Evolution of Rydberg atom clouds in a linear magnetic trap

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Rydberg Atom Overview

- Large since $r \sim n^2$
- Long lifetimes, $\tau \sim n^3$ for low angular momentum, $n^5$ for high angular momentum
- Very susceptible to electric fields, $\alpha \sim n^7$
- Strong interaction with other Rydberg atoms and also with blackbody radiation
Experiment Development

- Long term goals:
  - Continuous BEC to outcouple for a continuous atom laser
  - Atom interferometry
- Current project has roots in detection of atoms in a linear guide without fluorescence
  - Fluorescence destroys all atoms in the guide
  - Field ionization is only destructive to atoms in the region of interest
Experimental Setup

- 1.5 m high-gradient linear magnetic guide
- $^{87}$Rb
- $T_{\perp} \approx 420 \, \mu$K
- $T_{\parallel} \approx 1 \, \text{mK}$
- Atoms in $|F=1, m_F=-1\rangle$
- Central volume density $10^9 \, \text{cm}^{-3}$
- $\Phi \approx 2 \times 10^7 \, \text{s}^{-1}$

![Diagram of experimental setup]
Excitation/Extraction Region

- Atoms excited $5S \rightarrow 5P$ then $5P \rightarrow nS$ or $nD$
- Control various electrodes to apply electric fields
- Variable delay time between excitation and extraction
- Image onto a micro-channel plate (MCP) and collect counts as a function of time
Collision of two Rydberg atoms can result in Penning ionization, given by

\[ \text{Ry}(n_0) + \text{Ry}(n_0) \rightarrow \text{Ry}(n) + \text{ion} + e^- \]

- Inelastic process
- Ionization energy is taken from one atom, leaving it in a lower-\(n\) state with higher angular momentum
  - Longer lifetime
Horizontal Electric Field Zeroing

0.7V/cm  0.96V/cm  
0.8V/cm  1.0V/cm  
0.9V/cm  1.1V/cm
Vertical Tomography

-0.5V/cm

-0.6125V/cm

-0.75V/cm
Sample Signal at 500 μs

- Rydberg field ionization signal
- Free ion signal
- Penning signal
Rydberg Guiding

![Graph and images showing signal counts over time with different extraction settings.](image-url)
Velocity = 1.11 m/s
Overview

- Rydberg interactions in a linear magnetic guide
  - Penning ionization
  - Thermal ionization
  - Guiding of Rydberg atoms

- Next steps
  - Continue studies on 59D
  - Compare 59D to 61S
  - Complete setup for new experimental apparatus
# Raithel Group

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