

Challenging the quantum theory with ultra-accurate laser spectroscopy

We will develop an experimental setup that brings together some of the most advanced technologies in modern physics such as lasers of extraordinary precision, light-trapping devices called optical cavities, and extremely cold environments that will allow us to study molecules with greater accuracy than ever before. By carefully combining these tools, we aim to push the boundaries of how precisely we can measure the structure of the simplest molecules to test the predictions made by quantum theory.

At the core of our research is a deep question: How well does our current understanding of quantum physics hold up when we examine the smallest and simplest molecules in extreme detail? For example, the hydrogen molecule is the simplest molecule in nature whose structure can be calculated from the principles of the quantum theory extremely accurately. By measuring the energy of hydrogen's vibrations and rotations with unprecedented precision, we can directly test those predictions. If the theory matches reality perfectly, it will confirm some of the most advanced calculations ever made in physics. If not, it could point to new physics waiting to be discovered.

Beyond hydrogen molecule, we are also exploring slightly more complex molecules that are still simple enough to be modeled from first principles, but complex enough to reveal new physical behaviors. These molecules are important for understanding the foundations of chemistry. The technology we are developing has broad applications - from environmental science to fundamental physics - and the data we collect may help refine fundamental physical constants or uncover tiny effects revealing existence of new interactions in nature. In this way, our work connects cutting-edge laboratory science with some of the biggest questions in physics and nature.