A gas-filled cryogenic Radio-Frequency Quadrupole (RFQ) ion beam cooler for laser photodetachment at GUNILLA

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Laser photodetachment threshold spectroscopy (LPT) [1] has been commonly employed in studies of negative ions at Gothenburg University Negative Ion Laser LAboratory (GUNILLA), where photodetachment cross sections are measured by recording the number of neutral atoms produced as a function of photon energy in a laser-ion merged-beams format. In recent years, ion beam bunchers based on a gas-filled linear Radio-Frequency Quadrupole (RFQ) traps have become a standard tool to improve beam quality, i.e. good emittance/low energy spread [2]. For continuous-beam experiments as performed at GUNILLA, a single-pass cooling scheme is more advantageous, which has been successfully developed and applied for isobar suppression in Accelerator Mass Spectrometry (AMS) at the world leading facility VERA (Vienna Environmental Research Accelerator) [3]. Another advantage of ion cooling is an increased photon-ion interaction time, which may significantly enhance the photodetachment efficiency. This will also greatly reduce the experimental uncertainties. In the goal of a breakthrough in photon-ion experiments, implementation of a cryogenic RFQ ion beam cooler using helium buffer gas is proposed.

This cooler will first reduce the kinetic energy of negative ions down to the few eV range by means of electrostatic deceleration. Negative ions then undergo multiple collisions with high purity buffer gas inside the quadrupole, eventually equilibrate to an energy that corresponds to the temperature of the buffer gas. The RF field in the quadrupole will create a transversal average trapping potential that forces the ions close to the central axis of the quadrupole. Additional four tapered electrodes between the RF rods provide a small gradient field to guide the ions downstream through the cooler.

The whole system will be operating at a cryogenic temperature (10 K or even less) in order to achieve a very low velocity spread of the ions and a smaller beam diameter. The helium pressure inside the RFQ cooler will be of the order of 0.1 mbar. To limit losses via collisional detachment, high-vacuum conditions are preserved immediately before and after the RFQ cooling section. Thus, a multi-stage differential pumping system with several skimmer diaphragms and high gas throughput will be implemented. This will also serve as a thermal shielding for the central interaction region.

The RF setup will have two resonant circuits coiled in opposite direction driven via a ferrite transformer by a 200 W RF power amplifier and a function generator. A binary set of 9 purpose-built switchable inductors ensures resonance conditions for different frequency tunings. It may achieve zero-to-peak voltages of around 400 V in the frequency range of 1.2–6 MHz, thus, allow optimal cooling of ions with masses between 14 and 350 u. For ions outside this mass range, the RF-voltage has to be adjusted accordingly.

Detail design of the cooler will be presented in this work. Furthermore, the possibility of utilizing such a cooler in the injection beamlines of DESIRREE will be discussed.

References

[1] D. Hanstorp, *Nucl. Inst. Methods Phys. Res. B* vol. **100**, no. 1, pp. 165-175 (1995).
[2] R. Wester, *J. Phys. B* **42**, 154001, 2009
[3] M. Martschini *et al*., *Int. J. Mass Spectrom.* **415**, 9, 2017

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