



# ***MAGNETIC SCALES FOR LINEAR AND ANGULAR POSITION MEASUREMENT SYSTEMS***

**MICHAEL ORTNER**

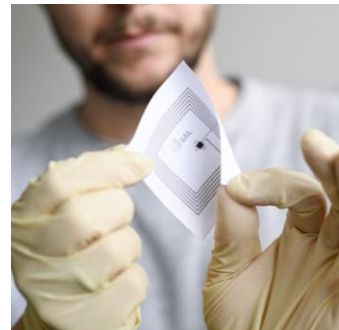
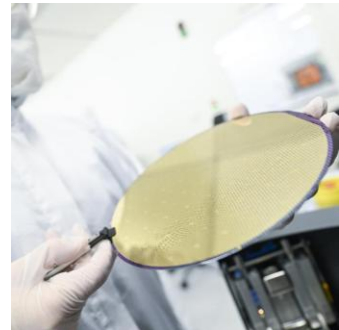
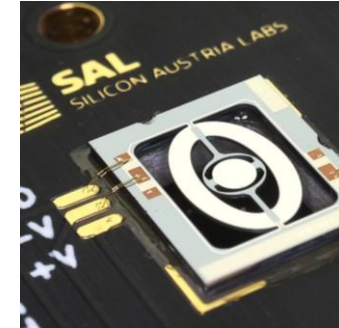
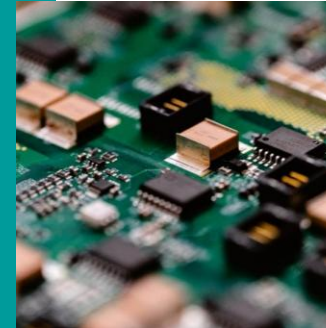
michael.ortner@silicon-austria.com,  
Jena, 16.09.2026

# SILICON AUSTRIA LABS

What do we do?



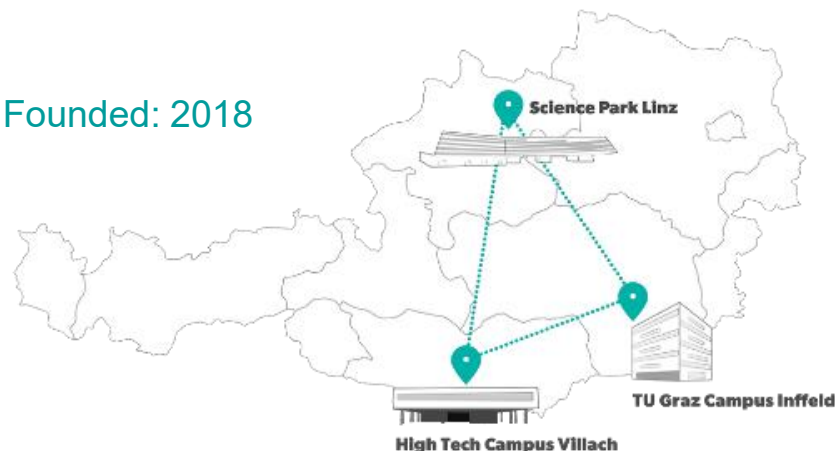
Silicon Austria Labs (SAL) is an **industry-oriented research** center with a focus on the development of efficient, sustainable and trustworthy technologies in the field of electronics & Software based systems (ESBS).



# KEY FACTS

Who we are\*

Founded: 2018



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## LOCATIONS

- Graz (HQ)
- Villach
- Linz



> 115

## PARTNER NETWORK

- From Industry & Research



5

## SHAREHOLDER

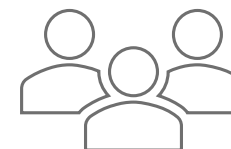
- 50,1 % Republic of Austria (BMK)
- 24,95 % FEEI
- 10 % Styria (SFG)
- 10 % State of Carinthia
- 4,95 % Upper Austria (UAR)



176

## PUBLICATIONS

- Peer-reviewed

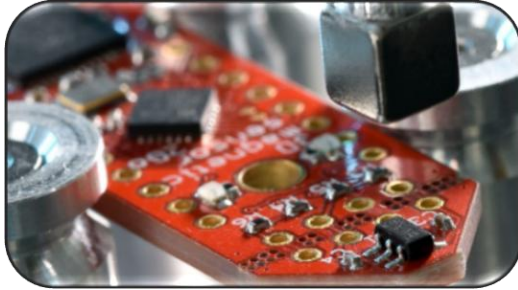


>400

## EXPERTS

- Experienced team
- 40 nations
- Multidisciplinary

# MAGNETIC MICROSYSTEM TECHNOLOGIES

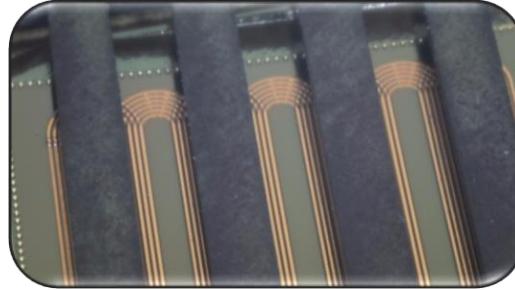


## Magnetic Sensor Systems

Magnetic Encoder

Magnetic Position Systems

Magnetic Sensors and Scales

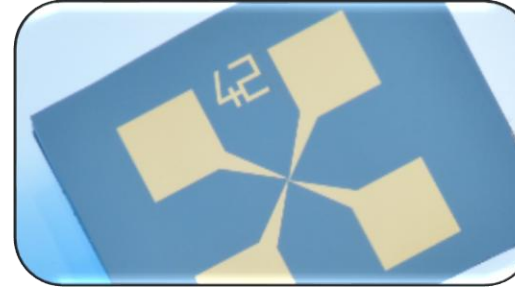


## Magnetic MEMS

Integrated Micro-Magnets

Micro-Actuators & Transducers

Spintronic MEMS

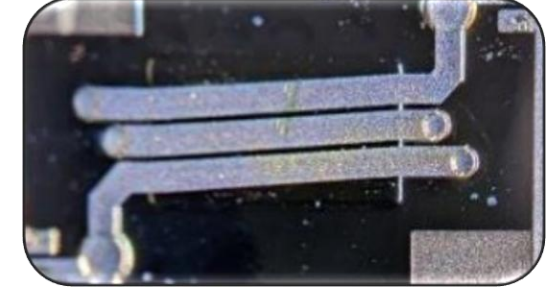


## Thin-Film Devices

XMR-Sensors

MTJ & Spintronic Components

ME-Devices



## RF Components

Micro-Circulators

Isolators, Filters, Resonators

5G/6G Communication

Theory and Computational Magnetism

Magnetic Simulation

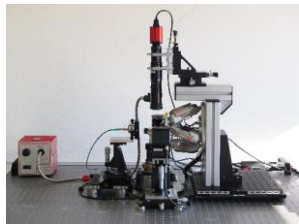
Lab Testing and Characterization

Microsystems and Microfabrication

Magnetic Lab

Magnetic Platform

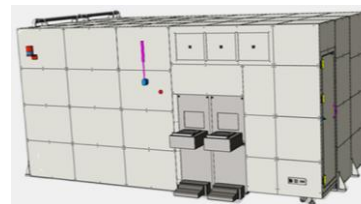
Cleanroom



**Polewheel Scanner**



**12-Target 8"/12" Magnetic Cluster Sputter Tool**



**8" Magnetic Annealing**



**12" Automated Magnetic Wafer Prober**



**200 mm Pilot Line Capabilities**

# MAGNETIC POSITION SYSTEMS

- In a **magnetic position system**, a permanent magnet moves relative to a magnetic sensor. From the modulation of the sensor output the mechanical motion can be inferred.
- Such systems are **commonly used** for position, angle, speed, and motion sensing in automotive, industrial, and consumer applications.
- The main **advantages** are precise, cost-efficient, robust, contactless position sensing and reliable operation in harsh environments.
- Today there is a steadily **increasing demand** for magnetic position systems. In 2023 > 1/3rd of the worlds magnetic sensors would go to position sensing (YOLE).

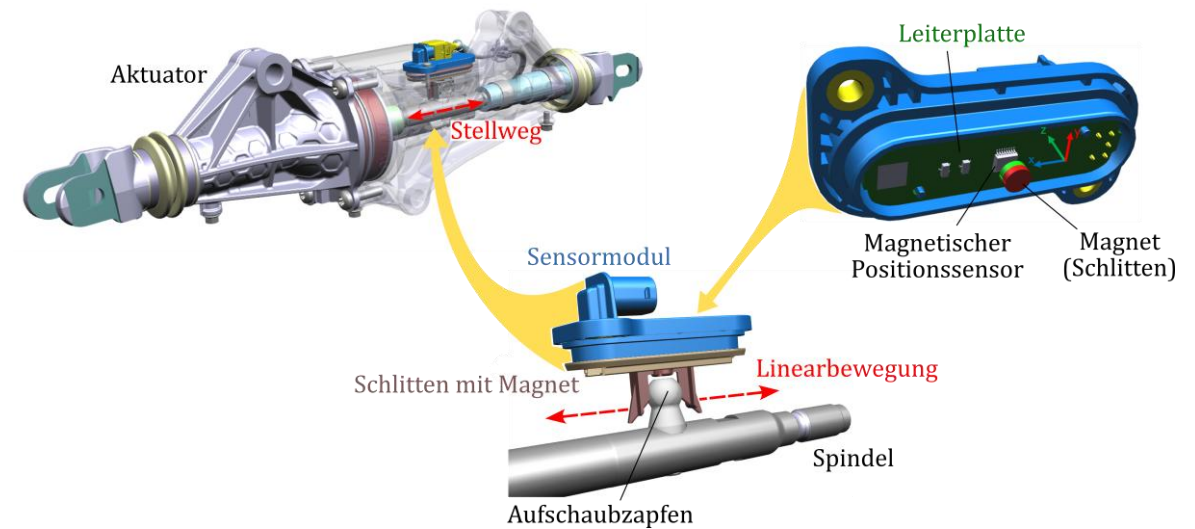


Image: Linear Position detection in a rear-axle steering system , © ZF Friedrichshafen AG

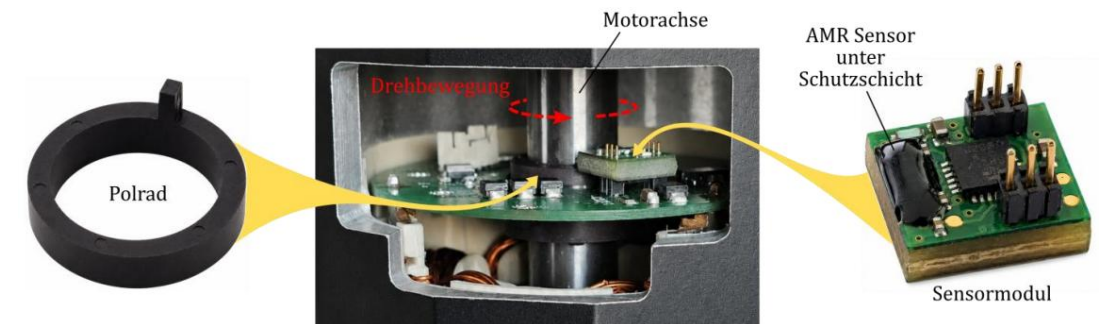


Image: Angular position detection in an E-motor, © Sensitec GmbH

# MAGNETIC MEASUREMENT SCALES

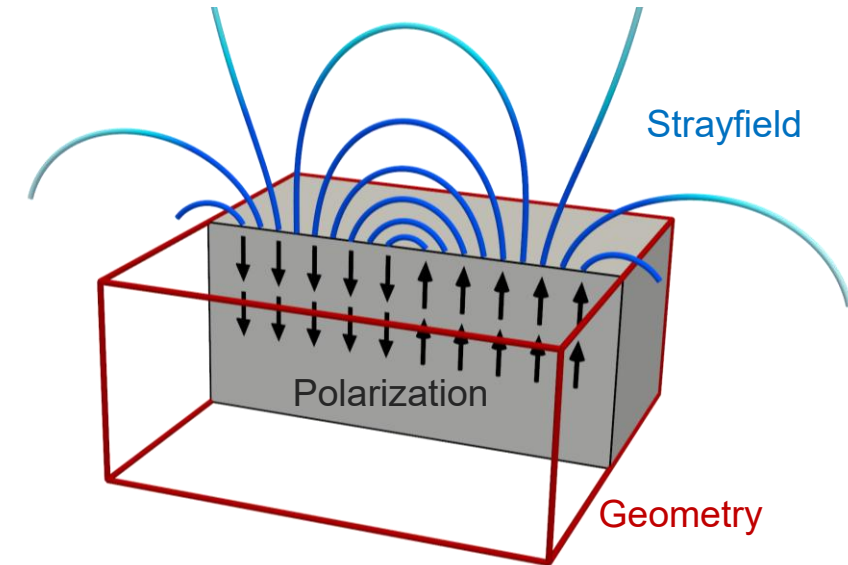
- Magnets used in magnetic position systems are commonly referred to as **Magnetic Measurement Scales**.
- They range from simple dipole magnets to multipole and patterned **magnetic structures**.
- **Materials** are selected according to field strength, size, temperature stability, cost, corrosion resistance, and manufacturability. Common materials include NdFeB, SmCo, ferrite, AlNiCo, and bonded rare-earth magnet materials.
- **Manufacturing methods** include sintering, polymer bonding, injection molding, additive manufacturing, and thick-film deposition.
- **System integration** is achieved by adhesive bonding, mechanical mounting, overmolding, or direct integration into a carrier.



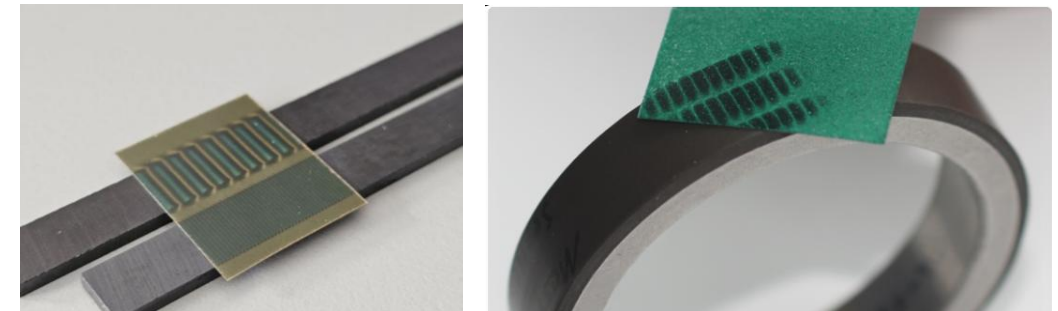
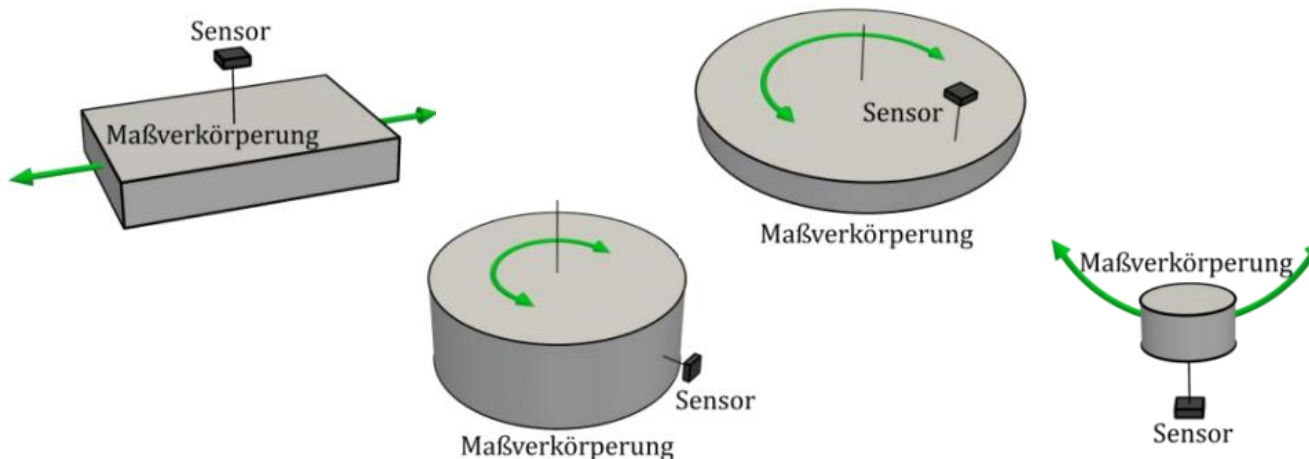
Image: Various types of magnetic scales

# PROPERTIES OF MAGNETIC SCALES

- **Geometry of the scale body:** Shape, dimension
- **Polarization pattern:** Direction, magnitude, and spatial distribution of the magnetization within the scale.
- **Magnetic field pattern:** Resulting spatial distribution of the magnetic field in the relevant measurement region.
- **Intended use:** Measurement task, orientation in system, system requirements.

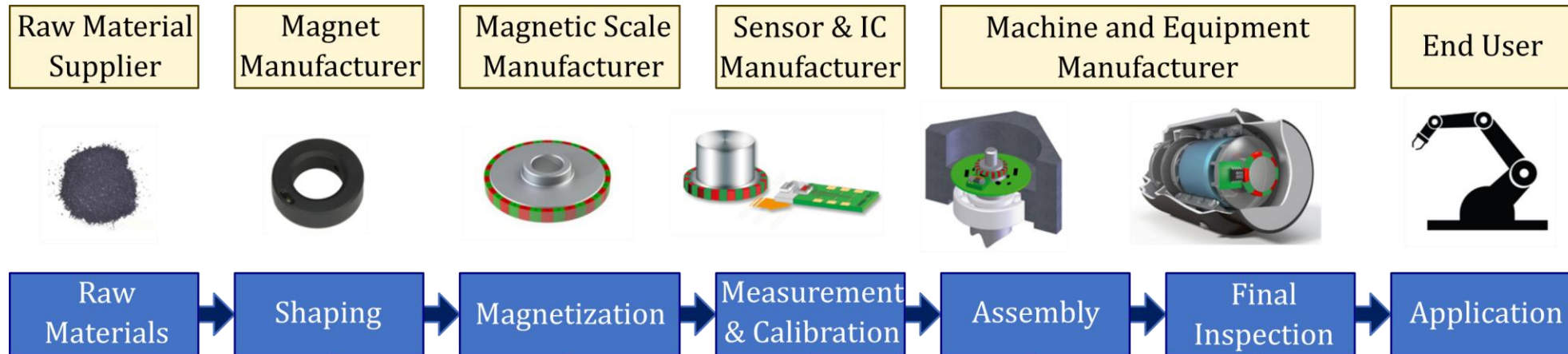


Polarization and magnetic field can be **complex patterns** – but still patterns that yearn for classification and description

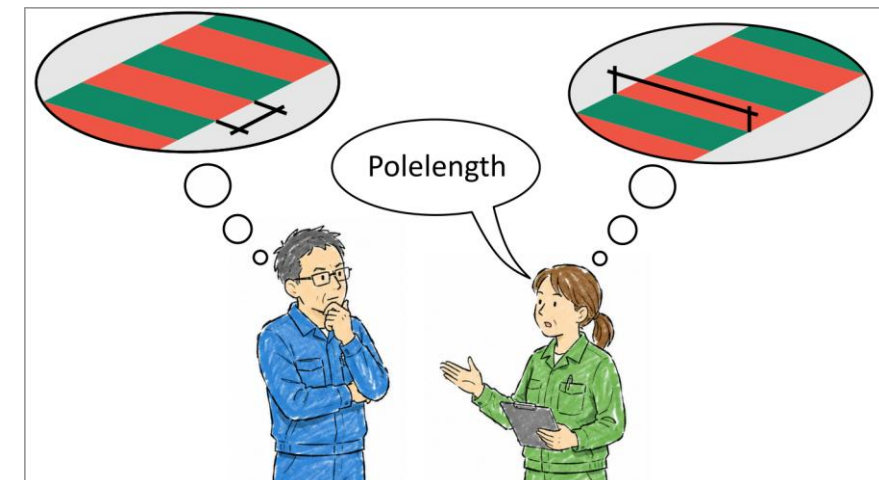


# VALUE CHAIN & COMMUNICATION

- Along the **value chain** there are multiple actors that need to communicate with each other.



- Everyone describes magnetic scales differently
  - No common terminology**
  - No standardization of representation**
  - No common quality criteria**
- This **lack of standardization** creates significant potential for errors and misunderstandings, resulting in unnecessary costs, quality issues, and delays.



- Consortium consisting of 20 members from 13 companies (12 of them INNOMAG members)
- Consortium chaired by Dr. Rolf Slatter
- All stages of the value chain represented:
  - Magnet manufacturers
  - Sensor manufacturers
  - Encoder manufacturers
  - Research institutions



**BALLUFF**  
HIGH RESOLUTION

 **BAM**

 **Baumer**  
Passion for Sensors

magnetfabrik  bonn

**BOGEN** 

  
**ELSOMA**

**FESTO**

  
**ITK**  
Dr. Kassen GmbH

 **INNOVENT**  
Technologieentwicklung Jena

  
**Kubler**

 **matesy**  
Magnetische Technologien & Systeme

 **SENSITEC**  
MAGNETORESISTIVE SENSORS

  
**TE**  
connectivity

# DIN SPEC 91411



2022-06-24



# 4 YEARS LATER ...

## ... lessons learned from living DIN-SPEC 91411

- Practical use has revealed the **need for revision** of several definitions.
- Revisions through DIN are **costly** and **administratively demanding**. Updating figures is particularly time-consuming.
- Access from DIN is restricted by a **paywall**.

## New Approach

- Apply revisions and establish the terminology in the form of a flexible **open-access guideline**.
- Gather feedback from both within and beyond the community. Refine and extend the terminology continuously as a **living document**.
- **Standardize when sufficiently mature**. Formal standardization remains essential but should be the final step.



V1.0 – 09/2026

## Magnetische Maßverkörperungen für Weg- und Winkelmesssysteme

*Terminologie, technische Darstellung, Einteilung, Vermessung  
und Bewertung*



*Version 1.0*

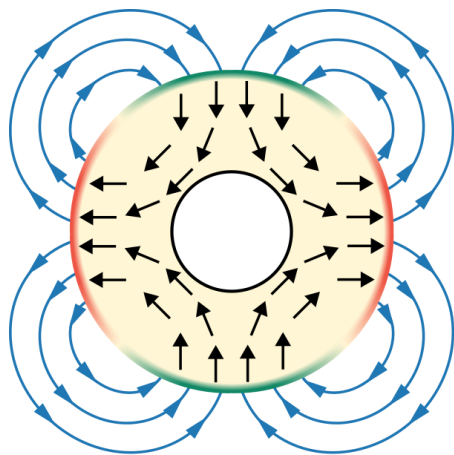
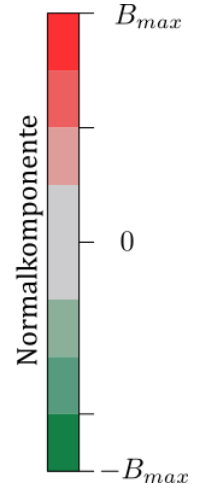
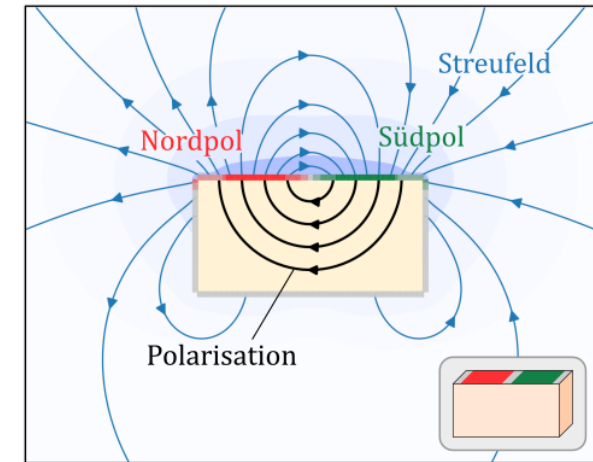
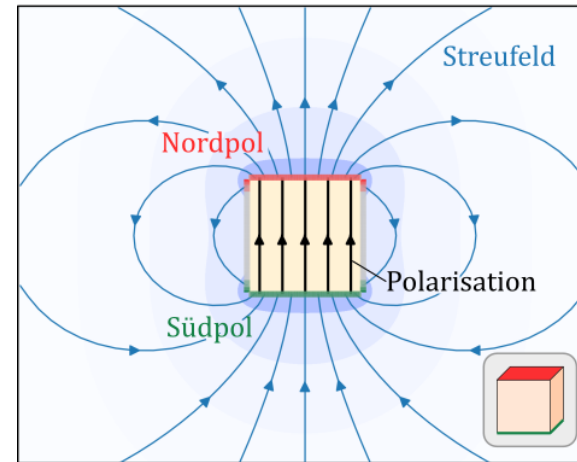
[guideline@innomag.org](mailto:guideline@innomag.org)

### Table of Content

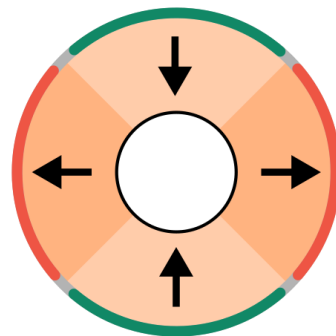
1. Introduction & Motivation
2. Examples of Magnetic Encoder Systems
3. Measurement System Fundamentals
4. Structure of Magnetic Scales
5. Strayfield of Magnetic Scales
6. Fundamentals of Measurement
7. Classification of Magnetic Scales
8. Sensors

## Self- and Physics-Consistent Terminology

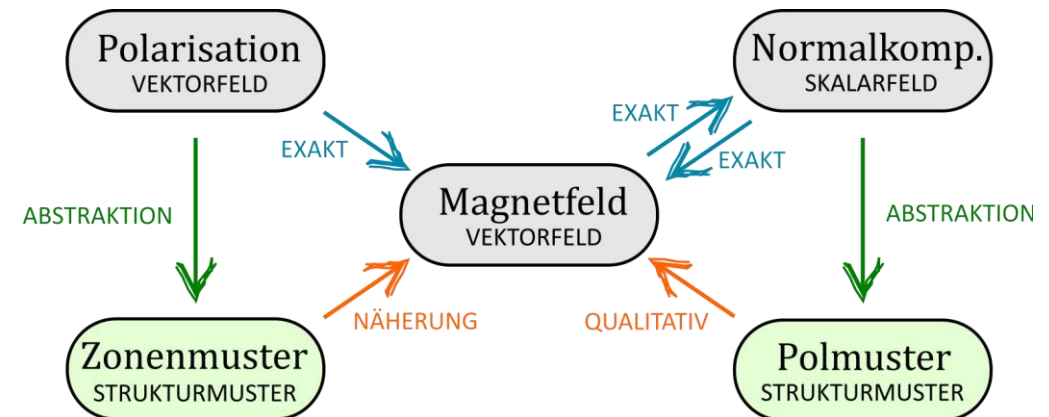
- **Separation of structural quantities** (polarization, poles) and **field-quantities**
- Physically accurate and practically relevant introduction of **poles**
- Distinguishing between physics and **structural models**



Physik

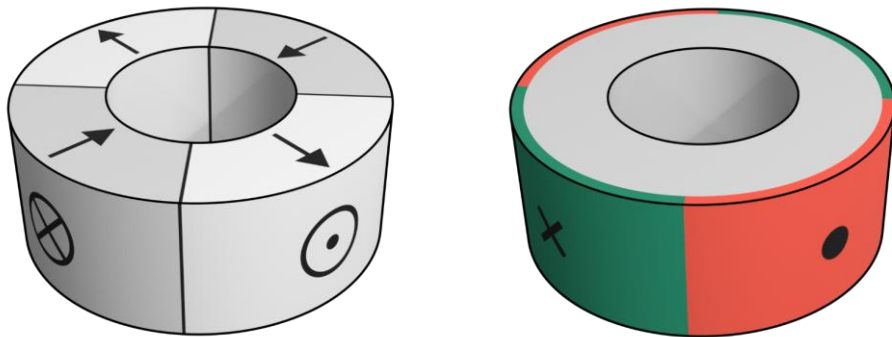
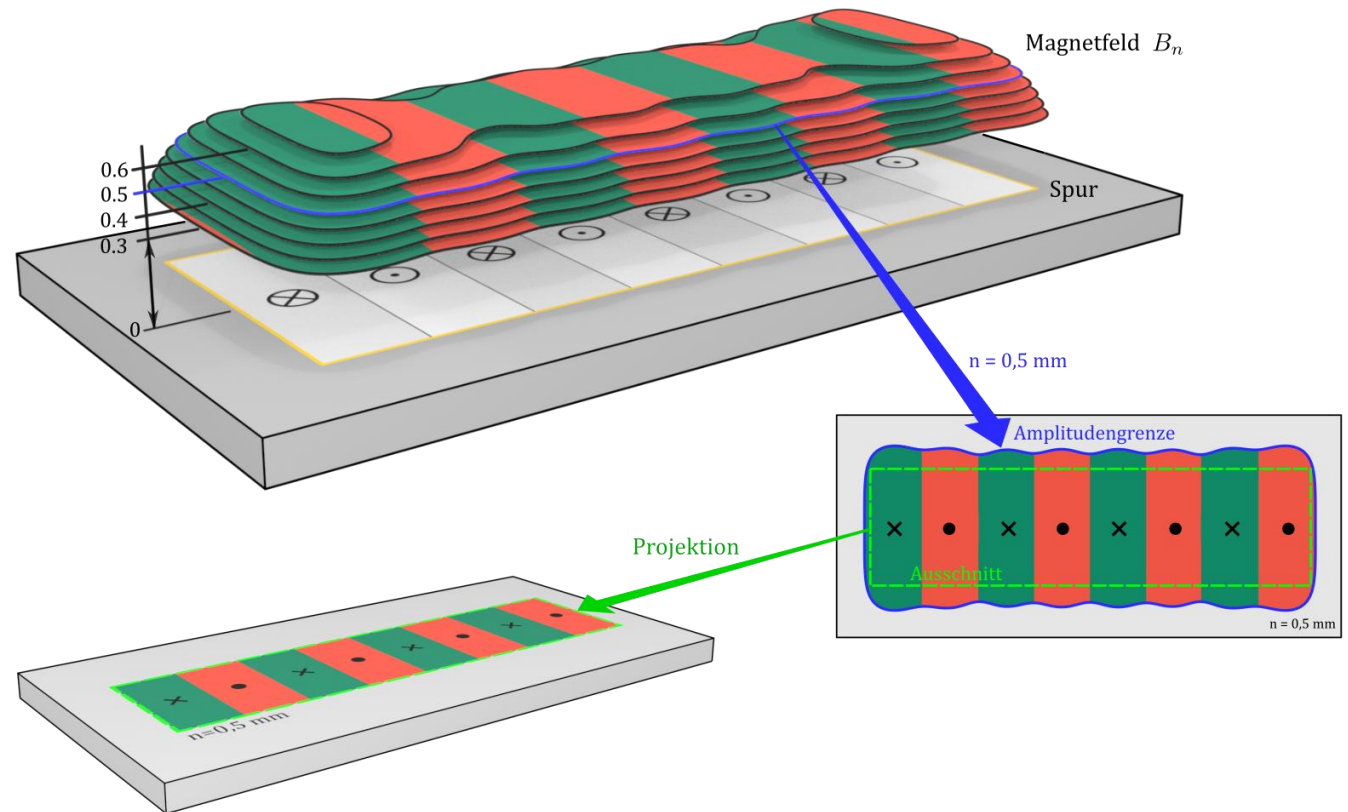


Struktur



## Standardization of Graphical Representation

- Distinguish between representation of the **Polarization**, the **Poles** or the **Strayfield** in finite height.
- The proposed method enables you to focus on what you want to communicate.

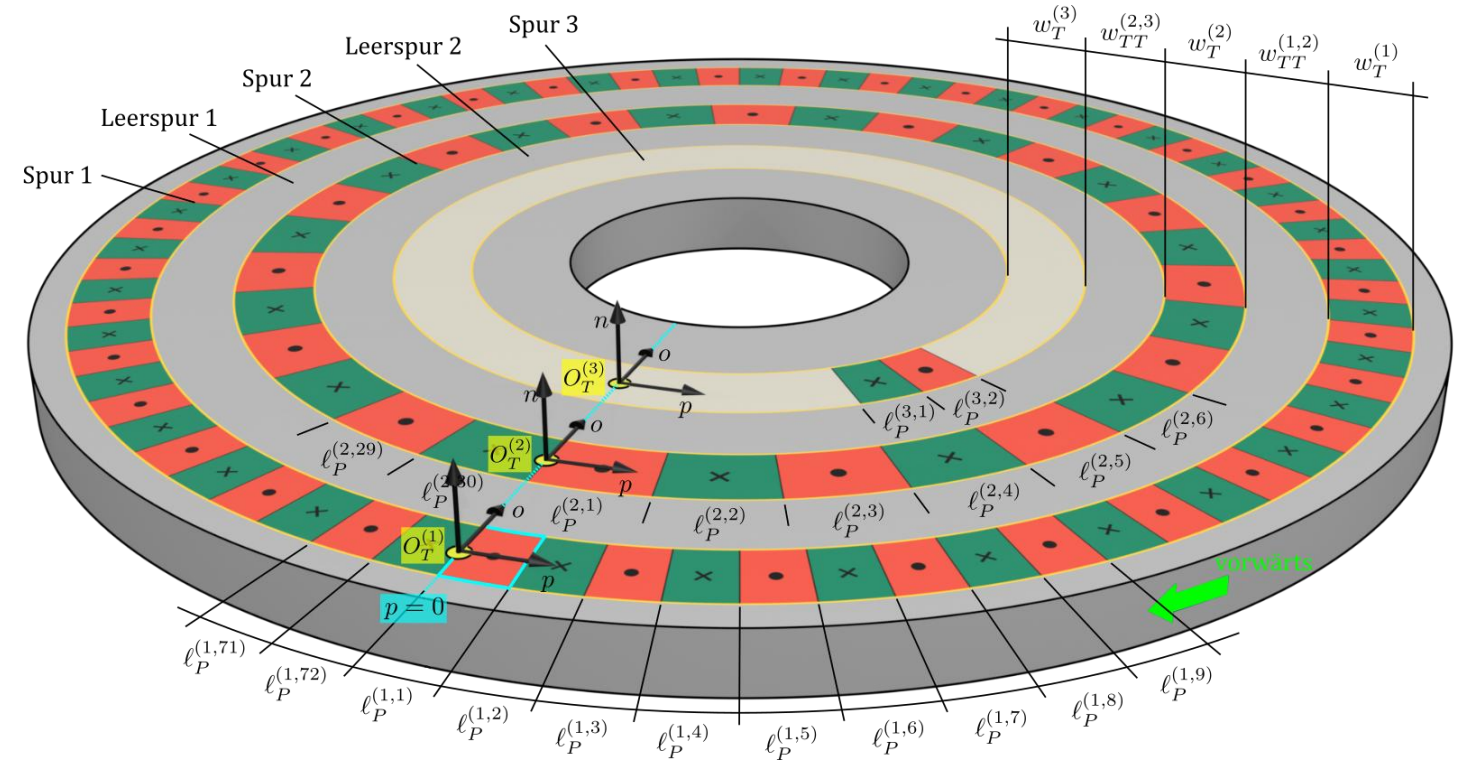


## Detailed Description of Structural Properties

- Terminology for the description of the magnetic structure **Zones**, **Poles** and **Tracks**
- Summary tables with terminology and respective symbols

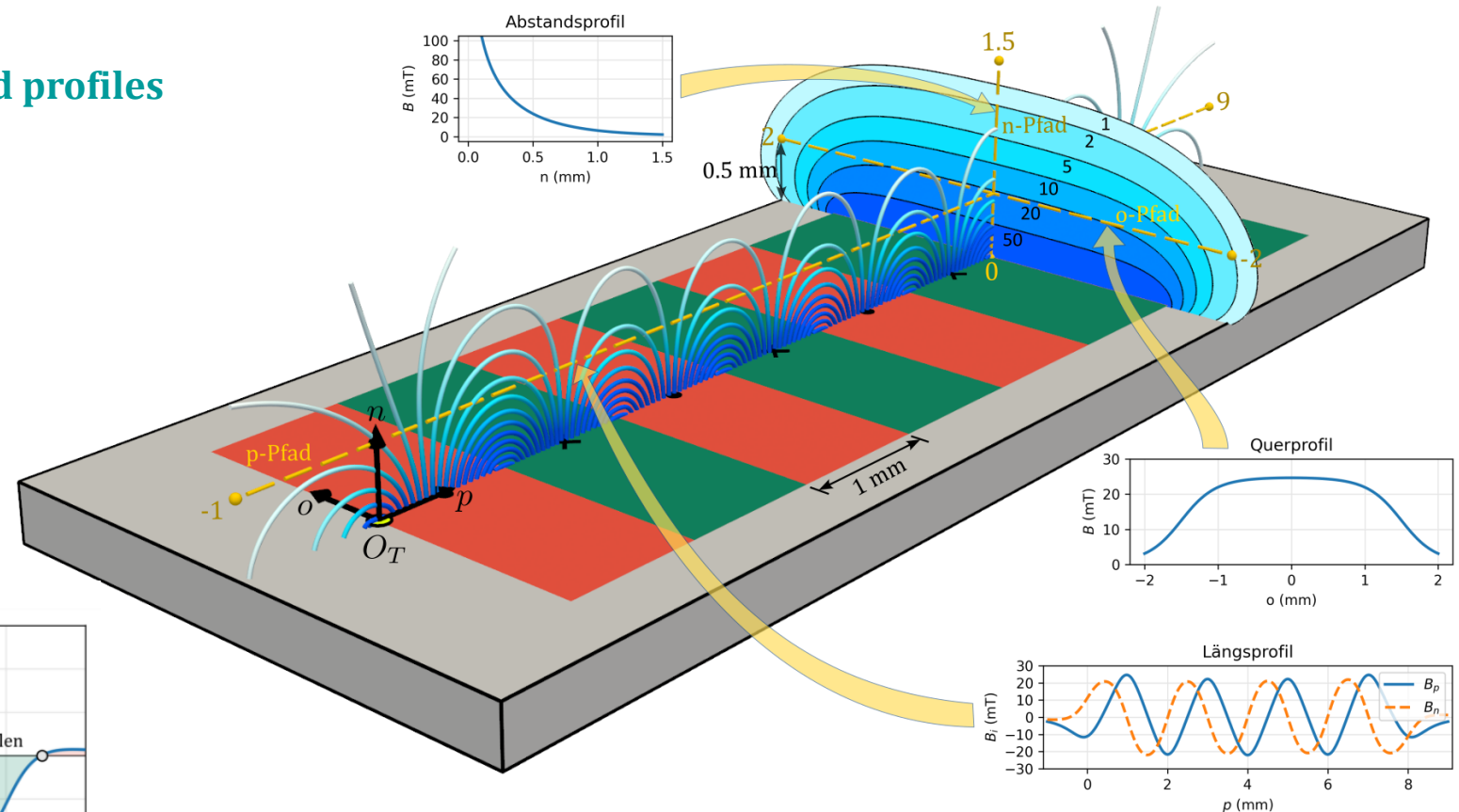
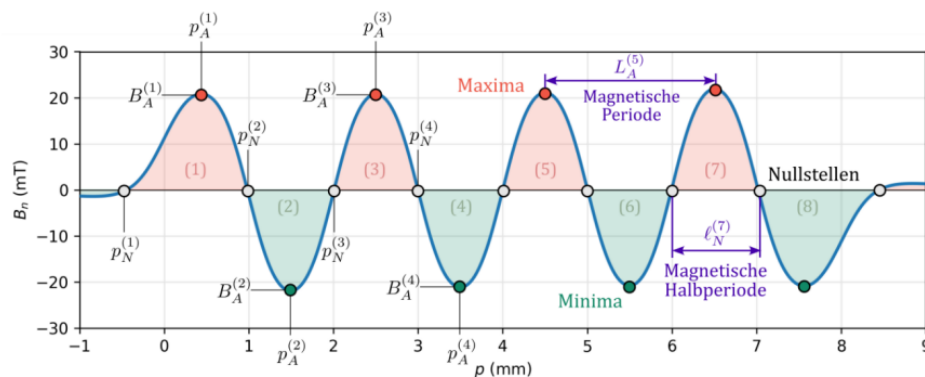
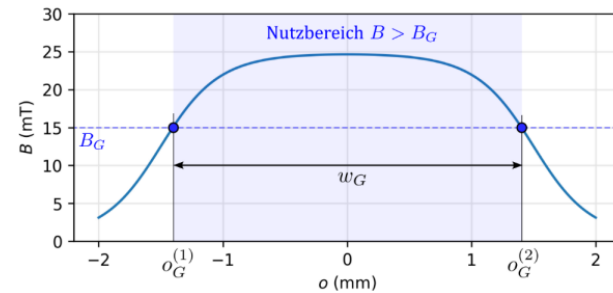
| Begriff     | Symbol               | Beschreibung                                                                                                                           |
|-------------|----------------------|----------------------------------------------------------------------------------------------------------------------------------------|
| Zonenanzahl | $N_Z$                | Gesamtzahl der nummerierten Zonen                                                                                                      |
| Zonenlänge  | $\ell_z^{(j)}$       | Ausdehnung der Zone $j$ in $p$ -Richtung                                                                                               |
| Zonenbreite | $w_z^{(j)}$          | Ausdehnung der Zone $j$ in $o$ -Richtung                                                                                               |
| Zonentiefe  | $d_z^{(j)}$          | Ausdehnung der Zone $j$ in $n$ -Richtung                                                                                               |
| Zonenspalt  | $\bar{\ell}_z^{(j)}$ | Ausdehnung des einer Zone $j$ folgenden, keiner Zone zugeordneten Zwischenraums in $p$ -Richtung                                       |
| Zonenlage   | $\vec{r}_z^{(j)}$    | Position des geometrischen Mittelpunkts des Begrenzungsboxkörpers der Zone $j$ ; Koordinaten $p_z^{(j)}$ , $o_z^{(j)}$ und $n_z^{(j)}$ |

| Begriff   | Symbol            | Beschreibung                                                                                                      |
|-----------|-------------------|-------------------------------------------------------------------------------------------------------------------|
| Polanzahl | $N_P$             | Gesamtzahl der nummerierten Pole                                                                                  |
| Pollänge  | $\ell_p^{(j)}$    | Ausdehnung des Pols $j$ in $p$ -Richtung                                                                          |
| Polbreite | $w_p^{(j)}$       | Ausdehnung des Pols $j$ in $o$ -Richtung                                                                          |
| Pollage   | $\vec{r}_p^{(j)}$ | Position des geometrischen Mittelpunkts der Begrenzungsbox des Pols $j$ ; Koordinaten $p_p^{(j)}$ und $o_p^{(j)}$ |



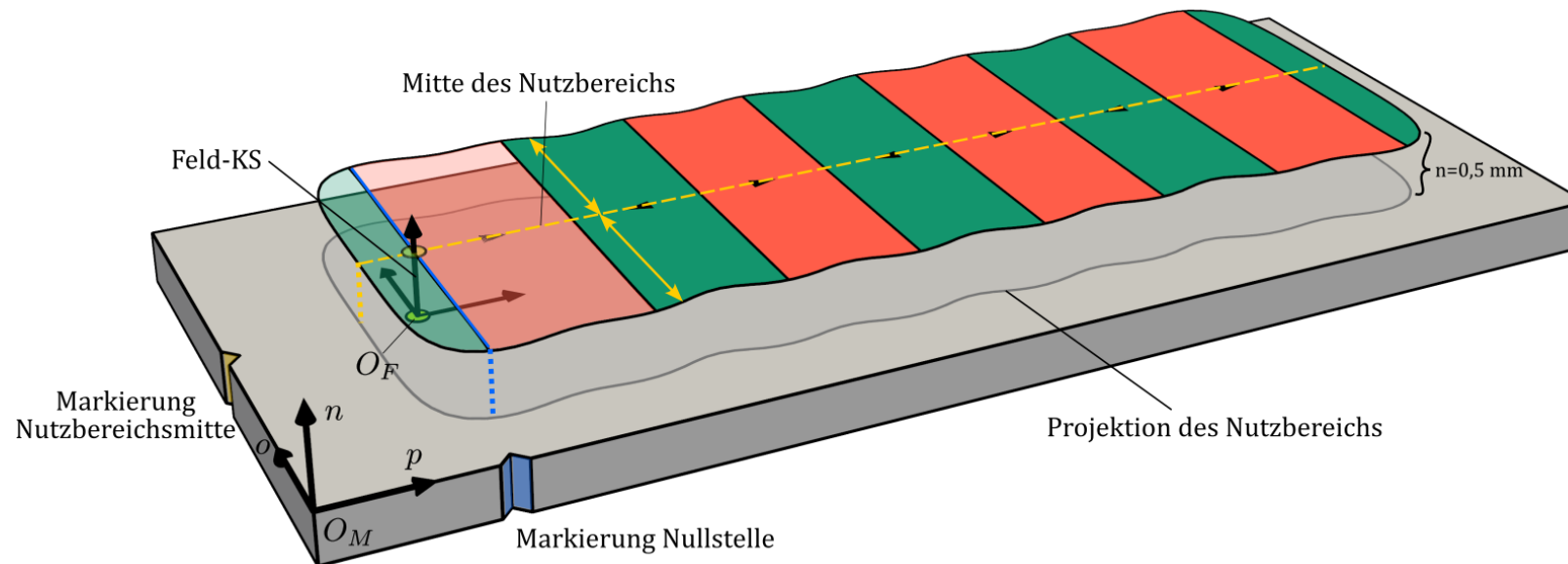
## Detailed Stray Field Profile Analysis

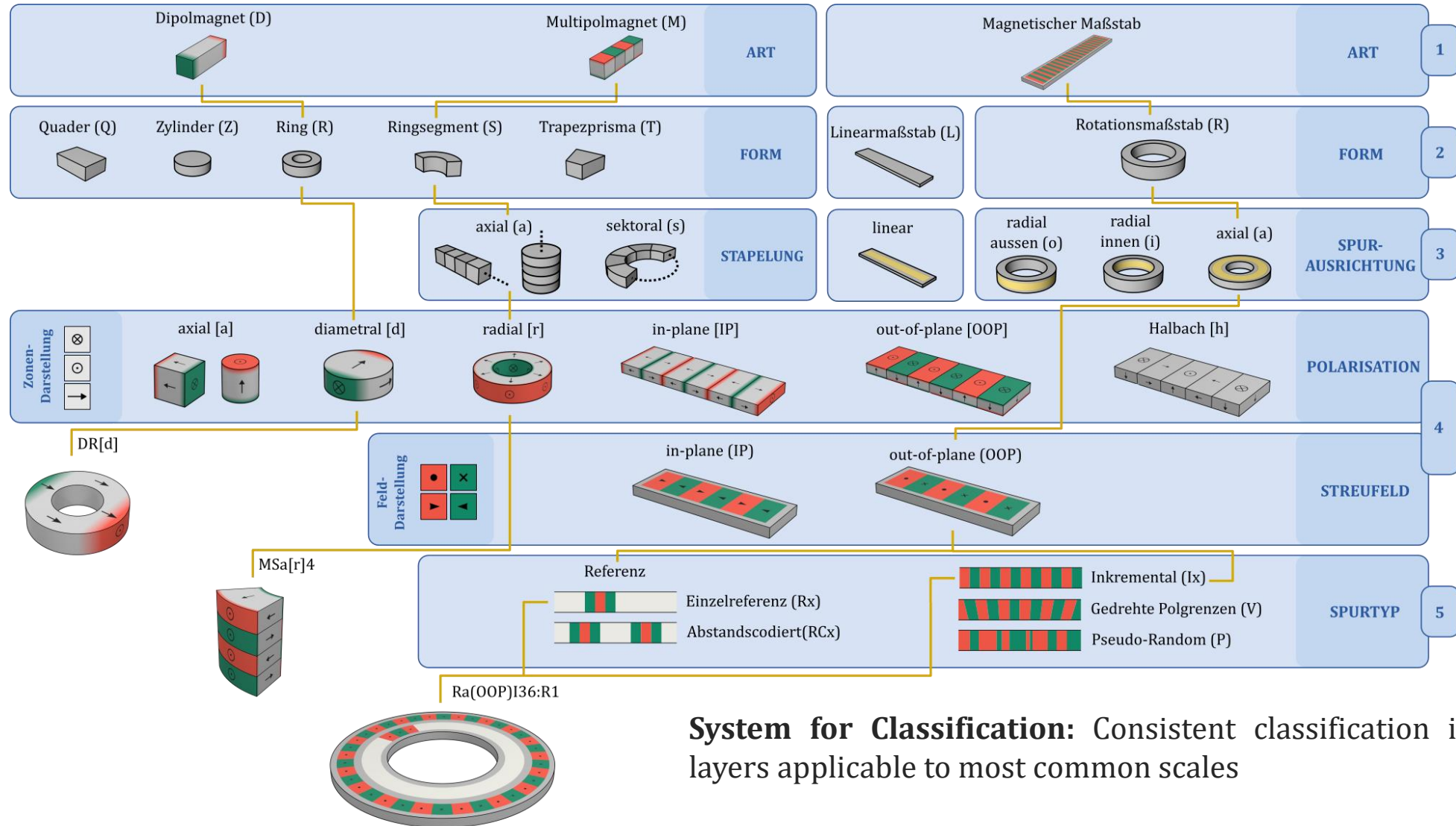
- Terminology for description of **stray field profiles**
- Enable future **quality measures**



## Magneto-Mechanical Reference and Measurement

- Standardizing commonly used connection between the measured stray field and the magnetic scale body – laying a common foundation for **measurements and referencing**.
- The IGL provides a **framework** for describing magnetic scales and referencing measurements, but it does not prescribe a **rigid set of rules** or require this formalism to be applied in every case.





**System for Classification:** Consistent classification in five layers applicable to most common scales

The IGL v1.0 is as of **now** freely available as download from the **INNOMAG** webpage.

Help us **improve** feedback

## Outlook (near future)

- Publishing reference
- Translation to English
- Future chapters
  - Sensors
  - Magnetic Scales
  - Scale Quality



Contact us with [info@innomag.org](mailto:info@innomag.org)

... maybe in print-format

of Scales (Quality of  
al setups, Uncertainty of  
ents)  
Scale data sheets, USR, ...)

## Autorschaft und Beiträge

### Autoren

Verantwortung für die jeweiligen Kapitel; Entwicklung und Ausarbeitung von Konzept, Struktur und Inhalten.

|                |                           |                       |
|----------------|---------------------------|-----------------------|
| Michael Ortner | Silicon Austria Labs GmbH | Kapitel 2 – 8, Editor |
| Rolf Slatter   | INNOMAG e. V.             | Kapitel 1             |

### Fachliche Mitwirkung

Fachlicher Austausch und Diskussion; fachliche Beiträge zu einzelnen Kapiteln; Rückmeldungen zu Inhalten; Review ausgewählter Abschnitte; Begleitung der konzeptionellen Weiterentwicklung.

|                    |                                                     |                                            |
|--------------------|-----------------------------------------------------|--------------------------------------------|
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| Axel Bartos        | TE Connectivity                                     | Fachliche Mitwirkung                       |
| Benjamin Wenzel    | Matesy GmbH                                         | Fachliche Mitwirkung                       |
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| Florian Slanovc    | Silicon Austria Labs GmbH                           | Fachliche Mitwirkung                       |
| Heiko Knoll        | ITK Precisioning GmbH                               | Fachliche Mitwirkung                       |
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| Sibylle Sievers    | Physikalisch-Technische Bundesanstalt               | Fachliche Mitwirkung                       |
| Stefan Herzog      | ZF Friedrichshafen AG                               | Fachliche Mitwirkung; Beitrag zu Kapitel 2 |
| Thomas Schliesch   | Max Baermann GmbH                                   | Fachliche Mitwirkung                       |
| Werner Pessenhofer | Nanomag GmbH                                        | Fachliche Mitwirkung                       |