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Study (of the) laser-plasma interaction in a preformed plasma channel in a high repetition rate regime

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Project

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The Project is aiming high-quality electron beam required for FEL.

Our aim

The FEL regime requires preservation the high-quality of the LPA electron beam by using a combination of advanced all-optical and conventional electromagnetic systems.

Modelling package:

ZSTAR is a 2D numerical code based on the equations of radiation magnetohydrodynamics (RMHD) and was developed for industrial and experimental modeling of multiply ionized plasma in a complex geometry of electrodes and insulators built on the base of the well-tested ZETA code

Experimental package:

Optimization of the self-injection and laser wakefield acceleration mechanisms to get electron beam with required parameters.

Extending of interaction length of the laser with the plasma above the diffraction limit can be useful for better laser acceleration of electrons to obtain SASE-FEL regime.

Collaboration with:

- **Different teams at ERIC-ELI and CVUT**
- **Fellows** from "Laser-Plasma" and "Applications" packages of the EuPRAXIA DN

Zstar code for RMHD simulation by S.Zakharov

- ZSTAR offers improved modeling in particular of the onset of cold plasma ionization and nonequilibrium radiation based on magnetohydrodynamic equations describing a plasma in a 2D geometry describing an axisymmetric environment

- plasma radiation parameters, ionization and kinetic coefficients are calculated using interpolation from pre-prepared tables

- the program includes an interactive environment for defining a 2D grid describing the distribution of electrodes, insulators and gas

- in the initial conditions, it is possible to define a pre-ionized plasma channel, initial density of the gas or plasma in the channel, initial gas temperature or electron temperature, etc.

- the RLC parameters of the external source are also entered (voltage, capacitor capacity, inductance)

Motivation: high-quality e-beam

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- for high-frequency applications: capillaries may not be suitable because of excess heat load and insufficient discharge interruption caused by capillary wall ablation or other kind of damage

- there are different methods: capillary tubes, self-conducting, or pre-prepared plasma channels

- electron acceleration: interesting results were achieved in capillary discharges heated by a laser pulse

- currently: hydrodynamic plasma channels created by optical field ionization

State of the Art: plasma channels created by optical field ionization

- using fs laser to create a channel by gas ionization and subsequent expansion
- the advantage of using the same laser for both channel and acceleration
- properties can be controlled by delay between pulses and by initial gas pressure
- channels can achieve low on-axis electron density (suitable for LWFA)
- disadvantage - low electron temperature and thus narrow waveguide shell
- it turns out that the conducted pulse itself ionizes a ring of neutral atoms, and thus its ionization-induced self-conduction occurs
- however, the threshold intensity for ionization of the given gas must be exceeded
- it is therefore appropriate to study other options to improve the efficiency of waveguides

State of the Art: plasma channels created by optical field ionization

- increasing the initial electron temperature by suitable polarization of the laser
- expansion does not depend on the initial density (even according to the theory of Sedov and Taylor)
- the electron density on the axis depends approximately linearly on the initial gas pressure
- the laser is needed mainly for ionization and the resulting drop of neutral particles on the axis of the channel, plasma is needed for expansion due to the pressure difference
- the guided laser pulse initially undergoes diffraction and becomes steeper
- the effect can be reduced by using the plasma created by additional heating

PhD plan

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Training: at Czech Technical University (Prague, CZ) + EuPRAXIA DN training courses

Research: at ELI-Beamlines + EuPRAXIA partners (INFN, CVUT, Foton) m2-m36

1 year	2 year	3 year
m1: preparatory phase m2: individual study plan m2-m12: 4 compulsory courses + exams **M12** agreement of program for the 2nd year of study	m18-22: A study for the doctoral Thesis State-doctoral exam **M24** Agreement of Thesis structure	m22-m36: work to PhD **M32**: 1st draft of PhD Thesis m36 Submission of Thesis m36-m39 PhD Thesis Defence

M milestone
D deliverable

Project Deliverables

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Research: at ELI-Beamlines + EuPRAXIA partners (INFN, CVUT, Foton)

2023 → 2024 → 2025 → 2026

Following Grant Agreement:

D 2.6 Laser beam diagnostics (R)

D 2.7 Prototype diagnostics (DEM)

D 2.8 Final laser beam focus (DEM)

30.06.2024 --> D 2.6

30.06.2025 --> D 2.7

30.04.2026 --> D 2.8

People involved

PhD student

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and Others

Thank you for attention

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