Measurement of Cs2Te Cathode Response in a High-Gradient Photoinjector.

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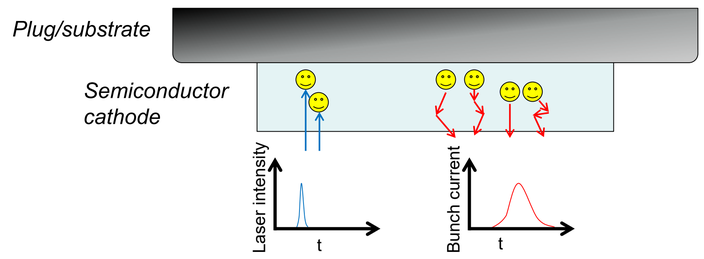
Abstract

Cesium-Telluride is a widely used semiconductor photocathode material in electron photoinjectors for its high quantum efficiency and its stability in a high-gradient RF-gun environment. Even though the properties of such cathodes have been studied extensively in the past decades, the emission process is still not fully understood. One of the parameters that has not been directly quantified in experiment is the lengthening of electron bunches in Cs_2Te with respect to the incident UV laser pulse length - often referred to as cathode response time - due to photon penetration depth variations and scattering processes. Especially for applications such as novel accelerator technologies, ultrafast electron diffraction and free electron lasers with ever higher demands on short bunch durations, the minimum attainable bunch length from the electron gun is a decisive quantity.
We present the first direct measurement of Cs_2Te cathode temporal response by measuring electron bunch lengths and profiles with a few tens of femtoseconds resolution at the Photoinjector Test facility at DESY Zeuthen (PITZ). We also show first results on the impact of photocathode thickness on cathode response.

Motivation

Cathode response time

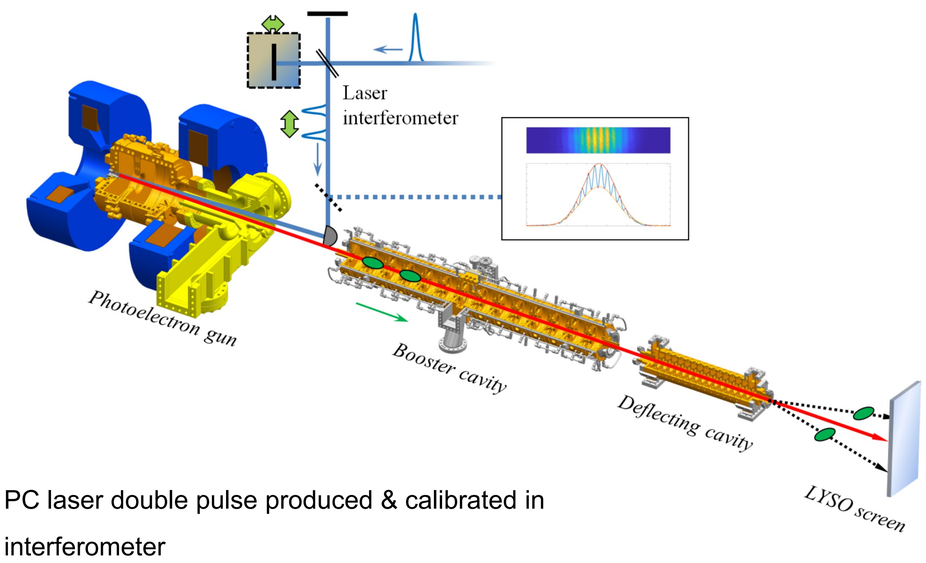
- "Spicer 3-step model": Excitation, Transmission, Emission
- Electron to photon delay variation
  - *Photon penetration depth*
  - *Electron scattering*
- Defines:
  - *Bunch shaping accuracy (PC-based)*
  - *Min. bunch length*
  - *Emission model accuracy*



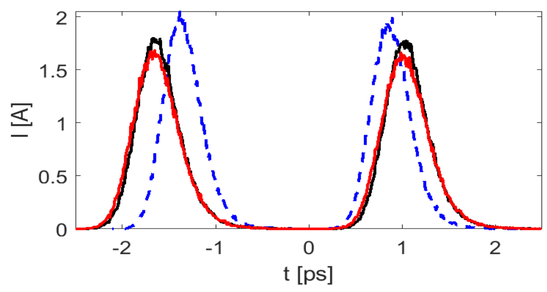
Insufficient data in literature

- Theoretical work available
- Published measurements only approximations
- No confirmation of response function shape
- No data on variation w/ cathode parameters
- Correlation w/ QE & thermal emittance unknown

Measurement setup



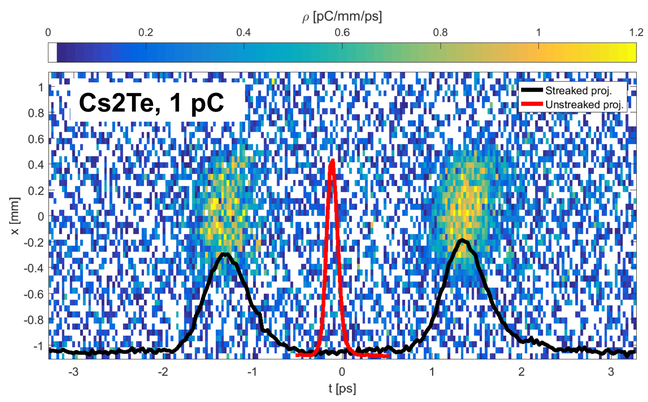
- PC laser double pulse produced & calibrated in interferometer
- Low charge (~pC) double bunch extracted from cathode
- Acceleration to ~22MeV
- Single-shot time-resolved measurement using transverse deflector (TDS)
  → RF & laser jitter irrelevant



ASTRA simulated bunch distributions
@cathode
@deflector
measured

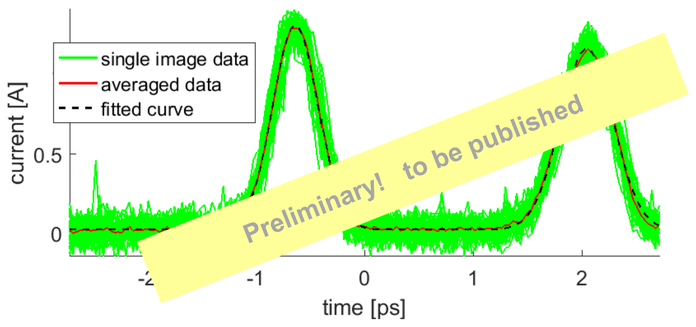
- Direct laser pulse to bunch delay time calibration
  → neglect RF-compression
- Extensive error studies for charge, delay, etc.
- Large noise due to dark current
  → large statistics
- Potentially high errors due to bunch/beam Y-Z-correlations
  → error mitigation procedure reduces error to ~statistical

Preliminary results

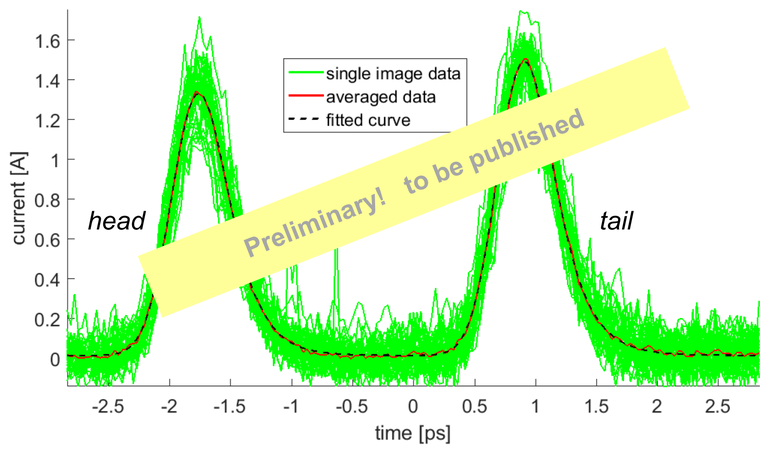


Measured cathodes

- Measured Mo & Au cathodes as reference
- Measured various Cs2Te cathodes:
  - Produced @DESY
  - Produced @INFN Milano
  - (5-15) nm Te thickness
  - Used & fresh cathodes



**Mo plug, 1 pC,
40 shots,
Gaussian fit**



**Cs2Te, 1.8 pC,
40 shots,
Gaussian exponential fit**

Results

- Symmetric ~Gaussian distributions observed w/ metal cathodes
- Cs2Te bunch shape matches predictions
  - ~Gaussian (~laser pulse shape)
  - Convoluted w/ exponential (cathode response)

- Min. measured exponential response: ~180 fs ± 40 fs
- Max. measured exponential response: ~250 fs ± 40 fs

- Significant deviations between DESY & INFN cathodes
- No direct correlation w/ QE
- No intuitive correlation w/ thickness

Preliminary! to be published

Summary & Outlook

- First measurement of Cs2Te cathode response function!
- Measurement procedure established and routinely used
- (Symmetric) measurement resolution ~ 45 fs
- Cs2Te exponential response ~ (180±40) fs – (250±40) fs [depends on cathode]

- Noise reduction being refined for lower statistical error
- Simulations match measurement results quite well

- Measurement of cathodes <5nm Te & CsKSb planned

HELMHOLTZ RESEARCH FOR GRAND CHALLENGES

PITZ Photo Injector Test Facility Zeuthen