上海交通大學
SHANGHAI JIAO TONG UNIVERSITY

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Overview of Laser-Plasma Acceleration Programs in Asia

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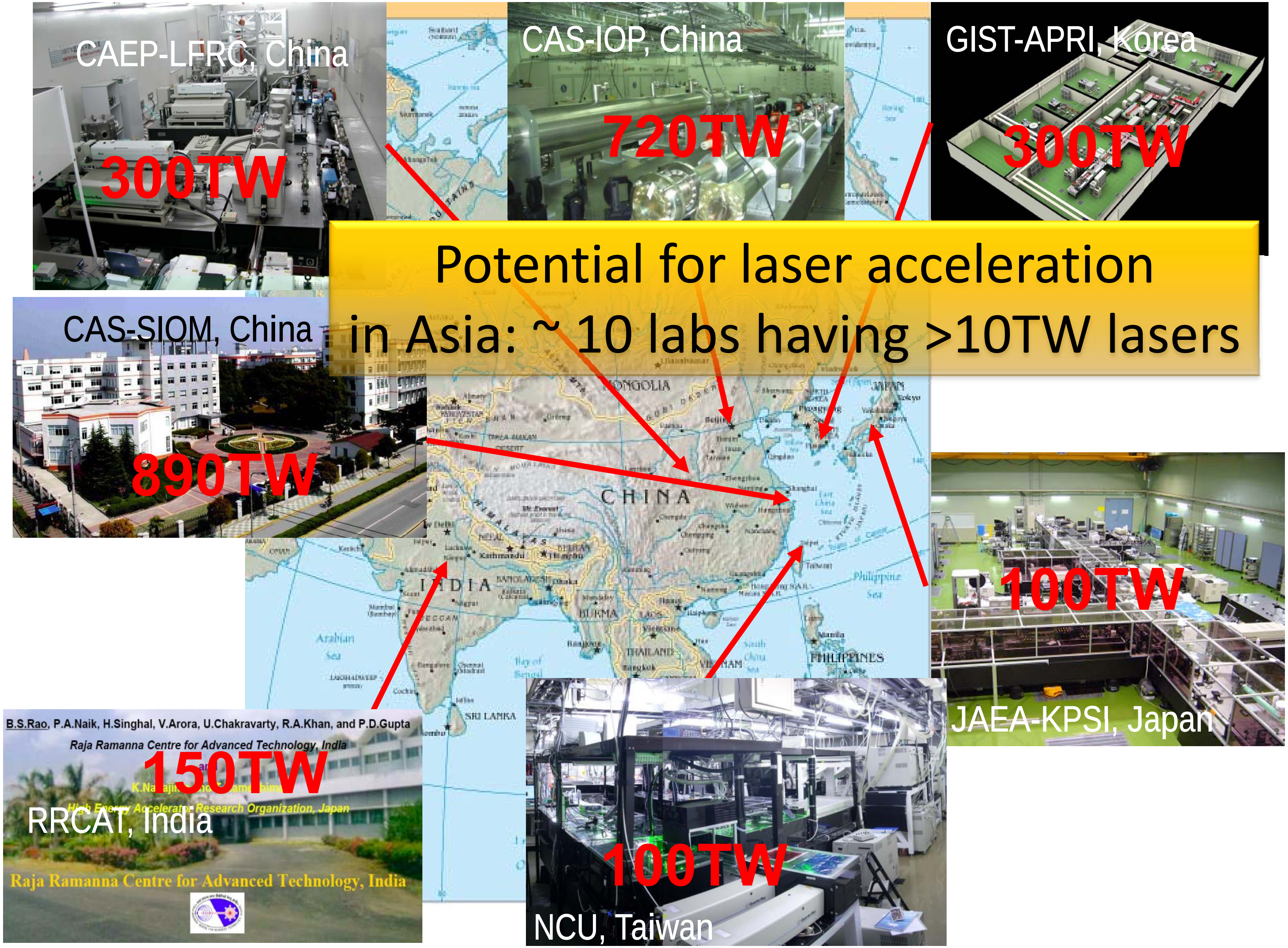
Outline

- Overview of the Asian Activities
- Progress on electron acceleration in China
- Progress on ion acceleration in China
- Concluding remarks



Potential for laser acceleration
in Asia: ~ 10 labs having >10TW lasers
CAEP-LFRC, China
300TW
CAS-IOP, China
720TW
GIST-APRI, Korea
300TW
CAS-SIOM, China
890TW
JAEA-KPSI, Japan
100TW
B.S.Rao, P.A.Naik, H.Singhal, V.Arora, U.Chakravarty, R.A.Khan, and P.D.Gupta
Raja Ramanna Centre for Advanced Technology, India
150TW
RRCAT, India
Raja Ramanna Centre for Advanced Technology, India
100TW
NCU, Taiwan
CHINA
MONGOLIA
INDIA
JAPAN
PHILIPPINES
THAILAND
BURMA
SRI LANKA
Arabian Sea
Bay of Bengal
Philippine Sea

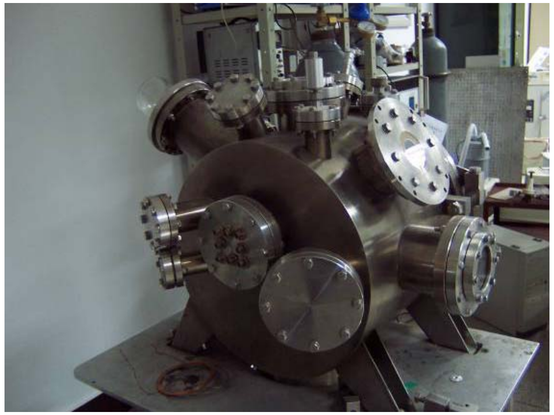

Asian Summer School on Laser Plasma Acceleration and Radiations
August 7-11, 2006, Beijing, China
The 2nd Asian Summer School
on Laser Plasma Acceleration and Radiations
August 6-10, 2007, Kyoto, Japan
5th Asia Summer School and Symposium on
Laser-Plasma Acceleration and Radiation
August 16~20,2010 Shanghai, China
Host Institute
State Key Laboratory of High Field Laser Physics
Shanghai Institute of Optics and Fine Mechanics,
Chinese Academy of Sciences
Sponsors:
National Natural Science Foundation of China,
Chinese Academy of Sciences
EXPO
SHANGHAI CHINA
Welcome to Shanghai
www.opticsjournal.net/ass2010.htm
SIOM
NSFC
Organized by ACFA, AILN

Development of laser facilities at IoP, CAS

XL-I laser system

XL-II laser system

XL-III laser system



1.4 TW
(1999)

20 TW
(2002)

350 TW
(2006)

Xtreme Light III laser system upgraded to 720TW

Institute of Physics, CAS, Beijing

XL-III laser
720TW/30fs/22J

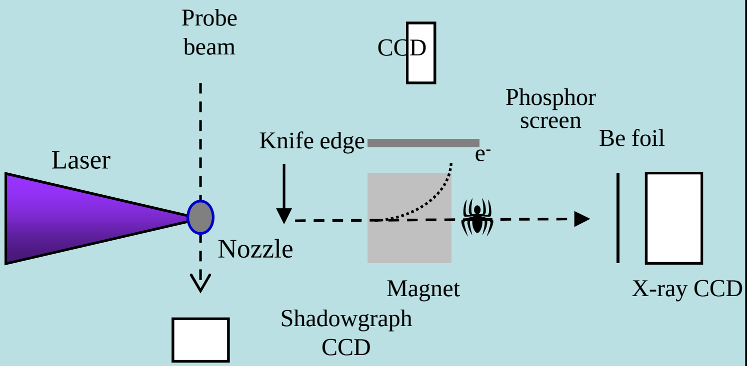
Target area and diagnostics

The group at IoP, CAS in Beijing

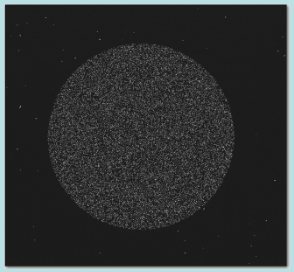
- **Fast ignition related physics (fast electrons, ions);**
- **Propagation of fs laser pulses in air and plasmas;**
- **Laser plasma acceleration for electrons and ions;**
- **Novel laser-based radiation sources (THz, x-ray, X-ray lasers) and applications;**
- **Ultrafast electron diffraction;**
- **Laboratory astrophysics;**
- **Theory and simulations on above subjects**

High contrast Ar K-shell keV source

Experimental setup

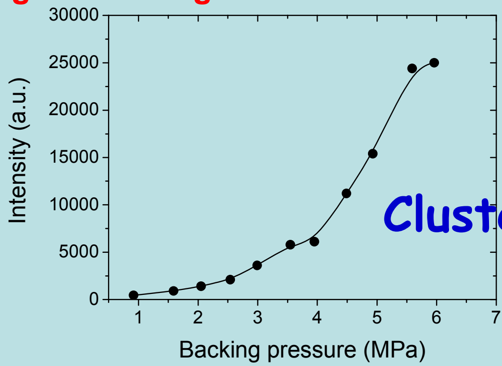


Source imaging on CCD



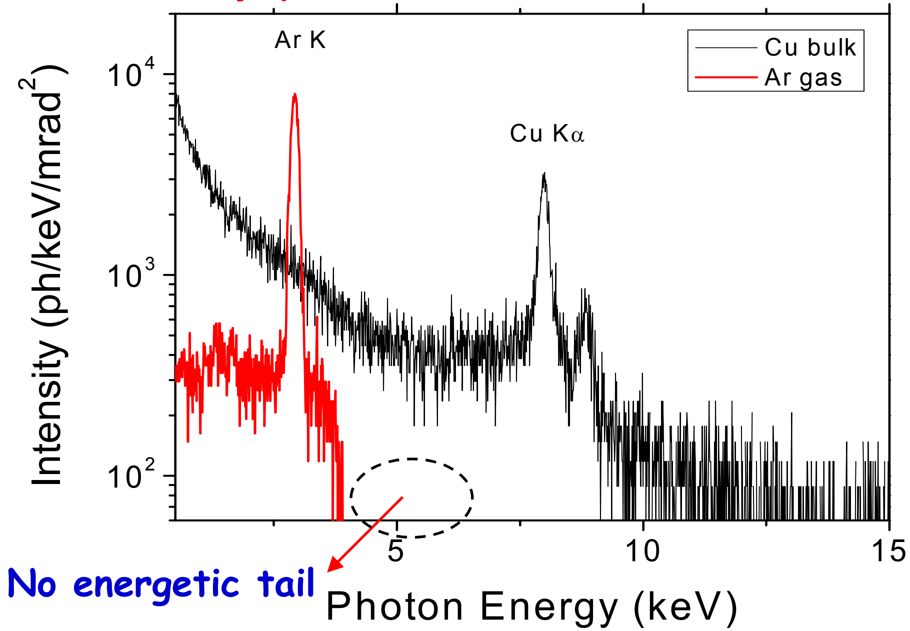
Pure, clear

Rayleigh scattering measurement



Cluster formed

X-ray spectrum



High contrast: peak/bkgd>20

E_K/E_{total}>70%

Quasi-monochromatic

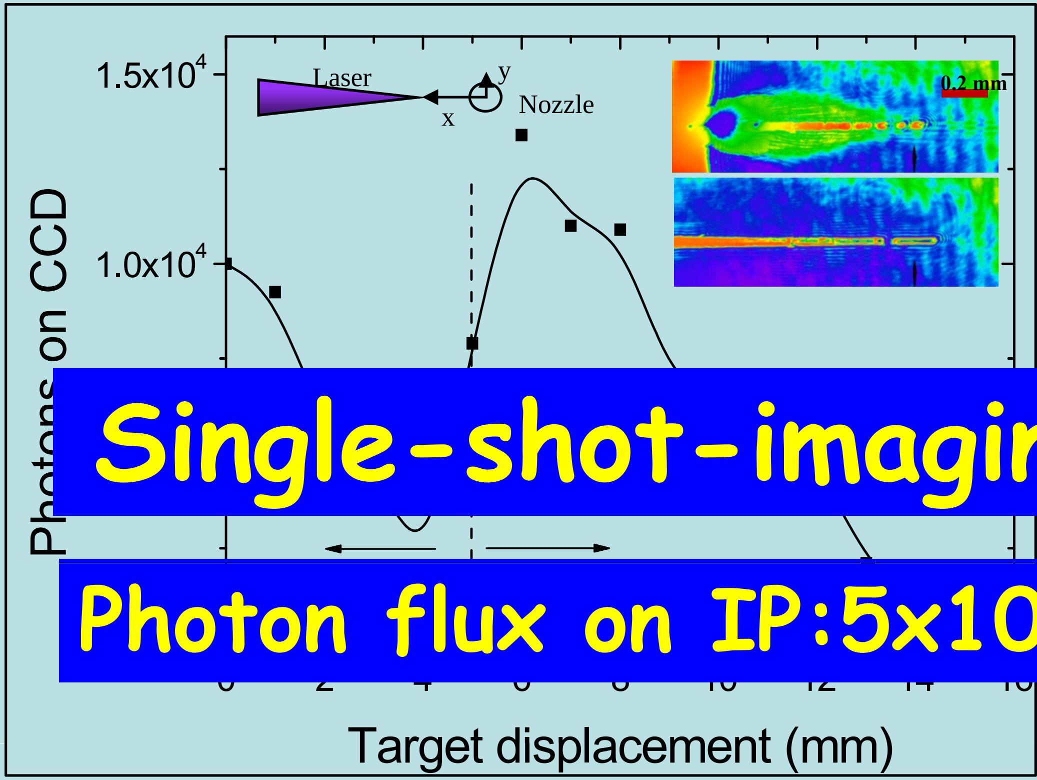
Intense: B=10^{20} phs/s/mm^2/mrad^2

Coherent (small size=12 μm)

Directional: $I_{Long.}/I_{Trans.}$>10

- Continuum background
  $\Sigma N_{K\alpha}/\Sigma N_{xray}$ ~ 10%
  --polychromatic

New progress: Ar keV flux x10 !!



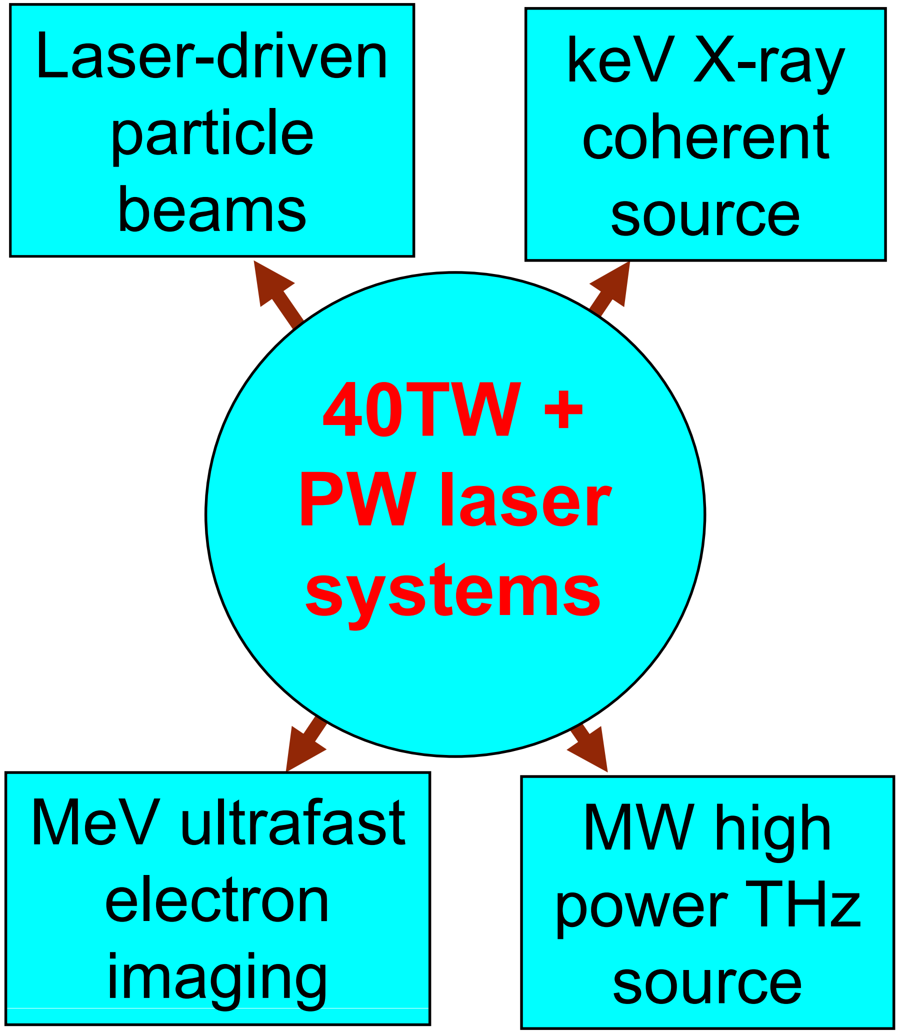
E_L(mJ)	800
τ (fs)	28
Contrast (ps ASE)	>10^9 (adj.)
Kα flux	1.1x10^4
	[illegible]0
Brightness (phs/s/mm²/mrad²)	**3.6x10^21**

Single-shot-imaging available !!

Photon flux on IP:5x10^6 phs/cm^2

L.M.Chen et al., PRL,104, 215004(2010)

New facilities to produce 4 beam lines for potential applications at SJTU



Potential applications: condensed matter physics, medical applications, laser fusion, etc.

LPA medical system R&D with Robotics

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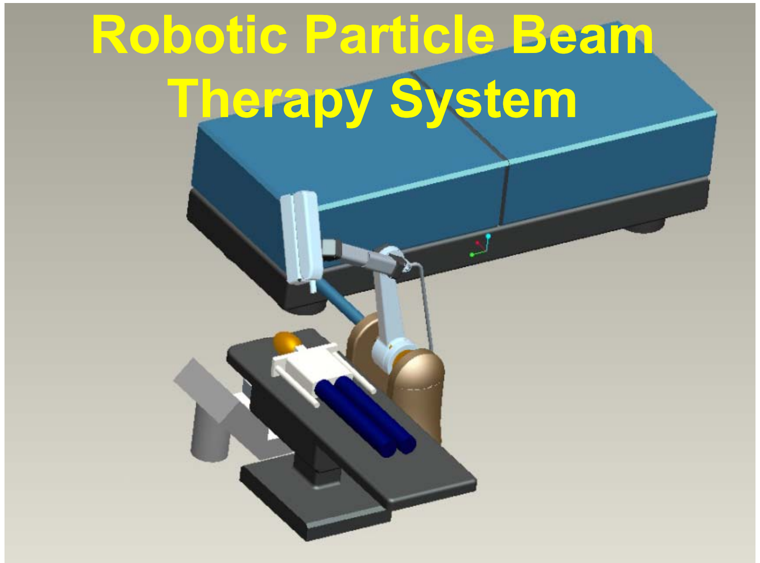
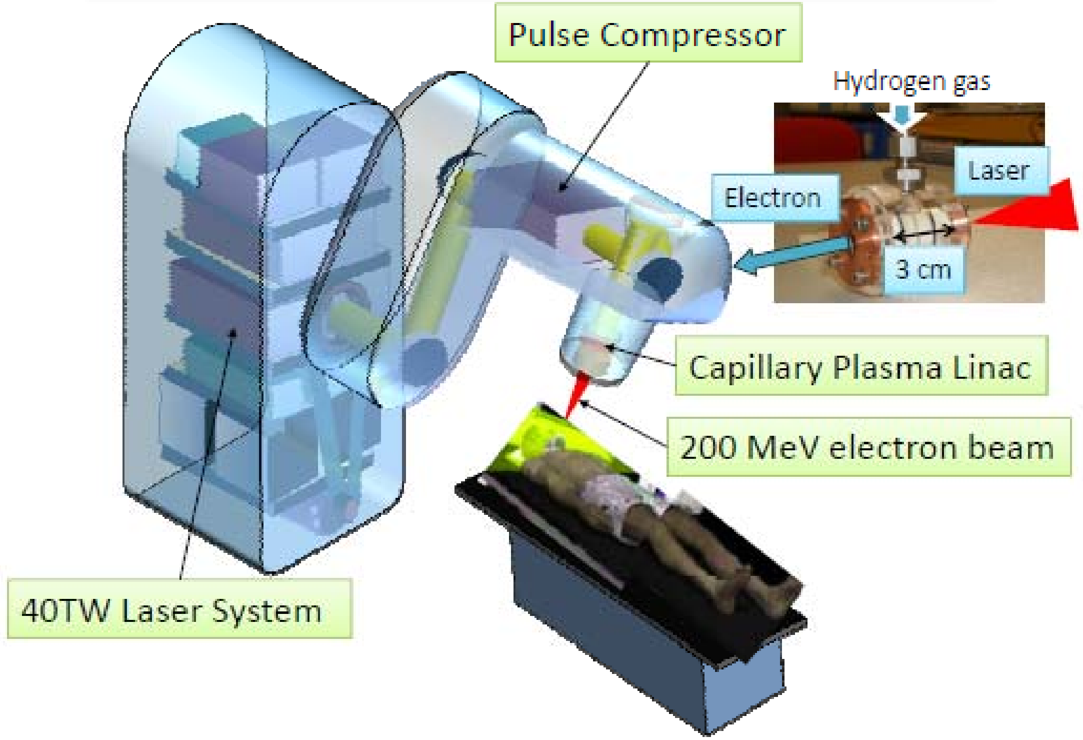
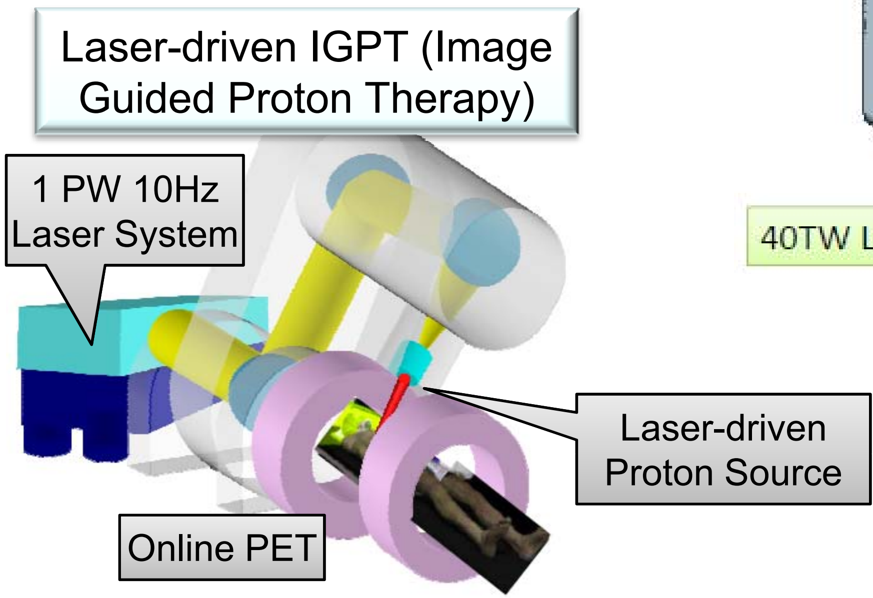


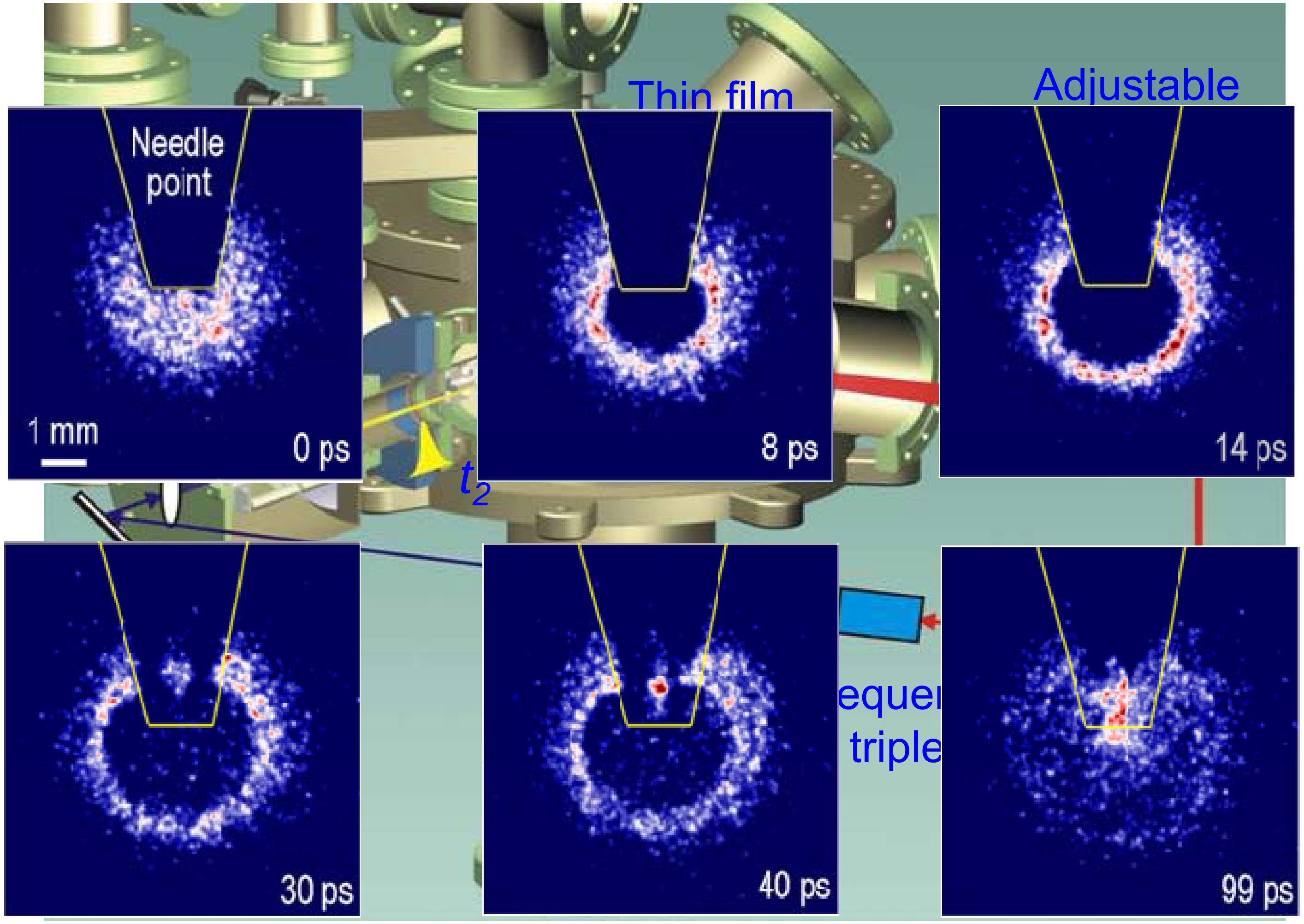
Laser-driven x-ray Imaging

Laser-driven Electron Therapy System





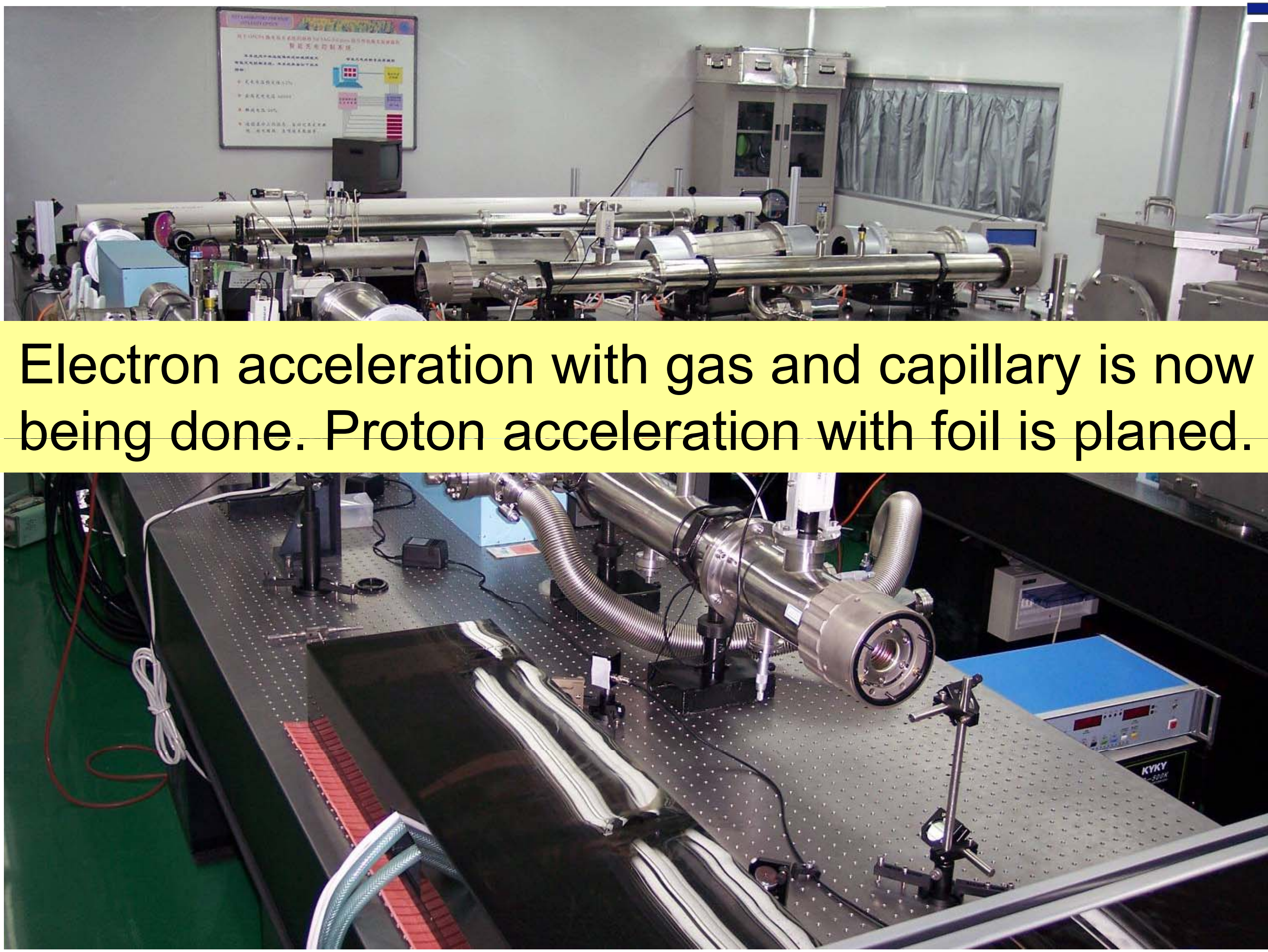
Using 500fs electron beams to diagnose the plasma dynamics



60keV-500fs Ultrafast electron diffraction imaging system

890TW/30fs CPA Short Pulse Laser

State Key Laboratory of High Field Laser Physics, SIOM, CAS

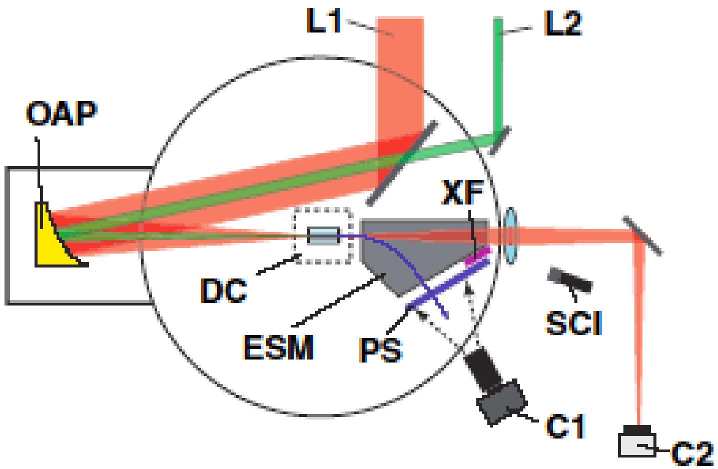


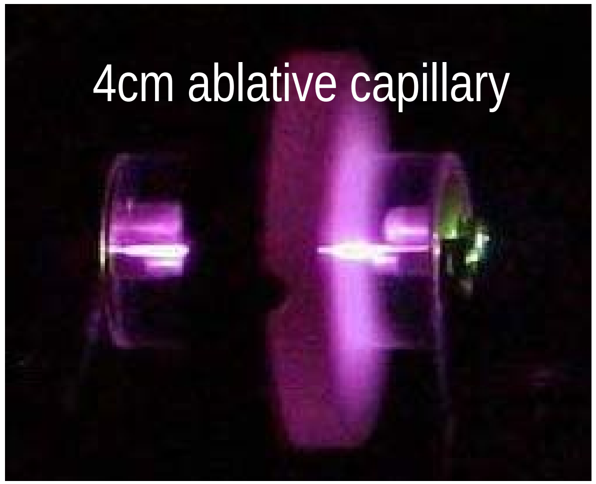
Electron acceleration with gas and capillary is now being done. Proton acceleration with foil is planed.

This system is based on CPA scheme, with a peak power of 890TW and a pulse duration of 29fs. It consists of a Ti:sapphire oscillator, a pulse stretcher, four stages of amplifiers and a four-grating pulse compressor.

Laser acceleration experiment at LFRC, CAEP

300TW 30fs laser
SILEX, CAEP, China





Accelerator Lab of Tsinghua University

- Faculty
  - 15 faculties and more employee
  - About 20 graduate students
- Research Activities
  - Low Energy Linear Accelerators and Their Applications
  - Fundamental Accelerator Physic and technology
    - High brightness electron injectors
    - Electron beam and laser beam interaction
    - Accelerating Structures
    - Beam dynamics

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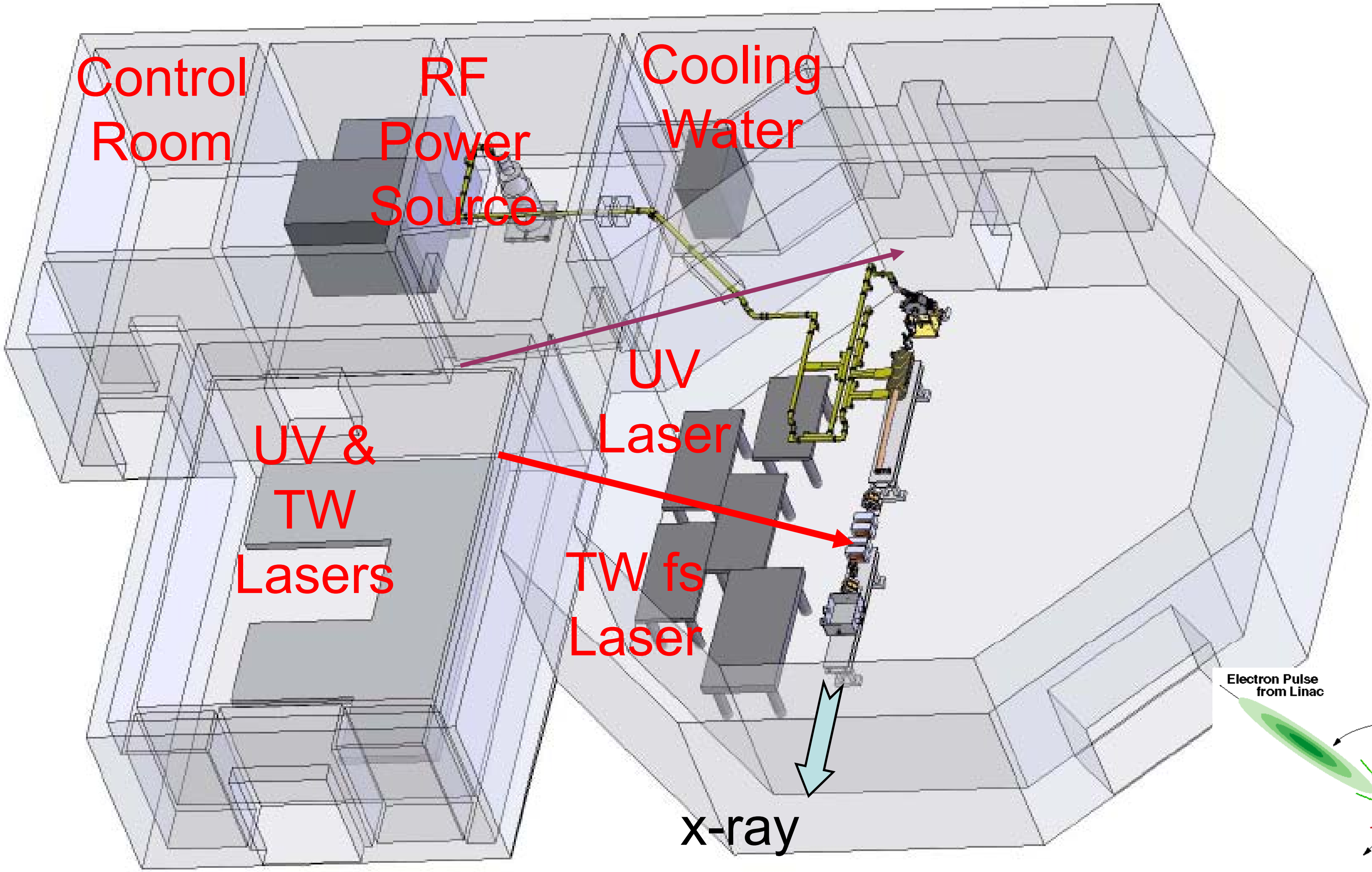
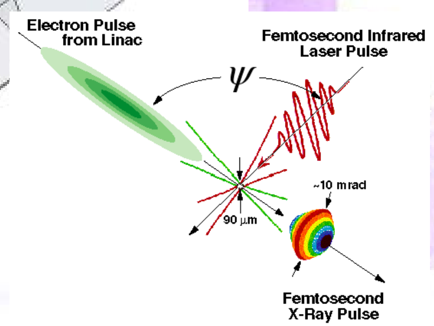
Tsinghua University

Research on Thomson scattering X-ray





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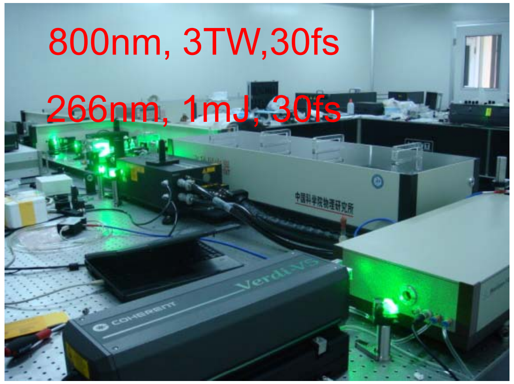
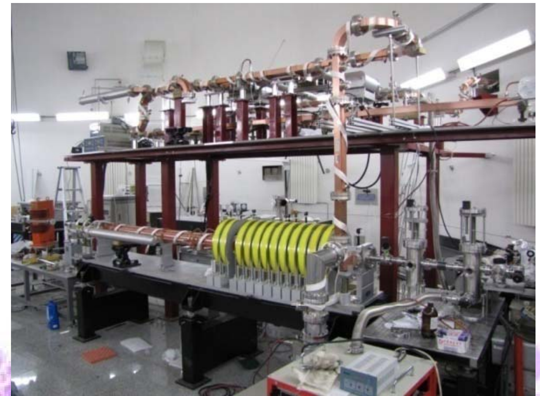
Thomson scattering experiment with photocathode RF gun and TW laser

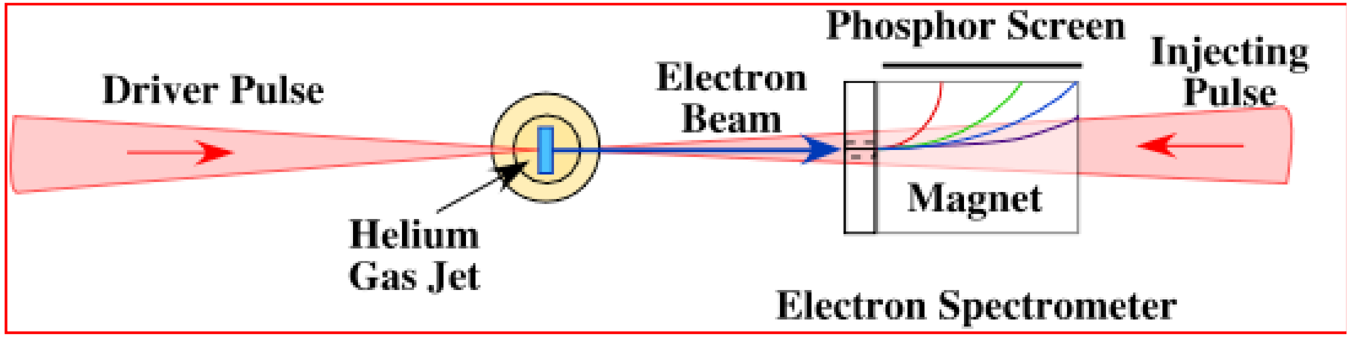




Subsystem installation completed

Experiment of head-on injection at JAEA-KPSI

Japan



Driver pulse
E=400 mJ, τ=40 fs
ϕ=34 μm, I=3x10^{18} W/cm^2

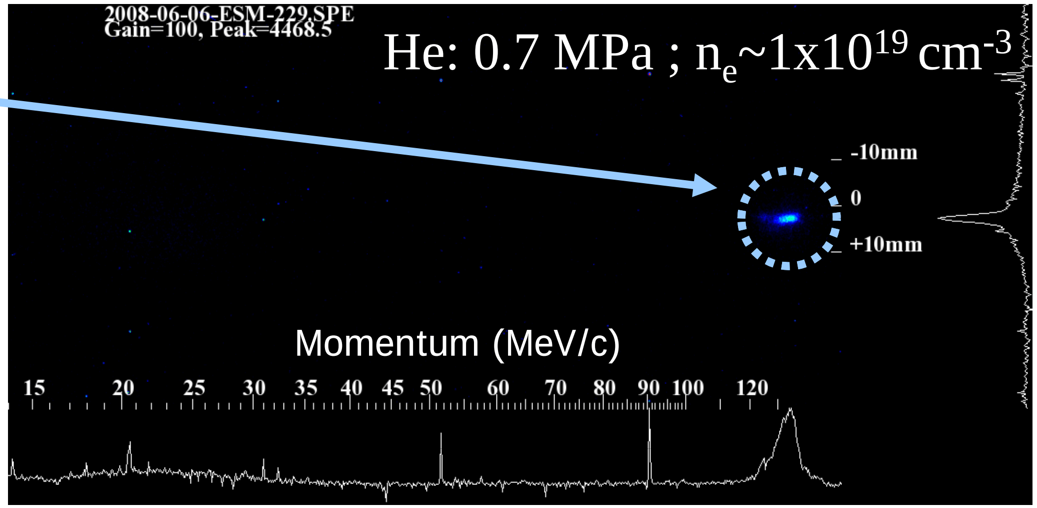
Injecting pulse
E=30 mJ, τ=50 fs
ϕ=50μm, I=8x10^{16} W/cm^2

Mono-energetic electron beam

Q=8.7 pC

p=134 MeV/c (FWHM 11MeV/c)

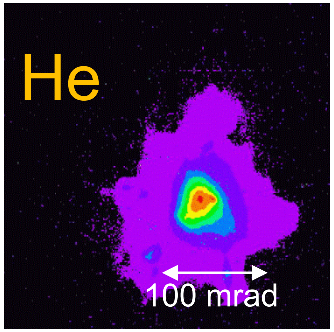
θ_{FWHM}=4 mrad

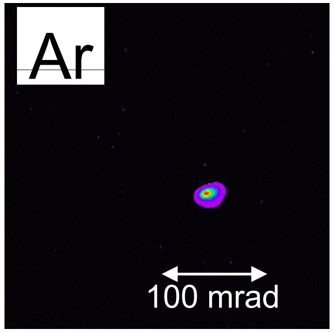


H. Kotaki, et al., Phys. Rev. Lett. **103**, 194803 (2009).

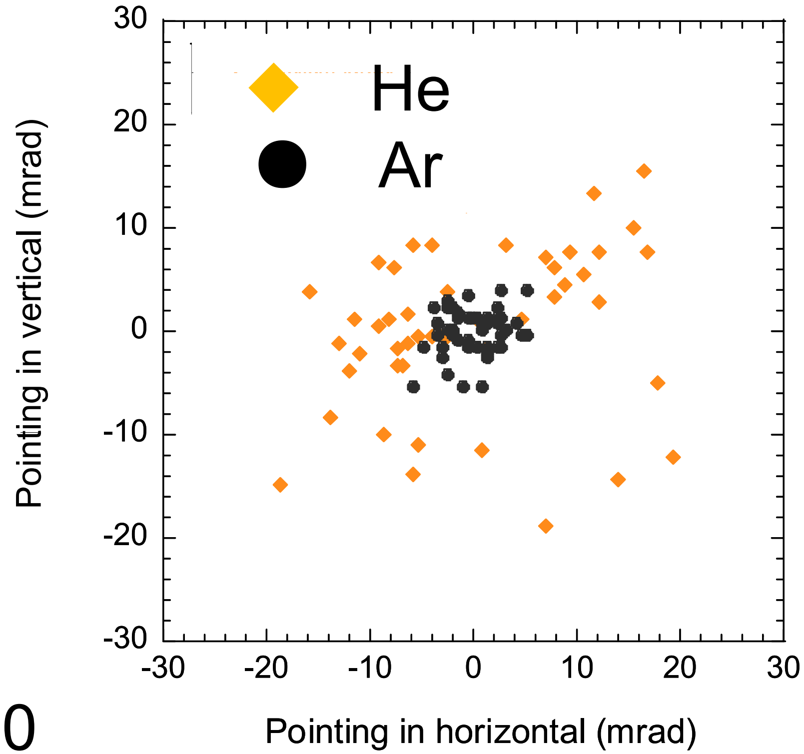
Stable e-beam generation by multi-stage ionization scheme

>1 MeV electrons





Speed x100



Laser:
E=160 mJ
t=40 fs
I=9x10^{17} W/cm^2

Pointing stability(RMS) for 50 shots
θ=9.8mrad@He
θ=2.4mrad@Ar

Beam divergence for 50 shot(RMS)
θ=29.8±8.8mrad@He
θ=10.4±2.0mrad@Ar

Helium (neutral gas density: 2.2x10^{19} cm^{-3})
Argon (neutral gas density: 0.5x10^{19} cm^{-3})

Pointing stability in Ar is 4 times better than that in He

M Mori et al., Phys. Rev. ST-AB 12, 082801 (2009)

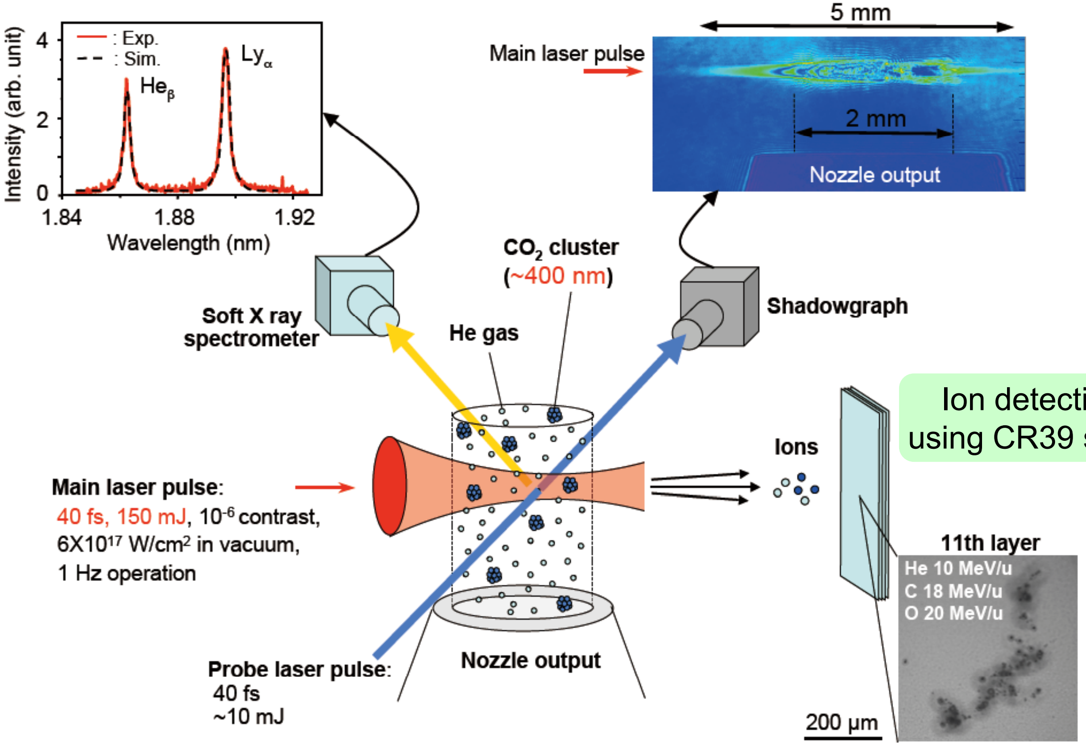
Energy Increase in Ion Acceleration via Cluster Target

振興調整費

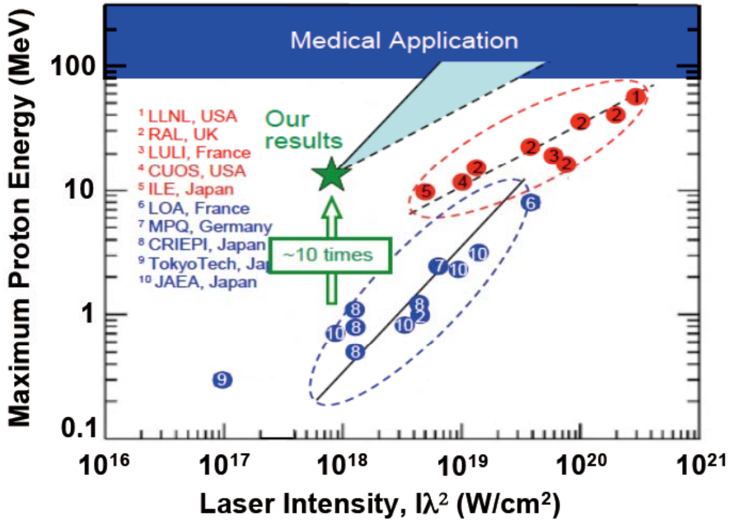
Soft X ray spectrum of sub-critical plasma

Long channel created in cluster target

Ion detection using CR39 stack



Tenfold improvement in maximum ion energy



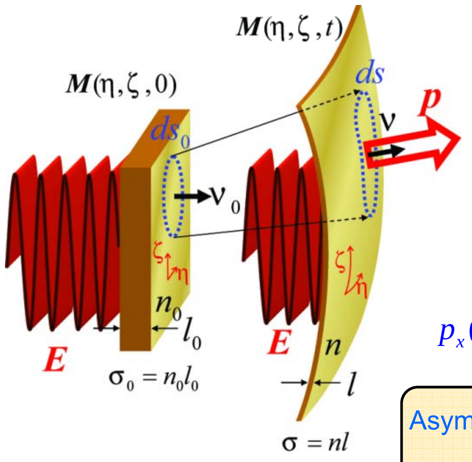
- **Ions, accelerated up to 10-20 MeV/u (Carbon) are detected.**
  → Different regime from the conventional TNSA scenario.
- **2D-PIC simulation predicts that Magnetic-Field-Assisted-TNSA might work.**

Y. Fukuda et al., Phys. Rev. Lett. 103, 165002 (2009)

Unlimited Ion Acceleration by Radiation Pressure

In the radiation pressure dominated regime, ion energy can be greatly enhanced by a transverse expansion of a thin target. The expansion decreases the number of accelerated ions in the irradiated region increasing the energy of the remaining ions. In the relativistic limit, the ions become phase-locked with respect to the electromagnetic wave resulting in an unlimited ion energy gain. This effect and the use of optimal laser pulse shape provide a new approach for great enhancing the energy of laser accelerated ions.

Evolution of thin shell irradiated by a strong electromagnetic wave



Equations of motion

$$\partial_t p_i = \frac{\mathcal{P}}{n_0 l_0}\varepsilon_{ijk}\partial_\eta x_j \partial_\eta x_k$$

$$\partial_t x_i = \frac{c p_i}{\sqrt{m_\alpha^2 c^2 + p_k p_k}}$$

$$i, j, k = 1, 2, 3$$

$$\mathcal{P} = \frac{E_L^2}{2\pi}\frac{c+v}{c-v}$$

$$p_x(t) = m_\alpha c \left(\frac{125 E_L^2 \pi_y^0 \pi_z^0}{48\pi n_0 l_0 m_\alpha^3 c}\right)^{1/5} t^{3/5}$$

Asymptotic solution for ion momentum dependence on time

Wave phase: $\psi = \omega_0\left(t - \frac{x}{c}\right) = \omega_0 \int_0^t (1-\beta(t'))dt'$

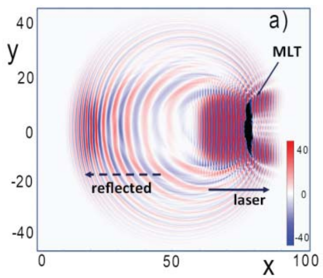
$$\rightarrow \omega_0 \tau_k \frac{(t/\tau_k)^{1-2k}}{1-2k} + \frac{\omega_0 \tau_k}{\pi^{1/2}}\Gamma\left(\frac{2k-1}{2k}\right)\Gamma\left(\frac{2k+1}{2k}\right)$$

$t \rightarrow \infty$

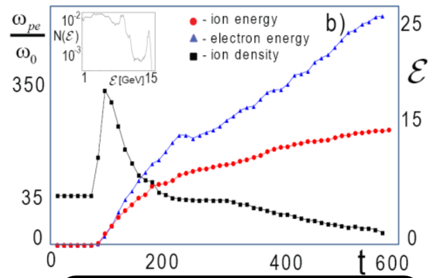
For $\frac{p_x(t)}{m_\alpha c} = \left(\frac{t}{\tau_k}\right)^k$

If k<1/2, the phase Is locked

Laser-Mass-Limited-Target interaction in Radiation Pressure Dominated Acceleration regime: PIC computer simulation



Laser pulse, reflected radiation and Mass Limited Target



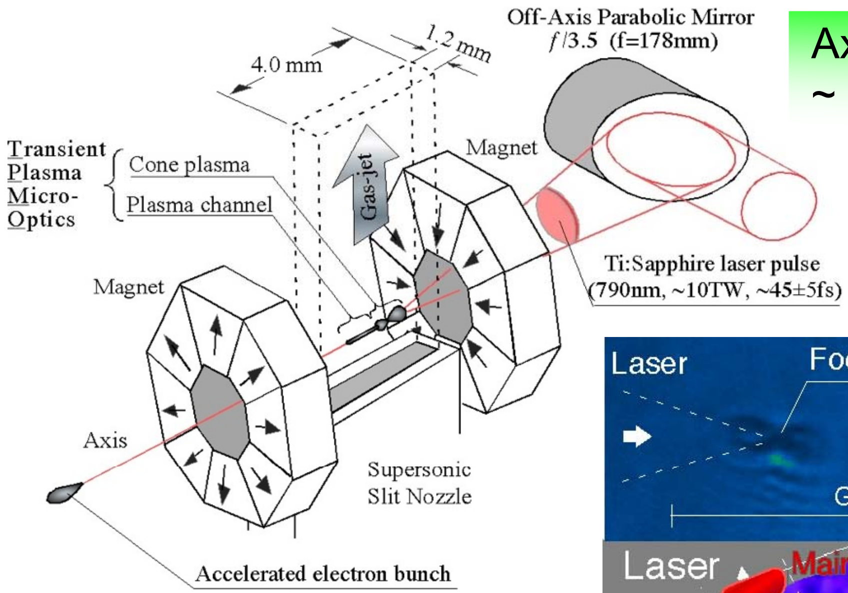
Electron and ion energy and density v.s. time
Inset: ion energy spectrum

S. V. Bulanov et al., Phys. Rev. Lett. 104, 135003 (2010)
S. V. Bulanov et al., Phys. Plasmas 17, in press (2010)

Photon Pioneers Center,
Osaka University

Repeatable e-beam generation by LWFA with a plasma micro optics

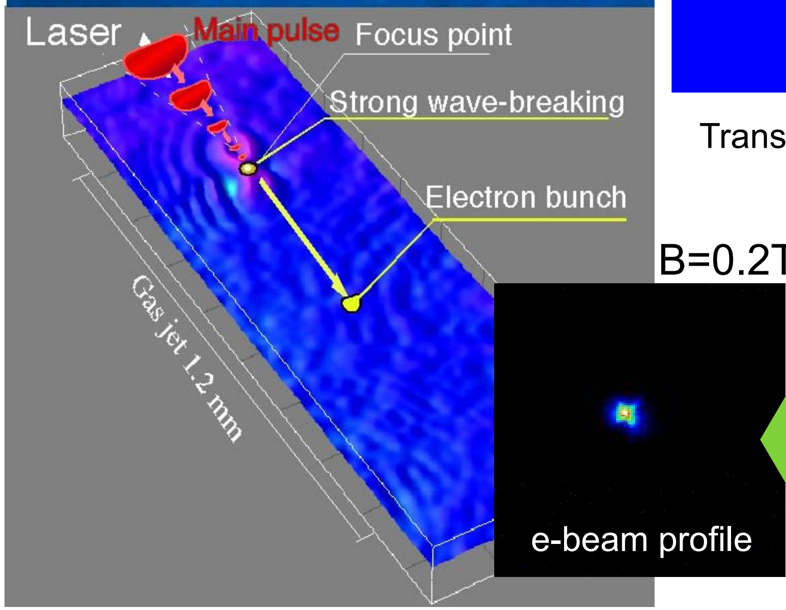
By T.Hosokai



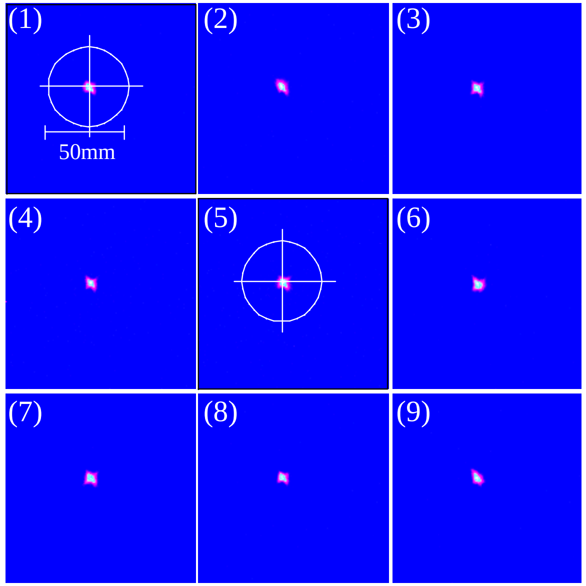
Experimental setup

Axal external B-field
~ up to 1T

Shadow graph image



9 successive shots



Transverse geometrical emittance
~0.02π mm mrad

He Gas ~4x10^{19}cm^{-3}

$F^{\#}$=3.5 (f = 178mm)

Laser 6 ~ 12 TW

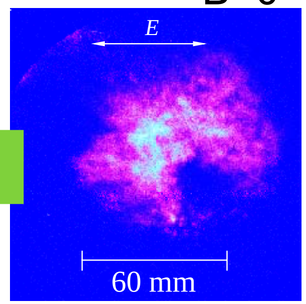
Focal spot ~ 5-7μm(1/e^2)

Rayleigh length ~50μm

B=0.2T

e-beam profile

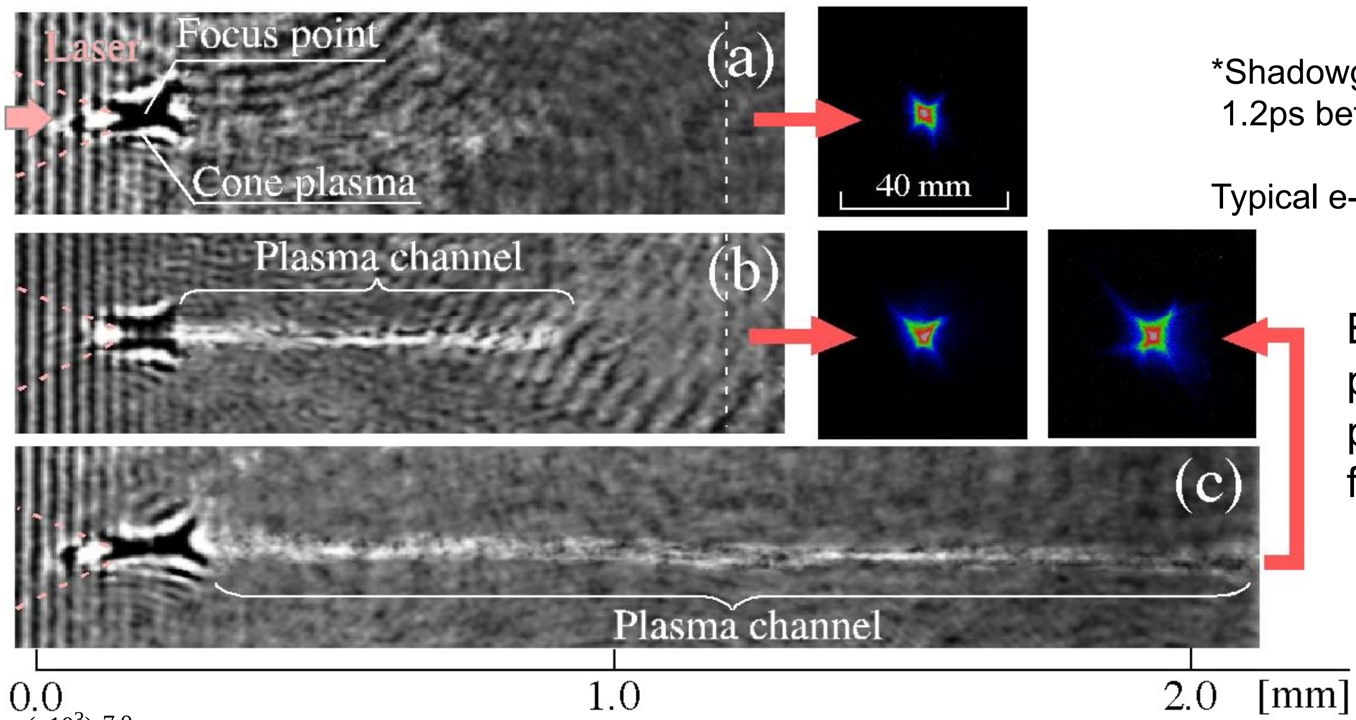
B=0



T.Hosokai,et al.,Phys Rev.Lett. 97, 075004 (2006)

Demonstration of 2-staged LWFA

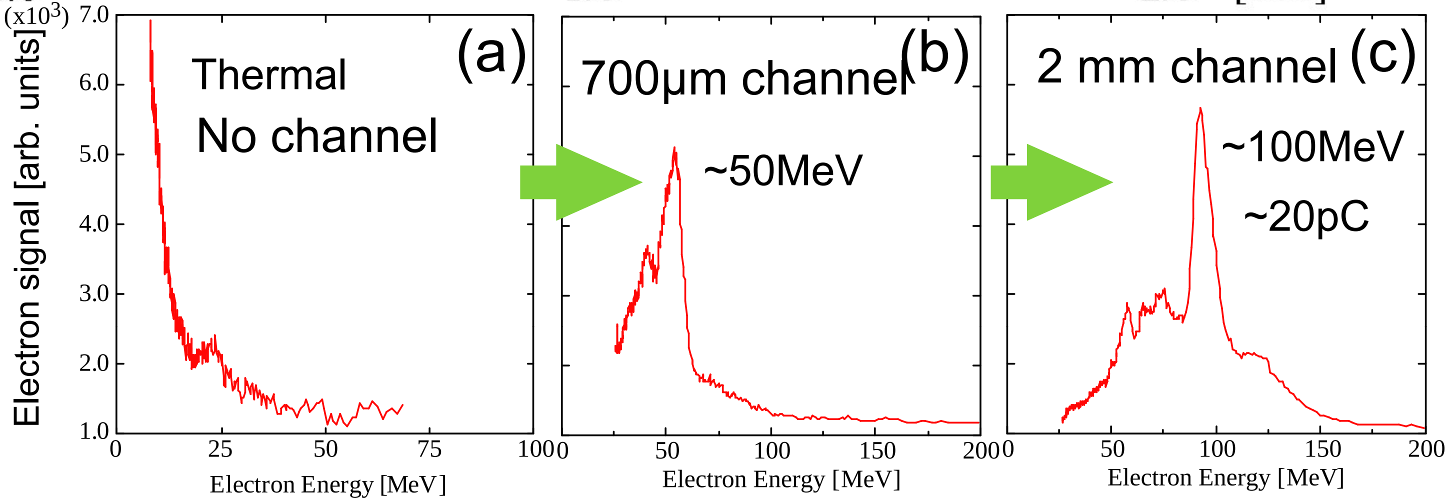
Osaka PhoPs
Photon Pioneers Center, Osaka University



*Shadowgraph:
1.2ps before main pulse

Typical e-beam profile

By increase the picosecond pedestal pulse energy and B fields



T.Hosokai,et al., Appl. Phys. Lett. **96**,121501 (2010)

S. Kawata/Utsnomiya Univ.

Summary: Dream of Laser Accelerators

=> Compact Accelerator

/ Atto physics – Atto Second~ 10^{-18}sec

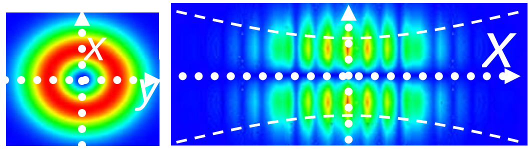
-> One can observe ---

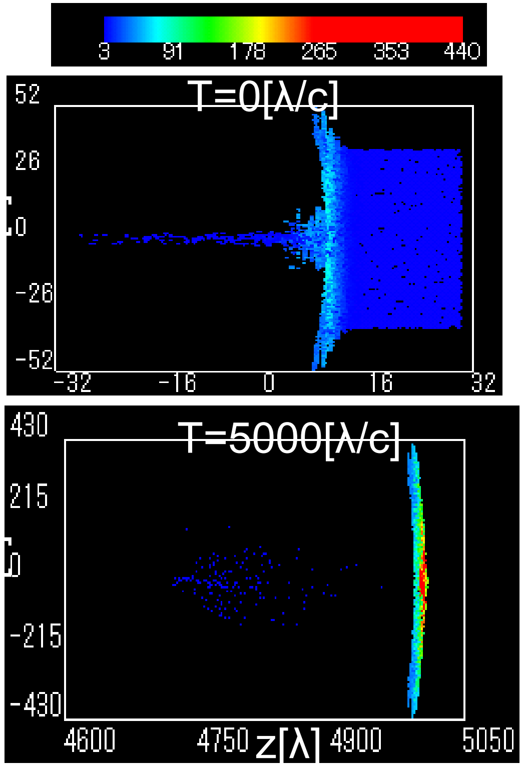
- electron motion in an atom
- light wave behavior
- electron motion in chemical reaction

~150atto second

<- electron movement time scale in Hydrogen atom

Pre-accelerated elecron beam is compressed and confined to produce an atto-second high-density e-bunch by a short-pulse **TEM10+01 mode laser**.





Results

bunch size: Transverse（Y）: 4.81λ

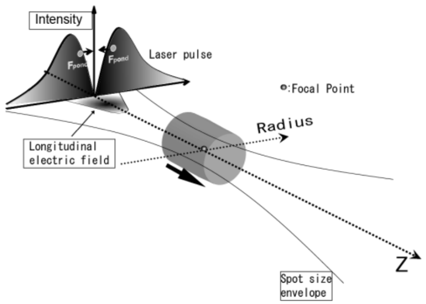
Longitudinal（Z）: 0.187λ (~500 attosecond)

Averaged energy ~231 (MeV)

Normalized transverse rms emittance 0.96 (π mm mrad)

Momentum spread 3.5%

Number density 43 times n_0

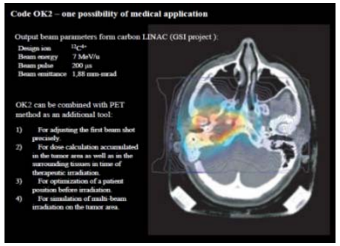


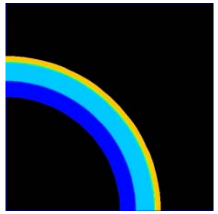
S. Kawata/Utsnomiya Univ.

Summary: Dream of Laser Accelerators

/ High-quality laser ion beam

- Cancer therapy
- Ion Inertial fusion

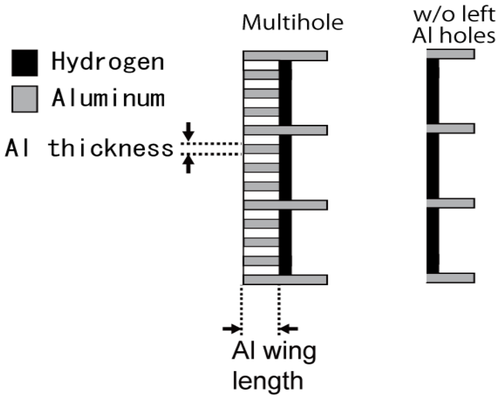


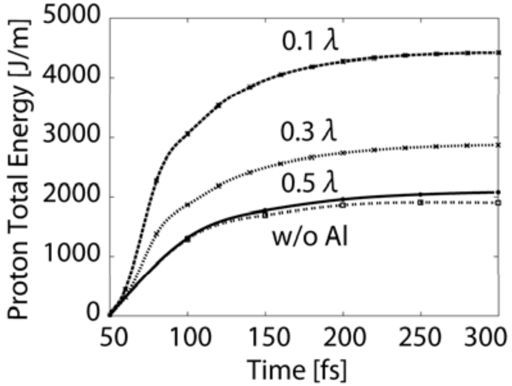


Results: 1. Collimation!

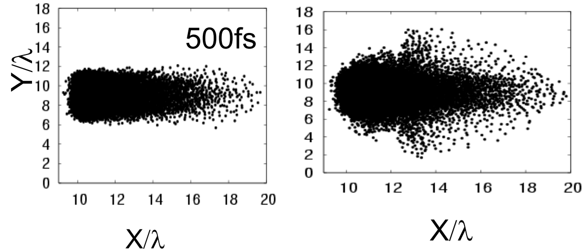
2. High-efficiency!: laser -> ions > ~26%;

laser->Proton energy conversion>13~15%





High-efficiency!



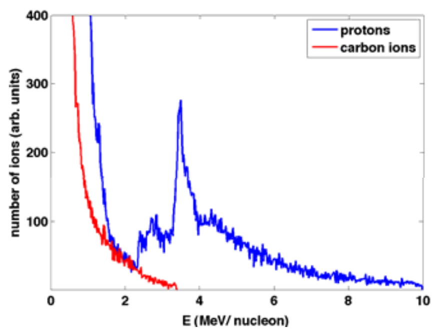
Collimation!

Structured target enhances laser-to-ion energy conversion efficiency. Backside structure produces a collimated ion beam.

Al + CH-ion source structured target: periodic array with structure composed of boxes of 60 nm × μm separated by 0.25 μm, material composition C^{6}+, density 0.35 g/cm^3

=> Flat target: 2.8% (Laser -> ions)

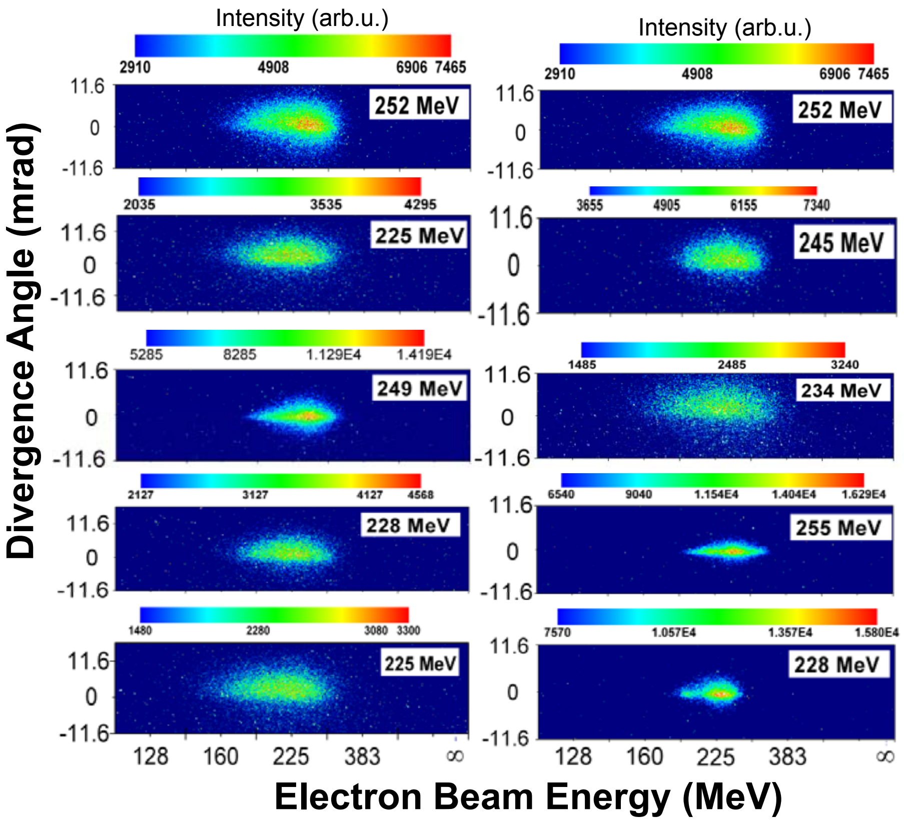
Structured target: 26%(Laser -> ions) case 3(20% C, 6%Protons)



Stable electron beams from 1 cm Gas jet and Gas-fill capillary accelerator at GIST

Korea

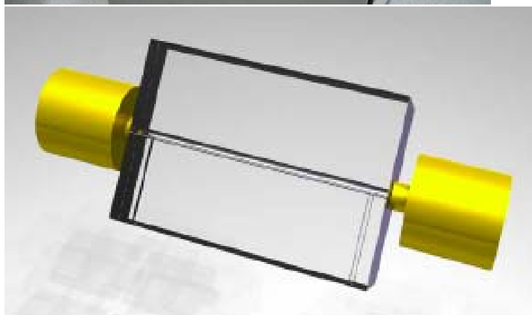
Mean electron energy = 236.9 MeV
SD/Mean E = 5 %
Charge: ~100pC
Divergence angle: ~a few mrad

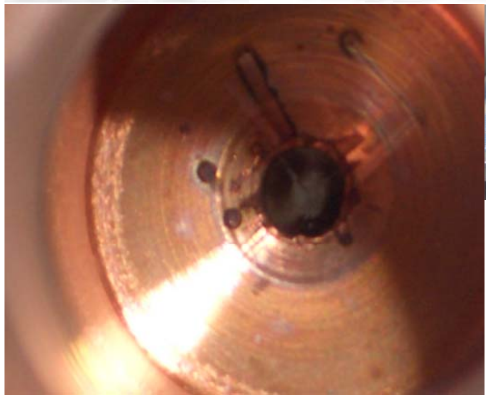


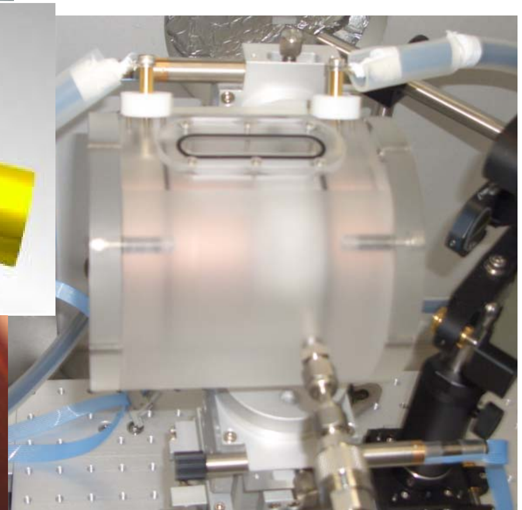
(N. Hafz et al., nature photonics, 2, 571, 2008)

GIST-APRI 100TW laser

Capillary Accelerator experiment under collaboration with GIST(Korea), Oxford Univ. (UK), KEK/JAEA(Japan)







3 cm Gas-fill Capillary

Laser-plasma based acceleration of electrons at RRCAT, Indore, India

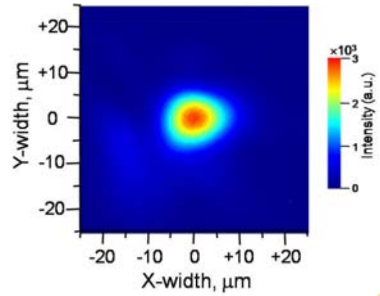
G. P. Gupta

10 TW Ti:sapphire Laser

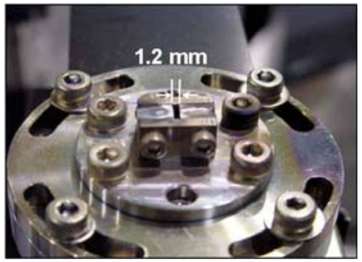
Laser Parameters

Pulse duration	- 45 fs
Pulse energy	- 450 mJ
Peak power	- 10 TW
Pre-pulse contrast	- 10^6

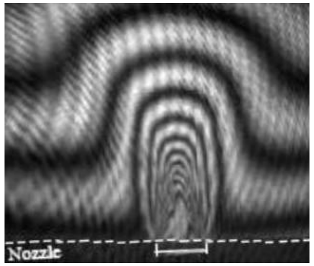
Focal spot



Supersonic helium gas-jet

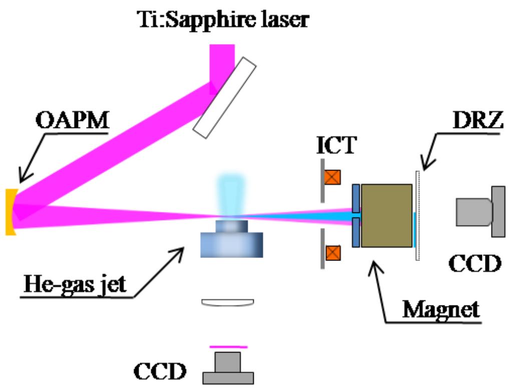


Supersonic nozzle

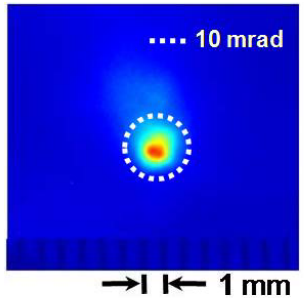


Interferogram of helium gas-jet

Experimental set-up



E-beam profile



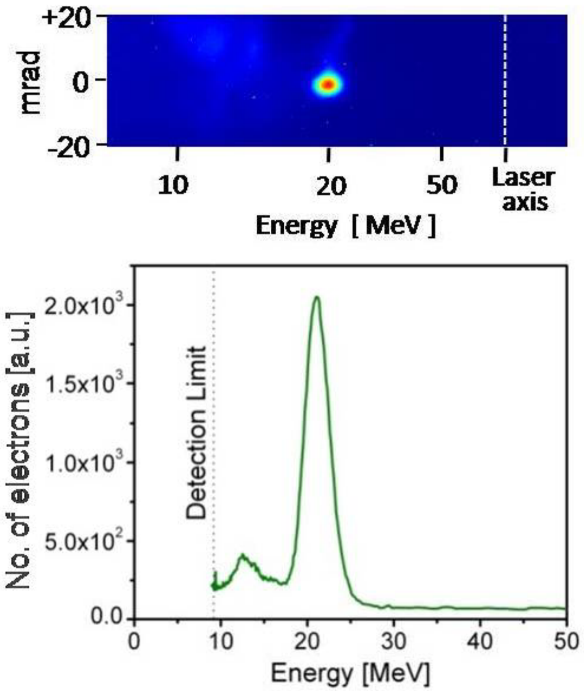
Without magnet

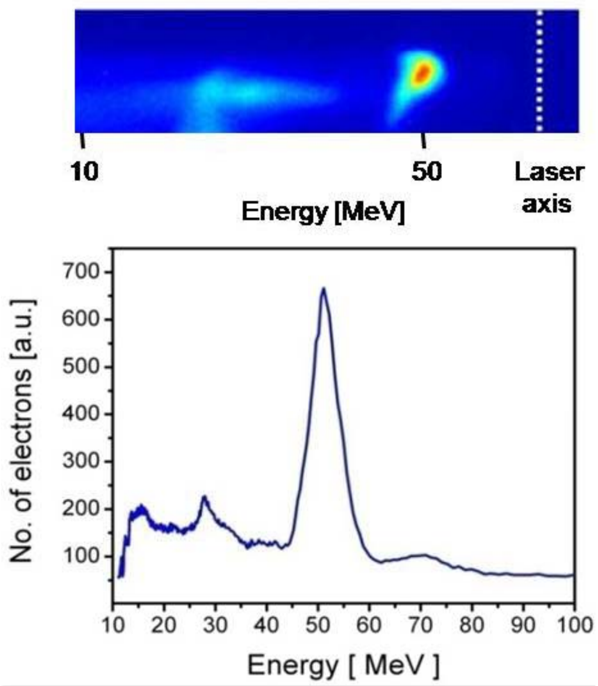
IEEE Trans. Plasma. Sci . 2008

Self-modulated laser wake-field acceleration regime

Laser-plasma based acceleration of electrons at RRCAT, Indore, India

G. P. Gupta





$n_e \sim 8.5\times10^{19}$ cm^{-3}

$I_L = 1.2\times10^{18}$ W/cm^2

$n_e \sim 6.5\times10^{19}$ cm^{-3}

$I_L = 2.4\times10^{18}$ W/cm^2

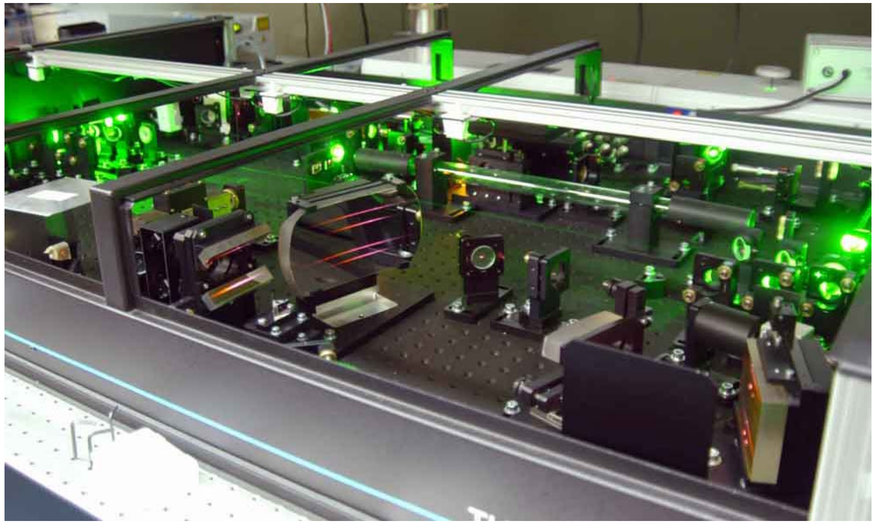
Mono-energetic electron beam occurred over a very narrow range of plasma density

New J. Phys. 12, 045011 (2010)

Mono-energetic beam parameters :

- Peak energy : 10 – 50 MeV
- Energy spread : 4 – 8 %
- Divergence (θ) : 4 – 7 mrad
- Charge : 10 – 60 pC

The power of HEDS-T [3] :
See Plasma Dynamics "as it happens"

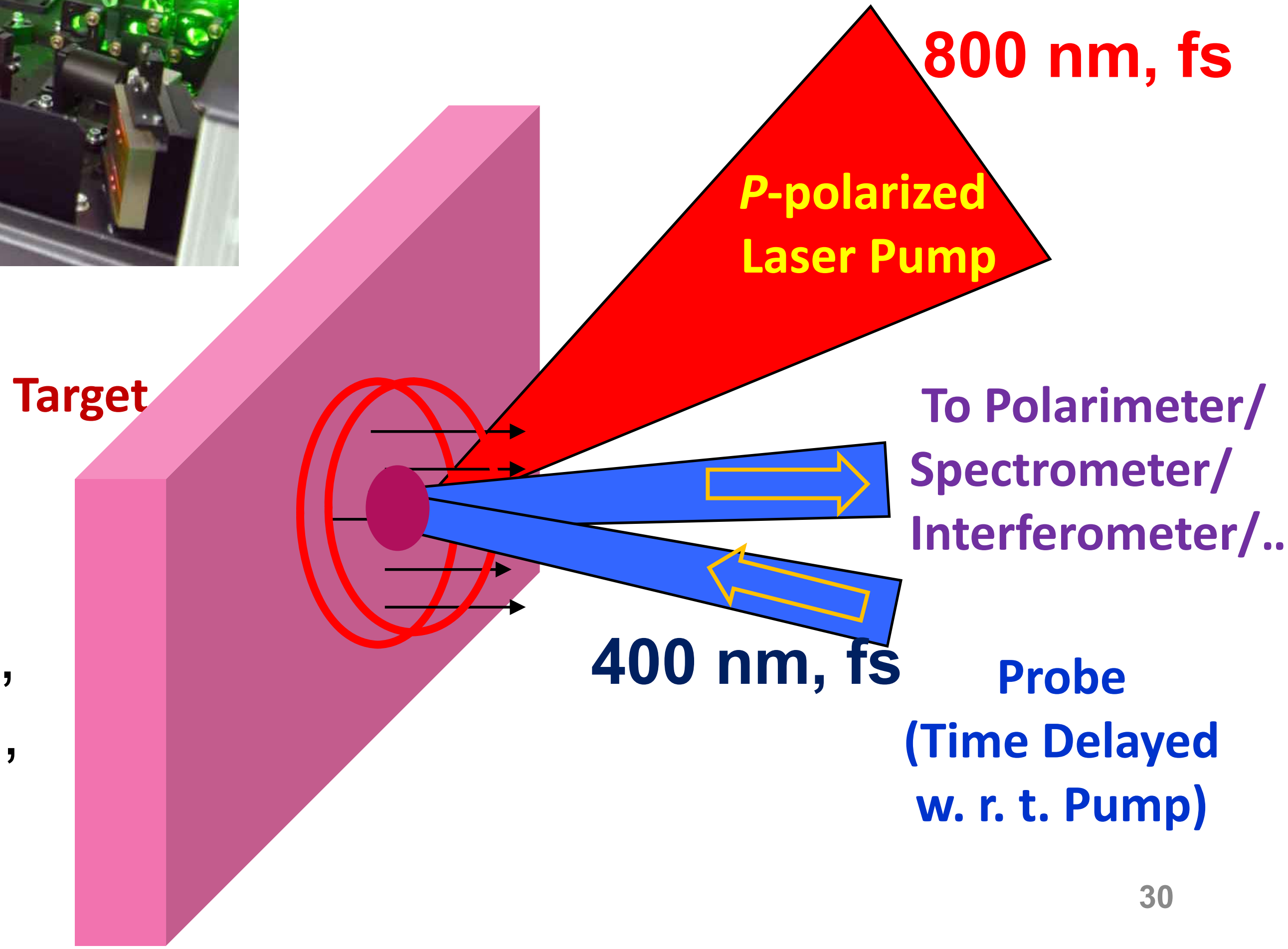


TIFR 20 TW, 30 fs CPA (100 TW by 2010)

R. Kumar

Pump-Probe Experiments :

Hot electron currents,
Giant magnetic fields,
Plasma motion…….



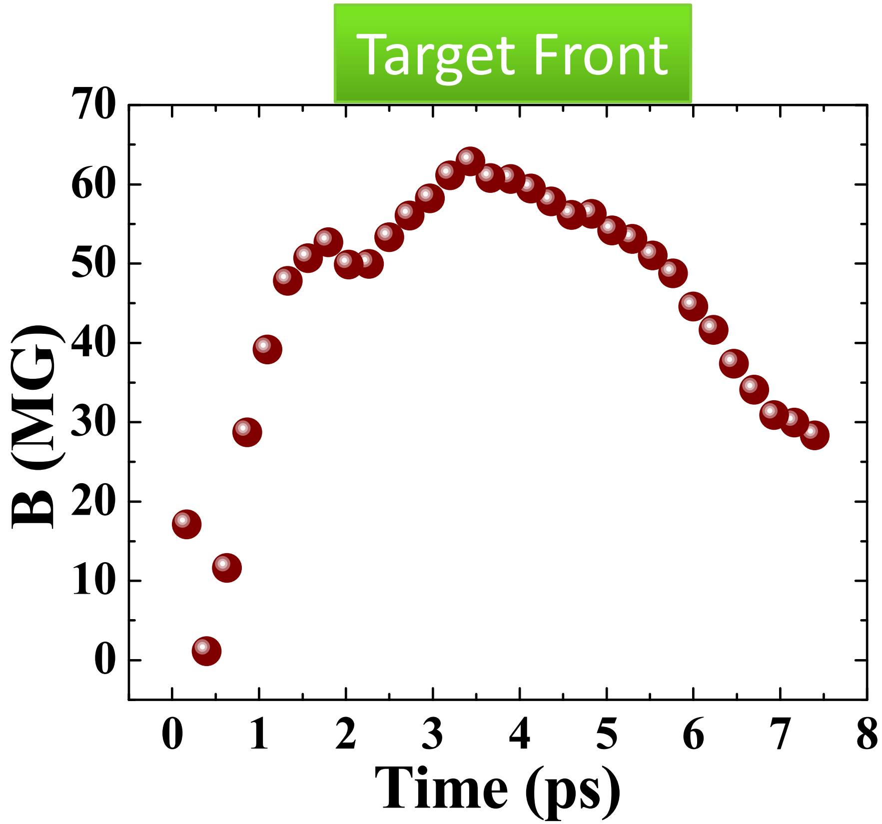
Measured Magnetic Field of Relativistic Electrons

New Results !

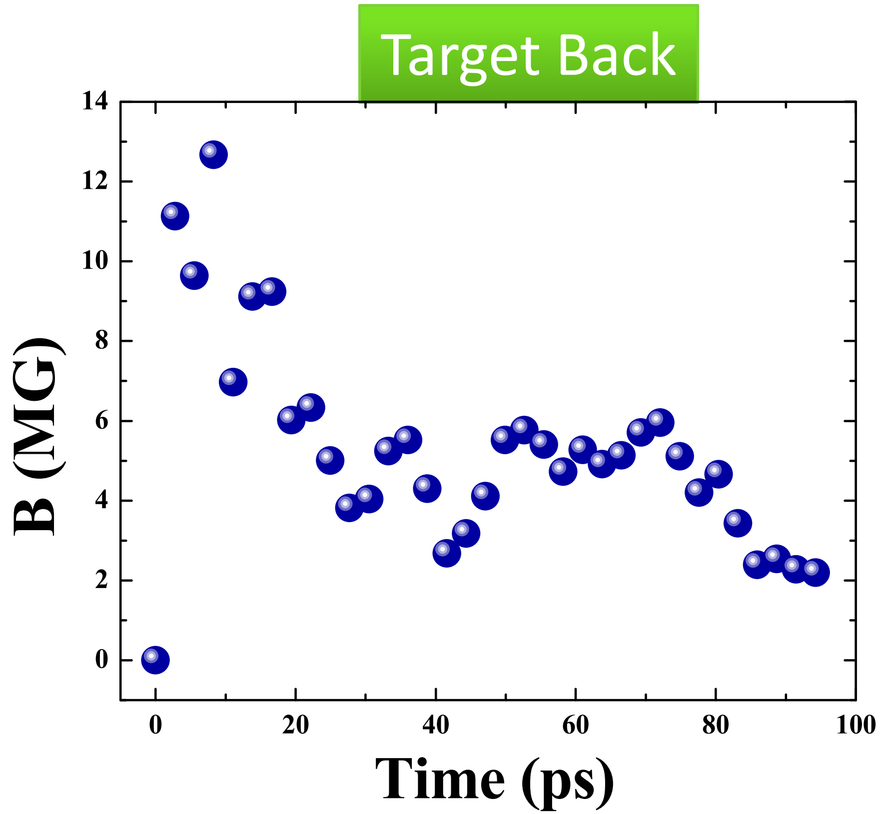
R. Kumar

Time Resolved , Space Integrated

Aluminium film coated glass



5×10^{18} W cm^{-2}



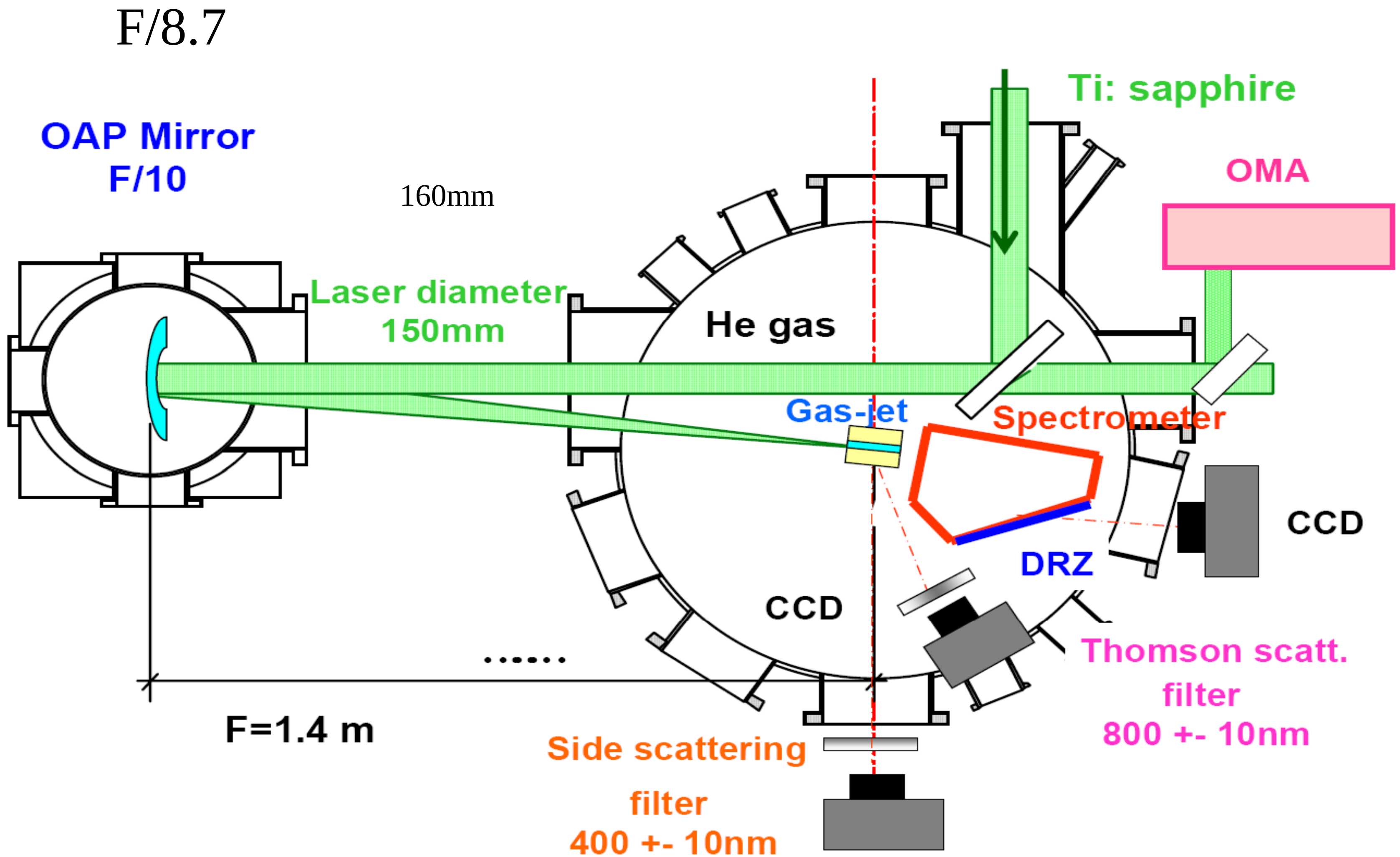
2×10^{18} W cm^{-2}

Outline

- Overview of the Asian Activities
- Progress on electron acceleration in China
- Progress on ion acceleration in China
- Concluding remarks

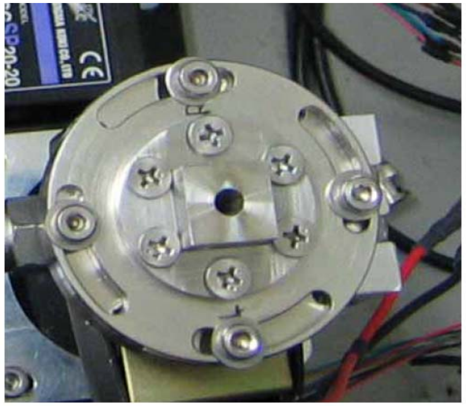
Experimental setup for electron acceleration with SILEX

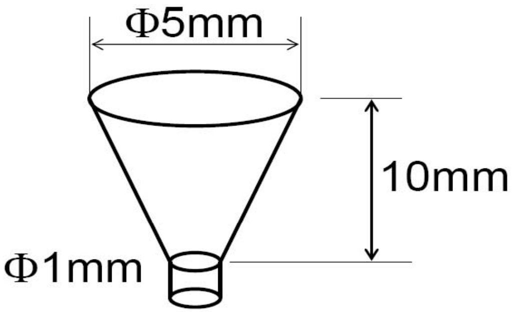
By Yuqiu Gu et al.

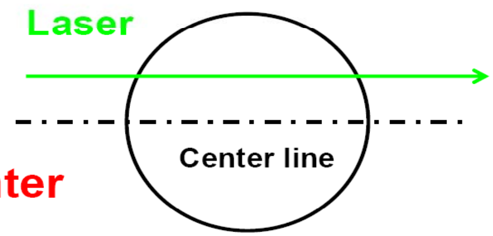


Gas nozzle and laser focusing

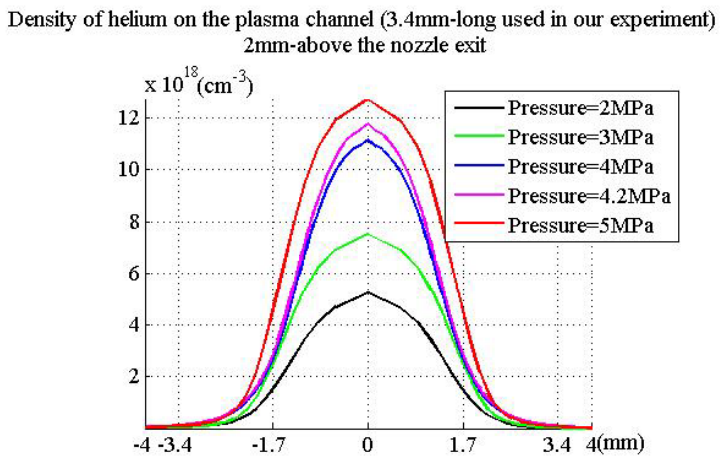
By Yuqiu Gu et al.

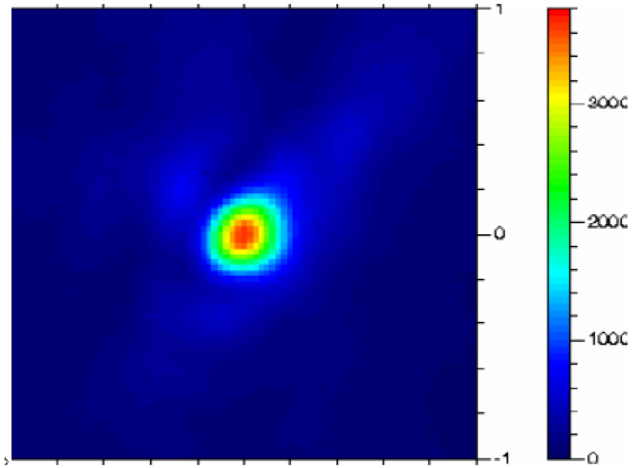






Adjusting plasma length by setting gas nozzle off-center





Focusing lens F/8.7 OAP

Φ=15μm (FWHM) （11％）

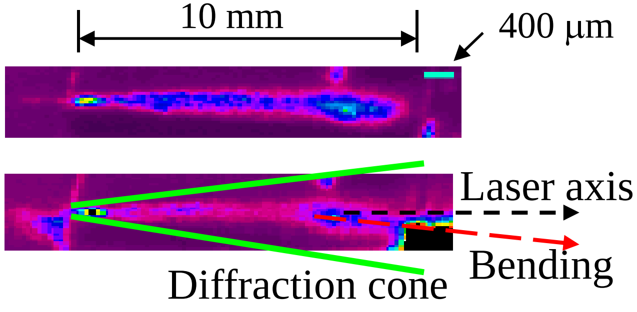
Φ=30μm (1/e^2)（20％）

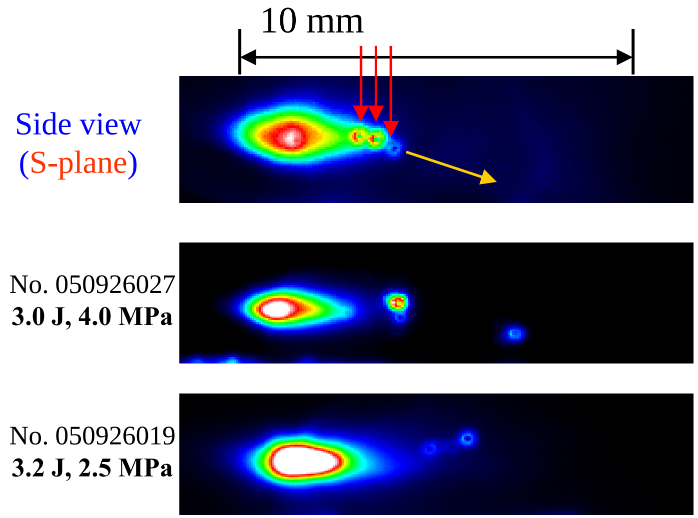
Contrast ratio better than 10^5

Self-guiding and soliton formation in Plasmas with SILEX at LFRC of CAEP

By L.M. Chen et al.

Thomson Scattering





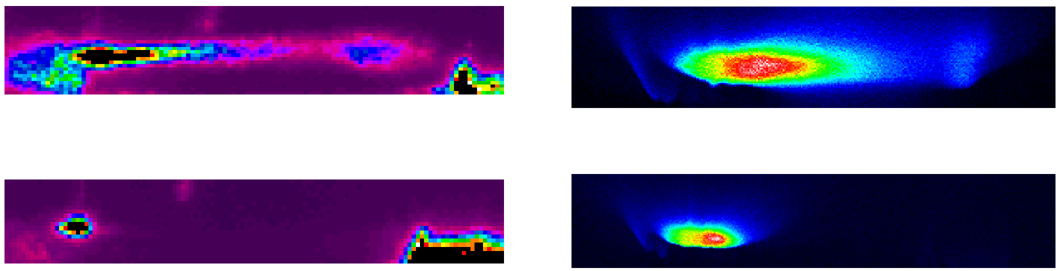
- Channel length ~ 10 mm
  (> 10 diffraction distance)
- Laser propagation show bending
- The "atoll" structure shows **plasma cavity**
  --- *the density valley ascribes to the postsoliton.*

L. M. Chen et al, Phys. Plasmas 14, 040703(2007)

$P > P_{cr};$ Pulse length l_{las} > Plasma wavelength λ_w $(\lambda_w \sim 2\pi c/\omega_p)$

2.1 J, 3.0 MPa

1.9 J, 1.5 MPa



$l_{las} > \lambda_w$

$l_{las} < \lambda_w$

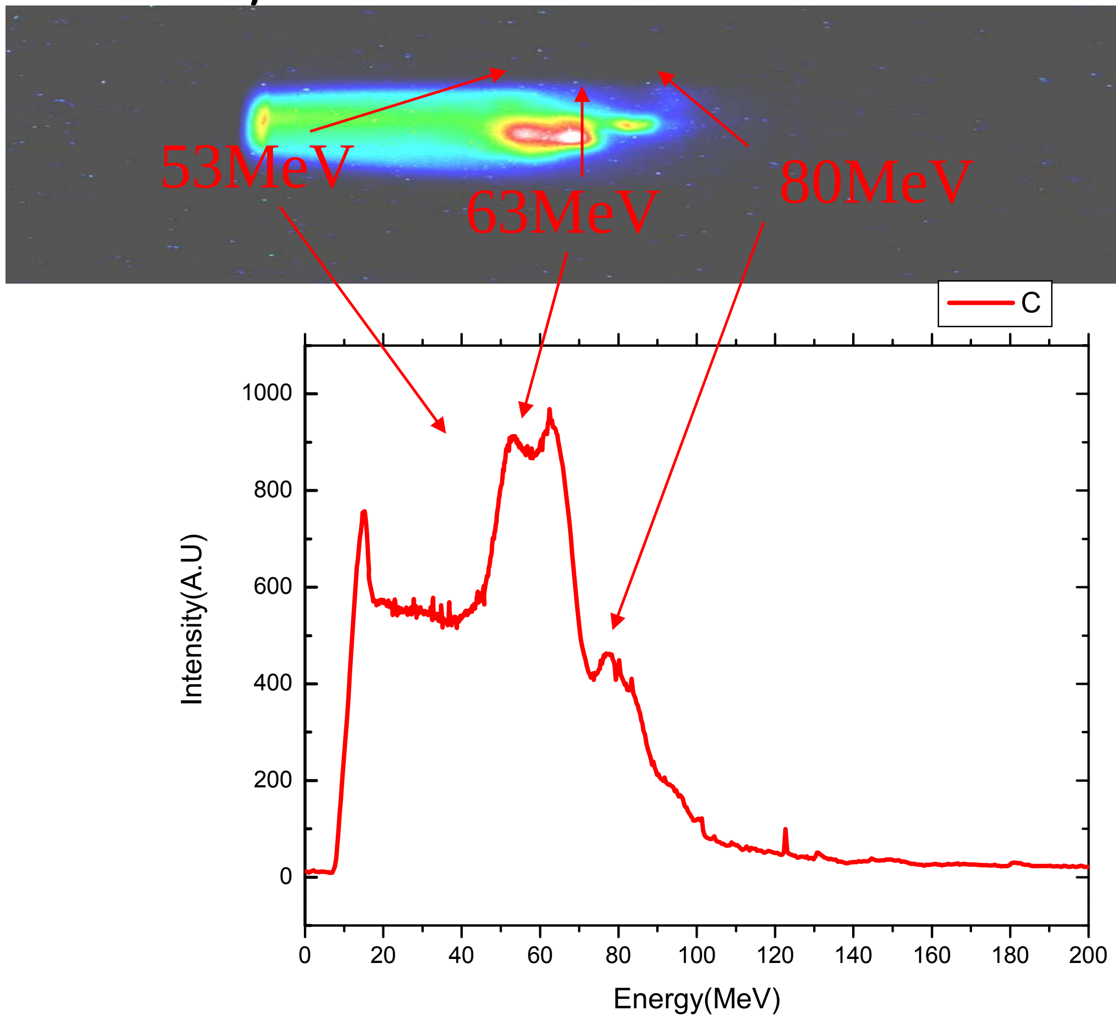
(plasma imaging) 410-532nm

Three energy peaks were observed

Shot No.104

By Yuqiu Gu et al.

Laser power:181TW /Gas Pressure: 4.23MPa

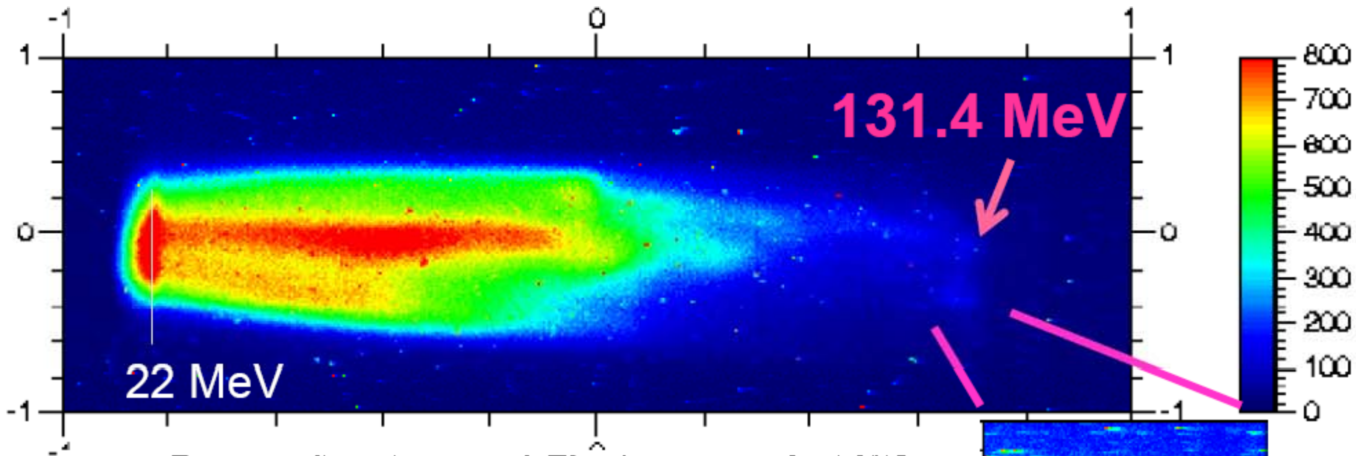


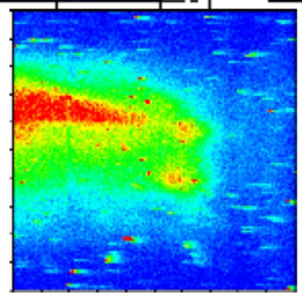
Electron spectrum from 10mm-long gas column

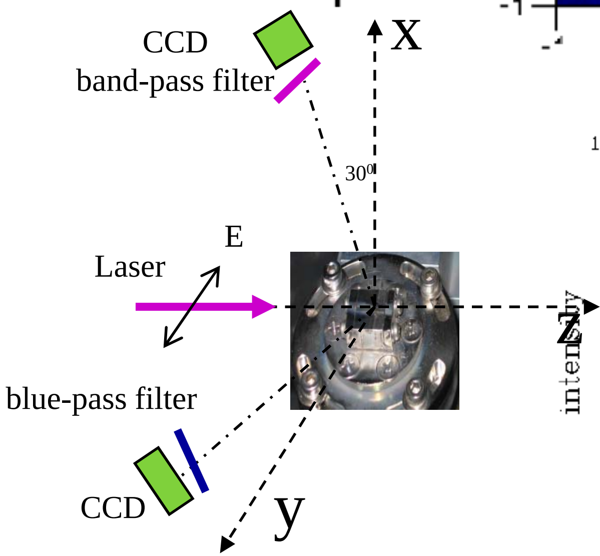
By Yuqiu Gu et al.

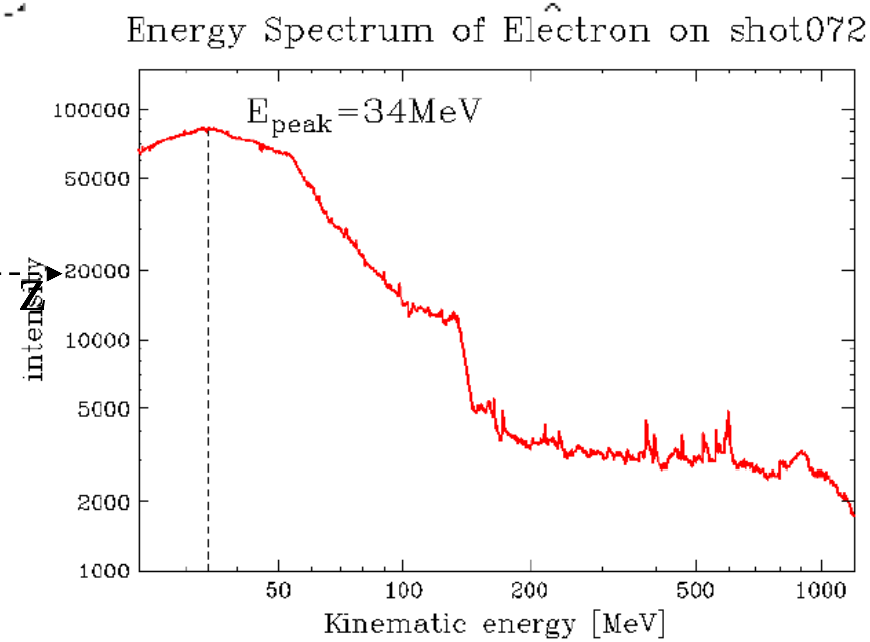
Laser Power
202 TW

Gas Pressure
2.5 Mpa





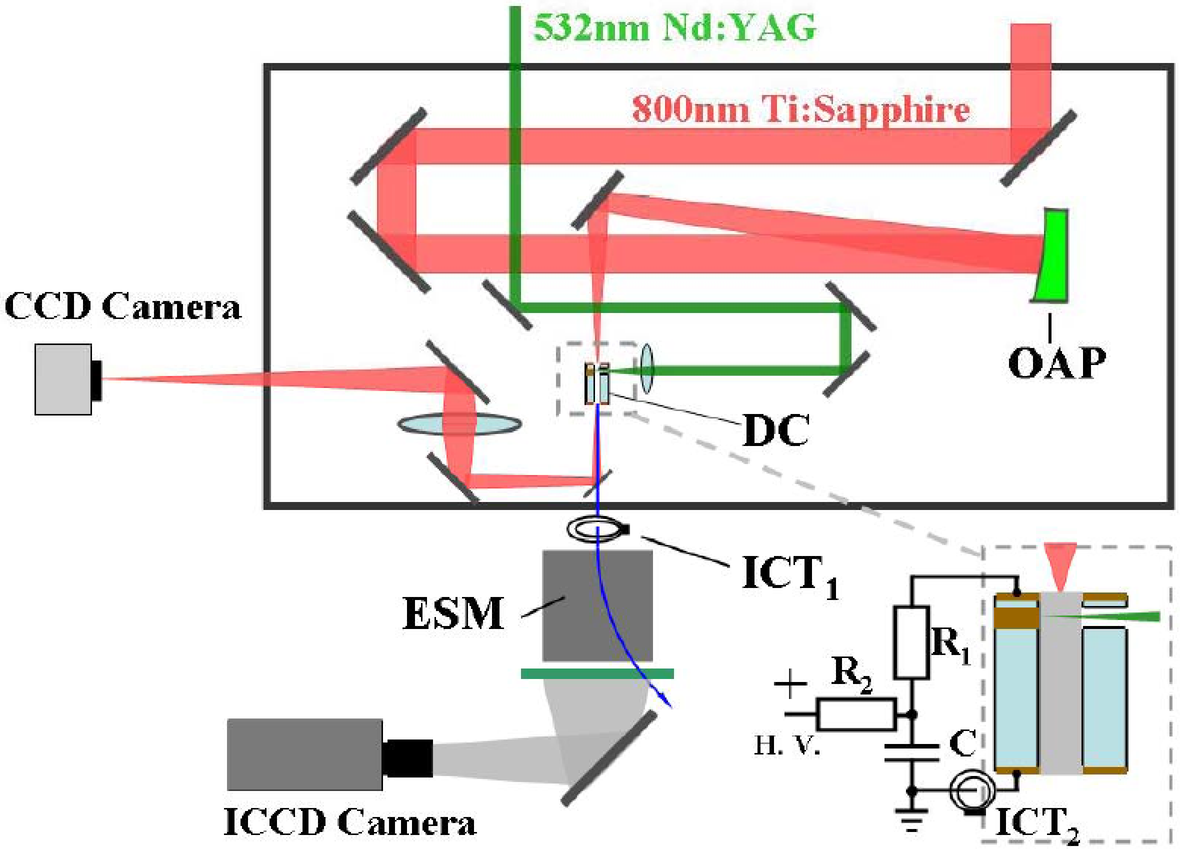


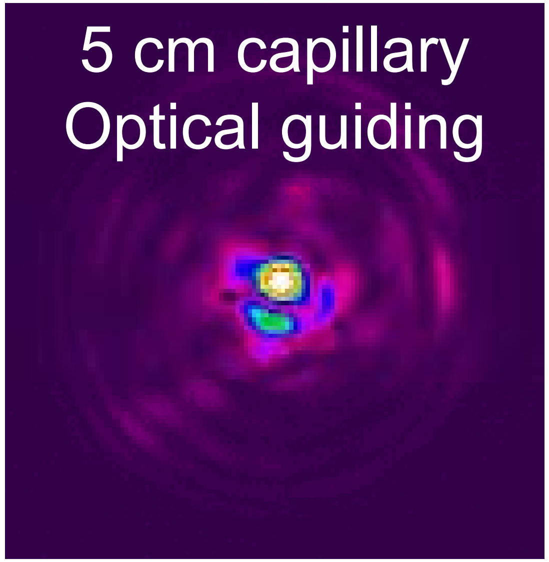


ICT-integrated total charge 15nC

Laser plasma acceleration experiment is underway, using PW laser and capillary at SIOM, CAS

under collaboration with KEK





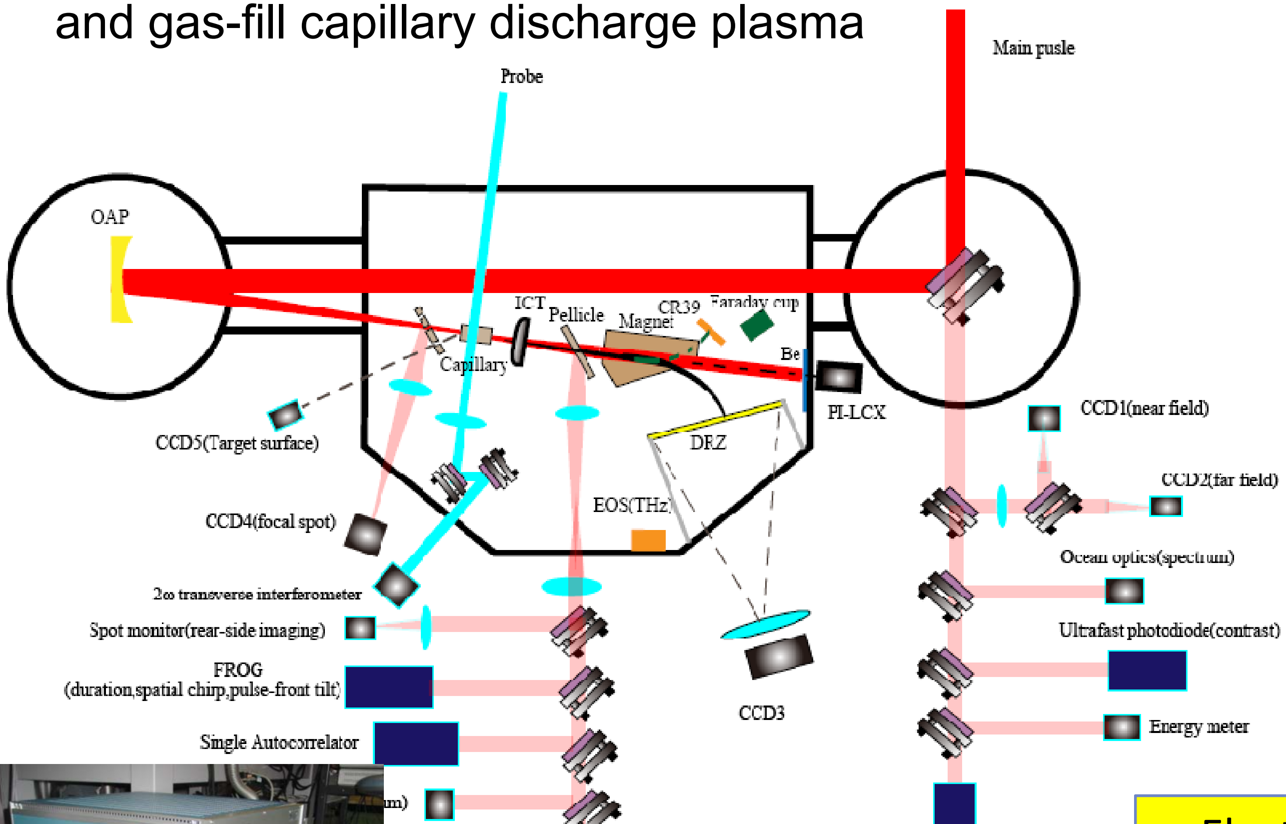
Recently successful optical guiding of 160TW (8J, 50fs) was achieved

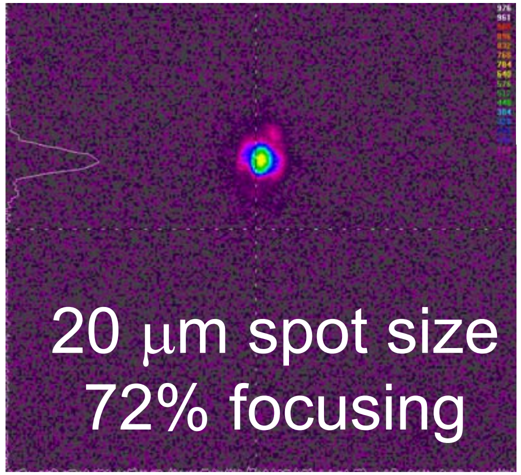
Setup with side-laser triggering ablative capillary acceleration driven by PW laser

Laser plasma acceleration experiment is underway at IOP, CAS with XL-III

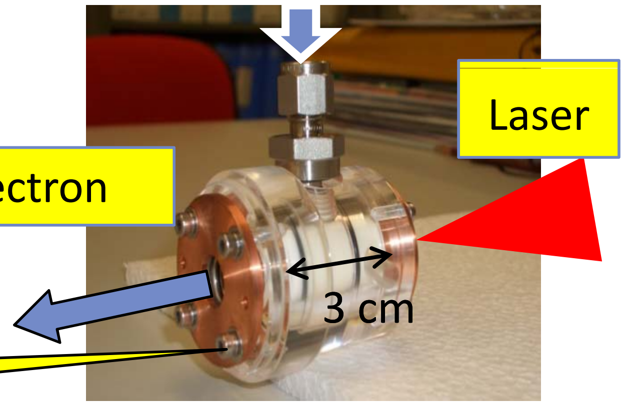
(under collaboration with IHEP and KEK)

Setup for LPA experiments with gas jet and gas-fill capillary discharge plasma





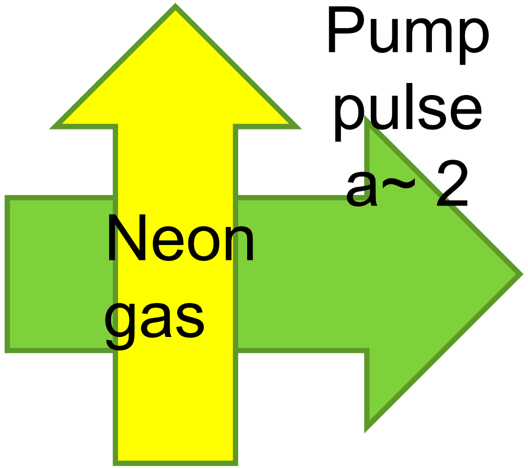
Hydrogen gas

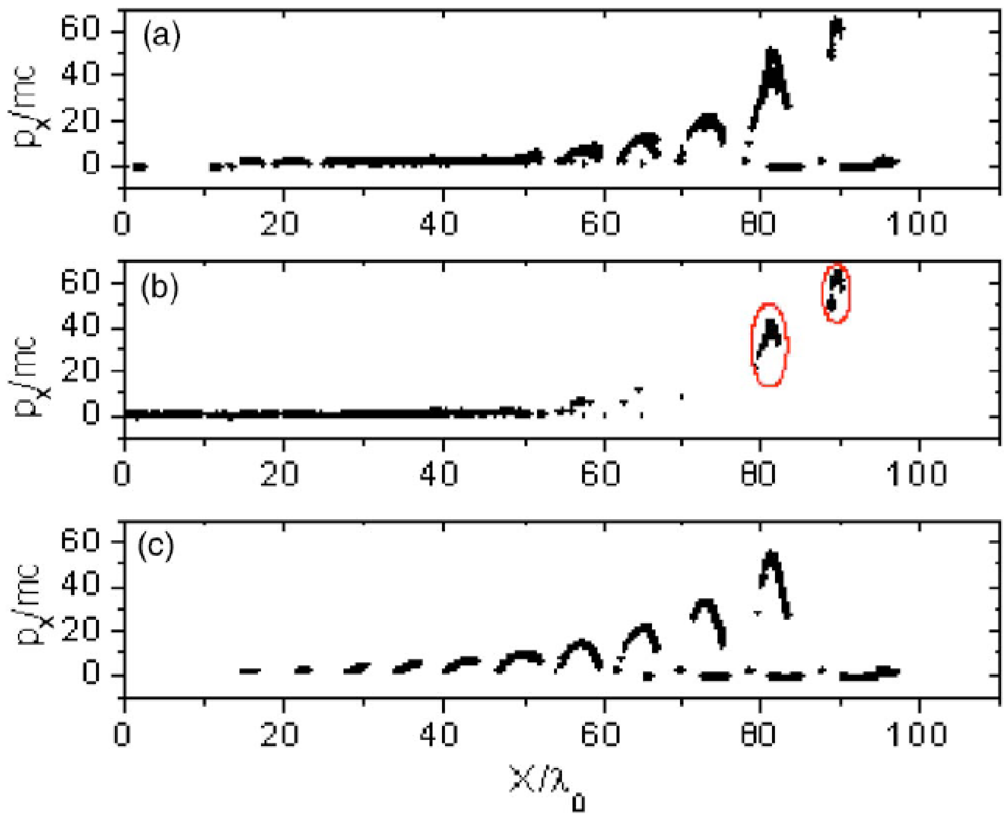


Discharge device

Ceramic gas-fill capillary

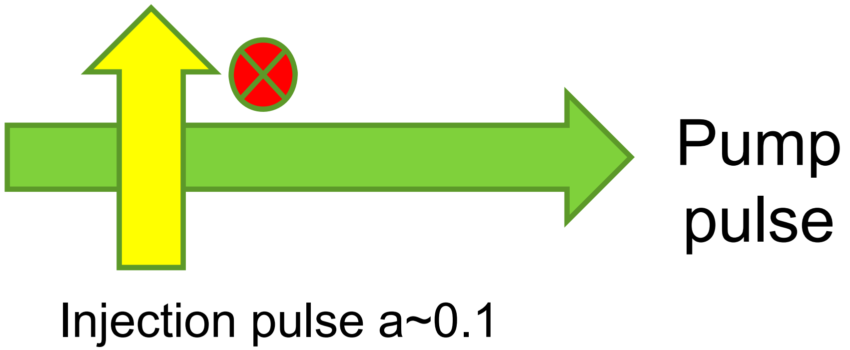
Electron injection into a laser wakefield by field ionization to high-charge states of gases

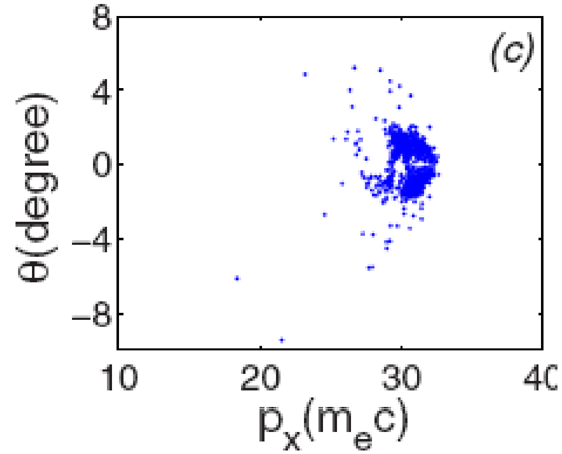


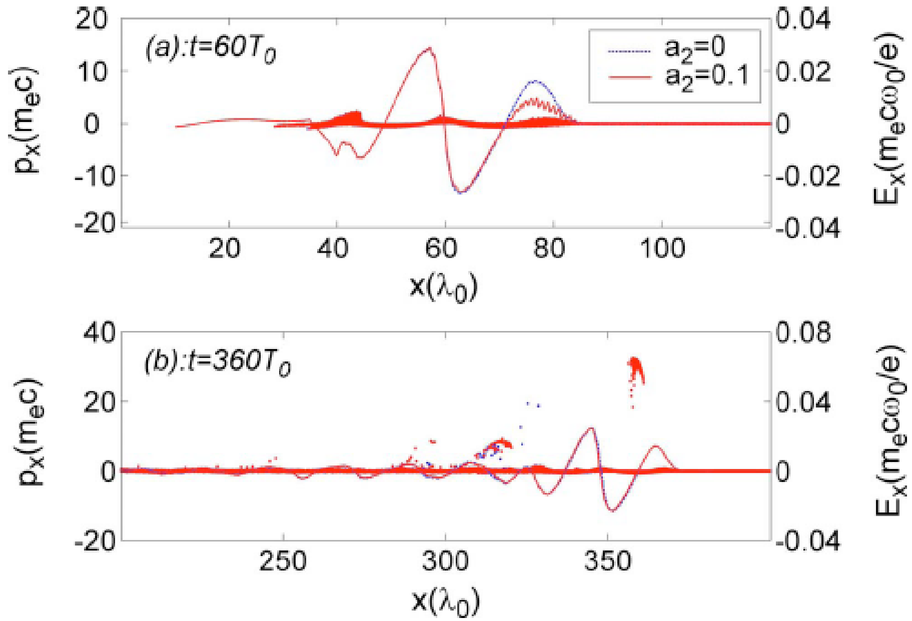


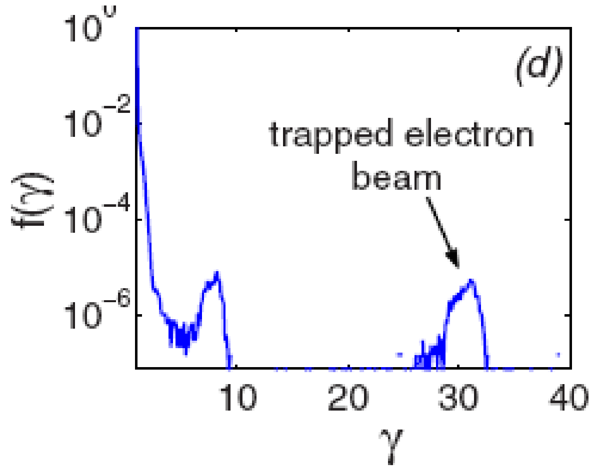
M. Chen et al., J. Appl. Phys. 99, 056109 (2006)

Electron Injection with a transversely propagating weak pulse: colinearly-polarized





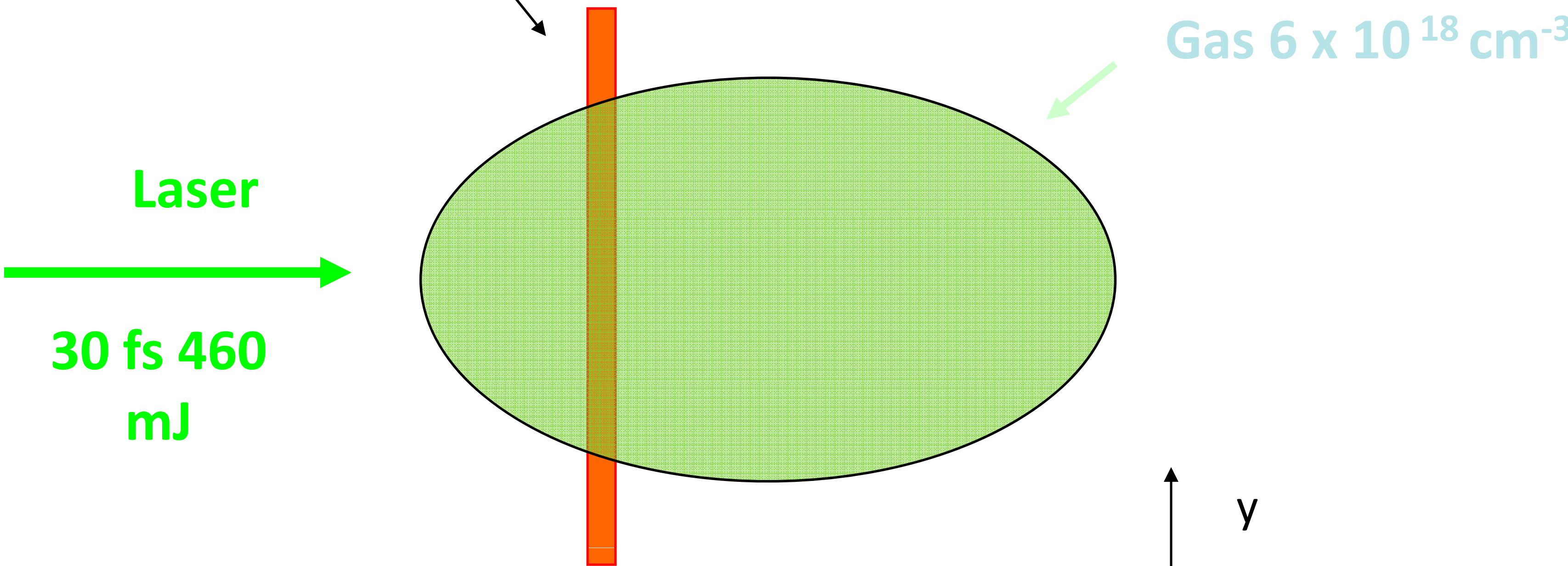


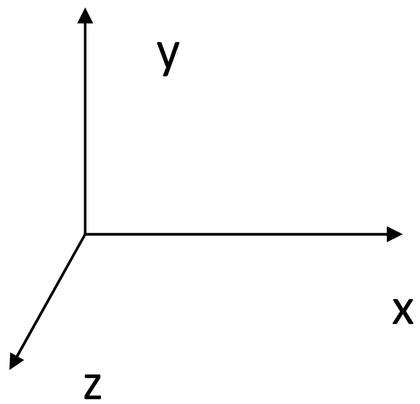


W.M. Wang et al., APL 93, 201502 (2008)

Electron injection triggered by a nanowire

Nanowire (0.7 x 0.7 μm^2, 1.2 x 10 ^{21} cm^3)

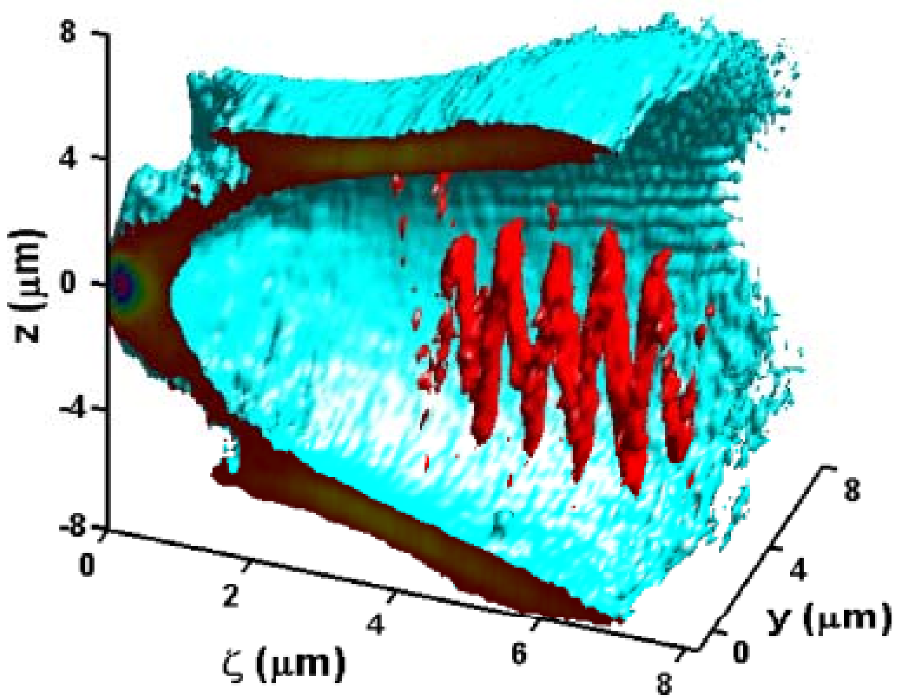




The wire is at x=200 μm, z=6.35 μm.

Baifei Shen et al., Phys. Plasmas, 053115(2007)

The energetic electron bunch is found to have a highly regular sinusoidal structure in the polarization plane of the laser.

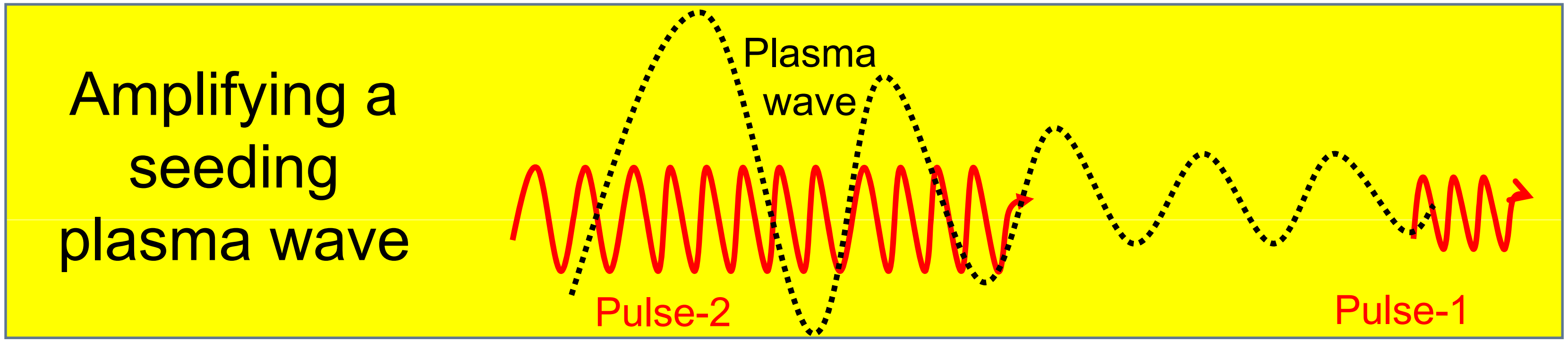


The period of the sinusoidal structure changes from about 660 nm to about 800 nm

We conclude that the betatron oscillations are driven directly by the laser Field.

Laser-driven coherent betatron oscillation in a laser-wakefield cavity, BF Shen with colleagues at ANL, *Phys. Rev. Lett.* 100, 095002 (2008).

Cross-Modulated Laser Wakefield Acceleration (XM-LWFA), partially confirmed in experiment



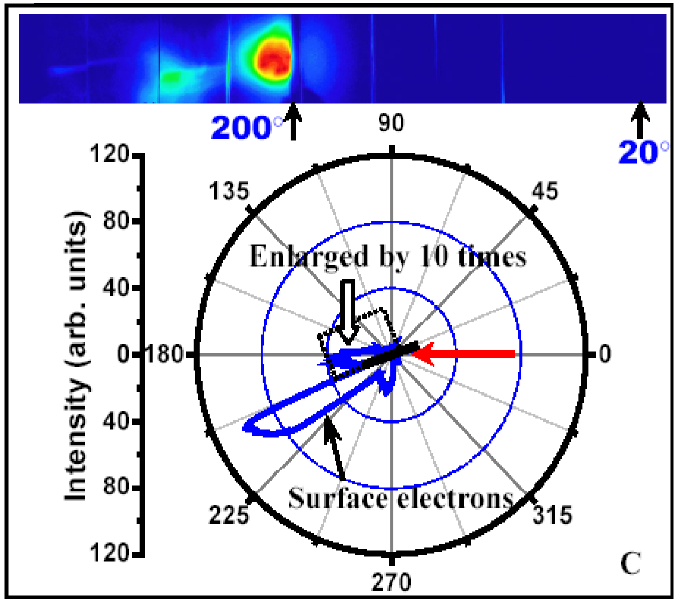
Advantages:

1. Using pulses with relatively low intensities;
2. Timing unnecessary for laser injections;
3. More controllable than the self-modulated laser wakefield accelerators;
4. Allowing for efficient energy transfer from laser to plasma waves

Z.-M. Sheng et al., *Phys. Plasmas 9, 3147 (2002).*

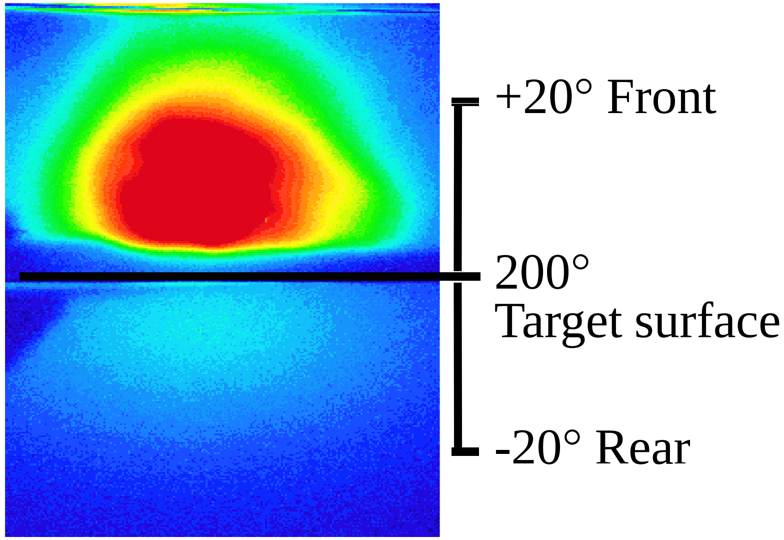
W.-T. Chen *et al.*, Phys. Rev. Lett. 92, 075003 (2004).

Fast electron emission for incidence angle 70°



70°

Angular distributions of > 300 keV fast electrons in the incident plane.



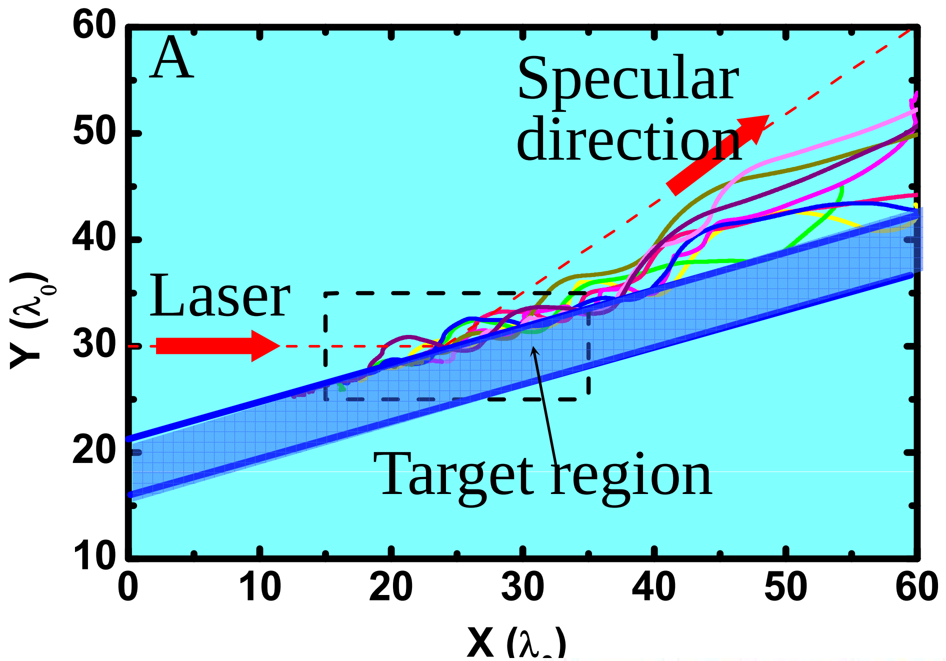
Typical pattern

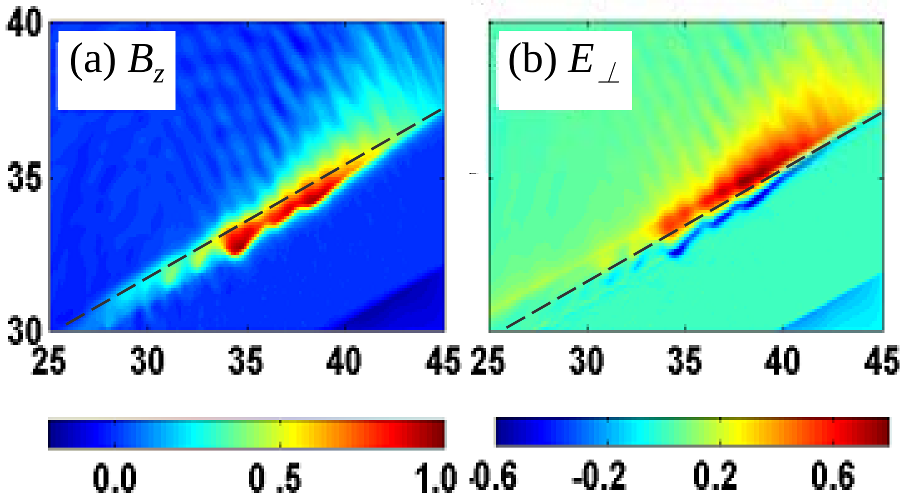
Cone angle <15° (FWHM)

A fast electron jet along the front target surface is observed.

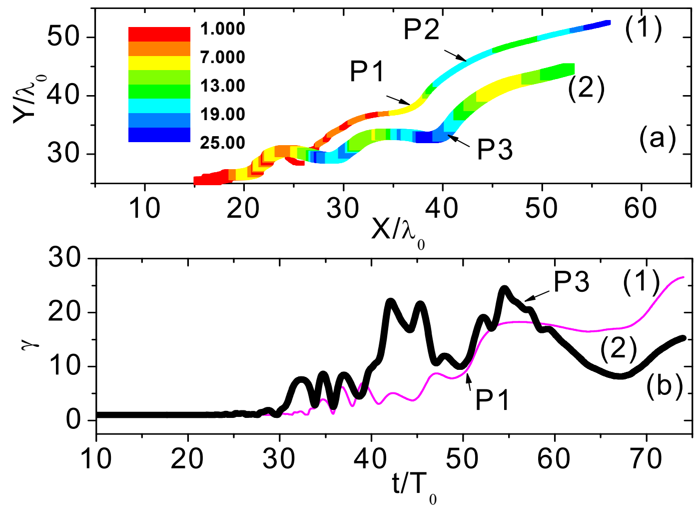
Y.T. Li et al., Phys. Rev. Lett. 96, 165003 (2006).

2D PIC simulations show that a kind of inverse free electron laser acceleration occurs at the target surface





- Fast electrons move along the surface in a oscillating form.

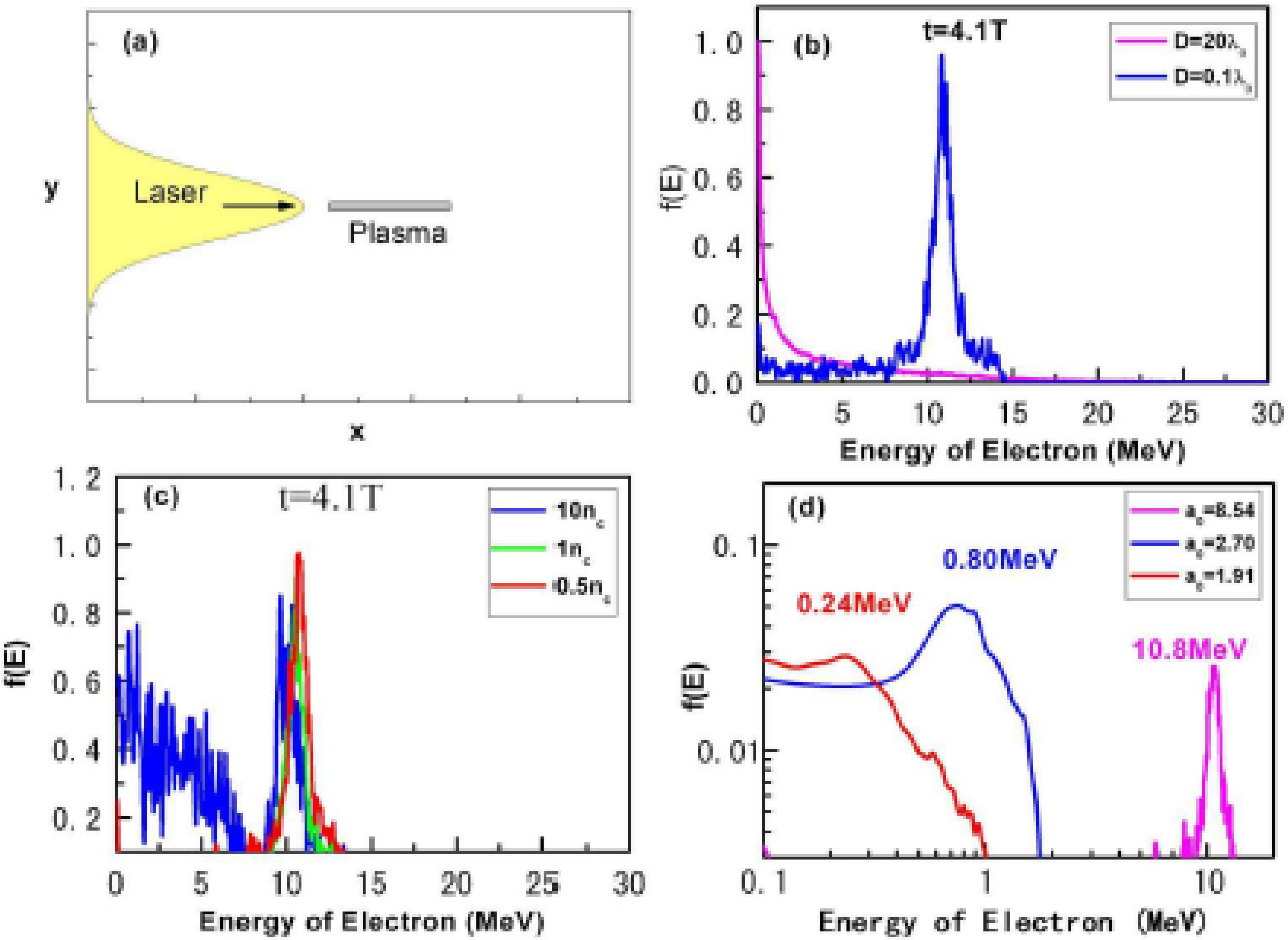


- Quasi-static magnetic and electric fields are self-induced around the surface.

As soon as the betatron frequency approaches the laser frequency, resonant acceleration occurs.

M. Chen et al., Opt. Express 14, 3093 (2006)

Quasi-monoenergetic electron bunches in laser interaction with a wire target

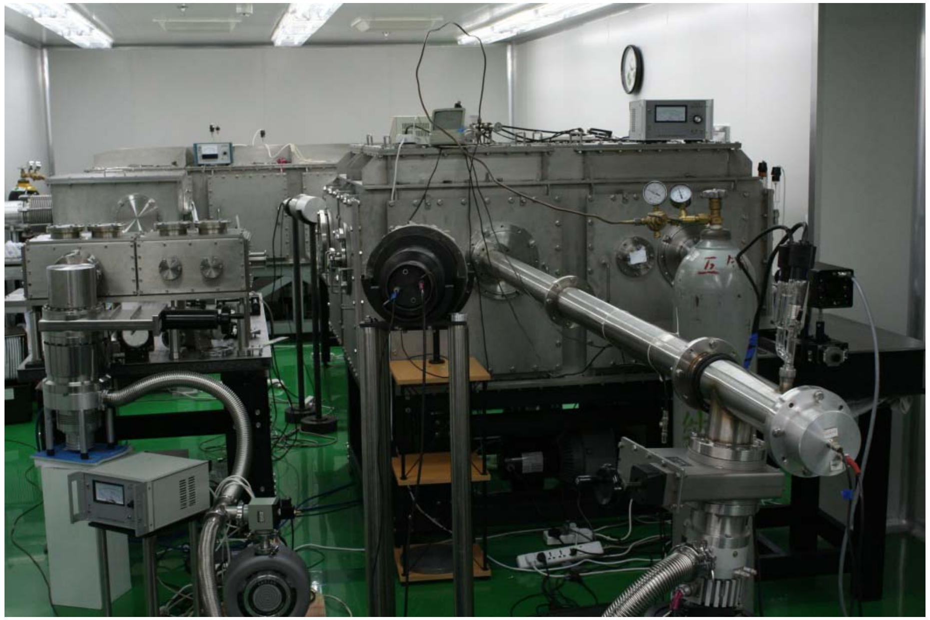


Y. Y. Ma et al., Phys. Plasmas (2006).

Outline

- Overview of the Asian Activities
- Progress on electron acceleration in China
- Progress on ion acceleration in China
- Concluding remarks

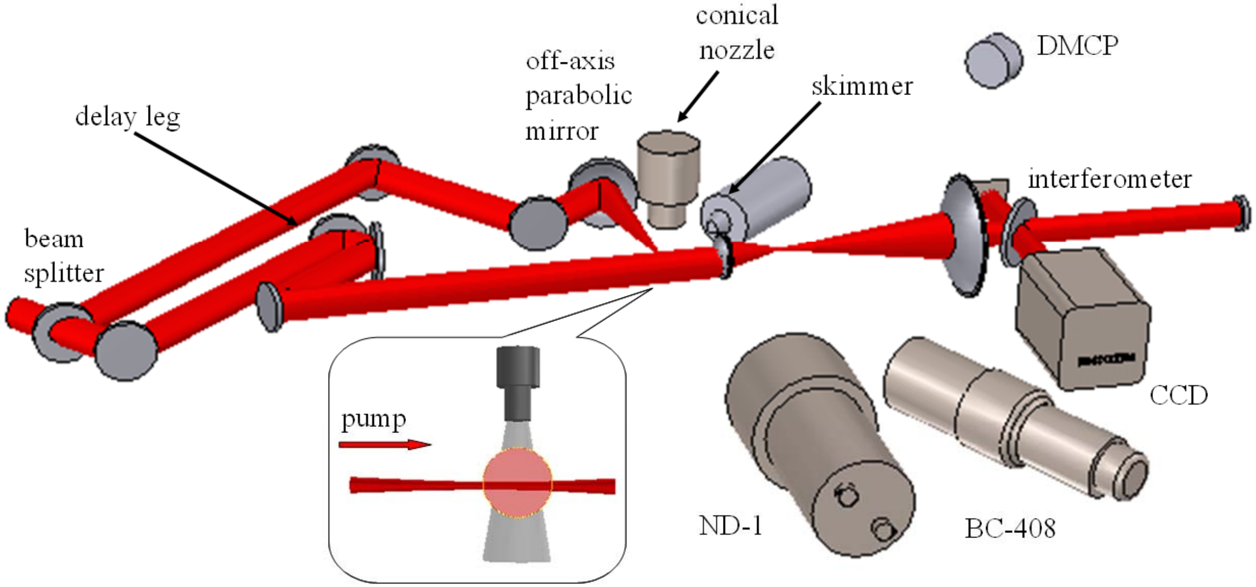
Laser Interaction with Clusters



TW Laser: 100-160mJ, 60fs, 10Hz

PW Laser: 1 − 5.4J, 50fs, single shot

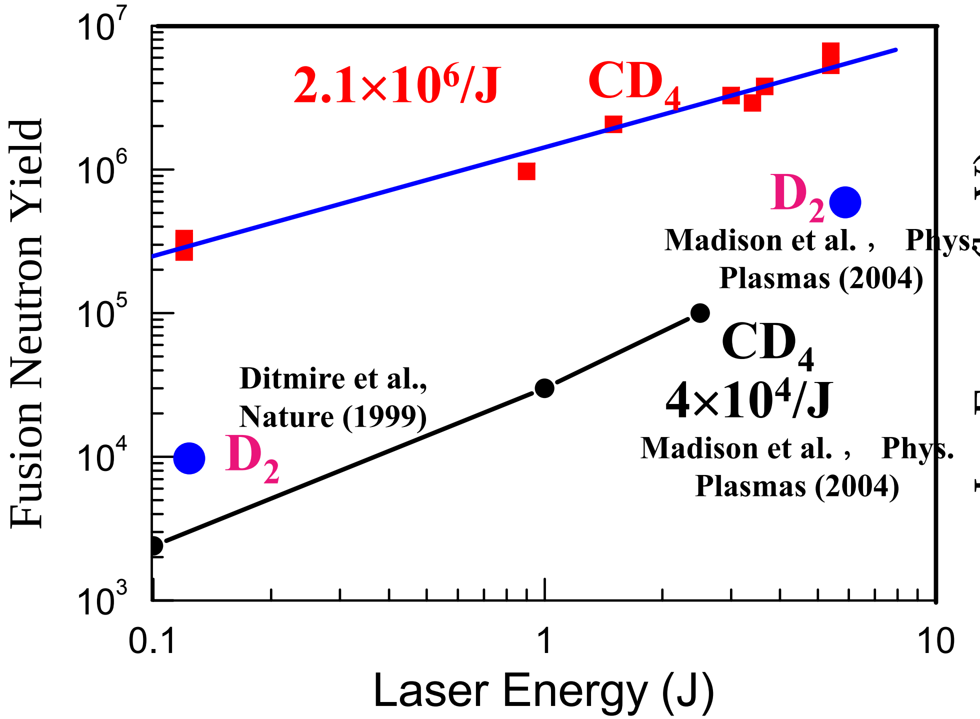
- •Plasma channel
- •Molecular density and cluster size
- •Ion energy
- •Neutron detection

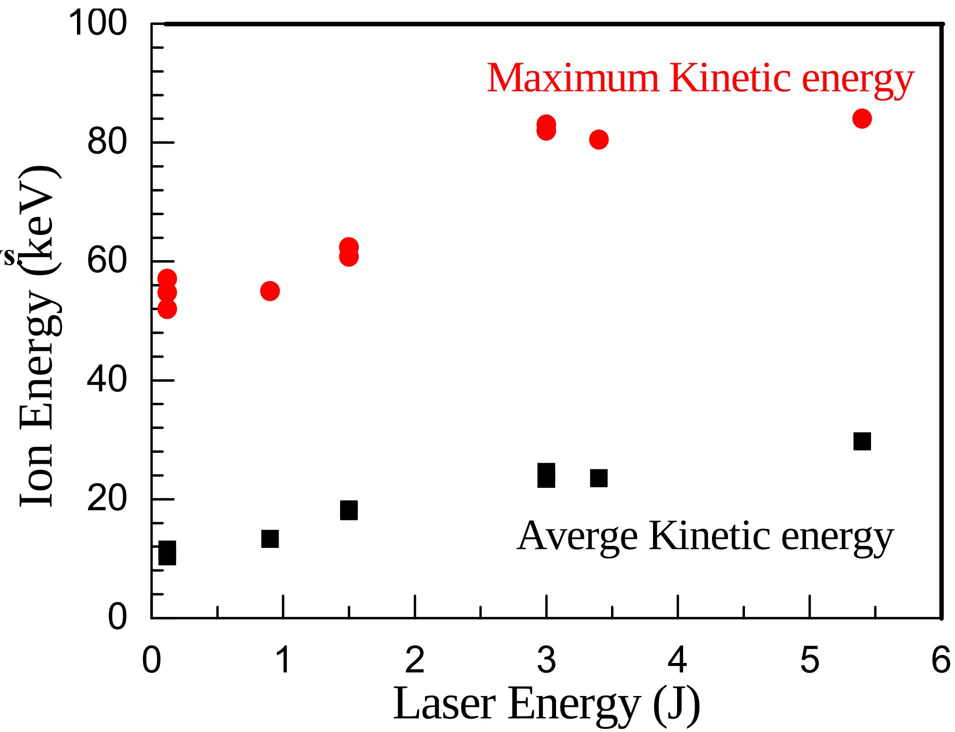


By Haiyang Lu, Guoquan Ni

With CD clusters with bigger size and higher density to achieve high D+ energy (E_{max}~90keV， E_{aver}~30keV)， and achieve neutron yield at 2.1 ×10⁶/J, 50 times larger than reported by other lab

Haiyang Lu *et al*. Phys.Plasmas 16,083107(2009)
Haiyang Lu *et al*. Phys.Rev.A 80,051201(R)(2009)

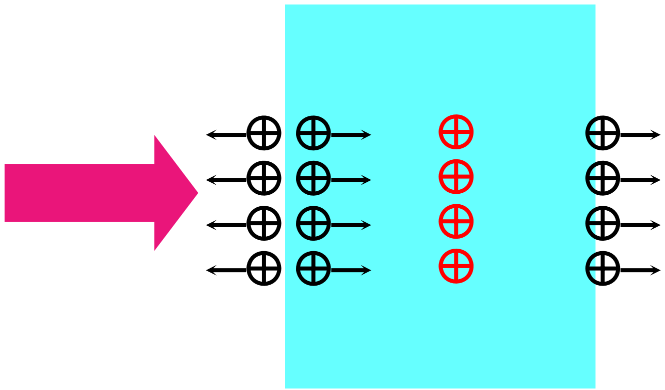


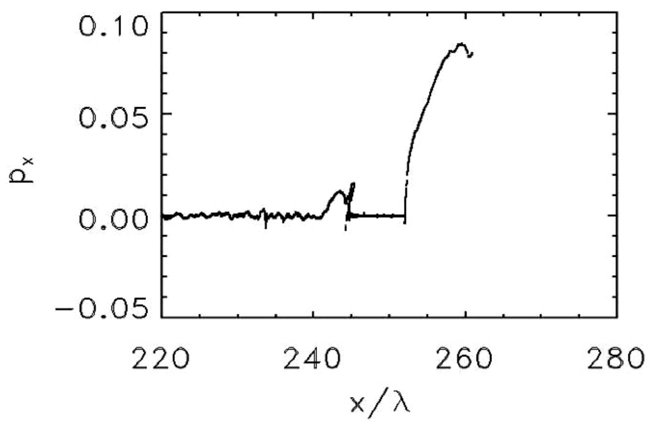


Back pressure 80bar， CD4 cluster diameter 12nm， atom density for D 1.5 $\times 10^{19}$cm^{-3},
Peak intensity I_{peak}=1.5 × 10^{19}W/cm^2， Pulse duration 50fs, Laser energy 5.4J,
Neutron yield 5.5 ×10^6

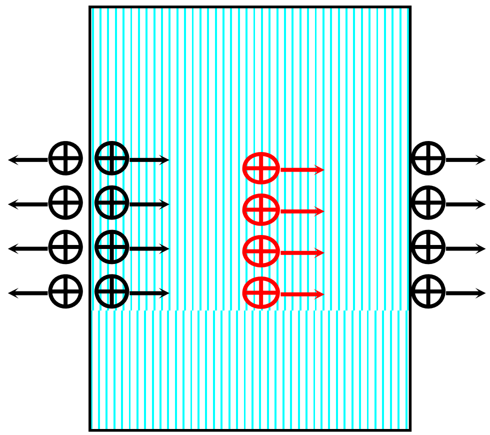
Bulk ion acceleration in foam target

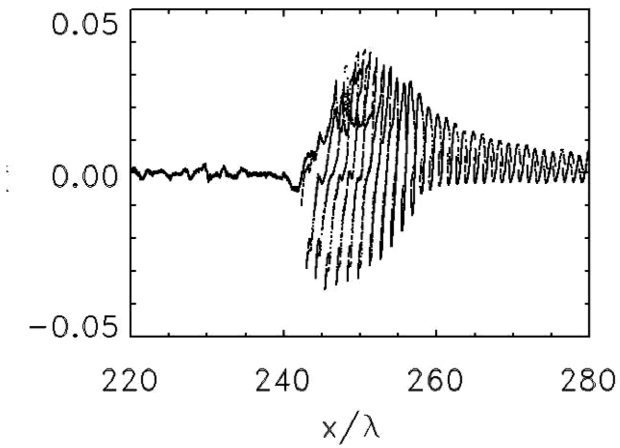
Solid target:
Surface acceleration



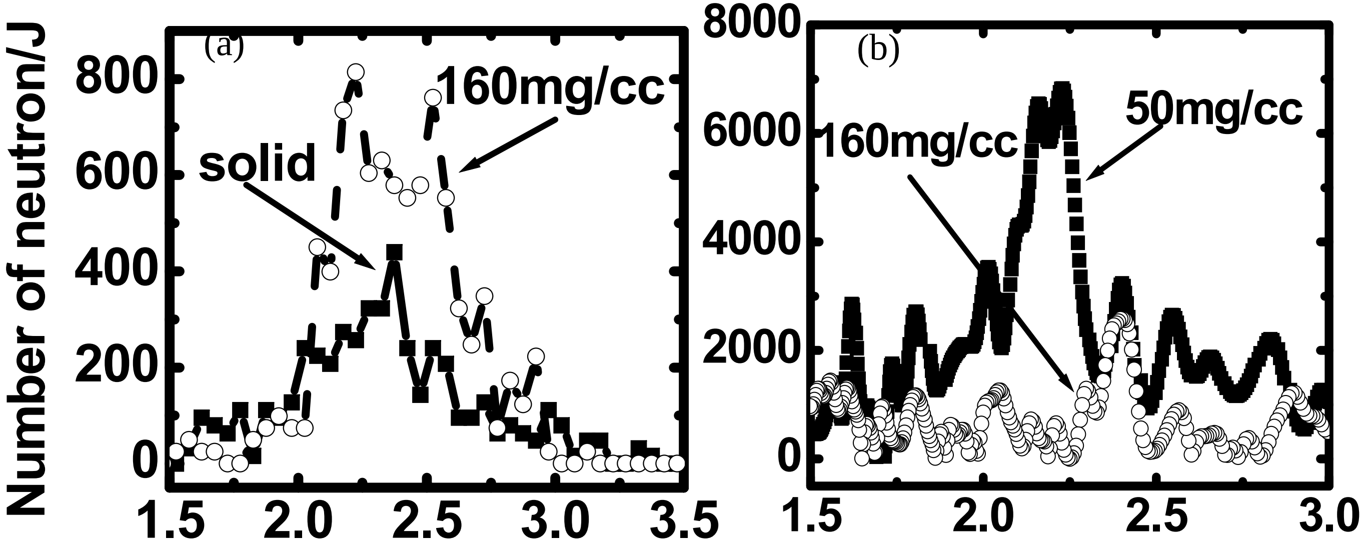


Foam target:
bulk acceleration





Neutron yields for different targets



Detecting angle 76°　　　Detecting angle 16°

Neutron yields for foam targets are higher than that for solid. This confirms the bulk acceleration.

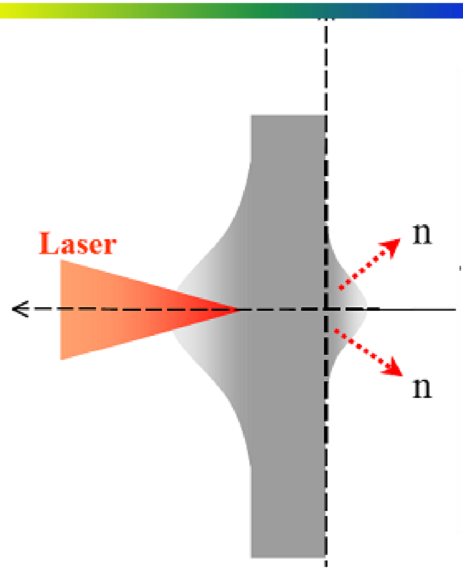
Y.T. Li et al., Phys. Rev. E (2005).

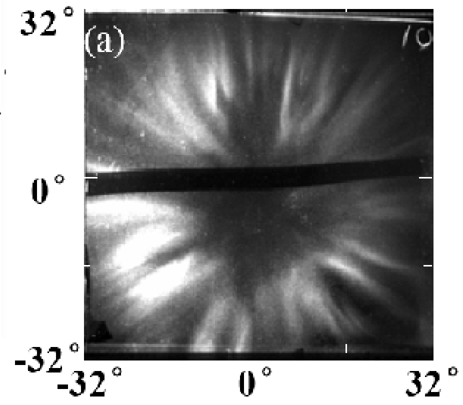
Effect of large prepulse on high energy ions:

Shock waves produced by the prepulse lead to large divergence angle

Shock ➔Deformation of the rear surface

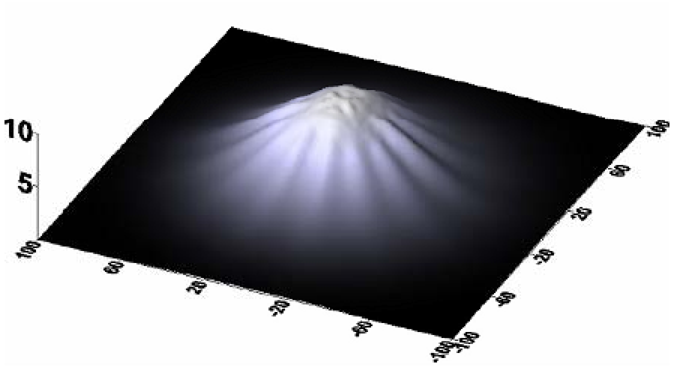
Proton accelerated in the local target normal direction





- Large diverg.
- Ring-like

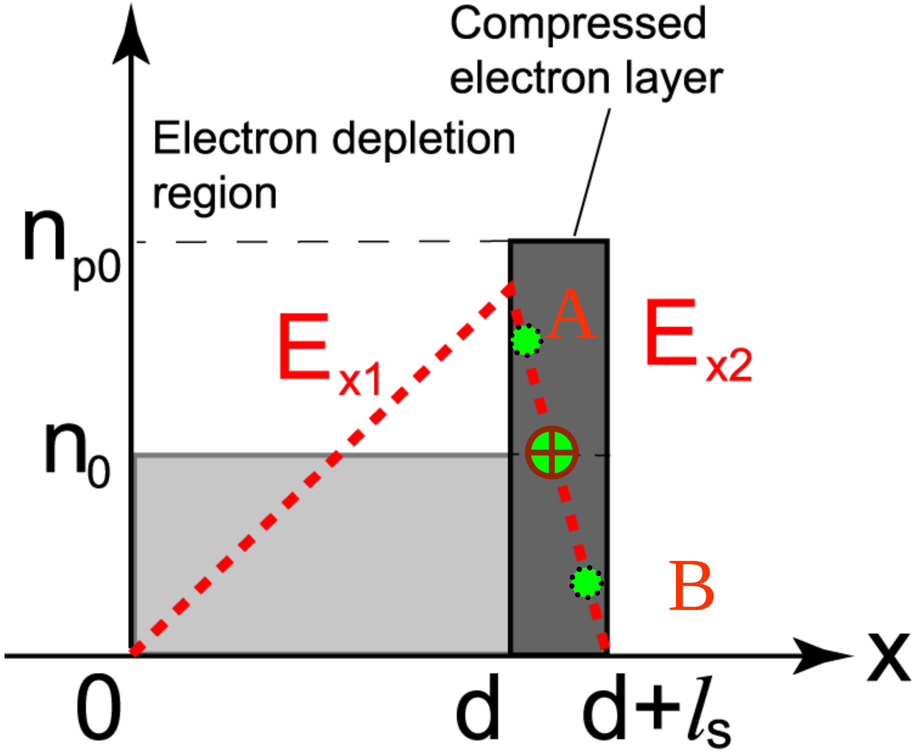
Shock ➔modulated Surface
Proton focusing and defocusing locally

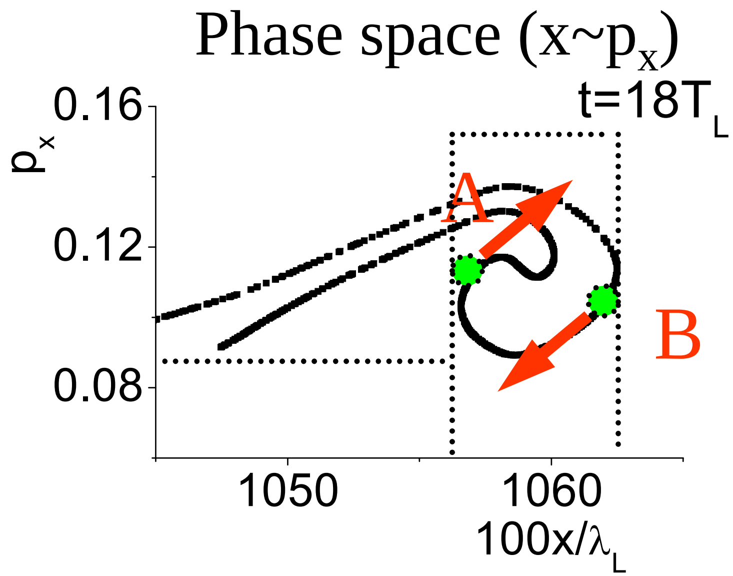


- Burst-like

Physics of Plasmas 13, 104507 (2006)

Ion Acceleration in the Phase Stable Acceleration Regime





$$E_{//} = 4\pi e n_0 d \sim (v_e \times B_L / c) \sim E_L$$

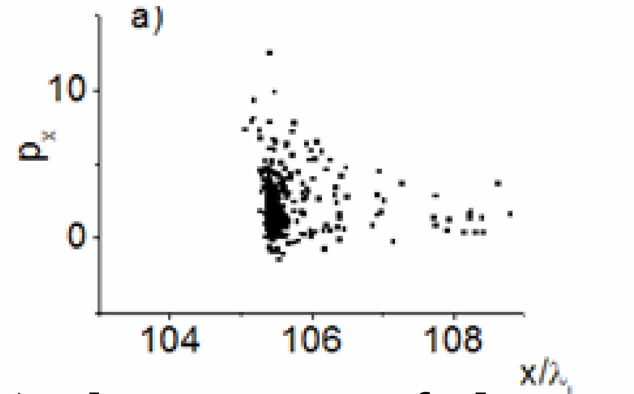
$$(n_0 / n_c)(d / \lambda_L) \sim a_L$$

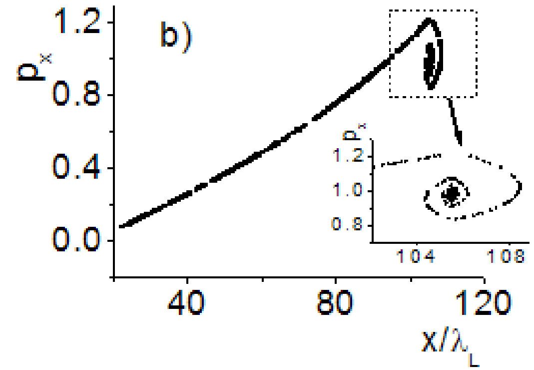
- Protons are:
  Bunched by E_{x2}
  Debunched by E_{x1} .

- Phase Oscillations!

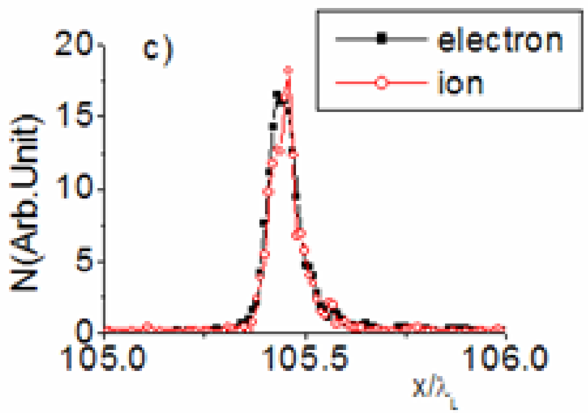
a=5, n_0/n_c=10, L=0.2λ, τ=100 T_L

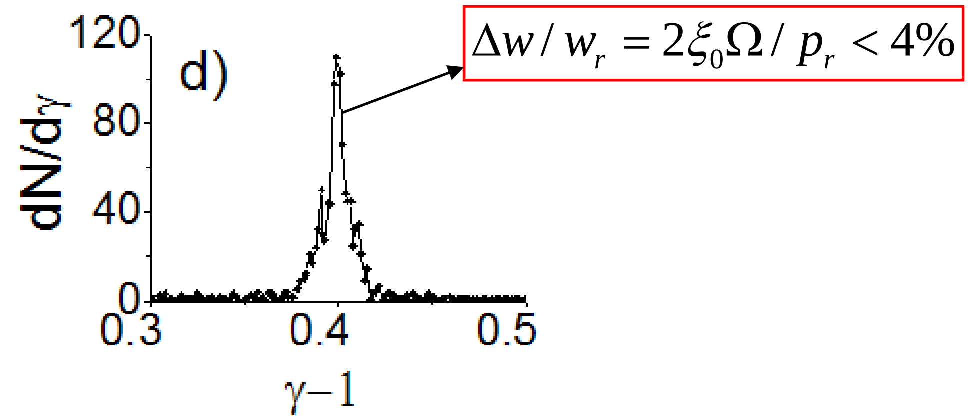
1D simulation results at t=200 T_L





(a) Phase space of electrons. (b) Phase space distribution of protons.





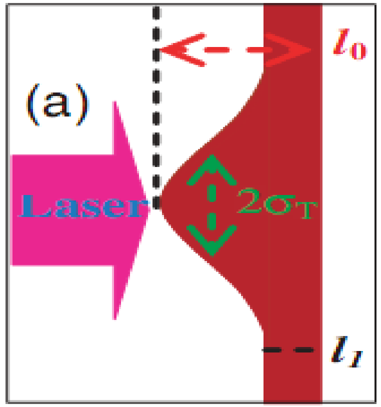
(c) Electrons and protons density profiles (d) Energy spectrum of protons

X. Q. Yan et al., PRL 100, 135003 (2008).

Stable acceleration in 3D geometry with a deformed target

M. Chen et al., PRL 103, 024801(2009)

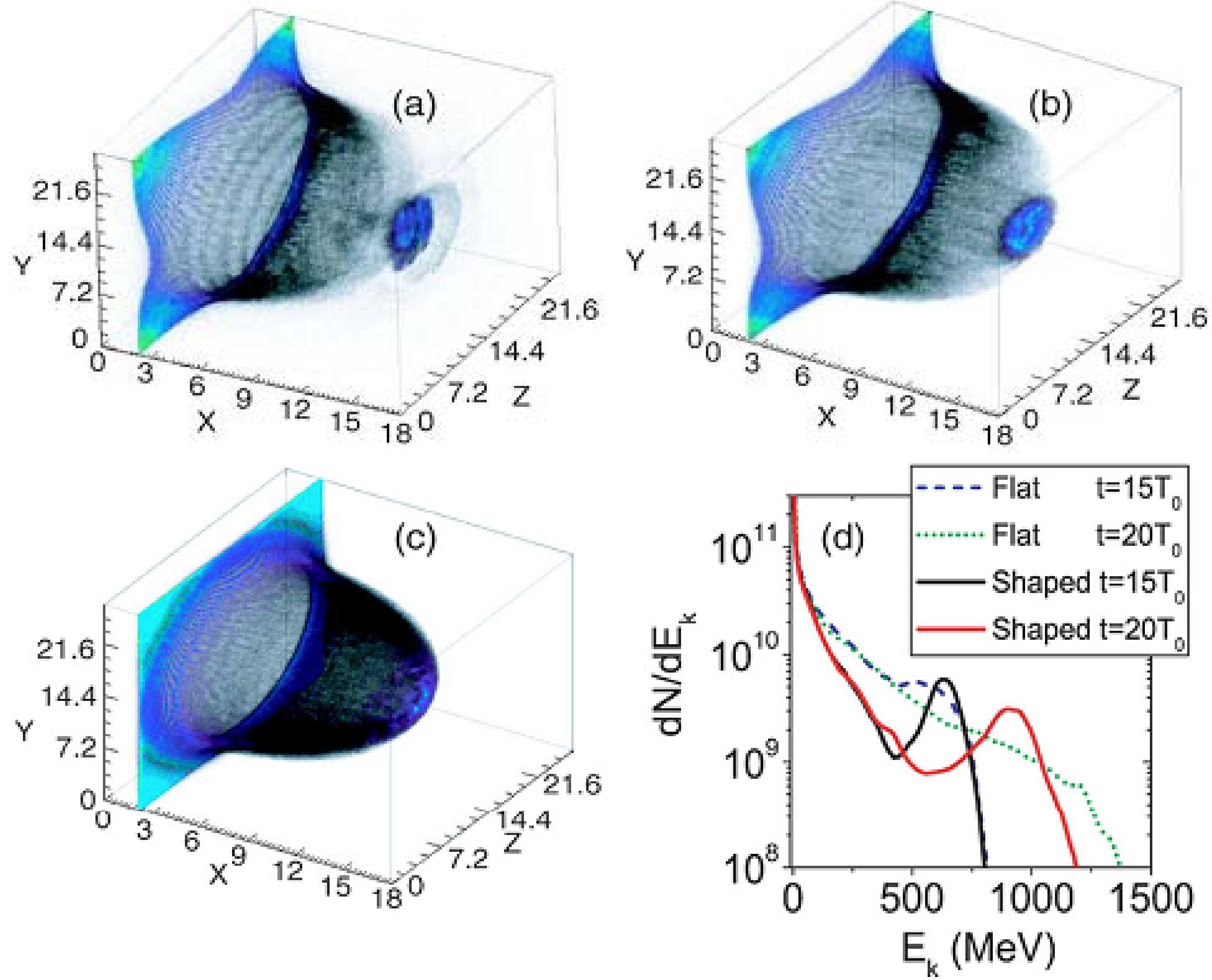
WG6 TH am, M. Chen



Electrons

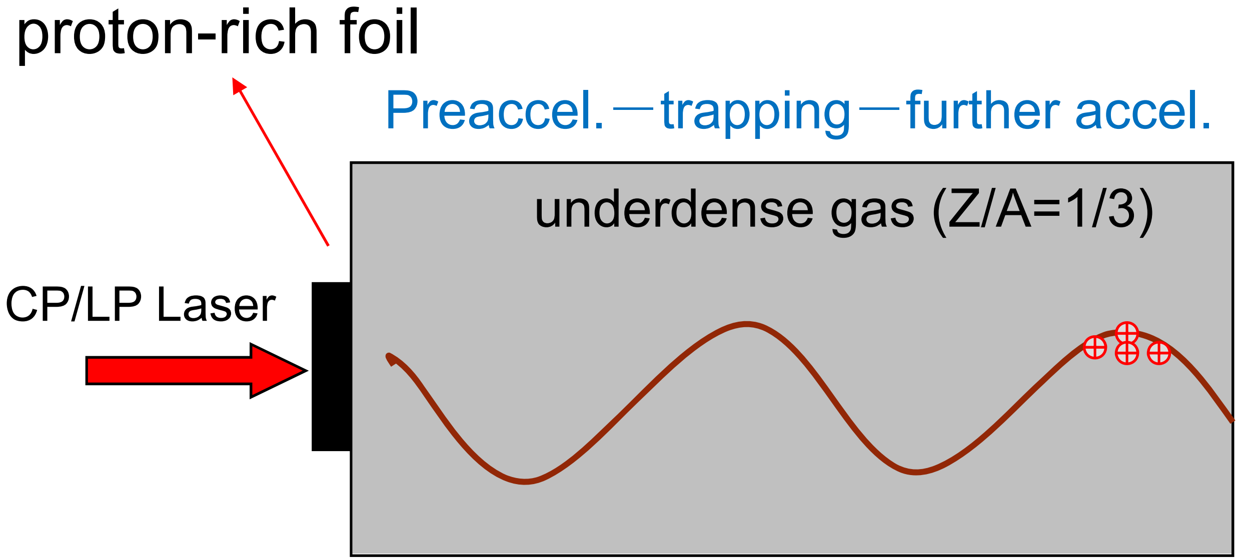
protons

Flat target



RPA+Laser wakefield acceleration

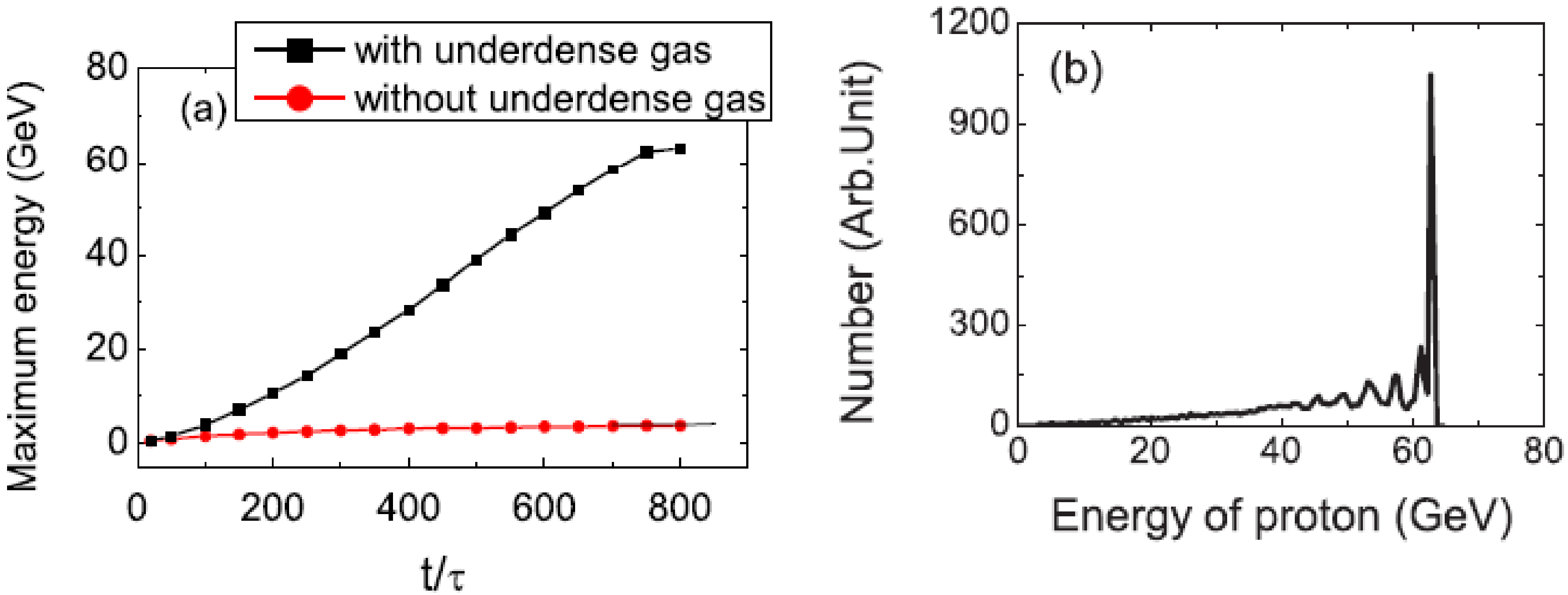
L.L. Yu et al., NJP 12 (2010) 045021
B.F. Shen et al., PRST (2009)



Two conditions:

- ◆ Protons in the high-density foil can be pre-accelerated to the GeV level in the RPA regime.
- ◆ The laser pulse can obviously transmit the overdense foil to generate wakefields in the underdense plasma.

Above 60 GeV proton beam accelerated in less than 1mm



About 10% of protons are trapped and accelerated to over 60GeV

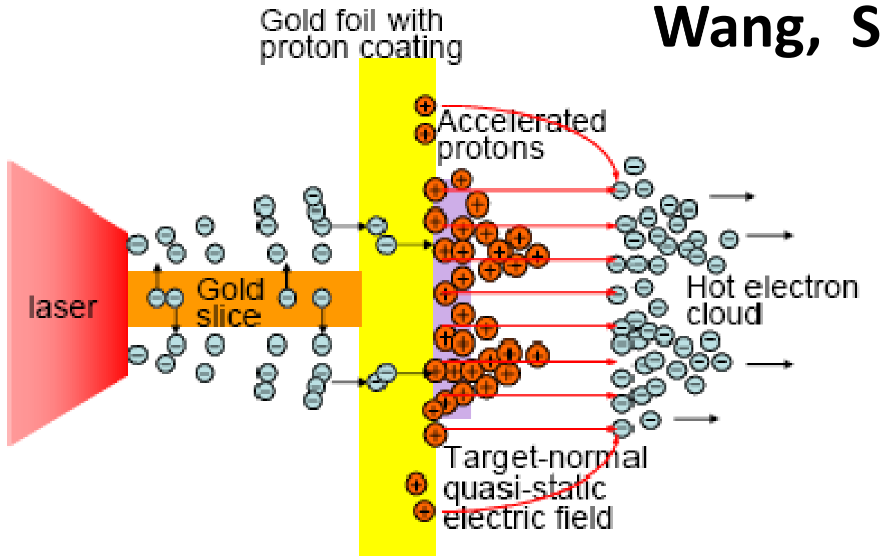
$$\bar{E}_{z,\max} \sim 28.92 m_e \omega c / e$$

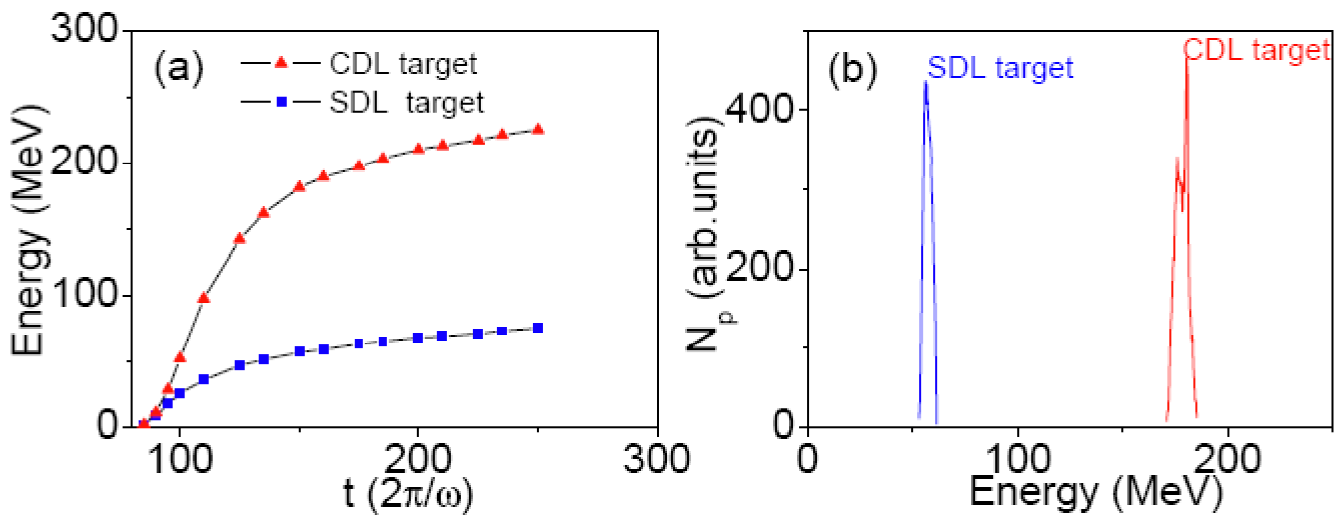
$$W_{\max} = e\bar{E}_{z,\max} L_{acc} \sim 69.6\text{GeV}$$

Protons in the complex target can be accelerated to energies more than three times, and the energy spread halved, that from the simple double layer target.

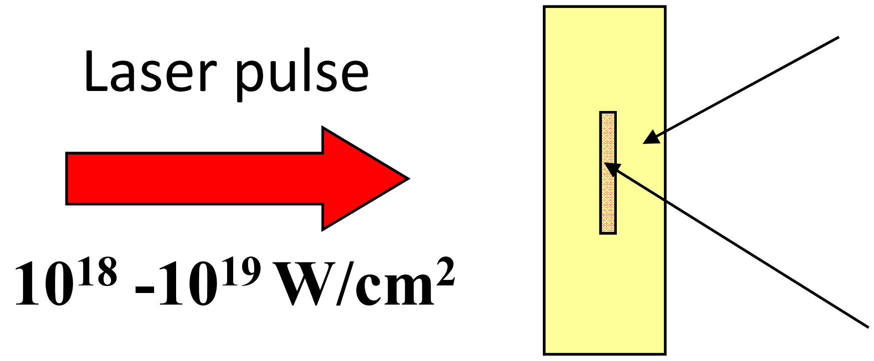
Wang, Shen et al., PoP2009

a=30



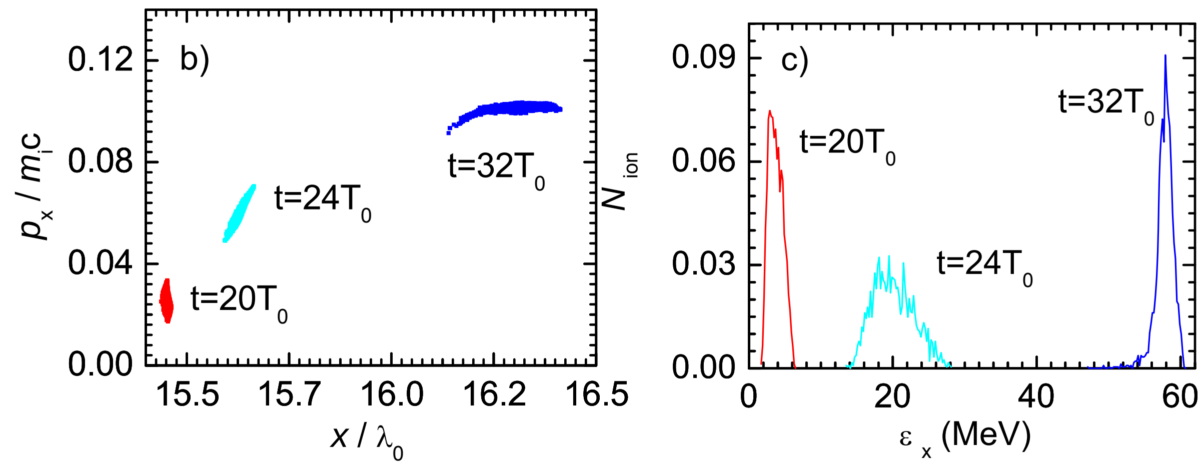


Heavy ions can be efficiently accelerated with electrostatic shock



Foil made of light ions, or protons

Microstructure made of heavy ions, ex. carbon.



phase space of heavy ions at different time

Corresponding energy spectrum

Laser a=6

Foil 2μm

Carbon layer 35 nm

Liangliang Ji, Baifei Shen et al., Phys. Rev. Lett., 101, 164802 (2008)

Concluding remarks

- The Asian community on laser plasma acceleration is growing both in theory/simulation and experiments. A few more new laser facilities are planned or under constructions.

- There have been quite a few collaborations in experiments between some labs/groups.

- Potential applications of laser-driven particle beams and radiation sources are expected to be significantly pursued among Asian research groups in the future.

Thank you for your attention!