Progress on the light ion guide project

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The Light Ion Guide will produce radioactive ion beams [1] using the well-established technique of the helium-jet method. The primary beam impinging on a production target produces ionized, radioactive products that are stopped and trapped in helium gas. These ions are transported by the helium flow through an aperture where after a small acceleration they immediately encounter an RF-only sextupole ion guide that confines them further along its length allowing the helium to be pumped away before accelerating toward the Charge Breeding ECR Ion Source (CB-ECRIS). The CB-ECRIS will change the initial charge-state of the radioactive ions to higher charge states appropriate for reacceleration by the K500 cyclotron.

After proving the charge-breeding capabilities of CB-ECRIS [2] and determining parameters for the injection of the initial beam into CB-ECRIS, our efforts were directed to the coupling of the Light Ion Guide assembly with CB-ECRIS. The 1 meter long RF-only sextupole was installed, and a gas cell was built for the first on-line experiments. An extraction assembly after the RF-only sextupole was also mounted consisting of a plate with a 4 mm hole followed by a tube and an Einzel lens assembly. The tube was deemed necessary to further shape the electric field.

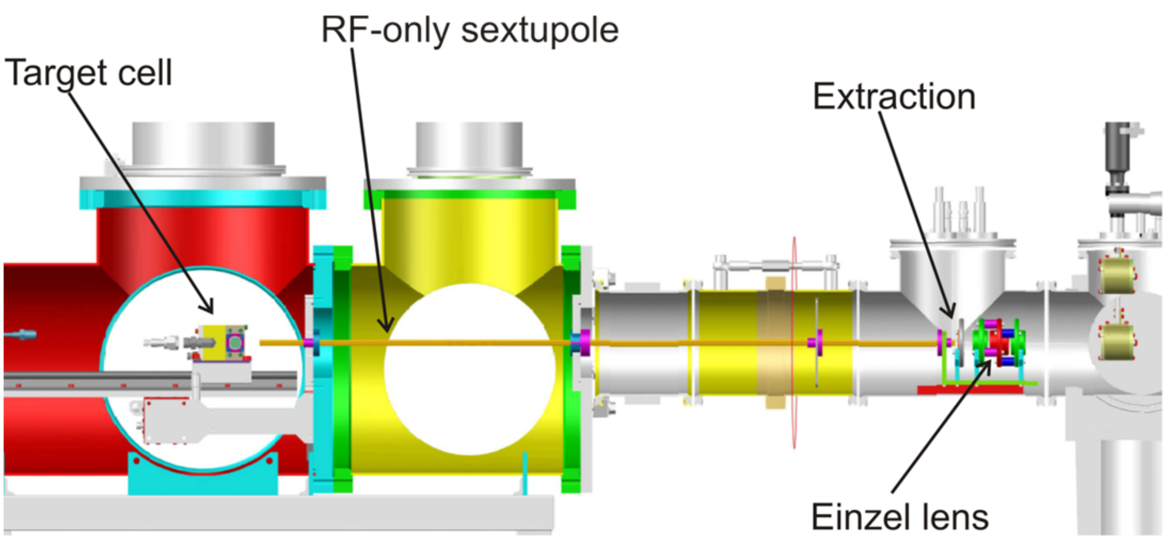

FIG. 1. View of the Light Ion Guide including the target chamber, the 1 meter long RF-only sextupole and the extraction part.

A series of experiments were performed with this configuration using a ^{228}Th radioactive source. We collected radioactivity as well as measured the current of ions coming from the target cell while also determining parameters for the operation of the Light Ion Guide. We found that once the CB-ECRIS was switched on, back-streaming beam from CB-ECRIS charged up the extraction part of the Light Ion Guide making difficult to transport any beam towards CB-ECRIS. Corrective measures were taken by replacing unnecessary plastic parts with metallic parts, reducing the size of some plastic parts and reducing the exposure of the extraction parts to the back-streaming beam by placing shielding plates inside the beam pipe. Placing permanent magnets around the beam pipe also helped because the electrons coming from the back-streaming ion beam hitting Einzel lens components are deflected by the magnetic field and are thus prevented from depositing charge onto the plastic support parts.

The first on-line experiments were performed with a ^{16}O beam, a ^{12}C beam and an alpha beam at the energy of 6.3 MeV/A and with a proton beam at 15 MeV energy. In the first two experiments we were focused on optimizing the secondary beam transport conditions and reducing the charging effect at the operation of the CB-ECRIS. The first attempts to charge-breed stable beams were unsuccessful raising again questions about the initial beam injection into CB-ECRIS. The proton beam was used to produce ^{64}Ga via the $^{nat}Zn(p,n)^{64}Ga$ reaction. The ^{64}Ga production cross-section is about 170 mbarn at 14.1 MeV proton beam energy providing sufficient yield to verify the functioning of the target cell. Two exit holes were used for the target cell: 1 mm and 2 mm diameter. A small collection plate was installed directly in front of the target cell and positive or negative voltage was applied to it; positive voltage repels ions and negative voltage attracts ions to the plate. After 15 minutes of collection time, the plate was placed in front of a Germanium detector for a 30 minutes and the gamma line of 991 KeV was recorded to establish the percentage of the ions out of the total radioactivity collected. Table I summarizes the findings of these measurements and shows very high efficiency in the production of radioactive ^{64}Ga ions using the 2 mm hole.

Table I. Peak integral of ^{64}Ga 991 keV line and ion percentage production for 1 mm and 2 mm hole.

		991 KeV line – peak integral		
	I_p[nA]	Collection plate voltage -100 V	Collection plate voltage +100 V	Ion percentage
1 mm hole	7	106	58	45 %
	90	1100	781	29 %
	650	9213	8133	12 %
2 mm hole	65	2013	148	93 %
	500	14715	1434	90 %

The transport of the radioactive ions through the RF-only sextupole was not successful; however stable ion beams were transported. Our initial explanation is that the radioactive ions are quickly neutralized by the electrons coming from the primary beam interacting with the target cell windows. In the initial 80 mm distance, the radioactive ions are confined inside the RF-only sextupole but the rods are completely exposed and electrons will be attracted to the positively charged rods increasing the probability of the ions being neutralized. Most probably the stable ions suffer the same interaction, but their number being larger, we still can measure them. In the future, the solution to this problem will be the construction of a new RF-only sextupole with a better shielding and much higher acceptance.

[1] G. Tabacaru, D.P. May, and J. Arje, Proceedings of ECRIS2010, Grenoble, France http://accelconf.web.cern.ch/AccelConf/ECRIS2010/papers/proceed.pdf, MOPOT10

[2] G. Tabacaru, J. Arje, and D.P. May, *Progress in Research*, Cyclotron Instiute, Texas A&M University (2012-2013), p. IV-23; http://cyclotron.tamu.edu/2013%20Progress%20Report/4%20Superconducting%20Cyclotron,%20Instrumentation%20and%20RIB%20Upgrade/IV_2325_oper_progress%20on%20charge%20breeder.pdf