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PROPOSAL FOR A PULSED LITHIUM BEAM POLARIZED TARGET*

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We propose a new method of increasing the density of a polarized atomic beam target by use of a pulsed atomic beam. In this method a beam of atoms is continuously deposited on the surface of a rotating disk. A high-power pulsed laser is then used to vaporize the condensed atoms at a spot on the disk. From the resulting burst of gas a second atomic beam is formed which may be polarized by the same methods used for dc beams.

In contrast to cryogenic targets, atomic beam targets may be polarized quite easily to high values, the polarization can be reversed rapidly, and the background contamination in a scattering experiment is very low.[1] Presently, the major limitation of polarized atomic beam targets is the low target density.

Generally atomic beams are polarized by first separating the electronic spin states in the inhomogeneous field of a multi-pole magnet, after which the desired vector and/or tensor polarization can be produced by inducing the appropriate rf transitions as the state-selected beam traverses a dc magnetic field.[2] In a crossed-beams experiment, target densities of $\sim 10^{11}$ particles/cm^2 could be expected using a high intensity atomic beam source. Such a source has been operated extensively at SLAC as part of the Yale/SLAC polarized electron gun.[3] The source produces a continuous state-selected ^{6}Li atomic beam 0.6 cm in diameter with an intensity of 10^{16} particles/s and an electronic polarization of 92%. Since the particles in the beam have a velocity of $\sim 2 \times 10^5$ cm/s, a target density as high as 10^{11} particles/cm^2 is available.

There are several ways in which the density of an atomic beam target can be increased. An enhancement of as much as 10^2 beyond that expected for a crossed-beams arrangement might be achieved in a co-linear beams experiment. An altogether different technique in which the polarized particles are stored on a surface ionizer has been used by the Hamburg group[4] to achieve an enhancement of $\sim 10^5$. Using a similar technique and a ^{6}Li atomic beam of the Yale/SLAC design, the Argonne/Stanford group[5] expects to achieve a target density of $\sim 10^{15}$ particles/cm^2. Densities for the pulsed beam target proposed here are estimated to be of similar magnitude.

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A schematic diagram of the target proposed here is shown in Fig. 1. In operation a ring of Li with a radial width of 2-3 mm is deposited on the oven side of the rotating disk. A high-power pulsed laser with a beam diameter of ~2 mm is used to vaporize the Li from a spot on the disk away from the oven beam. The phase of the angular velocity of the disk is made to change continuously so that the laser eventually hits all points on the disk at the radius of the Li ring. A pulsed atomic beam is formed by collimating the laser-vaporized Li atoms in the conventional manner.

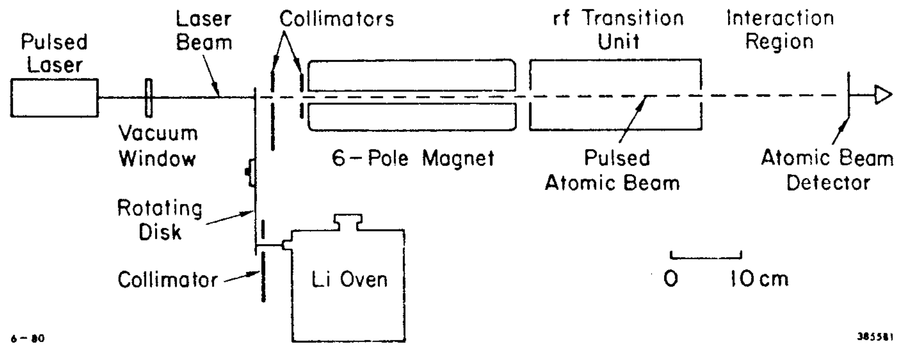

Fig. 1. Schematic diagram of pulsed beam polarized target. The dimensions are to scale except the i.d. of the beam defining orifices are as follows: oven orifice and oven beam collimator, 1.7 mm and 2 mm; laser beam (o.d.), pulsed beam collimators (2), and magnet gap, 2 mm, 2.2 mm, 3.8 mm, and 6.3 mm.

Since Li is being deposited continuously on the rotating disk while the final beam is pulsed, the peak intensity of the pulsed beam, I_{pulsed}, can in principle be far greater than that of a dc beam, I_{dc}, produced by the same atomic source. An enhancement factor F can be defined as $F \equiv I_{pulsed}/I_{dc}$. If I is the total number of particles/s emanating from the oven, d is the duty factor of the pulsed target (product of pulse width, W, and repetition rate, R), then $I_{pulsed} = I\epsilon_1\epsilon_2/d$ and $I_{dc} = I\epsilon_3$, where ϵ_1, ϵ_2, and ϵ_3 are the collimator efficiencies for the initial and final beams of the pulsed target and for the dc target respectively. Since it is assumed that $\epsilon_2 = \epsilon_3$, the enhancement is given by $F = \epsilon_1/d$. The rotating disk can be placed immediately behind the single collimator of the initial beam of the pulsed target. Thus ϵ_1 is taken to be the solid angle subtended by the collimator (5×10^{-3} sr) divided by 2π sr. Consequently F is greater than unity when the duty factor is $d < 10^{-3}$.

At the surface of the rotating disk the number of particles vaporized per pulse is given by $N = (Id_c/\epsilon_3)\epsilon_1 FW = (Id_c/\epsilon_3)\epsilon_1^2/R$. By using the Yale/SLAC source for which $I_{dc} \sim 2 \times 10^{16}$ particles/s and $\epsilon_3 = 10^{-4}$, a value of $N = 2 \times 10^{14}/R$ particles/pulse is expected. In comparison, as many as 10^{17} particles/pulse have been produced from thin metal films deposited on microscope slides using a 1 J, 80 ns laser pulse of 2 mm diameter.[6] Consequently the target should be operable at very low repetition rates. High intensities are produced by short pulse widths as well as low repetition rates. At a practical rate of 1 pulse/s, a pulse width of 80 ns gives an enhancement factor of $F \sim 10^4$.

The density of the proposed pulsed target is $\sim 10^{11}$ $F\kappa$ particles/cm^2, where κ is a factor which accounts for any difference in mean velocity between particles in the final and initial beams of the pulsed target. Based on the mean velocities measured for laser vaporized particles,[7] κ is expected to be between 0.1 and 1.

The practical realization of a high intensity pulsed target depends on the as yet unknown limitations due to beam-beam scattering and clogging of the multi-pole magnet. The latter problem could be avoided by using optical pumping to polarize the atomic beam.[8]

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