Photo Cathode Laser Pulse Shaping for Generating Ultimate Electron Beam Quality.

F. Stephan, J. Good, M. Gross, M. Khojoyan, Y. Krasilnikov, V. Renier, T. Rublack (DESY, Zeuthen, Germany), A. Andrianov, E. Gacheva, E. Khazanov, S. Mironov, A. Poteomkin, V. Zelenogorsky (IAP/RAS, Nizhny Novgorod, Russia), E. Syresin (JINR, Dubna, Russia), I. Hartl, S. Schreiber (DESY, Hamburg, Germany)

Abstract

The application of high brightness electron beams is of increasing importance. One of the driving forces in this field is Free Electron Laser (FEL) applications. One of the key elements for generating high brightness electron beams from photo injectors is the shaping of the laser pulses hitting the photo cathode. While it was already demonstrated that temporal and transverse flat-top laser pulses can produce very low emittance beams [1], the next step towards generating ultimate beam quality is the generation of 3D ellipsoidal electron bunches from the photo cathode. Therefore, a collaboration was built between DESY, the Institute of Applied Physics (IAP) in Nizhny Novgorod and the Joint Institute of Nuclear Research (JINR) in Dubna in order to develop a laser system which is capable of producing trains of micropulses, where each micropulse has a quasi 3D ellipsoidal pulse shape. The first prototype of such a laser system was installed at the Photo Injector Test facility at DESY in Zeuthen (PITZ) towards the end of 2014 and is now in the commissioning phase. Besides beam dynamics simulations describing the effect of the photo cathode laser shape on the electron beam quality (e.g. 30% reduction in transverse projected emittance at 1 nC bunch charge), the setup of the new laser system, its commissioning and first experimental results will be described in this contribution. Besides its importance for the generation of highest brightness electron beams from photo injectors for FEL applications, the laser pulse shaping technique can also find application in advanced plasma acceleration experiments.

Motivation and Beam Dynamics Simulations with ASTRA

Main idea: minimize the impact of the space charge on the transverse emittance.

Standard:

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Laser rms pulse duration</td>
<td>6 ps</td>
</tr>
<tr>
<td>Laser rms size</td>
<td>0.5 mm</td>
</tr>
<tr>
<td>Laser wavelength</td>
<td>355 nm</td>
</tr>
<tr>
<td>Laser frequency</td>
<td>1 MHz</td>
</tr>
<tr>
<td>Laser pulse train length</td>
<td>0.6 ms</td>
</tr>
</tbody>
</table>

New:

- 3D ellipsoid (in space and time)
- linear space charge forces and linear phase spaces

Slice emittance for 1 nC bunch charge

Projected emittance and tolerance studies

Modelling of shape imperfections

Setup of the Laser System

Laser system developed by the Institute of Applied Physics, Russian Academy of Sciences, Nizhny Novgorod in collaboration with DESY and JINR

First Experimental Results

Transverse-image from BBO-based cross-correlator (IR x IR), here 1.7 ps delay between two neighboring shots

First photo electrons generated in April 2015:

Laser pulse on virtual cathode:

Charge measurement:

Next steps: refinement of laser beam transport to photo cathode, optimization of laser pulse shape and integration of good synchronization

References


*Supported by the German Federal Ministry of education and Research, project 05K100CN: "Development and experimental test of a laser system for producing quasi 3D ellipsoidal laser pulses", Helmholtz Joint Research Groups, project HRJRG-405 and RFBR grant 13-02-91323.*