Lec 13
(MRI: relaxation)

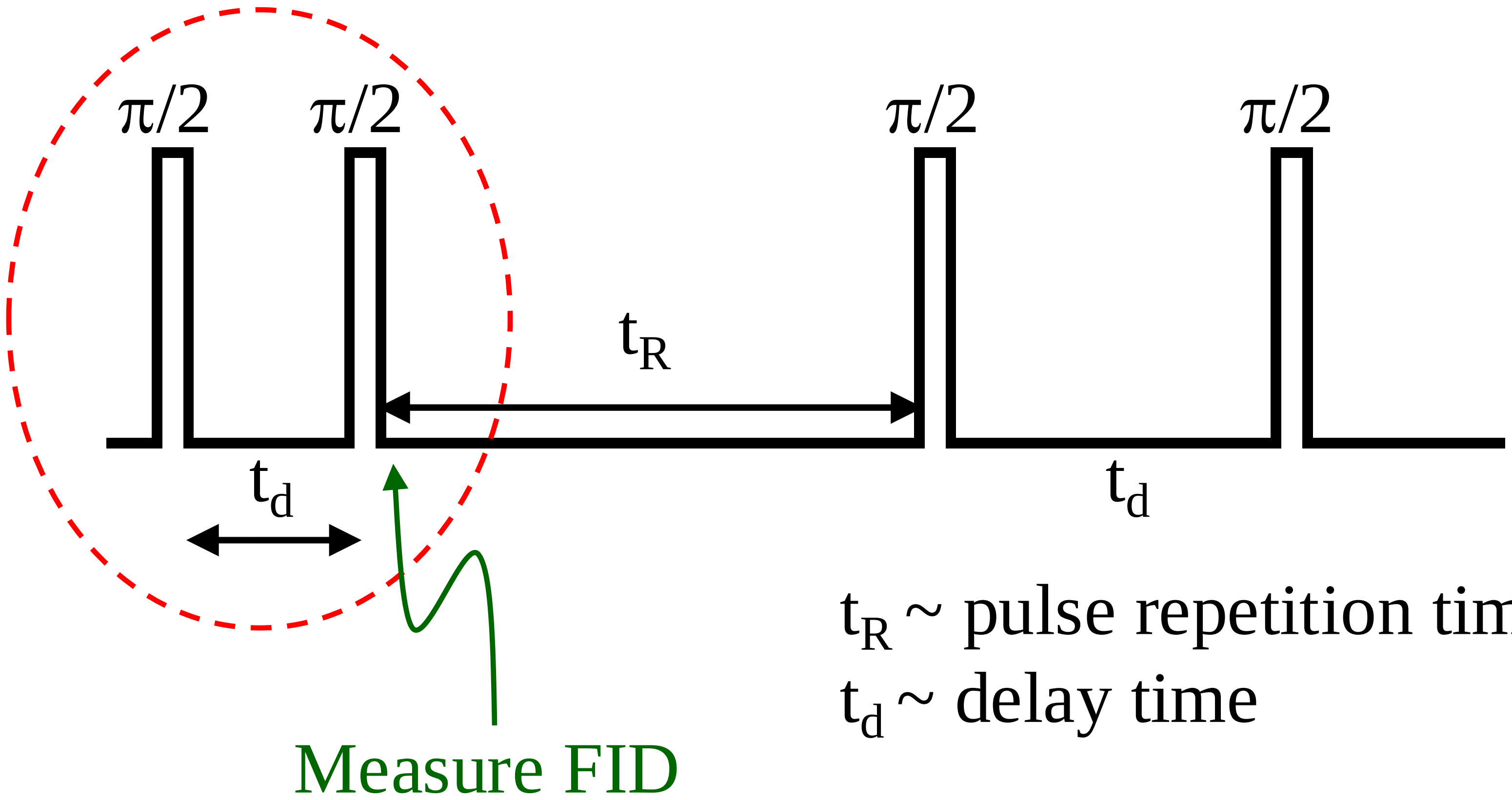
So we tweak the experiment a bit.

1. Apply one $\pi/2$ pulse.

2. Wait for time $\mathbf{t_d}$ for magnetization to relax partially without measuring anything. Will M_z be comparable to M_o after t_d?

3. The time $\mathbf{t_d}$ is set by you, and is, at first, a fraction of T_1. The relaxation of M_z over a period $\mathbf{t_d}$ is then incomplete.
4. The magnetization vector after $\mathbf{t_d}$ has a length that is much smaller than its equilibrium value M_o.

5. Now give a second $\pi/2$ pulse.
6. This forces M_z (**now with a value much smaller than M_o**) to get turned on to the x-y plane.
7. Allow this small M_z to relax completely. This time we will measure its relaxation.
8. Measure the FID signal during this relaxation step. This will give you the magnitude of M_z for the value of t_d you chose.
9. Repeat steps 1 – 8 by gradually increasing the value of t_d until it is at least ~ $5T_1$ - $10T_1$.

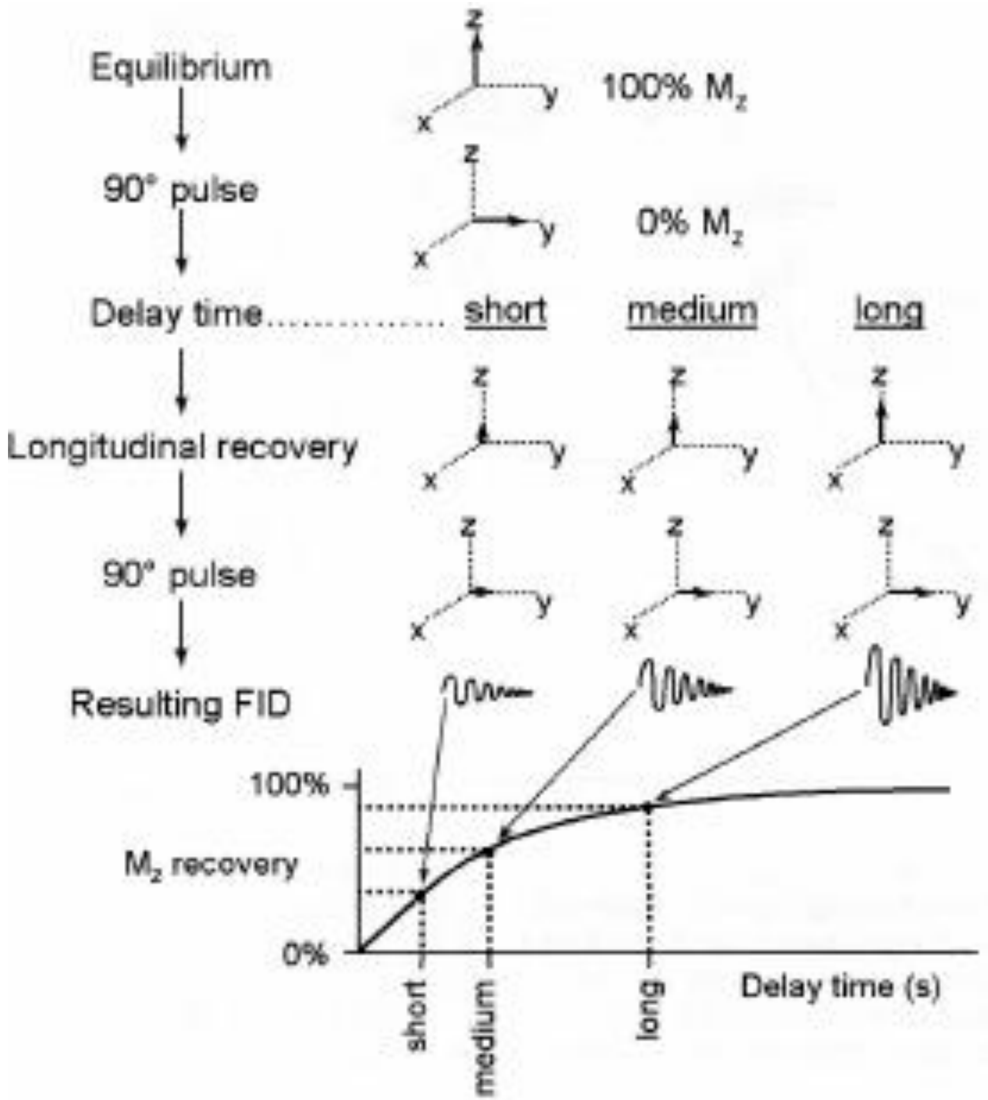


t_R ~ pulse repetition time

t_d ~ delay time

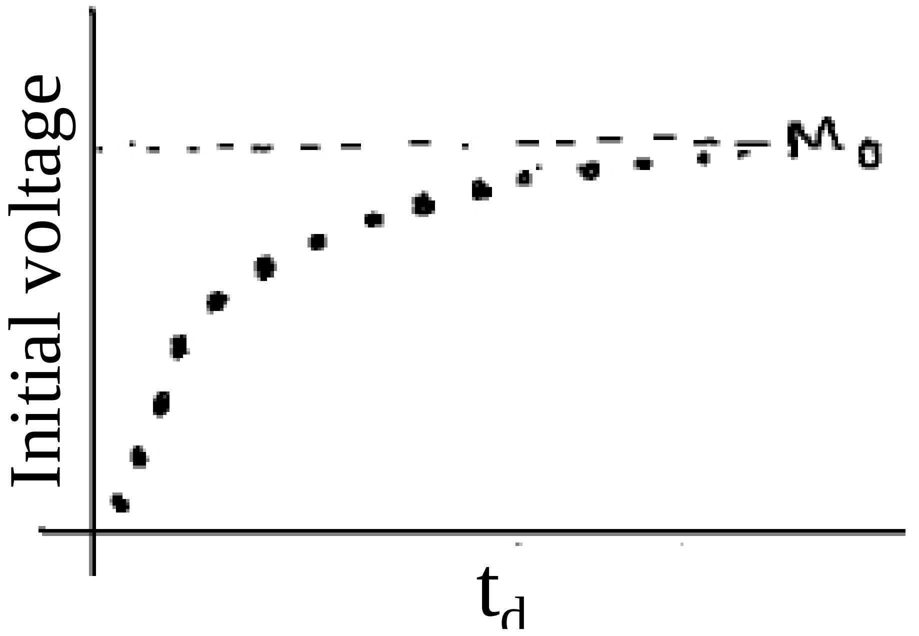
- Usually, $t_R \sim 5T_1$ => ensures full "<u>saturation</u>"
- Vary t_d (from a fraction of T_1 to a few times T_1).

Saturation recovery: $\pi/2 - t_d - \pi/2$ pulse



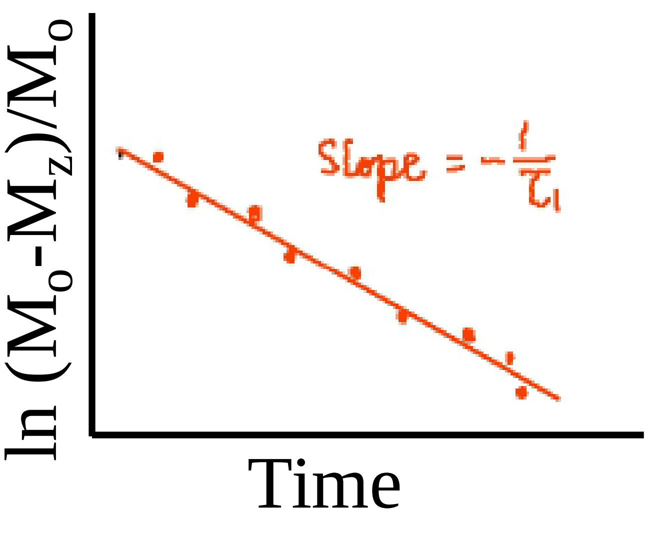
$$\boxed{M_z(t) = M_0(1 - e^{-t/\tau_1})}$$

At $t = \infty$, $M_z = M_o$

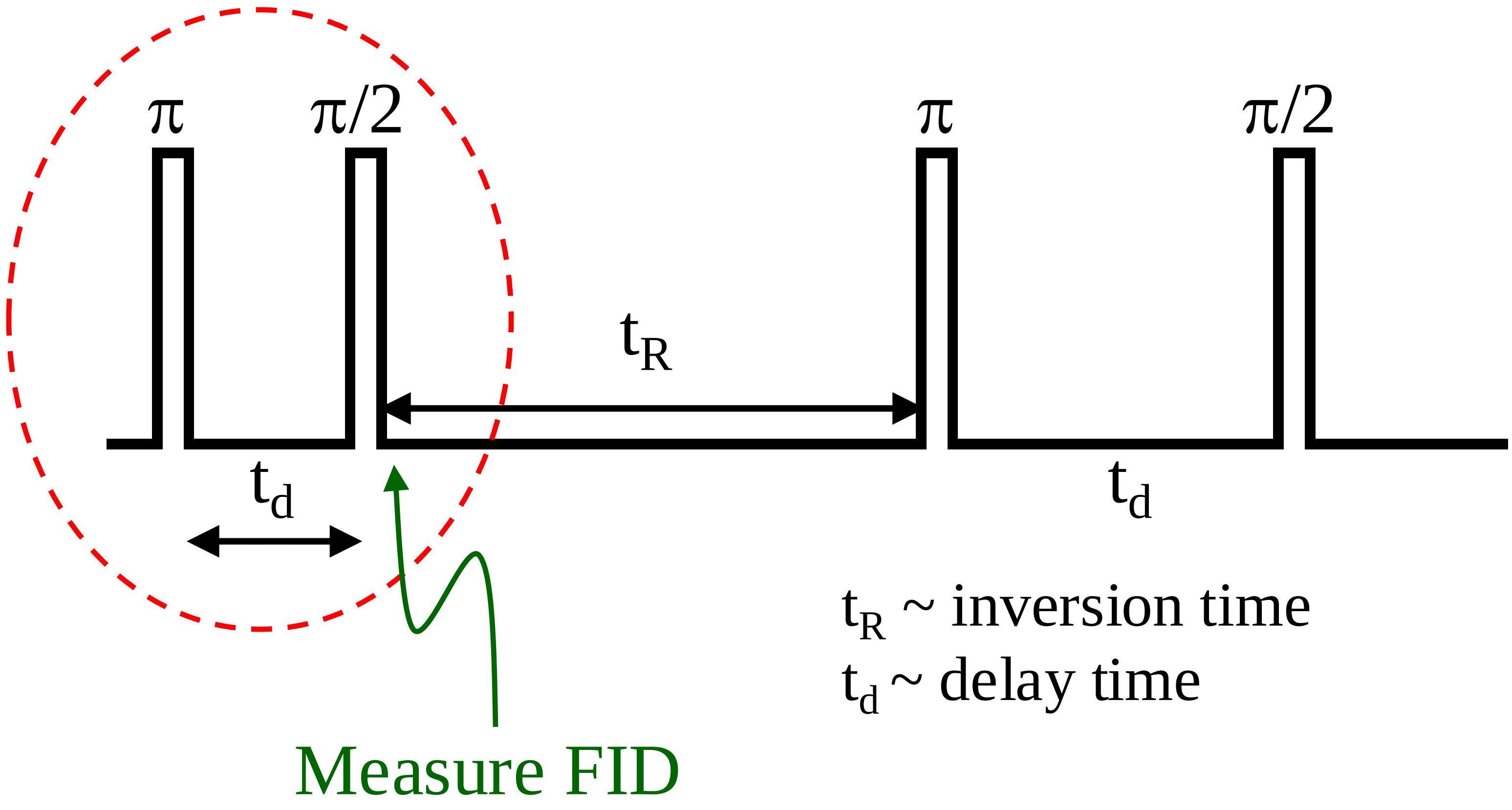


$$M_z(t) = M_0(1 - e^{-t/\tau_1})$$

$$\ln \frac{(Mo - Mz)}{M_o} = -\frac{t}{T_1}$$



2. Inversion recovery

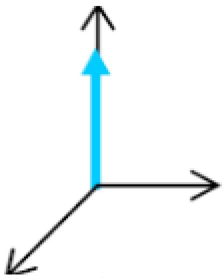


t_R ~ inversion time
t_d ~ delay time

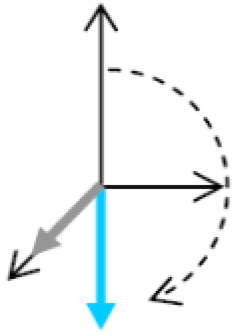
- Usually, $t_R \sim 5T_1$ => ensures full "saturation"
- Vary t_d (from a fraction of T_1 to a few times T_1).

Inversion recovery: $\pi - t_d - \pi/2$ pulse

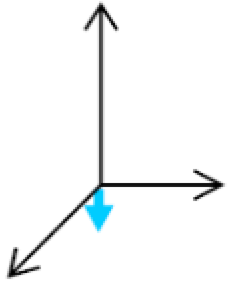
1. Thermal equilibrium



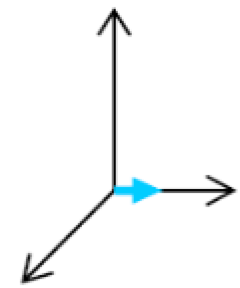
2. π–pulse "flips" magnetization



3. Wait for time t_d for relaxation.

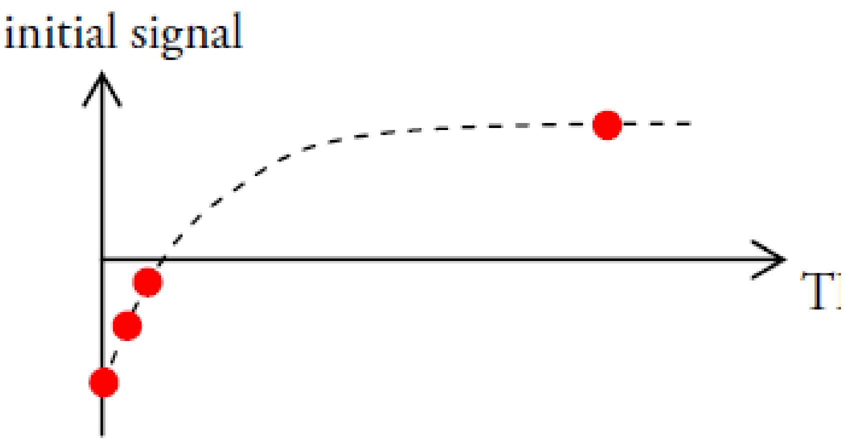


4. Excite spin onto X-Y plane
and measure (voltage maximum).



5. Repeat with a larger t_d.

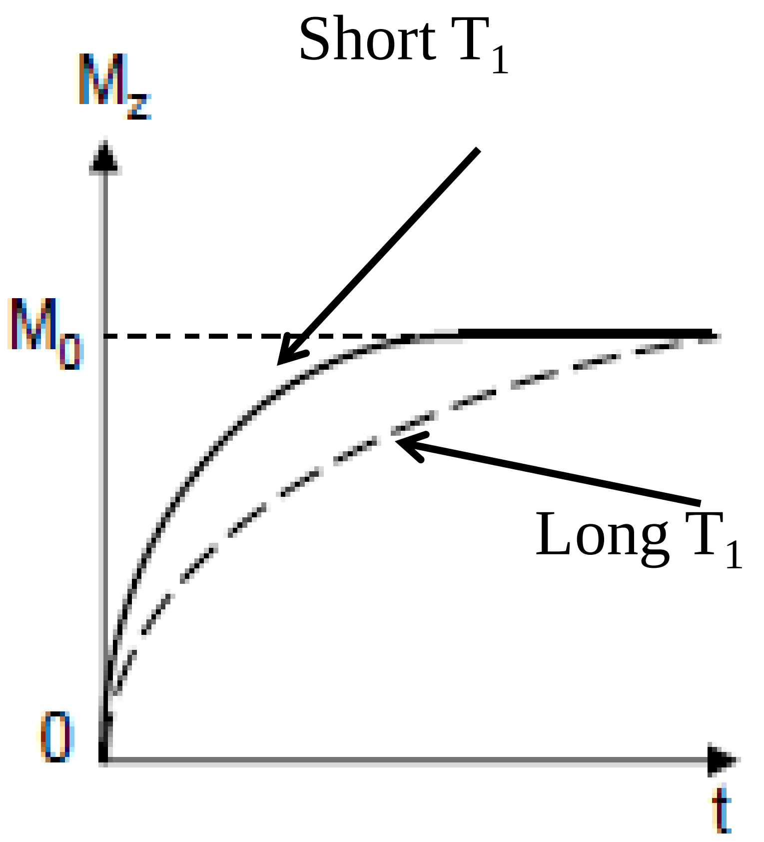
6. Plot the "initial amplitude" of each FID.



At $t = 0$, $M_z = - M_o$

$$\mathbf{M_z = M_o\, (1 - 2\, e^{\frac{-t}{T_1}})}$$

Do both sequences and compare the value of T_1



Short T_1
M_z
M_0
Long T_1
0
t

- By what mechanisms do the spins “relax”?

- Also, why are there two different relaxation time constants?

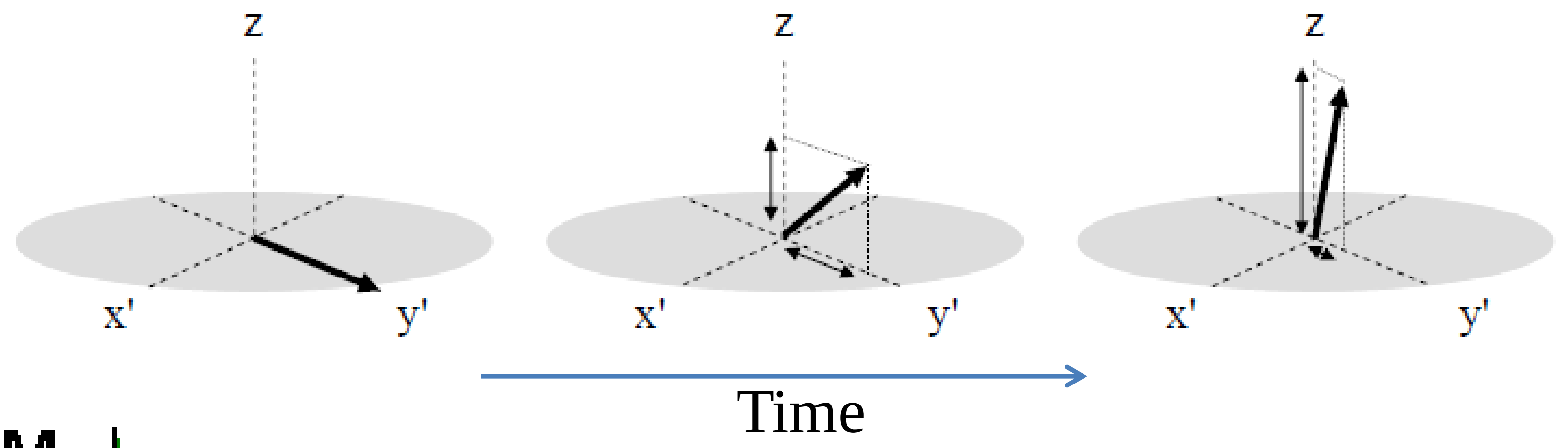
Spin-lattice interaction (T_1)

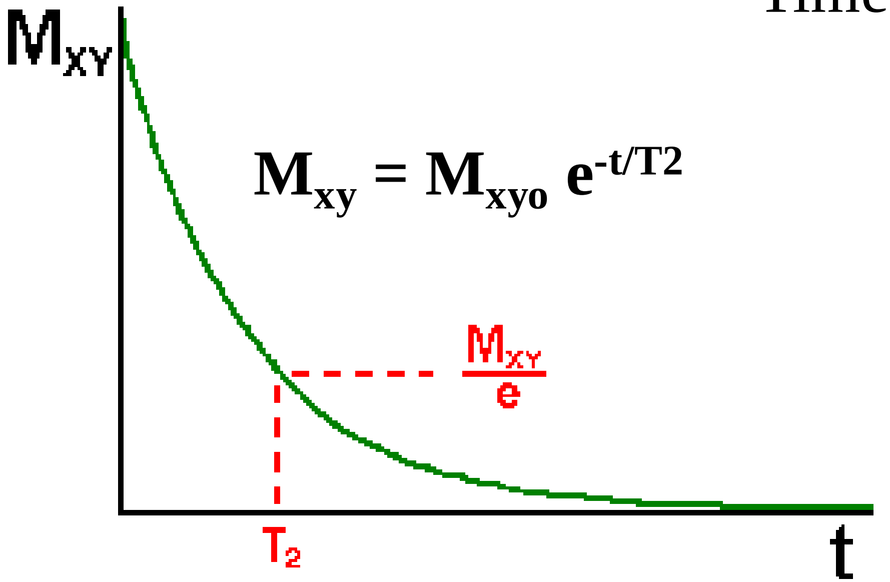
Energy of the spins in a magnetic field ~ $-\ \mathbf{M} \bullet \mathbf{B}$

Spins can return to the lower energy configuration by giving away the energy to the lattice.

T_2: spin-spin interaction

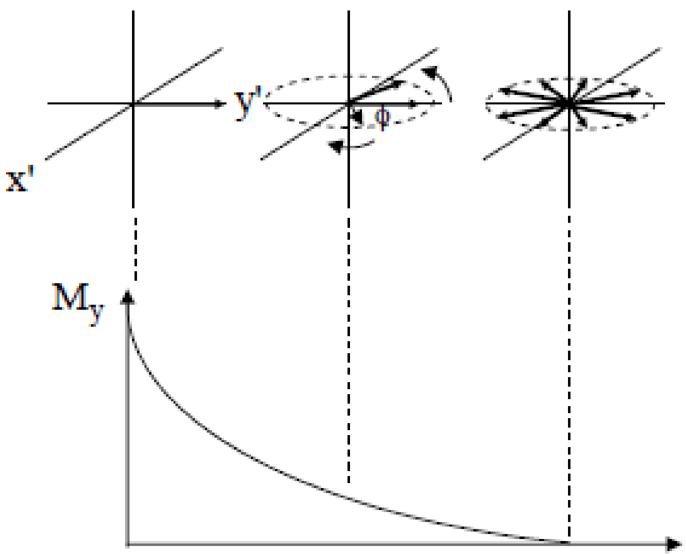
T_2-relaxation: transverse





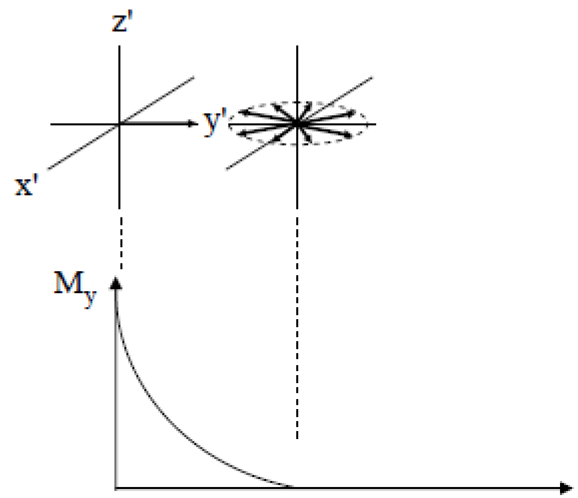
$$M_{xy} = M_{xyo}\, e^{-t/T2}$$

Return to equilibrium of the transverse component of magnetization.



Long T_2

(b)



Short T_2

Measuring T_2 from FID is difficult

- FID decays with T_2^* time constant.

$$\frac{1}{T_2^*} = \frac{1}{T_2^+} + \frac{1}{T_2}$$

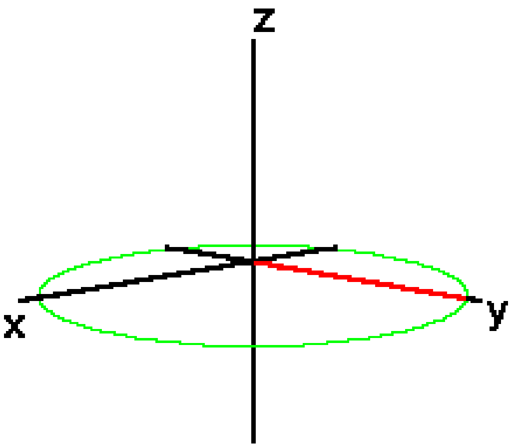
Inhomogeneous mag. field
(property of MR set-up)

spin-spin interaction

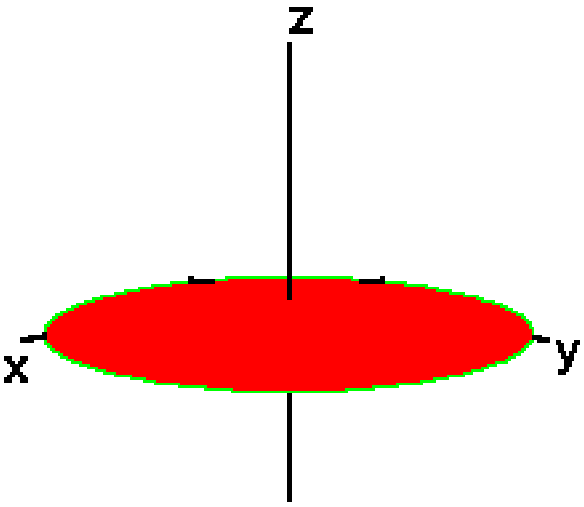
Dephasing of magnetization ("pure" T_2 effect)

- Each spin sees a slightly different magnetic field.
- Magnetization for each spin packet rotates at its own Larmor frequency.
- Net magnetization starts to dephase.
- Vector sum of transverse component is zero when totally dephased.

Dephasing of spins



No dephasing



Dephasing