Status of Diagnostic Development in JAEA

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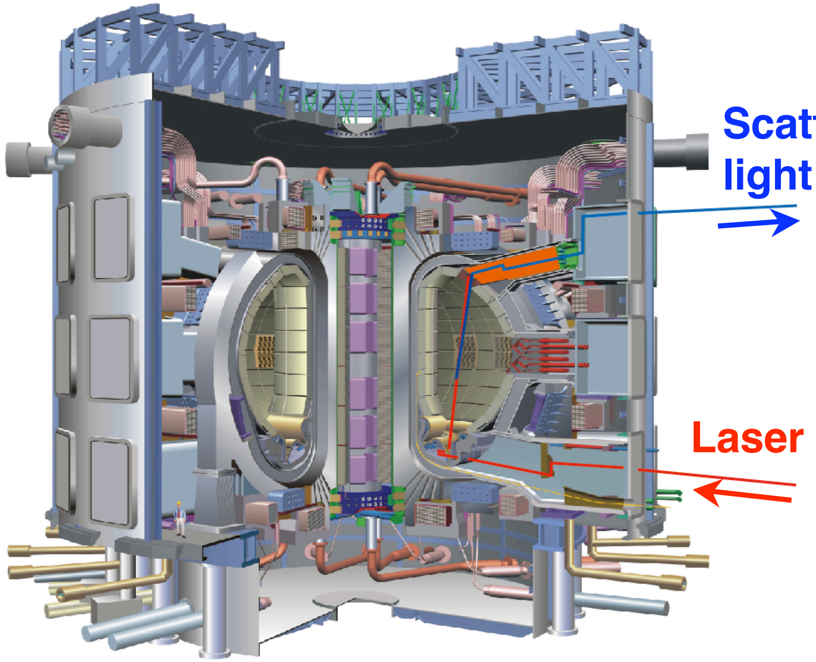
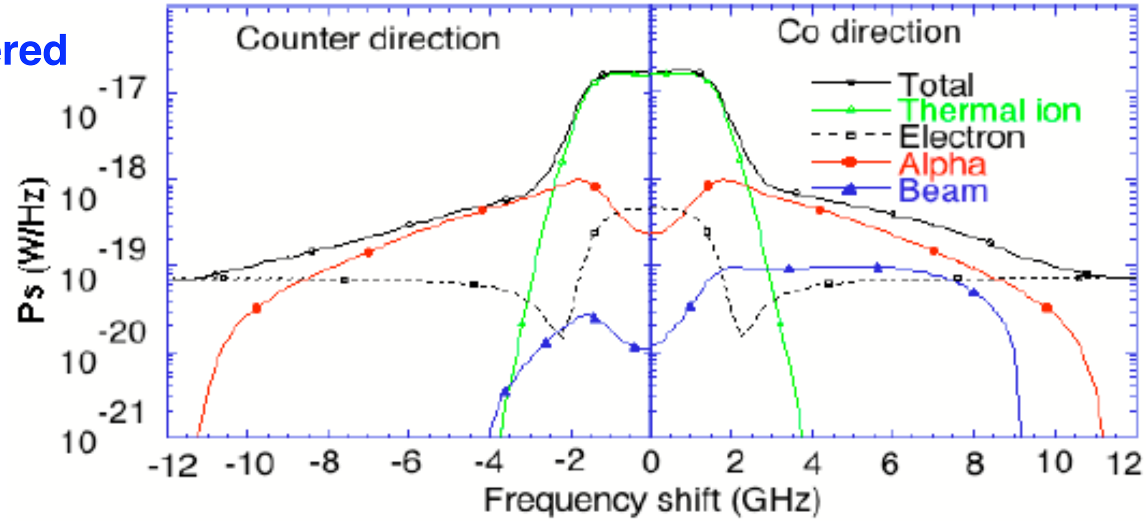
1 Development of CO_2 laser for collective Thomson scattering diagnostic

T. Kondoh, T. Hayashi, Y. Kawano, Y. Kusama, T. Sugie, Collective Thomson scattering for alpha-particle diagnostic in burning plasmas, submitted to J. Plasma and Fusion Research

Advanced Diagnostics for Burning Plasmas

ITER collective Thomson scattering using CO_2 laser



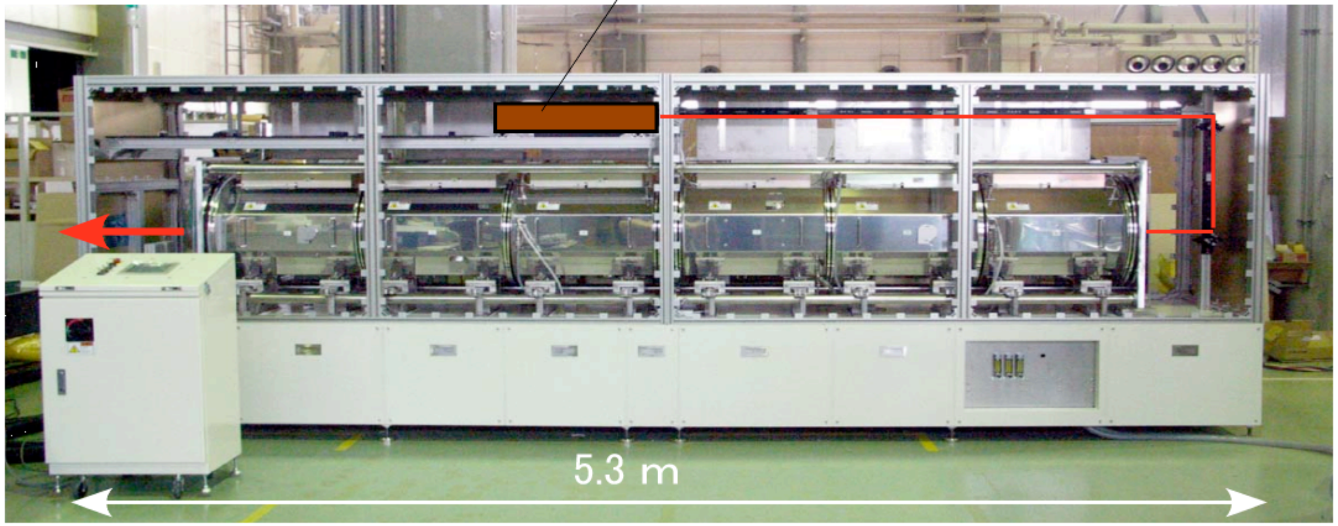


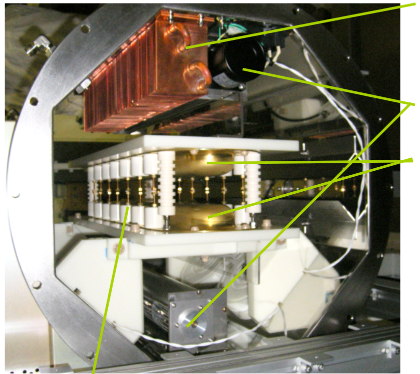
Expected spectra of the scattered light

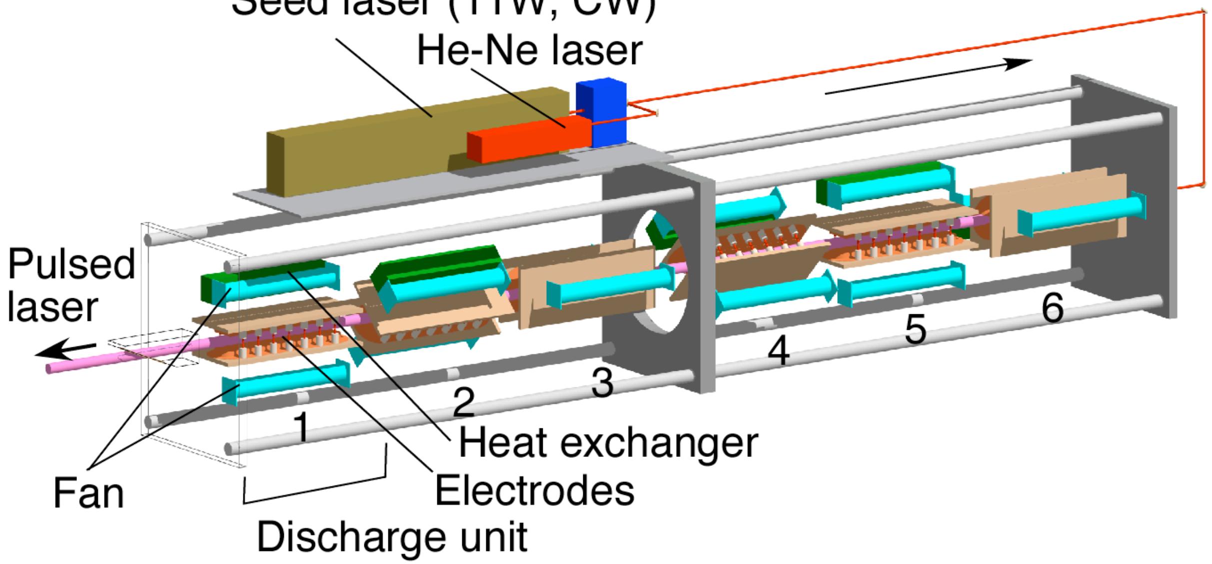
CO_2 laser: (20 J, 40 Hz), (30 J, 20 Hz), (50 J, 10 Hz)

T. Kondoh, T. Hayashi, Y. Kawano, Y. Kusama, T. Sugie, Y. Miura, High-repetition CO_2 laser for Collective Thomson scattering diagnostic of a particles in burning plasmas,16th HTPD (2006)

High power, high repetition rate single mode pulsed TEA CO_2 laser has been developed

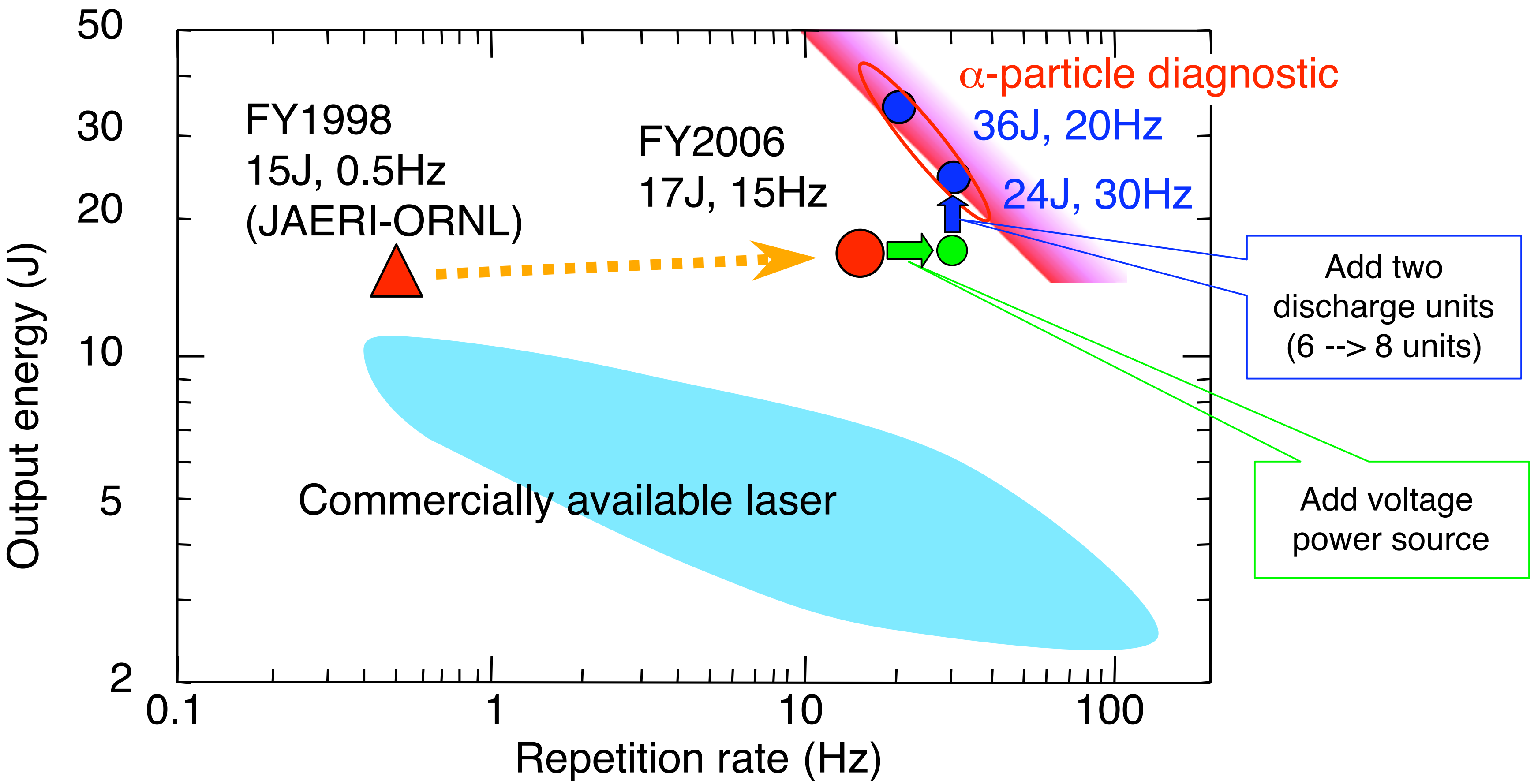






Output energy of 17J at a repetition rate of 15Hz has been achieved.

Prospect for α-particle diagnostic on ITER



- Output energy of 17J at 15Hz has been achieved so far.
- CO_2 laser for α-particle diagnostic will be obtained by adding high voltage power source and discharge units.

2 Thomson scattering diagnostics with Fourier transform spectroscopy

T. Hatae, J. Howard, Y. Hirano, H. Koguchi, O. Naito, S. Kitamura, Development of Polarization Interferometer Based on Fourier Transform Spectroscopy for Thomson Scattering Diagnostics, IEA RFP Workshop (2007)

THE AUSTRALIAN NATIONAL UNIVERSITY

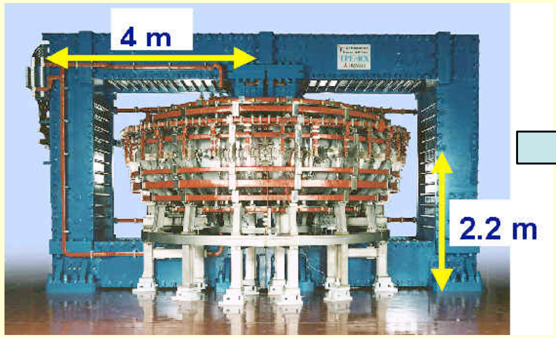
National Institute of Advanced Industrial Science and Technology
AIST

Advanced Diagnostics for Burning Plasmas

Development of a polarization interferometer for Thomson scattering

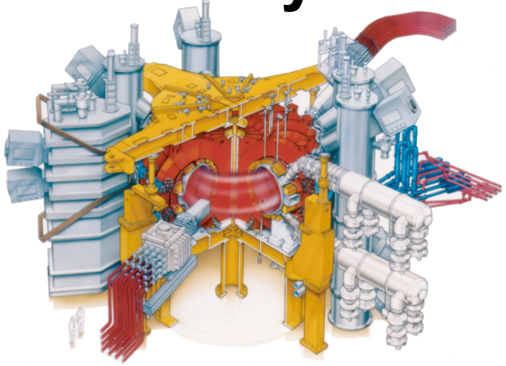
- A method based on measurement of the optical coherence of scattered radiation at a fixed optical delay has been proposed for incoherent Thomson scattering. **J. Howard, Plasma Phys. Control. Fusion 48, 777 (2006)**
- However, this method has not been demonstrated.
- We are developing a prototype polarization interferometer for Thomson scattering. Proof-of-principle tests will be carried out in TPE-RX reversed-field pinch (RFP) machine.

Proof-of-principle tests



TPE-RX (AIST)
T_e < ~1 keV

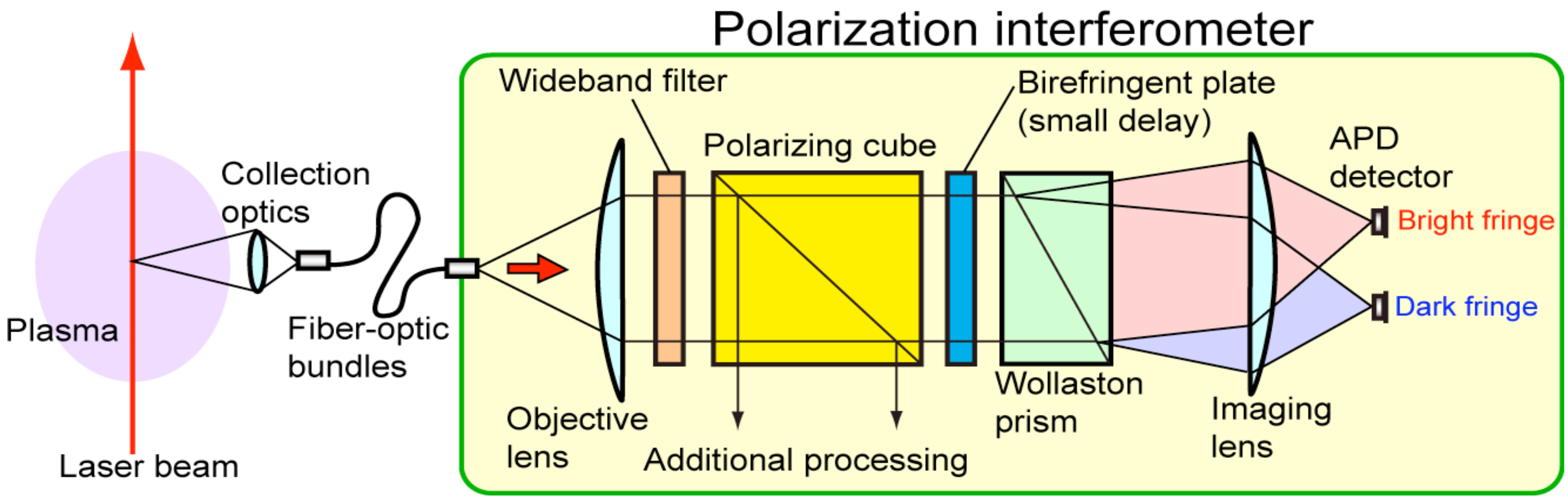
Feasibility check



JT-60U (JAEA)
T_e < ~30 keV

Apply to burning plasma or future program (ITER, JT-60SA)

Polarization interferometer for Thomson scattering diagnostics



- **The collected light is transmitted by a wideband filter to a polarization interferometer that generates an image of the optical coherence at a fixed delay.**
- **The delay plate fast axis is at 45° to the first polarizer axis.**
- **Depending on the orientation of the final polarizer, it is possible to measure either a 'bright' or 'dark' interference fringe.**
- **The final Wollaston polarizer produces separate images of the bright and dark fringes onto two APD detectors.**

J. Howard, Plasma Phys. Control. Fusion 48, 777 (2006)

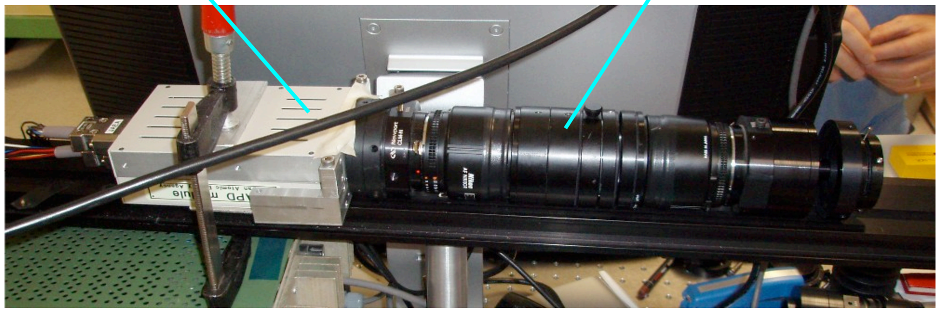
The magnitude of the change in fringe visibility agrees with the numerical calculation

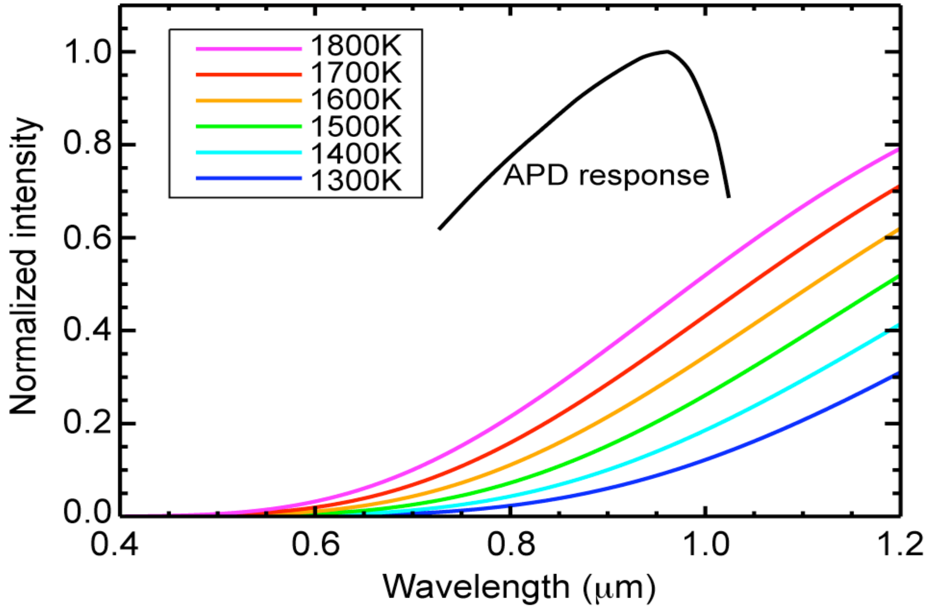
- **To compare between the numerical simulation and the experiment, initial test using a blackbody radiation source was carried out.**
- **When the temperature of the blackbody radiation source (LAND R1500T) was changed, fringe visibility was measured.**
- **T=1000,1100,1200,1300,1400,1500°C**

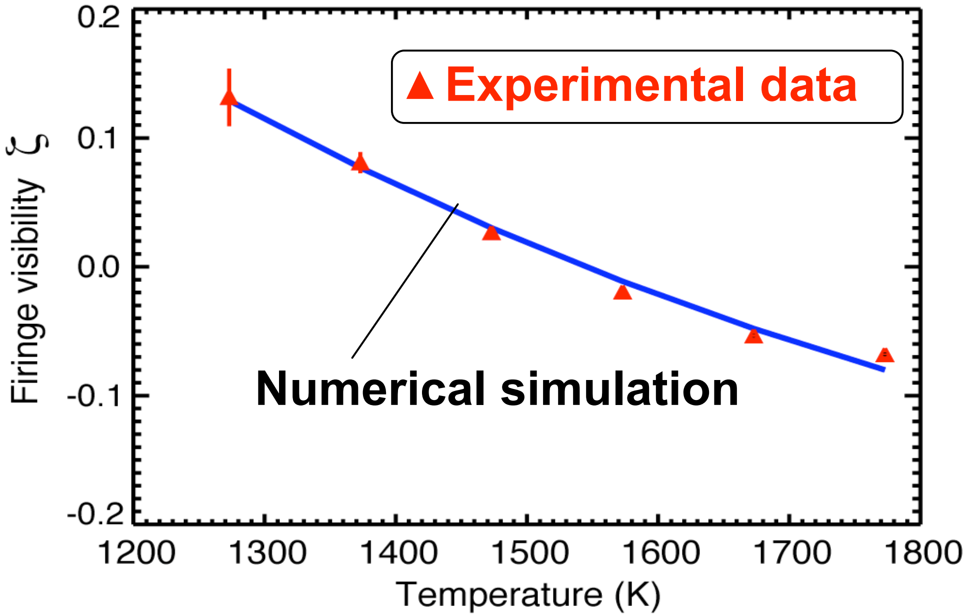
Next: PoP tests at TPE-RX

APD

Polarization interferometer







3 Fast measurement of neutron emission profile in JT-60U

M. Ishikawa, T. Itoga, T. Okuji, M. Nakhostin, K. Shinohara, T. Hayashi, A. Sukegawa, M. Baba, T. Nishitani, Fast collimated neutron flux measurement using stilbene scintillator and flashy analog-to-digital converter in JT-60U, Rev. Sci. Instrum. 77 (2006) 10E706

Profile measurements using multi-channel collimator array

JT-60U tokamak

- horizontal : 6 channels
- vertical : 8 channels
- detector : Stilbene neutron detector

Stilbene scintillator + analog n-γ pulse shape discrimination (PSD)

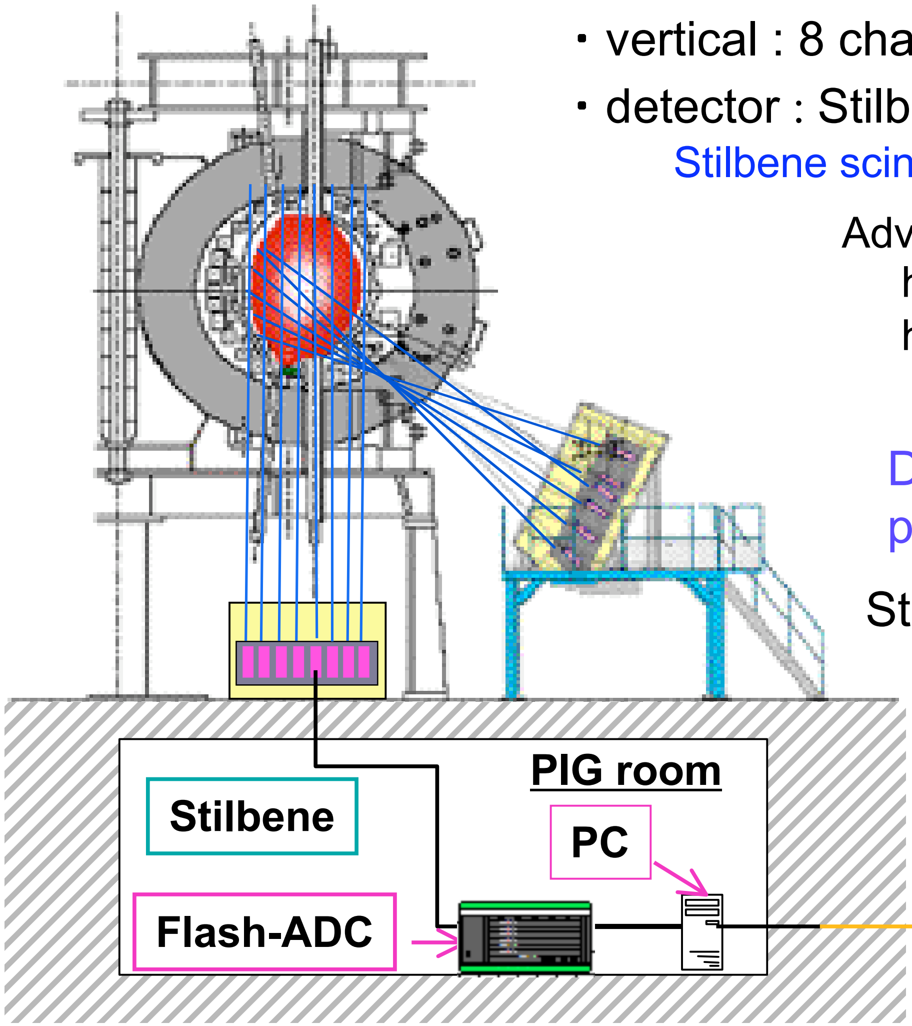
Advantage :
high n-γ discrimination
high energy resolution

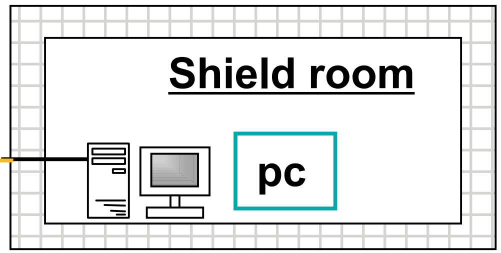
Disadvantage :
Max. count rate ~ 10^5 cps.
-> large statistical error

Development and Installation of a digital signal processing (DSP) system for fast measurements

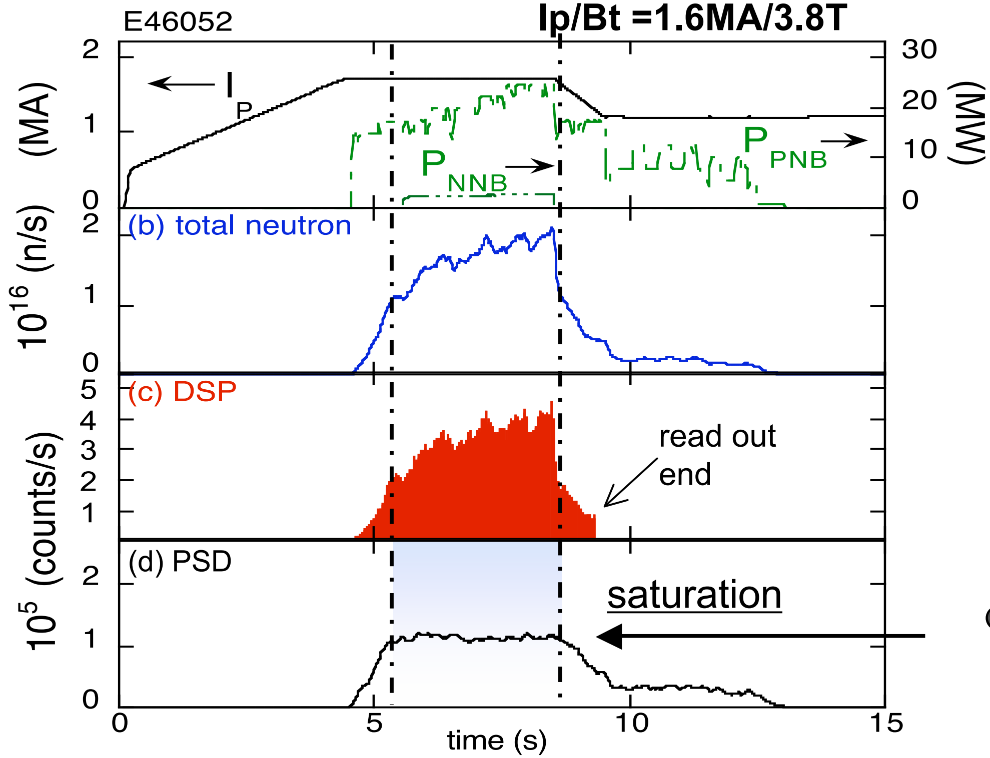
Stilbene scintillator + **Flash ADC (8GHz, 10bit) & PC**

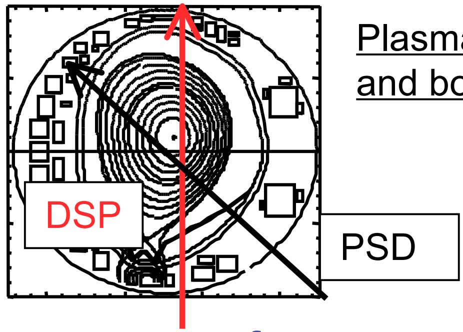
- Optimization of sampling time, integration time
- Correction of gain fluctuation of PMT.





Measurement of collimated neutron flux using the DSP system





Plasma configuration and both sight lines

- Time trace of neutron counts of the DSP system is almost agree with that of total neutron emission rate.
- Neutron counts of the PSD was saturated at ~ 1×10^5 cps due to pile up effect.

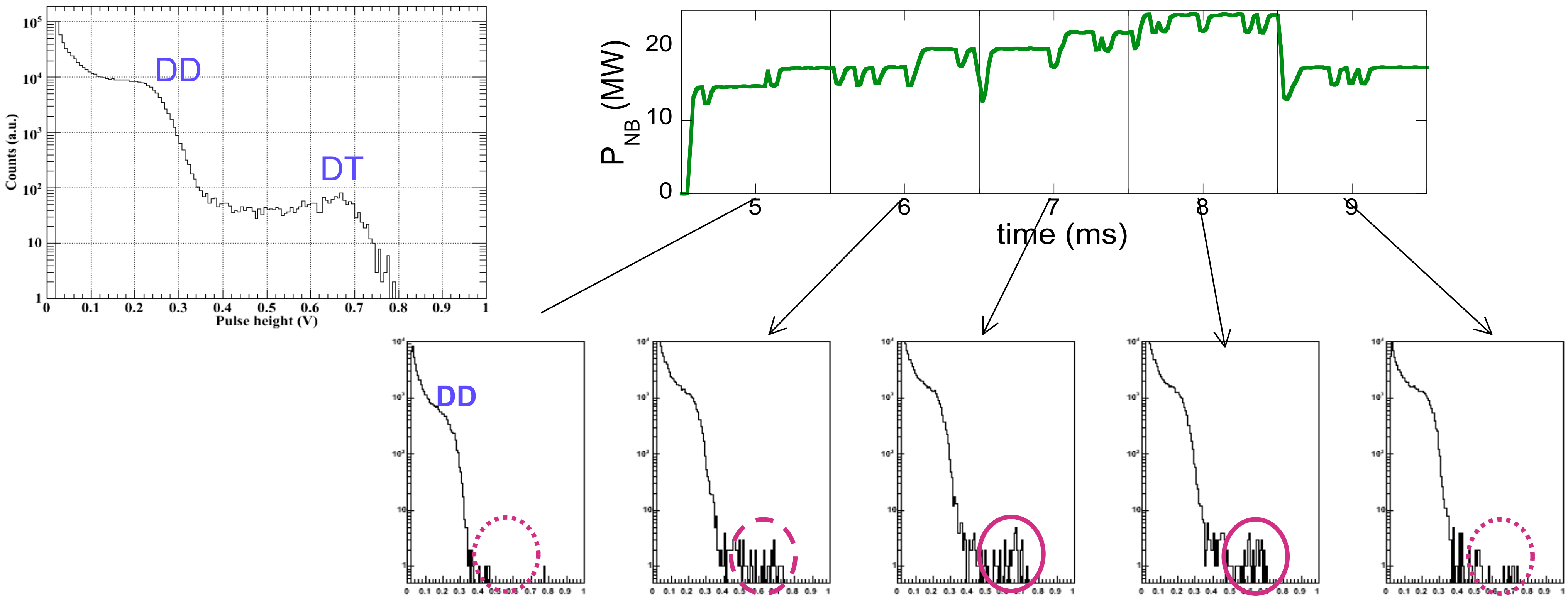
Neutron flux has been successfully measured with up to ~ 1×10^6 cps.
n-γ discrimination is possible in the case of pile-up events.

→ applicable to ITER as a neutron detector of neutron camera

A pipe line technique is needed for long time measurement ?

more detail investigation of energetic ions (α-particle) transport due to Alfven Eigenmode

Preliminary: Observation of change in pulse height spectrum



Pulse height spectrum of neutron counts for 1s

Pulse height spectrum of neutron counts (higher energy range) changes as the power of NBI changes

As a result of energy calibration, second peak (~ 0.7 V) of pulse height spectrum corresponds to energy of a DT neutron

➡ one of candidate for a neutron spectrometer

However, more detail analysis is needed.

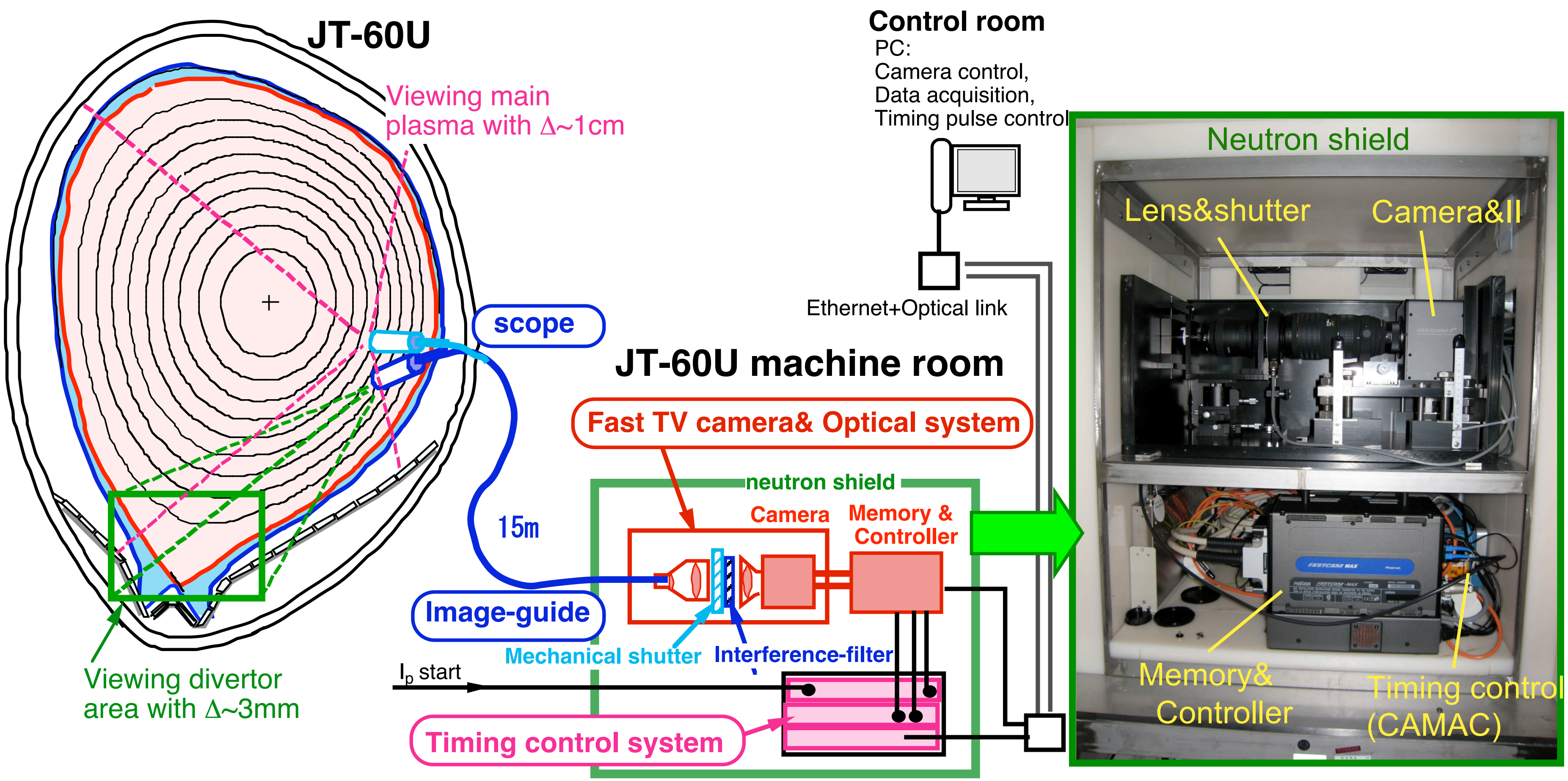
4 Dust measurement with fast TV camera

Nobuyuki Asakura, N.Ohno, H.Kawashima, T.Nakano, S.Takamura, Y.Uesugi, First report of dust movement in JT-60U discharges, Joint US-Japan workshops on "Dynamics of dust particles in fusion devices" & "Non-Diffusive Plasma Transport and Its Statistics in Edge Plasmas of Fusion", Nagoya Univ. January 10-11, 2007

Kanazawa University origin 1862
金沢大学

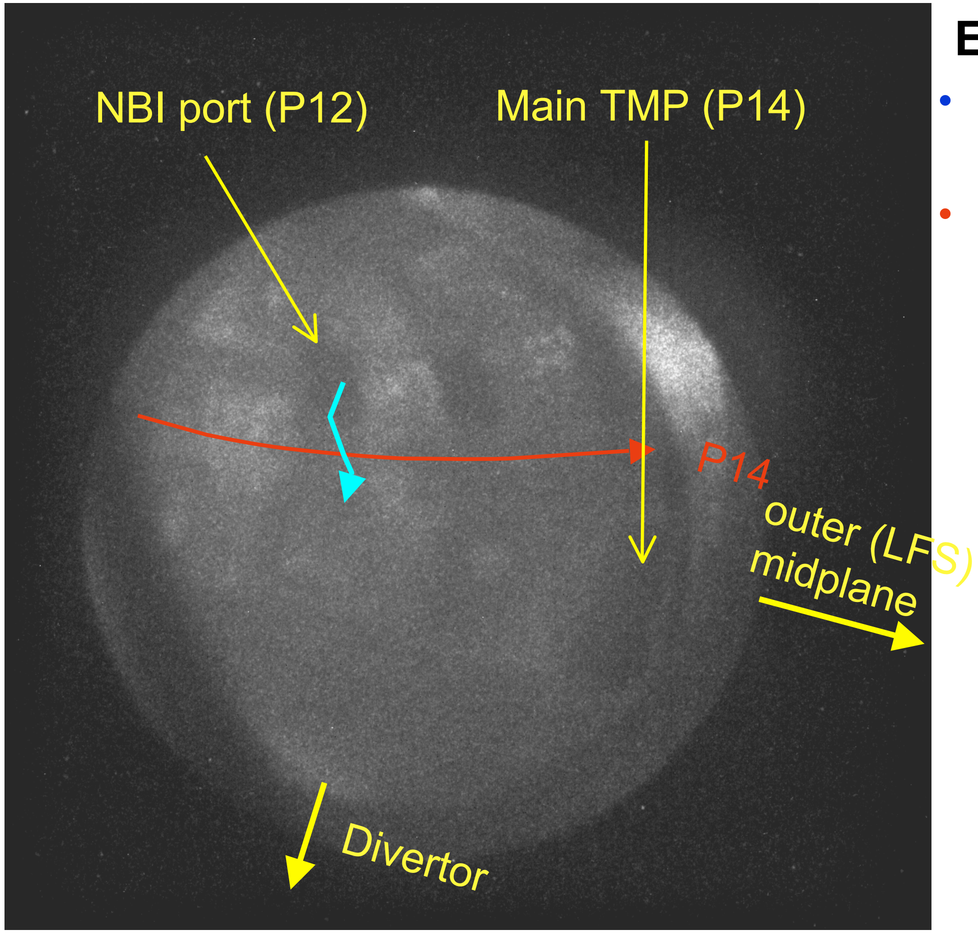
Dust measurement with fast TV camera

Visible light image was measured with fast TV camera from tangential port:
Typical frame rate of 2 kHz (1024x1024 pixs, 3s) - 8 kHz (256x256 pixs, 8s).
Narrow (9°) and wide (35°) viewing angles for divertor and main plasma, respectively, can be selected.



Dust movement in SOL

ELMy H-mode plasma (I_p=1.8MA, B_t=4T,P_{NBI}=17MW): many dusts were observed at start of the first shot *after high I_p plasma disruptions and overnight-GDC.*



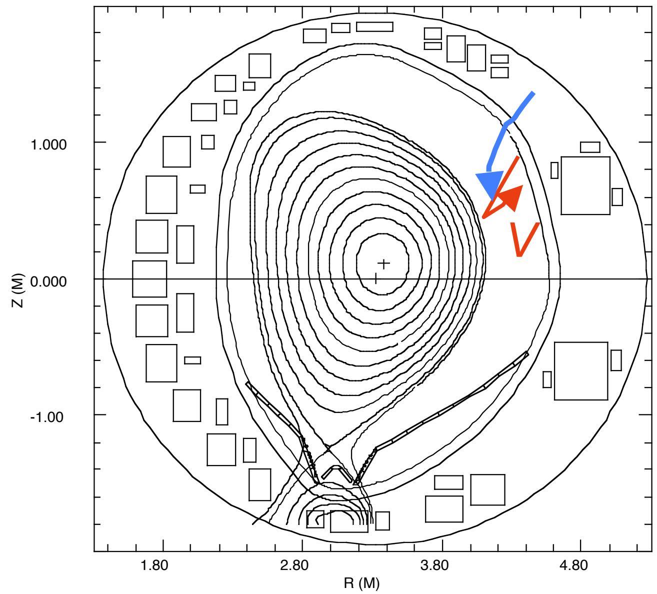
18 frames (9ms)

32 frames (16ms)

Example 1 (main SOL):

- A dust is exhausted from NBI port (P12): *V* =0.9m/(18frs x0.5ms)~0.1km/s
- A dust moves towards near-toroidal direction (ion drift),

  with *V* =5 m/(32frs x0.5ms)~0.3km/s

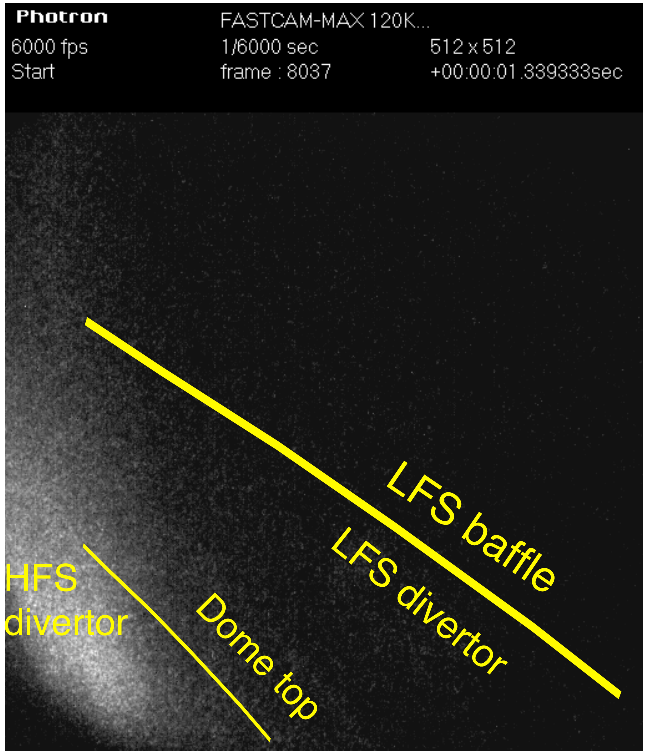


Dusts are produced at HFS (inner) divertor

ELMy H-mode (I_p=1.4MA, B_t=3.9T,P_{NBI}=12MW):
HFS strike-point was moved to upper target (on dense C-deposition layers)
=> Deposition layers at HFS divertor are removed by ELMs => Dusts are produced,

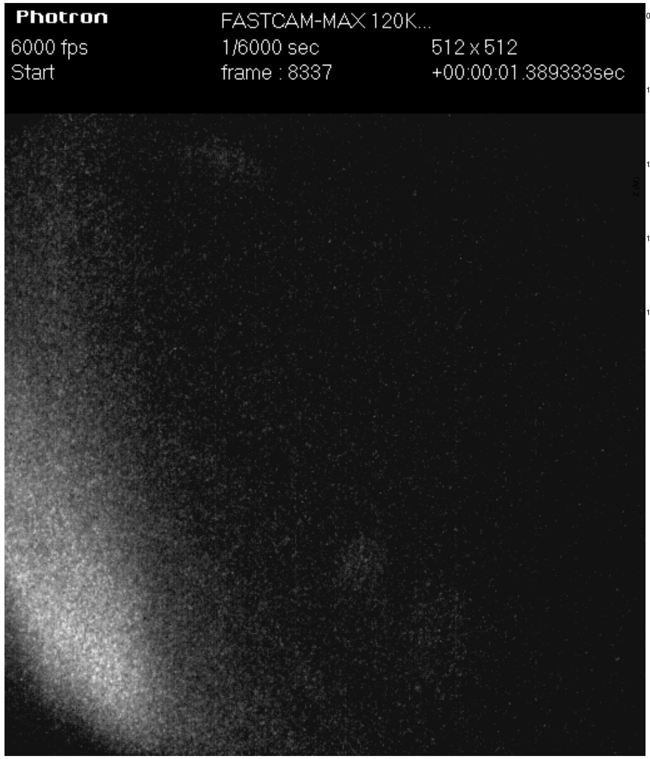
moving in toroidal direction (ion drift) with V = 0.8m/(17frsx0.16ms)~0.27km/s.

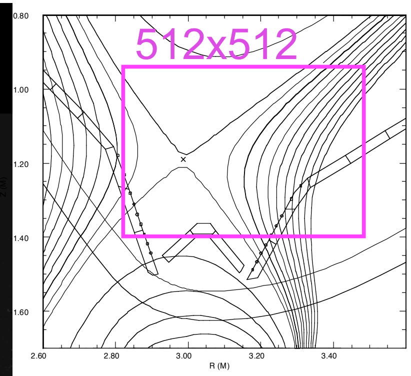
Large dusts from HFS divertor



ELM
17 frames (3ms)
32 frames (5.5ms)

Many small dusts from HFS divertor





ELM
Many dusts from inner divertor

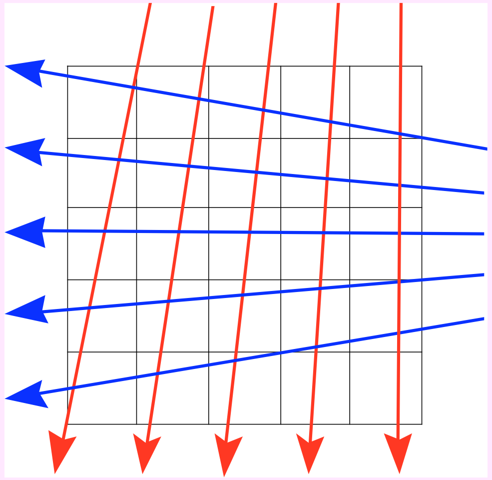
5 Computer tomography for divertor plasma spectroscopy

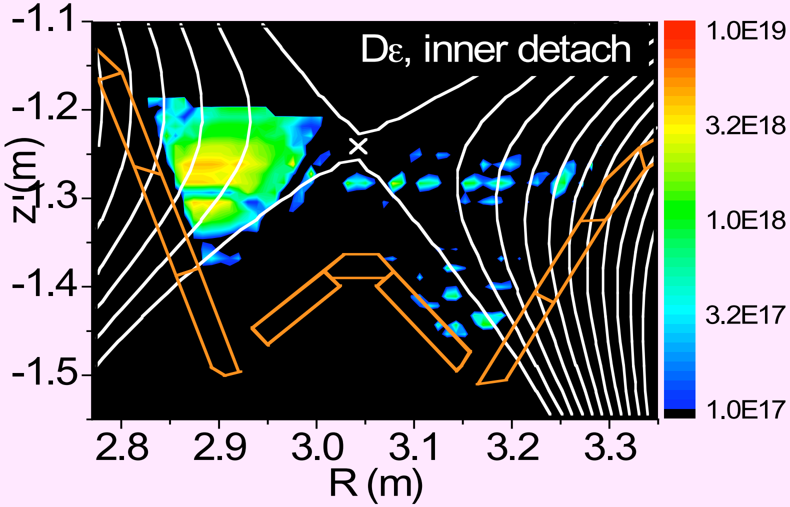
K. Fujimoto, T. Nakano, H. Kubo, K. Shimizu, T. Takizuka, K. Sawada, H. Kawashima, N. Asakura, Two-dimensional Spectroscopic Measurement of Deuterium Balmer-series lines in JT-60U Divertor Plasmas, submitted to J. Plasma and Fusion Research

信州大学
SHINSHU UNIVERSITY

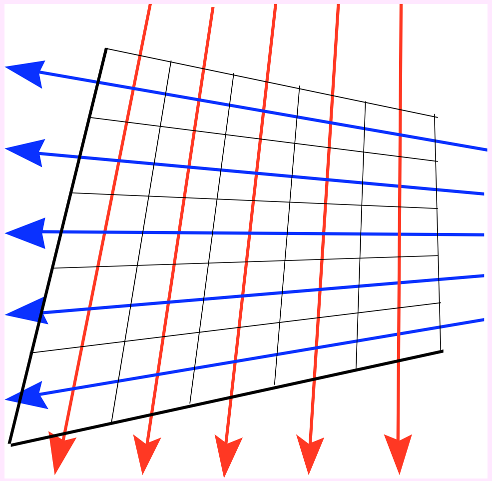
Two-dimensional distribution is obtained properly from two-directional measurement

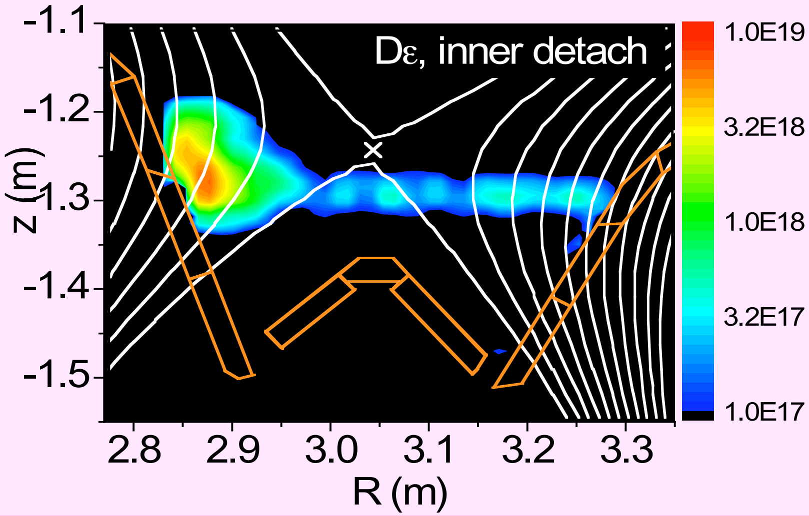
Square grid (traditional grid)



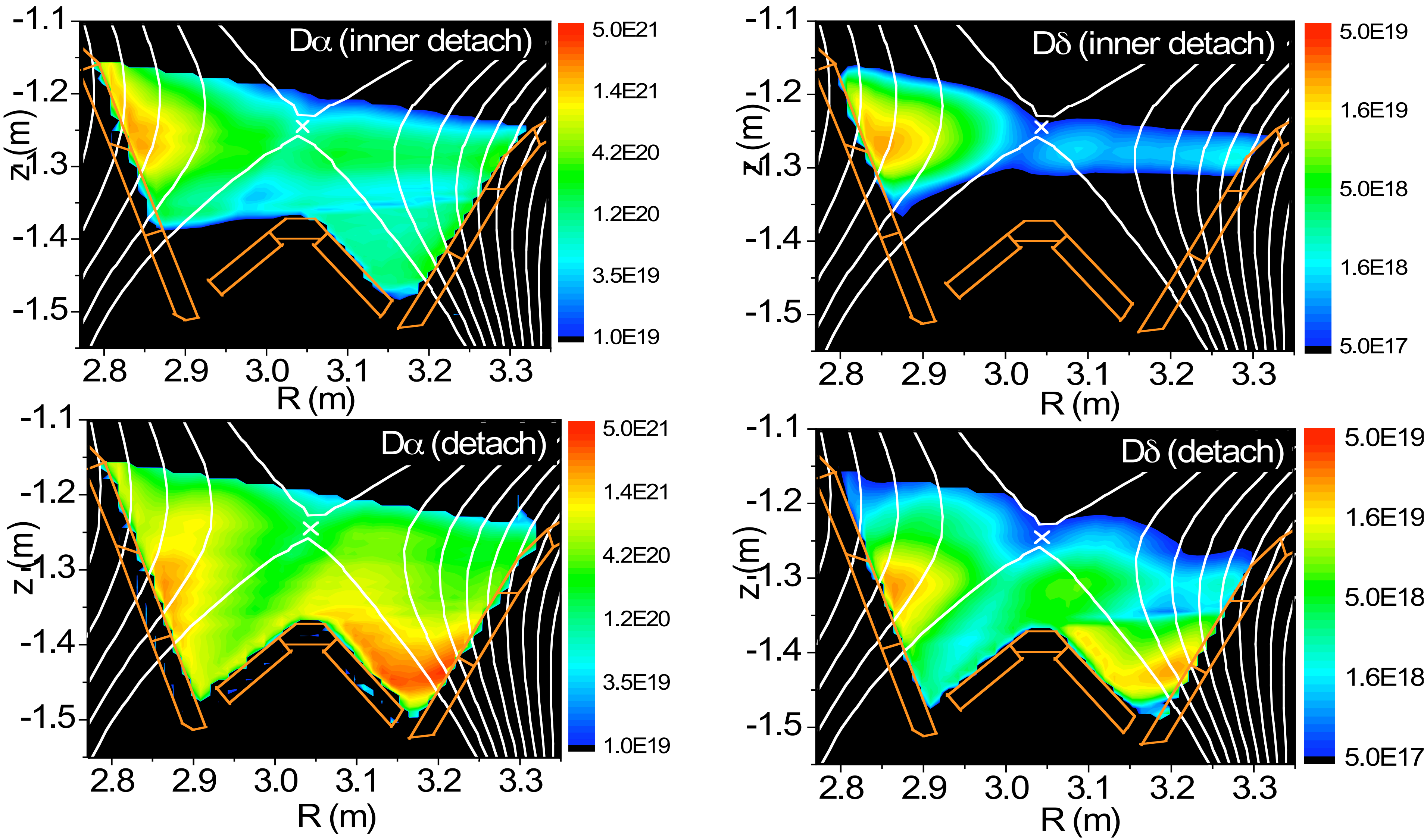


Grid along to view lines (improved grid)

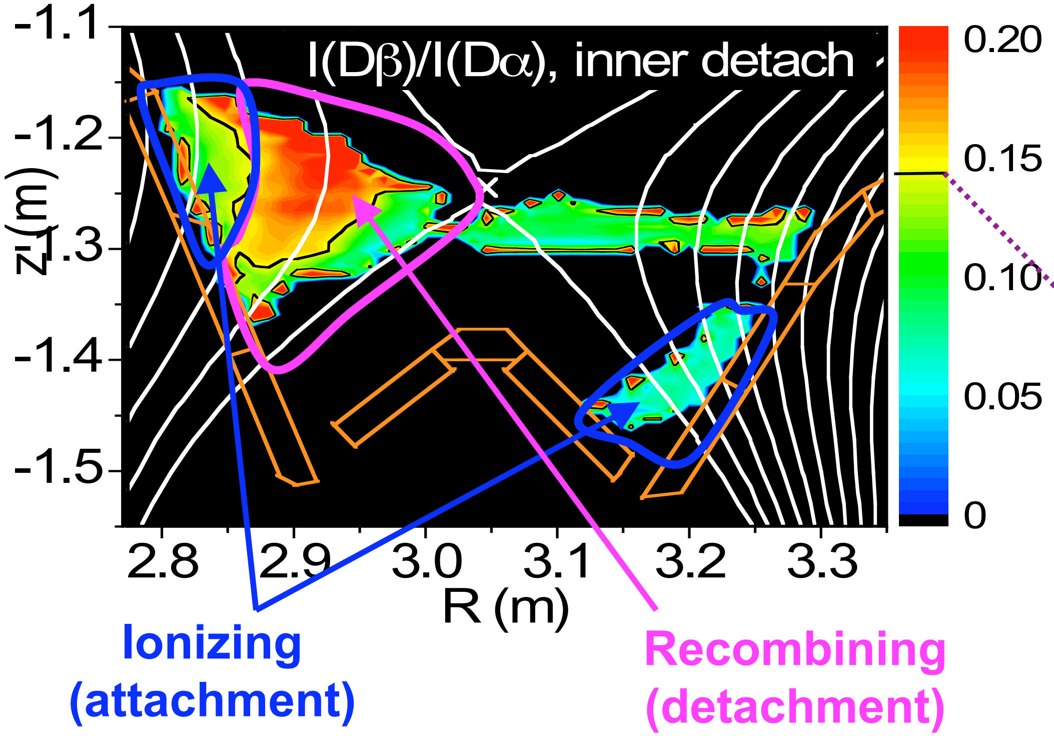


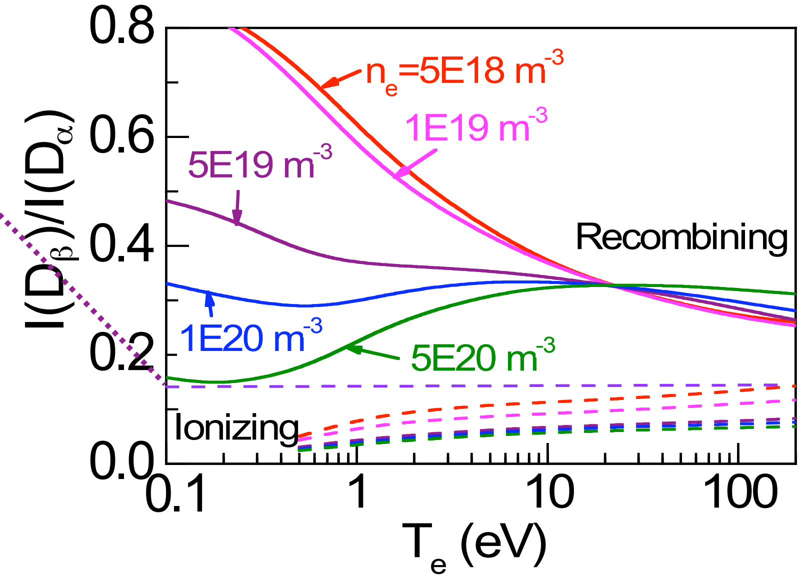


Radiation of Balmer-series lines (D_α and D_δ) in inner detached and detached plasma



Two-dimensional distribution of ionizing and recombining component makes clear





< Inner divertor region >

Recombining region distributes above the inner strike point along to separatrix.
Partial detached plasma is formed.

< Outer divertor region >

Ionizing region distributes around the outer strike point.
Attached plasma is formed.

Summary

1. ***Prospect of CO_2 laser for CTS in ITER was obtained.***
2. ***Development of Thomson scattering diagnostics with Fourier transform spectroscopy was progressed.***
3. ***Neutron spectra were obtained by SND (preliminary).***
4. ***Dust behavior was measured by fast TV camera.***
5. ***Computer tomography technique for divertor plasma spectroscopy was improved.***