Space-Charge Dominated Photoemission in High Gradient Photocathode RF Guns

Ye Chen and the DESY-PITZ team

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THPO116

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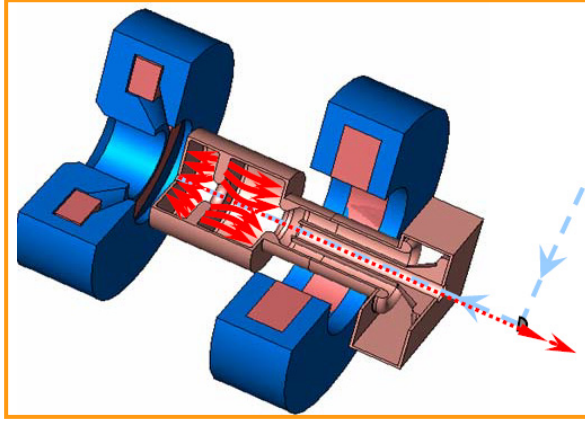
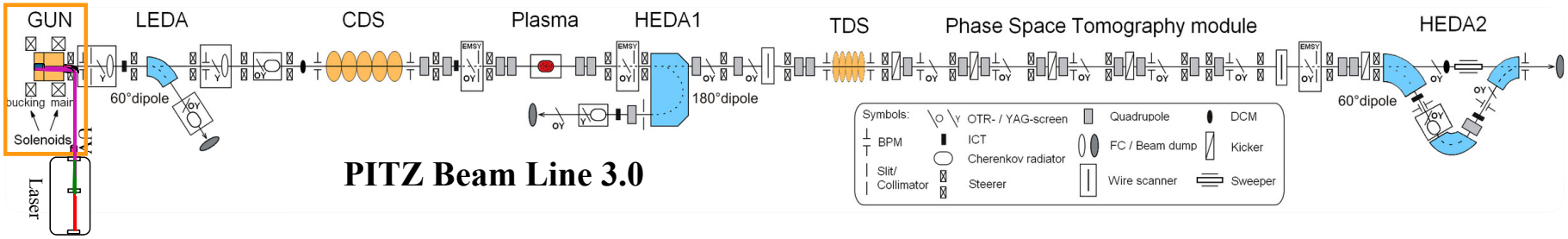
Photo Injector Test facility at DESY in Zeuthen



RF Gun

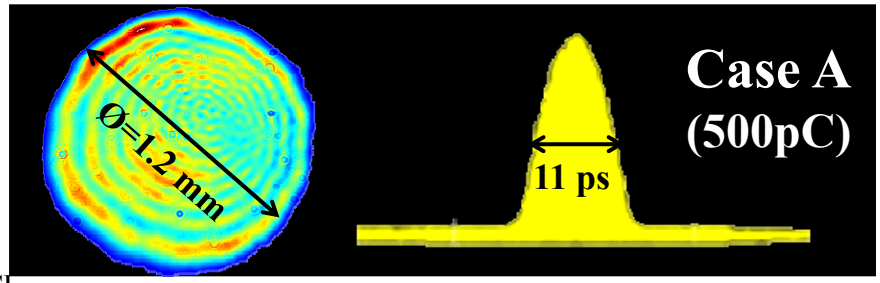
- **L-band** (1.3 GHz) 1.6-cell copper cavity
- Ecath ≥ **60 MV/m** → 7 MeV/c e-beams
- 650 µs ×10 Hz → up to **45 kW** av. RF power
- **Cs_2Te** PC (QE~5-10%) → up to 5 nC/bunch
- Solenoids for emittance compensation

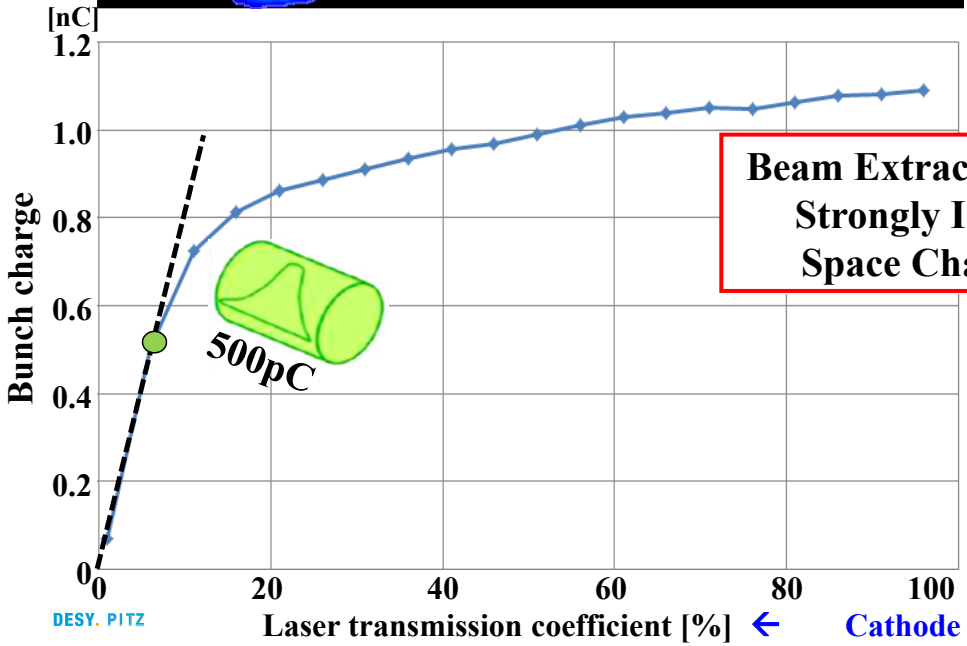
The PITZ gun copies are in use at the European X-ray Free Electron Laser (E-XFEL) and the Free electron LASer in Hamburg (FLASH).

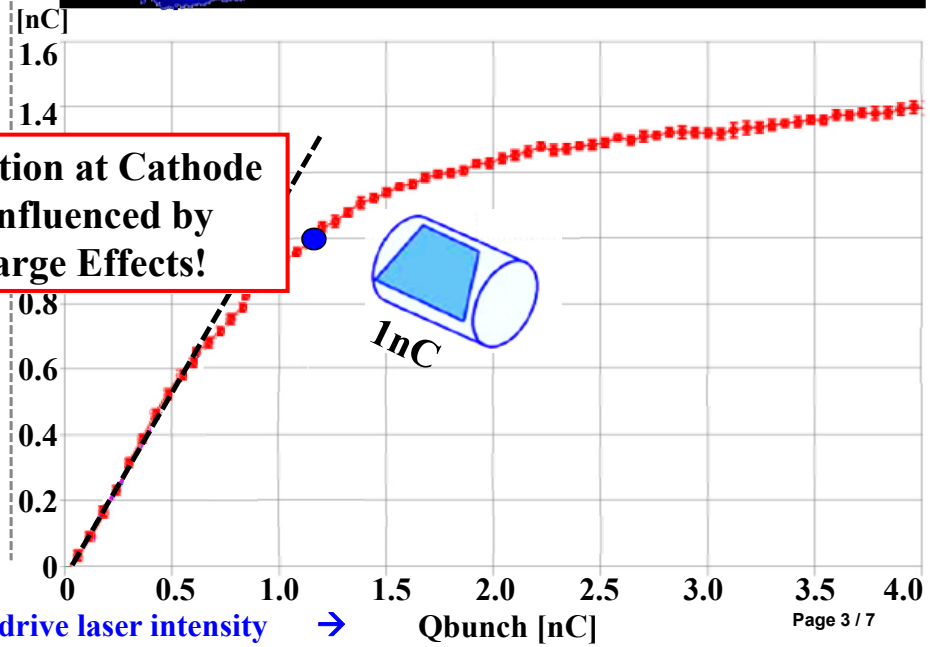


PITZ Beam Line 3.0

Standard Operation Conditions at PITZ for the E-XFEL Working Points (RF: 6.5 MW × 650 µs)







Beam Extraction at Cathode Strongly Influenced by Space Charge Effects!

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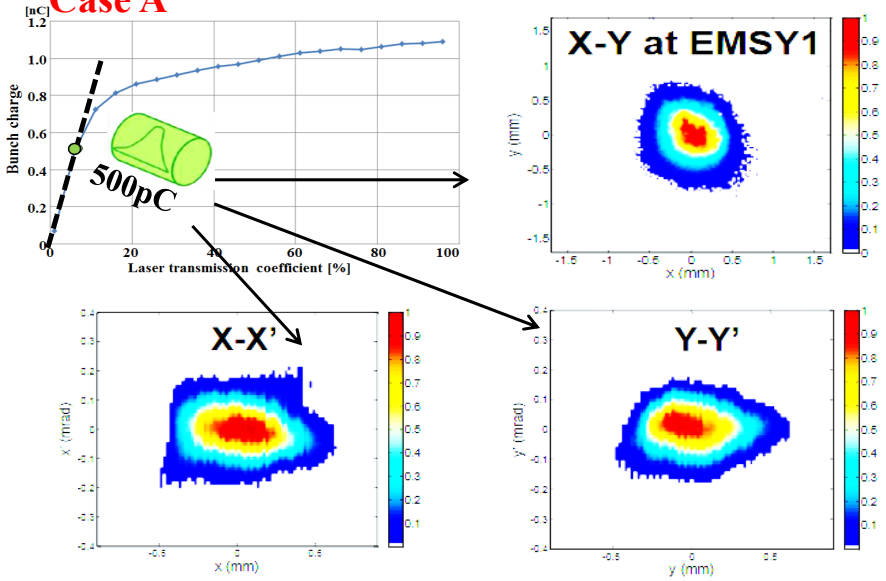
Laser transmission coefficient [%] ← Cathode drive laser intensity → Qbunch [nC]

Best Emittance Experimentally Demonstrated Using Space-Charge Dominated Beams

Measured Transverse Phase Spaces and Beam Profile @ Injector Exit

Case A

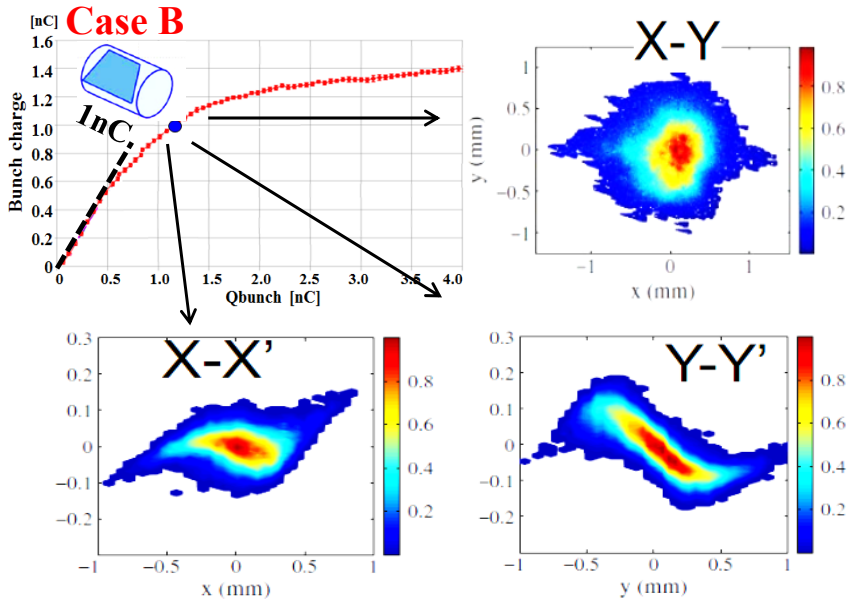


$\varepsilon_{x,n} \approx 0.82$ mm mrad

$\varepsilon_{y,n} \approx 0.84$ mm mrad

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

Case B



$\varepsilon_{x,n} \approx 0.72$ mm mrad

$\varepsilon_{y,n} \approx 0.60$ mm mrad

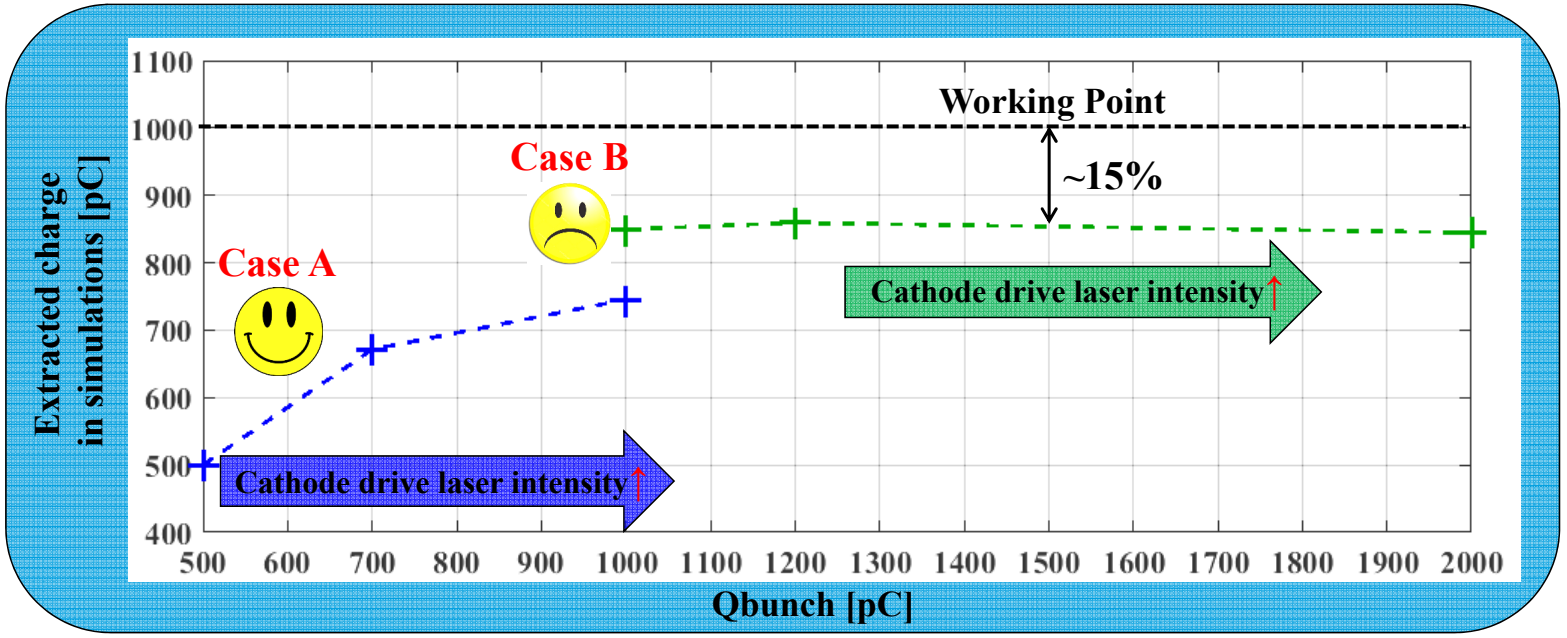
$\sqrt{\varepsilon_{x,n}\varepsilon_{y,n}} \approx 0.66$ mm mrad

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

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?

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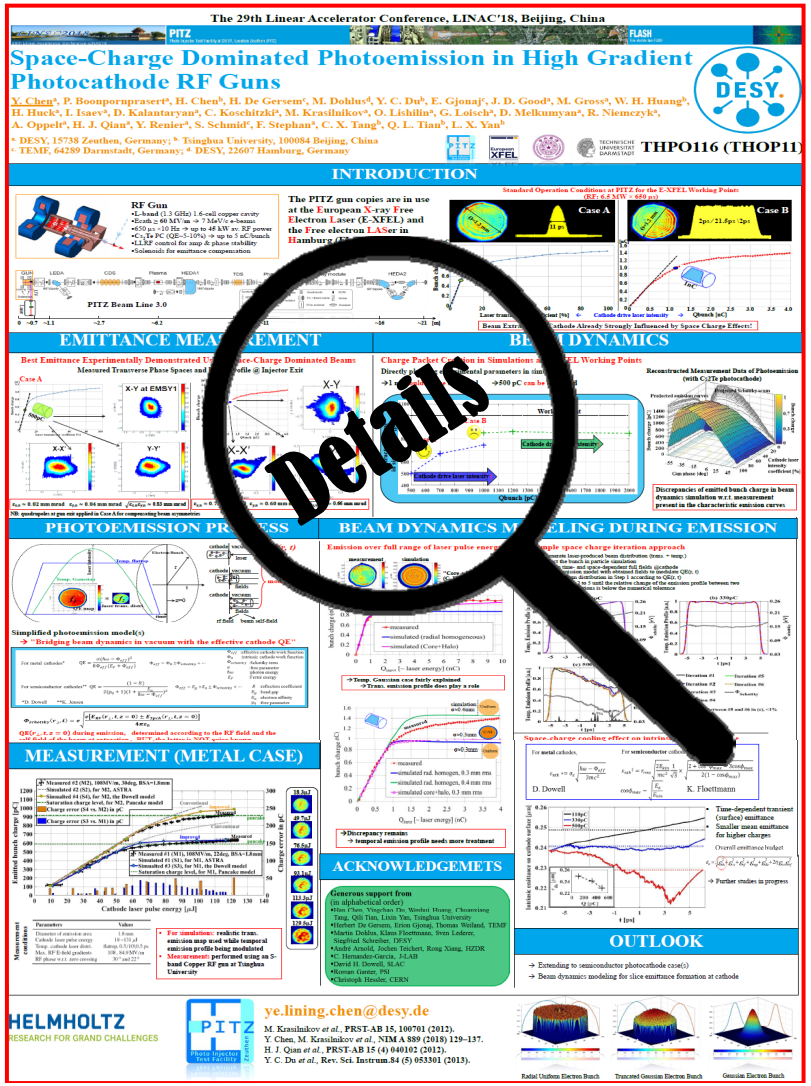

DESY Contributions to LINAC′18*

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

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