Introduction to Plasma Acceleration

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Outline

- Introduction
- Plasma Wakefield Acceleration
- Laser Wakefield Acceleration
- Conclusion

Introduction

Conventional Accelerator

Copper Structure with irises

Powered by microwaves

Energy Gain 20 MV/m

Structure Diameter 10cm

Plasma Accelerator

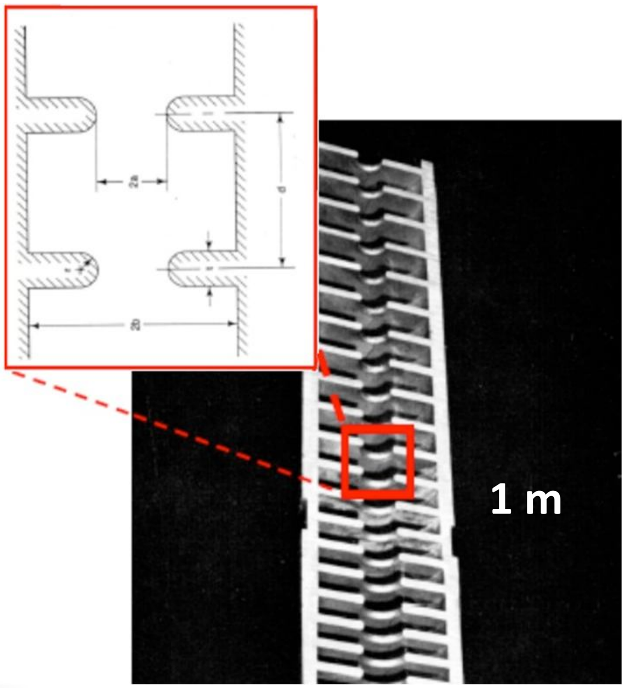
Ionized Gas

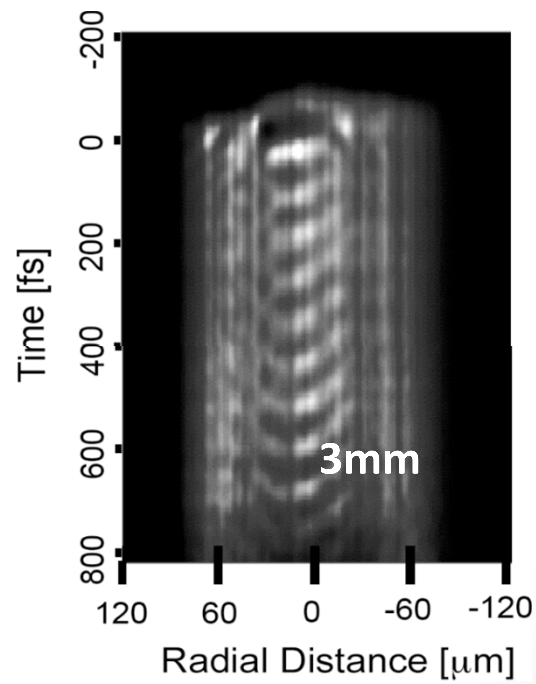
Lifetime, few picoseconds

Powered by a Laser or electron beam pulse

Energy Gain 20 GV/m

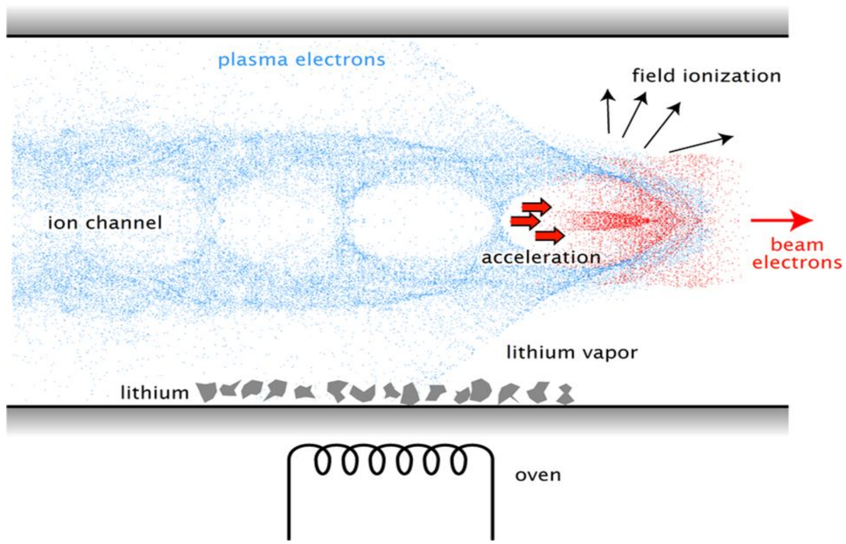
Diameter 0.1-1 mm





C. Joshi, Surfing Plasma Wakes:A New Paradigm for Particle Accelerators. UCLA

Plasma Wakefield Acceleration



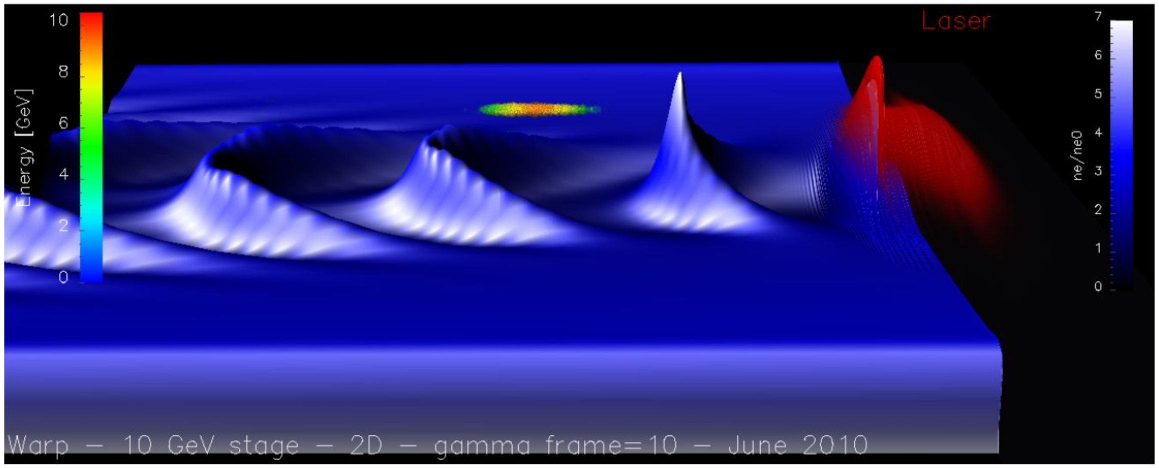
Space charge force of the beam pulse ($F_{sc} = -m_e c^2 \nabla\phi$) displaces plasma electrons.

Plasma ion channel exerts restoring force => space charge oscillations with

$\omega_p = \left(\frac{4\pi e^2 n_0}{m_e}\right)^{1/2}$ *plasma frequency.*

Plasma wakefield is generated with axial electric field
$E_z = 4\pi e(n_b/k_p) \cos k_p(z - ct)$.

Laser Wakefield Acceleration



Ponderomotive force of the laser pulse $\frac{dp}{dt} = -e[E + (v \times B)/c]$ *displaces plasma electrons.*

Plasma ion channel exerts restoring force => space charge oscillations with $\omega_p = \left(\frac{4\pi e^2 n_0}{m_e}\right)^{1/2}$ *plasma frequency.*

Laser Wakefield Acceleration

Necessary conditions

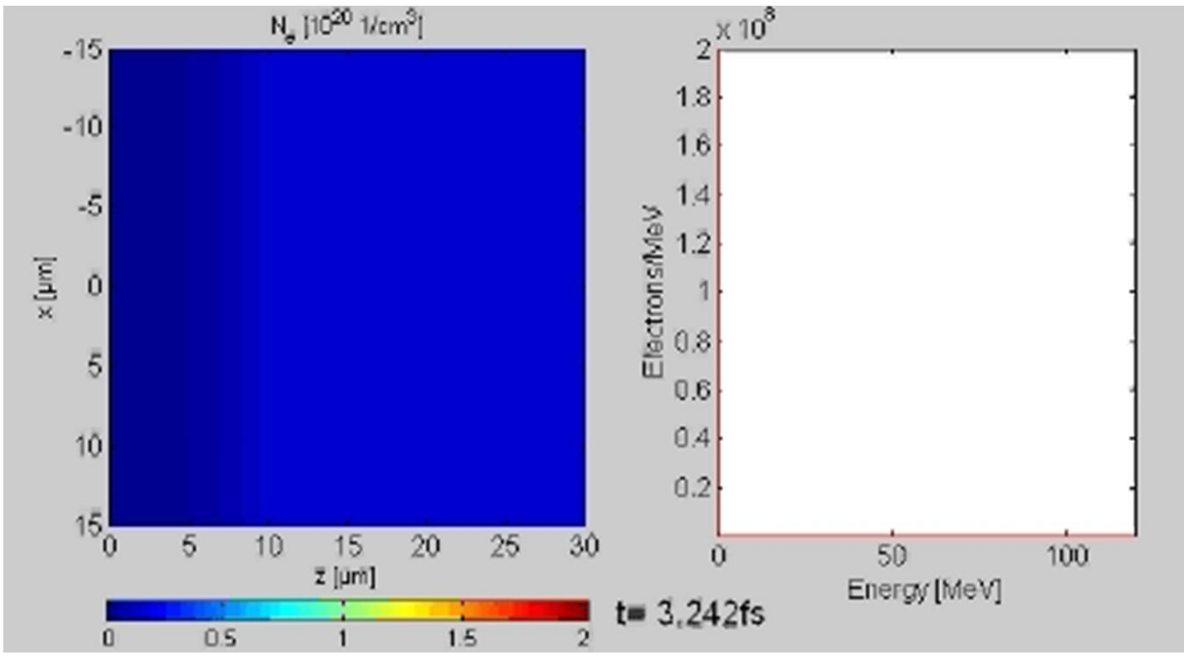
Short laser pulse ($< ps$)

Ultrahigh intensity ($> 10^{18} W/cm^2$)

Limited of Interaction length

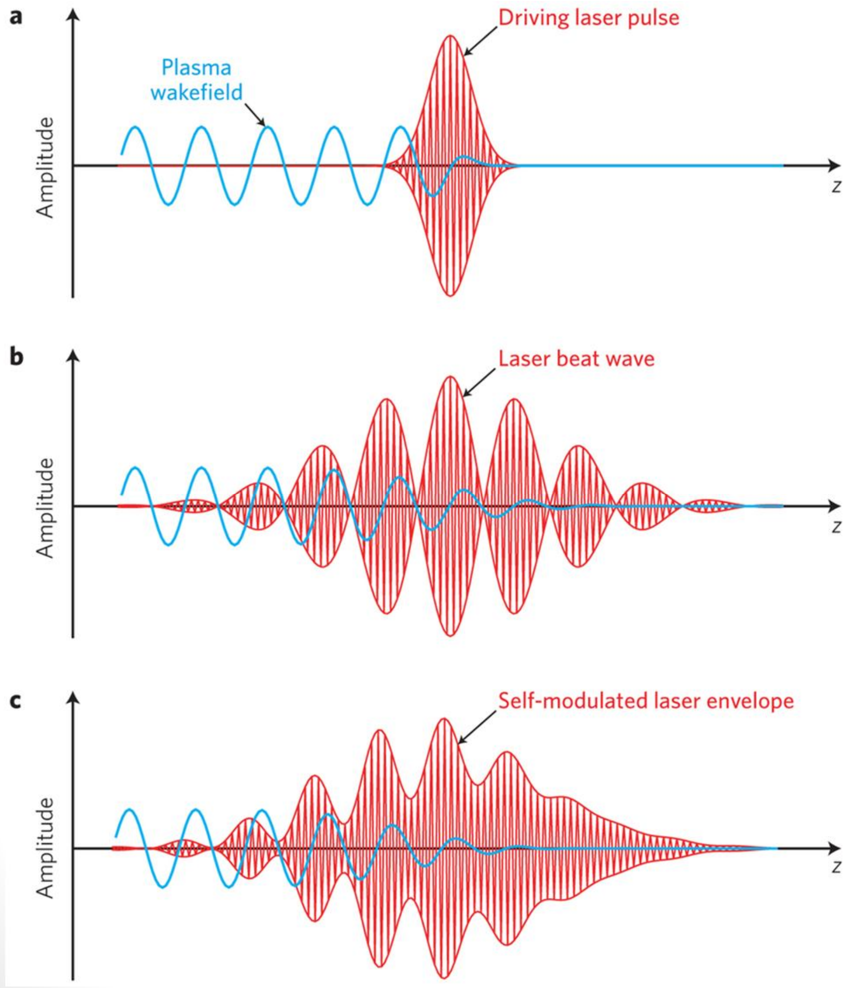
Rayleigh length $Z_R = \pi {w_0}^2/\lambda_0$ ($\sim mm$)

Dephasing length $L_d = {\lambda_p}^3/{\lambda_0}^2 (< 10mm)$



M. Geissler et. al., *New Journal of Physics* **8** (2006) 186.

Laser Wakefield Acceleration



$$\omega_1 - \omega_2 \cong \omega_p$$

Single short pulse $< 1ps$

$L > \lambda_p$

Conclusion

Successful Development of a Plasma Accelerator for High Energy Physics:

- High Gradient Acceleration of positrons as well as electrons.
- Focusing of positrons and electrons to nanometer size.
- Head erosion, hosing instability and ion motion.
- Small energy spread and beam divergence.
- Excellent pointing stability and minimum jitter.

C. Joshi, Surfing Plasma Wakes:A New Paradigm for Particle Accelerators. UCLA