Measurement of the longitudinal phase space for the photo injector test facility at DESY Zeuthen

D. Lipka[a], J. Bähr[a], I Bohnet[a], K. Flöttmann[b], D. Richter[c], F. Stephan[a], Q. Zhao[a]

[a]DESY Zeuthen, Platanenallee 6, 15738 Zeuthen, Germany

[b]DESY Hamburg, Notkestr. 85, 22607 Hamburg, Germany

[c]BESSY, Albert-Einstein-Str. 15, 12489 Berlin, Germany

A setup for measuring the longitudinal phase space of the photo injector test facility at DESY Zeuthen is described. This setup includes a YAG-screen and a Cherenkov detector which are used to convert the electron beam into a photon beam with the wavelength in the visible range. The momentum spread of the electron bunch can be measured with the YAG-screen. The Cherenkov radiation mechanism will be used to measure the bunch length with good time resolution. As radiators silica aerogels with very low refractive indices as well as a special shaped fused silica plate will be used. A streak camera system will measure the time dependent behavior of the photon bunch. The combination of bunch length measurement and momentum spread measurement gives the information about the whole longitudinal phase space. The design considerations of the radiators and their properties are discussed.

1. Introduction

A photo injector test facility at DESY Zeuthen (PITZ) for the development and operation of optimized photo injector for future free electron lasers and linear colliders will be commissioned in autumn 2001. The components of PITZ are described in [1–3].

The ability of beam diagnostics to investigate the properties of the electron bunch is the basic for a successful optimization and improvement of the performance of PITZ. In this contribution we focus on the design for measuring the longitudinal emittance. The diagnostics of the longitudinal phase space is expected to be done in a following way:

At first the momentum spread is measured using a dipole magnet and a YAG-screen. For this, the properties of a screen laminated with YAG-powder were studied and compared with an OTR-screen. Furthermore the error for measuring the momentum spread and the resolution of the momentum measurement are estimated.

The second step is to determine the bunch length. This will be done by using a radiation process, where the electrons produce light with the same time properties as the bunch has. Then a streak camera is used to observe the longitudinal pulse shape. A high number of photons and very good intrinsic time resolution become the main requirements to the radiator especially at low electron energies. Cherenkov radiation in aerogel and in special shaped quartz plates are discussed as possible options for photon production mechanism. The properties of aerogel material in vacuum will be shown.

Ideas to measure the bunch length and energy spread simultaneously will be described as well.

2. Momentum spread measurement

The momentum of the electrons will be measured via deflection of about 60^o caused by a magnetic field. The momentum is a linear function of the current in the dipole, while the momentum spread is a function of the spot size at the screen. The estimated energy spread is expected to be 2%. Therefore a screen with good resolution should be used.

The energy of the electrons at first will be up to 5 MeV. At these energies a small number of transition radiation photons with large angles whould be produced if an OTR-radiator whould be used. The number of scintillation photons in YAG-screens is much higher. On the other hand, YAG-screens at high electron densities will reach saturation. The image of 16 MeV electron bunches was measured at the Tesla Test Facility with increasing charge densities by OTR- and YAG-screens (figure 1). The intensity of the outgoing light from the YAG-material increases up to an electron density of about $4fC/\mu m^2$, the maximum density achived at this measurement. There was not seen a clear evidence of saturation. The intensity measured with the YAG-screen is lower at the maximum

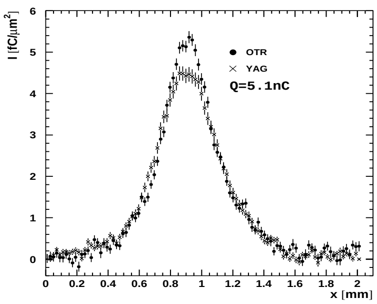

Figure 1. Beam profile of a 16 MeV 5.1 nC electron bunch

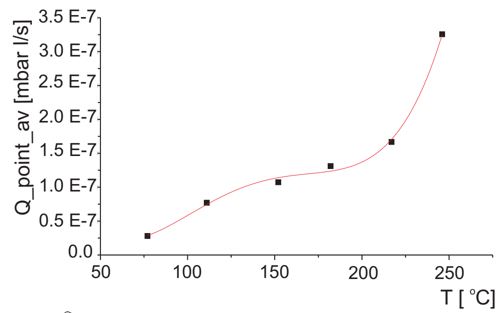

Figure 2. Average gas load after a certain aerogel temperature is reached

and shows a slightly wider distribution compared to the OTR-screen. The expected maximum electron density at the screen in the dispersive arm of PITZ is of the order of $1fC/\mu m^2$. Therefore no saturation is expected.

The momentum spread will be extracted from the projection of the distribution at the screen in the dispersive arm. For a correct calculation the bunch size, the divergence and their correlations at the entrance of the dipole should be known. They are not measured. If they are not taken into account the difference will be of the order of 3% of the estimated momentum spread.

The measured momentum will be smeared out due to the finite transverse emittance of the electron beam at the entrance of the dipole. Considering the expected emittances the momentum resolution will be better than 0.5% of the measured electron energy.

3. Bunch length measurement

The electron bunch length has to be converted into a photon bunch of corresponding length. It will be measured using a streak camera system. Therefore it needs a radiation process with enough photons being produced. Good time resolution is necessary. We will use Cherenkov radiators in order to obtain adequate photon yields. Aerogel and special machined quartz plates are possible options to produce a photon beam with the needed properties [4].

The vacuum properties of aerogel have been tested among other things by measuring the gas load coming from aerogel. A calculation of the pressure distribution of the whole injector estimates its influence on the pressure in the cavity section. The calculation shows that the gas load coming from the aerogel should be in the range of $10^{-6} mbar\ l/s$ or better to avoid damage of the Cs_2Te photo cathode. Tests with aerogel at different temperature shows that a temperature up to 200^oC can be allowed (figure 2). This can be ensured by adjusting the pulse train length.

4. Measurement of longitudinal phase space

To measure the longitudinal phase space the streak camera will detect photon beams from a Cherenkov radiator in the dispersive arm so that both distribution of electron momentum and longitudinal profile can be measured simultaneously. To obtain good time resolution for aerogel a slit mask before the radiator will be inserted to get small transverse bunch sizes. Therefore the whole energy spread is measured by moving the slit mask in the transverse direction.

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