RECENT CHANGES TO THE e^+/e^- INJECTOR (LINAC II) AT DESY

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Abstract

The Linac II at DESY consists of a 6A/150kV DC electron gun, a 400 MeV primary electron linac, an 800 MW positron converter, and a 450 MeV secondary electron/positron linac.

The Positron Intensity Accumulator (PIA) is also considered part of the injector complex accumulating and damping the 50 Hz beam pulses from the linac and transferring them with a rate of 6.25 Hz or 3.125 Hz into the Synchrotron DESY II. The typical positrons rates are $6{\cdot}10^{10}$/s.

DESY II and Linac II will serve as injectors for the two synchrotron light facilities PETRA III and DORIS. Since PETRA III will operate in top-up mode, Linac availability of 98-99% is required. DORIS requires positrons for operation. Therefore during top-up mode positrons are required for both rings. In order to maintain its reliability over the operation time of the new facility PETRA III, the major components of the linac were renovated. Some components were redesigned taking into account experience from 30 years of operation.

INTRODUCTION

The Linac II was built in the late 1960s to provide electrons and positrons for the Deutsches Elektronen Synchrotron (DESY) at higher energies (200 MeV) than the at that time existing linac (50 MeV) [1]. It consisted of 14 S-band travelling wave structures operating at 2.998 GHz and 20 MW input power and 4 µs pulse duration. The setup was modified since by introducing SLED (SLAC energy doubler) cavities for pulse compression and injecting into the Particle Intensity Accumulator (PIA). PIA was built to achieve short damping times for the positrons to be injected into the electron/positron storage ring collider PETRA. The pulse compression scheme enabled an energy increase to 450 MeV and allowed reduction of RF stations to 12, but required together with the high revolution frequency of PIA a reduction of beam pulse duration.

Today DESY II with its injector Linac II provides electrons and positrons for the synchrotron radiation facility DORIS, the synchrotron radiation facility under construction PETRA III, and for test beam targets inside DESY II. The injection into HERA via PETRA II is shut off, but there is an option to inject directly into HERA if there is the requirement by future projects.

LINAC OVERVIEW

Injection System

The primary electron beam is produced by a 120 kV pulsed DC diode gun. Beam pulses of up to 6 A and 4 µs duration are produced. The cathode is made by a thoriated tungsten plug, heated by a 3 kV, 1.2 kW bombarder. For best performance the cathode plug has to be carborized.

An electrostatic chopper forms beam pulses of 2 ns to 30 ns duration, depending on the operation conditions. In electron mode the primary beam is used directly, which reduces the required average beam current. A 2.998 GHz prebuncher cavity is fed by a portion of the first structure's forward RF power drawn from a directional coupler. The beam then enters the first accelerator section, which is not tapered.

Accelerator Sections

The linac sections are 5.2 m long travelling wave S-band structures, operating at 2.998 GHz. They are constant gradient structures with an on-axis load. Therefore the last six of their 154 cells are coated with an absorbing material and add little to the total accelerating voltage. The fill-time of the structures is 740 ns. The original structures were replaced by a design made for the S-Band Linear Collider Test Facility [2].

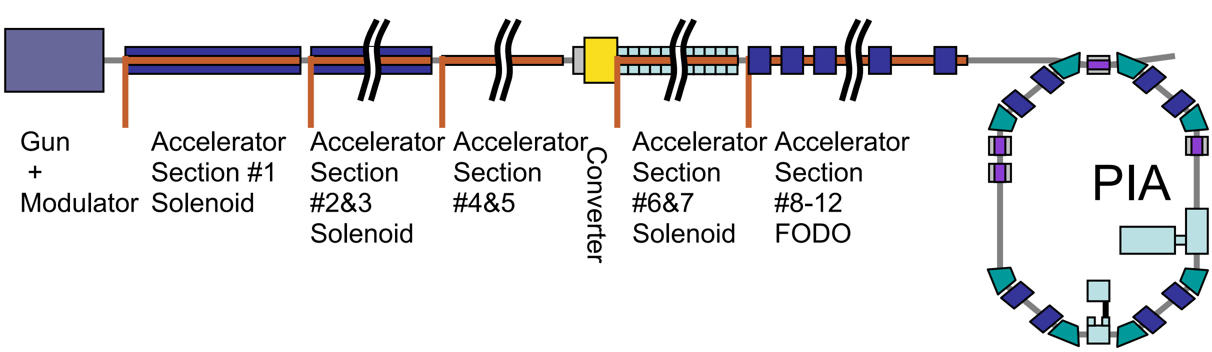

Figure 1: Schematic layout of the Linac II at DESY. The 6 A primary beam is produced in a 120 kV pulsed DC gun and directed onto a converter target at approximately 400 MeV. The secondary beam is accelerated to 450 MeV and injected into the Positron Intensity Accumulator (PIA).

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All but one RF stations are equipped with SLED cavities for pulse compression, increasing the peak power from 20 MW to 90 MW. With this the structures achieve an average gradient of 18 MV/m or 90 MV/structure. The klystron drive is provided by the RF station number 9, which therefore cannot use the SLED scheme. Phase and amplitude are adjusted via high power phase shifters and adjustable attenuators. The phase jump for the SLED is produced individually by PIN-diodes in the drive of each klystron.

Converter

At approximately 400 MeV there is the converter target. The beam current at this point usually is 2 A. The target consists of a tungsten plate with a thickness of 7 mm. An 1.8 T pulsed solenoid coil serves for focusing the secondary beam into the following acceleration sections, which in turn are surrounded completely by 0.4 T solenoid magnets. An off-axis hole in the target allows the primary beam to be steered through the target to be used directly in electron mode.

Six linac sections are available to bring the secondary beam energy to 450 MeV. Out of these six one usually is in stand-by mode and two are used off-crest with variable opposite phases to allow for adjustment of the final energy.

PIA

The electrons or positrons at 450 MeV are injected into the PIA ring. The revolution frequency in PIA is 10.4 MHz and so is the frequency of its RF system [3]. The beam is damped longitudinally with only the 10.4 MHz RF system to 1.2 ns (RMS) [4]. A second RF system at the 12^{th} harmonic produces a bunch length of 380 ps (RMS). The damping time of the synchrotron oscillation is 12.9 ms, the damping time of the betatron oscillation is 23.6 ms. The theoretical horizontal emittance is 300 nm, the vertical emittance is 15 nm.

One full accumulation lasts 160 ms or 320 ms, depending on the mode of operation. This corresponds to 8 or 16 pulses of the linac. Only 4 respectively 12 shots are injected, the other 20 ms cycles are: 1 empty, 1 additional damping with only 10.4 MHz RF, 2 damping with 10.4 MHz and 125 MHz RF.

In the 3.125 Hz mode of operation $2{\cdot}10^{10}$ positrons can be accumulated routinely. This corresponds to an efficiency of 4‰ from beam on target to accumulated particles.

MAJOR CHANGES

RF System

The klystrons are powered by line-type modulators which are switched with a thyratron. The thyratrons were successively changed from CX1168 to CX1836A, which can handle higher voltages. Although the switching voltage (up to 38 kV) is within the specifications of the old thyratron, a better lifetime and reliability is expected with the new one. Experience over 270000 hours of operation confirms this.

Converter

The target and its surroundings were rebuilt completely to remove technical risks and to allow better handling of the radioactive target after use. Firstly, all movable parts were eliminated because the high radiation levels around the target quickly destroy all motors and end-switches. Even the mechanical parts of the movers tend to suffer from corrosion. Secondly all braze joints of water filled parts were avoided or designed outside the vacuum. This applies especially to the vacuum feedthroughs of the solenoid coil and the water cooling of the target itself. Here the design benefits from the reduction of movable parts.

The output port was connected with a clamp-flange to minimize the time needed for dismounting the activated target. This turned out to be problematic for tightening the vacuum system. So in the new design a standard CF type flange is used. The copper seal at the same time serves as a collimator.

Handling the activated target after a few years of operation used to be a problem. Therefore the new target is equipped with a permanent shielding. A first layer of 20 cm Aluminium serves to reduce activation in the proximity of the converter while being little activated itself. A second layer of 5 cm lead protects persons working near the target.

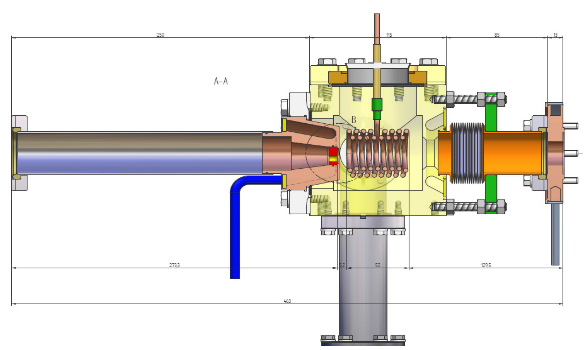

Figure 2: CAD model of the modified positron converter. In comparison to the old design all movable parts were eliminated and there are no more braze joints of water filled parts in vacuum.

A removable rail system eases the handling of the whole unit. Fixed end-points serve as references for the installation of prealigned converter targets.

Vacuum System

In places where it had not been done already, the vacuum chambers of aluminium and with DIN-type flanges were replaced by stainless steel with CF-flanges. In the wake of these works BPMs were introduced.

Beam Position Monitors

While PIA was equipped with BPMs from the beginning, the linac and the adjacent transport lines were not. In the recent shutdown Button-BPMs [5] were added to the transport line between linac and PIA (LP-Weg) and the transport line between PIA and DESY II (L-Weg). The BPM in the second straight – at 7 meters from the septum – was replaced by a new type of higher bandwidth.

Because of sensitivity and noise restrictions in the readout electronics, only damped bunches with high peak current can be resolved. For the BPMs before PIA and for the first turn in PIA readout electronics based on filtering the 3 GHz component of the button signal is being developed. For the first turn in PIA this adds the benefit of being able to distinguish the injected beam bunched at 3 GHz from the 10.4 MHz bunches already circulating in the ring.

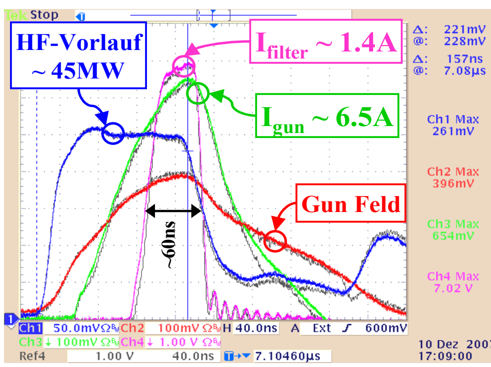

Figure 3: Scope traces of RF-gun pulses. At very high forward power of 45 MW over 160 ns filtered beam currents of 1.4 A are achieved

Gun

One problem connected with the current gun is the ceramic high voltage isolator at the same time sealing the vacuum against the oil of the modulator. Should this ceramic break, it would cause irreparable damage to probably the whole linac. Second, it is becoming increasingly harder to find suppliers for the carborized cathode plugs. Third, due to the bunching scheme a substantial portion of the primary beam is lost at high energies along the linac.

To remedy these problems a replacement of the gun is being considered. In the moment a design by MAX-Lab [6] is being evaluated. This is an RF-gun with thermionic cathode. To avoid beam losses along the linac, an energy filter is used to cut away low energy electrons. The required beam pulses are much shorter than the time constant of the gun cavity. Therefore very high forward power is used to power the gun.

At 20 MW forward power stable beam current of 900 mA has been achieved over 1 month of continuous operation. Since this current was measured behind the energy filter, it is assumed that it would reach the converter target. At higher forward power self-enhancement by back bombardment occurs. Higher beam currents are achieved at the cost of unstable operation.

With slightly reduced performance 900 mA are acceptable for the Linac II, nevertheless tests with laser enhancement are planned.

CONCLUSION

The Linac II provides electrons and positrons for the synchrotron and the storage rings at DESY. It has been renovated and upgraded to sustain its stable and reliable operation. The converter was completely redesigned, a new gun is still being evaluated.

ACKNOWLEDGEMENTS

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REFERENCES

[1] A. Febel et al., "General description and Performance Measurement of the DESY Linac II Electron-Positron Injector", Proc of PAC 1971

[2] R. Brinkmann, G. Materlik, J. Rossbach, A. Wagner (eds.) "Conceptual Design of a 500 GeV e+ e- Linear Collider with Integrated X-Ray Laser Facility", DESY 97-48, ECFA 97-182, 1997

[3] W. Ebeling et al., "The Radiofrequency Systems of PIA", Proc. of PAC 1981, Washington, DC, 1981

[4] A. Febel, G. Hemmie, "PIA, the Positron Intensity Accumulator for the PETRA Injection", PAC 1979, IEEE Trans on Nucl Sci Vol. NS-26, No 3, 3244

[5] G. Kube et al., "Overview of the Diagnostics Systems of PETRA III", Proc. of EPAC 08, Genoa, 2008

[6] B. Anderberg et al., "The Design of a 3 GHz thermionic RF-Gun and Energy Filter for MAX-Lab", Nucl Instr Meth A 491 (2002) 307