A SINGLE BUNCH ELECTRON GUN FOR THE ANKA INJECTOR

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Abstract

In the generation of coherent THz-radiation from short bunches the emitted radiation and wakefields act back on the beam and cause inter- and intra-bunch interactions, which lead to bunch deformations and can excite instabilities. In order to disentangle multi-bunch from single-bunch effects, a new electron gun was installed into ANKA, which allows multi- as well as single bunch operation. Here the design of the new gun and first measurements of its operation characteristics are discussed.

INTRODUCTION

The previous electron source at ANKA was a thermionic DC diode gun which allowed to generate long pulses of 1 µs length for multi bunch operation in the storage ring. Recently, a new thermionic DC triode gun was installed which is suitable for single- and multi-bunch operation. The characteristics of the new gun for the two operation modes are summarised in table 1.

NEW ELECTRON SOURCE

The geometry of the gun is shown in Figure 1. It is a standard gun for s-band linacs based on a Pierce type design [1] and produced by RI Research Instruments GmbH (formerly known as ACCEL). The cathode is heated up to 1200 °C and the distance between cathode and grid is 140 µm. Pulses are generated with a repetition rate of 1Hz.

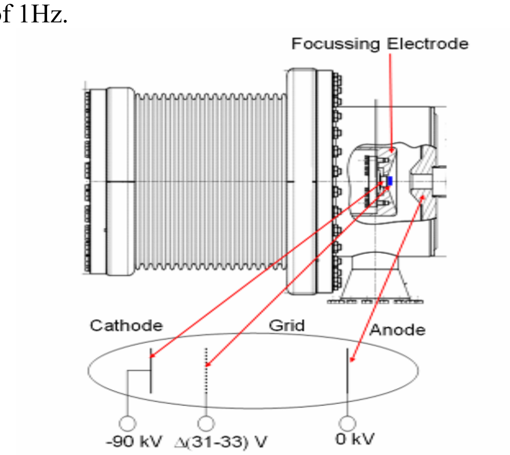

Figure 1: Design of the new electron source for ANKA. The grid voltage is given for multi bunch operation (compare with table 1)

Table 1: Parameters of the new electron gun for ANKA

Parameter	Single Bunch	Multi Bunch
Pulse Voltage	18V to 28V	18 V to 28V
Grid Voltage	50V to 120V	31 V to 33 V
Pulse Length	1 ns	50 ns to 500 ns
Charge/ Current	1.8 nC	0.2 A

OPTIMISATION OF THE GUN DESIGN

Before the gun was built, simulations were done to optimise its design. The beam transport inside the gun and from the gun to the following microtron was simulated with respect to emittance blow up due to space charge for different currents. The calculations for the gun itself were done with EGUN programme [2]. The resulting beam parameters then were used as starting values for the beam transport simulations to the microtron, which were done with OptiM32 [3]. The aim was to achieve a high current with a reasonably low emittance. The two parameters that could be varied at the gun, were the distance between cathode and anode and the layout of the cathode. The nominal distance between cathode and anode is d = 40 mm and there are two possible cathodes from the EIMAC company with different radii: Y–845 with r_1 = 4 mm and the YU–171 with r_2 = 5.6 mm. Figure 2 shows an example for the beam transport inside the gun for the Y-845 cathode, figure 3 shows the corresponding horizontal phase space plot.

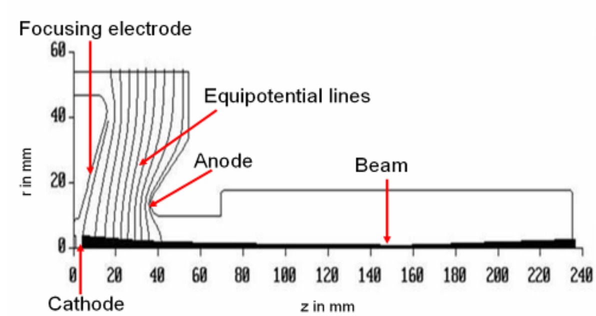

Figure 2: Beam transport inside the gun for the EIMAC Y–845 cathode and for a current of 0.2 A.

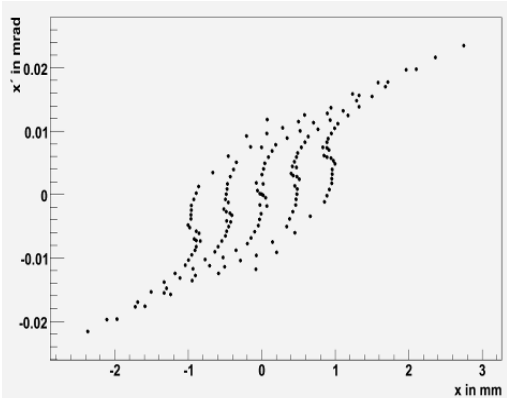

Figure 3: Expected phase space distribution after point reflection, calculated with the EGUN code at a distance of 235 mm from the cathode for a current of 0.2A.

The results of the simulations for the Y-845 cathode show an RMS emittance of about 10 mm.mrad or less for a beam current up to 0.5 A. The results are insensitive to the distance between anode and cathode. The alternative YU-171 cathode is more stable at higher currents but always has an emittance larger than 15 mm.mrad. The results of the simulations are shown in figure 4.

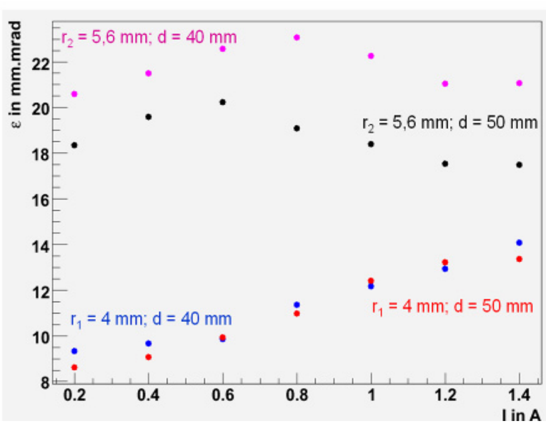

Figure 4: Emittance as a function of the current and the distance d between cathode and anode. Results are shown for the Y-845 cathode with r_1 = 4 mm and YU–171 with r_2 = 5.6 mm

As a conclusion from the simulations, the Y-845 cathode was chosen for the new gun with the nominal distance of 40 mm between cathode and anode.

EMITTANCE MEASUREMENT

The emittance of the new gun was measured with a "Pepper Pot" setup. The principle of the measurement is illustrated in figure 5.

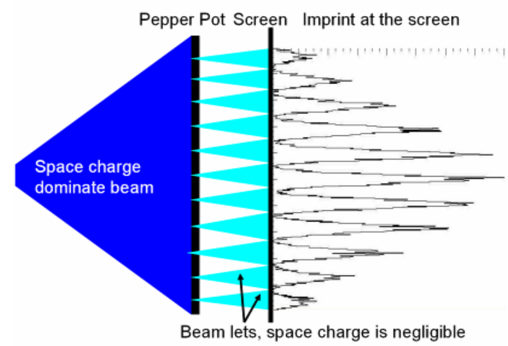

Figure 5: Principle of emittance measurement with a "Pepper Pot" device

A space charge dominated beam hits a hole mask and generates "beamlets", which are detected at a fluorescent screen. Because the current in the beamlets is much lower, the space charge is negligible and the divergence depends only on the emittance. From the beam parameters measured at the screen (position, width and intensity), using the known position of the holes at the "Pepper Pot" and from the distance between "Pepper Pot" and screen, the emittance could be estimated at the position of the "Pepper Pot" [4].

LAYOUT OF THE "PEPPER POT"

The sensitivity of a "Pepper Pot" to the beam parameters depends on the diameters of the holes, the spacing between the holes and the distance between "Pepper Pot" and screen [5]. The layout of the device was optimised using the results of the EGUN simulation for the new electron gun. The diameter of the "Pepper Pot" holes has to be chosen so, that the space charge in the beamlets has only negligible impact on the measured emittance. For typical operation parameters (multi bunch operation at a current of 0.2 A) the condition [3]

$$\frac{2Ir_0^2}{I_0\gamma\varepsilon_n^2} << 1$$

is satisfied, giving, with I = 30 µA (current in the beamlet), r = 50 µm (radius of the beamlet at the "Pepper Pot"), γ = 1.12 (the relativistic factor), ε_n = 0,02 mm.mrad (normalised emittance of the beamlet) and I_0 = 17000A (Alfven current), a value of 0.02 for the left hand side of the inequality.

The final layout of the "Pepper Pot" device is shown in Figure 6. It contains a 50 µm stainless steel disk with 20 mm diameter and 9x9 laser drilled holes of 50 µm diameter at 750 µm spacing [6]. The distance between "Pepper Pot" and screen is 32 mm. For the fluorescent screen YAG-Ce discs with 50 µm thickness and 20 mm diameter have been used. [6]

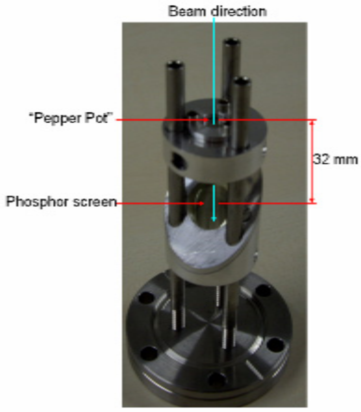

Figure 6: Photograph of the "Pepper Pot" device

MEASUREMENT AND FIRST RESULTS

The setup for the emittance measurement is shown in figure 7. Above the fluorescent screen, a CCD camera (Sony XCST 50) is mounted. The camera is controlled with the Matlab [9] Image Acquisition Toolbox. To measure the beam current, a Fast Current Transformer (Bergoz: FCT-082-20:1-H) was used.

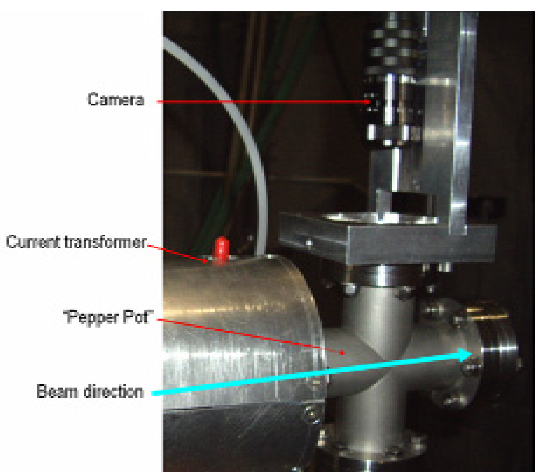

Figure 7: Experimental setup for the emittance measurement.

Figure 8 shows a measurement with the "Pepper Pot" setup and a first measurement of the emittance based on the horizontal projection of a slice of the image. A simple parameterisation is overlayed over the data. Varying the current from 50 mA to 250 mA one finds emittances around 17 +- 4 mm.mrad, i.e. on average slightly larger values than expected. One should, however, be aware that these figures are likely to overestimate the true emittance of the gun. A more detailed analysis which is still under way has to be done differentially in both dimensions, and has to take into account stray magnetic fields from the ion pump or the ion gauge, which could not be shielded, as well as the fact that the beamlets were not passing centrally through the holes which could lead to deformed images.

SUMMARY AND CONCLUSIONS

A new single bunch electron gun has been installed into the ANKA facility. The gun has been designed to have an emittance of 10 mm.mrad for beam currents up to 0.5 A. First test measurements indicate that this goal has been reached, although a first conservative estimate of the actual performance gave slightly worse figures.

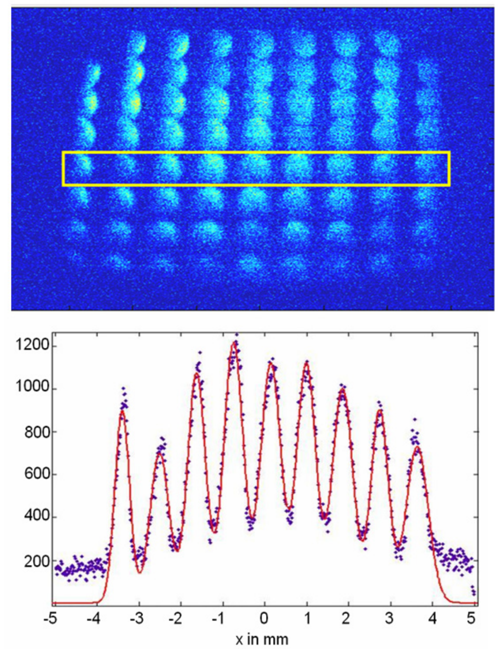

Figure 8: Emittance measurement for a current of 270 mA. The top plot shows the image from the "Pepper Pot" device, at the bottom the horizontal projection of the marked row is shown.

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