Laser ionization of muonium for low-energy muon source

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We have been developing a low-energy muon source at RIKEN-RAL muon facility [1,2]. Polarized muon beam has been used as a unique and powerful tool to investigate magnetic properties or spin fluctuation of materials using a technique called μSR [3]. The kinetic energy of muons available for such purpose at accelerator facilities like ISIS, TRIUMF and PSI is 4 MeV or above. This determines the stopping range of muon in a solid to typically a few tenths of mm or above. Our goal is to extend the scope of the μSR technique to nano-scale system like thin film, multi-layers, and inter-layers by providing a polarized muon beam whose kinetic energy can be varied from a few eV to a few tens keV. Our method to generate such beam is based on the fact that a large fraction of muons stopped in a heated tungsten film are re-emitted into a vacuum as muonium (μ^+e^-) atoms [4]. By ionizing muonium atoms, we obtain polarized muons which have thermal energy of around 0.2eV. We then accelerate them to desired energy in an electrostatic field in order to control their implantation depth.

The essential to this method is an efficient way for ionizing muonium atoms. For that purpose, we have developed a pulsed laser system which generates Lyman-α radiation to excite a muonium atom from 1S ground state to 2P state. The muonium atom is then ionized from 2P state by a 355nm photon generated as a third harmonic of an Nd:YAG laser. The Lyman–α photon is generated using a four-wave sum-difference frequency mixing technique in Kr gas.

Currently we observe around 15 low-energy muons per second. Overall efficiency to convert 4-MeV muon beam to 10-keV muon beam is around $3\text{x}10^{-5}$, which is about same as the other method developed at PSI [5]. We anticipate large increase of the conversion efficiency in the future, as we see no sign of saturation of muon yield as laser power increases.

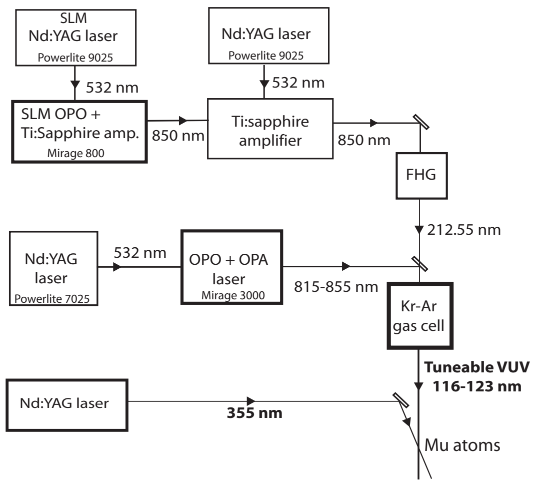

Figure 1: Schematic of the laser system

References

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