A high-field adiabatic spin flipper for strong neutron deceleration

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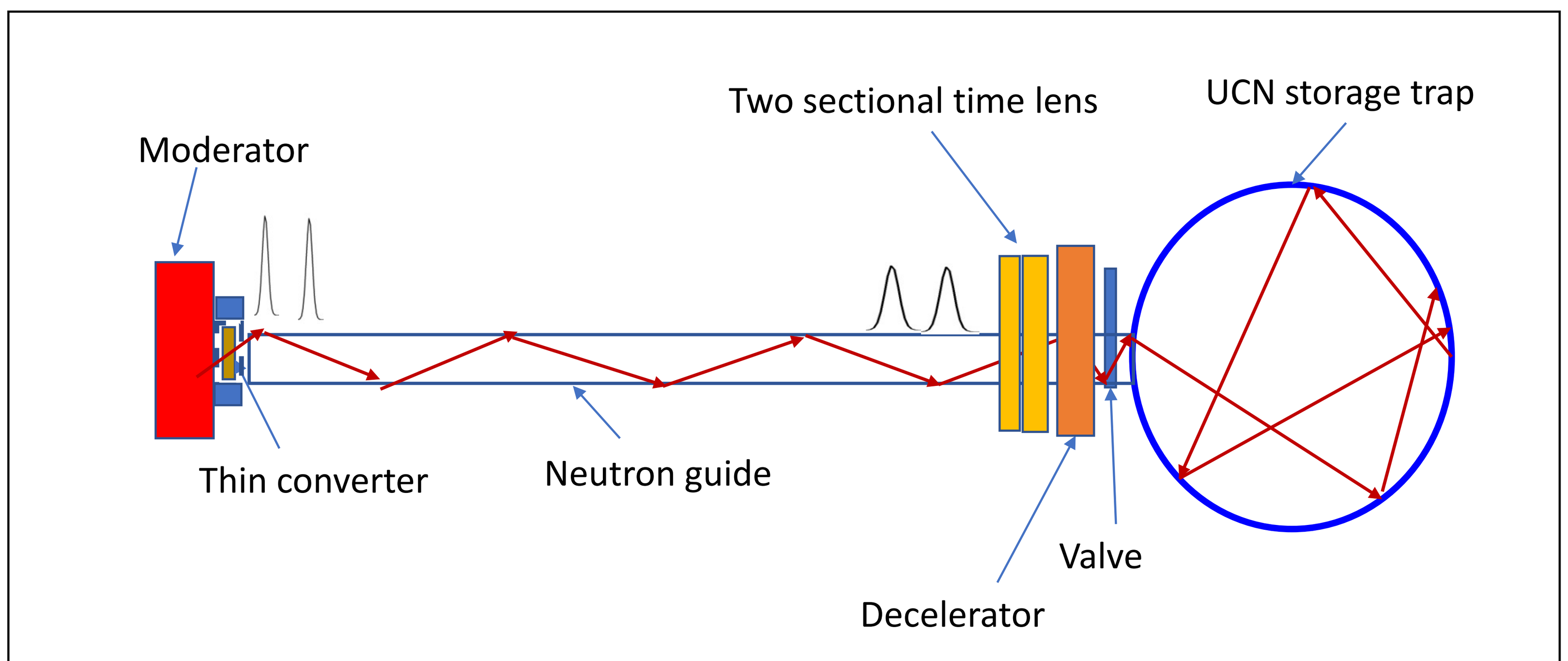
Motivation

Since the discovery of UCN in [1], a number of intense UCN sources have appeared in the world, and several more of them are under construction. There is no UCN source in Dubna, which is largely due to the features of the IBR-2M reactor. Its average power of 2 MW is relatively low for creating a continuous UCN source. However, the pulsed flux of thermal neutrons from this reactor is very high, since the interval between pulses is hundreds of times longer than their duration.
Apparently, the only way to create a sufficiently intense source of UCN in a pulsed reactor of moderate power is to implement Shapiro's idea of pulsed filling of a trap for UCN [2], in combination with the principle of temporal focusing of neutrons [3].

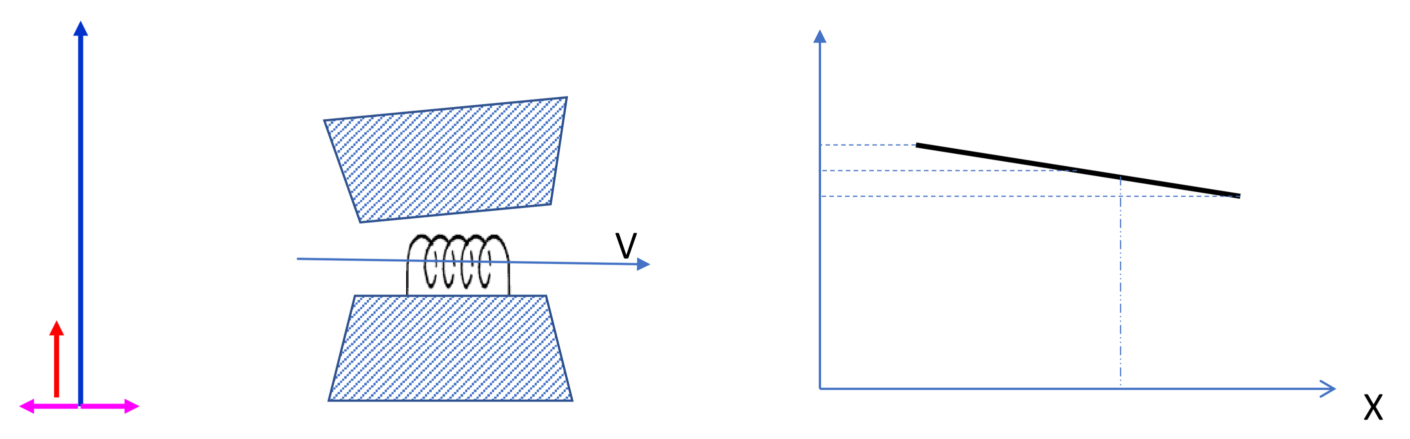


The concept of an ultracold neutron (UCN) source based on a pulsed reactor based on a combination of a magnetic time lens and a magnetic resonance device decelerating neutrons

Decelerator

Broadband gradient (adiabatic) spin flipper

An adiabatic radio frequency (RF) spin-flipper [4-6] is considered as a Decelerator. An adiabatic RF spin-flipper is a configuration of a constant space gradient magnetic field, on which a radiofrequency field is perpendicular applied.



Polarized neutrons passing through such a spin-flipper, not only change the direction of the spin to the opposite, but the neutron energy also changes

$$\Delta E = 2\mu B_{res}.$$

Required parameters

To decelerate a neutron at a speed of 20 m/s to a speed of 5 m/s

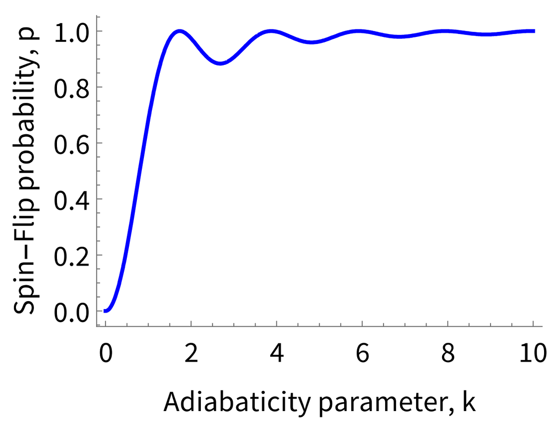
$$\Delta E \approx 2\ \mu eV,\ B = {}^{\Delta E}/_{2\mu} = 15\ T,\ f = {}^{\omega}/_{2\pi} = 470\ MHz$$

The adiabaticity parameter defines probability of the spin-flip.

At the resonance point

$$B \approx B_{\Omega},\quad B_{eff} \approx B_1,\quad k = \frac{\gamma B_1^2}{\left(\frac{dB}{dz}\right)V}$$

γ is the gyromagnetic ratio
V is the neutron velocity



At k=4, $V = 15\frac{m}{s}$ a relationship between the RF field strength

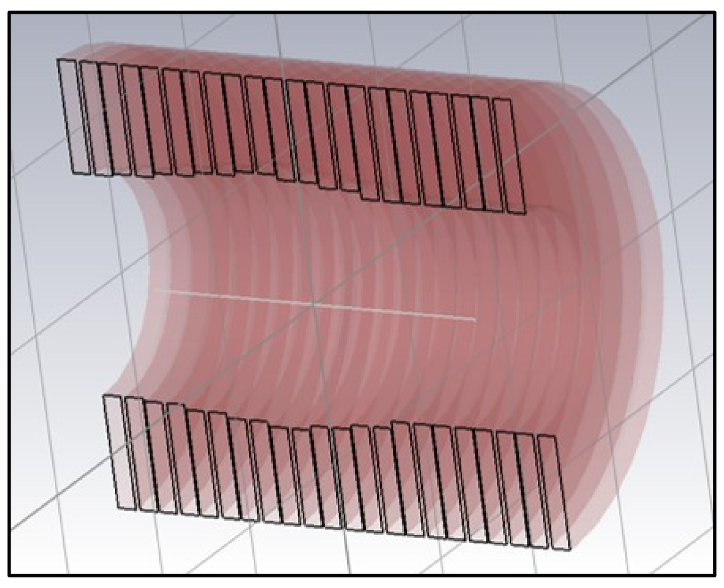
$$B_1^2 > \frac{dB}{dz} \times (3.3 \cdot 10^{-7})$$

For the value of the magnetic field gradient of 15 T/m, we have

$$B_1 \geq 2.2\ mT$$

Superconducting magnet

To create hight field with requied space gradient and good uniformity in large volume a superconducting magnet based on HTSC technology is proposed.



Possible design of a HTSC magnet

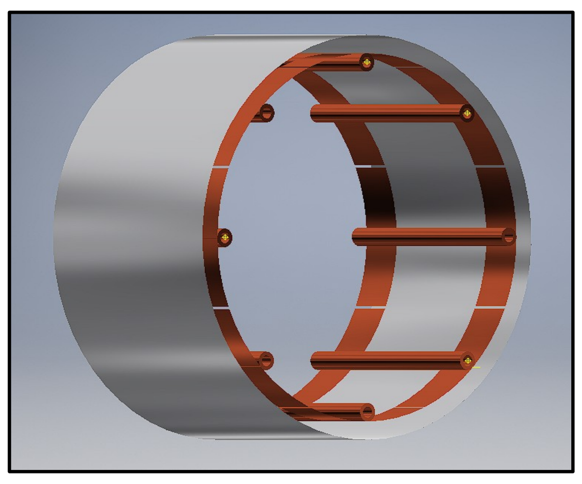
The magnetic field profle and the change in the speed of neutrons passing through the spin flipper field

Birdcage coil

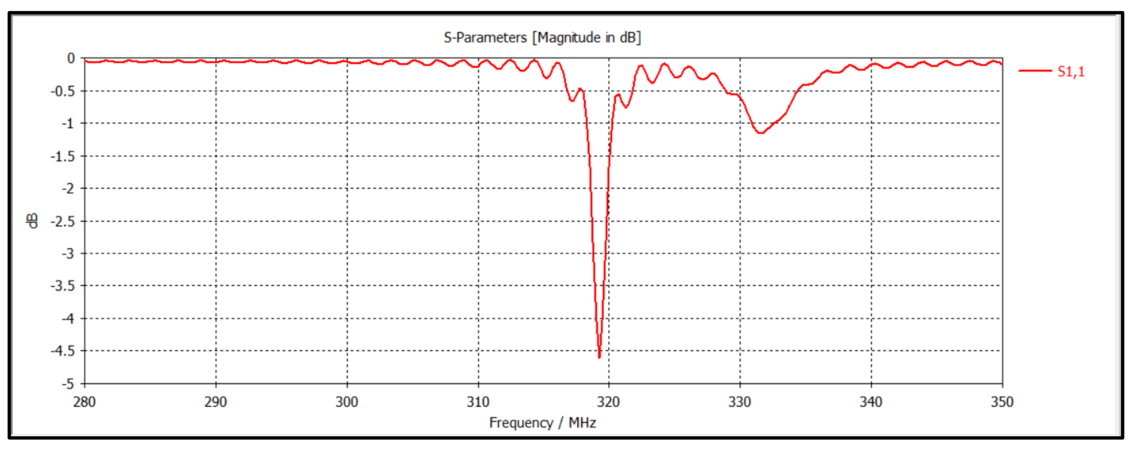
The birdcage resonator is a widely used device for generating alternating magnetic fields.

Significant advantages:

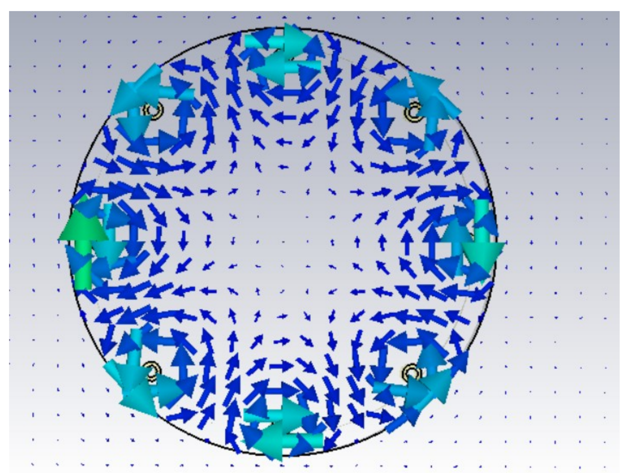
- Ability to generate a homogeneous magnetic field over a large volume.
- Allows for a high degree of control over the magnetic field's frequency and amplitude.
- Has an excellent Q-factor and rather small thermal losses.



Possible birdcage design (length of legs 5 cm, end ring radius 5 cm, shield radius 5.5 cm).



S-parameters graph



Distribution of the magnetic field in the volume of the resonator.

References:

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[3] Frank A.I., Gahler R. Proc. of ISINN-4. Dubna (1996) 308.; A.I.Frank and R.Gähler. Phys. At. Nuclei, 63 (2000) 545.
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