



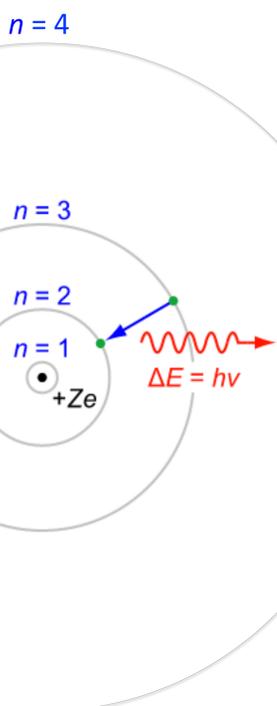
Using Laser Light to Excite Helium Atoms to High Energy States



Stony Brook University

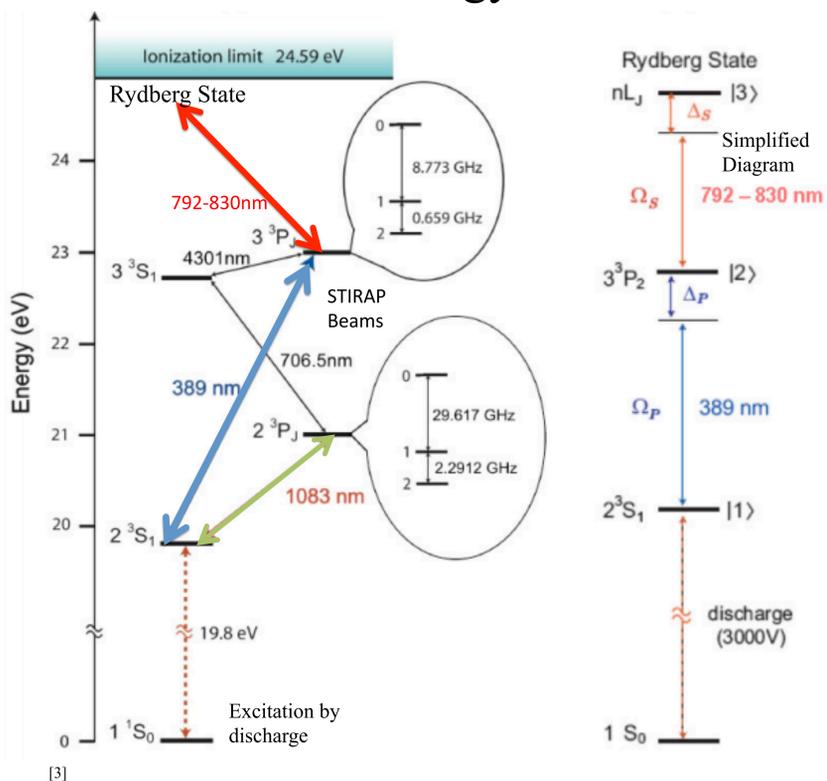
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Bohr Atom

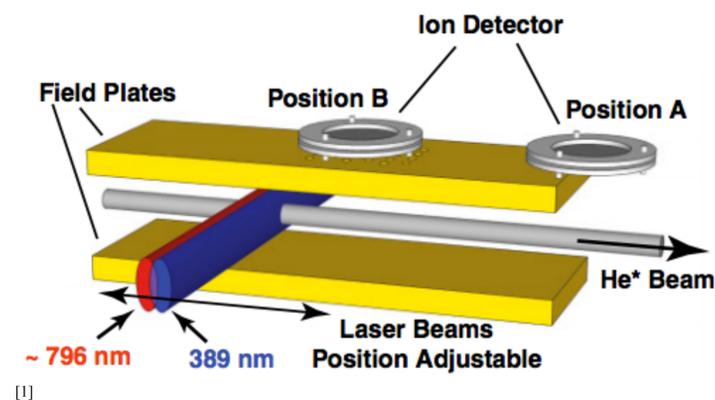


This is a diagram of Hydrogen as described by Neils Bohr in 1913. Note the increasing radial distance of each orbital as $r \propto n^2$

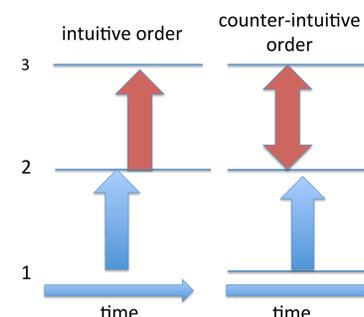
Helium Energy Levels



STIRAP



Stimulated Adiabatic Rapid Passage utilizes the counter-intuitive order to populate the third state



Atomic Physics

In 1888 Rydberg created a generalized version of Balmer's *simple empirical formula* for the wavelengths of the H atom. This is impressive because the structure of an atom was still being debated at this time.

We can then further expand our understanding of atoms by at Bohr's 1913 solar system-like picture to describe the Hydrogen Atom. This model corroborates the Rydberg formula and gives a basic picture to the structure of an atom.

Rydberg Atoms

A Rydberg atom is an excited atom with one or more electrons in a very high orbital n . The name is usually used when $n > 15$. Because of its large physical separation from the nucleus, the outer electron experiences a very weak attractive force from the nucleus and is therefore quite weakly bound to it.

These Rydberg atoms have several interesting properties.

- Exaggerated response to external electric and magnetic fields
- Under some conditions, the electron in the high n orbital behaves like a classical electron orbiting a nucleus
- Because of its huge size, $r \propto n^2$, the electron in the high energy state is actually quite fragile. This means we can remove it from its orbital by applying a voltage difference. This is how we measure how many Rydberg Atoms we have.
- Long lifetime

Due to these interesting properties, creating and studying Rydberg atoms has been the focus of many research projects in the past several decades.

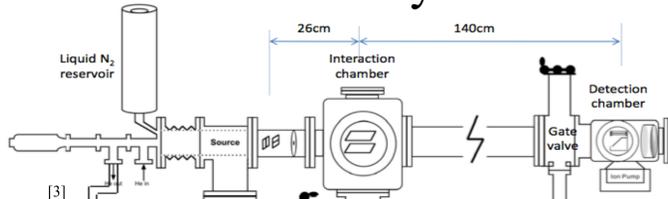
STIRAP

STIRAP, Stimulated Rapid Adiabatic Passage, is used in our experiments to excite atoms to Rydberg states with $n=15-50$. The theory of STIRAP describes how it can achieve 100% population transfer. This is possible because we effectively do not populate the intermediate state of the system if we use the counter-intuitive order. The counter-intuitive order means that the laser light associated with the 2 to 3 state transition interacts with the atomic beam before the light associated with the 1 to 2 transition. We excite an atomic beam of metastable state Helium (He^*) to Rydberg states by exploiting an intermediary state.

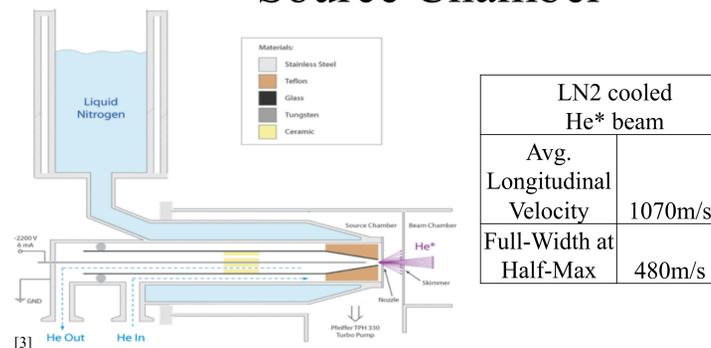
Figures from posters by :
[1] Xiaoxu Lu et al., Bull. Am. Phys. Soc. 55, No. 5, 119341 (2010) K1 00089
[2] Xiaoxu Lu et al., Bull. Am. Phys. Soc. 56, No. 5, 152 (2011) Q1 14.
[3] X. Lu, Ph.D. thesis, Stony Brook University, 2011
[4] Petr Anisimov et al., Bull. Am. Phys. Soc. 57, No. 5, 99 (2012) K1 19.

The Experimental Setup

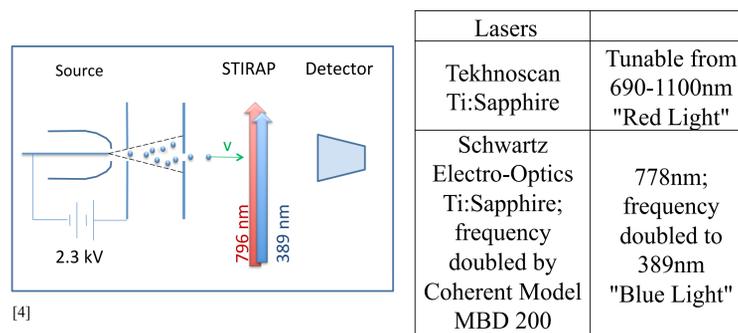
Vacuum System



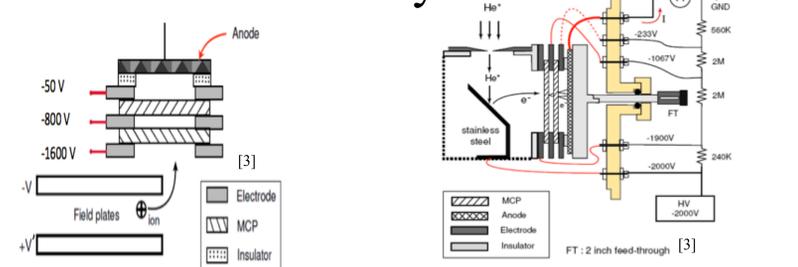
Source Chamber



Interaction Chamber



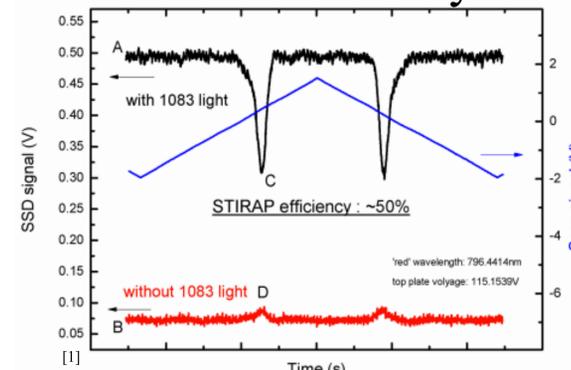
Detection Systems



Ion Detector-For Rydberg atom detection. Uses two microchannel plates (MCP) which amplify the original signal, gain is related to the electric field and geometry of MCP.

Stainless Steel Detector- The SSD uses two MCP's allowing us to detect electrons from the He^* . A He^* atom ejects an electron which results in a cascade of electrons from the MCP. We are able to move it perpendicular to the atomic beam giving us quantitative measurements on the atomic distribution.

Past Efficiency Measurements



These measurements show the efficiency of Rydberg Atom production as the He^* passes through the STIRAP light beams. This is done by deflecting all the unexcited He^* atoms using a laser of wavelength 1083 nm, after they pass through the STIRAP beam.

Theory suggests that we should be able to achieve 100% population transfer to the Rydberg state. Experimental results have only achieved ~50% population transfer. We believe this is due to the transverse velocity spread of atoms that results Doppler Shifting them out of resonance. Recent experiments have been conducted using optical molasses to decrease this velocity spread.