

Master thesis proposal

Title: Investigation of Rabi oscillations by optically-detected NMR in hyperpolarised He-3 gas

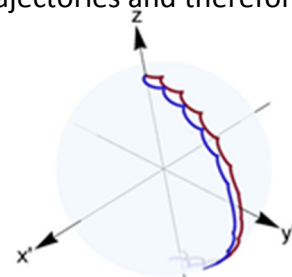
Keywords: Bloch sphere, 2-level system, NMR (Nuclear Magnetic Resonance); Beyond RWA (Rotating-Wave Approximation)

Scientific description:

Context: Pulses of resonant ac fields are generically used to control the internal state of 2-level systems. In magnetic resonance of spin-1/2 nuclei (NMR) elaborate sequences of rf pulses provide powerful tools for numerous applications in spectroscopy and imaging, for instance. Similar accurate manipulation of the internal state of various other 2-level quantum systems through controlled travel on the Bloch sphere is also needed, in particular for those that may be used as Qubits in the context of quantum technologies.

Travel on the Bloch sphere induced by a (near-) resonant pulse is a standard textbook item, but the presence of additional off-resonant or longitudinal oscillating field components, which are often unavoidable in practice, may deeply modify spin trajectories and therefore the spin response to complex trains of excitation pulses.

NMR in low magnetic fields is a versatile test bench for a variety of behaviours in response to well-controlled pulsed excitation, as recently demonstrated in our group.¹ In particular, conditions for operating outside the range of validity of the well-known rotating wave approximation are easily met at low (mT) magnetic field.



Internship project: Relying on the team's experience in (i) low-field NMR and (ii) optical pumping/probing of ³He in gas discharges, studies of Rabi oscillations driven by rf pulses will be performed. These oscillations of the nuclear spin state of the atomic ground state will be monitored by optical polarimetry involving a suitable atomic excited state. Thanks to the strong hyperfine coupling and a fast spin exchange enforced by collisions, the optically measured longitudinal *and* transverse time-dependent orientations accurately reflect the 3D travel of the pre-polarised ensemble of nuclear spins on the Bloch sphere during rf pulses.

Initial tests have shown the feasibility of such measurements. A new dedicated setup was designed and constructed. Different kinds of complex travel paths on the Bloch sphere will be explored and an associated suite of numerical and theoretical studies will be undertaken.

¹Bidinosti et al., *J. Magn. Reson.* **345** (2022) 107306, "Generating accurate tip angles for NMR outside the rotating-wave approximation". <https://hal.archives-ouvertes.fr/hal-03765938>

Techniques/methods in use: Optical pumping and probing, NMR control of nuclear spins

Applicant skills: Atomic and quantum physics; basics in hands-on optics and signal processing

Industrial partnership: N - **International collaboration:** C. Bidinosti, U. Winnipeg, Canada

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Possibility for a Doctoral thesis: Y (no secured funding)