Charge carrier dynamics and emission from Cu and Cs_2Te cathodes in RF photoguns

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e^- bunches and photoemission

Short e^- bunches allow for probing matter:

- Directly – UED, UEM.
- Indirectly – when generating radiation (FEL, SRF).

RF photoguns routinely provide such bunches.

Photoemission is a key phenomenon to account in RF guns. Well described by classical models (TSM, FD). However, these **do not provide** the initial e^- bunch distribution at the cathode.

Start-to-end modelling
The more correctly e-bunch distributions at the cathode surface are simulated, the more precisely we calculate beam dynamics and overall facility operation.

Transport equation formalism

In general: describing optoelectonic and photovoltaic applications.

We: transport equation formalism has been extensively used to study the photocathode physics:

- M. Vladimirov, V. Rashchikov, S. Polozov, *JINST*, **19** (2024),
- M.V. Vladimirov, S.M. Polozov, V.I. Rashchikov, *JETP Lett.*, **120** (2024),
- M. Vladimirov, V. Rashchikov, S. Polozov, *NIM-A*, **1045** (2025),
- M. Vladimirov, V. Rashchikov, S. Polozov, *EPJ ST*, **TBD** (2026).

Impact of initial electron distributions at the photocathode in RF photoinjectors on radiation parameters

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Abstract

The paper discusses the effect of the initial electron bunch distribution on the angular and spectral parameters of the radiation the bunch produces when passing periodic structures. The realistic electron bunch distributions in the vicinity of the photocathode are obtained with the use of the dedicated numerical code `PhDyn`. The beam dynamics for electron bunches in the radio-frequency photogun and the linear accelerator following it are calculated using the `BEAMDULAC_BL-photogun` code. The electron phase-space distributions obtained with this code are subsequently used to simulate spiral undulator and channeling radiations. The results reveal significant deviations in the spectral-angular distributions when realistic initial distributions are used, highlighting the importance of accurate modeling of the photocathode emission process.

Submitted to EPJ D (Proc. of RREPS-25).

Theoretical framework

Drift-diffusion equations:

$$\boxed{D\frac{\partial^2 n}{\partial z^2}} + \boxed{\frac{\partial}{\partial z}(v_n(E)n)} + \boxed{G(z,t)} - \boxed{\frac{n}{\tau_n}} = \frac{\partial n}{\partial t}$$

Mechanisms: drift, diffusion, generation

$$G(z,t) = \frac{W_{\text{pulse}}}{\pi r^2}\frac{\lambda\alpha(\lambda)}{hc}e^{-\alpha(\lambda)z}T_{\text{las}}(t)$$

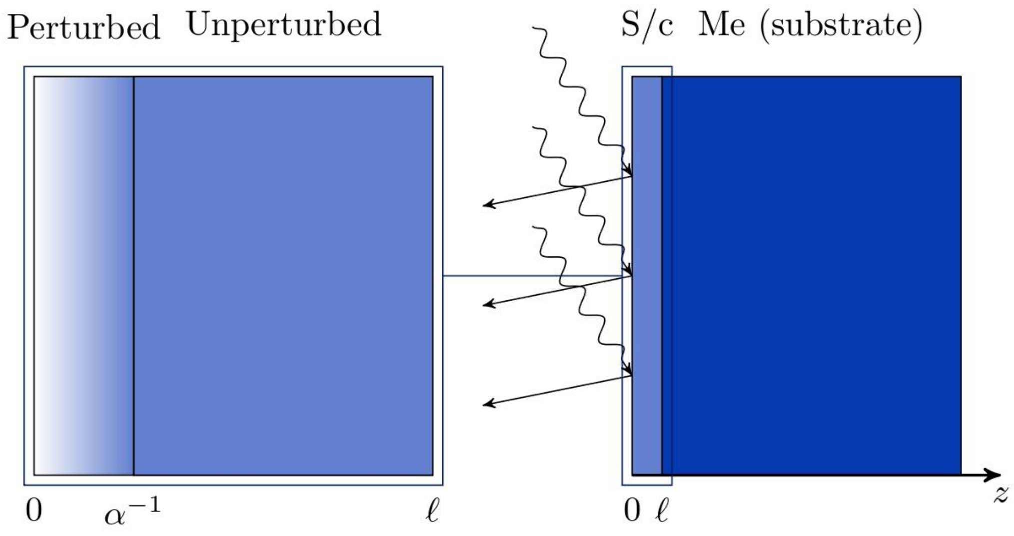
and recombination.

E consists of three terms:

- int. field (the Gauss law)
- ext. RF field
- the bunch field (the sum of charged slices)

$$E_{\text{b}}(z,t) \propto \int_0^t j_{\text{ph}}(t-t')\left(1 - \frac{v_n(E)t' - z + \ell}{(v_n(E) - z + \ell)^2 + R^2}\right)\mathrm{d}t'$$

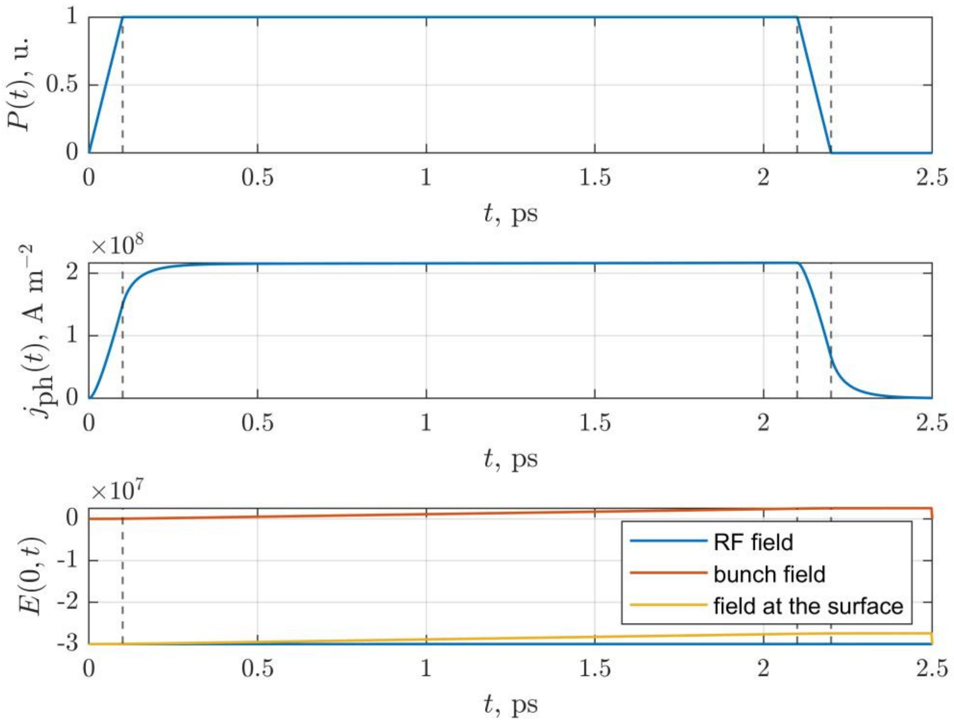
$j_{\text{ph}}(t) \propto n(0,t)$ => self-consistency

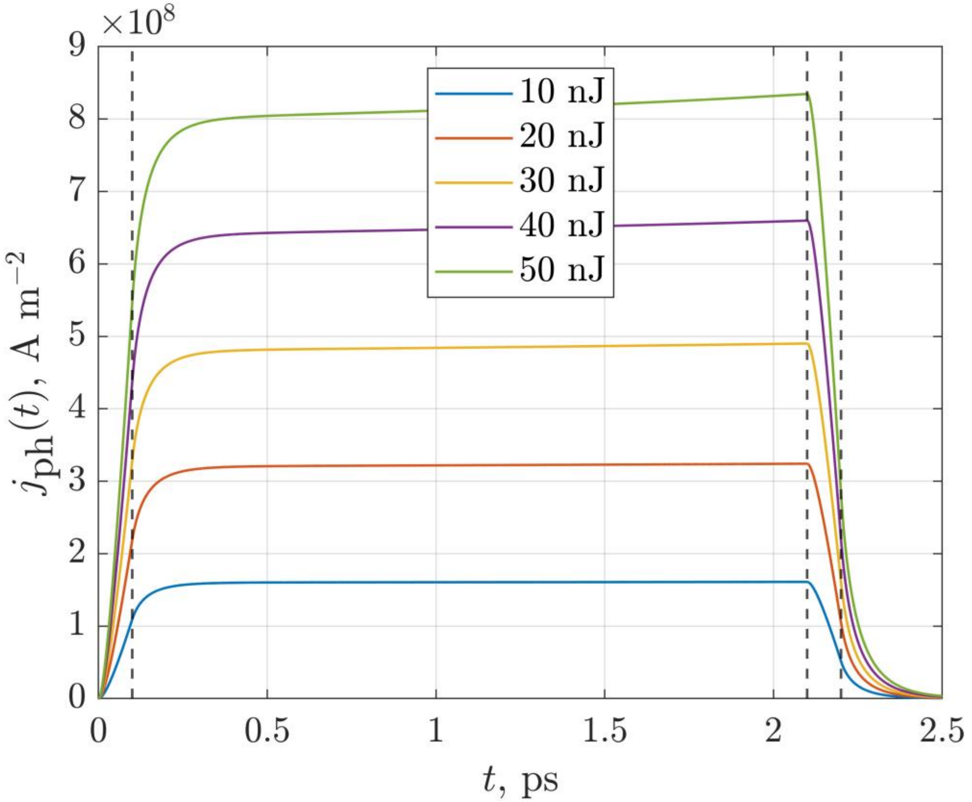


Semiconductor photocathode sketch. A perturbed region is the only one, where photoelectrons are generated (and, hence, the one of interest).
$\Rightarrow$ In this region DDP are posed and solved.

Linear regime

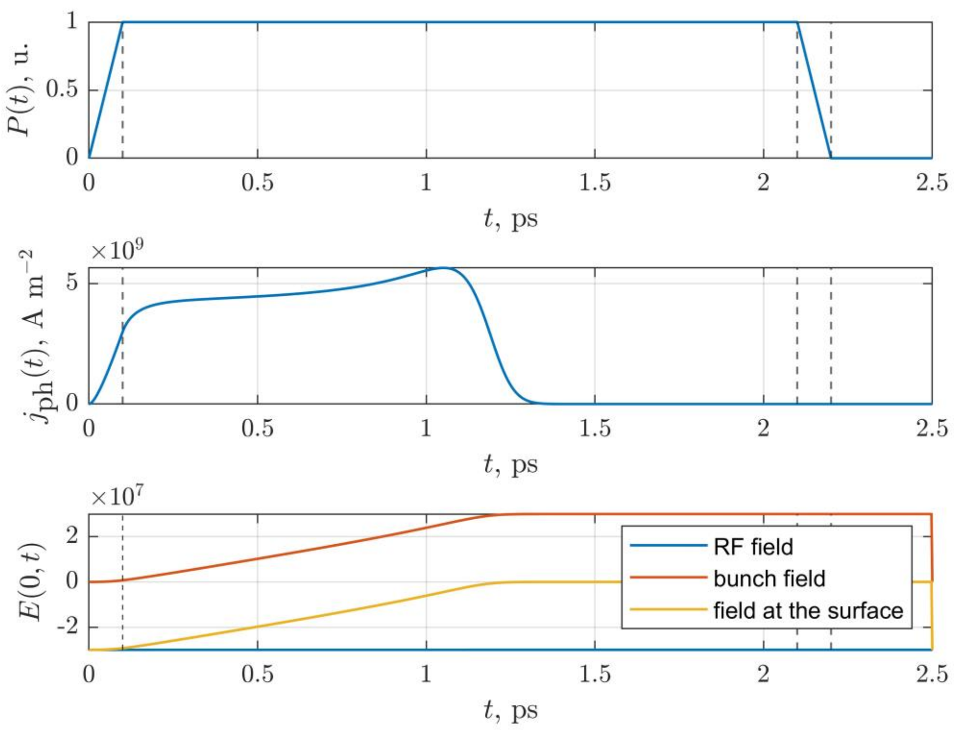
Vladimirov, M., Rashchikov, V. & Polozov, S. Self-consistent photocathode charge carrier dynamics in radiofrequency photoinjectors. *Eur. Phys. J. Spec. Top.* (2026). https://doi.org/10.1140/epjs/s11734-026-02273-3

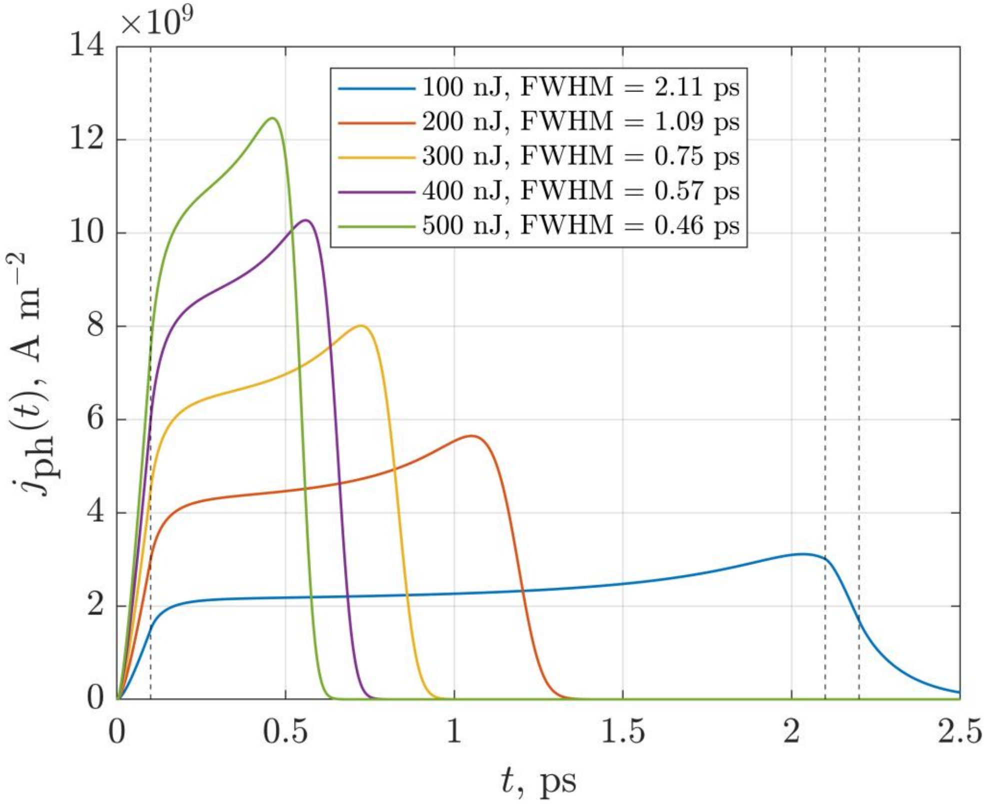




Saturated emission

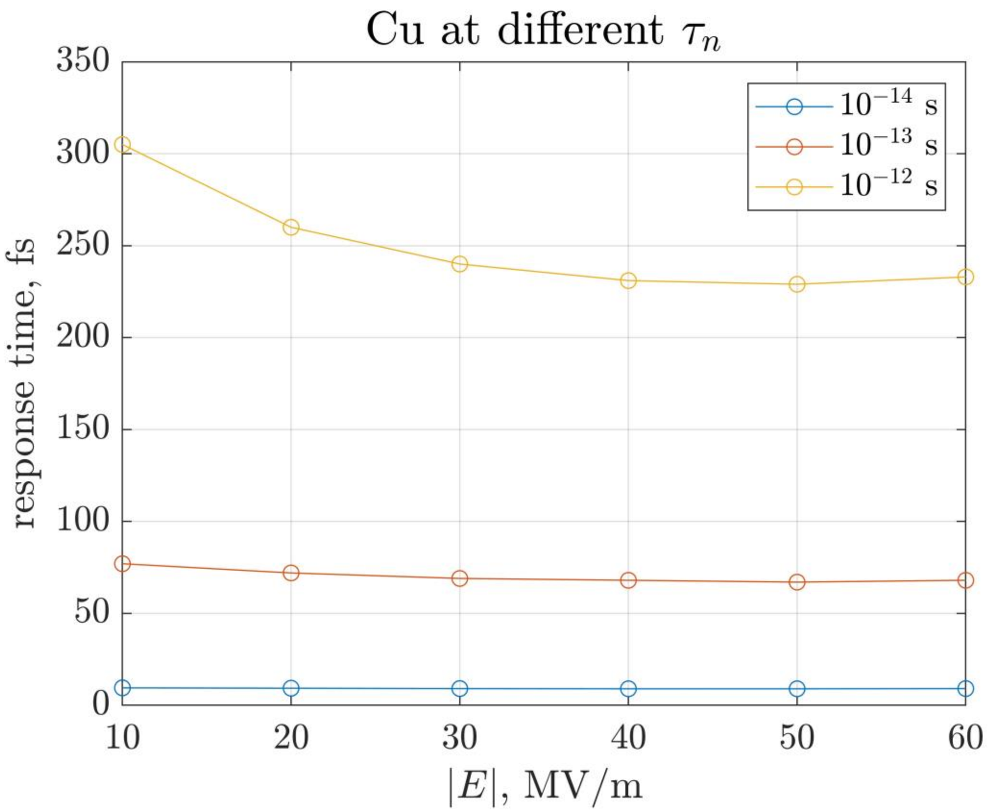
Vladimirov, M., Rashchikov, V. & Polozov, S. Self-consistent photocathode charge carrier dynamics in radiofrequency photoinjectors. *Eur. Phys. J. Spec. Top.* (2026). https://doi.org/10.1140/epjs/s11734-026-02273-3

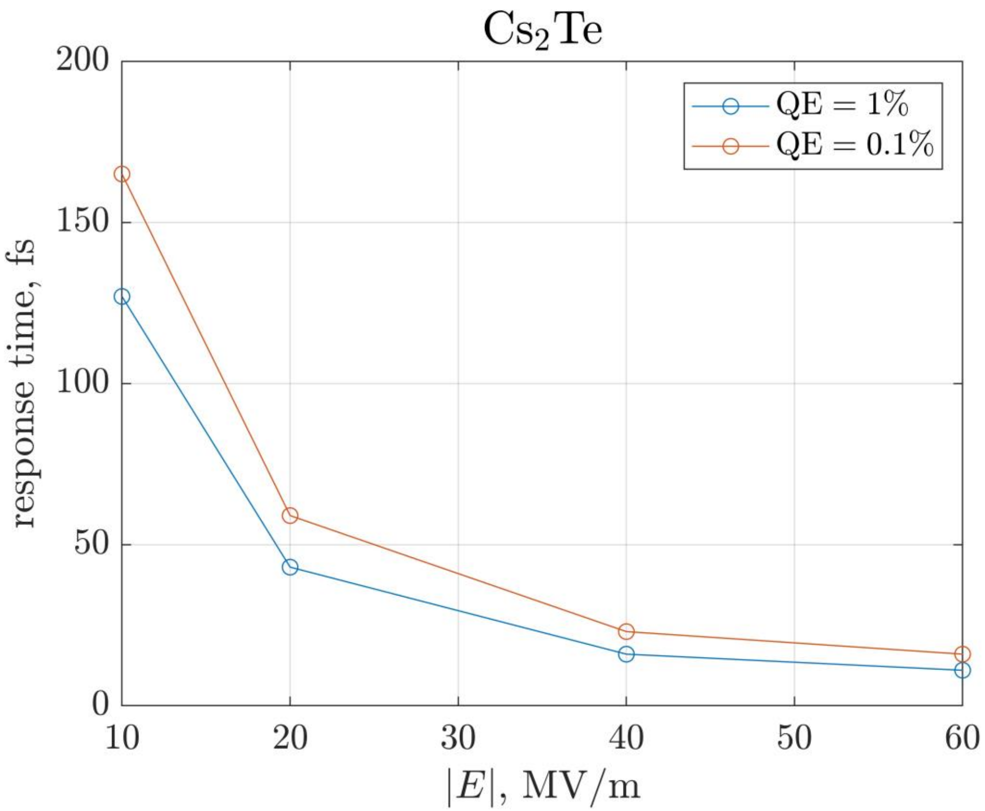




Response time estimations

Parameters for modelling can be found at the poster session (THPO086)





t_{resp} is defined by the slowest mechanism. The greater t_n is, the more t_{resp} becomes field-dependent (*drift*)

Summary

A fine temporal e-bunch structure can now be resolved using a self-consistent PDE based approach.

Photoemission from Cu and Cs_2Te cathodes is investigated, for which t_{resp} are estimated to be tens and hundreds of fs, respectively.

For future: defining the micro- and macroscopic parameters, including those hardly measurable ones.

Detailed discussion: THPO086 and/or via Mikhail.Vladimirov.PhD@gmail.com

We are looking for fruitful discussions and collaborations.

Thank you for your time.