Erice School 2017

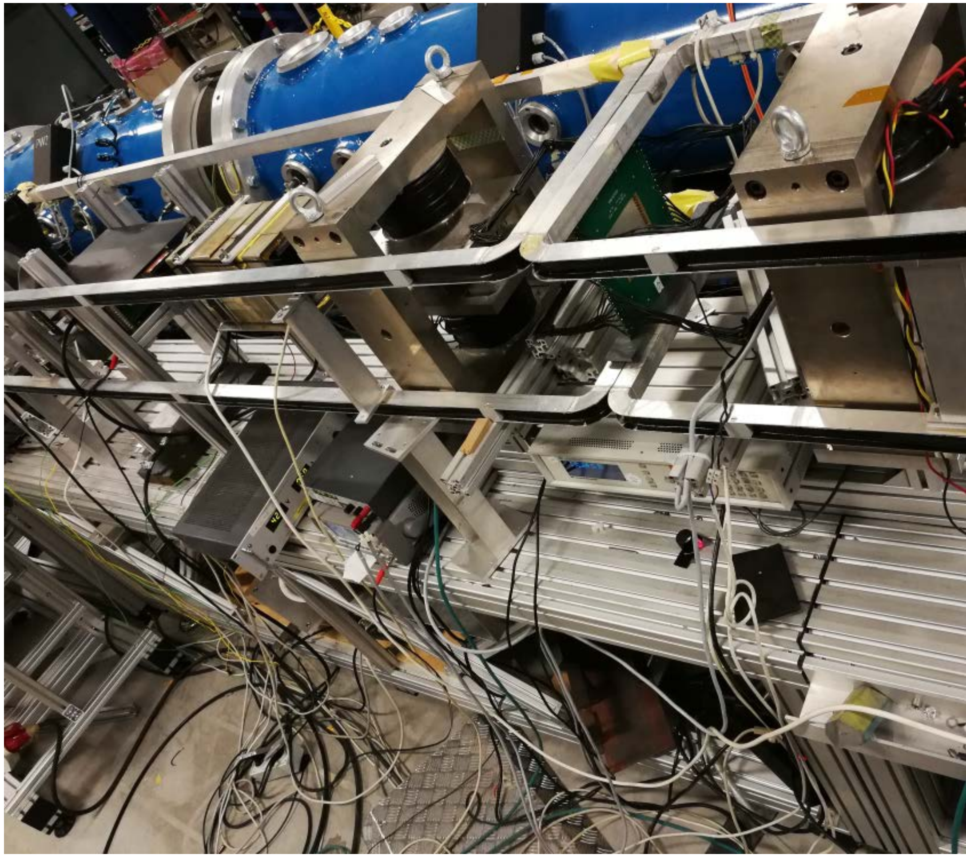
Spin Nutators, Foil-Based Flippers and RF-Flippers

Erice, 04-07-2017

Delft
University of
Technology

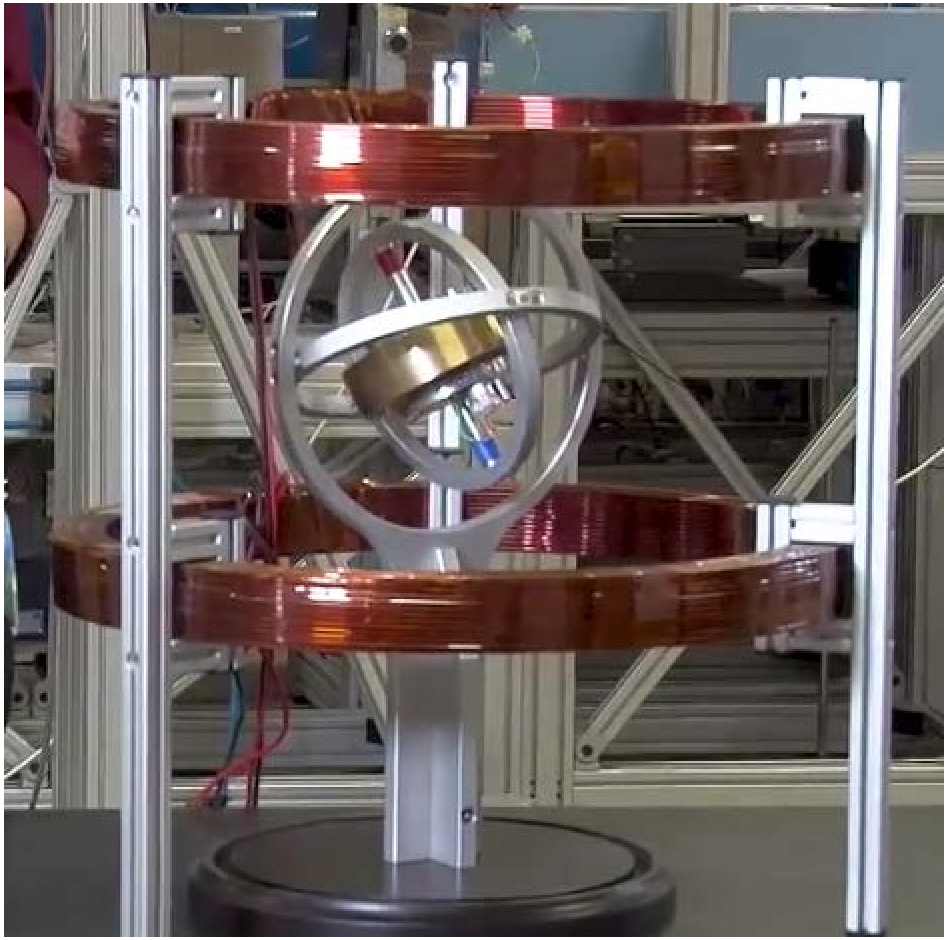
Ideal world…

My real world…



Precession

Larmor precession



Adiabaticity

The Larmor frequency and Larmor phase are defined as

$$\omega_L = \gamma_L B \quad ; \quad \varphi(t) = \omega_L t$$

When a neutron passes through a magnetic field of length, L, with a velocity, v, the Larmor phase is given by

$$\varphi = \omega_L t = \frac{\gamma_L B L}{v} = \frac{\gamma_L m B \lambda L}{h}$$

When the orientation of quantisation axis (magnetic field vector) is changed, the polarisation vector is not able to follow in all cases. Now we consider the quantisation axis stationary in magnitude and in time but change its orientation along the flight path of the neutron. For this, a geometric rotation angle, , and geometric rotation frequency, , can be defined. The neutron velocity will determine how fast the change is experienced by the neutron:

$$\omega_g = \frac{d\alpha_g}{dt} = \frac{d\alpha_g}{dx} v$$

$\pi/2$
$\pi/2$
$\pi/2$

Adiabaticity

•$\omega_L \gg \omega_g$: The rotation frequency, experienced by the neutron, of the quantisation axis is slow compared to the Larmor frequency. The precession cone can perfectly follow this geometrical rotation and conserve its top angle (measured polarisation remains constant). The polarisation of the beam is said to follow the field transitions adiabatic (adiabatic transitions).

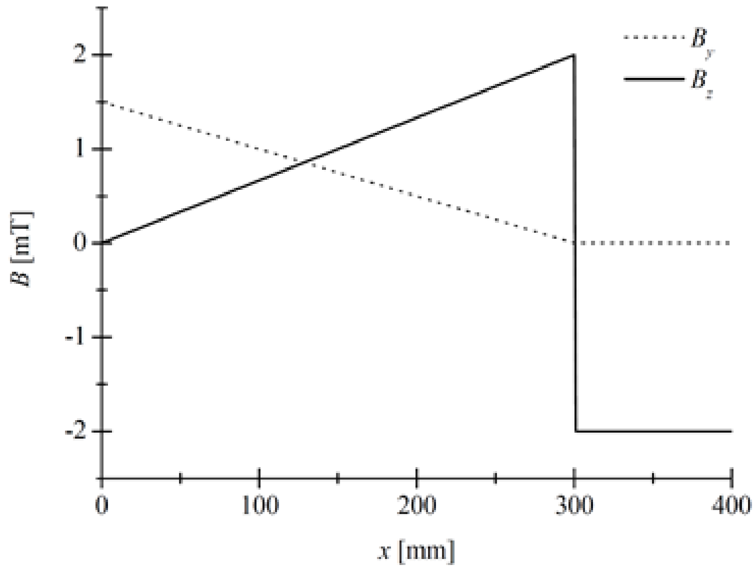
•$\omega_L \ll \omega_g$: The rotation frequency, experienced by the neutron, of the quantisation axis is very fast compared to the Larmor frequency. The precession cone can not follow this geometrical rotation and is experienced as instantly. A new precession cone will appear with a new top angle. These sudden field transitions are typically used in and -flippers. These field transitions are called Majorana flip or "fast" transitions.

The ratio between these two frequencies is often called adiabaticity parameter:

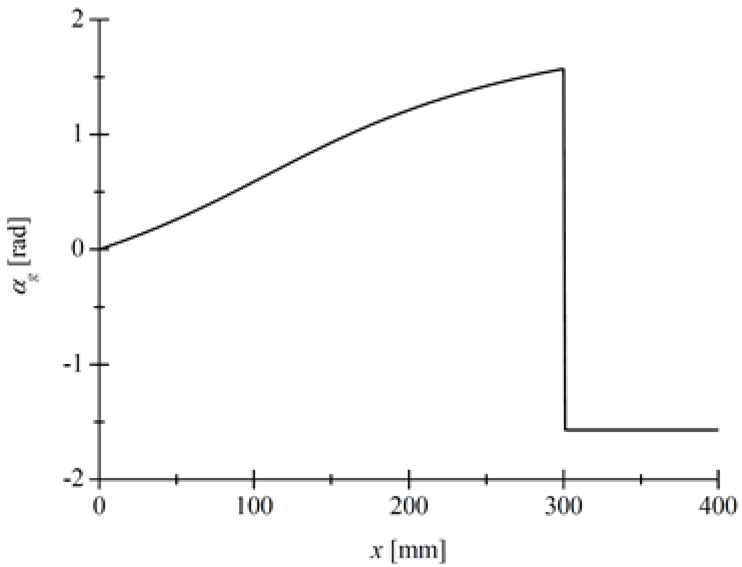
$$k = \frac{\omega_L}{\omega_g}$$

A rule of thumb would be if $k \geq 10$ the transition is adiabatic and the polarisation degree is conserved. If $k \leq 0.1$ the transition is fast and a well defined reorientation of the polarisation vector relative to the magnetic field occurs. If $0.1 \leq k \leq 10$ the transition will result in a more complex reorientation of the polarisation vector, in practice this situation usually is to be avoided.

Adiabaticity



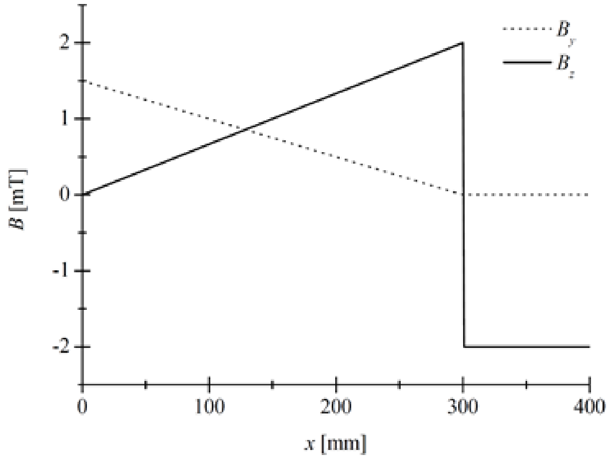
$$\boldsymbol{\alpha} = \mathrm{atan}\left(\frac{Bz}{By}\right)$$



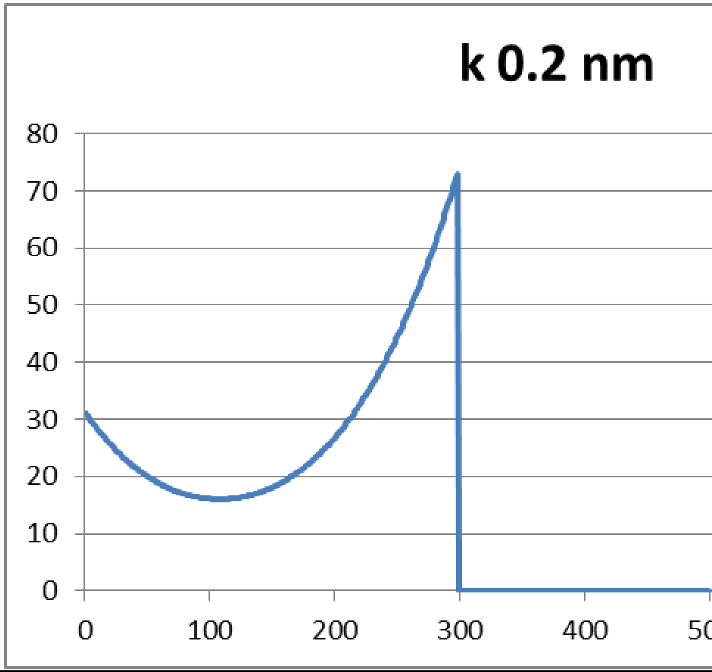
Adiabaticity

$$\omega_L = \gamma_L B = 183247800\sqrt{(By^2 + Bz^2)}$$

$$\omega_g = \frac{d\alpha_g}{dt} = \frac{d\alpha_g}{dx} v$$



$$k = \frac{\omega_L}{\omega_g}$$



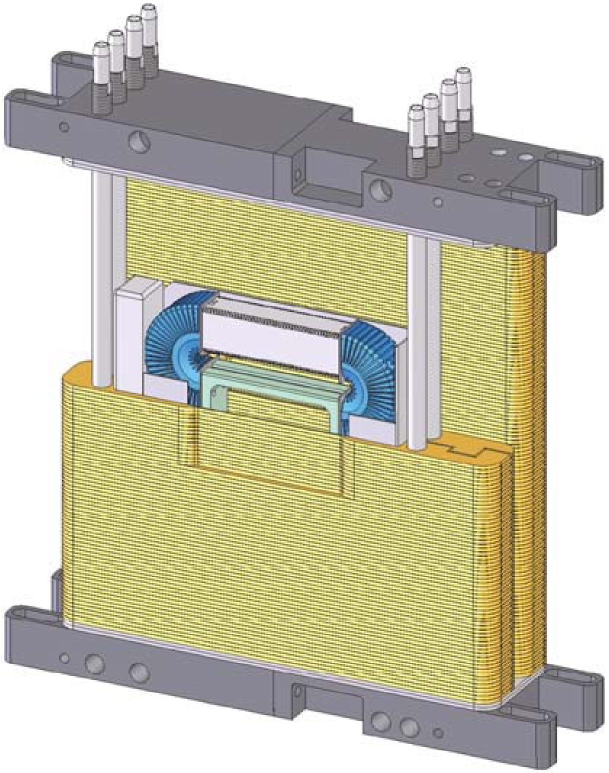
Useful stuff for a polarised neutron instrument

- RF flippers
- Foil flipper
- Field stepper, wire screens
- V-coils
- Mezei flipper

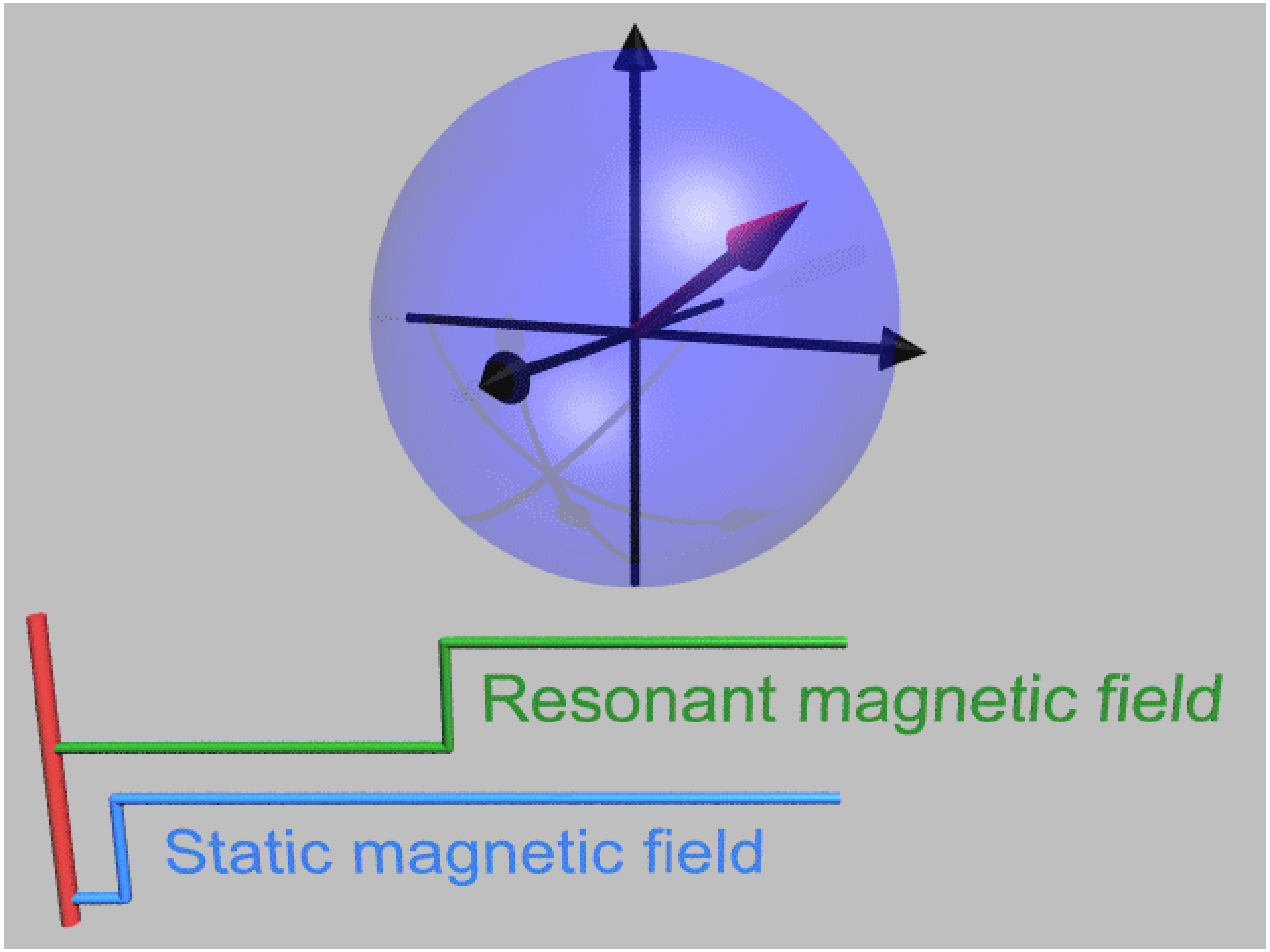
What is the use, are we in a encoding precession region? Monochromatic, Polychromatic, TOF?

This determines what components you can use and how tolerant the design can be.

RF flipper



RF flipper



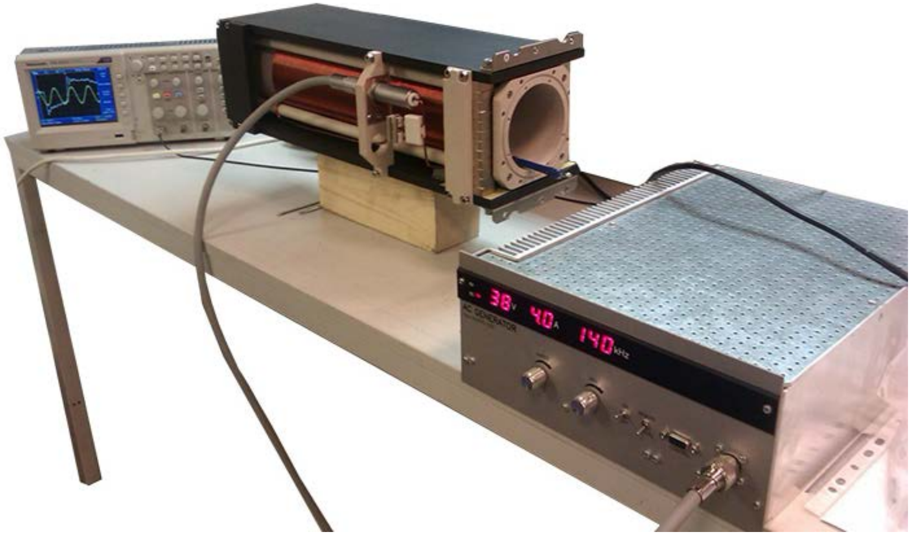
RF flipper (adiabatic)

1. RF (Radio Frequency) field (35 KHz to 3MHz as practical values)
2. Perpendicular DC field (B0, resonant field)
3. In adiabatic case, a gradient field (// DC)

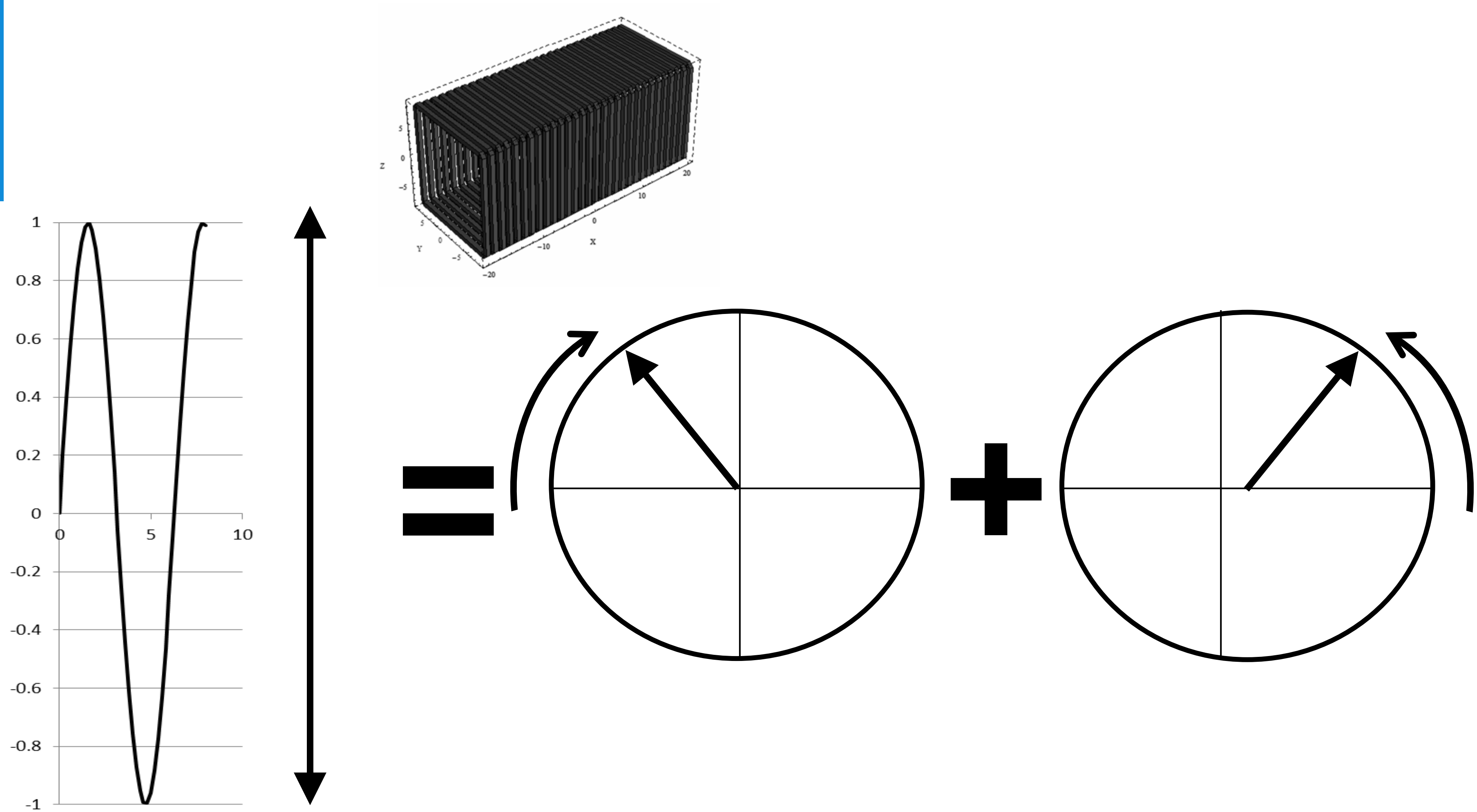
Frequency bands [edit]

Main article: Radio spectrum

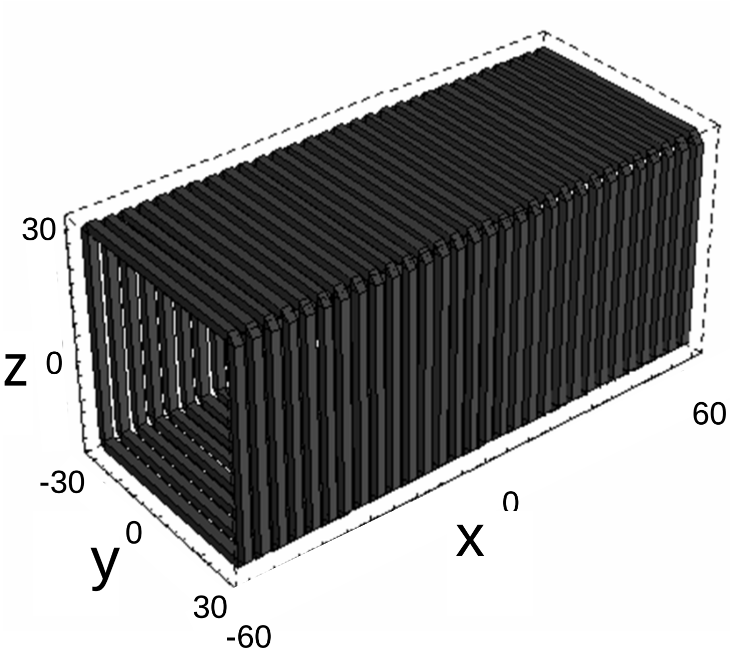
Frequency	Wavelength	Designation	Abbreviation[6]
3–30 Hz	10^5–10^4 km	Extremely low frequency	ELF
30–300 Hz	10^4–10^3 km	Super low frequency	SLF
300–3000 Hz	10^3–100 km	Ultra low frequency	ULF
3–30 kHz	100–10 km	Very low frequency	VLF
30–300 kHz	10–1 km	Low frequency	LF
300 kHz – 3 MHz	1 km – 100 m	Medium frequency	MF
3–30 MHz	100–10 m	High frequency	HF
30–300 MHz	10–1 m	Very high frequency	VHF
300 MHz – 3 GHz	1 m – 10 cm	Ultra high frequency	UHF
3–30 GHz	10–1 cm	Super high frequency	SHF
30–300 GHz	1 cm – 1 mm	Extremely high frequency	EHF
300 GHz – 3 THz	1 mm – 0.1 mm	Tremendously high frequency	THF



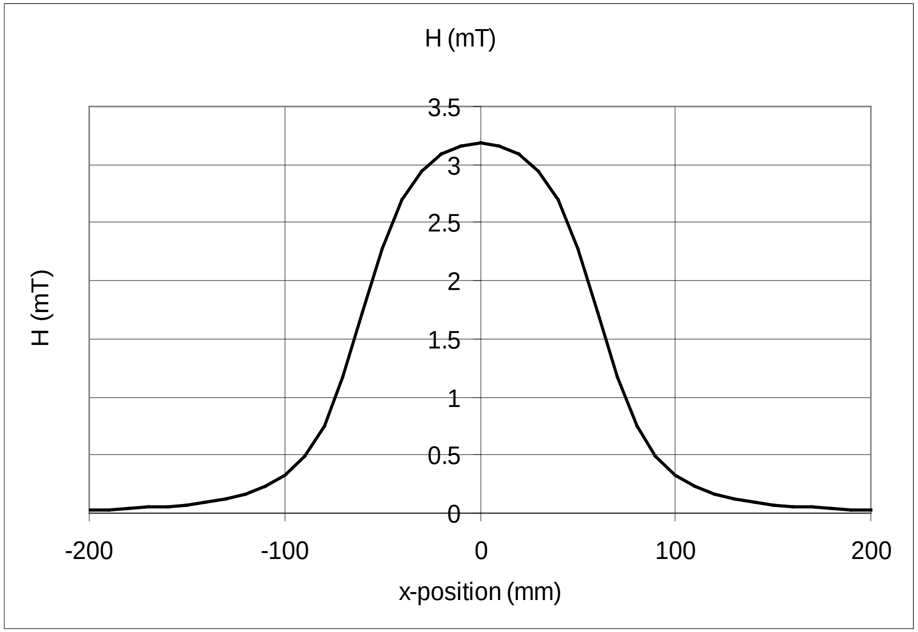
RF field in rotating frame



RF coil

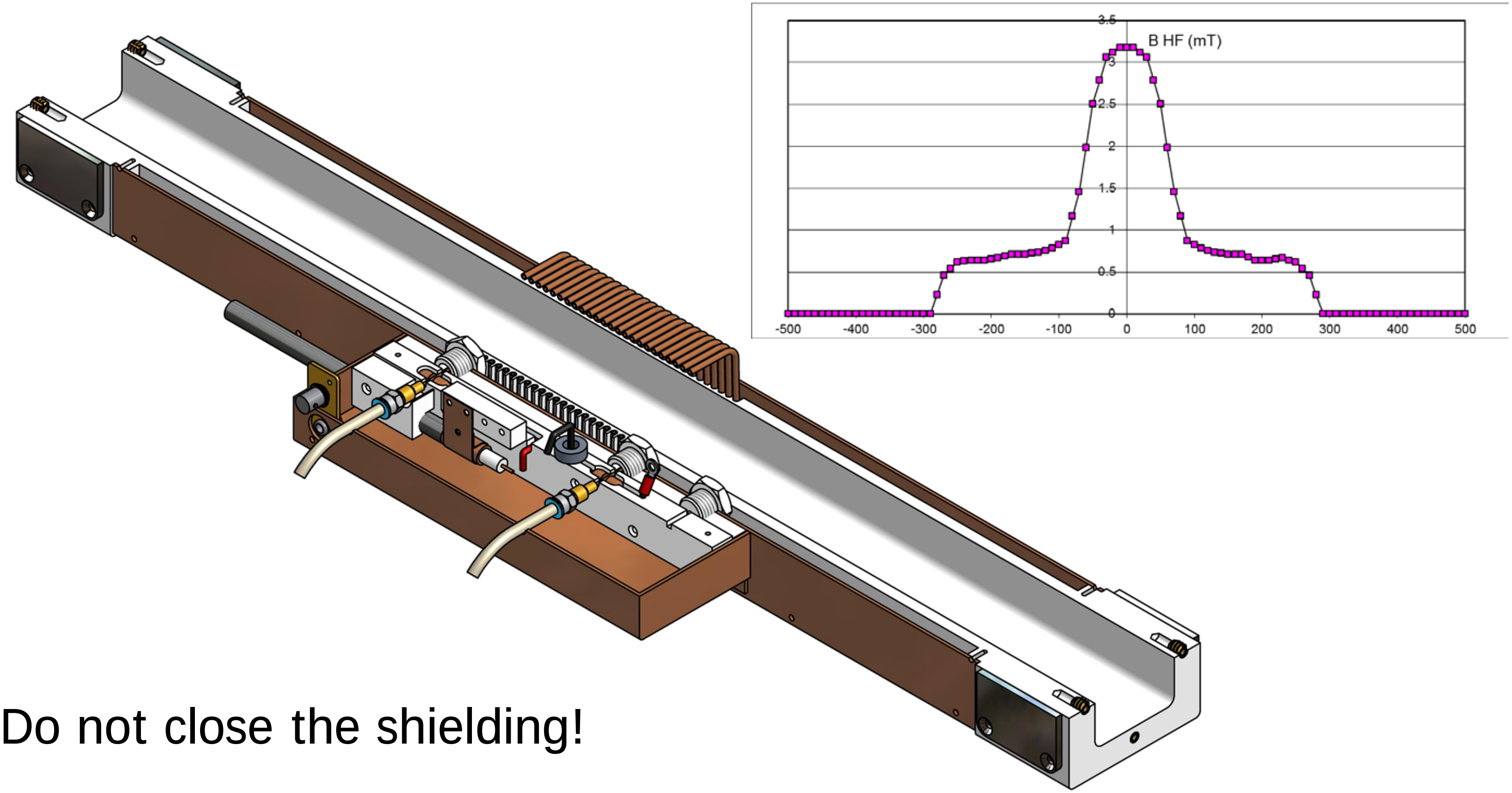


30
z
0
-30
y
0
30
-60
x
0
60



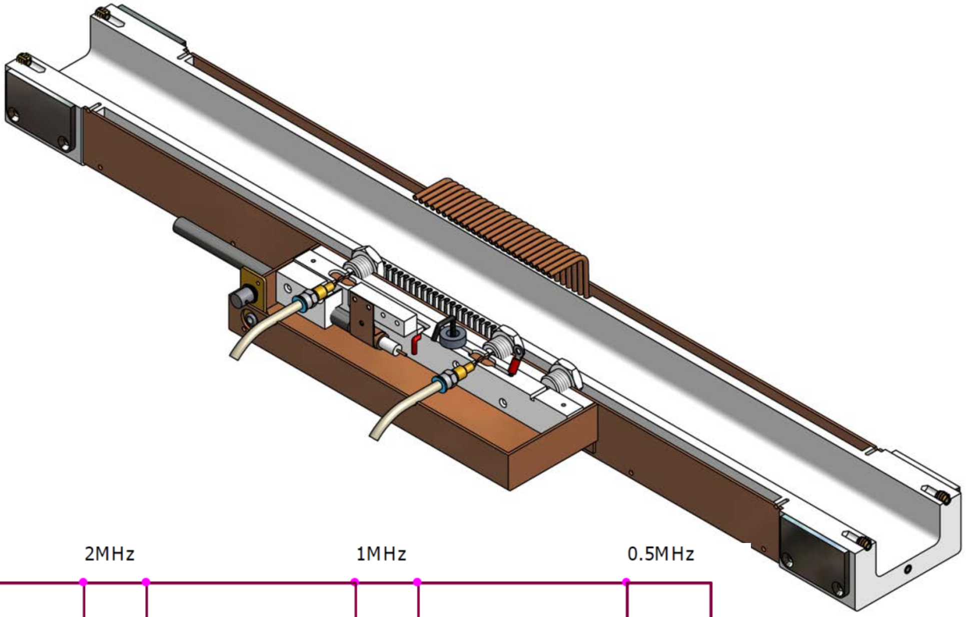
H (mT)
3.5
3
2.5
2
1.5
1
0.5
0
H (mT)
-200
-100
0
100
200
x-position (mm)

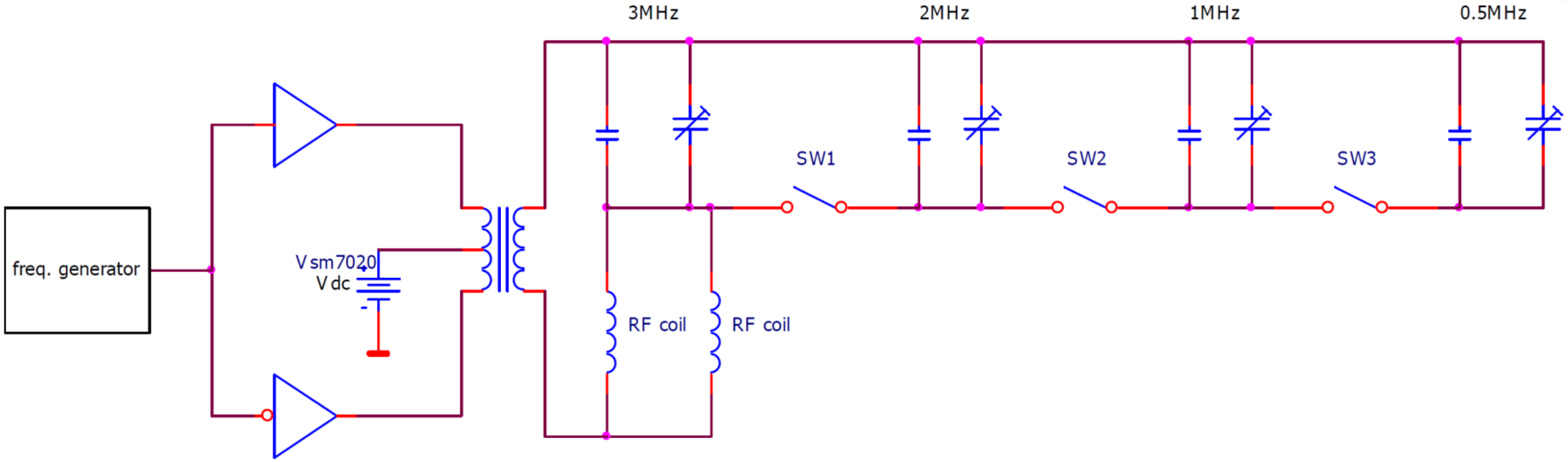
RF coil with cooling, shielding



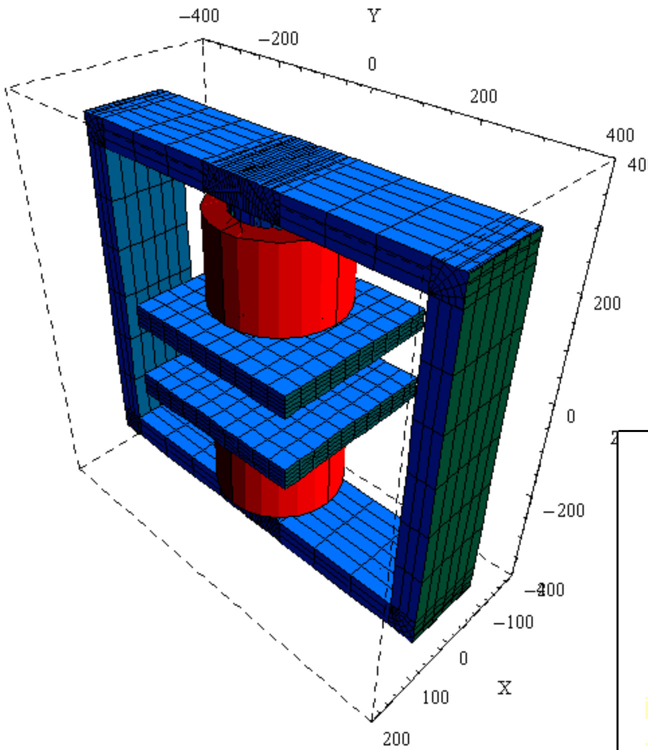
Do not close the shielding!

RF coil with cooling, shielding

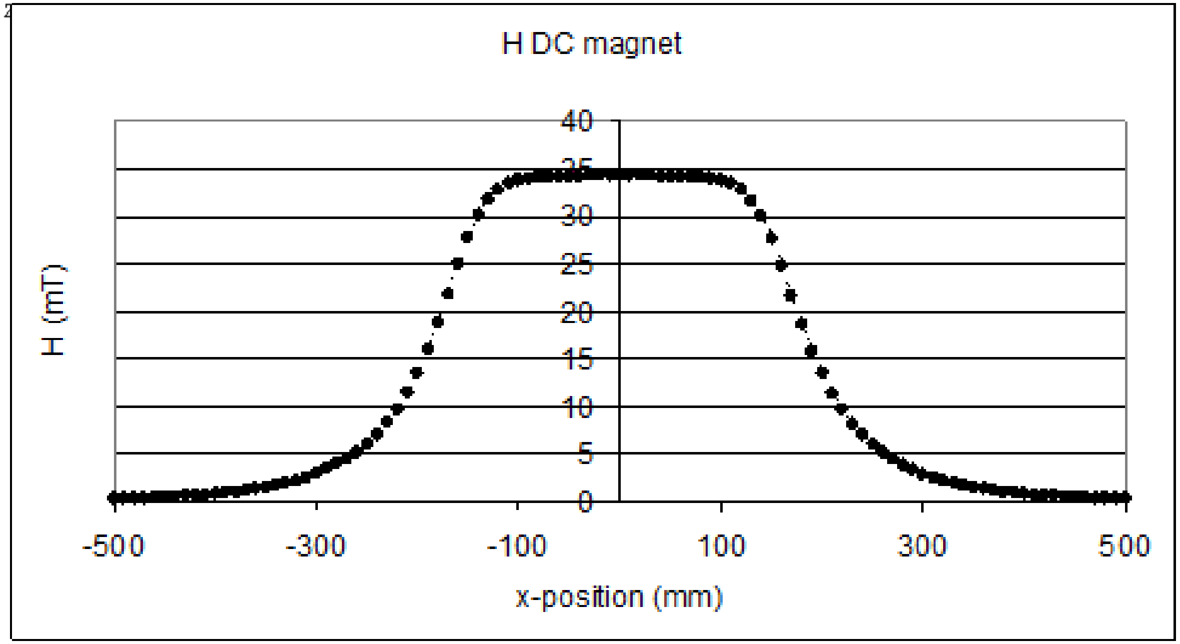




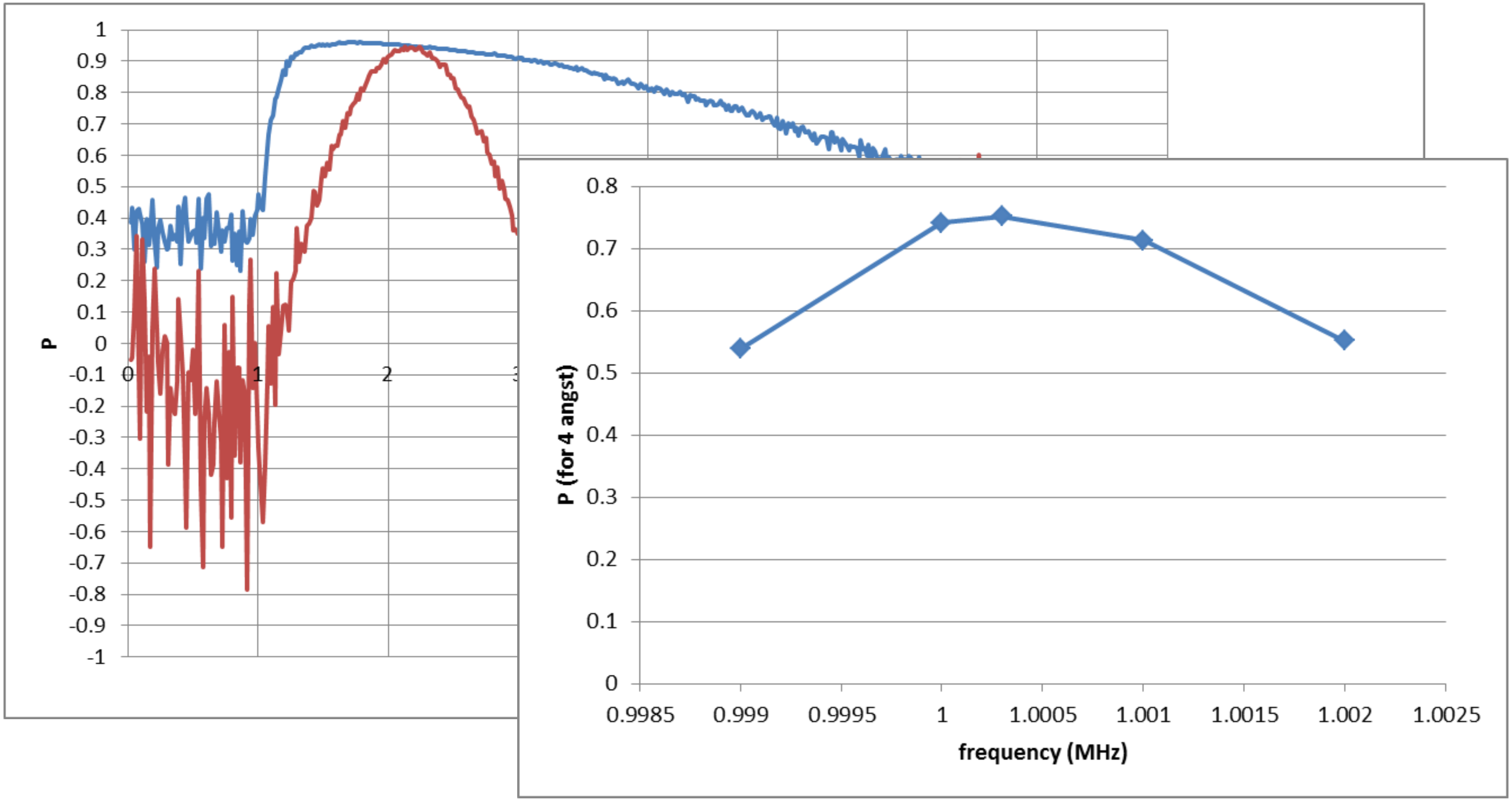
Gradient field



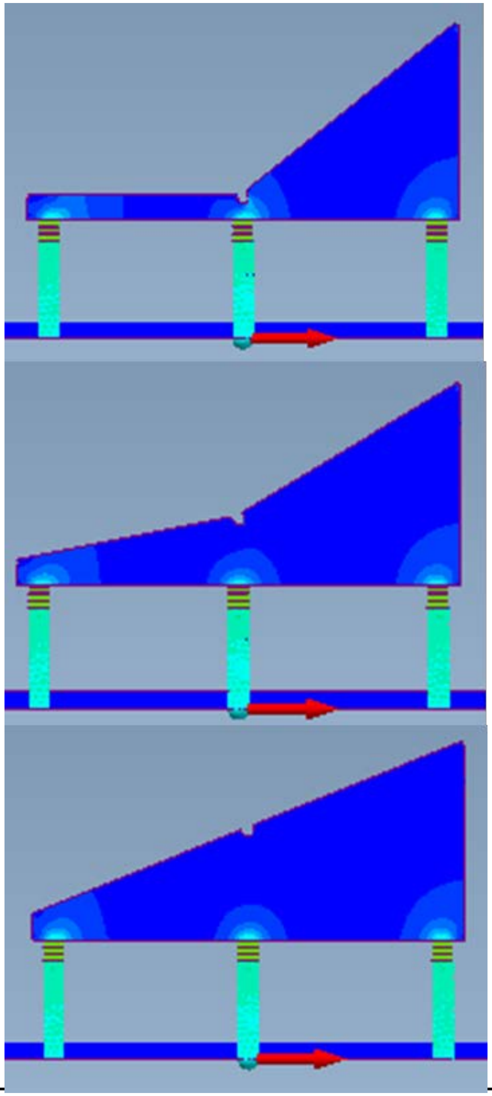
$$hf = 2\mu_n B_0$$



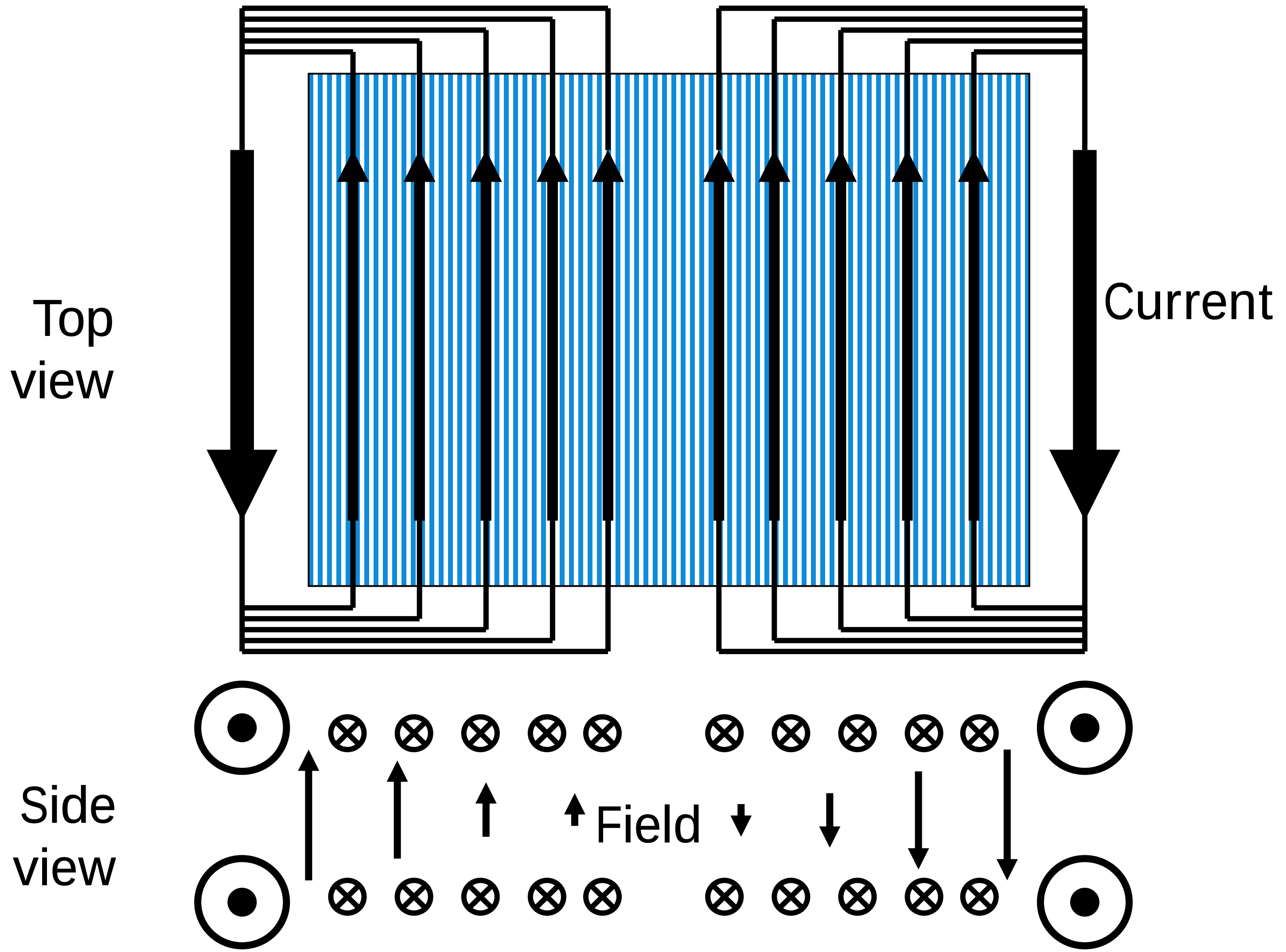
Monochromatic RF flipper



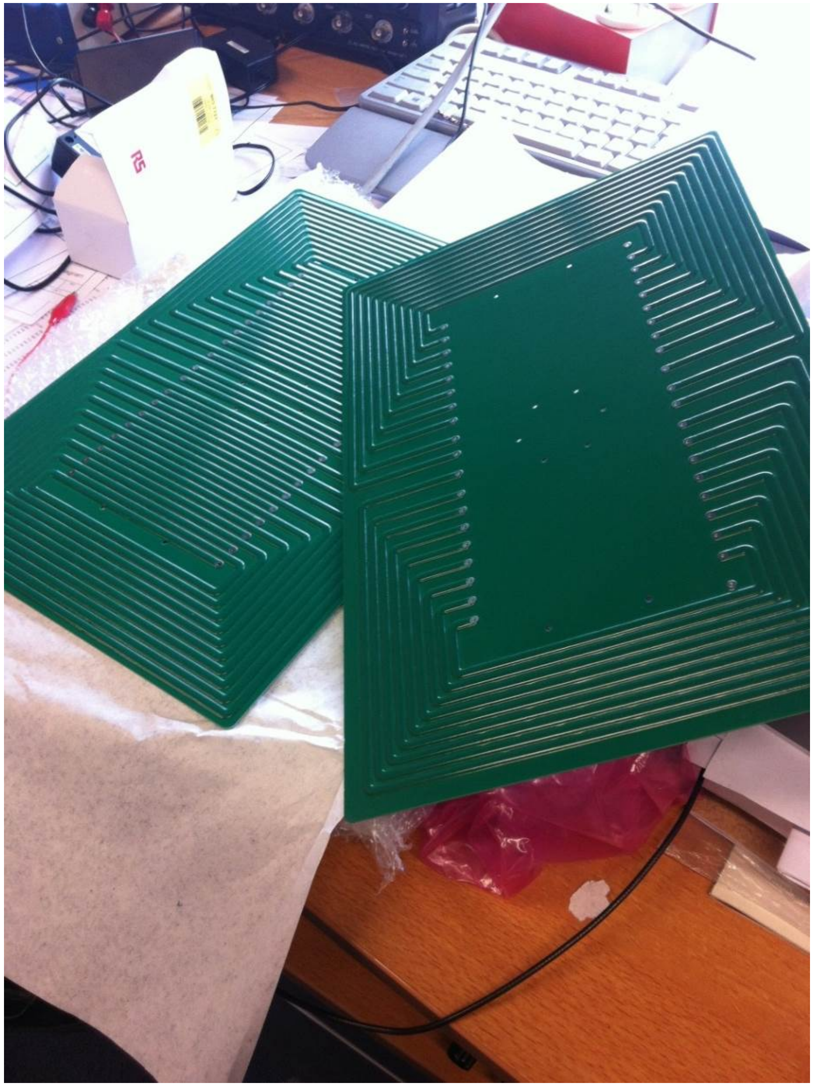
Gradient field

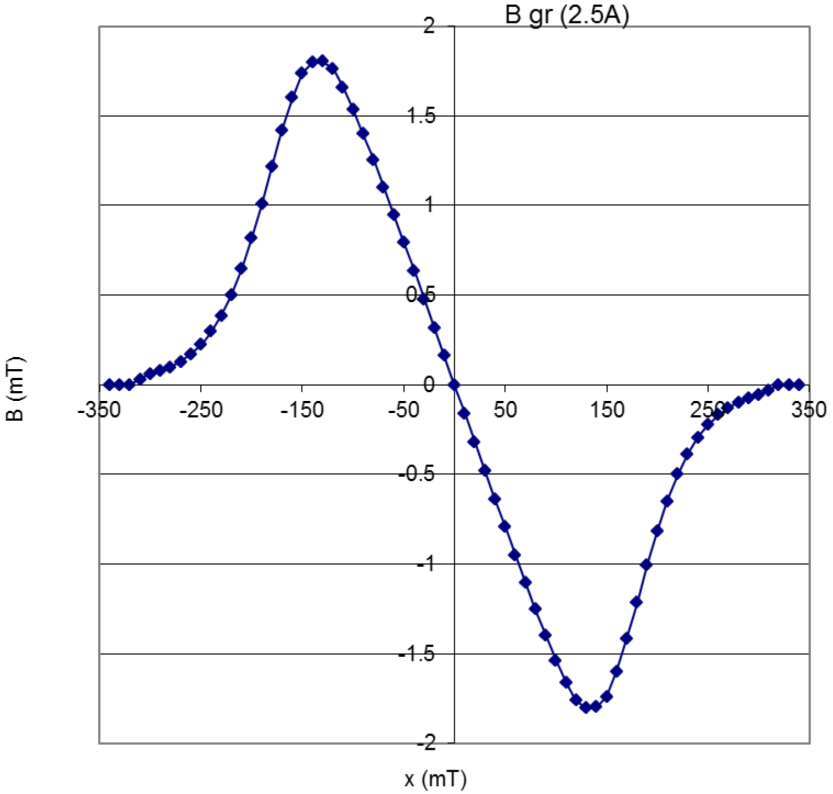


Gradient field

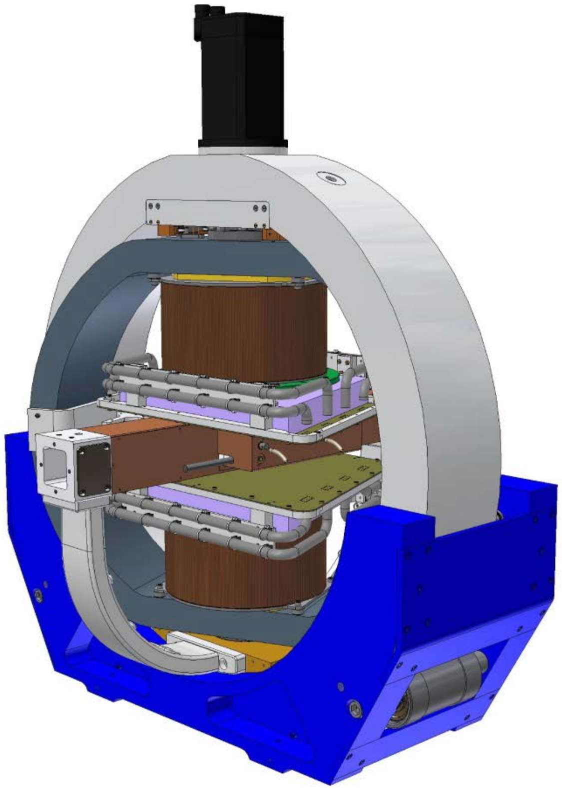


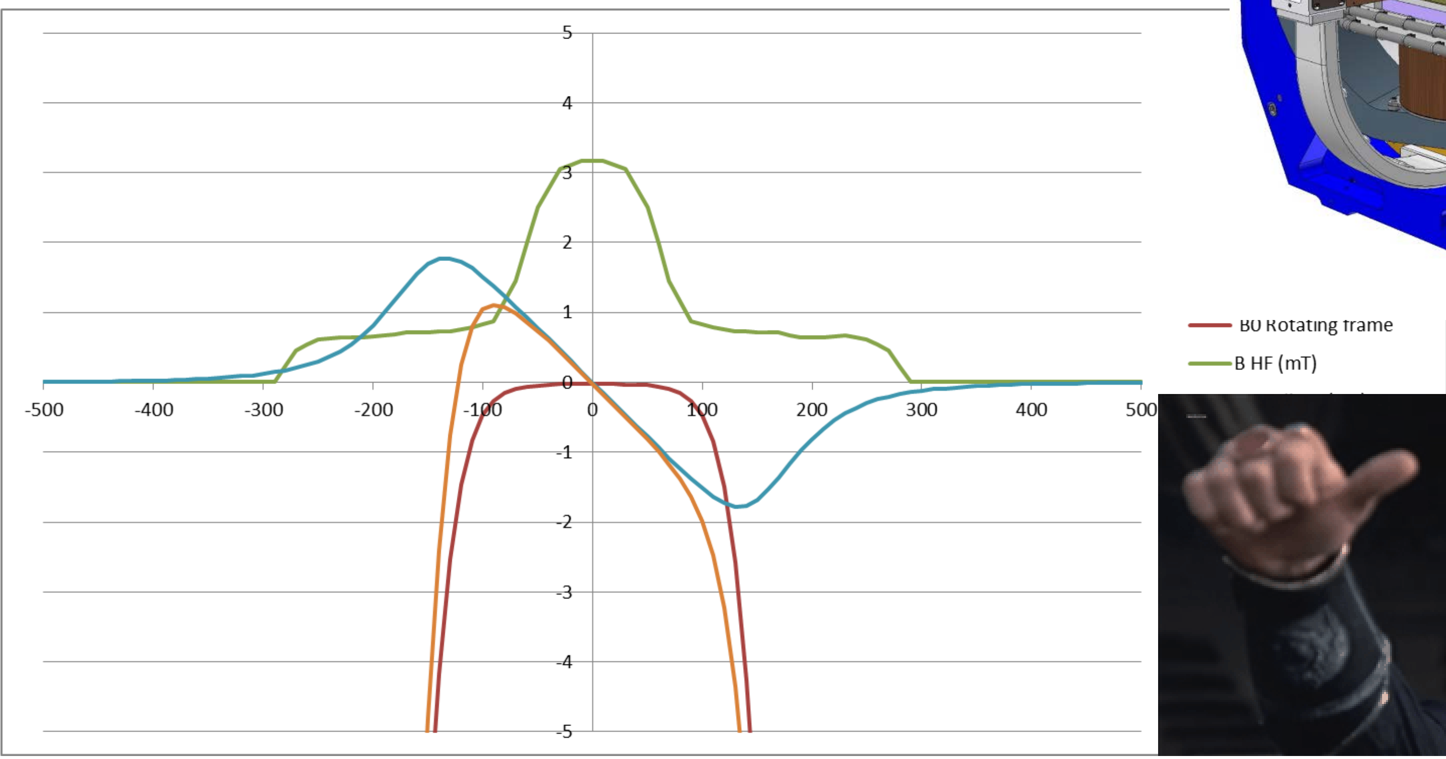
Gradient field





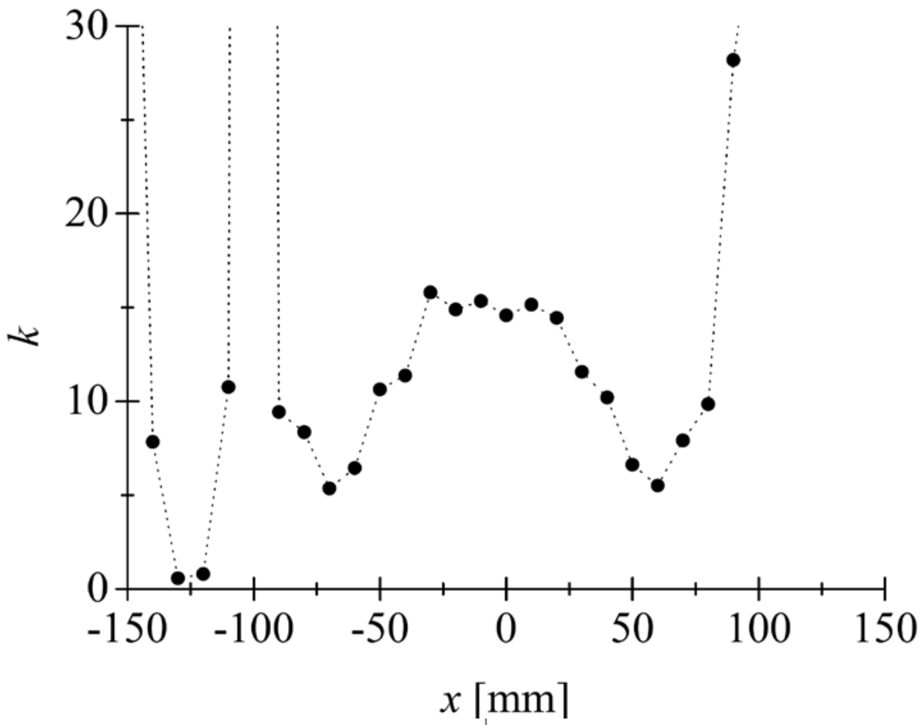
Gradient RF flipper

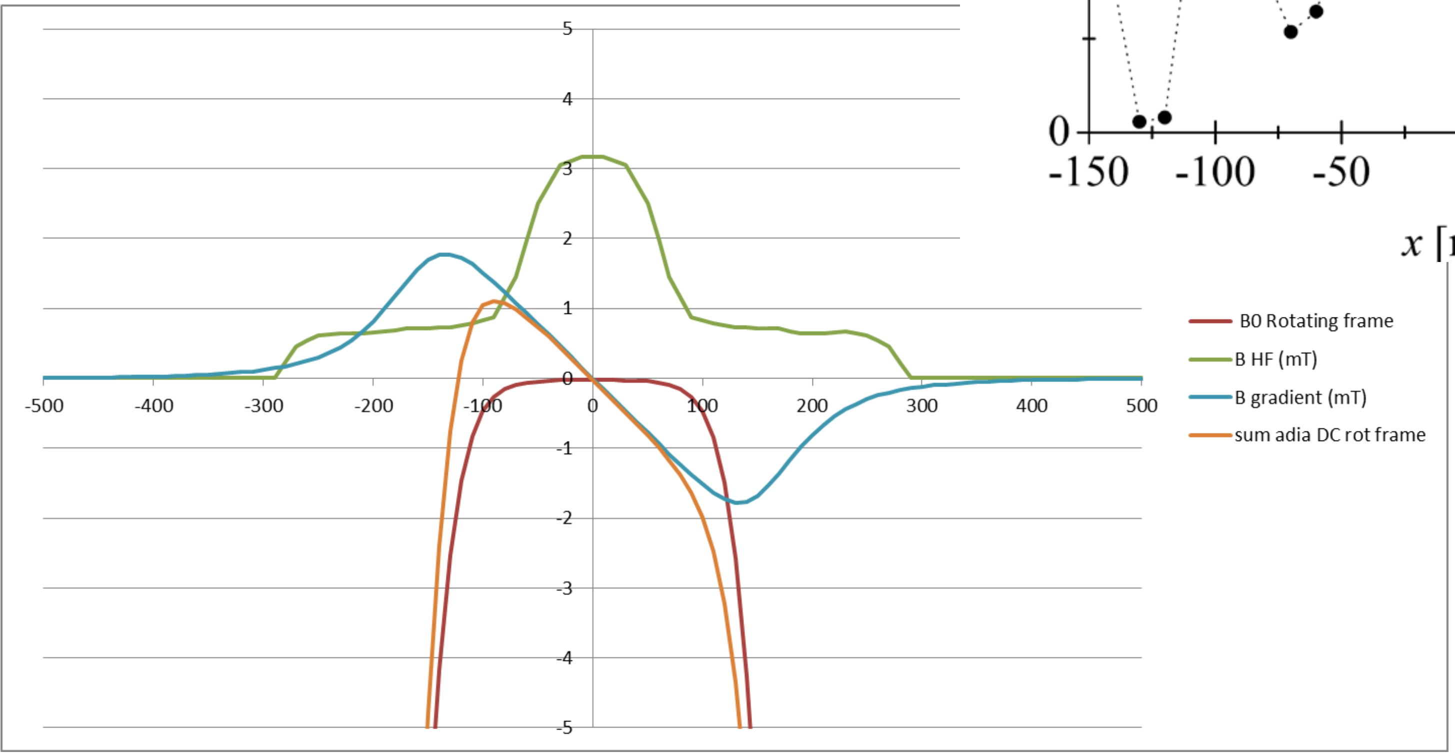




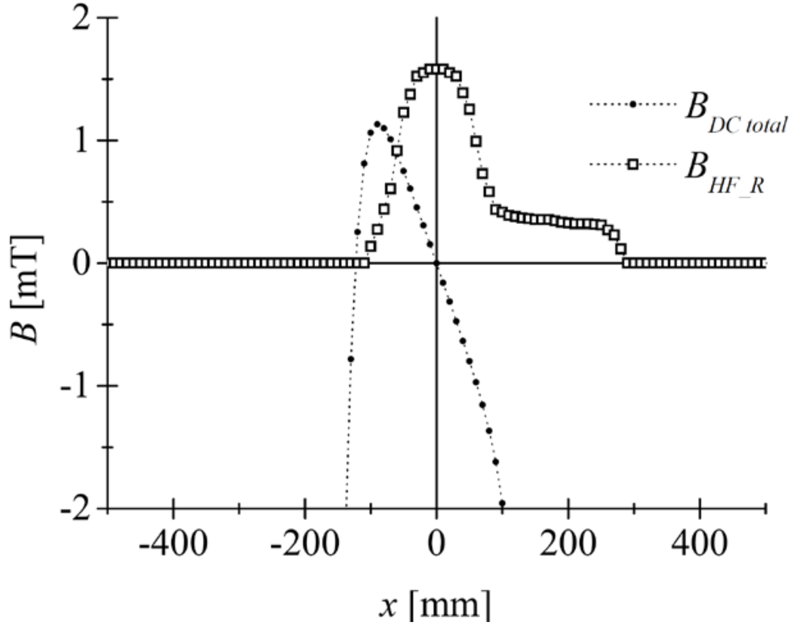
Gradient RF flipper

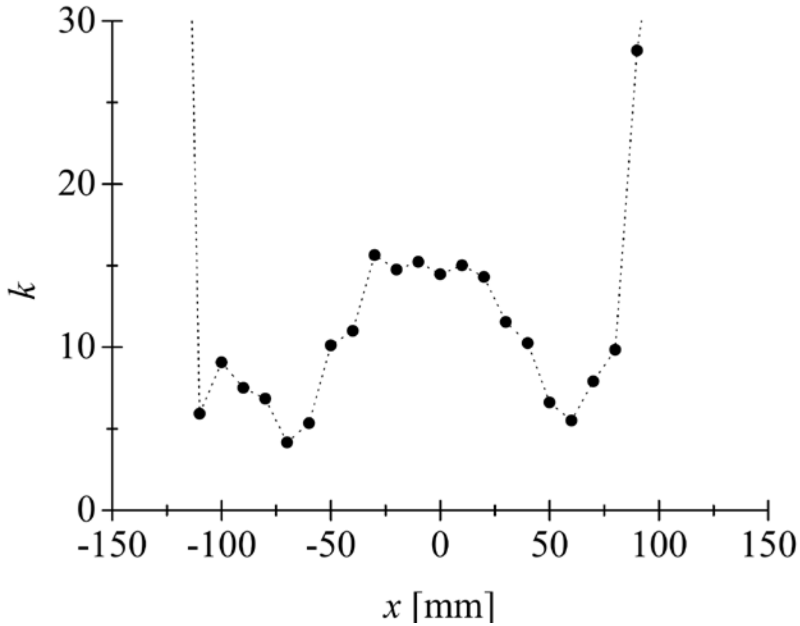
$$k = \frac{\omega_L}{\omega_g}$$



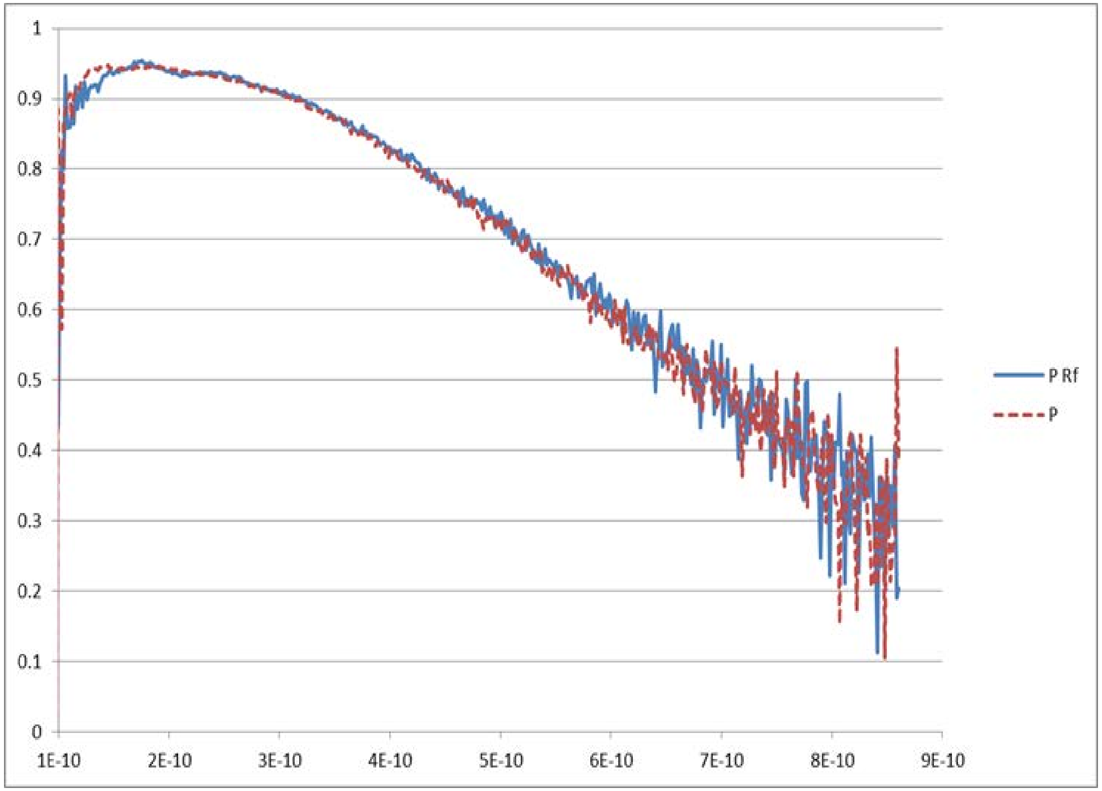


Gradient RF flipper

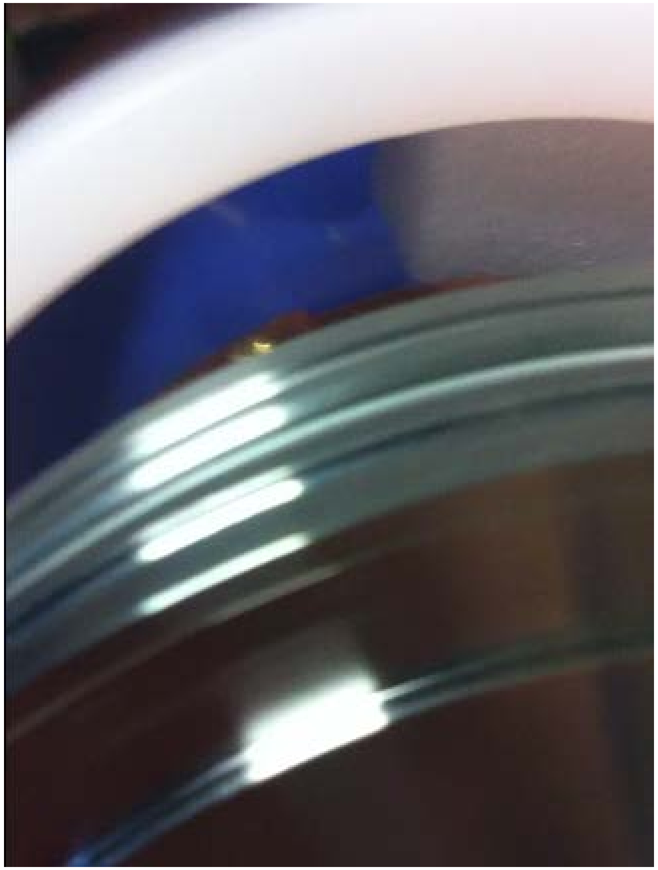


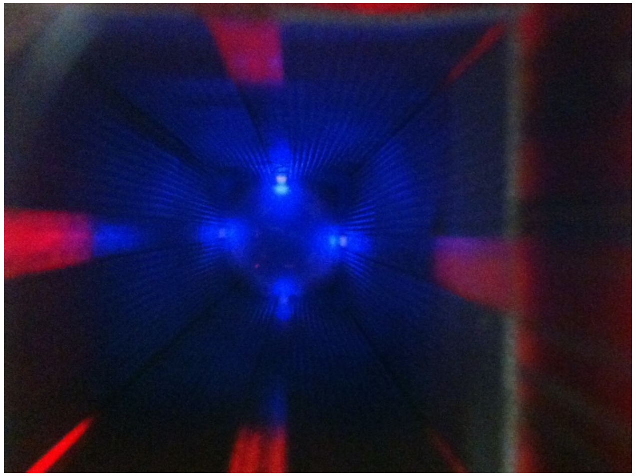


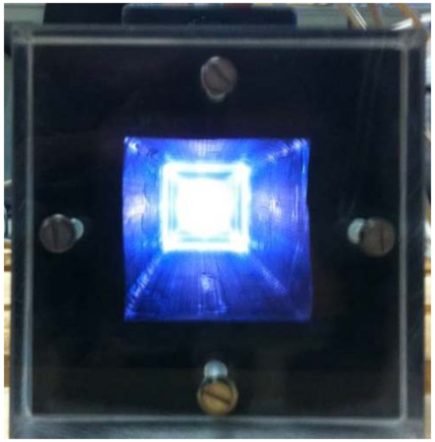
Gradient RF flipper



Gradient RF flipper in Vacuum

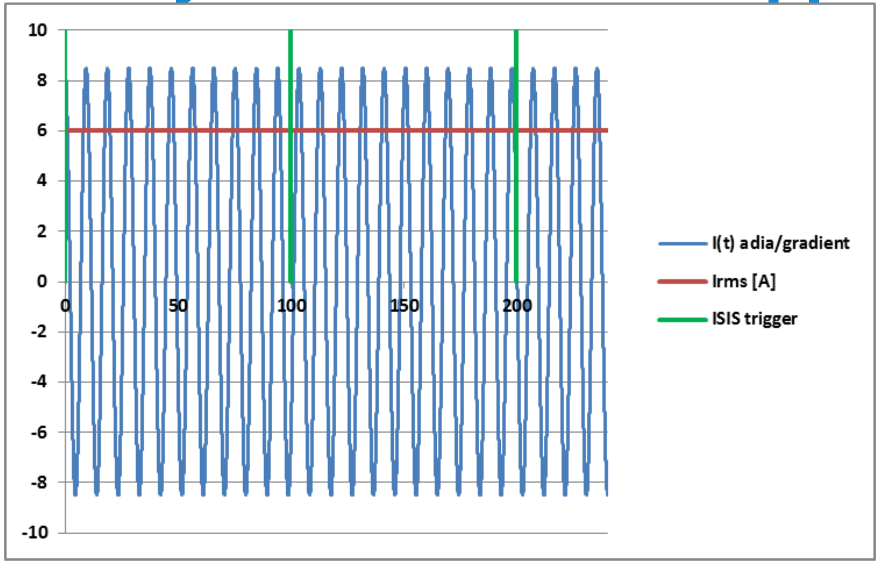


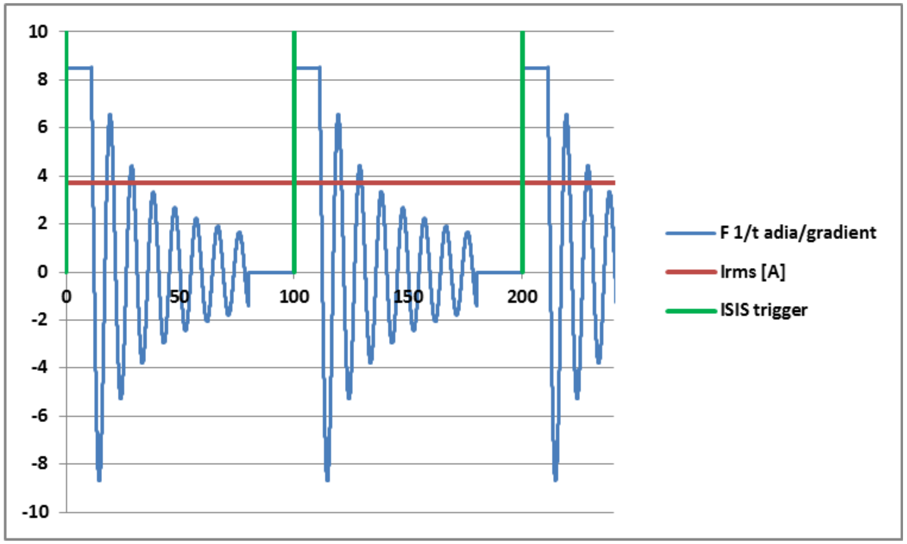


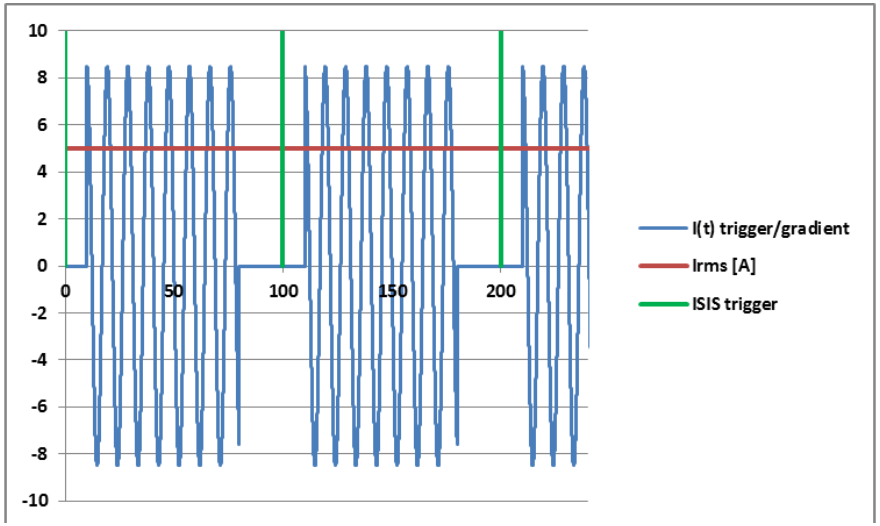


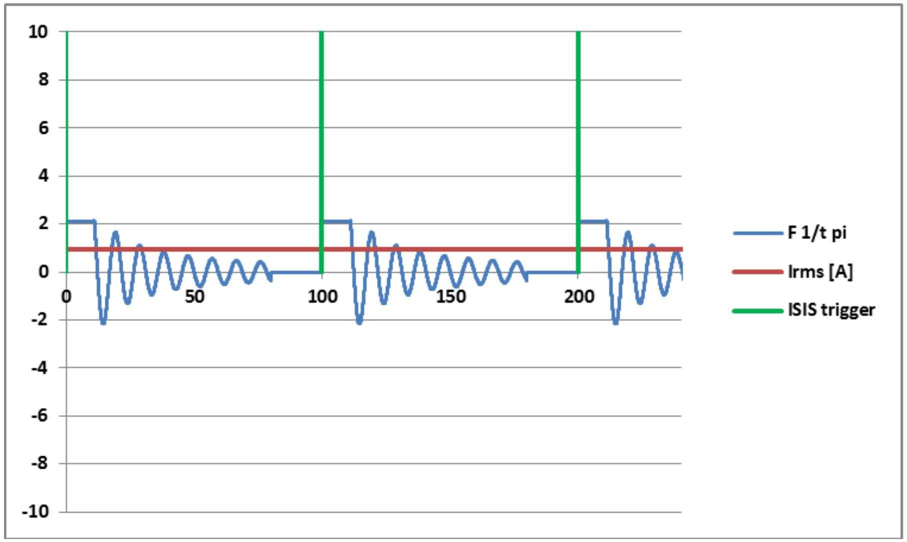
TU Delft

Ways to run the RF flipper on TOF source

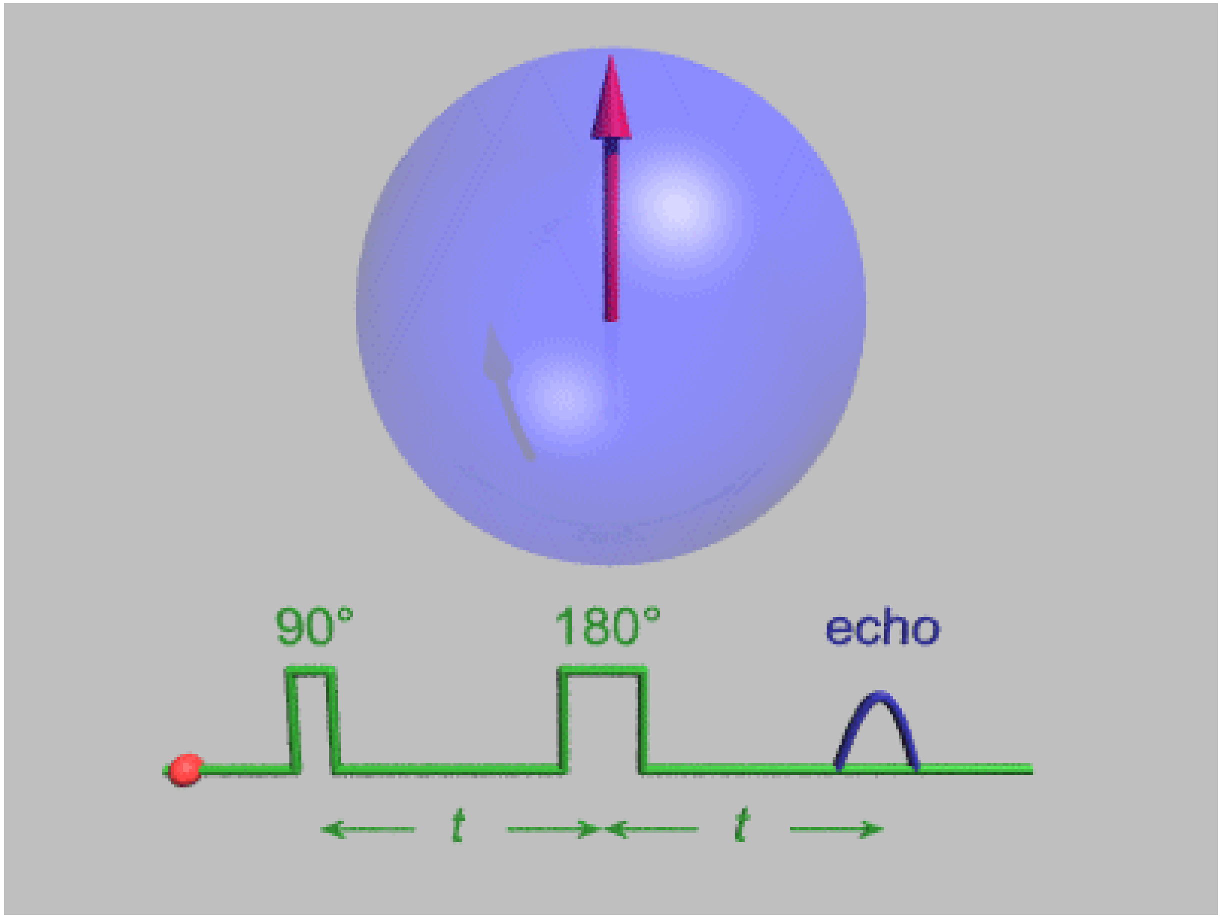








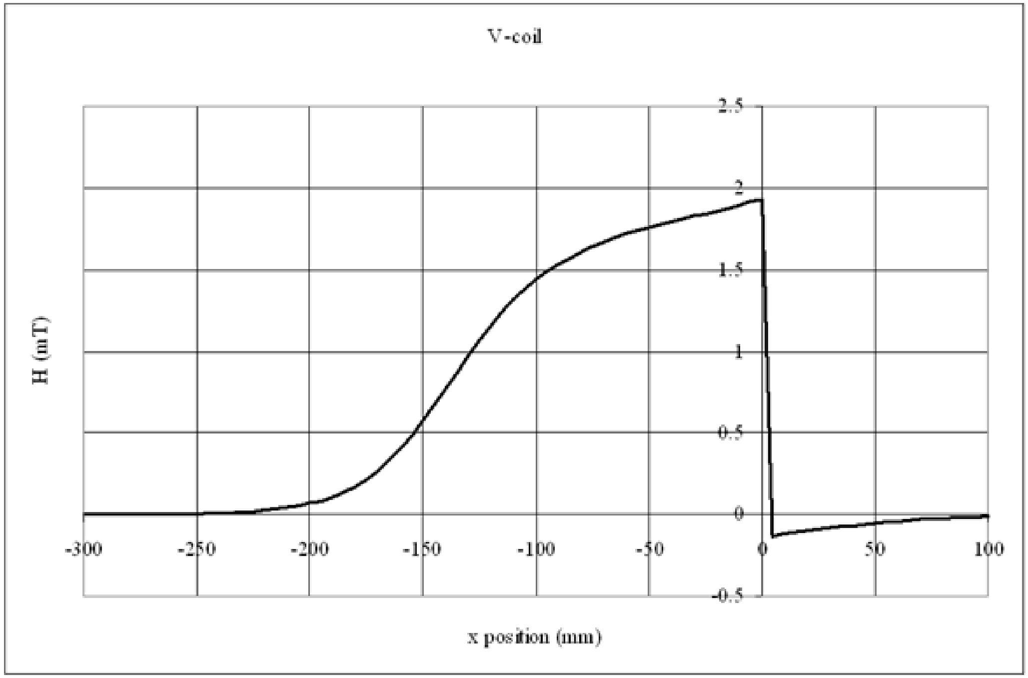
Start precession with π/2

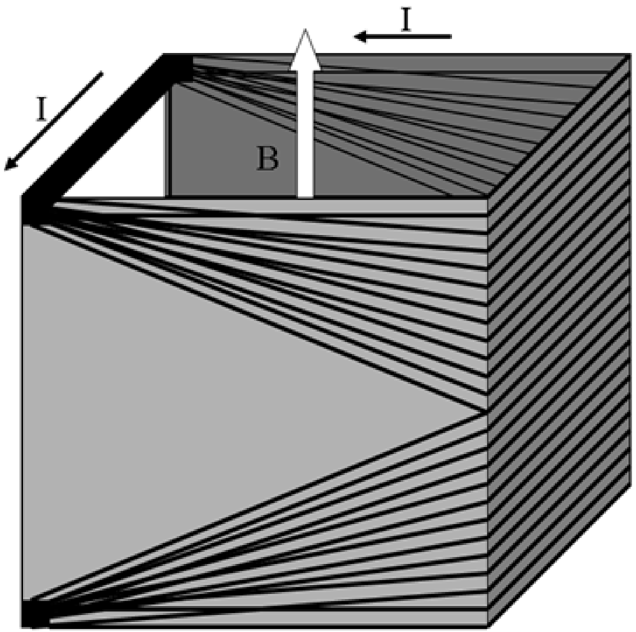


Vcoil

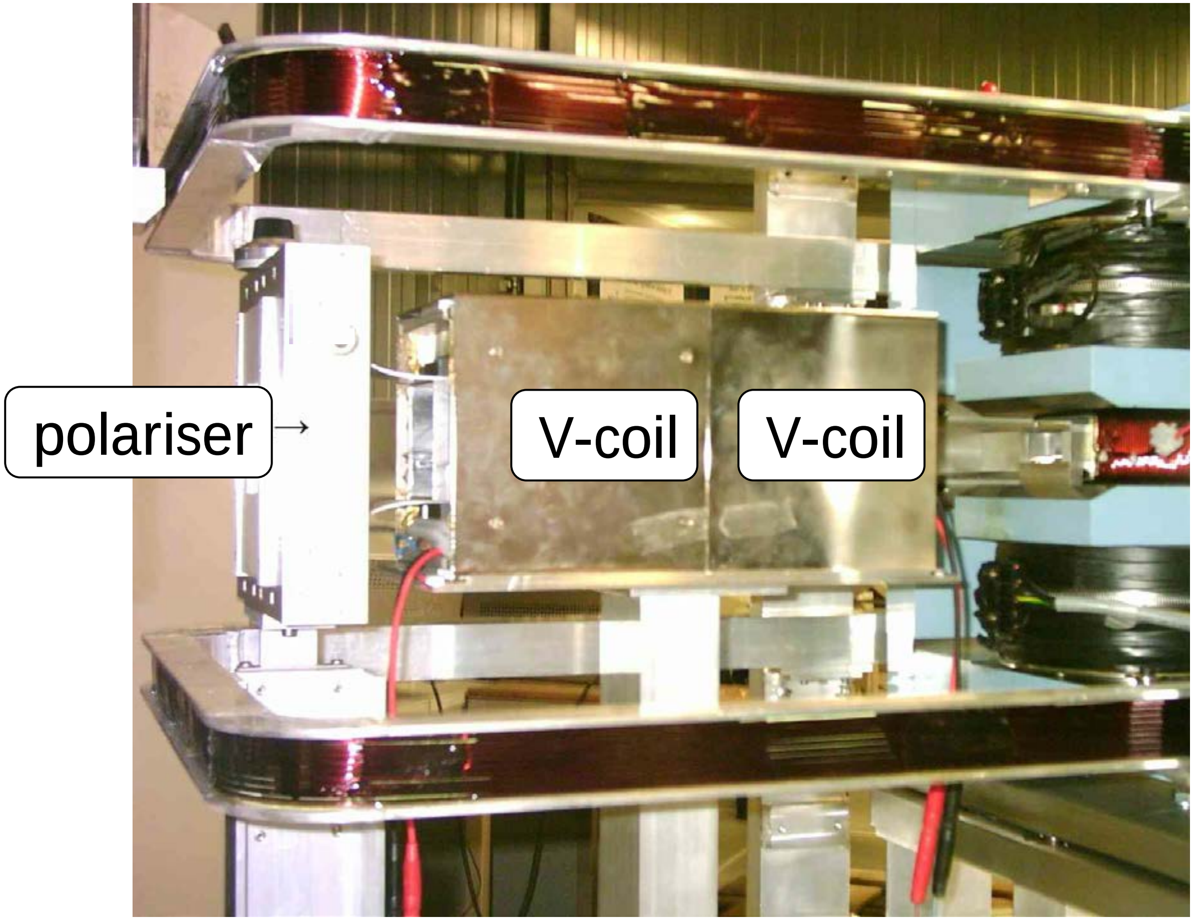
- White beam
- Nearly perfect
- Al wire in beam
- Not compact
-

Vcoil fields

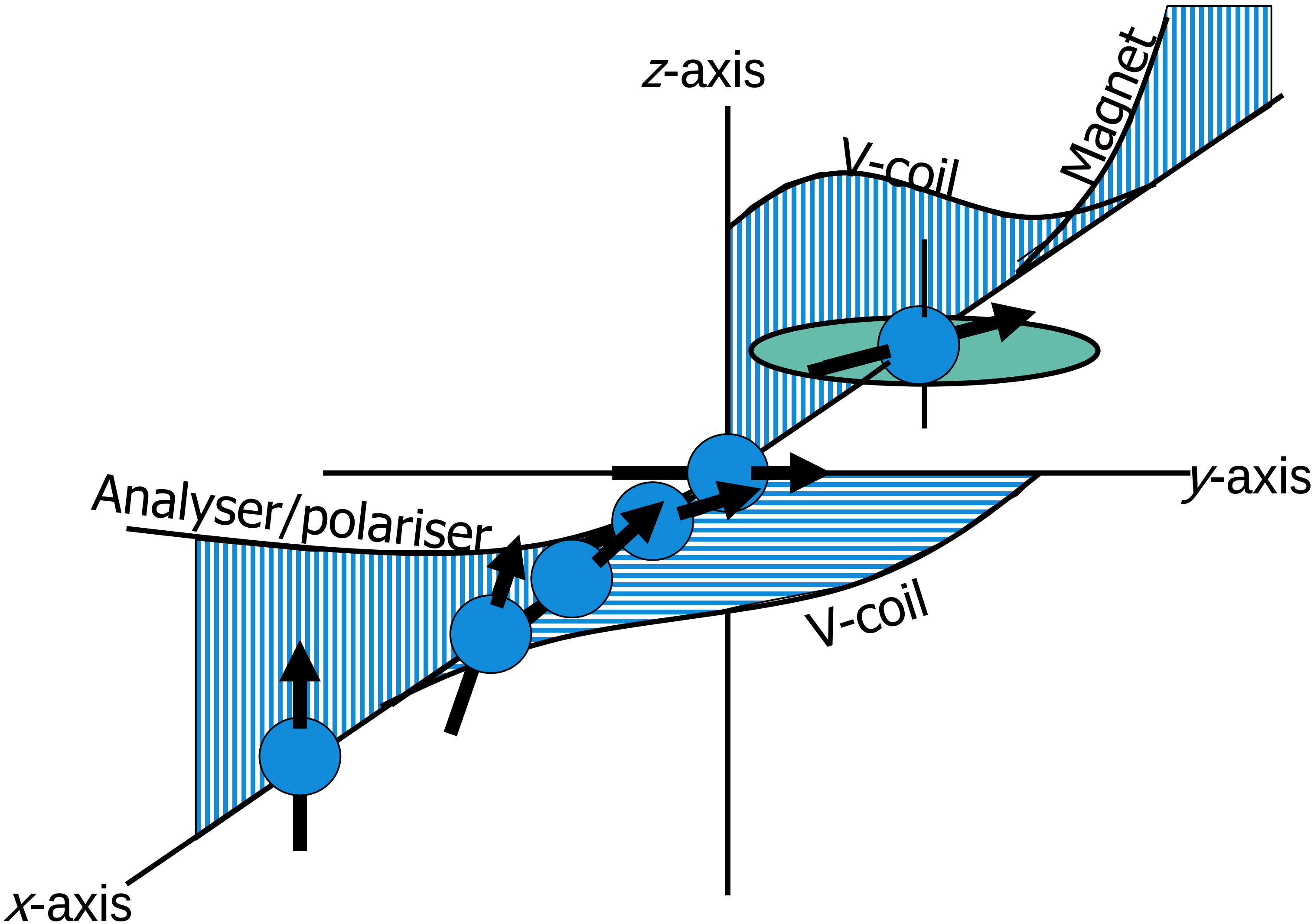




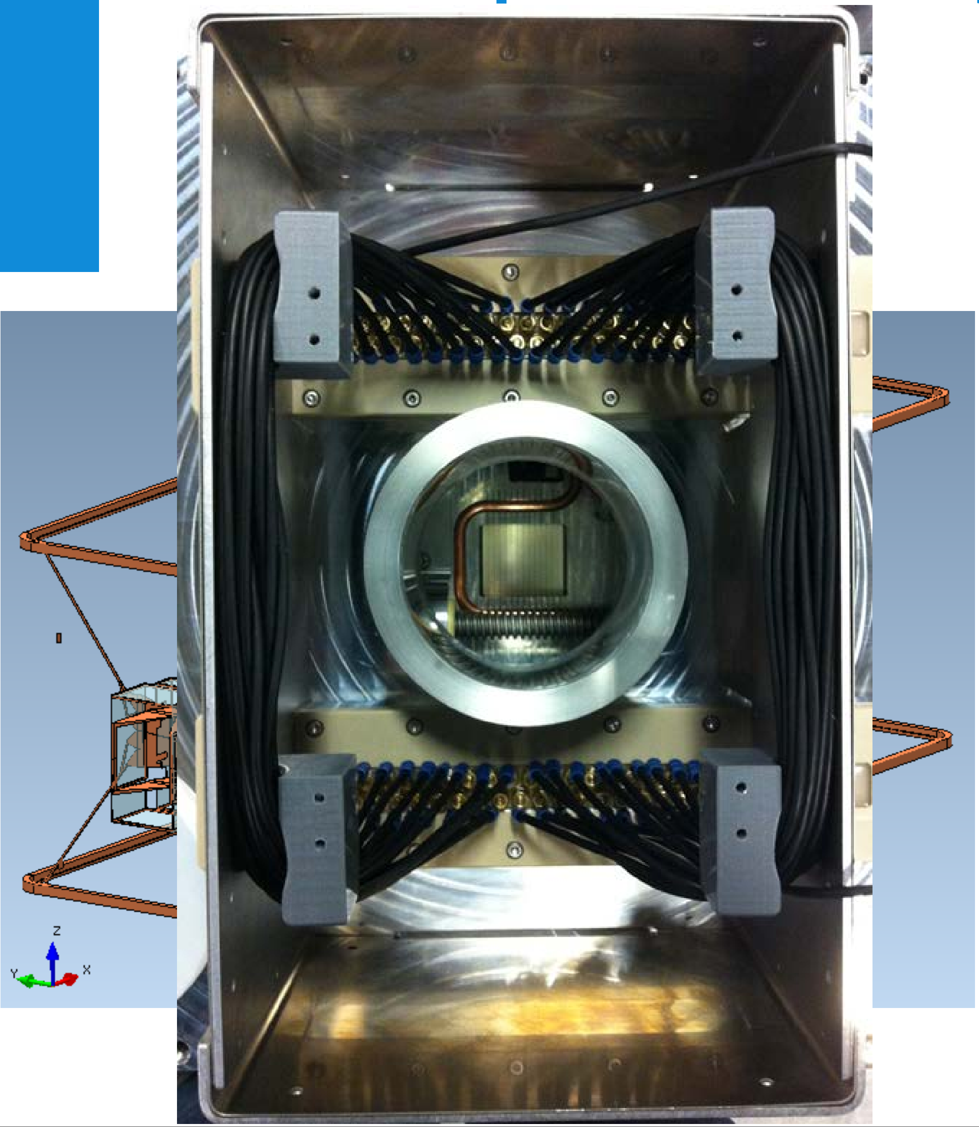
Start precession with Vcoil

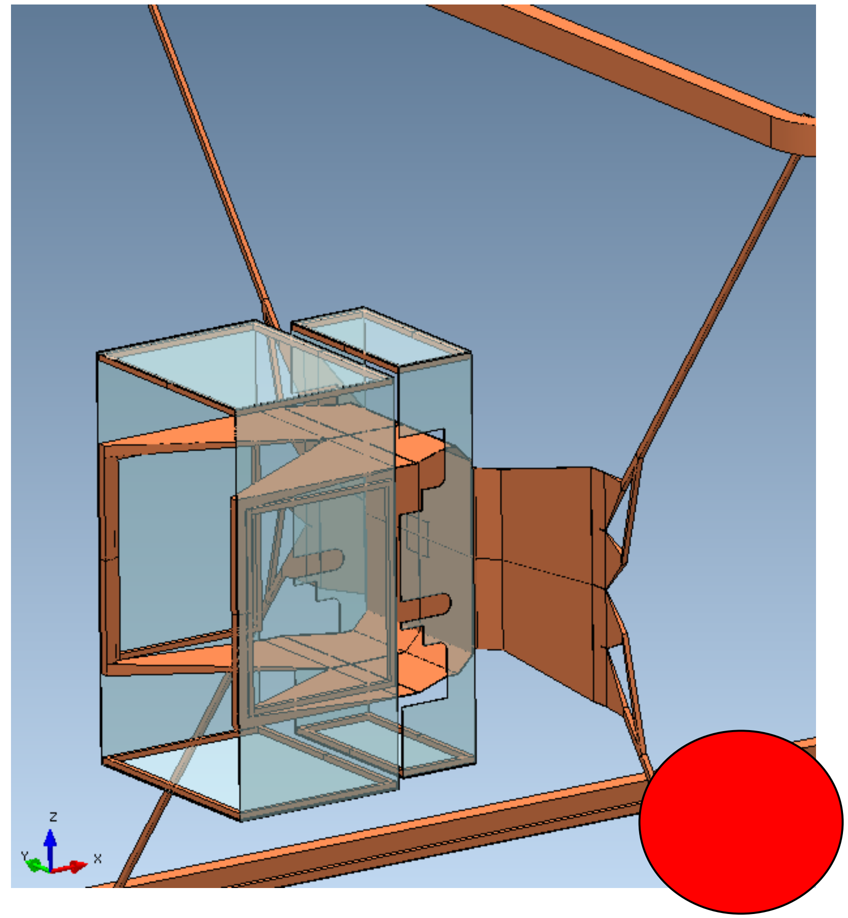


AAAA

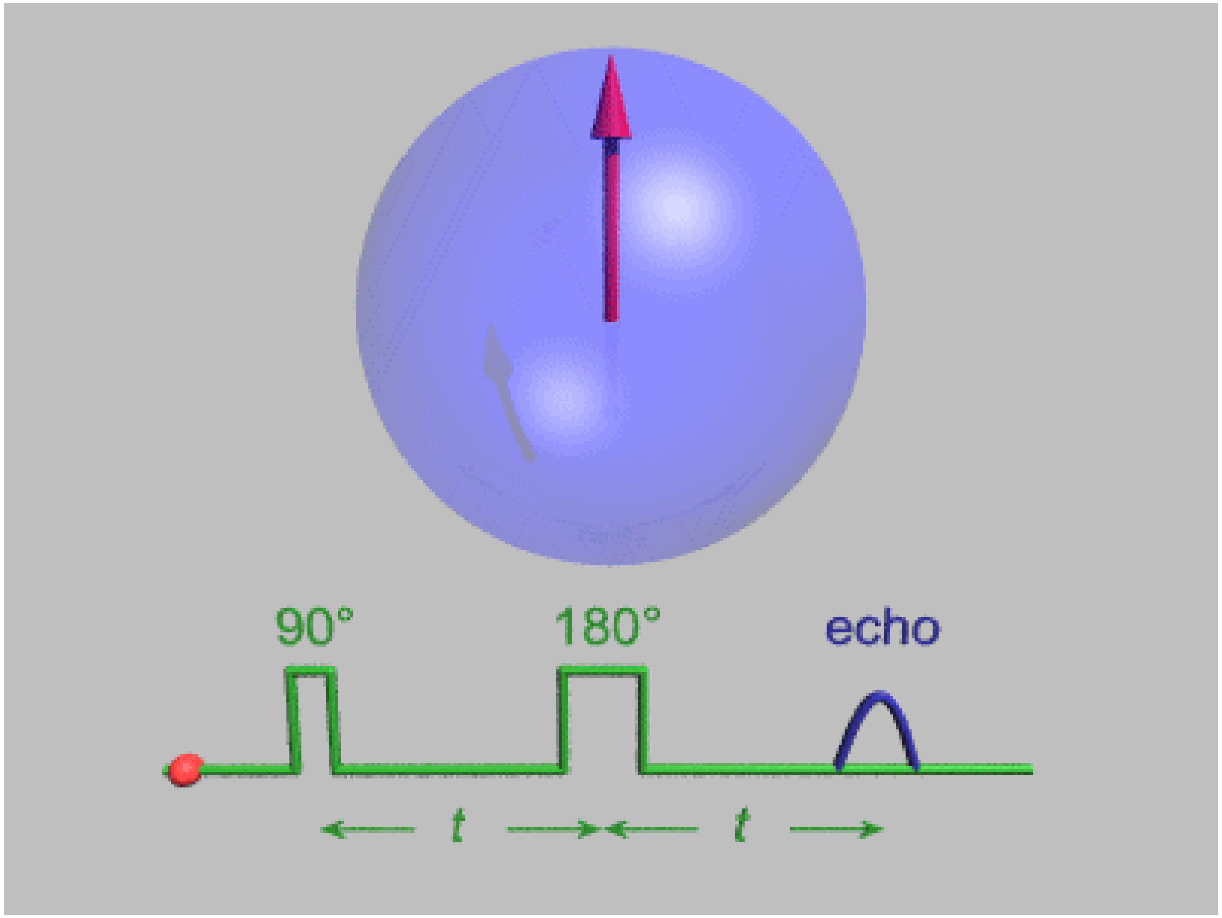


More complicated Vcoil system

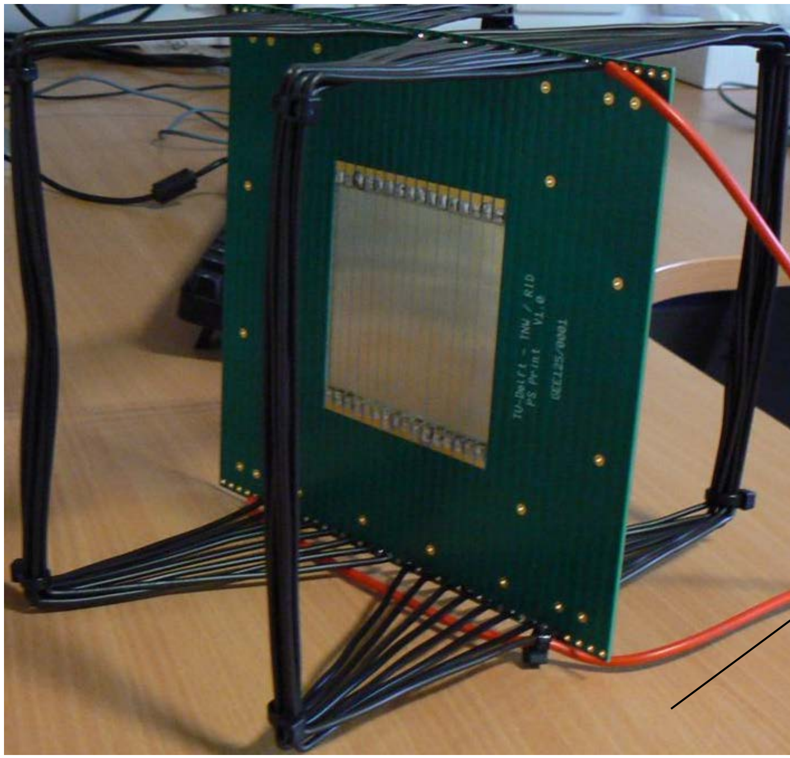


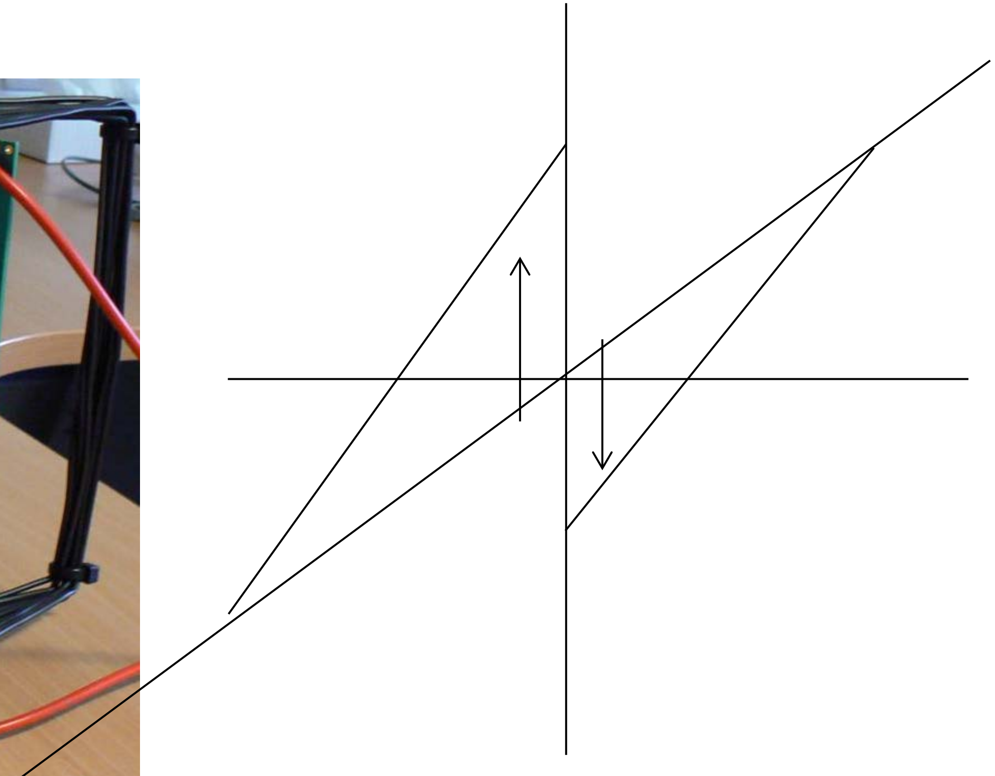


Start precession with $\pi/2$

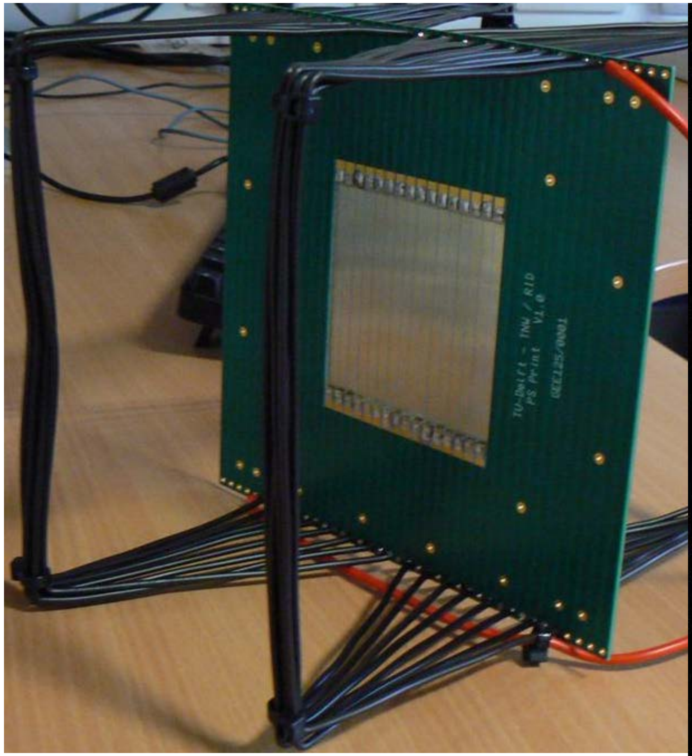


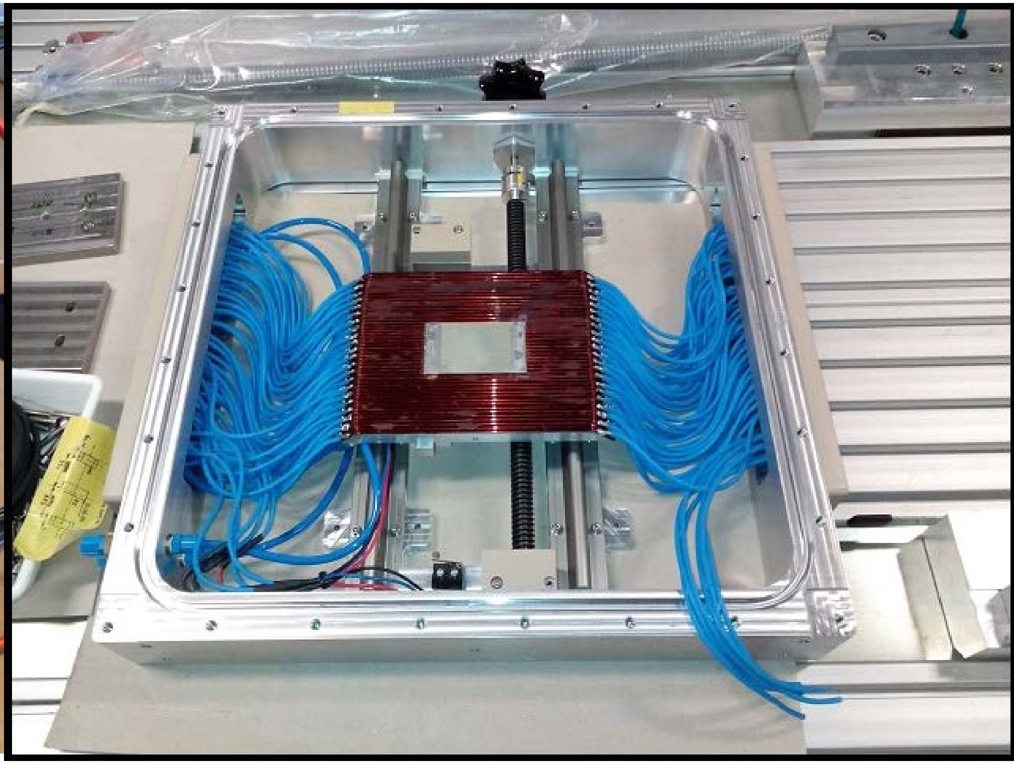
Field stepper or field reversal



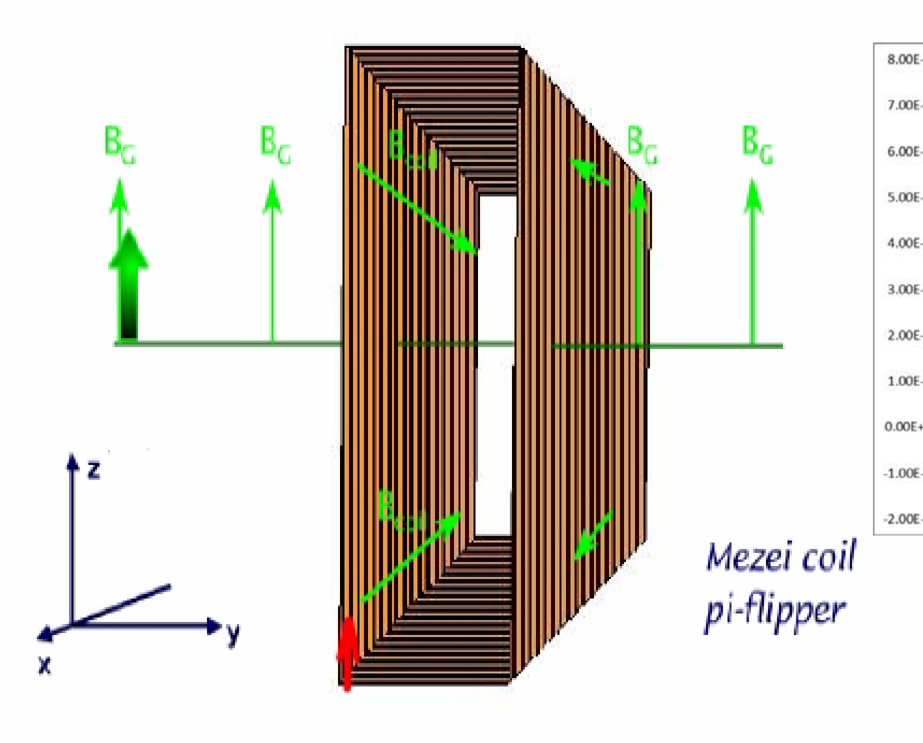


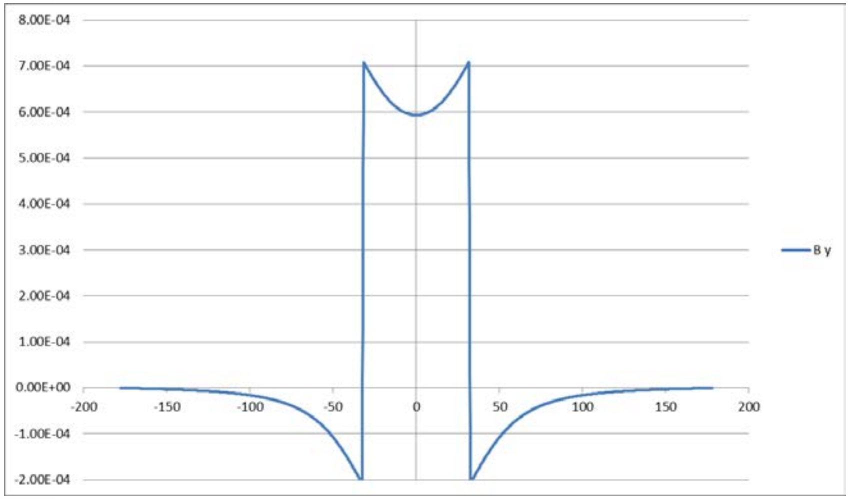
Field stepper or field reversal





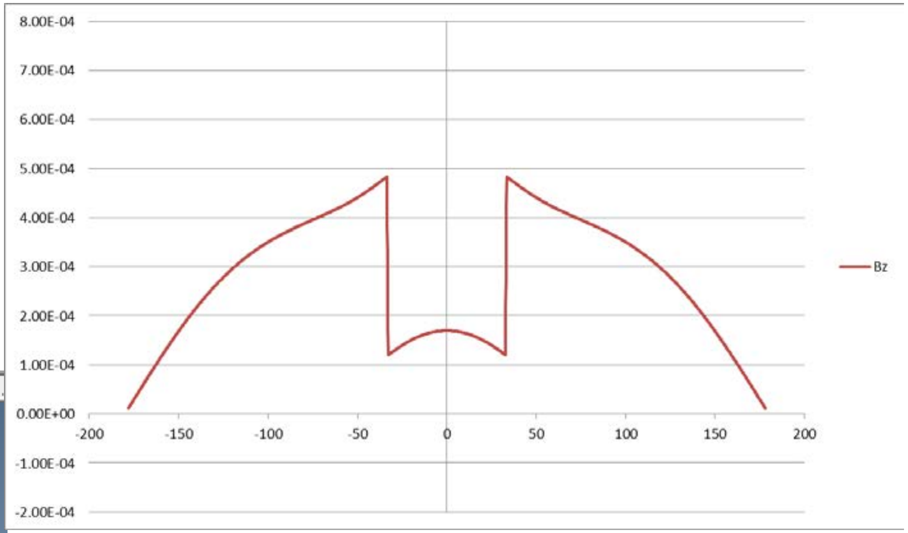
Pi flip Mezei



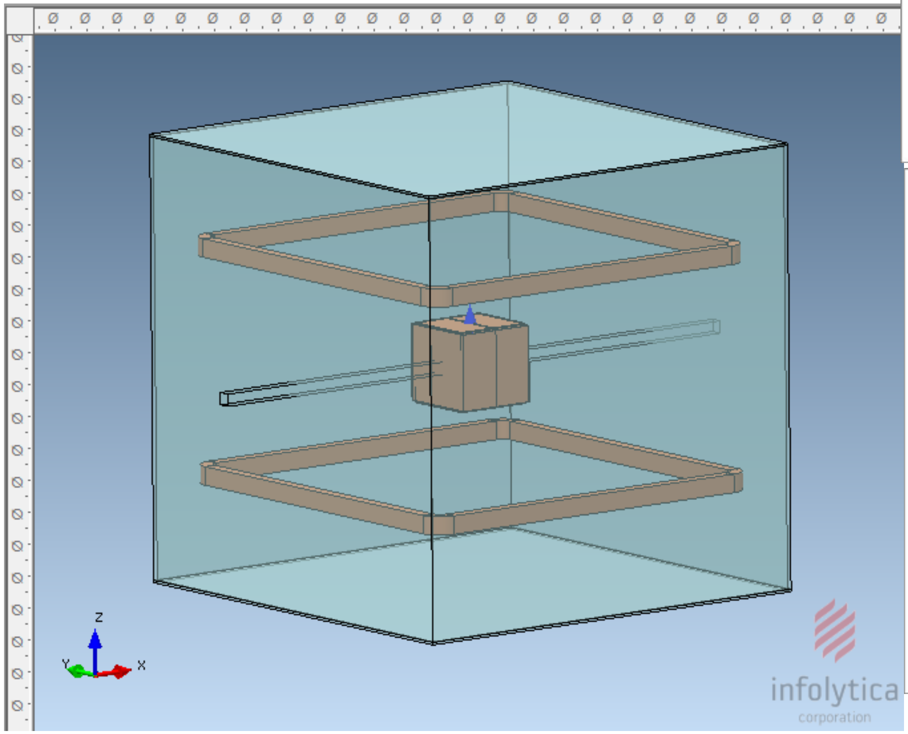


Hayter Z Physik B 31, 117 (1978)

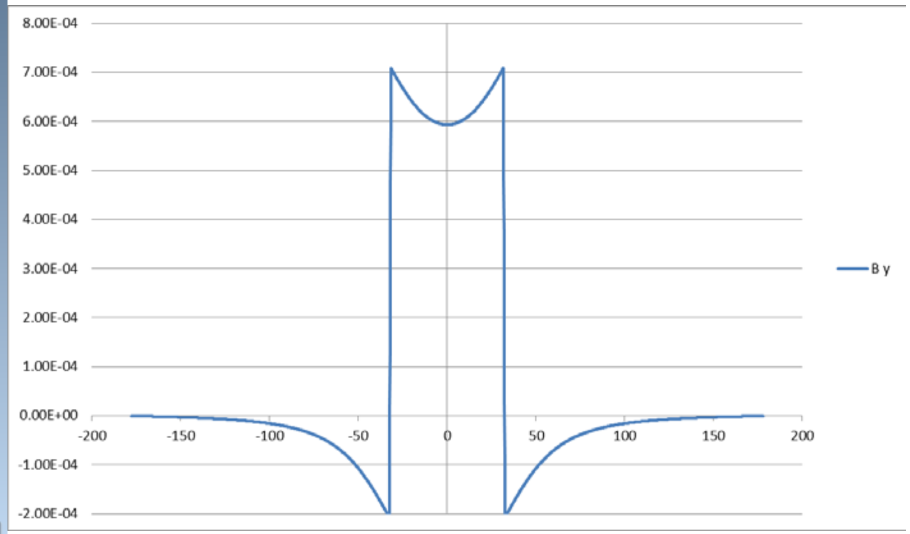
Pi flip



8.00E-04
7.00E-04
6.00E-04
5.00E-04
4.00E-04
3.00E-04
2.00E-04
1.00E-04
0.00E+00
-1.00E-04
-2.00E-04
-200
-150
-100
-50
0
50
100
150
200
Bz

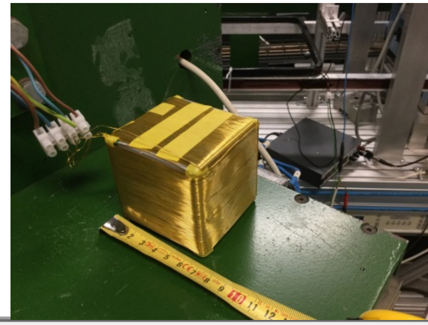


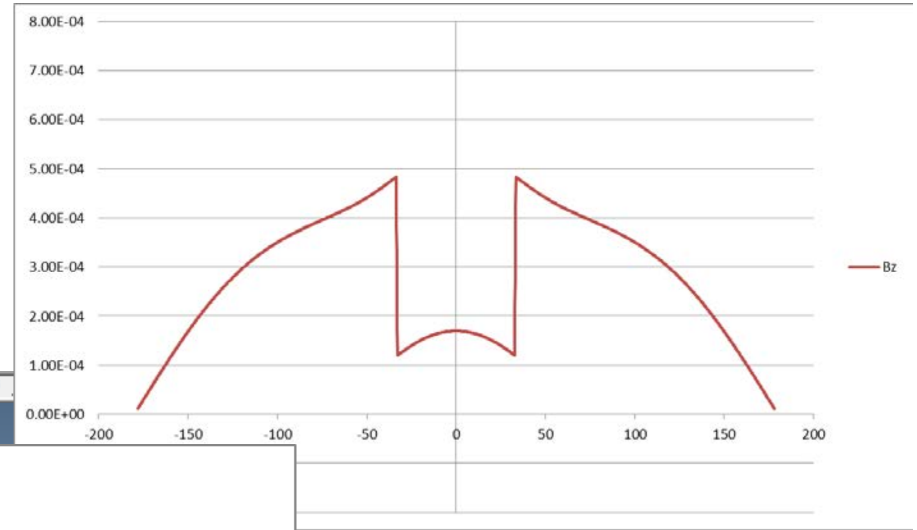
Z
Y
X
infolytica
corporation



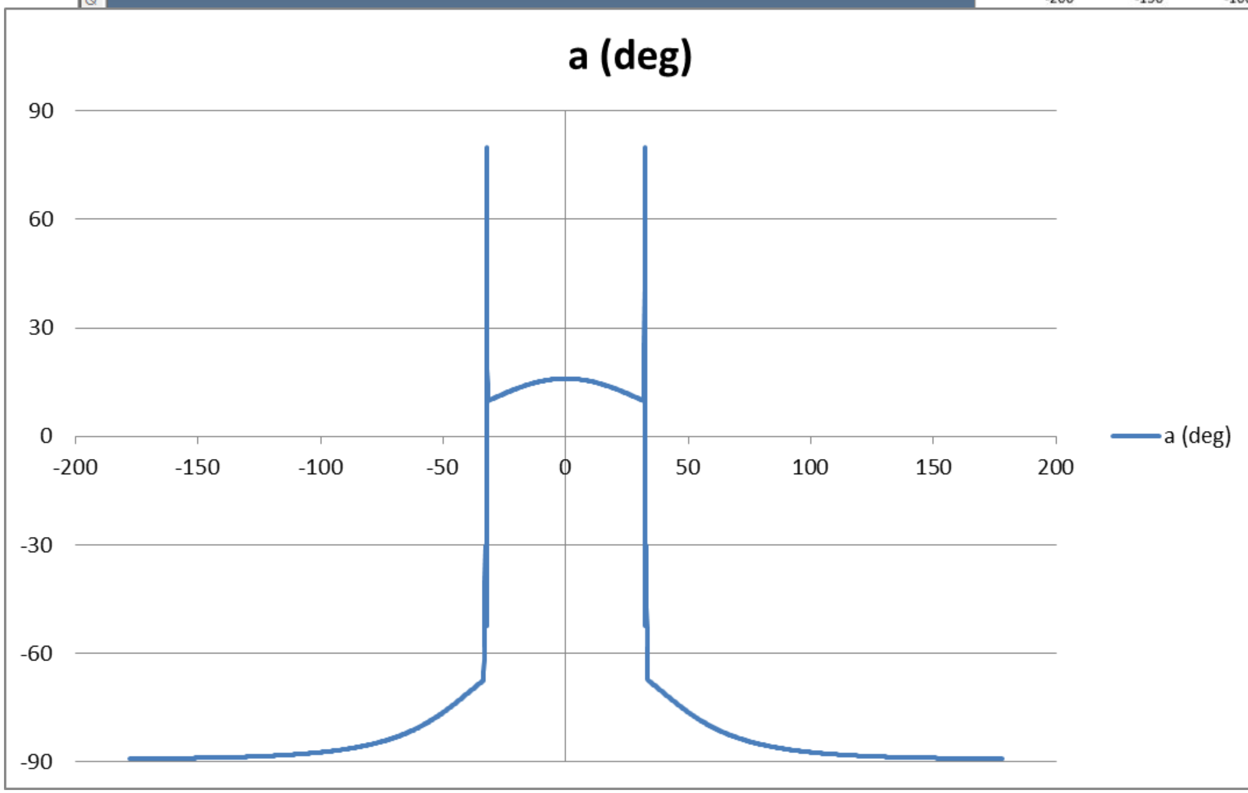
8.00E-04
7.00E-04
6.00E-04
5.00E-04
4.00E-04
3.00E-04
2.00E-04
1.00E-04
0.00E+00
-1.00E-04
-2.00E-04
-200
-150
-100
-50
0
50
100
150
200
B y

Pi flip

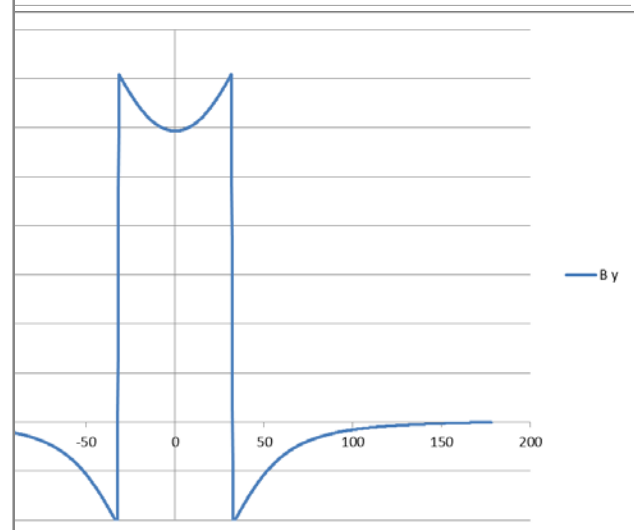




8.00E-04
7.00E-04
6.00E-04
5.00E-04
4.00E-04
3.00E-04
2.00E-04
1.00E-04
0.00E+00
-200
-150
-100
-50
0
50
100
150
200
Bz

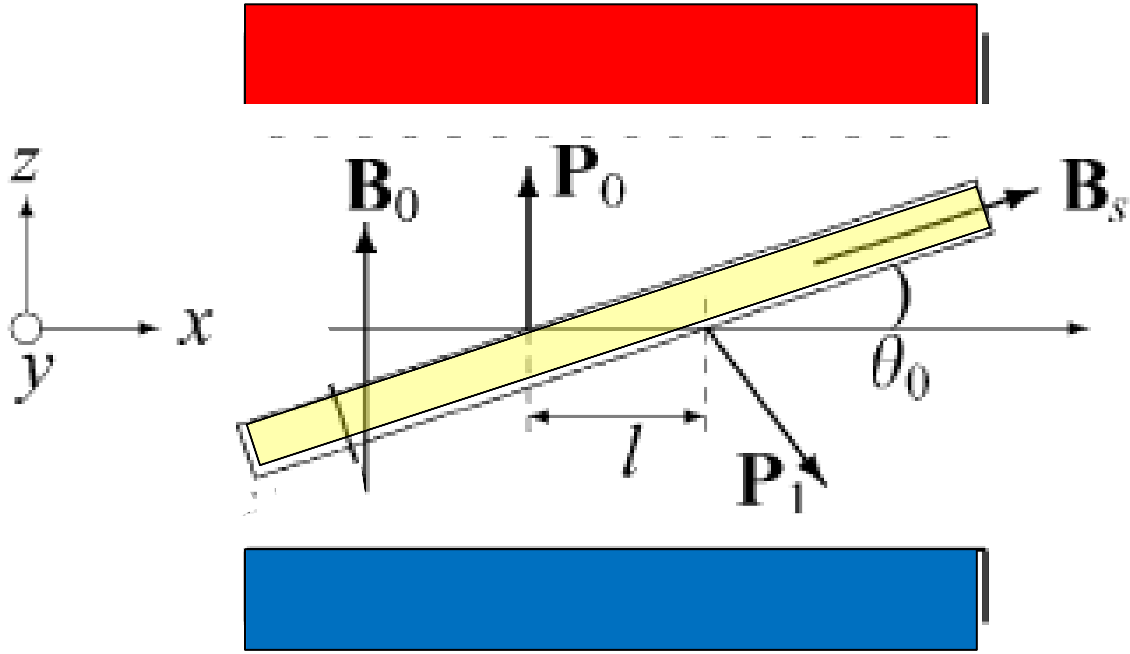


a (deg)
90
60
30
0
-30
-60
-90
-200
-150
-100
-50
0
50
100
150
200
a (deg)

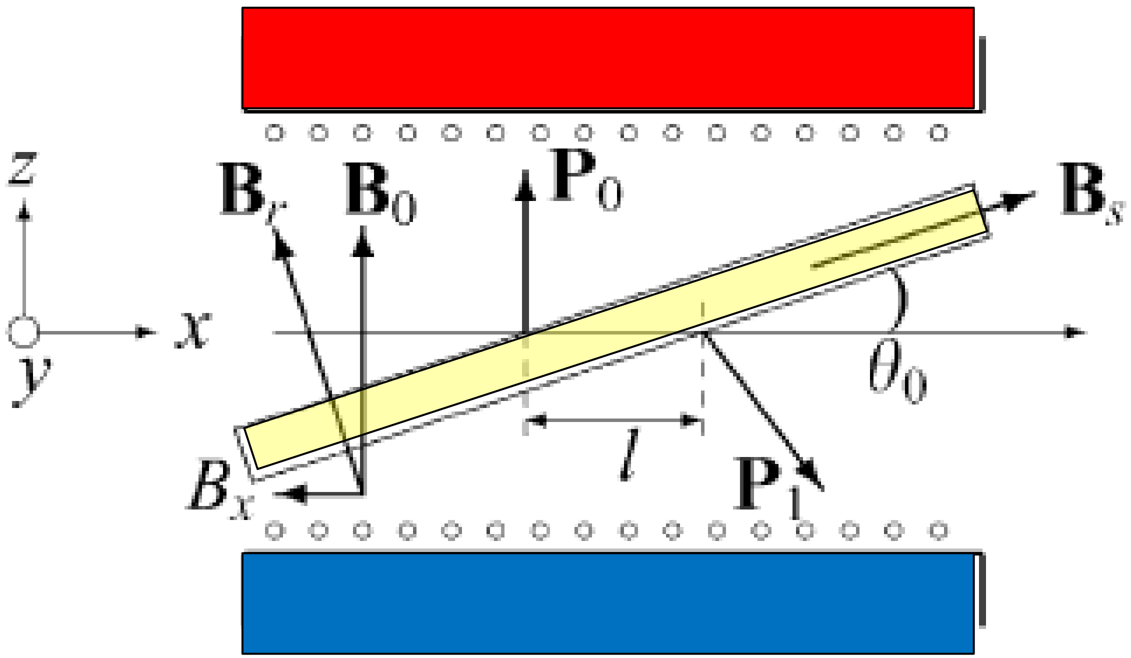


-50
0
50
100
150
200
B y

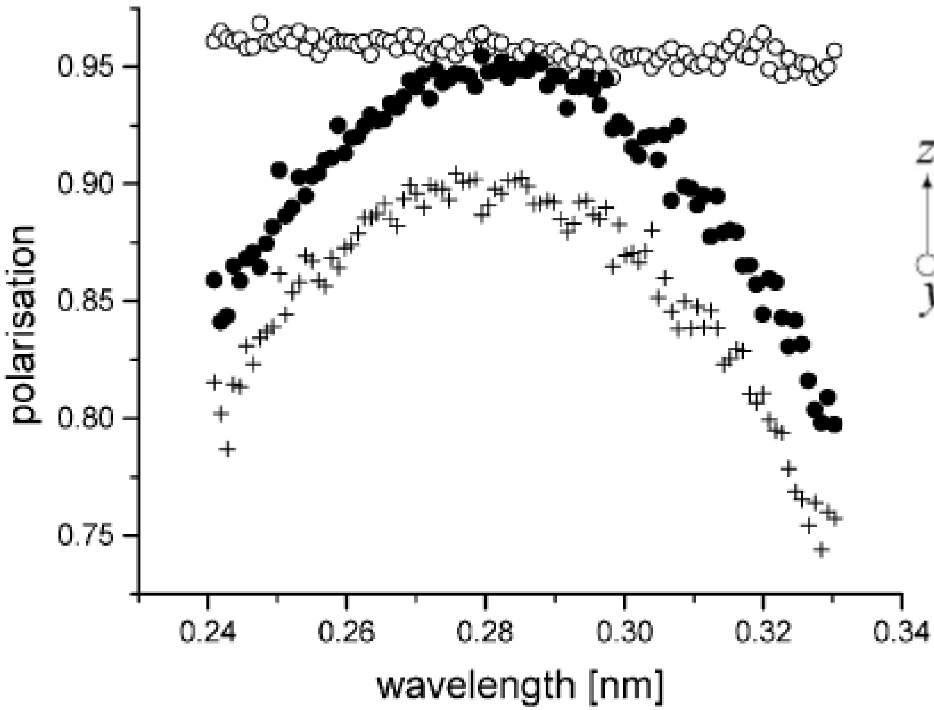
Foil π flipper

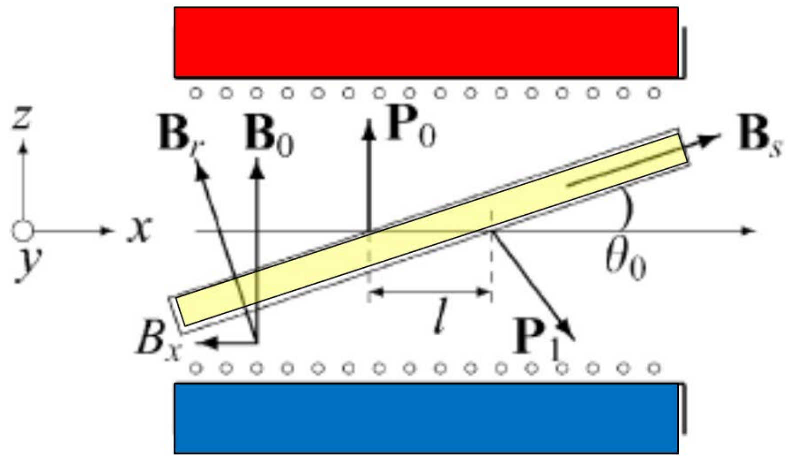


Foil flipper



Correction rotation axis





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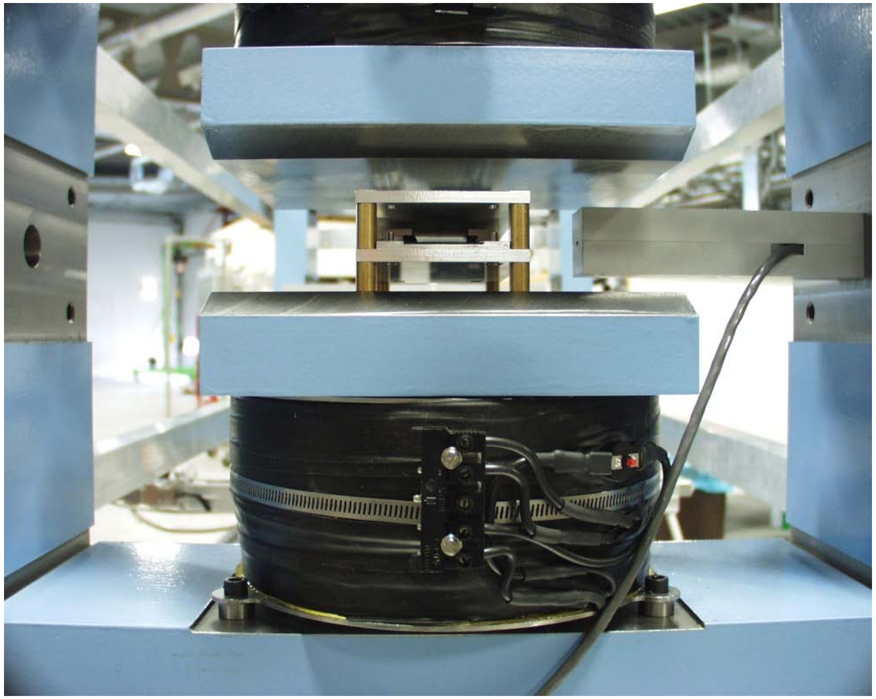
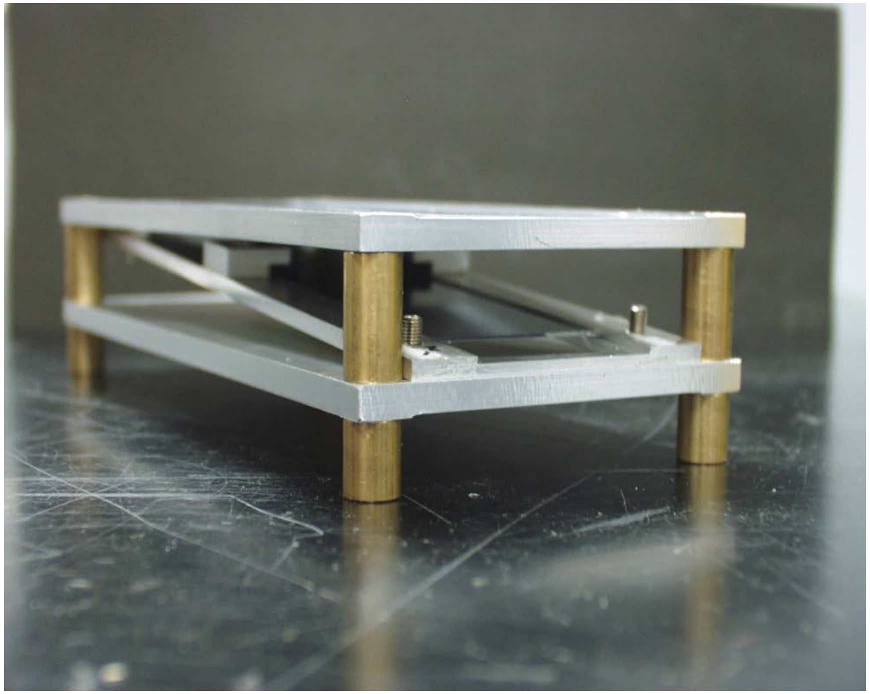
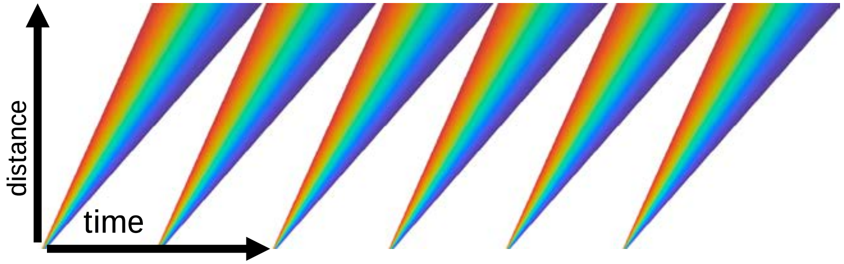
Used for SESANS

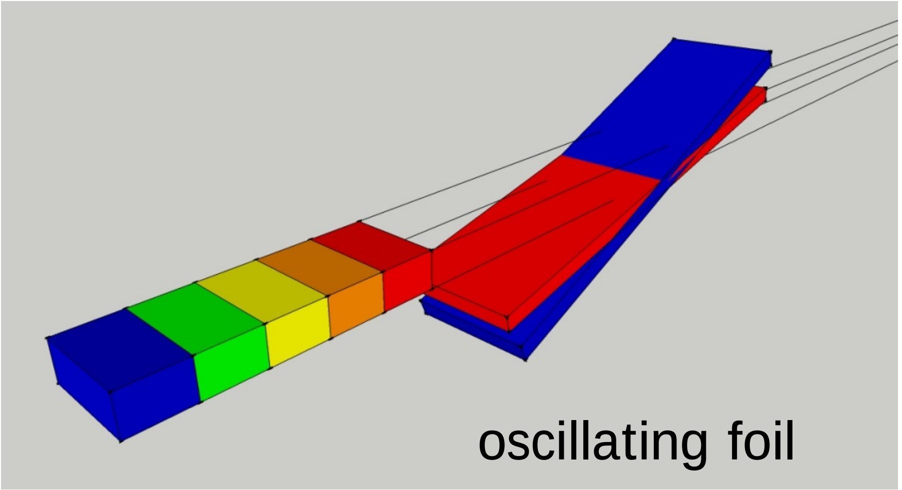


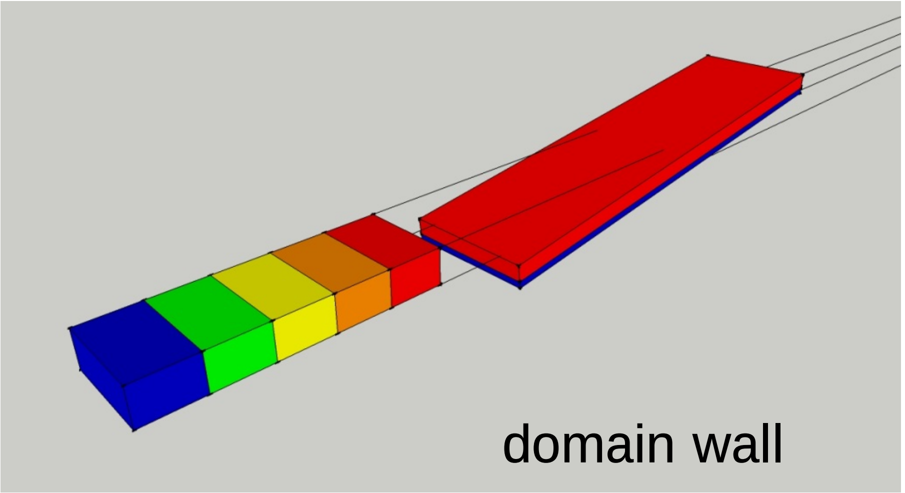


Used for SESANS

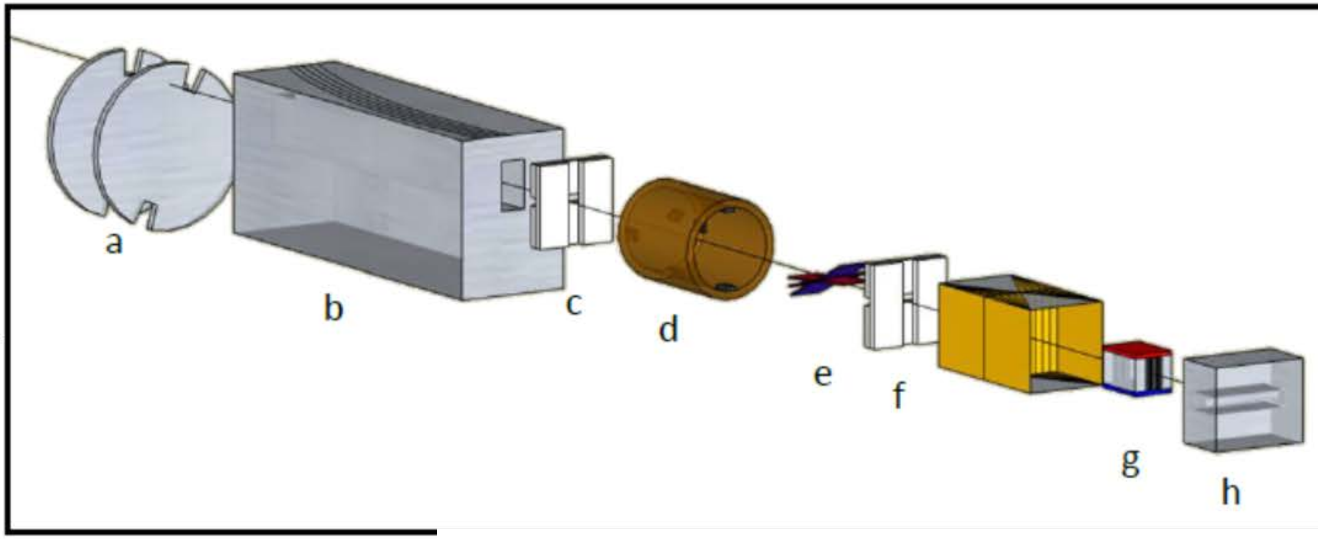
Polychromatic foil flipper

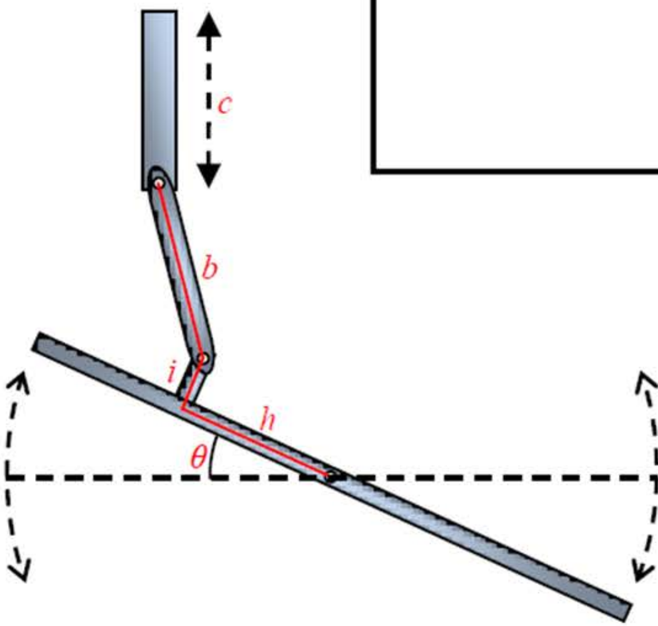


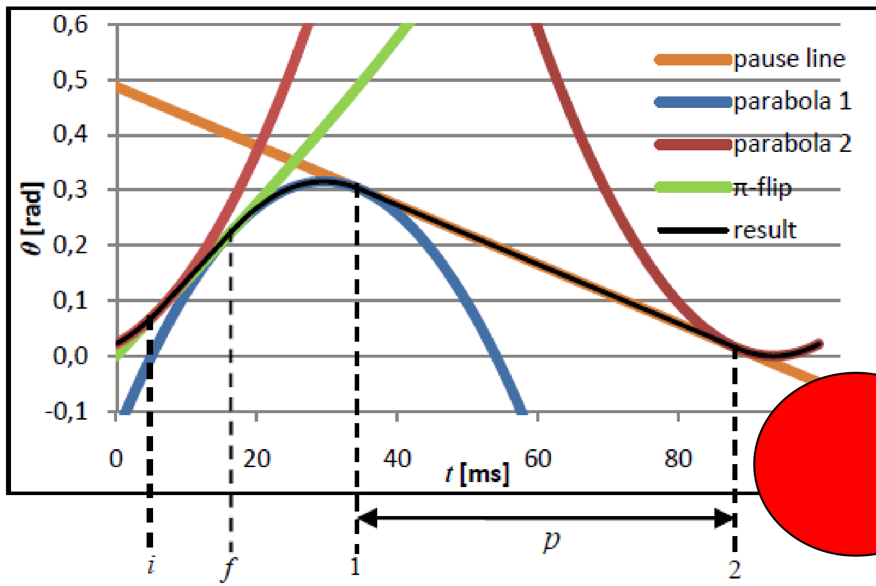




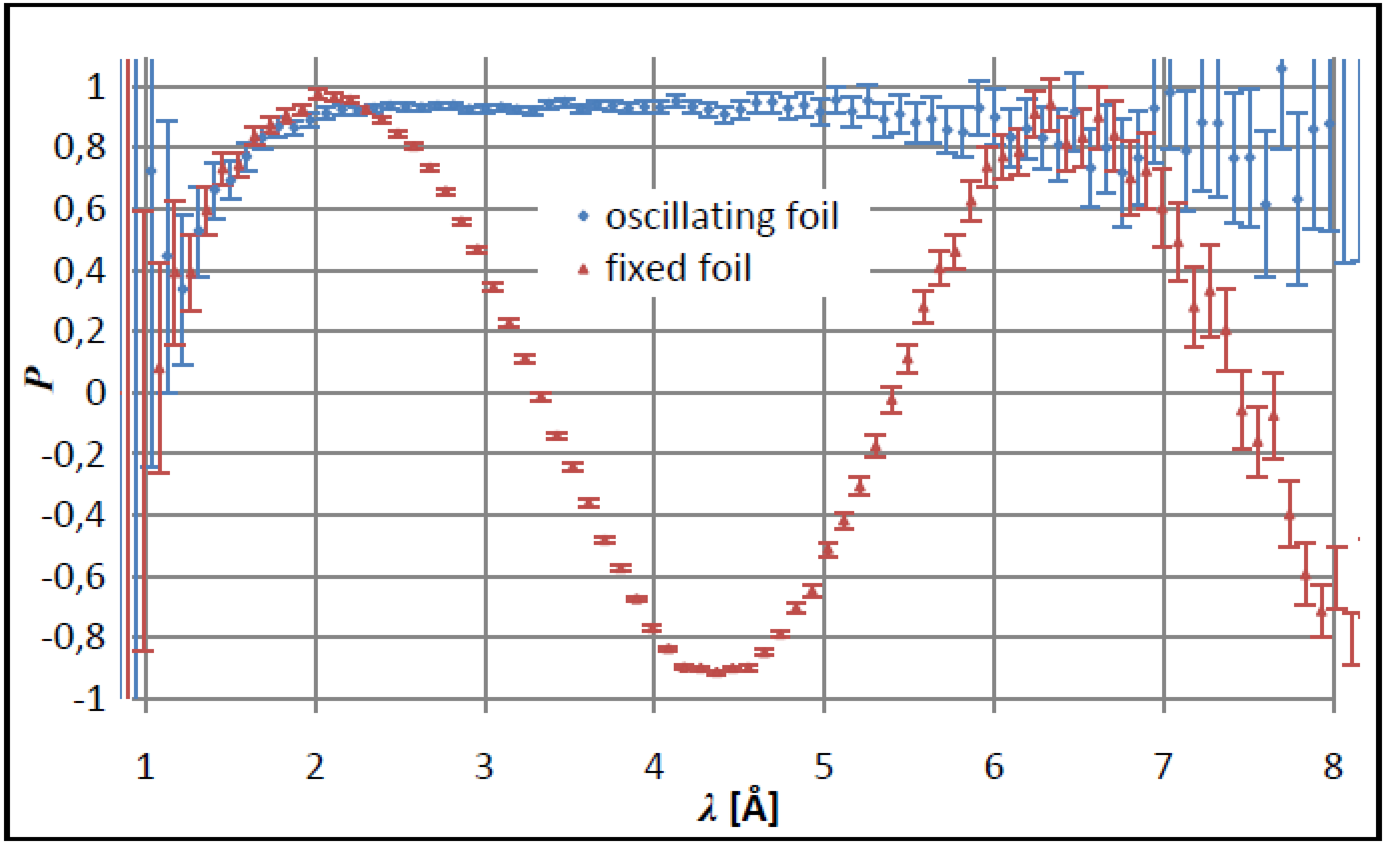
Oscillating foil





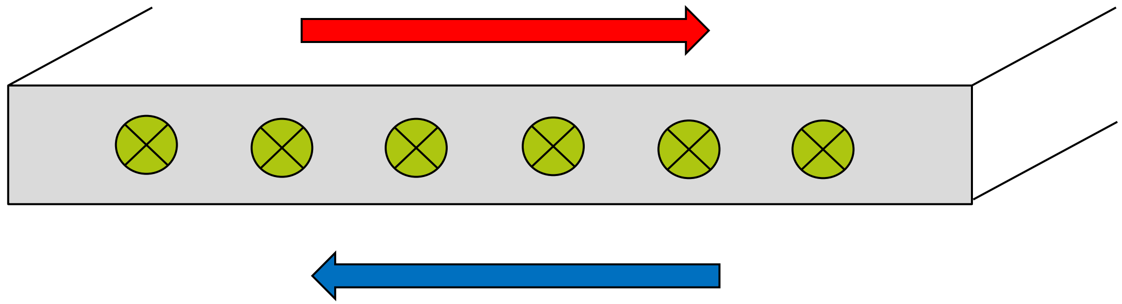


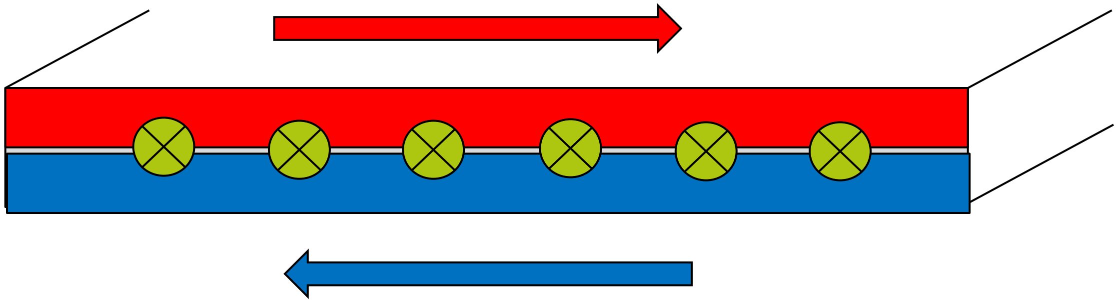
It works!



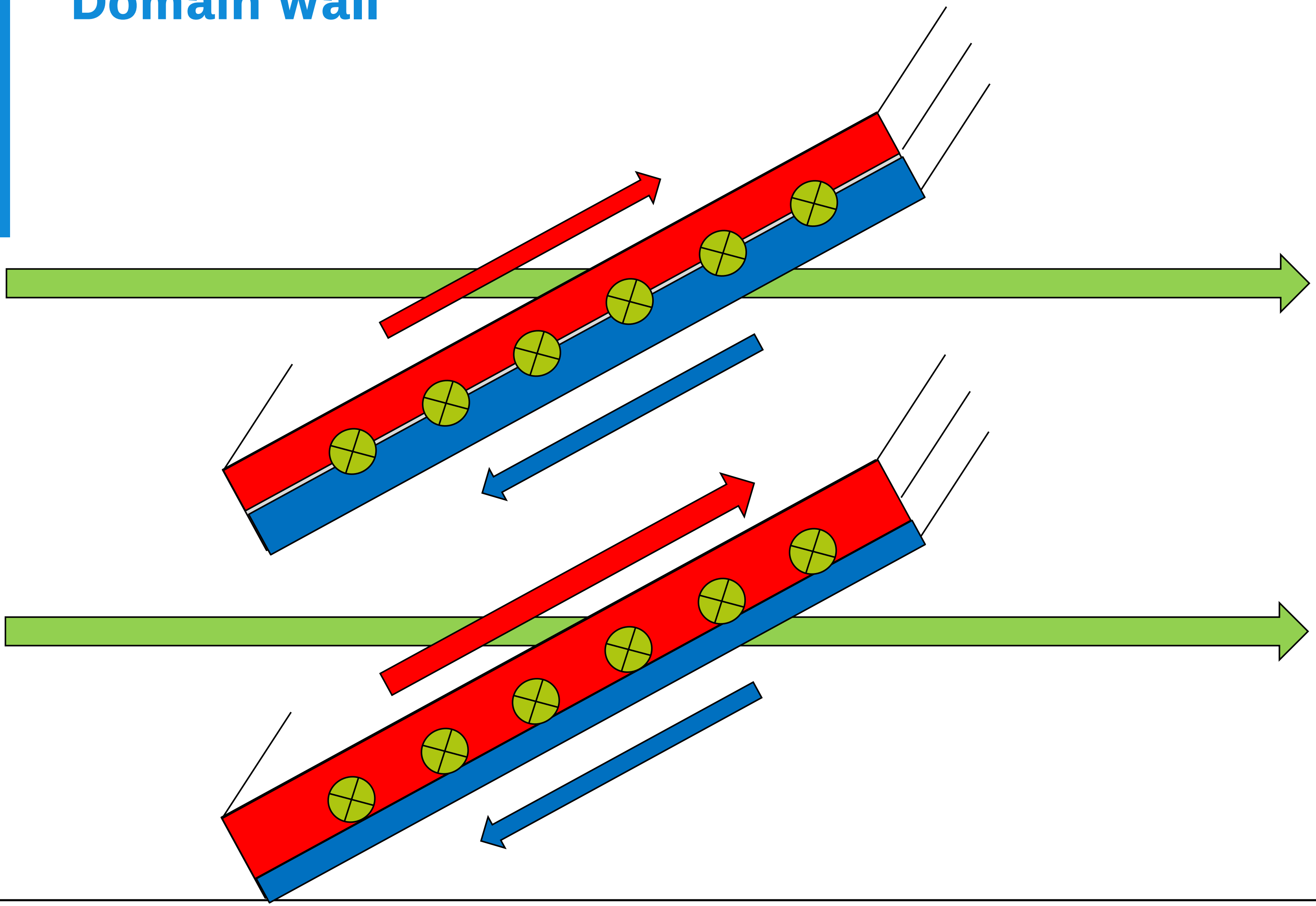
1
0,8
0,6
0,4
0,2
0
-0,2
-0,4
-0,6
-0,8
-1
P
oscillating foil
fixed foil
1
2
3
4
5
6
7
8
λ [Å]

Domain wall

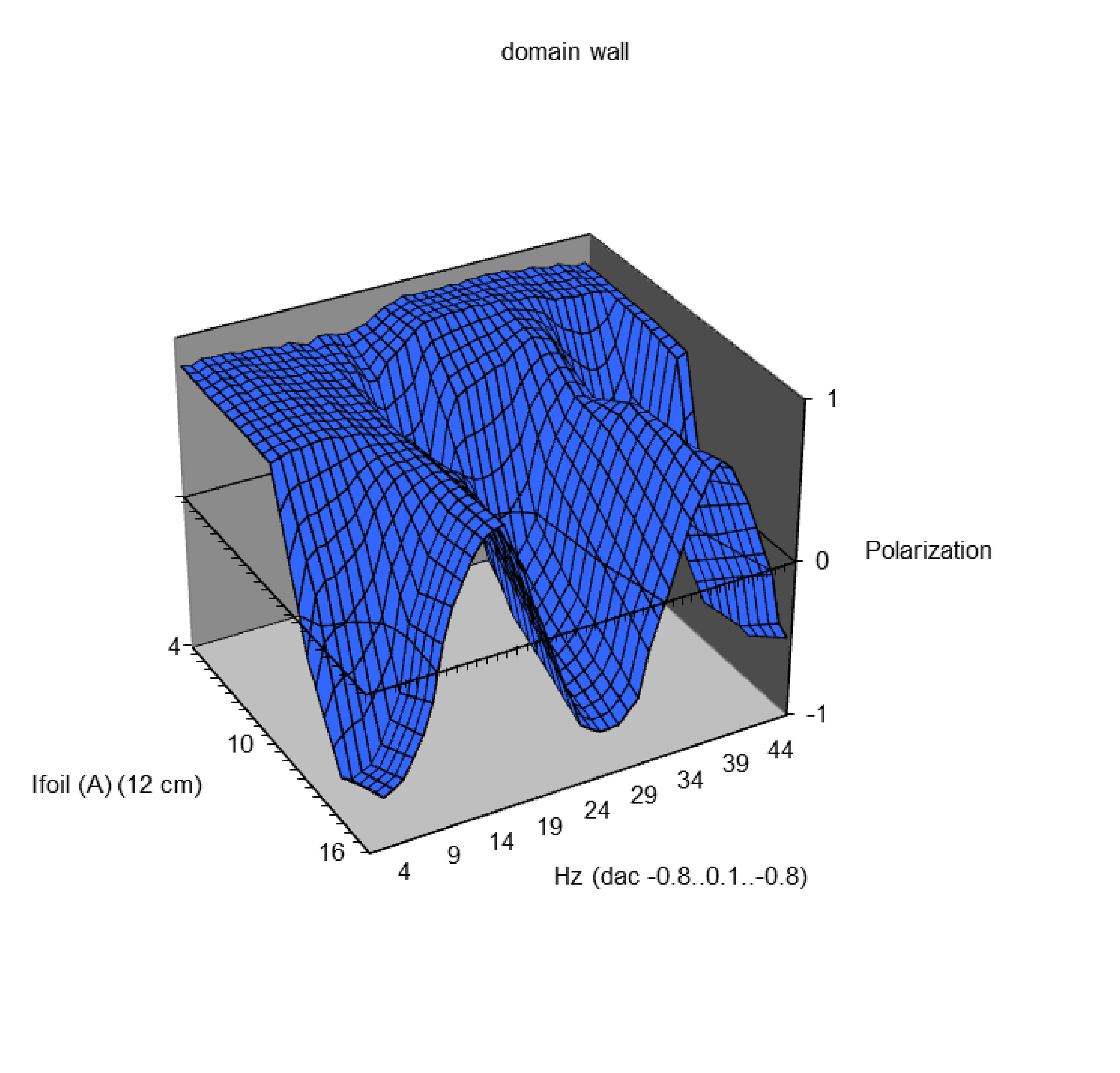


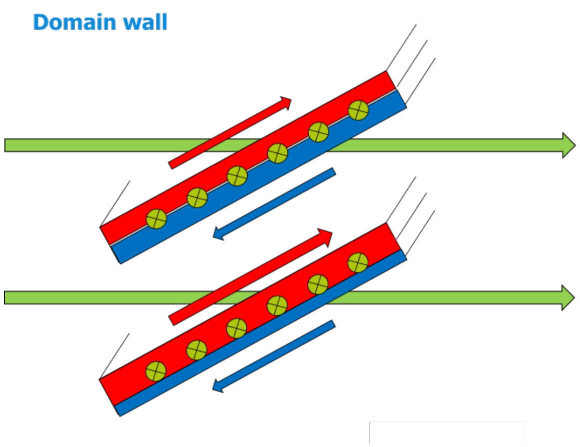


Domain wall



Domain wall


domain wall
1
0
-1
Polarization
4
10
16
Ifoil (A) (12 cm)
4
9
14
19
24
29
34
39
44
Hz (dac -0.8..0.1..-0.8)


Domain wall

Precession

Questions