USE OF ELECTROSTATIC GRIDDED LENSES IN THE LASER ION SOURCE AT CERN

V.Derbilov, P.Ostroumov; H.Kugler*, N.Lisi*, C.Meyer*, R.Scrivens*
INR RAS, Moscow, Russia; *CERN, Geneva, CH

For the transport and focusing of the LIS 60 kV and 60 mA multi-charge beam to the acceptance of the RFQ the gridded electrostatic lenses (GEL) have been proposed. Main features of the gridded lenses are:

- Simple and cheap performance;
- Stronger focusing in comparison with solenoids or standard Einzel lenses [1];
- There is no any type of aberrations (no aberrations have been observed in simulation of relatively large emittances ~200–320 π·mm·mrad).
- The secondary electrons are removed from the ion beam occupation area, it must help to stable transport of ion beam through LEBT.

As a grid the W-Re wires with 50 μm diameter have been used. The grid has been designed as a rectangular net of wires with 4 mm and 3 mm inter-wire space. Four-grid GEL system has a transparency of 94%. The own grid does not produce any emittance growth. As follows from the simulation an emittance growth occurs for a beam with very low emittance ~ 30 π·mm·mrad (unnormalised, 60 kV).

Another phenomena such as a heating of the wires and sputtering of the wire material can be neglected due to very low average intensity of the ion beam. Estimation of sputtering rate by available empirical formulas [2] shows that 10 μm wire material can be sputtered during 8500 hours of operation with the ion flow 10^{10} atoms/(sec·cm^2).

The LEBT containing 4 electrostatic lenses has been proposed and studied by the CPO code [3]. Simulation of GEL LEBT has been done with 3 values of the input emittances, shown in Tables 1 and 2.

Table 1

INPUT OF GEL	1	2	3
4 rms emittance, π·mm·mrad	**128**	**204**	**320**
Total emittance, π·mm·mrad	**200**	**320**	**500**
Number of particles inside 2D emittance 200 π·mm·mrad	**100%**	**88%**	**67%**
Number of particles inside 4D emittance with projections 200 π·mm·mrad	**100%**	**75%**	**38%**

Table 2

OUTPUT OF GEL			
4 rms emittance, π·mm·mrad	**228**	**328**	**488**
RMS emittance growth factor	**1.78**	**1.61**	**1.53**
Number of particles inside 2D emittance 200 π·mm·mrad	**82%**	**76%**	**52%**
Number of particles inside 4D emittance with projections 200 π·mm·mrad	**71%**	**62%**	**35%**

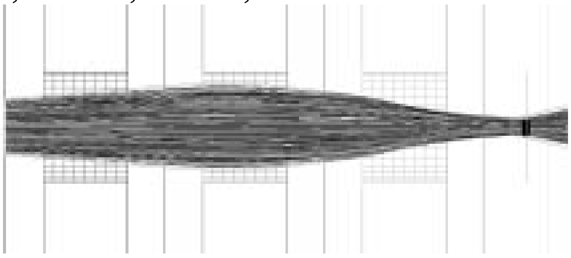

Fig.1. Beam envelope in GEL LEBT. V_1=7 kV, V_2=26 kV, V_3=36 kV. $E_{input, total}$ =500 π·mm·mrad. $E_{input, 4rms}$ = 320 π·mm·mrad. Mesh size =1mm, Total number of particles (taking into account symmetry planes) =2400. I_{beam}=60 mA, $U_{extraction}$=60 kV.

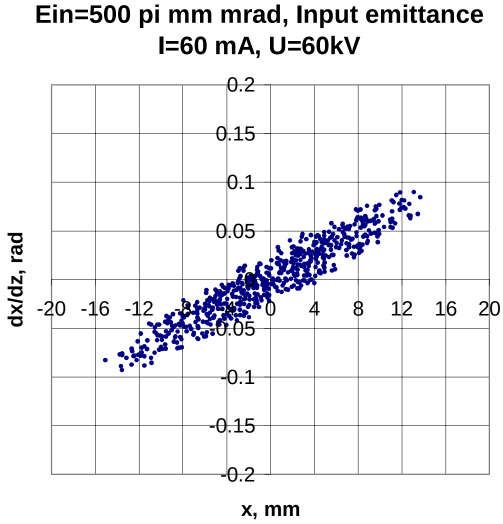

Fig. 2. Input distribution of 60 mA beam, E_{total}=500 π·mm·mrad, 4·E_{rms}=320 π·mm·mrad.

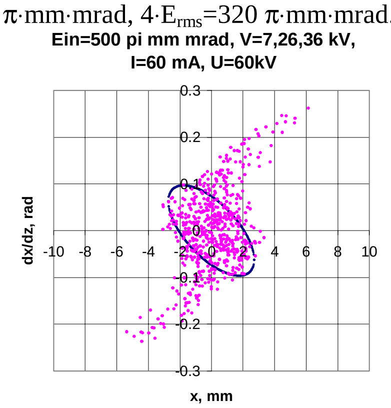

Fig. 3. Phase space plot in the entrance of the RFQ. The RFQ acceptance is shown. The total number of particles inside 4-dimensional phase space with 200 π·mm·mrad emittances in xx′ and yy′ is **35%.**

Fig. 1-3 show the beam envelopes along the GEL LEBT, initial and output phase space plots. The simulations have been done using 600 particles and 2 symmetry planes: x=0 and y=0. Mesh size for space charge calculations was 1 mm. The simulation time with 7 iterations is ~8 hours (at 200 MHz PC) and depends on the initial emittance.

SENSITIVITY OF THE GEL LEBT TO CURRENT VARIATION

For the initial total beam emittance 500 π·mm·mrad (case 3 in Table 1) the input current has been changed to 45 mA and 30 mA. Simulation has been done with the voltage setting shown in Fig. 1. As expected the yield of beam current drops as beam current is decreased because the voltage setting is optimized for the 60 mA beam current (see Fig. 4). The corresponding phase space plot for 45 mA beam is shown in Fig. 5.

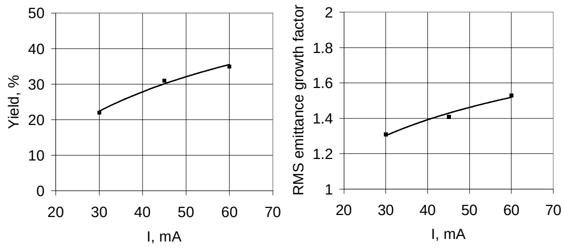

Fig. 4. Current yield into the 4D RFQ acceptance (left) and rms emittance growth factor (right) as a function of beam current. The voltage setting is optimised for 60 mA beam.

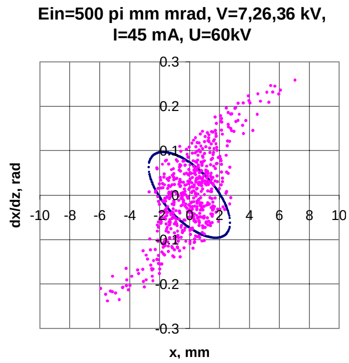

Fig. 5. Phase space plot in the entrance of the RFQ for 45 mA beam. The RFQ acceptance is shown. The total number of particles inside 4-dimensional phase space with 200 π·mm·mrad emittances in xx′ and yy′ is **31%.**

MECHANICAL DESIGN

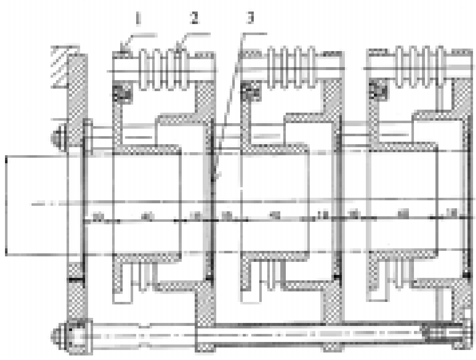

Fig. 6. Schematic view of the electrodes.
1 – electrode, 2 – isolator, 3 – grid.

The mechanical layout of the GEL is shown in Fig. 6 and 7. High voltage to the electrodes is supplied through the feedthroughs 4 (Fig. 7). The electrodes are isolated in vacuum by the shaped rods 2. The wires are mounted on aluminium support. The positive voltage is applied to the electrodes shown in Fig. 6 and 7.

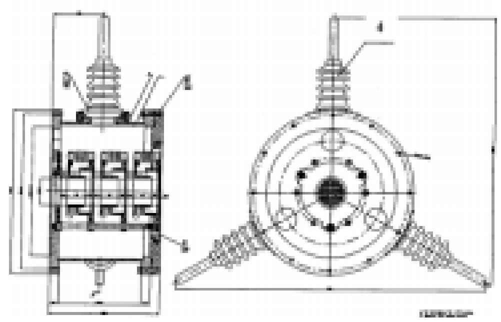

Fig. 7. General assembly drawings of the GEL LEBT.
4 – 50 kV HV feedthrough.

In this case the grids are grounded. However the electrode system with negative voltage on the grids can be used for the focusing too. The assembly drawings of such electrodes are shown in Fig. 8. The latter has better focusing properties because the focusing effect occurs with the acceleration of the beam. In addition the number of grids can be less than in the GEL shown in Fig. 6. However the disadvantage of such system is a production of some electrons which can reach the ion source, also the focusing voltage is higher. Both systems have been tested in the experiments. But main studies have been carried out with the system shown in Fig. 6, 7.

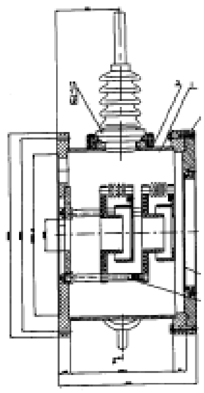

Fig. 8. General assembly drawings of the GEL LEBT.

An average current of 40 mA (for solenoid LEBTs it was 17 mA [4]) has been observed in the Faraday cup of ϕ = 6.5 mm. The source current was then 70 mA. Inserting the double aperture device gave a yield of 30 %. Near the focal plane, emittance measurements confirmed the predicted low emittance growth. The typical emittance of the extracted ion beam downstream of the GEL LEBT is shown in Fig. 9. In recent experiments the yield to the double aperture Faraday cup has been increased up to 35%.

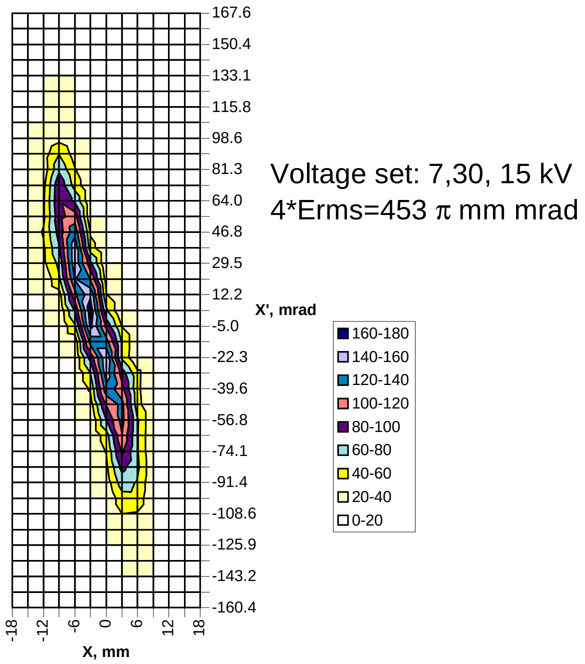

Fig. 9. Transverse emittance output of the GEL.

CONCLUSION

The GEL LEBT provides high efficiency beam transport and matching to the RFQ acceptance in the 4-dimensional phase space. The rms emittance growth is relatively small even for 60 kV extraction voltage. The number of particles occupying the 4-D RFQ acceptance strongly depends from the beam emittance at the entrance of the GEL LEBT. In most realistic case with the input emittance equal to the measured one, which is 320 π·mm·mrad (4·rms emittance) the number of particles inside the 4-D space with the projection emittance of 200 π·mm·mrad is 38% at the entrance and 35% at the output of GEL LEBT, which means that LEBT does not practically destroy beam emittance. The experimental value of the yield to the double aperture is 35% and confirms the expected performance of the GEL LEBT.

REFERENCES

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4. P. Fournier et al. CERN PS Laser Ion Source Development. Paper presented to PAC99, New-York, March 1999.