RADIATION TESTS OF AEROSPACE COMPONENTS AT ELBE*

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Abstract

The cw electron accelerator ELBE operates mainly in the beam energy range 6 to 32 MeV and beam current range 1µA to 1mA. For most experiments a thermionic gun is used as electron source. The cw electron pulse structure so as the pulse charge is realized by applying electrical pulses with specific amplitudes and frequencies on the grid of the gun. The standard cw operation frequency is 13 MHz but can be divided sequentially by the factor 2 down to 101 kHz. For very special pulse structures a so called single pulser module exist performing different patterns also with dark current suppression via a macro pulser gate. For evaluating the performance and hardness under irradiation of e.g. aerospace components much lower doses resp. currents lower than the µA range are required. Furthermore reproducible and stable doses in a specific area for consecutively radiation of samples are necessary. In the presentation the investigations and concepts used at ELBE for the irradiation of different aerospace components are described.

INTRODUCTION

The Elbe electron accelerator in the Helmholtz Zentrum Dresden Rossendorf has its main application in the conversion of higher electron currents into infrared, terahertz, gamma, positron and neutron radiation. While in the past biological cell irradiation study and single electron detector test had been performed in the radiation physics (RP) Cave (see Figure 1, indication: "radio biology, detector test"), there are also arising demands of low electron dose experiments to test e.g. aging effects of aerospace components. For such investigations electron energies in the minimal ionisation range (~20 MeV) are an important segment in the overall radiation exposure to such devices to model the conditions in the solar system and especially around other planets. For such experiments the ELBE RP-cave is well suited with two beam line outlets to air, where different samples can be placed.

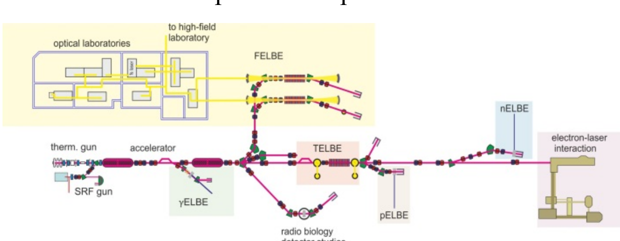

Figure 1: Basic layout of the ELBE facility. The area for the radiation experiments is named with "radio biology, detector studies".

Using low electron currents for e.g. detector tests or other radiation investigations is a side usage of ELBE, where the standard diagnostic tools like BPMs or normal beam dump electronic etc. of ELBE are not in the main scope of operation. Therefore some other diagnostic methods have to be used to characterise the radiation condition at these experimental stations.

CHARACTERISATION OF THE ELBE THERMIONIC GUN AT LOW CURRENTS

The electron bunch from the ELBE thermionic gun is produce by triggering the grid of the gun with a pulse produced by pulse shaper diodes above the cut-off voltage (-60 V). The amplitude or gate voltage on the grid determines the emitted current of the gun tetrode. The used repetition frequencies at ELBE for these pulses are on the basis of 26 MHz and can be sequentially divided by the factor 2 down to 101.5625 kHz. While the frequency should have no influence on the emitted charge per bunch in reality there is dependence – especially at low currents. Figure 2 shows the mean current of the gun measured as a function of gate voltage for cw operation at the irradiation place with a faraday cup for different repetition frequencies. These curves are the basis for planning and applying different irradiation scenarios.

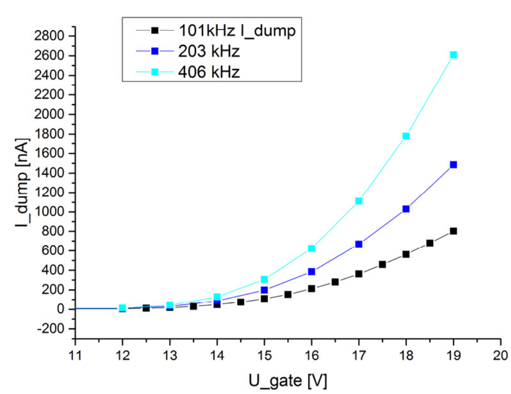

Figure 2: Faraday cup [1] current measured in the radiation physic beam line as a function of gate voltage of the thermionic gun.

SINGLE PULSER MODULE

At ELBE a single pulser module can be used to generate more complex pulse patterns or applying a defined number of pulses and therefore a dose or current to a probe. On the basis of the main frequency of the accelerator– normally 13 MHz but also the others are possible – a number n_{SP} of gun pulses (1 .. max. 477100@13 MHz) can be choose to fit into the specified Period T_{SP} (2/13

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MHz .. (2^{32}-1)/13MHz). (See Figure 3). This can be repeated N_{SP} times (1 .. 2^{32}-1).

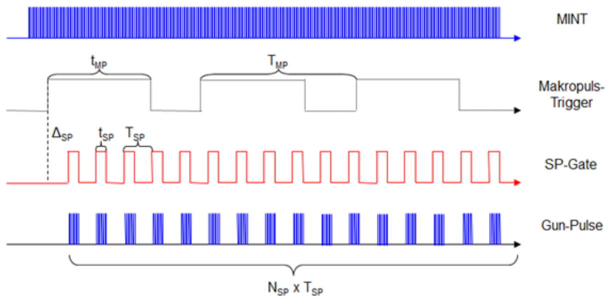

Figure 3: Schema of the single pulser module.

DIAGNOSTIC AND BEAM CHARACTERISATION AT THE RP-CAVE

The beam outlet at the RP-Cave is a 300µm Beryllium window. After the window the sample can be place in a predefined distance to the window. Depending also on the beam emittance a minimal area for the irradiation is determined through the small angle scattering in the window and in the air. Since the beam profile is nearly Gaussian the parameters of the sample like overall dimension, area to irradiate, irradiation profile etc. must be match or adapted to the used beam profile e.g. distance to window, divergence of the beam etc. Two major parameter must therefore be measured and then adapted to the experiment conditions, the profile and the dose at the place of the sample. The overall electron current can measured nearly at the place of the sample by switching the beam with a dipole to a Faraday cup [1], which is in the same distance in that beam path as the sample and also with the dump of that beam line. A second method is to use a calibrated ionisation chamber (IK) (Roos chamber type 34001 [2]) to measure the dose and the profile in one step. The profile can be scanned with the IK at the place of the sample with an my-stage and then reconstructed by the convolution integral assuming a Gaussian electron beam profile, see Figure 4.

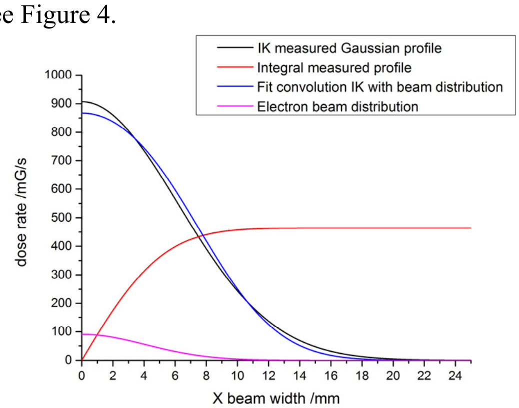

Figure 4: Dose and beam profile measurement and reconstruction with an ionisation chamber at the place of the sample. The x scale is in mm. Shown are black = profile measured with I-chamber, red = Integral of that function, blue = convolution of detector square profile with fitted beam profile function magenta.

EXAMPLES OF IRRADIATION EXPERIMENTS

In the following three irradiation experiments are shortly described. The irradiation of 1) carbon nano tube (CNT) structures, 2) satellite components for Airbus optronics GmbH and 3) response of and Micro Channel Plate to high energy electrons [3].

The aim of the first experiment was to investigate the structural effects of CNTs under different radiation scenarios. In this case the radiation dose to one sample was applied in sequential divisions to measure in-between the change of the structural effects. For that the single pulser was used to apply the predetermined dose (IK-measurements) in 10 divisions.

The experiment performed by Airbus optronics GmbH uses the xy-stage to investigate a large number of samples collected on one board (Figure 5) to study the behaviour of optical and electronic components on bread board level. This experiment was performed in preparation of a Jupiter mission where special strong electron irradiation scenarios exist. With a predefined movement and dose schedule the samples are scanned consecutively. Like for the first experiment the dose level and distribution so as the distance to the beam line extraction window was determined with IK measurements.

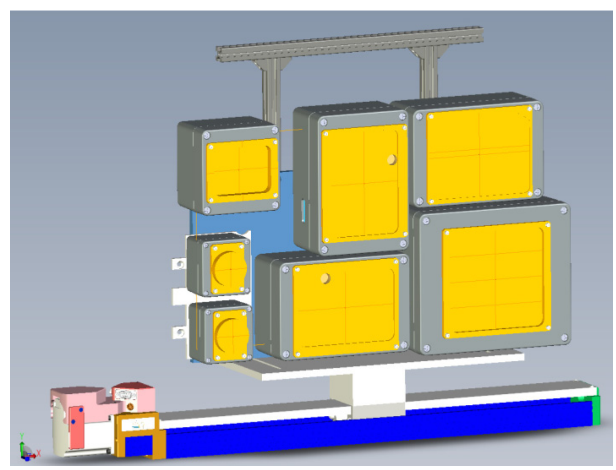

Figure 5: XY-stage with sample board to irradiate in a semi-automatic procedure.

The third experiment investigated a micro channel detector for a mass spectrometer which is foreseen for an unmanned mission to Europe, an icy moon of Jupiter. Radiation shielding to supress radiation induced noise under electron irradiation for different electron energies was one of the major investigation purpose of that experiment.

CONCLUSION

Applying electron currents in the region of 10 nA to some µA reflects very well the condensed radiation stress on aerospace components through electrons over many years. This situation in the range around 20 MeV (MIPS) for such components can be well simulated in e.g. the ELBE electron accelerator through applying long term doses or specific irradiation scenarios.

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