Laser focusing and energetic-ion generation by a conical target with openings on both ends

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Outline

1. Introduction
2. Laser Focusing by a Conical Target
3. Generation of Energetic Ion Bunches

1.Introduction

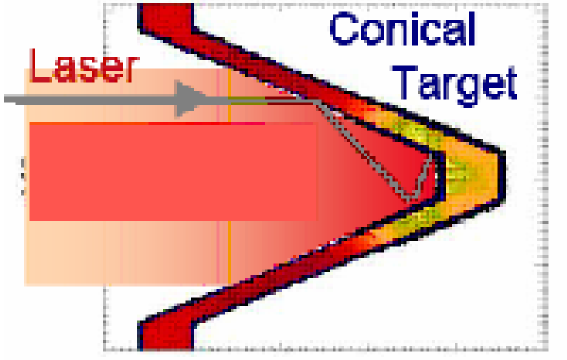
- **Strong-field physics depends on the concentration of laser energy in an extremely small time/space interval.**

- **Laser pulse with small time interval can be obtained by pulse compression. Femtosecond laser pulse has been used in the experiments.**

- **Laser pulse with small space interval can be obtained by tight focusing. The laser intensity will be greatly increased for tiny spot size. But it is difficult to focus a powerful laser to a spot of 10 microns or less.**

1.Introduction

Hollow metal cone target in FI

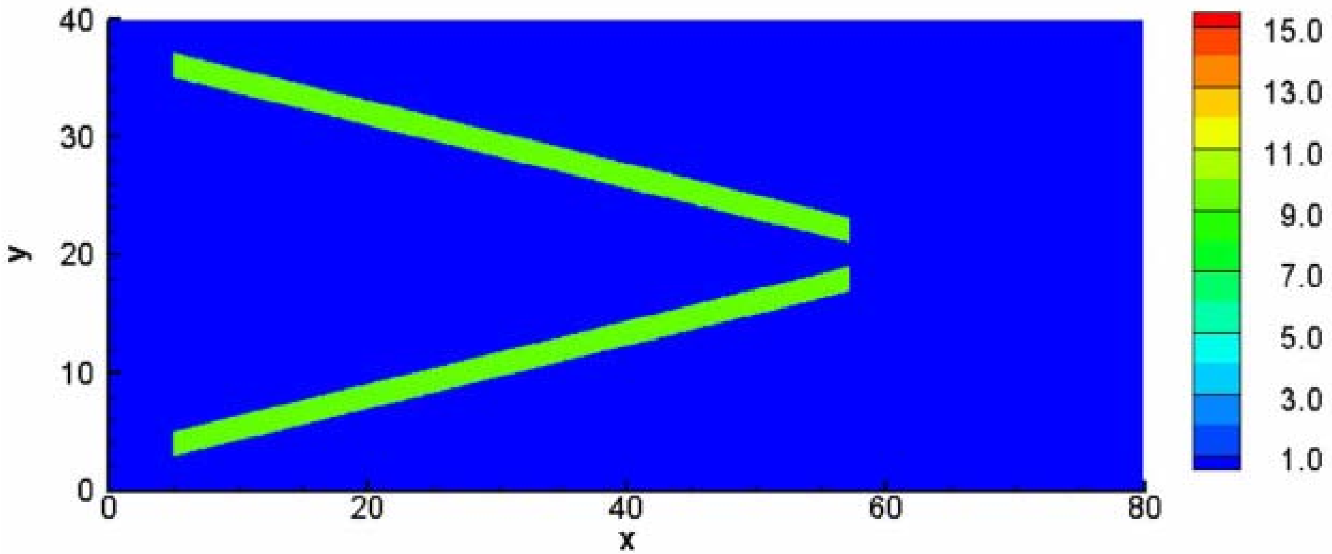


- A tiny cone target was first introduced in FI experiments.
- A remarkable increase in the thermal fusion-neutron yield was observed.
- PIC simulations showed that a cone-shaped target can guide and focus a laser beam.
- Both 2D and 3D simulations were performed and the similar conclusions were obtained.
- The tip of this kind of cone target is closed.

R. Kodama., Nature， 412, 798 (2001),Z. L. Chen, Phys. Rev. E,71, 036403 (2005),
Y. Sentoku., Phys. Plasmas,11,3083 (2004),T. Nakamura,Phys. Plasmas,14, 103105 (2007).

1.Introduction

Cone target with two openings for laser focusing



- A new cone target with two openings was proposed by Wei Yu.
- It serves as an optical device, whose aim is to output a tightly focused laser pulse.

2.Laser Focusing by a Conical Target

Parameters

Laser pulse:

- **Circular polarized，normal incidence，a_0=4, peak intensity:.4 ×10^{19}W/cm^2 , λ=1.06μm**
- **Gaussian spot and Gaussian envelop，w=10μm, τ＝t_0=25T**

$$a = a_0 \exp[-(t - t_0)^2 / \tau^2] \exp[-(y - y_0)^2 / w^2]$$

Cone target(plasma):

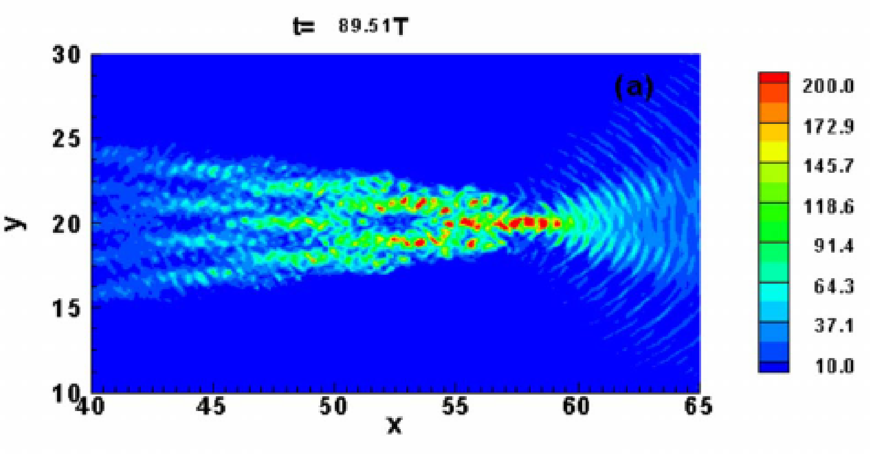
- **10n_c，thinkness:2λ，Te=4keV，Ti=1keV,M/m=1836**
- **the radius of left and right openings: 15μm and 1μm, they are fixed for cones with different angles.**

Simulation box:

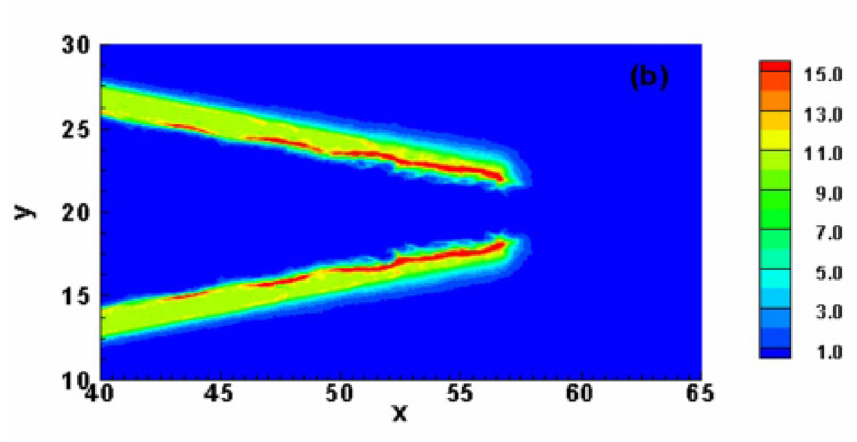
- **80λ ×40 λ, 1024 ×512， 2.56×10^7 electrons， 2.56×10^7 ions**
- **5λ vacuum at the left boundary**

2.Laser Focusing by a Conical Target

EM energy density (30° cone target)



electron density (30° cone target)

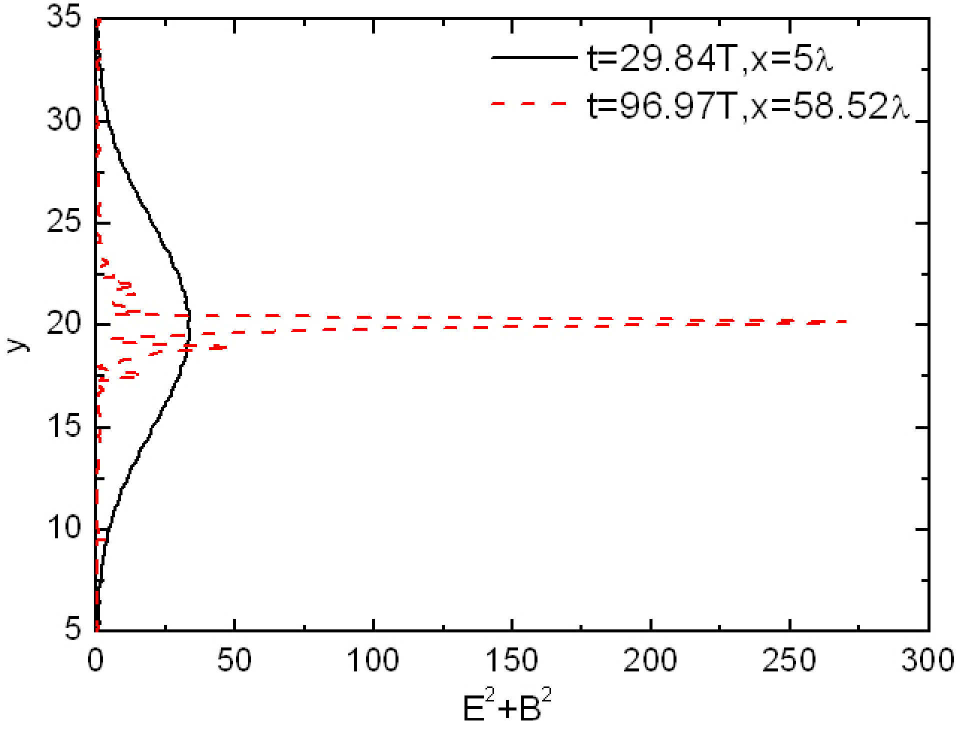


- ➢**The laser pulse is guided and reshaped until it leaves the right opening.**
- ➢**Beyond the tip, the laser can travel over a distance of several wavelengths , with higher intensity and smaller spot.**

- ➢**The electrons in the inner surface are compressed and heated.**
- ➢**The laser is in turn modulated by these electrons.**

2.Laser Focusing by a Conical Target

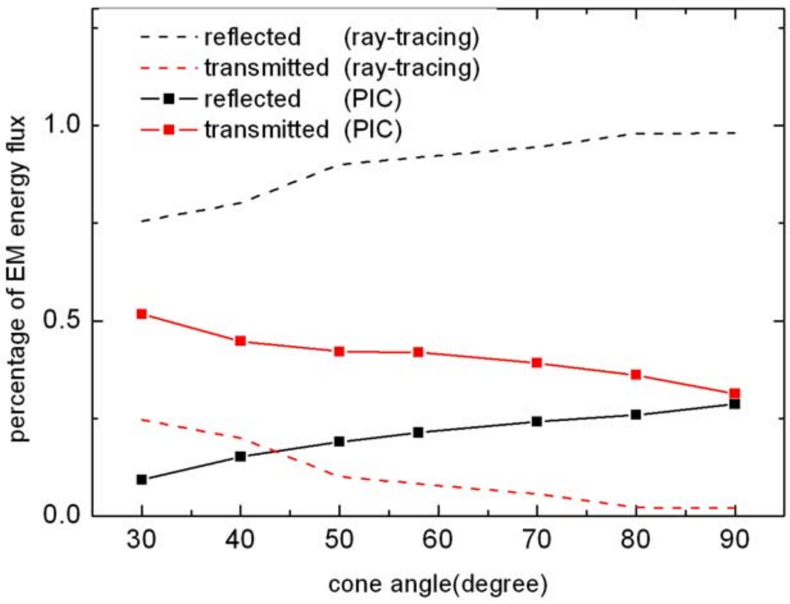
Radial profile of EM energy density, as the peak of laser pulse passes the left (black) and right (red) openings.



- **The laser is focused into a tiny spot with great enhancement in intensity.**

2.Laser Focusing by a Conical Target

The dependence of percentages of energy fluxes on cone angle **(a_0=4)**



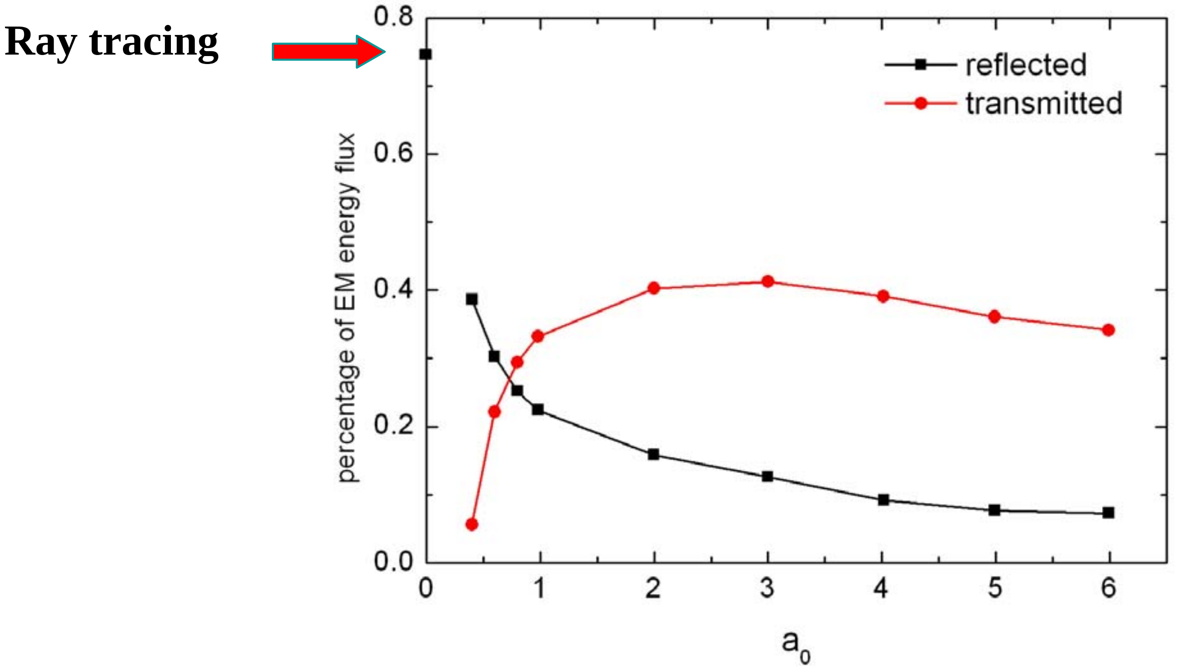
reflected (black)
transmitted (red)

— PIC simulations
--- Ray-tracing

- **The reflectivity increases and the transmission decreases with increasing cone angle.**
- **In our simulations, the conical channels have different lengths for different cone angles since the radii of the left and right openings are fixed.**

2.Laser Focusing by a Conical Target

The dependence of energy fluxes on laser intensity (30° cone target)

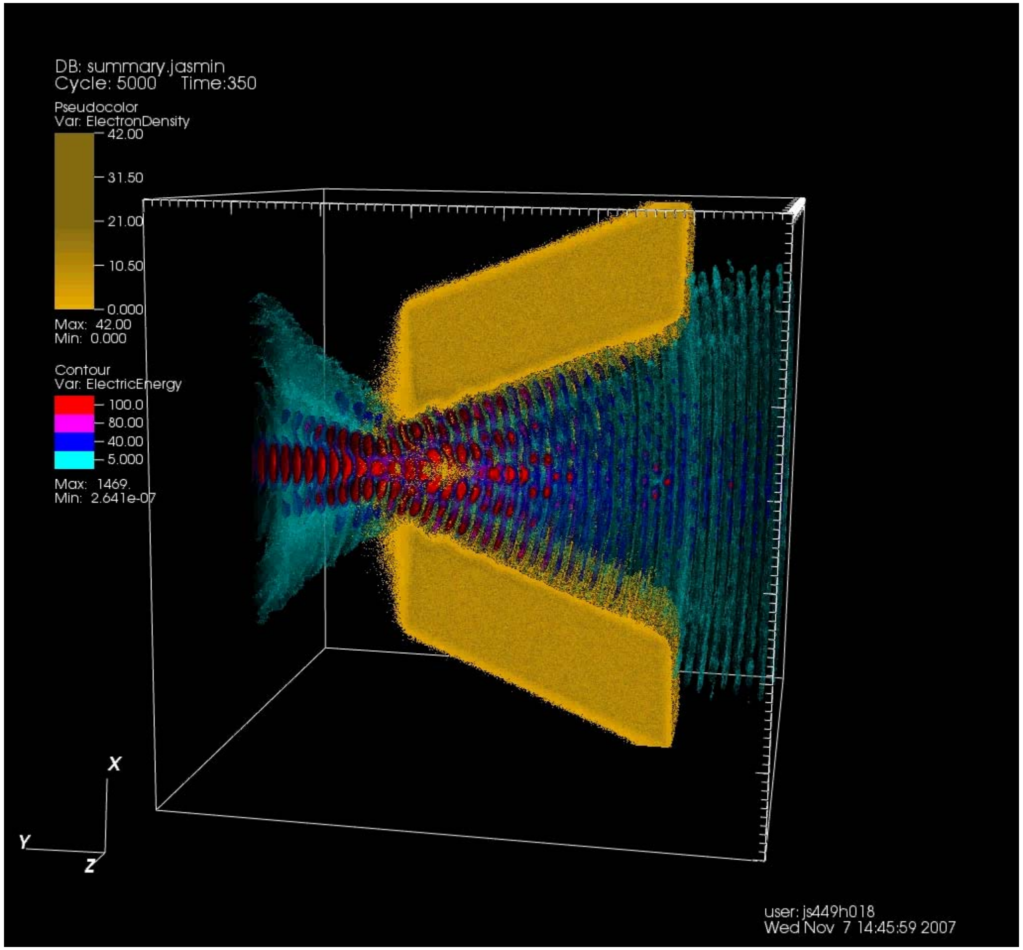


reflected (black)
transmitted (red)

- **With increasing laser strength, the modification on plasma boundary becomes more significant, as an expense, more laser energy is absorbed.**
- **For $a_0>1$, transmission remains in the level of 40%.**
- **For $a_0<1$,the reflection quickly increases while absorption decreases, approaching the limits of ray tracing.**

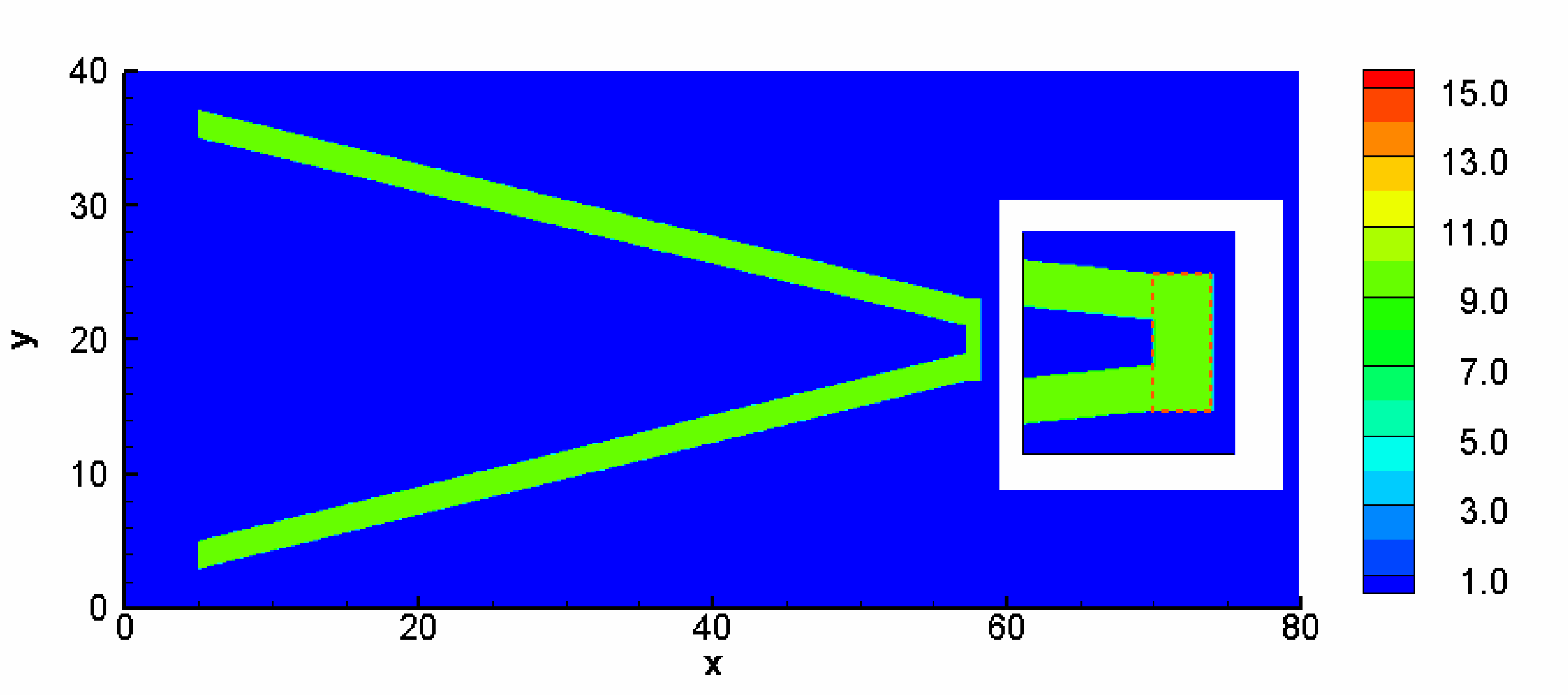
2.Laser Focusing by a Conical Target

3D simulations (by Zheng Chunyang)

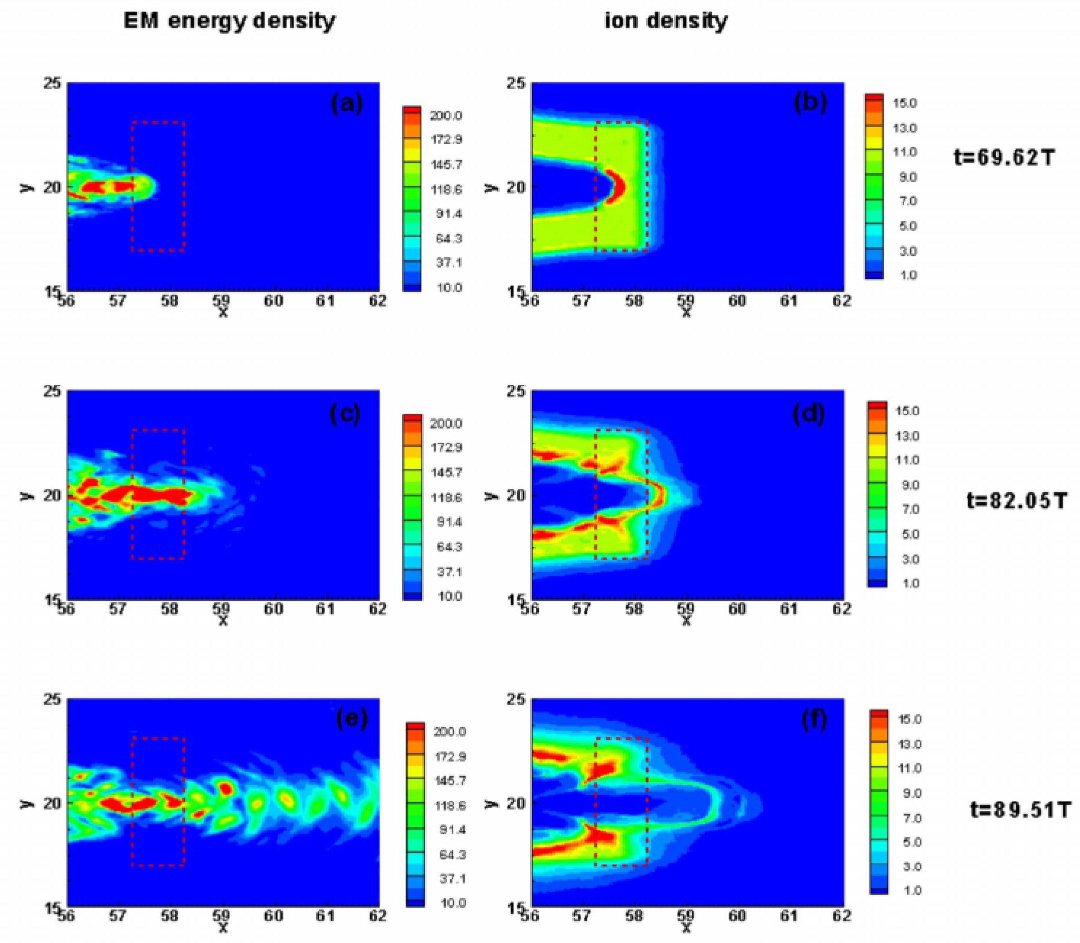


3.Generation of Energetic Ion Bunches

- **Can energetic ions be produced by such a highly concentrated laser pulse ?**
- **To investigate the ion acceleration, a foil (10n_c density, 1λ thickness) is attached to the tip of the conical target.**



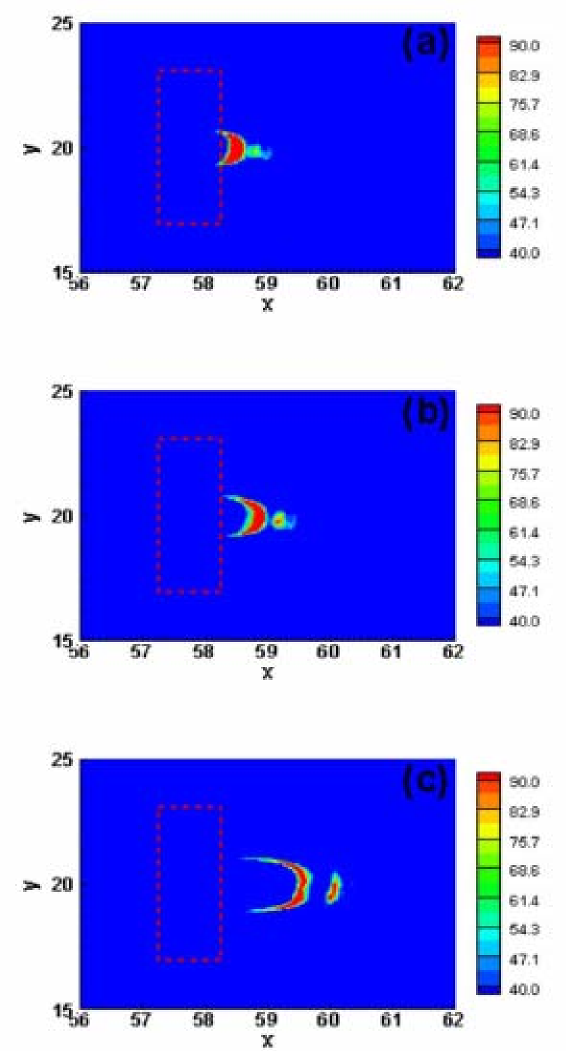
3.Generation of Energetic Ion Bunches



- **The enhanced light can pass though the foil.**
- **The center part of the foil is completely punched out.**

3.Generation of Energetic Ion Bunches

ion energy density



t=82.05T

t=84.53T

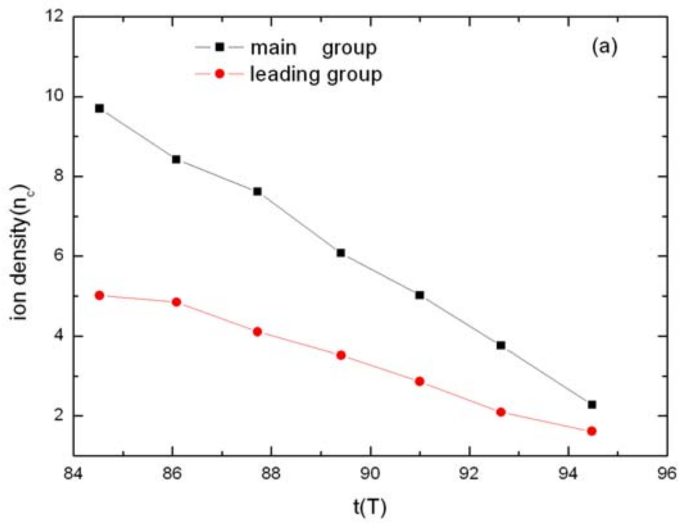
t=89.51T

- Two groups of highly localized energetic ion bunches are produced.
- The leading group, of low density and wide spatial spread, is due to TNSA.
- The main group, in the form of a thin high-density layer, is due to shock acceleration.

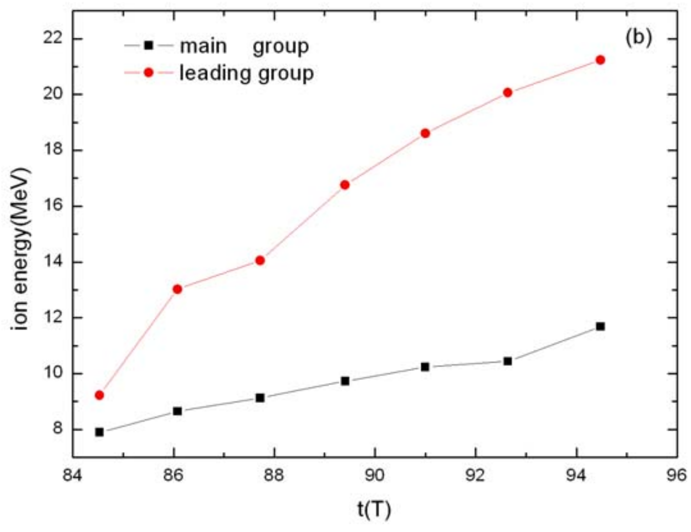
3.Generation of Energetic Ion Bunches

The evolutions of the peak ion densities and energies of two groups of ion bunches (the leading group (red), main groups (black))

ion density



ion energy

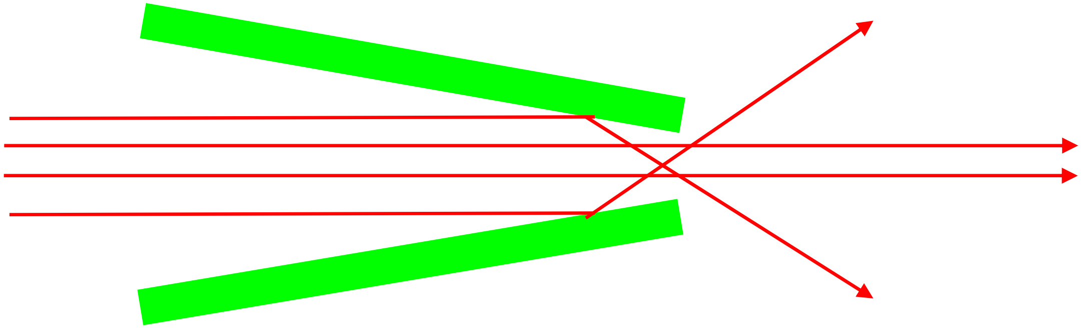


- **The energies (densities) of two groups of ion bunches continue to increase (decrease), respectively.**

Thanks for your attentions ！

2.Laser Focusing by Conical Target

- **For less intense light, the cone walls act like mirrors and the propagation of the laser pulse can be studied using ray tracing.**



- **The laser light reaching the tip is limited to the light near the center part of the cone.**
- **The transmission is limited, and transmitted rays will not be conversed, so light can not be focused by a cone.**