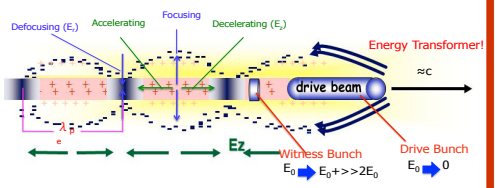
Ming Hsieh Department of Electrical Engineering

Seeding of Self modulation Instability of a Long Bunch in a Plasma

USC Viterbi School of Engineering

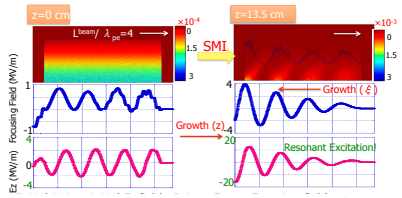
Yun Fang, Patric Muggli
EE-Physics (USC), Brookhaven National Lab

Plasma Wakefield Accelerator (PWFA)

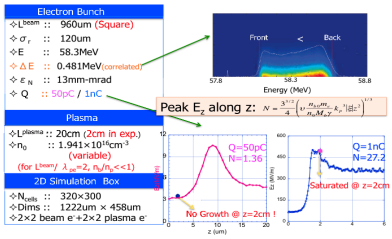


❑PWFA requires high-energy (TeV) and short drive beam (~100um)!
❑High energy bunch available at CERN, but too long (~12cm)
❑SMI could modulate long bunches into small ones

Self Mudulation Instability (SMI)

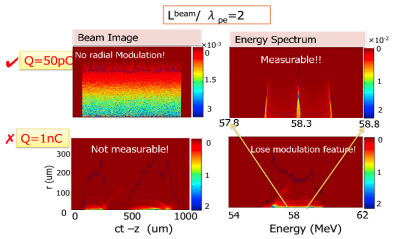


❑Initial Noise: initial E_z field, Driven Force: Focusing field
❑Demonstrated by simulation, by never by experiments yet!
❑No diagnostics to measure directly the radial modulation
❑Energy modulation is measurable, and is the seed for radial modulation



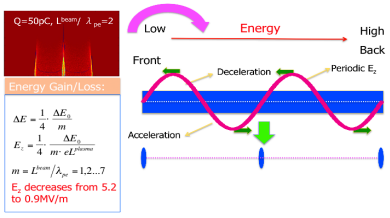
❑At z=2cm: Q=50pC has no SMI growth
Q=1nC reaches the saturation of SMI

Simulation



❑ Q=50pC is chosen in the experiment due to the energy modulation feature!

Simple Model

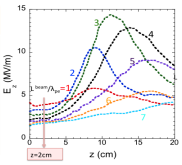


❑The energy beamlets are formed when the energy gain/loss is small compared to the initial energy spread of the beam ⇒ Q=50pC
❑L^{beam}/λ_{pe} ↑ ⇒ E_z ↓

Simulation

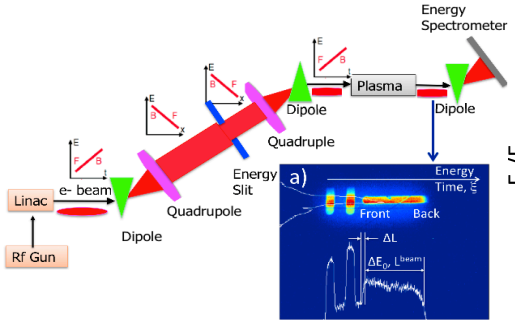
◆In experiment, the plasma density can be varied: 10^{14} ~10^{17}cm^{-3} (capillary discharge)

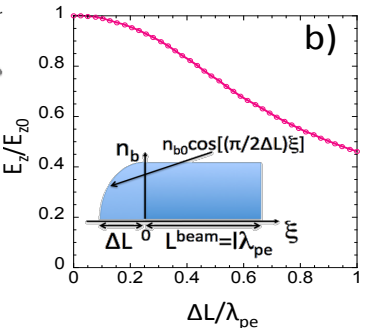
L/λ_{pe}	Plasma Density (cm^{-3})	n_{b0}/n_0
1	1.21×10^{15}	0.0030
2	4.85×10^{15}	0.00074
3	1.09×10^{16}	0.00033
4	1.94×10^{16}	0.00019
5	3.03×10^{16}	0.00012
6	4.36×10^{16}	0.000083
7	5.93×10^{16}	0.000061

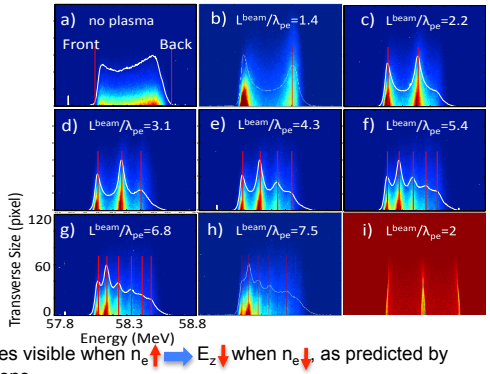


❖At z=2cm, no SMI growth for various plasma densities
❖Initial E_z decreases with n_0, ranging between 4-1.2MV/m, as desired for the energy modulation to be visible.
❖Consistent with linear theory calculation

Experimental Data







❑Large $\Delta L/\lambda_{pe}$→ less rapid current rise→ lower initial E_z→ slower saturation
❑In the experiment, $\Delta L/\lambda_{pe}$ <0.3 →E_z/E_{z0} >0.9→well seeded instability

❑ Fringes visible when n_e ↑ ⇒ E_z ↓ when n_e ↓, as predicted by simulations
❑Good agreement between simulation and experimental results

Conclusion

◆ Simulations show the 50pC ATF beam is subject to periodic energy modulation at 2cm propagation distance, which is an important evidence of SMI seeding.
◆ Simulations show that SMI does not grow significantly over the 2cm plasma for 50pC ATF beam
◆ Experiment demonstrates the first observation of SMI seeding through energy modulation
◆ Simulations show well-seeded instability in the experiments

yunf@usc.edu *All Work Supported by US. Department of Energy*

Ming Hsieh Institute
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