LWFA researches in China (SJTU, SIOM, HUST) & Possible connection with EuPRAXIA

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Laboratory for laser plasmas,
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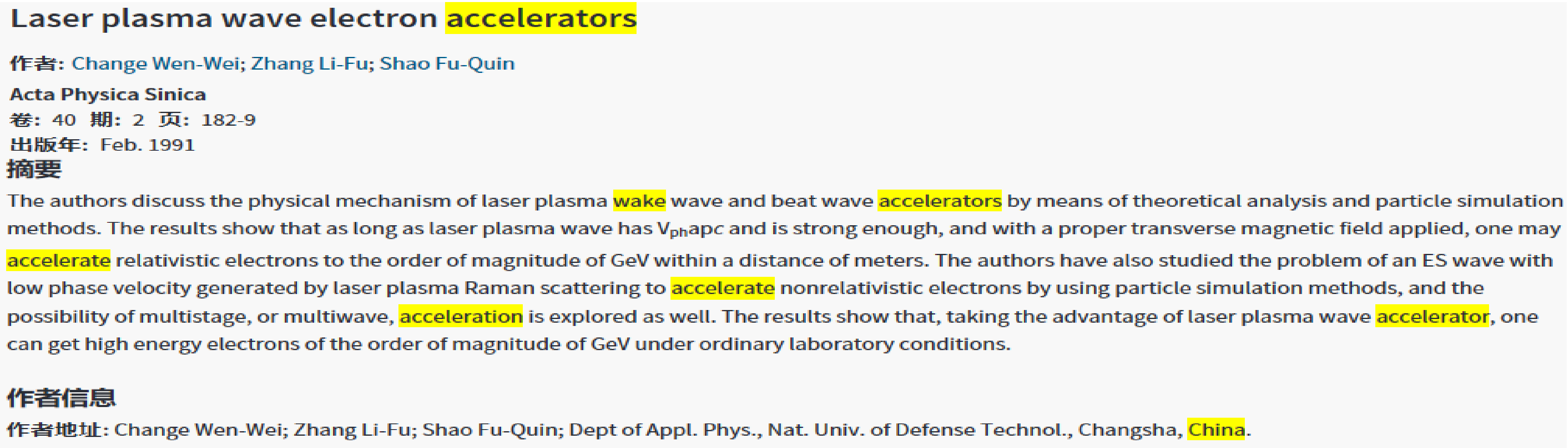
EuPRAXIA Design Report and Retreat, Feb. 25, 2019, Germany

LWFA researches in China



Laser plasma wave electron accelerators

作者: Change Wen-Wei; Zhang Li-Fu; Shao Fu-Quin

Acta Physica Sinica
卷: 40 期: 2 页: 182-9
出版年: Feb. 1991

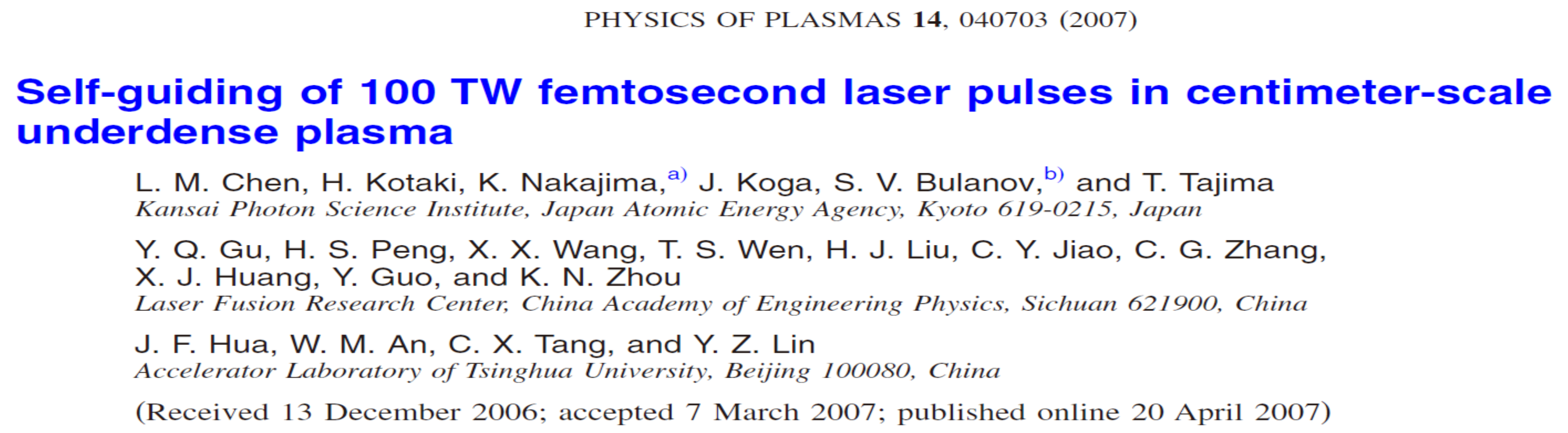
摘要

The authors discuss the physical mechanism of laser plasma wake wave and beat wave accelerators by means of theoretical analysis and particle simulation methods. The results show that as long as laser plasma wave has V_{ph}apc and is strong enough, and with a proper transverse magnetic field applied, one may accelerate relativistic electrons to the order of magnitude of GeV within a distance of meters. The authors have also studied the problem of an ES wave with low phase velocity generated by laser plasma Raman scattering to accelerate nonrelativistic electrons by using particle simulation methods, and the possibility of multistage, or multiwave, acceleration is explored as well. The results show that, taking the advantage of laser plasma wave accelerator, one can get high energy electrons of the order of GeV under ordinary laboratory conditions.

作者信息

作者地址: Change Wen-Wei; Zhang Li-Fu; Shao Fu-Quin; Dept of Appl. Phys., Nat. Univ. of Defense Technol., Changsha, China.

To my knowledge, the first introductory article was published in 1991 by Prof. Wen-Wei Chang. Theoretical researches were started after that, most of them began after 2000. The first experimental work in China was carried out in 2007.



PHYSICS OF PLASMAS **14**, 040703 (2007)

Self-guiding of 100 TW femtosecond laser pulses in centimeter-scale underdense plasma

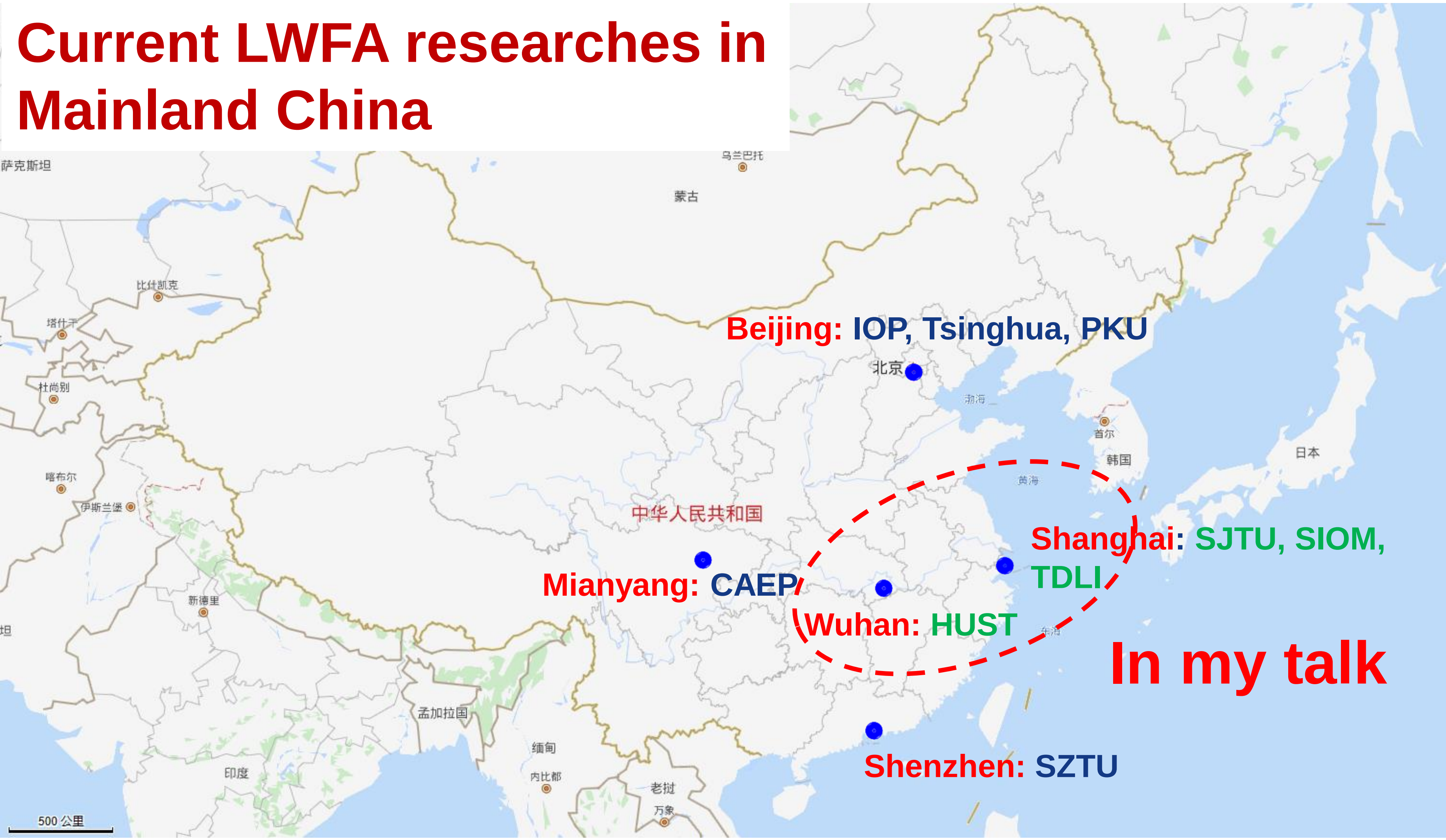
L. M. Chen, H. Kotaki, K. Nakajima,[a] J. Koga, S. V. Bulanov,[b] and T. Tajima
Kansai Photon Science Institute, Japan Atomic Energy Agency, Kyoto 619-0215, Japan

Y. Q. Gu, H. S. Peng, X. X. Wang, T. S. Wen, H. J. Liu, C. Y. Jiao, C. G. Zhang, X. J. Huang, Y. Guo, and K. N. Zhou
Laser Fusion Research Center, China Academy of Engineering Physics, Sichuan 621900, China

J. F. Hua, W. M. An, C. X. Tang, and Y. Z. Lin
Accelerator Laboratory of Tsinghua University, Beijing 100080, China

(Received 13 December 2006; accepted 7 March 2007; published online 20 April 2007)

Current LWFA researches in Mainland China



Beijing: **IOP, Tsinghua, PKU**

Mianyang: **CAEP**

Wuhan: **HUST**

Shanghai: **SJTU, SIOM, TDLI**

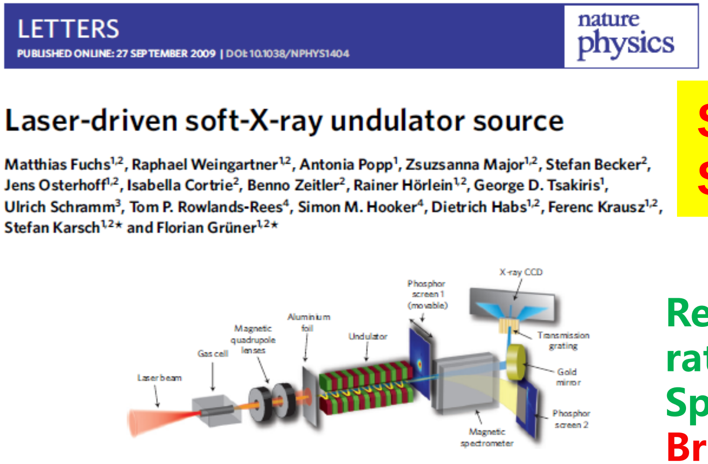
Shenzhen: **SZTU**

In my talk

SJTU: Shanghai Jiao Tong University (1896-)
PKU: Peking University (1898-)
Tsinghua: Tsinghua University (1911-)
IOP: Institute of Physics (CAS) (1928-)
HUST: Huazhong University of Science and Technology (1952-)
CAEP: China Academy of Engineering Physics (1958-)
SIOM: Shanghai Institute of Optics and Fine Mechanics (CAS) (1964-)
SZTU: Shenzhen Technology University (2016-)
TDLI: Tsung-Dao Lee Institute (2016-)

LWFA Potential Applications and Challenges

Betatron Radiation Source



LETTERS

PUBLISHED ONLINE: 27 SEPTEMBER 2009 | DOI: 10.1038/NPHYS1404

nature physics

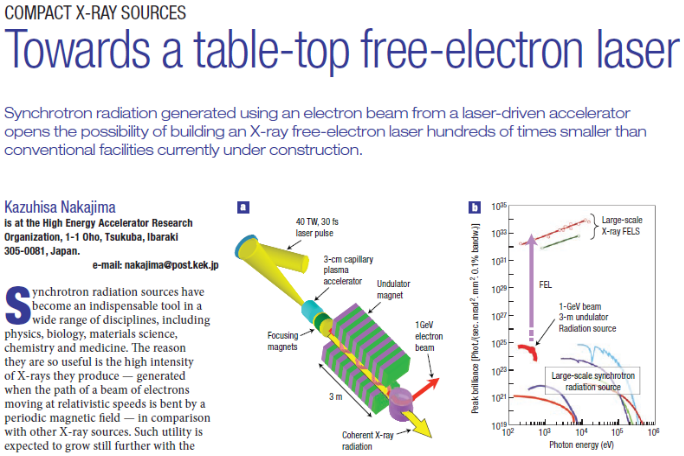
Laser-driven soft-X-ray undulator source

Matthias Fuchs[1,2], Raphael Weingartner[1,2], Antonia Popp[1], Zsuzsanna Major[1,2], Stefan Becker[2], Jens Osterhoff[1,2], Isabella Cortrie[2], Benno Zeitler[2], Rainer Hörlein[1,2], George D. Tsakiris[1], Ulrich Schramm[3], Tom P. Rowlands-Rees[4], Simon M. Hooker[4], Dietrich Habs[1,2], Ferenc Krausz[1,2], Stefan Karsch[1,2]* and Florian Grüner[1,2]*

SJTU
SIOM

Repetition rate
Spectrum
Brightness

LWFA based FEL



COMPACT X-RAY SOURCES

Towards a table-top free-electron laser

Synchrotron radiation generated using an electron beam from a laser-driven accelerator opens the possibility of building an X-ray free-electron laser hundreds of times smaller than conventional facilities currently under construction.

Kazuhisa Nakajima
is at the High Energy Accelerator Research Organization, 1-1 Oho, Tsukuba, Ibaraki 305-0081, Japan.
e-mail: nakajima@post.kek.jp

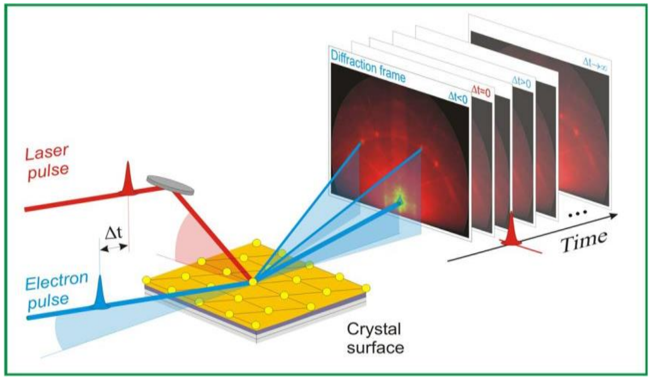
Synchrotron radiation sources have become an indispensable tool in a wide range of disciplines, including physics, biology, materials science, chemistry and medicine. The reason they are so useful is the high intensity of X-rays they produce — generated when the path of a beam of electrons moving at relativistic speeds is bent by a periodic magnetic field — in comparison with other X-ray sources. Such utility is expected to grow still further with the

SIOM

Repetition rate
E-Spread
Emittance

Ultra Fast Electron Diffraction

PRST-AB,19, 021302(2016); Nature Photonics, 10.1038/NPHOTON.2017.46



HUST

Repetition rate
Pulse duration

TeV e$^+$ e$^-$ Collider

Physics Today, March, 44, 2009

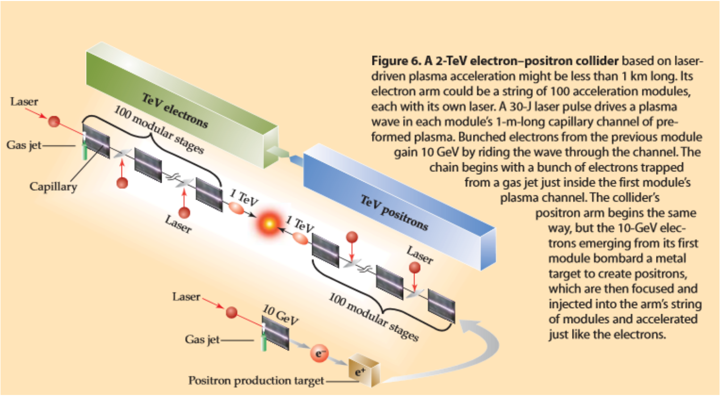


Figure 6. A 2-TeV electron–positron collider based on laser-driven plasma acceleration might be less than 1 km long. Its electron arm could be a string of 100 acceleration modules, each with its own laser. A 30-J laser pulse drives a plasma wave in each module's 1-m-long capillary channel of pre-formed plasma. Bunched electrons from the previous module gain 10 GeV by riding the wave through the channel. The chain begins with a bunch of electrons trapped from a gas jet just inside the first module's plasma channel. The collider's positron arm begins the same way, but the 10-GeV electrons emerging from its first module bombard a metal target to create positrons, which are then focused and injected into the arm's string of modules and accelerated just like the electrons.

SJTU

Repetition rate
Staging
Energy
Brightness

LWFA Studies at SJTU

Laser Plasmas Studies at SJTU

SJTU – Group (2007)

Leader: Prof. J. Zhang

Laser:

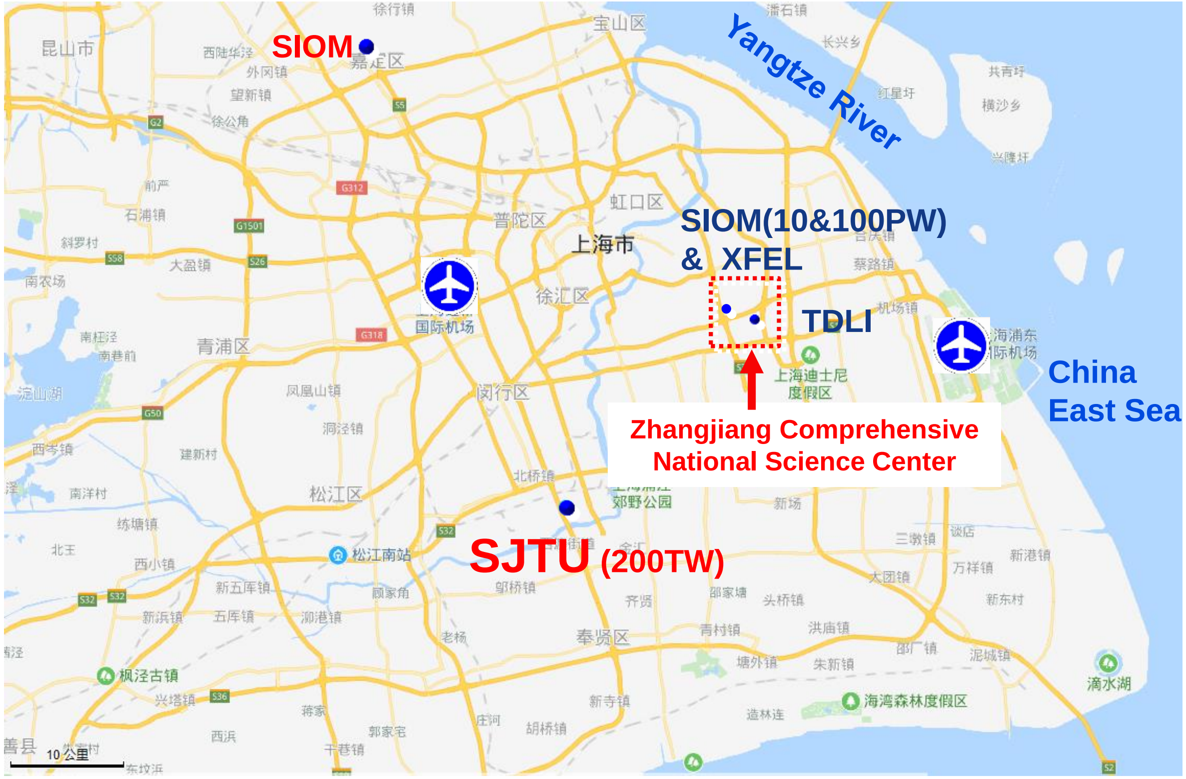
- ◆ 200TW laser system 10Hz, 5J/25fs;
- ◆ kHz laser system;
- ◆ 400J laser system.
- ◆ 100TW 2.2μm laser 100fs

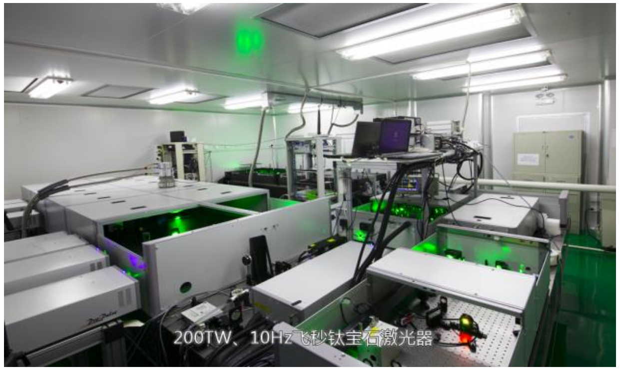
Topics:

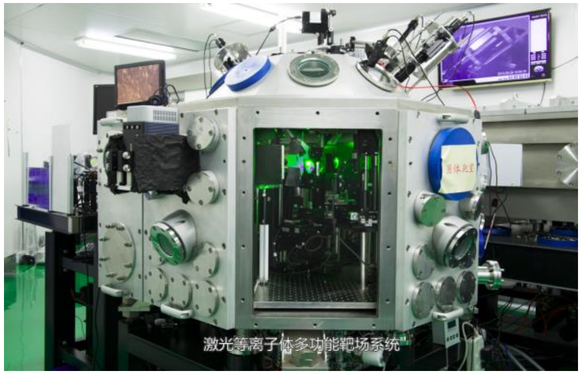
High power laser technology,

Fusion, Laser Plasma

Both laser, experiment & theory group.







LWFA studies at SJTU (2014-2018)

Funding: LWFA studies are partly supported by National Basic Research Program of China (2014-2018, ~2.0M Euros: **SJTU+IOP+Tsinghua**) & the National Natural Science Foundation of China (2015-2020, ~1.6M Euros: **SJTU**).

SJTU Main topics:

1. Electron injection in Wakefield

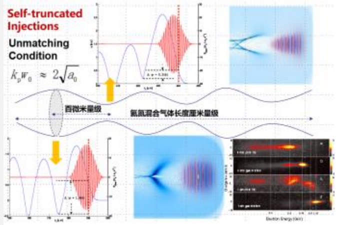
a) **Self-truncated ionization injection and experimental demonstration. Phys. Plasmas** 21, 030701 (2014); **Sci. Rep**. 5, 14659 (2015)

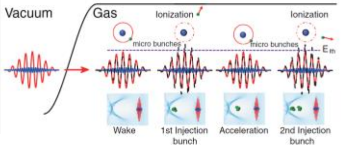
b) **Two-color laser induced ionization electron for energy spread as low as 0.29%. Phys. Rev. Lett**.114, 084801 (2015)

c) **External magnetic field assisted ionization injection. NJP**. 20, 063031 (2018)

d) **Electron Trapping from Interactions between Laser-Driven Relativistic Plasma Waves. Phys. Rev. Lett**., 121, 104801 (2018) Collaborated with UNL

e) …





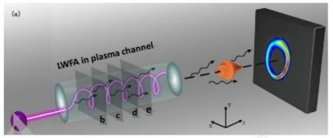
2. Radiation in Wakefield (From THz to γ-ray)

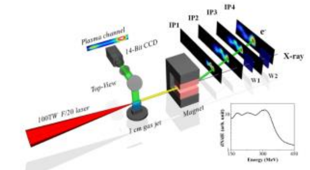
a) **Tunable synchrotron-like radiation from centimeter scale plasma channels. Light: Science & Applications**, 5, e16015 (2016).

b) **A compact tunable polarized X-ray source based on laser-plasma helical undulators. Sci. Rep**. 6, 29101 (2016)

c) **High-order multiphoton Thomson scattering. Nature Photonics**, 11, 514 (2017) with UNL

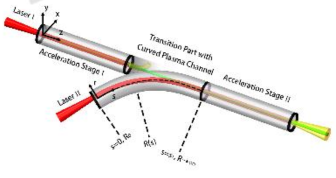
d) …





3. New staging scheme for LWFA

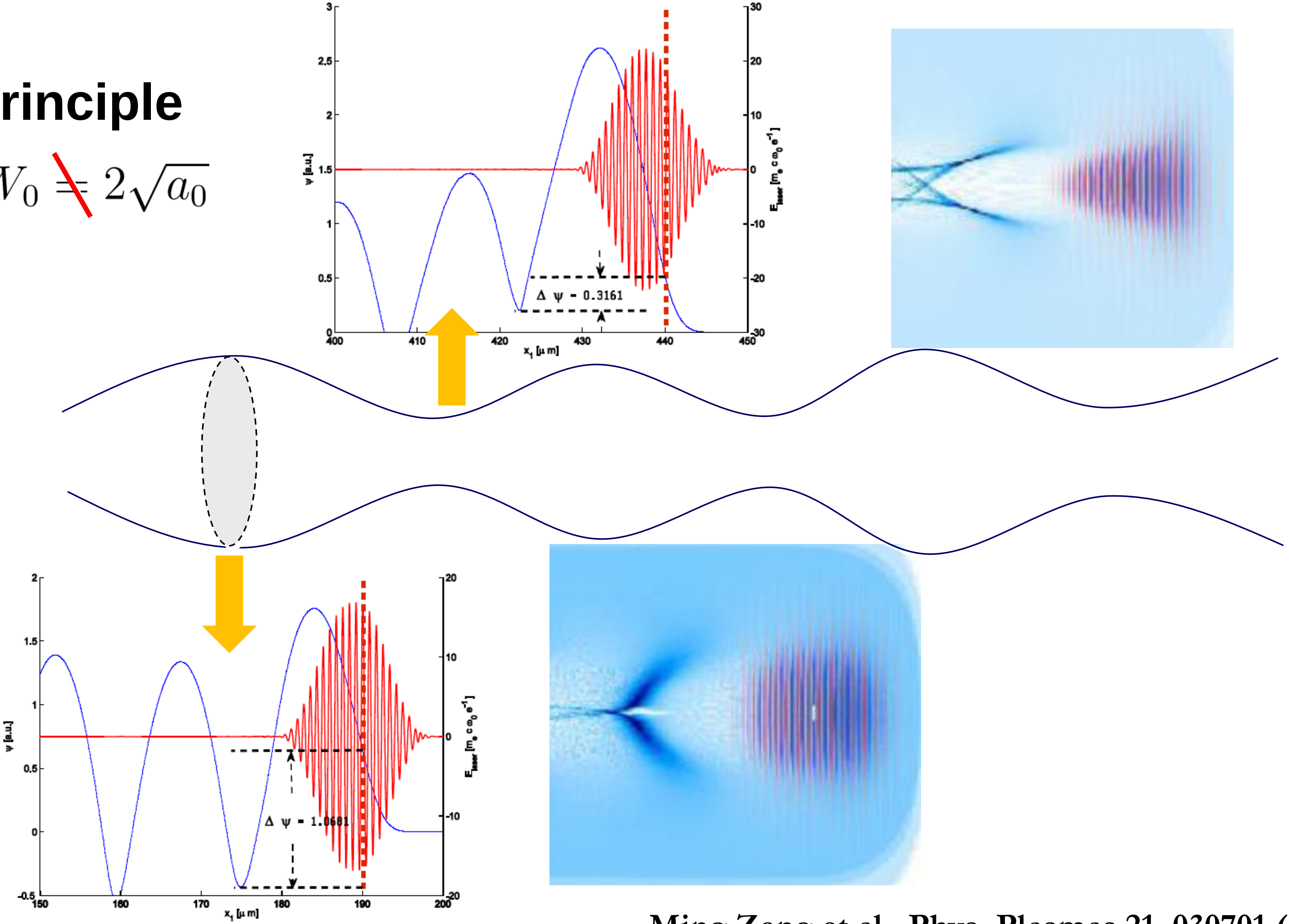
a) **Multistage Coupling of Laser-Wakefield Accelerators with Curved Plasma Channels. Phys. Rev. Lett**., 120, 154801 (2018)



1. Self-truncated ionization injection

Principle

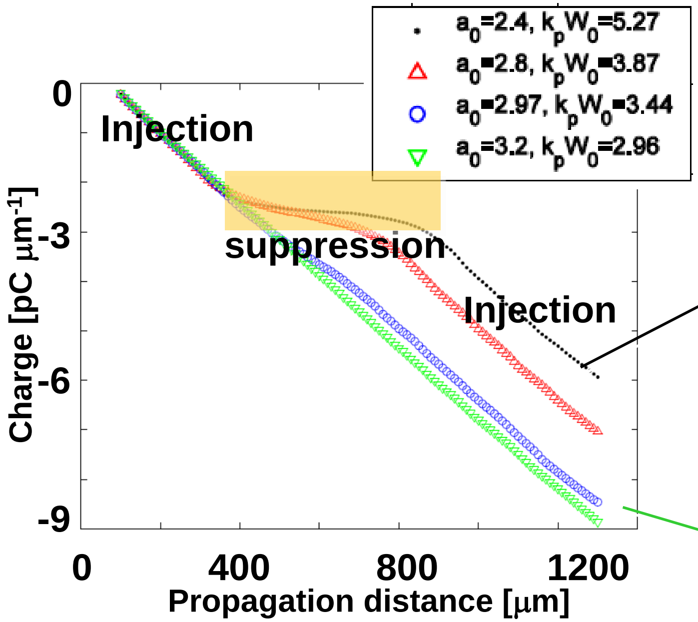
$$k_p W_0 \cancel{=} 2\sqrt{a_0}$$



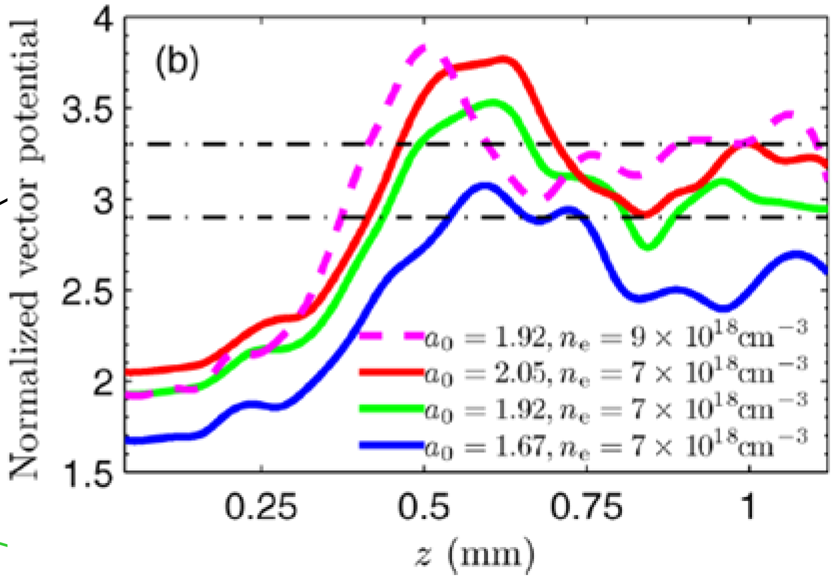
Ming Zeng et al., Phys. Plasmas 21, 030701 (2014).

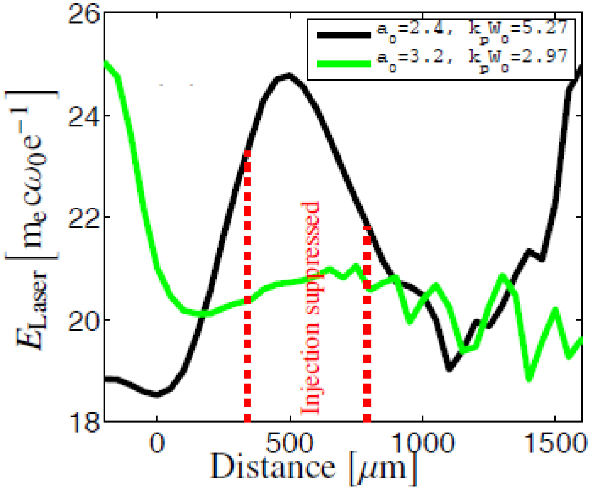
Effective injection length is controlled by changing the laser spot size

Injection charge VS laser propagation legnth



Ionization controlled truncation!

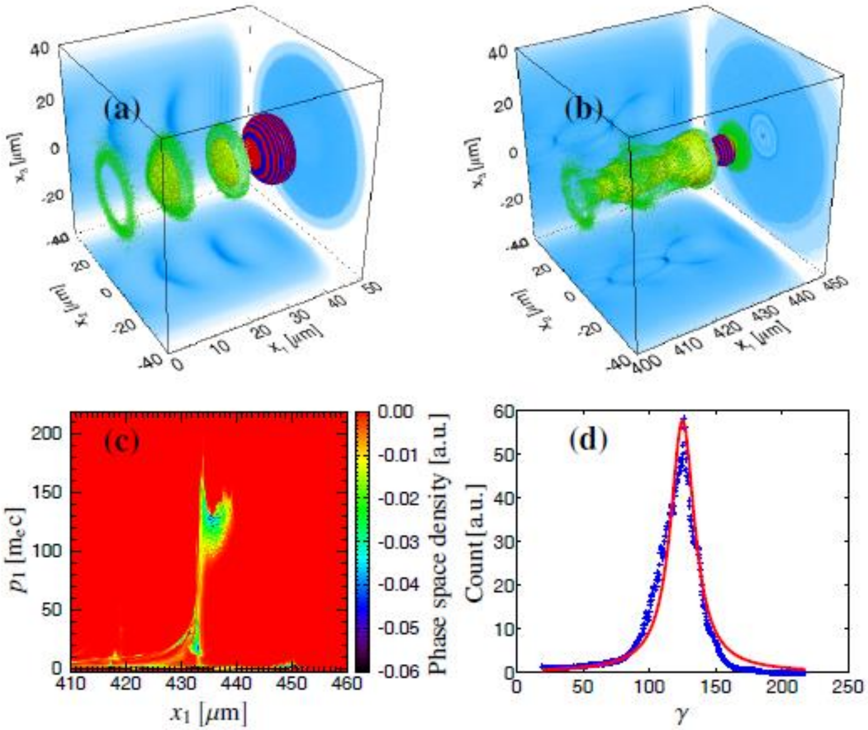




CQ Xia et al., POP **18**, 113101, 2011

The first stage injection length is only 250μm!

Three dimensional PIC simulations

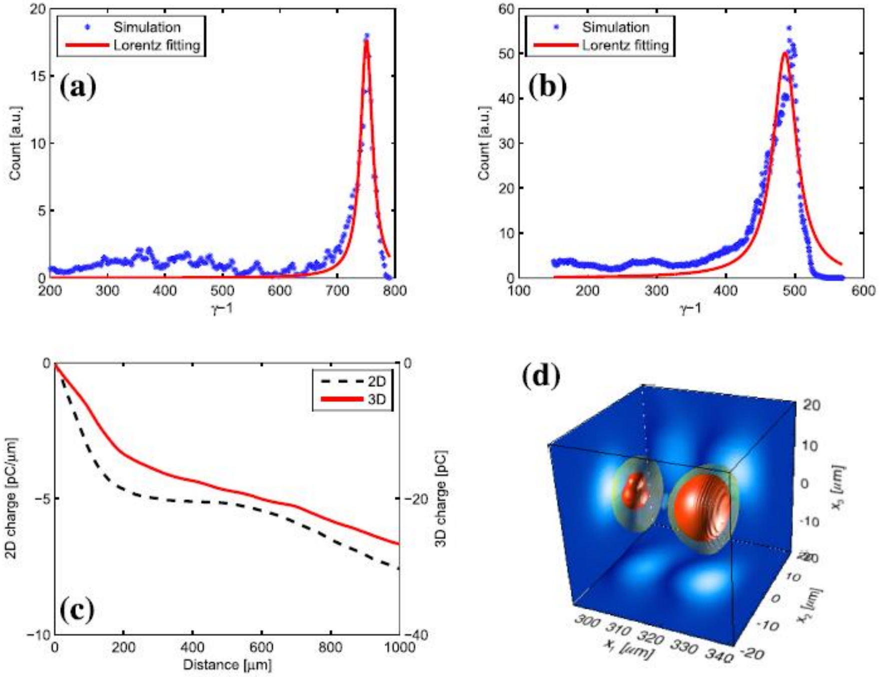


Injection process in 2D and 3D simulaitons

2D:n_{He}=2.8e18/cm^3, n_N=8.5e15/cm^3, a_0=2.9, and W_0=11.69um,14.58 pC, 383MeV 3.33% Energy spread

3D:n_{He}=8e-4n_c, a_0=2.3, and k_pW_0=4.066. 25.5 pC

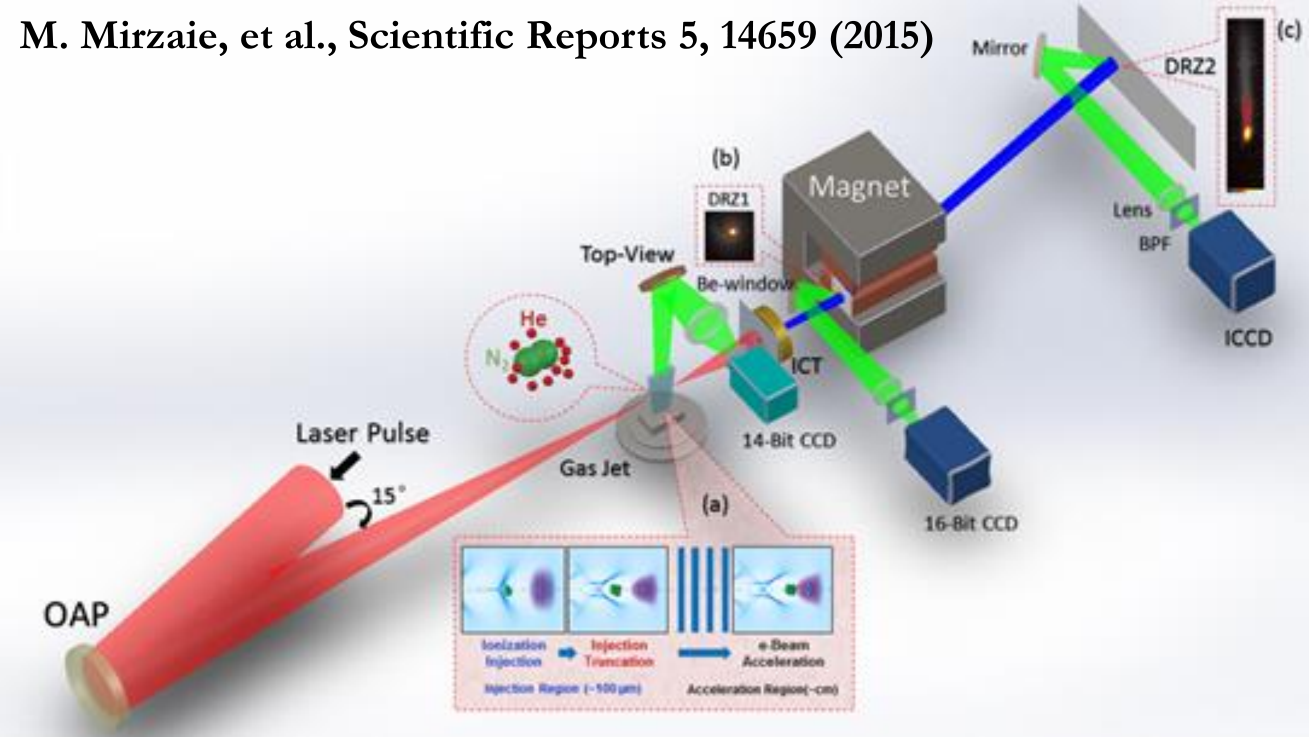
Laser evolution in 3D case



Ming Zeng et al., Phys. Plasmas 21, 030701 (2014).

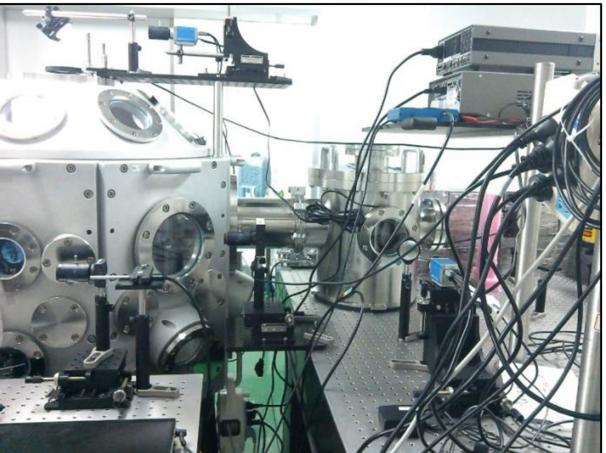
Experiment demonstration of self-truncated ionization injection

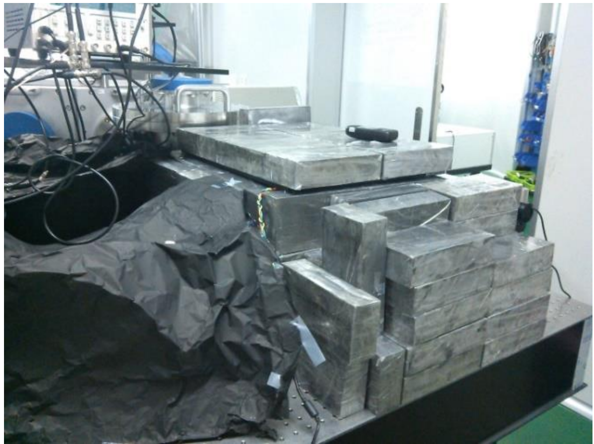
M. Mirzaie, et al., Scientific Reports 5, 14659 (2015)



30TW 30fs laser
4mm gas
5 % energy spread
at 412 MeV

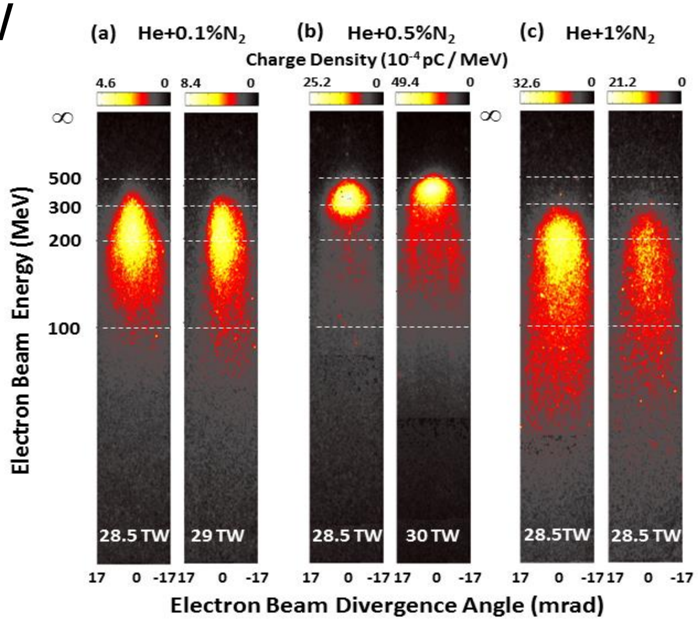
118TW 30fs laser
1cm gas
7% energy spread
at 1.2 GeV
acceleration





Experiment demonstration of self-truncated ionization injection

30TW

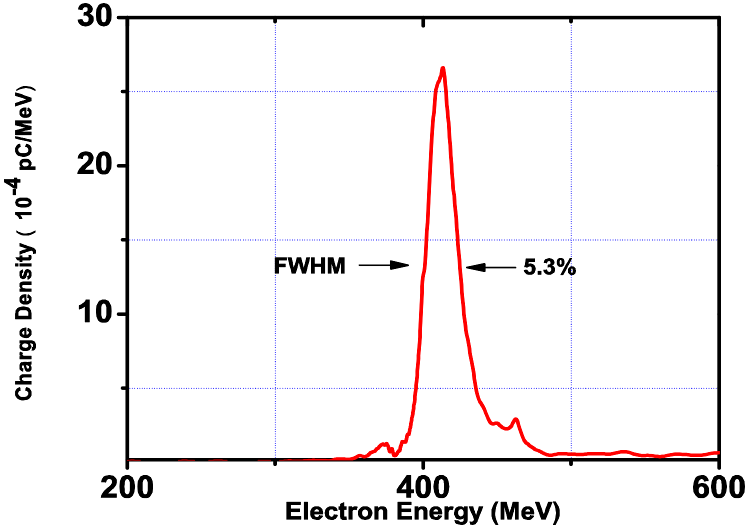


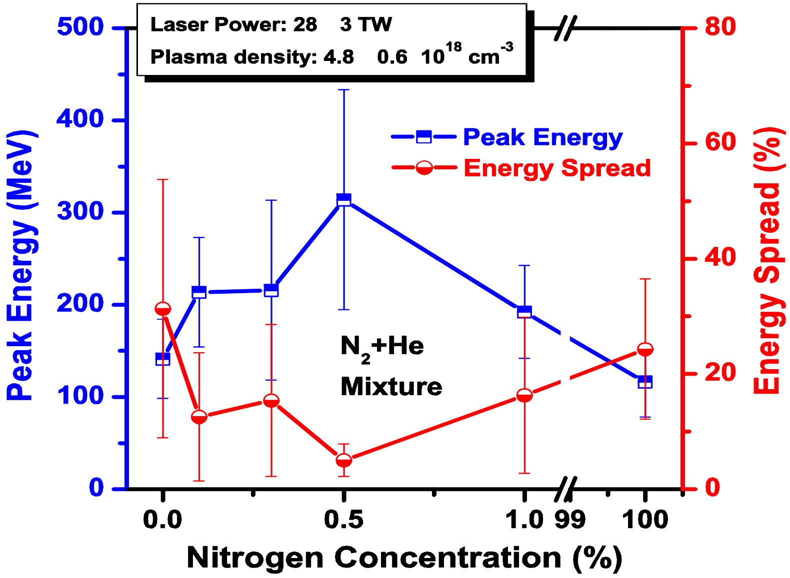
$$k_p w_0 = 10.8 - 12.2$$

$$\gg 2\sqrt{a_0} \approx 2.0 - 2.1$$

0.5%N_2 case: 412±10 MeV, 80 pC electron 7.1mrad

A typical energy spectrum





M. Mirzaie, et al., Scientific Reports 5, 14659 (2015)

Experiment demonstration of self-truncated ionization injection

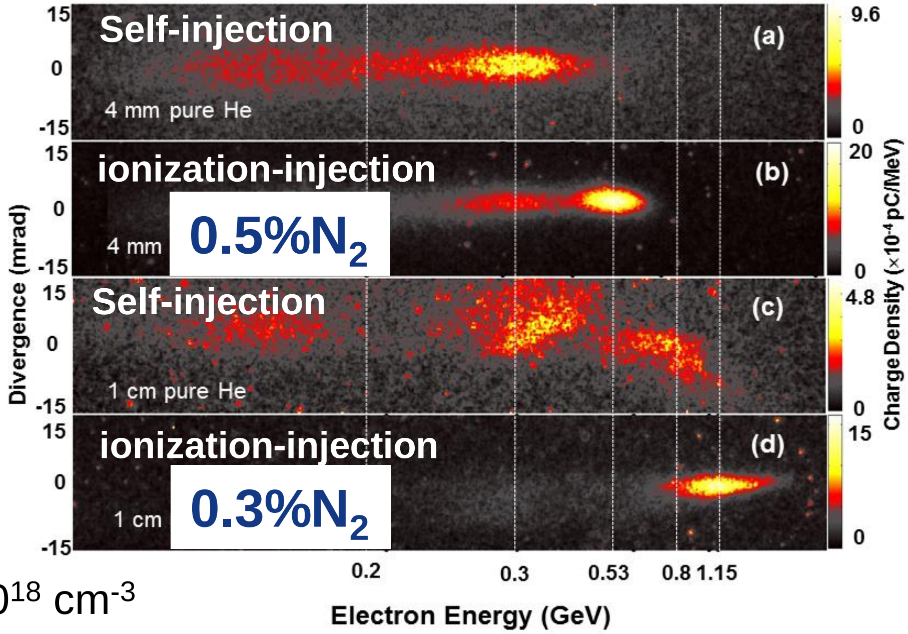
6.5 (±0.5)×10^{18} cm^{-3}

118TW

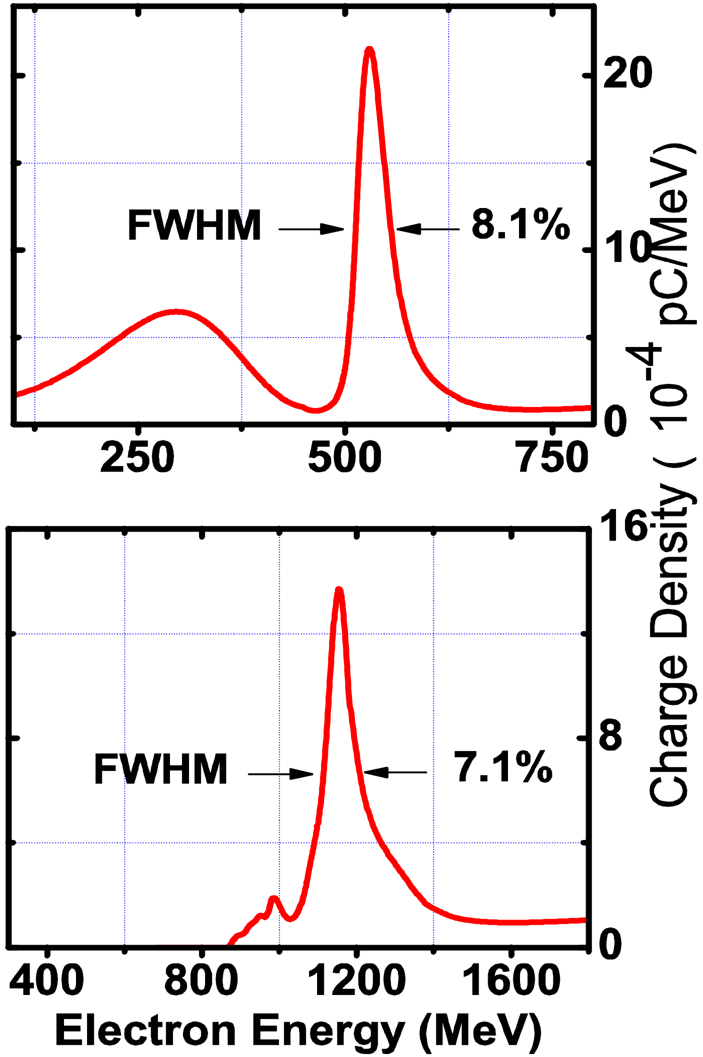
103TW

114TW

118TW



1.8×10^{18} cm^{-3}



$$k_p w_0 \approx 7.1 > 2(a_0)^{1/2} \approx 2.85$$

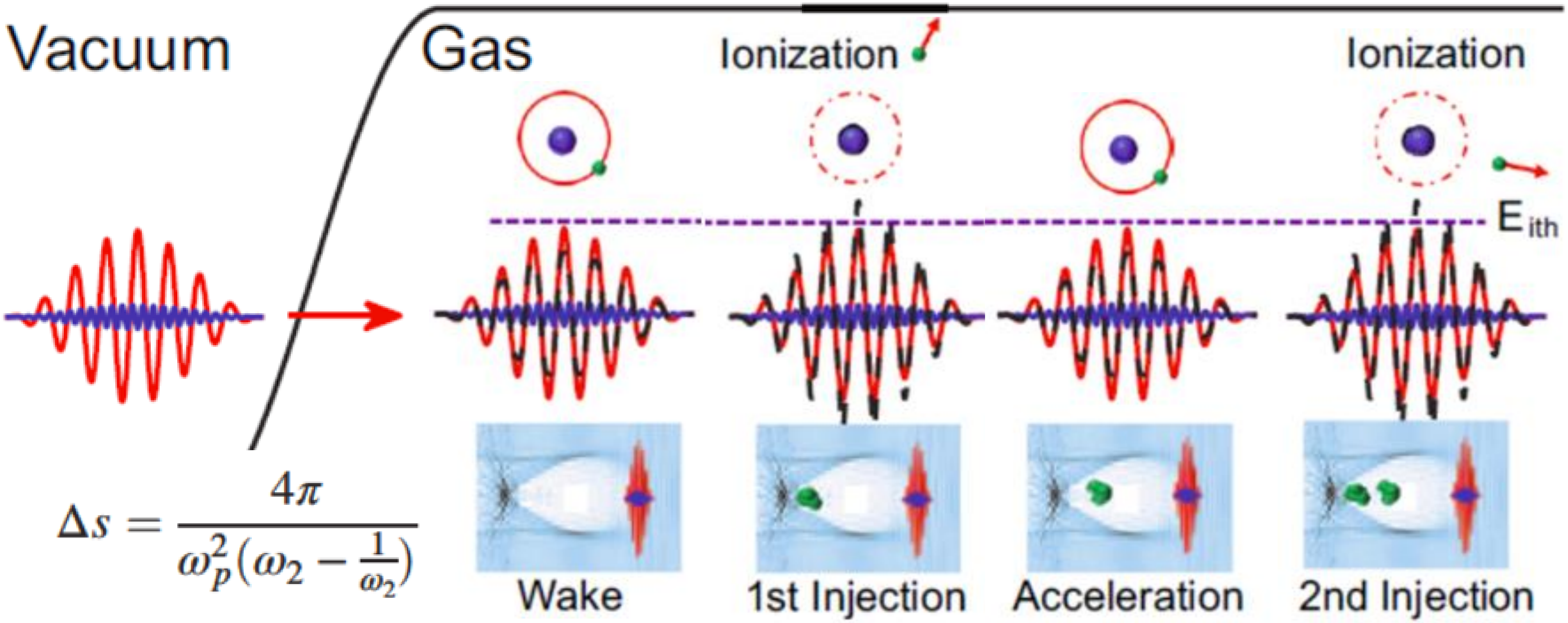
(a) *E* =300±4.5 MeV, Q =21 pC Δ*E*/*E* ≈ 25% divergence angle of 7.6 mrad

(b) E_{QME} = 530±8 MeV, Q (charge) =25 pC, Δ*E*/*E* ≈ 8 %, divergence angle of 5.2 mrad

(d) E_{QME} = 1.2±0.03 GeV, Q (charge) =16 pC, Δ*E*/*E* ≈ 7 %, divergence angle of 4.7 mrad

2. Two color laser ionization injection to get extreme low energy spread electron beam

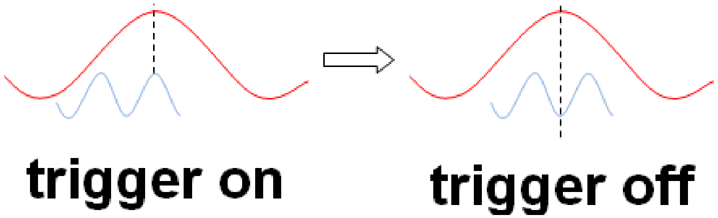
Laser pulses with different frequency have different v_p.



$$\Delta s = \frac{4\pi}{\omega_p^2(\omega_2 - \frac{1}{\omega_2})}$$

$$E_1(\xi, s) = a_{10}\cos\left(\xi + \frac{1}{2}\omega_p^2 s + \phi_1\right),$$

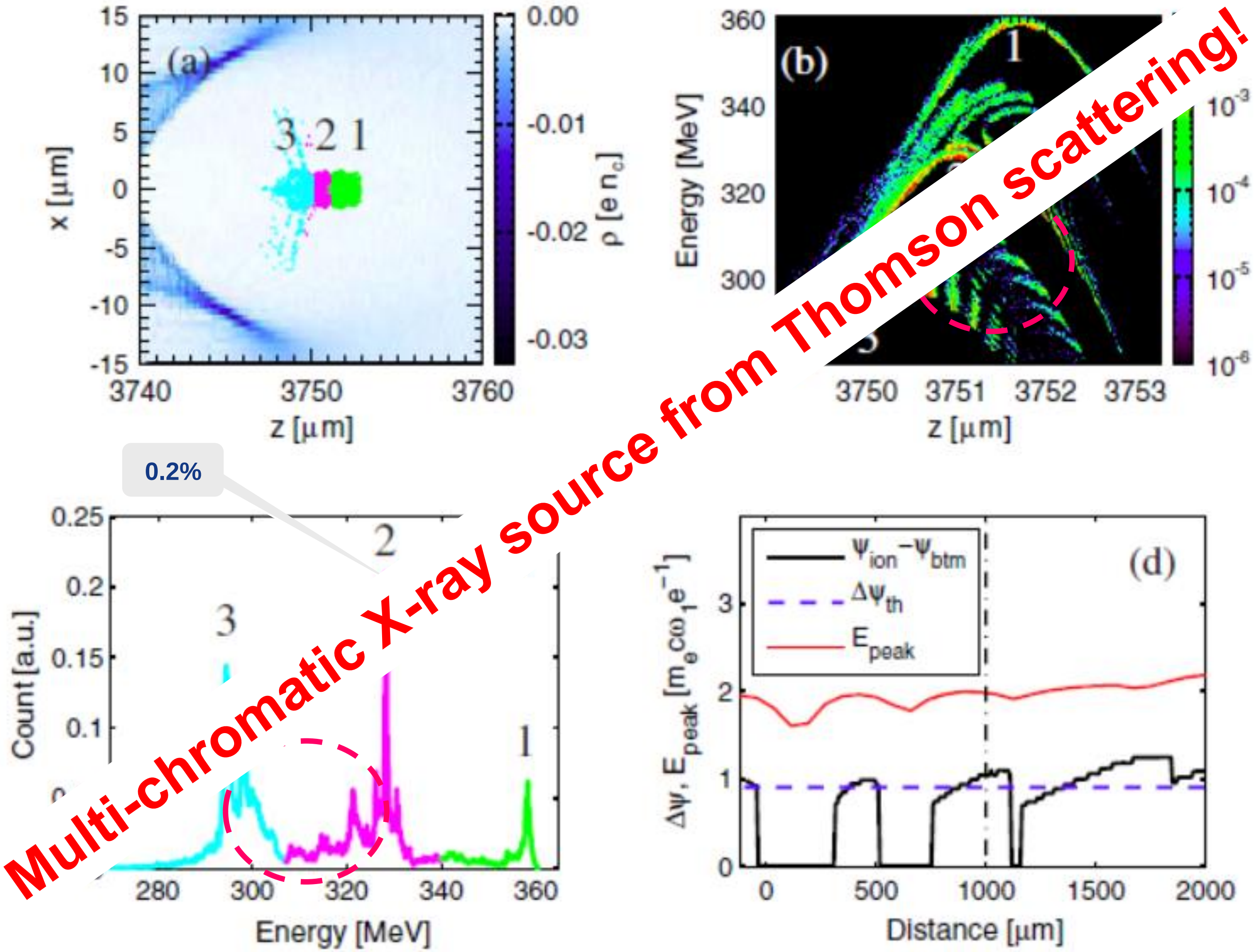
$$E_2(\xi, s) = a_{20}\omega_2\cos\left(\omega_2\xi + \frac{1}{2}\frac{\omega_p^2}{\omega_2}s + \phi_2\right)$$



Ionization happens locally within tens of mm and local wake phase.

M. Zeng, et al., PhysRevLett.114.084801 (2015)

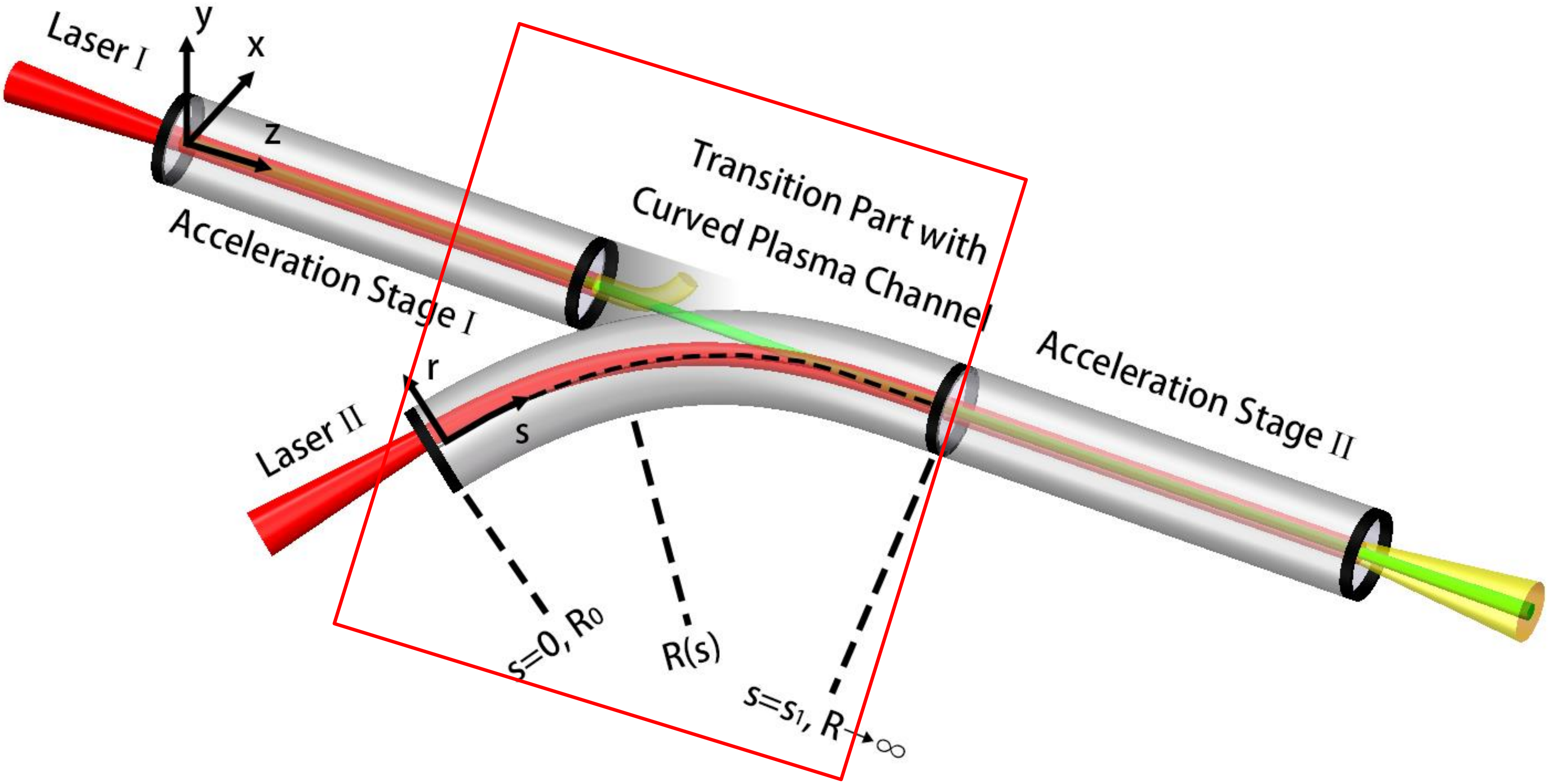
Comb like energy spectrum



0.2%

Multi-chromatic X-ray source from Thomson scattering!

3. Curved plasma channel based staging scheme



1. Electrons always move in straight plasma channel avoiding transverse dispersion
2. Driver laser is guided by a specially designed curved plasma channel to the following straight channel

J. Luo, et al. PRL, 120, 154801 (2018)

Laser propagation in a plasma channel

Laser vector potential evolution: $(c^2\nabla^2 - \partial^2/\partial t^2)A_y = \omega_p^2 A_y$

Parabolic plasma channel: $n_p(r) = n_0 + \Delta n \cdot (r^2/w_0^2)$

Laser Envelope Evolution Equation：

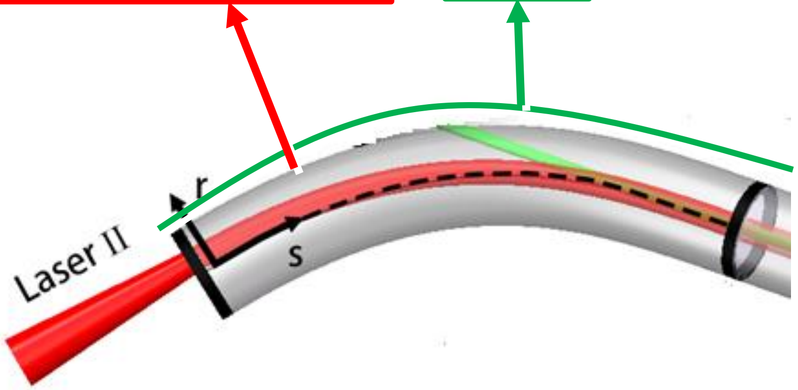
Channel term

Curvature term

$$i\frac{\partial a}{c\partial t} = \left[-\frac{c}{2\omega_l}\frac{\partial^2}{\partial r^2} + \boxed{\frac{\omega_l}{2c}\frac{n_0}{n_{cr}}\left(1+\frac{\Delta n}{n_0}\frac{r^2}{w_0^2}\right)} - \boxed{\frac{\omega_l}{c}\frac{r}{R}}\right] a$$

Initial condition:

$$a(t=0,r) = a_0 \exp[-(r-r_0)^2/w_0^2]$$



Time dependent Schroedinger Equation (TDSE)

A. J. W. Reitsma et al. POP 14, 053104 (2007)

Laser propagation in a curved plasma channel

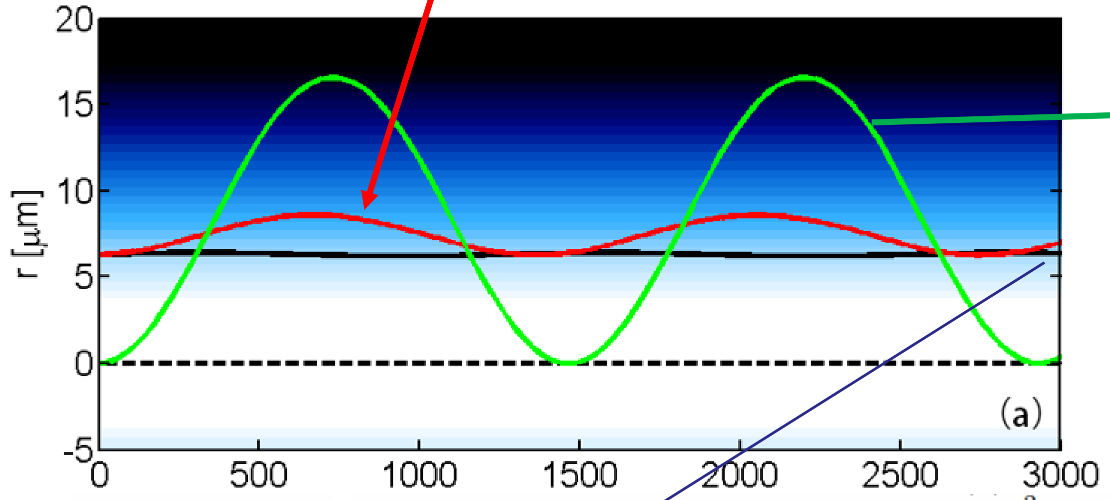
Laser intensity effect: $\frac{n_0}{(1+|a|^2/2)^{1/2}}$

Nonlinear-TDSE

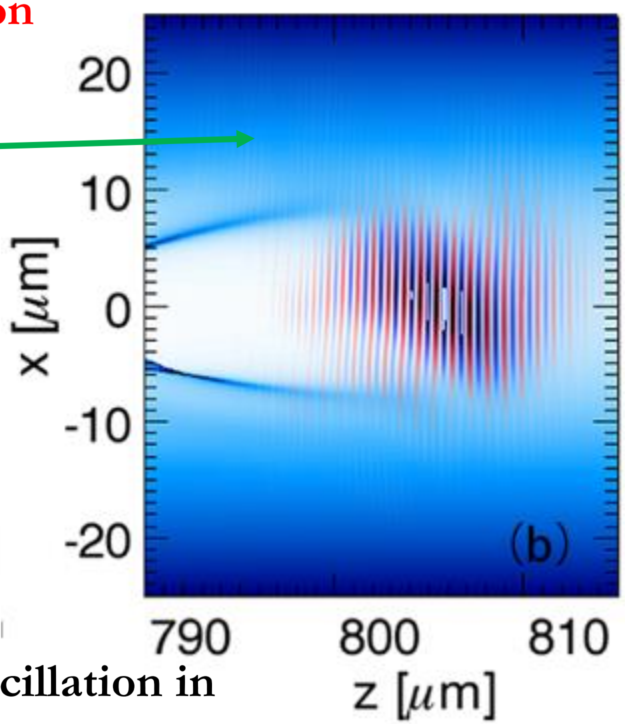
$$i\frac{\partial a}{c\partial t} = \left[-\frac{c}{2\omega_l}\frac{\partial^2}{\partial r^2} + \boxed{\frac{\omega_l}{2c}\frac{n_0}{n_{cr}}\left(1+\frac{\Delta n}{n_0}\frac{r^2}{w_0^2}\right) - \frac{\omega_l}{c}\frac{r}{R}}\right]a$$

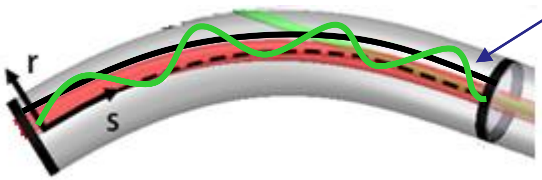
Equilibrium centroid trajectory: $\Rightarrow$ $r_{equ} = \frac{n_{cr}}{\Delta n}\frac{w_0^2}{R}$

Include the curvature effect in the centroid calculation



$\lambda_l = 0.8\ \mu\text{m},\ w_0 = 8\ \mu\text{m},\ R_0 = 10\ \text{mm},\ n_0 = 10^{-3}\ n_{cr}.$





Stable off-axis moving→ Oscillation in straight channel

Laser Oscillation → Laser wave front deformation

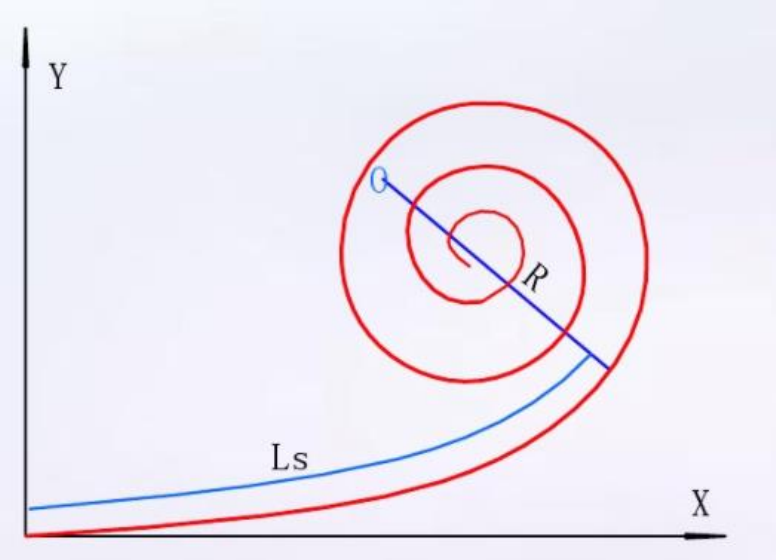
Transition line shaped curvature avoids laser oscillation

For motorcycles, when turning, you can tilt the body to keep the trajectory with fixed curvature. For laser, this means one should tilt the laser pulse front (with transverse chirp), which is difficult.

Why not tune the road curvature?

$$i\frac{\partial a}{\partial t} = \left[-\frac{c^2}{2\omega_l}\frac{\partial^2}{\partial r^2} + \frac{\omega_l}{2}\frac{n_0}{n_{cr}}\left(1+\frac{\Delta n}{n_0}\frac{r^2}{w_0^2}\right) - \omega_l\frac{r}{\boxed{R}}\right]a$$

Curvature varying



Laser propagation in plasma channel with transition line like curvature

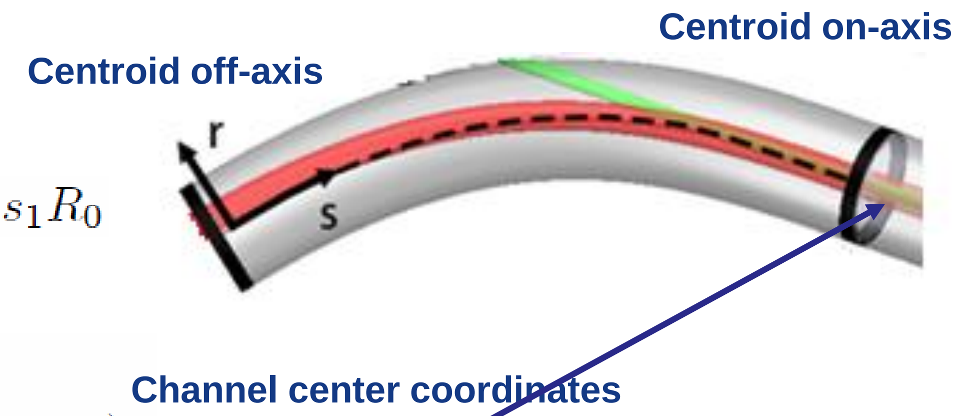
Transition Curve: $(s_1\text{-}s)\cdot R^{\alpha}$=Const

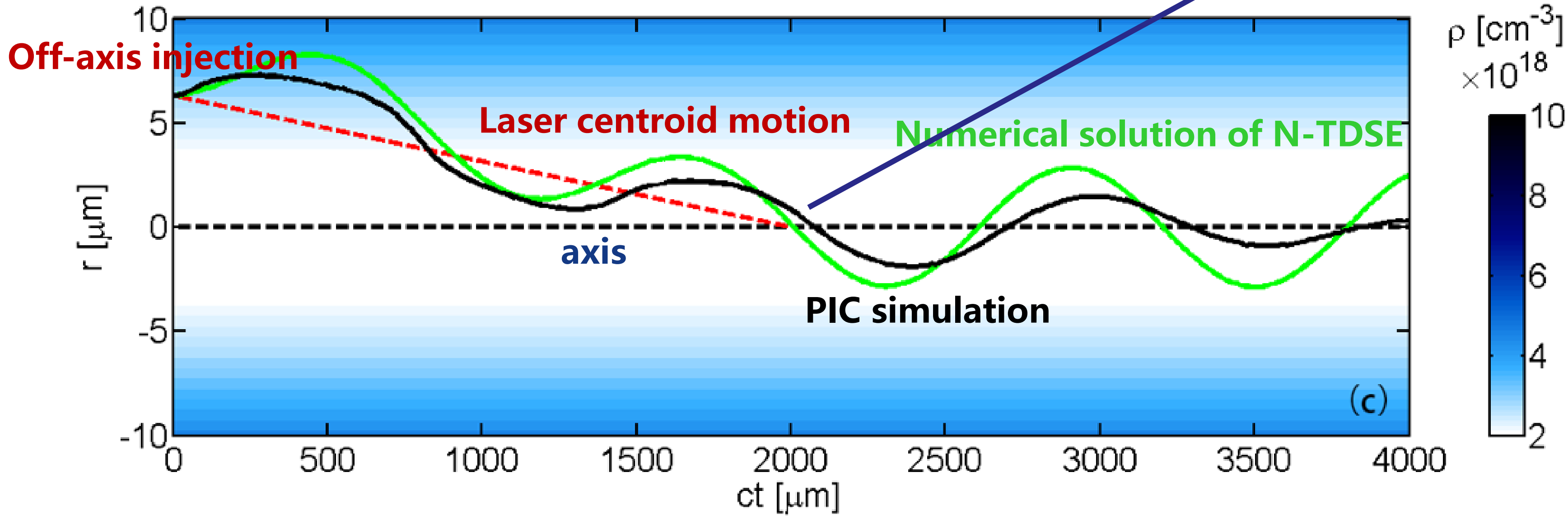
$$r_{equ} = \frac{n_{cr}}{\Delta n}\frac{w_0^2}{R} = \frac{n_{cr}}{\Delta n}\frac{w_0^2}{R_0}\left(\frac{s_1-s}{s_1}\right)^{1/\alpha}$$

Fixed dr_{equ}/ds ⇨ **α=1,** $(s_1-s)\cdot R = s_1 R_0$

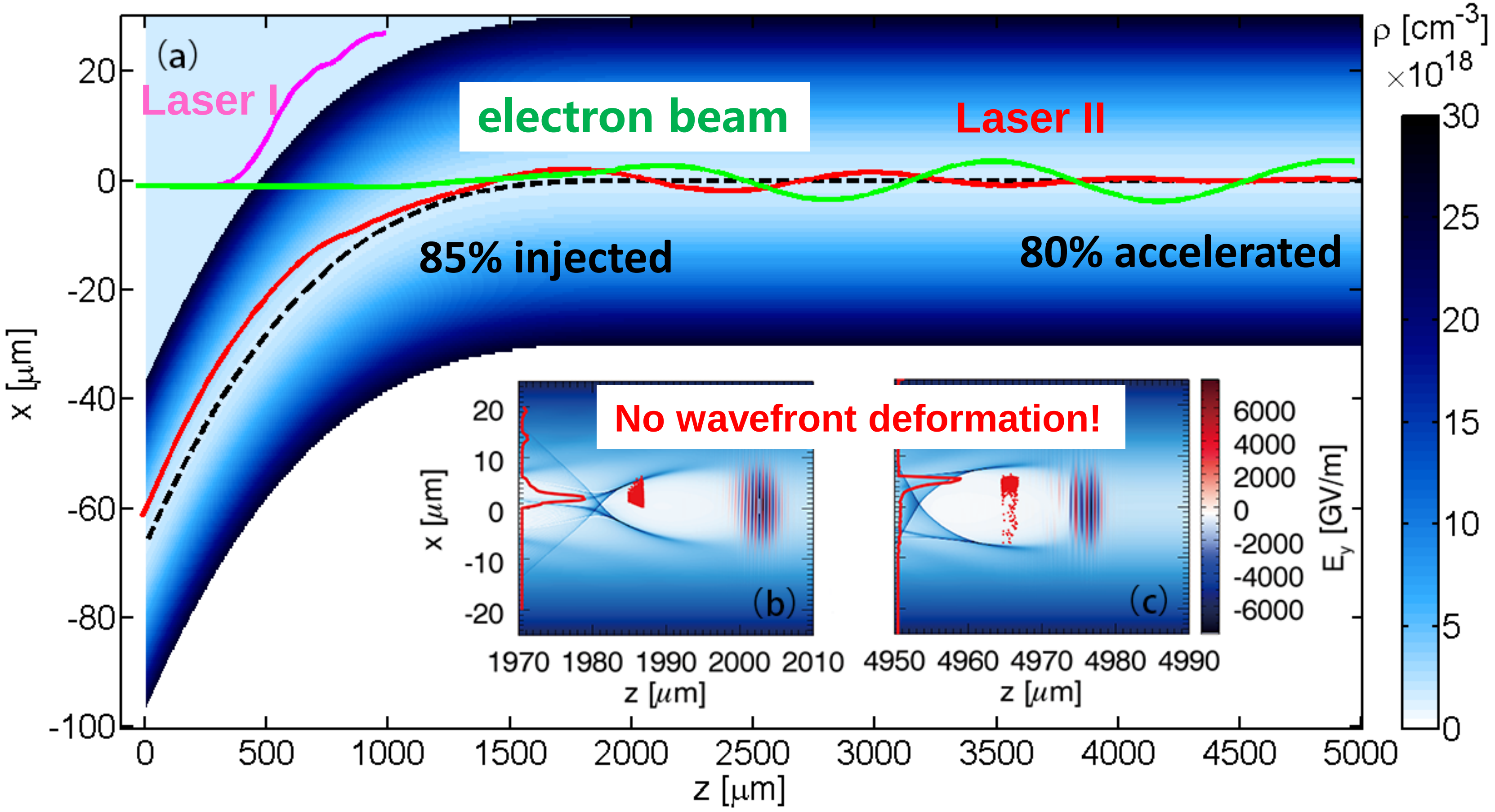
$$\theta = (s_1-s)^2/2s_1R_0.$$

$$\begin{cases} z = \int d(s_1-s)\cdot cos\theta \approx s \approx ct \\ x = \int d(s_1-s)\cdot sin\theta \approx (s_1-ct)^3/(6s_1R_0) \end{cases}$$





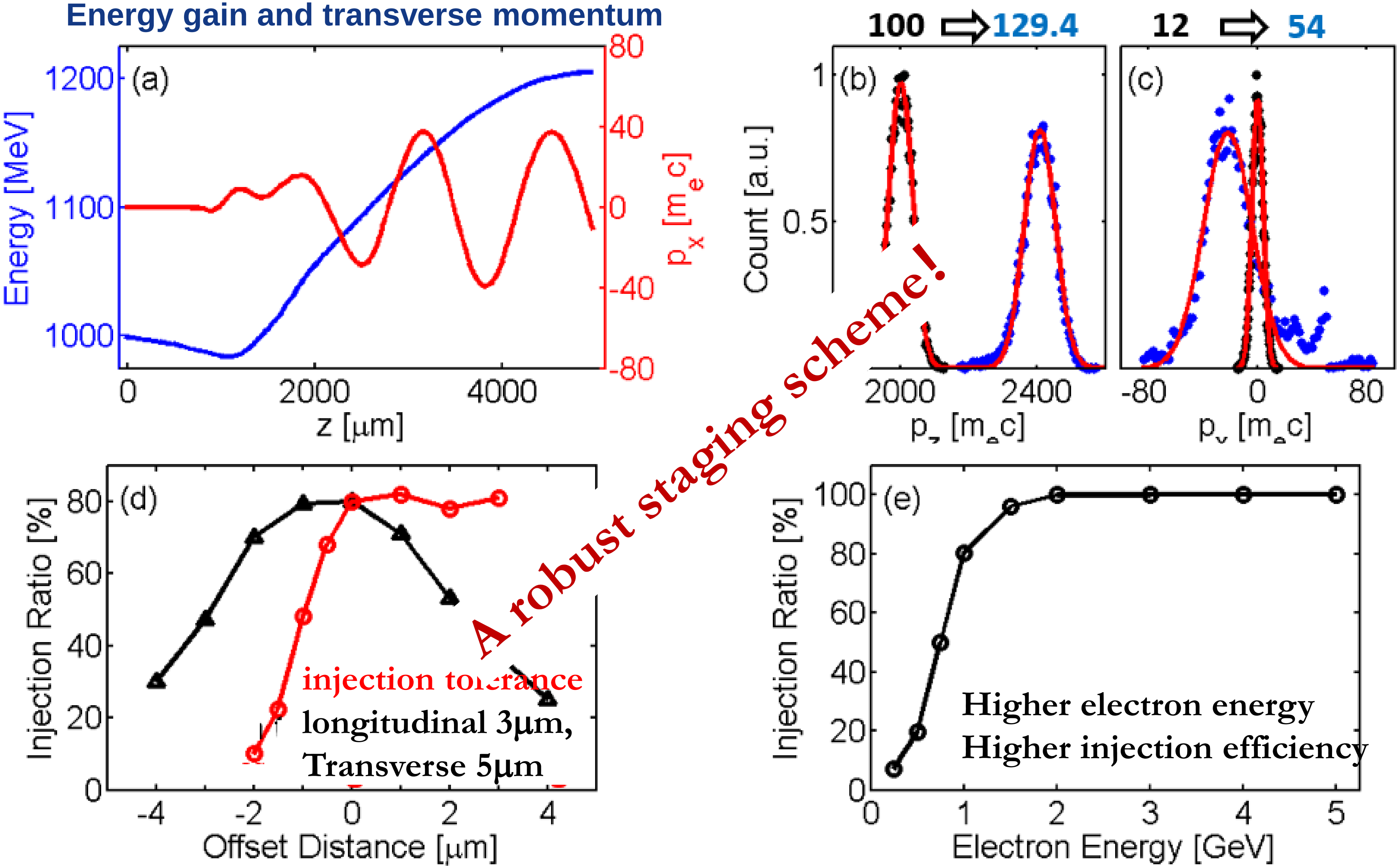
A full PIC simulation of staged LWFA



Laser I: a_0=0.7, Sin-squared longitudinally envelope, τ=15fs, w_0=8μm;
Laser II: a_0=2.0, Gaussian longitudinally envelope, τ=20fs, w_0=8μm.
e- beam: E_0=1GeV, $(\Delta E)_{FWHM}$=50MeV, $\langle p_x\rangle=p_y=0$, $(\Delta p_x)_{FWHM}=12m_ec$,
r_b=0.5μm, l_b=2μm, Incidence angle=5.7°, off-axis = 6.33μm,
Channel: R_0=10mm, s_1=2000μm.

Injected electron beam quality and injection tolerance

Energy gain and transverse momentum

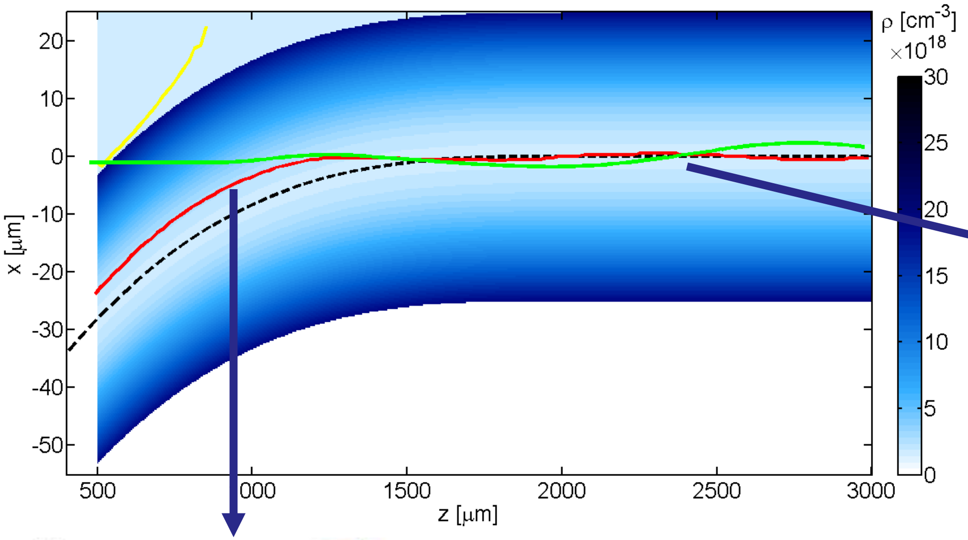


A robust staging scheme!

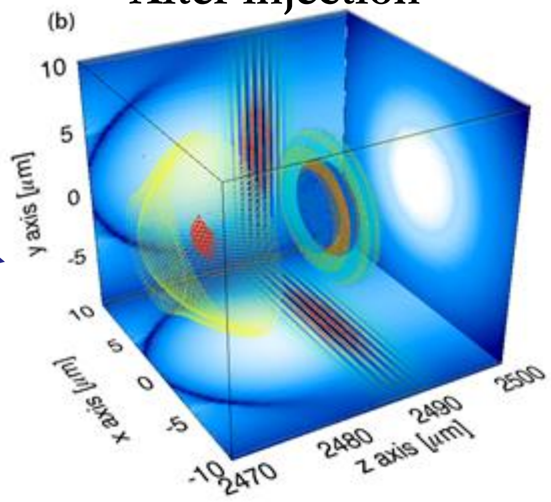
injection tolerance
longitudinal 3μm,
Transverse 5μm

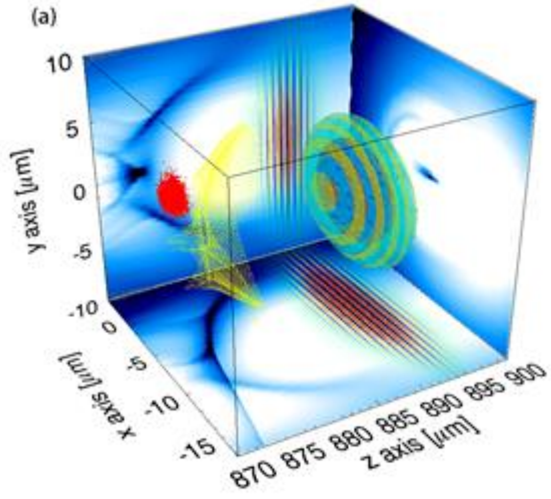
Higher electron energy
Higher injection efficiency

Three dimensional effects

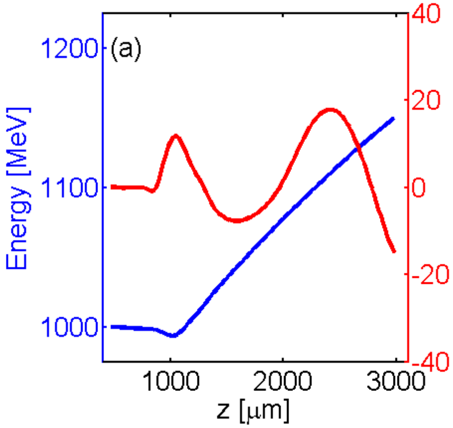


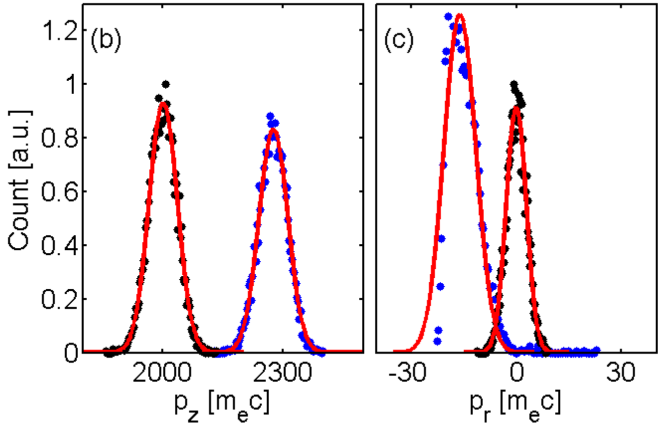
After injection





Before injection





About 92.6% of electrons in the electron beam are trapped and accelerated in the second straight channel.

J. Luo, et al. PRL, 120, 154801 (2018)

Nakajima *Light: Science & Applications* (2018)7:21
DOI 10.1038/s41377-018-0037-6

Official journal of the CIOMP 2047-7538
www.nature.com/lsa

NEWS AND VIEWS **Open Access**

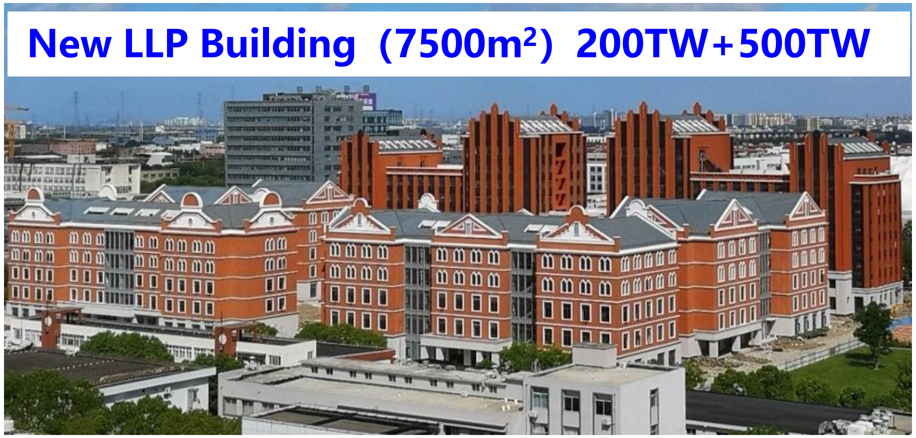
Seamless multistage laser-plasma acceleration toward future high-energy colliders

Kazuhisa Nakajima[1]

Future laser plasma studies at SJTU (2019-2024)

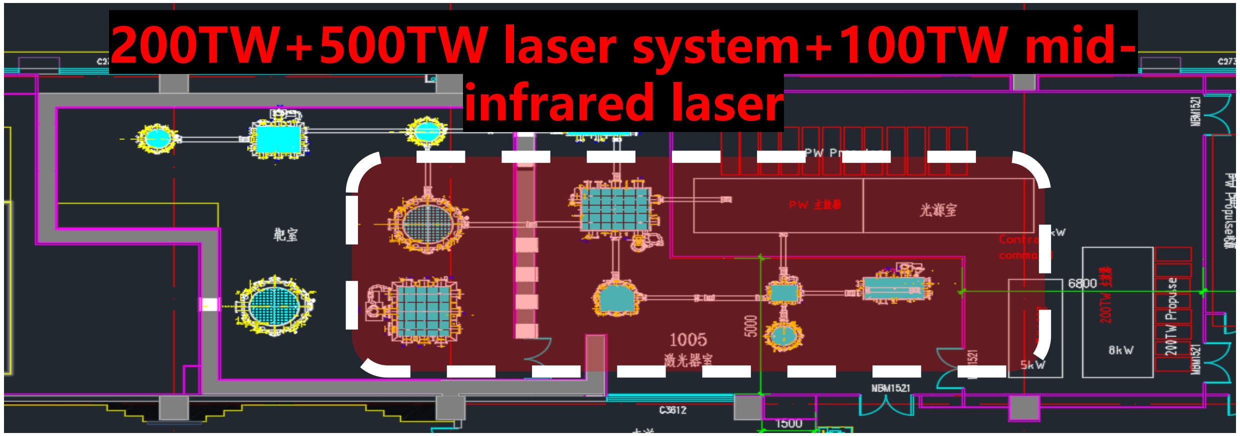
SJTU Main plans:

1. Demonstration of high quality two-color laser ionization injection (~0.1% Energy spread, low emittance)
2. Staged laser wakefield acceleration (curved plasma channel, 1GeV→ 1.5GeV)
3. LWFA based nonlinear Thomson scattering sources



New LLP Building (7500m²) 200TW+500TW

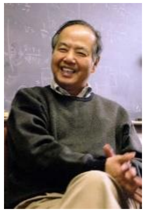
LWFA based electron, photon source & Applications



200TW+500TW laser system+100TW mid-infrared laser

TDLI-Laser Plasma part (2000m²) PWs

QED-plasma physics: radiation reaction, e⁺ & γ generation & Laboratory astrophysics



TD Lee Institute

- Particle & Nuclear
- Astronomy & Astrophysics;
- Quantum Physics

Tsung-Dao Lee,
1957 Nobel Prize

Founding Director
Frank Wilczek
2004 Nobel Prize

Possible connections with EuPRAXIA

1. **SJTU studies on “Electron injection in Wakefield; radiation applications of Wakefield; curved plasma channel based new staging scheme for LWFA” could be used in EuPRAXIA project.**

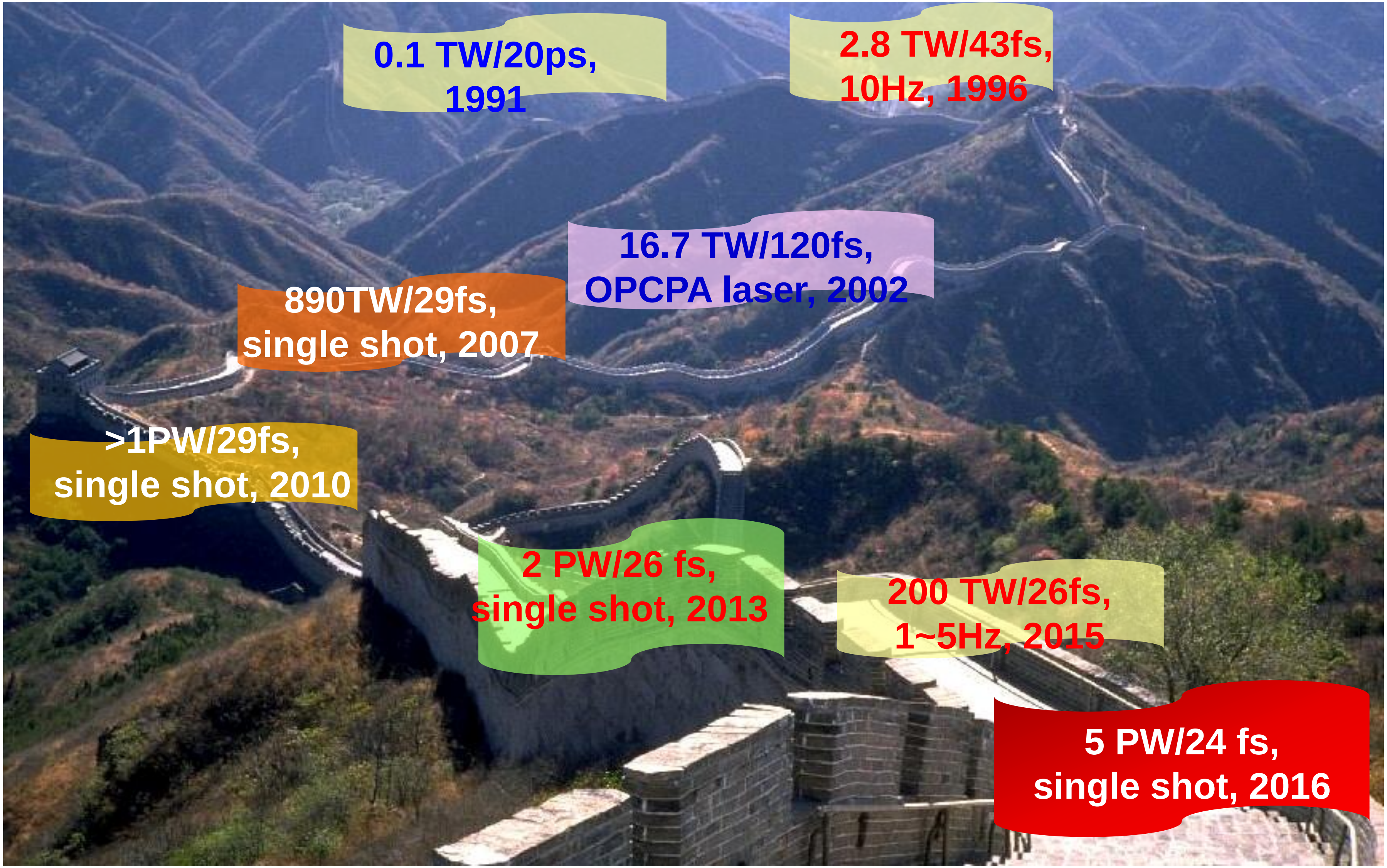
2. **SJTU 200+500TW laser and target system could be used by EuPRAXIA members.**

3. **Technologies from EuPRAXIA, such as staged wakefield acceleration, high repetition rate laser technique, plasma channel fabrication, …, maybe used by SJTU researchers.**

4. **SJTU users would like to use the 5GeV electron beam and radiation source for further studies, such as imaging.**

LWFA Studies in SIOM and HUST

Development of ultra-intense and ultra-short Laser in SIOM



0.1 TW/20ps, 1991

2.8 TW/43fs, 10Hz, 1996

16.7 TW/120fs, OPCPA laser, 2002

890TW/29fs, single shot, 2007

>1PW/29fs, single shot, 2010

2 PW/26 fs, single shot, 2013

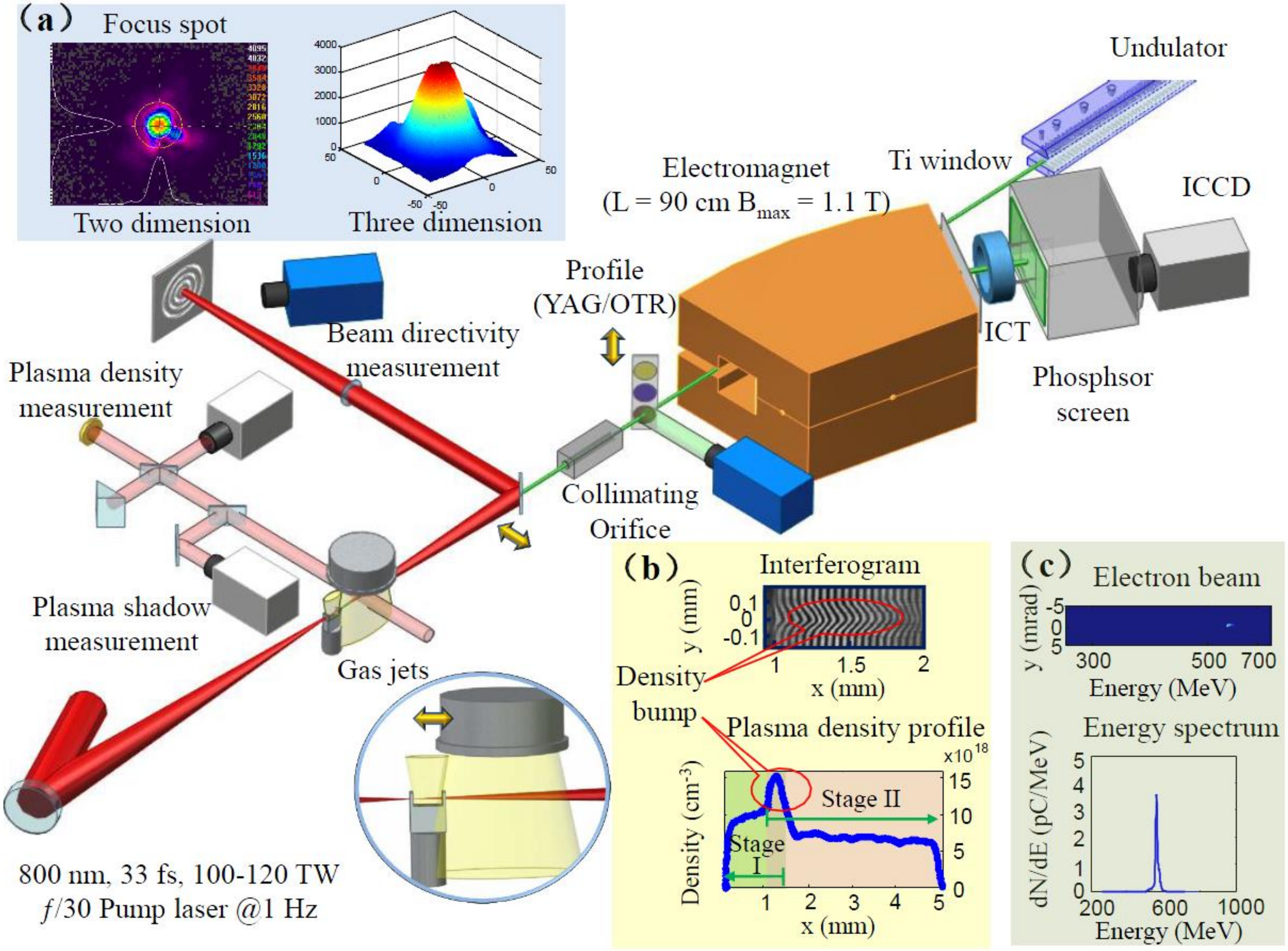
200 TW/26fs, 1~5Hz, 2015

5 PW/24 fs, single shot, 2016

Home made 200TW laser system

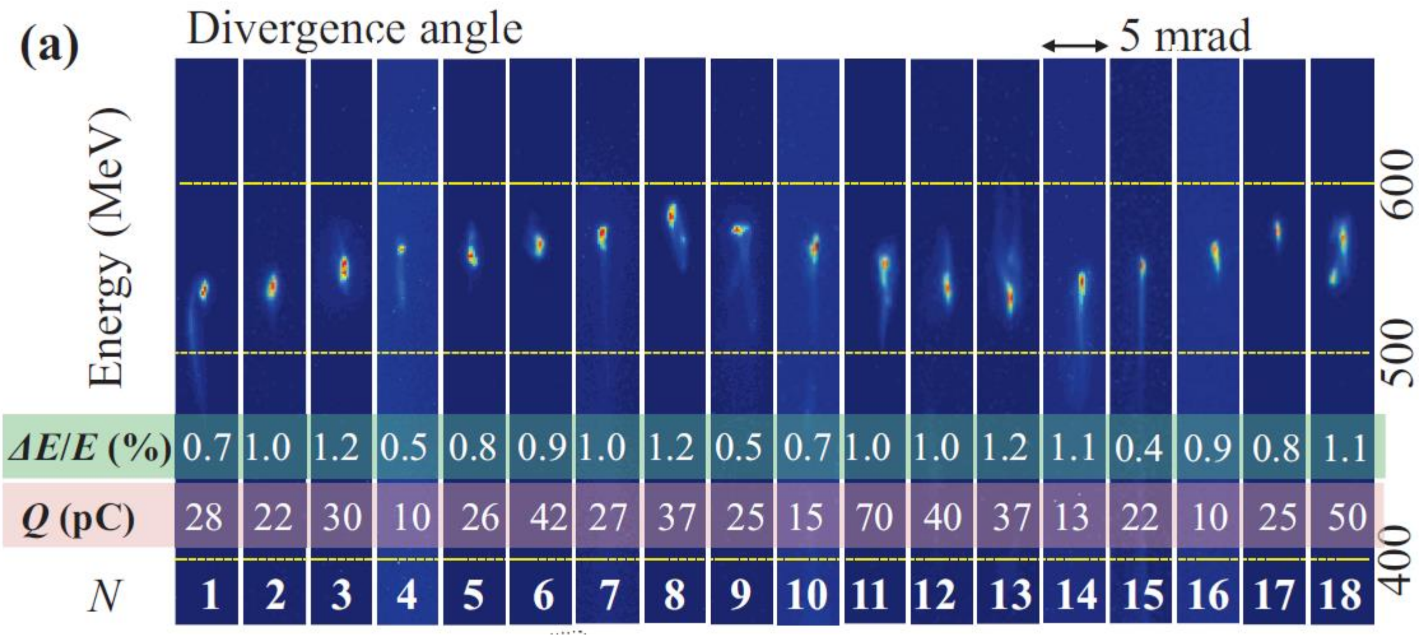
放大输出脉冲近场光斑：均匀的超高斯；放大输出脉冲波前：0.45λ (PV), 0.056(RMS);
放大输出脉冲能量：8J；放大输出脉冲能量稳定性：<2% rms; 压缩后的脉冲能量：5.6J;
放大输出脉冲光谱：73nm（FWHM）；压缩后的脉宽：27fs最大峰值功率：> 200TW；
基于XPW+OPA实现的放大脉冲信噪比：2×10^{-12}（主脉冲前沿100ps外）；重复频率：1Hz；

High-Brightness High-Energy Electron Beams from a Laser Wakefield Accelerator via Energy Chirp Control



W. Wang et al., PRL 117,124801(2016)

High-Brightness High-Energy Electron Beams



N	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
ΔE/E (%)	0.7	1.0	1.2	0.5	0.8	0.9	1.0	1.2	0.5	0.7	1.0	1.0	1.2	1.1	0.4	0.9	0.8	1.1
Q (pC)	28	22	30	10	26	42	27	37	25	15	70	40	37	13	22	10	25	50

Minimum energy spread ~0.4%

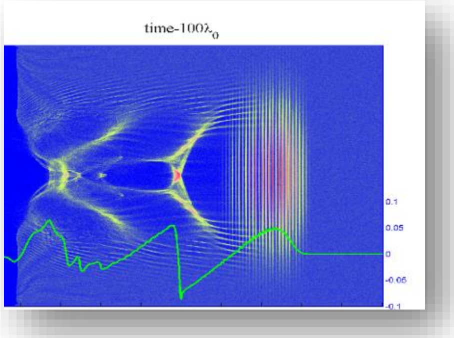
Maximum 6-D Brightness ~6.5×10^{15} A/m^2/0.1%, is comparable with the state of the art LINAC drivers

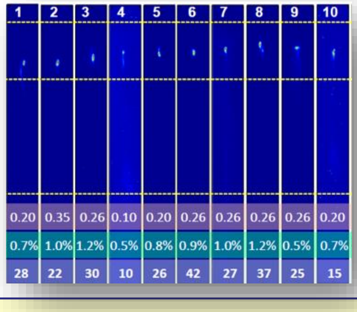
rms energy spread 0.4-1.2%, charge 10-80 pC, rms divergency ~0.2 mrad） in the energy region（200~600 MeV）

W. Wang et al., PRL 117,124801(2016)

Stable high quality electron beam from LWFA

Peak energy stability<3%， pointing stability 100μrad， divergence stability<5%

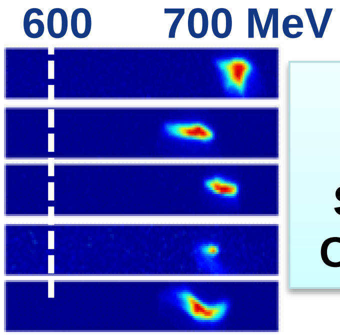




1	2	3	4	5	6	7	8	9	10
0.20	0.35	0.26	0.10	0.20	0.26	0.26	0.26	0.26	0.20
0.7%	1.0%	1.2%	0.5%	0.8%	0.9%	1.0%	1.2%	0.5%	0.7%
28	22	30	10	26	42	27	37	25	15

Year of 2014

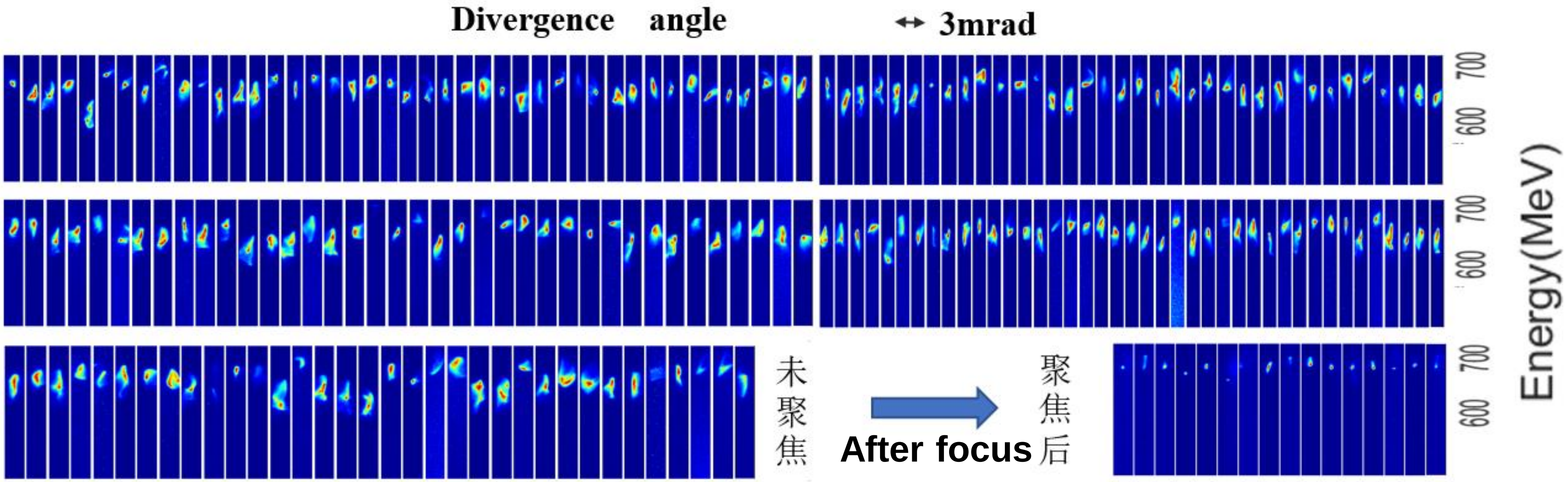
High quality electron beam



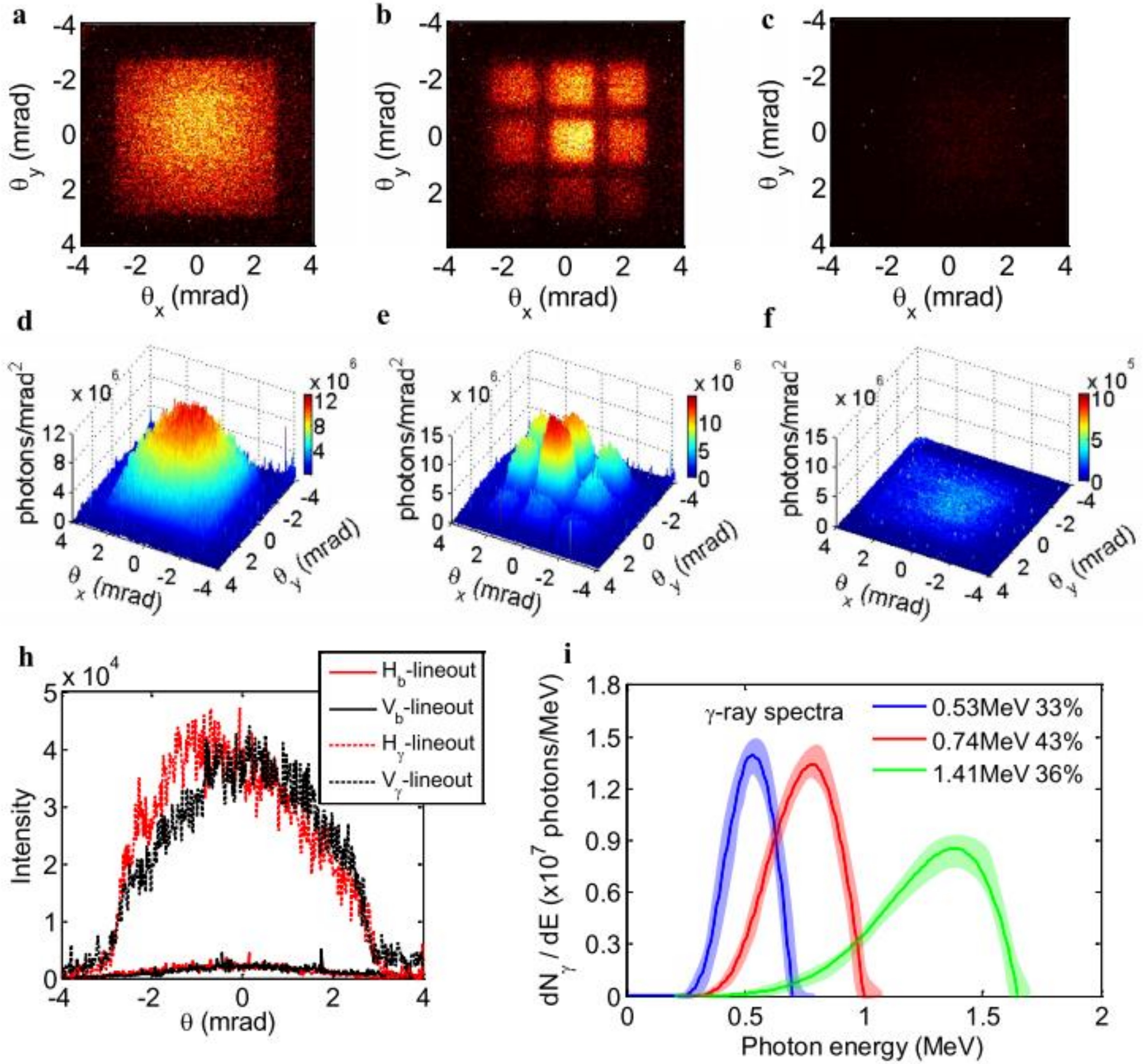
Energy: 680 MeV
Stability: 3%
Current:10 kA

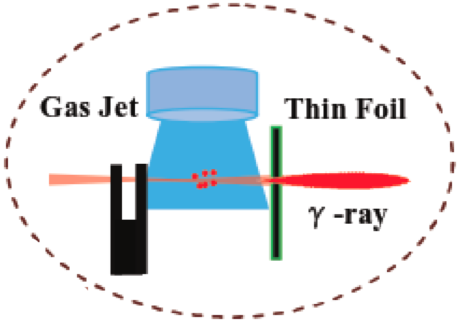
Year of 2018

300 continuous shots



High brightness Compton scattering radiation



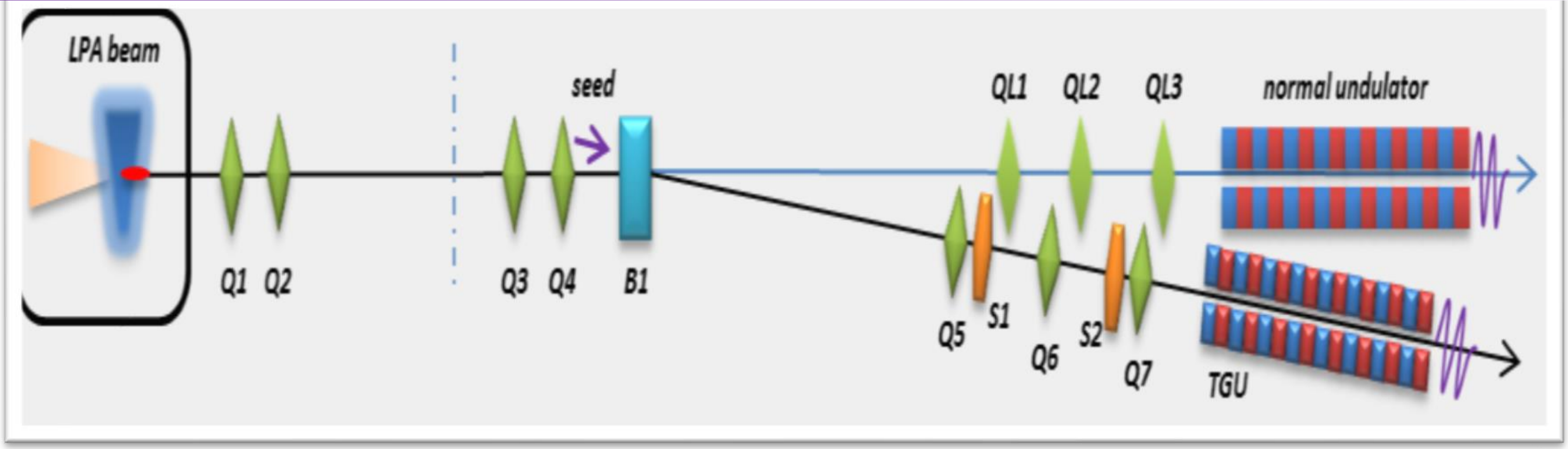


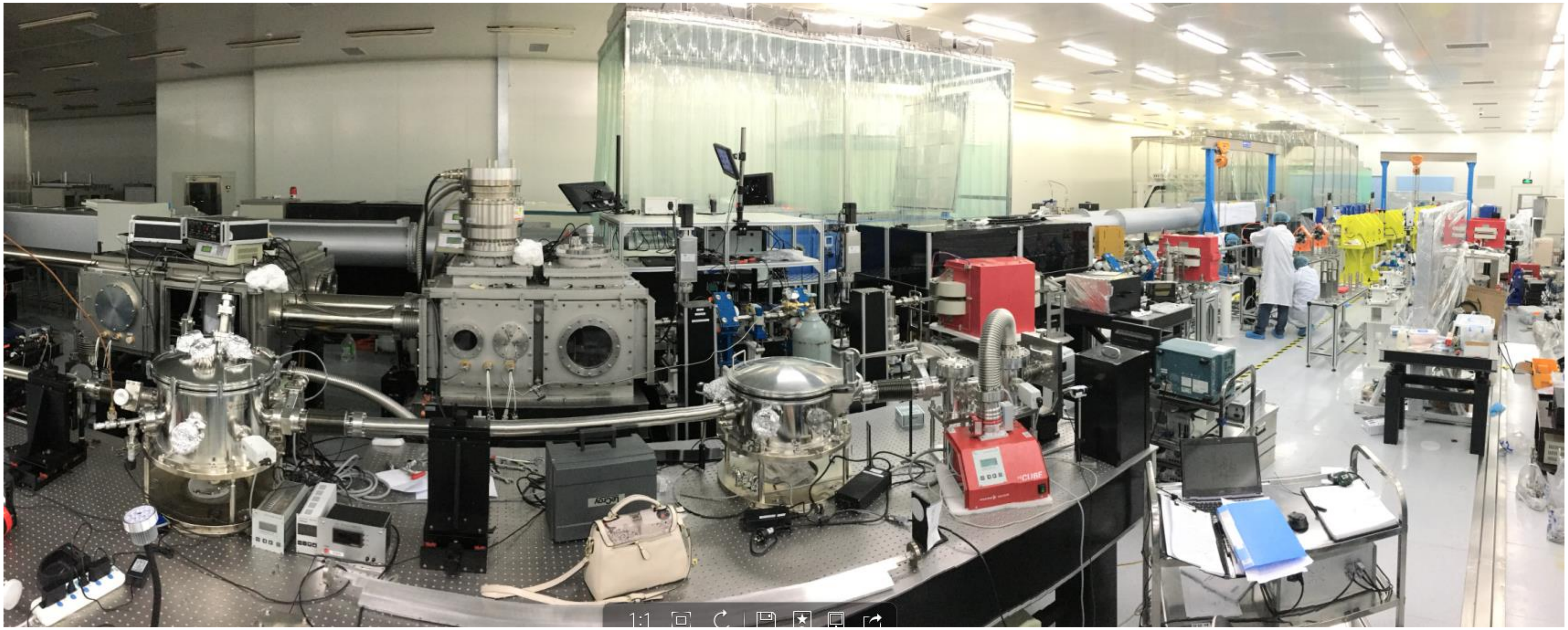
Compton scattering

We measured quasi-monochromatic γ-rays from 0.3 to 2 MeV, with ~5×10^7 photons per-shot with a typical bandwidth of ~33% (FWHM) and a divergence of ~4 mrad. A peak brilliance of ~3×10^{22} photons s^{-1} mm^{-2} mrad^{-2} 0.1% BW at 1 MeV is obained.

C. Yu et al., Scientific Reports, 6, 29518 (2016)

Future Plan1： XFEL platform based on the LWFA

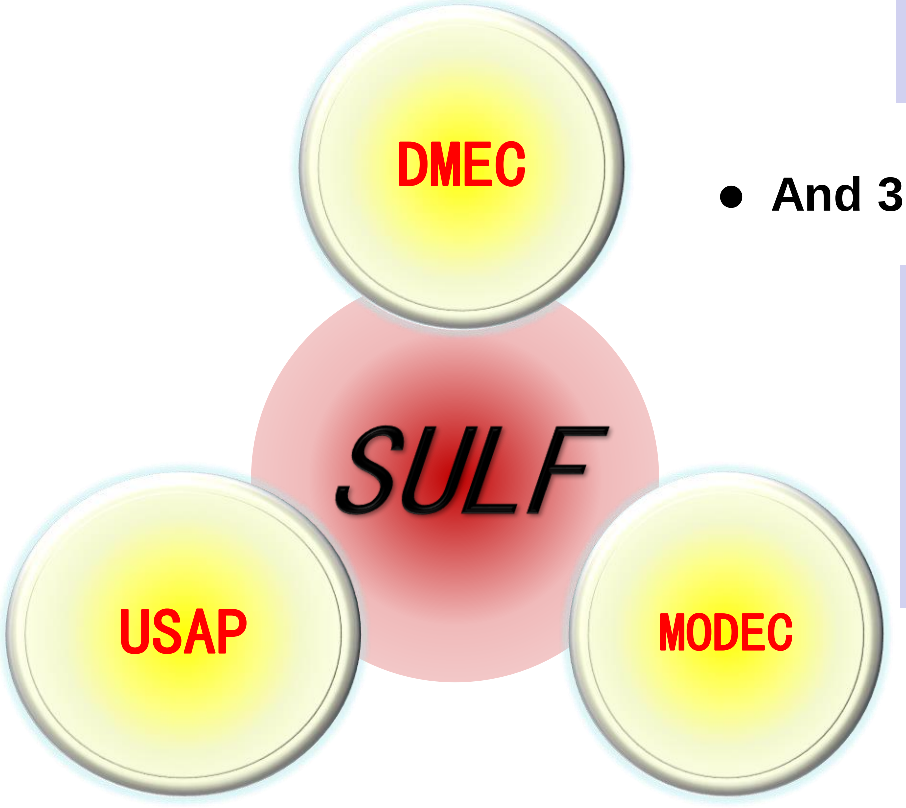




Future Plan2: An International User Facility-SULF

Shanghai super intense Ultrafast Laser Facility (SULF), completed in the end of 2018.

- **SULF contains 2 ultra-intense laser beamlines**
  - **A 10 PW beamline (1 shot/min)**
  - **An 1 PW beamline (0.1Hz)**



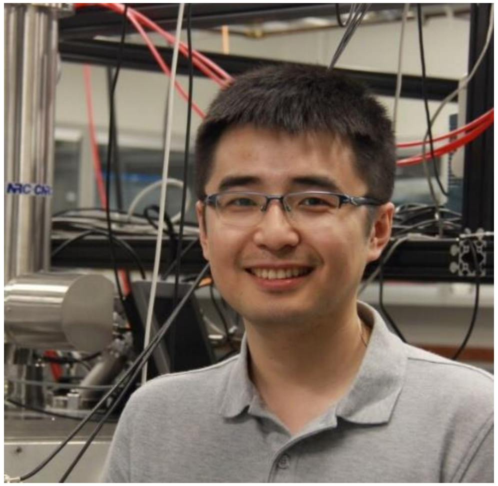
- **And 3 platforms for users**
  - **DMEC: Dynamic of Materials under Extreme Conditions**
  - **USAP: Ultrafast Sub-atomic Physics**
  - **MODEC: Big Molecule Dynamics and Extreme-fast Chemistry**

SULF- Parameters of 10 PW Laser system

Main parameters:

- Central wavelength: ~800nm
- Pulse energy: ~300 J
- Pulse duration: ~30 fs
- Temporal contrast: ~10^{11}
- Focused intensity: >10^{22}W/cm^2

Few-cycle laser wakefield acceleration for MeV ultrafast electron beam sources



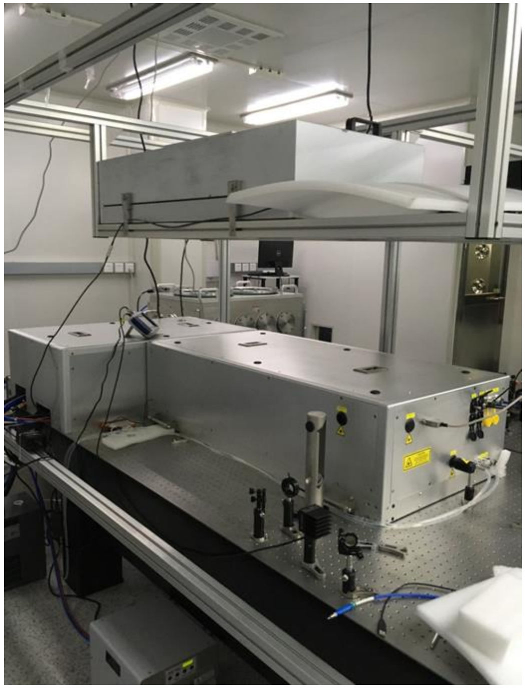
Dr. Zhengyan Li came back from Michael Downer's group. He has built his group at HUST in 2017.

Beyond the ponderomotive force framework, it is interesting to understand **laser wakefield excitation and acceleration** dynamics

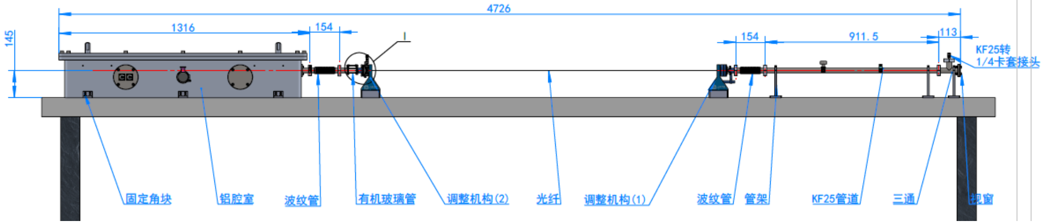
1. Accelerated electron beam parameter variations due to **CEP** instability
2. **Asymmetric plasma wakefield structure** and its visualization

Few-cycle LWFA and applications

1 kHz，7mJ，30fs laser



Vacuum chamber



Few cycle fiber compressor

Summary

1. LWFA studies (both theoretical and experimental work) in China have been **developed very quickly in recent 10 years!** Several major projects (SJTU, PKU, SIOM 3 projects）have been launched in the past five years (not only LWFA, but also ion acceleration, laboratory astrophysics…). There are 7 **200^{+}TW level laser systems are working.** Most of them are focused on **LWFA and ion acceleration.**

2. Researches are gradually focusing on a few clear directions, such as **LWFA based FEL, X-ray sources and applications, LWFA based UED. We are applying for a joint project** supported by National Natural Science Foundation for plasma channel based **staging acceleration** and **external RF accelerated electron beam injection**. The purpose is for the future **plasma based high energy electron accelerator**.

3. Big ambitions on extreme high power laser and related physics are underway. Three **5PW (SIOM, CAEP)** laser systems are almost ready for experiments. One **100PW (SIOM)** laser and several **10PW (SIOM, …)** lasers are under construction or in planning.

We welcome two-way international cooperation, such as to be an associated partners, contributor and user of EuPRAXIA project.

Acknowledgement

- Shanghai Jiao Tong University (LLP-SJTU): M. Zeng, J. Luo, B.Y. Li, G.B. Zhang, F. Liu, X.H. Yuan, S.M. Weng, Z.M. Sheng, J. Zhang
- University of Strathclyde (SUPA): D. A. Jaroszynski
- University of California: W.B. Mori
- Lawrence Berkeley National Lab (BELLA-Center): C.B. Schroeder, E. Esarey, W.P. Leemans
- University of Nebraska Lincoln: Wenchao Yan, G. Golovin, D. Umstadter, …
- Tsinghua University: J.F. Hua, Z.H. Pai, W. Lu,…
- SIOM: J.S. Liu, R.X. Li,…
- HUST: Z.Y. Li