Production of quasi-ellipsoidal laser pulses for next generation high brightness photoinjectors.

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Abstract

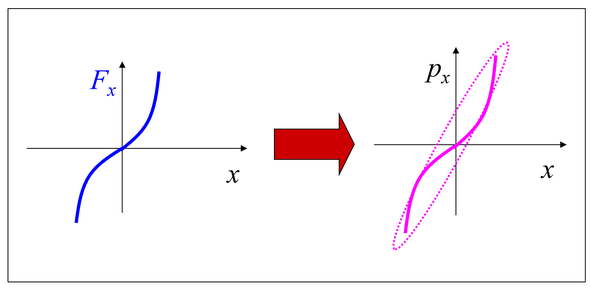
Free Electron Lasers (FELs) require high brightness electron beams . One of the most promising methods to generate such beams is the use of RF guns and a proper shaping of the corresponding photocathode laser pulses. It was already demonstrated that temporal and transverse flat-top laser pulses can produce very low emittance beams. Nevertheless, according to beam dynamics simulations further improvements can be achieved using quasi-ellipsoidal laser pulses, e.g. 30% reduction in transverse projected emittance at 1 nC bunch charge.

In a collaboration between DESY, the Institute of Applied Physics (IAP) in Nizhny Novgorod and the Joint Institute of Nuclear Research (JINR) in Dubna such a laser system capable of producing trains of micropulses, where each micropulse has a quasi-ellipsoidal pulse shape, has been developed. The prototype of the system was recently installed at the Photo Injector Test facility at DESY in Zeuthen (PITZ) and is now in the commissioning phase.

Motivation – Beam Dynamics Simulations with ASTRA

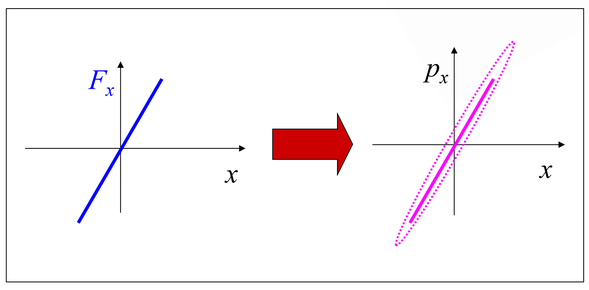
Space charge impact on transverse emittance minimization:

Laser pulses with cylindrical transverse shape and temporal Gauss / flat top profile



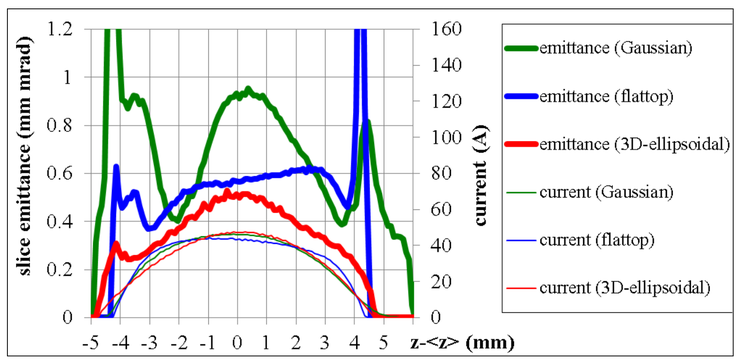
➔ **Non-linear** space charge forces and **non-linear** phase spaces !

3D ellipsoidal laser pulse
(spatially and transversely shaped)



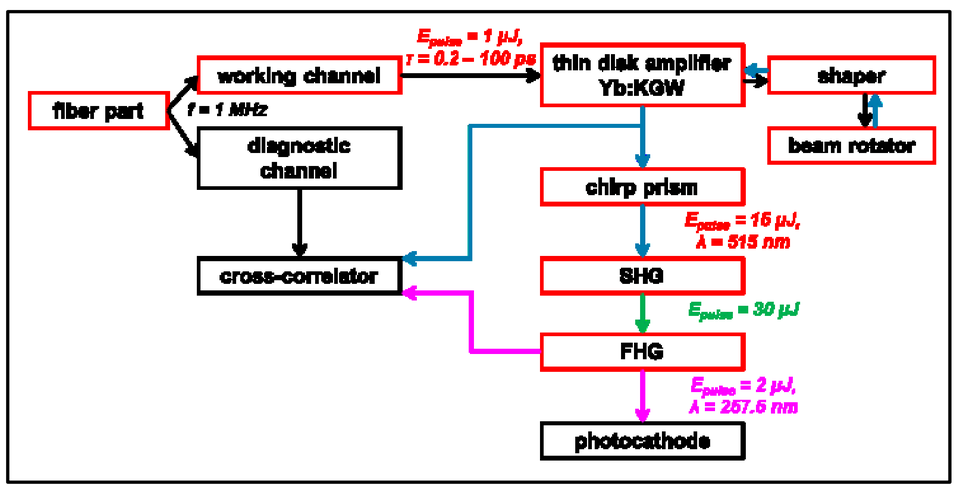
➔ **linear** space charge forces and **linear** phase spaces !

Slice emittance for 1 nC bunch charge

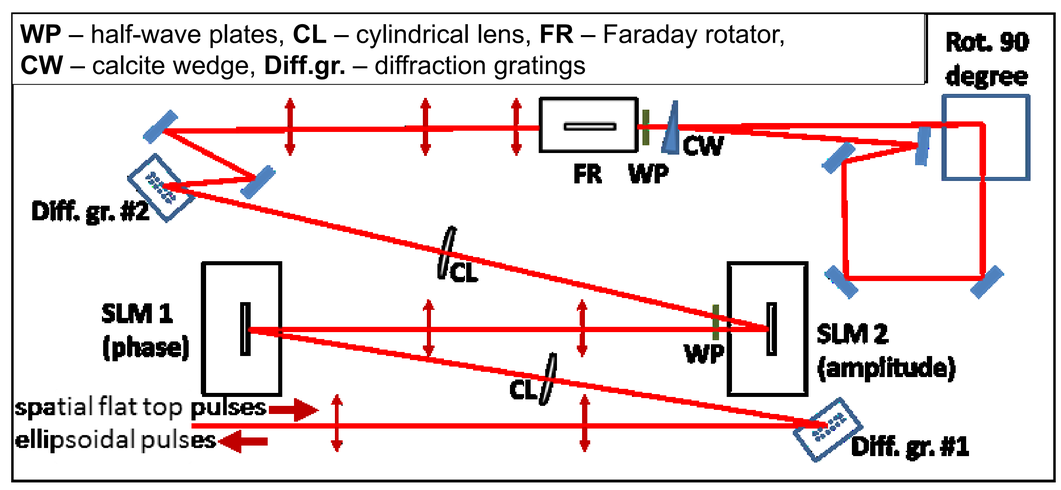


- 30 – 50 % lower average slice emittance
- better longitudinal compression
- reduced beam halo

Laser system and 3D pulse shaper setup

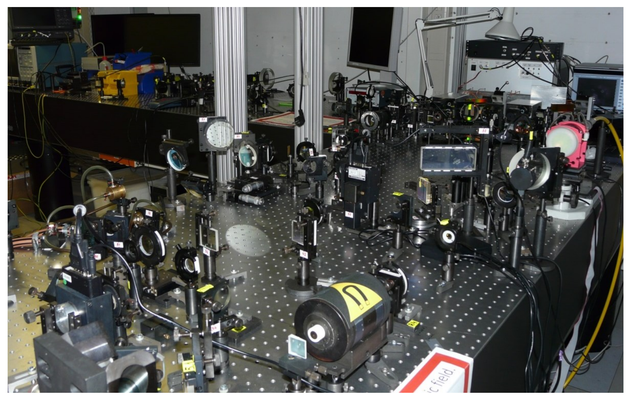


Top: general laser setup

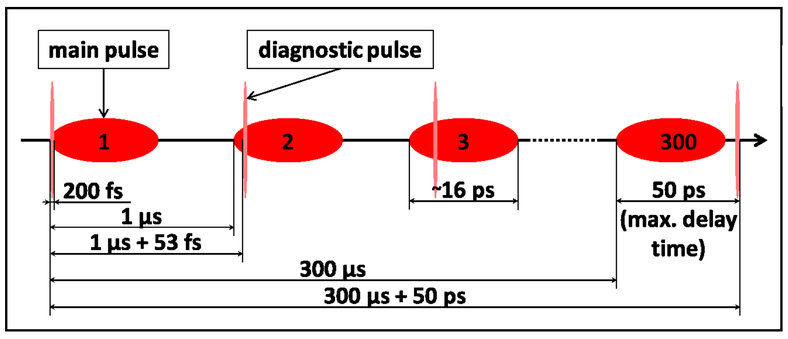


Top: pulse shaper setup

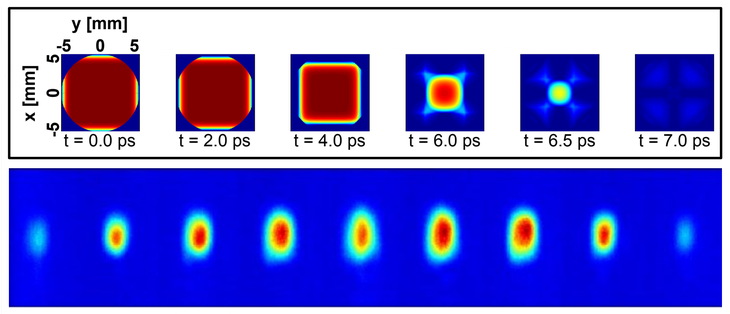
Bottom: picture of actual laser system at PITZ



Laser pulse characterization (scanning cross correlator)

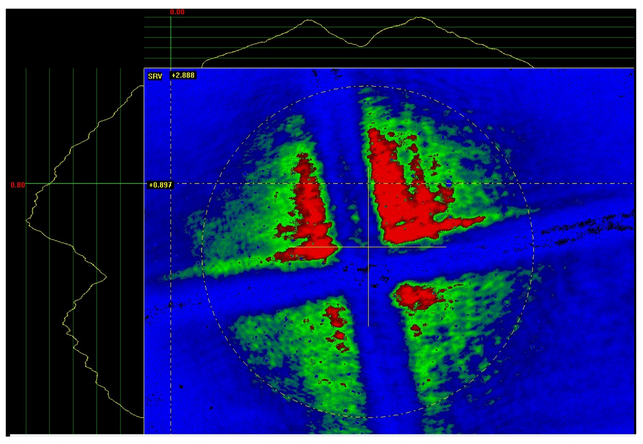


Top: Scanning cross correlator: working principle

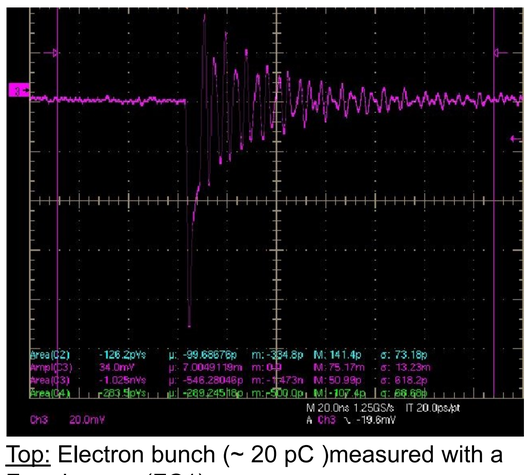


Top: simulated (ideal) 3D laser pulse shape; bottom: measured temporal laser pulse shape after shaping (IR)

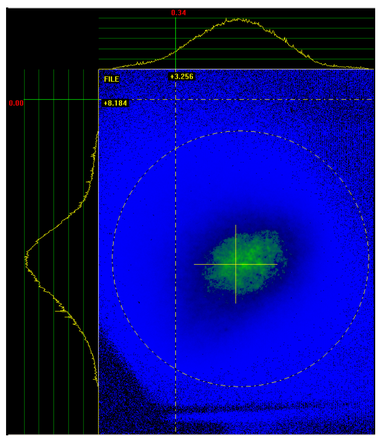
Experimental results (1st electrons generated in April 2015)



Top: Laser pulses imaged – by help of wire cross - onto the virtual cathode (VC2)



Top: Electron bunch (~ 20 pC)measured with a Faraday cup (FC1)



Top: Electron bunch behind booster, imaged at camera High1Scr1 (5.74 m behind cathode)

References

[1] M. Krasilnikov, et al., “Experimentally minimized beam emittance from an L-band photoinjector”, Phys. Rev. ST Accel. Beams 15, 1000701 (2012).
[2] F. Stephan, M. Krasilnikov, chapter “High brightness photo injectors for brilliant light sources” in book E. Jaeschke, S. Khan, J. Schneider, J. Hastings (ed) Synchrotron Light Sources and Free-Electron Lasers, published at Springer References.
[3] M. Khojoyan et al., “Studies on the Application of the 3D Ellipsoidal Cathode Laser Pulses at PITZ”, Proc. IPAC2014, Dresden, Germany.
[4] M. Khojoyan, et al., “Optimization of the PITZ photoinjector towards the best achievable beam quality”, Proc. FEL2014, Basel, Switzerland.
[5] M. Krasilnikov et al., “Development of a photo cathode laser system for quasi ellipsoidal bunches at PITZ”, Proc. FEL2013, Manhattan, USA.
[6] V.V. Zelenogorski et al., “Scanning cross-correlator for monitoring uniform 3D ellipsoidal laser beams”, Quantum Electron 44(1), p. 76 (2014).
[7] E.I. Gacheva et al., “Disk Yb:KGW amplifier of profiled pulses of laser driver for electron photoinjector”, Opt. Express **23**, 9627-9639 (2015).
[8] T. Rublack et al., “First Results Attained with the Quasi 3-D Ellipsoidal Photo Cathode Laser Pulse System at the High Brightness Photo Injector PITZ”, Proc. IPAC 2015, Richmond, USA.

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