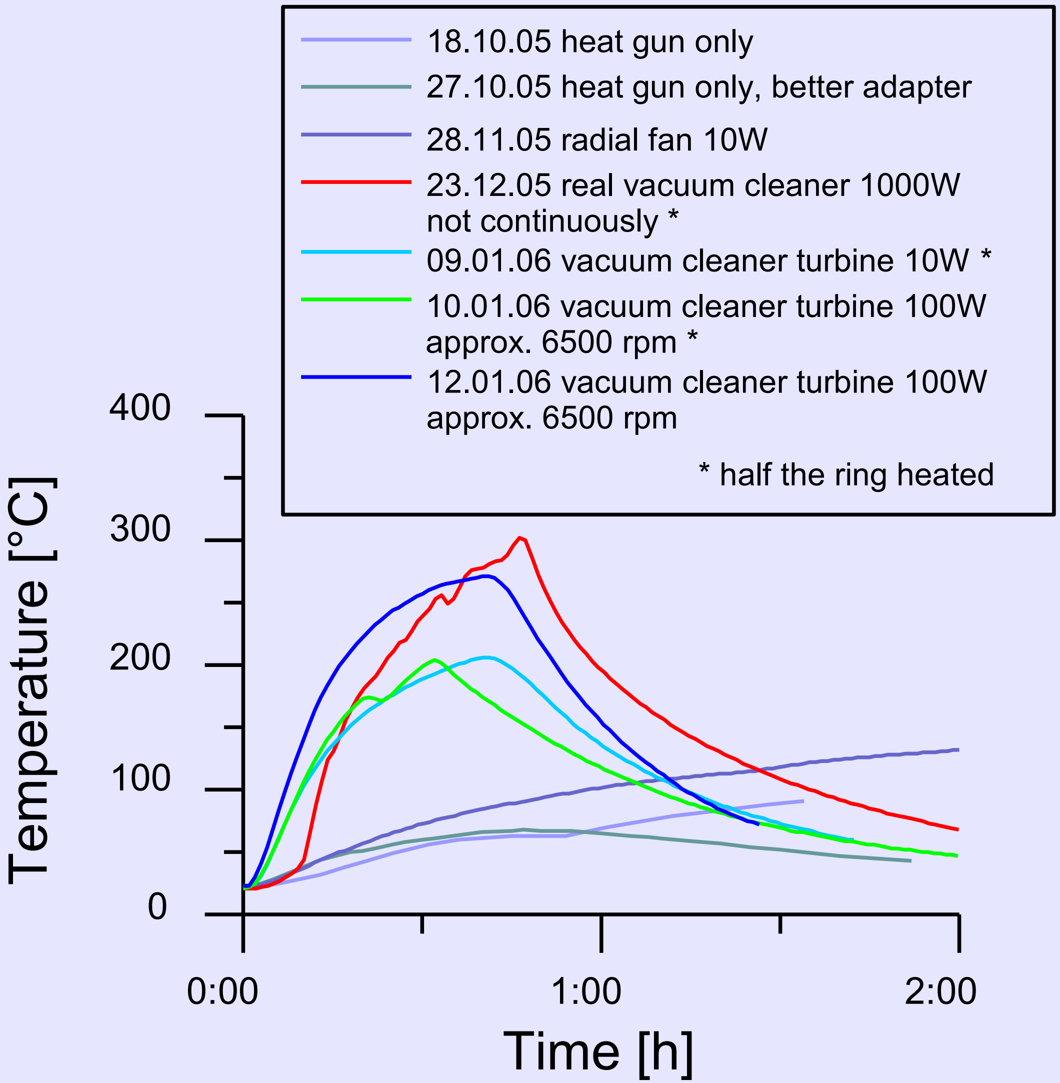
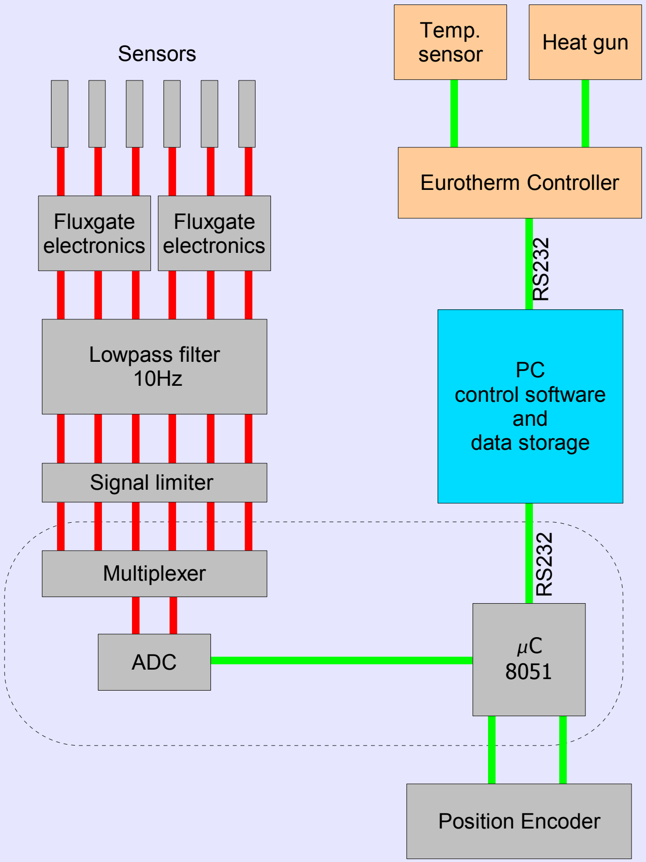
Heating Curves



- Heat accumulation directly behind the heat gun due to large flow resistance in the ring ⇒ improve air flow ⇒ draw air out of the ring
- Test with vacuum cleaner produced very promising results
- Vacuum cleaner turbine was modified for hot air
- Heating the whole ring produces higher temperatures than heating a half ⇒ power of heat gun is not the problem
- Next try will be the vacuum cleaner turbine with 500W, 13500 rpm

MichaelWack@gmx.net

Electronics



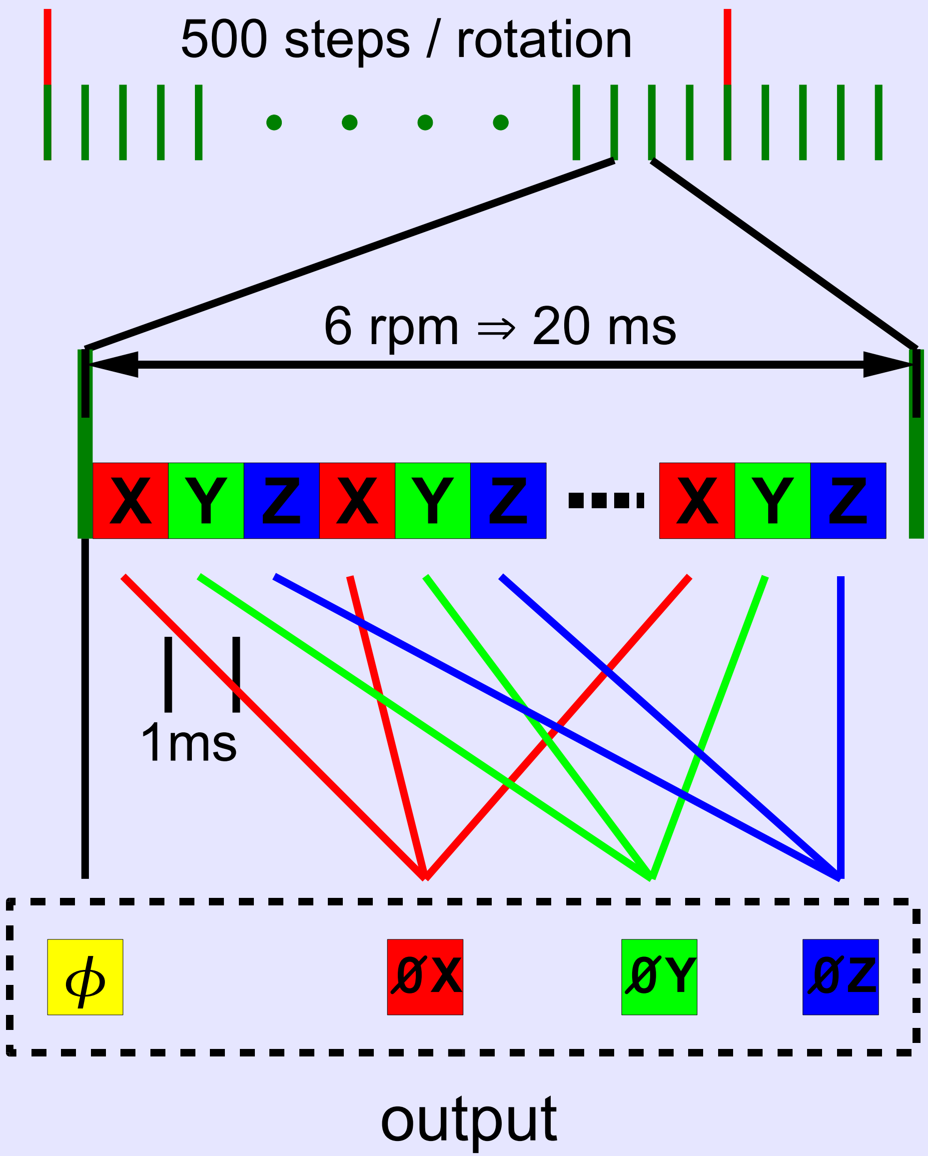
- Simple lowpass filter will be replace by 5th order filter with special purpose ICs (MAX280)
- Signal limiter to +-2.5V to protect the Analog Digital Converter (ADC)
- Other devices are operated manually (Helmholtz coils, actuation, exhaustion)

Microcontroller Board

- Compact unit including ADC (differential, 24 bit) and Multiplexer from Silicon Laboratories
- 8051 Compatible @ 24.5 MHz
- RS232 interface for programming and data exchange
- Program written in C

- What does it do?
  - Decodes encoder signals to get the sample position
  - Controls ADC (3 differential signals are sampled in alternating timeslices during each 1/500 rotation; see next slide)
  - Output: differential sensor signals and an absoute position via RS232

ADC Operation



- Number of samples per step depends on the rotational speed
- Best usage of time available for sampling data
- Best temporal average
- Noise reduction

MichaelWack@gmx.net

Mathematical Basis

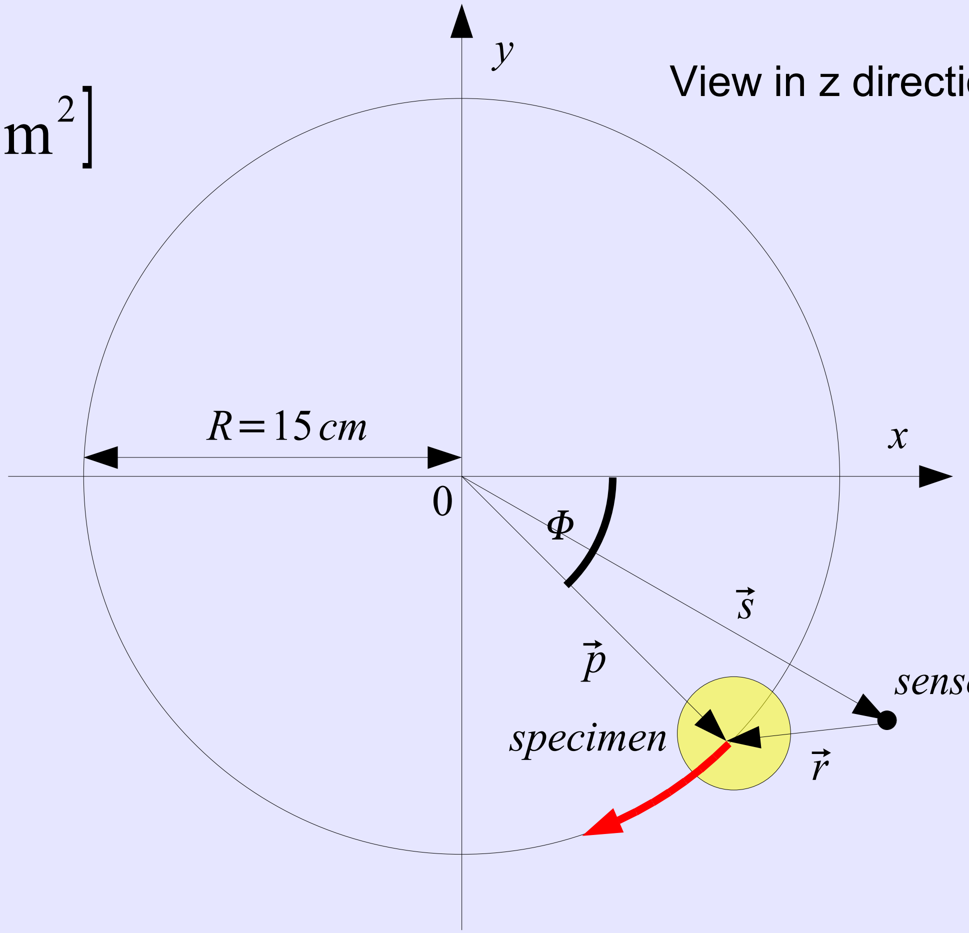
$$\vec{B}(\vec{r}) = \frac{3\vec{r}(\vec{r}\cdot\vec{m}) - \vec{m}r^2}{r^5}\left[10^7\,\mathrm{T}\right]$$ *

$\vec{m}$ = magnetic dipole moment $\left[\mathrm{A\,m^2}\right]$

$$\vec{r} = \vec{s} - \vec{p} = \begin{pmatrix} r_x \\ r_y \\ r_z \end{pmatrix} = \begin{pmatrix} s_x - R\cdot\cos\Phi \\ s_y - R\cdot\sin\Phi \\ s_z \end{pmatrix}$$

Magnetization $\vec{M} = \frac{\vec{m}}{V}\left[\frac{\mathrm{A}}{\mathrm{m}}\right]$

Coordinate system



* Reference: Fließbach, Elektrodynamik, 2000

MichaelWack@gmx.net

More Mathematics

$$\vec{B}(\vec{s},\Phi)=\breve{I}\cdot\vec{m}=\frac{1}{r^5}\begin{pmatrix}2r_x^2-r_y^2-r_z^2 & 3r_xr_y & 3r_xr_z\\ 3r_yr_x & 2r_y^2-r_x^2-r_z^2 & 3r_yr_z\\ 3r_zr_x & 3r_zr_y & 2r_z^2-r_x^2-r_y^2\end{pmatrix}\cdot\begin{pmatrix}m_x\\ m_y\\ m_z\end{pmatrix}$$

Column: magnetization component
Row: mounting direction

e.g. I_{Zy} Intensity of magnetization in y-direction measured by a sensor mounted in z-direction

Expected signal from a sensor mounted in x-direction located at s:

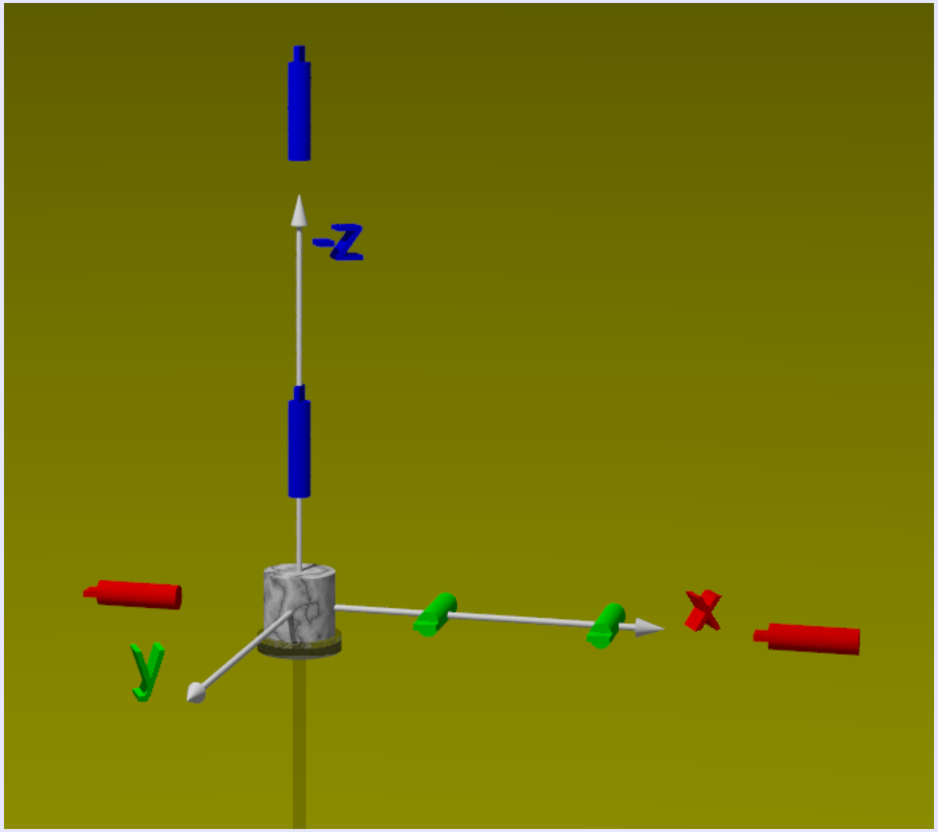
$$\vec{B}_x(\vec{s},\Phi)=I_{Xx}m_x+I_{Xy}m_y+I_{Xz}m_z=\frac{1}{r^5}\left((2r_x^2-r_y^2-r_z^2)m_x+3r_xr_ym_y+3r_xr_zm_z\right)$$

y and z analog

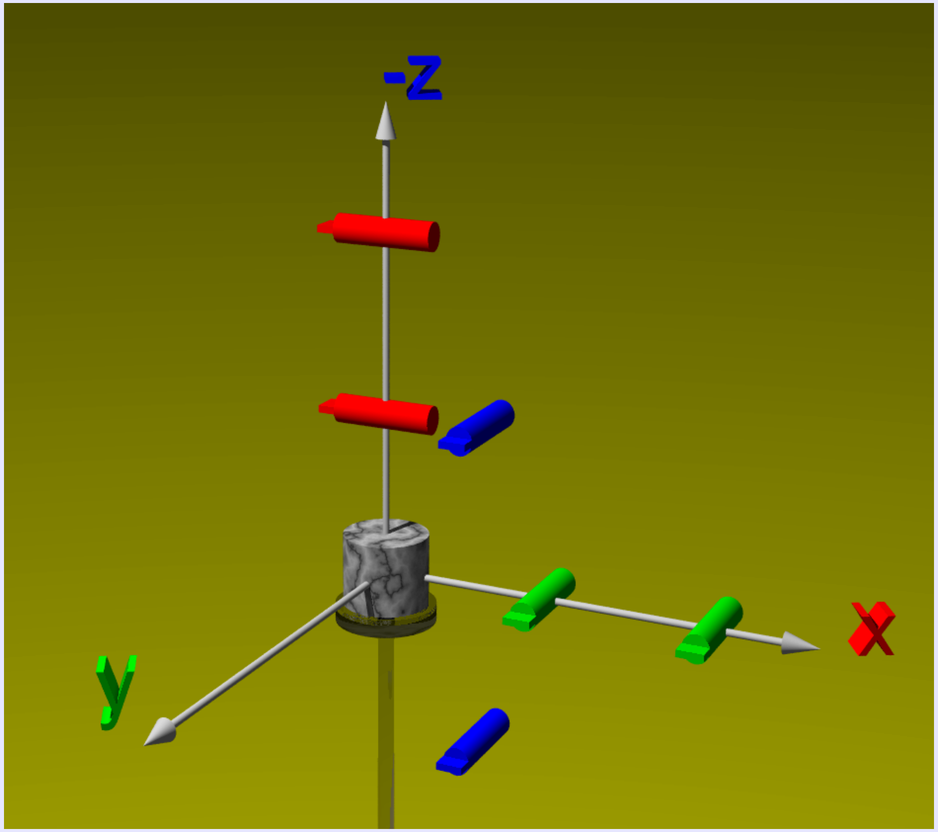
MichaelWack@gmx.net

Optimized Sensor Arrangement

New arrangement is mechanical more easily to buid and delivers better data.



old arrangement



new arrangement

MichaelWack@gmx.net

Optimized Sensor Positions

- Desirable
  - Big signal amplitude
  - Good seperation of magnetization components
  - Small distance between differential sensors, because of inhomogeneous background field variations
- Problem: many degrees of freedom (position in space, orientation, combination with second sensor)

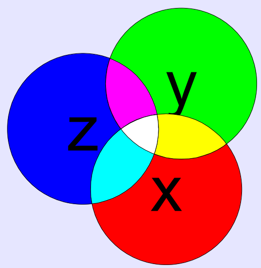
MichaelWack@gmx.net

Optimized Sensor Positions

- Simplifications:
  - Sensor orientation parallel to the principal axes
  - Sensors arranged in one plane (orthogonal to the path of specimen)
  - Sensors as close as possible to specimen
- For a given sensor position s one can calculate the amplitudes of the $I_{ij}(\Phi)$.
  - Amplitude($I_{ij}(\Phi)$) = max($I_{ij}(\Phi)$) - min($I_{ij}(\Phi)$) = A_{ij}

MichaelWack@gmx.net

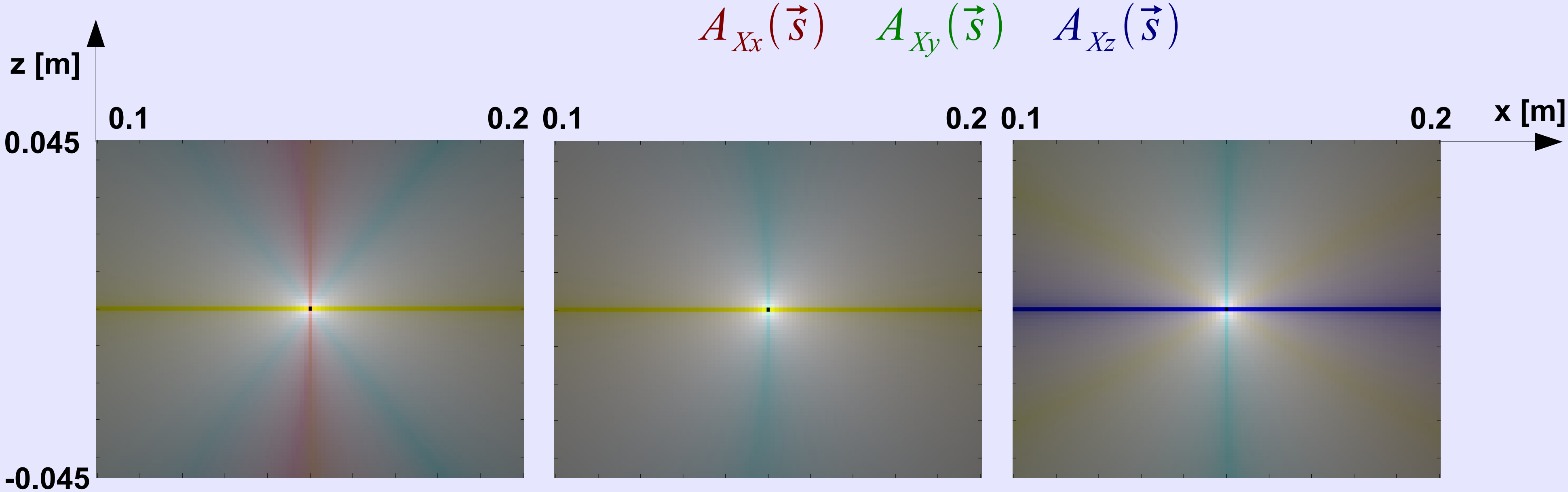
RGB amplitude plots



A RGB-Color representing sensitivity to the different magnetization components can be assigned to each sensor position.
There is no position to measure x or y separately.

e.g.: Color values for sensor mounted in X direction (left plot):

$A_{Xx}(\vec{s})$ $A_{Xy}(\vec{s})$ $A_{Xz}(\vec{s})$



X Y Z

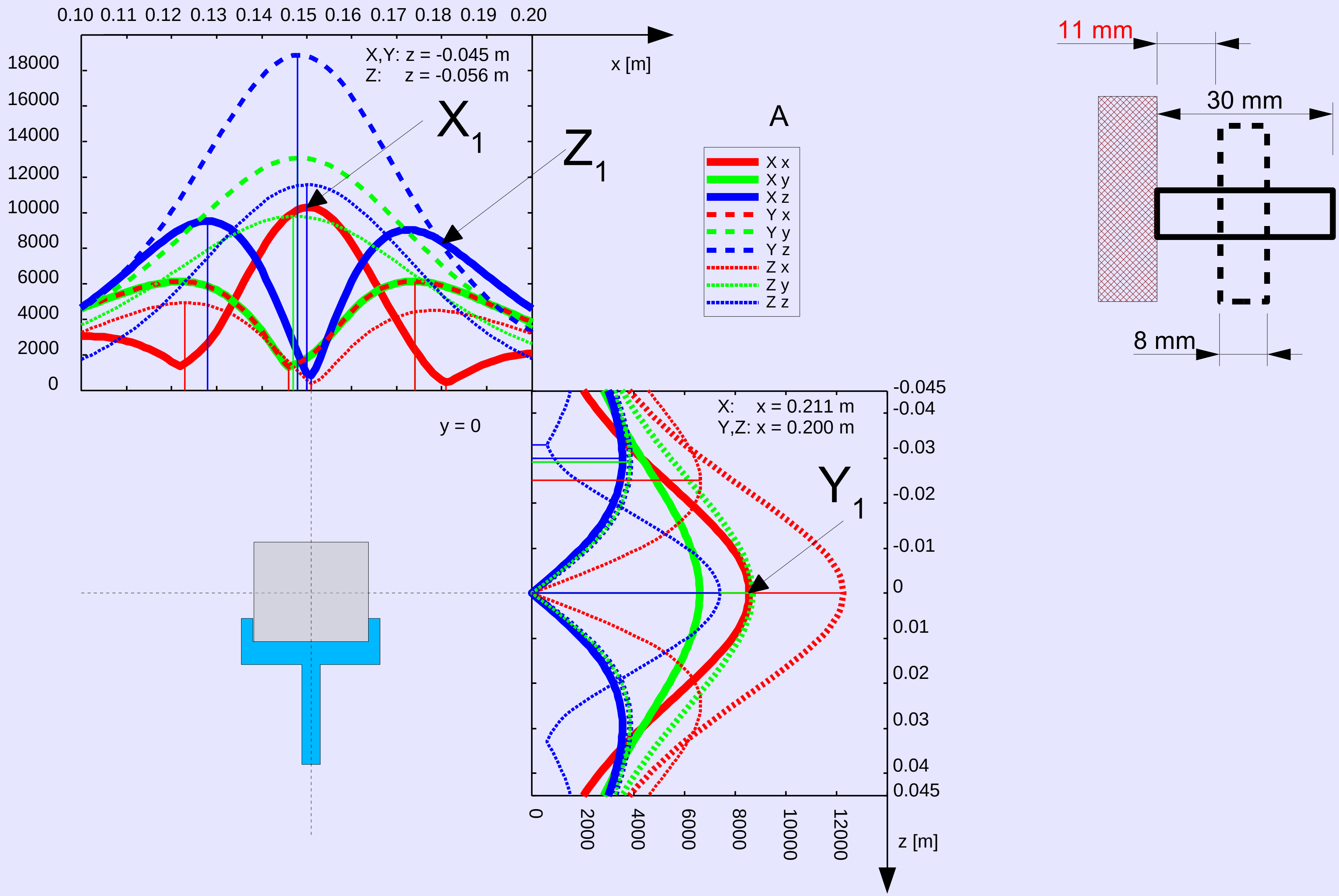
Sensor mounting direction

Color values are scaled logarithmic because of $1/r^3$ law

MichaelWack@gmx.net

Sensor geometry

signal amplitudes of single sensors

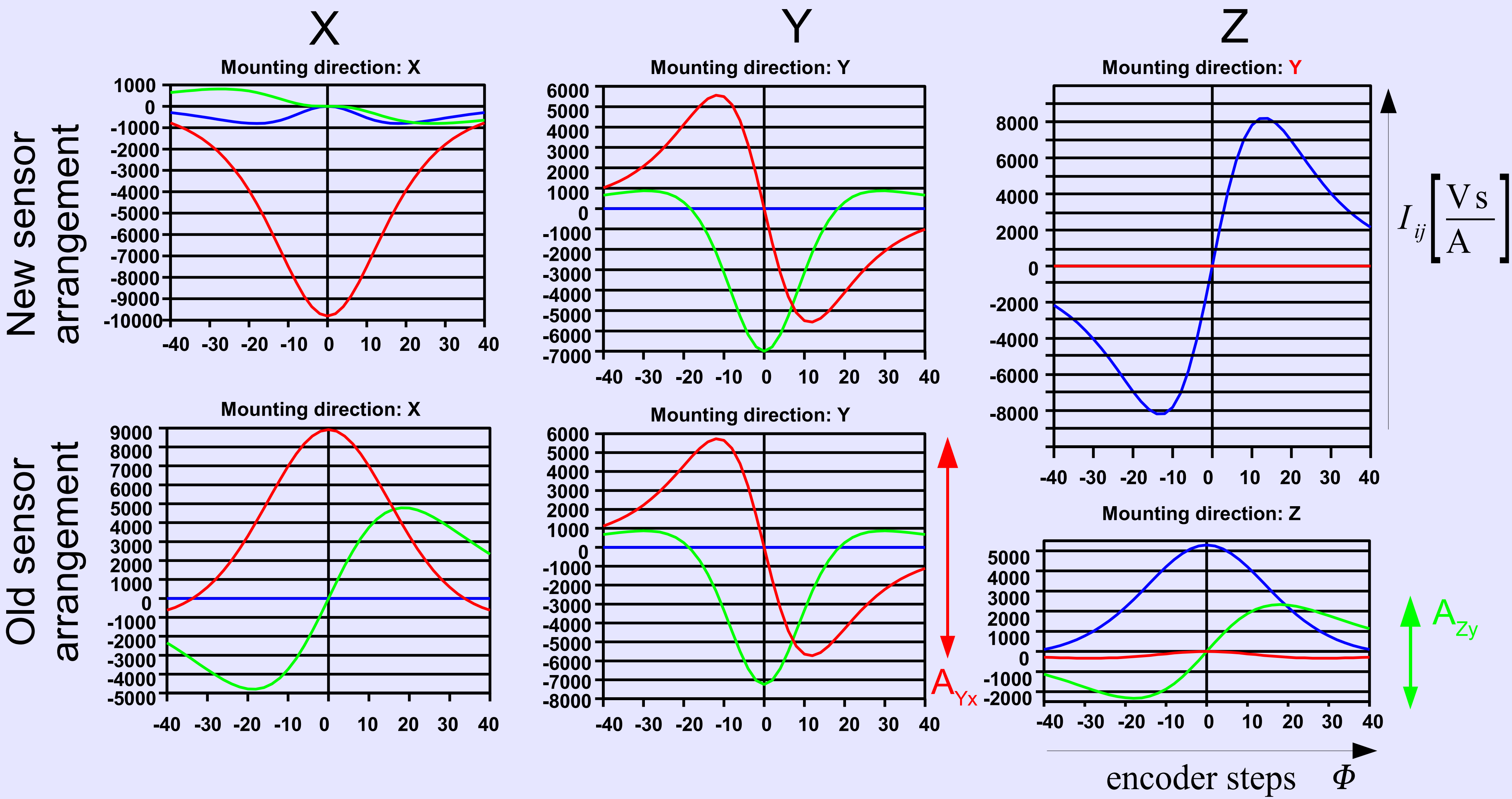


MichaelWack@gmx.net

Old vs. New Sensor Arrangement

differential signals of two sensors

- x component of magnetic moment (red)
- y component of magnetic moment (green)
- z component of magnetic moment (blue)



MichaelWack@gmx.net

Software

- Made with Labview
- Keep all raw data
- Post stacking
- Classic plots (Zijderveld, Stereo, Decay)
- Automatic data selection to eliminate disturbed signals (tram, machines in the workshop)
- Programmable temperature ramps and ranges

MichaelWack@gmx.net

Look yourself ...

... now in the basement.

Room K01

one door left of the VFTB

MichaelWack@gmx.net