Buffer Gas Trapping of Low Magnetic Moment Atoms

Using a High Speed Cryovalue

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Motivation

Trapper’s Periodic Table

- Ablation and Thermalization (A)
- Pump-out of buffer gas (P)
- Trapped sample (T)
- Valve opening (V)
- Valve closing (C)
- Thin-walled plastic (W)

Advantages of buffer gas loading
- capable of cooling atoms and molecules regardless of optical properties
- shown to load large samples of atoms (>10^13)

Goal
- extend buffer gas loading to 1 uJ atoms and evaporatively cool from 1 K to quantum degeneracy

Calculations show Na [1], He [2], and N [3] have favorable collisional properties up to 1K

Na inelastic and elastic cross section, using 14 partial waves in the potential of Samuelli et al., PRA 63, 012710 (2001)

1) Ablation and Thermalization (A)

2) Pump-out of buffer gas (P)

3) Trapped sample (T)

Cell design
- Buffer gas stored in “reservoir”
- Trap volume ~ 300 cm^3
- Valve aperture ~ 2.3 cm diameter
- Cell pump out time ~ 35 ms
- Valve actuates in 15 ms
- Insulating G-10 cell prevents thermal conductivity
- Vacuum seals compressed by valve force

3.5 He film desorption
- 3He film desorption
- 5.5 x 10^11 atoms trapped
- Laser detuning (GHz)

Cut-away Schematic

Valve

Buffer gas reservoir

Ablation target

Cut-away Schematic

Main cryopump

Valve

Ablation target

Mirror

Thin-walled plastic

Window

Trapping Data

Time Profile of Ablation and Buffer Gas Pump-out

Data

Pump-out

Time Profile of Trapped Atoms

Number of trapped Atoms vs Time

Effective Magnetic Moment \(B\) of Sample

- Number of atoms > 10^13 for \(B\) 
- Ablated Cr thermalizes with 600 mK buffer gas
- Valve opens and buffer gas is pumped away
- Trapped Cr atoms decay by 2-body Rb-Cr relaxation

Number of trapped Atoms vs Temperature

Buffer Gas Base Temp [K]

- Laser detuning (GHz)
- Spectrum of trapped Cr in End Reservoir
- Maximum distribution in the magnetic trap
- 5 x 10^13 atoms trapped

Evaporatively cooled Cr

Laser detuning (GHz)

Data

Heat Temperature Loading Contour

- Similar to lowering the trap depth, hotter buffer gas temperatures increase the loss in the “hard” and “fringe” regions
- Lowering the temperature dramatically decreases the number trapped

Efficient Magnetic Moment \(B\)

- Data points mark the 10^9 atom trapping contour
- With the present low pressure processes, efficient trapping requires \(B > 10\)
- For large magnetic moment atoms, trapping can be achieved at temperatures > 1.4 K, reachable by simple pumped He systems

Achievements

- New trapping experiment that realizes the advantages of buffer gas cooling
- Large trapped samples, 10^9 - 10^13 atoms depending upon initial loading
- Universality of trapping species, trapping of 2 - 6 magnetic moment atoms
- Simpler cryogenics than previous buffer gas experiments
- Cryovalue greatly simplifies cryogenic requirements.
- Able to trap Cr atoms at \(T > 1.4\) K, reachable by pumped 4He systems.
- Evaporative cooling of trapped Cr from 600 mK to 24 mK
- Achieved good vacuum (one body lifetime > 1000 s) using cryo-bakeout.
- Characterized both wind and film loss processes affecting the efficiency of the buffer gas loading technique.

Future Work

- Coat cell walls with alkali metal thin film to prevent the formation of a He film, thereby eliminating film loss process
- With present performance, capable of trapping N (3 uJ) and He (2 uJ)
- Optimize buffer gas removal to efficiently load 1 uJ species
- Trap a large number (~10^12) of sodium atoms.
- Evaporatively cool to quantum degeneracy with 10^9 - 10^10 atoms.