A NEW INJECTION SYSTEM FOR AN ELECTRON/POSITRON LINAC

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Abstract

For the Linac II, which supplies the accelerator chain at DESY with electrons and positrons, a new injection system is planned. It is supposed to ensure reliable operation and to avoid the beam loss of about 60% before the positron converter and the associated activation. The main components are a 6 A/100 kV triode gun, buncher and a dispersive section for energy collimation. The output energy is 5 MeV. The new buncher structure is a hybrid of a standing wave and traveling wave structure and allows a compact design and good electron capture. Its main part is a traveling wave structure in $2\pi/3$ mode, to which one capture cell is coupled in π mode. The function of the injector components, the entire injection system and the acceleration in the linac sections were optimized in simulations. In addition, the design is analysed in a test rig before final installation. Test rig and subsequent injector are equipped with extensive diagnostics. Besides the design of the injection system results of simulations and measurements on the test rig will be presented.

INTRODUCTION

The Linac II at DESY accelerates electrons to 400 MeV using five S-band traveling wave structures at 2.998 GHz. The 400 MeV electrons can be accelerated further or alternatively be used for positron production with a tungsten target at the electron-positron converter. The converter is followed by another linac which provides 450 MeV positrons or electrons for the Positron Intensity Accumulator (PIA). Besides accumulation PIA serves for damping and compression of the pulses. An overview of the Linac II and PIA is shown in Figure 1. PIA ejects the beam to the DESY II synchrotron that supplies the storage rings DORIS III and PETRA III, which serve as sources of synchrotron radiation [1].

At the moment 4 µs electron pulses with up to 6 A beam current are generated by a 150 kV DC Gun whose tungsten cathode is heated via electron bombardment from the rear side. For electrical and heat extraction purposes the gun is operated in an oil bath, which is separated from the beam vacuum only by a ceramic. An electrostatic chopper cuts out pulses of 2 ns to 30 ns length and a prebuncher engraves the 3GHz time structure to the pulses. The 150 keV beam is injected directly into the first linac accelerator section. In the accelerator structures the electron bunches are accelerated with an average gradient of about 80 MV/structure. Therefor the RF stations are equipped with SLED cavities, which increase the RF pulse power from 20 MW to up to 90 MW.

The major difficulties of this design are that in the linac sections losses of about 60% occur at high energies on the way to the converter and cause activation. Except current

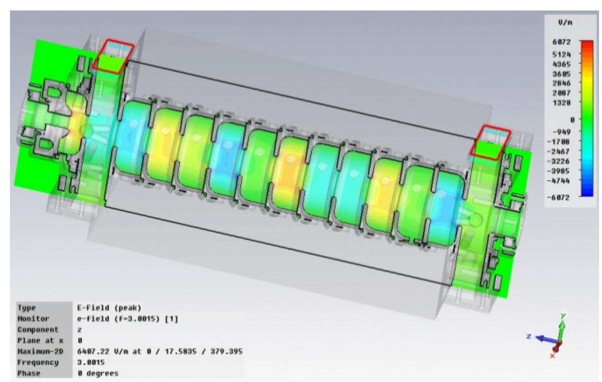

Figure 2: MWS simulation of the new hybrid buncher structure.

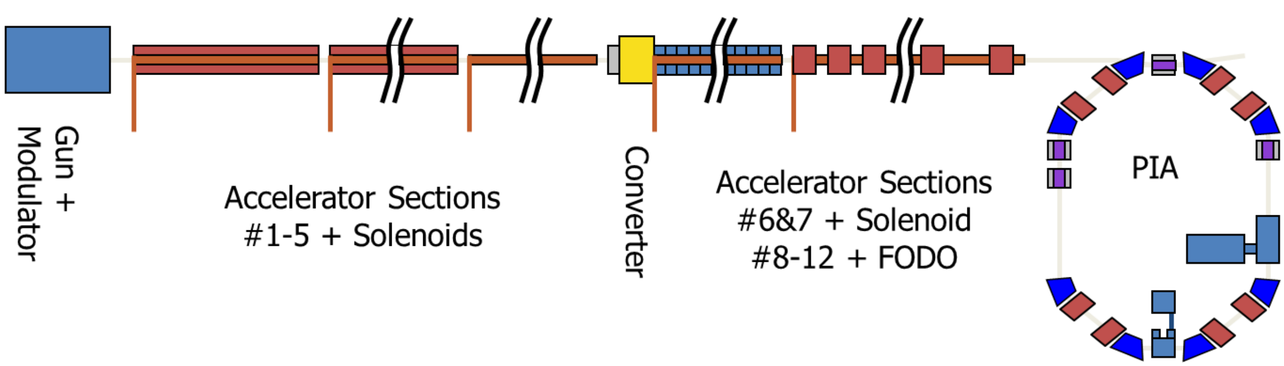

Figure 1: Overview of the Linac II and the positron intensity accumulator PIA. The first five accelerator sections deliver 400 MeV electrons. The converter can be used for positron production. It is followed by seven further accelerator structures which deliver 450 MeV positrons or electrons for accumulation in PIA.

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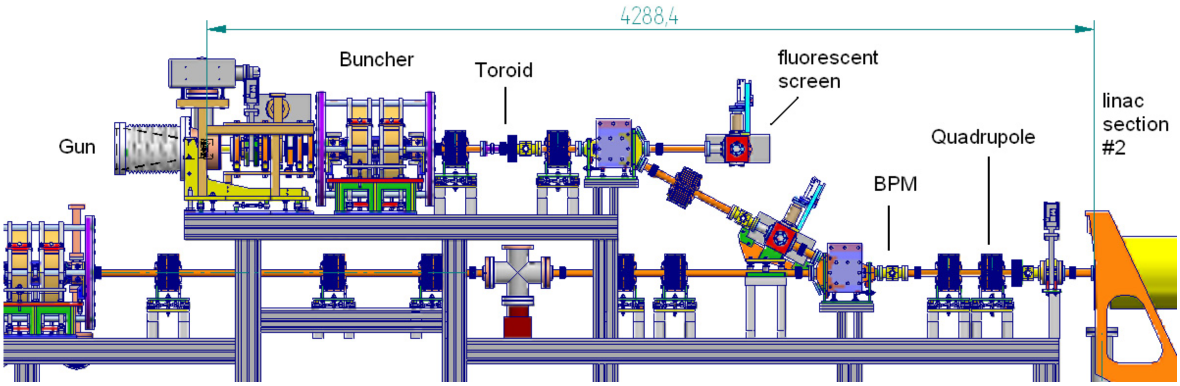

Figure 3: Solid Edge model of the new injection system mounted in place of the currently first 5.2 m accelerator section. Underneath the old gun equipped with a second hybrid buncher structure will serve as backup system.

monitors no diagnostics are installed there at present to identify possible reasons for the losses. Furthermore, there is the risk that the ceramic of the gun takes damage and oil gets inside the vacuum system, which would lead to high costs and long downtime. In addition, the cathode preparation for the existing gun is not trivial, so that an alternative for the future had to be found.

THE NEW INJECTION SYSTEM

The new injection system uses a 100 kV DC triode gun as an electron source. To achieve a current of 6 A, which is provided by the old gun, the commercially available EIMAC Y796 was chosen as a cathode. The gun delivers pulses with 5 ns to 50 ns length at a repetition rate of 50 Hz. Thus a chopper like in the old system is not required because of the triode construction. The electron pulses are formed into a 3 GHz structure by a prebuncher and focused by four solenoid magnets in front of the new hybrid buncher structure [2] which is shown in Figure 2. That has a $\beta = 0.5$ capture cell, which is operated in the π mode with a standing wave, while the other 13 cells are operated in $2\pi/3$ mode as a travelling wave structure.

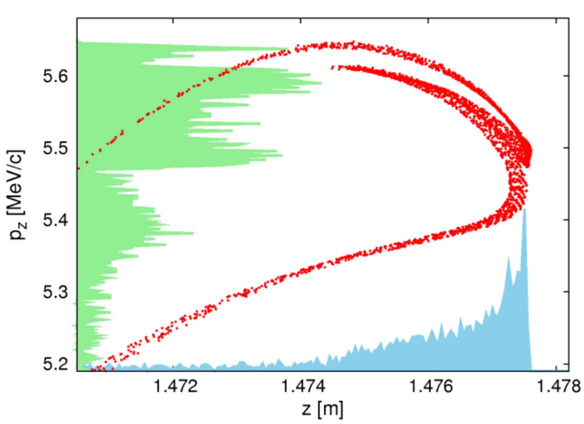

Figure 4: ASTRA electron distribution in longitudinal phase space at a distance of 0.4 m behind the buncher. In addition the projection of the distribution to the axis is shown.

The travelling wave part corresponds to the design of the other linac accelerator structures. With a buncher gradient of 15 MV/m, the electrons are accelerated to 5 MeV.

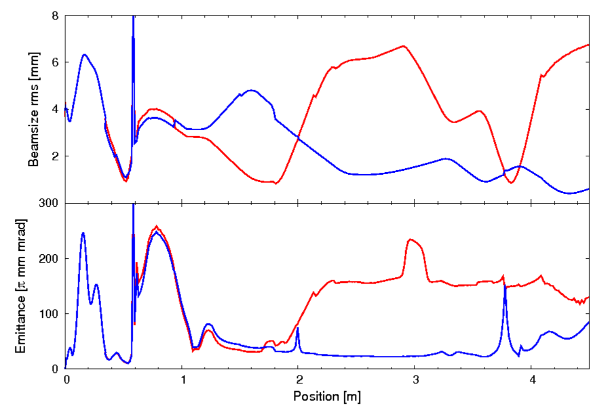

Figure 5: Horizontal (blue) and vertical (red) rms beam size and emittance in the new Linac II injection system computed with ASTRA.

By means of a second coupling cell the remaining RF power is used to feed the following accelerator structure. Downstream of the buncher a dispersive section directs the beam on the axis of the Linac II accelerator sections. This allows keeping the old gun as a backup system that will finally be fully replaced by a second identical triode gun setup. Additionally the dispersive section removes the fraction of beam which would be lost anyhow, but later at higher energies where it causes activation. Inside the dispersive section at around 5 MeV no activation can be expected. Electron distributions with an energy width of 250 keV can be transmitted through this chicane.

Between buncher and first accelerator section five quadrupole magnets are placed for focusing. The improved electron capture in the hybrid buncher structure and the energy collimation in the dispersive section promise a lossless acceleration in the Linac II sections up to the converter. In order to optimally adjust the injector and to detect problems such as misalignment the use of extensive diagnostics is planned. Since the first accelerator section will be removed to make room for the new injector, the old gun is also equipped with a

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13 1/2 cell hybrid buncher structure. The layout of the new injection is shown in Figure 3.

SIMULATIONS

The design of the new injection system was optimized using ASTRA simulations. Figure 4 shows the electron distribution in the longitudinal phase space behind the buncher. The quadrupole gradients were adjusted in MADX. With the illustrated exemplary electron distribution ASTRA showed no losses at energies above 10 MeV. About 45% of the beam are lost at low energies at the buncher aperture, in the magnetic chicane and at the section #2 aperture. Figure 5 shows the projected emittance and rms beam size between cathode and injection to linac section #2. For the emittance calculation all particles were taken into account and it is performed for fixed time steps leading to emittance changes when the electron bunch enters or leaves magnetic fields.

TEST RIG CONSTRUCTION

To be able to verify the simulation results before the modification of the Linac II injection a test rig is under construction, where measurements will analyse the

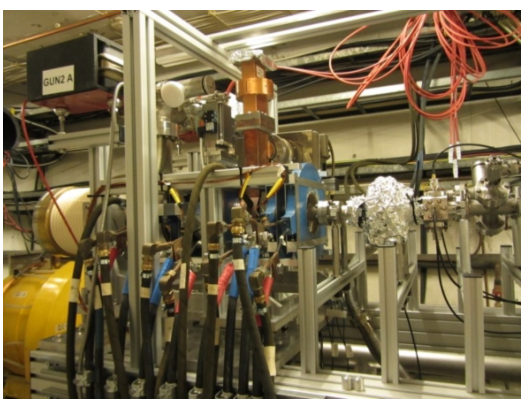

Figure 6: Test rig in Linac II tunnel. The gun is equipped with current monitor and button BPM for analysing its properties and testing diagnostic electronics. The buncher is not mounted yet.

injector properties. The new injection system will be built up and tested there separately, before it is integrated into the Linac II as shown in Figure 3. There it will be mounted above the current injector and in place of the first accelerator structure. The current status of the test rig can be seen in Figure 6. For the planned measurements the new injection system is equipped with extensive diagnostics. It consists of four button BPMs, two toroid current monitors, two fluorescent screens with integrated Faraday cup and another Faraday cup at the end of the beamline. The entire diagnostics is located between the buncher and the following accelerator section. One BPM is located in front of the dispersive section, one in the dispersive section and two behind it. The fluorescent screens are built up straight ahead of the buncher, passing the first dipole of the chicane, and in the dispersive section respectively. The current monitors are mounted in front of and behind the dispersive section. During a first test of the gun pulser the current has been measured with a Bergoz FCT 122 inductive current monitor. Figure 7 shows as an example a 40 ns long 3 A pulse.

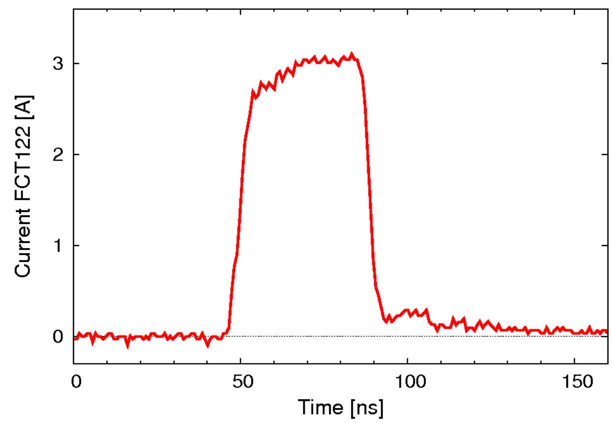

Figure 7: 100 keV electron pulse measured with Bergoz FCT 122 current monitor at z = 0.6 m behind the cathode of the triode gun.

By means of the diagnostics in the dispersive section, beam energy and energy distribution can be measured.

COMMISSIONING IN THE LINAC II

After successful tests of the new injection system it will be installed and commissioned in the Linac II during the next shutdown in spring 2013. Therefor the current Section #1 of the linac will be completely removed. The old gun, which will remain in place temporarily as a back up system, will then be equipped with a hybrid buncher structure as well.

CONCLUSION

The new injection system with a hybrid buncher structure for Linac II at DESY will allow reliable operation of the Linac II and thus improve the availability of the following storage ring light sources. The simulations of the new system are promising and extensive tests in a test rig have started.

REFERENCES

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[2] M. Huening, C. Liebig, M. Schmitz, “An electron linac injector with a hybrid buncher structure”, LINAC2010, Tsukuba, Japan, 2010.