Optimization of Static Magnetic Fields for Neutron Science

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INTRODUCTION: Neutrons are a powerful research tool and provide scientists unprecedented insight into the structure and properties of materials. Experiments with spin-polarized neutrons demand sophisticated neutron optical devices embedded in tailored static magnetic fields. For this study we performed a depolarization analysis of a magnetic guide field interface at a neutron beam-line. The magnetic guide fields are realized by a simple arrangement of permanent magnets (columns) and ferromagnetic yoke plates (see Fig. 3). At interfaces, where the magnetic field direction changes, depolarization of the neutron beam may occur.

Based on the rate of angular magnetic field rotation, ω_B , we can define an adiabaticity parameter, E, where

$$E = \frac{w_L}{w_B} = \frac{|g_n| B}{\frac{dq_B}{dy} v}$$

For an adiabatic magnetic field rotation without loss of neutron polarization an adiabaticity parameter of E>10 is essential [1] (see Fig. 3). This criterion one may use to define a critical neutron wavelength

$$l_{crit.} @ \frac{dq_B}{dy} \times \frac{1}{2.65B}$$

with B in mT, θ in degrees, distance y in cm and the neutron wavelength, λ in Å.

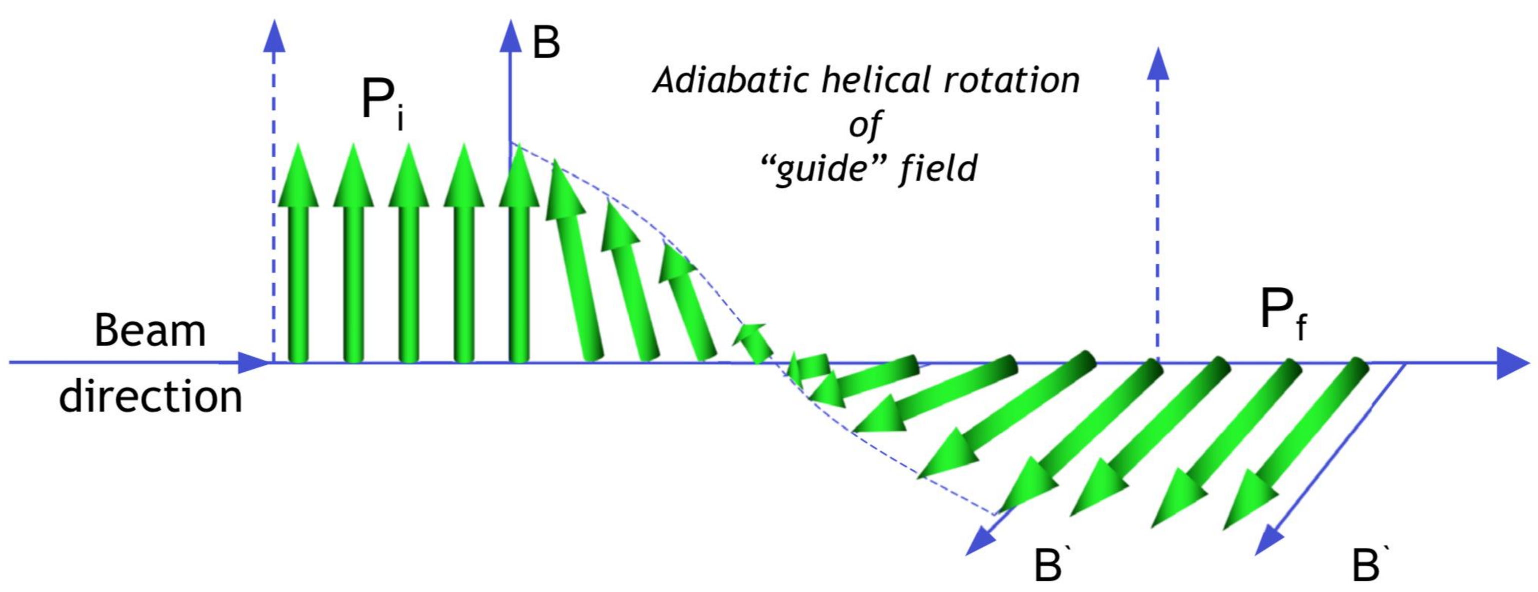

Figure 1. Adiabatic change of magnetic field direction. If the direction of the field B changes sufficiently slowly, then the polarization component parallel to B is conserved – i.e. there is an adiabatic (or reversible) rotation of the polarization [1]

COMPUTATIONAL METHODS: By using the AC-DC module of COMSOL Multiphysics® the magnetic flux density and the corresponding critical wavelength were calculated for different static guide field configurations. The standard method for the simulation of static magnetic fields was used.

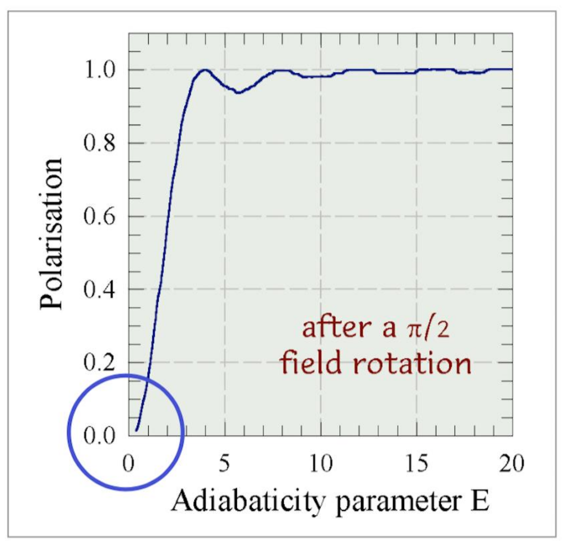

Figure 2. neutron polarization as function of E after a $\pi/2$ field rotation.

Variable		Units
ω_L	Larmor frequ., Neutron	rad s-1
ω_B	Rate of angular rotation B-field (along y)	rad s-1
λ	Wavelength, Neutron	Å
B	Magnetic field	mT
γ_n	Gyromagnetic ratio, Neutron	rad s-1 T-1
v	Velocity, Neutron	m s-1
θ	angle	rad

Table 1. Variables

RESULTS: The depolarization analysis of the initial guide field concept reveals an upper limit for the critical neutron wavelength of about 3.5Å in the beam-volume at the $\pi/2$-interface (see Fig. 3&4). By adding an appropriate guide field extension (see Fig. 5) the upper limit for the critical wavelength could be lowered to approx. 1Å for the entire volume of interest.

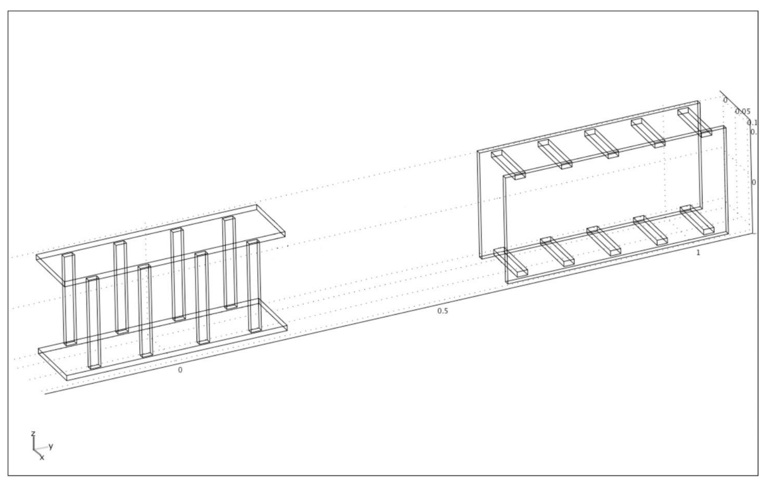

Figure 3. Initial concept of the guide field at the $\pi/2$-interface

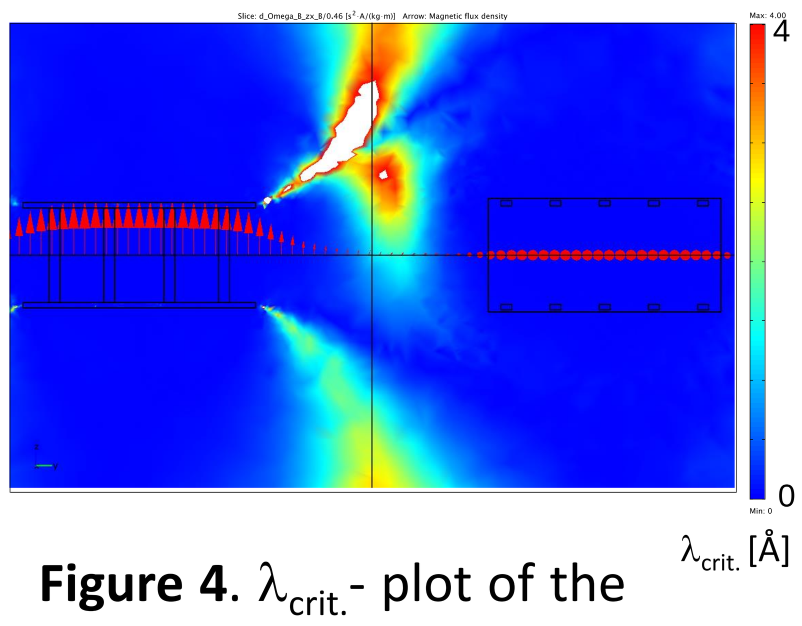

Figure 4. $\lambda_{crit.}$- plot of the initial concept

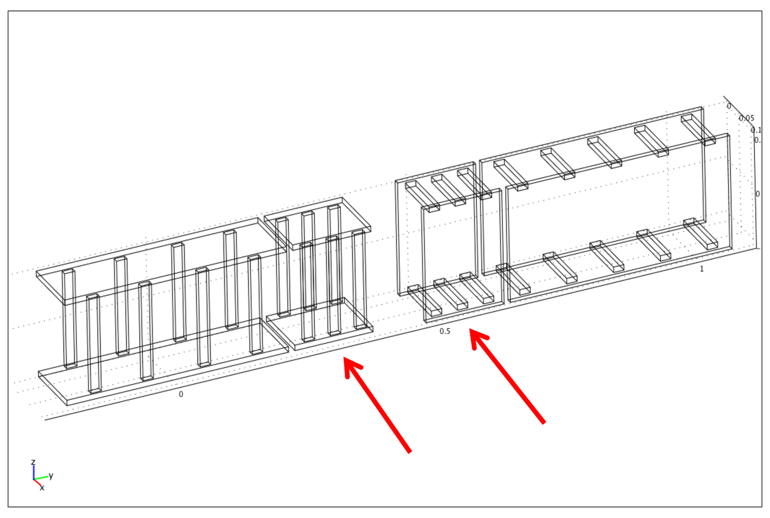

Figure 5. final optimized concept of the guide field

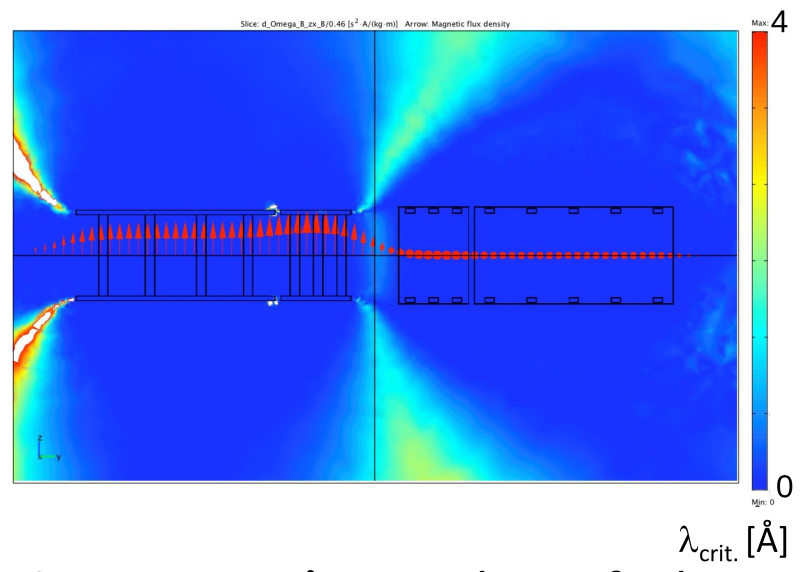

Figure 6. $\lambda_{crit.}$- plot of the optimized guide field concept

CONCLUSIONS: In the design phase of polarized neutron beam lines COMSOL Multiphysics® is a valuable tool in order to perform depolarization analysis. Critical interfaces are identified in an early stage of the project and costly amendments can be avoided.

REFERENCES:

1. R. Stewart, Polarized Neutrons OSNS10, talk (2010)