Technical Summary of Upgrade of the Laser Ion Source to 110kV

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Note

This is not a finalised document. The authors are just the people who have written the summary and does not include the others who have worked on the source. We suggest that a report is written later.

Summary

The source has now been upgraded and runs with good reliability at high voltage. The GEL appears to comfortably give the required voltages for focusing, without dark current. The currents into double aperture cups are 20-25% higher than at 60kV. The result is that we suggest the RFQ be designed for this input energy (unless its own technical constraints say otherwise).
The decision to increase up to 250kV is not addressed yet and is not excluded, but there is no time to build such a system before deciding to make the RFQ, and then hoping to have such an RFQ in 2000.

Electrical Scheme

The Heisinger 100kV, 20mA supply was exchanged for a FuG 120kV, 1.2mA supply. The controls of this supply were modified.

Even though the original target was for the source to be run at 120kV, there are four reasons to stop at 110kV and suggest this as the RFQ input energy.

1. The source is so far quite stable at 110kV but cannot be run easily higher than 115kV. This can be improved over the following months.
2. Most of the measurements have been completed for voltages only up to 115kV.
3. The HV supply is limited to 120kV and the chance of it breaking is hopefully lower at 110kV. Nearly all sources appear to run 5-10% lower than the maximum of their HV supply (e.g. Linac 2, SIHLI (source 95kV, HV supply 100kV).
4. If the RFQ is designed to run at 120kV, it will not be at all easy to make tests that the transmission is improved for high input energies.
5. The same velocity for 19+ would be close to 116kV, well within the supply specifications. If for some reason the source is not supplying a lot of 20+ we can switch.

None of these reasons are sufficient to run at 110kV, but together they strongly suggest we should limit the RFQ to this voltage, i.e. Ta20+ @ 110kV = 12.15 keV/u.

HV breakdown protection

Numerous parts of the system were changed to allow the source to run to 120kV. The most important were 1) extra shielding on the HV ceramics to avoid external breakdowns, 2) extra Plexiglas around the source, 3) a new shorting system.
At the desired 110kV, a significant corona current is still being drawn. This may lead us to start an upgrade program to house some of the source inside a shielded aluminium box. Another weak point is the shorting solenoid, which was placed under the table. This is a very restrictive position, which inhibits us from

allowing large distances to avoid flashovers. Finding a new position will not be easy unless the cage is enlarged.

Electrode Shaping

The extraction electrodes shaping was simulated with IGUN, taking into account a grid on the plasma electrode. This lead to a 45^{o} angle on the plasma electrode and optimisation of the gap distance (plasma to puller electrode) to minimise the emittance of the beam. For these simulations the plasma electrode was at 120kV. Simulations in KOBRA confirmed that the normalised emittance was reduced when compared to the 60kV scheme.

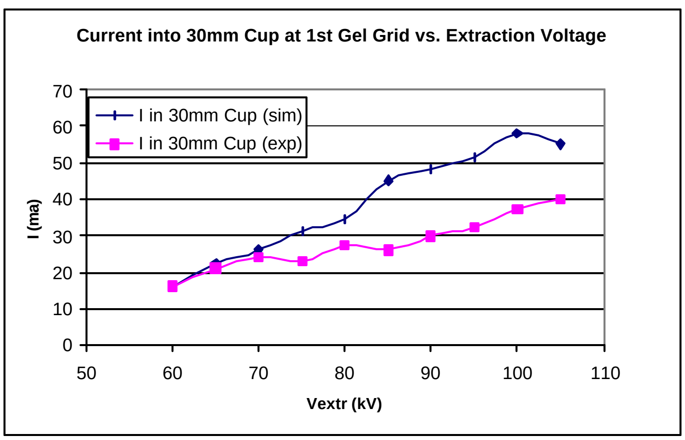
GEL

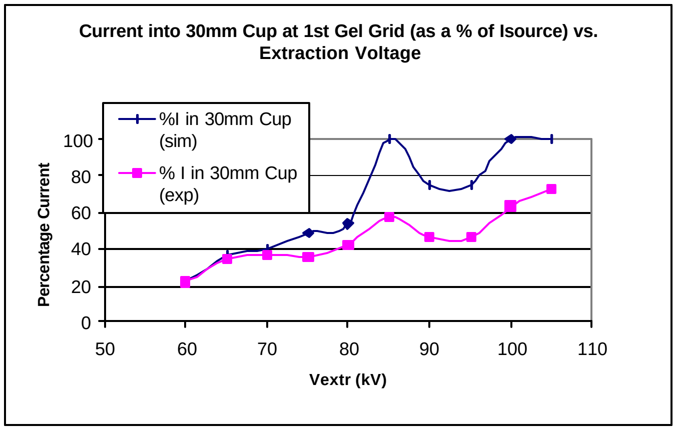
No specific changes to the GEL were made, but the improvements of earlier in 2000 now allow it to hold 40-50kV on all electrodes without problems. These voltages are sufficient for 110kV beams.

Beam Measurements

1. Measurement of Extraction Output Current:

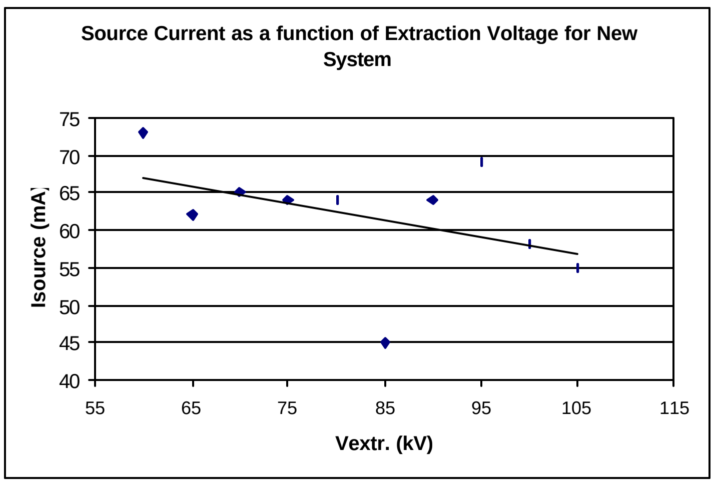
A 30mm aperture Faraday Cup was placed after extraction, at the position of the first GEL Grid (48mm after ground electrode). The current into the cup was measured for a series of extraction voltages and the results, along with those simulated in IGUN, are shown below:





IGUN simulations predict that for voltages lower than 80kV beam scraping occurs along the supressor and ground electrodes. Any drop in transmission for higher voltages is due to the output beam size being larger than the cup aperture (30mm).

The following plot shows the average source current over five shots measured with a current transformer, as a function of extraction potential.

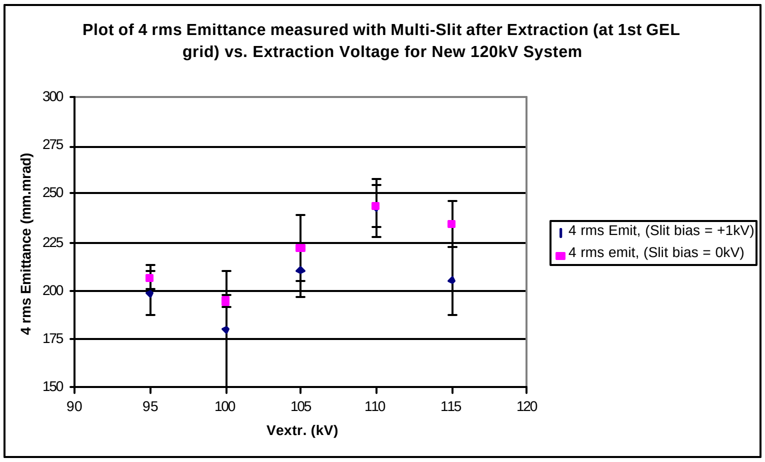


The decreasing trend in Isource is not well defined suggesting that the positive to puller electrode separation has yet to be optimised.

2. Measurements of emittance after extraction:

The 4-rms emittance was measured after extraction at the position of the first GEL grid (48mm after the ground electrode). The measurement apparatus comprised a multi-slit device (5mm spacing) to which a bias could be applied, followed 60mm downstream by a phosphor screen. The measurement apparatus was not the set normally used and in some of the received images damage to this older screen, (intensity drop), could be seen.

Many data sets were taken and the following plot shows the 4-rms emittance, averaged over at least three shots, as a function of slit bias and extraction potential. The error bars shown are the std. errors in the mean.

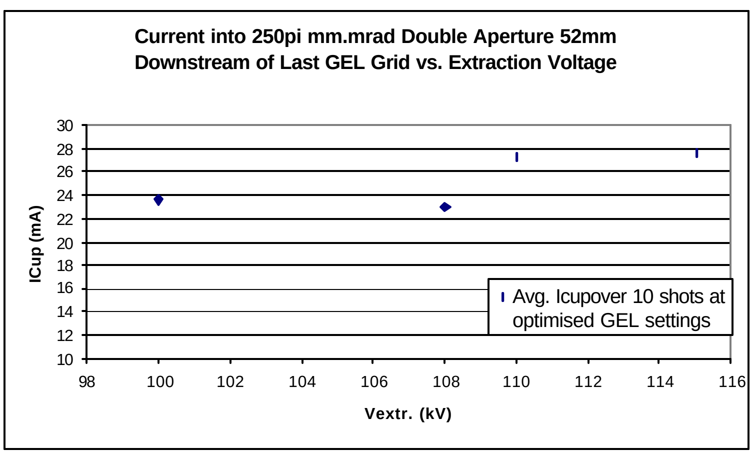


One can see that the average 4-rms emittance is about 220mm.mrad +/- 15%. Lower emittance values are recorded for 95-105 kV but it is unclear whether the IGUN predicted beam scraping may occur at higher voltages in reality and thus loss of ions at large radius could give the observed reduction in emittance in the range 95-105 kV.

3. Measurements of Current after GEL:

Currents were measured into a defined geometrical acceptance 52mm downstream of the final GEL grid. The desired acceptance was modelled using a double aperture system bolted directly to a Faraday cup. The emittances modelled were 250pi mm.mrad (5.9mm apertures separated by 44.7mm and corresponding to a normalised emittance of 1.32 mm.mrad at 120kV) and 190 mm.mrad (5.16mm apertures separated by 44.7mm and corresponding to a normalised emittance of 1.00 mm.mrad at 120kV). In both cases the acceptance was defined at the centre of the double aperture separation.

The current transmitted to the cup through the 250pi mm.mrad double aperture was measured at a range of extraction potentials. At each potential a scan of GEL settings was made to achieve optimum focussing. The cup suppression was –2.7 kV.



Here, one can see that the best-achieved cup current was about 27.5mA (std. dev. = 6%) at 115 kV (GEL = 20, 40, 40), for a source current of 86mA (std. dev. = 20%). However, the avg. current achieved at 110 kV (GEL = 20, 40, 35) was about 27.0mA (std. dev. = 7%) for a source current of 75mA (std.dev. = 14%), a loss of only 2%.

These values should be compared to a similar measurement carried out in April 2000. Here a 6.9mm double aperture system with a spacing of 44.7mm, was used to simulate the same normalised emittance (1.32mm.mrad corresponding to about 350mm.mrad at 60 kV) 14.9mm after the final GEL grid.

The cup bias was set to –2.7kV and the extraction potential to 65kV. Again, a scan of GEL settings was made and the optimum decided to be at 7.58, 34.7, 22 kV. Here the average cup current over 20 shots was found to be 21mA (std. dev. = 13%) for an average source current of 73mA (std. dev. = 24%).

The results suggest a 25% improvement in the current into a 1.32mm.mrad normalised acceptance after the GEL.

Data for the 1mm.mrad normalised acceptance is still being collected.

4. Effect of removing the supressor electrode:

It has been suggested that it may be desirable to remove the supressor electrode in favour of a two-electrode (HV and ground) extraction system. A quick experiment was made to study the effect applying no voltage to the suppressor. Extraction potentials of 110 and 105 kV were used and 10 measurements of the current into the 250pi mm.mrad acceptance (as detailed previously) were made for each voltage. The optimal GEL settings of 20,40,35 and 20,40,40 kV were used accordingly.

A reduction in the mean current transmitted to the cup was seen (26mA at 115kV, 24mA at 110kV).

An interesting point is that the source current tends to be on average about 21mA higher without suppression than with (more pronounced at 110kV) giving a level of the electron current.

In the future the following measurements should also be done.

1. Test of current in double aperture as function of distance after the source. If this can be long, it may allow easier coupling of the two, and some diagnostics.
2. Change of the plasma-puller electrode gap distance.
3. Remeasure emittance after the source with normal device. We did not find the nominal emittance system at the time.
4.