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Validation of optically polarized alkali metal atoms for muonic helium measurements

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Muonic helium is an exotic atom with one of the two electrons replaced by a negative muon. This three-body atomic system provides opportunities to precisely study the negative muon magnetic moment and mass as well as bound-state QED through the hyperfine structure interval. Muonic helium atoms are formed by stopping a negative muon beam in dense helium gas. Although the muon beam is primarily spin-aligned, the resulting muonic helium atoms lose their polarization by a factor of ten or more in the capturing process. The muon spins can, however, be repolarized by spin-exchange collisions with polarized alkali metal atoms [1], which is essentially the same as spin-exchange optical pumping used to polarize noble gas nuclei [2]. This experiment is now underway at the J-PARC Muon Science Facility (MUSE) [3]. To efficiently repolarize muonic helium atoms, it is essential to maximize the number of spin-polarized alkali metal atoms by optimizing the optical pumping conditions. The alkali metal state can be spectroscopically validated with a wavelength tunable laser. We have recently developed a probe laser that covers a wide wavelength range from 762 nm to 790 nm. It successfully accommodates the K D2 line (766.701 nm), K D1 line (770.108 nm), and Rb D2 line (780.241 nm) so that their absorption spectra and other properties can be studied at the same time and in the same condition. We present our newly developed wavelength tunable laser and some spectral measurements that evaluate the number densities and polarizations of alkali metal atoms. [1] A. S. Barton et al., Phys. Rev. Lett. 70, 758 (1993). [2] T.R. Gentile, P.J. Nacher, B. Saam, and T.G. Walker, Rev. Mod. Phys. 89, 045004 (2017). [3] P. Strasser et al., Eur. Phys. J. D 79, 20 (2025).

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