Electron heating in Radiation Pressure driven Acceleration (RPA) with a circularly polarized laser

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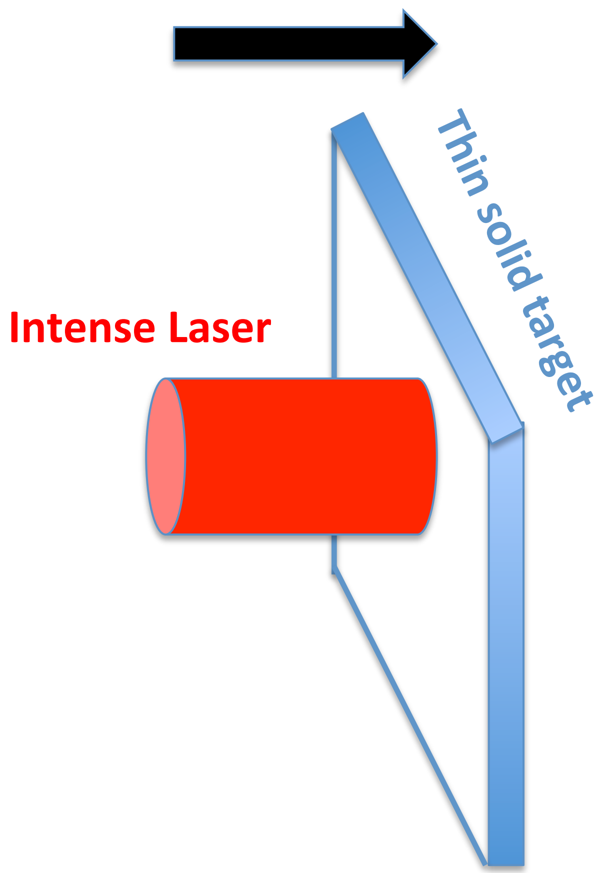
RPA: A promising scheme for ion acceleration using intense lasers



Optimal target thickness is given by

$$l_{opt} \cong \frac{a_0}{\pi} \frac{n_c}{n} \lambda_0$$

Typical target thickness:

$$a_0 = 10 \qquad \frac{n}{n_c} = 100 \qquad \lambda_0 = 1\mu m$$

$$\boxed{l_{opt} = 30nm}$$

Radiation Pressure Acceleration (RPA) can potentially lead to mono-energetic ion bunch compared to Target Normal Sheath Acceleration (TNSA) scheme.

Controlling the electron heating is critical for reducing the ion energy spread.

- For linearly polarized laser, the **ponderomotive force oscillates at $2\omega_0$ frequency**.

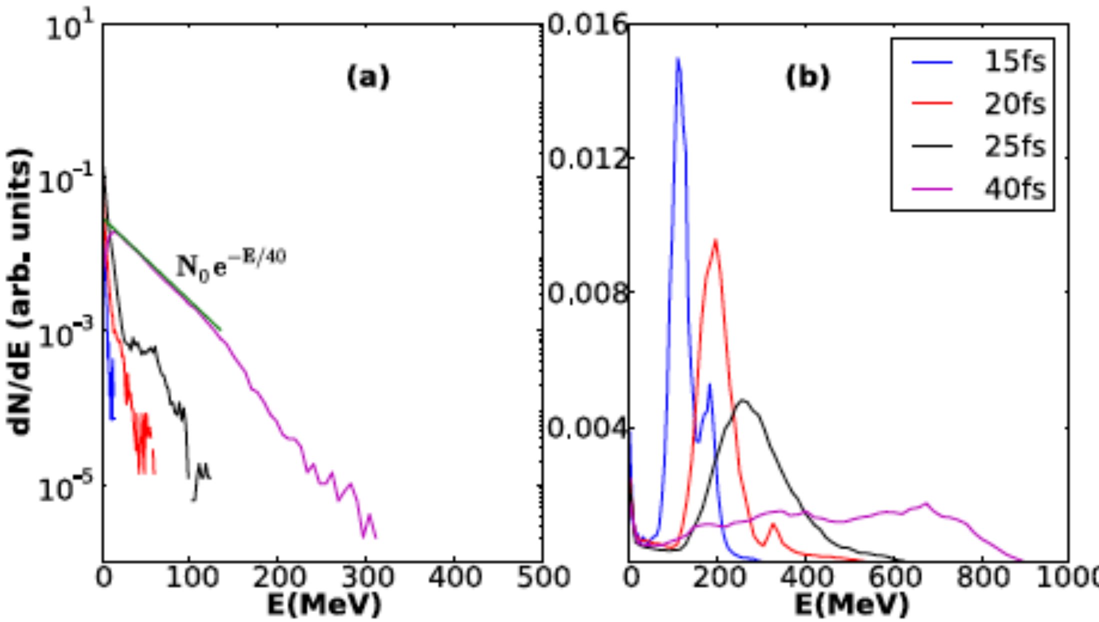
- This leads to ***J X B* heating for electrons**, which adversely affects ion acceleration process. In particular, the **spread in the ion energy spectrum increases**.

- **For Circularly polarized laser, *J X B* heating is absent [1]**. Therefore, it is expected that such laser will lead to reduced electron heating and quasi-mono energetic ion beam.

[1] A. Robinson, M. Zepf, S. Kar, R. Evans, and C. Bellei, New J. Phys. 10, 013021 (2008).

Significant electron heating is found even with a circularly polarized laser.

Electron Spectrum **Proton Spectrum**



Simulation Details :

-> 2-D PIC simulations with open source code WARP[2]

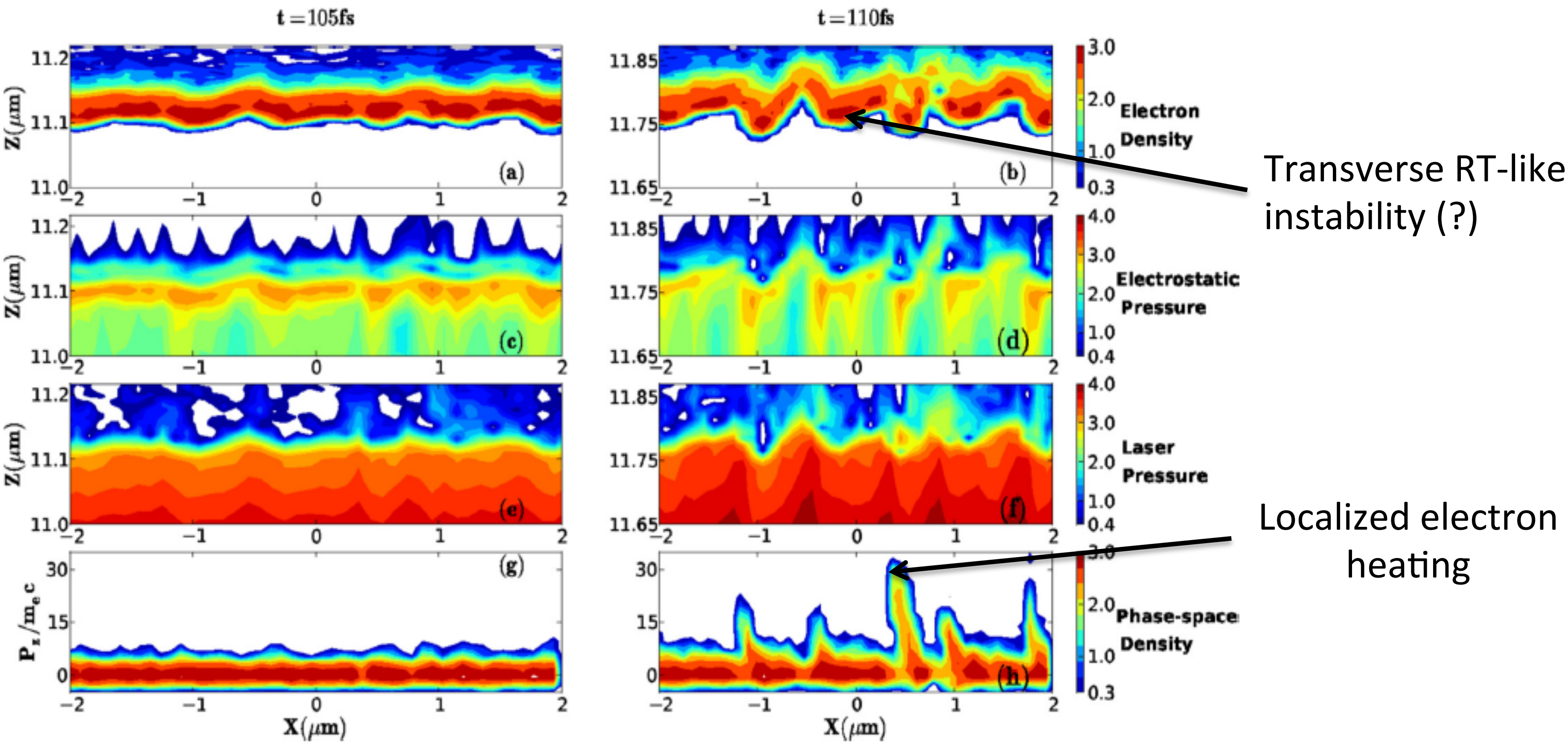
-> Laser : a_0 = 60; W_0 = 10 μm

-> Target : n_0 = 100 n_c ; L = 200 nm

Stronger electron heating was found for longer pulse duration lasers

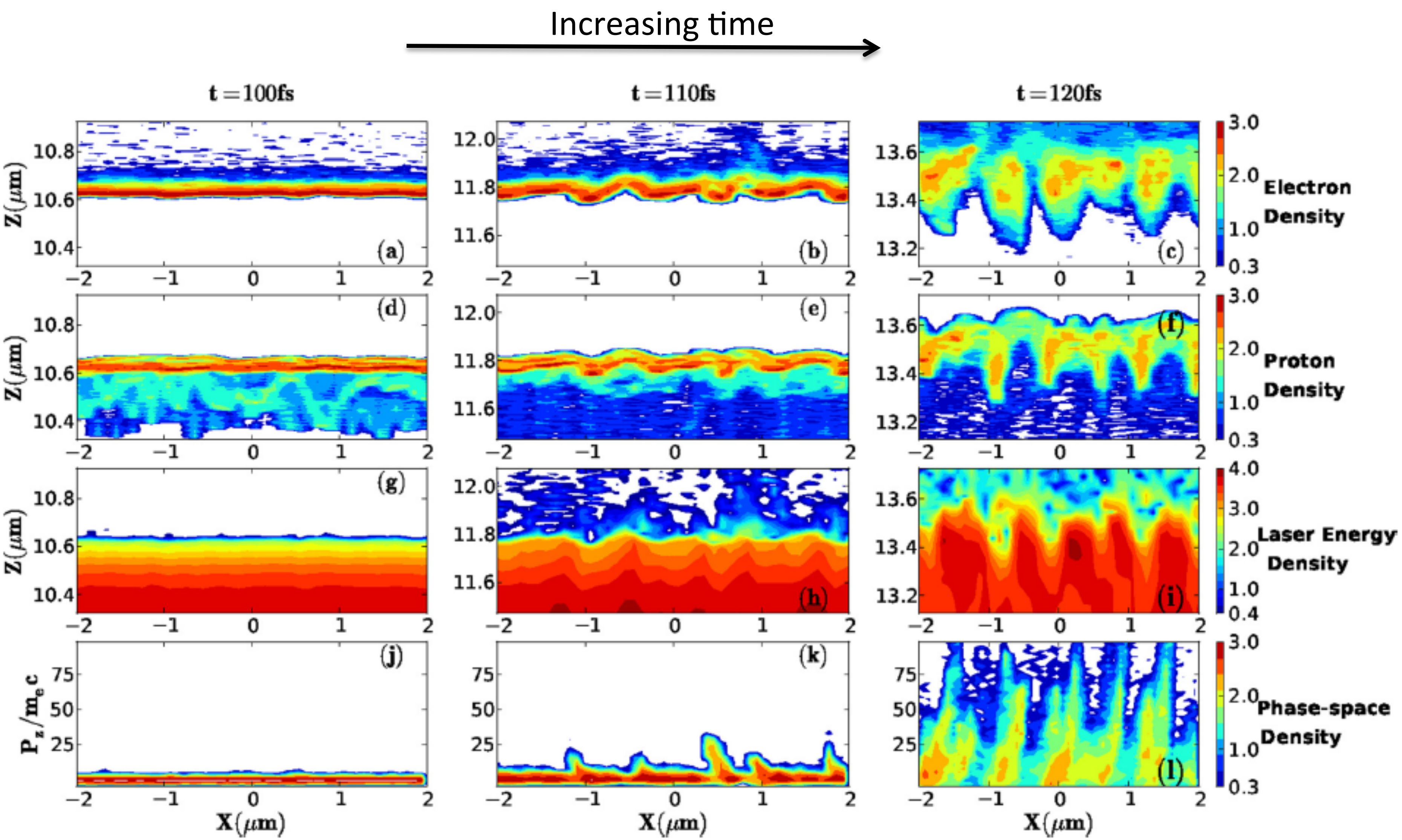
[1] B. S. Paradkar and S. Krishnagopal, Phys. Rev. E **93**, 023203 (2016).
[2] J.-L.Vay et al, Comput. Sci. Discovery **5**, 014019 (2012).

Localized electron heating in the initial phase of acceleration



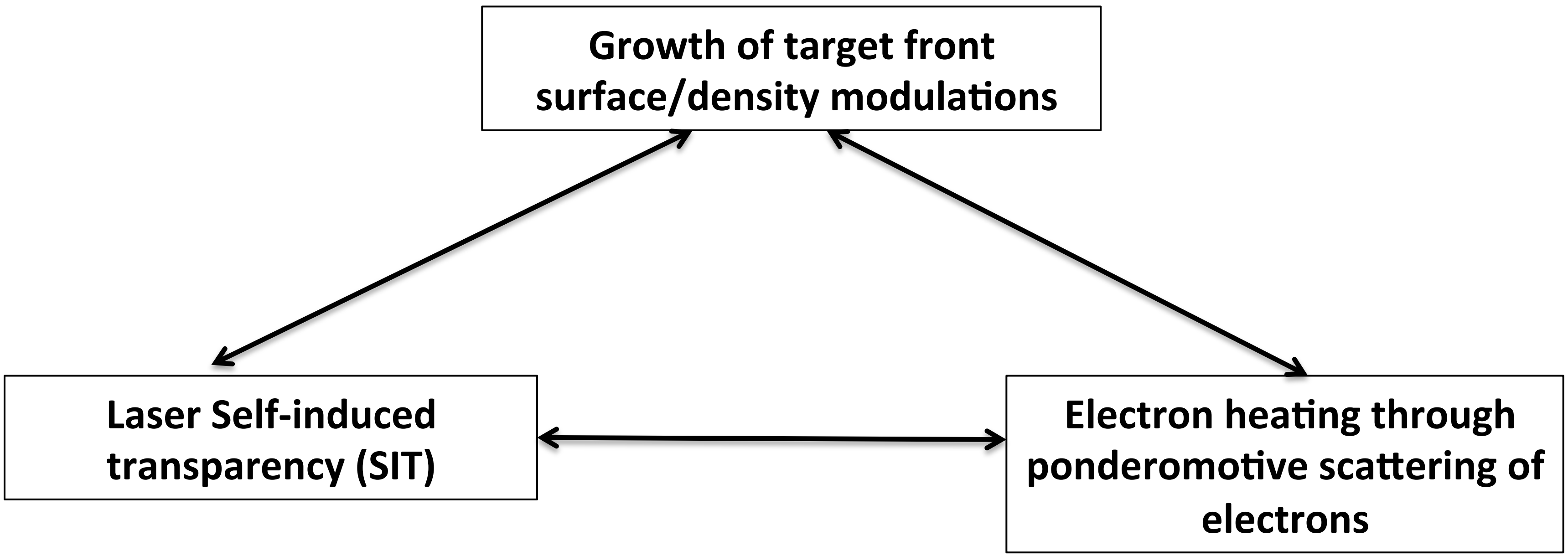
Electrons are ponderomotively scattered once the balance between electrostatic pressure and laser pressure is disturbed.

Electron heating accompanied by self-induced transparency of the laser.

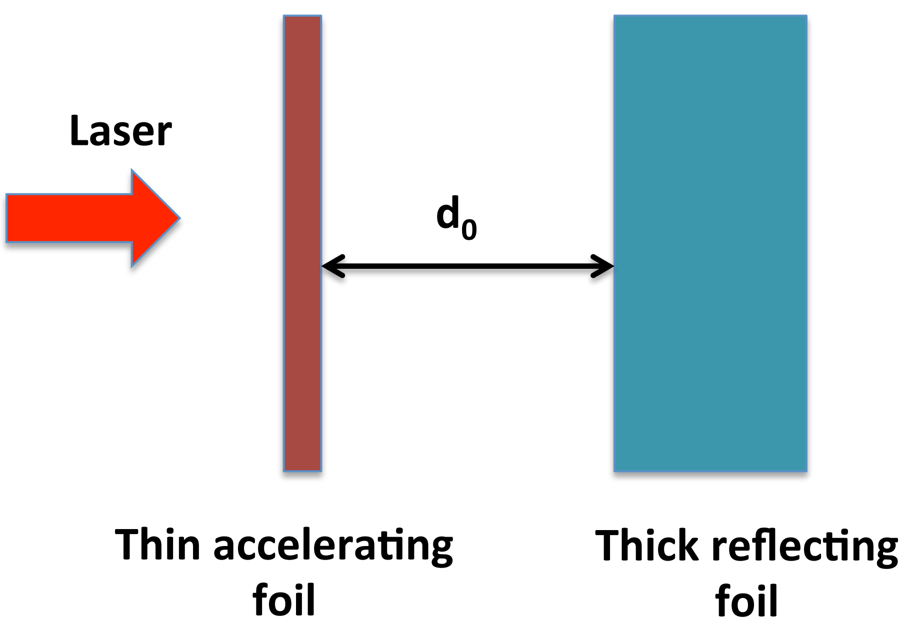


Physical picture of electron heating

Feedback loop for electron heating, self-induced transparency of laser and growth of front surface modulations

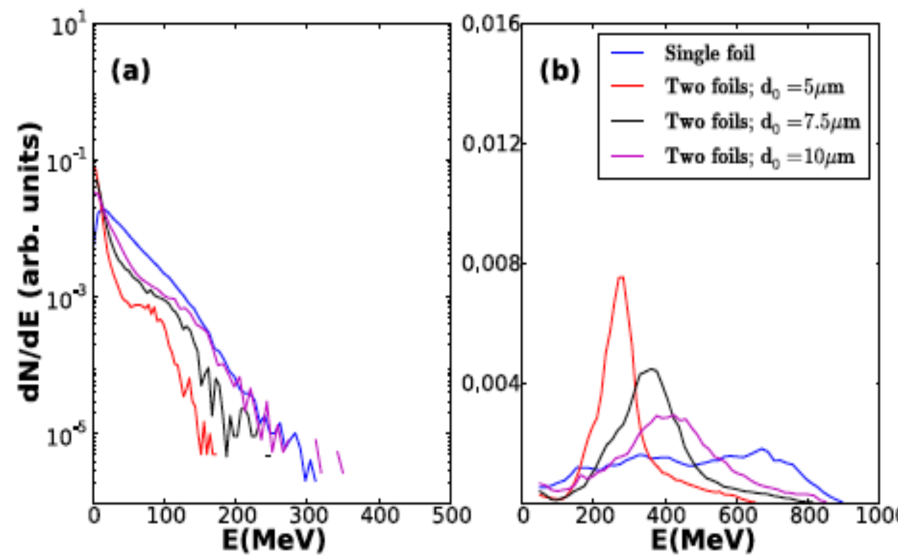


Two foil target assembly to suppress the electron heating and self-induced transparency



Electron energy spectrum

Proton energy spectrum



-> Second thick foil reflects the laser before it goes into Self-induced transparency phase resulting in reduced electron heating.

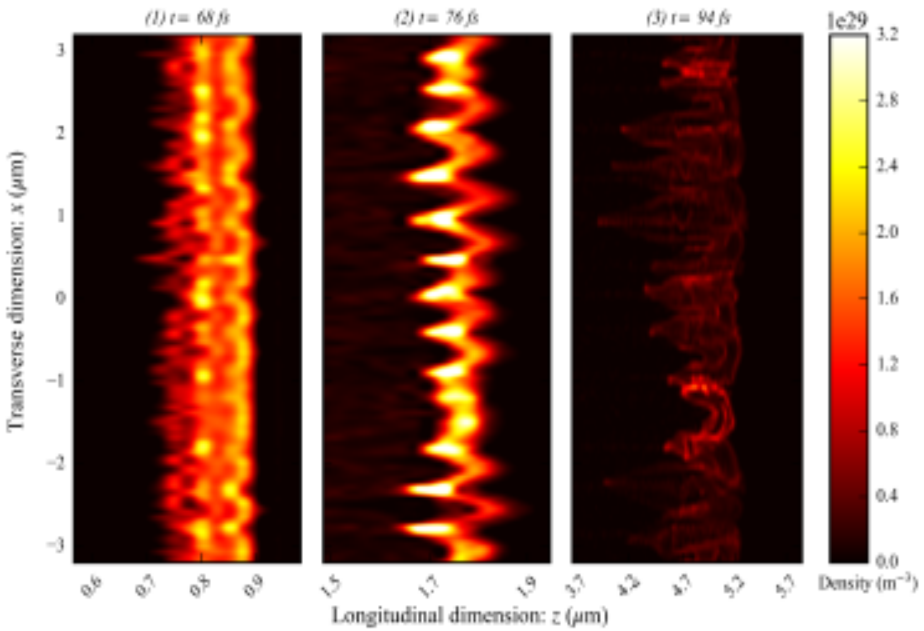
Quasi-mono energetic proton beam due to reduced electron heating.

Preliminary results on investigation of transverse-instability in RPA

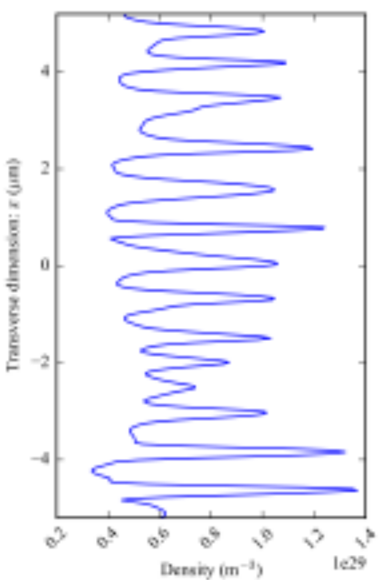
Work of CEBS student N. Krishnadev

Transverse density modulations are Fourier analyzed.

Transverse density modulations at various stages of accelerations

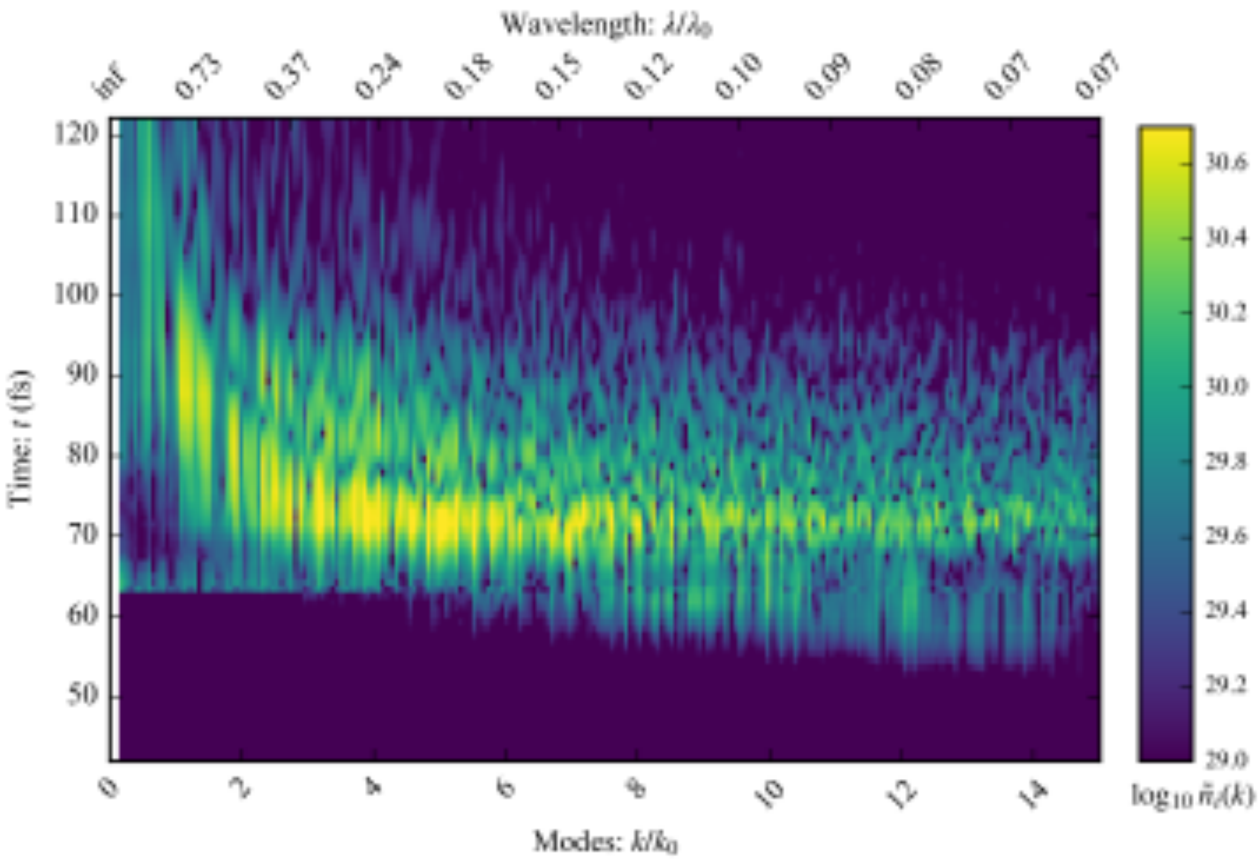


Longitudinally averaged transverse ion density profile



Fourier transform of longitudinally average transverse density profile gives the dominant wavelength at the give time of acceleration.

Dominant k-mode moves from high to low as acceleration proceeds



Conclusions

- Electron heating mechanism in RPA with a circularly polarized laser is investigated.
- Reduced electron heating is observed for shorter pulse duration lasers.
- Strong heating is observed during the self-induced transparency (SIT) phase of the laser. SIT causes further increase in the front surface modulation which in turn results in electron heating. Thus completing the feedback loop.
- Experimentally viable two foil target assembly can potentially reduce the energy spread of the accelerated protons.
- Detail investigation is needed for the complete understanding of transverse instability.