

Magnetic behavior of steel studied by *in-situ* Lorentz microscopy, magnetic force microscopy and micromagnetic simulations

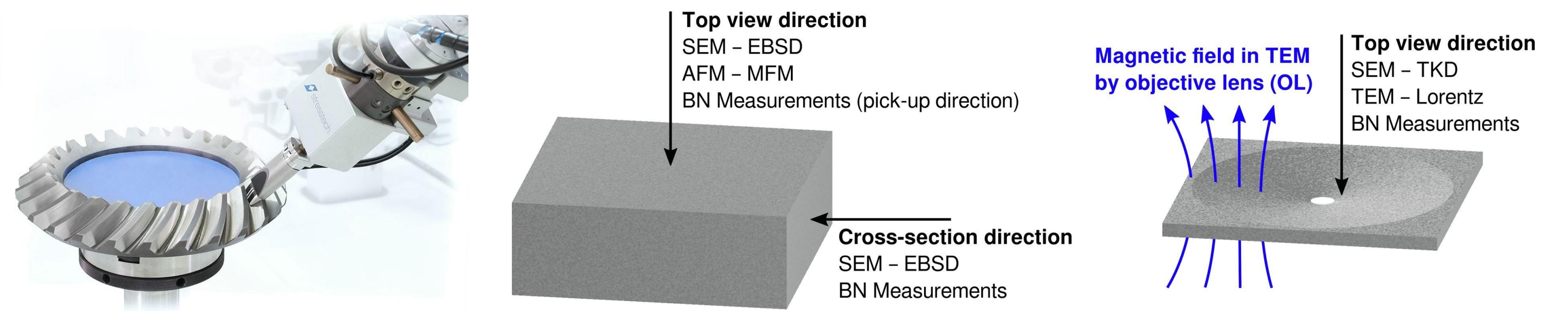
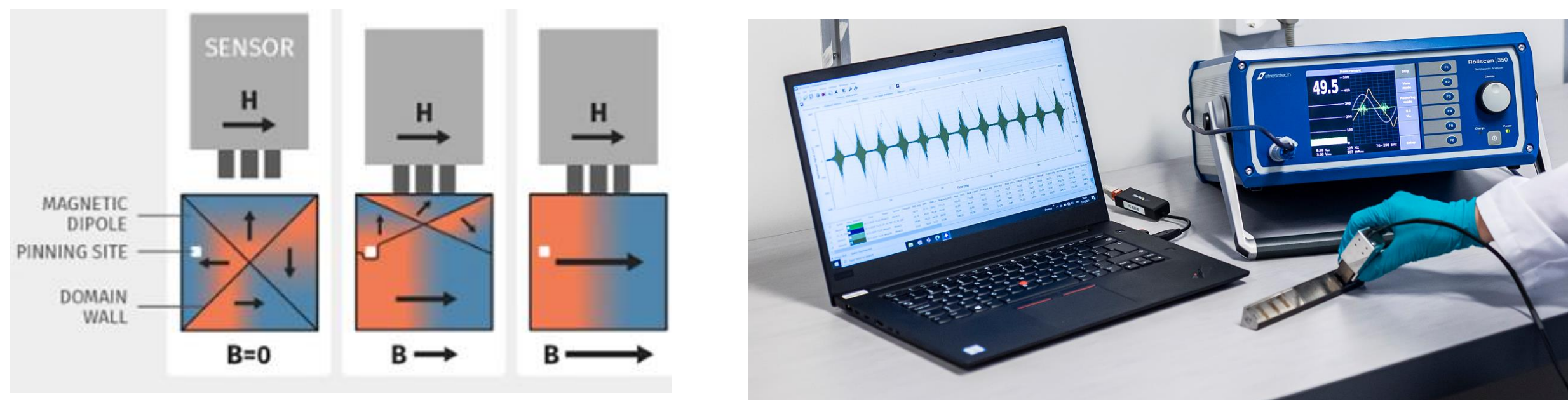
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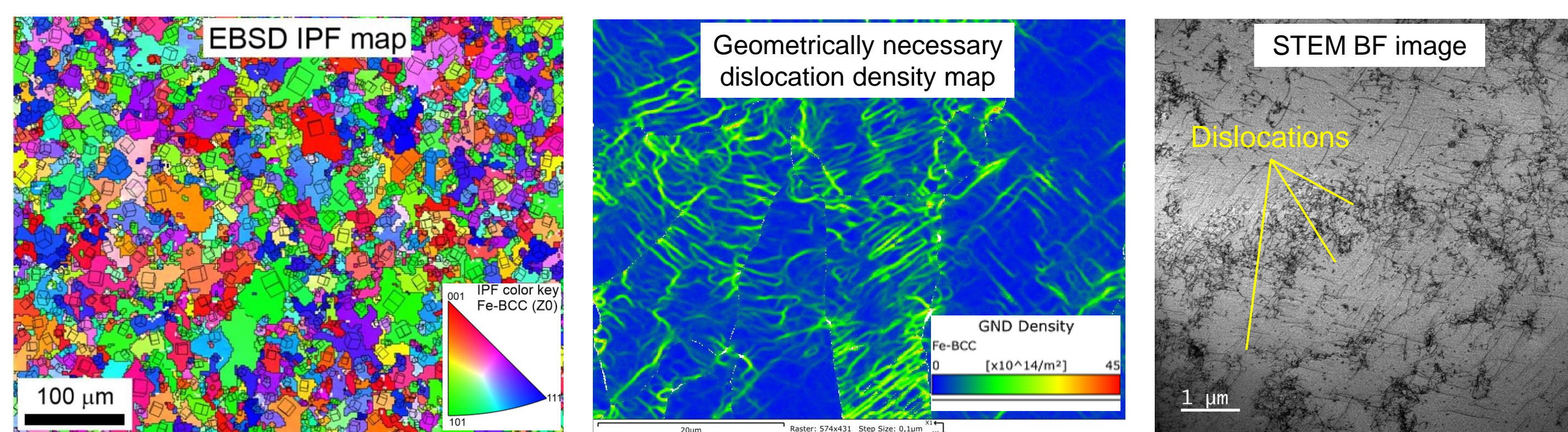
Background and motivation

- Barkhausen noise (BN) measurement is an important industrial non-destructive quality control method for ferromagnetic materials (evaluation of residual stresses and hardness, testing of surface defects)
- BN measurement: External AC magnetic field excites magnetic domain wall dynamics → Microstructural features inhibit domain wall motion → Discontinuous changes in the magnetization → Barkhausen noise signal

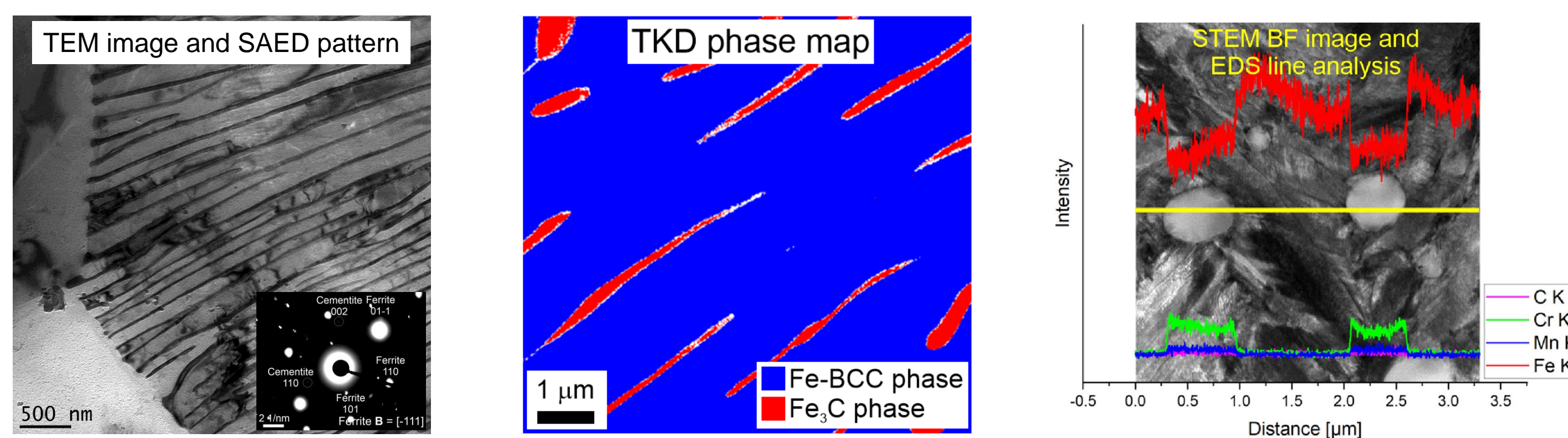
- BN technique would have even wider potential in industry if the structural details of the material could be thoroughly linked with its BN signal → Our combined multi-instrumental and computational approach:
 - Characterizations for bulk samples (SEM-EBSD, magnetic force microscopy, MFM) and thin samples (SEM-TKD, S/TEM-EDS, (*in-situ*) Lorentz microscopy)
 - Micromagnetic simulations



Microstructure

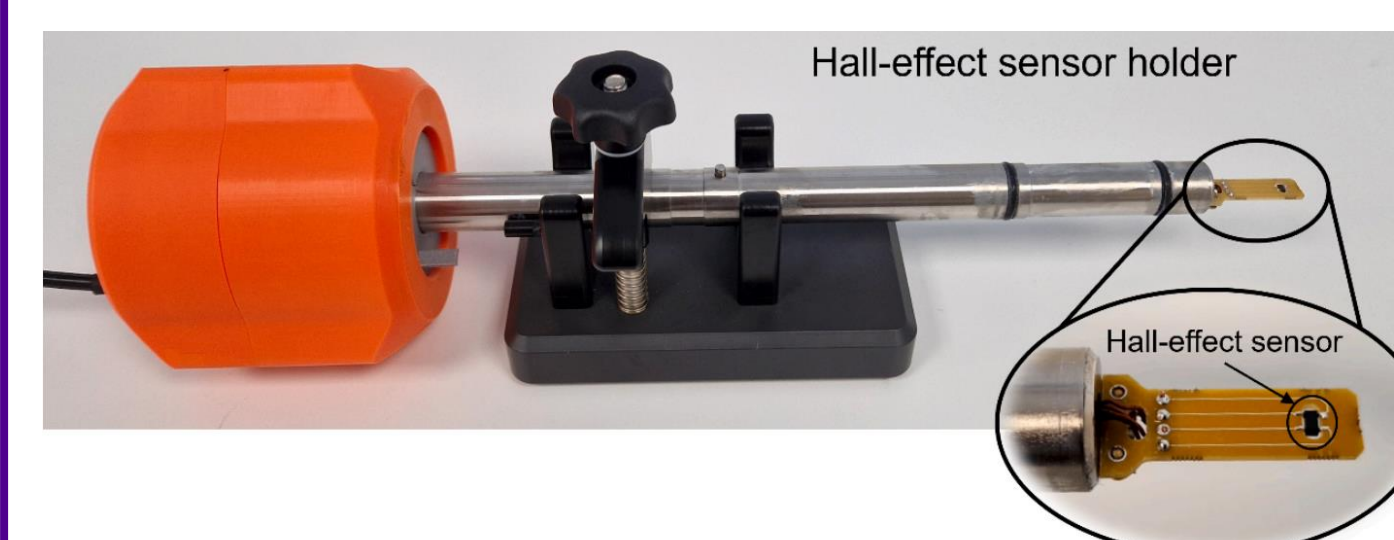


Grain size, orientation, texture, and dislocation analyses

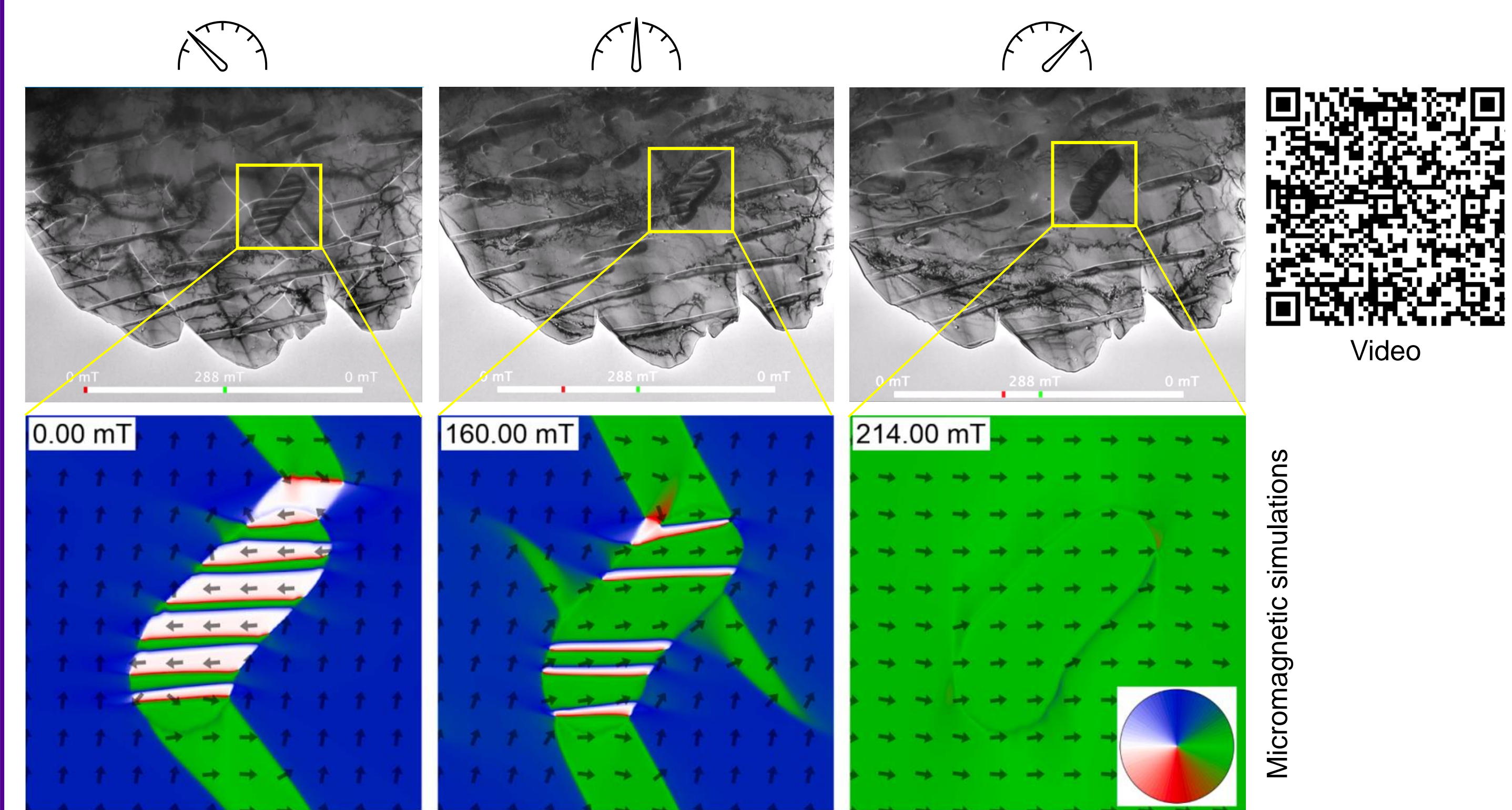


Phase and elemental analyses

Domain wall dynamics

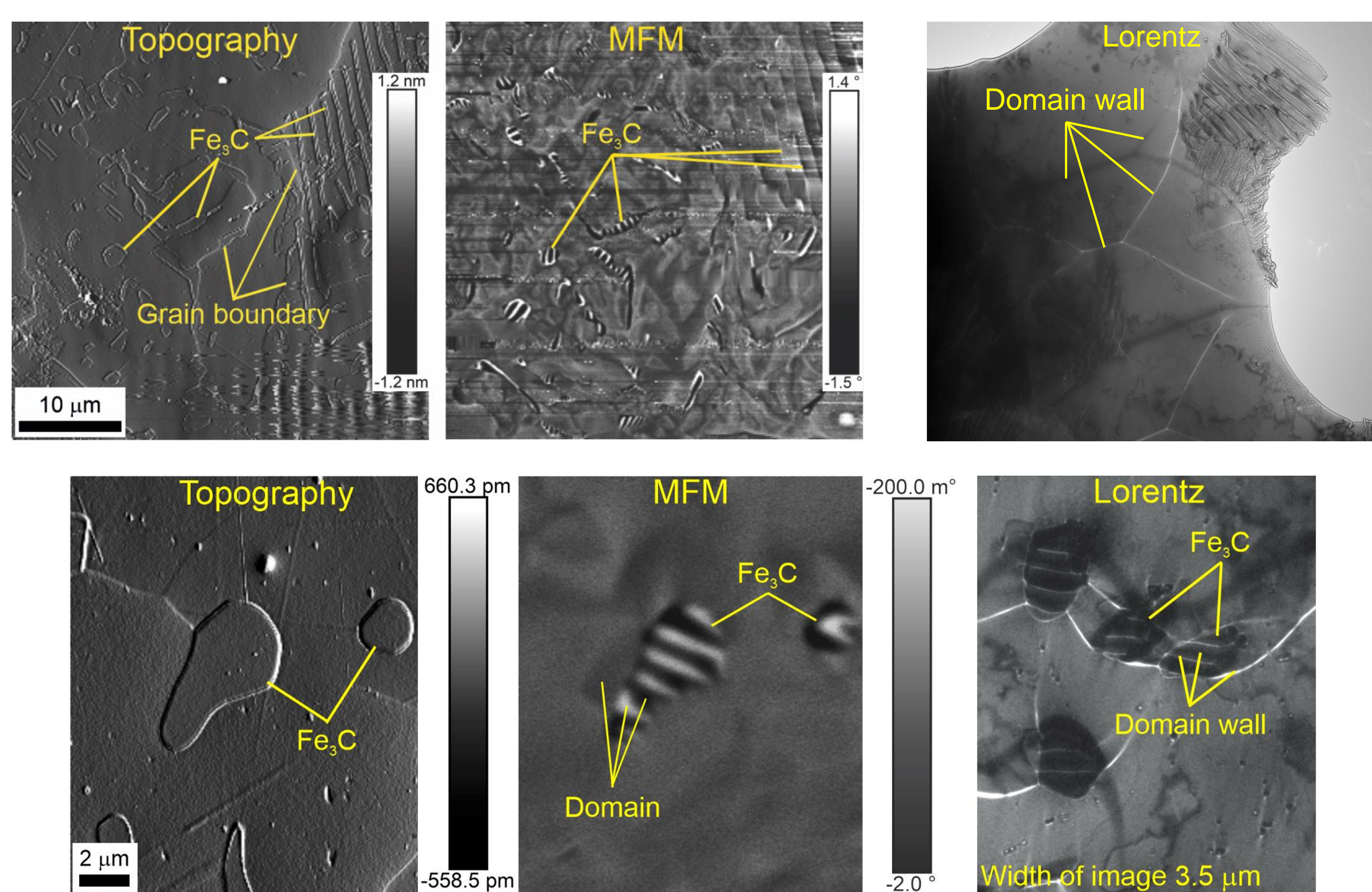


- We built a custom-made holder with a Hall-effect sensor to measure a single point flux density at the sample location in the TEM JEOL JEM-F200.
- We generated time-varying external magnetic fields to the sample using TEM's objective lens, imaging with an objective mini lens.



Micromagnetic simulations

Magnetic structure



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Combined multi-instrumental and computational approach

Novel knowledge on magnetic behavior of ferromagnetic steel

In the future: Together with DTU Nanolab, off-axis electron holography and transport of intensity equation (TIE) studies are going on.

References
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Honkanen et al. *Ultramicroscopy* 262 (2024) 113979
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