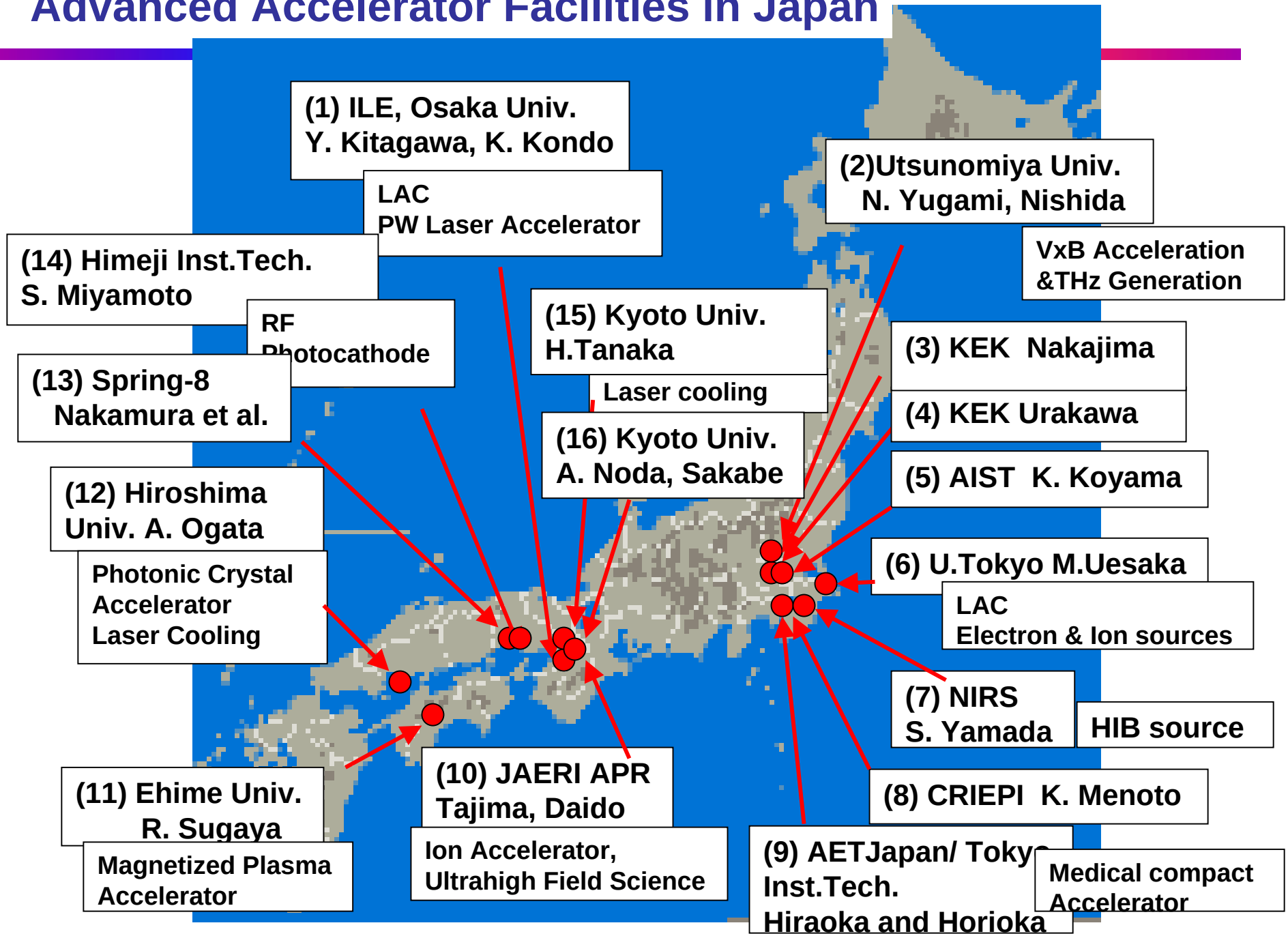
The 11th Advanced Accelerator Concepts Workshop
Stony Brooks, New York, June 21, 2004

Review of Advanced Accelerator Concepts R & D in Japan
with Asian activities

Yoneyoshi Kitagawa

Institute of Laser Engineering, Osaka University

Advanced Accelerator Facilities in Japan



Outline of Talk

[1] Activities of Japanese laboratories

- **Electron and Ion acceleration:**

  Kitagawa group, *Osaka University*
  Uesaka group, *University of Tokyo*
  Koyama group, *National Inst. of Advanced Industrial Science and Technology*
  Nakajima group, *Japan Atomic Energy Research Inst. APR*

- **Ion acceleration:**

  Tajima and Daido group, *Japan Atomic Energy Research Inst. APR*
  Ogata group, *Hiroshima University*
  Nemoto group, *Central Research Inst. of Electric Power Industry*

- **LAC and THz Generation:**

  Nishida and Yugami group, *Utsunomiya University*

- **RF photo cathode:**

  Miyamoto group, *Himeji Inst. of Technology*

- **Radiology Application:**

  Uesaka, U. Tokyo and Dobashi, National Institute of Radiology Science

[2] Advanced Compact Accelerator Project (NIRS)

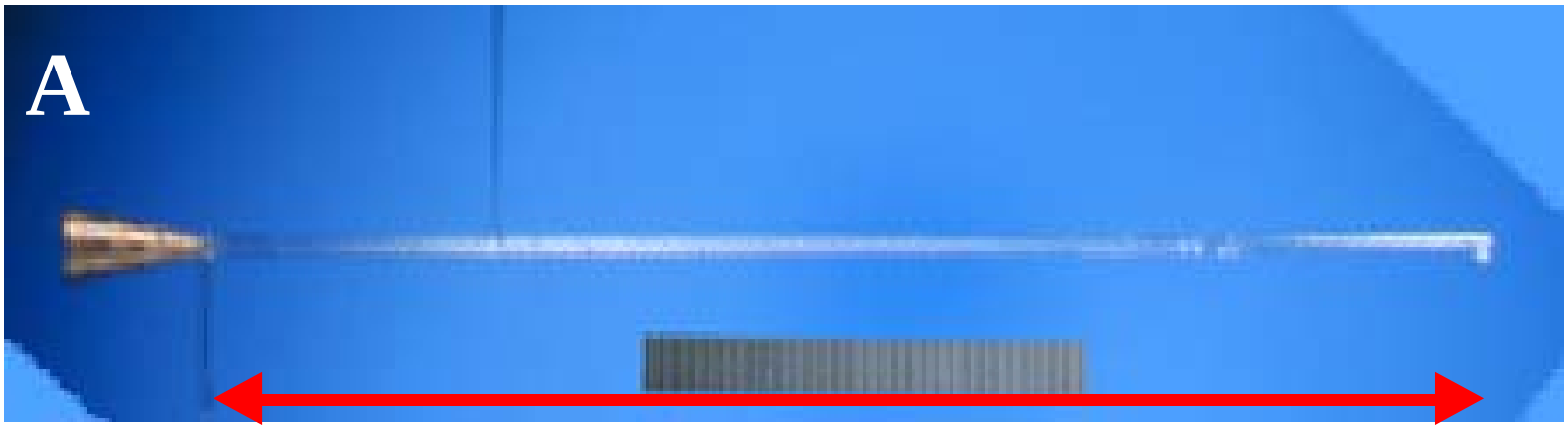
[3] Asian AAC activities

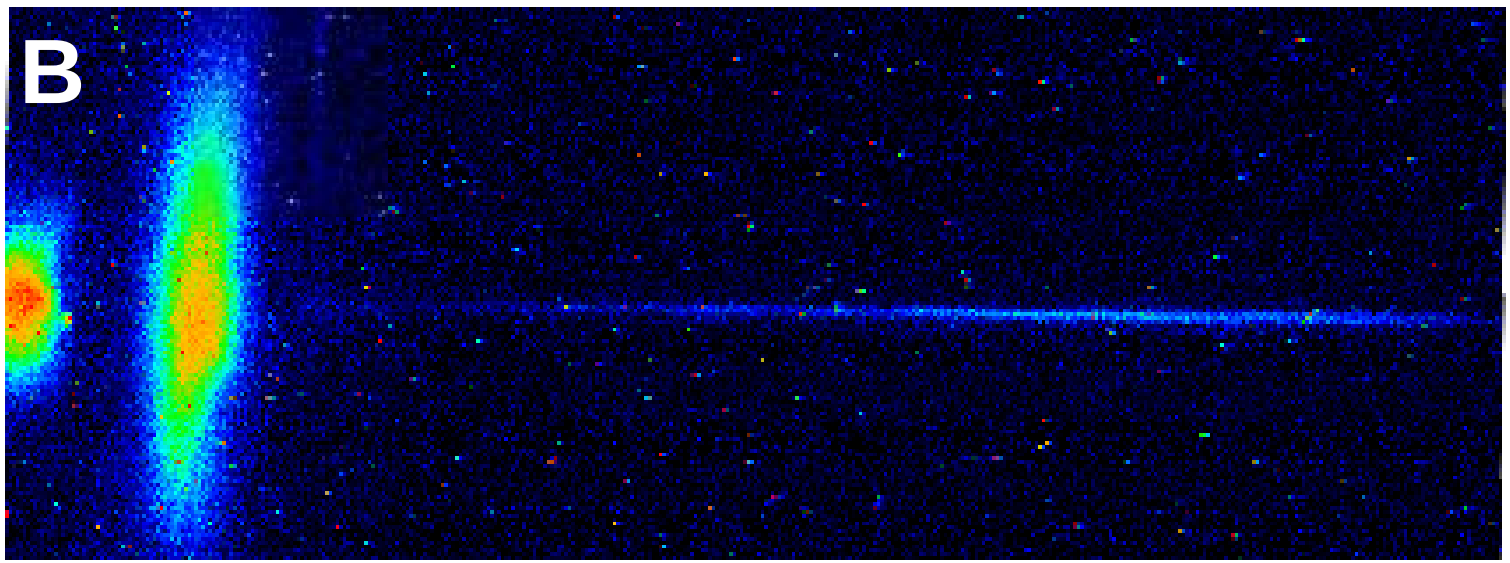
Electron and Ion acceleration:

Y. Kitagawa,Y. Sentoku,
R. Kodama, K. A. Tanaka, T. Norimatsu,
Institute of Laser Engineering, Osaka University,
University of Nevada, Rino

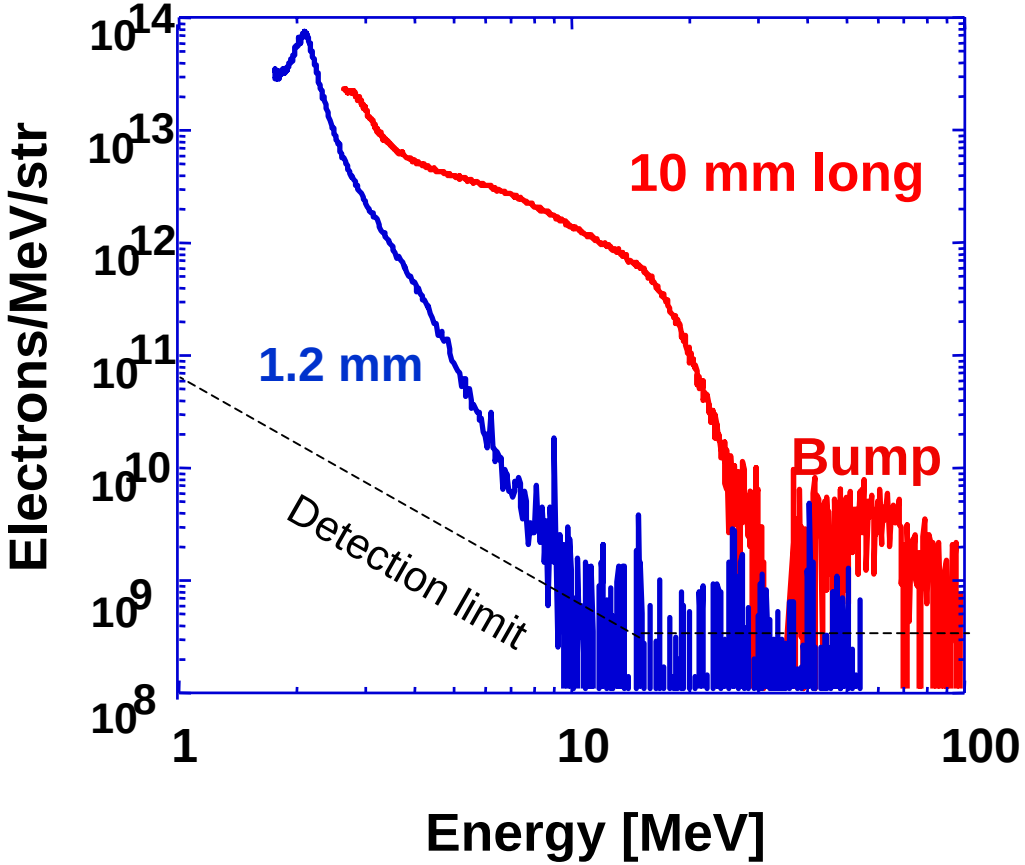
Electron Acceleration to 100 MeV in an Ultra-Intense Laser Illuminated Capillary

Electron Acceleration to 100 MeV in an Ultra-Intense Laser Illuminated Capillary

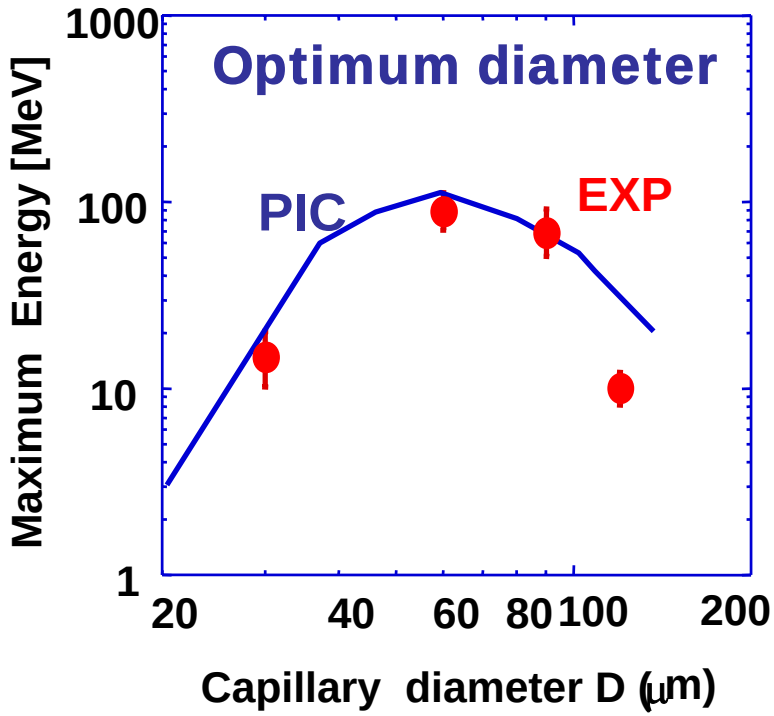




Electron Spectra from 1.2 mm and 10 mm-long Capillaries



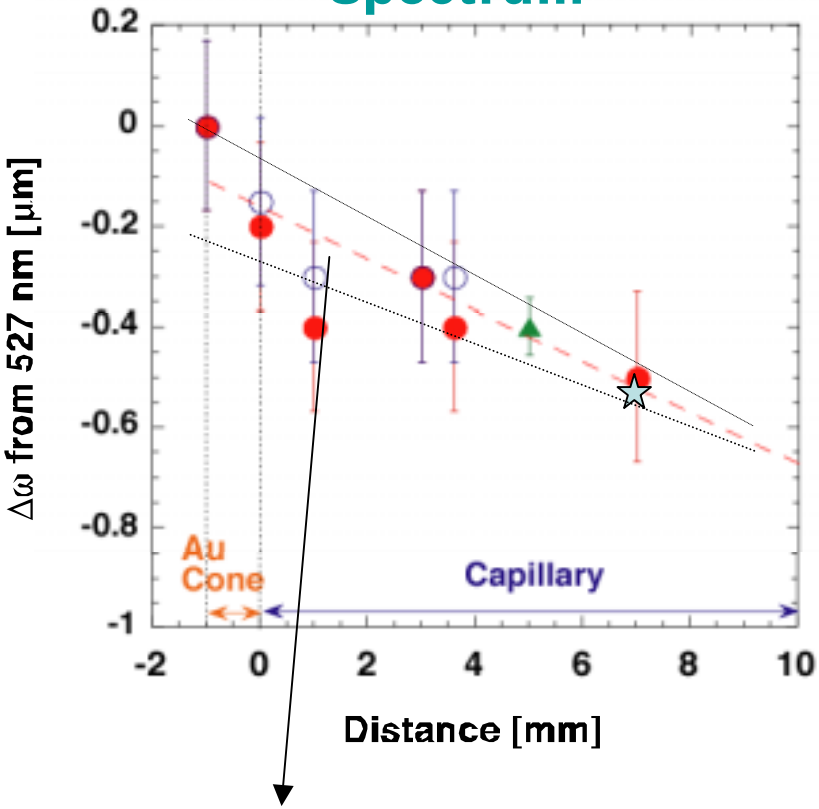
Field = 10 GV/m



PRL Vol.92, No.20 (2004)

Laser Wakefield Excitation in Capillary Plasma

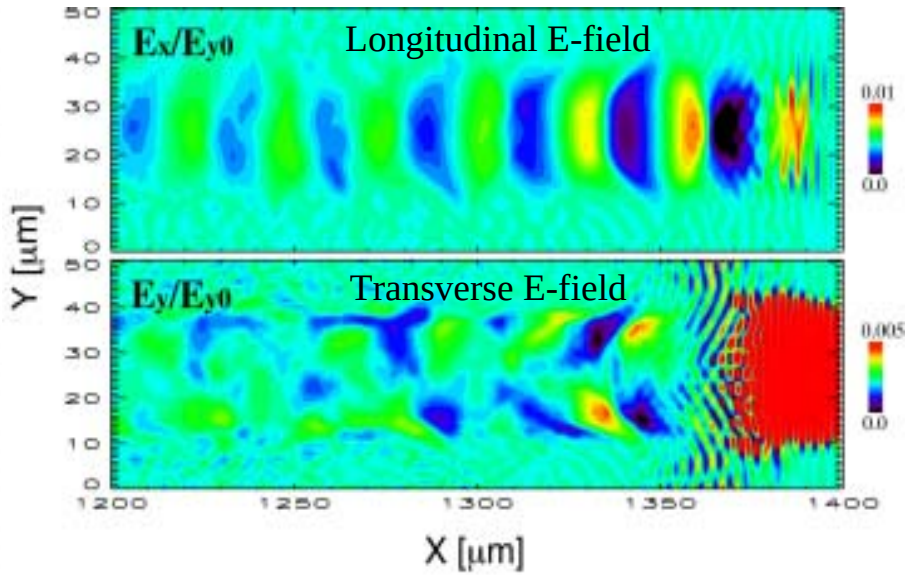
Ionization shift of laser Spectrum

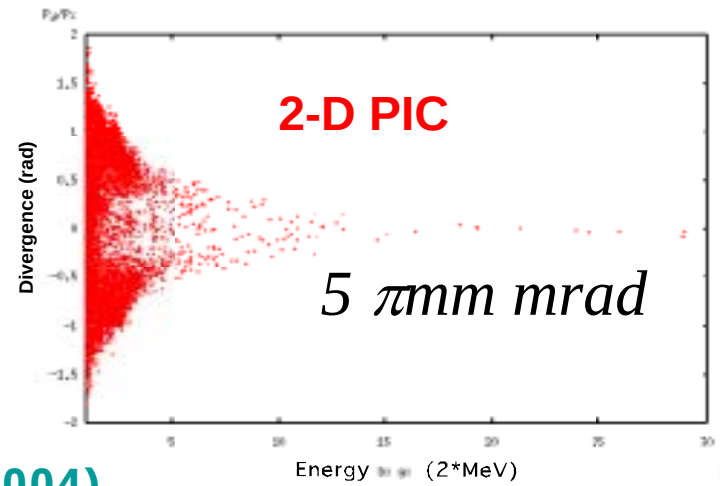


5.9×10^{16} cm^{-3}

Resonant to 500 fs pulse width!

Electrostatic waves at 4.6 psec

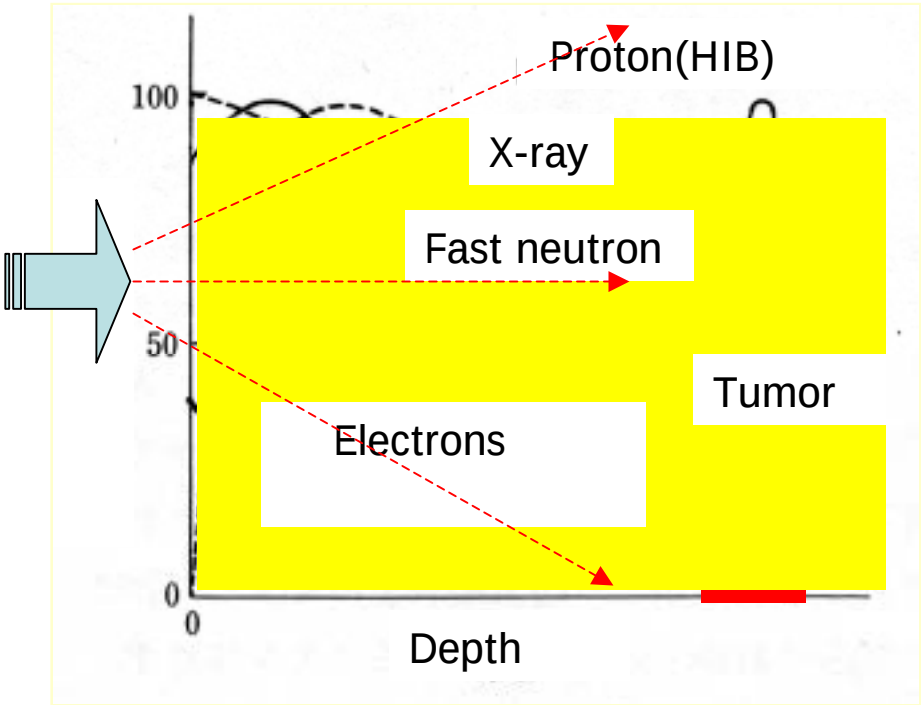




PRL Vol.92, No.20 (2004)

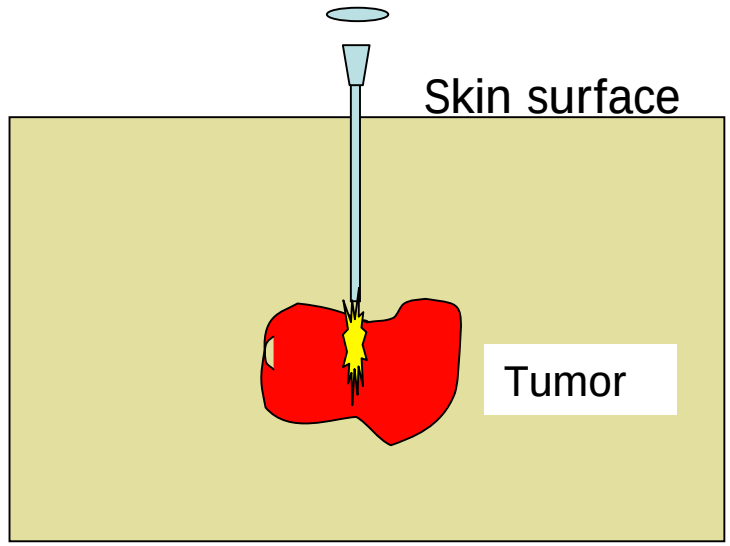
Medical Application of Capillary Accelerator

External (Far field) Illumination



Beam Species, Emittance and Spectrum are required

Capillary (Near field) Injection



Beam Species, Emittance and Spectrum are not required

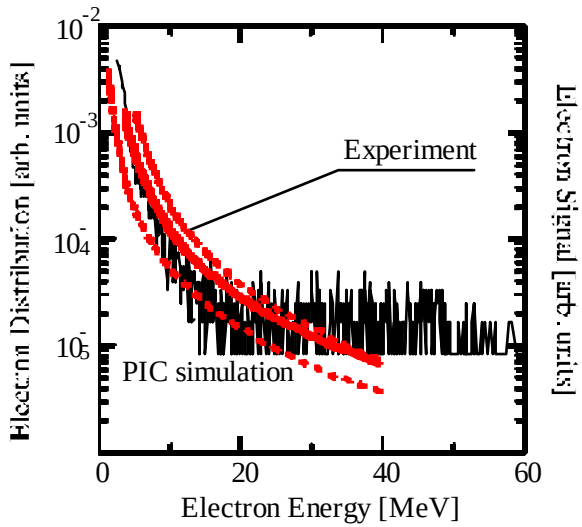
Electron and Ion acceleration:

M. Uesaka,T. Hosakai, K. Kinoshita, A. Zihidkov
NERL University of Tokyo

Plasma Cathode Experiment

to be presented to the Workshop

e-Spectrum



Ref.T.Hosokai,*et al.*,Phys Rev.E 67,036407 (2003)

T.Hosokai *et al*., Phys. Plasmas (In press 2004)

Electron acceleration:

K. Koyama and E. Miura,
National Institute of Advanced Industrial Science and Technology

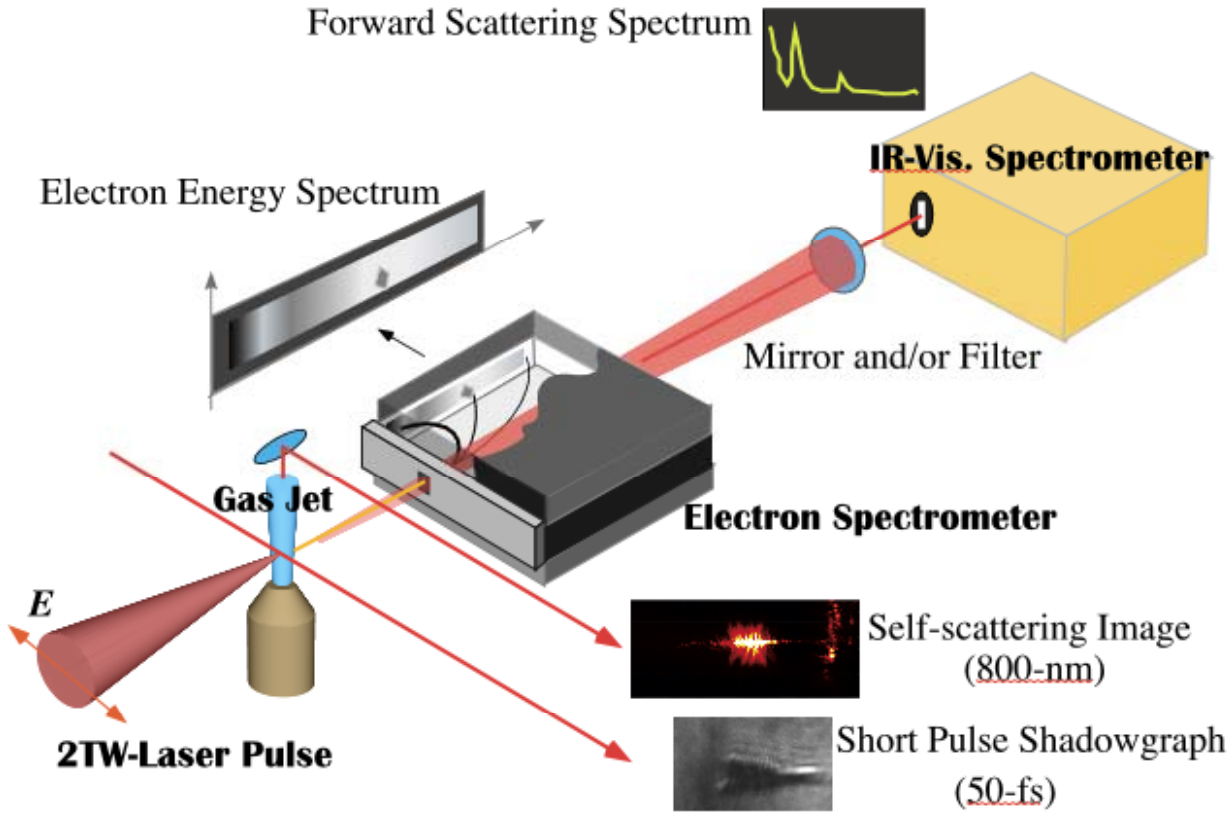
Quasi-mono-energetic electron beam at *AIST* / Tsukuba

to be presented to the Workshop

Quasi-monoenergetic electron beam was obtained at *AIST* / Tsukuba

AIST

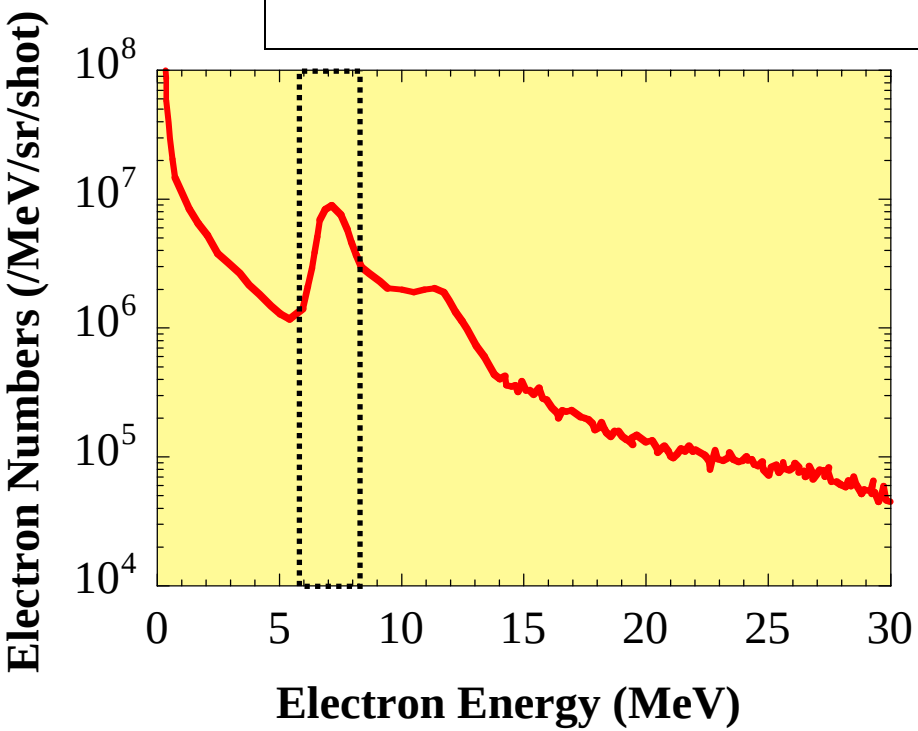
by focusing a 2-TW laser pulse on a dense-gas jet of $n_e \approx 10^{20} cm^{-3}$.

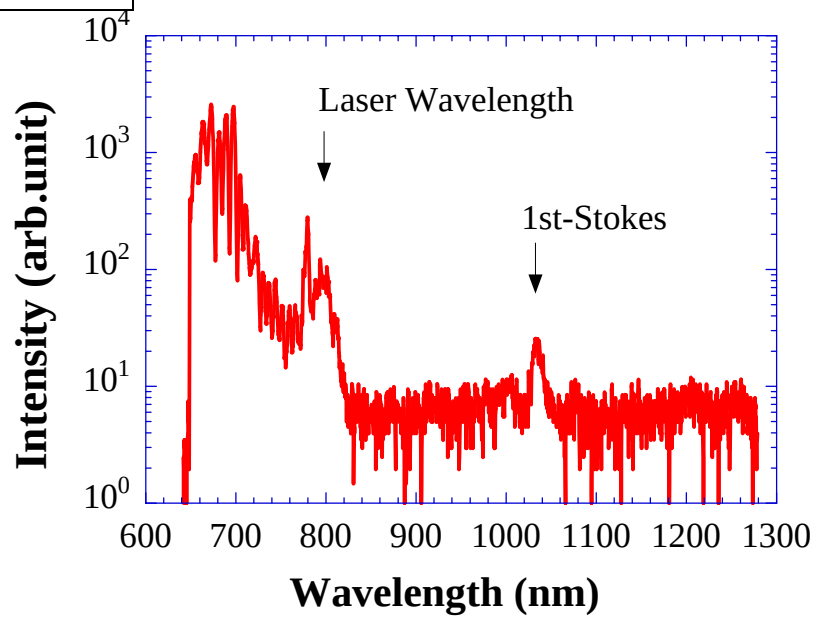


K.KOYAMA

Electron Energy Spectrum including quasi-monoenergetic beam

Monoenergetic beam was emitted in an narrow divergence angle.





Electron acceleration:

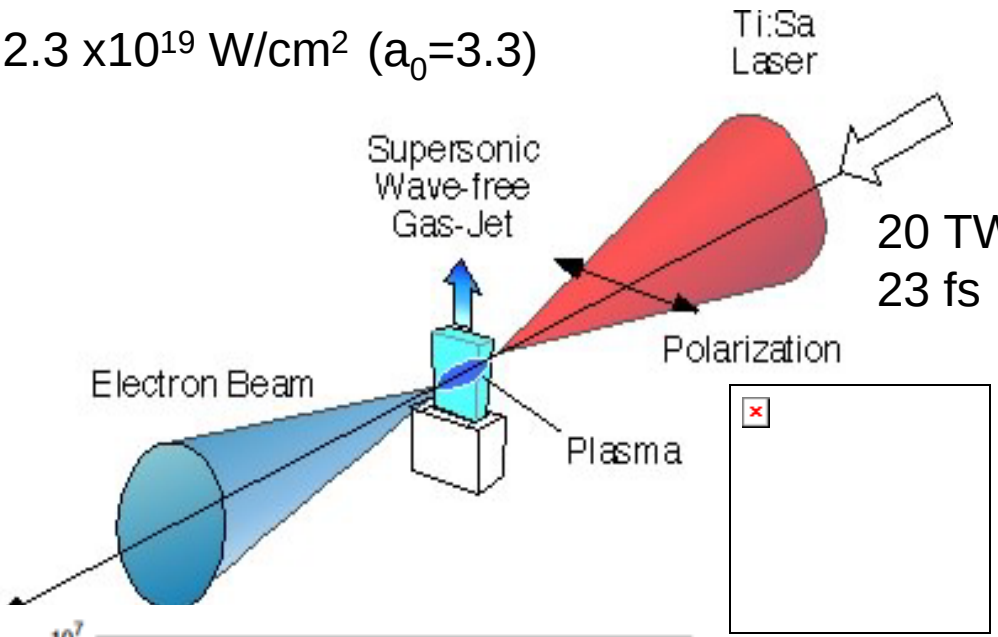
K. Nakajima, M. Kando and group
Japan Atomic Energy Research Institute APR

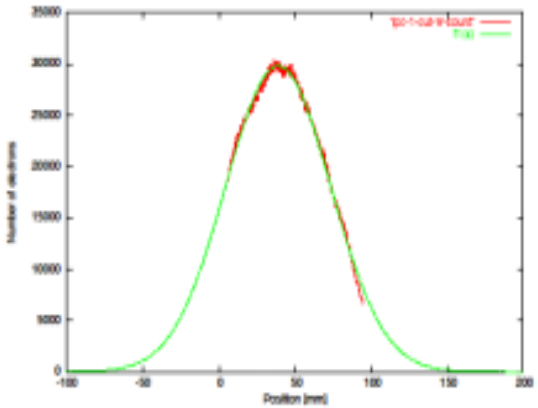
High current electron beam generated with a short (23fs) laser at a high density regime

to be presented to the Workshop

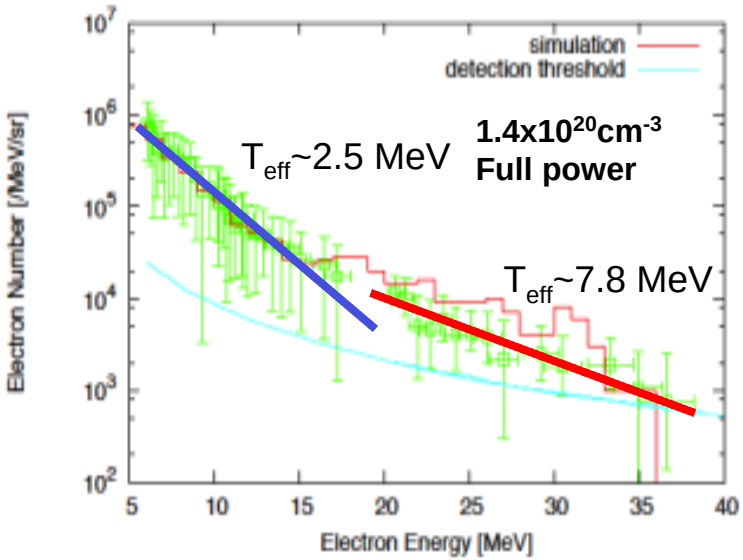
High current electron beam generated with a short (23fs) laser

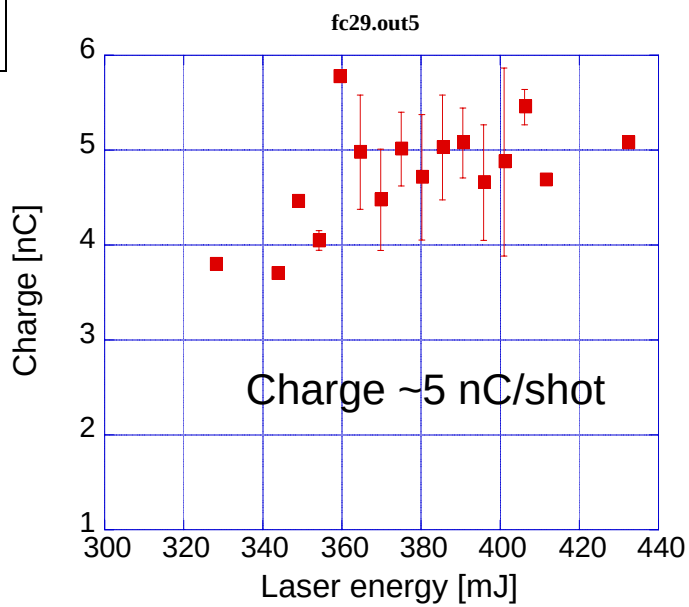
2.3 x10^{19} W/cm^2 (a_0=3.3)





Divergence Angle ~ 10deg





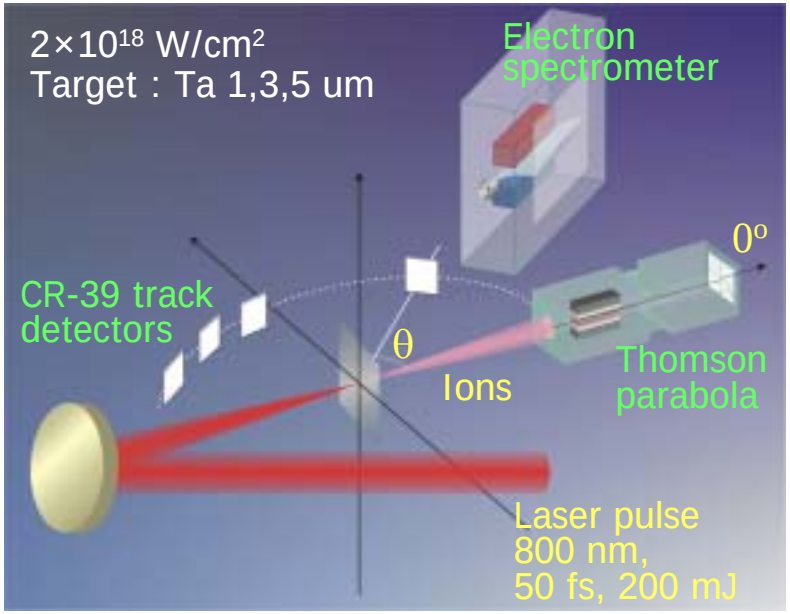
Ion acceleration:

Daido, A. Fukumi, K. Matsukado et al.
Japan Atomic Energy Research Institute APR

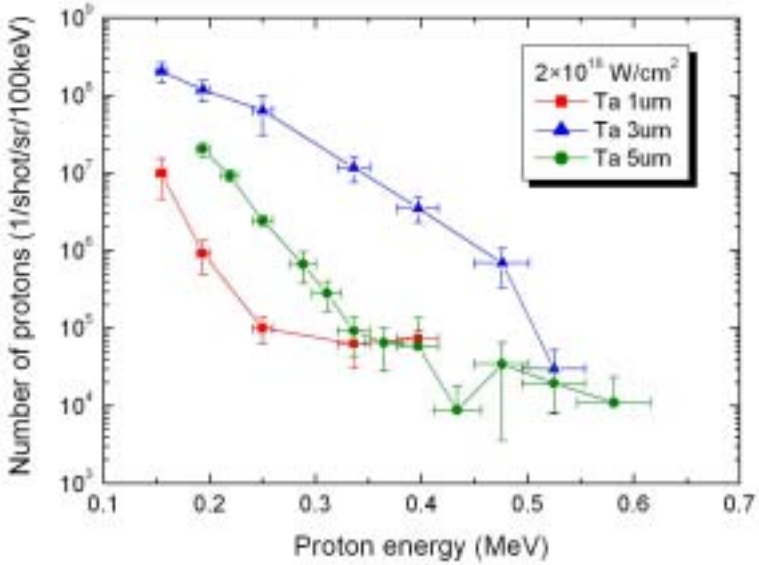
Ion Generation Experiments @JAERI APR

to be presented to the Workshop

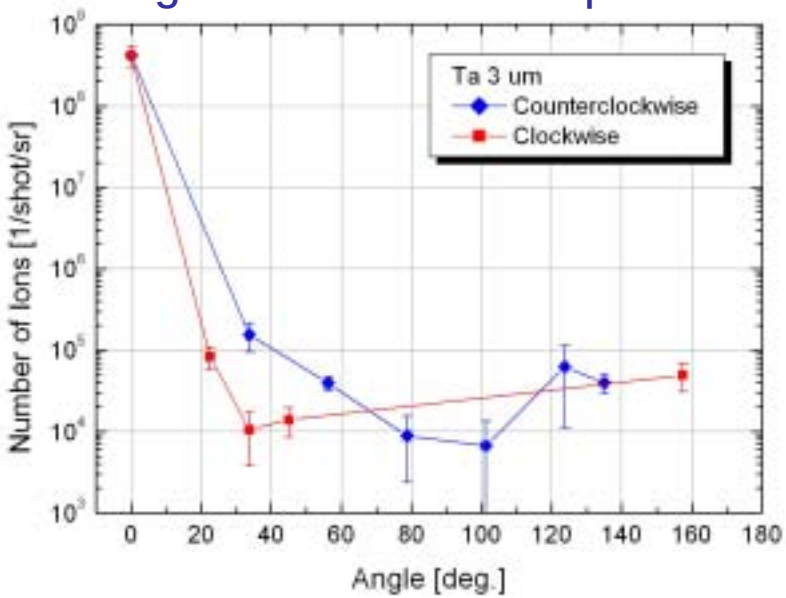
Ion Generation Experiments @JAERI APR

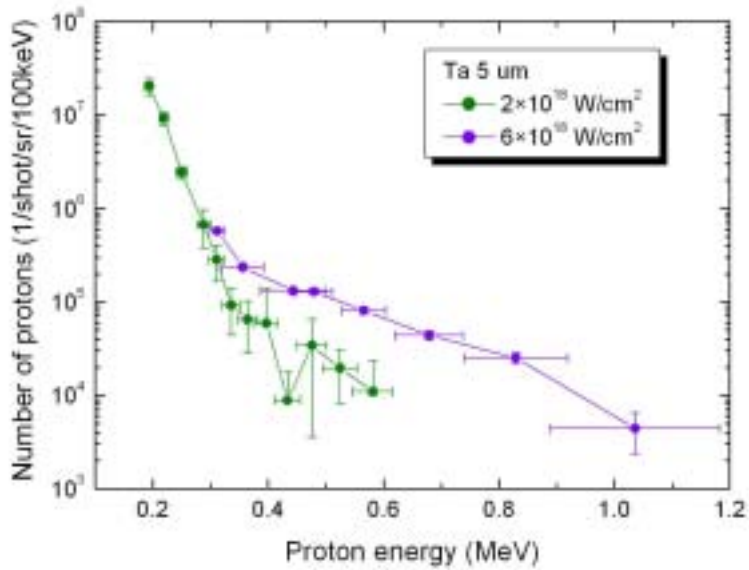


Energy spectra of protons

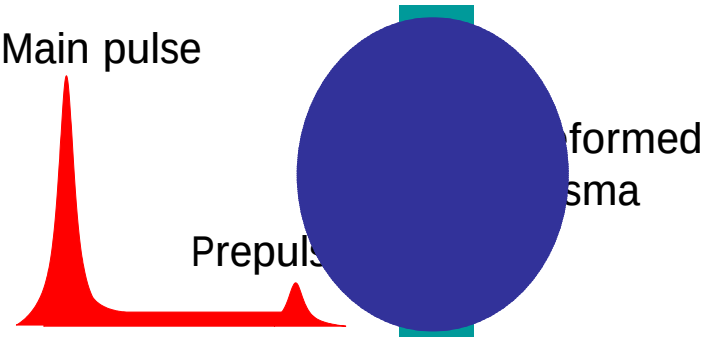


Angular distribution of protons





Prediction of Underdense Plasma Model

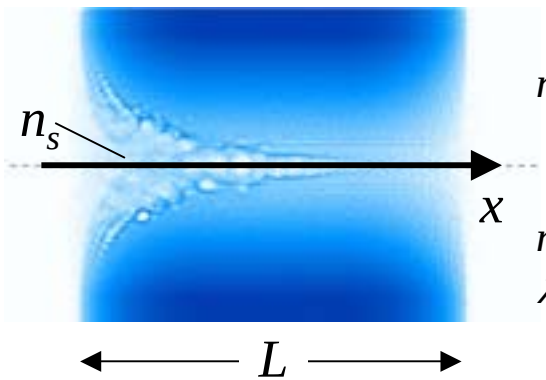


a : Dimensionless amplitude of laser pulse

$$a = \frac{eA}{m_e c^2} = 0.85 \times 10^{-9} [I(\mathrm{W/cm^2})]^{1/2} [\lambda(\mu\mathrm{m})]$$

σ : Normalized density integrated along the channel axis

$$\sigma = \int_0^L n_s dx \Big/ n_{cr} \lambda$$



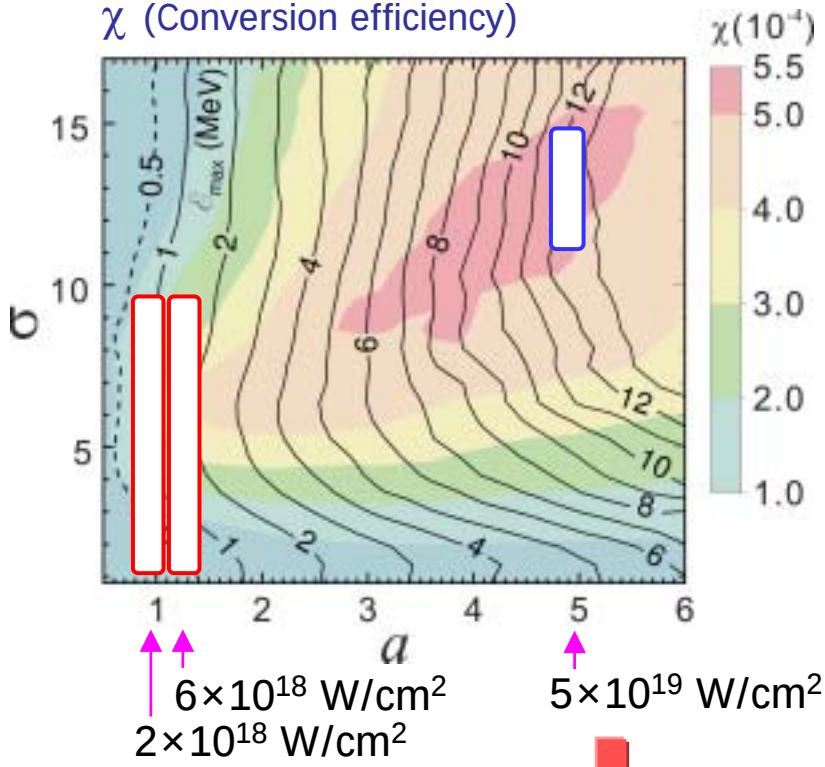
n_s : Electron density along plasma channel

n_{cr} : Critical density

λ : Laser wavelength

E_{max} (Maximum energy of protons [MeV])

χ (Conversion efficiency)



6×10^{18} W/cm^2

2×10^{18} W/cm^2

5×10^{19} W/cm^2

a~5, σ=11~13

E_{max}=10~12 MeV

E_{eff}~2 MeV

N~10^8 protons/shot

(2 MeV ± 100 keV)

Ion acceleration:

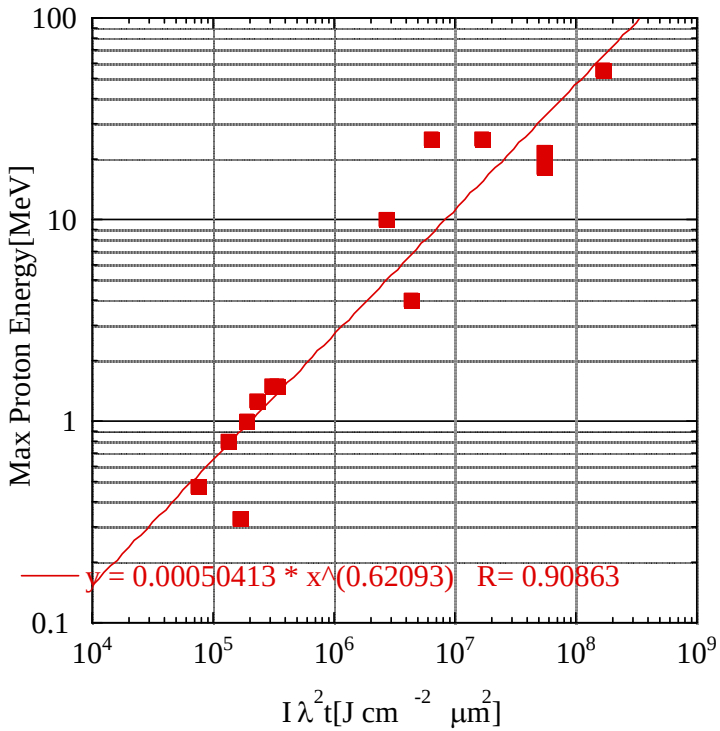
Ogata group
AdSM Hiroshima University

Ion production enhancement by rear-focusing and prepulse with foil target.

talk by A. Ogata at
High Energy Density Physics and Exotic Acceleration Schemes SUBGROUP
13:25-13:50 Tuesday

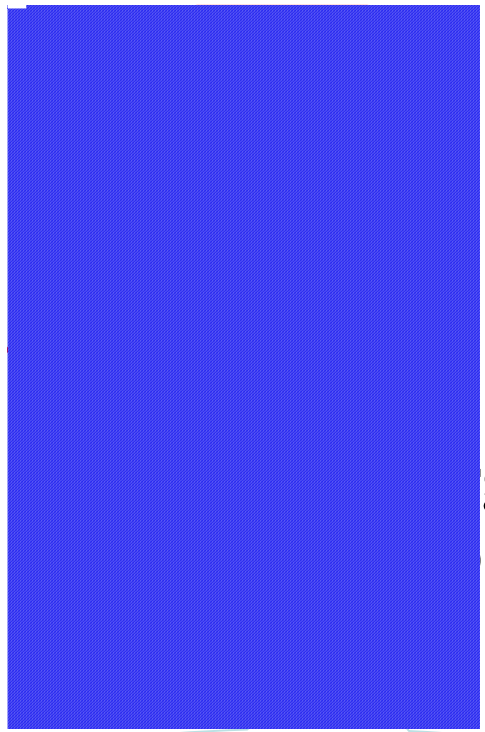
In fs-lasers the energies should be scaled by fluence.

10^{17}Wcm^{-2}(1TW10μmϕ) for 50fs
makes only 5x10^{3}Jcm^{-2}
out of this figure



Y. Oishi *et al.*, Rev. Laser Engineering, **31** (2003) 742.

In our experiment
T^3 laser with a 10^{-3} prepulse

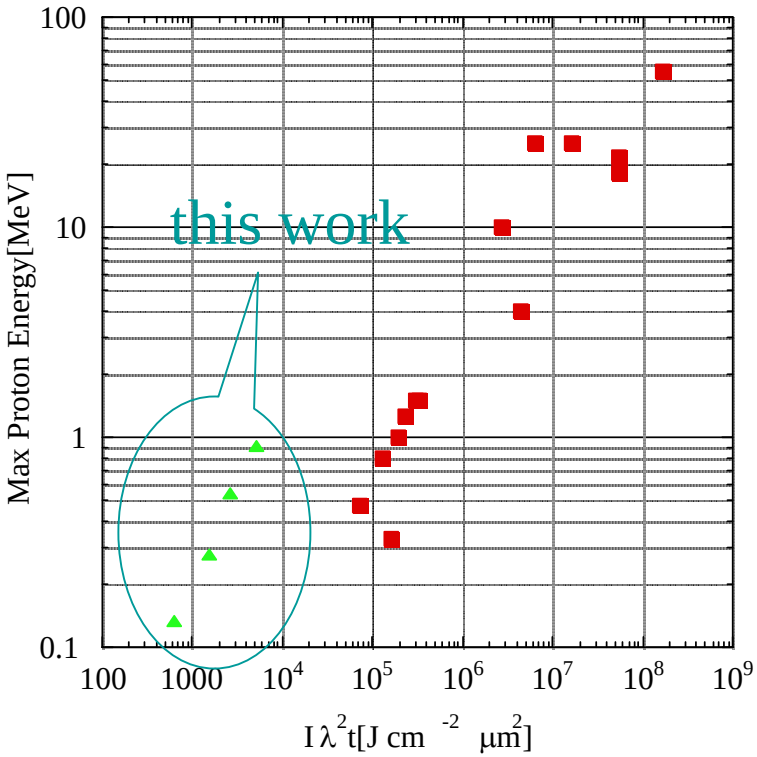


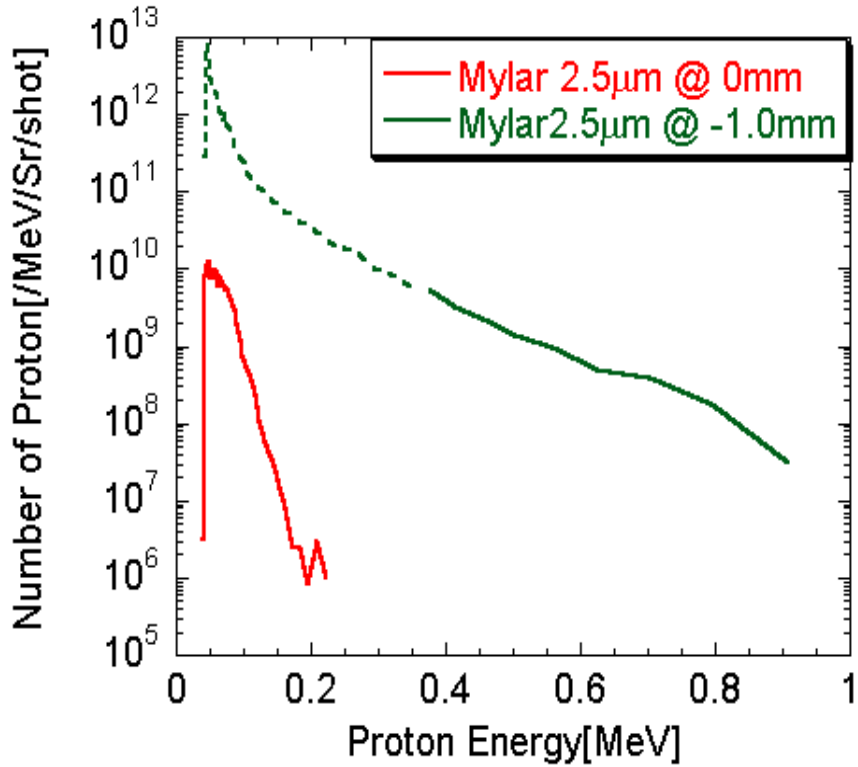
getic ions
oth sides

shift the film target position
from the laser waist

AdSM
Hiroshima U.

positioning the target ~1mm before the laser waist under the existence of prepulses.





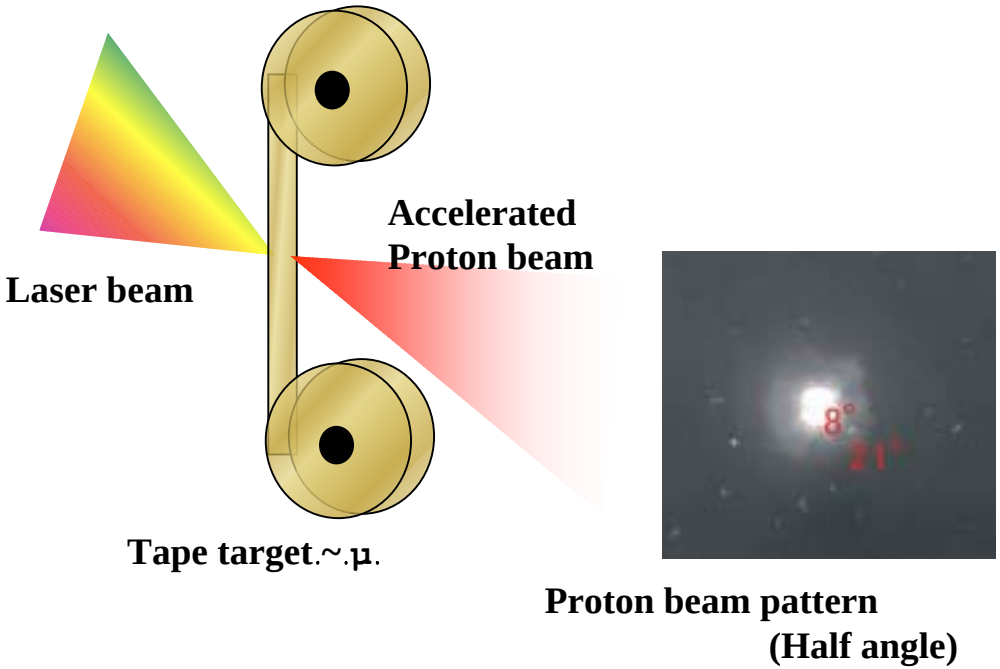
50mJ, 50fs, 800nm Ti-sapphire laser. Contrast 10^{-3}.

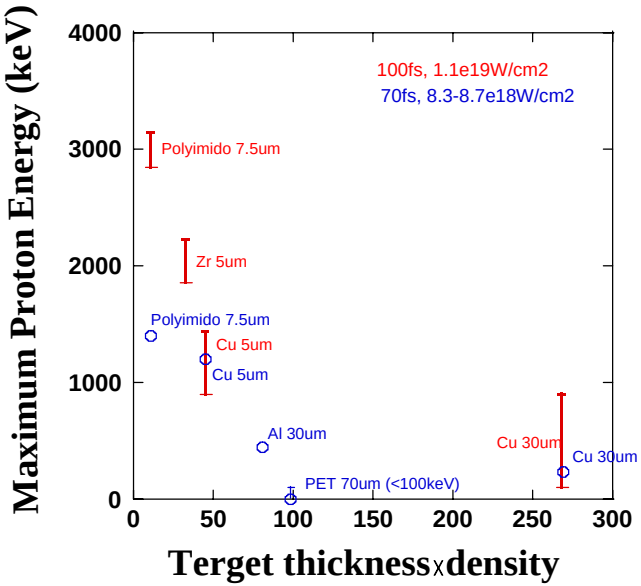
Ion Acceleration:

Nemoto group
Central Research Institute of Electric Power Industry

Energetic particle generation using Ultra-short pulse laser

Energetic particle generation using Ultra-short pulse laser



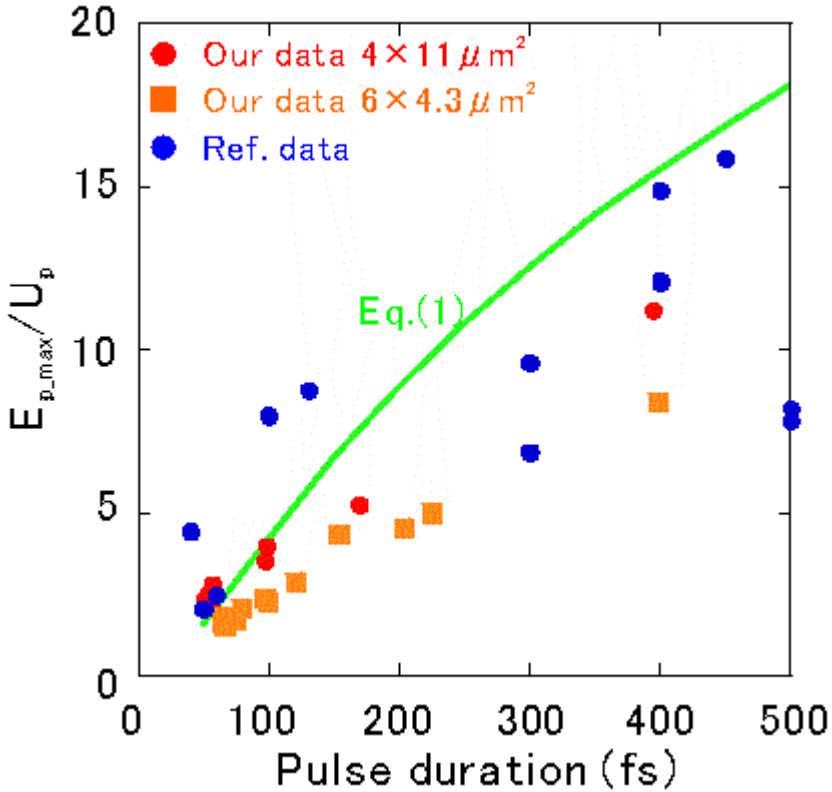


Energetic Ion acceleration

T-cube laser system
20TW, 1J, 50fs, 10Hz

Maximum proton energy

Simple iso-thermal plasma expansion model well describes the experimental results



$$E_{p-\max}/U_p \approx 2Z\left[\ln\left(\omega_{pi}t_{ef} + \sqrt{1+\left(\omega_{pi}t_{ef}\right)^2}\right)\right]^2 \quad \text{Eq.(1)}$$

E_{p-max}/U_p : Maximum proton energy normalized by ponderomotive potential

Here, hot electron temperature is assumed to be U_p.

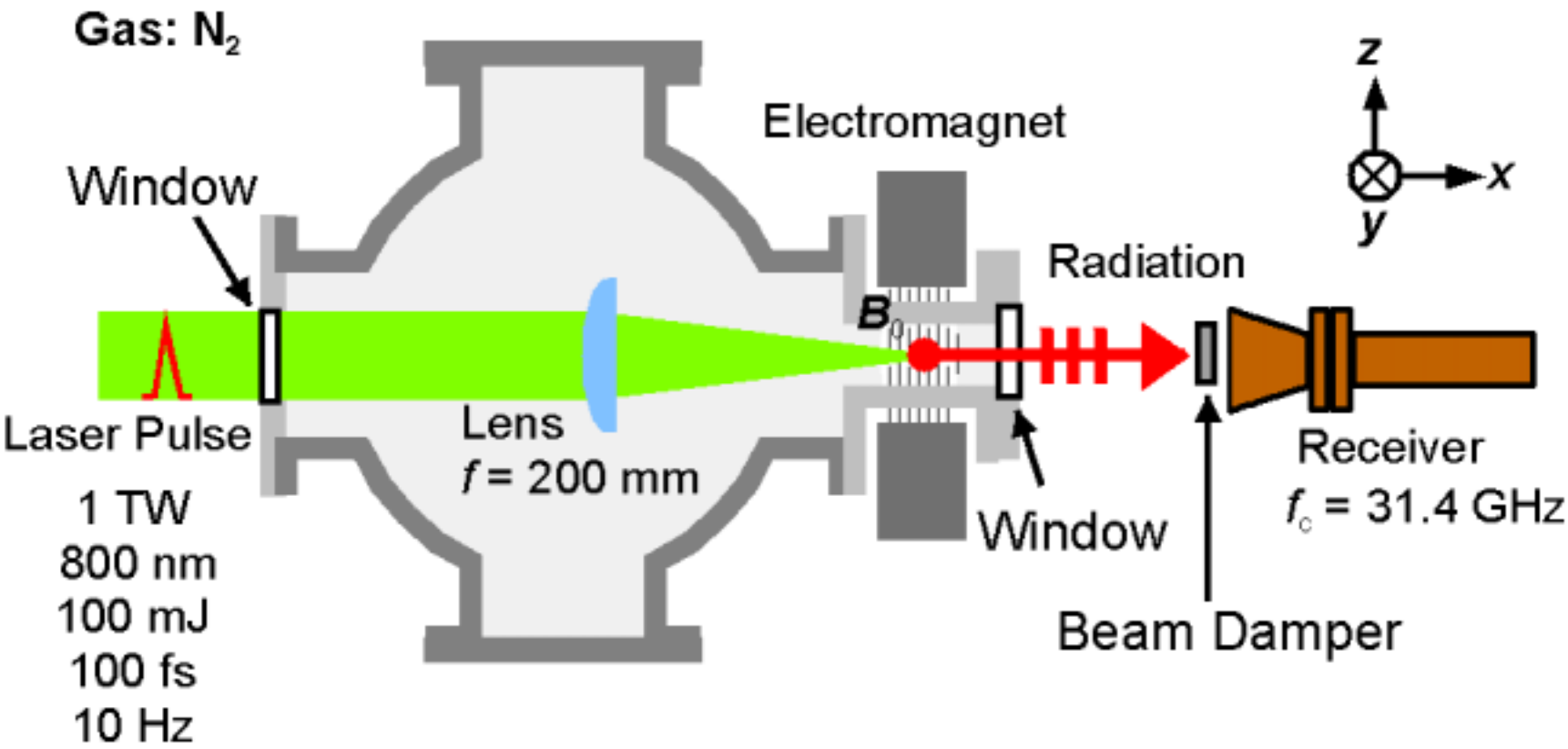
RF Generation:

N. Yugami, Y.Nishida et al.,
Utsunomiya University

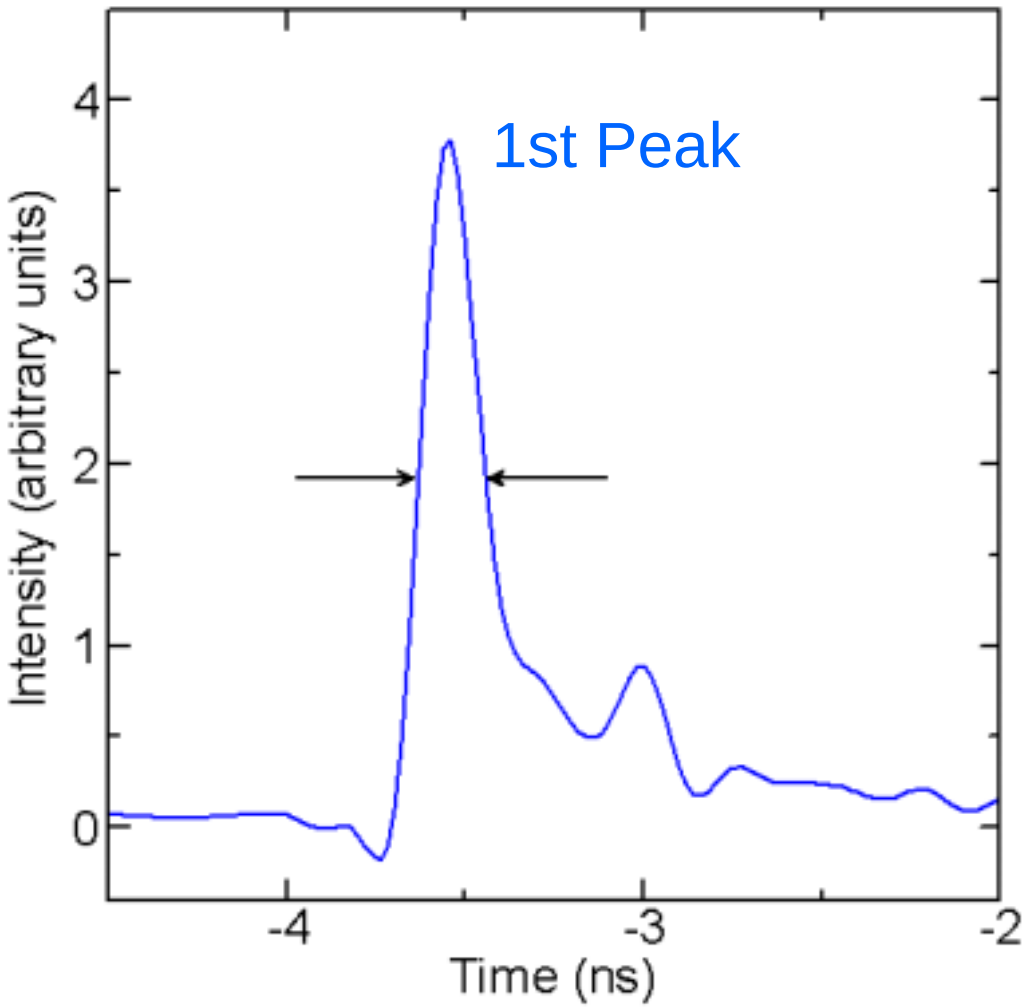
51 GHz radiations from magnetized short-pulse laser plasmas

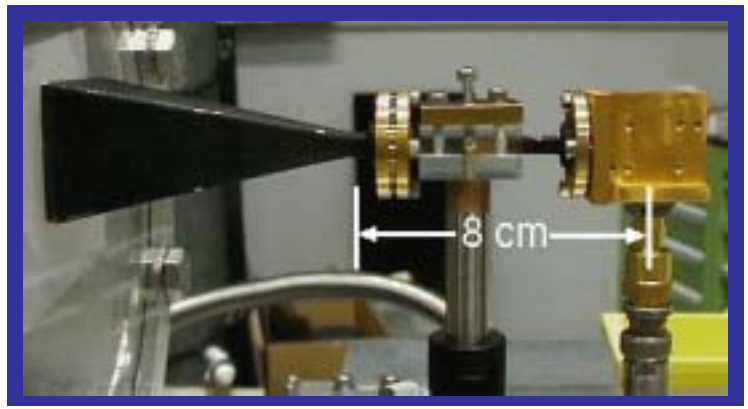
to be presented to the Workshop

Experimental Setup



Observed radiation Pulse





Cut-off freq.

f_c = 31.4 GHz

Pulse width(FWHM)

1st Peak 185 ps

B_0 = 5.44 kG

N_2 : 4.5 Torr

Laser power 0.5TW

Radiology Application:

M. Uesaka, A. Fukasawa et al., U. Tokyo

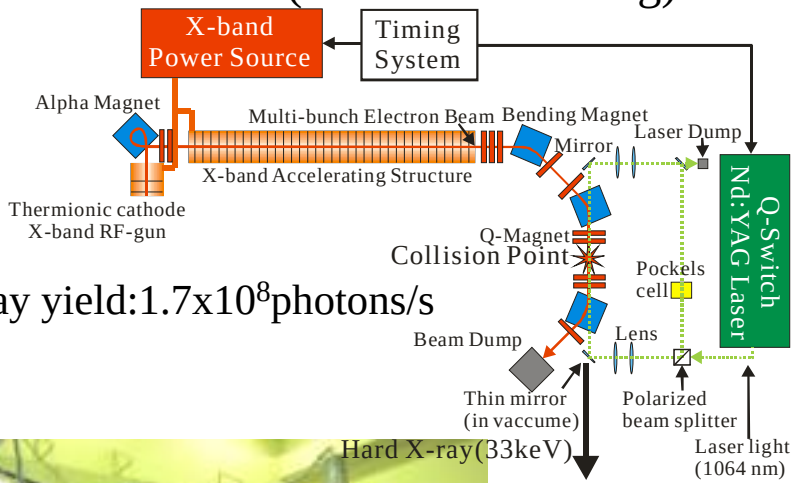
K. Dobashi, NIRS

J. Urakawa, KEK

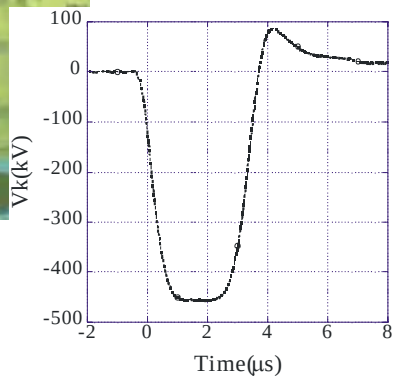
Compact Laser-Compton Hard X-ray source based on X-band linac

Compact Hard X-ray source based on X-band linac

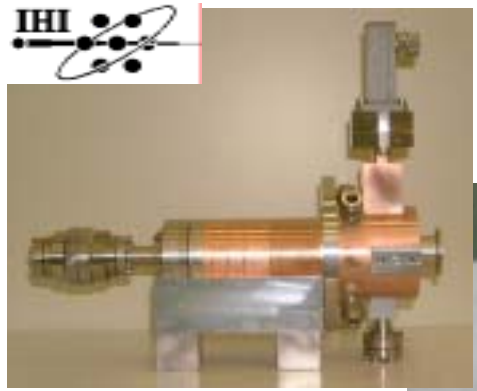
Compact Hard X-ray source based on X-band linac (under constructing)



X-ray yield:1.7x10^{8}photons/s

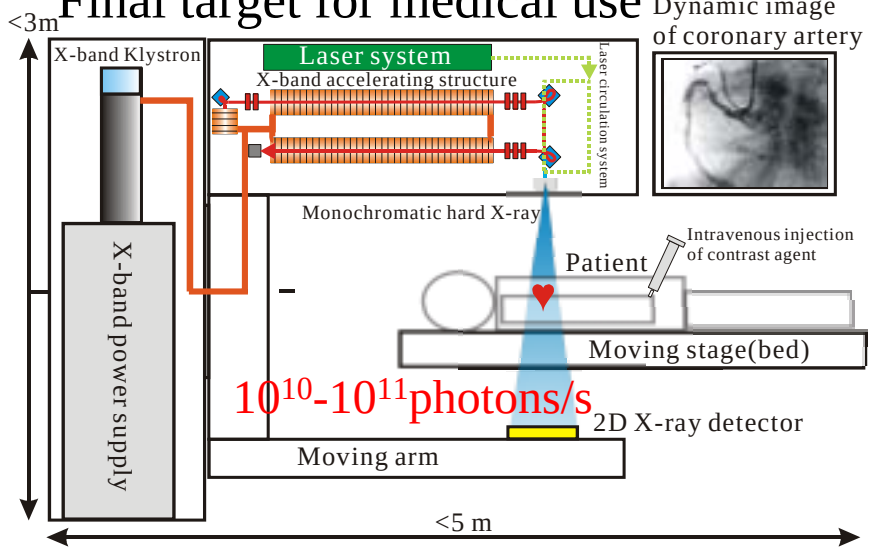


X-band RF source
50MW 50pps



Thermionic cathode X-band RF-gun (2.6cell)

Final target for medical use



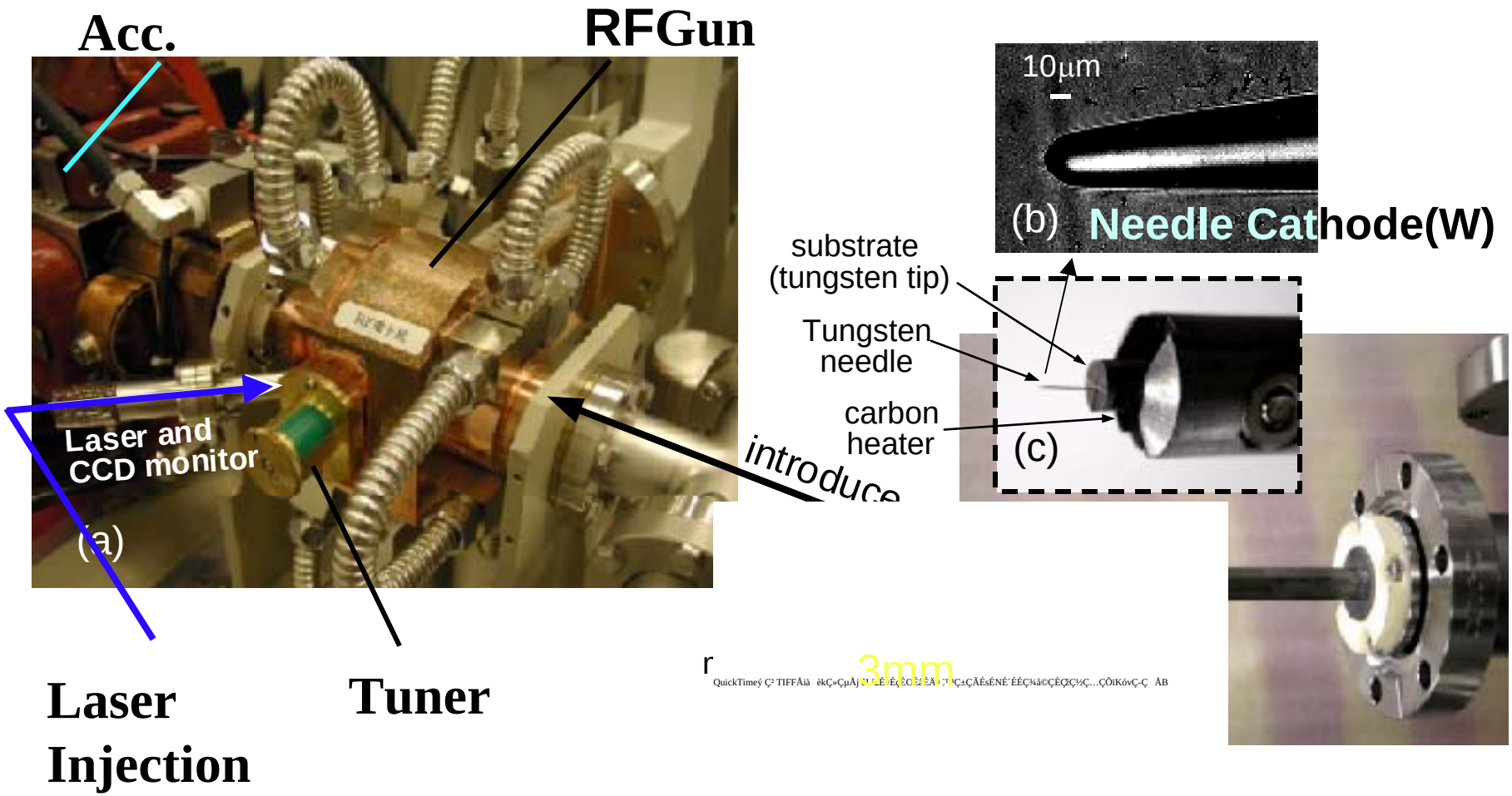
Dynamic image of coronary artery

RF photo cathode:

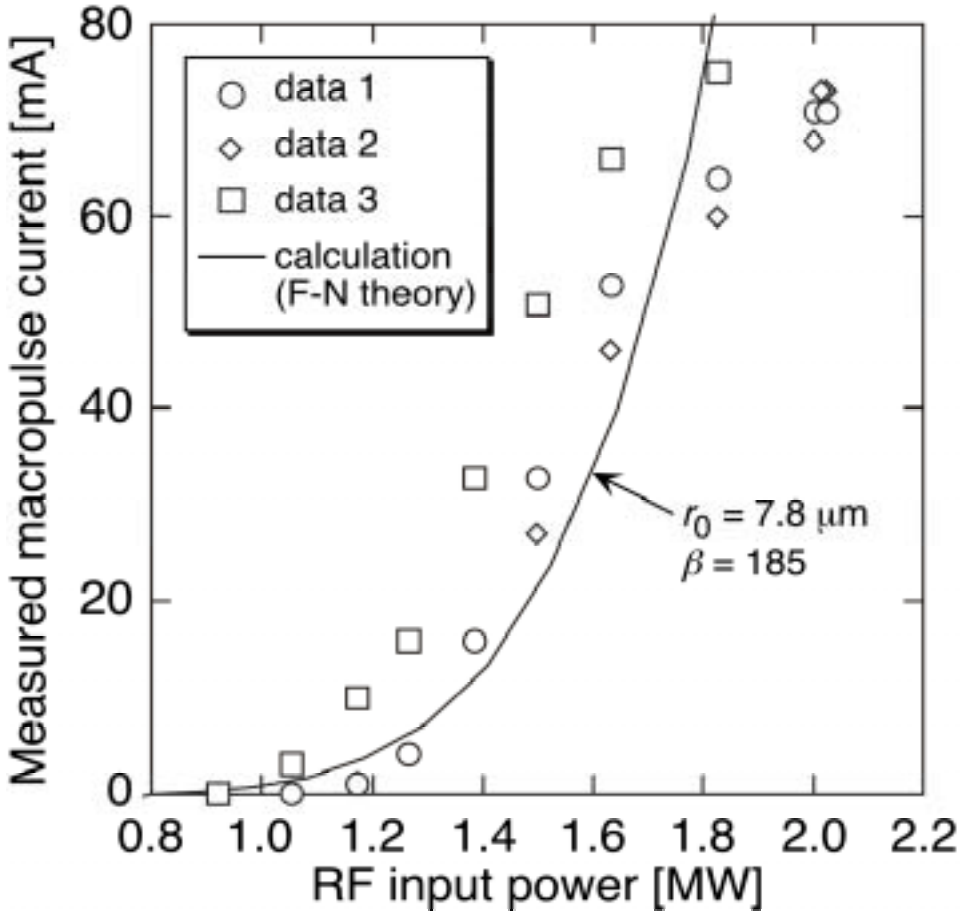
Miyamoto group
Himeji Inst. of Technology

Plane and Needle Photocathode

Plane and Needle Photocathode



Field emission current vs. RF Power



[2] National Institute of Radiological Sciences Project

Advanced and Compact Accelerator Development PROJECT

PROJECT organization

I. Compact Synchroton for proton and heavy Ion

- Laser ion source

JAERI APR, U. Tokyo, Hiroshima U.

- Beam storage and cooling

Kyoto U.

- Synchrotron ring

KEK

- FFAG accelerator

NIRS

II. Compact hard X-ray radiation source

- Intense and short pulse radiation source:Laser electron source

U. Tokyo, Osaka U., AIST

- X-band electron beam linac

U. Tokyo

- High flux radiation source

KEK

[3] Asian AAC activities

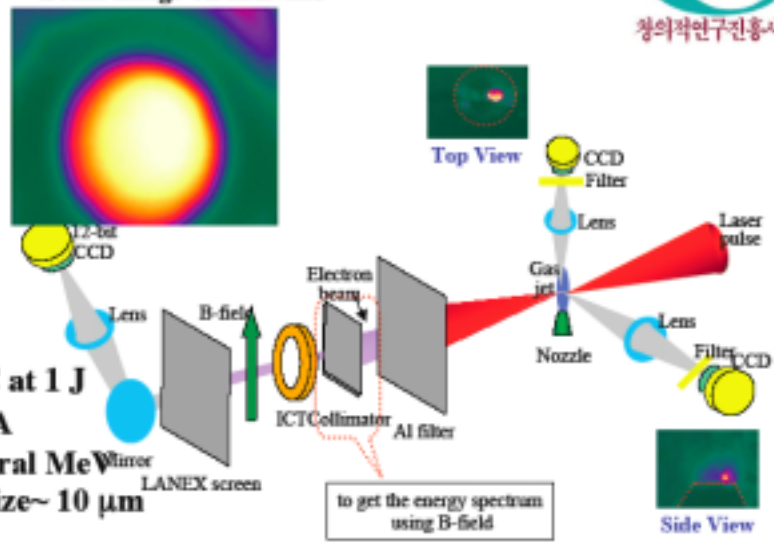
to be presented

by Kazuhisa Nakajima, KEK

Advanced Accelerator Research at KERI, Korea

SM-LWFA experiments

Hyyong Suk et al.



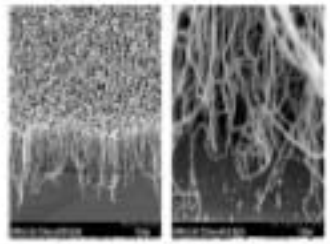
Q~2 nC at 1 J
I~ 10 kA
E~ several MeV
Beam size~ 10 μm

Application of Accelerator Technology to High-Power Laser at KAERI, Korea, B. C. Lee et al.

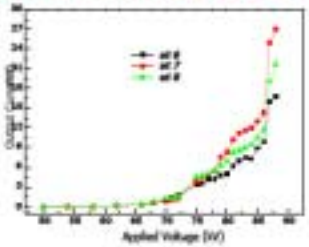
KAERI SC RF LINAC SYSTEM for FEL, Compton X-ray, IFEL

- Energy : 10 MeV (40MeV max)
- Average current : 10 mA

Development of CNT cathode



Total current of 1.5 mA at 95 kV !

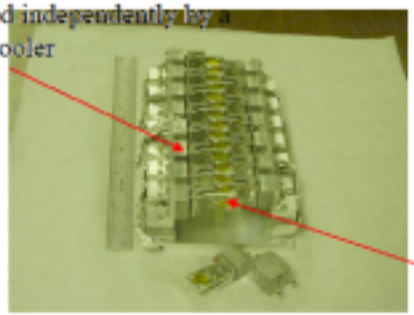


Taiwan Optical Particle (TOP) Accelerator

The NTHU Relativistic Photon-electron Dynamics Lab at *National Tsinghua University*, Yen-Chieh Huang et al.

A Proof-of-principle Experiment for Structure-loaded Vacuum Acceleration
16-stage lens-array structure driven by CO_2 laser

Each lens' temperature is varied independently by a TE cooler



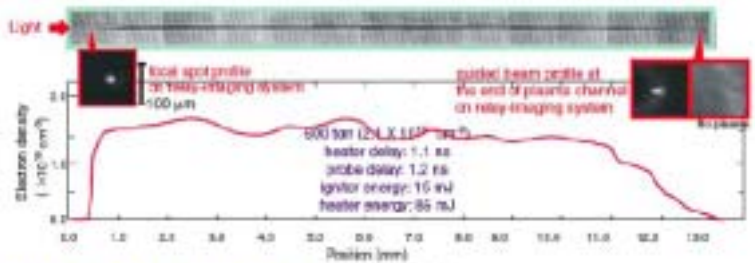
ZnSe lens

E_max=132M V/m

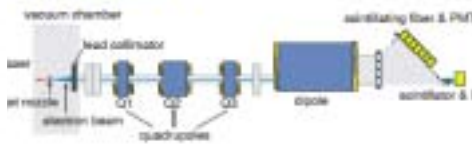
Energy gain=250 keV

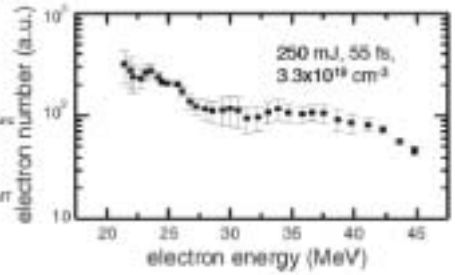
Institute of Atomic and Molecular Sciences, Academia Sinica, Taiwan, Szu-yuan Chen et al.

A uniform plasma waveguide extending over 1.2 cm

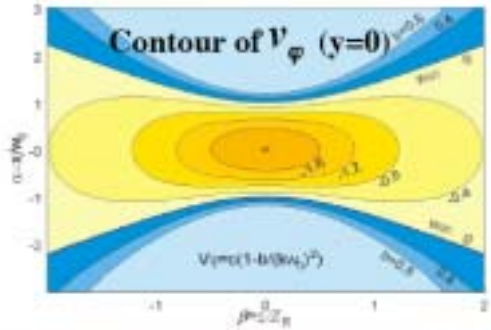


High-energy electron spectrum up to 45 MeV





Vacuum Laser Acceleration at Fudan University, China Yu-Kun Ho et al.



a_0	80
E_{max}(MeV)	1281
Fraction (%)	48
Mean scattering angle (θ_f)	0.71^0
$\Delta\overline{\theta}_f$ RMS	$\pm 0.23^0$
Emittance x	0.086
$\gamma_f \pm 15\%\gamma_f$ y	0.40
$\gamma_f = 0.8\gamma_{max}$	
incident emittance: $0.1\pi \cdot mm \cdot mrad$	

- Novel vacuum laser accelerator scheme:
  - a_0=10: 100MeV; a_0=100: 2GeV.
  - No laser-plasma instabilities.
  - No optics near the focus region.

Laser-plasma electron acceleration in China

Shanghai Institute of Optics and Fine Machine, Z.Z. Xu

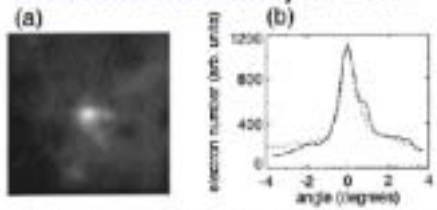
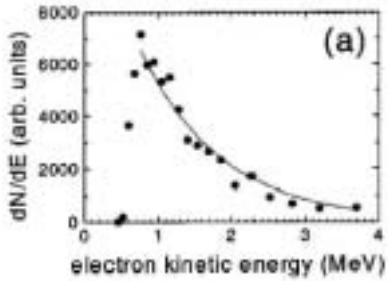


Fig. 4. (a) Laser image of the main electron beam component and (b) linescan in the horizontal (solid curve) and vertical (dotted curve) directions through the beam center.



Institute of Physics, Beijing Electron injection, J. Zhang

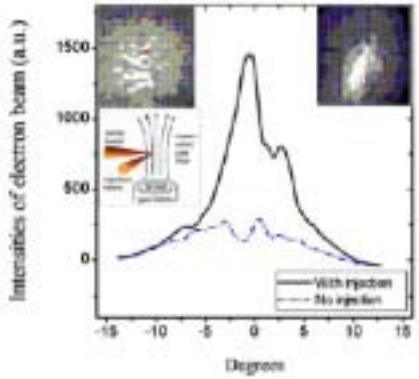
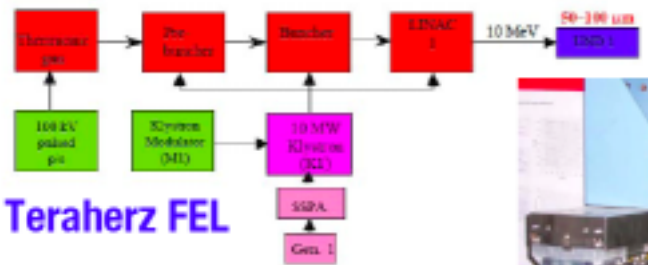


FIG. 1 (color online). Profiles of the spatial distributions of the electron beams (kinetic energies above 370 keV) in the direction of the pump at pump laser power of 1.5 TW, with (right inset) and without injection (left inset). Schematic diagram of the laser beams intersecting in the gas flow (middle left inset).

Advanced Accelerator at TIFR and CAT,India, Srinivas Krishnagopal et al.

- Self-Modulated Laser Wake Field Acceleration by the use of 7TW, 60fs laser soon
- Particle Wake Field Acceleration by the use of Photocathode beam source + Linac system at CAT 1 nC, 10ps



Teraherz FEL

- 1 MW peak power
- Tunable radiation from 50 -100 μm
- A few ps pulse length

Advanced Accelerator research in Israel

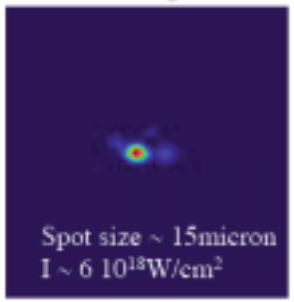
Electron Acceleration using Intense Lasers in Plasma

Arie Zigler

Hebrew Univ., Jerusalem

- Plasma channels based on capillary discharge

Optical guiding - guiding up to **6 cm** (hundreds of Rayleigh lengths) and laser intensities in range of 10^{18} W/cm^2



Electron Acceleration with Intense Lasers in Vacuum

Levi Schächter

Technion-IIT, Haifa

Optical Bragg Accelerator

- Interaction impedance in a Bragg structure of the order of 2000Ω.
- Maximum surface field for 1GV/m gradient of the order of 2GV/m

Asian Advanced Accelerator Community

is organized at APAC2004

Japan
Korea
China
Taiwan
India
Israel
Ukraine

Chair: Kazuhisa NAKAJIMA

The largest number of labs are involved in Advanced Accelerator R&D in Asia.

Acknowledgment

We acknowledge the organizing committee, Japanese community member and all the the workshop participants for the given chance of presentation.

Thank you very much for listening to my talk.