Laser Wakefield Acceleration in the Bubble Regime

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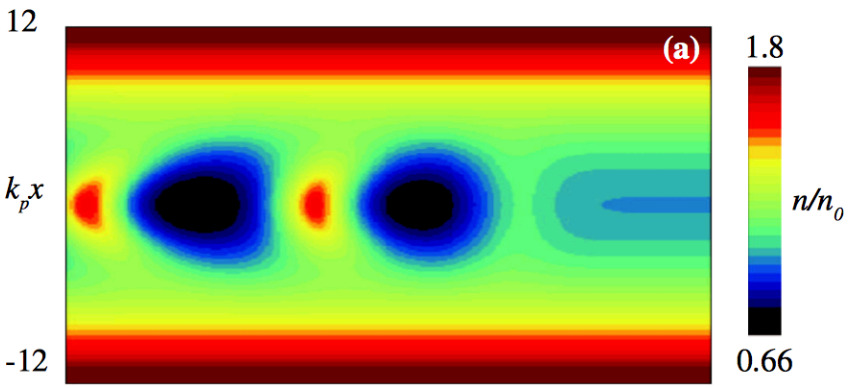
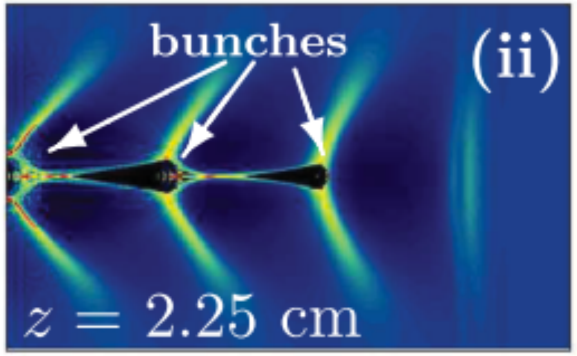
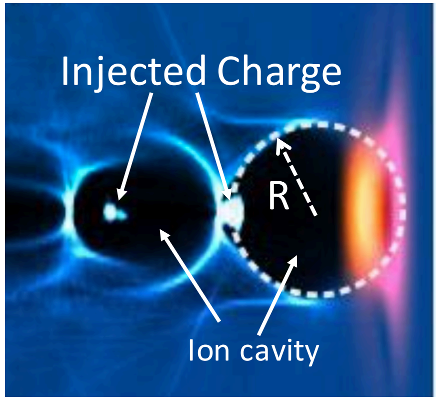
Laser Driven Plasma Waves



a_0 >1: Nonlinear Regime



a_0 >2: Blowout Regime



a_0 >4: Bubble Regime (spherical blowout)

Vector Potential $a_0 = \frac{eA_{laser}}{mc^2} = 8.6\times10^{-10}\sqrt{I[\mathrm{Wcm}^{-2}](\lambda[\mu\mathrm{m}])^2}$

High accelerating field and linear focusing forces in the bubble regime are very advantageous for electrons acceleration

C. B. Schroeder *PRSTAB* **13** (2010): 101301
W. Leemans, et al. *PRL* **113** (2014): 245002
W. Lu, et al., *PRSTAB* **10** (2007): 61301

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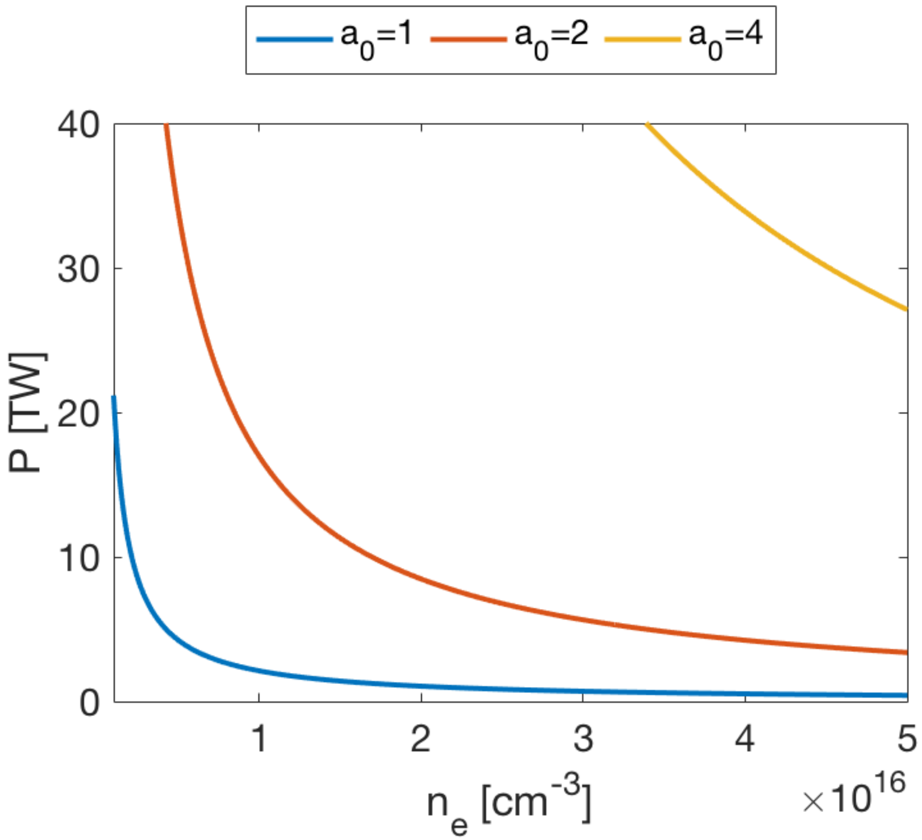
Laser Power Constraint

<u>Transverse Matching:</u>
"Self propagation of the laser in the wakefield with little transverse modification"

Condition for laser power

$$P/P_c = (a_0/2)^3$$

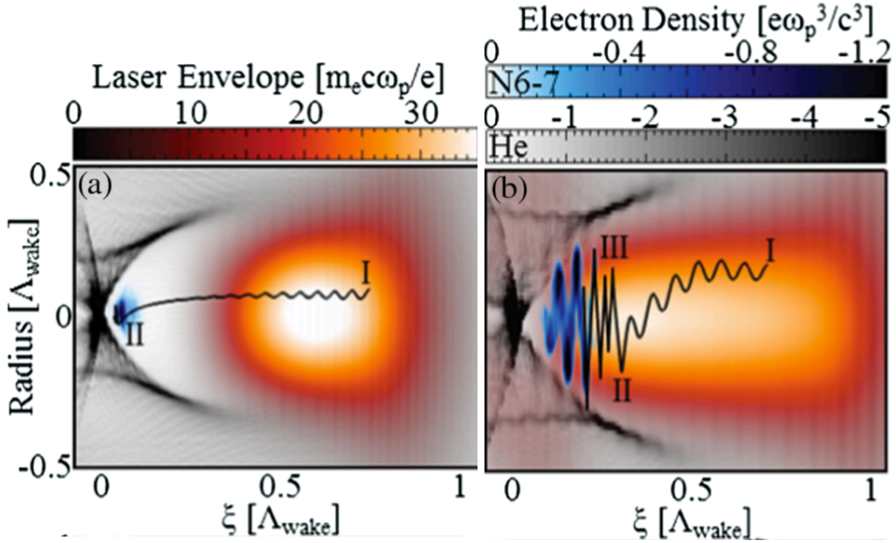
$$P_c[GW] = 17(\omega_0/\omega_p)^2$$

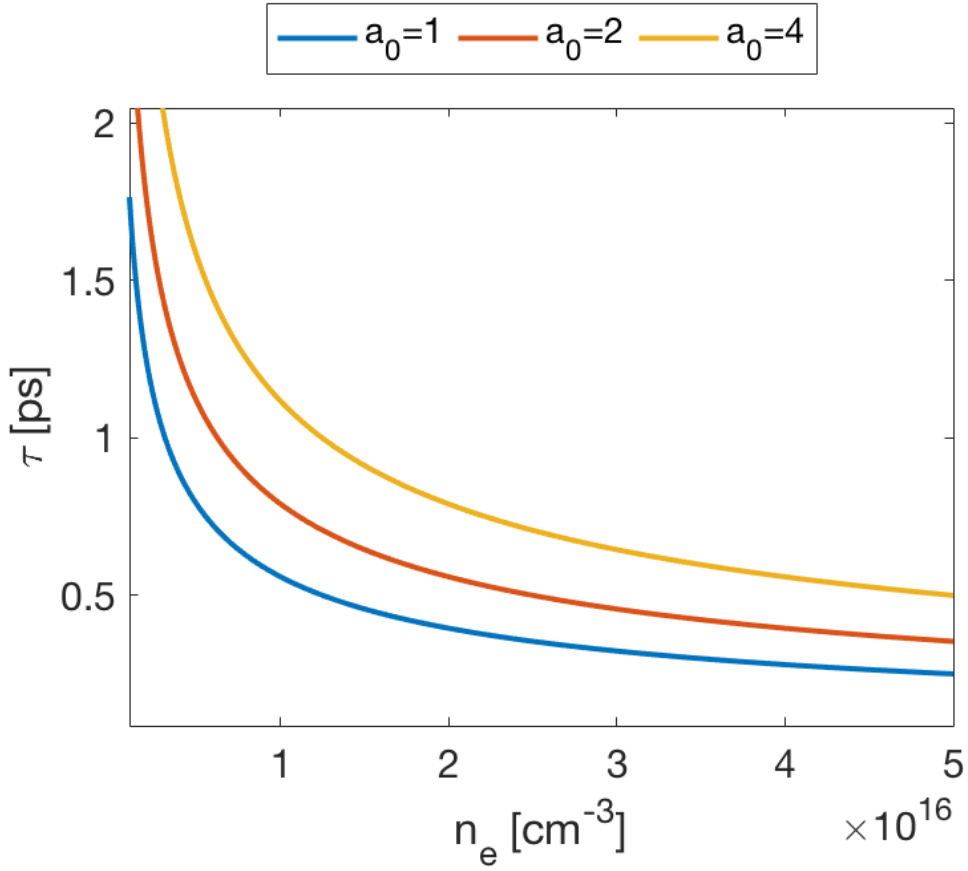


For a stable wakefield, the laser power has to be greater than the critical power for self-focusing

W. Lu, et al., *PRSTAB* **10** (2007): 61301

Pulse Length Constraint





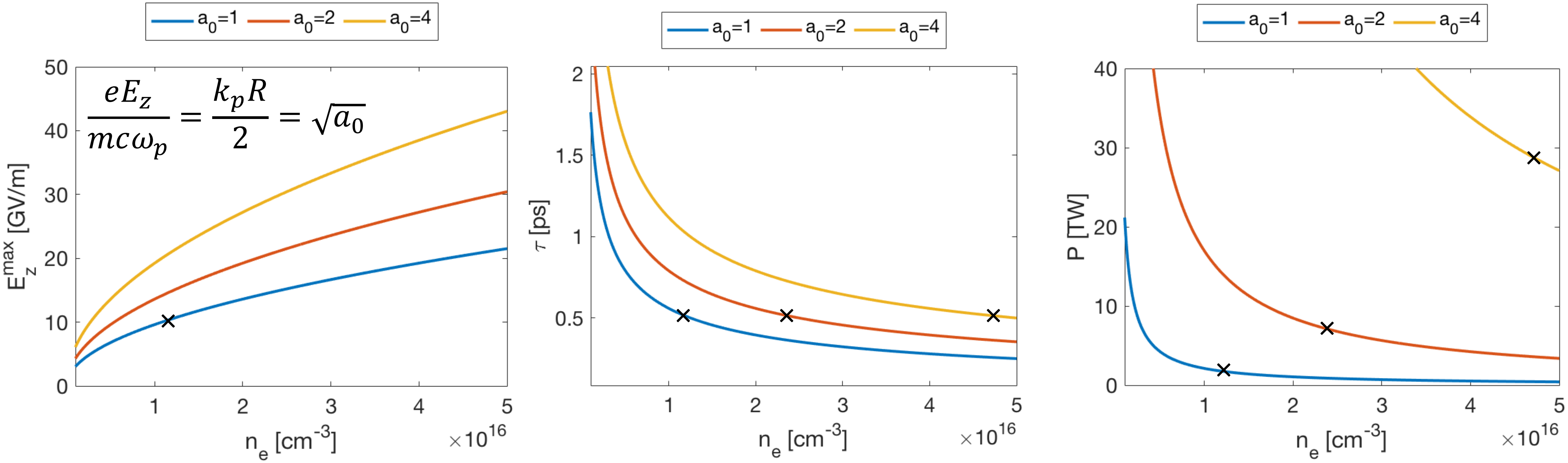
Pulse length has to ideally be less than half of the length of the wake to avoid interaction between laser and accelerated electrons

$$T_p = \frac{\omega_p \tau_{laser}}{2\pi {a_0}^{1/2}} < \frac{1}{2}$$

Matched pulse gets smaller at higher density

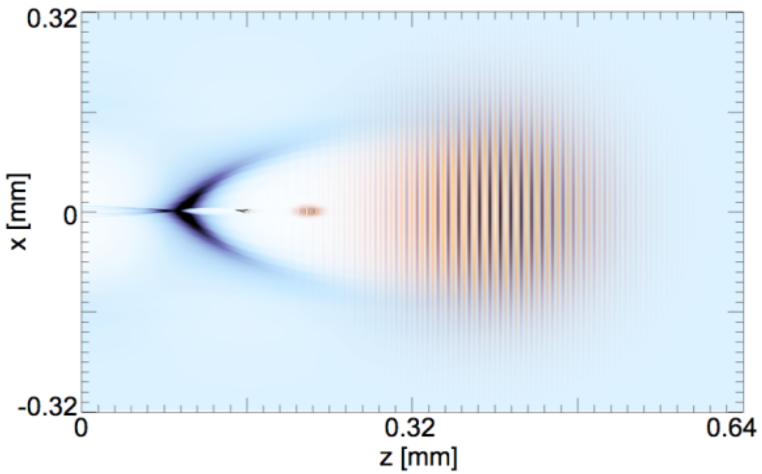
J.L. Shaw, *PPCF* **56** (2014): 084006.
J.L. Shaw, *PRL* **118** (2017):064801.

A Suggestion for a Path

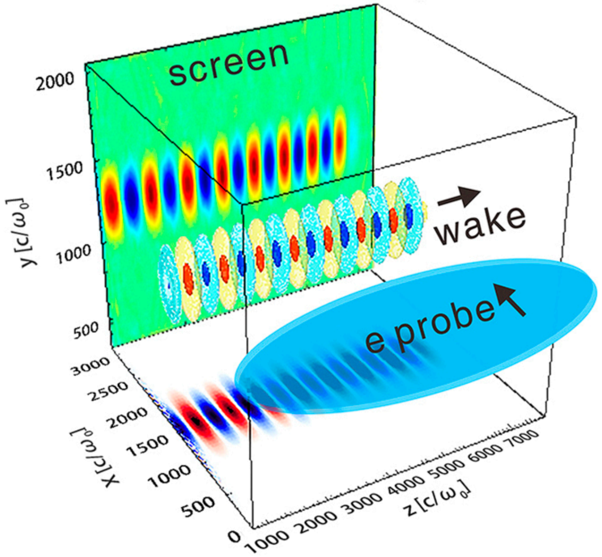


a_0	Wakefield Characterization	P (TW)	n_e (cm^{-3})	E_z^{max}(GV/m)
1	Nonlinear Regime	2	1.2e16	11
2	Blowout Regime	7	2.5e16	21
4	Bubble Regime	27	5.0e16	43

Additional Beams Can Exploit the Larger Wavelength of Mid-IR Driven LWFA

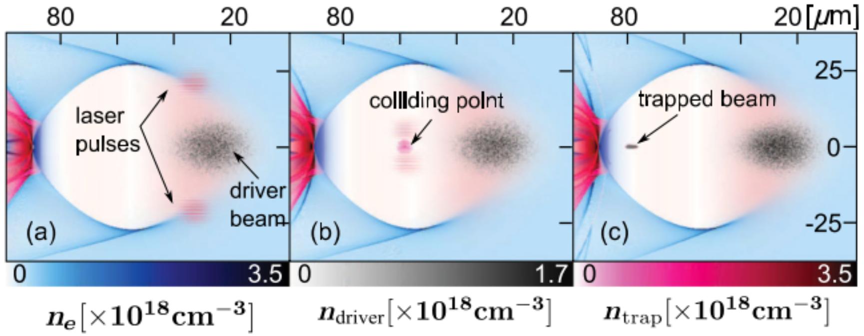


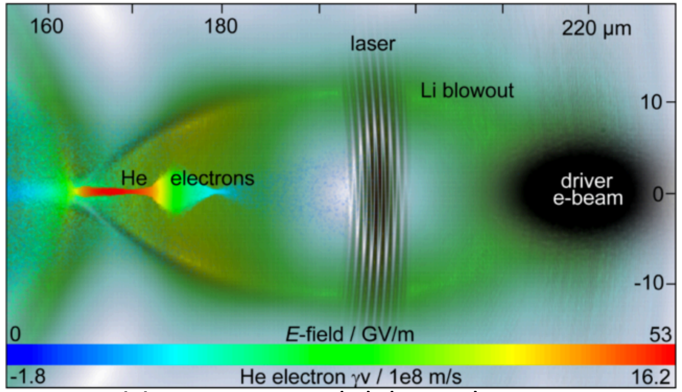
Simulated bubble in plasma density 1.1 x 10^{16} cm^{-3} ,driven by 500 fsec CO_2 laser with a_0 =1.4 *(Courtesy of Wei Lu)*



C. J. Zhang, Sci. Rep. **6** (2016): 29485.

F. Li *PRL* **111** (2013):015003





B. Hidding *PRL*, **108**(3) (2012):035001

Study of electron beam to plasma wave coupling

Imaging of wakefields using transverse probes

“two color” ionization injection for high quality beams

Conclusions

- The ultimate goal of LWFA experiments in the bubble regime can be divided into three distinct milestones of a_0>1, a_0>2, and a_0>4
- For experiments with plasma density in 10^{16} cm^{-3} range (reasonable peak accelerating field), pulse length will need to be below a picosecond, and likely close to 0.5 ps
- In the same plasma density range, laser power in the tens of terawatt range will be the minimum required power to reach a_0>4
- Additional e-beam/near IR sources can be use to exploit the large blowout radius with great scientific potential

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The End