PHOTO INJECTOR CATHODE LASER BEAM INTENSITY AND POINTING STABILITY DIAGNOSTICS.[*]

Y. Ivanisenko[†], G. Asova, J. Bähr, S. Korepanov, M. Krasilnikov,
B. Petrosyan, F. Stephan, DESY, Zeuthen, D 15738, Germany
O. Kalekin, Physikalisches Institut der Universität Erlangen - Nürnberg, Erlangen, Germany

Abstract

A photo cathode laser with unique parameters is used at the Photo Injector Test facility at DESY in Zeuthen, PITZ [1, 2]. It is capable of producing laser pulse trains consisting of up to 800 pulses with a separation of 1 μs where each laser pulse has a flat-top temporal profile. The knowledge of the laser stability is very important for the emittance measurements procedure. Therefore, a system for monitoring the laser beam intensity and pointing position stability was created at PITZ. It is capable of measuring the laser spot position and pulse intensity for each of the laser pulses in the train using a quadrant diode and a photomultiplier tube, respectively. Taking into account the laser beam spot transverse intensity distribution measured by a CCD camera allows to study the position of the laser spot on the photo cathode with a resolution of 8.3 μm. Laser intensity measurements can be done for a wide dynamical range of intensities due to the tuneable photo multiplier tube gain. The first experiments with the new system show very small laser spot position jitter on the cathode surface of about 20 μm and laser intensity fluctuations of about 14 %.

INTRODUCTION

PITZ is a test facility for photoinjectors designed for FEL operation. The PITZ group develops the measurement methods and the equipment for the injector characterization.

PITZ operates at 10 Hz repetition rate, and in each cycle the injector can produce up to 800 electron bunches with an emission frequency of 1 MHz. The generation is based on electron photoemission from a Cs2Te cathode impinged by laser light of 262 nm wavelength. Formation of a flat-top laser pulse of about 18 ps length is the initial process [2]. Then the laser light is transmitted from the laser table to the tunnel through a 22 m optical beam line [3] and enters the vacuum through the input window. It is directed to the cathode by a mirror.

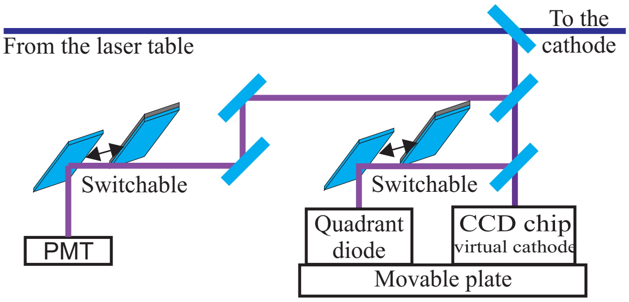

Figure 1: Optical scheme of the laser beam stability diagnostics

DIAGNOSTICS SYSTEM

On the path of the laser beam there is a beam splitter, which directs 2% of the light to the laser beam diagnostics system.

Before the entrance to the laser beam diagnostics there is a beam limiting aperture, which makes the laser spot size fixed at the cathode. The transverse displacement of the laser beam before the aperture will result in the laser beam center of gravity movement, if the intensity profile is non-homogeneous along the displacement direction. This change is detected then by the quadrant diode - one should observe a repartition of the quadrant diode signals.

The measurement system scheme is shown in Fig. 1. The quartz beam divider plates are inserted before the detectors in order to match the input intensity range and the linear response range of the devices. A CCD matrix chip is situated so, that the optical path length for the laser radiation is the same as the path to the photocathode. The camera is used for the transverse laser beam profile measurements. The quadrant diode is used for the laser beam pointing position monitoring - the software analyzes the transverse profile from the CCD together with the quadrant diode signals and calculates the laser beam position. Photomultiplier (PM) is used for the laser beam intensity measurements.

INTENSITY MEASUREMENTS

The structure of the pulse train defines that the response time should be much less than 1 μs, and there is a 10^4 dynamical range to cover. The PM module H6780 (Hamamatsu) with integrated high-voltage converter was chosen.

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[†] yevgeniy.ivanisenko@desy.de

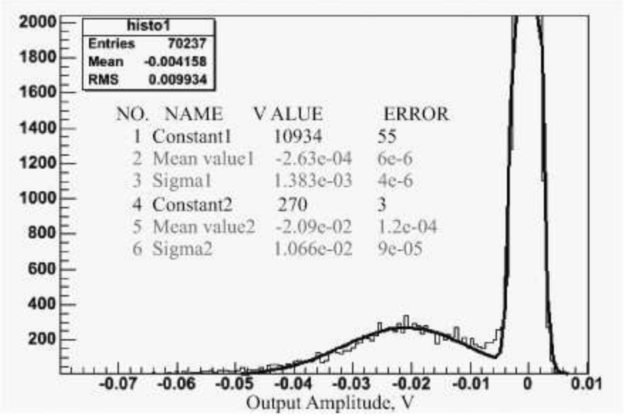

Figure 2: Single photoelectron spectrum

This PM module has a bialkali type cathode with quantum efficiency of 0.8 % at 260 nm and an effective area diameter of 8 mm.

Another UV-sensitive type H6780-03 has a quantum efficiency ≈ 4.5%. The gain of the PM can be regulated externally in the range from 100 to 10^6. Maximum linear output current is 100 μA. The photocathode saturation current is 0.1 μA for the bialkali. If the gain is less then 10^3 the linear output is limited by the cathode current, otherwise by the space charge forces in the dynode system during the multiplication.

To analyze the PM response function and noise level a single photoelectron measurement was done. Result of the analysis is shown in Fig. 2. For the PM gain 10^6 the mean response signal is $\approx 21mV$ and the standard deviation is 10 mV.

POINTING POSITION MEASUREMENTS

A charge coupled discrete elements detector is used for the transverse laser beam intensity distribution measurements. It is not fast enough, to satisfy the demands for a parallel to facility operation measurement of the transverse distribution of the individual micropulses in a bunch train.

The idea of a hybrid detector was proposed for the first time and the equipment was developed for PITZ. The laser beam intensity distribution is measured by a CCD matrix. From the distribution it is possible to find a relation between the geometric center and the gravity center of the laser beam, which is also measured by the quadrant diode. Applying this method there is no demand on the laser beam transverse profile cylindric symmetry. The cathode laser beam at PITZ should have a flat-top, radius transverse intensity distribution, which in some cases can be distorted in practice (Fig. 3).

For the measurements in our case the PIN quadrant photodiode S4349 (Hamamatsu) was chosen. The response time is ≈ 100 ns. The QD has 40% quantum efficiency at 262 nm. Four signals are transmitted to the electronics, they are integrated, digitized and stored on the hard drive. The sensitive area is a square with 3 mm side length. The gap between the quadrants is 0.1 mm. The separating gaps of the CCD matrix are parallel or perpendicular to the gap lines, which divides the quadrant photodiode in four parts.

For the position measurements it is important to have symmetry of the four channels of the quadrant diode. If the condition is not matched at the level of the equipment then it can be corrected by the analyzing software. To check this a test was made for identity of the quads and their electronic circuits. The integrator channels after the test and the recalibration (is done in the analysis software) are found to be within an accuracy of 1%.

Test of the full QD readout showed the same accuracy as the previous test, what means the discrepancy exist they are much smaller than 1%.

The linear response of the quadrants are limited by the electronic interference at the low intensities and by the saturation at the high intensities. For this reason a switchable quartz to mirror reflector before the quadrant diode. The mirror reflects ten times more light than the quartz plate does.

Each quadrant integrates the light signal over its surface. The same is done in the software for the four parts of the spatial intensity distribution, which is divided by the virtual gap cross. The cross can be moved with the resolution of 8.3 μm - the dimension of the square pixel of the CCD. The quadrant diode signals are simulated by the software and compared with the normalized real ones. The position of the cross relative to the intensity distribution corresponds to the minimal discrepancy between the real and simulated values, defined as:

$$X = \frac{S_1 + S_2 - (S_3 + S_4)}{S_1 + S_2 + S_3 + S_4} \tag{1}$$

$$Y = \frac{S_1 + S_4 - (S_2 + S_3)}{S_1 + S_2 + S_3 + S_4} \tag{2}$$

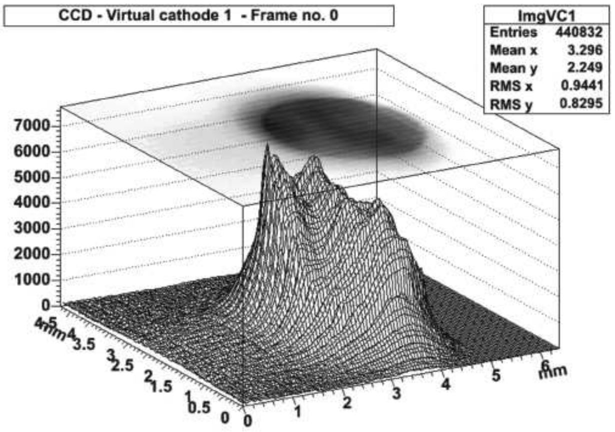

Figure 3: One special example of the laser beam transverse intensity distribution

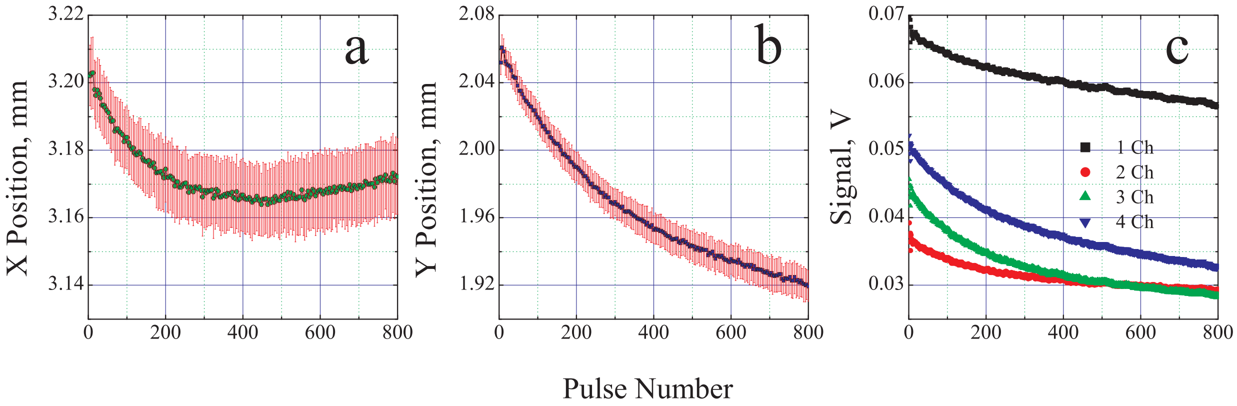

Figure 4: Averaged over 300 trains pulse positions (800 pulses train): a - along the X axis; b - along the Y axis; c - the quadrant diode signals

where X and Y are independent and define the position on the surface. S_i - is a signal from the i^{th} quadrant. Quadrants are numbered clockwise.

RESULTS

The sample of the laser intensity measured for 800 micropulses train averaged over 300 samples is shown in Fig. 5. The intensity jitter amounts 14% (red bars). Furthermore the decreasing about 20% of the laser intensity during the train exists. The accuracy of the measurements depends on the laser intensity level and for the work regime is about 1 %.

The pointing position measurements results are presented in Fig. 4. Each microbunch position in the 800 pulse train is averaged over 300 trains. Standard deviation of a laser beam micropulse position equals to 18 μm for the measurement. The observed position change (drift) during the train (Fig.4 a and b) it is thought to be connected to the laser elements heating - the drift corresponds to the pointing angle deviation inside the laser system of about 10^{-5} rad.

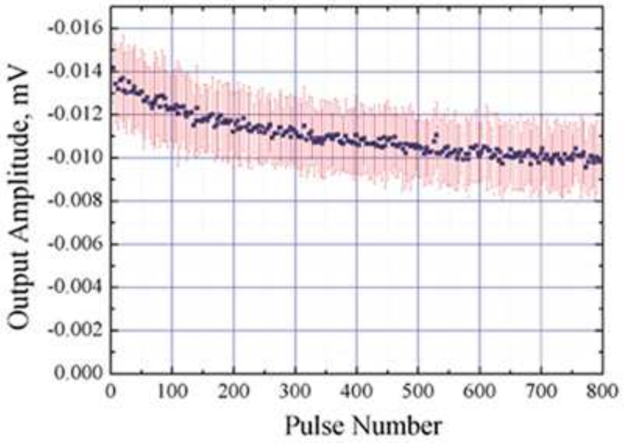

Figure 5: Laser beam intensity measurements. Averaged over 300 trains pulse intensities

CONCLUSIONS

The laser beam intensity and pointing stability diagnostics have been developed at PITZ. They allow to analyze the laser beam microbunches with arbitrary transverse intensity distribution. The laser microbunches emission frequency is up to $1\ MHz$. The accuracy of the pointing position measurements is $8.3\ \mu m$.

The next step is the implementation of the diagnostics in the PITZ control and measuring complex to make these diagnostics routine.

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