Target Isotope	Natural Abundance	Laser λ (nm)	Ground State	Guiding Length (m)	Enrich-ment	Collected Isotope %
^{6}Li	7.6%	670.96	$^{2}S_{1/2}$	Quad. 0.5	95.0%	36.8%
^{44}Ca	2.1%	272.2	$^{1}S_{0}$	Hex. 2.0	99.9%	9.0%
^{150}Nd	5.6%	471.9	$^{5}I_{4}$	Hex. 2.0	97.9%	23.0%

TABLE I: Simulation results of isotope separation from single-photon atomic sorting.

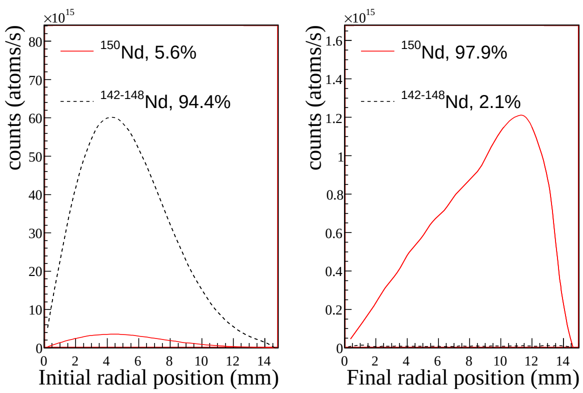

FIG. 5: The radial positions of the neodymium isotopes as they enter the magnetic gradient that separates them isotopically, followed by their radial positions upon exiting.

hexapole magnetic field was a 2 m long tube like the one described for ^{44}Ca but without the bend. Similar separation results can be achieved using a 1.8 m long tube with a slight 1 cm bend to aid in eliminating unwanted isotopes. The precise shape of this bend could be further tuned to achieve the optimal separation geometry.

The isotope ^{150}Nd is of particular interest because it is a double-beta emitter. Many experiments are currently investigating neutrinoless double beta decay in order to determine the neutrino mass and whether neutrinos are Dirac or Majorana particles [17]. SNO+ is one such experiment currently under development, and it plans to use a large amount of enriched neodymium to search for neutrinoless double beta decay [18]. Enriching neodymium is very difficult and can currently only be done using the atomic vapor laser isotope separation technique [19]. Hopefully this simpler approach can aid in the separation of ^{150}Nd, as well as other isotopes of interest to physics, medicine, and industry.

In conclusion, we have presented single-photon atomic sorting as a very general and scalable approach to isotope separation. The efficiency of separation is such that every photon in the laser can provide one atom of isotopic interest. The laser can be recycled in a multi-pass configuration until it is depleted. To put that in perspective, a laser with 1 Watt power could separate approximately 10^{19} atoms per second, or roughly 500 Moles per year. A supersonic beam can be operated in a continuous mode, and the flux is limited only by available vacuum pump speed. Diffusion pumps are available with pumping speeds of over 60,000 L/s, so that large scale separation seems feasible. The next step will be a first experimental demonstration of single-photon atomic sorting.

M.G.R. acknowledges support from the State of Texas Advanced Research Program and the Sid W. Richardson Foundation.

[1] J. W. Beams and F. B. Haynes, Phys. Rev. **50**, 491 (1936).
[2] W. W. Watson, Phys. Rev. **56**, 703 (1939).
[3] W. H. Furry, R. C. Jones, and L. Onsager, Phys. Rev. **55**, 1083 (1939).
[4] R. J. Bartlett and J. R. Morrey, US Patent 4,105,921, August 8 (1978).
[5] A. O. Nier Phys. Rev. **52**, 933 (1937).
[6] L. Love Science **182**, 343 (1973).
[7] P. A. Bokhan *et al.*, *Laser Isotope Separation in Atomic Vapor*, WILEY-VCH Verlag GmbH & Co. KGaA, Weinheim, (2006).
[8] Ralchenko, Yu., Kramida, A.E., Reader, J., and NIST ASD Team (2008) *NIST Atomic Spectra Database (version 3.1.5)*, [Online] Available: http://physics.nist.gov/asd3. National Institute of Standards and Technology, Gaithersburg, MD.
[9] M. G. Raizen, Science **324**, 1403 (2009).
[10] A. Amirav and U. Even, J. Appl. Phys. **51**, 1 (1980).
[11] W. A. van Wijngaarden and J. Li, Phys. Rev. A **49**, 1158 (1994).
[12] G. Scoles, ed. *Atomic and Molecular Beam Methods*, Oxford University Press, New York, Vol. 1 and 2, (2000).
[13] U. Even, M. Hillenkamp, and S. Keinan, J. Chem. Phys., **118**, 8699 (2003).
[14] R. D. Swenumson and U. Even, Rev. Sci. Instrum. **52**, 559 (1980).
[15] U. Even and M. G. Raizen, in preparation.
[16] V. N. Gorshkov *et al.*, Astrophysics **17**, 437 (1982).
[17] S. Elliot and J. Engel, J. Phys. G **30**, R183 (2004).
[18] SNO+, K. Zuber *et al.*, AIP Conf. Proc. **942**, 101 (2007).
[19] S. K. Kovalevich, V. P. Labozin, and G. O. Tsvetkov, Tech. Phys. **50**, 96 (2005).
[20] K.C. Kuiper, MS. thesis, Eindhoven University of Technology (2007).
[21] J. P. Beardmore, A. J. Palmer, K. C. Kuiper, and R. T. Sang, Rev. Sci. Intrum., **80**, 073105 (2009).
[22] W. G. Kaenders *et al.*, Phys. Rev. A **54**, 5067 (1996).