# Efficient Entrainment of Lithium Atoms Into a Supersonic Beam and Magnetic Deceleration

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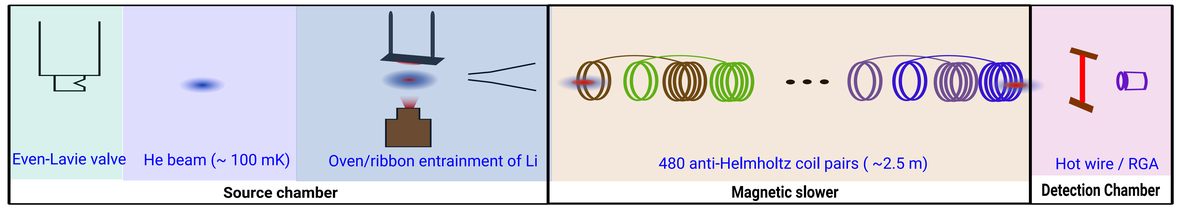
## 1. Introduction

We report our progress on the development of an alternative cooling method of neutral atoms, using alkali atoms as the benchmark to demonstrate this method. Our approach has the following advantages:

- Ultra-high atom flux per shot with low beam temperature.
- An Universal method which is applicable to atoms and molecules being paramagnetic. t
  Relies on magnetic force to remove the kinetic energy of atoms and molecules.

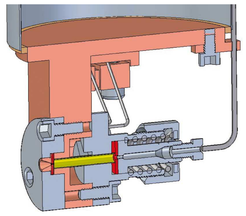
## 2. Overview of Experiment

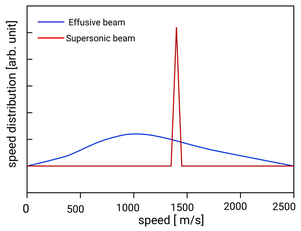



## 3. Even-Lavie Valve as a Source of Supersonic Carrier Gas

Beam temperature and atom flux are the two essential parameters. we relyon Even-Lavie valve as the beam source, which provides us:

- Low beam velocity divergence -- low beam temperature (100 mK)
- High atom flux -- $10^{17}$atoms / pulse



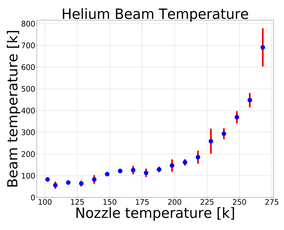


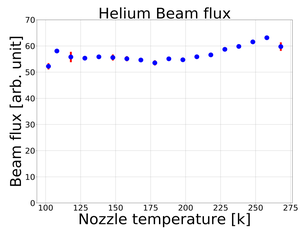

There are two main prarameters of Even-Lavie valve can be tuned to optimize the beam quality: gas stagnation pressure and nozzle temperature.

Beam parallel temperature:

$$T_{\parallel} = T_0(1+\tfrac{2}{5}S^2)^{-1}$$

$$S = 2\sqrt{ln2}\frac{t_0}{FWHM}$$

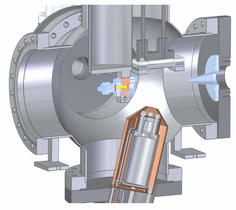


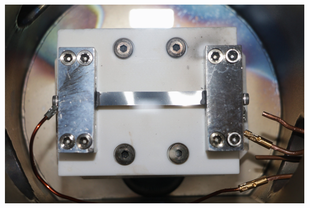




Clustering and skimmer transmission are the main limitation for achieveing beam with lower temperatures and higher flux, we chose the operating stagnation pressure 300 psi and temperature 100 K of Even-Lavie valve to optimize the beam quality.

## 4. Entrainment of Lithium Atoms Into Helium Carrier Beam

Goal: entrain Li atoms into He carrier gas by collision and maximize the number



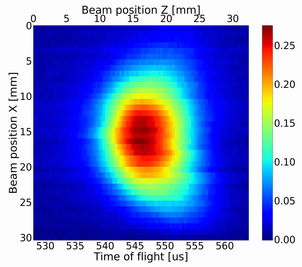


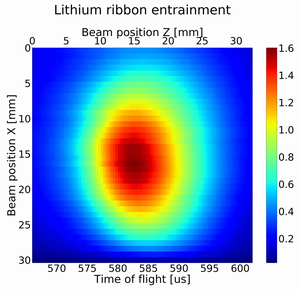
Lithium oven entrainment

### A. Oven entrainment

- Lithium oven temperature: 550C.
- Limitation: low efficiency, as a DC source. 99% of lithium atoms coming out from oven are wasted.

Result: $3.4 \times 10^{10}\ ^7Li$ atoms/pulse




### B. Ribbon assisted entrainment

- Ribbon material: Nichrome
- Peak current: 1000 A
- Pulse length: 80 μs
- Peak temperature: ~ 900 C

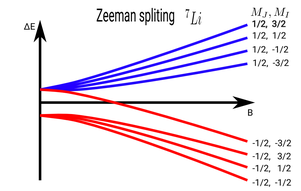
Result: $6.0 \times 10^{11}\ ^7Li$ atom/pulse

The nichrome ribbon is heated up by a 1000 ampere current pulse from a charged capacitor bank. The pulse is drived by a high power Insulated Gate Bipolar Transistor (IGBT).

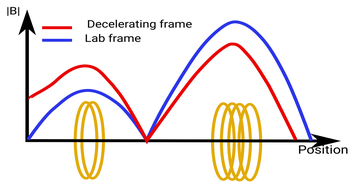
## 5. Magnetic Deceleration of Lithium Atoms

### A. General idea:

- Li beam travels at 500 m/s in the lab frame. We use moving magnetic trap to decelerate it while keep the high atom flux and low temperature properities.
- Atoms in the low-field-seeking states are trapped at the field minimium of anti-Helmholtz coils.
- Through individually controlling the time sequence of spatially overlapped 480 traps we control the final speed of the beam.



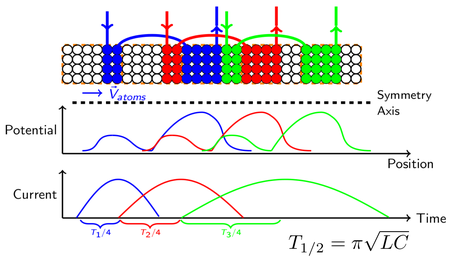

### B. Magnetic field in the decelerating frame




•The magnetic fieldi n the decelerating frame is 'tilted' given by:

$$B_{dec} = B_{lab} \pm \frac{MaL}{2\mu_B g_J m_J}$$

•To compensate this, we use asymmetric coil windings




### C. Magnetic field generation

- We generate magnetic field of 0.8 T at front peak and 0.3 T at back peak by 500 A half sine wave current pulses.
- We can freely tune the generated current pulses of individual coils from 20 μs to 200 μs , which corresponding to velocity from 500 m/s to 50 m/s with trap depth of 300 mK.

### D. Electronics

- Various of current pulse lenghs are generated by chosing corresponding discharging capacitors and inductors
- Capacitors and inductors are in binary values, controlled by Field Programmable Gate Array (FPGA).
- These 480 coils are powered by cycling through 10 sets of circuit boards.

## Acknowledgment

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## References

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