Laser Control for the Production of Excited Positronium in GBAR

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GBAR - Grav. Behavior of Antihydrogen at Rest [1]

- Does antimatter fall just like matter?
  - Does it fall up or down?
  - Direct test of weak equivalence principle and baryon asymmetry.

- **Goal:** Produce positively charged antihydrogen ions.
  - Permits record cooling of antihydrogen to tens of μK.
  - More manipulatable than neutral antihydrogen.

A 3D diagram of the experiment and an image of the experimental zone.
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Making “H-Bar-Plus” via 2x Positron Capture

- Must produce positive antihydrogen via the “double-capture” of positrons from positronium.
- Excited positronium has a higher x-section than lone positrons or ground state positronium. [1]
- Must be excited shortly before capture.

\[
\bar{p} + Ps^* \rightarrow \bar{H}^* + e^- \\
\bar{H}^* + Ps^* \rightarrow \bar{H}^+ + e^-
\]
Preparing Excited Positronium

- Ortho-positronium (parallel spins, long lifetime ~142 ns) excited to the 3D state.
- Requires an intense light source to efficiently excite a large number of positronium.
- A pulsed laser precisely timed with the arrival of bunches of positronium provides this environment.

Positronium excited by 410 nm light from the ground state to the 3D state.
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Project Overview - Laser Control + Prep

- Developed several Python libraries for remote systems control.
- Frequency calibration of the beam
- Tested and calibrated beam stabilization
- Set up pre-chamber optics.
Remote Control of the Laser Hut

Devices now remotely accessible:
- Pulsed Laser (Quantel CFR-400)
- Wavemeter (HighFinesse WS/7)
- Oscilloscope (Tektronix MSO3014)
- More may be added easily
Frequency Calibration of CW IR Laser

- Monitored by a wavemeter (HighFinesse WS/7).
- Validated by comparing reported frequency to detected fluorescence of a cesium transition.
- Cesium transition could be used as an additional stabilizing mechanism.

We monitor the frequency several ways, this is critical for efficient production of positronium.
Stabilization of Transported Beam

- Stable beam transport from the laser hut to the reaction chamber is needed.
- These are not co-moving, alignment is always changing.

**Solution:**
- Position-sensitive photodiodes know when the beam moves.
- This error signal is sent to piezo-controlled mirrors that counters this movement.
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Recent post-reaction chamber optics

- Recently built the laser safety box for the experimental zone.
- Begin migrating optics from the test bench down to the experiment.
- Set up + calibrate the laser stabilization.
- Excite positronium!

(Left) Detection of positronium annihilation signal, confirmed by lifetime analysis.
Adventures @ CERN and in Switzerland
Thanks for listening!

Questions?

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References


Bonus slide: Optics details

- Combination of pulsed + CW green light pumps Ti-Sa crystals.
- Ti-Sapphire crystal produces infrared light.
- Infrared light is frequency-doubled to pulses of blue light.

Block diagram of the pulsed 410 nm system. [2]
Bonus slide: Why positronium?

- Higher x-section than a positron beam.
- You can practice with normal matter under identical conditions! Useful during LS2.

Antimatter:

Matter: