"Quantum logic spectroscopy and precision measurements"

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One of the most challenging goals of modern physics is the unification of all four forces and an explanation for dark matter, dark energy and many other experimental facts not contained in the standard model. Theories beyond the standard model typically allow for a variation of fundamental constants. Probing such a time variation might indicate which of the possible candidates provides the most appropriate description of our universe.

Quasar absorption spectroscopy is one approach to determine such a time variation. For this, absorption lines of atoms and molecules in inter-stellar clouds are compared with laboratory data. There are hints that e.g. the fine-structure constant had a different value in the early universe. However, the analysis is limited by the availability of accurate laboratory spectra.

I will report on the status of an experiment aimed towards obtaining more accurate spectral information on metal ions, such as Ca^+, Ti^+ and Fe^+ relevant to quasar absorption spectroscopy. Precision spectroscopy of atoms with a complex level structure is typically limited by the absence of an appropriate transition for laser cooling and detection. We overcome this restriction by trapping a so-called logic ion simultaneously with the spectroscopy ion to provide sympathetic cooling and detection. Spectroscopy is performed using an optical frequency comb that provides light for all transitions of interest. I will report on the development of a laser system for ground state cooling and coherent manipulation of the logic ion and present results on the simulation of direct frequency comb spectroscopy of calcium ions.

The presented techniques will also allow the deterministic preparation and precision spectroscopy of the internal state of molecular ions. This opens the door to investigate atoms and molecules with interesting properties that have resisted precision spectroscopy in the past.