

DIAGNOSTICS AT JINR LHEP PHOTOGUN BENCH

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Abstract

The photoinjector electron beam quality strongly depends on the laser driver beam quality. For laser beam diagnostics, a “virtual cathode” system was realized at the photogun bench located in the Veksler and Baldin Laboratory of High Energy Physics (LHEP) of the Joint Institute for Nuclear Research (JINR). The system allows one to image laser beam profile at the cathode. For imaging, the AVINE software suite developed in DESY Zeuthen is used. Equipment for emittance measurement using the slit method was installed. The original emittance calculation software EmCa was created and tested with laser beam.

INTRODUCTION

Photogun bench of JINR LHEP [1, 2] aims to develop and improve “transmissive” photocathodes to increase quantum efficiency, lifetime and to decrease vacuum requirements. “Transmissive” photocathode is the development of the “Hollow” photocathode conception developed at JINR [3, 4]. It consists of micron-sized metal mesh or quartz/sapphire plate with thin-film coating: either metal or semiconductor.

Beam diagnostics, both electron and laser, is important in order to investigate cathode characteristics. To accomplish this, a set of diagnostics subsystems is installed at the bench.

BENCH EQUIPMENT

Main bench elements (Fig. 1) are DC photogun with the maximum voltage of 30 kV, focusing magnet with correction windings, diagnostics and driver laser. Bench beamline vacuum is less than 10^{-8} torr. A faraday cup is used for electron bunch charge measurement. Laser pulse energy is measured by an Ophir Nova II power/energy meter equipped with PE25 pyroelectric sensor.

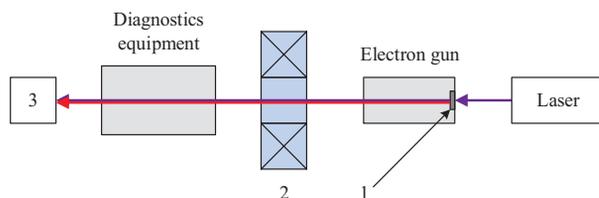


Figure 1: Photogun bench scheme: 1 - “transmissive” photocathode; 2 - focusing magnet with correction windings; 3 - beam dump.

Lasers

The main laser driver currently is LS-2134 by LOTIS TII (Minsk, Belarus). Also LS-2151 model was used,

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LS-2132UTF model is being commissioned now. As next step, the new—photoinjector—bench is being constructed. It will use the unique laser system [5, 6] by IAP RAS (Nizhny Novgorod, Russia) and will have a maximum electron energy of 400 keV. Key parameters of the aforementioned laser systems are listed in Table 1.

Emittance Measurement Equipment

Emittance is one of the main particle beam parameters, its measurement is one of the key photocathode investigation tasks. Therefore, a slit emittance measurement system is being developed at the bench. It consists of the following equipment:

- slit mask, 1 mm thick tungsten plate with 9 50 μm slits located at 3 mm distance from each other;
- vacuum chamber with 2-position pneumatic actuator where the slit mask is installed;
- scintillator screen;
- high sensitivity CCD camera Prosilica GC1380 for beam imaging;
- compressor with 7 atm maximum pressure for pneumatic actuator operation.

Imaging Equipment

A high sensitivity Gigabit Ethernet CCD camera AVT Prosilica GC1380 [7], together with a lens Kowa LM50JCM, is used at the bench. Camera parameters are given in Table 2. Two external trigger inputs are provided: isolated (trigger latency 5 μs, jitter ±0.5 μs) and non-isolated (trigger latency 3.7 μs, jitter ±20 ns). As potential differences are not expected on the local bench setup and due to absence of powerful noise sources, the non-isolated channel is used.

Table 1: Lasers Parameters

Parameter [units]	LS-2134	LS-2151	LS-2132	IAP RAS
Wavelength [nm]	266	266	266	260–266
Micropulse length [ps]	15,000	75	5,000	8–12
Micropulse energy [μJ]	15,000	5,000	30,000	1,85
Macropulse length [μs]	—	—	—	800
Micropulses in macropulse	—	—	—	8 000
Macropulse repetition rate [Hz]	—	—	—	10

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Table 2: Prosilica CCD Camera Parameters

Sensor	2.3" Sony ICX285AL CCD
Resolution	1360 (H) × 1024 (V)
Pixel Size	6.45 μm × 6.45 μm
Frame rate	20,2 fps
Power Requirements	Less than 3,3 W (5-25 VDC)
Hardware Interface	IEEE 802.3 1000baseT
Software Interface	GigE Vision Standard 1.0
Digitization (ADC)	12 bit

SOFTWARE

Vimba SDK Based Software

AVT Vimba SDK [8] includes Vimba Viewer software which can be used for basic imaging. However, for advanced diagnostics purposes, the software lacks functionality. Hence, development of a custom application using the above mentioned SDK was started. Microsoft Visual Studio 2010 and C++ programming language were used for development. The following functions are provided:

- identify and connect to camera using its unique number;
- asynchronous video acquisition and displaying;
- real time displaying of the intensity distribution in operator specified cross-sections.

At this stage of development an offer from DESY Zeuthen colleagues to use DESY-developed Advanced Video and Imaging Network Environment (AVINE) software [9] was received. As AVINE has necessary features already implemented and provides a well-tested interface to AVT Prosilica cameras, especially of GC type, it is a good match for our use-case. In this regard, the development of our own software was postponed.

ELECTRON BEAM DIAGNOSTICS

Setup

Current electron beam diagnostics setup is shown at Fig. 2 (1 - LS-2134 laser, 2 - electron gun, 3 - focusing magnet, 4 - emittance measurement station, 5 - camera). The yellow arrow indicates the scintillating screen (phosphor and potassium glass were used) position.

Laser Light Issue

The main problem for electron beam imaging is the simultaneous laser beam at the scintillating screen, which also becomes a part of the video image. This issue is redoubled due to low electron energy. The separation of electron and laser beam is not possible in the current setup. The following mitigation scenarios are being considered:

- usage of different screen materials (i.e. YAG and P-22 phosphor);
- electron beam deflection with a dipole magnet;
- foil, transparent for electron beam and opaque for laser.

Transverse Emittance

Currently, the setup for vertical plane transverse emittance calculation is developed and tested with the laser beam. De-

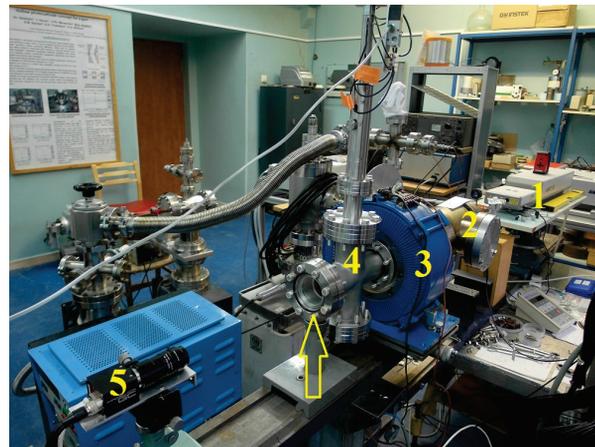


Figure 2: Electron beam diagnostics setup.

pending on the electron beam test results, either the pneumatic actuator will be changed to a 3-position one (with two masks with mutually perpendicular slits) or the pepper-pot method will be used.

EmCa software (Fig. 3) was developed for emittance calculation out of images (sequences) previously saved with AVINE Video Client 3. Microsoft Visual Studio 2010 and C++ programming language were used. A formula derived from [10] is used for calculation.

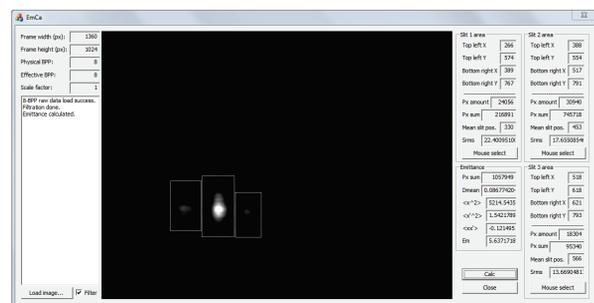


Figure 3: EmCa software.

Algorithm is the following:

1. Open image file. After file has been loaded, image and its parameters (size, physical and effective bits per pixel amount, scale factor value) are displayed. Currently, *.imm format of AVINE (no compression) with 8 bits per pixel (BPP) resolution is supported.
2. Cut-off filtering. If this option is enabled, all pixels with values 0 to 15 will be set to black (value 0).
3. Beamlet selection. Beamlets are manually selected by mouse: press button and select box. Program was tested using a laser beam image showing 3 beamlets, hence beamlet amount is fixed to 3 so far.
4. Emittance calculation. After Calc button has been pressed, Emittance is being computed.

The following program development is planned for future:

- support for arbitrary amount of beamlets;
- beam image in the phase space;
- 16 BPP resolution and AVINE *.imc format (zlib compression) support;
- automatic beamlet selection;

- two-plane transverse emittance calculation (after hardware realization).

LASER BEAM DIAGNOSTICS

Virtual cathode setup was realized at the bench. The equipment setup and a sample beam profile image are shown at Fig. 4.

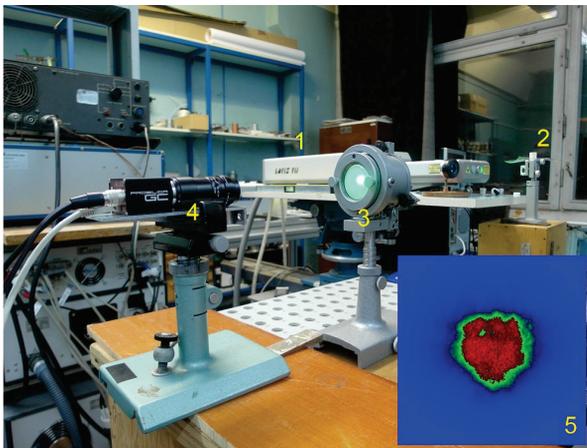


Figure 4: Virtual cathode equipment: 1 - laser, 2 - mirror, 3 - phosphor screen, 4 - camera, 5 - laser beam profile at the virtual cathode.

Stability measurements of the laser beam position and rms size were done. Result for beam position is given at Fig. 5. As one can see, the beam trends to horizontal shift. Further investigations are planned to understand this effect. Similar to beam position, rms size has been measured for 30 minutes. A drift could not be observed. Beam rms size was stable at 1.64 mm in x ($\sigma = 0.011$) and 1.55 mm in y ($\sigma = 0.013$).

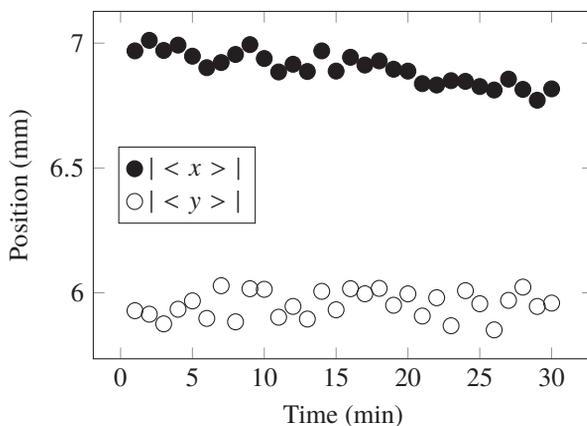


Figure 5: Stability measurement for beam position.

CONCLUSION

Virtual cathode setup was realized at JINR LHEP photogun bench. Imaging is realized using the AVINE construction toolkit developed at DESY Zeuthen. Equipment for slit emittance measurement was installed; software for emittance calculation was developed and tested with laser.

First priority issue is the separation of electron and laser beam at the screen using either a window being transparent for electron beam while being opaque for laser beam or a magnet-based electron beam deflection. Afterwards, realization of the 2-plane emittance measurement with the slit/pepper-pot method is foreseen.

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