BWA/cg

PS/DI/Note 98-18(Min.)
19 October 1998

Minutes of PS Technical Meeting N°103
held on 7th October 1998

Review of Laser Ion Source Work

Présents: *B.W. Allardyce, J. Boillot, D. Boimond, M. Boutheon, R. Cappi, B.Frammery, R. Garoby, J.Gruber, H. Haseroth, C. Hill, H.Koziol, H. Kugler, D. Kuchler, N. Lisi, D. Möhl, J.P. Potier, J.P. Riunaud, K. Schindl, J.C. Schnuriger, R. Scrivens, D. Simon,*

C.C.: *B. Autin, P. Bryant, V. Chohan, J.P. Delahaye, K. Hübner, S. Maury.*

1. The previous review of LIS was held nearly a year ago (PS Technical Meeting N°96 on 12/11/97) and H. Kugler reported good progress in that time towards the ultimate goal of 1.4 10^{10} Pb ions in charge state 25+, in a pulse of 5.5 μsec and with a small emittance. He presented a list of the topics to be covered, see annex 1.

2. R. Scrivens explained the careful search that had been carried out with respect to the observed shot-to-shot instabilities of the ion pulse (which are of the order of ± 25%). In spite of these efforts, no reason has been found so far, but attempts will be made to stabilize the output ion current during the pulse. He also explained the work done on plasma extraction matching and on measuring the spectrum of charge states produced from different target materials.

3. N. Lisi presented the work done on the LEBT and the layout of the master oscillator (MO) and pre-amplifier, providing a laser system pulsing every 2 to 3sec. They have used a carbon target (polythene) to produce C^{4+} ions (100 mJ pulse from the laser at the high repetition rate of 1 Hz) which resulted in 25 mA total current of which 10% was C^{4+}. The high repetition rate was important in that it allowed the work to proceed faster than using higher mass & charge ions when a higher power in needed, with consequent much lower repetition rate. Incidentally, N. Lisi pointed out that this result with C^{4+} would be a very good, cheap ion source for a future medical accelerator.

4. N. Lisi explained the work carried out in collaboration with Frascati, where a short wavelength commercial laser (factor 30 shorter wavelength) was used to try to produce Ta ions. The results were not encouraging as only Ta^{4+} could be produced. Another collaboration with INTAS was also described where soft X-rays emittted from the expanding plasma are studied and different lasers will be tested with respect to ion yields and pulse stabilities.
A new operation mode of the master oscillator (mode-locked operation) will be tried out. Instead of one smooth pulse of 70 ns, a pulse train of pulses of 1 ns will be produced. This may lead to a high yield of ions from the plasma at lower total energy.

5. R. Scrivens then presented the latest results from TRINITI where Pb^{26+} with an intensity of 9 10^9 in a 6 µsec pulse from a 60J laser has been achieved.

6. J.C. Schnuriger presented some results obtained of simulations of the LEBT using one or two solenoids. In the spring of this year a short workshop on different simulation programs took place. As a result a new 3-D program has been chosen, called KOBRA 3 (used at GSI). It allows the treatment of space charge compensation.

7. H. Kugler mentioned briefly some of the LEBT studies such as whether an electrostatic LEBT would be better than the solenoids, and the latest idea of installing an accelerating section immediately after the extraction electrode so as to avoid the very low energy regime. He also told us that there are very exciting developments in other laboratories with femtosecond pulses from lasers yielding terrawatts of power in the pulse : such developments are clearly of interest to us in view of the production of heavy ions at very high charge states.

8. H. Kugler summarized by saying that the last year has shown very good progress, both here and in TRINITI. He presented a budget report for 1999 involving a total of 180 kCHF plus 60 kCHF for the collaboration.

   A selection of the many transparencies shown is included in annex, and a complete set can be obtained from B.W. Allardyce.

B.W. Allardyce

PS Technical Meeting, Wednesday, 7th October 1998
Review of LIS work

1) What has been done since the last review

Nicola Lisi, Richard Scrivens, Jean-Claude Schnuriger, Hartmut Kugler

R.S. " Further attempt to identify ion current instabilities "

R.S. " Matching of plasma density and extraction "

R.S. " Application of 30 J LIS to produce Mg, Ti, Cu and Au ions "

N.L. " Transmission in present LEBT "

N.L. " High rep rate Master-oscillator and Pre-amplifier "

N.L. " C4+ production, using the Master-Oscillator "

N.L. " Frascati experiment: ion production with short-wave lasers "
"INTAS grant" (research programme and list of participants)

R.S. " First achievements with respect to the Russian 100 J amplifier "

J.C. S. " Our programs for beam simulations "

H.K. " Report on Beam Simulations in an Electro-static LEBT, done by Peter Ostroumov "

H.K. " HV test of a 120 kV platform "

2) Plans for the next year

Hartmut Kugler

N.LIS1

LASER Development for the LIS

PRESENT STATUS

The laser of the LIS experience had so far worked in the following mode:

1) Maser Oscillator, Single Longitudinal Mode (SM) and Multiple Longitudinal Mode (MM), 1Hz, 0.1J
2) Master Oscillator LUmonics Power Amplifier, both SM and MM, 6J, 0.05Hz
3) Free running Oscillator (MM)

Meanwhile we acquired a new laser system. Such system is a 1Hz, 10J laser, it was bought second hand and successfully put in operation at CERN. Such system, that we define as Preamplifier will allow us more configurations (see Mopa.1).

4) MO + Preamplifier, 1J 1Hz, SM or MM
5) MO + Preamplifier + Lumonics Power Amplifier, 12J, 0.05Hz

Recently we installed at CERN a saturable absorber gas cell (SF6) from our colleagues of TRINITI (Moscow region) . Such device will allow us two improvements with respect to all the above points (1 to 5) .

a) Suppression of laser Propels, that can impair the amplification process
b) variation of the pulse risetime (Mopa.2)

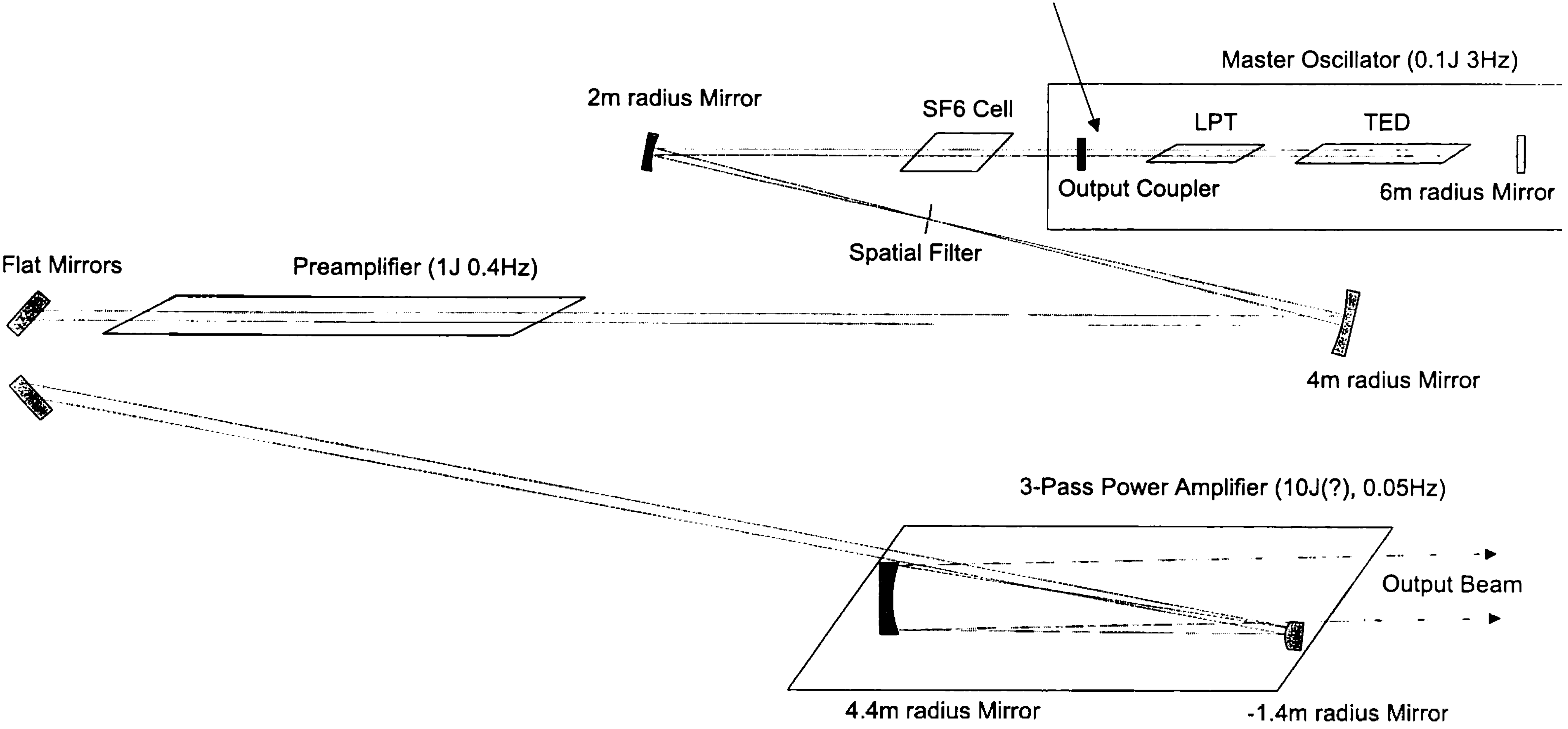
NEXT FUTURE

We plan to modify the MO by the installation of a Mode Locker, for example Mopa.3. Such device will substantially change the time structure of the laser pulse. It will allow to achieve higher laser intensities on target with lower total laser energy and it might be more favourable for the CERN LIS. Such time structure of the laser pulse can be exported to all the above configurations (1 to 5) but with a reduction of the laser energy.

MOPA1

Maser Oscillator, Preamplifier Power Amplifier: Optical layout

Add P-Type Ge for Passive Mode Locking
or Ge AO Modulator for Active Mode Loking
in the MO cavity



N.LIS1

N.LIS1

ONE AND TWO SOLENOID LEBT FOR THE LIS SOURCE

The LEBT should transport the Ta ion beam from the extraction region to the entrance of the RFQ. There is still open discussion on which is the best solution, due to the strong space charge interaction and to the time varying structure of the beam.
We have been experimentally characterising a possible LIS LEBT by using one and two solenoid. The improvements with respect to previous measurements are:

1) The new extraction system goes up to higher voltages (+ 95KV,-10KV)
2) The new plasma expansion chamber allows the variation of plasma a current in order to achieve a better extraction matching.
3) we can move the solenoid across the beam, both vertically and horizontally in order to have a correct beam alignment
4) Moreover we have been characterising for the first time a LEBT based on a single solenoid which could achieve better performances that the two solenoid one.

In page LEBT.2 we can see how the first solenoid was aligned. While in the tables in LEBT.3 and LEBT.6 we report the results for the transmission in a 6.5mm Faraday cup.

Total current transmissions of 24% and 18% were obtained for the one and two solenoid cases respectively.

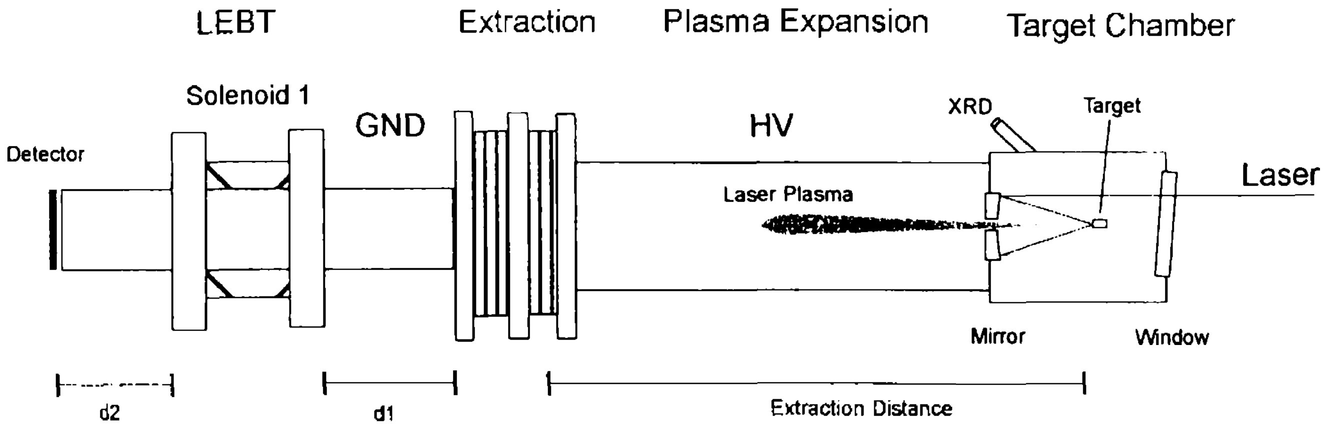
7% transmission were obtained for a double aperture Faraday cup (6.5mm apertures spaced of 65mm) that could partially reproduce the acceptance of an RFQ for both cases, but optimisation work was not devoted to this case.

In order to translate such numbers in transmissions to the RFQ we remember that we must take into account the following two effects:
1) The acceptance angle of the RFQ
2) The charge dependence of the solenoid's focusing.

Simulations are difficult to tune to such system for the following effects
a) Time structure of the current pulse with variations in the sub µs timescale
b) Partial space charge neutralisation (or compensation) of the beam by secondary electrons produced in transport channel.

As a result only an experimental characterisation of such system can be satisfactory and proper simulation can work at close contact with the measurements.

N.LIS1 LEBT 1



Present CERN-LIS Scheme

N.US1

SOFT X-RAY DIAGNOSTIC OF LIS LASER PLASMA

INTRODUCTION

Soft x-rays have an energy around 1KeV and are emitted by the region of the laser plasma closer to the target where the laser power density is transferred to the plasma.
From the spectral point of view, the soft x-ray emission is both continuos (brehmstraalhung) and line emission. Very generally speaking most of the x-ray energy is emitted around the electron temperature.
Hence a diagnostic based on soft x-rays will look at the mechanism responsible for the production of high charge states and for the plasma expansion.

DIAGNOSTICS AND APPLICATIONS

The simplest x-ray diagnostics consists of PIN diodes. They can measure the time evolution of the soft x-ray emission in a spectral window that can be selected using an appropriate filter (x_ray.4 and x_ray.5). Such window can be changed both by varying the filter thickness as by varying the filter material.
Oscilloscope traces are shown in figure x_ray.6. It can be noticed that the harder x-ray emission lasts for a shorter time than the softer component, in according with the rapid cooling of the plasma.
A first immediate application of x-ray detectors is a rapid procedure to find the laser focus, in fact the soft x-ray emission changes rapidly with the intensity on target.
Another application is the study of the shot to shot instability. So far no correlation was found between the x-ray signal and the high charge state current (x_ray.6), but further measurements are planned.

A more sophisticated diagnostics consist of high resolution spectroscopy of the laser plasma. Such technique is far more complex than simple PIN diode measurements, but can investigate the details of the processes of laser plasma interaction. In particular we hope that it will allow to measure the electron density, electron temperature and ion population distributions as a function of distance from the target. Experiments are planned on the basis of a European collaboration (INTAS, see x_ray.1, x_ray.2 and x_ray.3) both at CERN as in other laboratories.

N LIS1 [illegible]

Work Program
INTAS project
proposal number 2090

1. TITLE

Development of X-ray diagnostics for the determination of the ionic composition of a plasma produced by lasers of different wavelength and pulse duration: experiment and theory.

2. OBJECTIVES AND BACKGROUND

2.1 OBJECTIVES

- To investigate experimentally the ionic composition of a laser-produced plasma, near the target surface, for elements with atomic number N~10-25. The plasma will be formed by a laser pulse from gaseous CO_2-laser (λ=10.6 μm, pulse duration ~50-100 ns) and an excimer XeCl-laser (λ=0.308 μm, pulse duration 10-120 ns); the intensity of the laser radiation will vary from 10^{12} to 10^{14} W/cm^2.

- To develop an X-ray spectrograph with high spectral and spatial resolution (in $0.5<\lambda<5$ keV).

- To measure the spectral characteristics of a laser-produced plasma (for $0.5<\lambda<5$ keV).

- To develop a suitable theoretical model of laser-produced plasma motion and population kinetics of ion levels for the range of plasma parameters expected in the planned experiments.

- To perform numerical simulation of laser-produced plasma motion near the target surface and calculate the spectral characteristics of the plasma radiation, taking into account reabsorption of line radiation.

- To perform comparative analysis of different line radiation reabsorption models using the experimental and calculated spectral data.

- To investigate experimentally the laser-produced plasma ionic composition far from the target surface (several meters) using an electrostatic ion analyser.

- To investigate numerically the recombination channels in moving laser-produced plasma, based on data obtained in the above experiments.

- To investigate experimentally the laser-produced plasma ionic composition for complex ions of heavy elements (Pb (N=82), Ta (N=73)).

- To study the parameters which cause ion current instabilities and to investigate (theoretically and experimentally) the techniques for improving the stability of the ion current emission.

2.2 BACKGROUND

The Laser Ion Source project at CERN was started in order to investigate whether an intense source of heavy multicharge-state ions can be produced by a laser, so that the resulting beam could be directly injected into the accelerator for the Large Hadron Collider (LHC) ion operation. This would be an alternative to obtaining the required LHC intensity by stacking heavy ions from a conventional source.

N L151 x-ray2

5.1 DIVISION AND TASKS

ENEA Frascati Centre, National Agency for New Technologies, Energy and the Environment, Italy.
Department of Innovation Technologies
Lasers and Accelerators Laboratory
Dr. Tommaso Letardi
Ion energy spectra and X-ray spectra measurements (using an excimer laser source).
Ion energy spectra and X-ray spectra analysis.

IPNE, University of Liege / Belgium,
Research Director of the Belgian FNRS
Prof. Dr. E. Biemont,
Atomic data calculation and X-ray spectra analysis.

CERN, European Organization for Nuclear Research, Geneva, CH.
Proton Synchrotron Division (PSD)
Hadron Production Group (HPG)
Dr. Hartmut Kugler
Ion yield spectra and X-ray spectra measurements.
Correlation measurements of parameters wrt ion current stability.

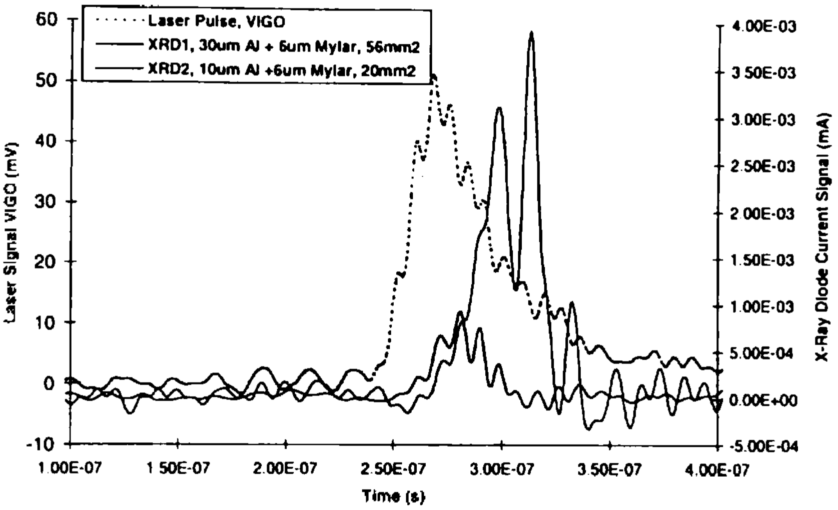
TRINITI, Troitsk Institute for Innovation and Fusion Research, Moscow region, Russia
Laboratory of Pulsed Plasma,
Dr. Yu.A.Satov
Ion energy spectra and X-ray spectra measurements.
Atomic data calculation and atomic models development.
Numerical simulations of laser produced plasma hydrodynamics and kinetics.

VNIIFTRI National Institute for Physical and Radiotechnical Measurements
Mendeleevo, Moscow Region, Russia
Dr. A.Y. Faenov
X-ray spectrometer construction and design.
X-ray spectra measurements and interpretation

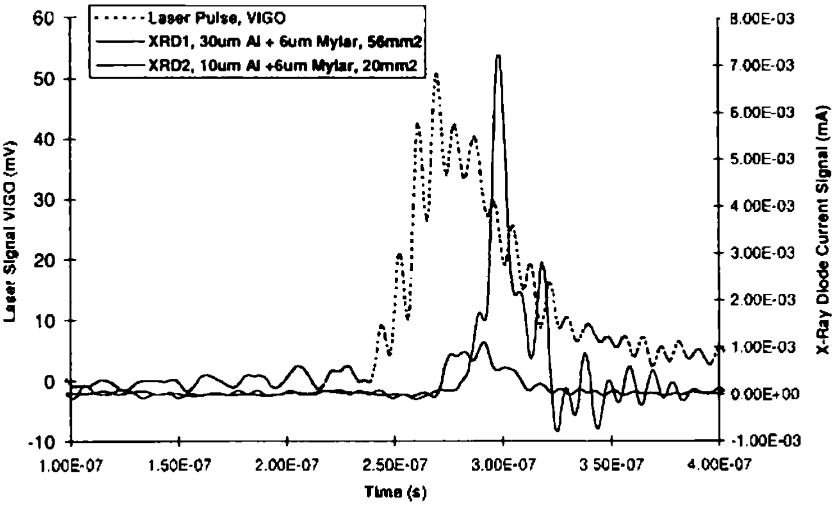
Kiev Shevchenko University, Radiophysical Faculty,
Department of Theoretical Radiophysics and "Laser Engeneering" Laboratory, Ukraine
Prof. V.I. Vysotskii
Theoretical analysis of elementary processes in hot dense plasma.

N. L15/ x rays

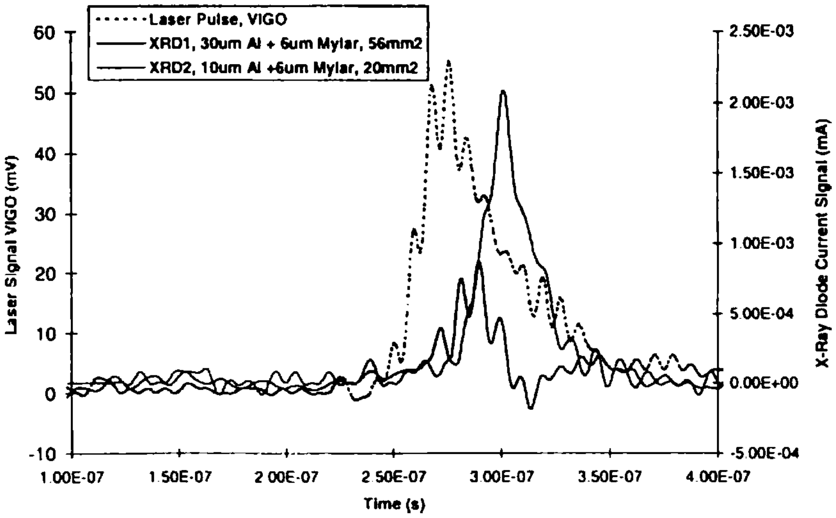
I Fcup= 1.69mA



I Fcup= 0.52mA



I Fcup= 0.83mA



Laser Beam and X-Ray Signal. Time evolutions, Three laser shots

N.LISI

Visit to Frascati: short wavelength low intensity

(PS HP Note 97/07)

During this two weeks experiments performed in Frascati (ENEA) we wanted to find out whether with a short wavelength laser and relatively low intensity it would be possible to obtain a high current of high charge states. The idea behind is that with the continuos development of more compact and powerful laser sources we could build a cheaper and more reliable laser ion source.
Previous spectroscopic measurements clearly show that high charge states are present in the regions near the target surface. The question was whether they will come out of the plasma or they will recombine.
We remember that in a first approximation the plasma density is inversely proportional to the wavelength squared, thus the recombination promised to be a relevant process.
During this experiment we observed only low charge states coming out of the plasma, 4+ and 6+ Ta depending on the laser parameters (frascati.1 and frscati.2). Still we recognise that this is a preliminary experiment and that there could be more favourable geometries. This and previous experiments seem to show that considerably higher intensities should be used for short wavelength lasers. This translates directly in short pulse durations, thus lower energies and major technological challenges for a real source .

N.LIS1

CARBON LIS: Low Laser Energy High Current

(Ps/Hp Note 97/04)

INTRODUCTION

The generation of high charge to mass ratio ions in the laser plasma sets stringent requirements on a CO_2 laser beam performances in terms of Energy (>100J) and beam quality (Single Transverse Mode and perhaps some control on the Longitudinal Mode also).
The next stage of LIS development, in collaboration with the TRINITI institute (Moscow Region) is the construction of a novel concept 100J, 1Hz repetition rate CO_2 laser amplifier.
The laser system currently under development at CERN and in Russia consists of a Master Oscillator Power Amplifier (MOPA). While the power amplifier is currently under development and construction in Russia, the Master Oscillator was installed at CERN in July 1997
The new optical configuration allowed some measurement on the scaling of the ion production yield and charge state and at different laser energies and power densities on target, in particular both charge states distributions and ion current were found to be higher than expected at low intensity.

Moreover it allows 1Hz operation of a high current Carbon ion beam, by using a plastic target (Polyethylene). The $C4^+$ current (carbon.1 and carbon.2) was found to satisfy some of the parameters for PIMMS, specifically the Intensity and the pulse length.

APPLICATIONS

The high repetition rate of a high current beam with a plastic target will allow us to test some of the parameters of the future LHC LIS at high repetition rate. For example the gas load and may be beam alignment through the LEBT.
The study of the physics of the ion expansion from the target can be easier for lighter elements, for example there seems to be a consistent difference in the current waveforms for the SM and MM laser beams cases (carbon.2).

LARSON C

N.LISI

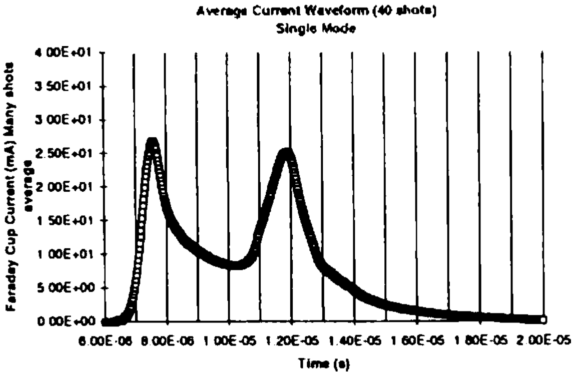


Figure 4 Average ion current waveform for Single Mode beam . Faraday cup measurement at a distance of 1m from the target. A second bump is a consistent feature of a single mode laser beam.

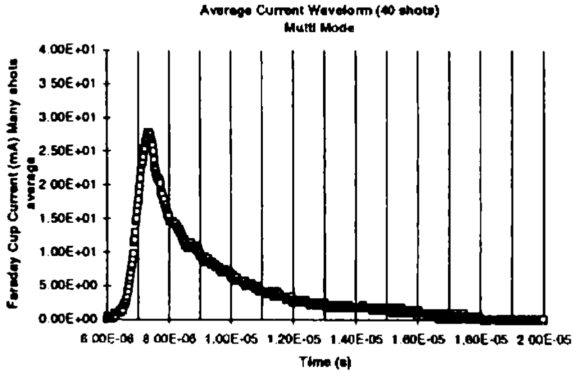


Figure 5 Average ion current waveform for Multimode beam. Faraday cup measurement at a distance of 1m from the target. The ions are slightly faster.

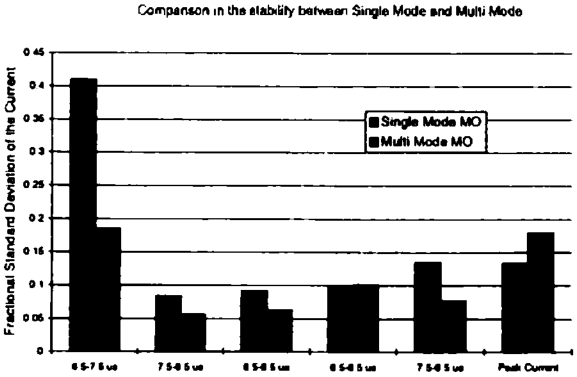


Figure 8. Ion current stability for different intervals. Single Mode and Multimode comparison.

R SCRIVENS

Ion current Fluctuations

The fact that the ion current from a Laser Ion Source (LIS) fluctuates is well known. We have tried to experimentally find reasons for this instability. We concentrated on assessing the value of the average current from the source in a time window of 5µs after the laser pulse. Five specific tests were done

a) The MO-LPA (Master Oscillator - Lumonics Power Amplifier with 6J) laser system was used, and compared in single-mode and multi-mode (strongly peaked temporal wave-form) regimes. Neither mode was significantly more stable.
b) Laser energy vs ion beam current, no strong correlation.
c) On and Off axis illumination of the target surface did not cause any difference to stability.
d) The number of shots per target position did not significantly change the stability (1, 5 and 25 shots per position were tested).
e) Measurements of the laser beam focal distribution revealed the beam to be quite stable. A drift of the beam position from shot to shot was found, but did not greatly affect the stability. This drift was later cured.

The final point required the building of an on-line measurement system for the laser beam focal profile, involving large aperture optics and a Pyroelectric - Infra red imaging array camera. This also allowed us to view the real distribution for comparison with estimation and simulation. The real spot was found to exhibit astigmatism which will result in a small increase in the spot size on the target.

Plasma - Extraction matching

The matching of the plasma density to the extraction system is difficult in the case of the LIS because:

1. The current waveform is modulated.
2. The charge state distribution changes during the pulse.
3. The total current fluctuates.
4. The plasma ions have a very significant initial velocity.
5. The plasma density is not easily varied.

A re-design of the source allowed improved alignment of the extraction electrodes and allowed the distance from target to extraction (hence the plasma density) to be varied more easily. Extraction was characterised by the measurement of the ion beam current into a restricted aperture Faraday cup (I_{cup}) as a function of the source positive potential.

For all plasma densities the I_{cup} shows a linear increase with potential, saturating at some point. We estimate that the voltage at which saturation occurs is close to the best working pint of the source. We then tried to verify that the source current and saturation potential obeyed the relation $I_{source} \propto V^{3/2}$ (with some success).

However, simulation of the extraction and comparison with measured data does not reveal a good fit. Adjustment of the space-charge to account for compensation helps, but does not allow us to fully re-create the results. The effects of a modulated source current should therefore be included into the simulation.

Furthermore, it is still not possible to fully explain why the ion beam expands more quickly such that it strikes the chamber walls before reaching the first solenoid. Simulations with full space charge do not show such effects.

We have identified a much better working point than that used in the 1996 experiments with the RFQ.

Other Elements

The charge-state distributions (CSD) have been measured for a range of materials, both heavy elements near lead and for some lighter materials. In all cases the current density is calculated for a target to extraction distance of 100 cm.

Element	Charge-state	j (mAcm^{-2})	Duration (µs)
Pb	23	0.5	5
Au	22	1.2	5
Ta	20	1.8	5
Cu	18	4.2	3
Ti	13	27	3
Mg	10	43	2.75
C	5	39	2.5

The CSD using bulk Ta as a target, and a 100 µm thick foil target were compared, and gave near identical results.

Activities in TRINITI

The work in TRINITI is followed chronologically with respect to experiments on the generation of ions.

1. In Feb 1998 Nicola Lisi and Richard Scrivens visited TRINITI. The final amplifier (with e-beam sustained discharge) had been modified to accept a MO beam, and produce 60-70 J in 70-80 ns. Focusing the 14 cm diameter

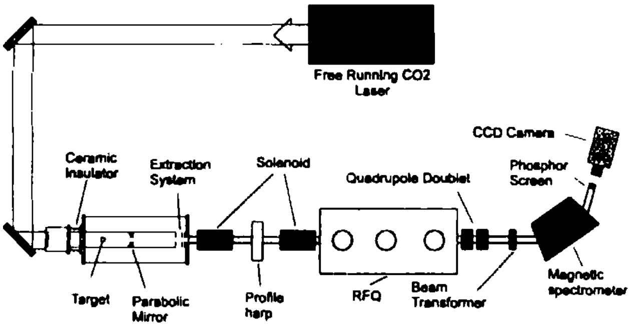
R_SCRIVENS

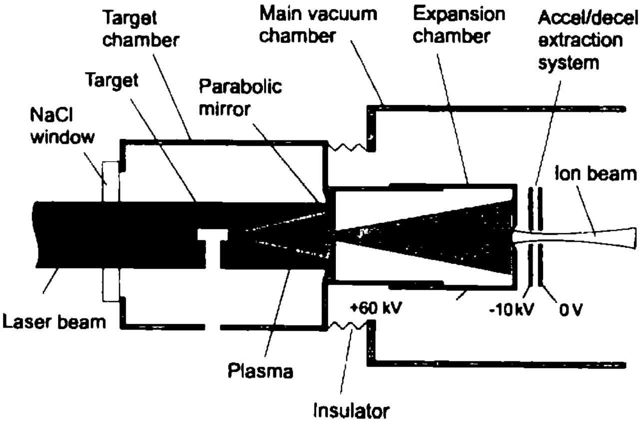
beam onto a Pb target with a 60 cm focal length lens (spot size ~60 µm) gave Z=23+, with 0.5 mAcm^{-2} 3 meters from the target.

2. In the weeks after the visit the optical scheme was improved with more saturable absorber gas to remove pre-pulses, self-lasing and decrease laser rise-time. Z=24+ was achieved, the current was less but with a longer pulse length. Scaling of the results to an LHC injector type configuration (scaling energy and target to extraction distance) gave results closer to that required.
3. The Laser pulse length was decreased to 30 ns, and with only 25 J on target Z=26+ was achieved with 2.5x10^{13} Wcm^{-2}. This now scales very closely to the final requirements.
4. Future: We will visit in Nov 1998 to test the short pulse length with higher energy (for scaling purposes) and perform some investigations of the spatial density uniformity, which may be a reason for instabilities.

Richard Scrivens, 9/10/98

LAYOUT OF THE LASER ION SOURCE





MATCHING OF PLASMA TO EXTRACTION

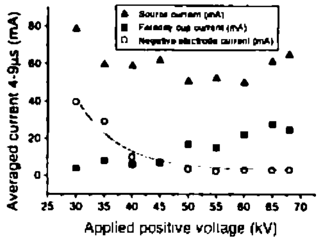


Figure 0 1 Current and source potential characteristics measured with a target to extraction distance of 717 mm.

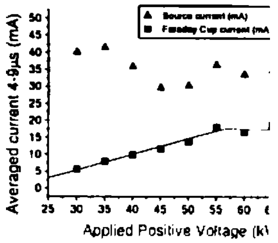
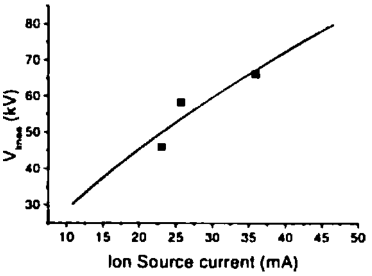


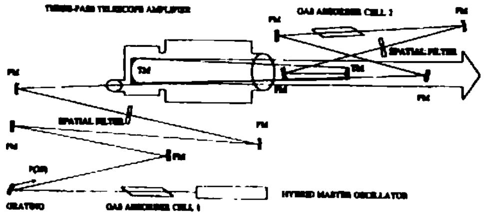
Figure 0 2 Current and source potential chara measured with a target to extraction distance c mm.

DEFINES THE IvV CHARACTERISTICS OF THE SOURCE

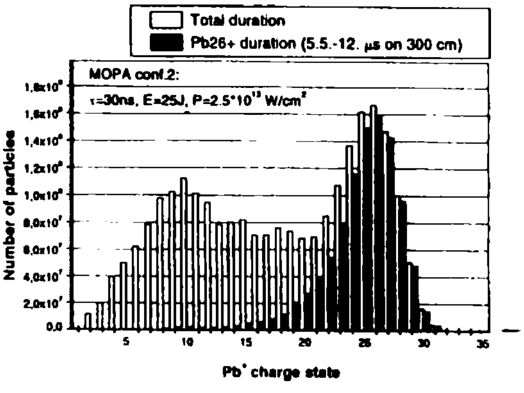
$$I = 2.06\times10^{-9}V^{3/2} = 6.9\times10^{-9}\sqrt{\frac{Z}{A}}V^{3/2}$$



LATEST RESULTS OF IONS IN TRINITI



MO – Power Amplifier layout



Number of particles for 1mA/cm^{2} current density at the distance of 3 m (E = 25 J, τ = 30 ns)

H. KUGLER

av_cur SK, HK 10/7

Brief analysis of recent results (Satov 28/6, 3,4/7) from TRINITI
" Ion yields with 30 ns laser pulses "

Note:

if
- a) in the pulse the number of charge-states is low (3-5) and the distribution around the "peak" charge state is nearly symmetric,
- b) the coefficient of secondary electrons from the electrode of the SEM is set the same for the 3-5 charge-states

then

the percentage of the current for one charge-state wrt the total average current can be set equal to the percentage of ions of one charge-state wrt the total number of ions.

3 measurements were reported: 17, 25 and 55 J.
For 25J the power-density on the target gives $Z_{peak} = 26+$, most comparable to the desired charge-state 25 (this case is analysed first).

The following assumptions and/or scalings are applied:
- the efficient Energy $E = 0.8 * E_0$, E_0 given,
- scaling to a time interval of $\Delta t_0 = 5.5$ µsec >> $I/I_0 = \Delta t/\Delta t_0$,
- current density scales linearly with energy E, and plasma expansion length l at l^{-3}
- the extraction aperture $\Phi = 3.4$ cm.

Case $E_0 = 25$ J:
One finds for E = 80J: **7.62 mA @ 5.5 µsec Pb 25+** (we aim at 10 mA).
Looking at the other cases (17 and 55 J) one can assume a percentage of 16, instead of 14.8, when the power-density will be tuned to $Z_{peak} = 25+$ which leads to
8.2 mA @ 5.5 µsec Pb 25+ (1.13 exp10 ions, we aim at 1.4 exp10).

Case $E_0 = 17$ J:
One finds for E = 80J: **10.2 mA @ 5.5 µsec Pb24+**

Case $E_0 = 55$ J:
on the target, power-density is too high, peak to average current becomes very high when tuning to wanted average current density (1.1 mA/cm^2).

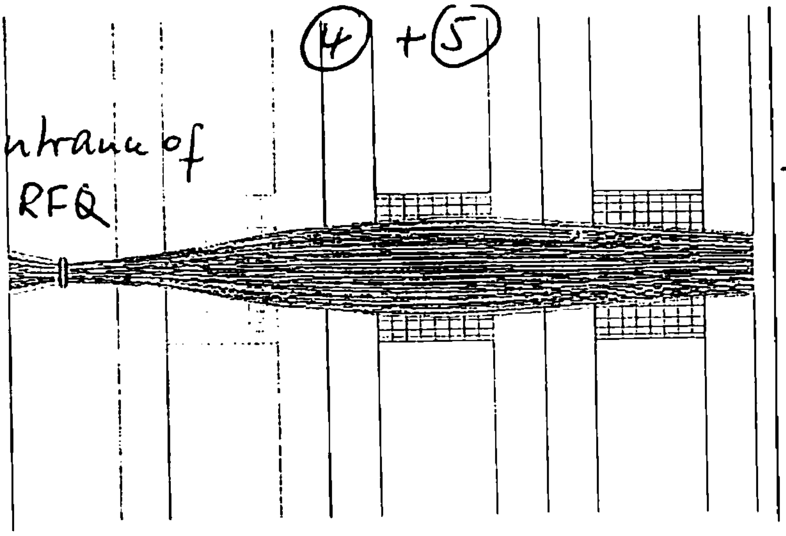
See topic : R.S. "1st achievements
w.r.t. the Russian
100 J amplifier"

H KUGLER

x

electrostatic

LEBT



④ + ⑤

entrance of RFQ

Fig. 4. Beam envelope in GEL LEBT. V_1=7 kV, V_2=28 kV, V_3=40 kV. $E_{input, total}$ =320 π·mm·mrad. $E_{input, 4rms}$ = 204 π·mm·mrad. Mesh size =1mm, Total number of particles (taking into account symmetry planes) =2400. Current=60 mA, Uextraction=60 kV.

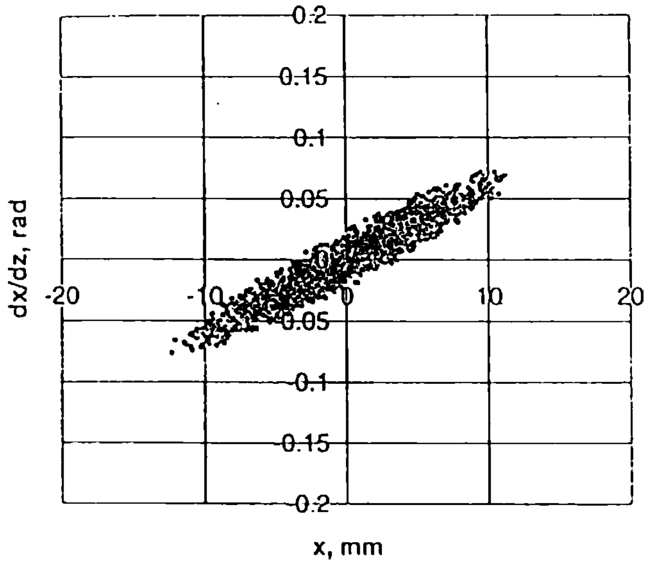


Fig. 5. Input distribution of 60 mA beam, E_{total}=320 π·mm·mrad, 4·E_{rms}=204 π·mm·mrad.

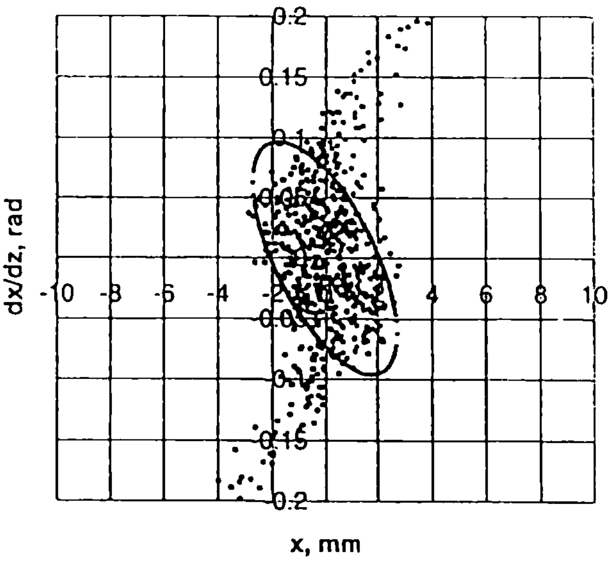


Fig. 6. Phase space plot in the entrance of the RFQ. The RFQ acceptance is shown. The total number of particles inside 4-dimensional phase space with 200 π·mm·mrad emittances in xx' and yy' is 62%.

H. KUGLER

x

inside vacuum box. The bellow 10 serves for the alignment purpose under the vacuum. The distance between the last grid and the RFQ input flange must be ~20 mm.

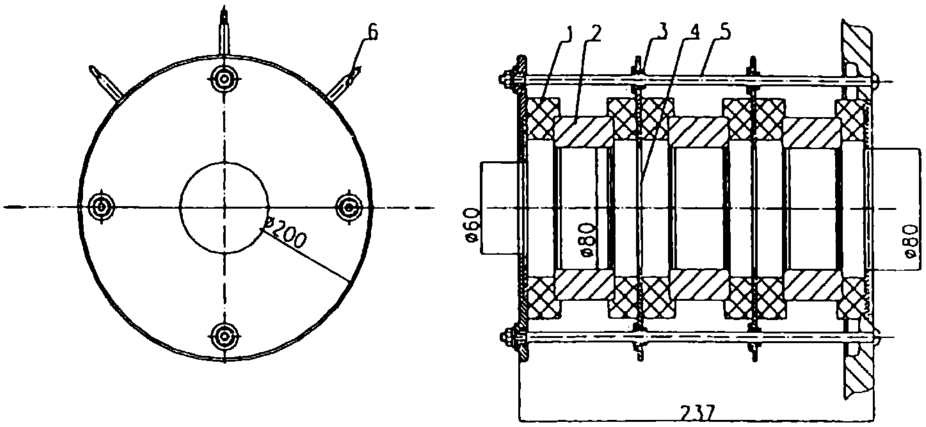


Fig. 15. Schematic view of the electrodes.
1 – isolator, 2 – electrode, 3 – isolator, 4 – grid, 5 –rod, 6 – conductor.

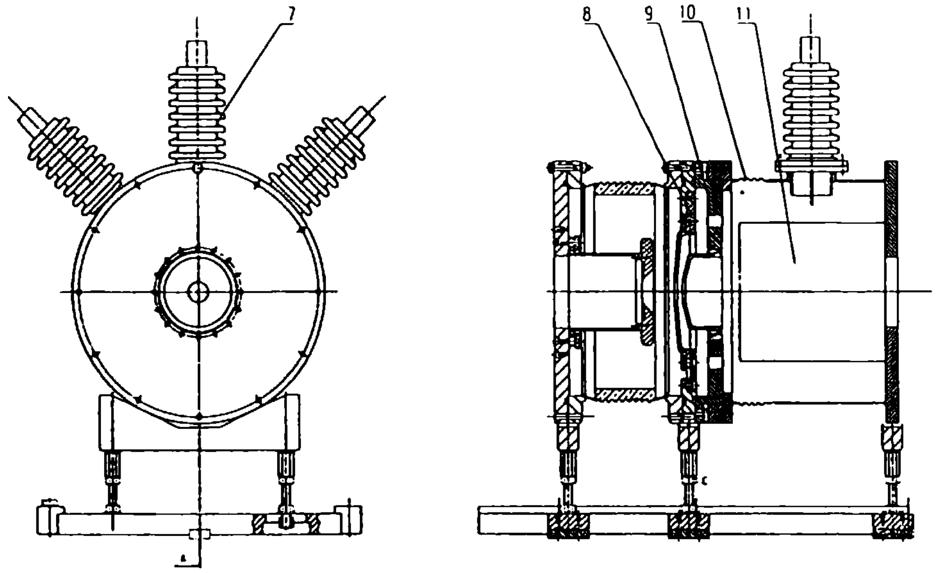


Fig. 16. Adaptation of the GEL into the extraction system of the LIS.
7 – 50 kV HV feedthrough, 8 - -10 kV electrode, 9 – zero voltage electrode, 10 – bellow, 11 – gridded lenses (see fig.15).

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

H KUGLER

Plans for the next year

a) Ongoing activities

1) re-assembly – also in some different configurations – of the present source + LEBT (modified extraction: decrease distance extraction/solenoid) and measurement of charge-state distributions.
   If the "1 solenoid" LEBT leads to about <I> = 5 mA, Ta18-20+ ions with 6.9 keV/u in an aperture of 6.5 mm, the RFQ should be re-installed,
2) participation in work on the 100 J amplifier at TRINITI,
3) further completion of the new modular source: installation of target chamber, illumination scheme, vacuum system,
4) further improvement (or acquisition) of diagnostic tools (e.g. increased resolution of electro-static spectrometer), Langmuir probes, detection of x-ray spectra.

b) New (* activity with yet not decided starting date)

1) run of MO + Pre-Amplifier (about 1 J at 1/3 Hz) for regular high rep rate operation with lighter elements (e.g. Al) to allow high current / high rep rate work,
2) * set-up of MO + Pre-Amplifier + Lumonics,
3) commissioning of an electro-static LEBT, experiments
   possibly try out of such LEBT together with one solenoid,
4) * experiment: stabilisation of plasma meniscus by insertion of a grid at positive extraction electrode,
5) resume on space-charge compensation schemes
   compensation by fields, by electrons,
   study of figures of merit "gain of ions at desired charge-state versus losses due to recombination",
6) * study of a multi – electrode extraction system to modulate "Twiss parameters" as function of ion current,
7) * Plasma cutting to suppress tails of the ion current pulse,
8) * HV pulsing of extraction electrodes,
9) Addition of new MO pulse mode : pulse-train by mode locking,
10) participation in the comparison of different laser types wrt ion yields and pulse performance, beam stability as function of plasma parameters..., x-ray diagnostics c. à. d. INTAS (Int. Assoc. for the promotion of cooperation with scientists from the New Independent States of the former Soviet Union),
11) * study of a LEBT with built-in pre-acceleration,
12) get in touch with fs lasers (Ti:Sa) to sound out their capability of high charge state ion production (Inst. for Optik und Quantenelektronic, JENA, 50 fs 800 mJ (16 TW), Imperial College, London, 150 fs, 20 mJ, here high charge state ions were observed),
13) * study of the correction of aberration of solenoids, super-posing multi-pole fields
14) numerical simulations:
    extraction systems with more than 3 electrodes, time varying current at extraction, magnetic LEBT, electro-static LEBT, LEBT(s) with built-in pre-acceleration, systems with (partial) space-charge compensation, modulation of extraction
15) * civil engineering: preparation (and in 2001) installation of complete laser system

H. KUGLER

Budget 1999 (in kCHF)

1)	Consumables (maintenance)	65
2)	Mechanics for completion of new LIS	35
3)	Up-grade of diagnostic tools	5
4)	Completion of MO + Booster + Lumonics	10
5)	Up-grading of 1 J 1/3 Hz to 2 J	15
6)	Pulsing of extraction (and/or plasma)	15
7)	Hard-ware for INTAS work	3
8)	Hard-ware for fs laser stands	5
9)	Ceramics (insulations 50 ... 120 kV)	15
10)	Hard-ware for devices for charge-state compensation	12
1-10		180
Collaboration	(visitors, meetings ...) Int. Adv. Board	60