Solid-state continuous Lyman-alpha source for laser-cooling of antihydrogen and the prospect of antihydrogen gravity measurements

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Future high-resolution laser-spectroscopy of antihydrogen in a magnetic trap can provide very stringent tests of the fundamental symmetry between matter and antimatter (CPT symmetry). The extremely narrow 1S–2S two-photon transition is an excellent candidate for such experiments. However, the 1S–2S ($F = 1, m_F = 1 \rightarrow F = 1, m_F = 1$) transition frequency at 2466 THz has a residual dependence on the magnetic field of 186 kHz per Tesla. This will broaden and shift the spectral line of antihydrogen atoms in a magnetic trap. It will thus be very important to cool antihydrogen atoms, thereby reducing their spatial spread in the inhomogeneous magnetic field of the trap.

Laser cooling of antihydrogen to the milli-Kelvin temperature range can be done on the strong Lyman-alpha transition at 121.6 nm wavelength from the 1S ground state to the 2P excited state. Continuous coherent four-wave mixing can be used to generate radiation at Lyman-alpha. For this process, three laser-beams at 254 nm, 408 nm, and 545 nm wavelength generate a beam at the sum-frequency, using mercury vapor as a nonlinear optical medium.

At Mainz we are setting up a new continuous-wave coherent Lyman-alpha source which is based on solid-state laser-systems. The beam at 254 nm is generated by frequency-quadrupling the radiation of an Yb:YAG disk-laser in two enhancement cavities. Output powers of up to 1 W have been generated. The beam at 408 nm will come from frequency-doubling the radiation of a Titanium:Sapphire laser in an enhancement cavity. The beam at 545 nm is generated by frequency-doubling the radiation of an Yb fiber-laser in an enhancement cavity. Output powers of up to 4 W have been produced. The talk will discuss the status of the new Lyman-alpha source.

In addition to testing CPT at unprecedented levels of experimental precision with antihydrogen there is also the exciting chance to measure the gravitational acceleration of antihydrogen for the first time. Ultracold temperatures in the sub-millikelvin range are desirable for practical experiments. These temperatures are beyond standard laser-cooling limits for (anti-)hydrogen and ideas to cool antihydrogen atoms to ultracold temperatures will be discussed.