Laser Wakefield Accelerators - a status report

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quasi-monoenergetic beams


Matsuoka, T et al. “Stimulated Raman Side Scattering in Laser Wakefield Acceleration.” *PHYSICAL REVIEW LETTERS* 105, no. 3 (July 2010).
Mordovanakis, A, G et al. “Quasimonenergetic Electron Beams with Relativistic Energies and Ultrashort Duration from Laser-Solid Interactions at 0.5 kHz.” *PHYSICAL REVIEW LETTERS* 103, no. 23 (December 2009).
Ping, Y, R et al. “Absorption of Short Laser Pulses on Solid Targets in the Ultrarelativistic Regime.” *PHYSICAL REVIEW LETTERS* 100, no. 8 (February 2008).
“bubble” plasma wave
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acceleration
acceleration
acceleration
acceleration

\[ E \sim 2\gamma^2 m_e c^2 \cdot \epsilon \]


Gemini 2008 - Setup and Diagnostics

10 J, 55 fs
f/20 parabolic mirror
25 µm FWHM
a = 3.8 I = 2 x 10^{19} W cm^{-2}
Gemini 2008 - Setup and Diagnostics

3-10 mm nozzle

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25µm FWHM
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centimetre scale channel

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Gemini 2008 - Setup and Diagnostics

Self-guiding >10mm

<table>
<thead>
<tr>
<th>100 µm</th>
</tr>
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</table>

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| 10 mm |

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>90% e-beams < 4 mrad

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Tuesday, 4 June 13
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Up to 0.8 GeV e-beams

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Spatially resolved spectrum measurement of guided laser filament

Redshift of the entire pulse spectrum in the guided filament

Guiding over 4 cm of plasma (tens of $z_R$)
Depletion of laser energy

Compression of laser pulse

FROG measures laser pulse shape

Input pulse

After 15 mm of $n_e = 8 \times 10^{17} \text{ cm}^{-3}$
**latest Gemini GeV self guided acceleration**

Energies observed $> 1.3$ GeV
Typical charge $> 100$ pC @ $> 0.5$ GeV

Change in behaviour of electron beam with increasing density
GeV channel guided acceleration


latest Gemini GeV channel guided acceleration

2.5 mm  f 300 mm  2 - 4 cm

C. Russo, et al., submitted (2013)
optically induced injection


### optically induced injection - Gemini

<table>
<thead>
<tr>
<th>50um early</th>
<th>$T_0$</th>
<th>50um late</th>
</tr>
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<tbody>
<tr>
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<td><img src="image2.png" alt="Image" /></td>
<td><img src="image3.png" alt="Image" /></td>
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</tbody>
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Tuesday, 4 June 13
density modulation injection


gas cell development
latest Gemini density modulation injection

gas cell with density step
  first subcell density $1.2 \times 10^{19} \text{ cm}^{-3}$
  remaining cell $3.4 \times 10^{18} \text{ cm}^{-3}$
  laser energy $\sim 4.3 - 4.9 \text{ J}$
  $a_0 \sim 1.6$

charge 50 - 250 pC
energy 300 MeV - 650 MeV
beam diameter $\sim 1.3 \text{ mm}$
divergence $\sim 2 \text{ mrad}$
pointing $\sim 8-10 \text{ mrad}$
minimum energy spread 8 MeV/460 MeV
$< 2\%$ (main spot on last shot on image)


latest Gemini ionisation injection

Gas cell

He + 5% N2

Laser energy = 12.6
τ = 45 fs
w₀ = 16.6 um
a₀ = 4.0
nₑ = 1.6 × 10¹⁸ cm⁻³

e-spectrometer screen

Eₑ = 726 MeV
ΔE = 3.0%
Charge ≈ 17 pC
acceleration
acceleration
acceleration
radiation
radiation
\[ P_s = \frac{e^2 c}{3} \gamma_z^2 k^2 a^2 \]

\[ a_\beta = \gamma_z r_\beta k_\beta \]

\[ \omega_c = 3\gamma^3 \omega_{\beta}^2 r_\beta / c \]

E Esarey PRE 65, 056505 (2002)
Betatron Oscillations directly observed


latest Gemini betatron results
acheta domestica (house cricket)
Conclusions...
Conclusions...
Conclusions... to be made here