Numerical modelling of the pulse magnetization of a bulk array used as field poles of a superconducting machine.

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Summary

- Introduction
- Model used in the simulation
- Different geometries
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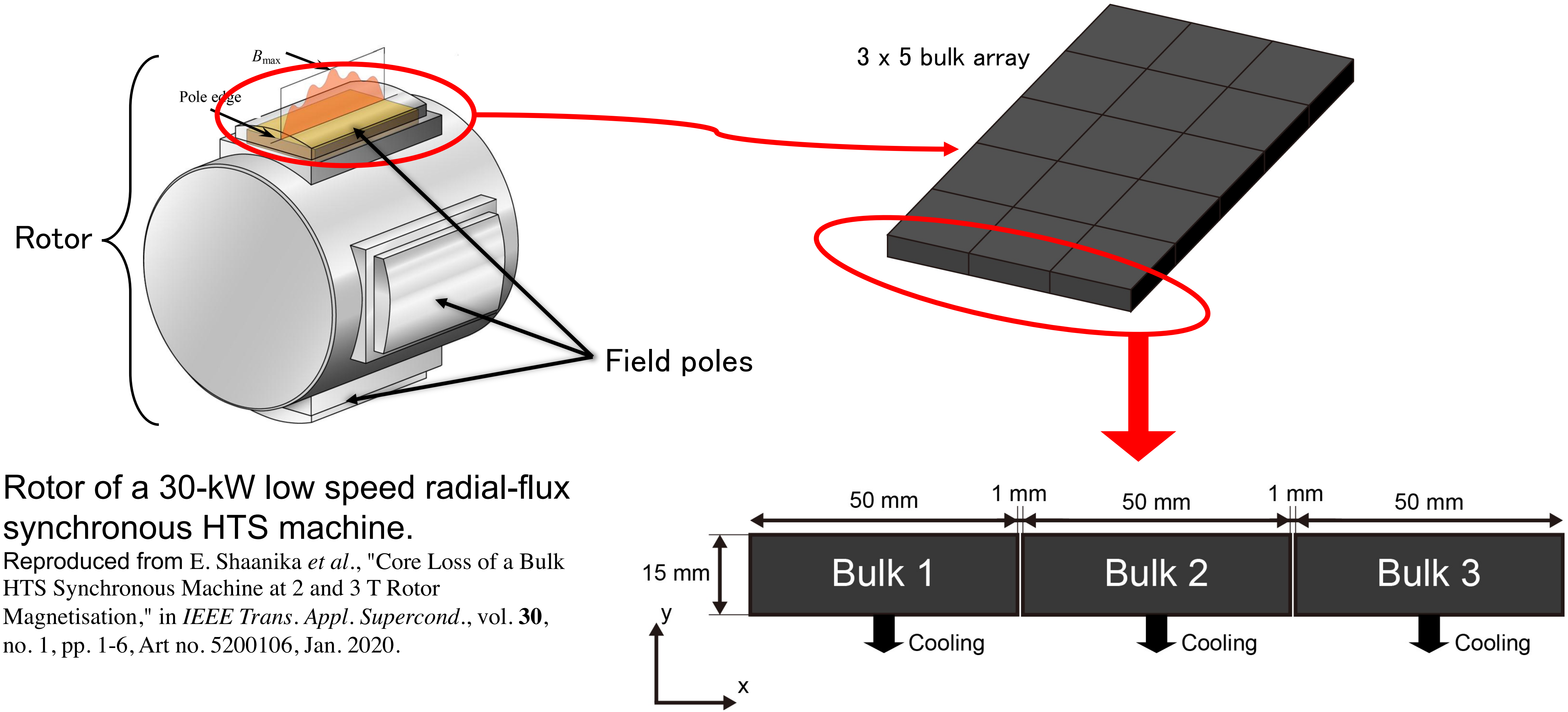
- Conclusion

Introduction



Rotor of a 30-kW low speed radial-flux synchronous HTS machine.

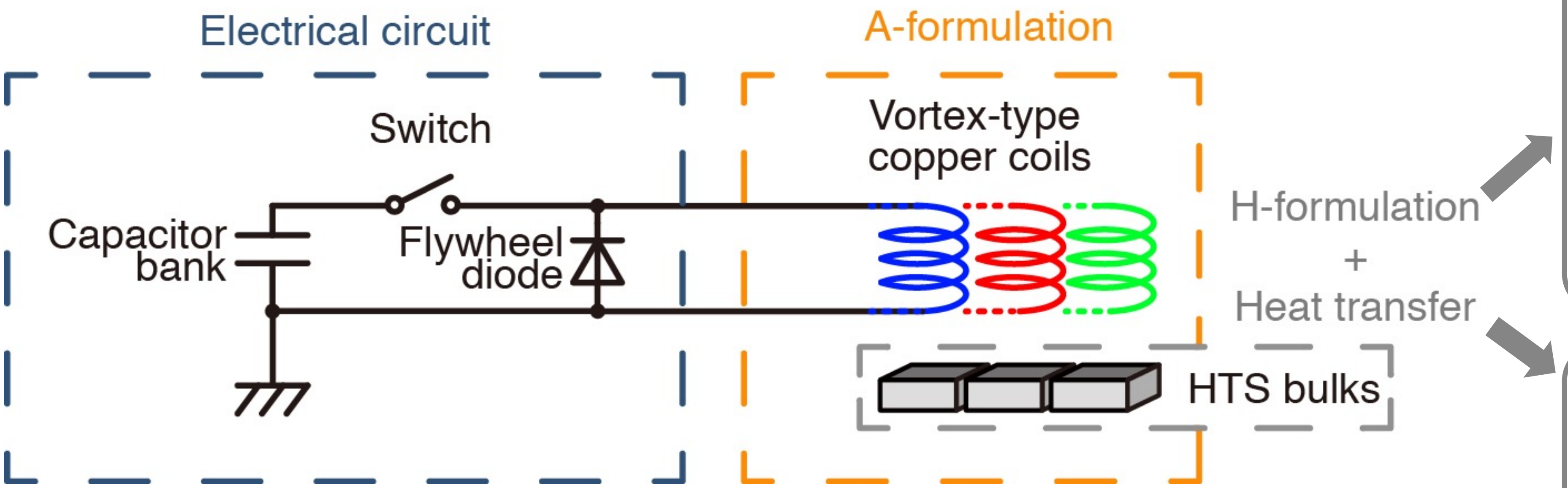
Reproduced from E. Shaanika *et al*., "Core Loss of a Bulk HTS Synchronous Machine at 2 and 3 T Rotor Magnetisation," in *IEEE Trans. Appl. Supercond.*, vol. **30**, no. 1, pp. 1-6, Art no. 5200106, Jan. 2020.

Models used in the simulation

A–formulation:

$$\sigma\frac{\partial A}{\partial t} - \nabla\times\frac{1}{\mu_0\mu_r}\nabla\times A = J_{app}$$

$$B = \nabla\times A,\qquad E = -\frac{\partial A}{\partial t},\qquad J = \sigma E + J_{app}$$



H–formulation:

$$\nabla\times\mathbf{H} = \mathbf{J}$$

$$\nabla\times\mathbf{E} + \frac{\partial(\mu_0\mu_r\mathbf{H})}{\partial t} = \mathbf{0}$$

E–J power law:

$$\mathbf{E} = \rho\mathbf{J}\,;\,\rho = \frac{E_0}{J_c(B,T)}\left|\frac{J}{J_c(B,T)}\right|^{n-1}$$

Kim model:

$$J_c(B,T) = J_{c0}(T)\frac{B_0}{|B| + B_0}$$

$$J_{c0}(T) = \alpha\left[1 - \left(\frac{T}{T_c}\right)^2\right]^{\frac{3}{2}}$$

Thermal transient equation:

$$\rho\cdot C\frac{dT}{dt} = \nabla\cdot(\kappa\nabla T) + Q$$

$$Q = J\cdot E$$

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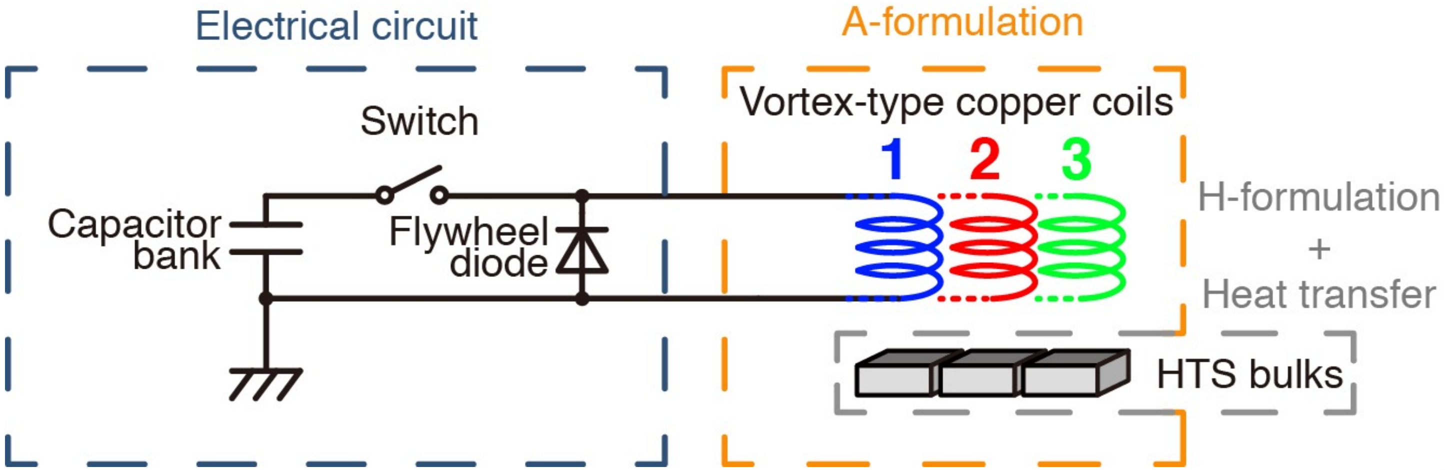
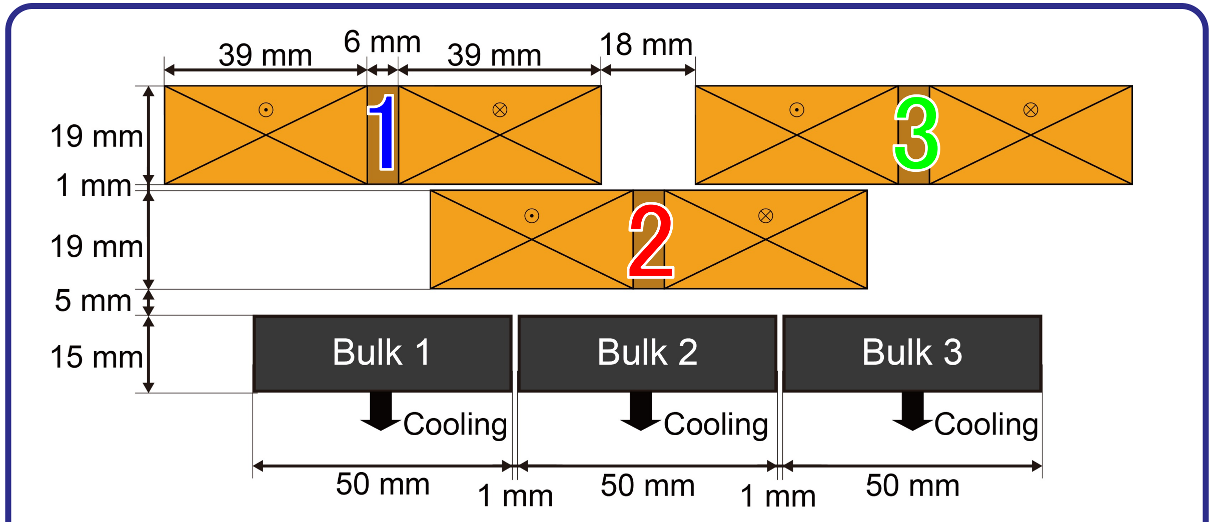
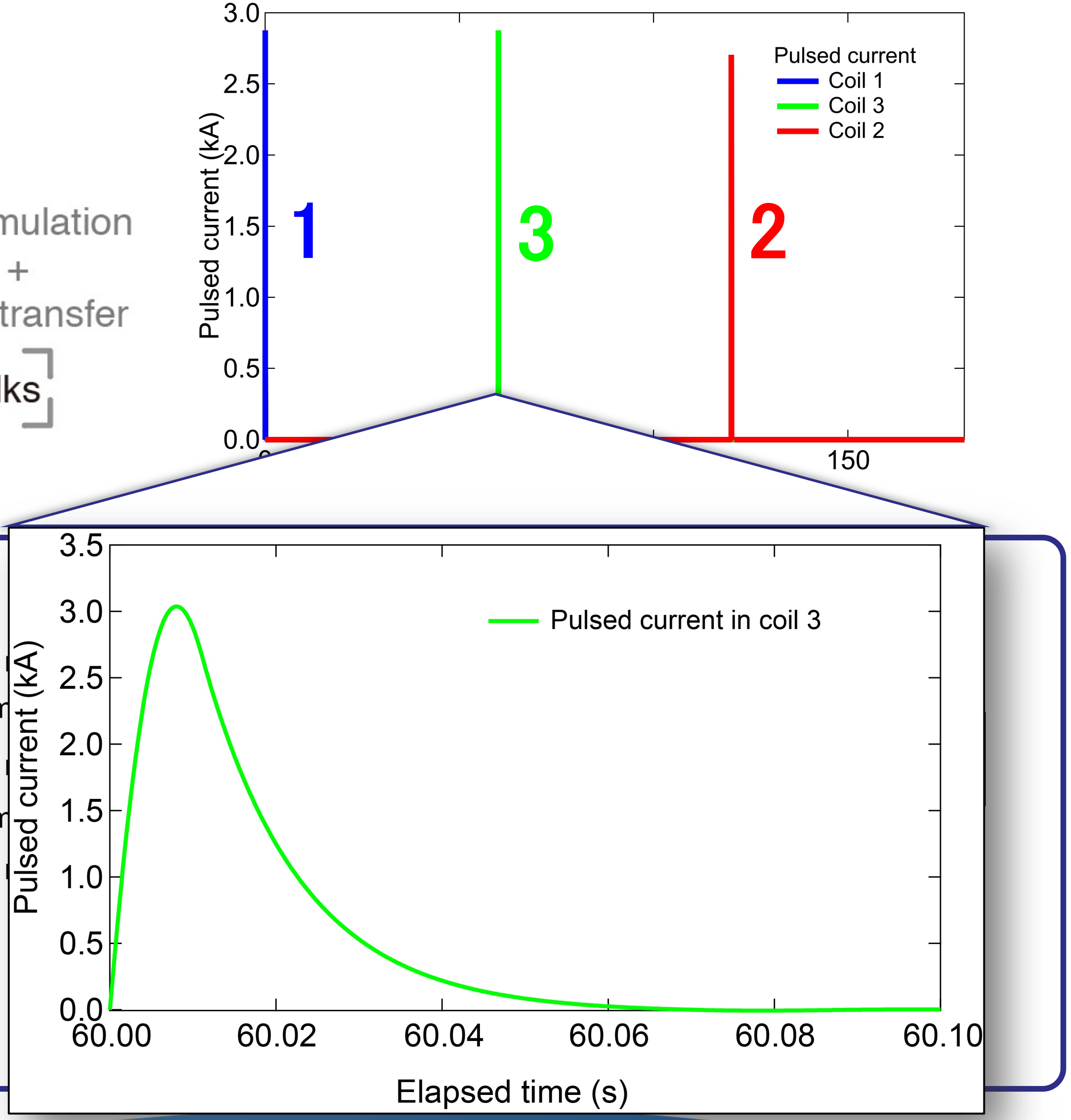
Different geometries used: multiple coils

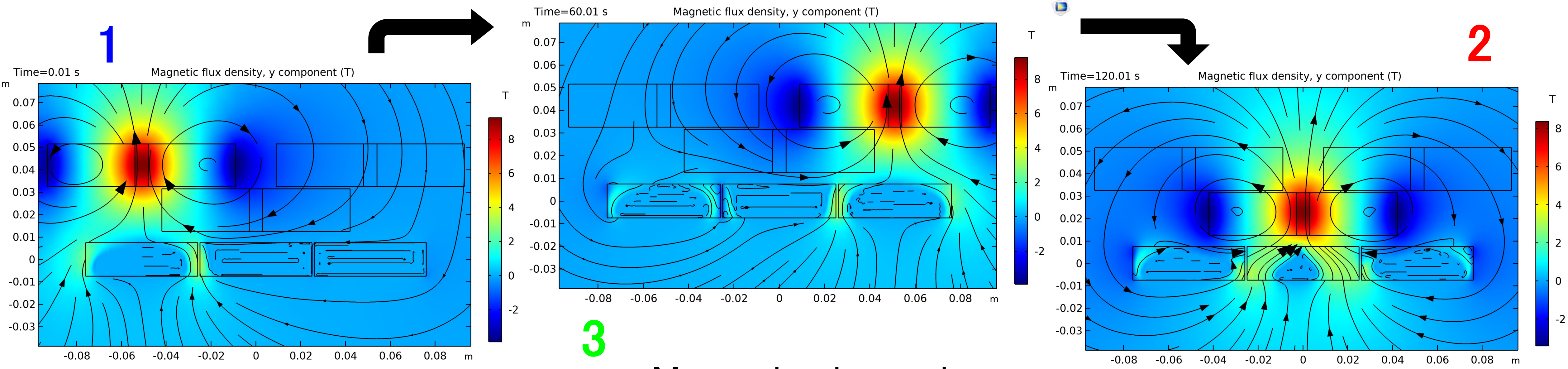




3 vortex-type coils, "V shape"

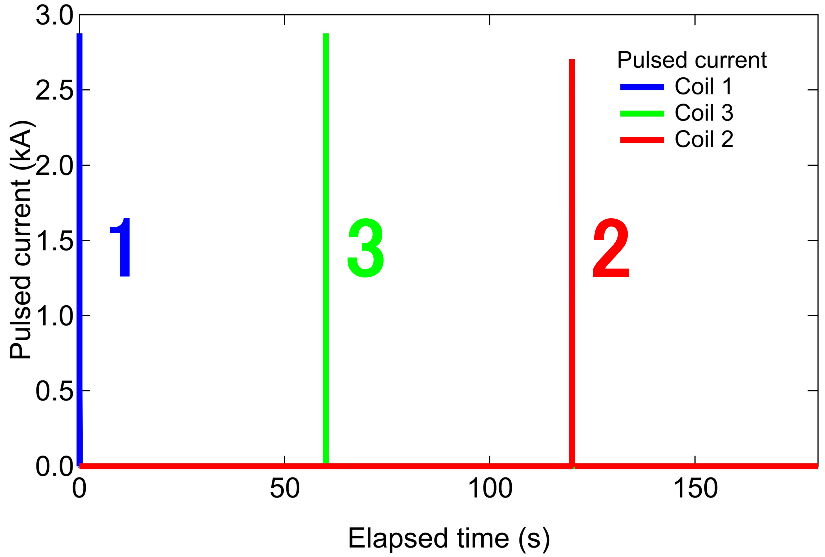


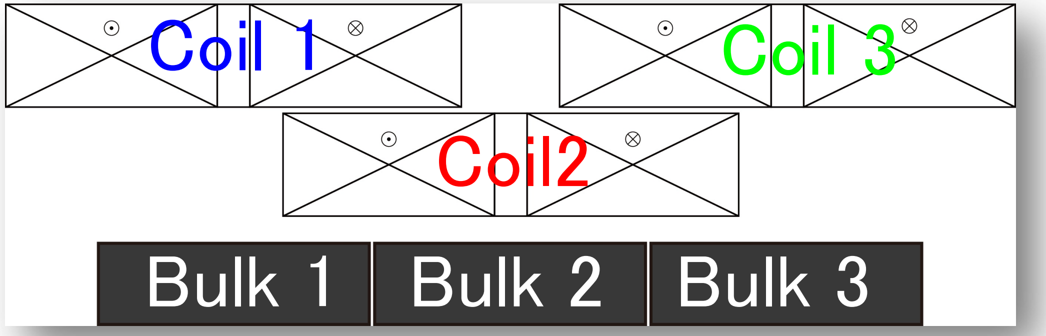
Example of magnetization process



Magnetization order:

1 ➡ 3 ➡ 2





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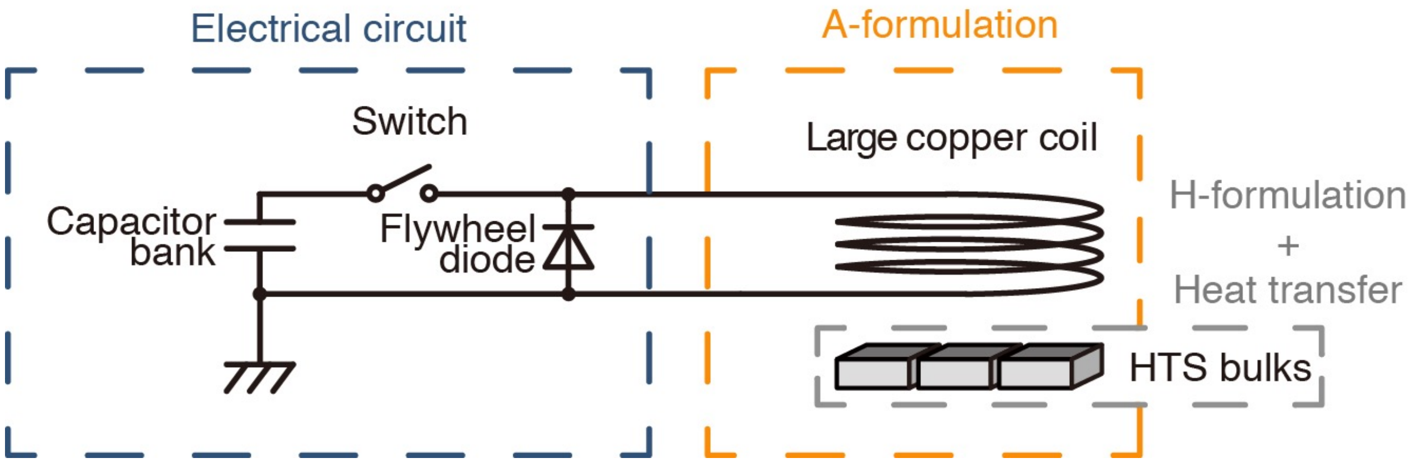
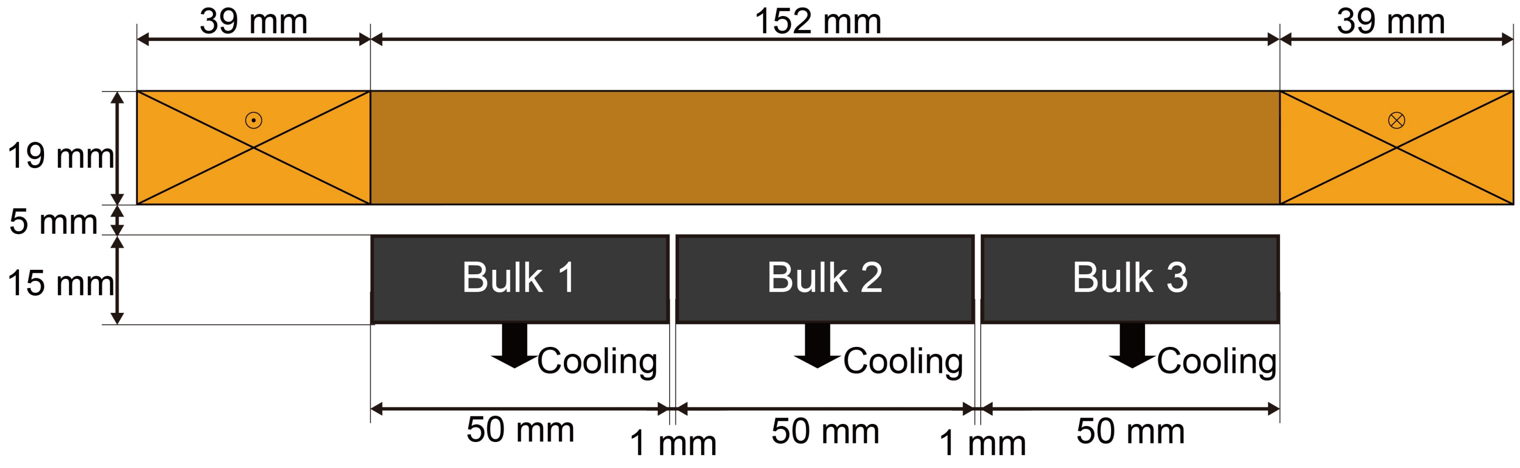
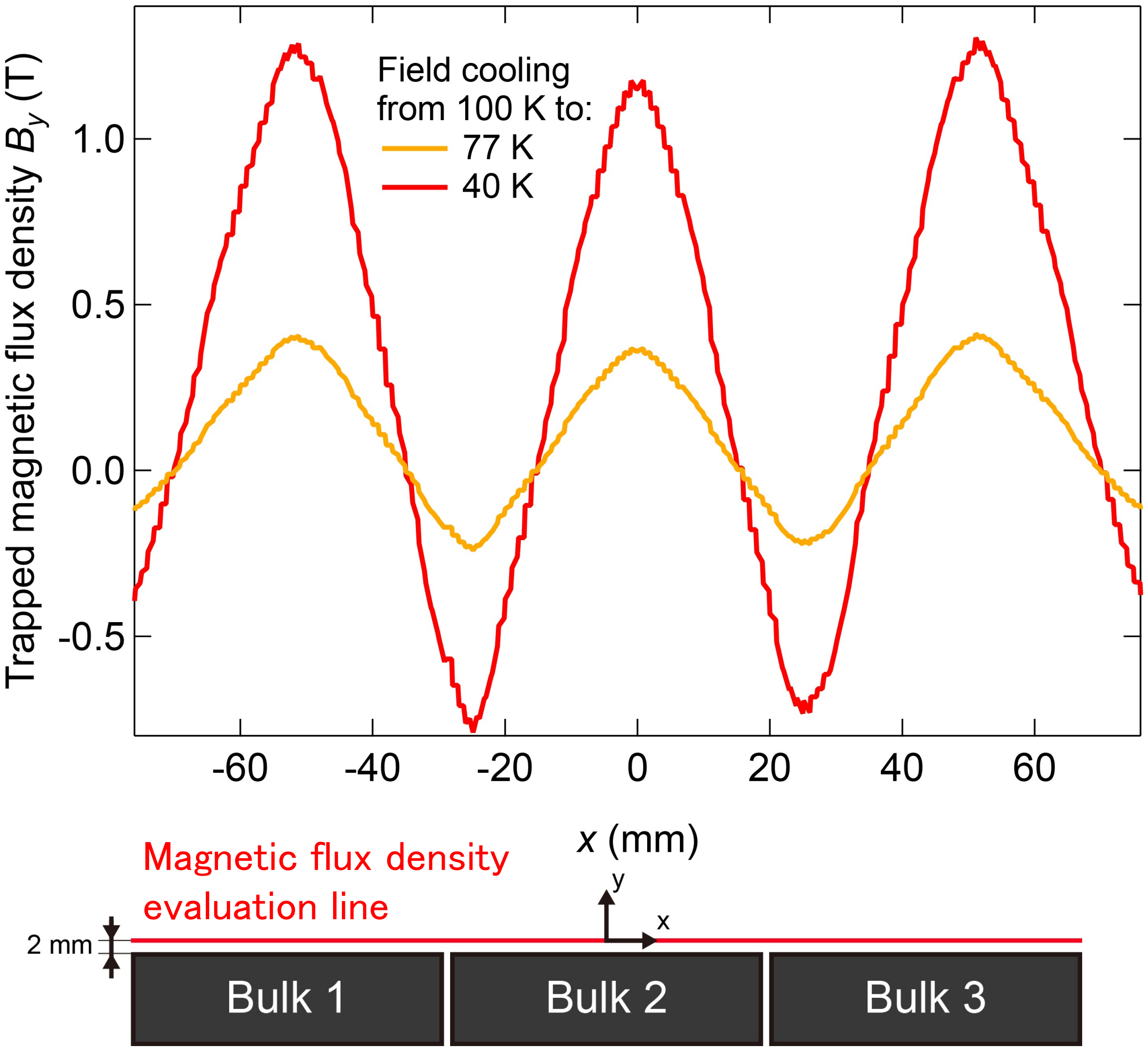
Different geometries used: unique coil

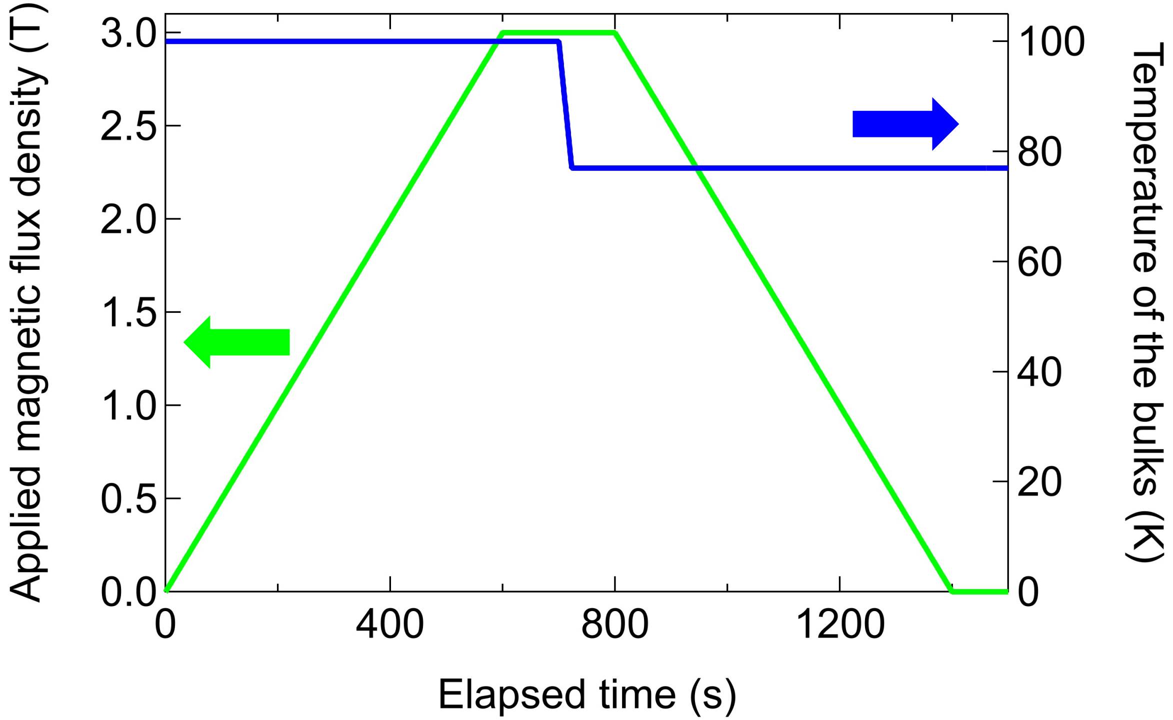




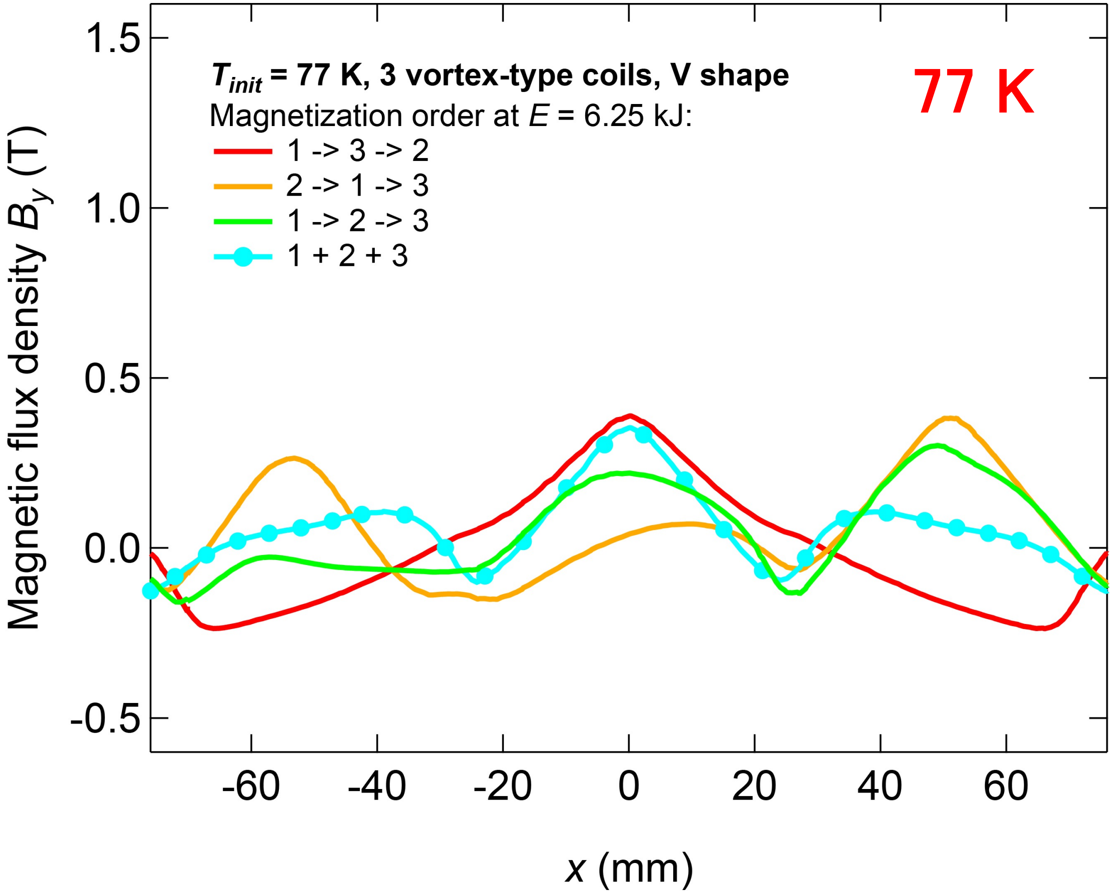
1 large coil

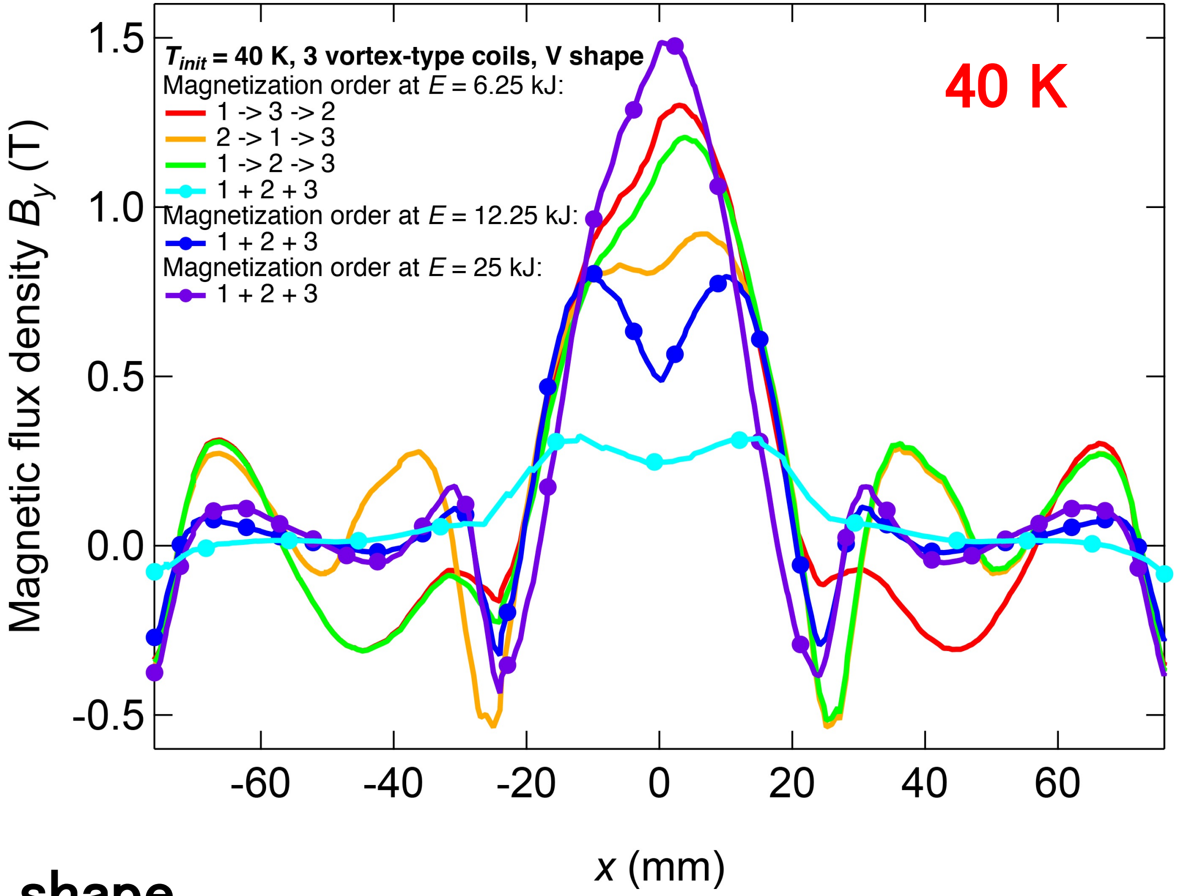
Results using a field cooling method



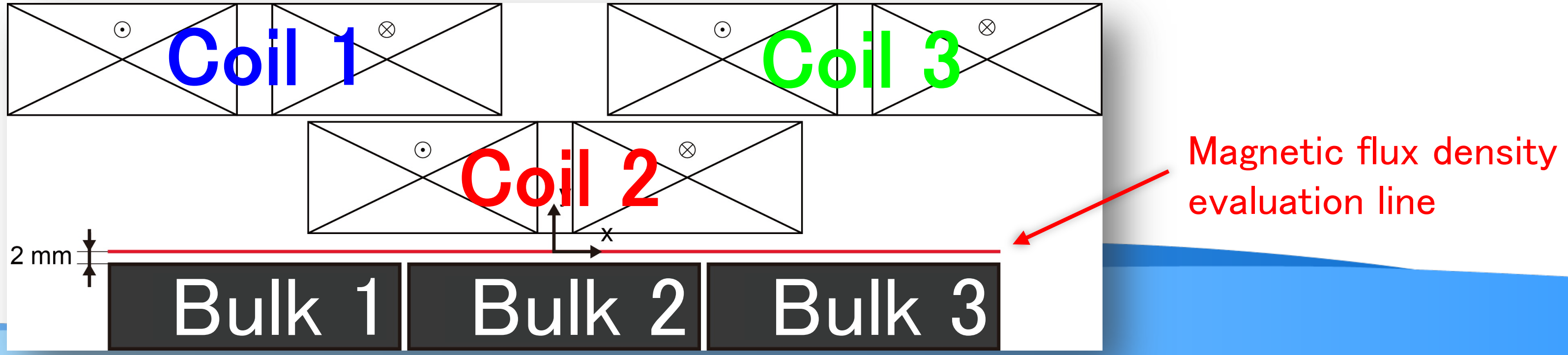


Results with 3 coils V shape

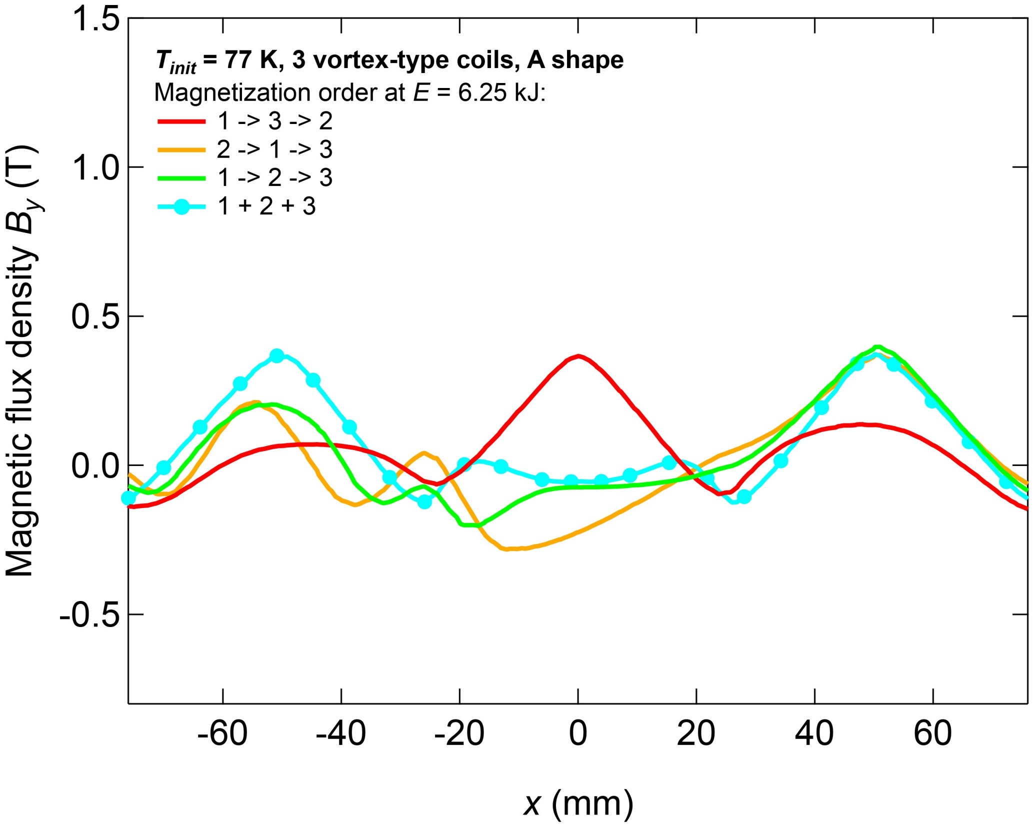


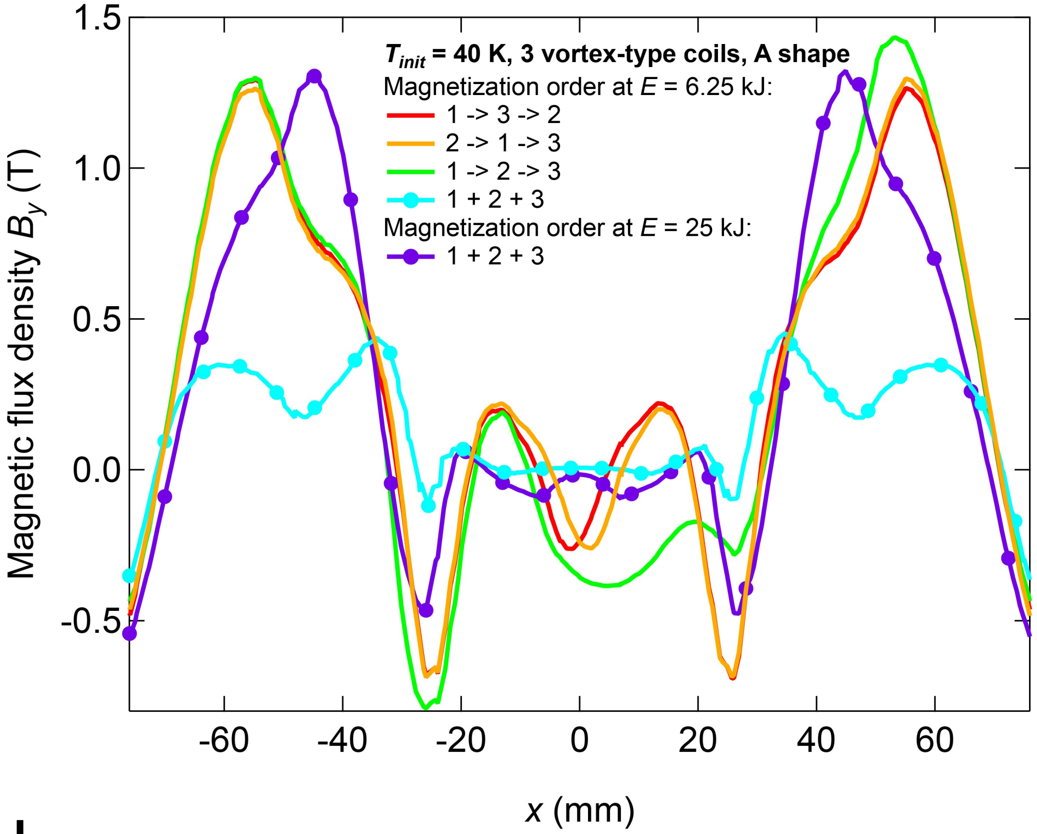


V shape

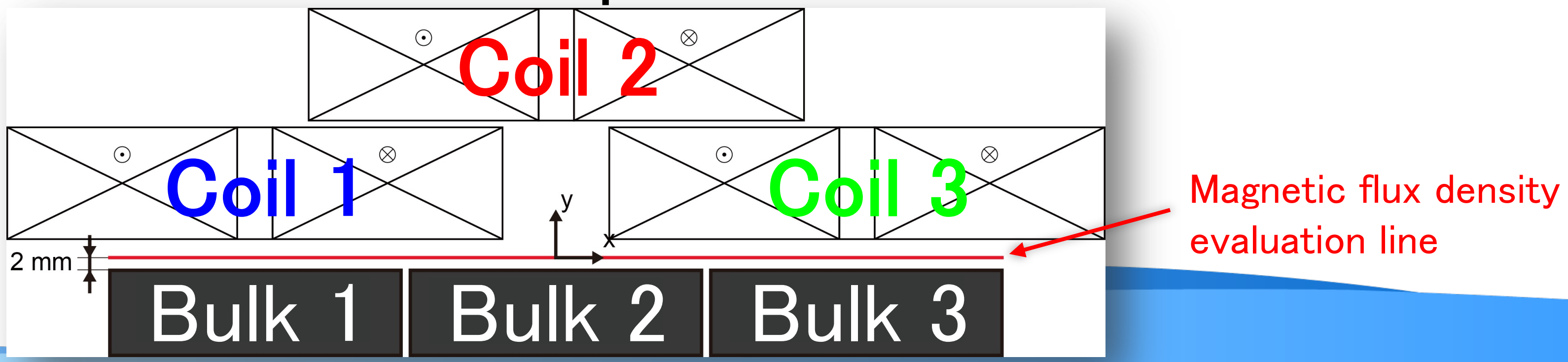


Results with 3 coils A shape

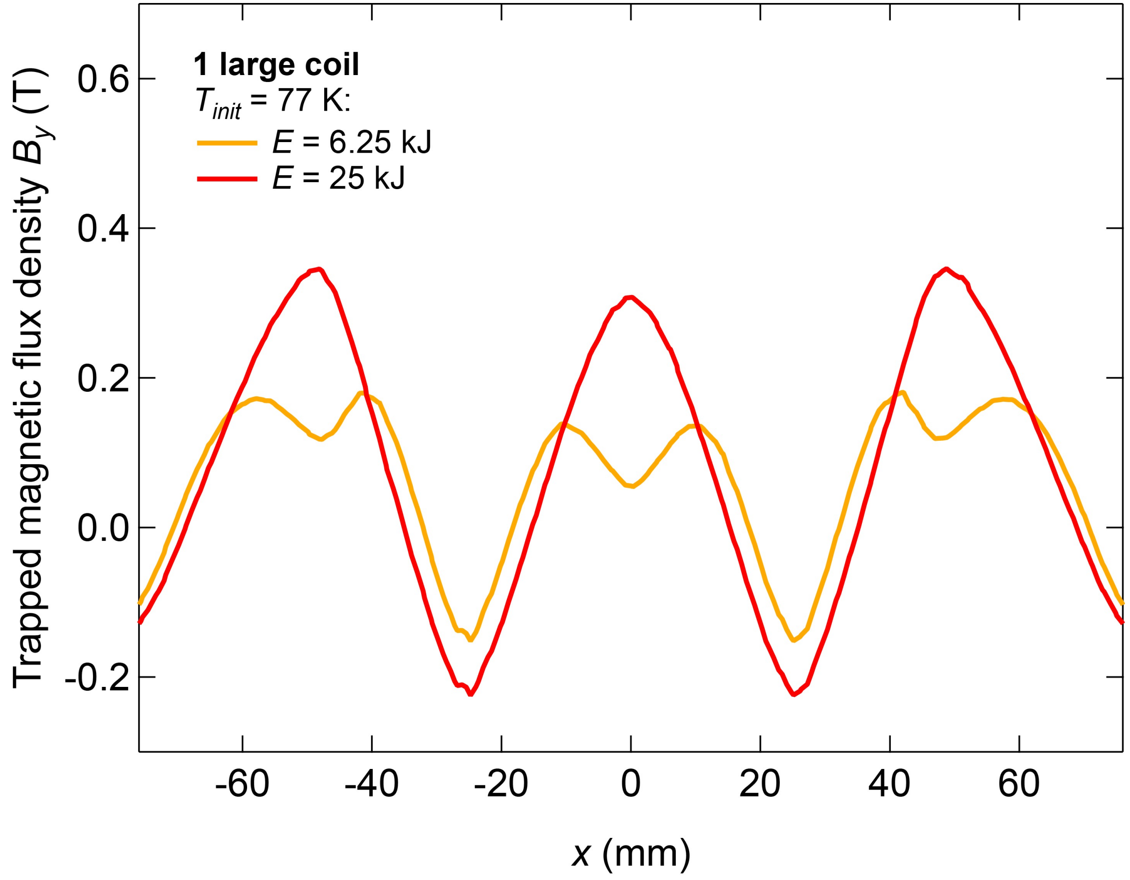


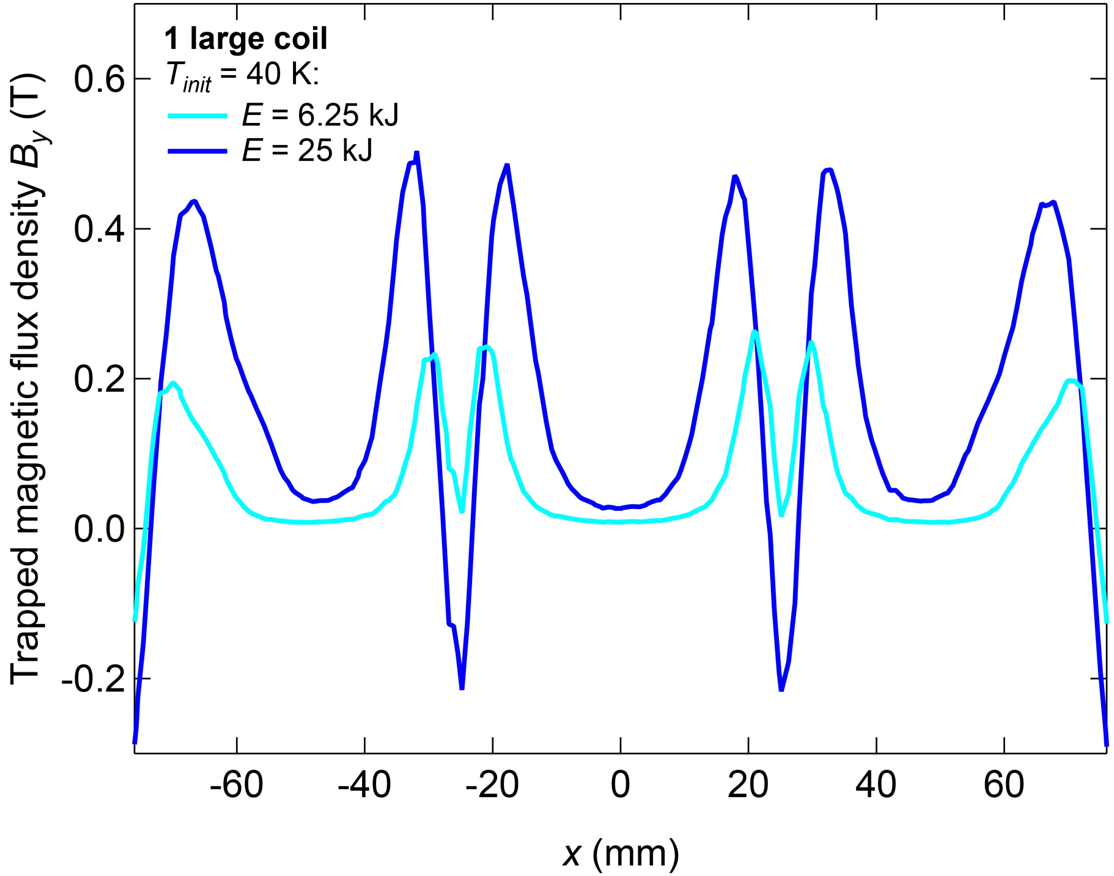


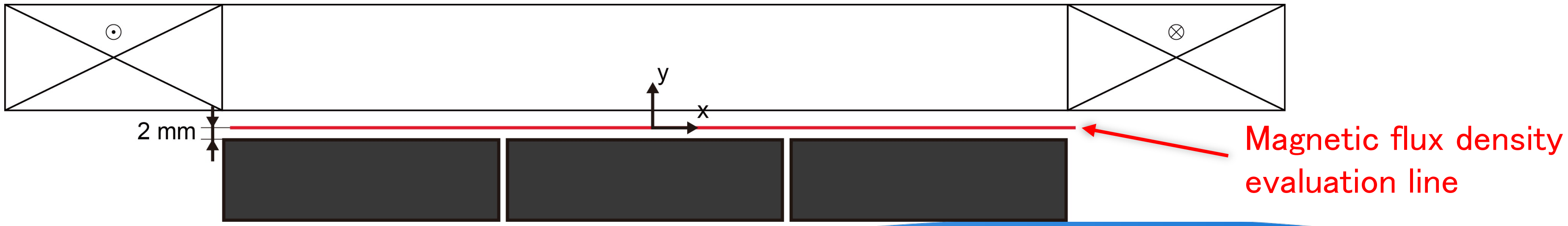
A shape



Results with 1 large coil







Conclusion

- Pulse-field magnetization using 1 large copper coil can trap a similar distribution of magnetic flux density in the 3 bulks to a field cooling method at 77 K.

- The 1 large coil may not be suitable for practical application due to the high magnetizing energy required to obtain a good magnetization.

- 3 vortex-type coils in a “V shape” connected in series allowed to trap a better distribution of the magnetic flux density at 40 K compared to other geometries.