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Superconducting Magnetic Heterostructured Components for Electric Motor Applications

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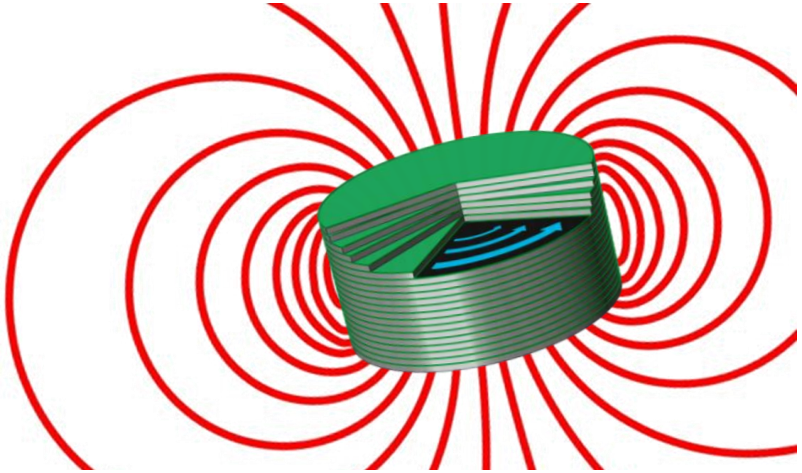
ASCG APPLIED SUPERCONDUCTIVITY AND CRYOSCIENCE GROUP

Outline of the presentation

Problem:

Stacks magnetization in an electrical machine

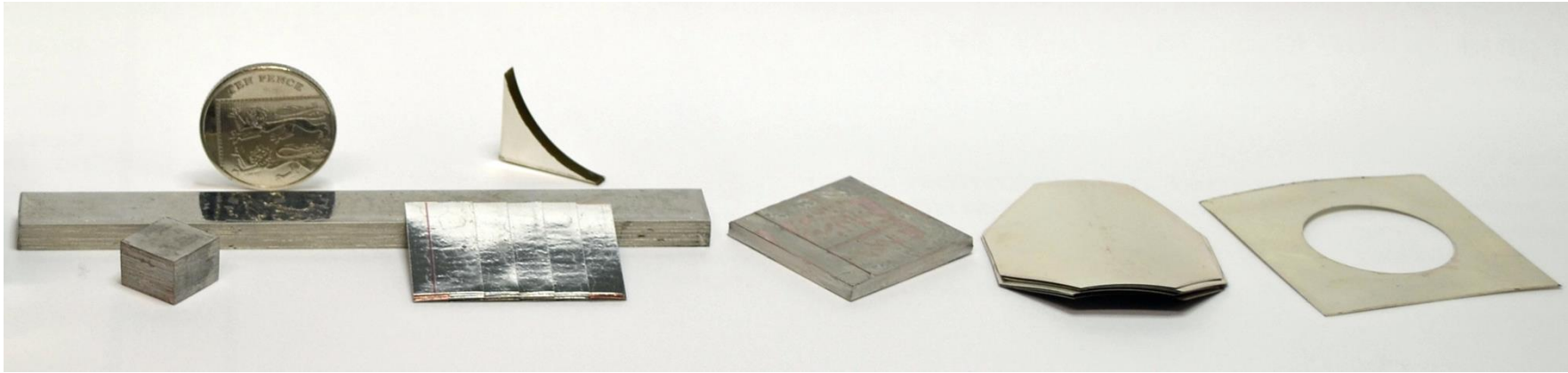
Leakage flux



Proposed solution:

Heterostructures

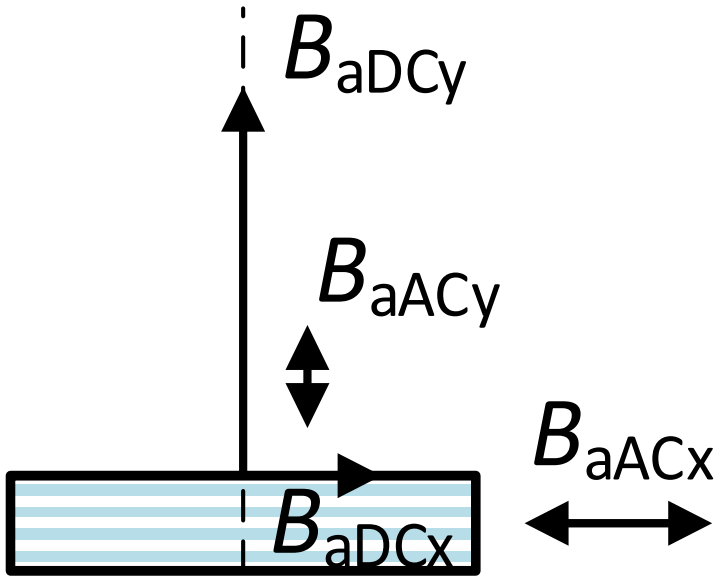
Some experimental measurements



Stacks magnetization in an EM

The conditions in an electrical machine (EM) limit the alternatives:

- Field cooling magnetization using stator (DC)
- No stator teeth
- Interior mounted stacks without iron bridges:
  to avoid losses
  to avoid demagnetization from stator harmonics
- substrate: μ_r = 10 (Ni-5%W @ 25 K)



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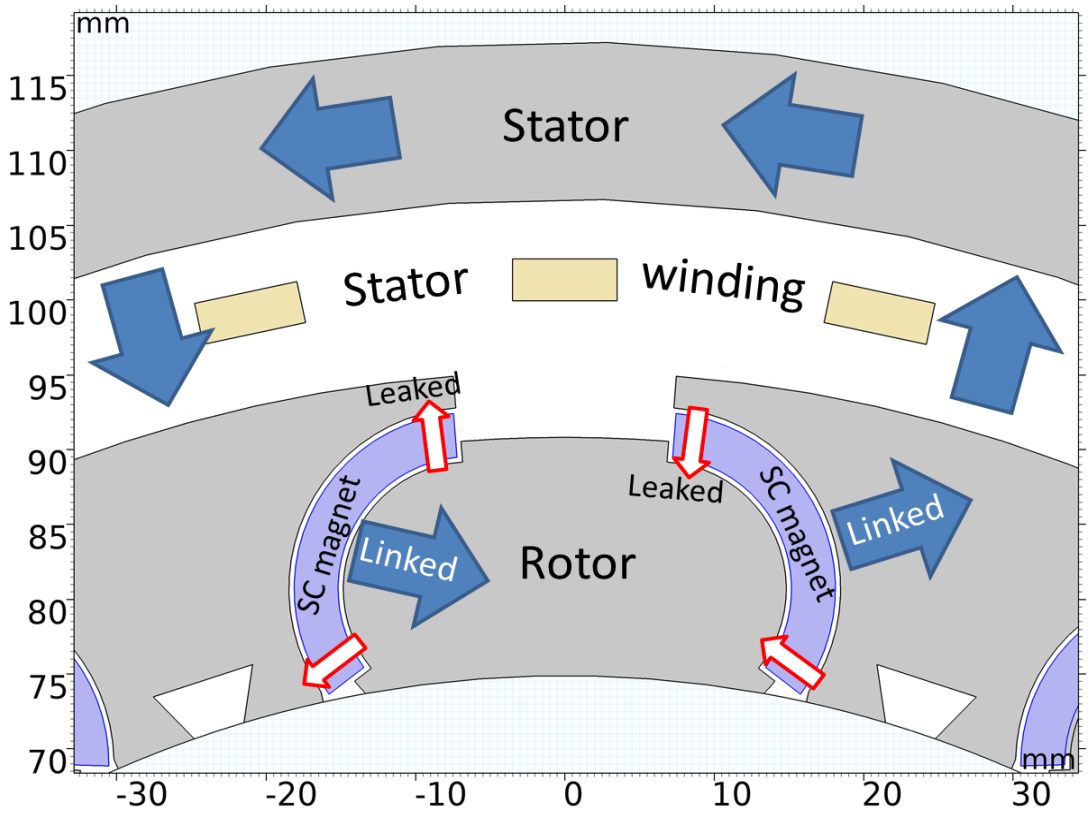
ASuMED motor geometry*



*V. Climente-Alarcon et al., “Field Cooling Magnetization and Losses of an Improved Architecture of Trapped-Field Superconducting Rotor for Aircraft Applications,” *AIAA Propulsion and Energy Forum and Exposition,* Indianapolis, USA, 19–22 August 2019, AIAA 2019-4313.

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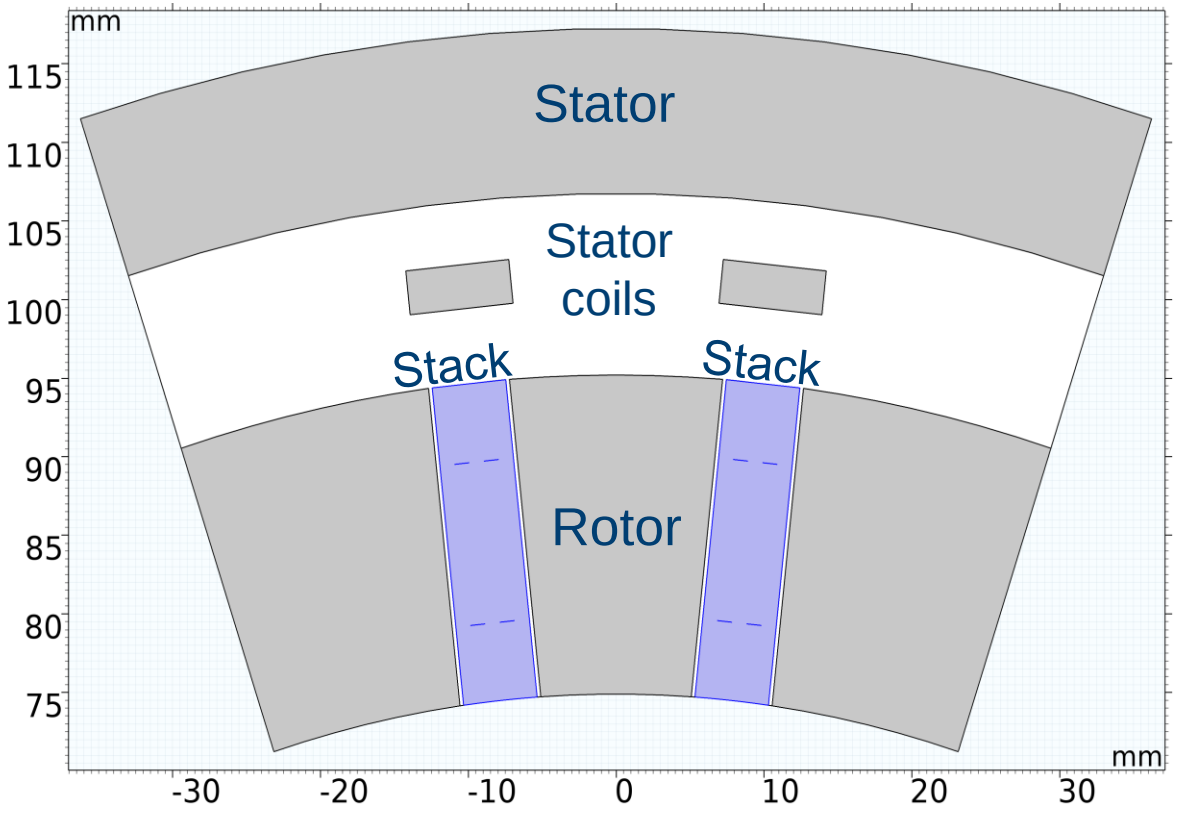
Simplified motor geometry



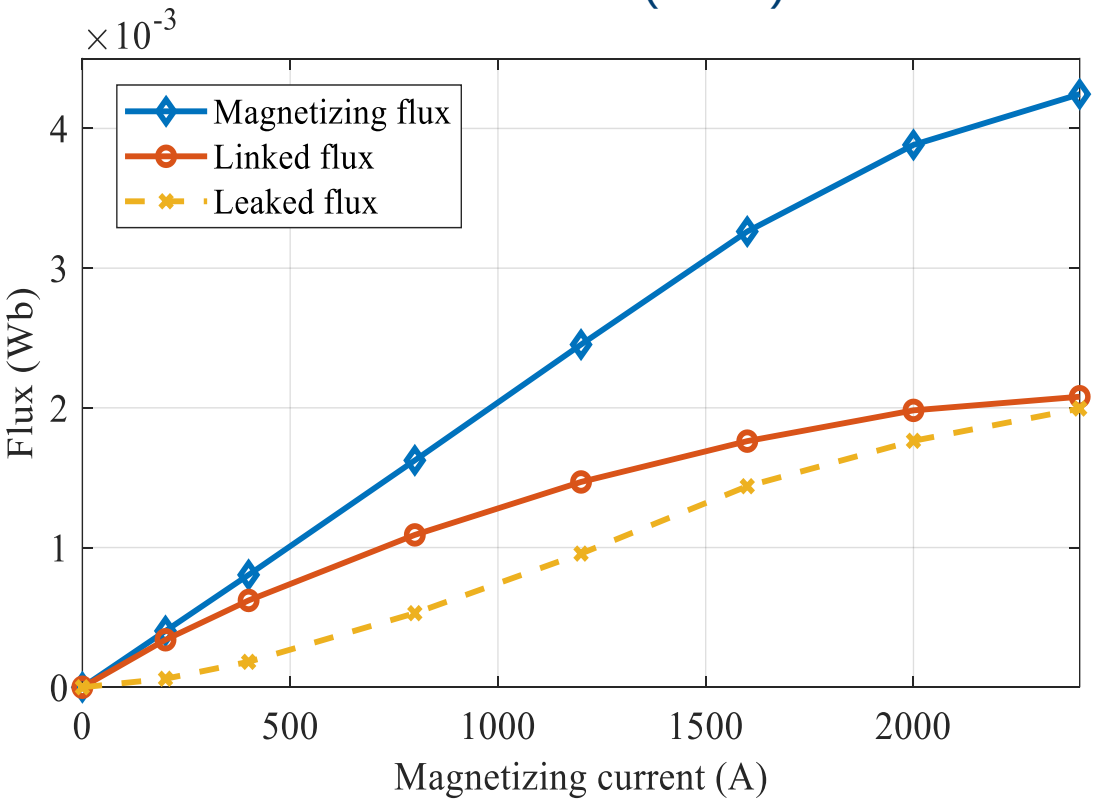
Stacks magnetization in an EM

The conditions in an electrical machine (EM) limit the alternatives:

- Field cooling magnetization using stator (DC)
- No stator teeth
- Interior mounted stacks without iron bridges
- μ_r = 10 (Ni-5%W @ 25 K)
- After mag. -> small available flux

Leakage flux

FEM results (stack)

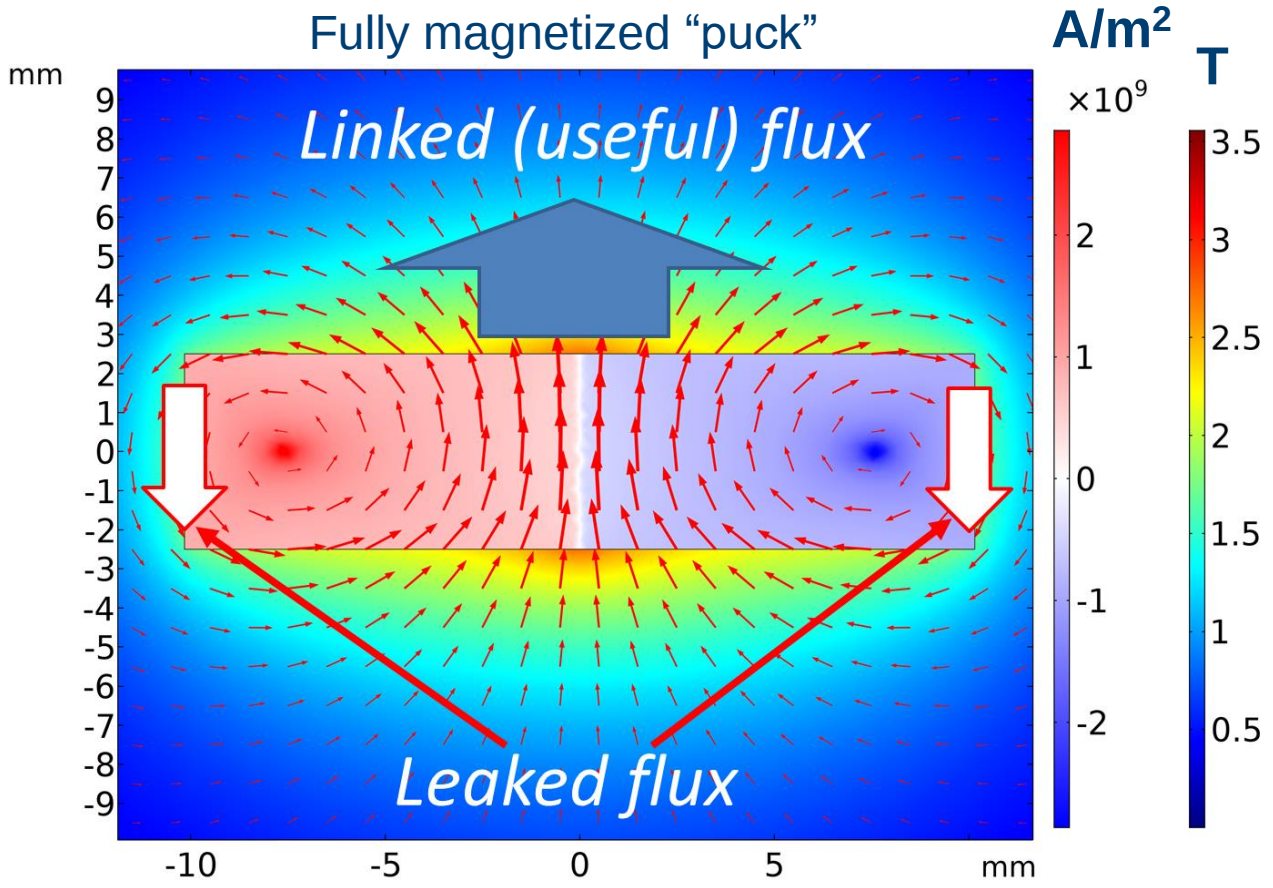


Leakage flux

Higher intrinsic leakage flux is inherent to stacks (trapezoidal-triangular *mmf*)

Leakage increases with current (I_{mag})

Exacerbated when embedding the stack in iron



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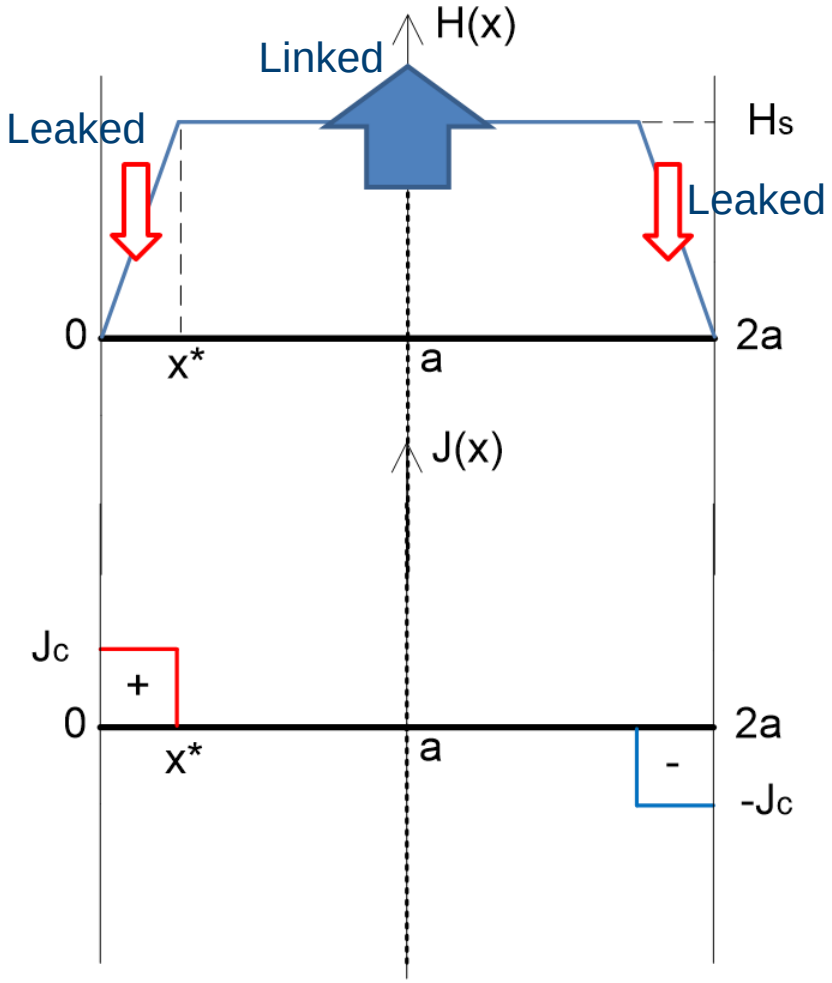

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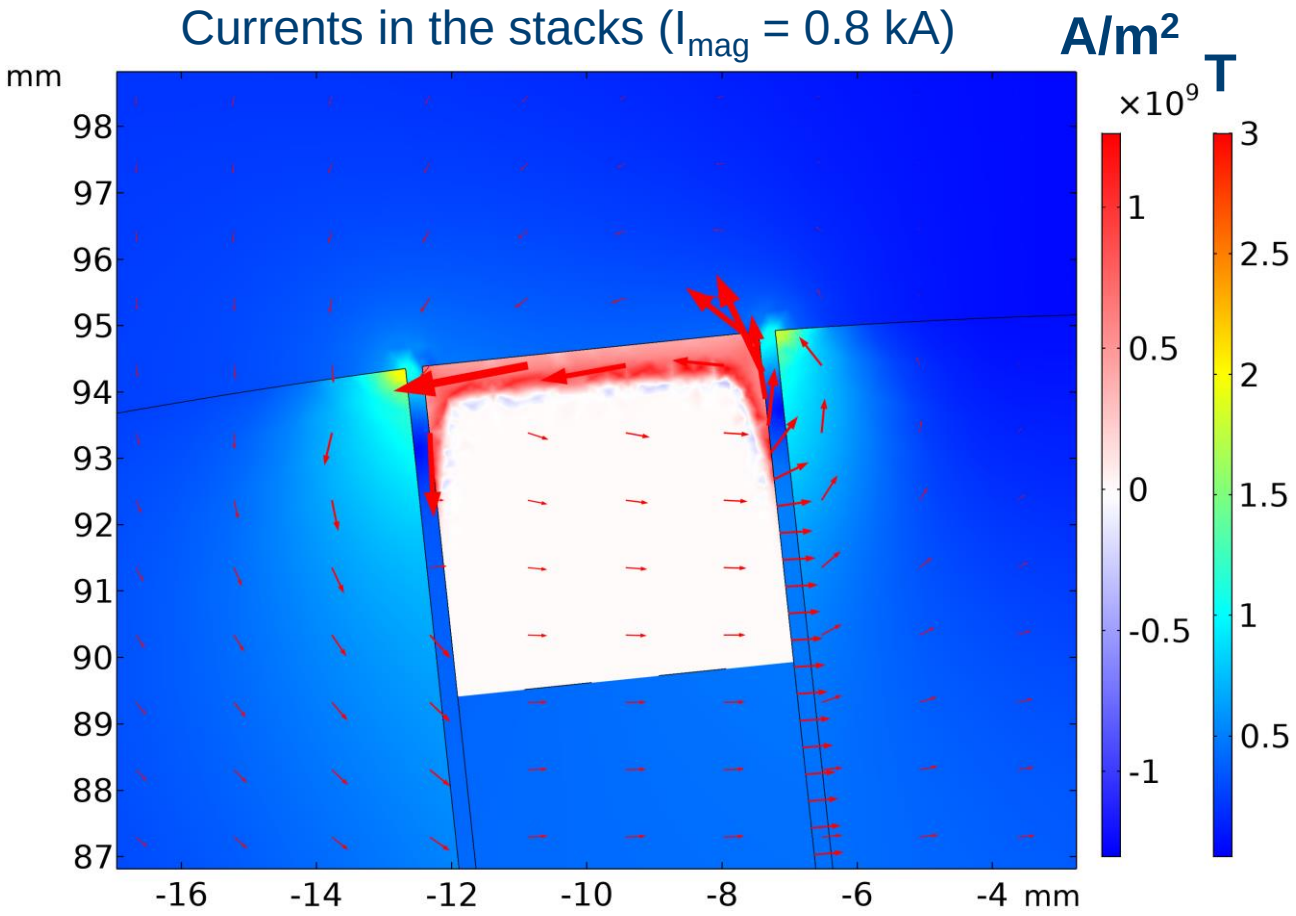

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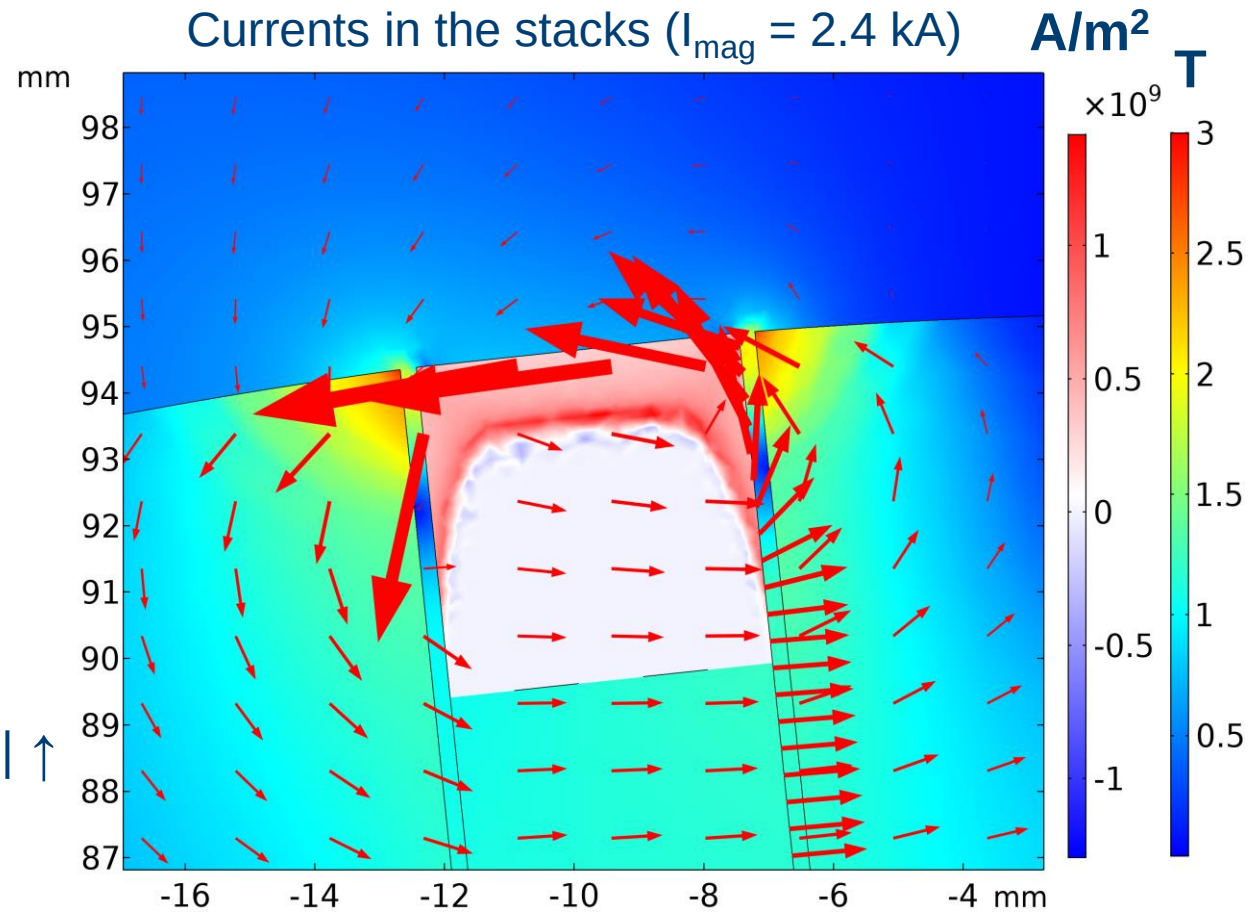
FE simulation increases its effect since $J_c \downarrow$ when $|\boldsymbol{B}| \uparrow$



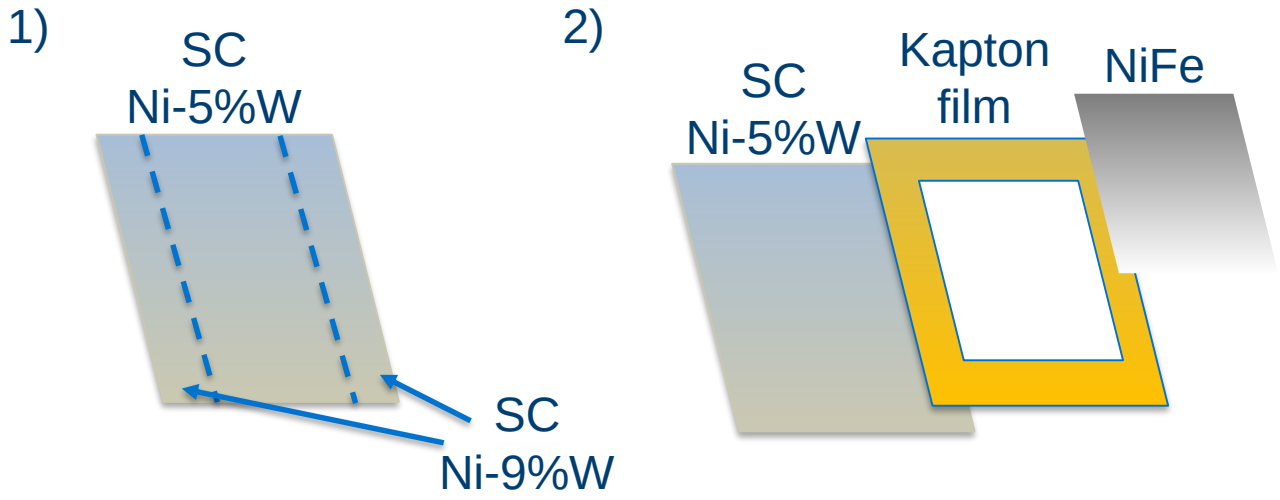
Proposed solution

The arrangement of a stack with lower μ_r at its sides (25%)

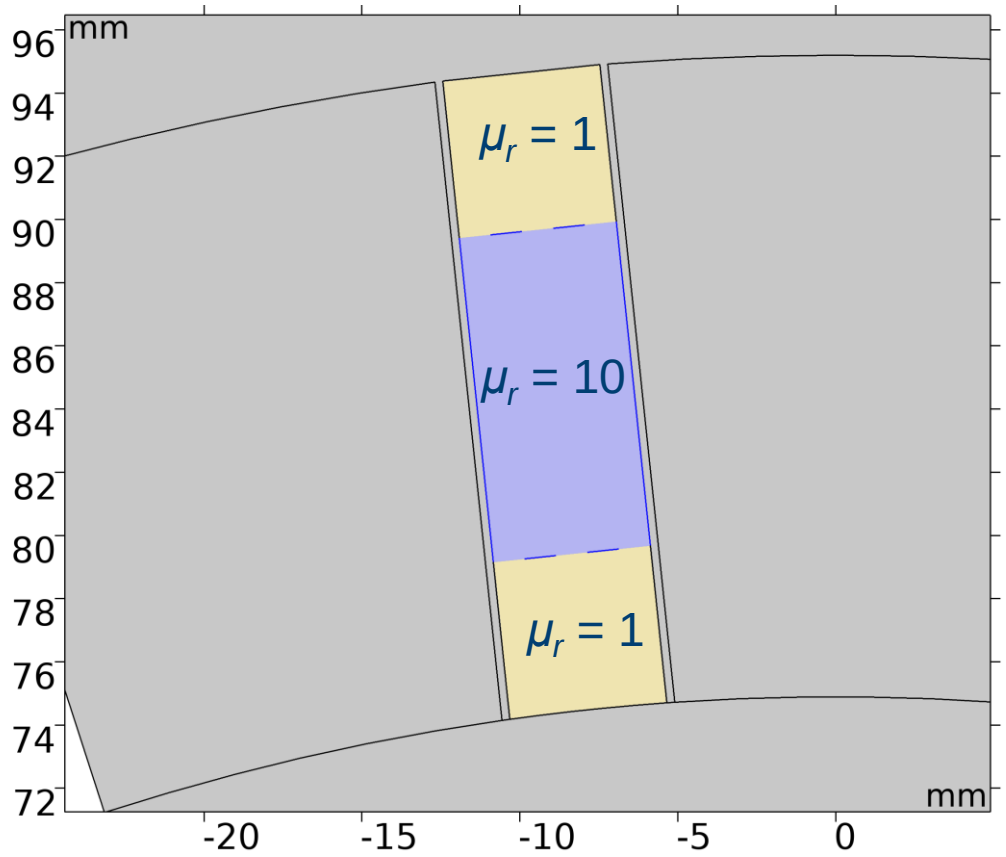
Either:

1) Ni-9.5%W at its sides*

2) Heterogeneous construction



Newly computed stack



*J. H. Claassen, C. L. H. Thieme, “Magnetic properties of Ni-based substrates for HTS tape,” *SuST,* 21 1050030 2008

Proposed solution

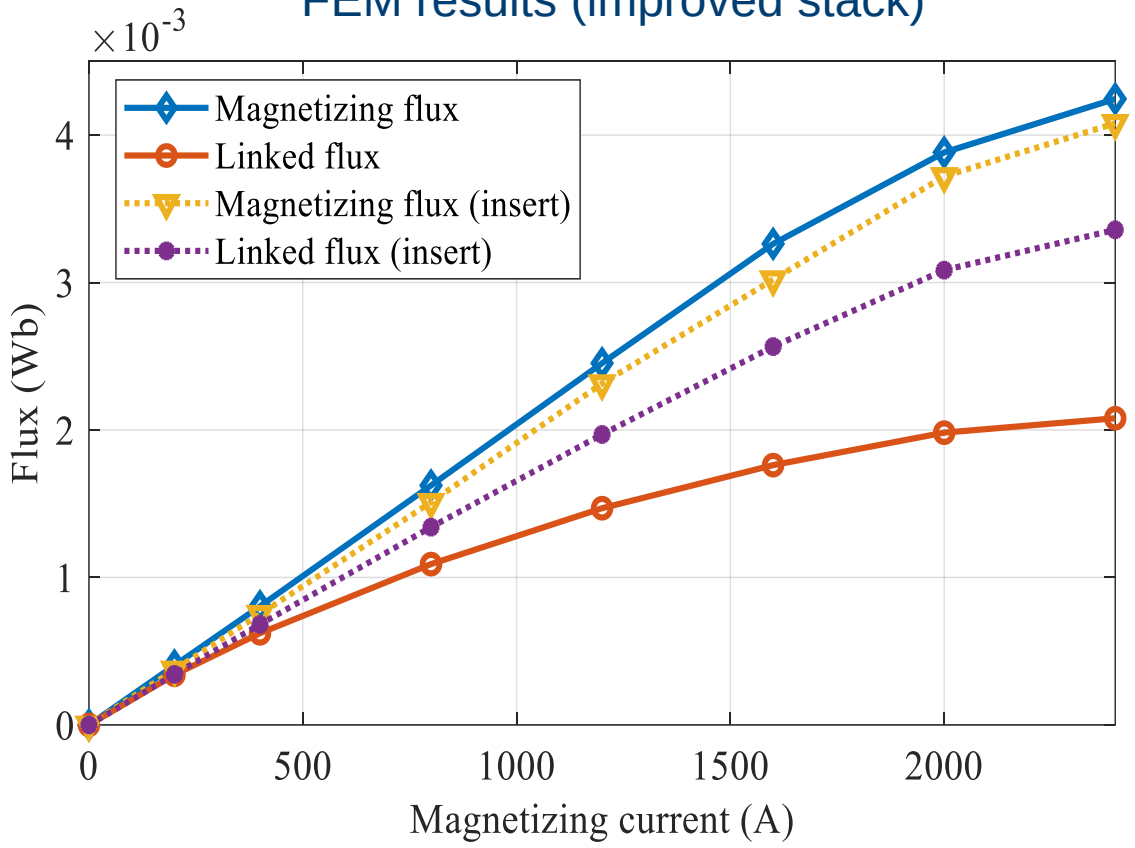
For μ_r = 1 at both sides (25%) and μ_r = 10 in the rest of the stack:

Small (6%) reduction of magnetizing flux

Increase of linked flux up to 61 % at I_{mag} = 2.4 kA

Max. total (stack + airgap) leaked flux 20 %

FEM results (improved stack)



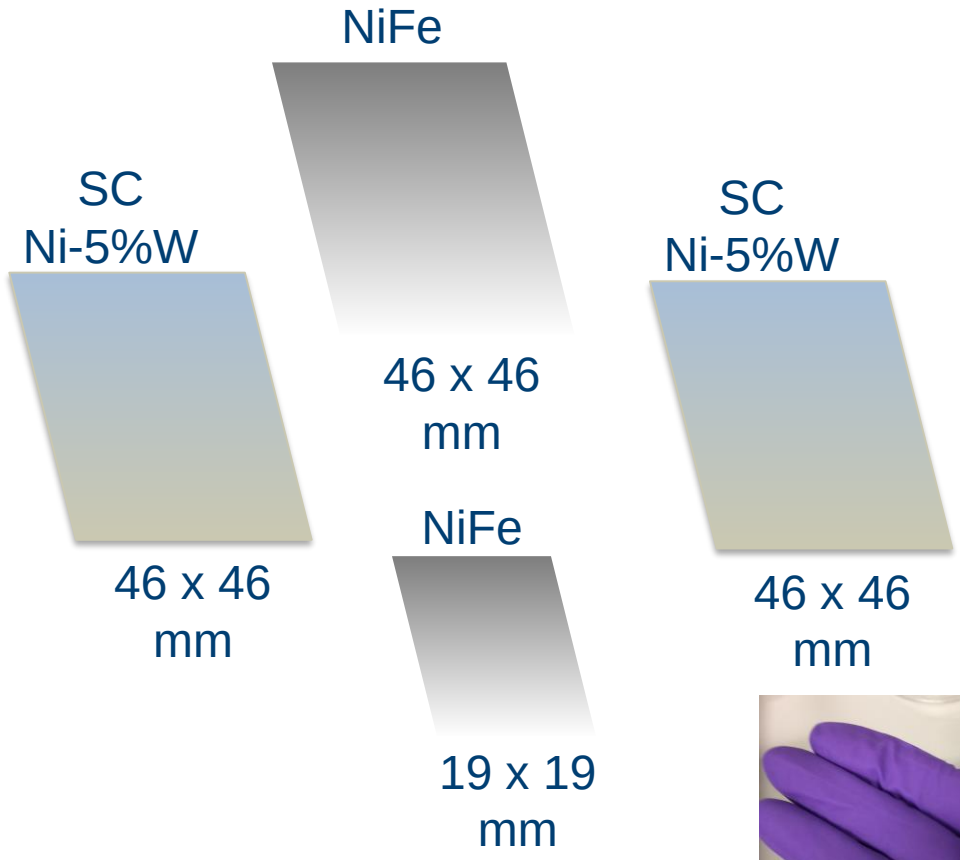
Experimental results

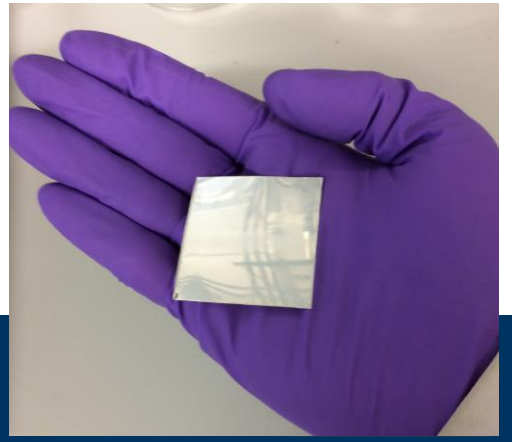
Heterogenous construction has been used for a preliminary assessment of the approach

Two layers of AMSC tape in air (50 mT), and either:

- No NiFe layer
- One NiFe layer
- One NiFe insert at the center

Zero field cooling, undersaturated by 110 mT field





Experimental results

- 19 x 19 mm central area scanned:

  two tapes + ferromag. layer

  two tapes + ferromag. insert

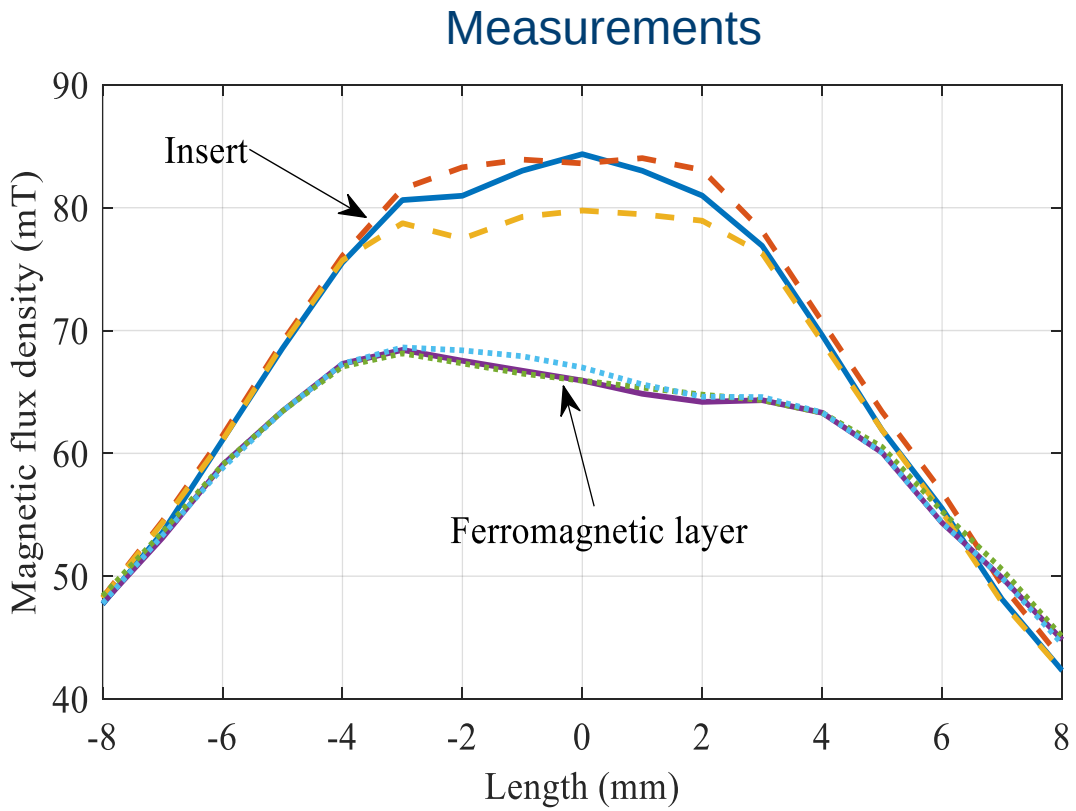
- Flux increased at the center of the stack

- Mean trapped flux in the area:

  No ferromag: 34.2 mT

  Ferromag. layer: 48.6 mT

  Ferromag. Insert: 54.6 mT



Conclusions

- ✓ Stacks need to be surrounded by iron (shielding) in the rotor of an electrical machine
- ✓ The low reluctance path between its center and its sides increases flux leakage
- ✓ Leakage increases with the saturation of the stack and μ_r
- ✓ Structures with different magnetic permeability would greatly reduce leakage