# Thin film compression & applications to high energies

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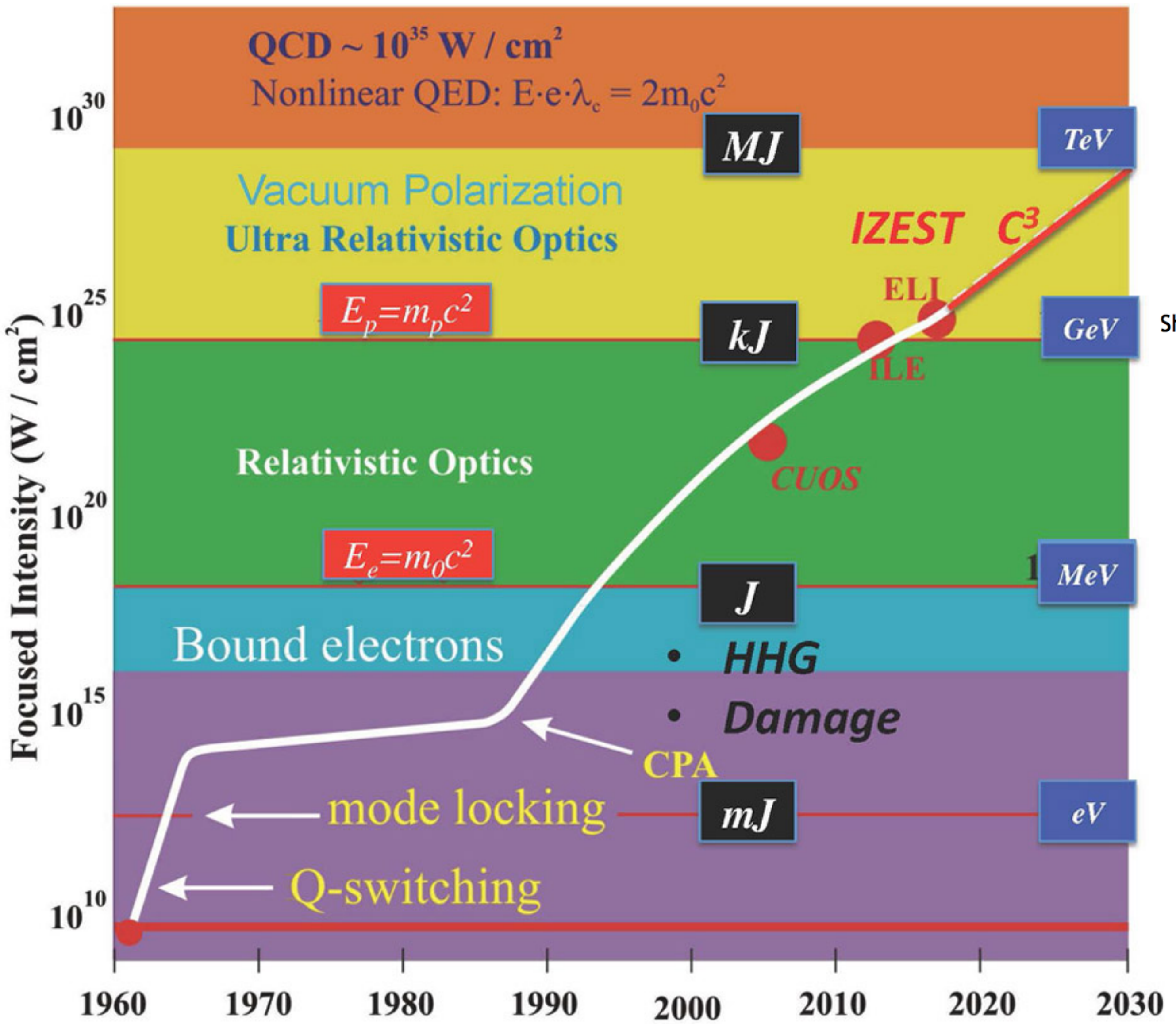
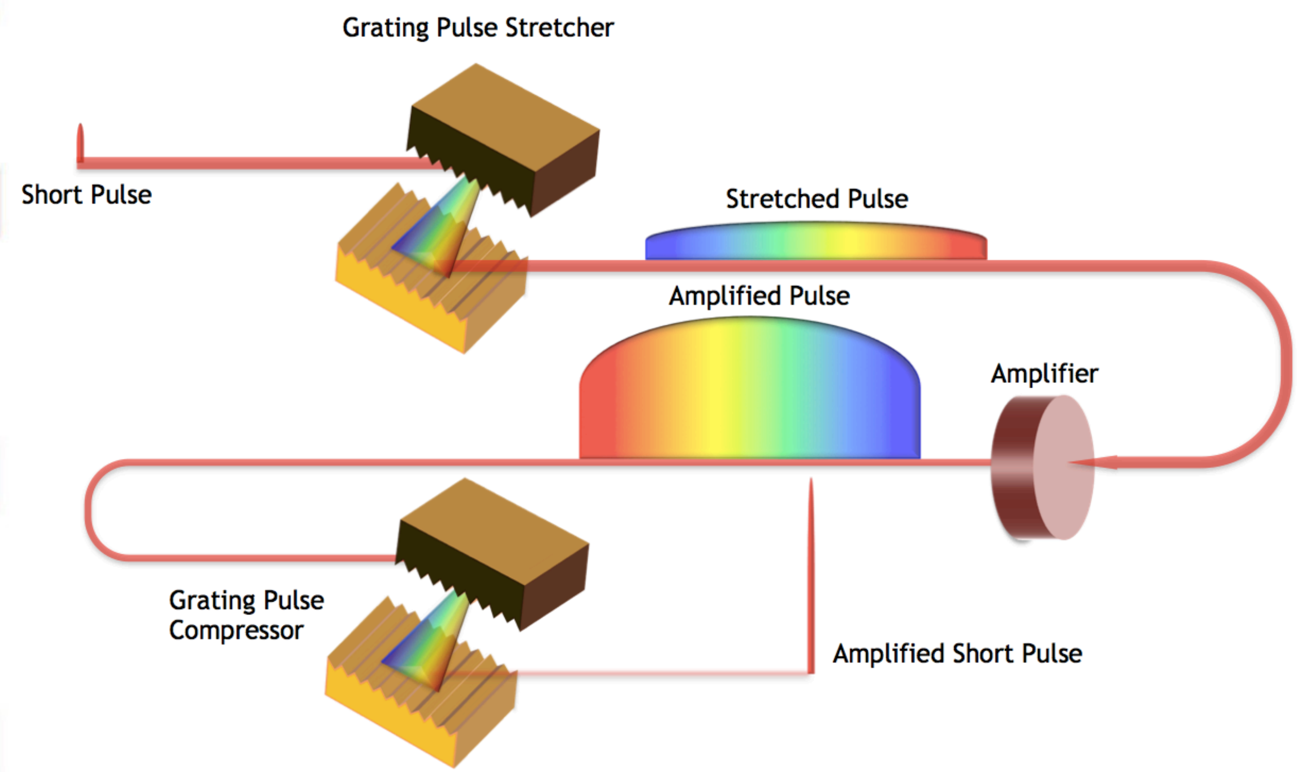
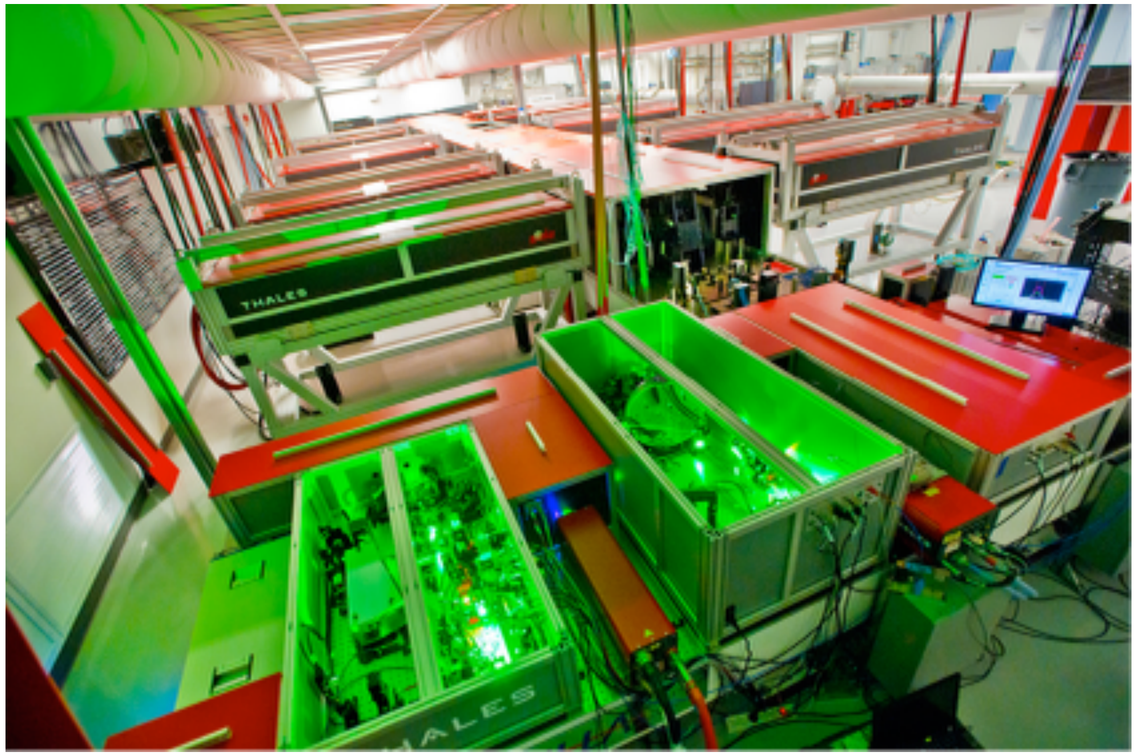
# Rapid laser evolution



# Increasing intensity

$$\text{Intensity} = \frac{\text{Energy}}{\text{Time}}$$

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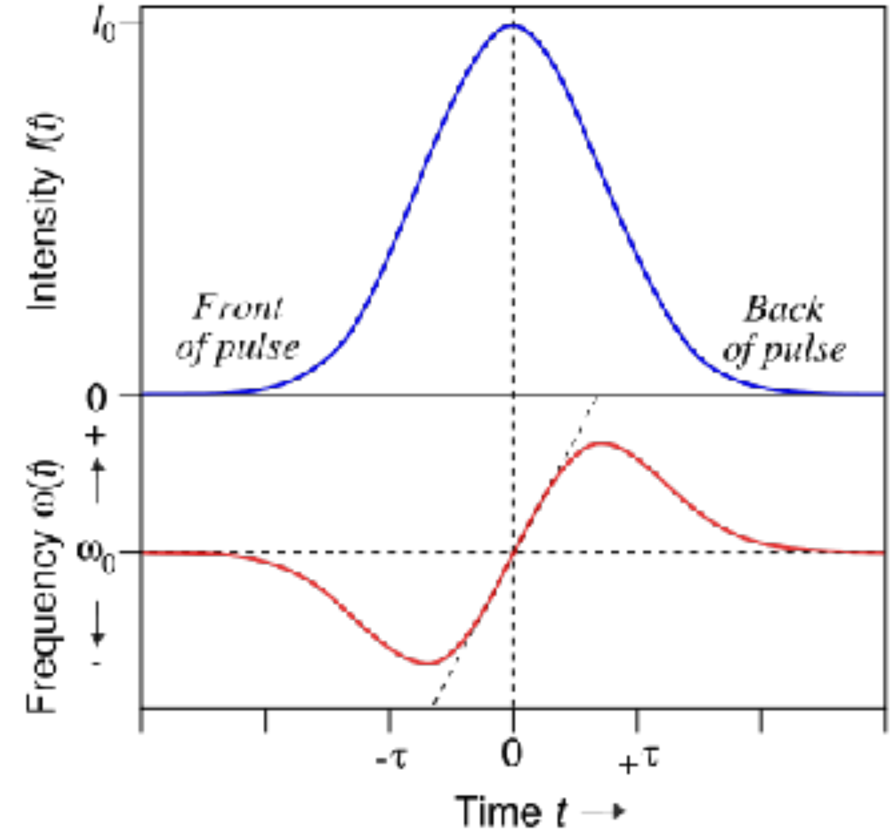
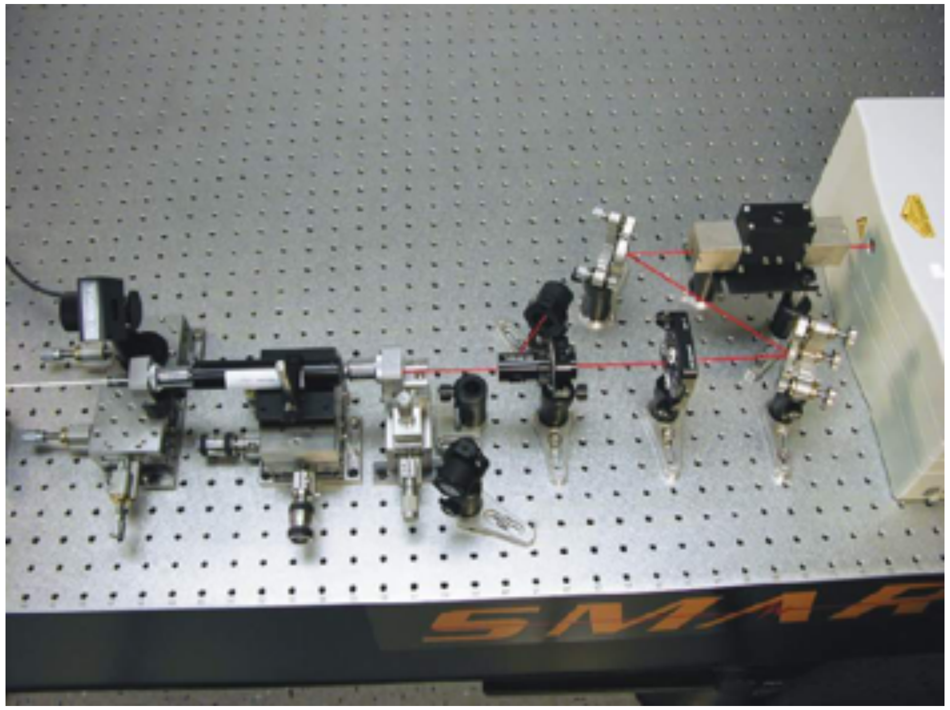
# Single cycle generation

$$n(\omega) \cong n + n_2 I$$

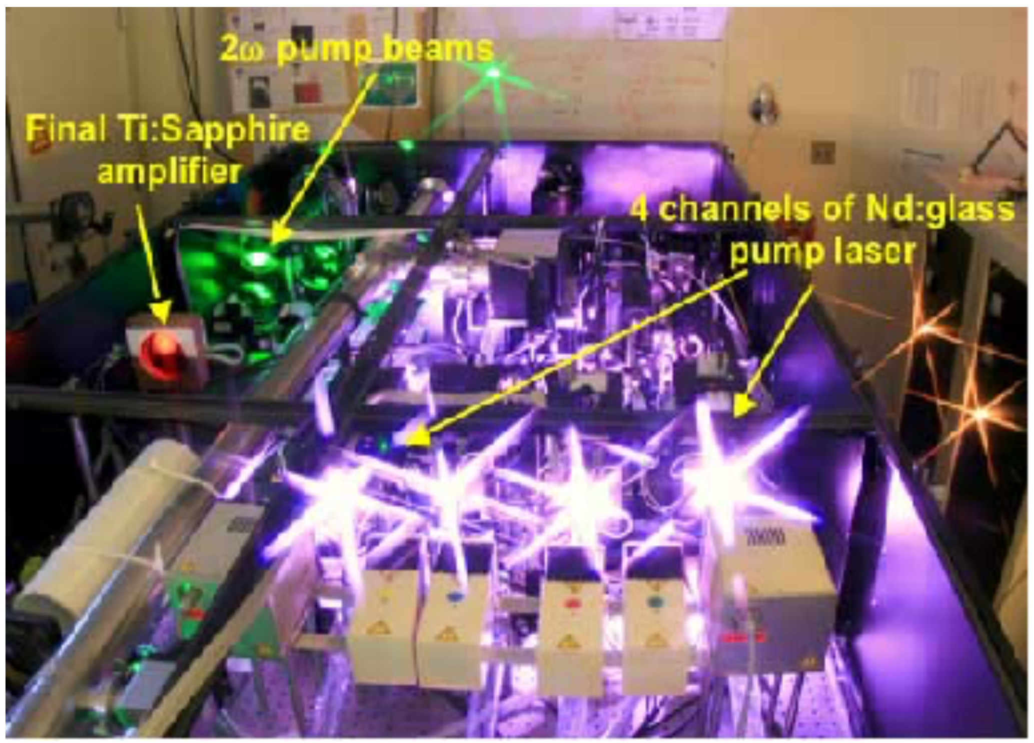
- Self-phase modulation
- Gaussian pulses undergo Kerr nonlinearity adding frequencies

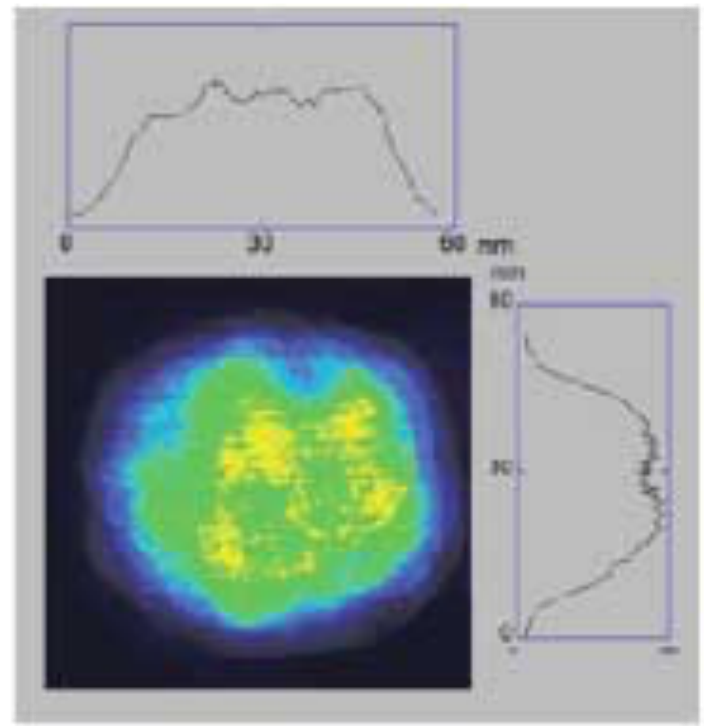


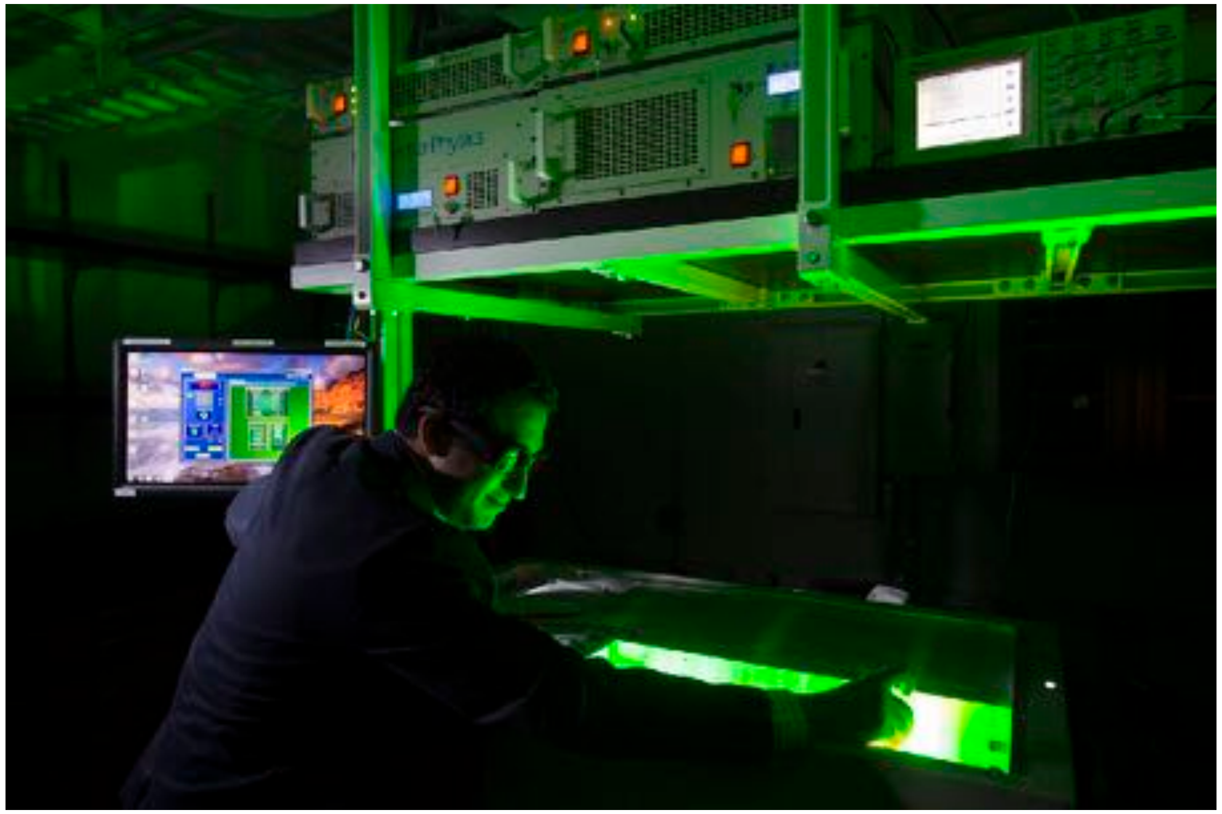
# Thin Film Compression

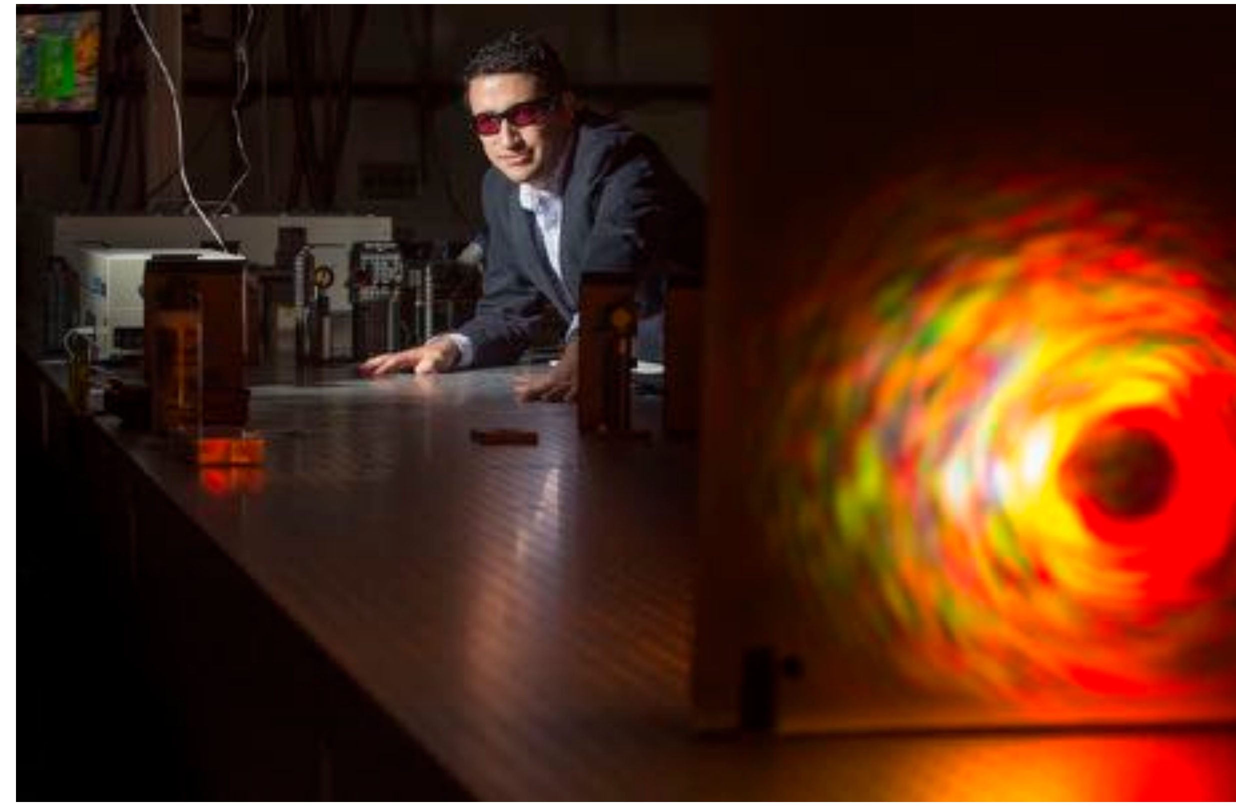
High energy lasers have “flat top” profiles



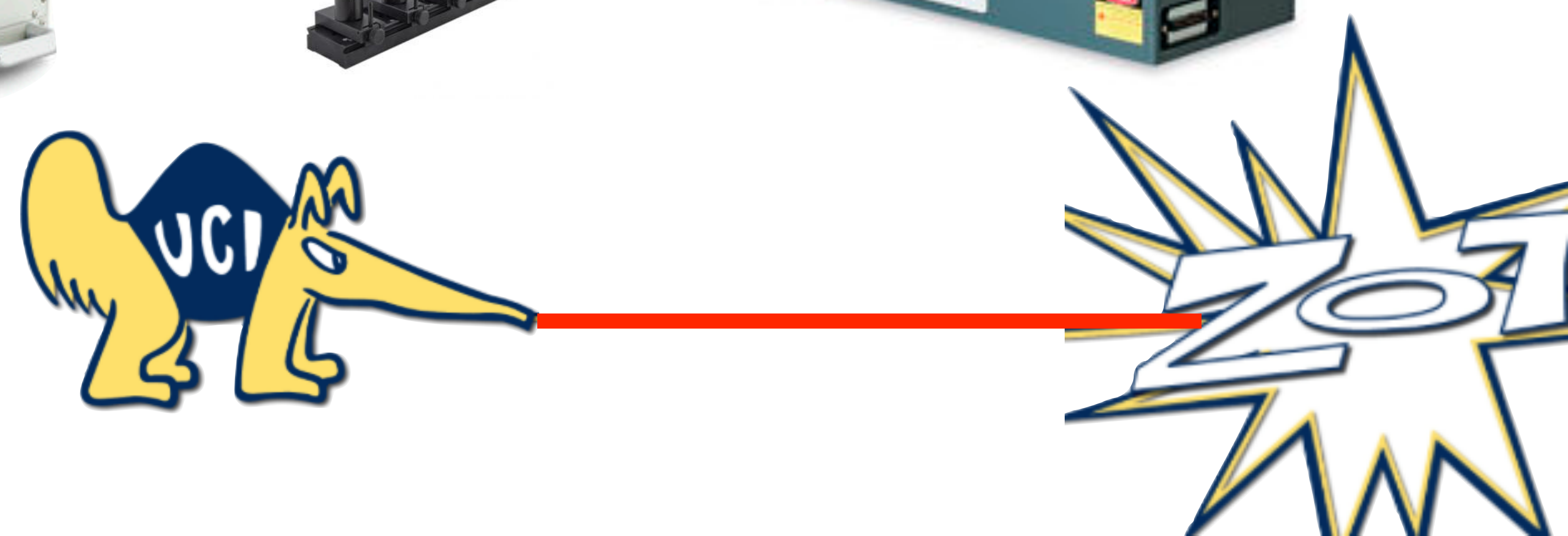
# Laser system at UCI







1 kHz, 35 fs, 0.3 TW

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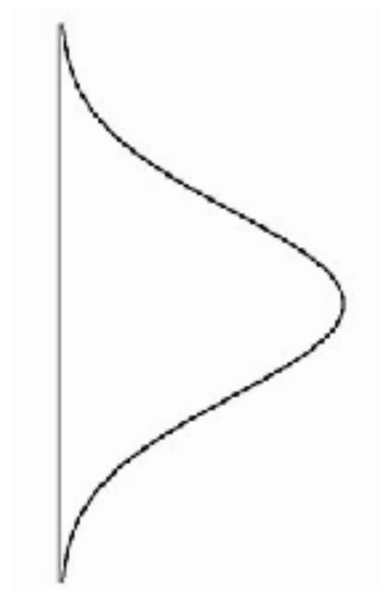
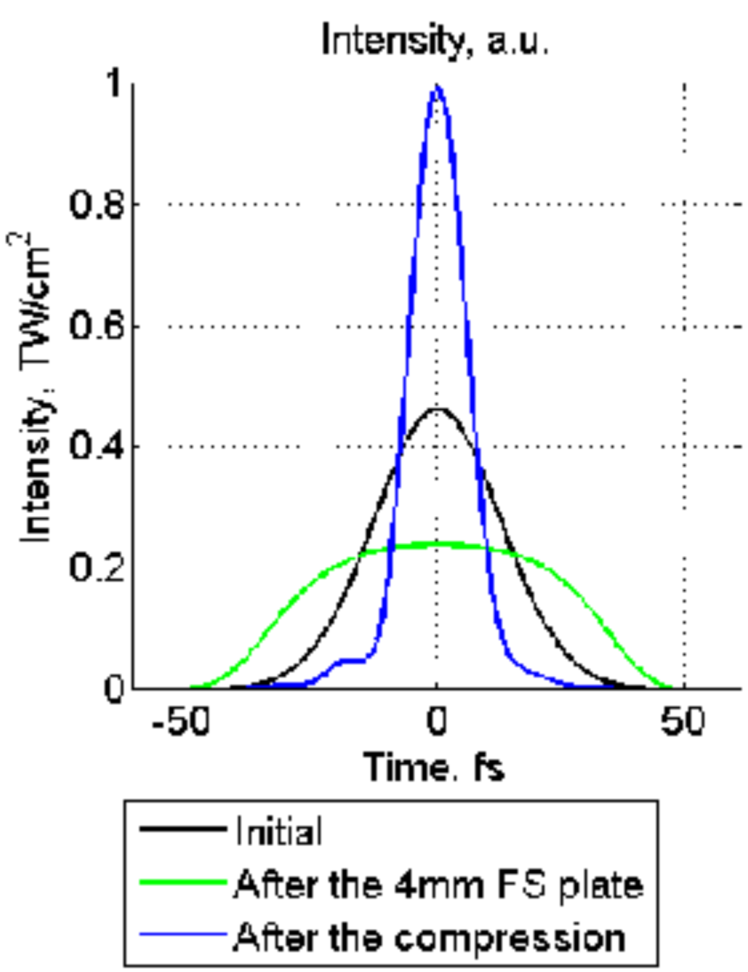
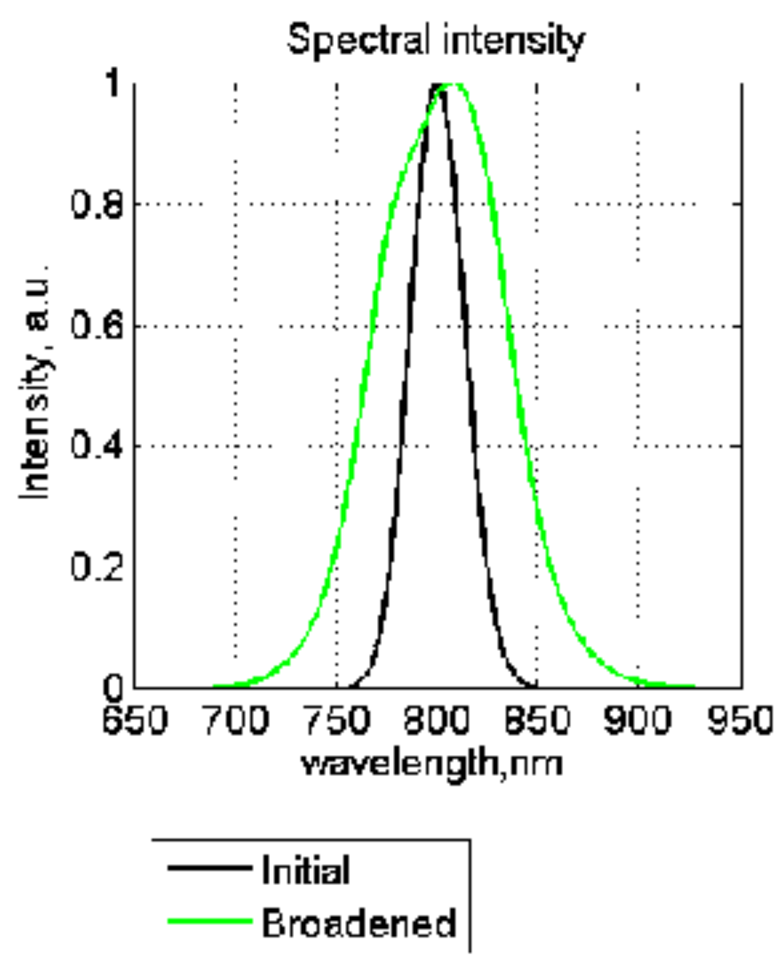
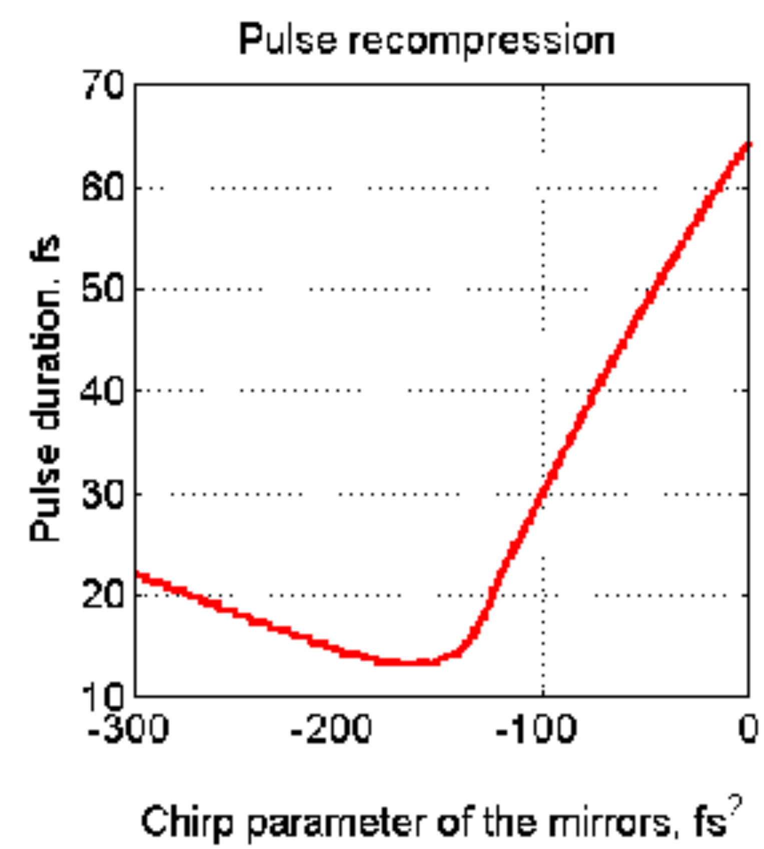
# TFC for Gaussian beams



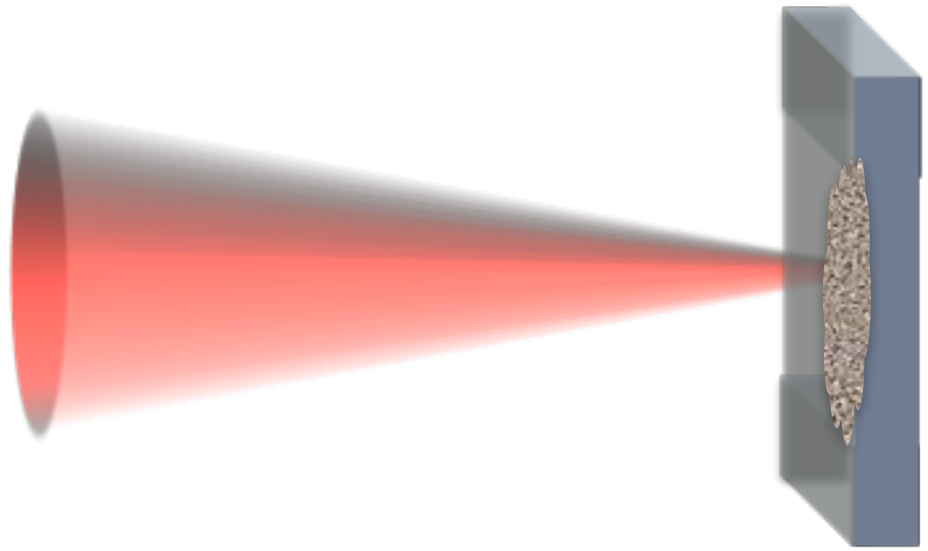



# Radiation pressure acceleration

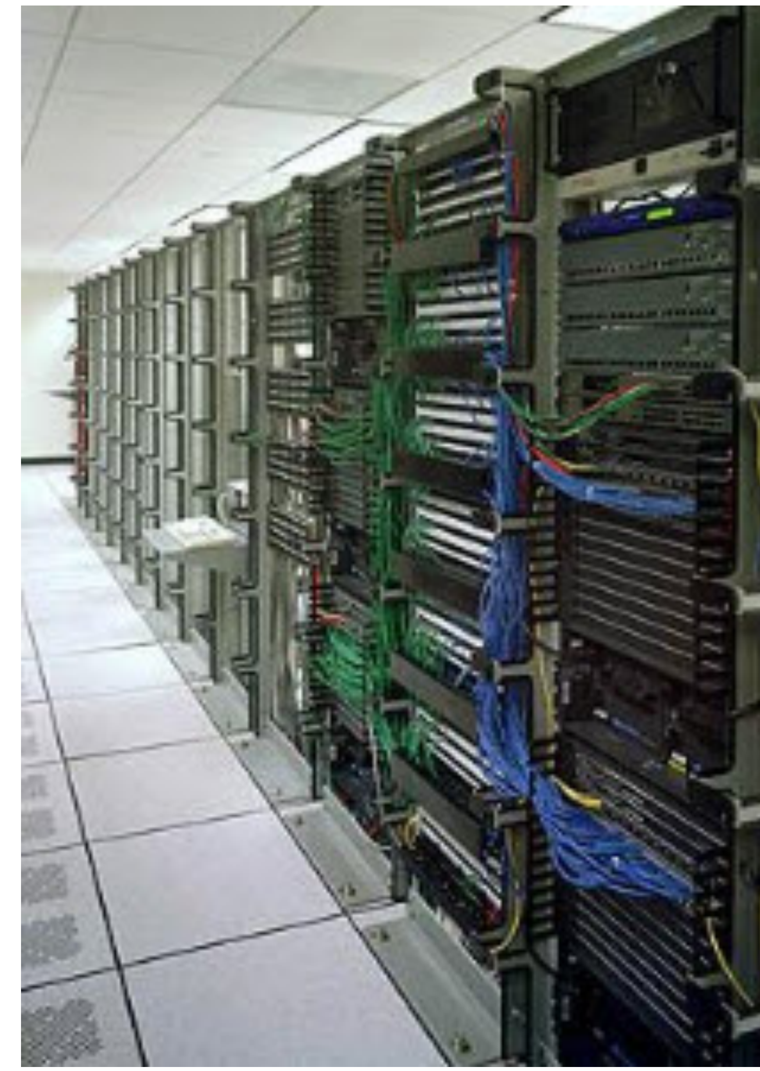
- Circularly polarized light inhibits electron heating
- Radiation pressure directly accelerates electrons
- For thin foils, can displace all electrons, accelerating all ions
- Optimal thickness is $(n_c/n_e)\ a_0\ \lambda$



F. Dollar, et al., Phys. Rev. Lett., 108 (17), 175005 (2012)

# Computing Resources

- 592 cores available on GreenPlanet high performance computing center
- Epoch and OSIRIS Particle-in-cell simulations performed
- 3D3V Simulation capabilities



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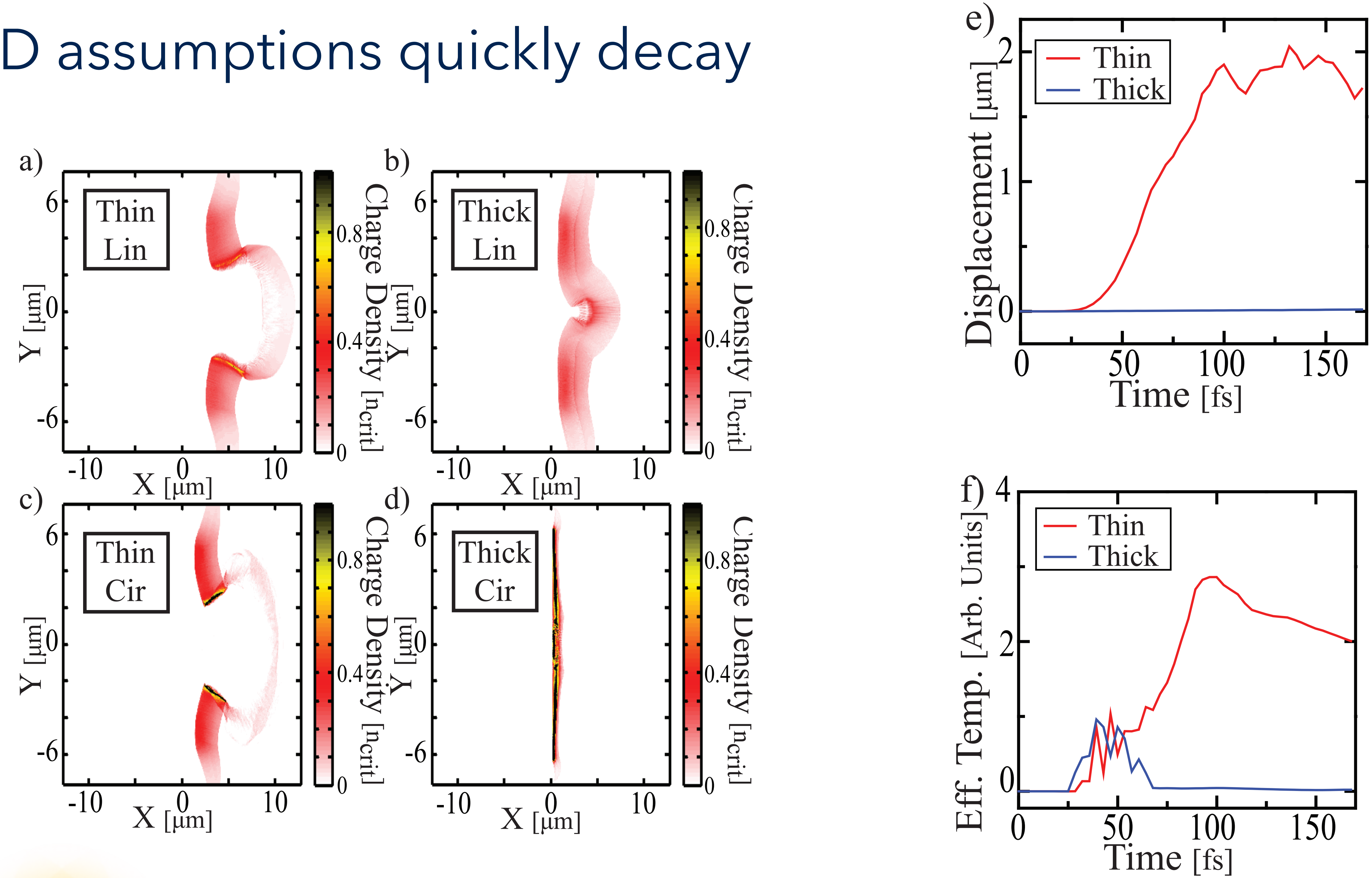
# Instabilities for RPA

- 1D assumptions quickly decay

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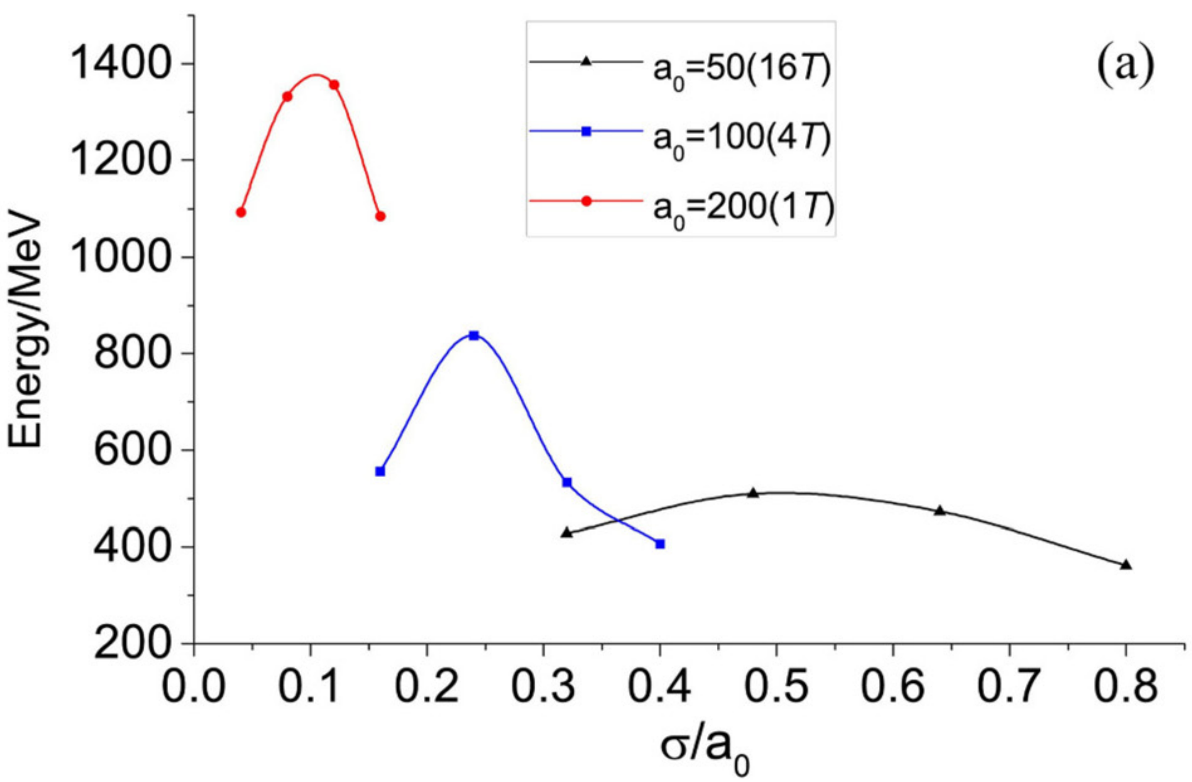
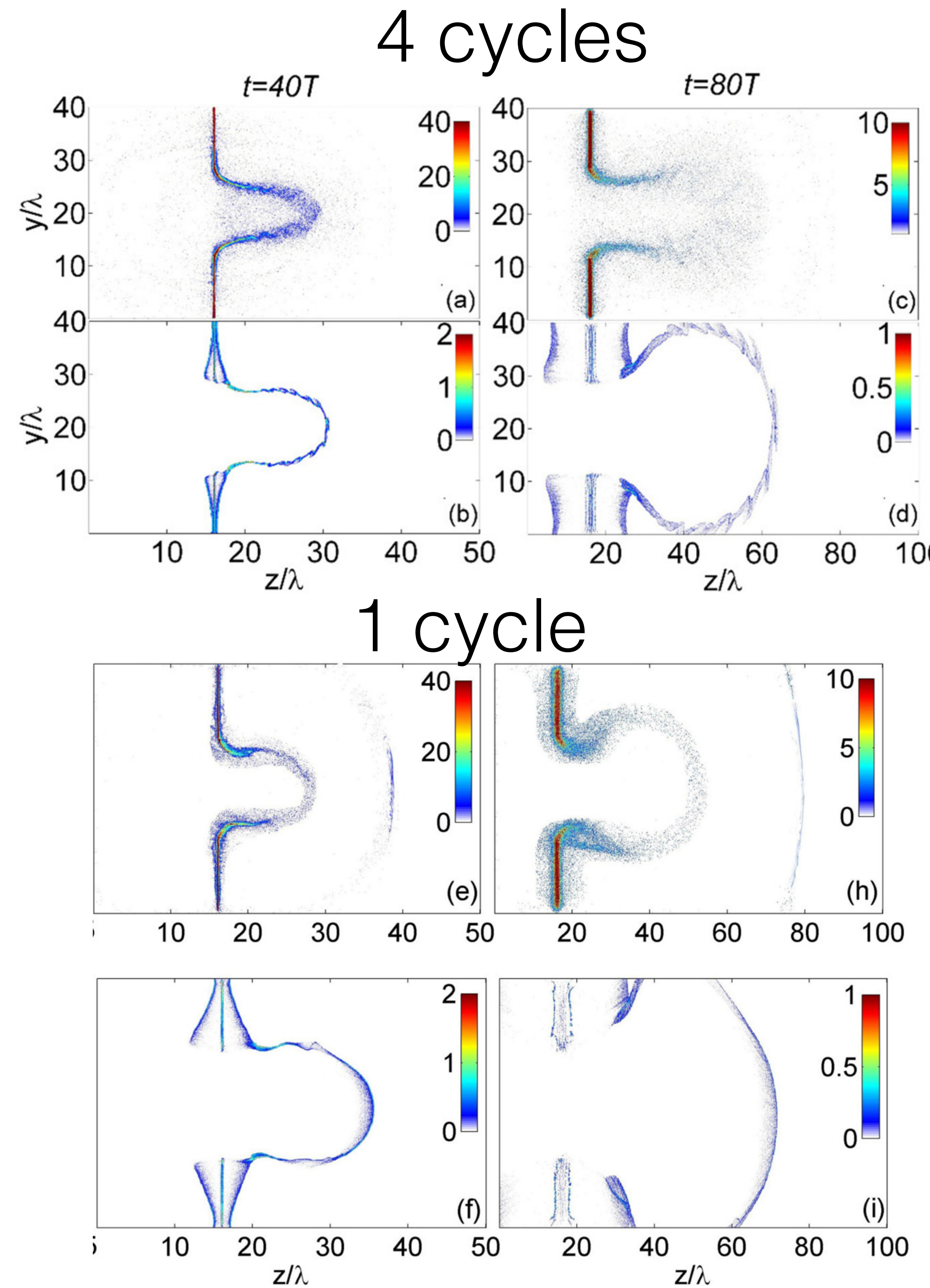
F. Dollar, et al., Phys. Rev. Lett., 108 (17), 175005 (2012)

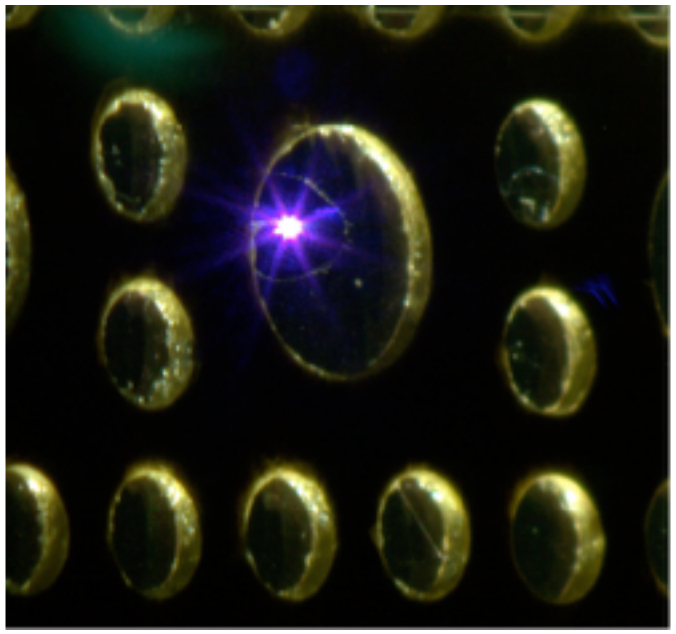
# Single cycle ion acceleration

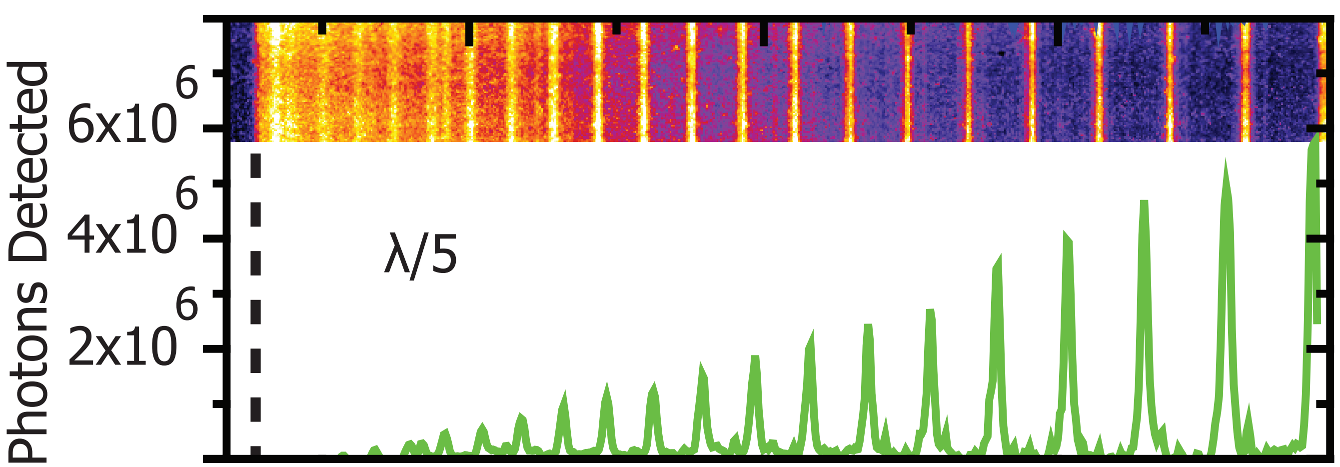


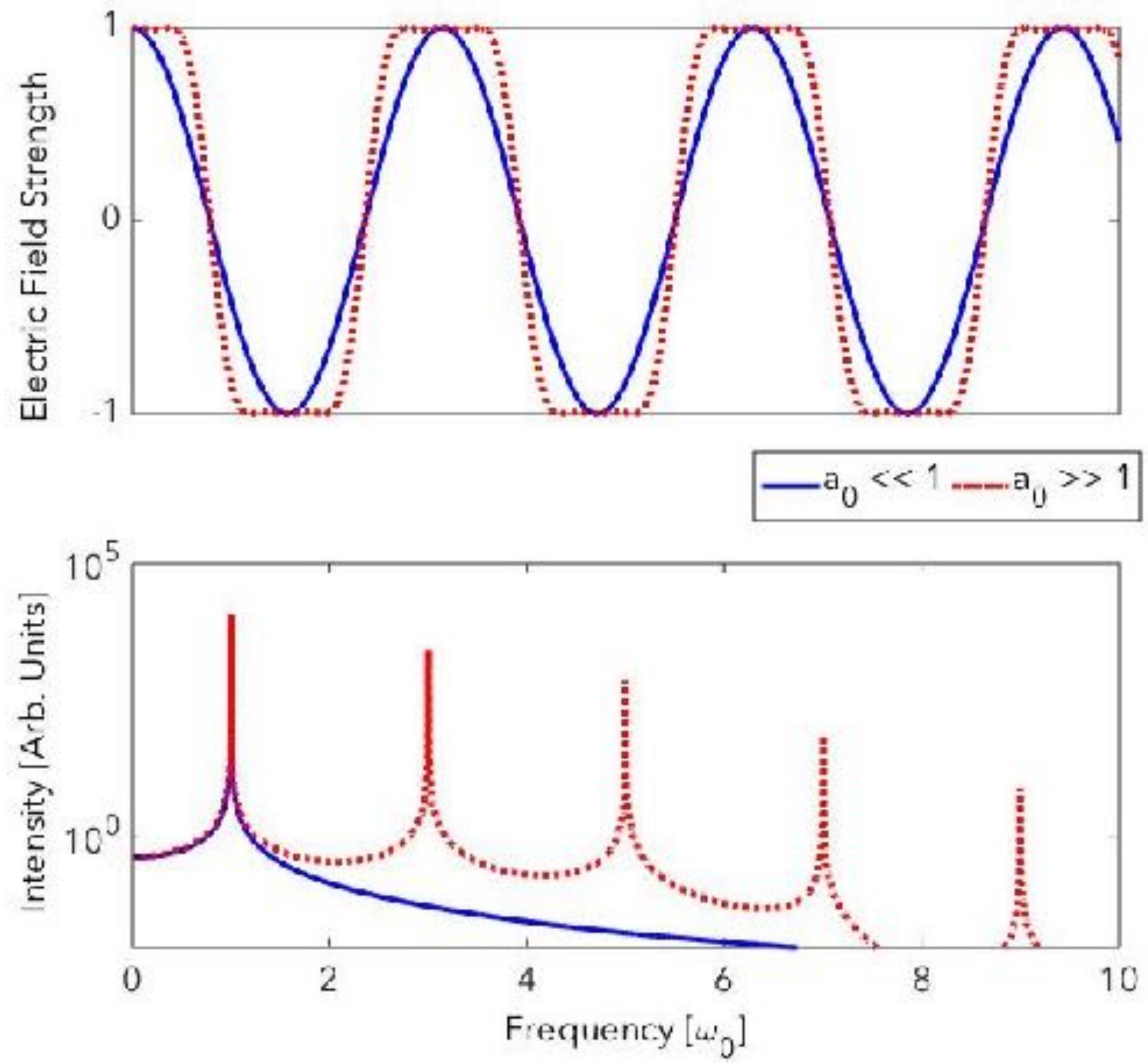




M. L. Zhou, et al., Phys. Plasm., 23(4), 043112 (2016)

# High harmonic generation



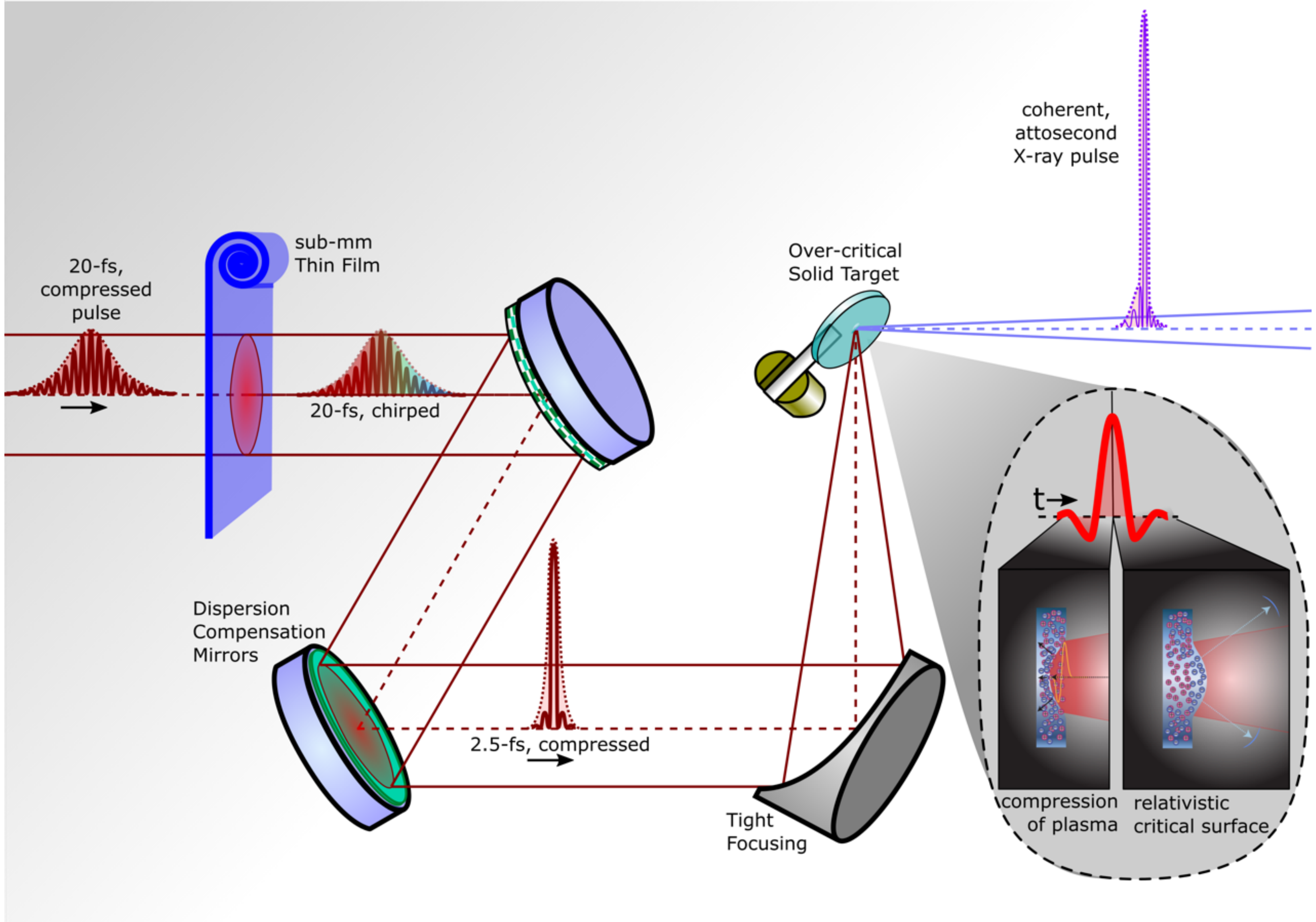



F. Dollar, et al., Phys. Rev. Lett., 110 (17), 175002 (2013)

# Single cycle advantages

- Nonlinearity cleans pulse
- Instabilities suppressed in single cycle
- Questions over absorption remain

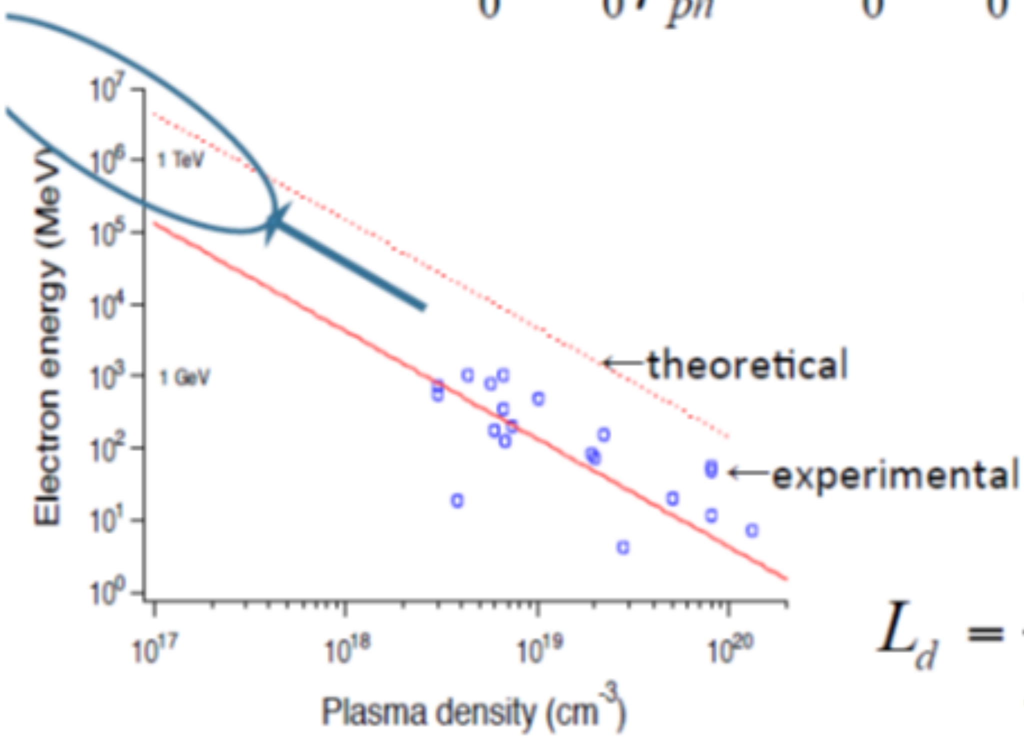



G. Mourou, et al., Euro. Phys. J. Spec. Top. (2014)

# Single cycle electron acceleration

**Theory of wakefield toward extreme energy**

$$\Delta E \approx 2m_0c^2a_0^2\gamma_{ph}^2 = 2m_0c^2a_0^2\left(\frac{n_{cr}}{n_e}\right),$$ (when 1D theory applies)




$n_{cr}$ =$10^{21}$ (1eV photon)
→ $10^{29}$ (10keV photon)
$n_e$ = $10^{16}$ (gas) → $10^{23}$ (solid)

$$L_d = \frac{2}{\pi}\lambda_p a_0^2\left(\frac{n_{cr}}{n_e}\right),\quad L_p = \frac{1}{3\pi}\lambda_p a_0\left(\frac{n_{cr}}{n_e}\right)$$

dephasing length — pump depletion length

High energy gain requires lower densities and longer lengths

OR … by scaling to shorter wavelengths much higher densities can be used

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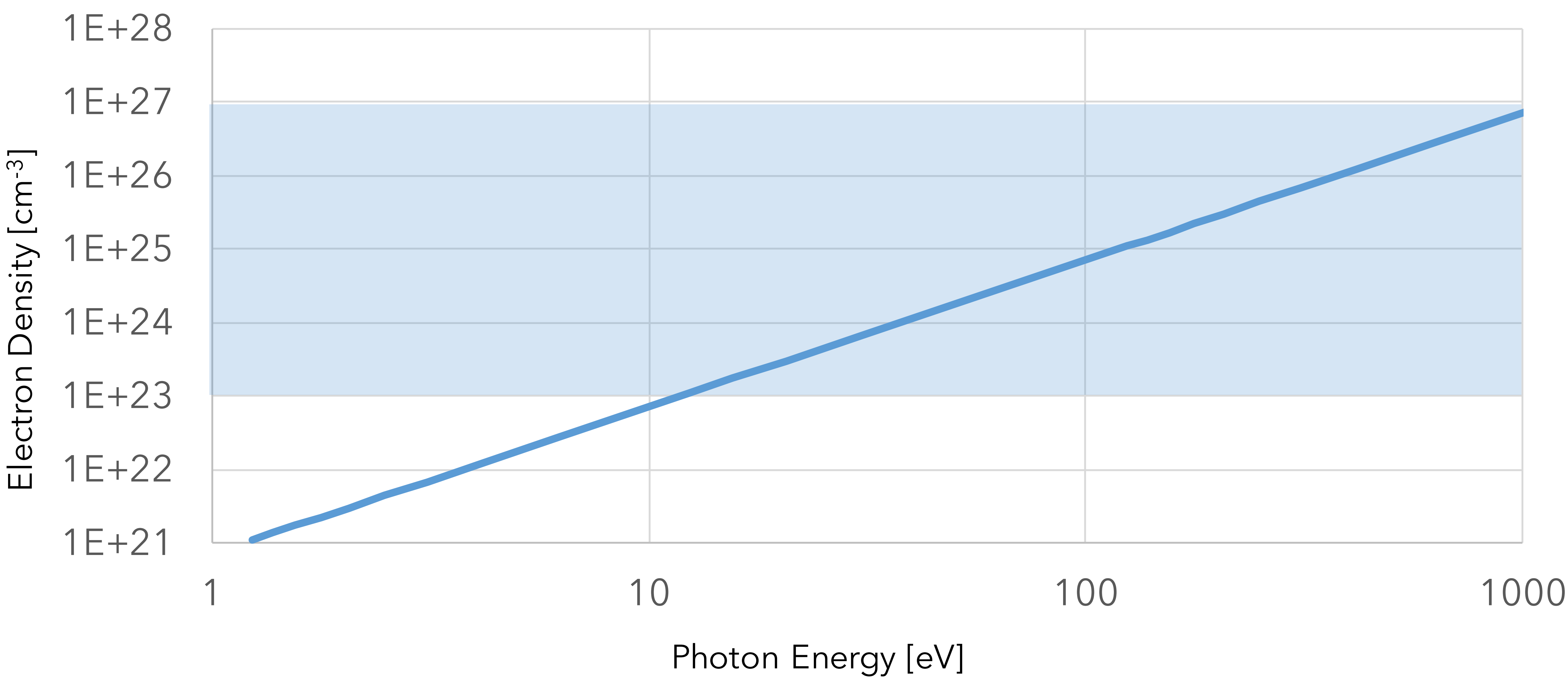
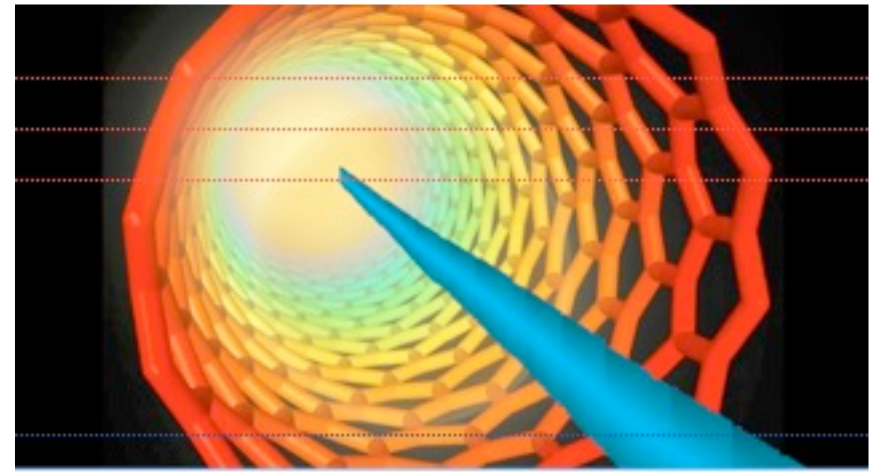
# Critical density

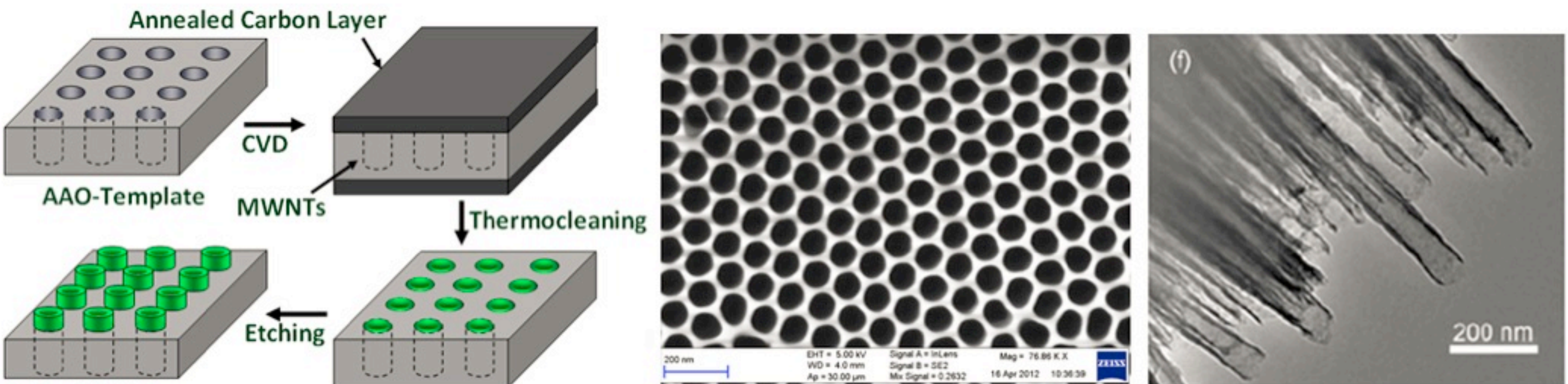


# Nanowaveguides

Nanotubes



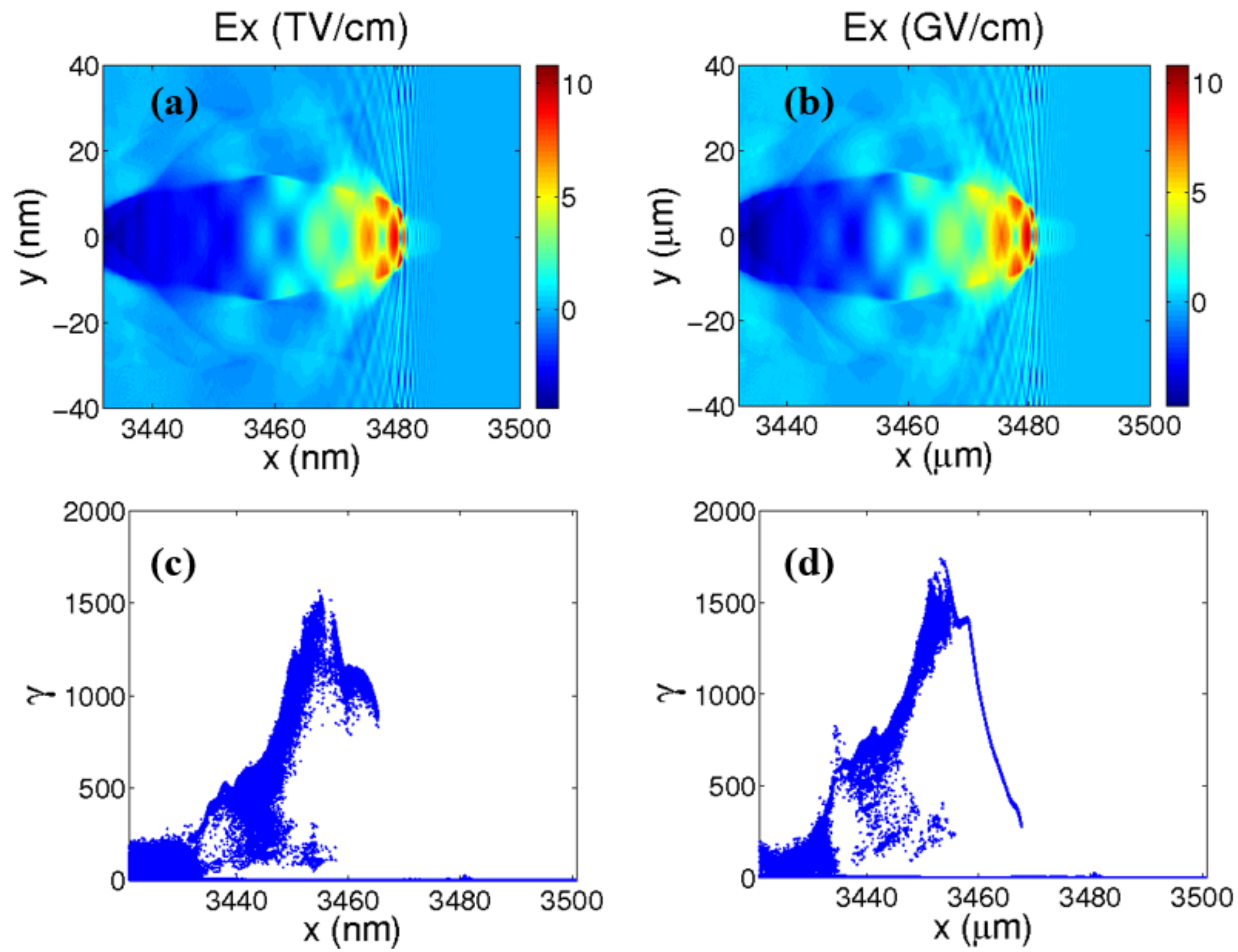
Porous nanomaterial




(a) (b) (c)

# PIC Simulations

1 nm and 1000 nm laser confined in tubes of diameter $5\lambda_L$ and intensity $a_0 = 10$

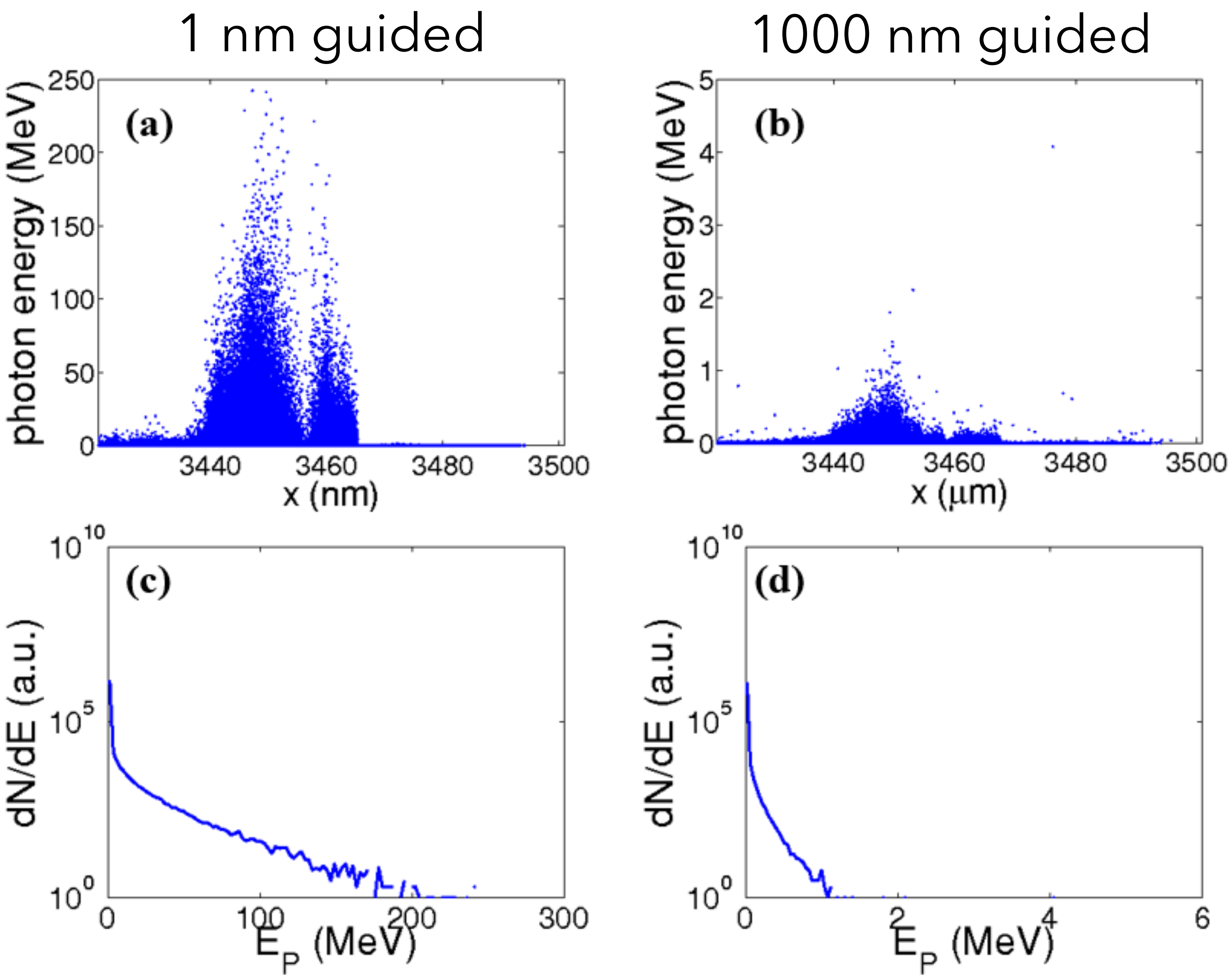



Maintaining laser wavelength to plasma wavelength ratio preserves wakefield structure

Since scaling is based over $n_c/n_e$, energy and momentum is maintained but transverse motion is drastically reduced, so emittance is much greater

M. L. Zhou, et al., PRAB, 19(10), 101004 (2016)

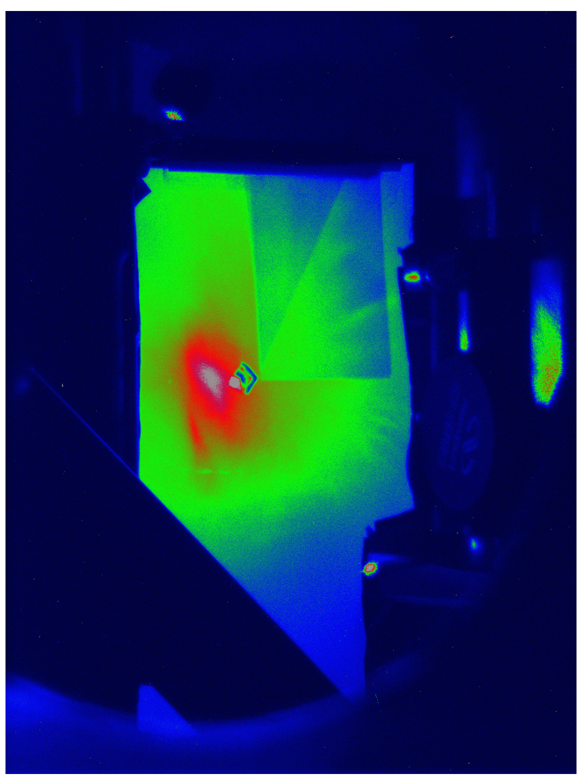
# Photon factories

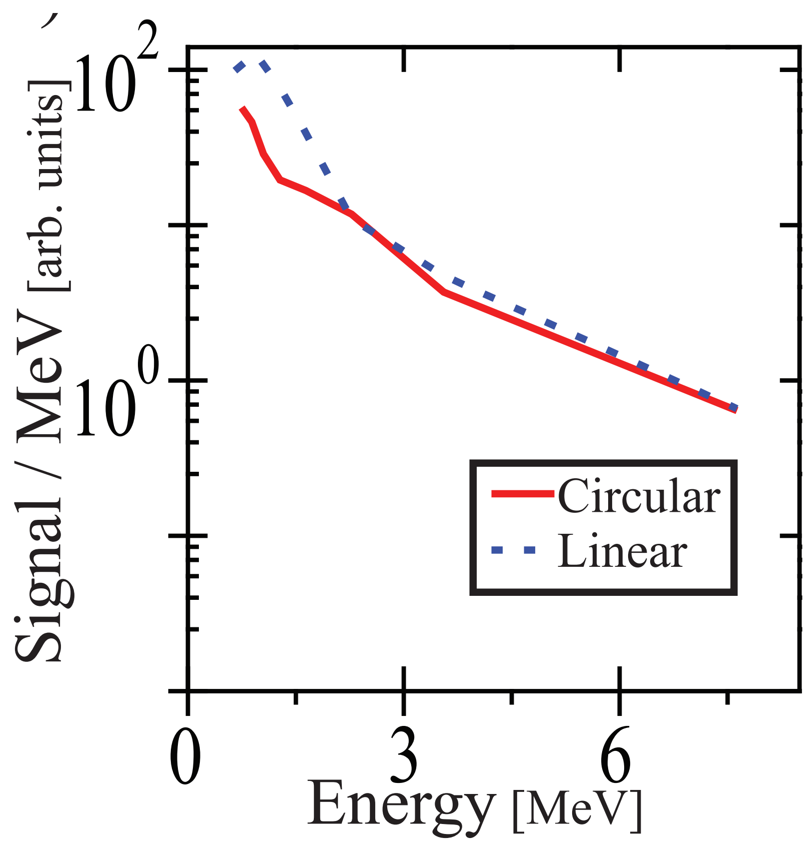


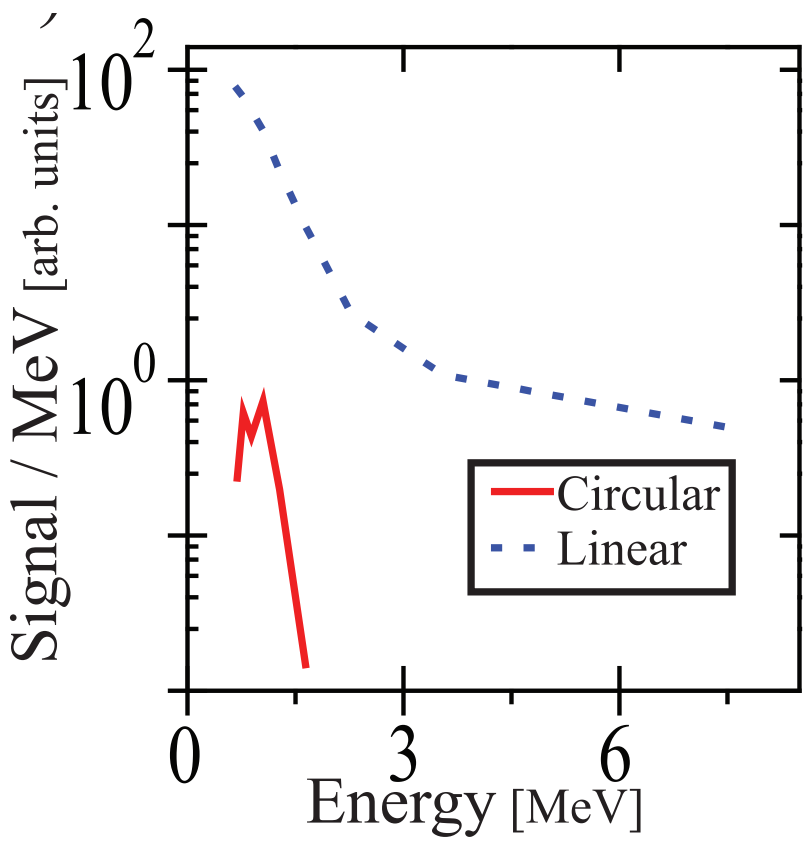

Photon emission scales with the real electric field while the energy gain scales with the normalized laser amplitude $a_0$

# RPA redux

Short pulse interactions with solids don't generate high energy electrons, but they generate high currents



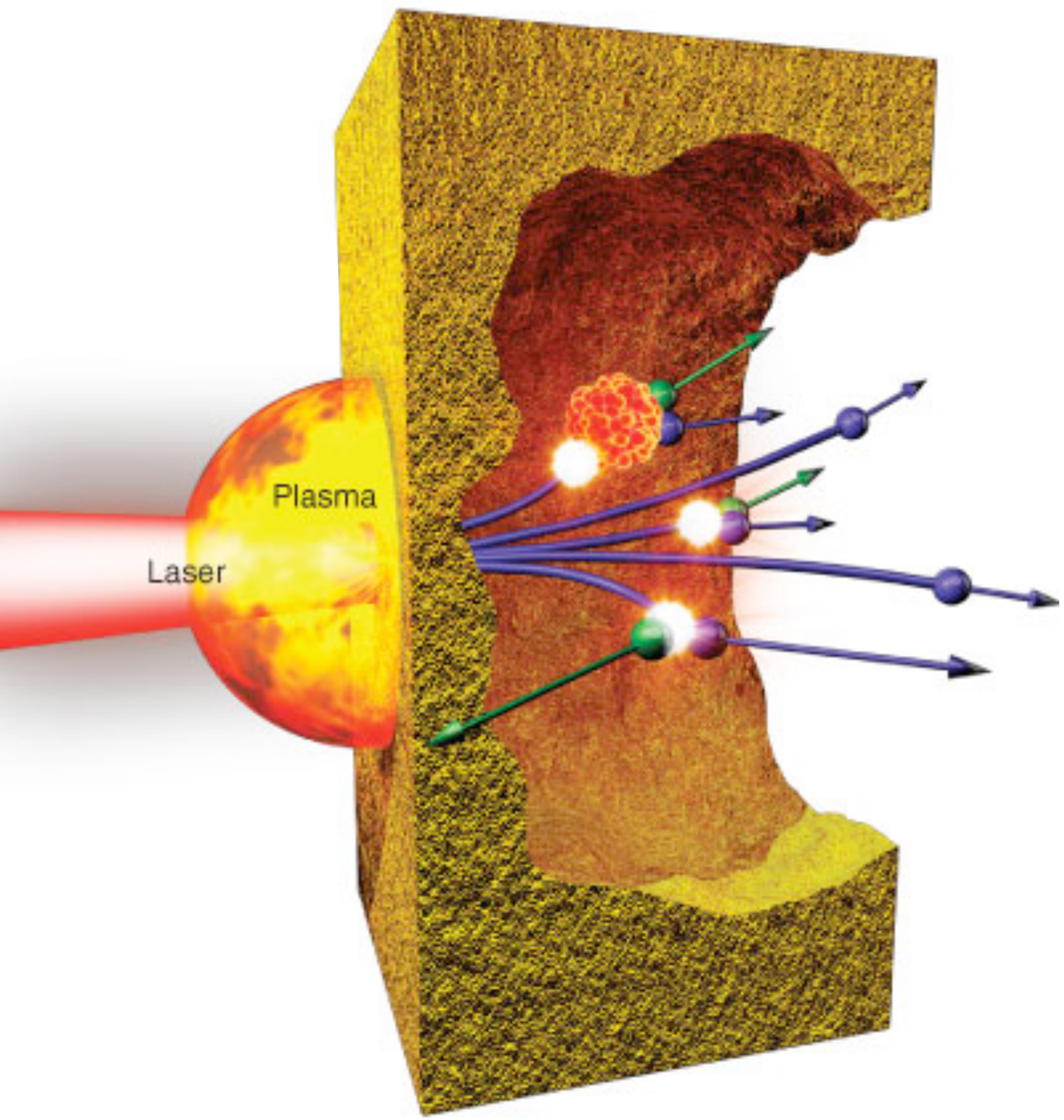


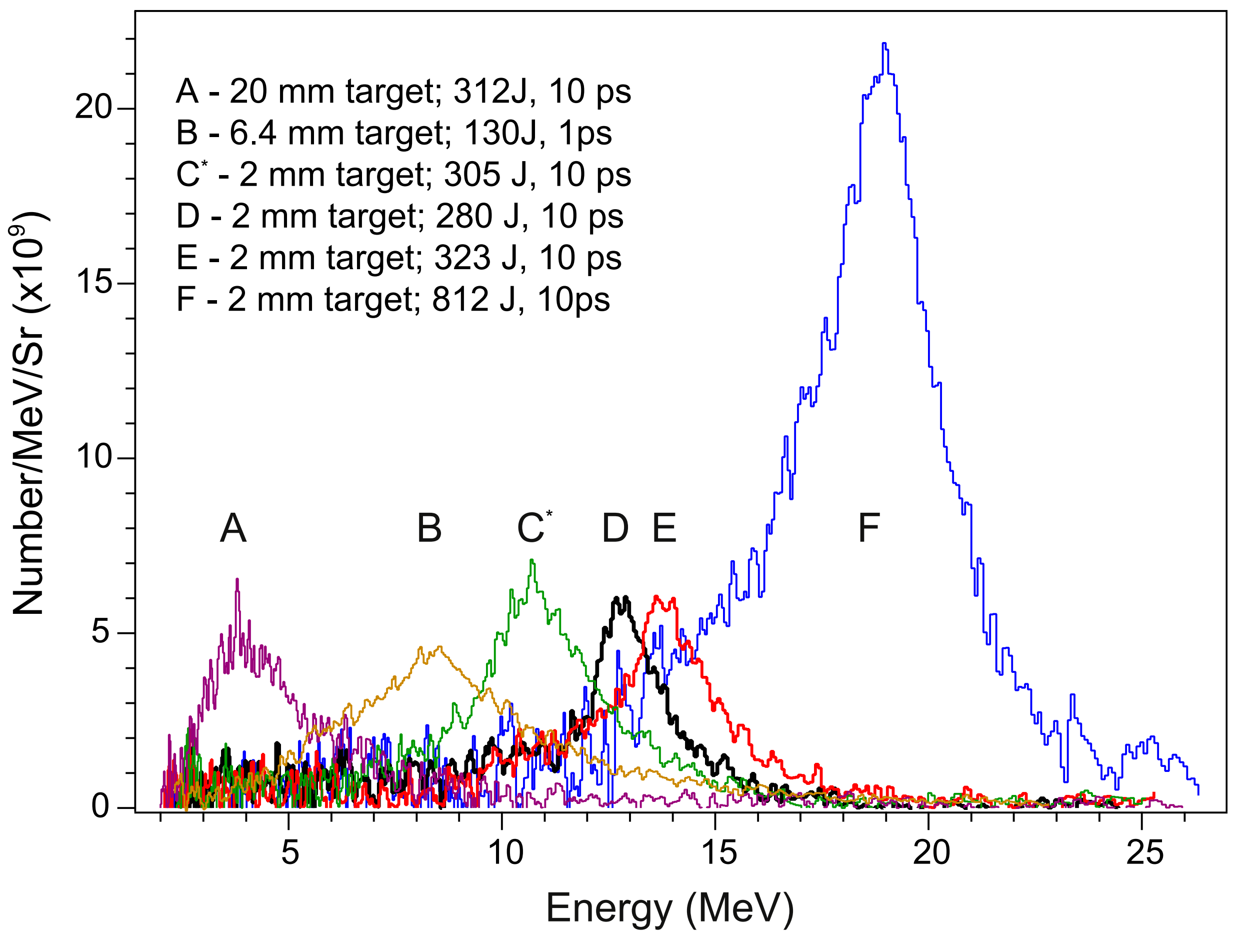




F. Dollar, et al., Phys. Plasm., 20(5), 056703 (2013)

# Positron generation

Courtesy of K.-Y. Chu




H. Chen, et al., HEDP, 7, 225-229 (2011)

# Acknowledgements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  - Louise Willingale


Thank you for listening!