RECENT MEASUREMENTS OF THE LONGITUDINAL PHASE SPACE AT THE PHOTO INJECTOR TEST FACILITY AT DESY IN ZEUTHEN (PITZ)*

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Abstract

The Photo Injector Test facility at DESY in Zeuthen (PITZ) was built to test and optimize electron guns for short wavelength Free-Electron Lasers (FELs) like FLASH and XFEL at DESY in Hamburg. For a detailed analysis of the behaviour of the electron bunch, the longitudinal phase space and its projections can be measured behind the gun cavity. The electric field at the photo cathode was increased from 40 MV/m to 60 MV/m to optimize the transverse emittance. The momentum distributions for different gradients and gun phases will be presented. In order to study emittance conservation, a booster cavity and additional diagnostics were installed. The evolution of the longitudinal phase space in the booster cavity will be investigated. Measurements of the momentum distribution and longitudinal distribution behind the booster cavity will be discussed.

INTRODUCTION

The main goal of PITZ is to test and to optimize L-Band RF photo injectors for Free-Electron Lasers. The requirements on such a photo injector are small transverse emittances, charge of about 1 nC, short bunches (FWHM of about 20 ps) and the possibility of long bunch trains of 800 pulses emitted with a frequency of 1 MHz. The heart of PITZ is a copper gun cavity with a solenoid magnet that is used to focus the beam. Detailed analyses of the gun cavity at a gradient of 40-45 MV/m were presented in [1, 2, 3]. In order to decrease the effects of space charge forces and thus decrease the transverse emittance, the gradient at the cathode was increased to 60 MV/m. Experience of the conditioning and the first run period at high gradient are presented in [4, 5]. In this paper the influence of the higher gradient on the momentum distribution will be discussed.

MOMENTUM

In order to understand the behaviour of the gun for higher gradients at the cathode, measurements and simulations for different gradients were done. Figure 1 shows measurements and simulations of the maximum mean momentum reached for different powers in the gun. The trend

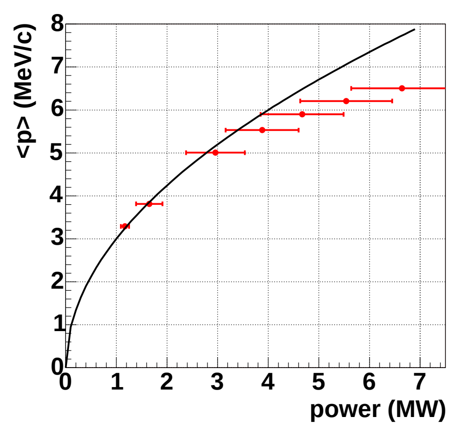

Figure 1: Measured mean momentum as a function of the power in the gun (red dots). the black curve describes the expectation, it is fitted with the square root of the power.

of the measured mean momentum fits to the expectations up to a power in the gun of about 3.5 MW. For higher powers the mean momentum stays below the expectation. The power in the gun cannot be measured directly in the gun and the error of the power measurement is quite large (± 0.5 MW). One possible explanation would be that the measurement of power the is not correct, it is for example possible, that it measures higher order modes or the cavity is misshapen and field balance could change. Another possibility is, that we are loosing power between the point of

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power measurement and the gun, for example in the coupler due to misalignment.

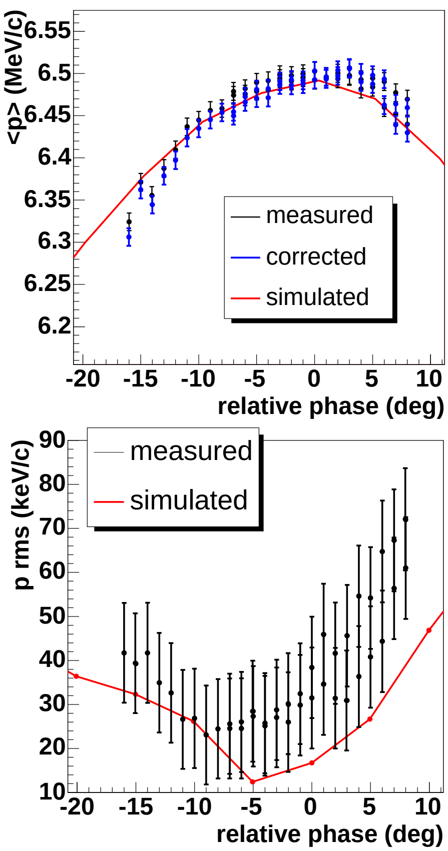

Figure 2: Mean momentum (top) and momentum spread (bottom) as a function of the gun phase.

The maximum mean momentum reached in the gun was about 6.5 MeV/c. Figure 2 shows a measurement and the corresponding simulation of the mean momentum (top) and momentum spread (bottom) as a function of the gun phase. The phase with maximum mean momentum gain was defined as zero for both measurement and simulation. Simulation and measurement of mean momentum fit not completely. The measured momentum spread is larger than the simulation, one reason for the large error bars that the subtraction of the background (dark current), whose momentum is very close to the one of the beam, is not perfect. Another point is that the phase of the minimum is different for measurement and simulation. Due to the large error bars this effect is not so clear in this graph and has to be investigated in more detail.

For the gun phase with maximum momentum gain of 6.4 MeV/c, the momentum was measured after the booster cavity for different booster phases and settings. Figure 3 shows the measured mean momentum and momentum spread of the electron beam as a function of the booster phase for different power (0.6 and 1.9 MW) in the booster. The phase with the smallest momentum spread is in both cases: phase with maximum energy gain - 5 deg. There is a

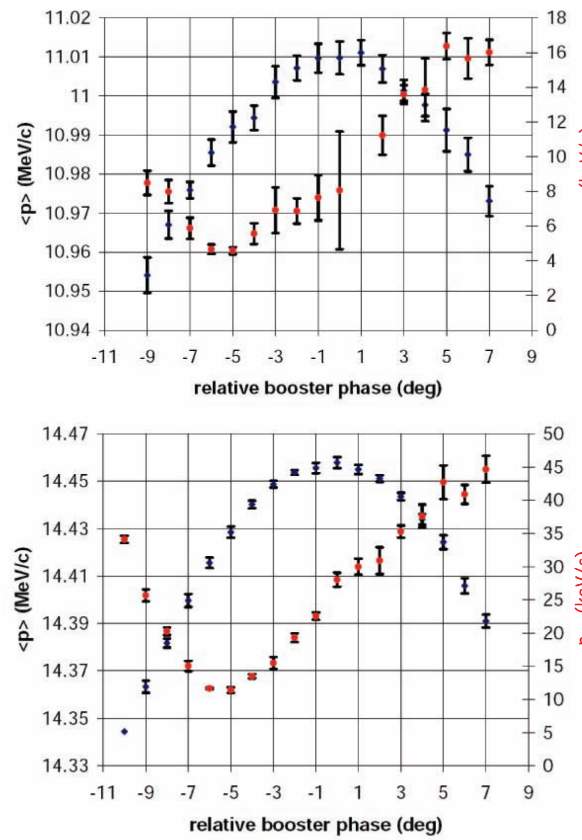

Figure 3: Mean momentum and momentum spread as a function of the booster phase for about 0.6 (top) and 1.9 MW (bottom) in the booster.

strong difference in the value of the momentum spread for the two cases. This might be due to some incorrect setting of the camera or wrong focusing. It was also seen that the YAG-screen, which were used for the measurements were burned, this could falsify the results. More detailed studies have to be performed.

LONGITUDINAL DISTRIBUTION

A screen station (HIGH1.Scr2) for the measurement of the longitudinal distribution of the electron bunch was installed about 1.4 m downstream the exit of the booster cavity (about 5 m downstream the cathode). For the measurement of the bunch length aerogel (n = 1.008), an optical transmission line and a streak camera is used. It was designed such that bunch length measurements can be done with booster cavity turned on and off, i.e. a momentum range from 5 to 40 MeV/c is covered [6]. First measurements were done in the summer of this year with and without booster cavity. Figure 4 shows the measured and simulated rms bunch length done without booster at an energy of about 6 MeV/c for a charge of about 0.6 nC within the measurement range. The phase with the highest momentum gain was determined using dipole magnet and is set to zero in the graph. Unfortunately, it was not possi-

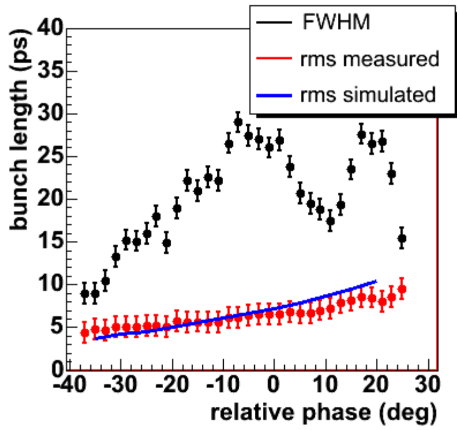

Figure 4: Measurements and simulations of the electron bunch length as a function of the gun phase

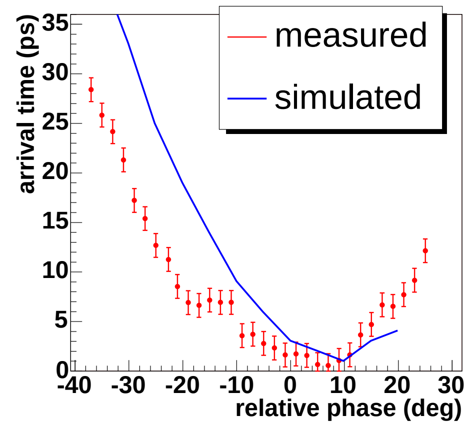

Figure 6: Relative arrival time of the bunch at the streak camera.

ble to make comparable measurements at screen station for bunch length measurement before the booster (about 1.7 m downstream the cathode) due to radiation damage of some components. The rms value is increasing with the phase. The full width half maximum (FWHM) behaves differently. The FWHM is large around the phase with the highest momentum gain (-7 deg to 2 deg), while the rms value is medium range. A large FWHM can be found for higher phases as well, but the rms value of the bunch length is also large. Figure shows the longitudinal distribution for three cases for a better understanding of curve. For the phase

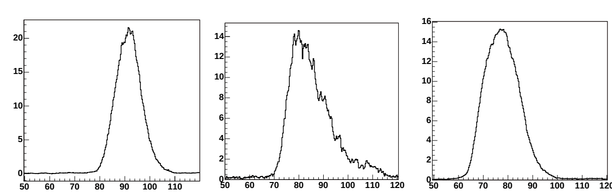

Figure 5: Longitudinal distribution of the electron bunch for phase with maximum mean momentum gain -30 deg +0 deg and 20 deg

with maximum momentum gain (0 deg) the FWHM and the rms values is larger than for -30 deg. This leads to a higher peak current for -30 deg. For 20 deg the FWHM is large, but the rms values as well, due some long tail of the distribution. So cases with large FWHM and and small rms-values is favourable, since the charge is distributed more homogeneous and the influence of space charge forces can be reduced.

The arrival time of the bunches as a function of the gun phase in plotted in figure 6. Here one can see a difference in the arrival time between simulation and measurement. This difference in phase between measurement and simulation is comparable to the one we see in the curve of the momentum spread (Fig. 2). This could be a hint for a systematical error in the set up, but this could be also cause by a shift in the phase during the measurement.

Figure 7 shows the measured and simulated rms bunch length at an energy of about 16 MeV/c, for the gun phase with the highest energy, as a function of the booster phase. The booster phase with the maximum momentum gain was defined as 0 deg. The measurement cover a large phase range (120 deg). The rms bunch length stays almost con-

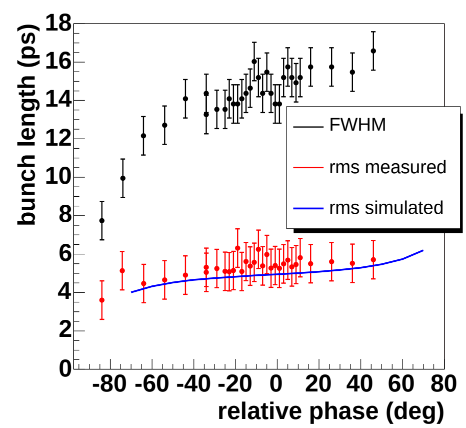

Figure 7: Measurements and simulations of the electron bunch length as a function of the booster phase

stant over a large range around the phase with the maximum momentum gain. For an off-crest the bunch length changes stronger. Figure 8 shows the arrival time of the bunch for the same measurement. Measurement and simulation fit well within the range of -60 to 10 deg. Starting for 10 deg the measurement shows an unexpected behaviour, but the values in the plot of the bunch length seems to be reasonable. It seems to be a measurement artefact, maybe there was a jump in the delay of the streak camera.

SUMMARY

The measurement of mean momentum, momentum spread upstream and downstream the booster was presented. Observed problems and inconsistencies were de-

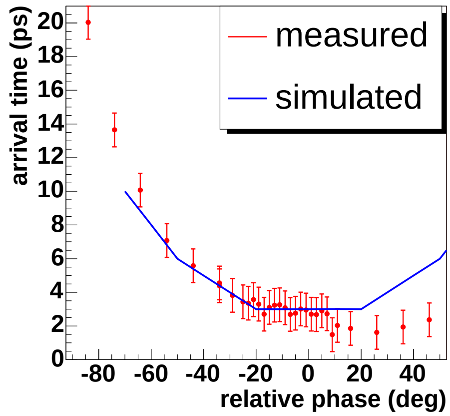

Figure 8: Relative arrival time of the photon pulse produce by the electron bunch at the streak camera as a function of the booster phase. This is assumed to be equal with arrival time of the electron bunch at the screen station

scried and have to be analysed further to understand in detail the problems of this gun and to avoid them in future. A new screen station for the measurement of bunch lengths was put into operation successfully, first measurements were presented and discussed.

REFERENCES

[1] V. Miltchev et al., "Transverse emittance measurements at the photo injector test facility at DESY Zeuthen", FEL'04, Elettra , Triestre, Italy, 2004.

[2] D. Lipka, "Investigations about the longitudinal phase space at a photo injector for minimized emittance", PhD Thesis 2004 Humboldt University Berlin

[3] M. Krasilnikov et al., "Characterization of the electron source at the photo injector test facility at DESY Zeuthen", NIM A 528(2004)360-365.

[4] S. Lederer et al., "Conditioning of a new Gun Cavity Towards 60 MV/m at PITZ", PAC'07, Albuquerque, NM, USA, 2007.

[5] S. Rimjeam et al., "Status and Perspectives of the PITZ Facility Upgrade", FEL'07, Budker Institut of Nuclear Physics, Novosibisk, Russia, 2007.

[6] J. Rönsch et al., "Investigations of the Longitudinal Beam Properties at the Photoinjector Test Facility in Zeuthen", FEL'06, BESSY, Berlin, Germany, 2006.