# Nuclear decoupling techniques at the nanoscale

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NQUIRE

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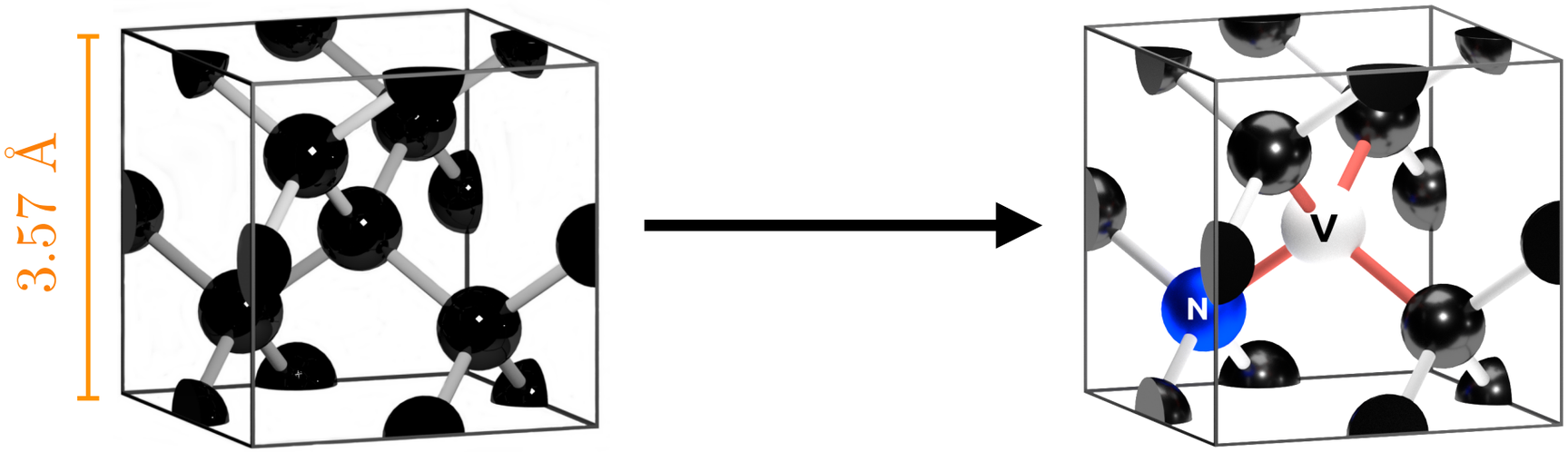
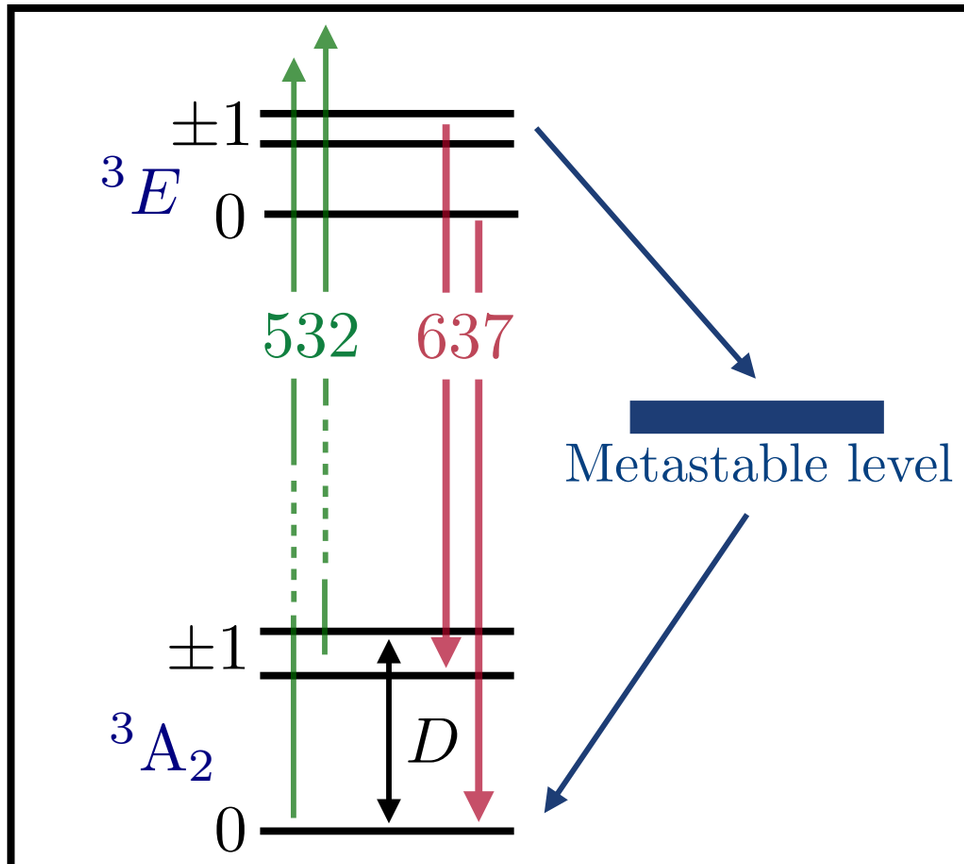
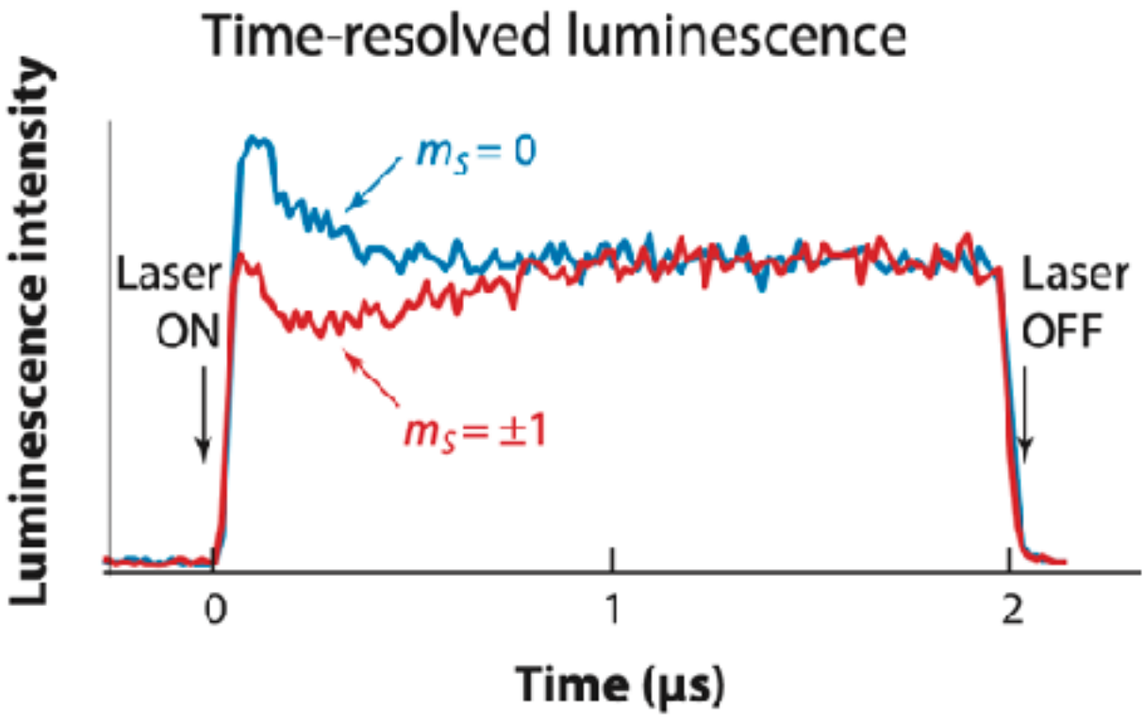
# The Nitrogen-Vacancy Center



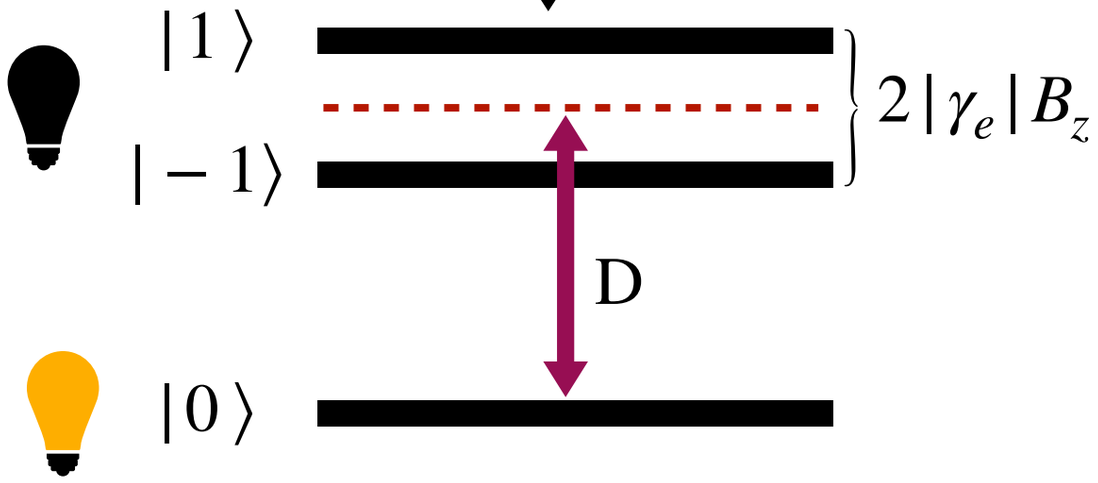

- Diamond point defects.
- Interacts with light.
- Robust quantum properties.

# Properties



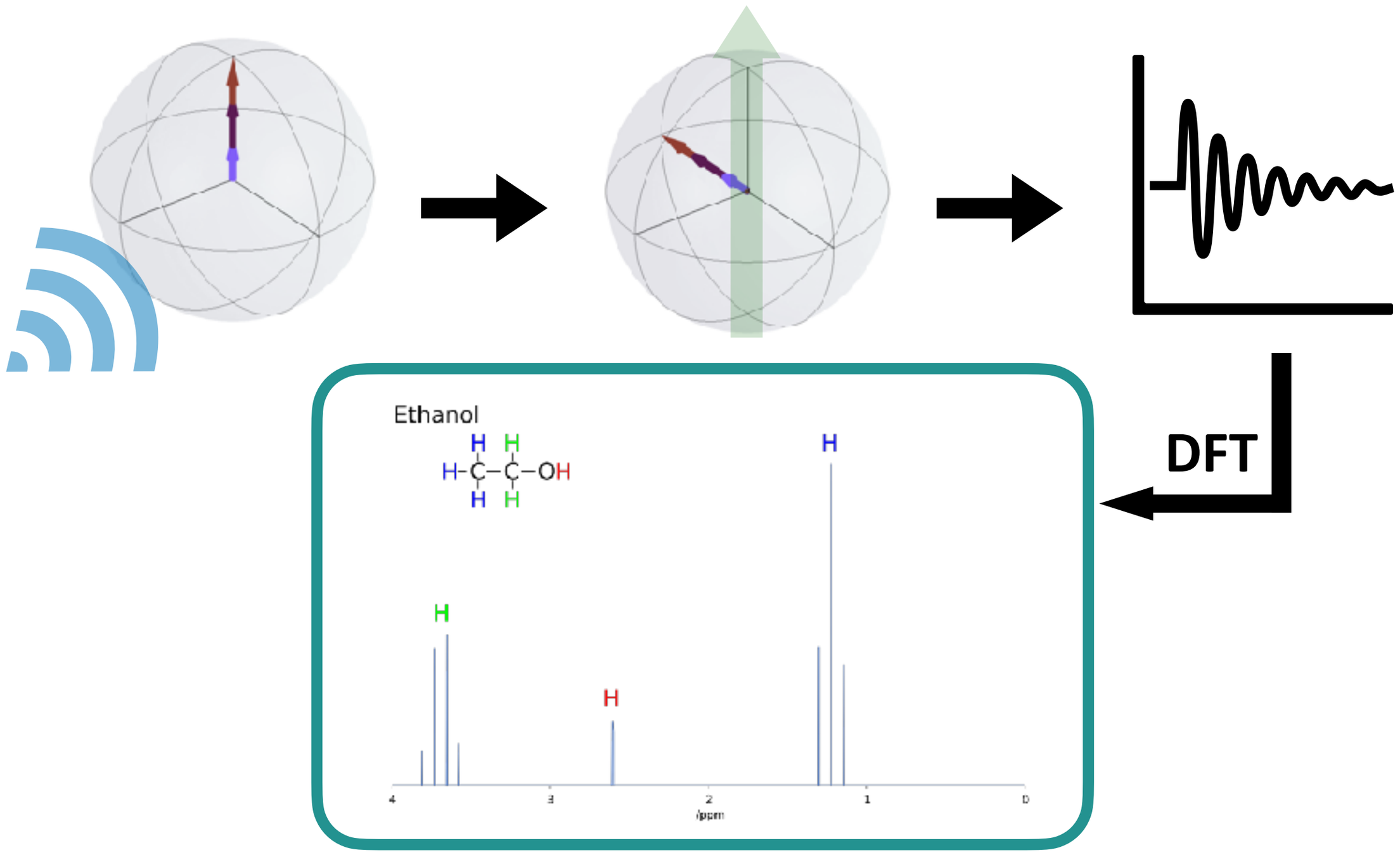

Annu. Rev. Phys. Chem. **65**, 83 (2014) from R. Schirhagl,.. C.L. Degen.




- Spin-1 system.
- Easy to read, initialize and control.
- Coherent at room temperature.

# Nuclear Magnetic Resonance with NVs

# NMR FID



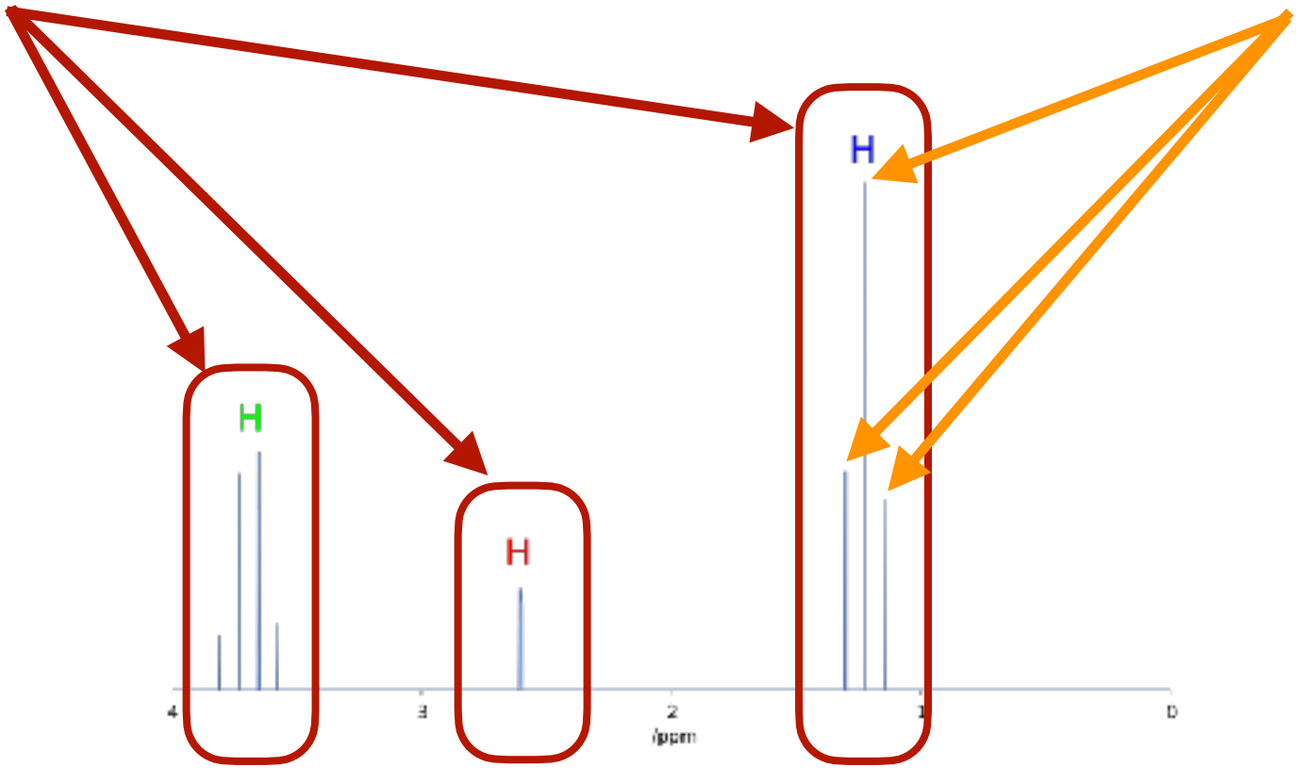
# NMR Hamiltonian

Averaged out by movement

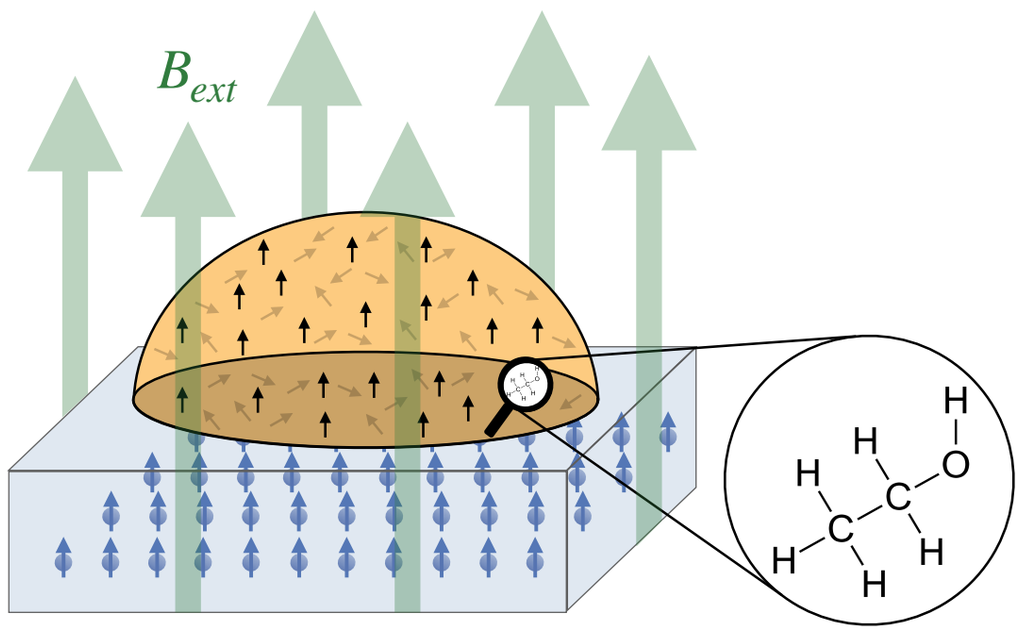
$$H = \underbrace{\sum_j \delta_j I_z^j} + \overbrace{\sum_{j>k} d_{jk}\left(3I_j^z I_k^z - \vec{I}_j \cdot \vec{I}_k\right)} + \underbrace{\sum_{j>k} J_{jk}\vec{I}_j \cdot \vec{I}_k}$$

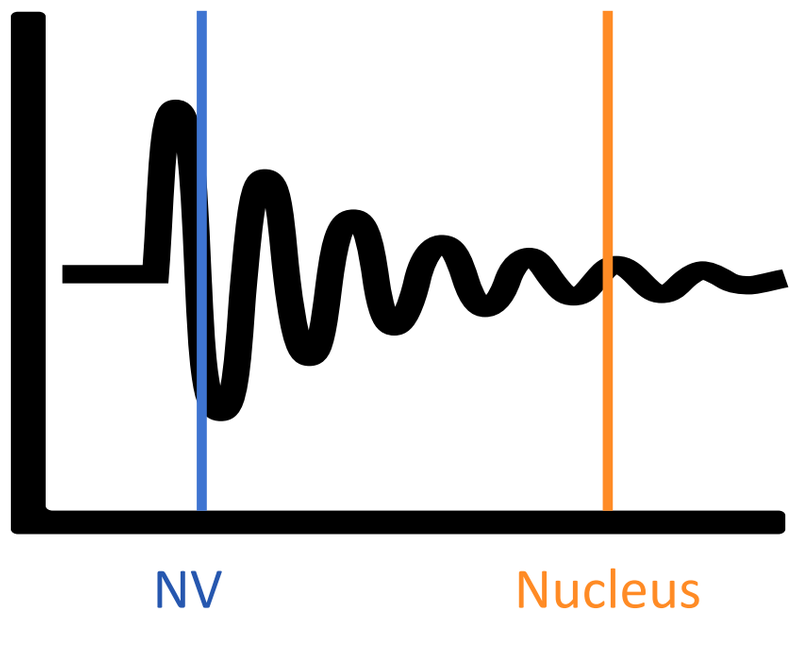
Moves peaks

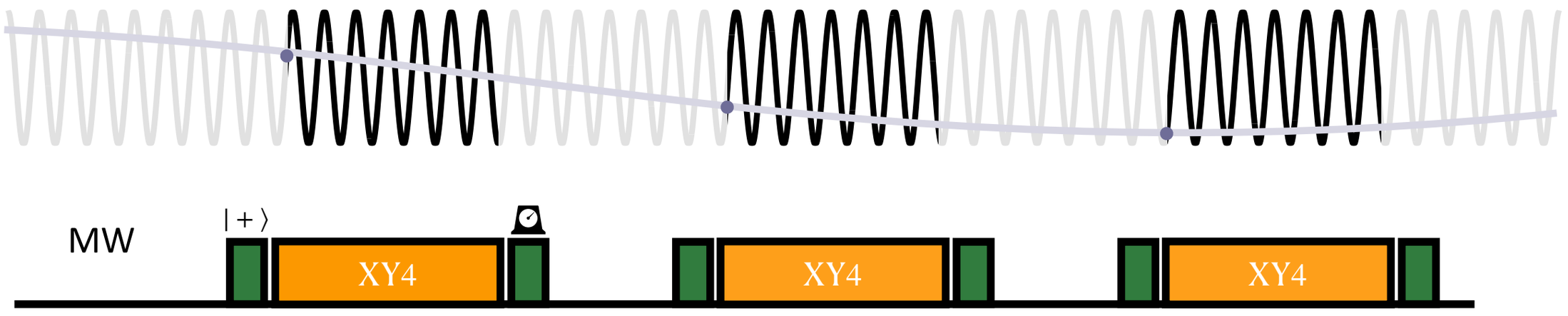
Splits peaks



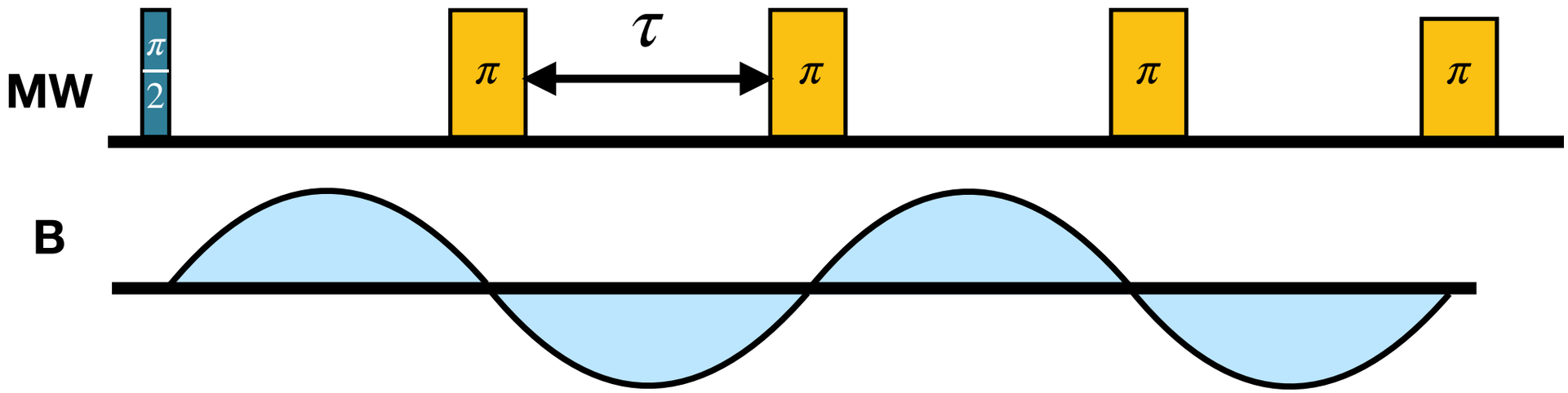
# Microscale NMR



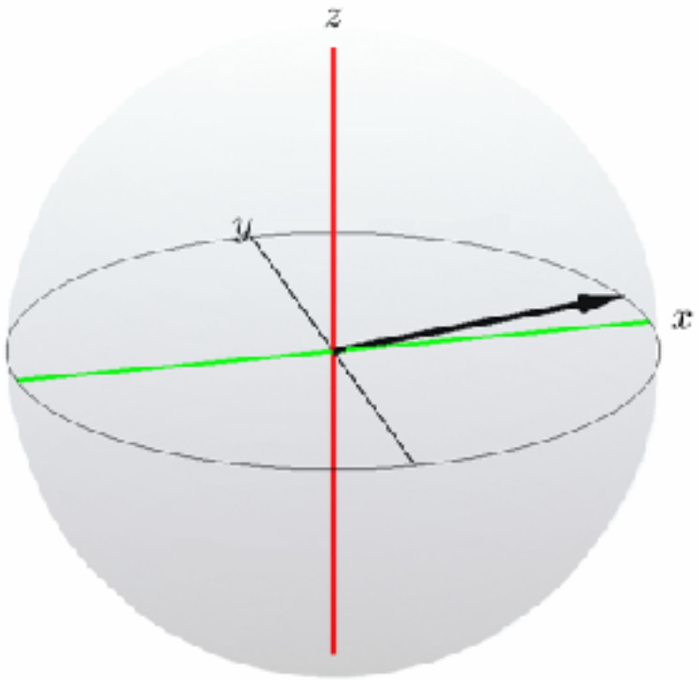
# High-Frequency Problem

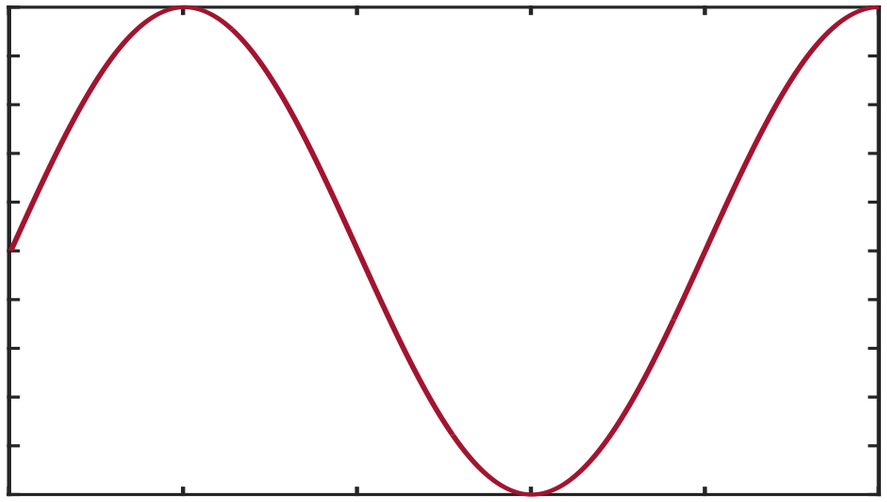


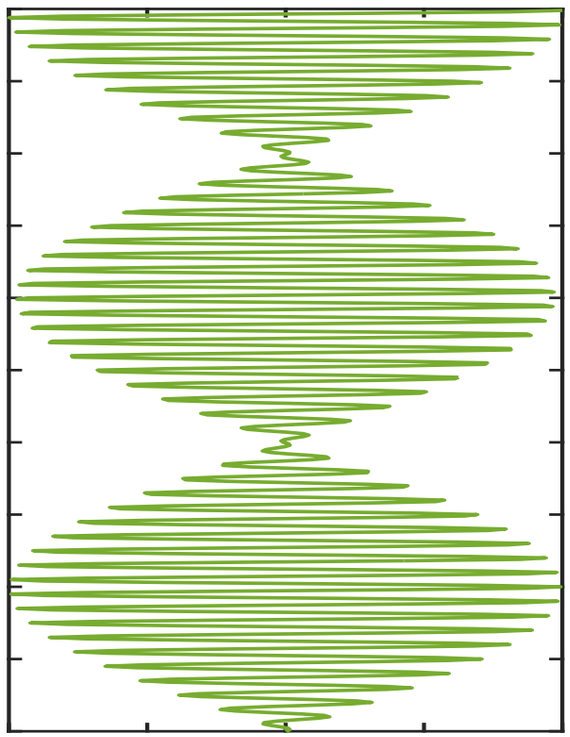

- The pulse Rabi has to be larger than the signal frequency.

- At 2.1 T hydrogen has a 90 MHz Larmor frequency.

# The Parallel Interaction



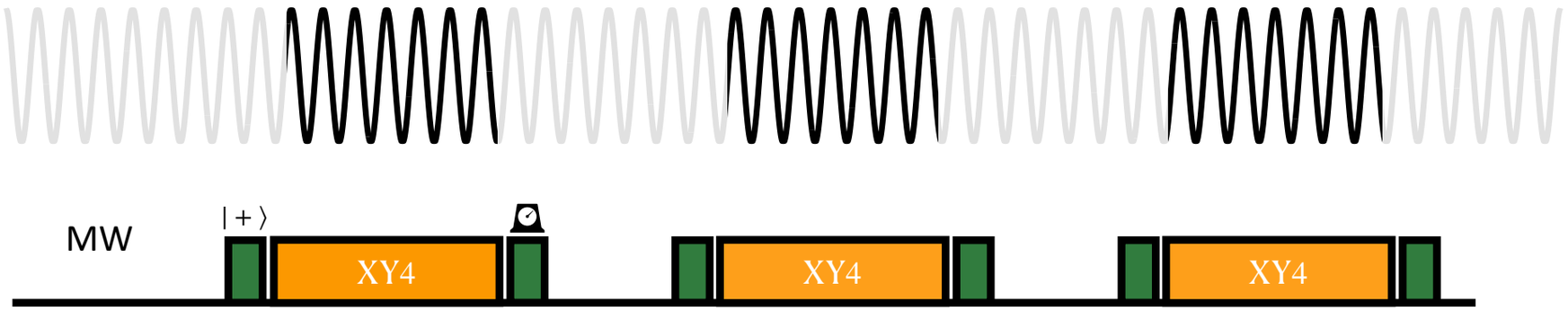





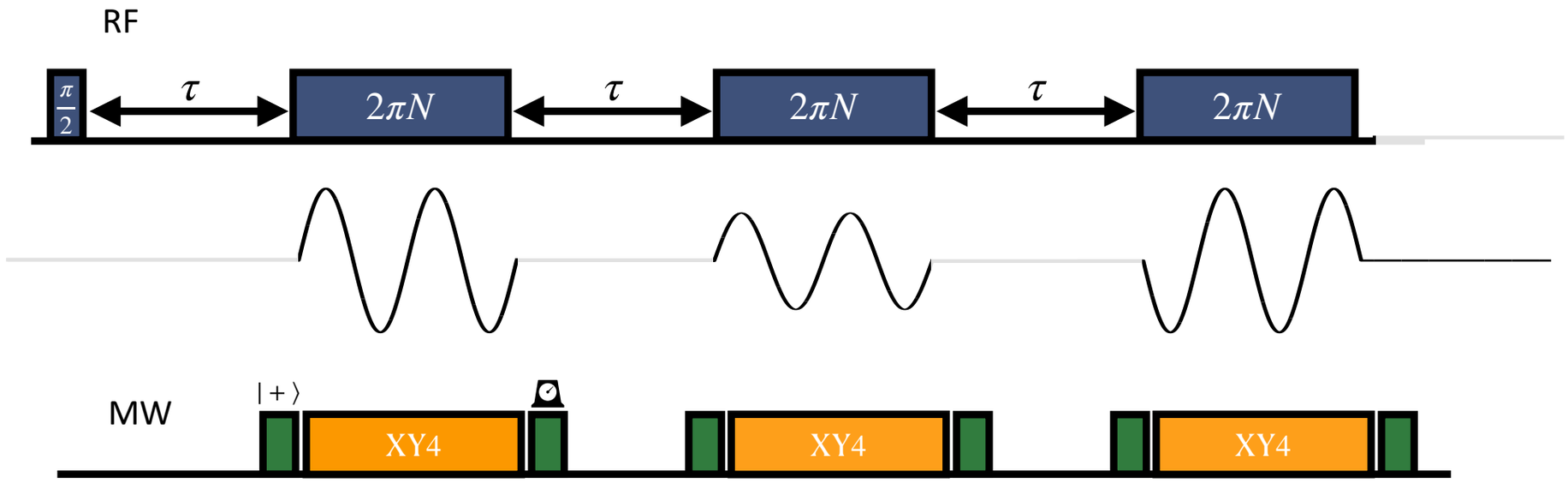
- The Z projection does not contain fast oscillating terms.
- Slow frequencies naturally emerge while driving.

# AERIS

- Standard approach




- AERIS approach

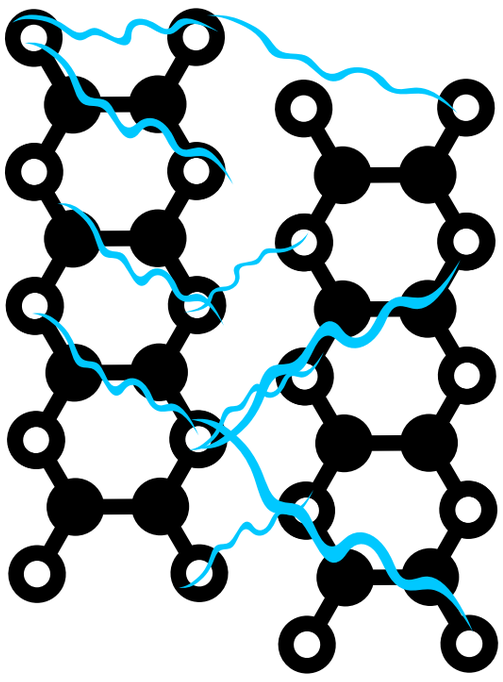



Phys. Rev. Lett. 130, 133603 (2023) from C. Munuera-Javaloy, A. Tobalina and J. Casanova.

# Solid-State NMR

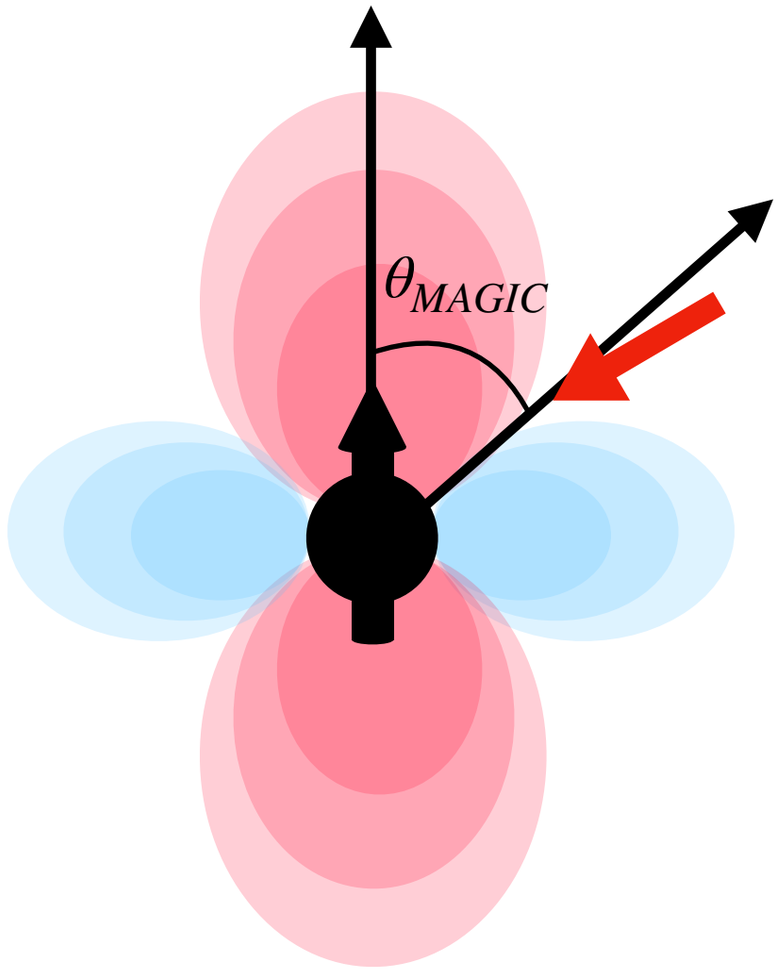
# Solid-State Systems

$$H = \sum_j \delta_j I_z^j + \overbrace{\sum_{j>k} d_{jk}\left(3I_j^z I_k^z - \vec{I}_j \cdot \vec{I}_k\right)}^{\text{Averaged out by movement}} + \sum_{j>k} J_{jk}\vec{I}_j \cdot \vec{I}_k$$

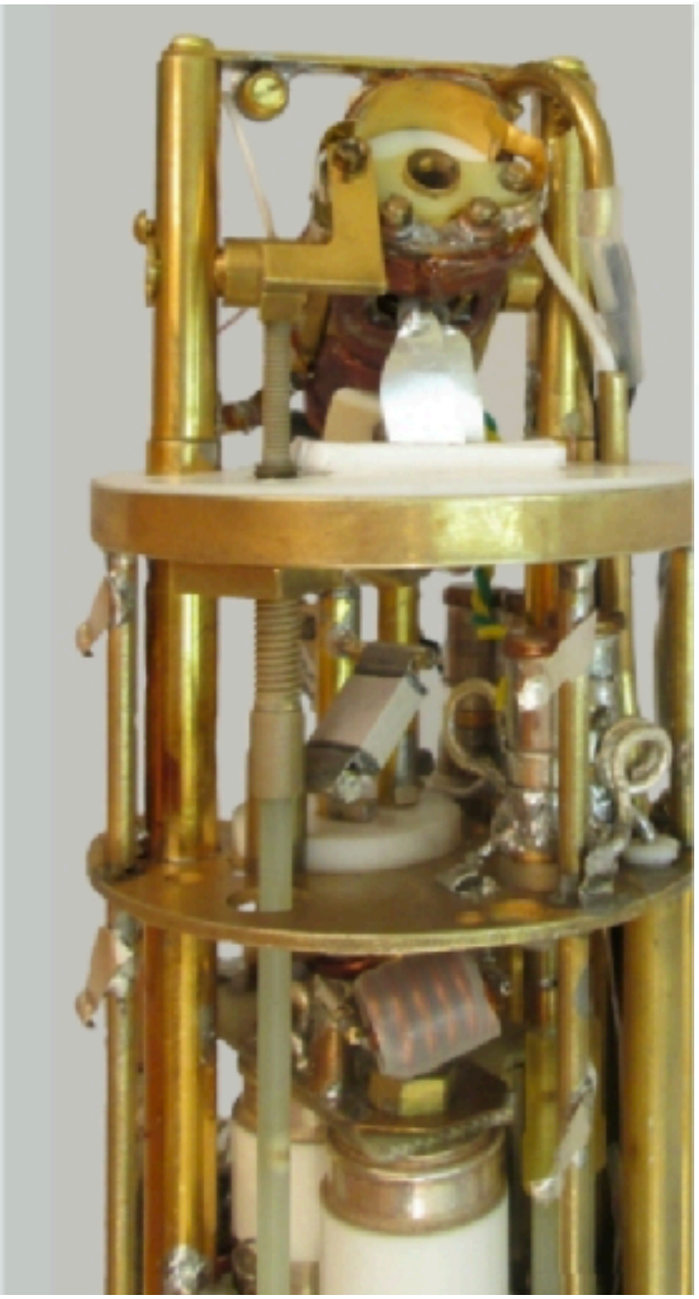


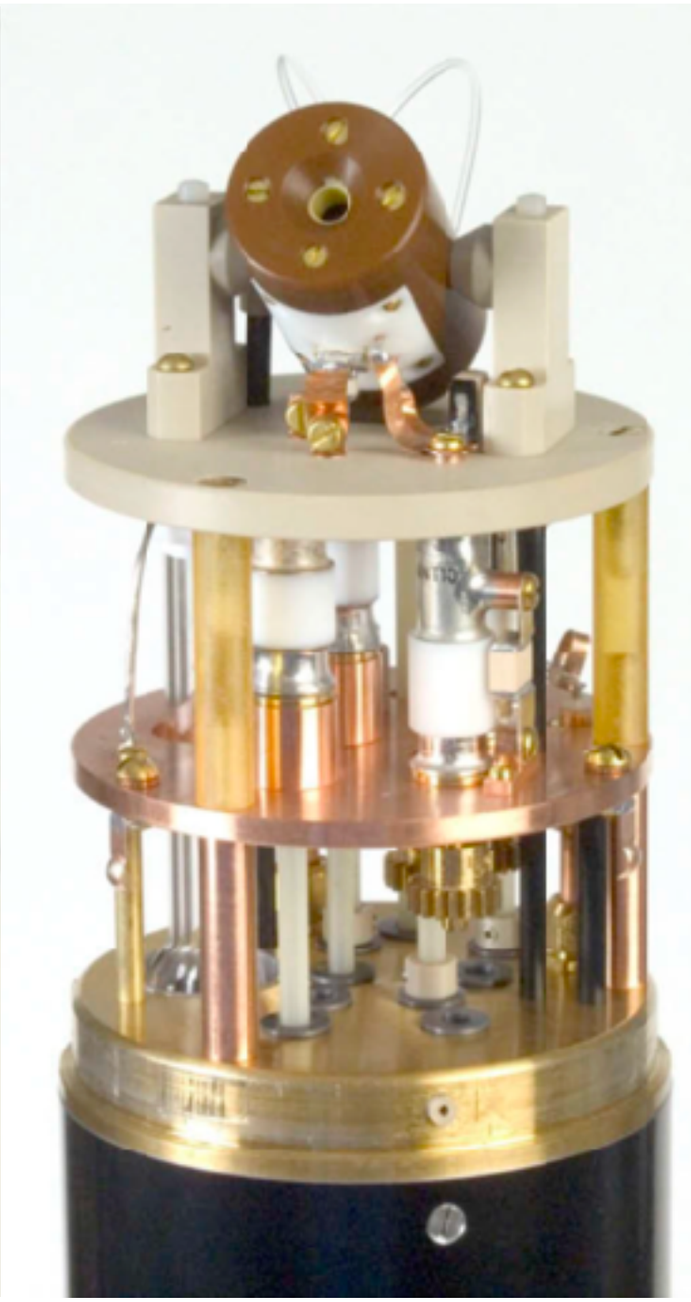
- Massive splitting
- Peaks become very broad
- Complex interaction network
- Less coherence

# The Magic Angle



# Magic Angle Spectroscopy





# Lee-Goldburg

Can we drive like that?

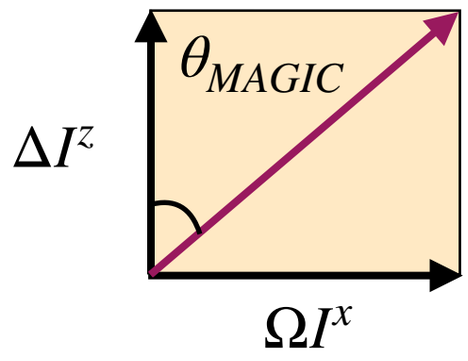
$$H = \omega_o I^z + 2\Omega I^x \cos(\omega_D t)$$

$\omega_0 - \omega_D = 0$

$$H_I = \Omega I^x$$

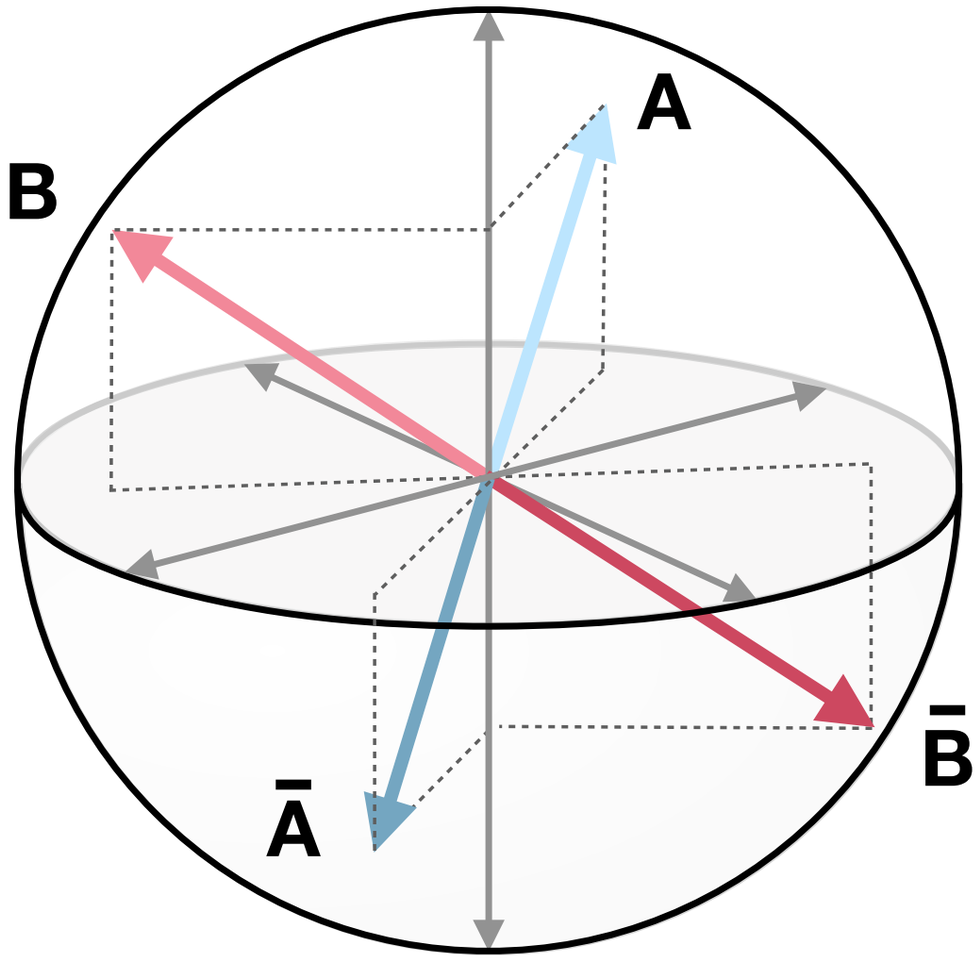
$\omega_0 - \omega_D = \Delta$

$$H_I = \Omega I^x + \Delta I^z$$




Lee-Goldburg decoupling.

# LEE-GOLDBURG 4

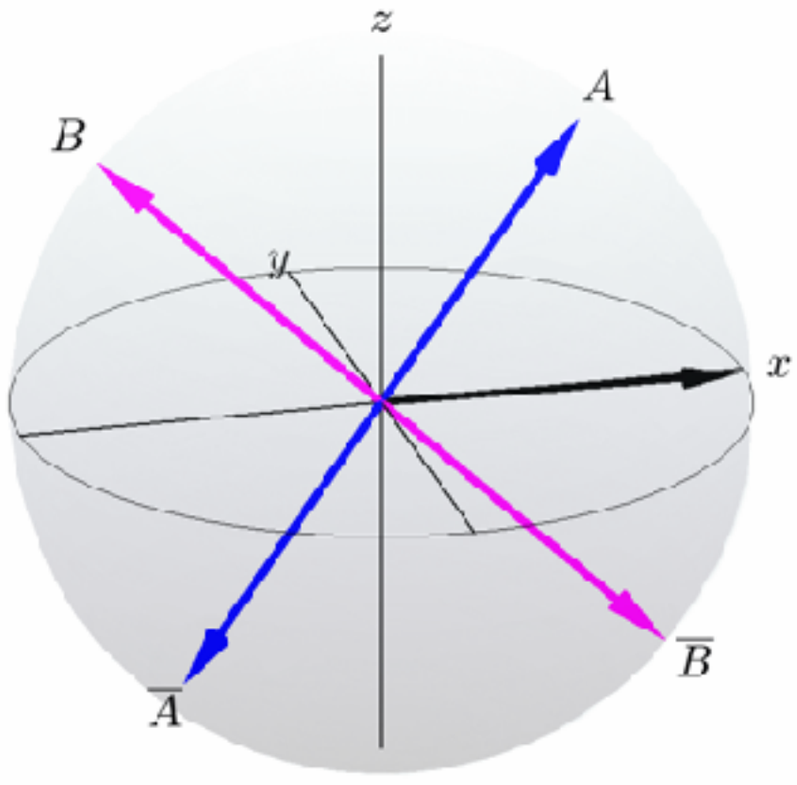


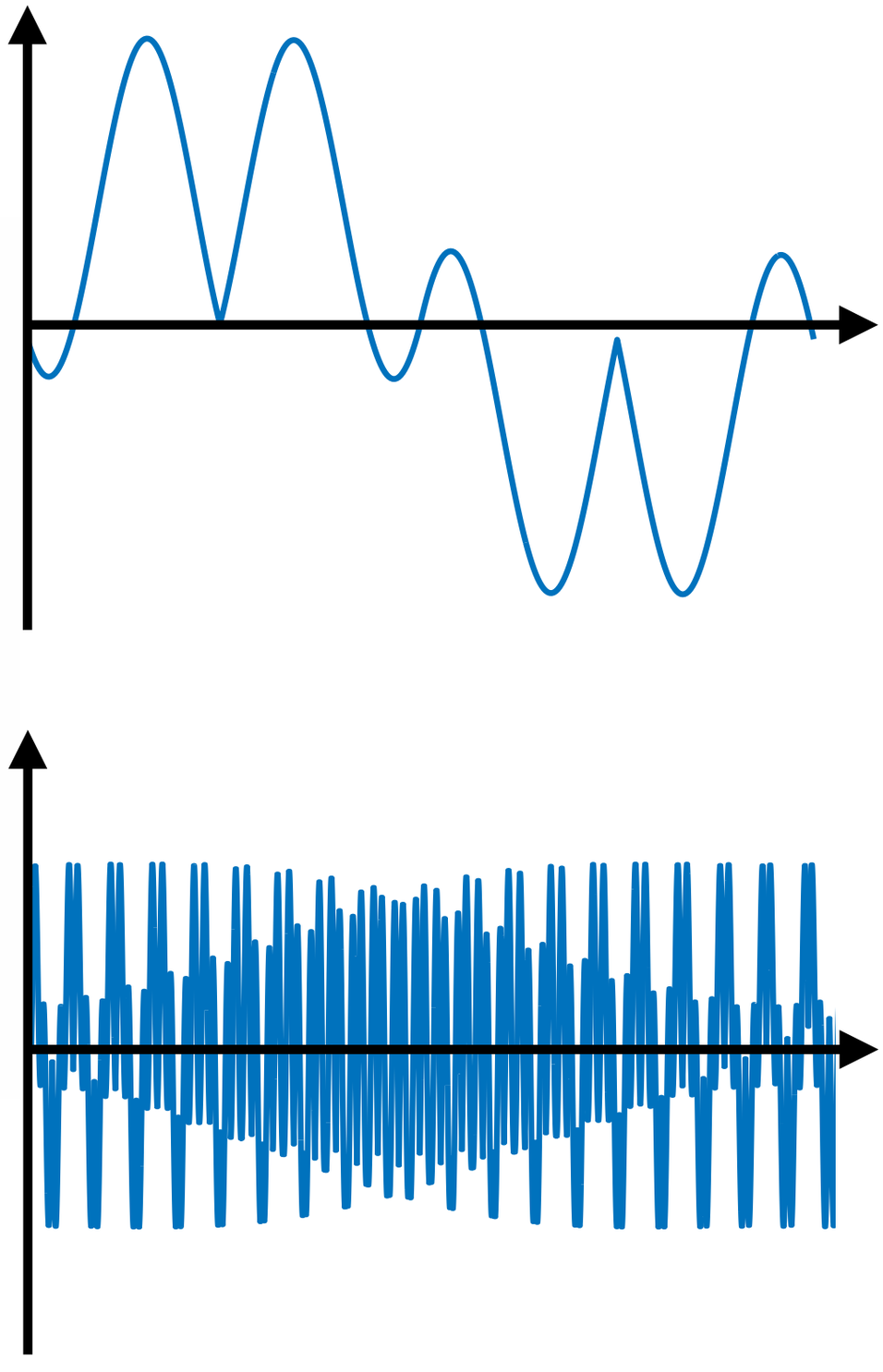

Complex composed sequence:

$$[A, \bar{A}, \bar{B}, B]$$

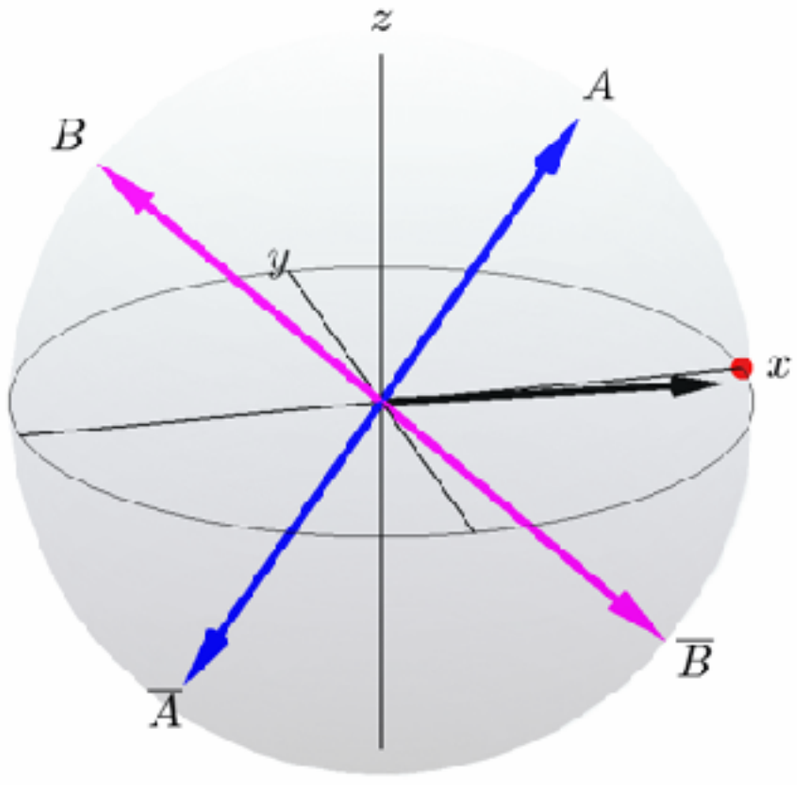
# Microscale NMR with LG4 decoupling

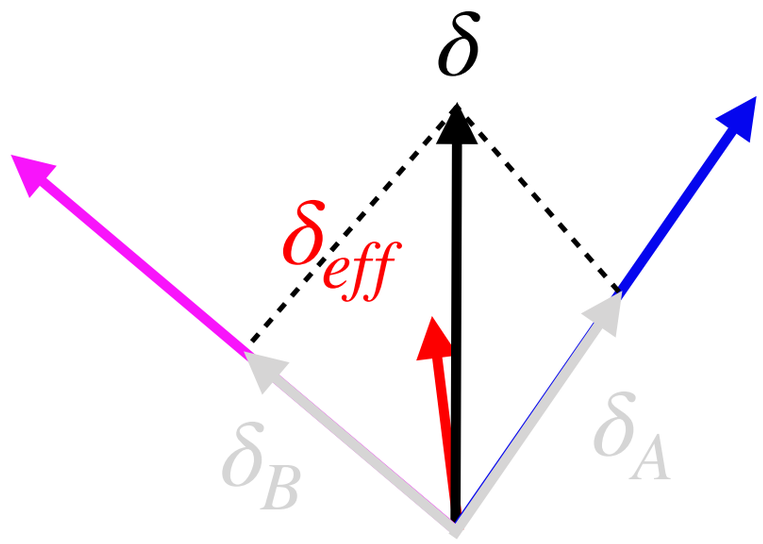
# SIGNAL PRODUCED



# EFFECTIVE SHIFT

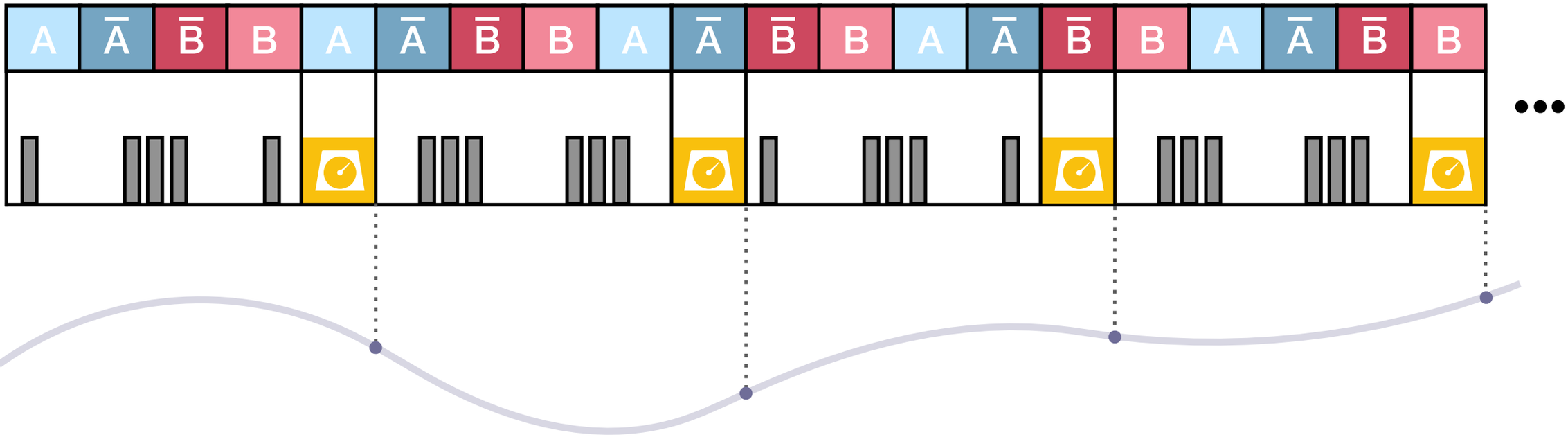


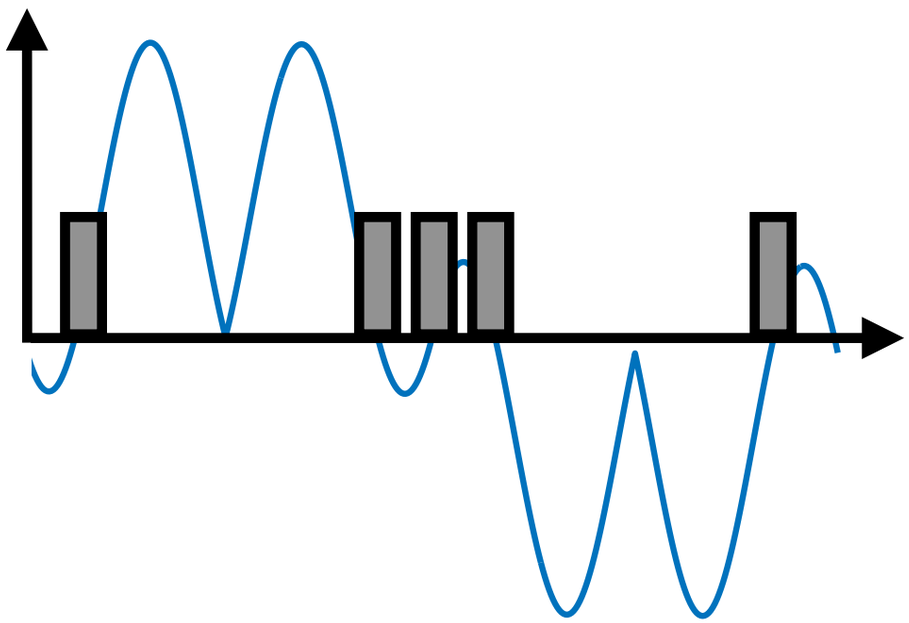




- Only the parallel component of the shift is relevant during each driving.

- The fast alternation creates a middle effective shift.

# SEQUENCE

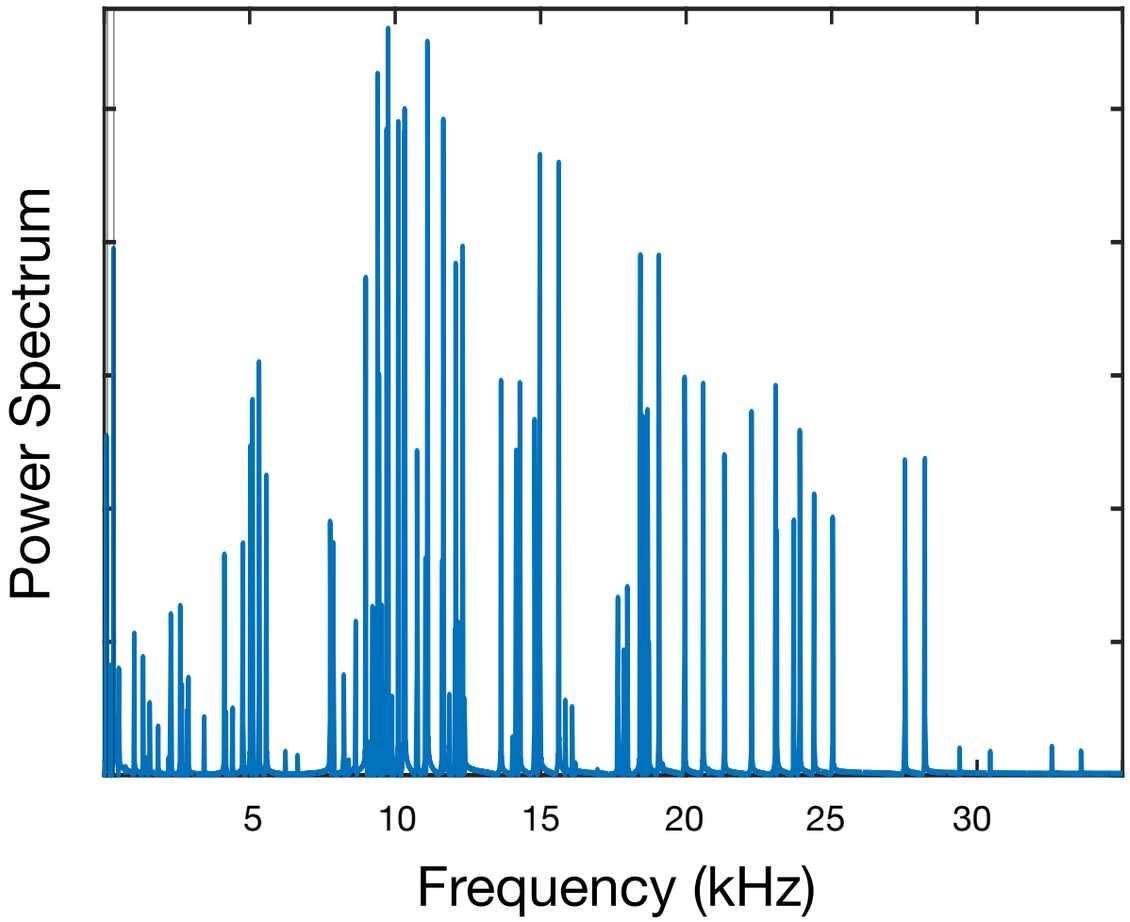


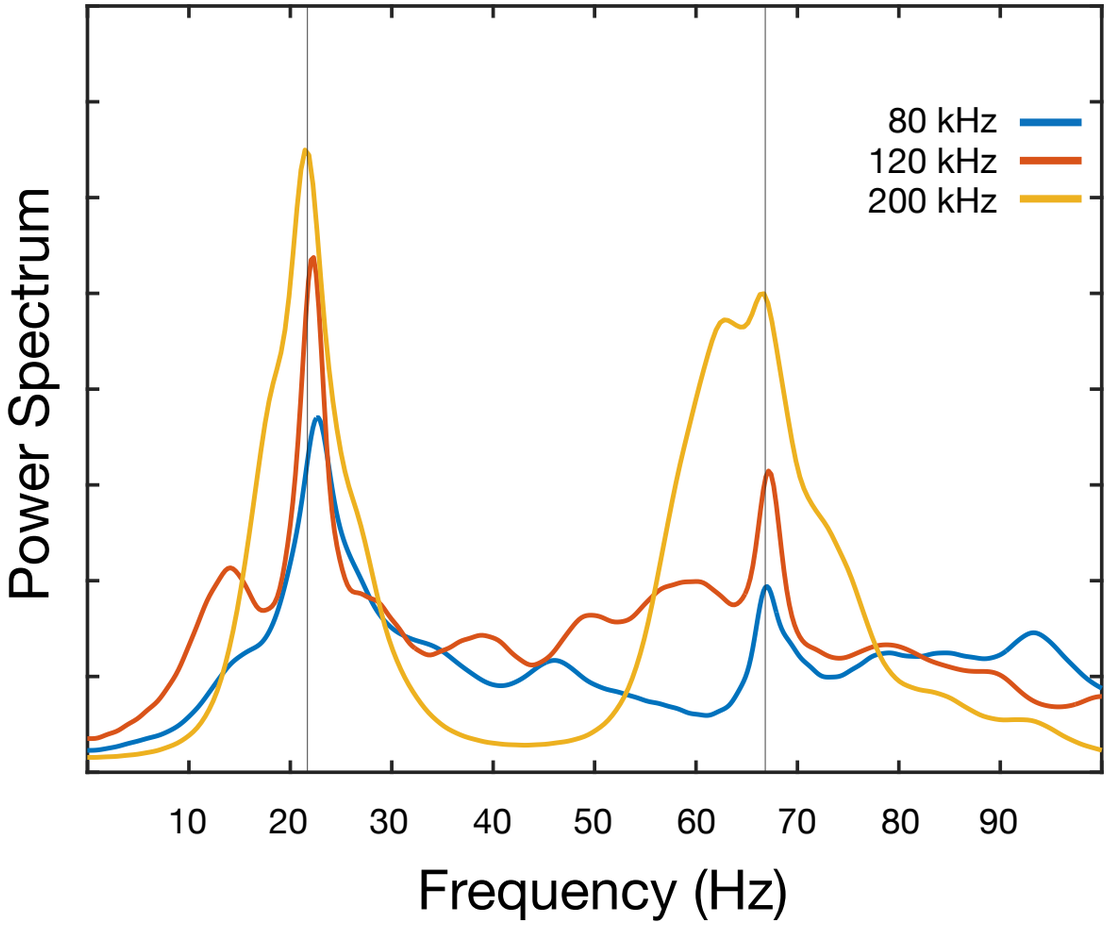
- A pulse per axis detects the shifts.
- We optimize the timing to obtain maximum initial amplitude.

# PRELIMINARY RESULTS

## SIMPLE FID




## OUR TECHNIQUE



# CONCLUSIONS

- Homonuclear decoupling makes readable spectra.

- Solid-state NMR has great potential at the microscale.

- We extend Rabi-mediated schemes to include LG4.