Optical Pumping Simulation of Copper for Beta-NMR Experiment

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ISOLDE, CERN

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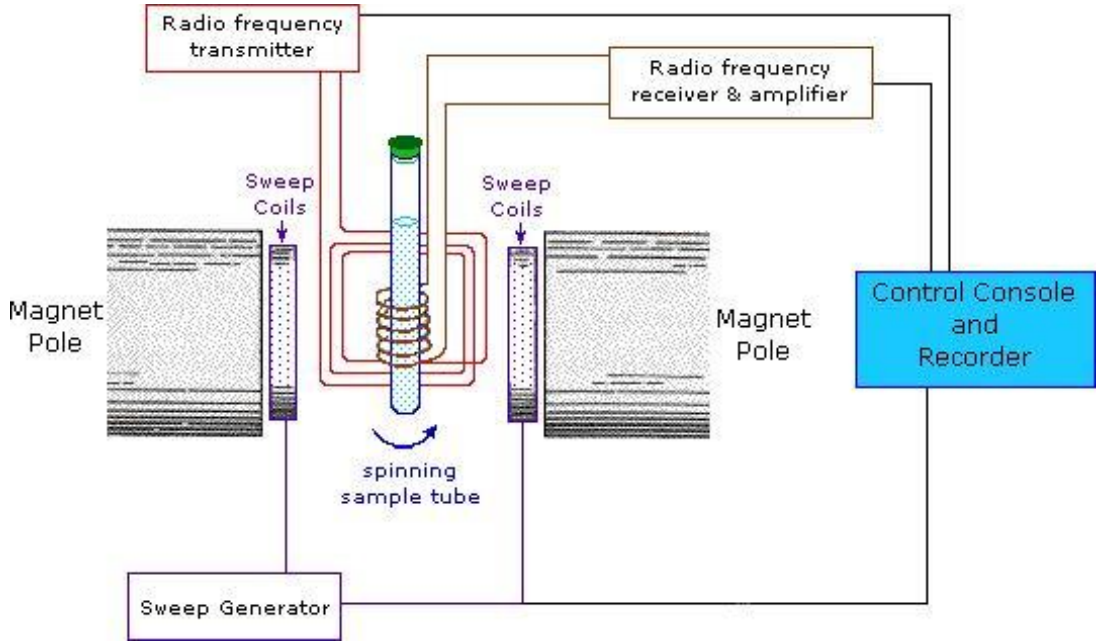
ISOLDE

NMR (continued)



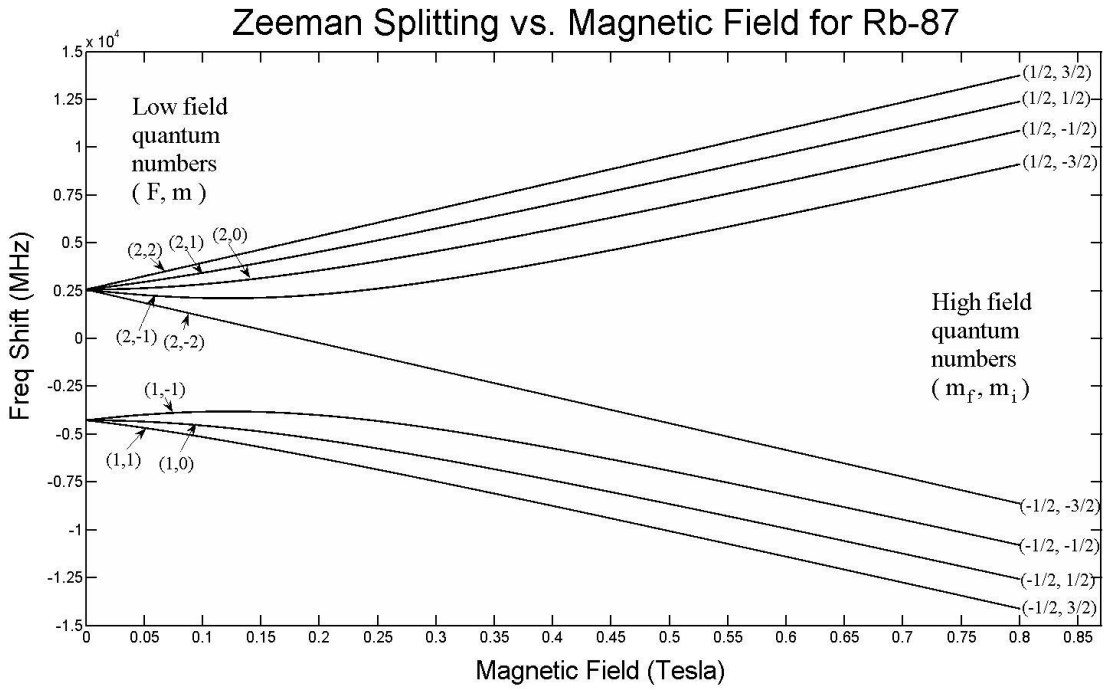
- Beta-NMR
  - Requires less atoms.
  - 10 orders of magnitude better precision than traditional NMR.
  - Uses radioactive isotopes.

NMR (nuclear magnetic resonance)

- A sample is wrapped in two solenoids between two strong magnets. One solenoid is pulsed with a signal corresponding to the Larmor frequency, and the other solenoid is attached to an oscilloscope which measures the response frequency of the sample.
  - Larmor frequency is the resonant frequency. ($\omega_{Larmor} = \frac{egB}{2m}$, where e is the charge of an electron, g is the gyromagnetic ratio, B is the magnitude of the applied magnetic field, and m is the mass of the particle.)
  - This response frequency is then Fourier transformed to show the various resonances which correspond to the electrons' spin.

Purpose of Magnets

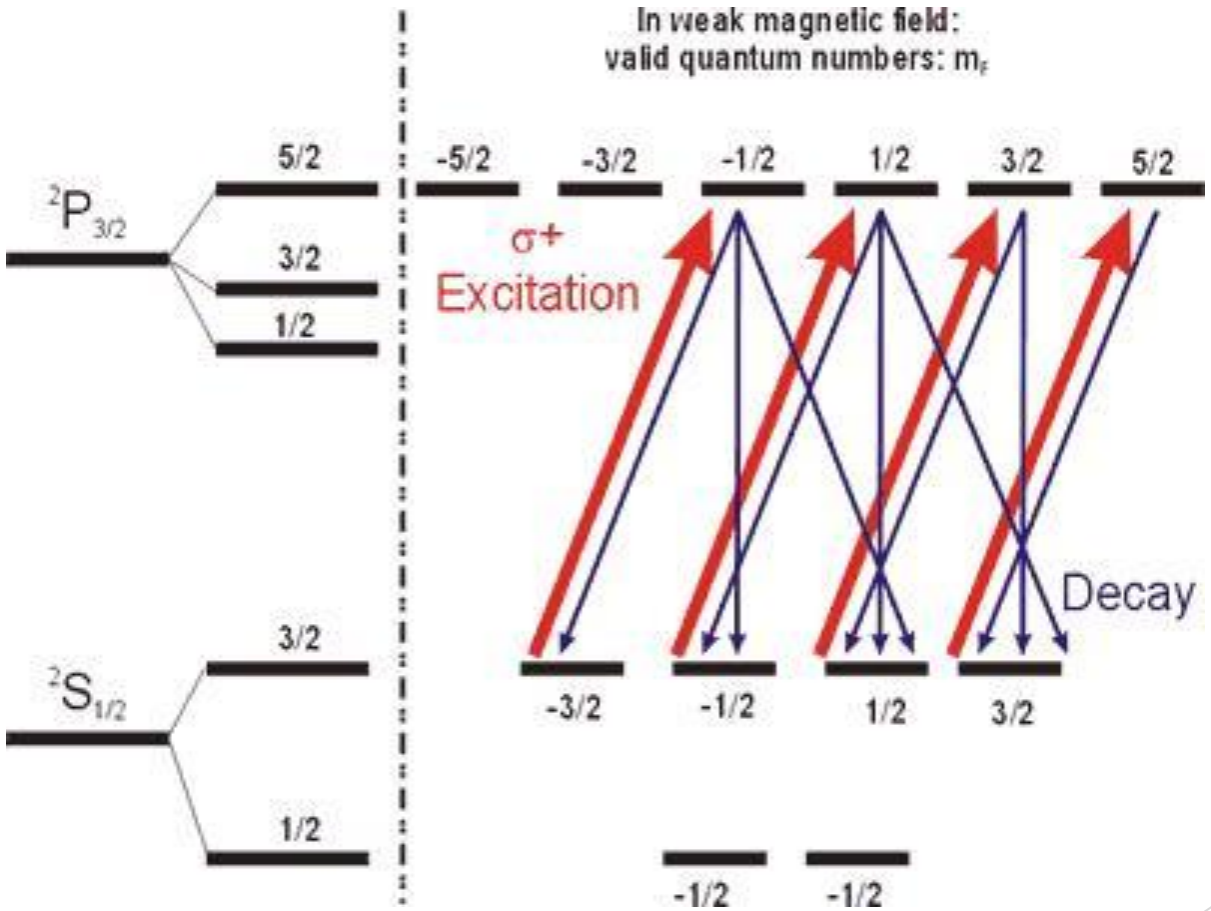
- Presence of magnetic field gives rise to energy splitting between the states. A weak magnetic field (0.1 T) gives rise to the Zeeman effect, which splits according to the nuclear spin. A stronger magnetic field (0.2 T) gives rise to the Paschen-Back effect, which splits according to the electronic angular momentum.



Polarizing the Valence Electrons

- A laser whose frequency matches the energy difference between the electron orbitals is used to bump the electrons into the more energetic orbitals.
  - At ISOLDE, dye lasers are used, whose frequency is variable.
  - Polarization comes from the spin of the photon which, as bosons, have spin-1, as opposed to fermions who have spin-1/2.
  - Can be done using positively polarized light (+σ), negatively circularly polarized light (-σ), or linear polarized light (0) (a superposition of the two circular polarizations).
  - Selection rules: $\Delta l = +/- 1$.

Optical Pumping



Simulating Optical Pumping in C

- The rate of the change in each population corresponds to a differential equation which is dependent on the current population as well as the populations of the other states.
- These differential equations are coupled and are approximated by the Runge-Kutta method.
- Using a computer simulation will give us better accuracy, as the number of repetitions may be very large as the increment is very small.

What I’m Doing

- Getting my computer to recognize the IT++ library.
- Learning energy splitting diagrams to find the possible energy transitions in copper.
  - Calculating nuclear spin.
- Finding the constants to put into the differential equations:
  - Einstein emission and absorption coefficients
  - Using the Heisenberg Uncertainty Principle to calculate the lifetimes of the different states. ($\Delta E \, \Delta t >= h/4\pi$)
  - Larmor frequency.
  - Coding this in C to run the approximation.