

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



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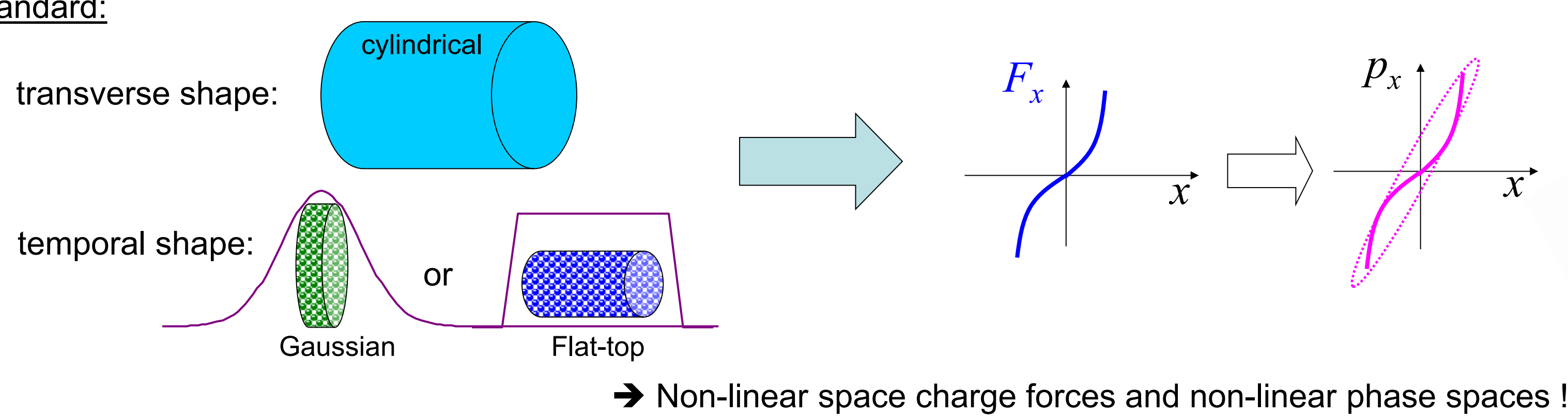
Abstract

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.

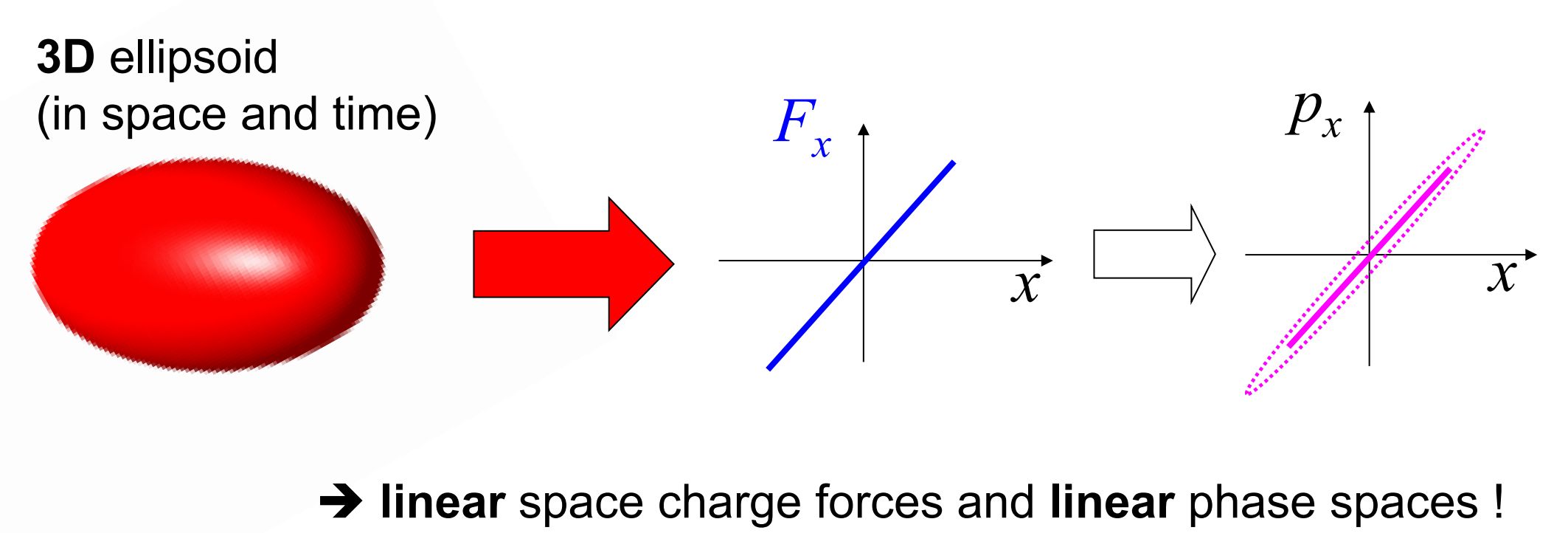
Motivation and Beam Dynamics Simulations with ASTRA

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

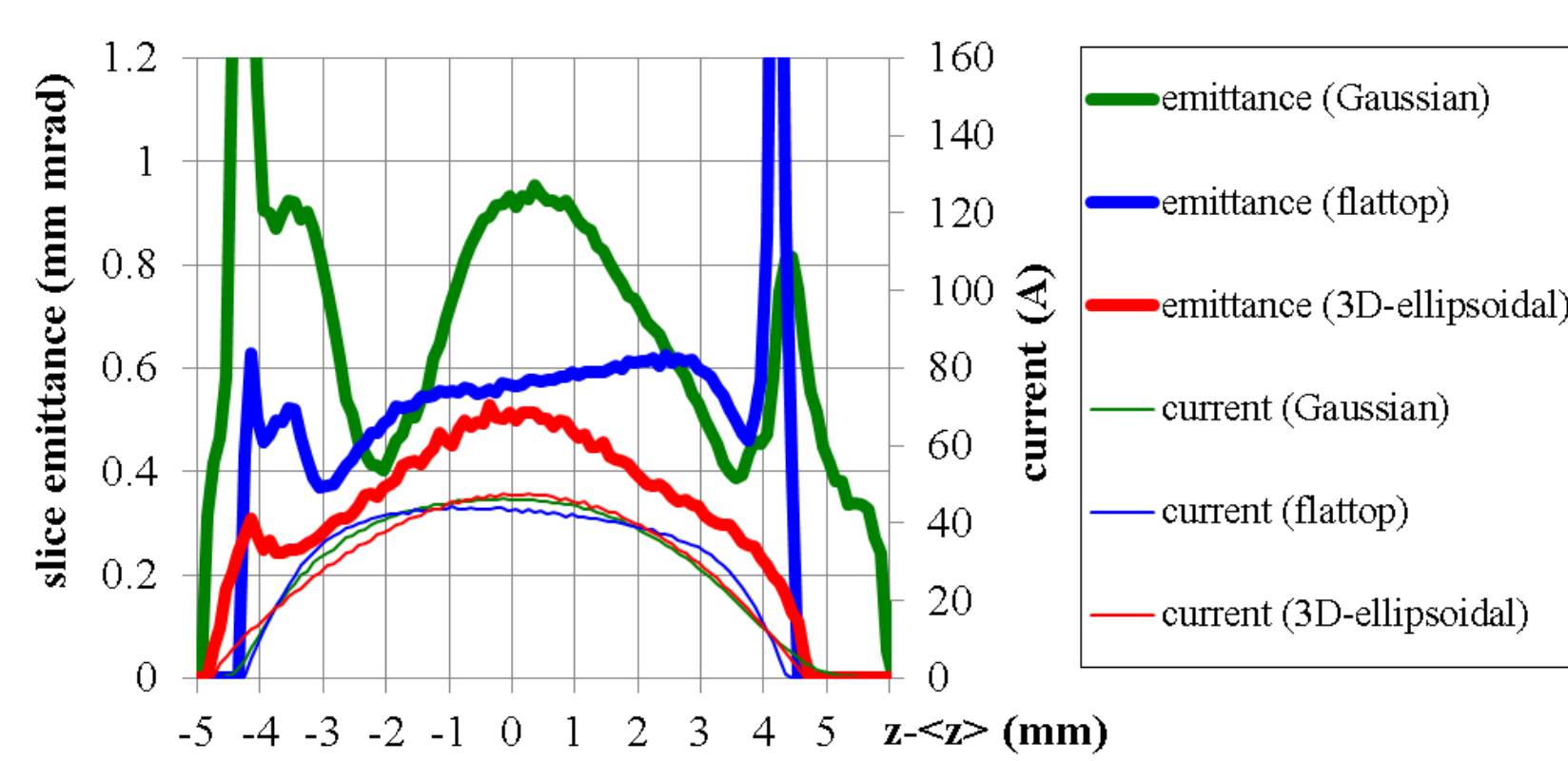
Standard:



New:

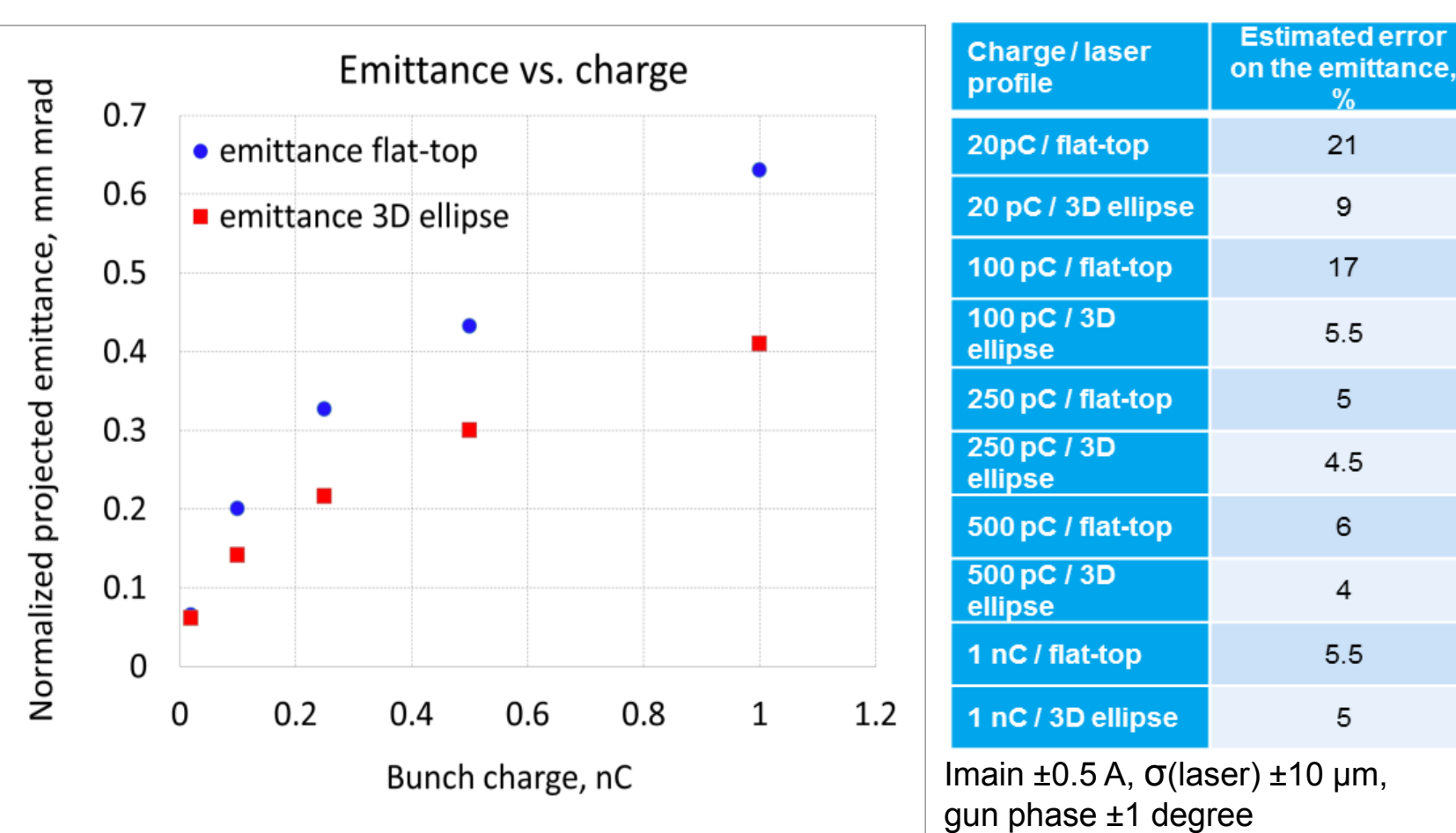


Slice emittance for 1 nC bunch charge



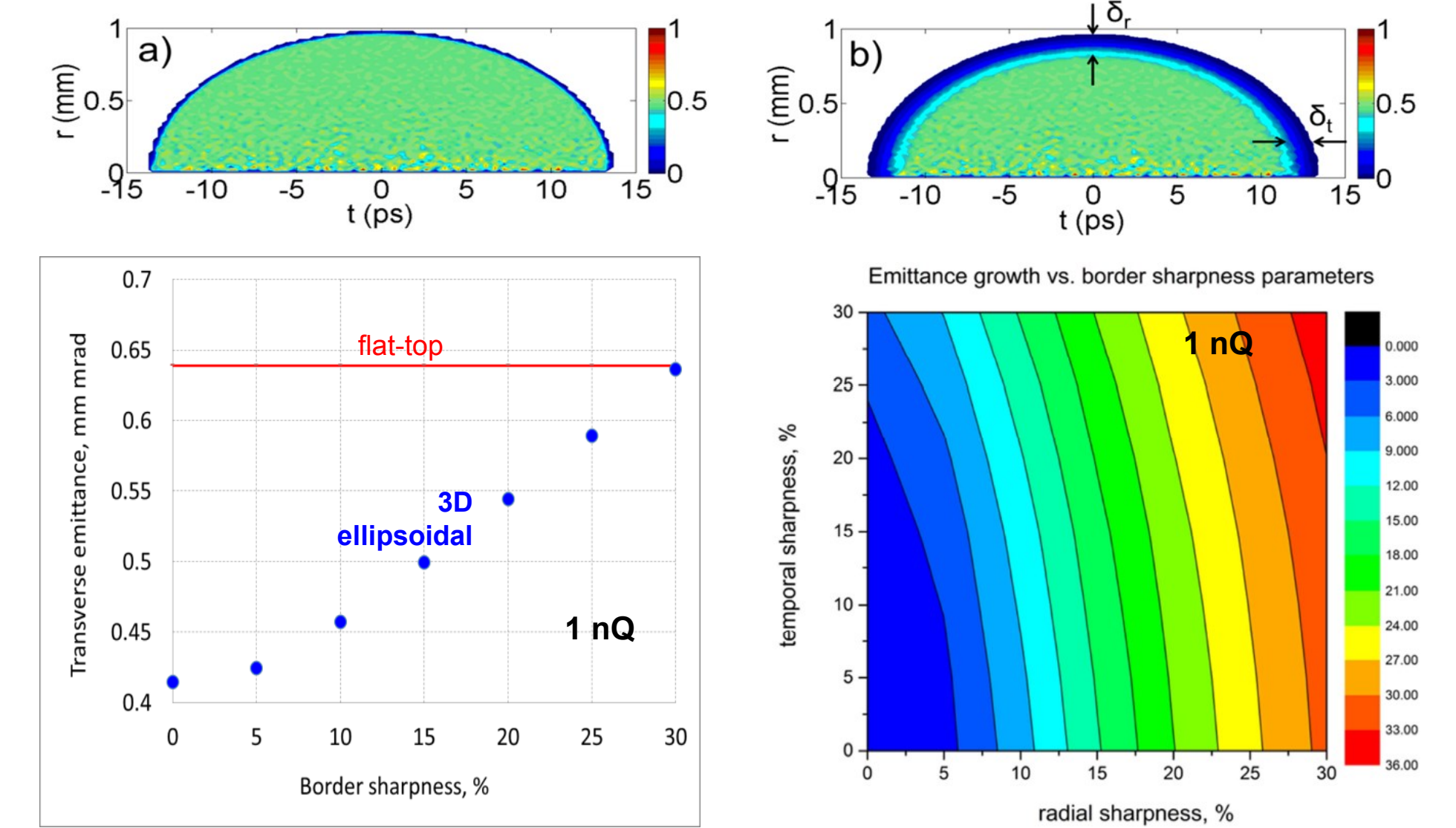
- > 30-50% lower av. slice emittance
- > better longitudinal compression
- > reduced beam halo

Projected emittance and tolerance studies



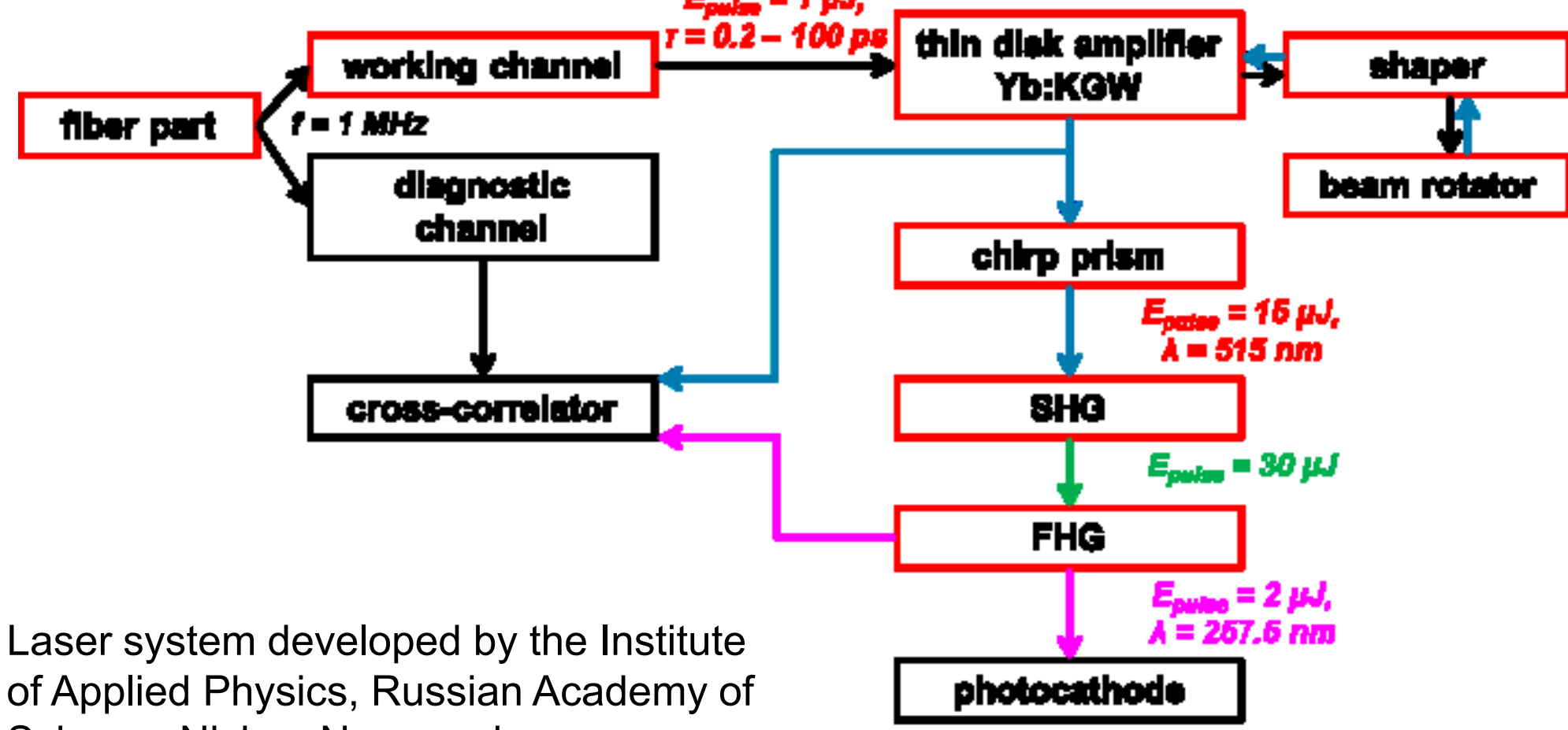
> less sensitivity to machine settings

Modelling of shape imperfections

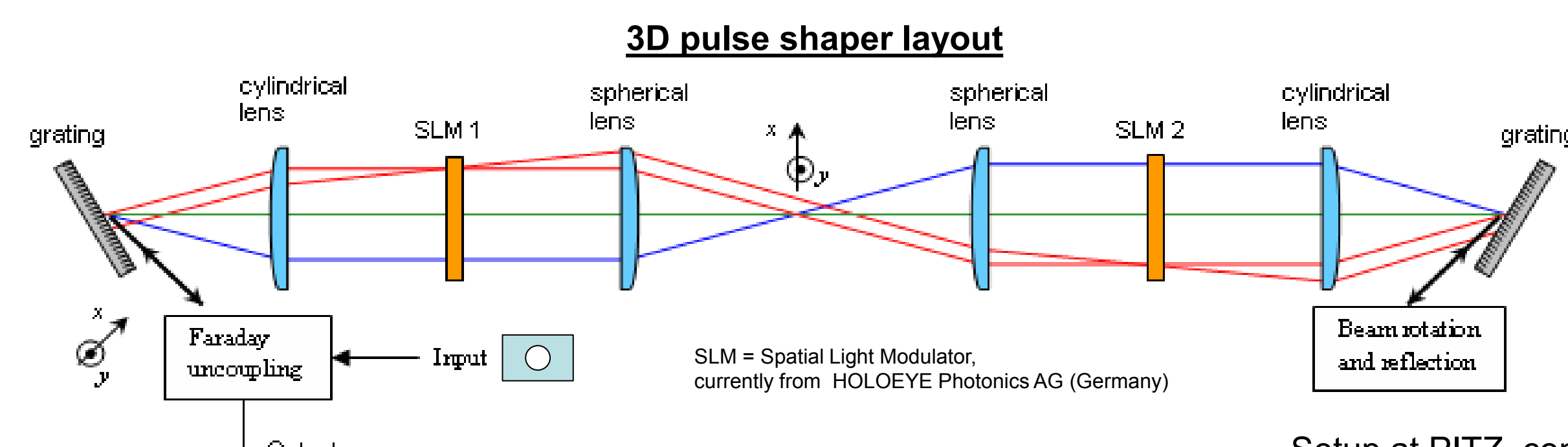


Setup of the Laser System

General setup:

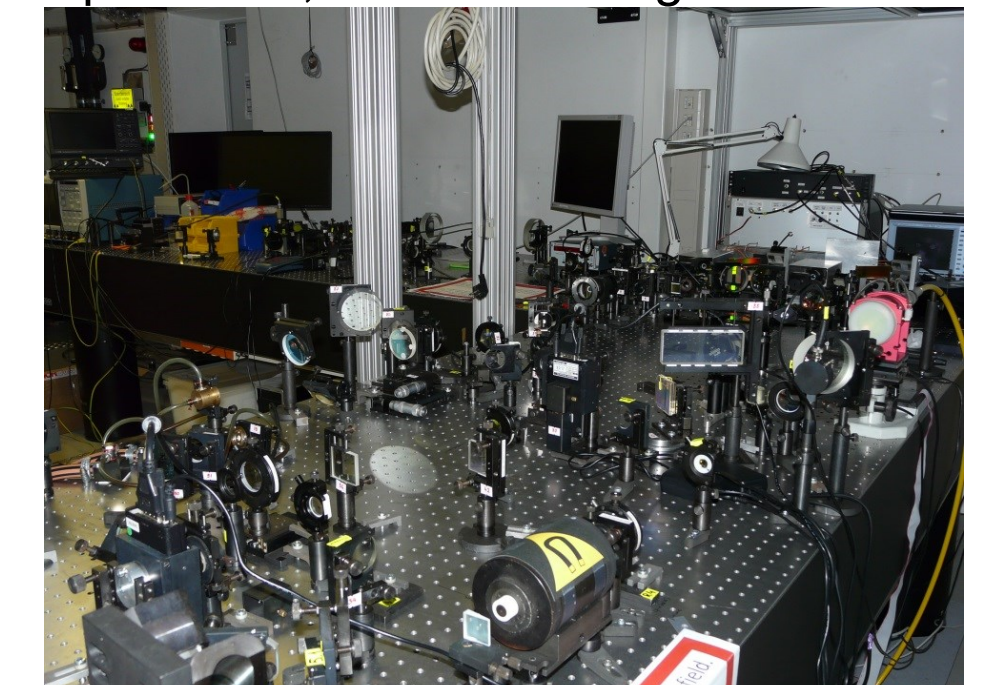


Laser system developed by the Institute of Applied Physics, Russian Academy of Science, Nizhny Novgorod, in collaboration with DESY and JINR



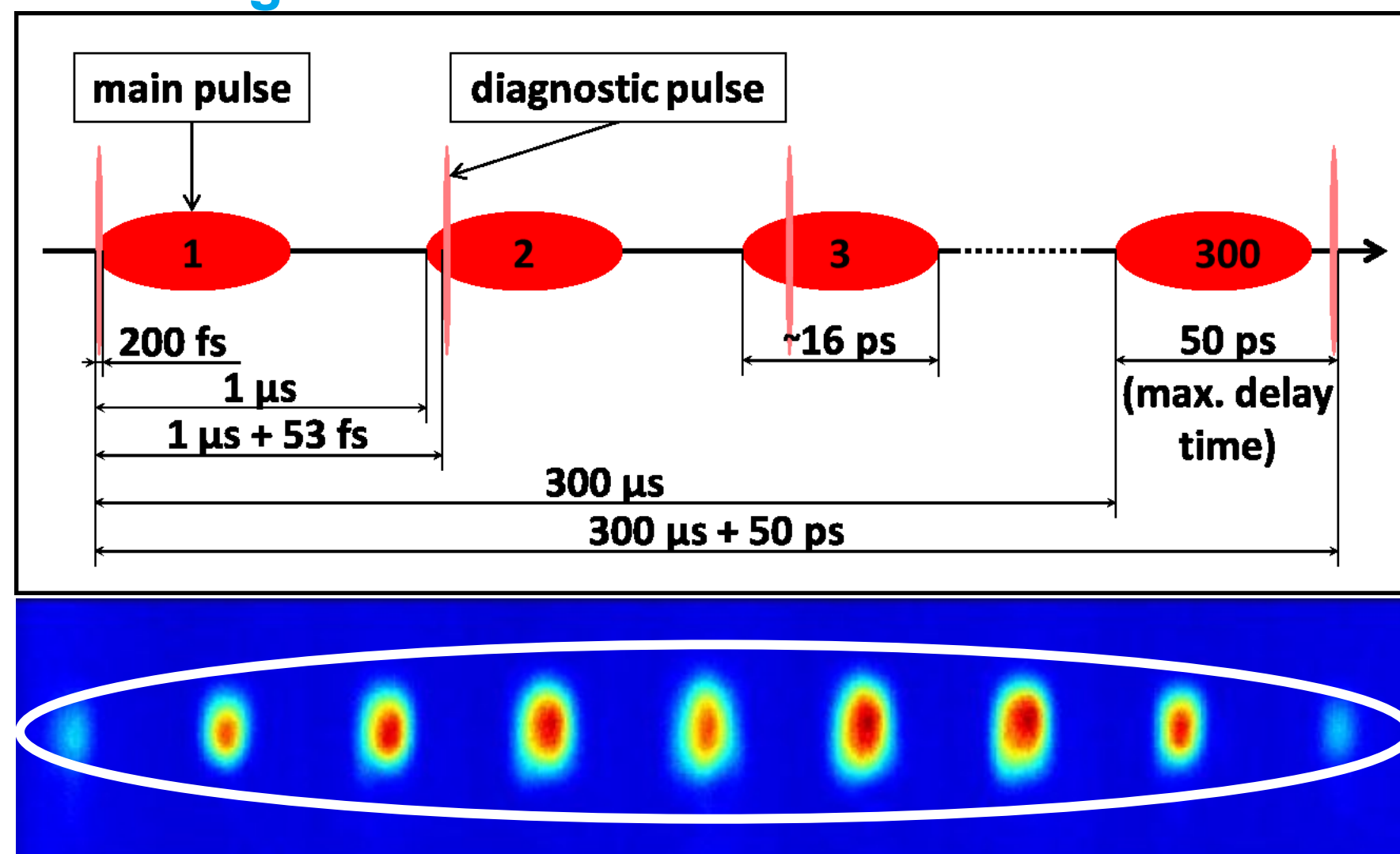
parameter	value	unit	remark
wavelength	258	nm	1030 nm fundamental
pulse energy	15	μJ	for 1 nC bunch production from Cs ₂ Te photo cathodes
repetition frequency	1	MHz	4.5 MHz will be the goal in the future
train length	0.3	ms	0.6 ms will be the goal in the future
train rep. rate	10	Hz	1,2,5 Hz as an option
micropulse rms duration	6 ± 2	ps	3D quasi ellipsoidal distribution
transverse rms size	0.5 ± 0.25	mm	

Setup at PITZ, commissioning since 01/2015



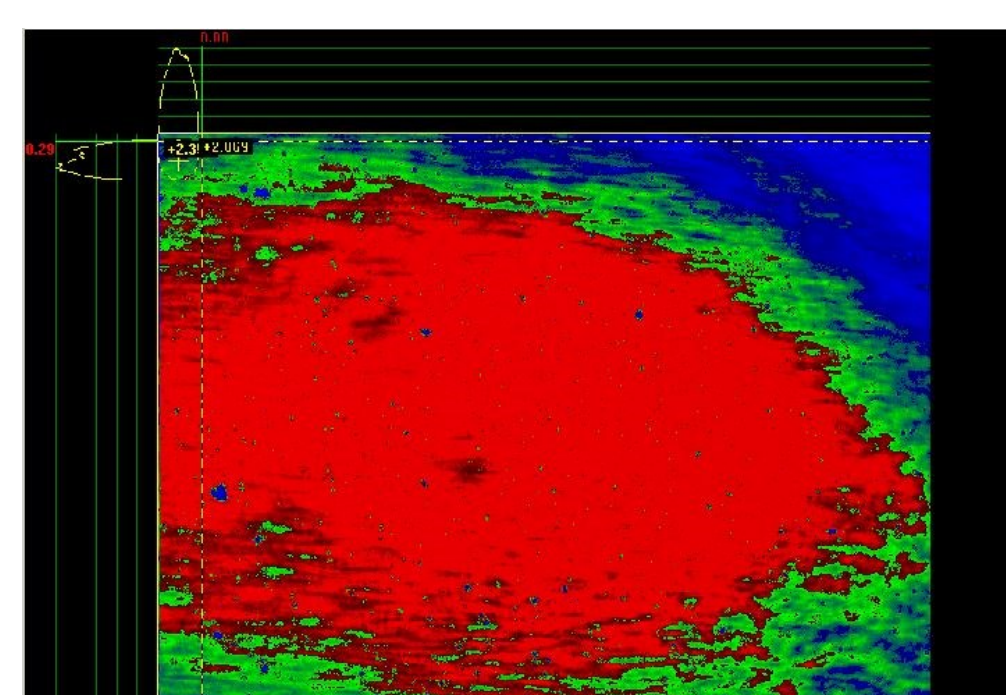
First Experimental Results

Scanning-cross correlator measurements:

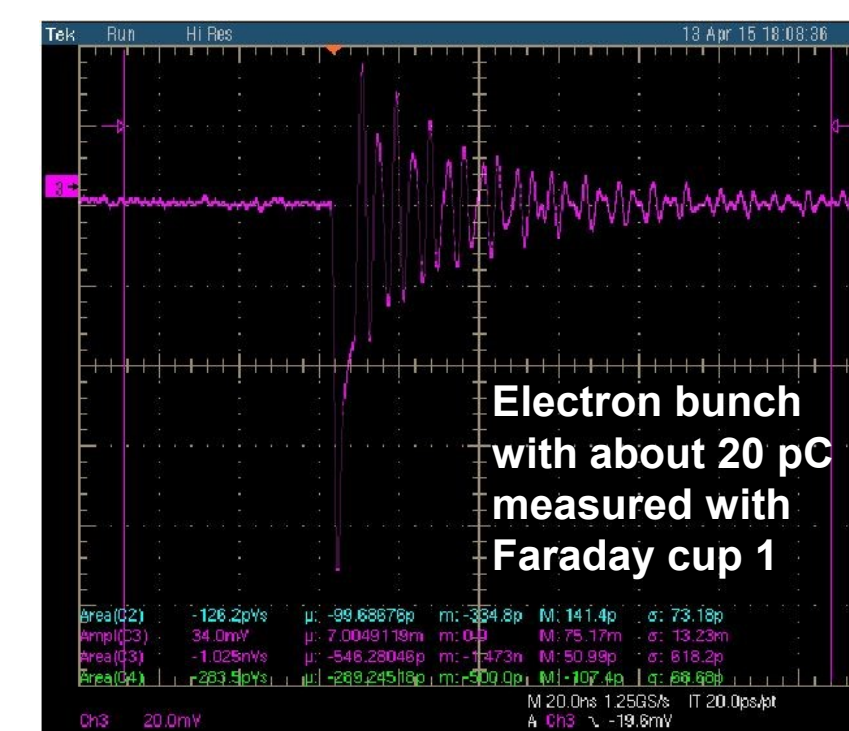


First photo electrons generated in April 2015 :

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

- [1] M. Kraslinikov, F. Stephan et al., "Experimentally minimized beam emittance from an L-band photoinjector", Phys. Rev. ST Accel. Beams 15, 1000701 (2012).
- [2] F. Stephan, M. Kraslinikov, 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*, to be published by Springer References.
- [3] M. Khojayan et al., "Studies on the Application of the 3D Ellipsoidal Cathode Laser Pulses at PITZ", Proc. IPAC2014, Dresden, Germany.
- [4] M. Khojayan, et al., "Optimization of the PITZ photoinjector towards the best achievable beam quality", Proc. FEL2014, Basel, Switzerland.
- [5] M. Kraslinikov 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. 78 (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.