3D-FEM-Simulation of Magnetic Shape Memory Actuators

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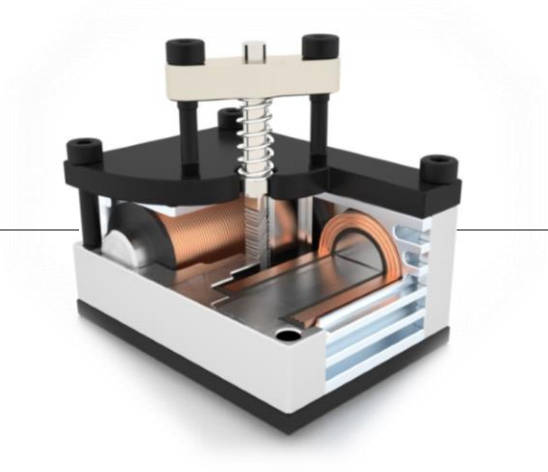

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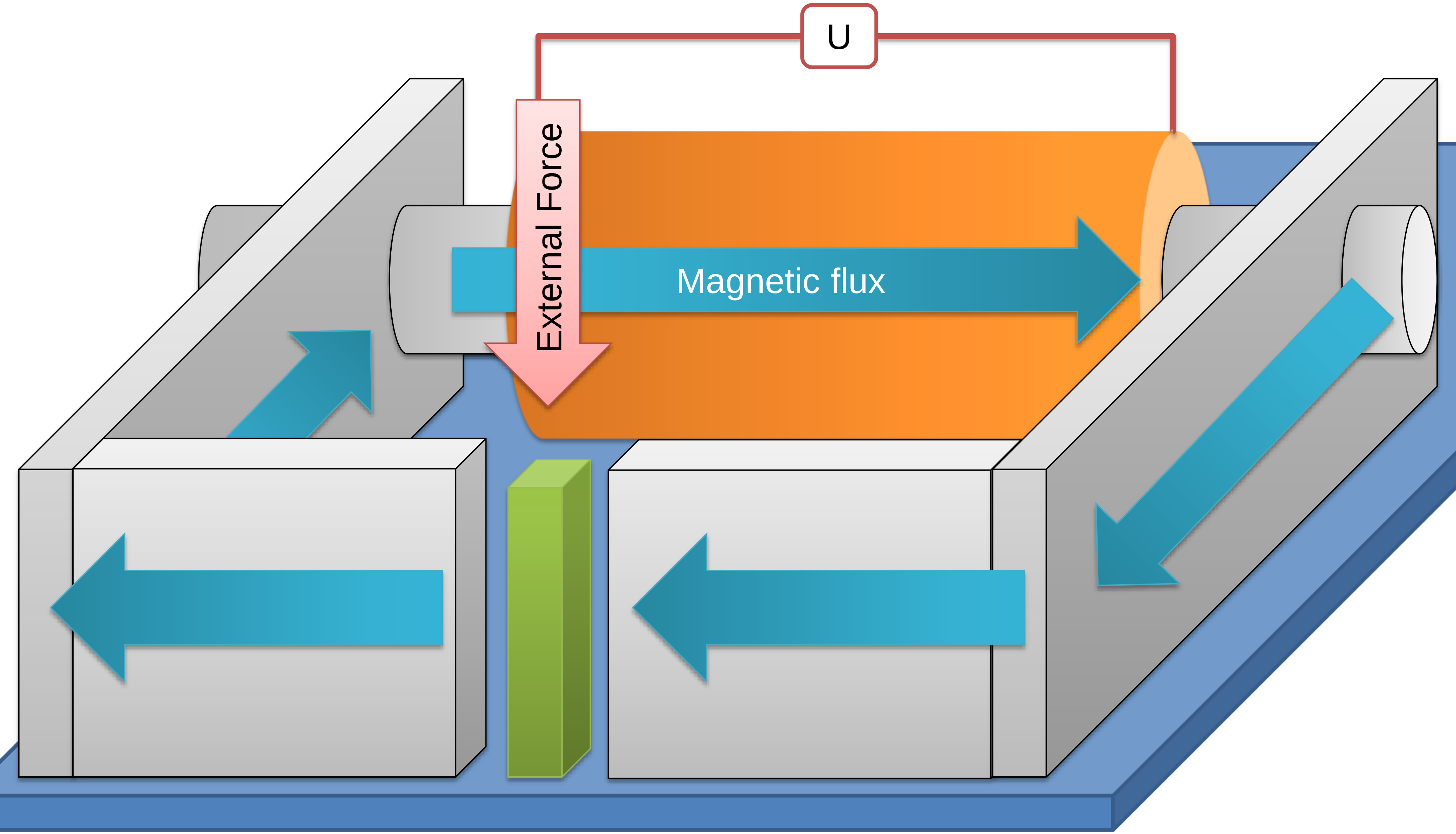
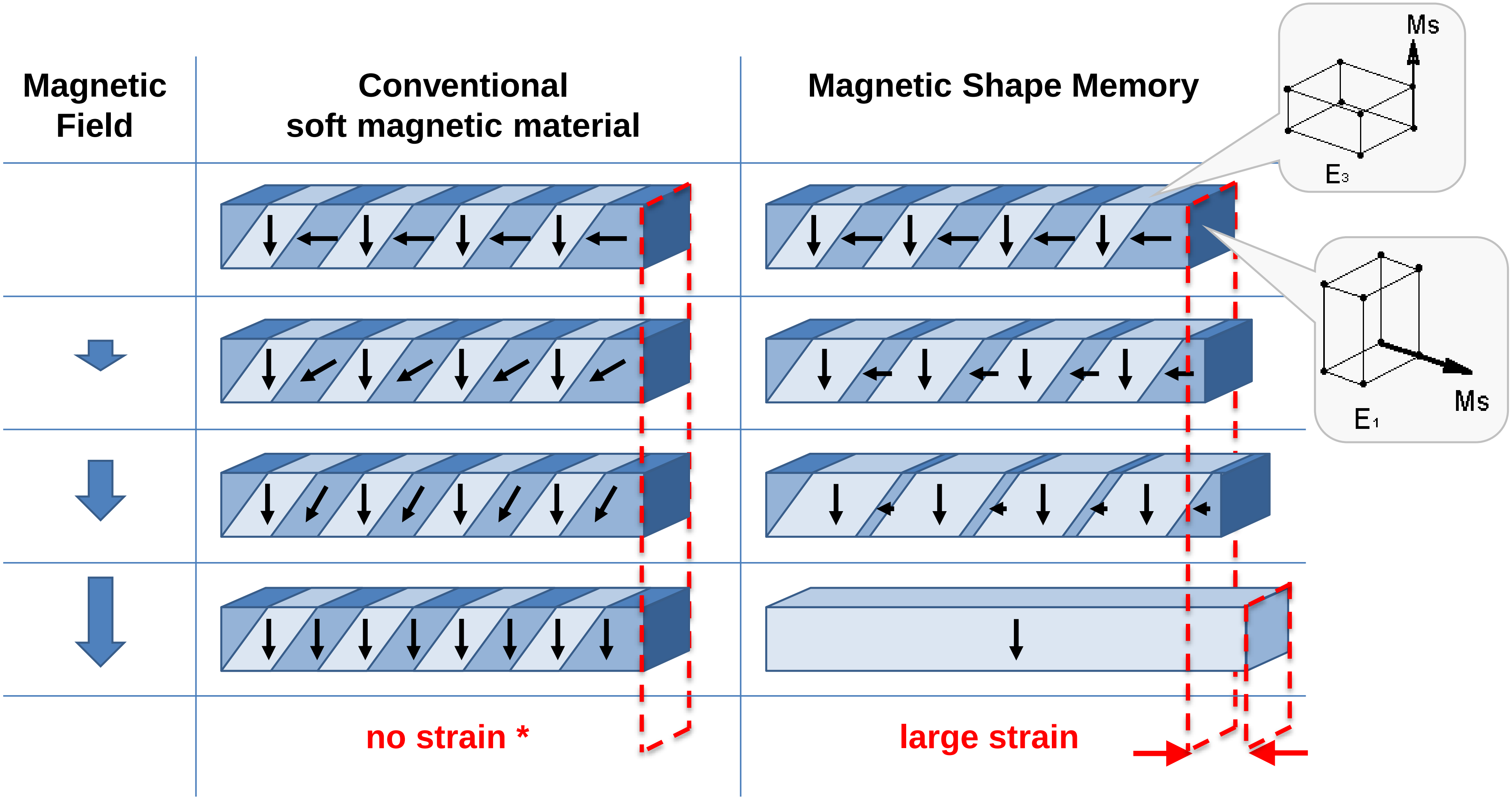
Short Introduction (MSM)

Schematic illustration



Magnetic Shape Memory Effect



* Magnetostriction may occur, but is neglected here.

Short Introduction (MSM)

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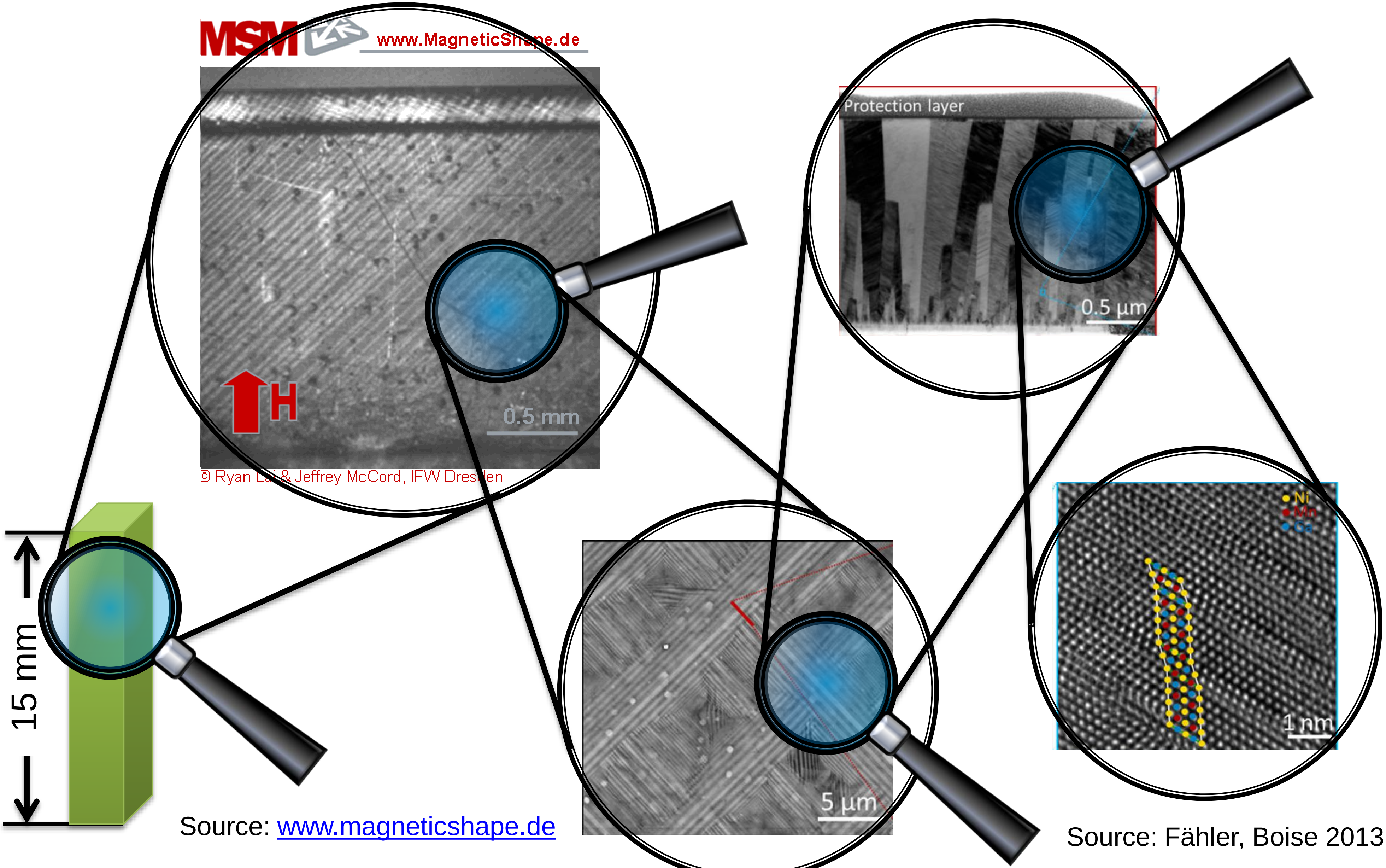
From macro-twins to nano-twins



Source: www.magneticshape.de

Source: Fähler, Boise 2013

MSM Production: Process Steps

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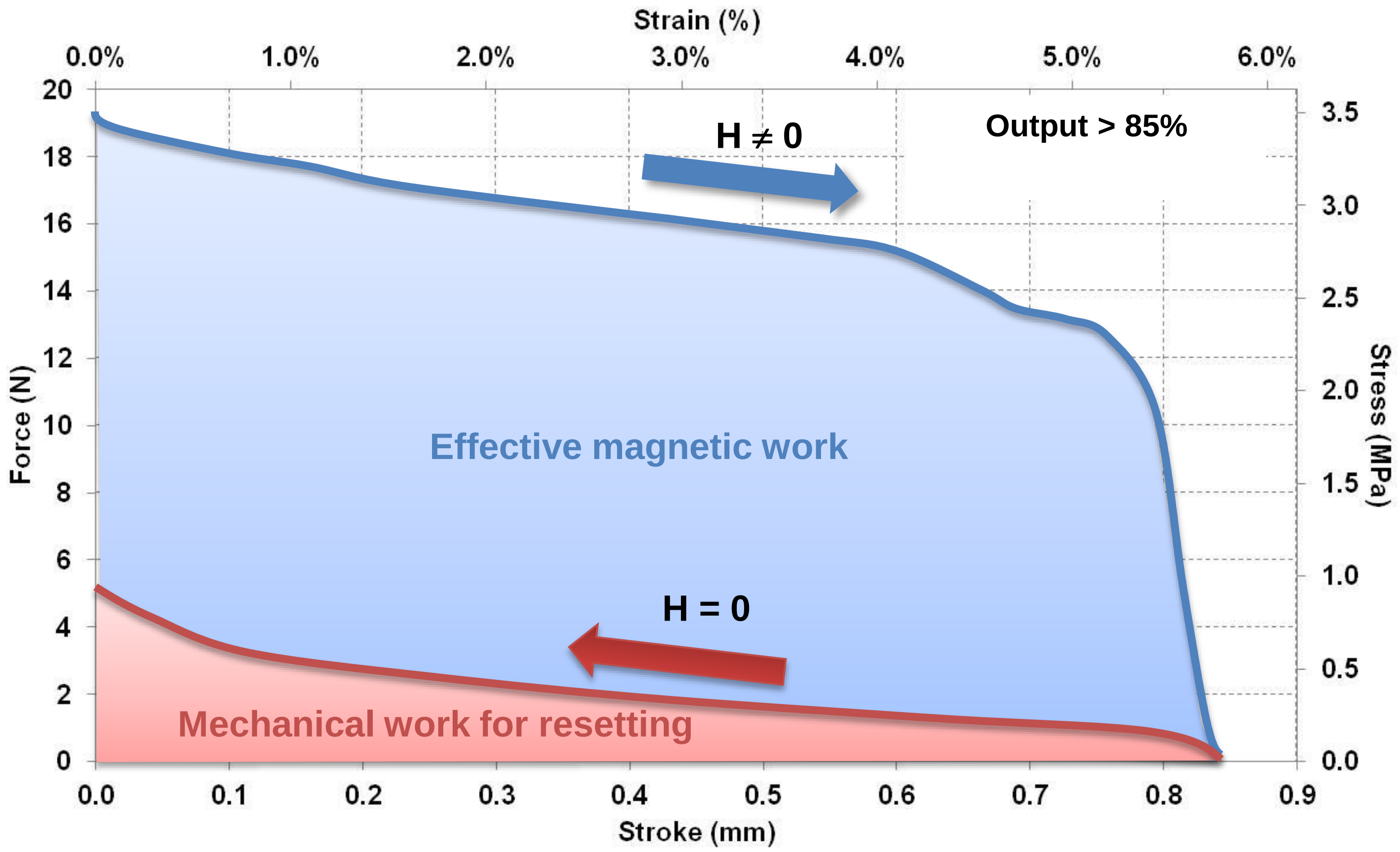
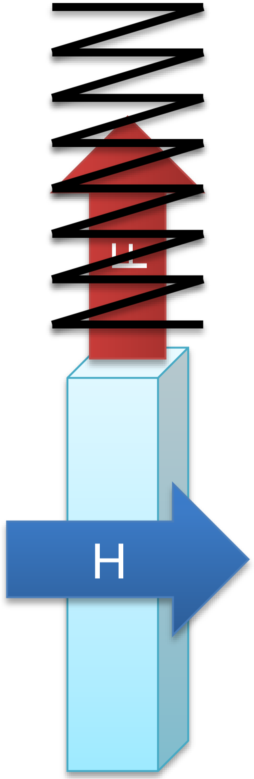
MSM Material Production

Single crystalline MAGNETOSHAPE® material (Ni-Mn-Ga)

High Work Output Ratio

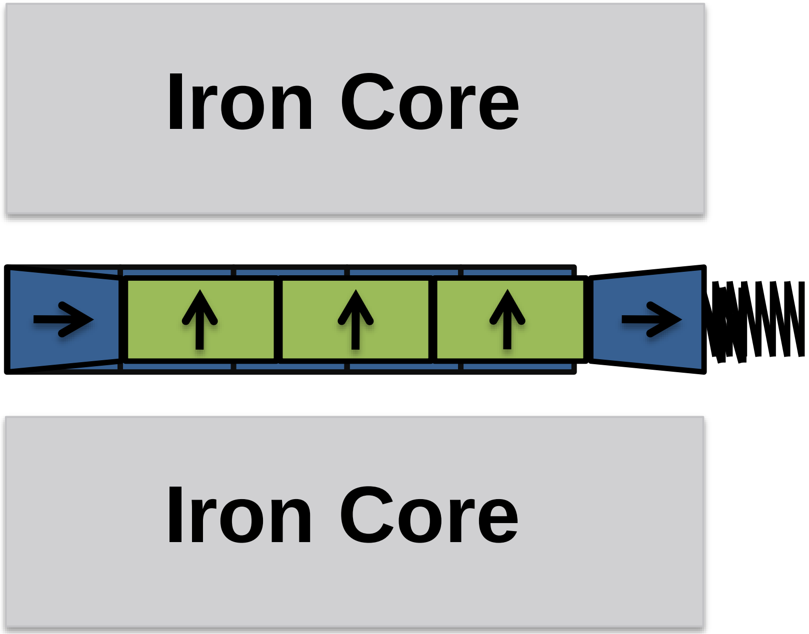
MSM-Werkstoff

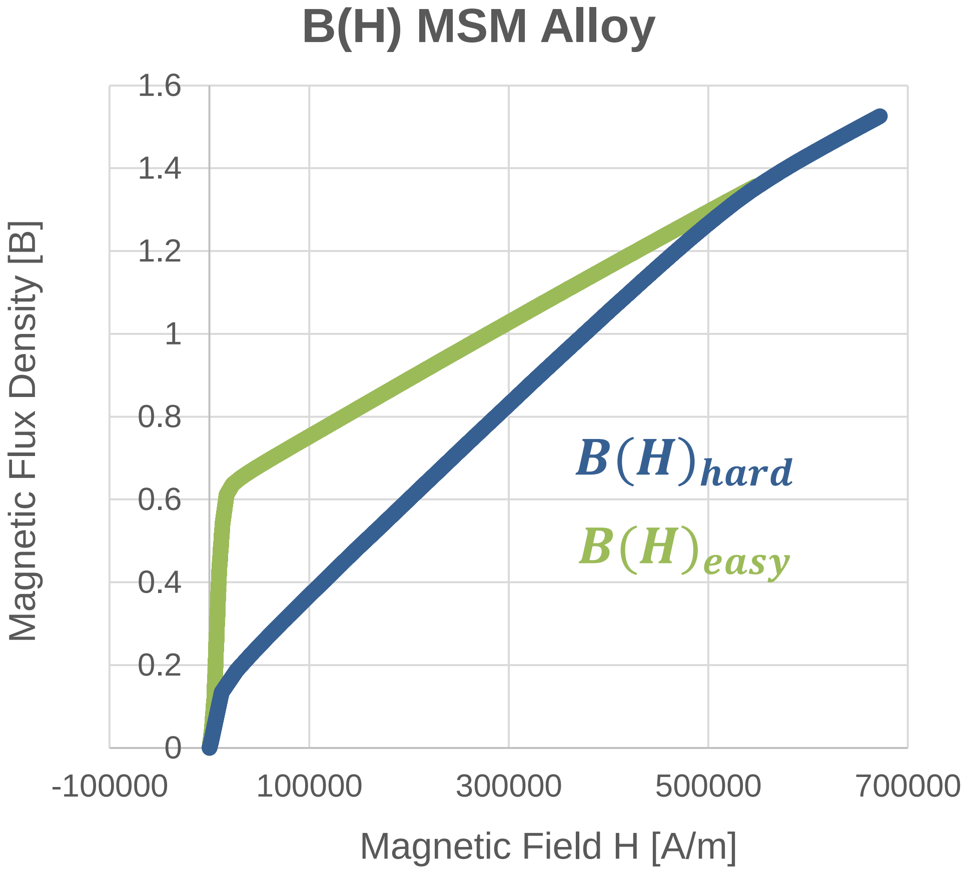




Simulation of Magnetic Shape Memory Actuators

Implementation of magnetomechanical behaviour in 3D-FEM-Model



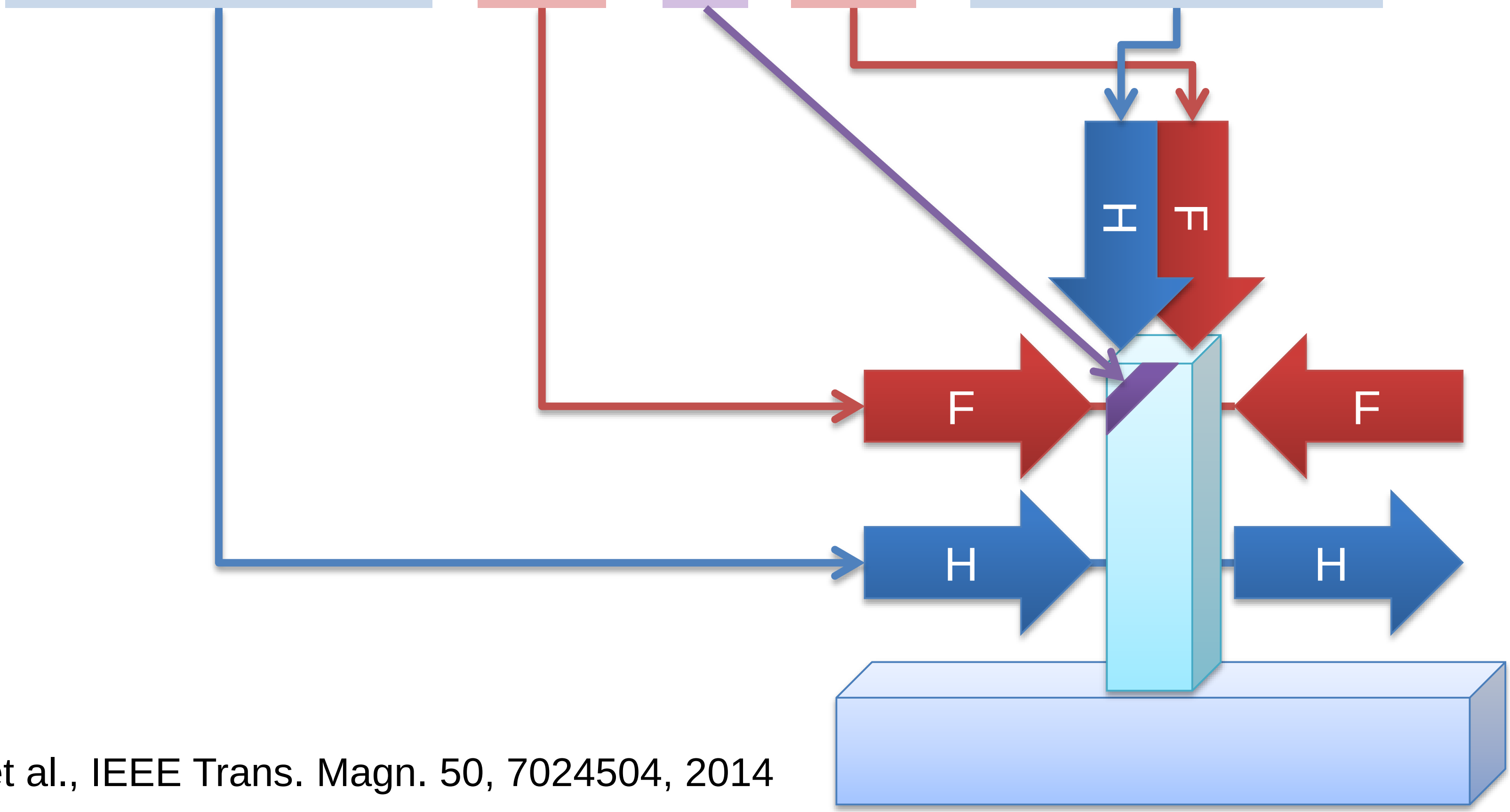


Simulation of Magnetic Shape Memory Actuators

Stress Based Approach

In Magnetic Shape Memory material the magnetic filed generates a magneto-mechanical stress that leads to a shape change under this condition:

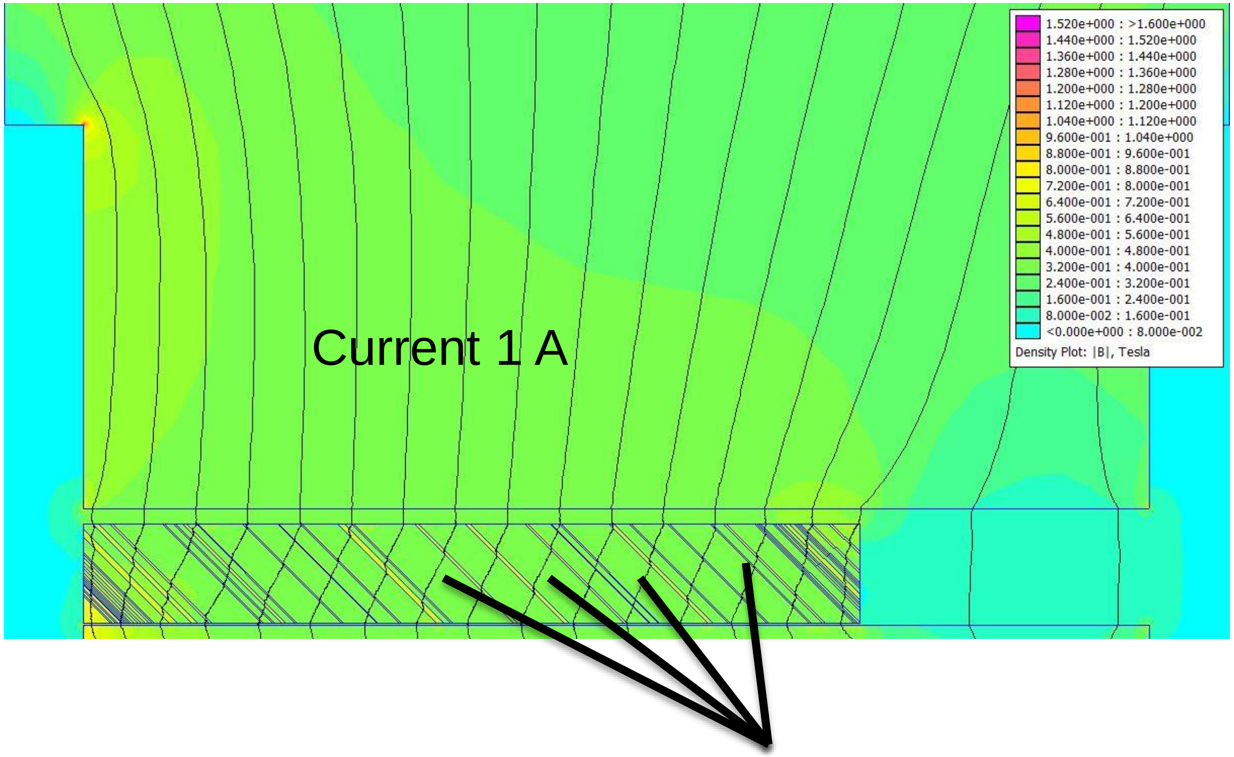
$$\sigma_{x}^{mag}(\sigma_{max}^{mag}, H) + \sigma_{x}^{ext} > \sigma_{t} + \sigma_{y}^{ext} + \sigma_{y}^{mag}(\sigma_{max}^{mag}, H)$$



Schiepp et al., IEEE Trans. Magn. 50, 7024504, 2014

2D Simulation with FEMM

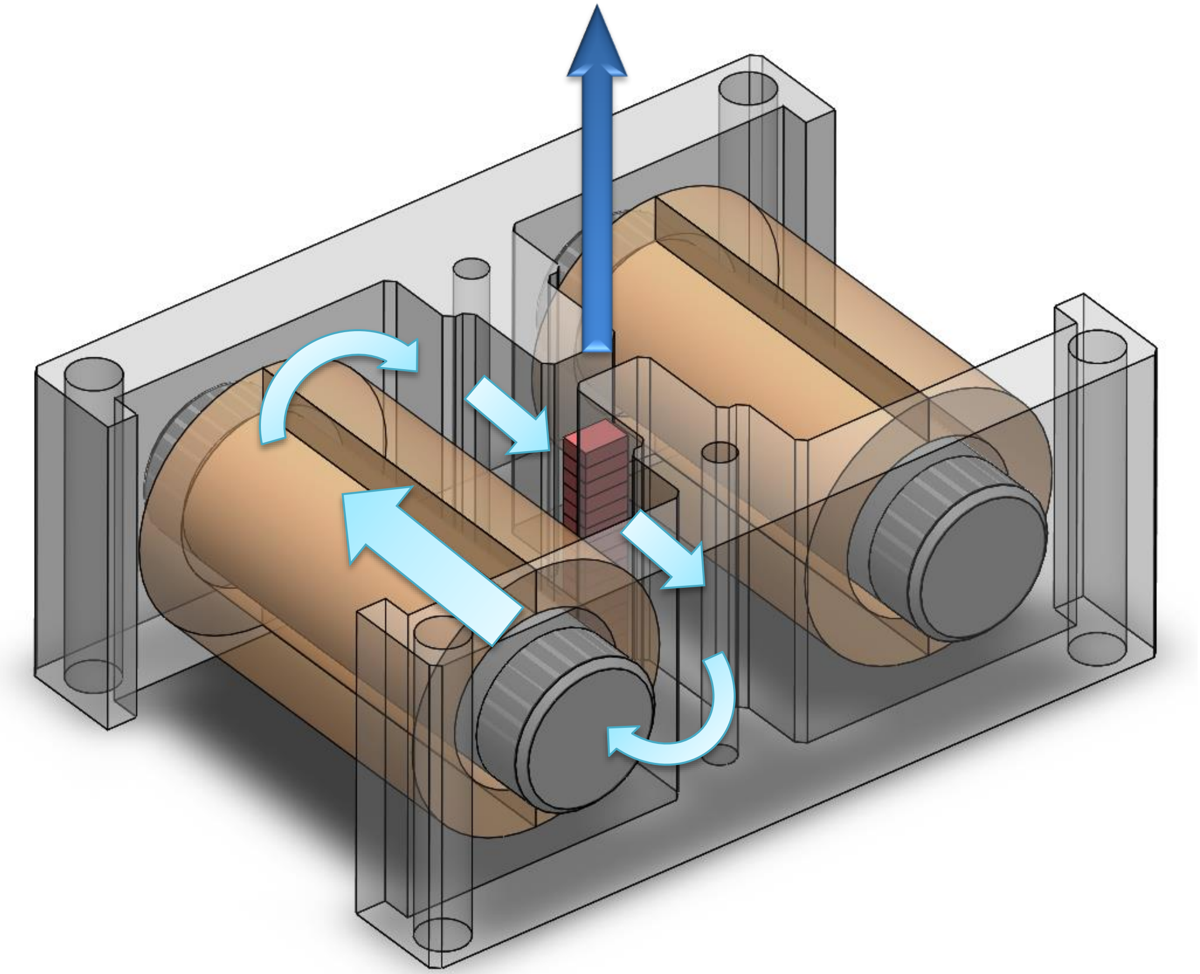
Simulation results



$$\sigma_x^{mag}\left(\sigma_{max}^{mag}, H\right) + \sigma_x^{ext} > \sigma_t + \sigma_y^{ext} + \sigma_y^{mag}\left(\sigma_{max}^{mag}, H\right)$$

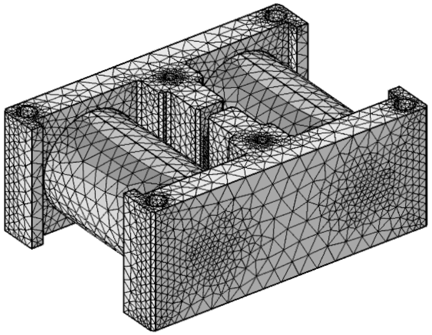
3D Simulation with COMSOL

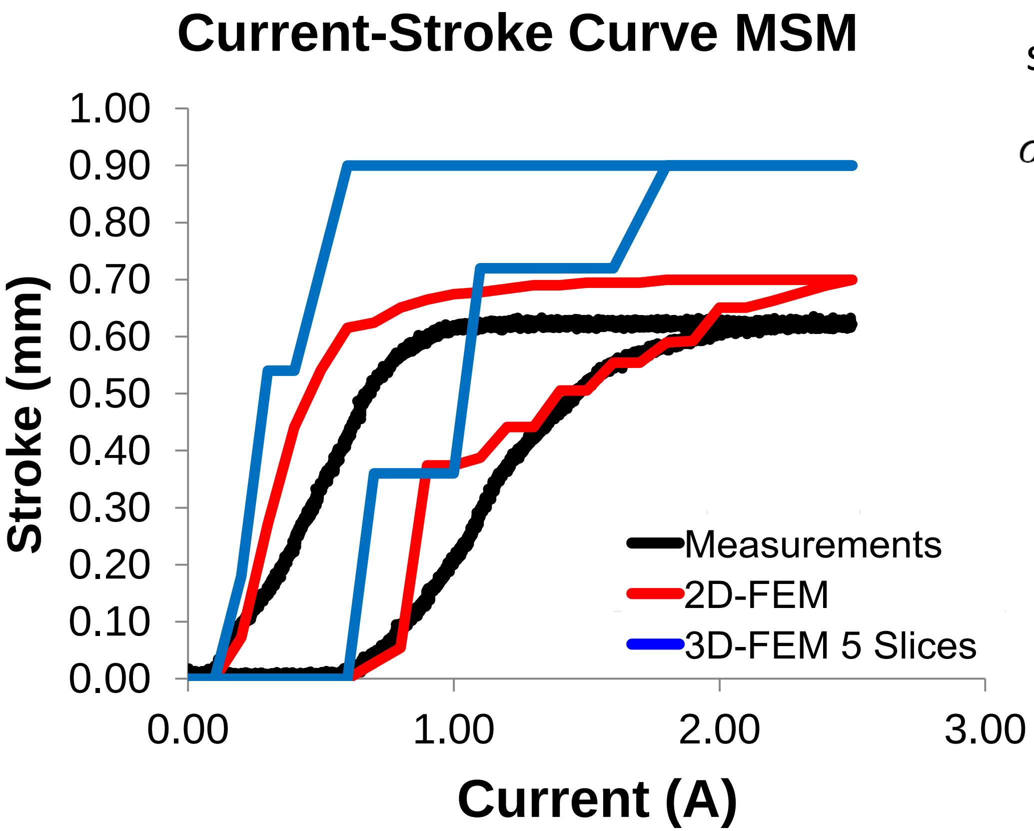
The simulated Actuator – Fast Switching Spring Actuator



Spring actuator	
Actuator size	35 × 40 × 20 mm³
MSM size	2 × 3 × 15 mm³
Cu weight	14 g
Current	3 A
Stroke	0.7 mm
Force	7 N
Switching time	1.6 ms

The simulated Actuator – Fast Switching Spring Actuator – 3D-FEM-Plots

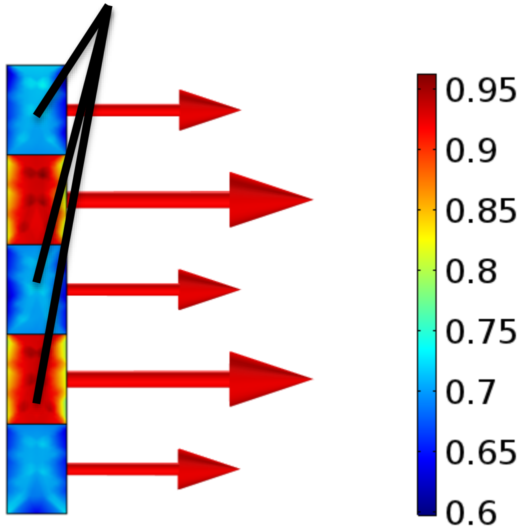




First 3D simulation with this Model:

- Magneto-Static simulation
- Subdivided in 5 elements
- Each with individual twinning stress
- Magneto-mechanical behaviour is calculated separately

$$\sigma_{x}^{mag}(\sigma_{max}^{mag}, H) + \sigma_{x}^{ext} > \sigma_{t} + \sigma_{y}^{ext} + \sigma_{y}^{mag}(\sigma_{max}^{mag}, H)$$



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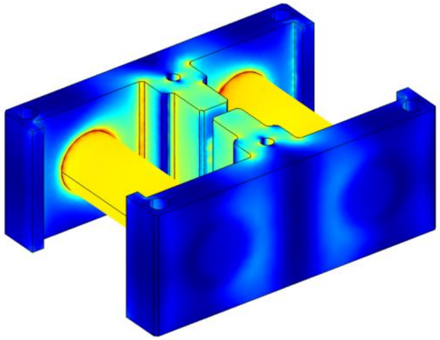
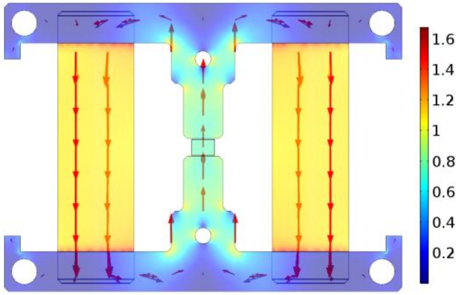
The simulated Actuator – Fast Switching Spring Actuator – 3D-FEM-Plots

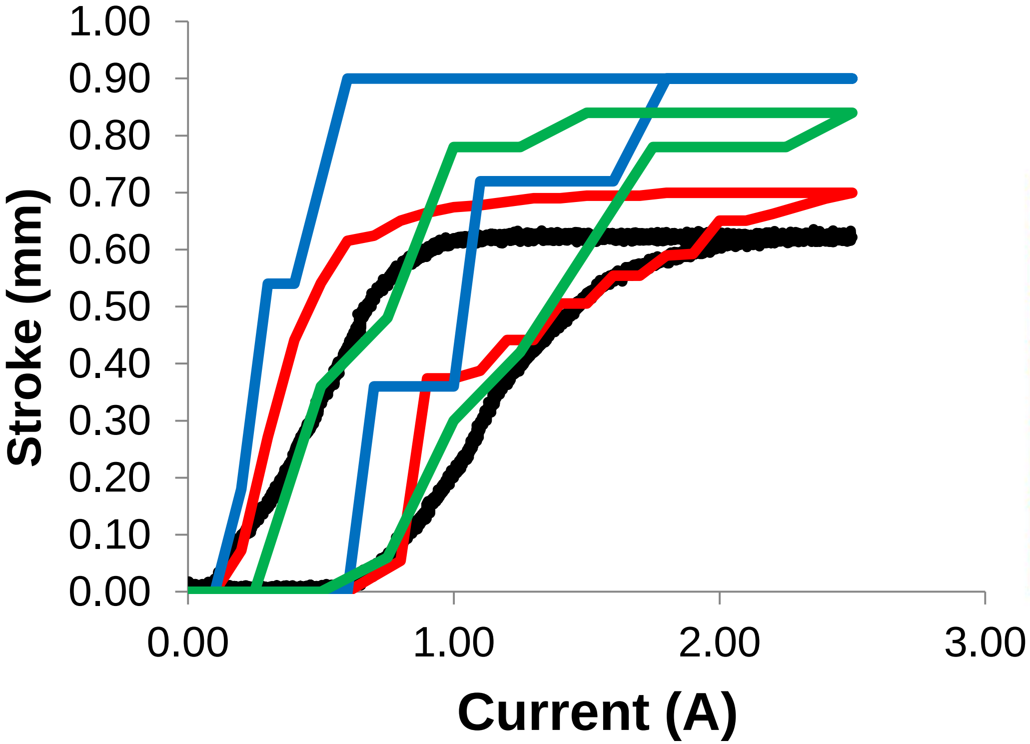


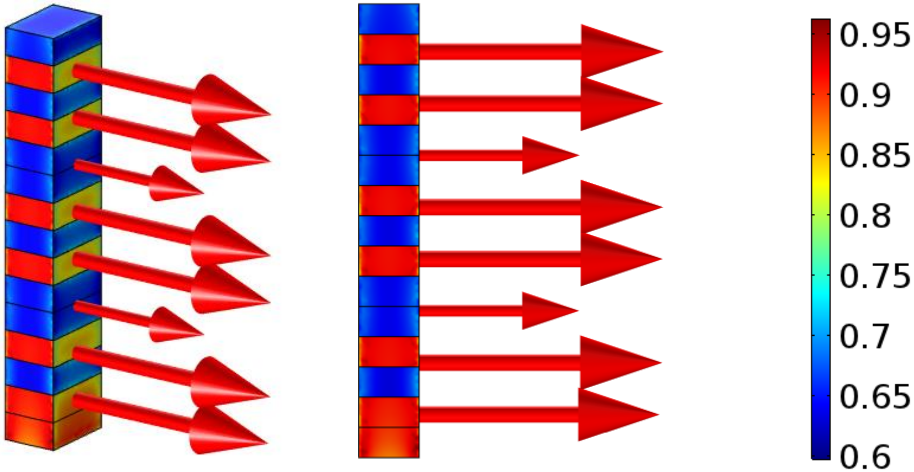


Second 3D simulation more Elements:

- Magneto-Static simulation
- Subdivided in 15 Elements
- Each with individual twinning stress
- Magneto-mechanical behaviour is calculated separately

Current-Stroke Curve MSM

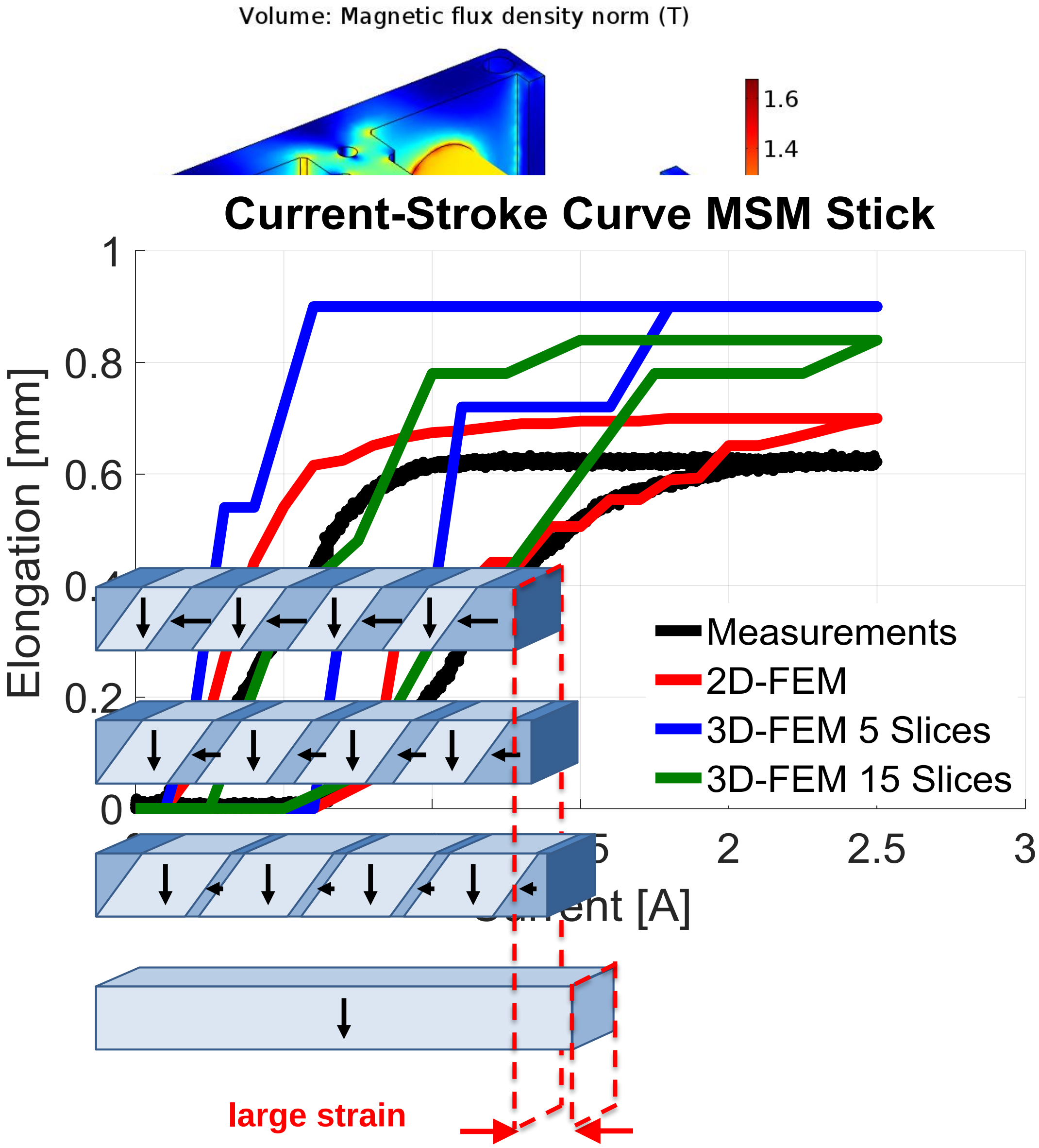




Simulation of Magnetic Shape Memory Actuators

Conclusion and Outlook

- 3D-FEM simulation results are presented that demonstrate a possibility of modeling MSM actuators
- Taking into account the anisotropic behavior of MSM materials
- Appropriate representation of the twin structure
- The flux density within the magnetic circuit of an MSM actuator is analyzed using COMSOL® Multiphysics
- The results agree with previous 2D-Fem simulations as well as measurements
- To reduce the divergence between the 3D-FEM-simulations results and the measurements, a increased amount of slices will be necessary
- Therefore an automated and adaptive evaluating process is indispensable



Thank you for your attention,
do have any questions?