1. Guide magnetic field

To guide neutron polarization without losses to the sample position the appropriative magnetic field along all the neutron path should be applied. The configuration, strength and homogeneity of the field are defined by the neutron wavelength, neutron beam cross-section and possible perturbations in the neutron beam path like choppers, collimation systems, neutron guide joints et cetera. We proposed to use well known guide magnetic system consisting of two parallel soft iron plates connected by permanent magnets in such a way that most of stray fields from the poles of magnet loop are enclosed between these two plates Fig. *4.3.4.1.1*

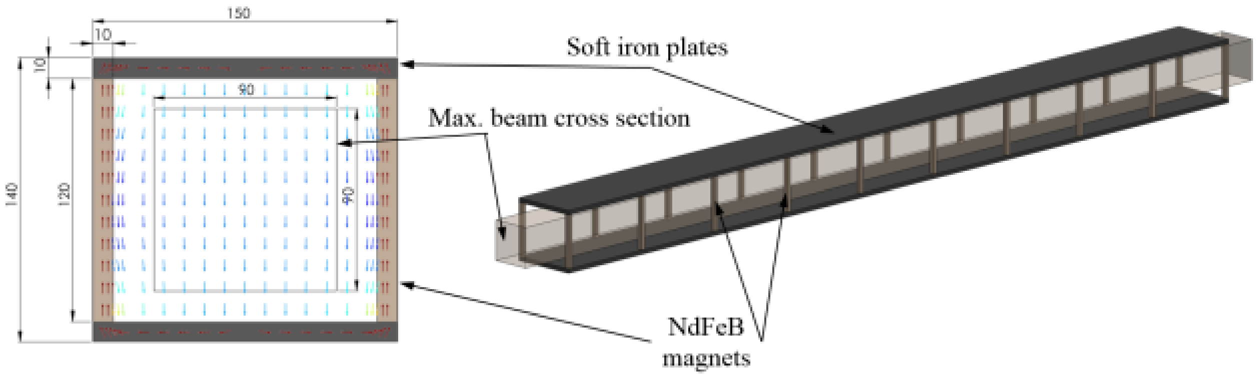

Fig. 4.3.4.1.1: *The magnetic system of the magnetic guide for MAGIC.*

The main parameters of the magnetic system (width and thickness of the plates, distance between plates, strength of the permanent magnets, number of the magnets per length, *Fig. 4.3.4.1.1*) defining the guide field were obtained by Comsol [https://www.comsol.com/] calculations. The strength of the guide field needed for the shortest neutron wavelength 0.6 Å is about 60 Gauss. This value was chosen to ensure “adiabatic” transition neutron polarization through all the neutron path including possible perturbations of the magnetic field. The NdFeB (N42) magnets with cross section 10x10mm and height 120mm can be used to get 60 Gauss (*Fig. 4.3.4.1.2.*) field in the volume corresponding maximal neutron guide cross section. 20 magnets are necessary for each 2 m long guide section. The orientation of the guide field is vertical.

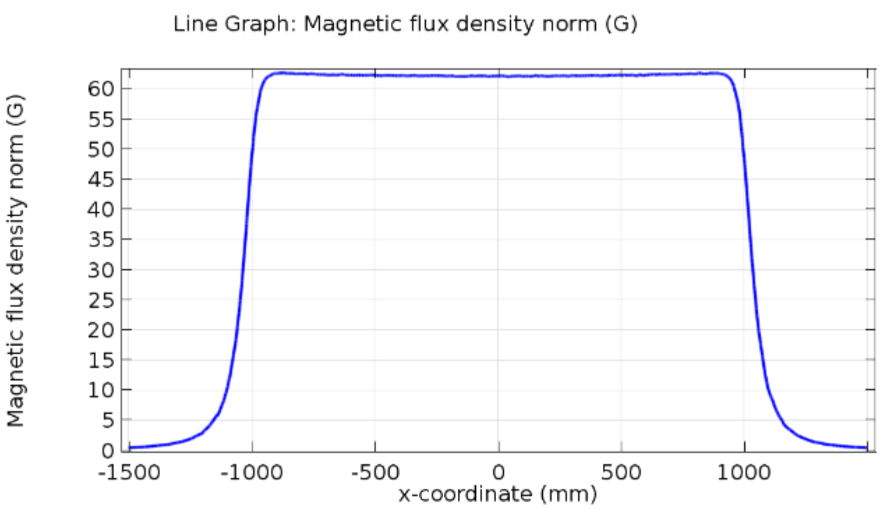

Fig. 4.3.4.1.2: *The calculated value of the magnetic field in the center of the neutron guide.*

The condition corresponds to the so called adiabatic transition of the neutron polarization is following: $\boldsymbol{\omega_B \ll \omega_L}$, where:

- $\omega_B = \left|\frac{d\overrightarrow{U_B}}{dt}\right|$ is the frequency associated with the variation of the magnetic field in the neutron reference frame ($\overrightarrow{U_B}$ is the unit vector defining the field direction);
- $\omega_L = |\gamma_N|\,|\overrightarrow{\boldsymbol{B}}|$ is the Larmor frequency ($\gamma_N = 1.83 \cdot 10^8\, T \cdot s^{-1}$) corresponding to the precession of neutron polarization. The neutron beam polarization is conserved as long as $\omega_B \ll \omega_L$.

An extreme case for MAGiC would be a polarized neutron of $\lambda = 0.4$Å in the 60 G guide field rotating by 180° over 8 cm. In this case, we have:

- $\boldsymbol{\omega_B} = 0.5 \cdot \frac{9890}{0.08} = \boldsymbol{0.6181 \cdot 10^5\ s^{-1}}$
- $\boldsymbol{\omega_L} = 6 \cdot 10^{-3} \cdot 1.83 \cdot 10^8 = \boldsymbol{10.98 \cdot 10^5\ s^{-1}}$
- $\boldsymbol{\omega_B \ll \omega_L}$: polarization is conserved

2. Rotators

The direction of the polarization after the solid-state bender and in the elliptic sections, is vertical. The orientation of the saturation field in the thermal neutron polarizer is horizontal due to horizontal orientation of the super-mirrors (vertical kink) Fig.4.3.3.2. Hence it is necessary to rotate polarization from vertical to horizontal direction at the thermal polarizer entrance. The opposite rotation will be done at the polarizer exit to match the polarization direction with the superconducting magnet stray field.

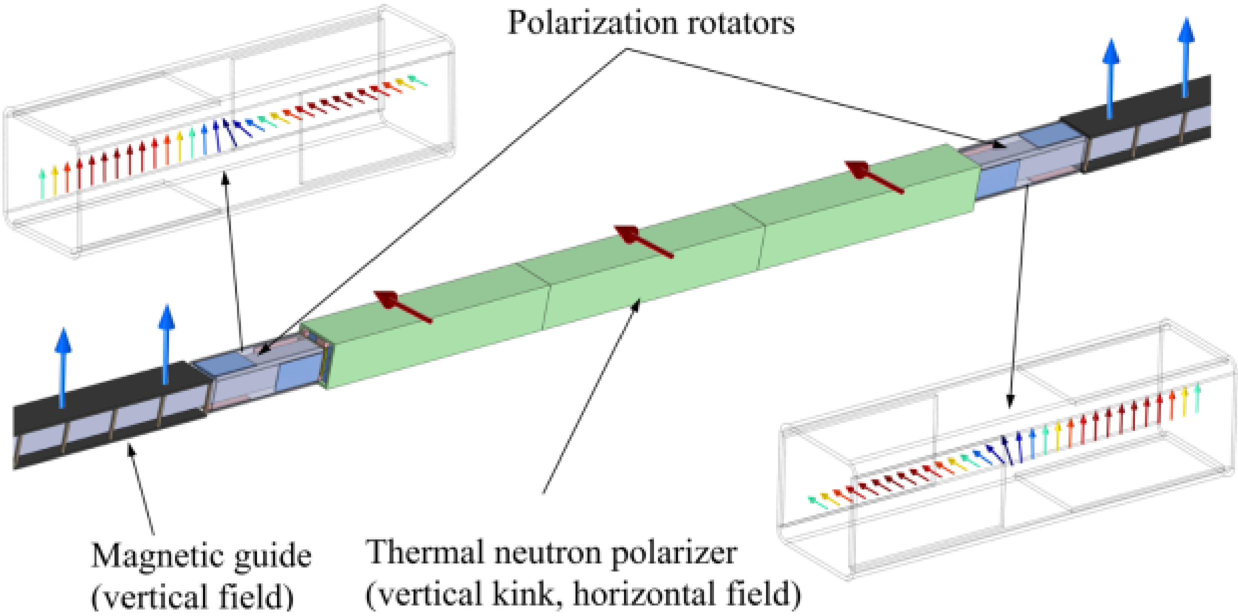

Fig.4.3.3.2. *Rotators turn polarization from vertical to horizontal direction at the polarizer entrance and turn it back to vertical at the exit.*

Each rotator consists of two pairs of NdFeB (N42) magnets placed inside of a soft iron yoke. The orientation of the magnetic field created by a pair of magnet is perpendicular to the field orientation of the second pair. Between the pairs, the magnetic field rotates by 90°. This rotation should be "adiabatic" with respect to the Larmor precession as described in the previous section. The final parameters of the rotators will be defined during detailed design of MAGiC (*Fig.4.3.3.2.1*).

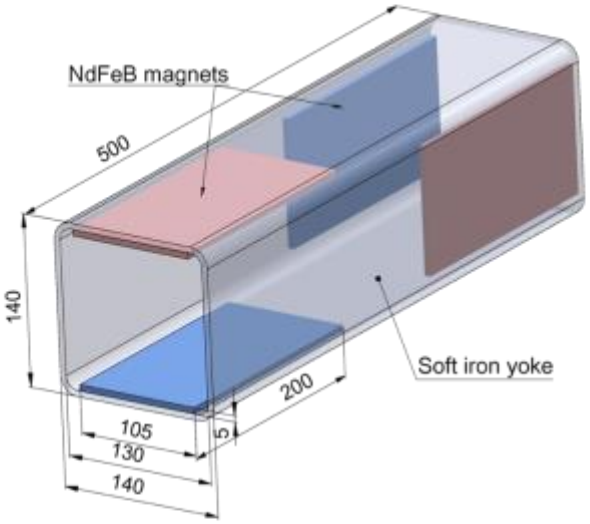

Fig.4.3.3.2.1: *The preliminary parameters of the polarization rotor of MAGiC.*

3. Spin flipper

As a polarized instrument, MAGiC will be equipped with a RF adiabatic spin flipper. The advantages to use this type of flipper are the following:

1. Spin flip probability is close to one for a neutron spectrum limited only by its minimum wavelength.
2. The flipper can be adapted to neutron beams with large cross section.
3. The beam path through the flipper is free.
4. Flipper has high inhomogeneity and perturbation tolerance.

The general description of the flipper can be found in [*Nuclear Instr. and Methods in Phys. Res. A, 332, 534-536 (1993)*]. The spin flipper for MAGiC is composed of a solenoidal coil producing the oscillating radio-frequency field, a guide gradient magnetic field and a RF generator with amplifier (Fig *4.3.3.3).*

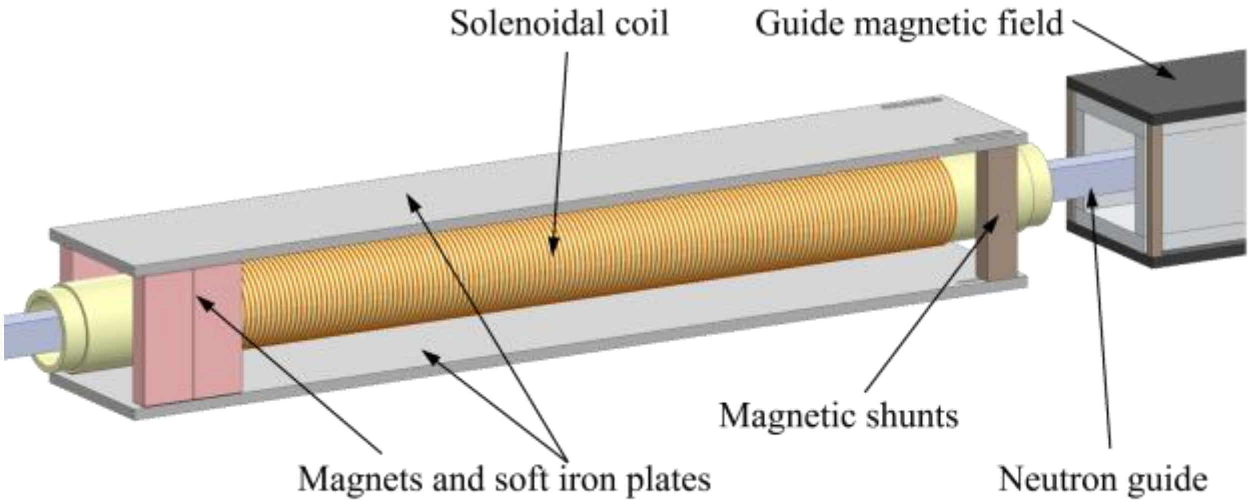

Fig 4.3.3.3.1: *draft of the adiabatic spin-flipper. Horizontal oscillating field is generated by the RF solenoid placed inside of the gradient filed assembly. Two soft iron plates, magnets and magnetic shunts create a vertical field with gradient along the neutron beam. The neutron guide is inserted inside of the solenoid.*

The basic parameters of the flipper (length, amplitude of the oscillating field) are defined by minimum wavelength and spin-flip probability for this wavelength by the relation:

$$p = \frac{k^2 + cos^2((\pi/2)\sqrt{1+k^2})}{1+k^2}$$

Where p is the spin flip probability and k is relation between flipper length L, minimal wavelength (maximal neutron velocity v) and amplitude of the oscillating field B_{RF}:

$$k = (\gamma \cdot L \cdot B_{RF})/(\pi \cdot v)$$

where γ is the gyromagnetic ratio of the neutron. The dependence p as a function of k is presented in Fig 4.3.3.3.2.

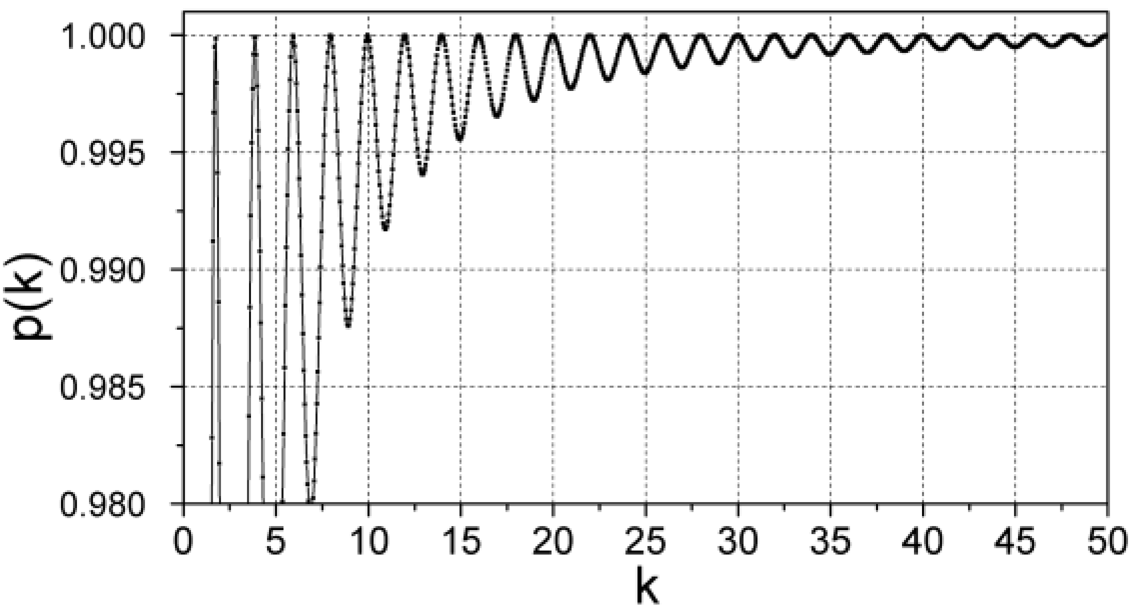

Fig 4.3.3.3.2: *The dependence p as a function of k.*

For a spin-flip probability p = 0.99, k is about 9. Taking the shortest wavelength λ=0.4Å (neutron velocity v = 9890m/s), gives the relation between length of flipper and amplitude of the oscillating field:

$$L \cdot B_{RF} \approx 15\ G.m$$

If we take a length of the flipper about 1 m the amplitude of the oscillating field is about 15 Gauss. The parameters of gradient magnetic field and frequency of the oscillating field depends on tolerance to the external magnetic field perturbation. As some preliminary values, we have set B_{max}= 250G, B_{min}=60G, B_{centre}=90G and a frequency of 270kHz.

As a RF power supply for the solenoidal coil, the RF Generators & Amplifiers from "T&C Power Conversion" company can be used. The spin flipper will be installed in the second guide section at distance from the sample position where the stray field from the sample environment is limited.