

Downramp-assisted underdense photocathode electron bunch generation in plasma wakefield accelerators

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The underdense photocathode PWFA "Trojan Horse"





PRL 108, 035001 (2012)

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- Injection process decoupled from acceleration
- High quality beams
- Extremely low emittances ~ 10⁻⁸ m rad

Ultracold Electron Bunch Generation via Plasma Photocathode Emission and Acceleration in a Beam-Driven Plasma Blowout

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The proof of concept E210 experiment at Facet







Q _{bunch}	Up to 3 nC
I _{peak}	30 kA
Energy	23 GeV

- Well suited driver beam
- LIT medium: H₂ pre-ionized by laser
- HIT medium: He

Ionization corridor hydrogen and helium





Dark current suppression (see poster session)





- Dark current reduction studied in simulations[1] and experiment
- Ionization by strong driver beams or strong wakefields[2] can ionize Helium and lead to unwanted dark current
- Driver bunch charge reduction is one possible measure for dark current suppression



[1] G. G. Manahan et al., submitted [2] A. Martinez et al., PRL 2013

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- Assume weak driver beam
- Stay in blowout regime

 $n_{b} > n_{0}$

 \tilde{Q} > 1

$$\tilde{Q} = N_{\rm b}k_{\rm p}^3/n_{\rm e}$$

Trapping condition [3]





- Assume weak driver beam
- Stay in blowout regime

 $n_{b} > n_{0}$

 \tilde{Q} > 1

$$\tilde{Q} = N_{\rm b}k_{\rm p}^3/n_{\rm e}$$

Trapping condition [3]



Phase velocity reduction on a soft density downramp







- Blowout expands on downramp due to an increasing plasma wavelength
- Decreased phase velocity on ramp facilitates trapping
- No Trapping outside of downramp region
 → Dark current supression
- Enabeling underdense photocathode PWFA for a wider range of driver beams

[4] G. Fubiani et al., Phys. Rev. E 73, 026402 (2006).

Avoid Downramp injection





Avoid downramp injection into first blowout

 $k_{p} \frac{n}{|dn/dz|} > 1 \quad [5]$

• DR Injection into subsequent blowout possible

concept





Simulation parameters



Laser	
parameter	
a ₀	0.02
w ₀	6 µm
τ	20 fs



Medium	H ₂ 13 % (pre- ionized) He 87 %		
		Driver bunch	
n _i 1	1.5e17 cm ⁻³	Q	200 pC
		σ_r / σ_z	6 µm / 7 µm
n _f 0.6e17 cm ⁻³	0.6e17 cm ⁻³		
		I _{peak}	3.4 kA
L 50 µm	50 µm		
		$ ilde{Q}$	2-2.45

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Simulation results





- No trapped electrons without downramp
- Downramp-assisted case: 11 pC trapped
- Norm. rms emittance saturates at 5x10⁻⁸ m rad
- After 7 mm propagation 62 MeV

Slice values





Summary



- Excellent tool for dark current suppression
- Witness bunch is stretched longitudinally
- Downramp injection into subsequent blowout likely
- Emittances compareable to the straight forward trojan horse PWFA achieveable.
- Downramp-assisted trojan horse PWFA can significantly lower the requirement for the driver beam in peak current



Thanks ?

Questions ?

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