

Space-Charge Dominated Photoemission in High Gradient Photocathode RF Guns

Ye Chen and the DESY-PITZ team

LINAC'18, Beijing, China, September 20th, 2018

THPO116

Acknowledgements to

Frank Brinker, Martin Dohlus, Klaus Floettmann, Wolfgang Hillert, Sven Lederer, Siegfried Schreiber, **DESY, Germany**

Han Chen, Yingchao Du, Wenhui Huang, Chuanxiang Tang, Qili Tian, Lixin Yan, **Tsinghua University, China**

Paolo Michelato, Laura Monaco, Carlo Pagani, Daniele Sertore, **INFN, Italy**

Herbert De Gersem, Erion Gjonaj, Thomas Weiland, **TEMF, TU Darmstadt, Germany**

André Arnold, Jochen Teichert, Rong Xiang, **HZDR, Germany**

C. Hernandez-Garcia, **J-lab, USA**

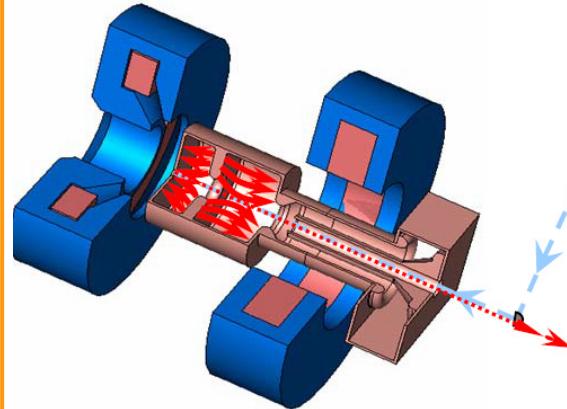
David H. Dowell, **SLAC, USA**

Roman Ganter, **PSI, Switzerland**

Christoph Hessler, **CERN, Switzerland**



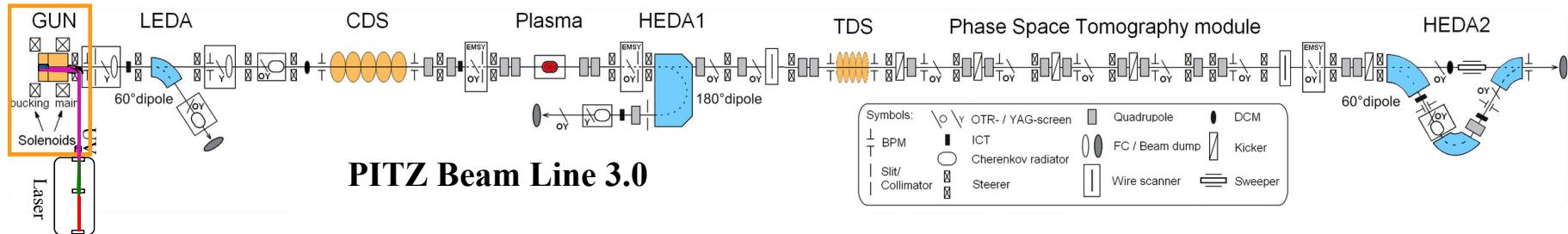
Photo Injector Test facility at DESY in Zeuthen



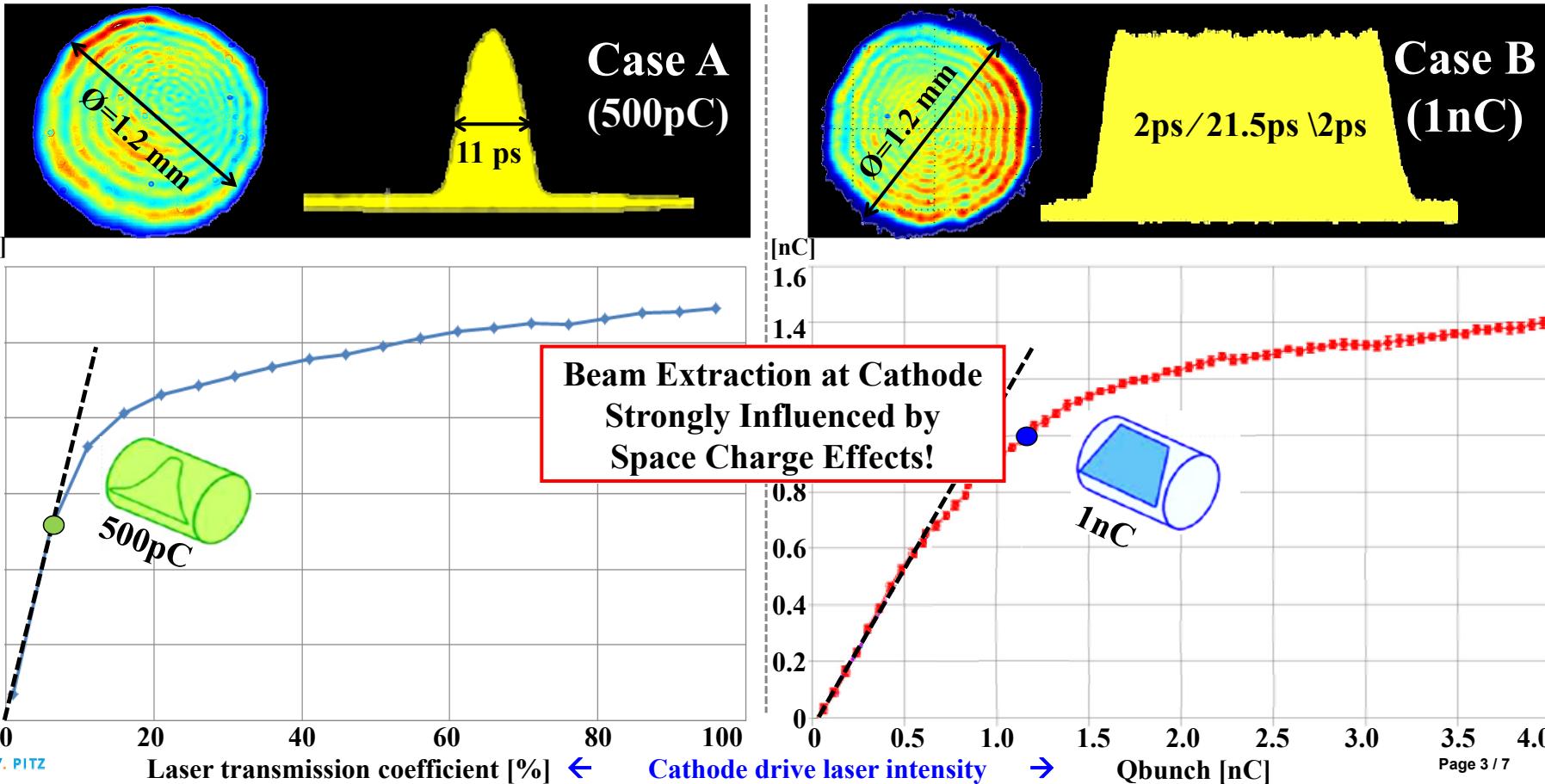
RF Gun

- L-band (1.3 GHz) 1.6-cell copper cavity
- Ecath $\geq 60 \text{ MV/m}$ \rightarrow 7 MeV/c e-beams
- $650 \mu\text{s} \times 10 \text{ Hz}$ \rightarrow up to 45 kW av. RF power
- Cs_2Te PC (QE~5-10%) \rightarrow up to 5 nC/bunch
- Solenoids for emittance compensation

The PITZ gun copies are in use at the European X-ray Free Electron Laser (E-XFEL) and the Free electron LASer in Hamburg (FLASH).

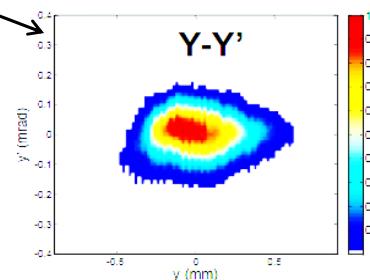
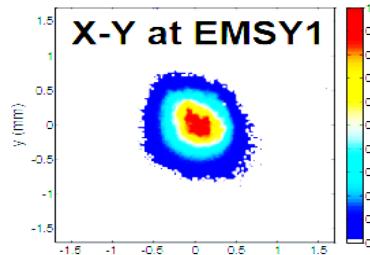
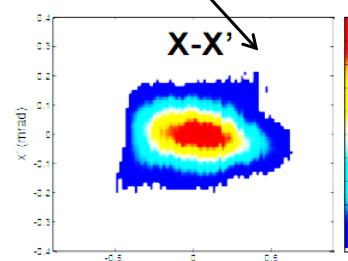
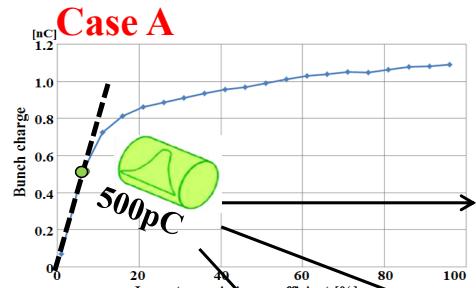


Standard Operation Conditions at PITZ for the E-XFEL Working Points (RF: 6.5 MW \times 650 μ s)



Best Emittance Experimentally Demonstrated Using Space-Charge Dominated Beams

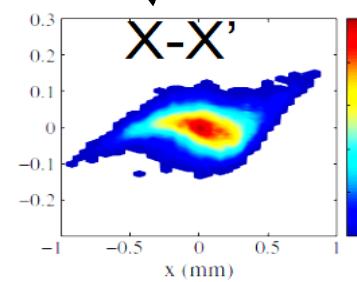
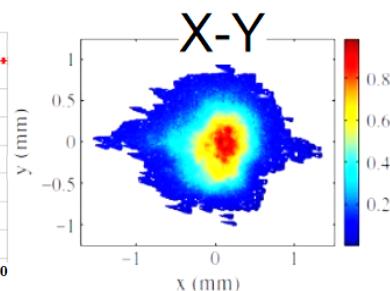
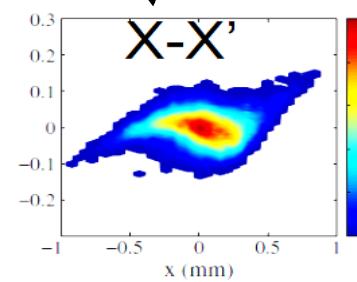
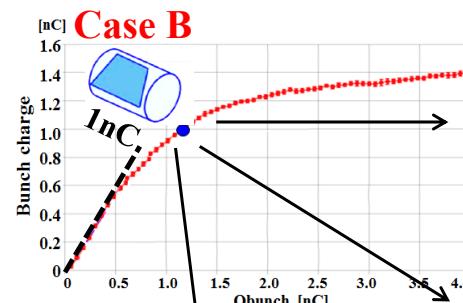
Measured Transverse Phase Spaces and Beam Profile @ Injector Exit



$$\epsilon_{x,n} \approx 0.82 \text{ mm mrad}$$

$$\epsilon_{y,n} \approx 0.84 \text{ mm mrad}$$

$$\sqrt{\epsilon_{x,n}\epsilon_{y,n}} \approx 0.83 \text{ mm mrad}$$



$$\epsilon_{x,n} \approx 0.72 \text{ mm mrad}$$

$$\epsilon_{y,n} \approx 0.60 \text{ mm mrad}$$

$$\sqrt{\epsilon_{x,n}\epsilon_{y,n}} \approx 0.66 \text{ mm mrad}$$

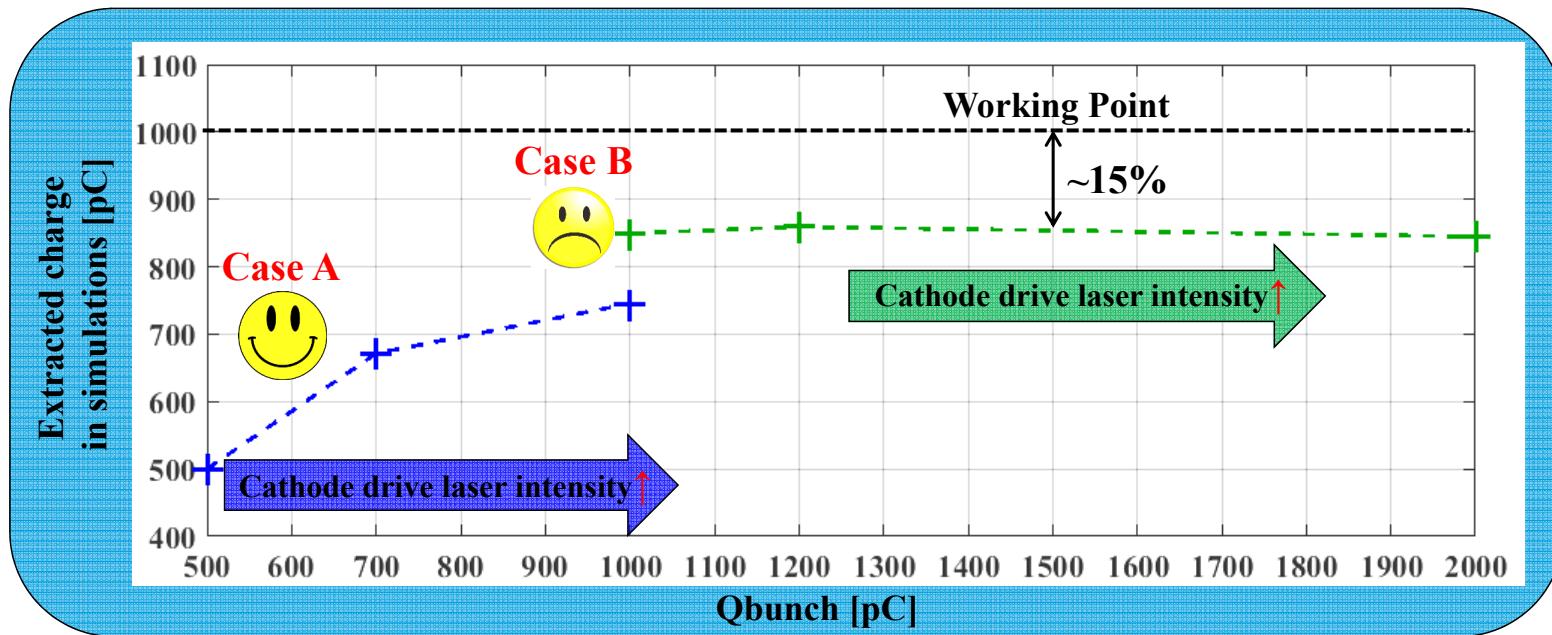
NB: quadrupoles at gun exit applied in Case A for compensating beam asymmetries

DESY, PITZ

Beam Dynamics: Charge Packet Creation in Simulations at E-XFEL Working Points

Directly plugging experimental parameters in simulations,

→ 1 nC can not be extracted → 500 pC can be extracted



Conventional beam dynamics
needs improvements

Advanced beam dynamics modeling required,
especially for the transient process of space-charge
dominated photoemission in the gun!

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Space-Charge Dominated Photoemission in High Gradient Photocathode RF Guns

- What is the physics behind?
- How to model transient photoemission?
 - How to consider it in beam dynamics simulations?
 - What is the effect on e.g., intrinsic emittance?



DESY. PITZ

The 29th Linear Accelerator Conference, LINAC'18, Beijing, China

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INTRODUCTION

RF Gun
 • Lineard (1.3 GHz) 1.6-cell copper cavity
 • Beam current up to 10 mA
 • Up to 40 kV ac RF power
 • $\times 1.1 \mu\text{C}$ PC (QE = 17%)
 • Up to 5.5 kV bunch energy
 • 100 pC bunch size
 • 100 pC bunch length
 • 100 pC bunch emittance
 • 100 pC bunch compression

PITZ Beam Line 3.0

EMITTANCE MEASUREMENT

BEST EMMITTANCE Experimentally Demonstrated Using Space-Charge Dominated Beams
 Measured Transverse Phase Space and Beam Profile at Injector Exit

BEAM DYNAMICS

Charge Packet Creation in Simulation at XFEL Working Points
 Directly after the photocathode parameters are simulated
 $\rightarrow 100 \text{ pC} \text{ can be accelerated}$

PHOTOEMISSION PROCESS

BEAM DYNAMICS MODELING DURING EMISSION

MEASUREMENT (METAL CASE)

ACKNOWLEDGEMENTS

OUTLOOK

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HELMHOLTZ
 RESEARCH FOR GRAND CHALLENGES

PITZ
 PHOTOEMISSION INSTITUTE, DESY GERMANY

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 H. De Gersen et al., Phys. Rev. Lett. A 359 (2013) 129–137.
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 V. C. Du et al., Rev. Sci. Instrum. 84 (5) 053301 (2013).

details



DESY Contributions to LINAC'18*

Vladimir Vogel, MOPO036, *Status of the 10 MW MBKs During Commissioning of the European XFEL in DESY*

Elmar Vogel, MOPO037, *SRF Gun Development at DESY*

Julien Branlard, MOPO038, *RF Operation Experience at the European XFEL*

Julien Branlard, MOPO039, *Status Update of the Fast Energy Corrector Cavity at FLASH*

Cagil Gumus, MOPO102, *Progress of MicroTCA.4 based LLRF System of TARLA*

Andrea Bellandi, MOPO104, *LLRF R&D Towards CW Operation of the European XFEL*

Holger Schlarb, MOPO121, *Large-Scale Optical Synchronization System of the European XFEL*

Jens-Peter Jensen, MOPO122, *European XFEL Cooling and Ventilation Systems*

Burcu Yildirim, TUPO027, *Series Production of the Specific Waveguide Distribution for the European XFEL at DESY*

Sven Sievers, TUPO028, *Retreatment of European XFEL Series Cavities at DESY as Part of the Repair of European XFEL Accelerating Modules*

Julien Branlard, TUPO029, *Highlights of the XM-3 Cryomodule Tests at DESY*

Raffael Niemczyk, TUPO098, *Proof-of-Principle Tests for Slit-scan-based Slice Emittance Measurements at PITZ*

Lukasz Butkowski, TUPO132, *Implementation of the Beam Loading Compensation Algorithm in the LLRF System of the European XFEL*

Stefan Choroba, WE1A04, *The High Power RF System for the European XFEL*

Marc Wenskat, TH2A01, *Nitrogen Infusion R&D for CW Operation at DESY*

Ye Chen, THPO116, *Space-Charge Dominated Photoemission in High Gradient Photocathode RF Guns*

Quantang Zhao, THPO118, *Beam Transverse Coupling and 4D Emittance Measurement Simulation Studies for PITZ*

Markus Huening, FR1A02, *Bunch Length Measurements Using Transverse Deflecting Systems*

Dirk Noelle, FR2A02, *Commissioning of the European XFEL*

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*Data taken from LINAC'18 JACoW online submission system

Apologies to the colleagues whose contributions are possibly missing