In Honor of Toshiki Tajima

Laser-driven Ultrafast X-ray Sources and Application in IOP/SJTU

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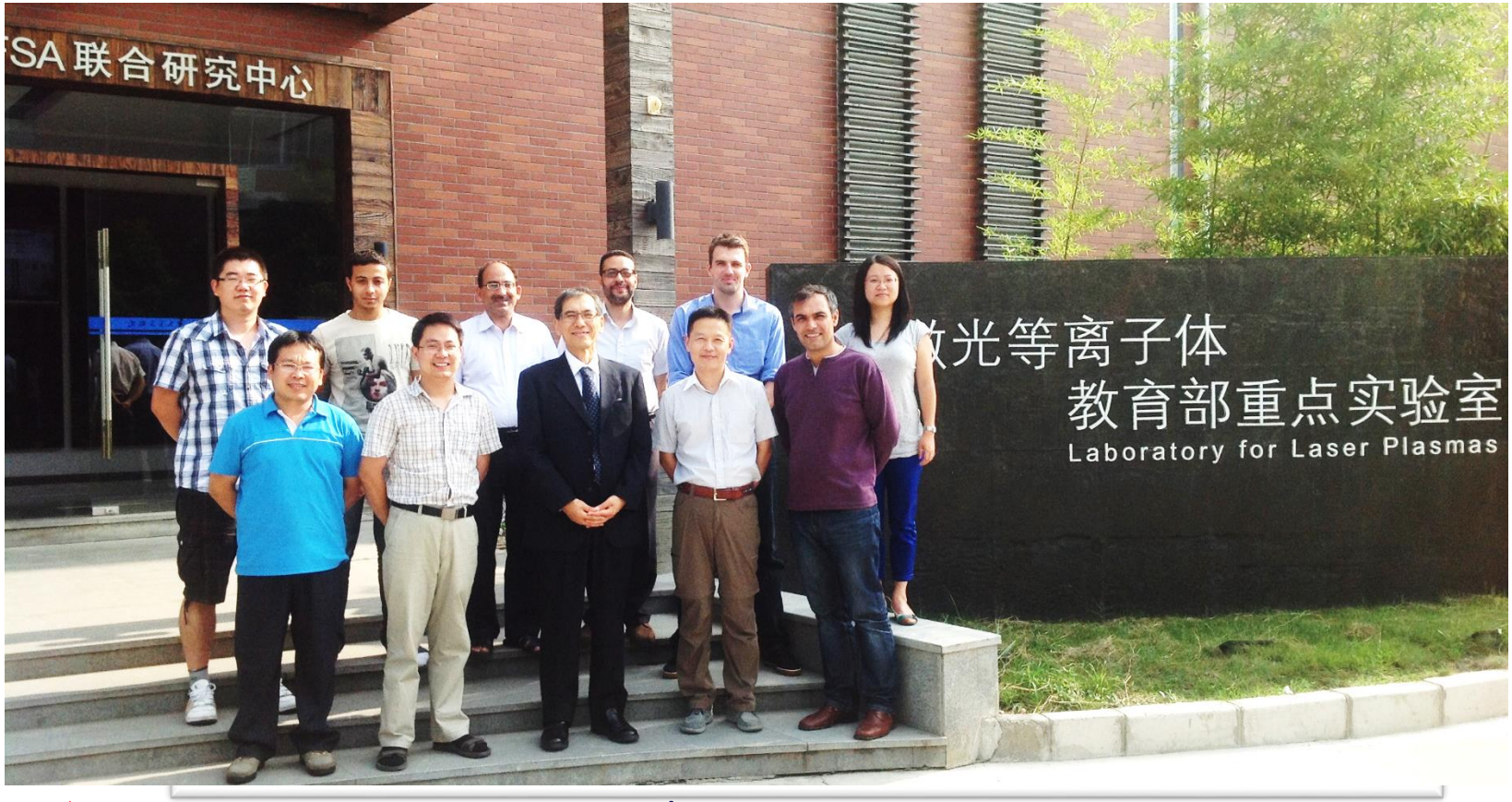
Meet with Toshi 14 years ago

- Before 2004: know Toshi as the inventor of LWFA (PRL, 1979);
- 2004: move from INRS (Prof. J. C. Kieffer), Quebec to JAEA, Japan



- 2008: move to IOP, CAS/SJTU and continue cooperation with Toshi…….

Cooperators

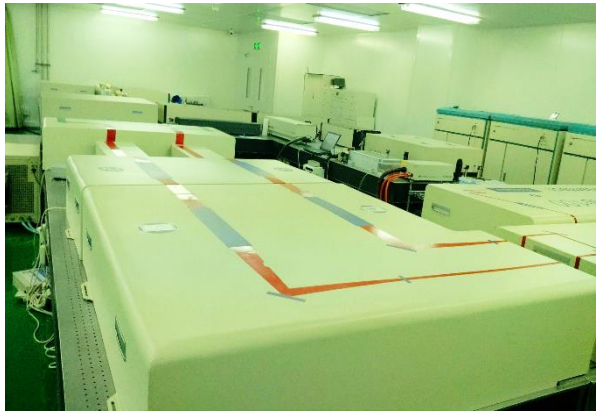
W. M. Wang, J. L. Ma, Y. T. Li	IOP, CAS
N. Hafz, M. Chen, Z. M. Sheng, J. Zhang	SJTU

Facility I ---IOP XL Lasers

~1 PW(30fs, 20 min.)

100TW (30fs, 0.1Hz)

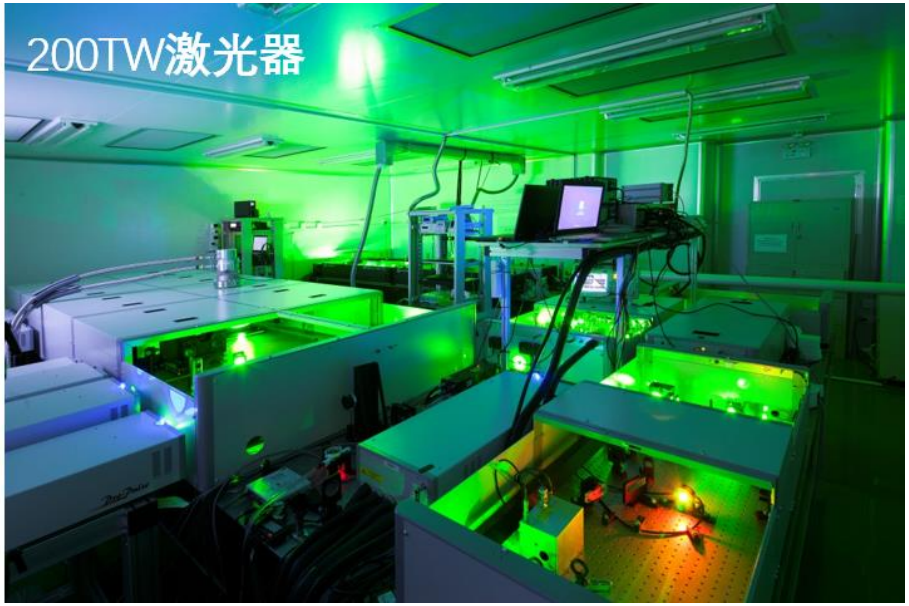
20TW (30fs, 10Hz)



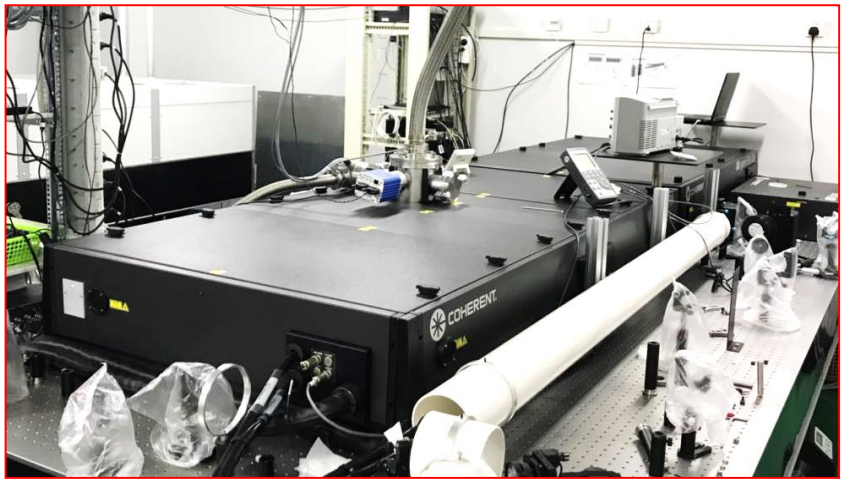
3 target areas

650 m²

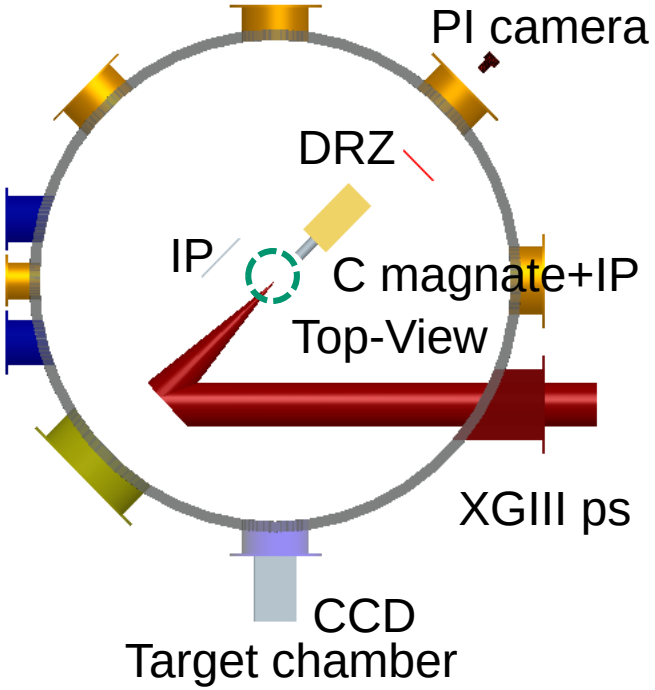
Facility II ---SJTU LPL



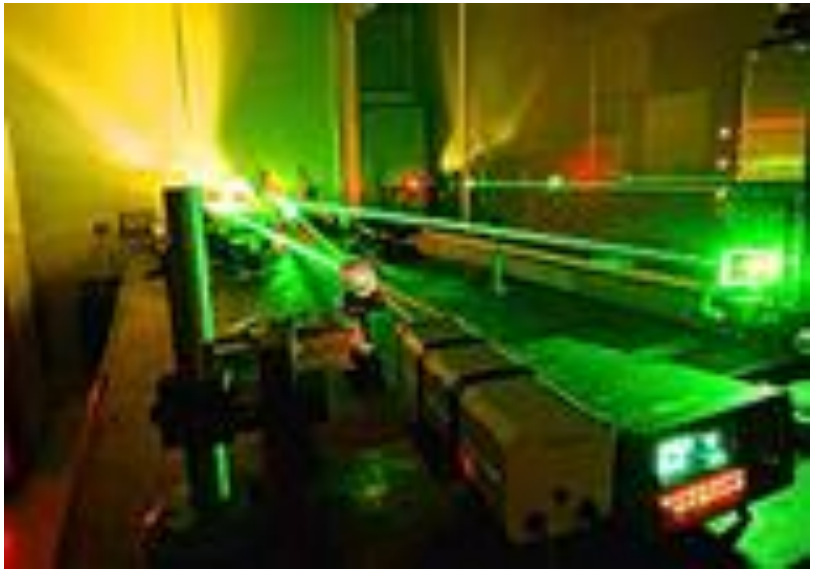
KHz, 20mJ, 30fs

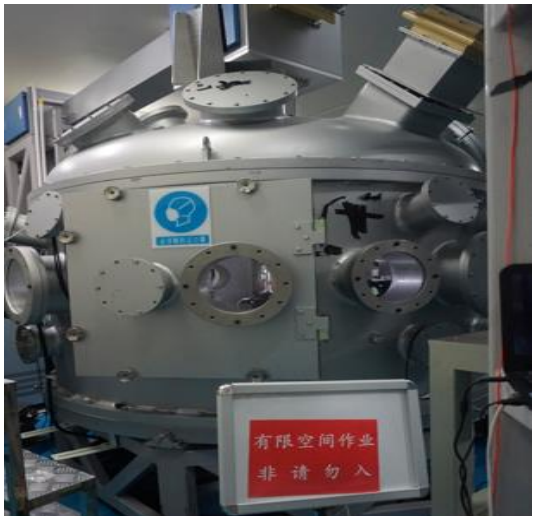


Facility III --- XG-III ps in LFRC (China)



2016、2017





XG-III ns/ps laser facility

Pulse energy: 100-400J
Pulse duration: 0.9ps
Contrast: $>10^8$
Focus power density: $>10^{19}W/cm^2$

Pulse Energy: 250kJ x
Pulse duration: 1ns
Focus w_0: 100μm

Selected Progress

(with Toshi)

(1) K-alpha radiation with clusters

Laser plasma X-ray generator generates high contrast, monochromatic and coherent X-ray by condensing gas jet target generated from gas supply apparatus by irradiating with laser having high contrast ratio

Print E-mail more options

Patent Number(s): JP2008277204-A

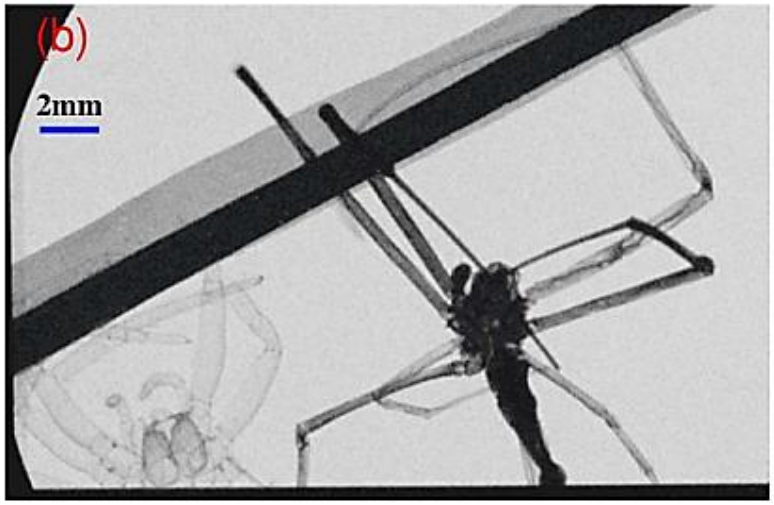
Inventor(s): CHEN L M, KAMIKADO M, TAJIMA T, KATO Y

Patent Assignee(s) and Codes(s):DOKURITSU GYOSEI HOJIN NIPPON GAKUJUTSU (DOKU-Non-standard)

Derwent Primary Accession Number: 2008-N13205 [77]

Abstract: NOVELTY - The laser plasma X-ray generator has a gas supply apparatus (6) which generates gas jet target inside a vacuum chamber (1). A laser (3) irradiates and condenses with respect to the gas jet target. A high contrast, monochromatic and coherent X-ray (10) is generated with laser having high contrast ratio.

USE - Laser plasma X-ray generator for use with imaging device for imaging phase contrast image of spider.



HYSICS LETTERS **90**, 211501 (2007)

vith intense Ar *Kα* radiation
gas target

aki, Y. Fukuda, Y. Hayashi, I. Daito, T. Homma,
Koga, H. Daido, S. V. Bulanov,[b] T. Kimura,

nic Energy Agency, 8-1 Umemidai Kizugawa,

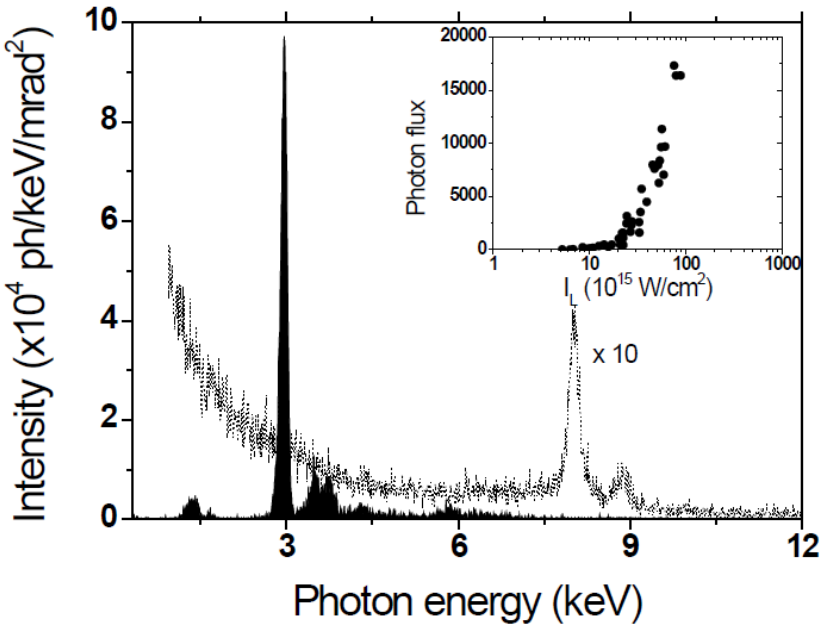
K-alpha radiation with clusters

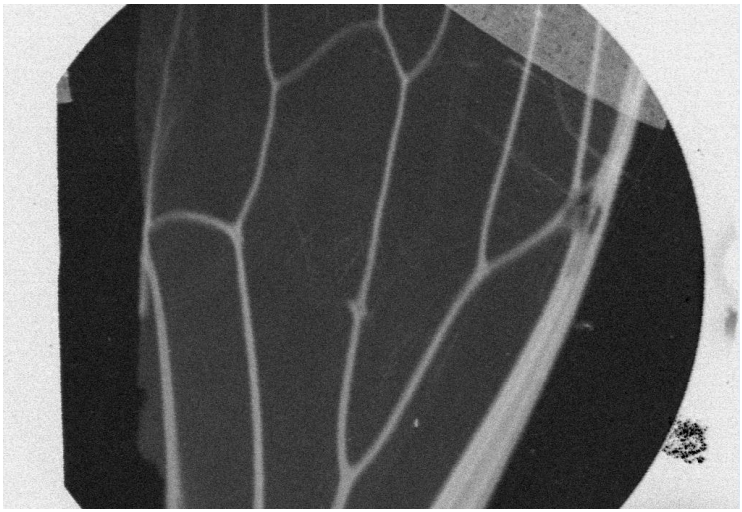
PRL **104,** 215004 (2010) PHYSICAL REVIEW LETTERS week ending 28 MAY 2010

Intense High-Contrast Femtosecond *K*-Shell X-Ray Source from Laser-Driven Ar Clusters

L. M. Chen,[1,*] F. Liu,[1] W. M. Wang,[1] M. Kando,[2] J. Y. Mao,[1] L. Zhang,[1] J. L. Ma,[1] Y. T. Li,[1] S. V. Bulanov,[2] T. Tajima,[2] Y. Kato,[2] Z. M. Sheng,[1,3] Z. Y. Wei,[1] and J. Zhang[1,3,†]

[1]*Beijing National Laboratory of Condensed Matter Physics, Institute of Physics, CAS, Beijing 100080, China*
[2]*Advanced Photon Research Center, Japan Atomic Energy Agency, 8-1 Umemidai Kizugawa, Kyoto 619-0215, Japan*
[3]*Department of Physics, Shanghai Jiao Tong University, Shanghai 200240, China*
(Received 23 January 2010; published 27 May 2010)





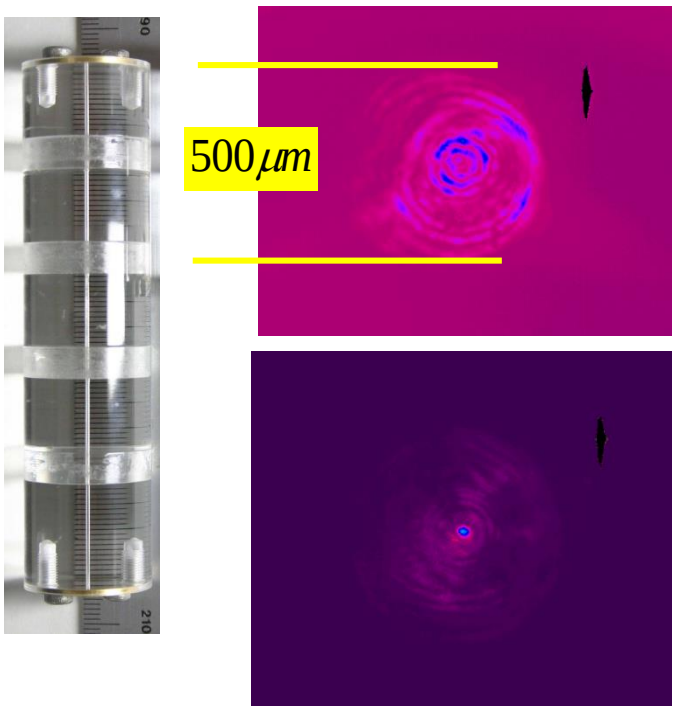
Single shot imaging

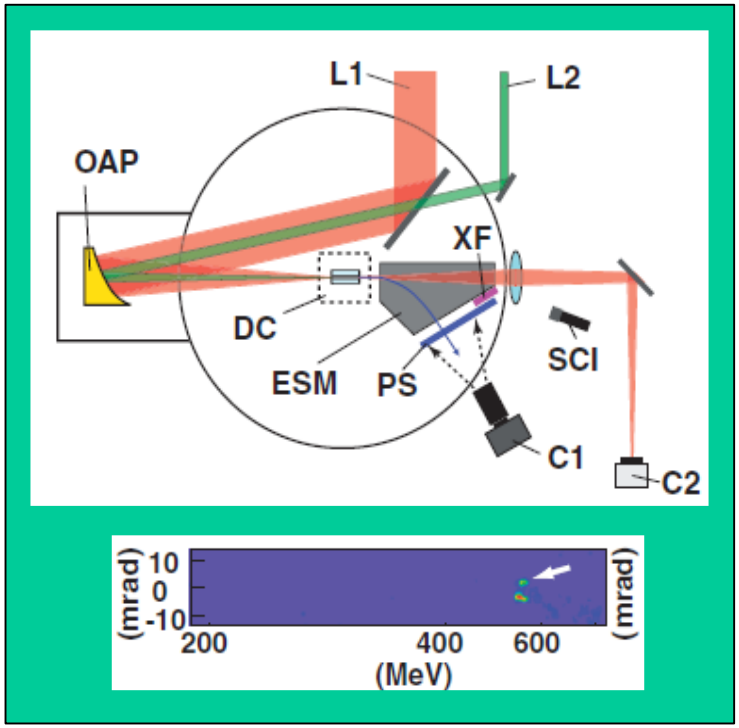
Photon flux on IP:5×10^6 phs/cm^2

Opt. Express (2009); (2011)

(2) Laser accelerator using ablative capillary

- **The first experiment of LWFA performed in China. (CAEP, JAEA, KEK)**
- **0.56 GeV monoenergetic electron beam is achieved.**





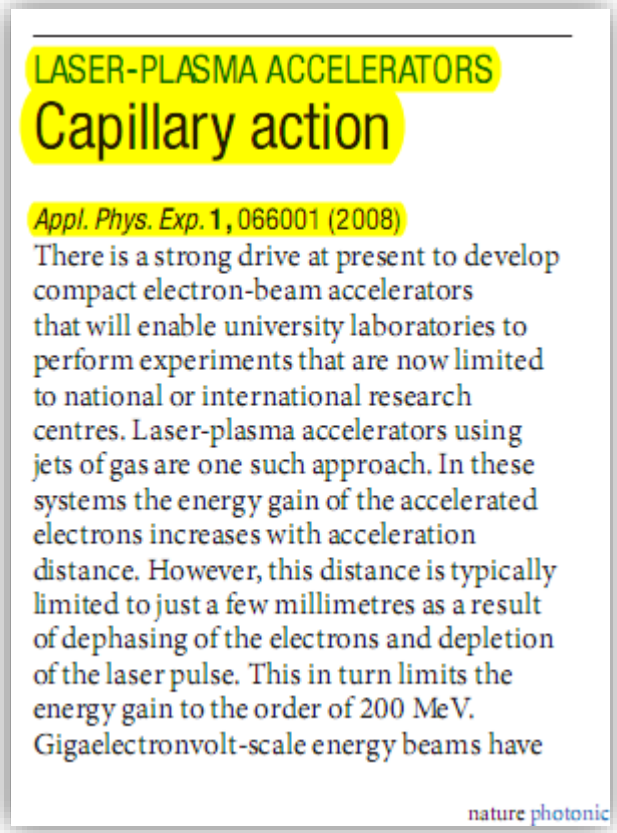
Obtained electron bunch with the minimum energy spread（~0.1%）and minimum divergence(~ 0.6 mrad), suitable for free electron laser。

Chen, IEEE (2008); Appl. Phys. Exp. (2008)

Applied Physics Express **1** (2008) 066001

0.56 GeV Laser Electron Acceleration in Ablative-Capillary-Discharge Plasma Channel

Takashi Kameshima[1,5], Wei Hong[2], Kiyohiro Sugiyama[3], Xianlun Wen[2], Yuchi Wu[2], Chuanming Tang[2], Qihua Zhu[2], Yuqiu Gu[2], Baohan Zhang[2], Hansheng Peng[2], Shin-ichi Kurokawa[1,4], Liming Chen[5], Toshiki Tajima[5], Tetsuro Kumita[6], and Kazuhisa Nakajima[1,3,4,5]



LASER-PLASMA ACCELERATORS

Capillary action

Appl. Phys. Exp. **1**, 066001 (2008)

There is a strong drive at present to develop compact electron-beam accelerators that will enable university laboratories to perform experiments that are now limited to national or international research centres. Laser-plasma accelerators using jets of gas are one such approach. In these systems the energy gain of the accelerated electrons increases with acceleration distance. However, this distance is typically limited to just a few millimetres as a result of dephasing of the electrons and depletion of the laser pulse. This in turn limits the energy gain to the order of 200 MeV. Gigaelectronvolt-scale energy beams have

nature photonic

【Nature Photonics】Highlight

(3) Betatron enhance. via Double Injection

Envolution of plasma density

PIC parameter :

Laser : Callisto

P=200 TW

w_0=18 μm

τ=60 fs

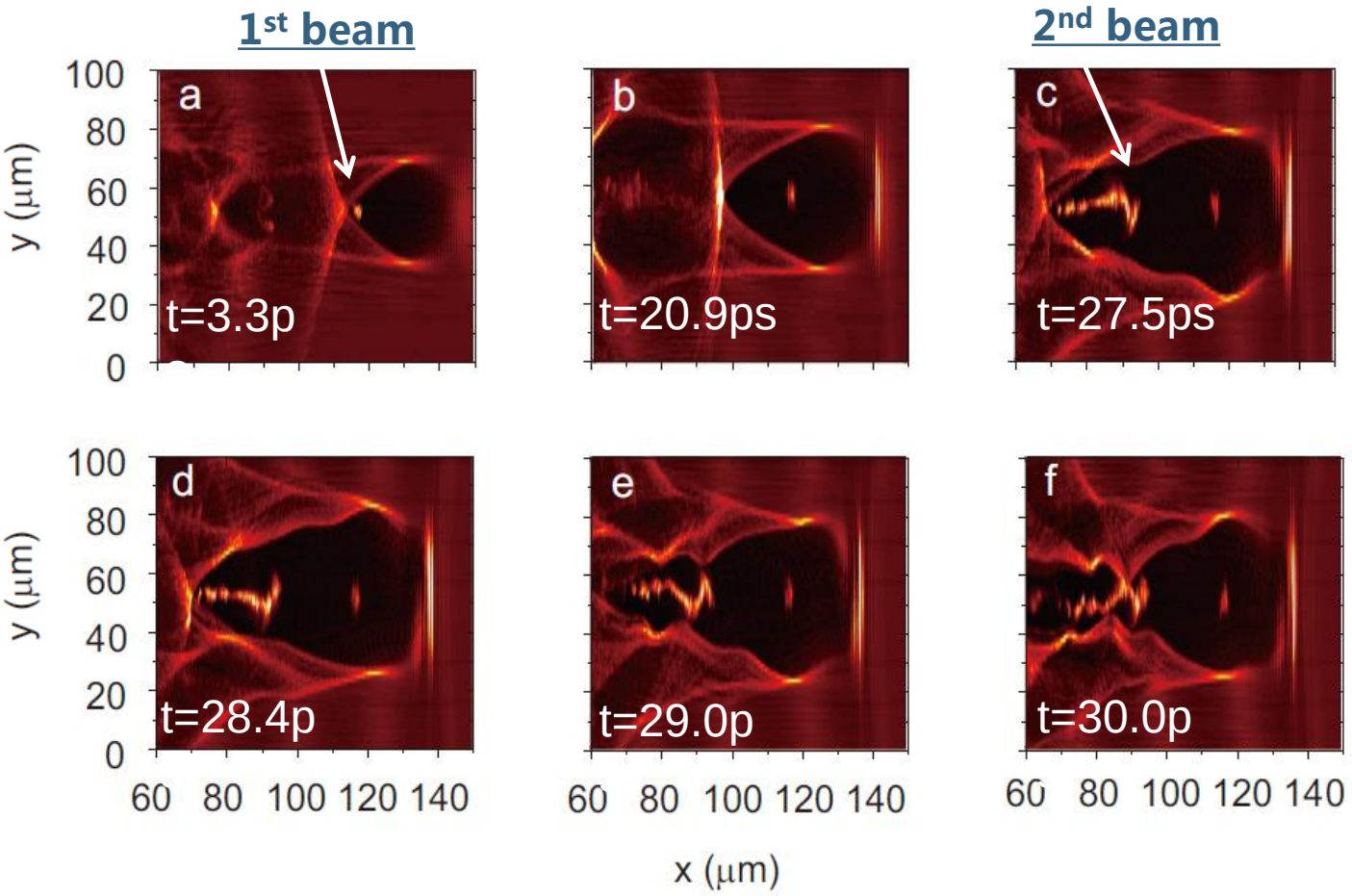
a_0=3.6

Plasma :

$n_e=2\times10^{18}$ cm^{-3}

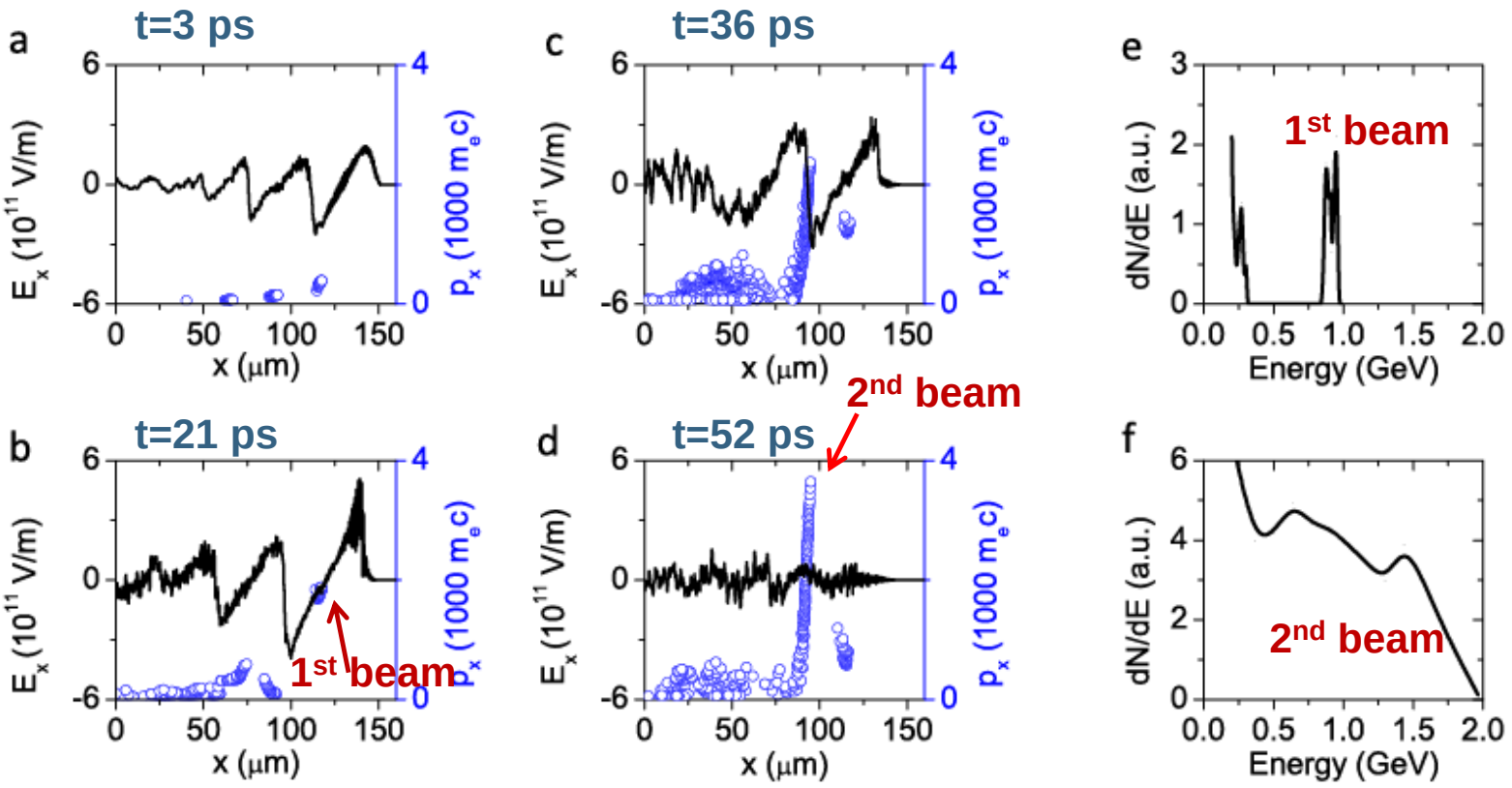
Matched bubble :

1.3×10^{18} cm^{-3}



Experiment was performed using Callisto laser at LLNL, and experimental result was published in **PNAS** 111, 5825(2014) in which we proposed double injection.

Comparison of energy and charge



1st beam :
Max. Energy γ=2000 $\gamma \uparrow$

Sharp field distribution

2nd beam
Max. energy γ=4000

Smoothly field

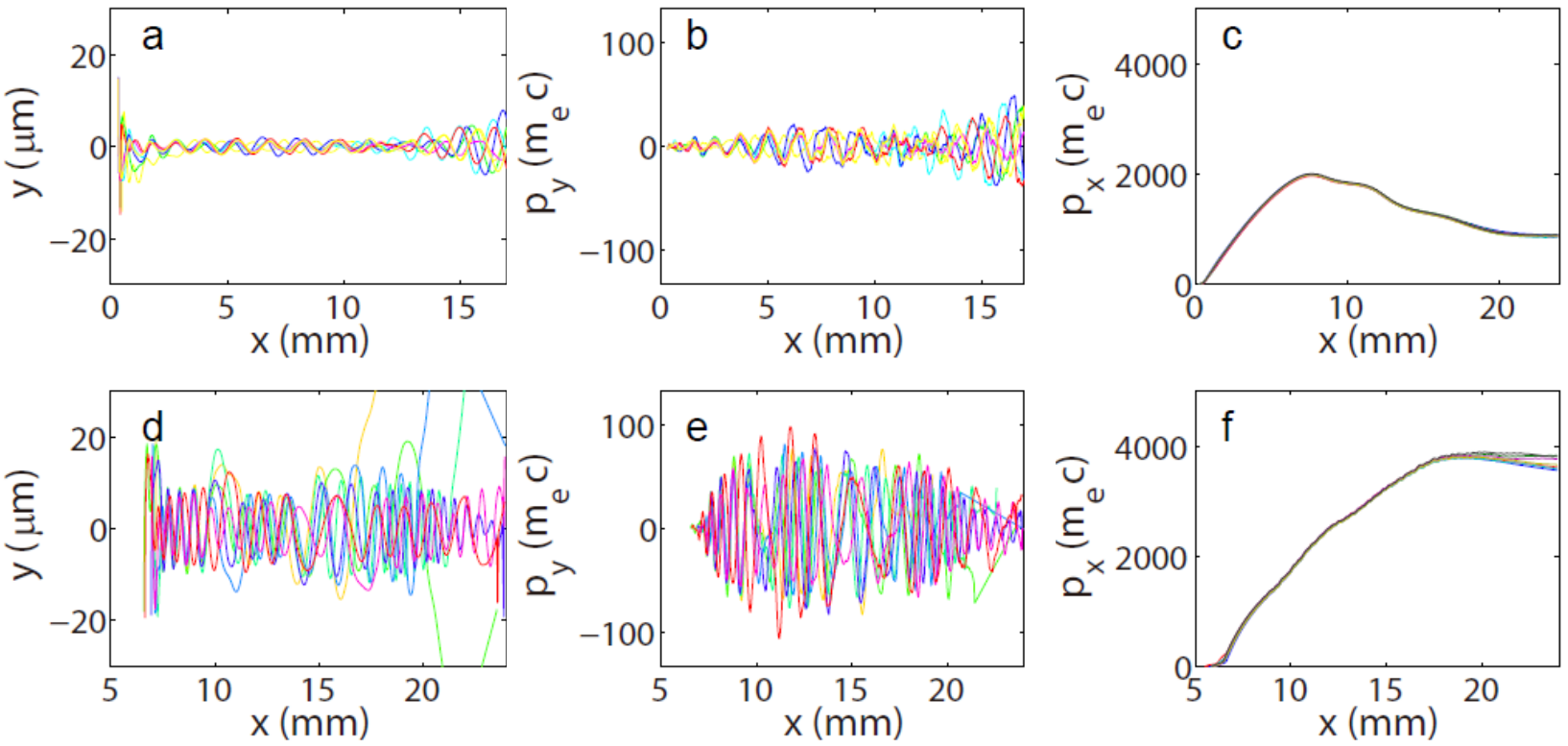
$N_{e2}/N_{e1} \approx 10$

$N_e \uparrow$

Electron beams analysis

1st beam

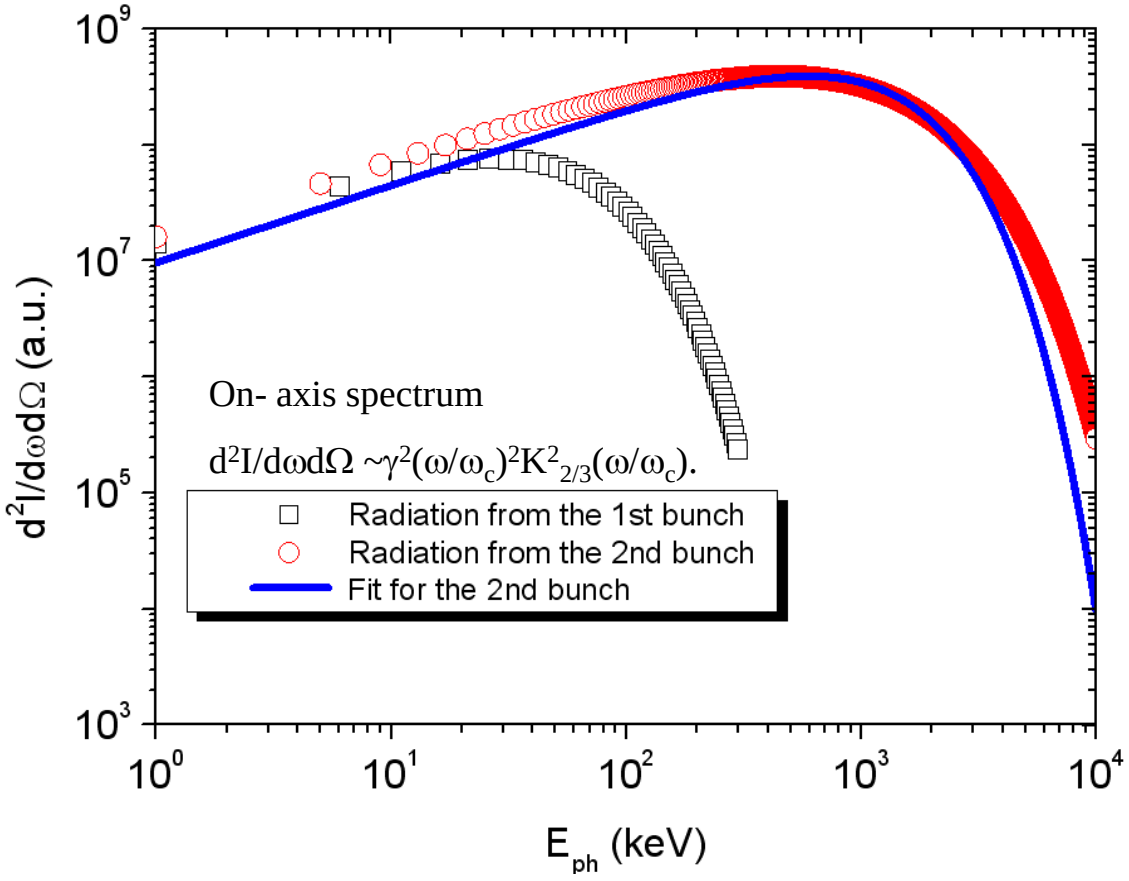
2nd beam



Trajectory **Transverse P** **Longitudial P**

1st beam:	$r_\beta = 1$ μm	×		**Quickly reduce**
2nd beam:	$r_\beta = 10$ μm	**r_β ↑**	√	**N_β ↑**	**Maintain >20 ps**

Bright betatron γ-rays



1st pulse: E_c ~ 80 keV

2nd pulse: E_c ~ 1.2 MeV

Photon-nuclear reaction

SCIENTIFIC REPORTS

OPEN

Generation of femtosecond γ-ray bursts stimulated by laser-driven hosing evolution

Received: 10 March 2016
Accepted: 06 July 2016

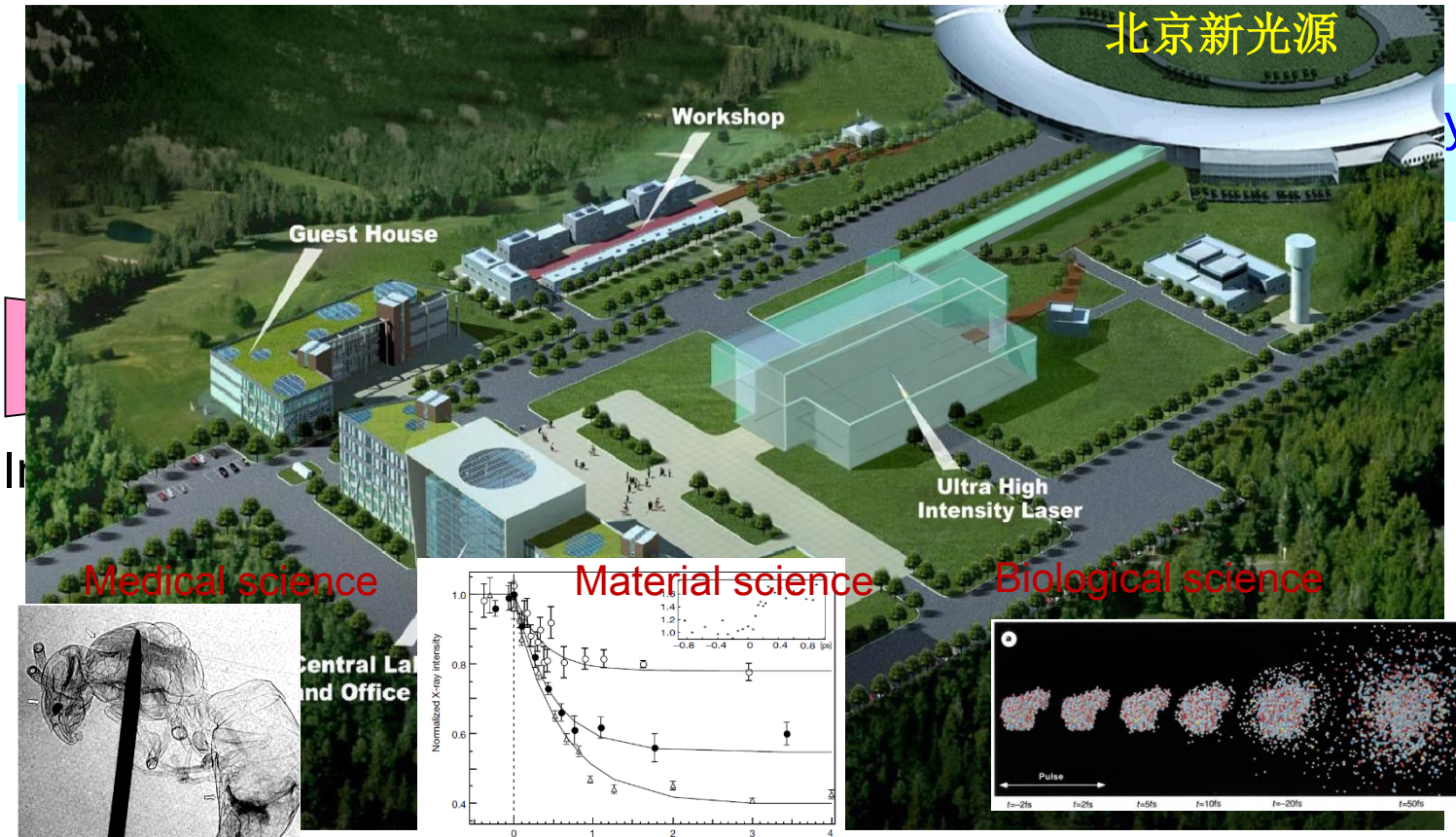
Yong Ma[1], Liming Chen[1,2], Dazhang Li[3], Wenchao Yan[1], Kai Huang[1], Min Chen[2,4], Zhengming Sheng[2,4,5], Kazuhisa Nakajima[6], Toshiki Tajima[7] & Jie Zhang[2,4]

Synergetic Extreme Condition User Facilities (SECUF)

Huai Rou Science City, Beijing.

Beijing Synchrotron + [Ultra-high pressure; Ultra-low temperature, Ultra-high B-field, Ultra-fast sources*] (200M$)

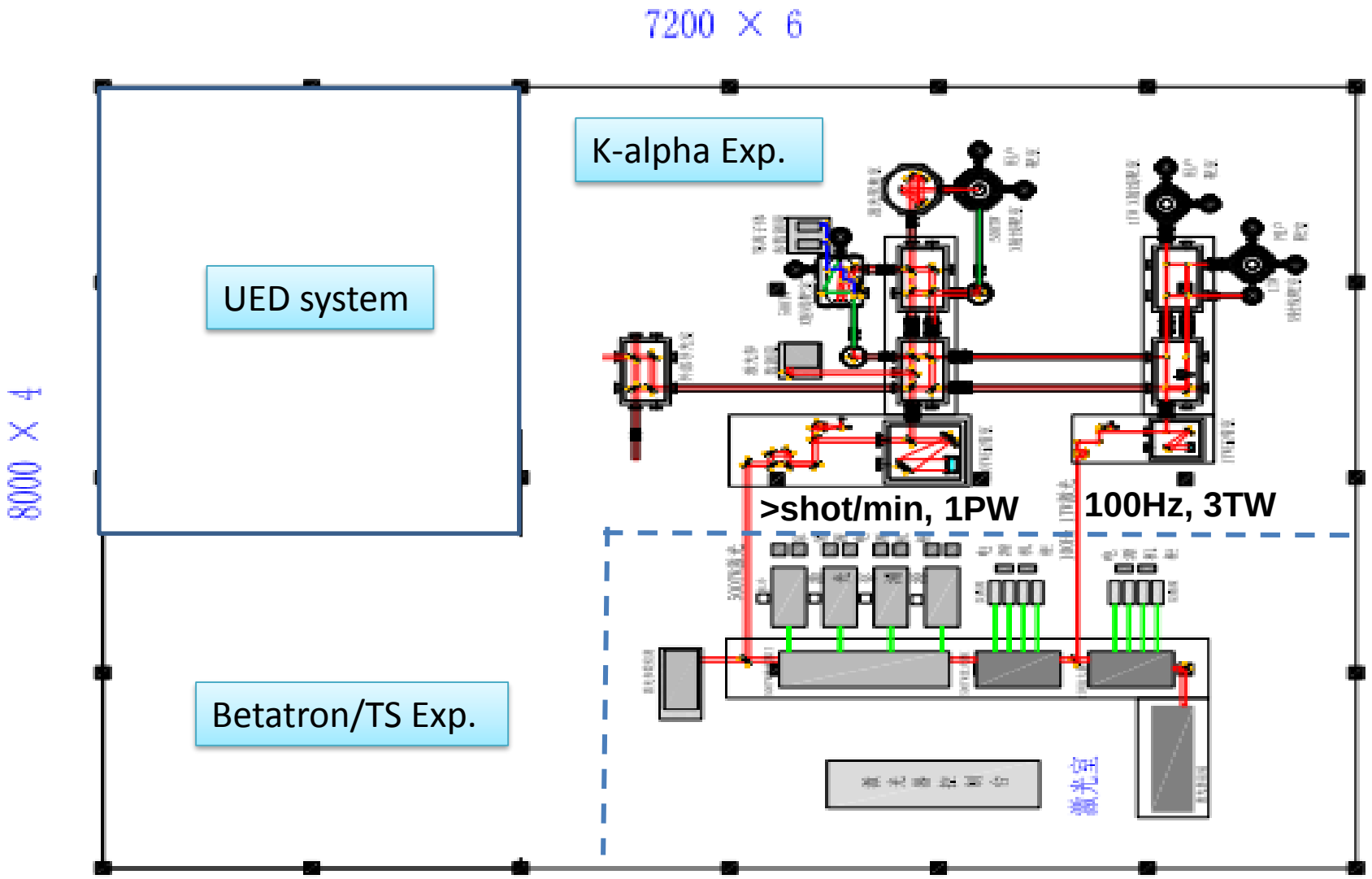
*Laser-driven ultrafast X-ray dynamic detection system



A. Rousse, Nature 410, 65 (2001) R. Neutze, et al, Nature 406, 752 (2000)

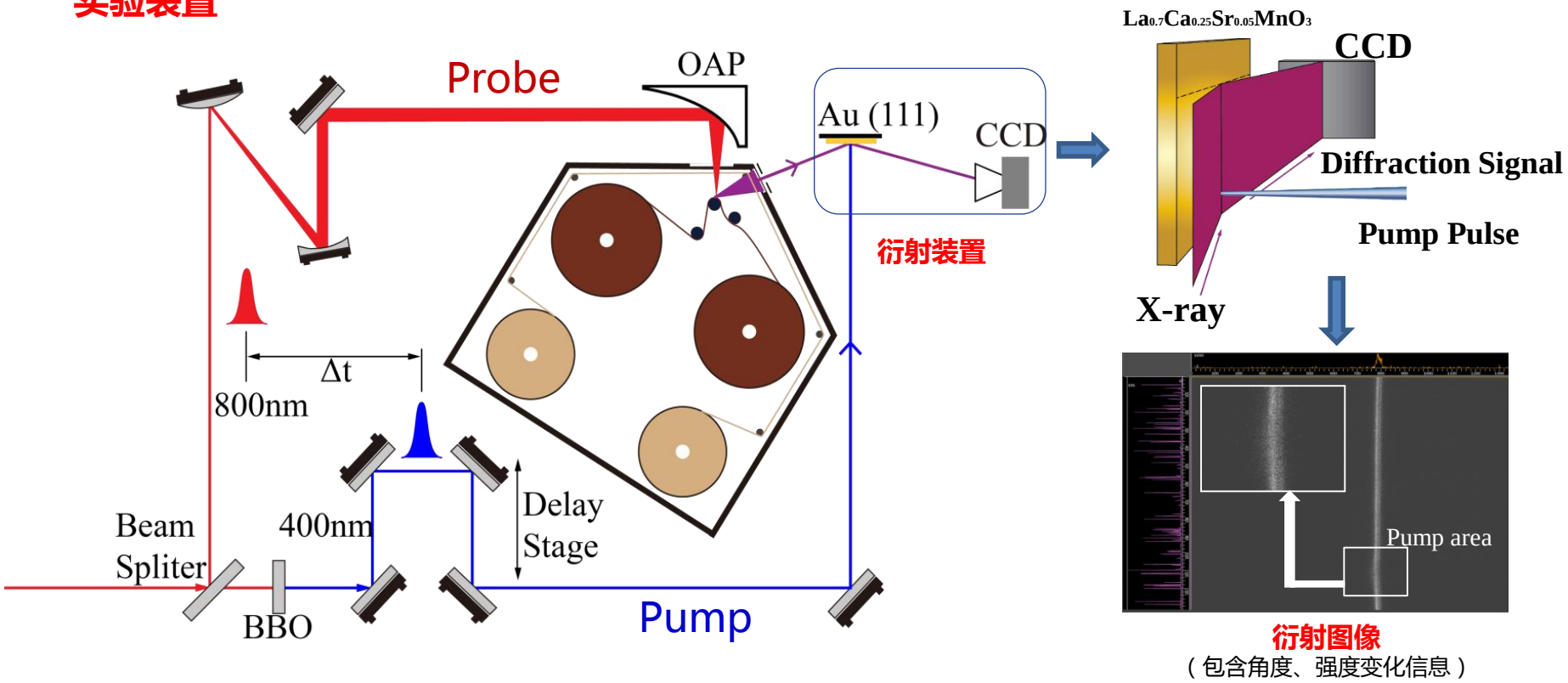
SECUF campus

Design of lab



First stage for pump-probe detection

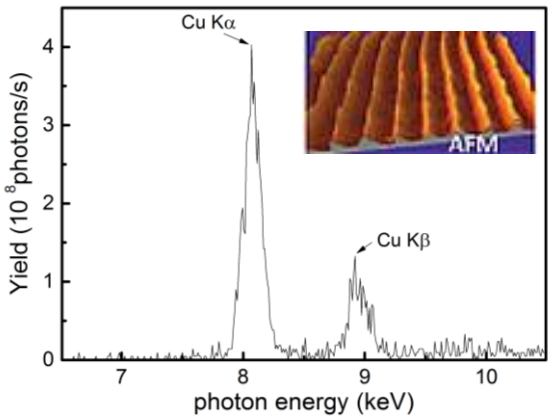
实验装置

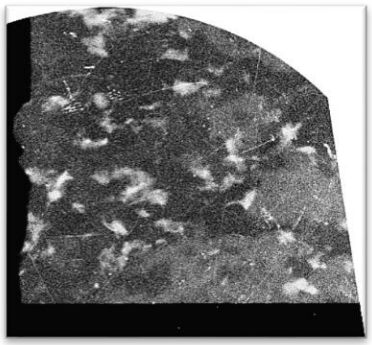


衍射图像

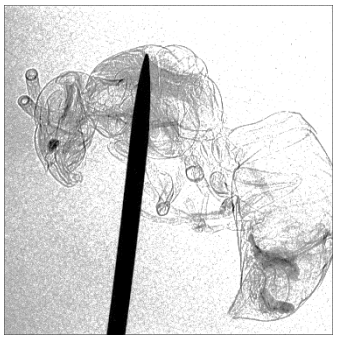
（包含角度、强度变化信息）

X 射线源：
5μm，10^{11}/秒





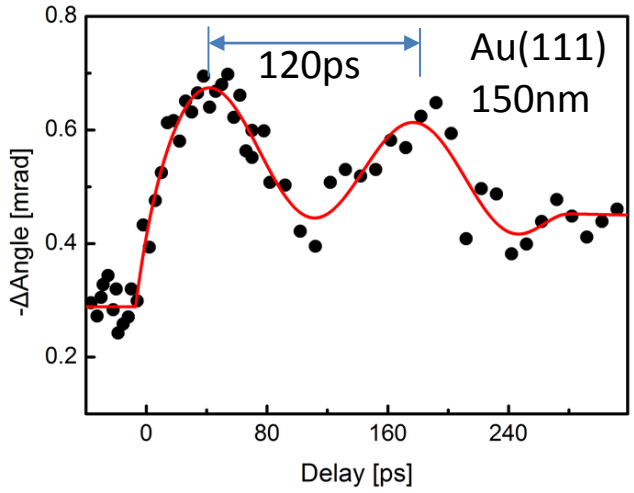
岩石透视成像



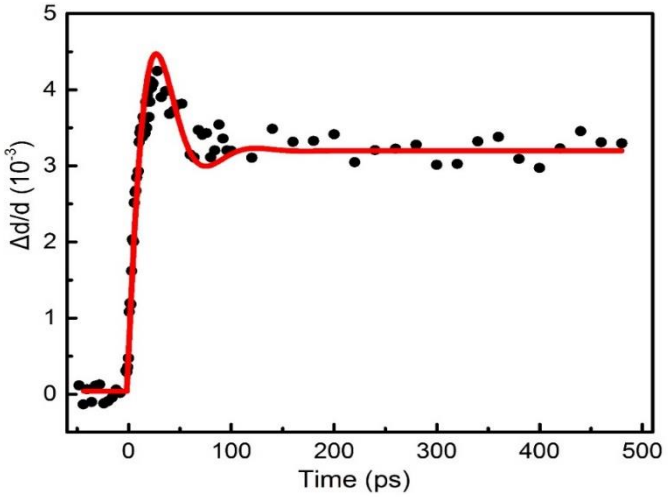
蜜蜂相衬成像

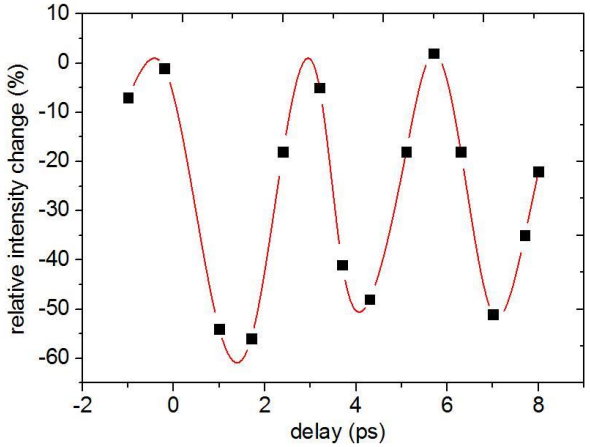
Dynamic detection of samples

结果举例

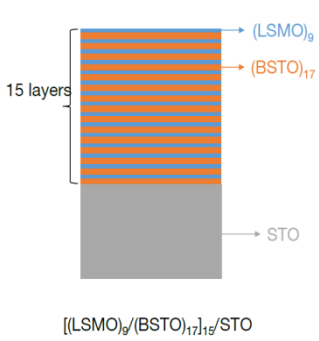


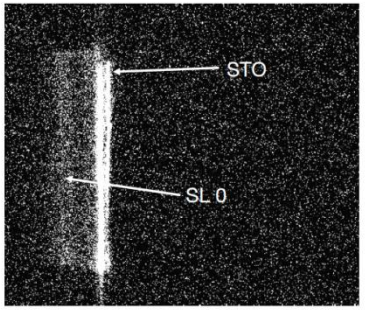
120 nm
La0.7Ca0.25Sr0.05MnO3 / LaAlO3 (001)





$SrRuO_3/SrTiO_3$ 超晶格声子振荡曲线
Time resolving 150fs

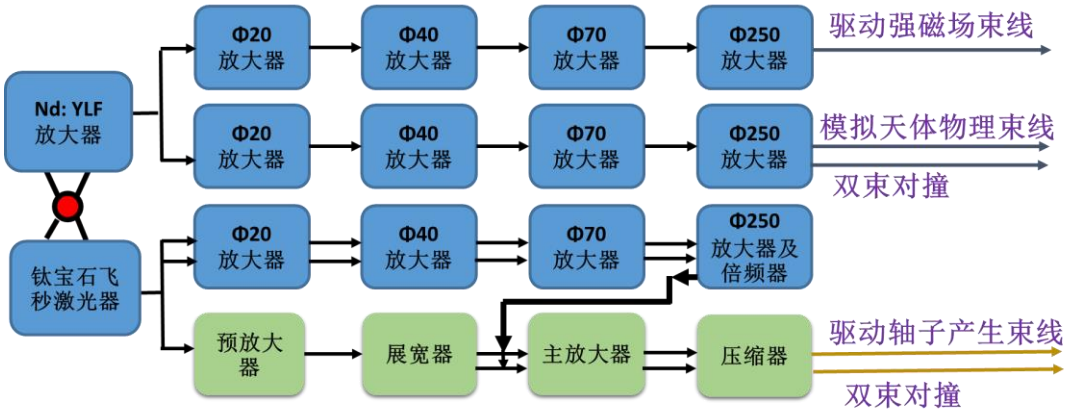




实验获得LSMO新的超晶格结构

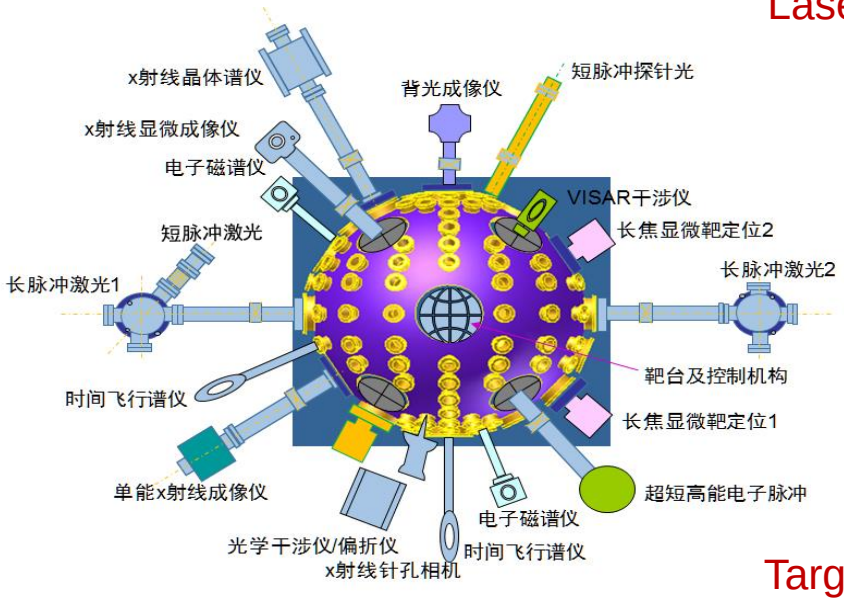
What will do in SJTU

Lab astrophysics platform in Tsung-Dao Lee Institute

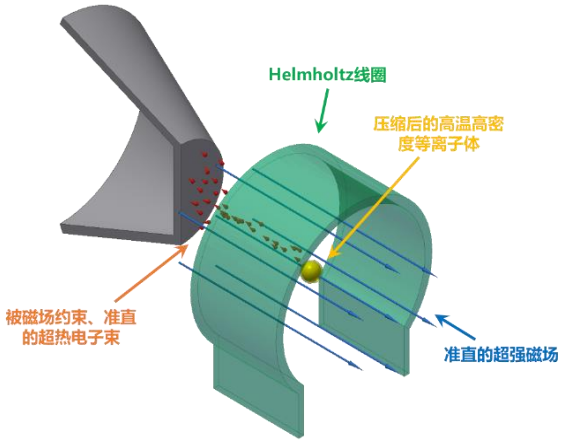


Lasers

- 【High power lasers】
（2xKJ ns+ 2x 100J fs colliding）
- 【Laser+targets】
（靶场 + KT磁场 + 光场提高）
- 【Detection systems】
（多种粒子辐射源）



Targets



KT-B field

Celebrating Toshi's 70th Birthday!!