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IMPROVED FOUR-STAGE ACCEL-DECEL PRODUCTION OF LOW-ENERGY HIGHLY STRIPPED HEAVY IONS

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Summary

The two model MP Tandem Van de Graaff accelerators at Brookhaven have been used in a four-stage accel-decel configuration to produce highly stripped low energy heavy ions.[1] The performance in this mode of operation has now been substantially improved by modifications of the second accelerator. The inclined field acceleration tube electrodes at the exit of this accelerator were replaced by straight electrodes, the vacuum was improved and the maximum negative terminal potential was increased. Higher intensity beams of heavier highly stripped ions can now be produced at lower energies than before.

Introduction

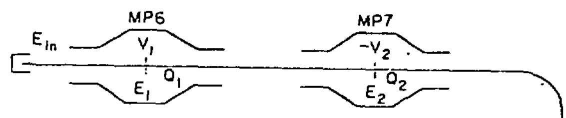
Atomic-collision experiments using highly stripped low velocity heavy-ions are of great interest both for basic atomic physics studies as well as for important applied work. Examples of these types of research are given elsewhere in these proceedings.[2] A convenient method of producing variable energy beams of such ions is to first accelerate lower charge ions to velocities sufficiently high so that the desired charge state can be produced by electron stripping in a thin foil, and then to decelerate the resulting ions to the desired final energy. Electrostatic accelerators are particularly suitable for this kind of operation due to their excellent energy stability and variability and due to the fact that DC fields are used, thus avoiding low velocity limitations imposed by radio frequency phasing problems in other types of accelerators.

The production of low energy highly stripped ions with electrostatic accelerators was first demonstrated at Pittsburgh[3] where their two model EN tandem accelerators were used in a three-stage configuration. At the Brookhaven double MP facility, a four-stage configuration has been implemented[1] in which three stages of acceleration are followed by one stage of deceleration as shown in Fig. 1. The last stripping takes place at much higher energies and therefore higher charge states can be reached. A detailed discussion of this mode of operation was given in Ref. 1. Here, recent improvements relevant to four-stage operation will be described and some plans for future developments will be mentioned.

Vacuum Improvements

The vacuum in the acceleration tubes was previously maintained by vacuum pumps located at both ends and inside of the high voltage terminal of each accelerator. Due to the low vacuum conductance of the acceleration tubes the vacuum at points far removed from the pumps was poor enough to affect the heavy ion transmission of the accelerators. This problem becomes especially important for low energy highly stripped ions because the electron pick-up cross sections increase rapidly as the energy is lowered.

The vacuum in the acceleration tubes was improved by the installation of additional ion pumps between the high voltage terminals and the ends of the accelerators. In particular, the most critical region from the four-stage operation point of view, namely the deceleration stage, was provided with three additional ion-pumps in the three field-free regions along the acceleration tube. Power driveshaft systems consisting of motors at ground potential driving generators at each pump location through insulating plexiglass shafts were provided to power the vacuum pumps.



$$E_1 = V_1 + E_{in}$$
$$E_2 = V_1 + Q_1(V_1 + V_2) + E_{in}$$
$$E_f = V_1 + Q_1(V_1 + V_2) - Q_2V_2 + E_{in}$$

Fig. 1 Schematic diagram of the two accelerators MP6 and MP7 coupled into the four-stage accel-decel configuration. Negative ions leaving the injector with an energy E_{in} are accelerated to the positive potential V_1 where they reach an energy E_1 and are stripped to a charge state Q_1. These positive ions are then accelerated to ground potential and further accelerated to the negative potential $-V_2$ of the high voltage terminal in the second accelerator. There the energy is E_2 and charge state Q_2 is reached by stripping in a second carbon foil. These highly charged ions are then decelerated to the final energy E_f and separated from other beam components by means of a 90° analyzing magnet.

Increase of Maximum Terminal Voltages

In order to obtain the highest possible charge states, the second stripping must take place at the highest possible energy (E2 in Fig. 1). This energy can be increased by increasing the voltage, V1 of the first accelerator, or V2 of the second accelerator. But V1 and V2 cannot be varied independently; they have to be adjusted appropriately to yield the desired final energy, E_f. The voltage capabilities of both accelerators have been increased by improving the electrostatic configuration of the high-voltage terminals. This was done by installing smooth appropriately shaped stainless steel shields replacing the standard parallel-bar cage. This change was especially effective for the second accelerator which can now reach -12 MV while it could previously only reach about -9 MV.

Also, the acceleration tubes in the second accelerator have been lengthened so that they now protrude into previously field-free regions of the column. Consequently, with the same acceleration tube gradient higher terminal voltages can be reached. For negative operation, the acceleration tube gradient is not the limiting factor and therefore the tube extension in itself is not of great importance for the four-stage mode. However, the tube extension permitted the introduction of a modification specially designed to improve four-stage operation. This special modification is described in the next section.