HV Design of a Pulsed Lifetime Beam with a Grounded Sample

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Keywords: Pulsed positron beam, High voltage

Abstract

A pulsed positron lifetime beam designed for semiconductor studies is under construction at Helsinki University of Technology [1]. The target of the beam is kept at ground potential to simplify the use of the beam and facilitate sample manipulation while the source and pulsing components are floating. Due to this it is necessary to pay attention to the realization of the high voltage power supply configuration and the HV surge protection. Details of the measurement chamber and the accelerator-decelerator structure are presented.

Introduction

Positron lifetime studies with a low energy positron beam have proven their usefulness in defect studies in thin samples. Versatile sample manipulation is an essential feature of a positron lifetime measurement equipment. In our facility usability and sample manipulation (heating, cooling, biasing and illumination) are made simpler and safer by keeping the measurement chamber and the studied sample at ground potential. The source and the pulsing components are thus at high potential. Therefore, voltage supplies, radio frequency signal generators and the control electronics are floating at high potential. A drawback of this concept is a more complex configuration of the pulsing and HV electronics. Because electrical breakdowns are inevitable a proper HV surge protection is required to avoid damages.

Technical setup

HV configuration. To get the desired final energy for positrons the source end of the lifetime beam is kept at high voltage. This is done by a HV power supply (U_1 in Fig. 1) which is adjustable between 2 kV and 30 kV. Another fixed HV supply (U_2) keeps the voltage over the accelerator constant at -32 kV. With these two power supplies the end energy of the beam can be adjusted from 2 keV to 30 keV.

Due to the sourcing-only nature of switching-mode HV power supplies they can not operate as current sinks and some extra resistors (R_1 and R_4 in Fig. 1) must be used parallel with them (Fig. 1). The resistance of these additional HV resistors is low compared with accelerator-decelerator resistors R_5 and R_6. Therefore they have only a slight effect on the voltage division. Resistors R_2 and R_3 are load resistances to protect the HV supplies in case of a short circuit created by a breakdown in the accelerator-decelerator structure.

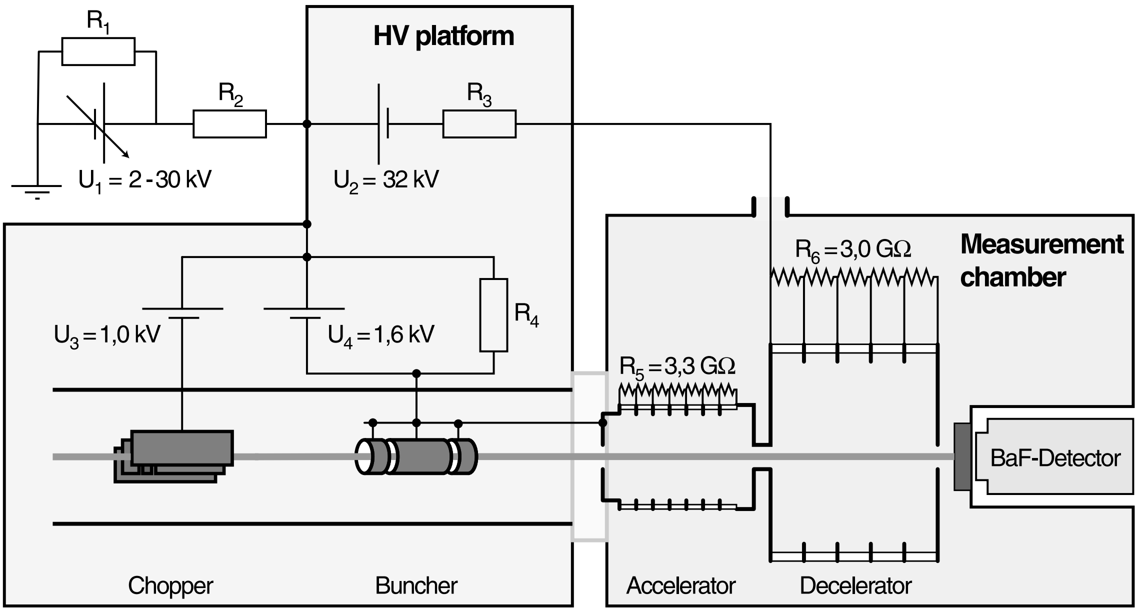

Figure 1: High voltage diagram of the lifetime beam.

Positrons are accelerated before the main accelerator by high-voltage biasing the chopper and the buncher. This is done by floating the pulsing components by two separate HV supplies (U_3 and U_4 in Fig. 1) connected to the HV platform. The radio-frequency power amplifiers are at different potential than the pulsing components and the RF signal must be fed through DC blocks where the outer and the inner conductor of a coaxial cable are isolated using HV capacitors. This block is enclosed in a RF proof can.

HV surge suppression. Our equipment with a surrounding grounded cage forms a large capacitor ($C \sim 1$ nF). When the beam is floating at a high voltage the stored capacitive energy is of the order of 1 J. Because of eventual breakdowns instruments connected to the beam must be protected against these HV surges.

To prevent voltage breakdown induced damages in DC electronics we use commercial DC line filters which comprise capacitors and inductors. These function as low-pass filters letting the DC current flow. Additionally we use multi stage protection to suppress lower residual voltage impulses. This is built up using gas-discharge tubes, varistors and breakdown diodes connected between the signal line and the ground. Isolation inductances between the stages are used to slow down the impulse and reduce its peak voltage. Also the mains side of the instruments is protected by AC line surge arresters.

The RF power amplifiers and pulsing electronics must be protected using a different technique. In our facility their outputs are protected by Quarter Wavelength Transient Protection Devices. These are quarter wavelength stubs which work as band-pass filters and shunt the shortcircuit currents to the ground. The bandwidth of the filters are 20% of the center frequency and the energy of a 1 J pulse is reduced to micro-joule range. These protectors are matched to the pulsing signal frequencies (16.6 MHz, 33.3 MHz, 66.6 MHz and 166.6 MHz).

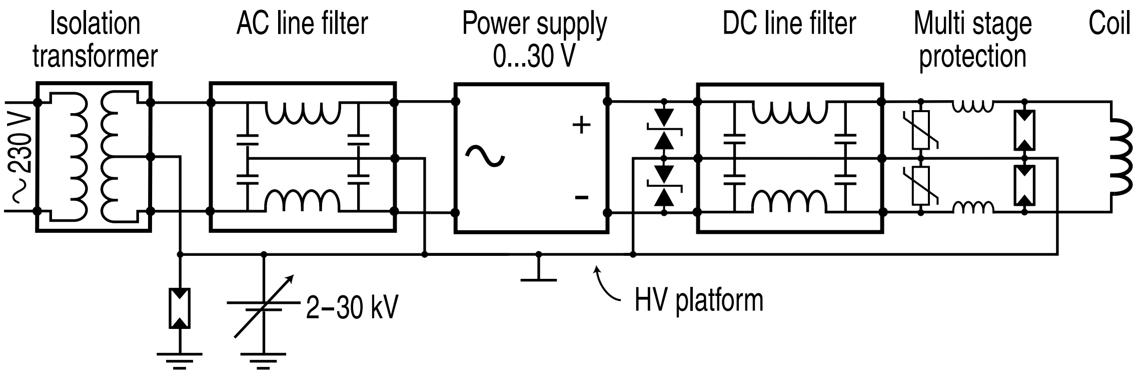

Figure 2: High voltage surge protection of power supplies of the beam. Most breakdowns are expected near the coils. Voltage spikes are guided round the power supplies to ground via the HV platform.

Measurement chamber and sample manipulation. The measurement chamber is designed to enclose the accelerator-decelerator, reduce the problems due to the backscattered positrons and facilitate versatile sample manipulation.

The accelerator-decelerator is designed to reduce the time of flight variations between different final energies of the beam. The accelerator-decelerator is a conventional set of coaxial rings which are connected to each other by high resistance (500 MΩ) HV resistors to form a resistive voltage divider chain.

When the backscattered positron annihilates near the sample it causes unwanted event to the lifetime spectrum. Our measurement chamber is large to reduce this problem. The average flight time of backscattered positrons is long in a large chamber and the undesired annihilations can be distinguished from the intentional ones. The decelerator structure is directly in front of the sample to accelerate backscattered positrons away from the sample and so prevents them from annihilating near the sample. This also helps to reduce effects of the backscattering.

The grounded sample makes it possible to use an easily accessible prechamber which is connected to the main measurement chamber to simplify changing of the sample without breaking the vacuum. Sample manipulation is realized by two manipulators, one for room temperature and another also for low and high temperature measurements from 6.5 K to 800 K.

A BaF-scintillation detector is placed into a magnetically shielded detector well right behind the sample to catch maximum number of annihilation photons. The new digital lifetime measurement system [2] will be used.

References

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