Modelling of laser-plasma acceleration of relativistic electrons in the frame of ESCULAP project


Introduction

Objective of ESCULAP project is the experimental study of laser-plasma acceleration of relativistic electron bunch [1]. LAL photoinjector (PHIL) will be used to inject electron beam in plasma wakefield created by high power laser (LASERIX) in the plasma cell. Control of the quality of the accelerated bunch is one of the main difficulties in laser-plasma acceleration.

Experimental parameters

<table>
<thead>
<tr>
<th>Modelling parameters</th>
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<tbody>
<tr>
<td>Gaussian electron bunch / or one from Astra</td>
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</table>

Beam Duration 100 fs
Beam Gamma Mean = 19; Beam Gamma rms = 1
Beam Width X = Beam Width Y = 50 mum
Beam Width Theta X /beam Width Theta Y = 10 mrad

LASERIX

2 J, 45 fs FWHM high-power Ti:Sa laser (800 nm)

Gaussian Laser
Laser Duration 45 fs FWHM
Laser Energy 1 J
Laser Waist ~50 mum

Plasma cell

2-4 e17 cm-3 variable density profile, total length of 9 cm

Plasma density
Uniform 2e17 cm-3

Parametric study with reference electron bunch

Linear approach: analytical expression for wake fields [2, 3]

Non-linear approach, Electric fields from WakeAC [4, 5]

Dependence on the start position (focusing)

Comparison of electric fields in linear and non-linear approach

Results for the realistic bunch [6]

Start position -2.5 cm, ~80% electrons captured
In order to decrease dE/E, optimization of the density profile should be performed

References

1. Project overview is presented in the poster of Nicolas Delerue
6. Bunch compression is presented in the poster of Ke Wang

Features of WakeTraj code

- 2D3V axisymmetric tracking implemented in Fortran
- Particle distribution generator / external file
- Linear approach / potential from WakeAC (calculated once)
- Non-uniform plasma density profile
- No space-charge effect

Conclusions

- Parametric study of laser plasma acceleration in 9 cm plasma cell is performed
- Nearly 30% of electrons can be captured and accelerated to 150 MeV with 10% energy spread
- Non-linear approach appears to be beneficial, resulting in the acceleration offset of ~25 MeV
- Stronger focusing
- Need of density profile

Experimental setup scheme

Parametric study of laser-plasma acceleration of relativistic electron bunch

Experimental parameters

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<tr>
<td>Laser Energy 2 J</td>
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<tr>
<td>Laser Duraon 45 fs</td>
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LASERIX

2 J, 45 fs FWHM high-power Ti:Sa laser (800 nm)

Gaussian Laser
Laser Duration 45 fs FWHM
Laser Energy 1 J
Laser Waist ~50 mum

WakeTraj

Distribuon of gamma for various start posiion (WAKEAC)

Total number of accelerated electrons

Comparison of electric fields in linear and non-linear approach

Results for the realistic bunch [6]

Start position -2.5 cm, ~80% electrons captured
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