Measurement of the longitudinal phase space at the Photo Injector Test Facility at DESY Zeuthen

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A setup for the measurement of the longitudinal phase space at the photo injector test facility at DESY Zeuthen is described. The measurements of the momentum distribution, the length of the electron bunch and of their correlated energy spread are discussed.

1. Introduction

The photo injector test facility at DESY Zeuthen (PITZ) has been developed with the aim to deliver low emittance electron beams and study their characteristics for future applications at free electron lasers and linear accelerators. The energy of the electron beam varies in the range between 4 and 5 MeV. A detailed description of PITZ can be found in [1].

Successful optimisation and improvement of the PITZ performance requires good beam diagnostics for investigation of the electron bunch properties. This contribution is focused on longitudinal emittance measurements.

2. Momentum distribution

A spectrometer dipole and a YAG screen are used for the measurement of the momentum distribution of the electron bunch. The electrons gain different energies depending on the time when the laser hits the cathode. The latter can be expressed in terms of a phase between laser pulse and accelerating field (SP phase). The maximum mean momentum of an electron bunch is (4.72 ± 0.03) MeV/c, the corresponding SP phase is choosen to be 0^{o}. According to simulation this corresponds to a gun gradient of (41.8 ± 0.3) MV/m and a RF power of (3.15 ± 0.05) MW.

The smallest momentum spread of (33 ± 7) keV/c is observed at a SP phase of 10^{o} and an electron bunch charge of 1 nC (see Fig. 1).

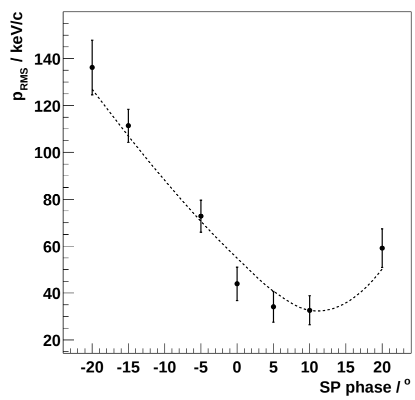

Figure 1. RMS momentum spread of the electron bunch as a function of SP phase for a gradient of 41.8 MV/m compared to simulation results (dashed line) [2].

3. Bunch length

The electron bunch length is measured using a Cherenkov radiator, an optical transmission line [3] and a streak camera (bunch length measurement system). In order to obtain an adequate photon yield [4] Silica aerogel (SiO_2) with n = 1.03 and thickness of 2 mm is used. The aerogel is placed in vacuum (for details see [5]).

To gain enough intensity multiple photon bunches are collected for the longitudinal distribution measurement. This requires a small jit-

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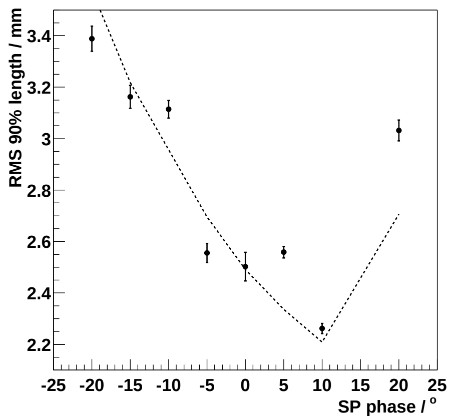

Figure 2. RMS 90 % length as a function of SP phase for electron bunches with a charge of 1 nC compared with a simulation (dashed line).

ter of the whole system (laser, accelerating field, streak camera) compared to the time resolution of the bunch length measurement system. The jitter was investigated by measuring the bunch length as a function of the number of laser pulses in the train. All bunches of the train are overlayed at the streak camera. A significant jitter would lead to an increase of the bunch length with increasing number of laser pulses. The bunch length of $\sigma = 27.2$ ps was measured and appered to be stable within the statistical uncertainties. In addition the standard deviation of the mean of 100 single bunches is calculated to be 1 ps which corresponds to the time jitter.

Dispersion between radiator and streak camera elongates the photon bunch. To suppress the dispersion a bandpass filter with 12 nm bandwidth is used. 10 % of the tails in the longitudinal distribution, originating from the noise were cutted off. The remaining 90 % of the distribution were used for extraction of the bunch length as RMS 90 %. The value of the bunch length as a function of SP phase is shown in Fig. 2 compared to the results (RMS 90 %) from a simulation [2] where corresponding input parameters of the gun are applied. By increasing the phase the accelerating field becomes weaker on the cathode. Therefore the longitudinal space charge becomes more dominant and the bunch is longer at a phase of 20^o. The shortest bunch has a length of 2.25 mm, corresponding to a FWHM of 6.3 mm or 21 ps at a phase of 10^o.

4. Longitudinal phase space

It is planned to measure the full longitudinal phase space of the electron bunch by using a dipole, a Cherenkov radiator and a streak camera. The produced photon bunch provides the information about the time properties and the momentum spread of the electron bunch. The photon bunch is transported to the streak camera, where its momentum and longitudinal distribution can be measured simultaneously, their correlation will be obtained (for details see [6]).

5. Outlook

The commissioning of the setup to measure the full longitudinal phase space is scheduled for end of 2003. First results are expected in the beginning of 2004.

In 2004 the photo injector will be extended by a booster cavity. The energy of the electrons after the booster will be about 30 MeV. At this energy optical transition radiation can be used in order to transform the electron bunch into a photon bunch instead of Cherenkov radiation mechanism, which provides an even better time resolution than the Cherenkov effect.

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