UPGRADES OF THE LASER BEAM-LINE AT PITZ[&]

J.Bähr*, K.Abrahamyan[#], G.Asova[§], G.Dimitrov[§], H.Grabosch, J.H.Han, H.Henschel, S.Khodyachykh, M.Krasilnikov, S.Liu, H.Lüdecke, V.Miltchev, A.Oppelt, B.Petrosyan, S.Riemann, L.Staykov, F.Stephan, M.Winde, DESY, D-15738 Zeuthen, Germany
M.v.Hartrott, D.Richter, BESSY, D-12489 Berlin, Germany
I.Will, G.Klemz, Max-Born-Institute D-12489 Berlin, Germany
V.Boccone, O.Kalekin, Humboldt University, D-12489 Berlin, Germany
J.Röensch, University of Hamburg, D-22761 Hamburg, Germany

Abstract

In spring of 2005 an essential upgrade of the photocathode laser and of the 20 m long laser beam-line took place at PITZ. A detectable improvement of the laser beam profile at the photocathode is observed. This improvement should lead to an additional reduction of the transverse emittance of the electron beam. The upgraded laser consists of a fully laser diode pumped scheme of pulse train oscillator, pre-amplifiers and booster amplifiers. The main advantages of this upgrade are improved stability, easier maintenance and long-term operations at 10 Hz repetition rate. In addition, the scheme of the optical beam-line was changed: The distance between the beam shaping aperture and the cathode was strongly reduced. Therefore a further improvement of the laser beam profile at the photocathode is expected. The laser beam-line is upgraded by an enlarged number of remotely controlled optical elements that allows the fine tuning of the laser beam characteristics during the running. New diagnostics tools are included in the laser beam-line. The paper focuses on the design of the new optical beam-line.

INTRODUCTION

The photo injector PITZ at Zeuthen [1] is a dedicated facility for the investigation of rf-guns for FELs, i.e. the VUV-FEL and the XFEL at DESY. An essential upgrade program is ongoing in the years 2004-2006 resulting in the project phase PITZ2 [2]. The essential goals of PITZ2 are the proof of the emittance conservation principle [3] by using a booster cavity and the running of the rf-gun with a higher gradient using a 10 MW Multi-Beam Klystron (MBK) which should lead to an improved emittance immediately behind the gun. The diagnostics beam-line of the first milestone of PITZ2 was commissioned in spring 2005 and has gone into operation. One of the most important sub-systems of a photo injector is the photocathode laser including the laser beam transport system. Especially in the case of FELs the transverse emittance is one of the basic characteristics which determine the performance of the SASE lasing. As simulations [4] and the results of PITZ [5] show, flat-top shape of the transverse and longitudinal profile of the laser beam are essential pre-conditions for a low transverse emittance of the electron beam. The photocathode laser at PITZ is developed by the Max-Born Institute Berlin (MBI) [6]. The laser produces pulses in a rather complicated time scheme according to the needs of the VUV-FEL and the XFEL. The maximum repetition rate at present is 10 Hz. The bunch train consists of 1…800 pulses emitted with a frequency of 1 MHz. The emitted wavelength is 262 nm which matches to the used Cesium-Telluride cathodes.

The last upgrade of the laser was performed in spring 2005. The essential improvement consists in the change of the pumping scheme of the amplifier stages. After the upgrade all amplifier stages are laser-diode pumped. It is expected, that this will result in a higher lifetime and more stability. Exchange of flash-lamps is not needed anymore. The laser can be operated now with a repetition rate of 10 Hz instead of 5 Hz before. Furthermore, the tuning of the laser pulse energy is realized exclusively by an attenuator behind the laser. This results in the advantage that the change of the laser pulse energy will not influence anymore on the transverse and longitudinal beam profile. Besides this, the laser control was improved.

The essential property of the laser beam-line should consist in the undisturbed transport of laser pulses to the photocathode keeping the transverse and longitudinal laser beam profile produced in the laser and in the laser beam-line. To improve the characteristics an upgrade of the laser beam-line was performed in spring 2005 as described in the next chapters.

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* presenting author: juergen.baehr@desy.de

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on leave from YERPHI, 375036 Yerevan, Armenia
§ on leave from INRNE 1784 Sofia, Bulgaria

THE LASER BEAM-LINE

The basic idea of the laser beam-line is the imaging of the beam-shaping aperture (BSA) onto the cathode such, that a flat-top transversal laser beam profile is produced. The BSA is illuminated by the laser beam, whereby the laser spot on the BSA is essentially larger than the inner diameter of the BSA.

During the upgrade of the laser beam-line in 2005 the distance of the BSA to the cathode has been essentially reduced. Besides this, more optical elements are remotely controlled, which gives the possibility of fine tuning of the laser beam parameters during running.

Furthermore the laser beam diagnostics is extended, this upgrade is still ongoing. All this upgrades should result in an improvement of the laser beam spot on the photocathode which should result in a decreased transverse emittance. The optical scheme of the upgraded laser beam-line was proposed and calculated by I.Will [7], see fig.1. This beam-line was commissioned in spring 2005. Fig.2 shows a schematic containing part of the laser beam-line diagnostics elements and the arrangement in the 3D-space. The overall length of the beam-line is about 20 m.

For 10 optical elements a remote control was developed. Usually 2 degrees of freedom – translation or rotation - are remotely controlled. For the technical solution an integrated system of MICOS [8] is used. A zero-position detector is added to all axes. The motor control is realized by a LAbView program which itself is connected to the general control of PITZ. In fig.3 the main window of the laser beam-line control is shown.

The BSA consists of a metal plate with about 10 apertures of different diameter which can be positioned exactly and reproducibly on the axis of the laser beam. It can be moved by about 80 mm along the optical axis to optimize the focus.

LASER BEAM DIAGNOSTICS

Several properties of the laser beam have to be controlled all the time. For this purpose appropriate diagnostics elements are needed. In Tab.1 these properties, the diagnostics elements and the tools to control the properties are shown.

Virtual Cathodes

The virtual cathodes are realized by CCD-cameras which are UV sensitive and mounted exactly in a position corresponding to the gun photocathode. The analogous cameras of type M10SX (former: M10RS) are produced by JAI [9]. The cameras have a small but not negligible UV sensitivity in the range of the laser wavelength. The cameras are externally triggered,gain and shutter speed can be controlled using a RS232 interface. The pixel number is 782 x 582, the pixel size is 8.37 microns in both dimensions.

There are 2 virtual cathodes in use for different ranges of mean laser pulse train energy. The cameras are integrated in the general PITZ TV-system. The virtual cathodes are used for relative laser beam spot positioning and for the measurement of the transverse laser beam profile. A problem in the application is the limited radiation hardness of the cameras. Lead bricks are used to shield the cameras. Besides this, we observe a space dependent sensitivity of the camera sensor after some weeks or months running of the virtual cathode. We try to limit this effect by a shutter before the virtual cathode. An example for a laser beam transverse profile measured by the virtual cathode is shown in fig.4.

The measurement of the position jitter of the laser beam spot on the virtual cathode measured over 9 hours is shown in fig. 5. The amplitude of the jitter is of the order of 10 microns which is roughly the size of one camera pixel. The systematic increase the y-coordinate of about 10 microns has to be investigated.

The virtual cathodes do not resolve single laser pulses in the pulse train but measure mean values over all pulses in one pulse train. This will partly be improved in the near future by applying a quadrant diode. Using the quadrant diode one will be able to monitor the beam position with a pulse to pulse resolution. This option is under development and will be commissioned in a few weeks.

Photomultiplier

A photomultiplier (PM) is used for the relative laser pulse energy monitoring. The applied PM type is H6780-03 by Hamamatsu[10]. The device is UV sensitive (quantum efficiency at 262 nm is about 14%) and the HV-power

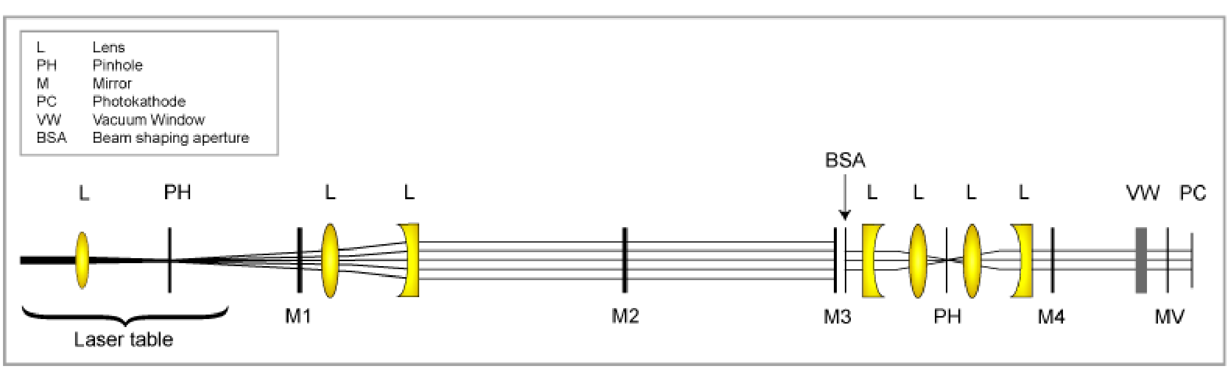

Figure 1: Optical scheme of laser beam-line (I. Will)

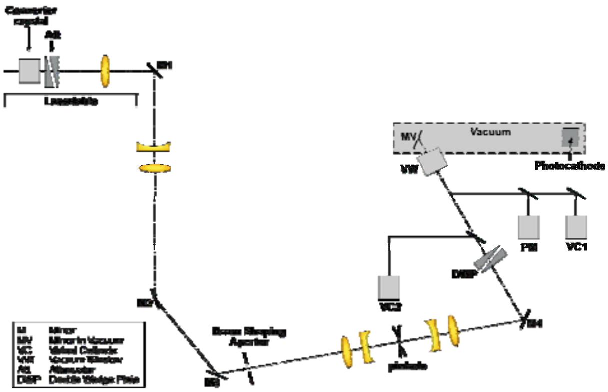

Figure 2: Schematic of the laser beam-line

supply is integrated in the device. It has a metal channel dynode structure. The needed dynamic range is about 4 orders of magnitude. The device is commissioned, the calibration is ongoing.

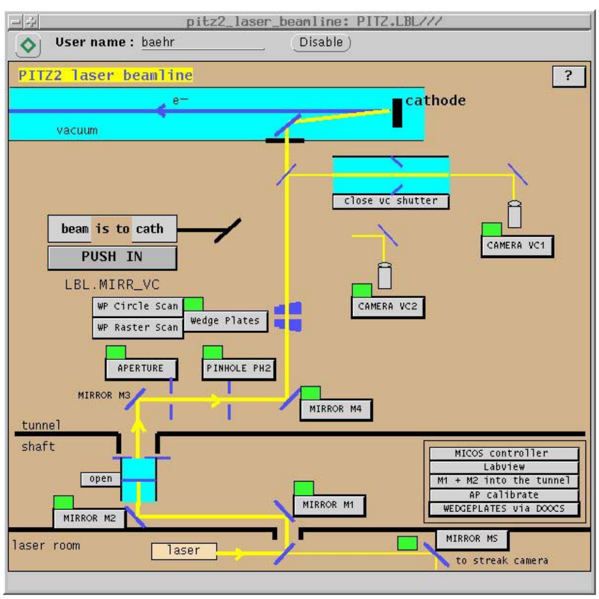

Figure 3: Main control window of laser beam-line

Streak camera

The longitudinal laser pulse profile is monitored using a streak camera. A fraction of the laser light is imaged by a second branch of the laser beam-line, which is not shown in fig. 2 onto the entrance slit of the streak camera. The used camera is of type C5680 produced by Hamamatsu. It is UV-sensitive and has a synchro-scan option. The resolution is 2 ps. An exam ple of a longitudinal laser beam pulse profile is shown in fig.6.

The parameters of the longitudinal profile measured at different days for two values of repetition rate are shown in table 2. The data show the relative stability of the longitudinal profile, the pulse shaper was not tuned between the measurements.

Table 1: Laser beam properties, diagnostics element and tuning tool for this property

Property	Measurement	Tuning
Pulse number	Oscilloscope	Laser control
Intensity envelope of pulse train	oscilloscope	Laser control
Pulse energy	Power meter	Attenuator on laser table
Relative pulse energy	Photomultiplier	Laser system tuning
Longitudinal profile	Streak camera	Pulse shaper in laser
Transverse beam profile	Virtual cathode VC1, VC2	Inclination of converter crystals, focus, laser system tuning
Nominal laser beam diameter	VC1, VC2	Beam shaping aperture
Laser beam inclination at entrance of laser beam-line	TV-system on laser table	Mirror at laser exit
Laser beam position on cathode, integrated	VC1, VC2 (relative)	Mirror4, double wedge system
Beam on virtual cathodes	VC1,VC2	x,y drive of cameras
Laser beam position on cathode, time resolved	Quadrant diode (relative)	Mirror4, double wedge system

TV-cameras on laser table

A system of 2 TV-cameras will be arranged on the laser table. It allows the monitoring of the transverse beam profile, the relative laser beam position (near field) and t he laser beam inclination (far field) immediately behind the laser.

Besides the monitoring of these properties it is useful for the laser beam-line alignment after laser adjustment. One can easily align the laser beam behind the laser in 4 degrees of freedom to match into the laser beam-line.

Table 2: Longitudinal laser beam profile

Date	Rep. rate/Hz	Width(FWHM)/ps	T(rise)/ps	Mod./%
01/08/05	10	23.5	6.5	5.0
10/08/05	10	25.5	6.9	5.7
11/08/05	5	25.3	7.5	6.5

The system is in preparation and will be commissioned in a few weeks.

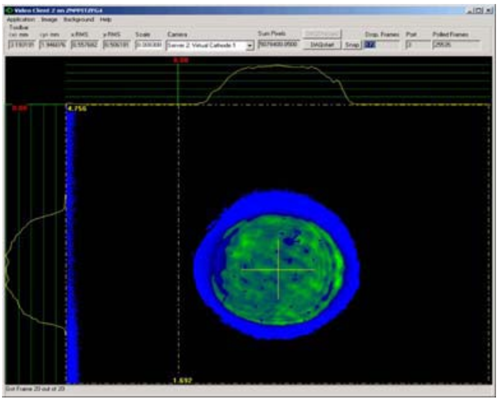

Figure 4: Laser beam profile on virtual cathode

Resolution grid

A resolution grid is integrated into the plane of the BSA. The aim is to verify that a certain spatial resolution in the structure of the laser beam can be transferred onto the cathode. It is the aim to find this structure in the electron beam hitting a view-screen.

Laser pulse energy measurement

The laser pulse energy measurement is realized using a mobile absolutely measuring laser power meter. Ports for the detector are prepared immediately behind the laser and just before the vacuum window near to the cathode. The PM announced above can be calibrated by the laser power meter.

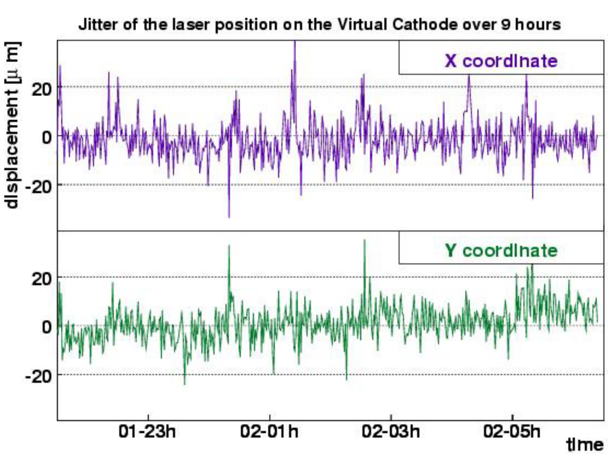

Figure 5: Jitter of the laser position on VC1 over 9 hours

SUMMARY

At the PITZ facility an upgrade of the photocathode laser and the laser beam-line was performed. The essential change in the laser upgrade was the exchange of all flash-lamp pumped amplifier stages by laser-diode pumped amplifier stages. This leads to a higher laser

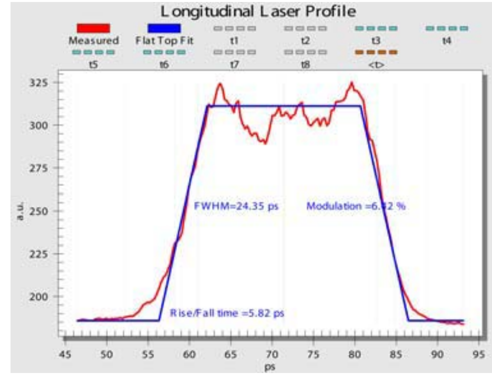

Figure 6: Longitudinal laser pulse profile

stability and lifetime, easier maintenance and the possibility to run the laser with a repetition rate of 10 Hz. The goal of the upgrade of the laser beam-line was to improve the stability and the transversal optical profile on the photocathode. This should be reached by moving the beam shaping aperture closer to the photocathode. The optical scheme was completely changed. The number of remotely controlled optical elements was increased. Several diagnostics tools are integrated in the laser beam-line. First investigations on the stability of laser and the laser beam-line show an improved stability.

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