ASACUSA’s Ramsey spectrometer for high precision hyperfine spectroscopy

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MOTIVATION: CPT SYMMETRY and HYPERFINE STRUCTURE

The Standard Model manifests the CPT symmetry to be the most fundamental symmetry in particle physics.

SME effect on $\theta_c$: shift in hyperfine structure

Non-minimal SME: $\pi$-transition affected by B-field direction.

The interaction of the proton and electron spin splits up the ground state of hydrogen to four different Zeeman levels, which depends on an external magnetic field. The Standard model extension predicts the hyperfine structure to be different for hydrogen and antihydrogen.

SPECTROSCOPY: RABI TO RAMSEY

Hyperfine transitions are driven by applying an oscillating magnetic field (perturbation) in the presence of an external magnetic field. Transition probability as a function of frequency looks like a resonance-like shape.

Precision measurement of the resonant frequency demands the width of the line-shape to be as narrow as possible.

\[ \theta_{HF} = 1 \, 420 \, 405 \, 748.4 \, (3.4) \, (1.6) \, \text{Hz} \]


COMBINATION OF STANDING AND TRAVELLING WAVES

Linear dependence of electron cyclotron frequency:
- Broadband striplines: both hydrogen and deuterium
- Differential mode operation of striplines
- Electrostatics study to realize a 90 Li structure

COILS FOR STATIC FIELD

- 1D coil array simulations: each individual coil with 3 layer shielding
- Matrix inversion: optimal number of turns for each coil
- Used these numbers for simulation of coil array in 3D
- Better than 100 ppm homogeneity

TE110 MODE CAVITY

- TE-110 mode cavity at 3.42 GHz
- Magnetic field along cavity axis
- No zero crossings of the magnetic field
- Circulating electric field
- Can be used for transition from hydrogen
- Geometry restricted by the frequency for deuterium, the optimally a split ring resonator can be inserted

OUTLOOK

- Feedthroughs and excitation of stripline
- Coils vs. solenoid: if the coils are too close to each other, with not much accessible space, solenoid is still an option
- Simulation for line-shape with counter-propagating waves
- Higher order dipole effects
- Isolation of the microwaves: we have to restrict the microwaves exactly in the interaction zone

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