

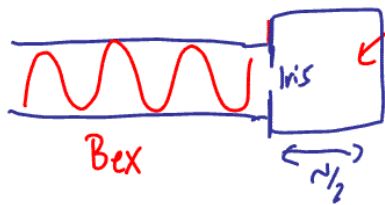
### 3. Kurseinführung

#### Puls-EPR

- ① Erzeugung von MW-Magnetfeld
- ② Was tun die mit den Spins?
- ③ Relaxationszeiten
- ④ Einfache Experimente zur Bestimmung von Relaxationszeiten

#### ① Erzeugung von MW (B-Feld)

S-Band 3 GHz  
X-Band 9 GHz



$$B_{res} = \sqrt{Q} \cdot B_{ex}$$

$Q = \text{Gütefaktor}$

$$P_{mw} \sim B_{mw}^2$$

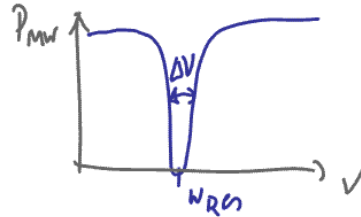
$$P_{res} = Q \cdot P_{ex}$$

$$B_{res} = B_1 = \underbrace{C}_{\text{Konversionsfaktor}} \cdot \sqrt{Q} \cdot \sqrt{P_{mw}}$$

Konversionsfaktor

typische Werte:  $B_1 = 106 = 1 \text{ mT}$   $Q = 100$   $P_{mw} = 1 \text{ kW}$

$Q$  kann für Pulsexp. nicht beliebig groß gewählt werden

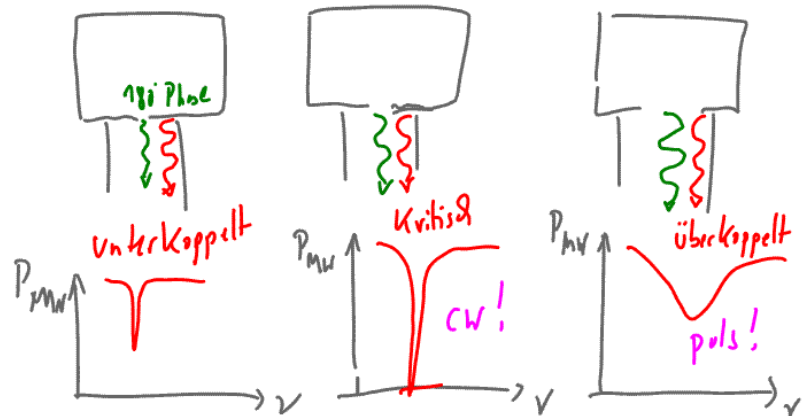
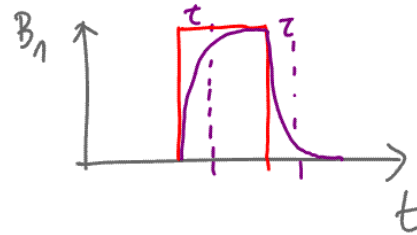


$$\frac{\nu}{\Delta \nu} = Q$$

Zeitkonstante  $\tau = \frac{1}{\Delta \omega} = \frac{Q}{\omega}$

$\omega \approx 10^{11}$   
 $Q \approx 100$

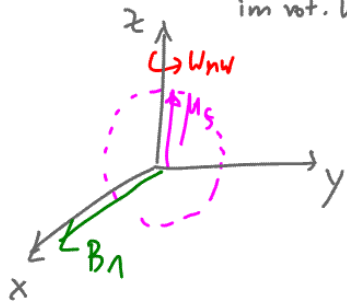
$\tau = 1 \text{ ns}$



② Wie reagiert magn. Moment  $\vec{\mu}_S$  auf  $B_{MW}$ ?

on-res:  $\omega_{MW} = \omega_L (= \gamma_S \cdot B_0)$

im rot. KS:  $\omega_{MW}$  um z-Achse



Notation um  $B_1$ -Feld mit der Rabi-Frequenz

$$\omega_R = \gamma_S \cdot B_1$$

$$\gamma_S = 2.8 \text{ MHz/G}$$



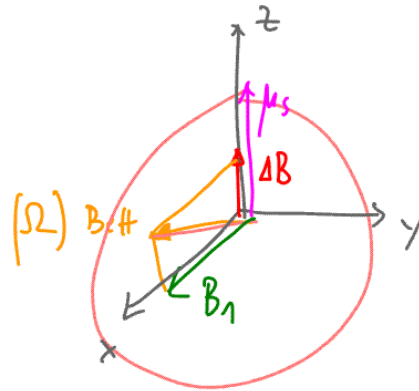
im LAS

$\pi/2$ -Puls:  $\omega_R \cdot t_p = \pi/2$

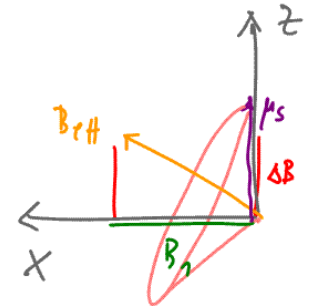
Beispiel:  $B_1 = 10 \text{ G} \rightarrow t_p(\pi/2) = 9 \text{ ns}$

$\pi$ -Puls:  $\omega_R \cdot t_p = \pi$

off-resonanz:  $\omega_{MW} \neq \omega_L$   $\omega_{MW} - \omega_L = \Delta\omega$



$$\Delta B = \frac{1}{\gamma_S} \Delta\omega$$

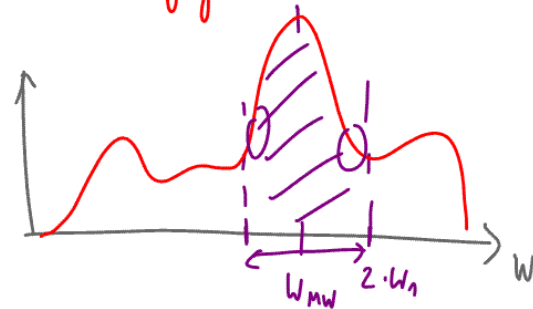


$$\omega_R = \gamma_S \cdot B_{eff}$$

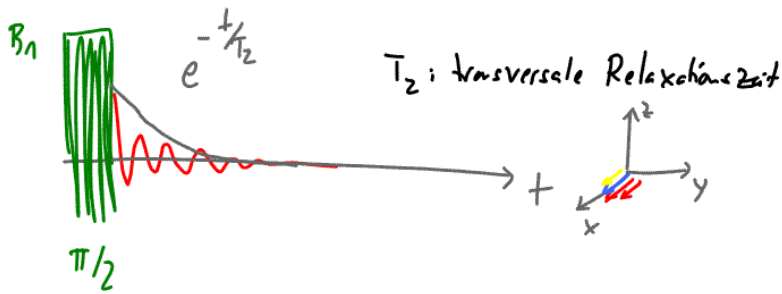
$$= \sqrt{\Delta\omega^2 + \omega_R^2}$$

$$= \gamma_S \cdot \sqrt{\Delta B^2 + B_1^2}$$

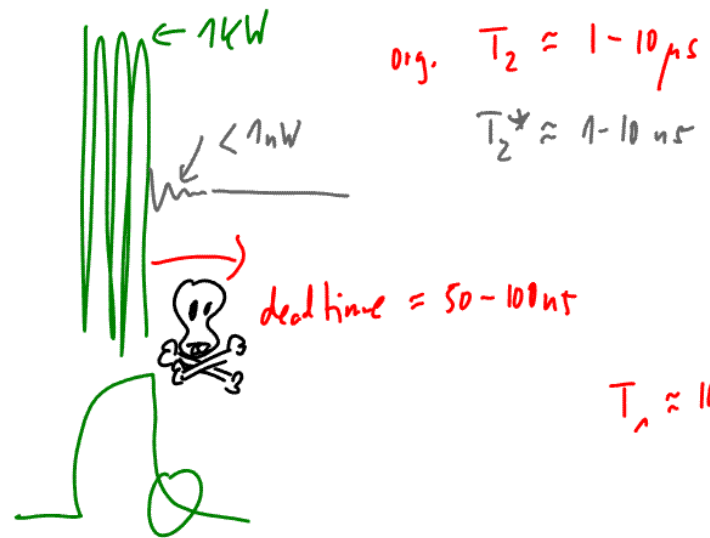
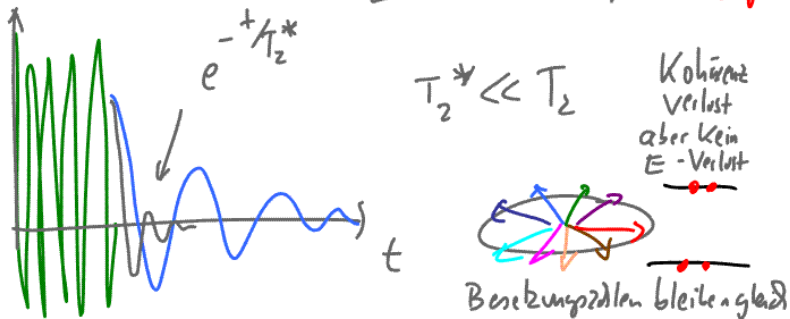
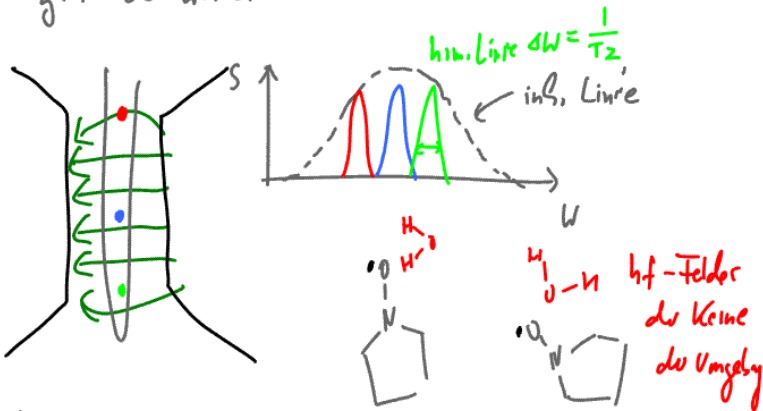
effektive Anregung:  $\Delta\omega \leq \omega_1$



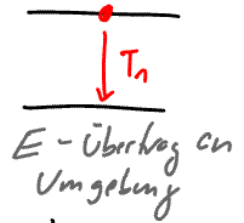
### ③ Relaxationsprozesse in Solid-EPR



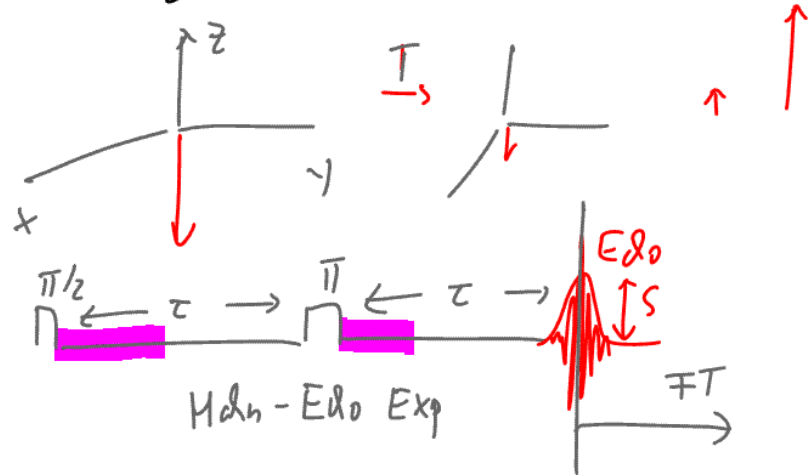
Wenn  $B_0$  nicht für alle Moleküle gleich ist  
gilt es weitere Relaxationseffekte

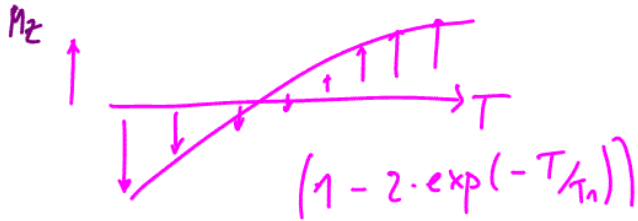
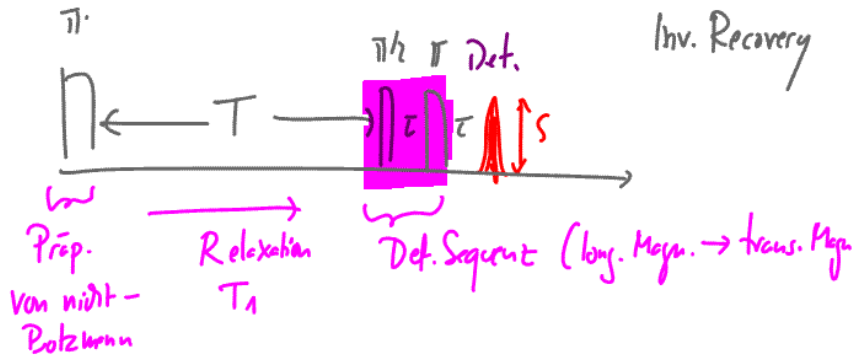
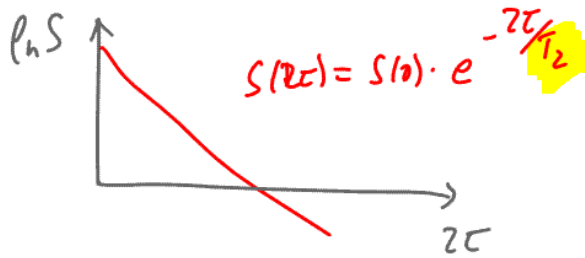


longitudinale Relaxationszeit  $T_1$



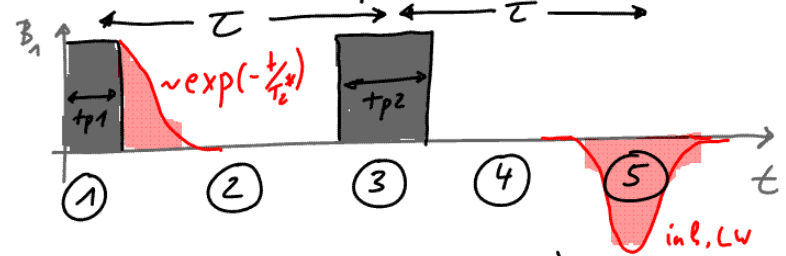
$$T_2^* \approx \frac{1}{100} T_2 \quad T_2 \approx \frac{1}{100} T_1$$



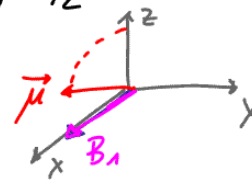


Inv. Recovery

## Das Hahn-Edo Experiment

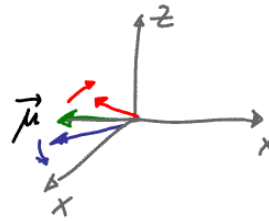


①  $\pi/2$ -Puls : ( $\omega_R \cdot t_{p1} = \pi/2$ )

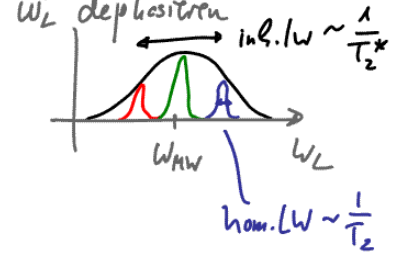


Klappt Magnetisierung in Transversalebene

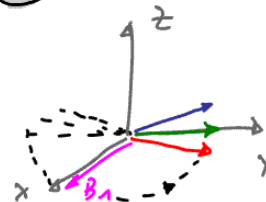
② Zeit  $\tau$  :



Magnetisierung mit unterschiedl.  $\omega_L$  dephasieren

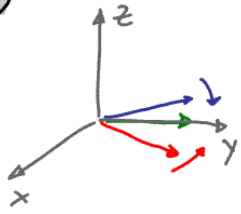


③  $\pi$ -Puls : ( $\omega_R \cdot t_{p2} = \pi$ )



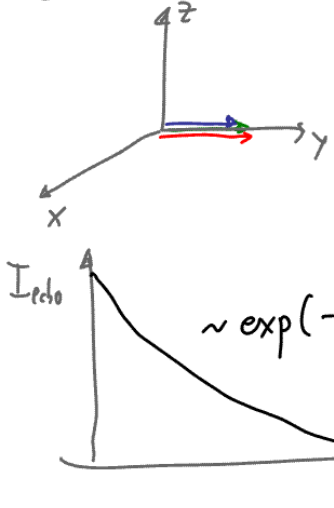
Invertiert Magnetisierung

④ Zeit  $\tau$  :



Magnetisierung mit unterschiedl. Larmorfrequenz  $\omega_L$  refokussieren

⑤ Echo



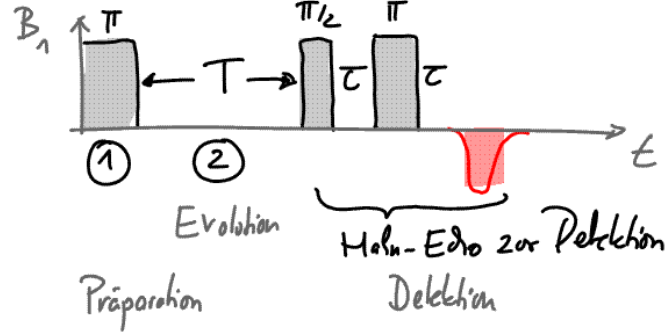
Alle Magnetisierung  $\parallel y$  im rot. KS m-x-Signal

$\sim \exp(-\frac{z\tau}{T_2})$  hom. LW

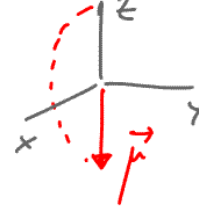
Durch das Hahn-Echo werden alle statischen Inhomogenitäten refokussiert.

Bedingungen:  $t_{p1}, t_{p2} < T_2, T_1$   
 $B_1 > \text{inh. LW} (t_{p1}, t_{p2} < T_2^*)$

## Das Inversion-Recovery Experiment



① Inversion von  $\vec{\mu}$  ( $\omega_R \cdot t_p = \pi$ )



② Relaxation von  $-\mu_z \rightarrow +\mu_z$   
 $\mu_z(t) = \mu_{z0} (1 - 2 \cdot e^{-\frac{t}{T_1}})$

