THE NEW SINGLE BUNCH INJECTOR FOR ELSA

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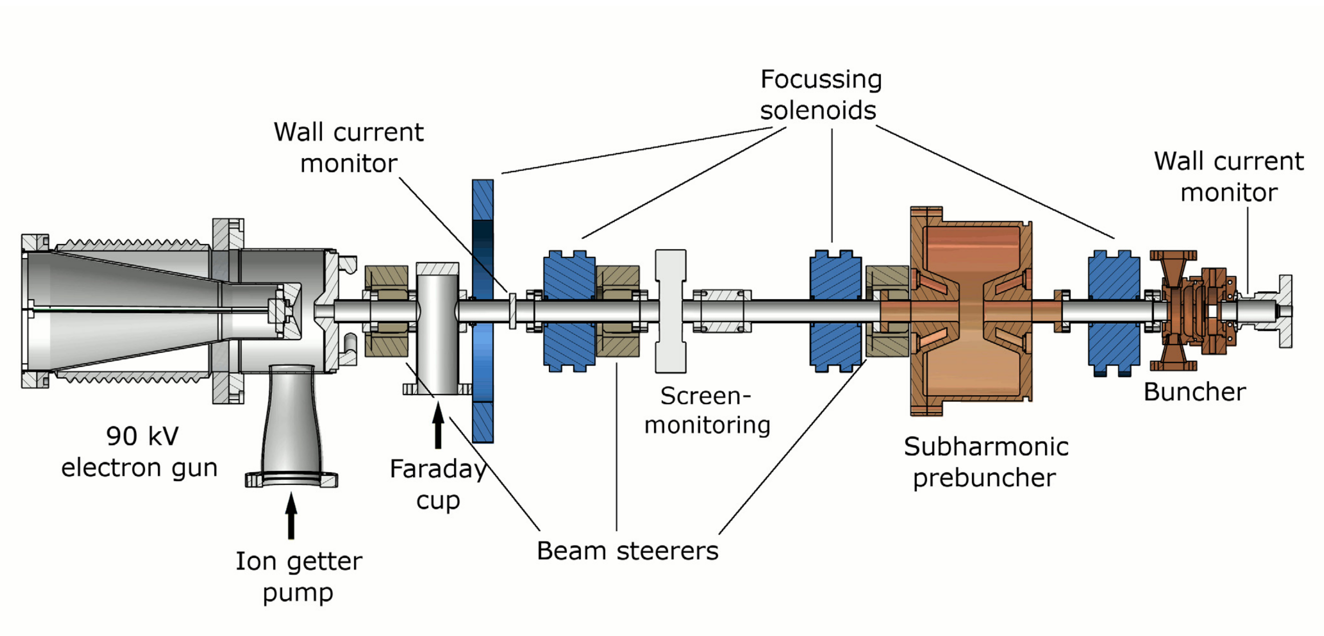

Figure 1: Overview of the new injection system which will be installed at the linear accelerator LINAC I at ELSA.

Abstract

Since 1966 a Varian manufactured injector is in use at the ELSA accelerator facility of the University of Bonn for several experiments investigating the subnuclear structure of matter.

The new injector for Linac 1 currently under construction at ELSA is expected to operate in a single bunch mode of 2 A beam current. This mode gives the possibility of deeper background studies in the experimental setup of the CB experiment sponsored by the "Deutsche Forschungsgesellschaft" and to investigate single bunch instabilities within the Helmholtz alliance "Physics at the Terascale". Also, a 2 µs long pulse mode of 500 mA beam current will be available for normal thermionic electron service. The injector delivering a single bunch was designed and optimised with EGUN and numerical simulations based on the paraxial equations. The compression of the pulses created by a pulsed thermionic 90 kV gun is achieved by a 500 MHz prebuncher as well as a β-matching travelling wave buncher running at the linac frequency.

90 KV ELECTRON GUN

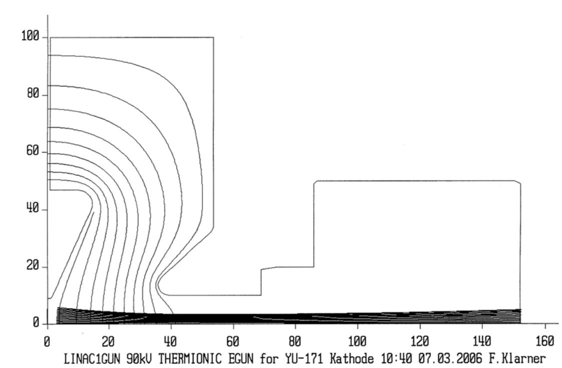

Figure 2: Gun geometry *r* vs. *z* in mm with equipotential lines and space charge limited electron rays calculated with EGUN for an anode voltage of 90 kV.

The 90 kV gun is based on a design used in the SBTF test facility at DESY. The design of the cathode conus was adjusted with the computer code EGUN to fulfill the requirements of 2 A single pulse and 500 mA long pulse operation. With a 34 mm wide anode cathode gap this gun has a perveance of 0.16 $\mu A/V^{3/2}$ and delivers a 4.3 A space charge limited current at 90 kV. The EGUN calculated beam propagation is shown in figure 2. The cathode is carried by a conical metallic tube that runs through the 250 mm long ceramic and is flanged at the high voltage end of the isolator. The gun needs a grid electrode near the cathode in order to be pulsed. The EMAC Y-171 cathode-grid assembly, which emits from a circular area of 1 cm² equivalent to 5.64 mm in radius, is used here. The normalized emittance for a 2 A pulse at the gun exit is $\varepsilon = 22.8\ \pi$ mm mrad. Pulsing the cathode will be done by a fast gun pulser housed inside the conical tube right behind the cathode. In single pulse mode the gun, together with this pulser, is expected to deliver FWHM ≤ 2 ns pulses with a peak current of 2 A.

PREBUNCHING

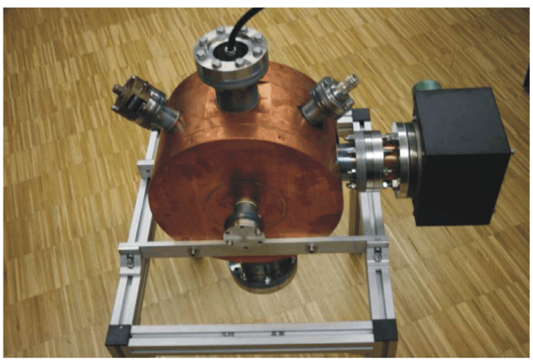

Figure 3: 500 MHz prebuncher.

The 40 mm wide gap of the 500 MHz nosecone prebuncher is centred at z = 112 cm. In order to weaken the requirements for the gun this frequency has to be as low as possible, but nevertheless has to match with the time structure of the bunch train in the stretcher ring ELSA. Therefore in our case the prebuncher has to work at 500 MHz, which implies that the gun pulse for the single bunch has a length in the order of 2 ns. The chosen prebuncher has an untuned resonance frequency of ν_0 = (499.819 ± 0.001) MHz, an unloaded quality factor of Q_0 = 15220 ± 196 and a shunt impedance of R_s = (1.63 ± 0.05) MΩ. With an injected RF power of 400 W a gap voltage of 36 kV is excited. For a critical RF coupling a new coupling loop has been designed. In figure 4 the measurement of the new coupling loop into the cavity at the first resonance is shown [1].

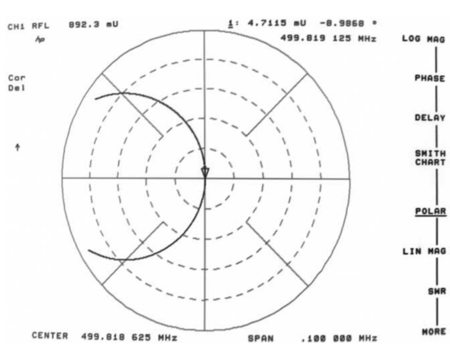

Figure 4: Polar plot of the complex reflection factor close to the first resonance of the prebuncher.

TRAVELLING WAVE BUNCHER

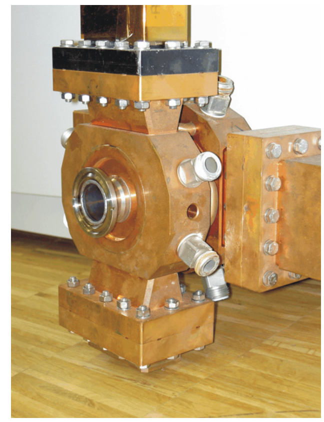

Figure 5: The travelling wave buncher with a view of the exit of the structure. On top a waterload is flanged. On the right hand side is the input of the accelerating RF.

The first cell of the travelling wave buncher is centred 34 cm behind the center of the prebuncher. The 4 cell, 6.7 MV/m structure further compresses the bunches and matches the beta to β = 0.891 at the exit of the structure. The design of the buncher implements a phase velocity of v_p = 0.0575 c and a group velocity of v_g = 0.010 c. The structure is driven by 2 MW RF power coupled from the linac RF. The passband of the structure is shown in figure 6. After a drift space of 8 cm beyond the buncher the beam is injected into the linac section.

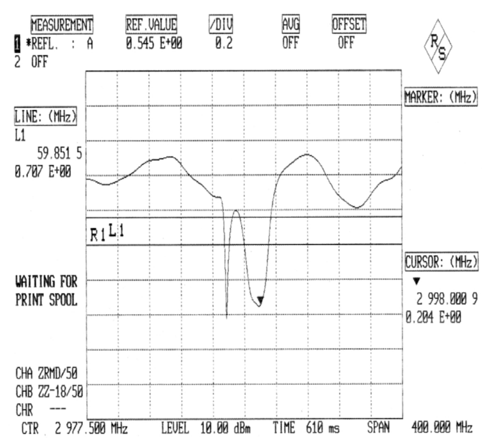

Figure 6: Plot of the reflected power against the RF frequency. The plot shows the passband of the structure.

TRANSVERSE BEAM DYNAMICS

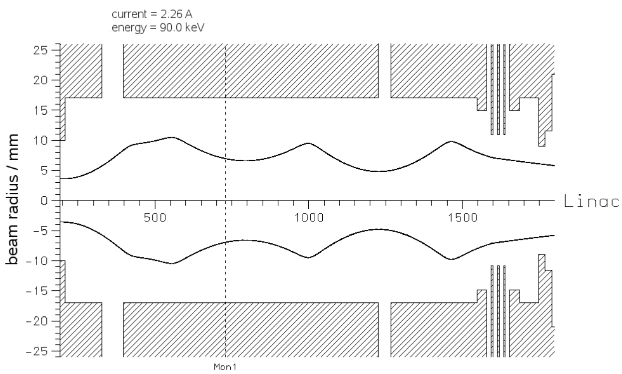

Figure 7: Simulation of a 2 A beam propagating through the beam guiding elements based on the paraxial equations.

The beam pipe has an inner diameter of 34 mm along the injector. Just in front of the entrance of the linear accelerator the aperture is reduced to 21 mm in order to minimize RF leakage out of the linac. Transverse focussing of the beam is achieved by four solenoids. The position and the strength of the solenoids were determined by numerical calculations based on the paraxial equations. The resulting beam propagation is shown in figure 7. Three solenoids with a diameter of 37 mm and a length of 75 mm produce a longitudinal field of 110 Gauss/A.
Due to spacing problems the first solenoid has a diameter of 150 mm. This causes a produced field of 1.1 Gauss/A. Additionally the field is set to zero at the gun cathode by means of a bucking coil.

MONITORING

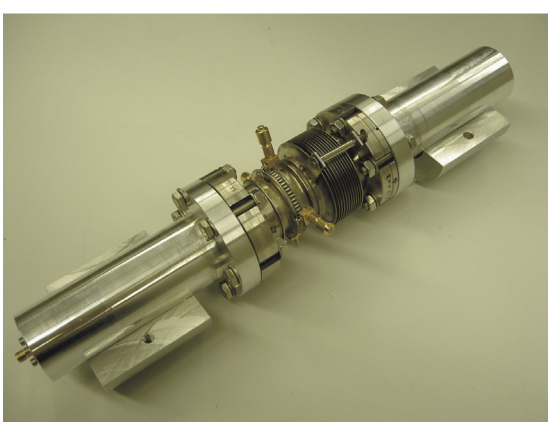

Figure 8: Wall current monitor with a bandwidth of 3 GHz, mounted on a special measurement setup to determine the bandwidth.

The driftspace in front of the prebuncher is used for beam instrumentation to measure the position, the current and the emittance as well as the beam profile. A wall current monitor with higher bandwidth up to 3 GHz is used in order to measure the charge distribution of a single bunch [2]. In figure 8 the wall current monitor is shown on a special measurement setup to determine the bandwidth of the monitor. The measurement has shown that the monitor is useable for signals up to 3 GHz.

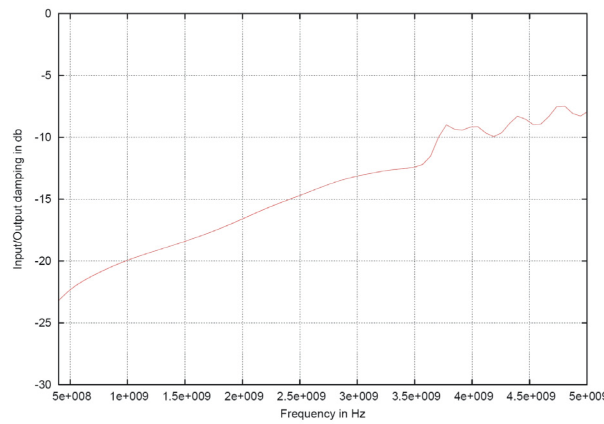

Figure 9: Measurements of the bandwidth of the wall current monitor. The results give an estimate of the bandwidth of the monitor. It appears, that the monitor will be useable for a range up to 3 – 3.5 GHz.

CONCLUSION

In order to achieve the possibility of operating ELSA in a single bunch mode a new injector is designed and still under construction. The design of the injector for Linac 1 at ELSA is based on a conservative scheme using a thermionic high intensity pulsed gun, one subharmonic bunchercavity and a travelling wave buncher. The bunching is expected to compress the bunches to less than 0.1 ns before entering the linear accelerator. To specify the real bunch length deeper studies with a computer code like PARMELA are necessary. Unwanted transverse dynamics are compensated by solenoid fields and correctors. The bunch leaves the injector with an energy of about 615 keV.

REFERENCES

[1] S. Aderhold, “Ein System zur Puls- und Energiekompression am Elektronenbeschleuniger ELSA”, University of Bonn, Germany, January 2008, http://www-elsa.physik.uni-bonn.de/Publikationen/

[2] O. Boldt, personal notice, September 2008 in preparation of “Ein Breitband-Wandstrom-Monitor für ELSA”, University of Bonn, Germany