β-detected nuclear magnetic resonance of ^{8}Li ions implanted in ZnO

THE UNIVERSITY OF BRITISH COLUMBIA

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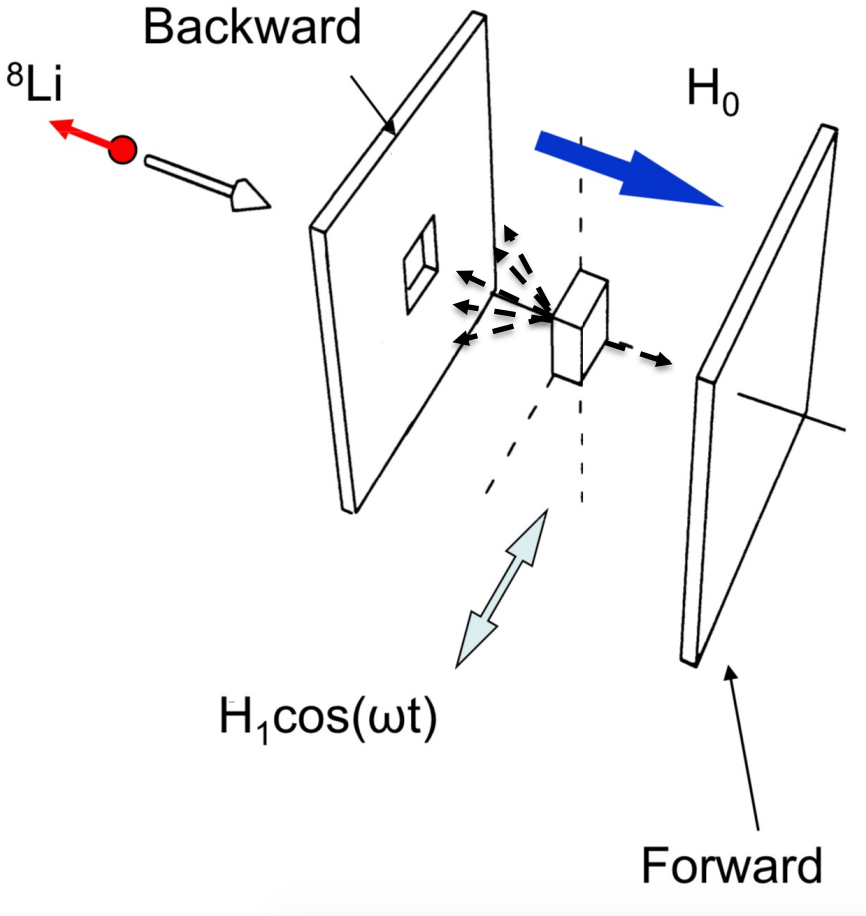
UBC Chemistry

August 28th, 2022

What is β-detected NMR?



$$^8\text{Li} \rightarrow {}^8\text{Be} + e^- + \nu_e$$

Spin = 2
Lifetime ~ 1.2 s
γ ~ 6.3 MHz/T

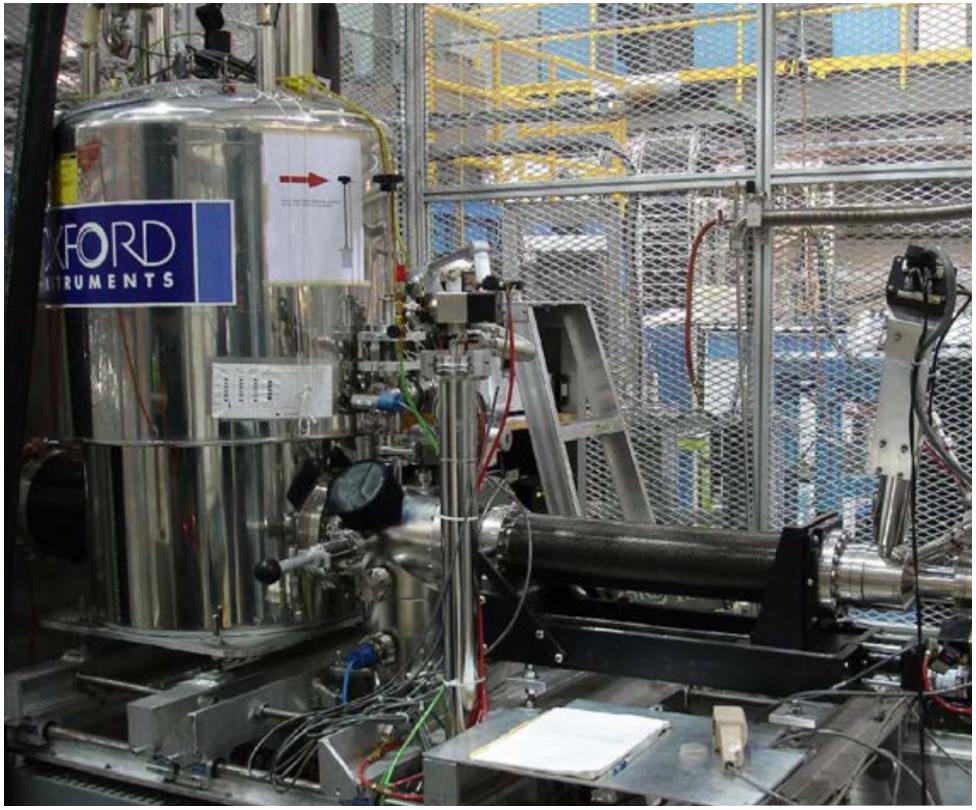
$$\mu^+ \rightarrow e^+ + \nu_e + \bar{\nu}_\mu$$

Spin = ½
Lifetime ~ 2.2 μs
γ ~ 135 MHz/T

$$A(t) = \frac{N_F(t) - N_B(t)}{N_F(t) + N_B(t)} = a_0 p_z(t)$$

β-detected NMR at TRIUMF

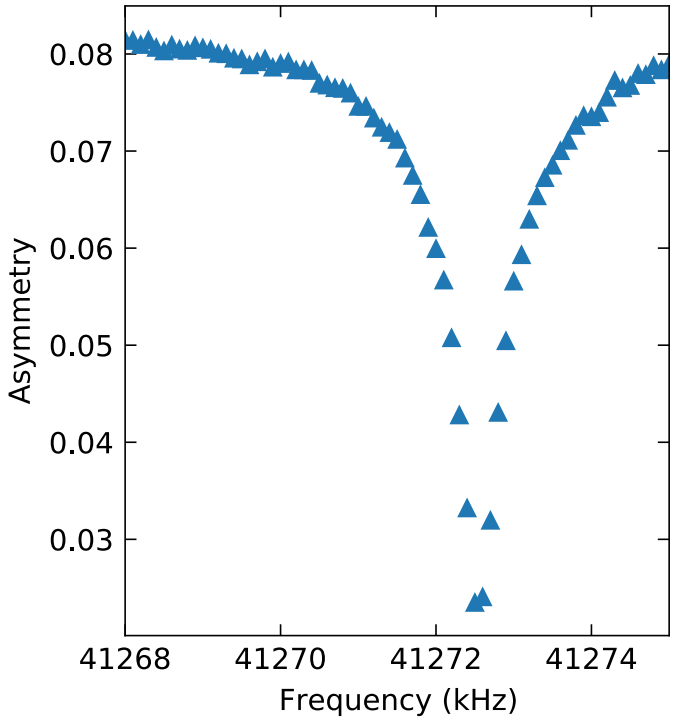
9T high field spectrometer



G. D. Morris, Hyperfine Interact. 225, 173 (2014)
C. D. P. Levy et al., Hyperfine Interact. 225, 165 (2014)

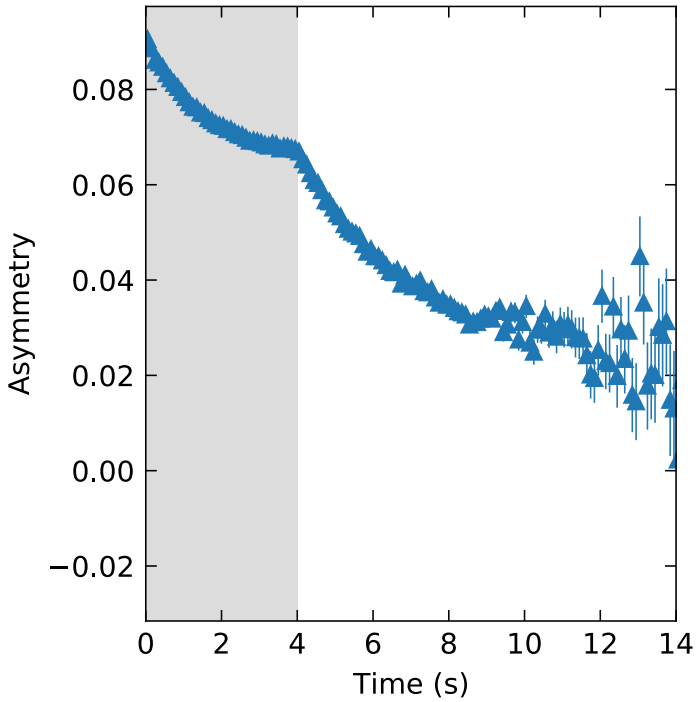
β-detected NMR measurement modes

Continuous wave and beam



- **Asymmetry loss when transverse RF field on-resonance**

Pulsed beam

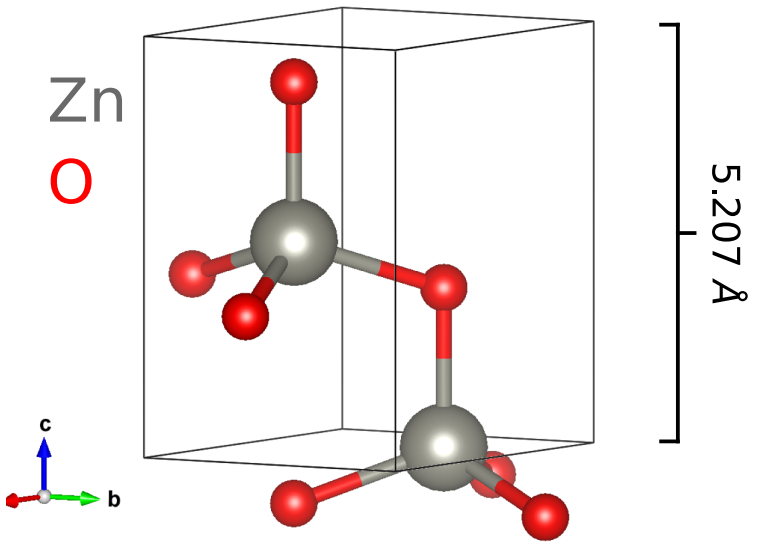


- **Measures p_z decay overtime**

W. A. MacFarlane, Z. Phys. Chem. 236, 757 (2021)

β-detected NMR of ZnO

Why is ZnO difficult to hole dope?



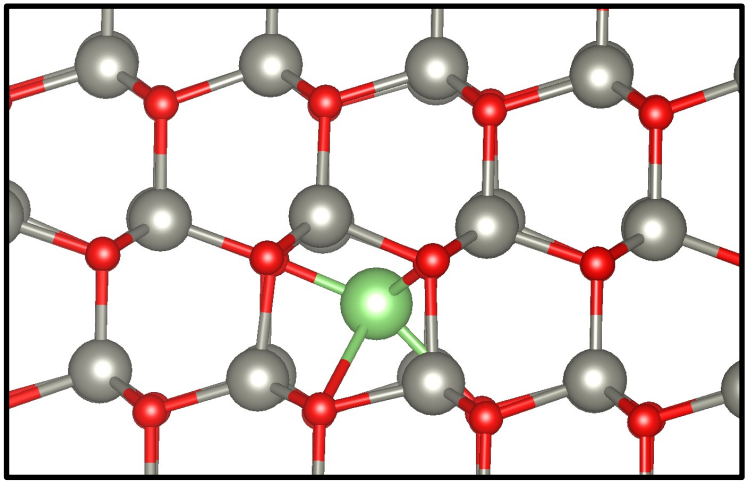
Why β-NMR?

- **<u>Hyperpolarized</u> dopant elements**
- **Probe of local <u>magnetic fields</u> and <u>charge density</u>**

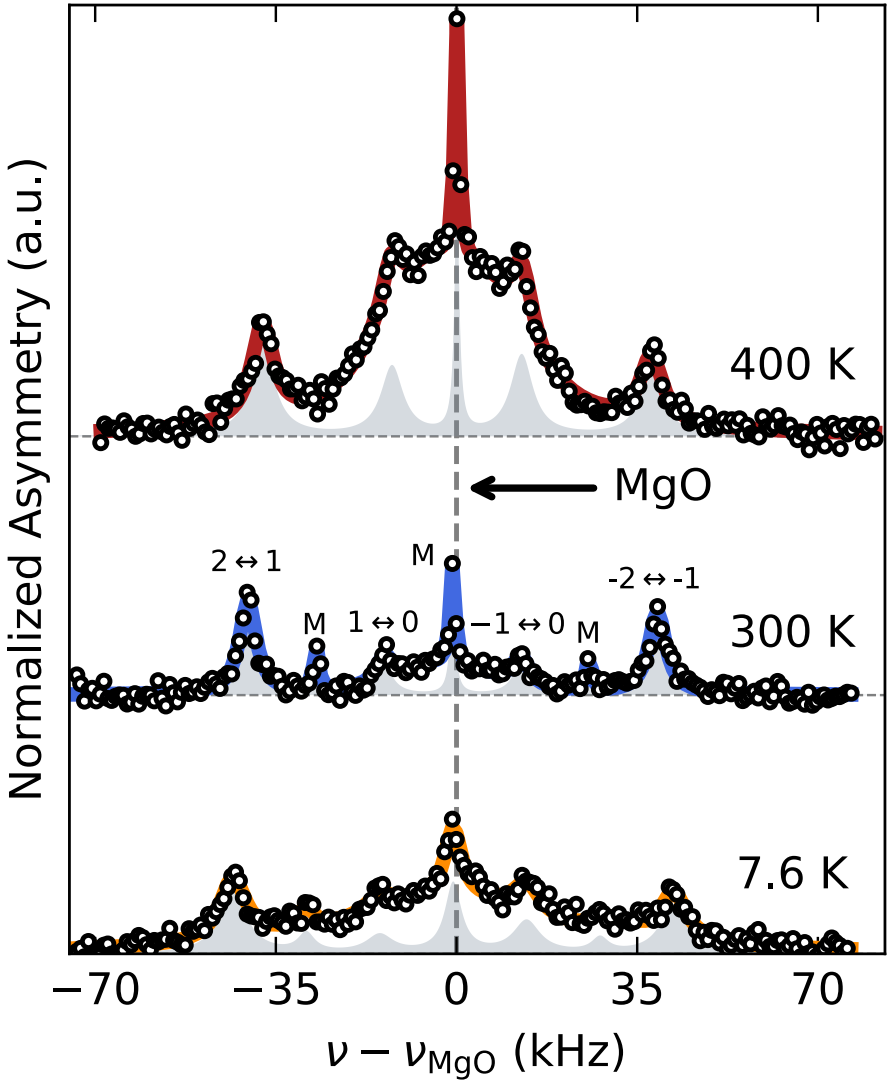
J. R. Adelman et al., Phys. Rev. B 106, 035205 (2022)

Single RF resonance spectra

Donor octahedral interstitial $^{8}Li^{+}$



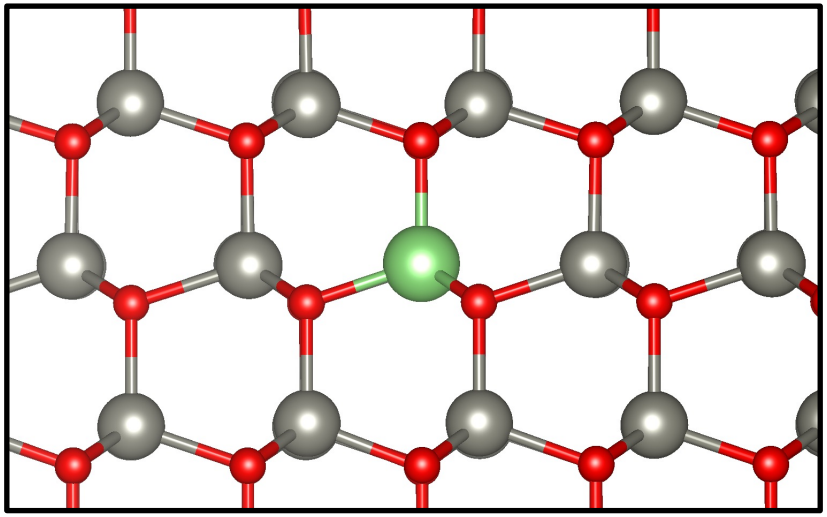
Experiment ν_q: 13.2 kHz
Theory ν_q: 12 kHz



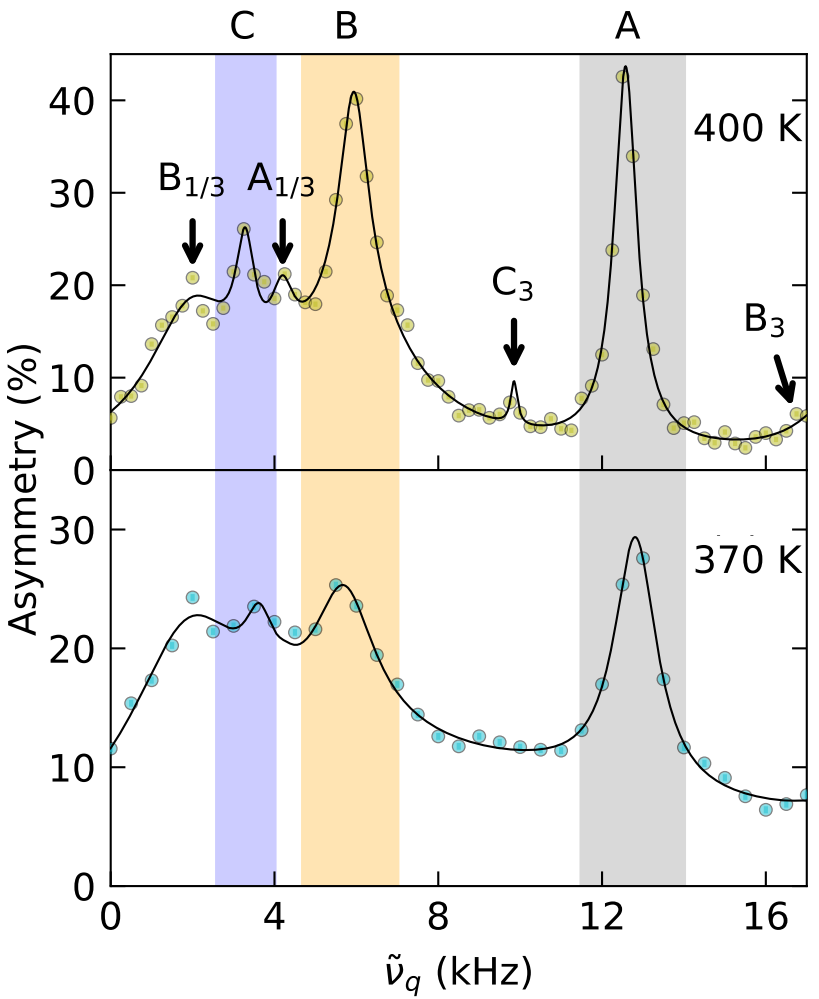
RF comb resonance spectra

- Li_{Zn} forms at expense of Li_i^+ near vacancy

Acceptor ionized substitutional Li_{Zn}



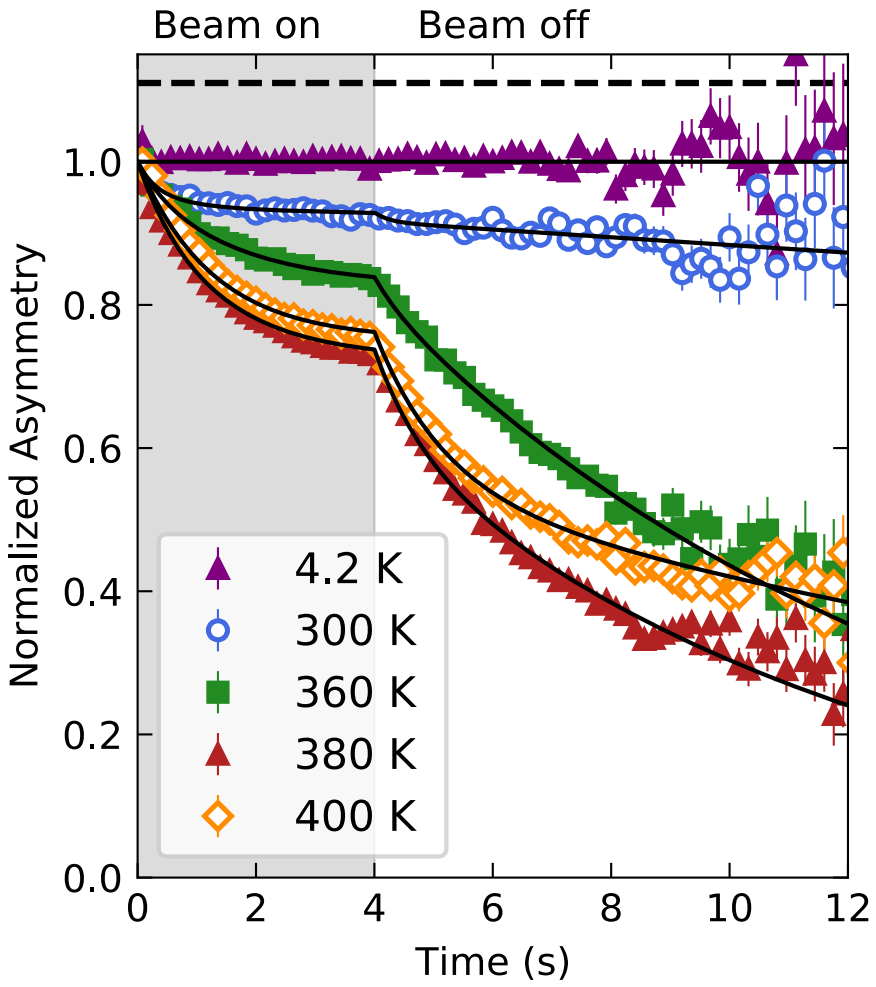
3 distinct sites



J. R. Adelman et al., Phys. Rev. B 106, 035205 (2022)

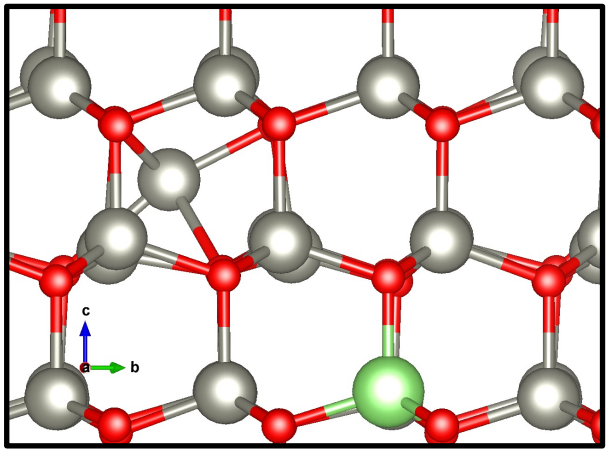
Pulsed beam: ^{8}Li spin-lattice relaxation

$1/T_1$ relaxation rate: measurement of magnetic and quadrupolar fluctuations at ν_r

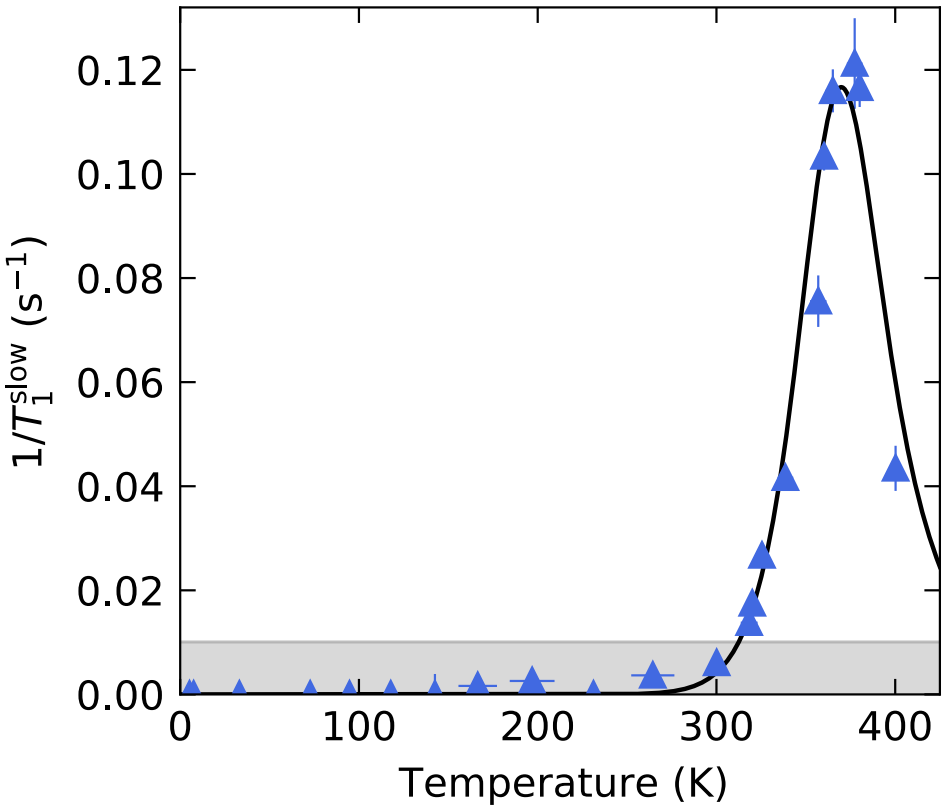


Motional dynamics of defects

Frenkel pair + ^{8}Li



$1/T_1$ fits BPP model

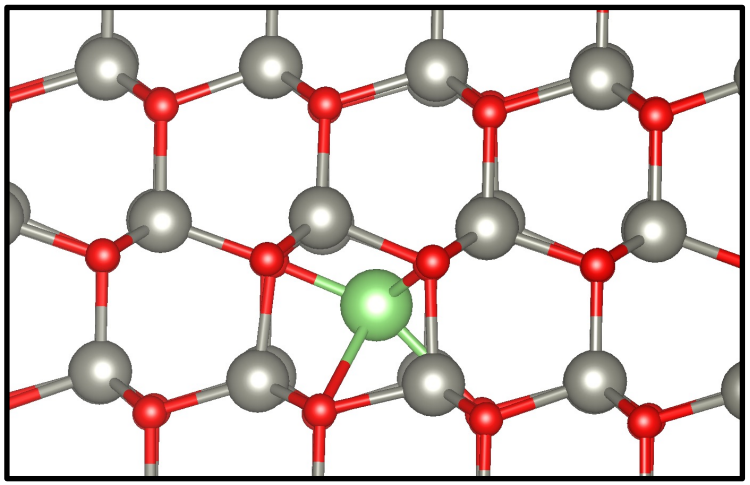


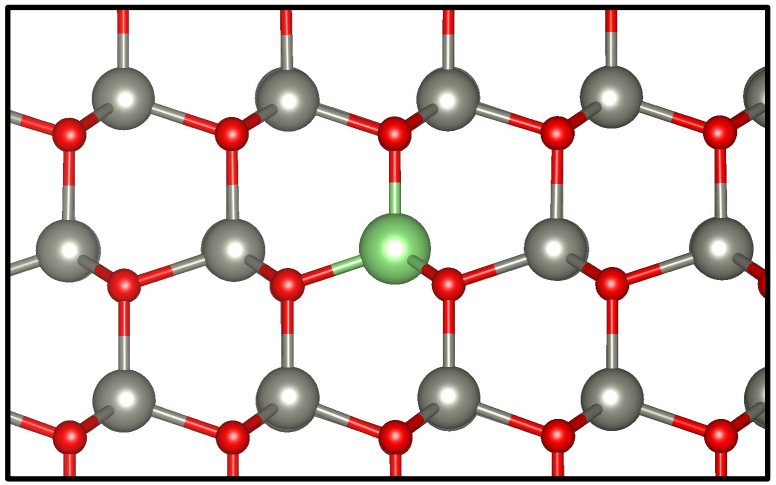
N. Bloembergen, E. M. Purcell, and R. V. Pound, Phys. Rev. 73, 679 (1948)

Summary of ^{8}Li NMR in ZnO

1. β-NMR probes the charge density distribution and magnetic fields at dopants

2. Both shallow donors and acceptors coexist





Acknowledgements

NSERC CRSNG

CMMS

University of British Columbia

Andrew MacFarlane
Derek Fujimoto
Martin Dehn
Victoria Karner
Ryan McFadden
John Ticknor
Edward Thoeng

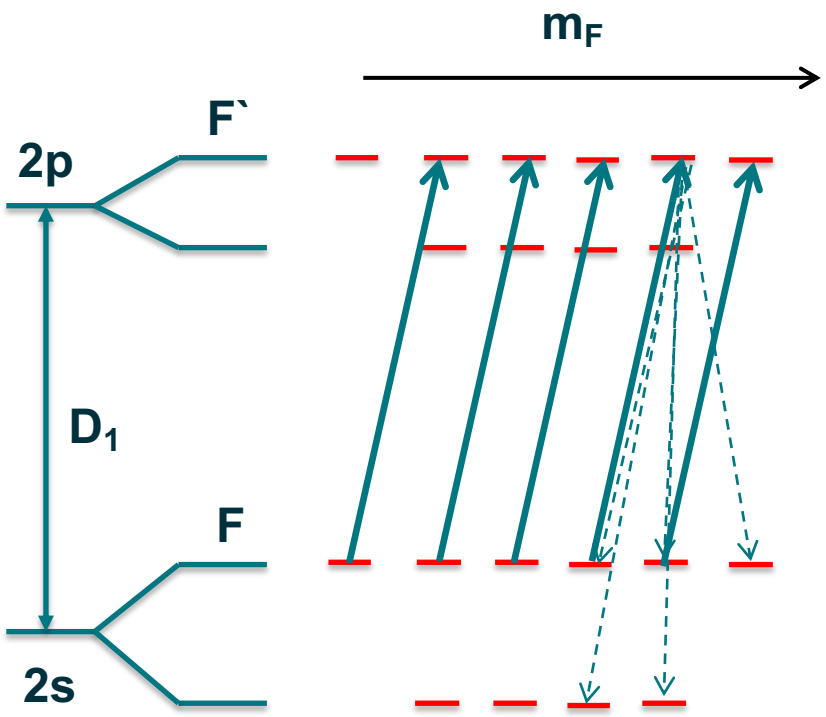
UBC THE UNIVERSITY OF BRITISH COLUMBIA

TRIUMF

Kenji Kojima
Sarah Dunsiger
Philip Levy
Ruohong Li
Iain McKenzie
Gerald Morris
Matthew Pearson
Monika Stachura

Optical pumping of ^{8}Li at TRIUMF

^{8}Li online optical pumping

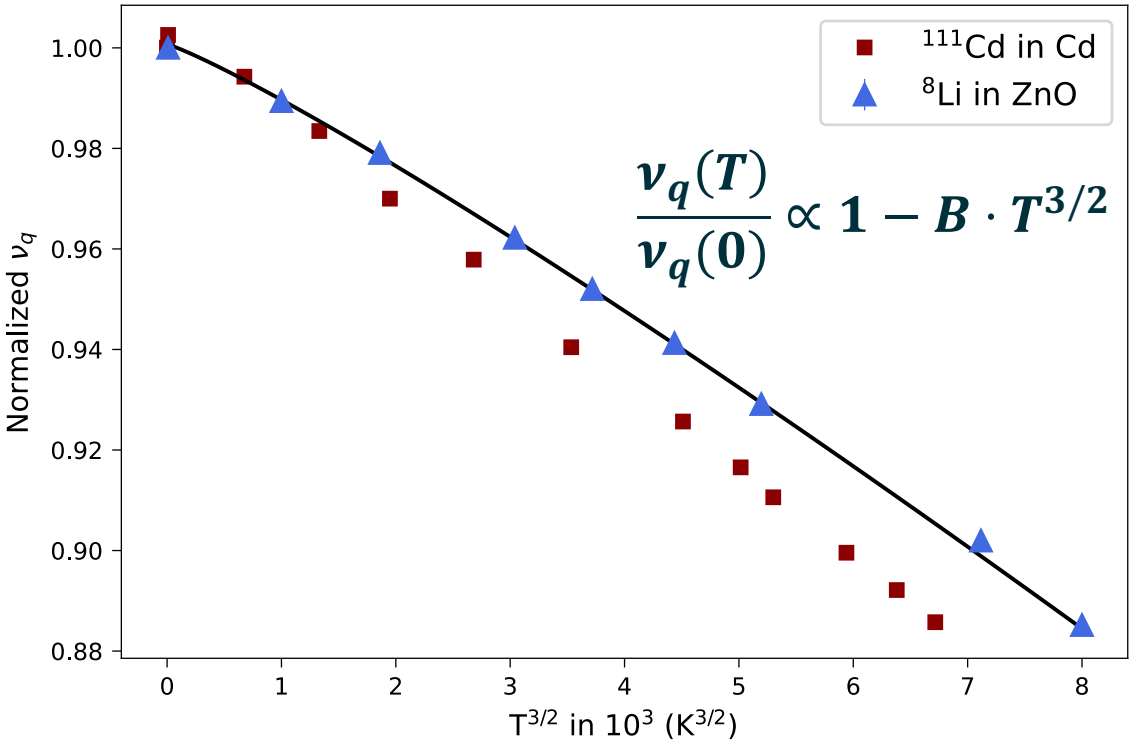


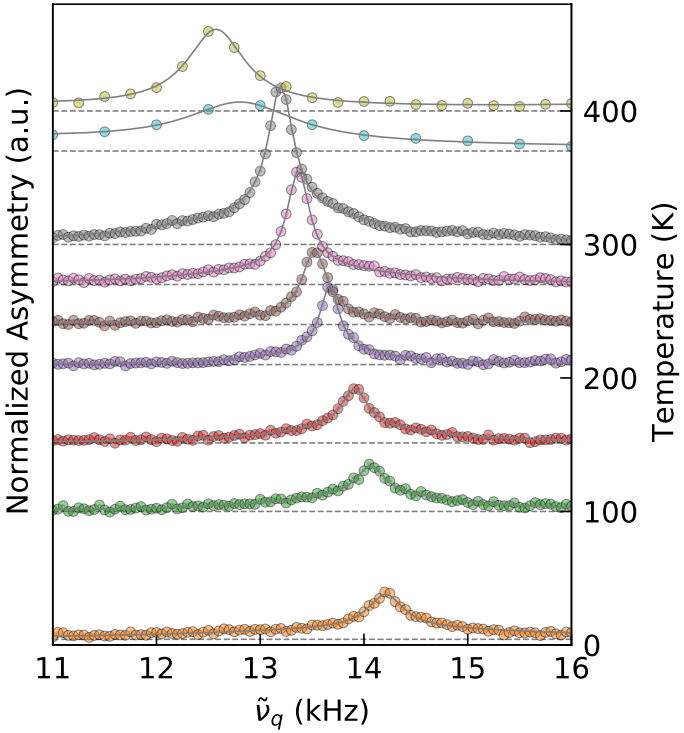
- **optical pumping cycles in presence of weak Zeeman splitting**
- **Transfer polarization via hyperfine coupling**

C. D. P. Levy et al., Hyperfine Interact. 225, 165 (2014)

T-dependence of quadrupole interaction

Population of phonons causes time-averaging of quadrupole interaction, power law typical of noncubic metals





^{111}Cd data points from J. Christiansen, et al., Z. Phys. B **24**, 177 (1976)