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Magnetometry with laser-cooled beryllium ions in ALPHA Antihydrogen Experiment

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In the ALPHA Experiment, laser-cooling of beryllium ions has been introduced to sympathetically cool positrons [1], which is anticipated to increase antihydrogen production [2]. Beryllium ions are generated through Pulsed Laser Ablation [3] and are trapped in the same Penning-Malmberg trap utilized for trapping and preparing antiproton and positron plasmas for antihydrogen synthesis. Cold beryllium ions may be employed for in-situ measurements of magnetic fields in the ALPHA antihydrogen traps. Magnetometry is critical for trapped antihydrogen research, particularly for antimatter gravity measurements conducted at high magnetic fields. As the precision of antihydrogen spectroscopy measurements increases, the uncertainty of the magnetic field will contribute more to systematic errors. Beryllium ion magnetometry presents a promising alternative to the currently used Electron Cyclotron Resonance (ECR) technique [4] and it requires no major hardware upgrades to the ALPHA apparatus.

The proposed method involves measuring an electron spin-flip transition frequency in the ground state of $^{9}Be^{+}$, which is highly sensitive to external magnetic field strength. The electron spin-flip transition can be induced by microwave radiation in a Rabi-style experiment and detected through fluorescence from a laser-cooling transition, analogous to an experiment performed at NIST with beryllium ions confined in a Penning trap [5]. An additional advantage of utilizing electron spin-flip in Be^{+} is its capability to characterize the strength of the microwave field within the ALPHA-2 trap. Microwaves are used in ALPHA Experiment to drive the ground-state hyperfine transition of the antihydrogen (positron spin-flip) [6] and the intensity of microwave field is known to vary inside the the ALPHA-2 Penning trap. Previously, estimates of microwave intensity inside the trap were determined using the ECR technique, which is sensitive to the microwave electric field component. Both positron spin-flip in antihydrogen and electron spin-flip in $^{9}Be^{+}$ are magnetic dipole transitions, enabling beryllium ions to characterize the magnetic field component of microwaves, which would enhance the measurement of hyperfine splitting in antihydrogen.

For the first time within the ALPHA apparatus, microwave-induced electron spin-flip in Be^{+} was observed. The precision of the external magnetic field measurement derived from this proof-of-principle study was comparable to the currently used Electron Cyclotron Resonance method, and there is potential for significant improvement.

[1] ALPHA Collaboration, Sympathetic cooling of positrons to cryogenic temperatures for antihydrogen production. Nat Commun 12, 6139 (2021). https://doi.org/10.1038/s41467-021-26086-1

[2] N. Madsen, F. Robicheaux, S. Jonsell, Antihydrogen trapping assisted by sympathetically cooled positrons. N. J. Phys. 16, 063046 (2014). https://doi.org/10.1088/1367-2630/16/6/063046

[3] Muhammed Sameed et al, Ion generation and loading of a Penning trap using pulsed laser ablation, 2020 New J. Phys. 22 013009 https://doi.org/10.1088/1367-2630/ab6066

[4] ALPHA Collaboration, In situ electromagnetic field diagnostics with an electron plasma in a Penning–Malmberg trap, 2014 New J. Phys. 16 013037 https://doi.org/10.1088/1367-2630/16/1/013037

[5] N. Shiga, W. M. Itano, and J. J. Bollinger, Diamagnetic correction to the 9Be+ ground-state hyperfine constant, Phys. Rev. A 84, 012510 (2011) https://doi.org/10.1103/PhysRevA.84.012510

[6] ALPHA Collaboration, Observation of the hyperfine spectrum of antihydrogen. Nature 548, 66–69 (2017). https://doi.org/10.1038/nature23446

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