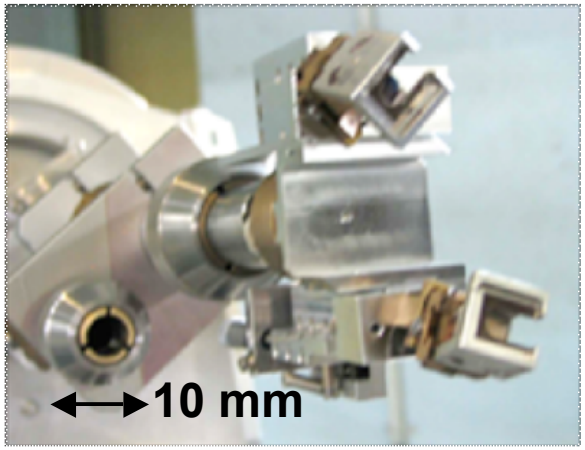
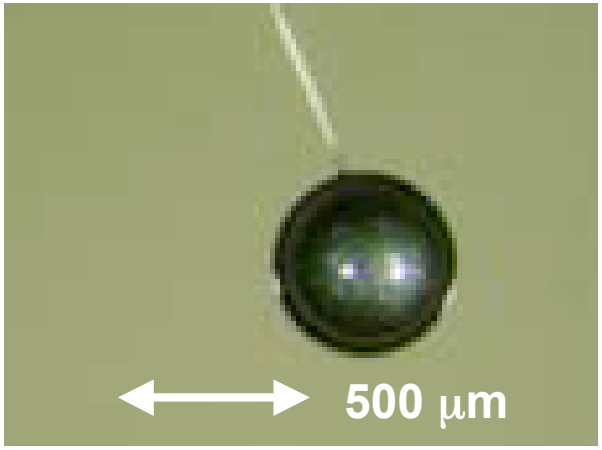
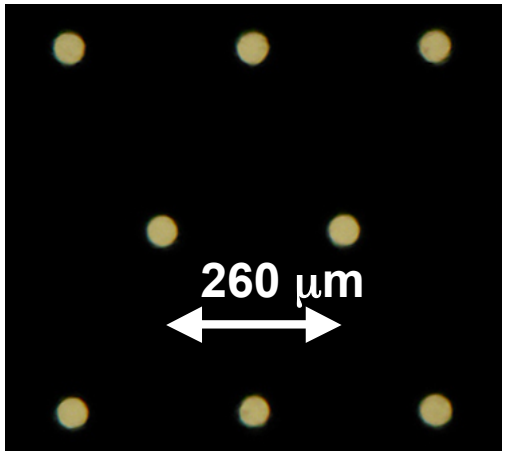
X-ray spectroscopic diagnostics for laser-imploded core plasmas with high spatial and temporal resolutions







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16th International Toki Conference Advanced Imaging and Plasma Diagnostics
Ceratopia Toki, Gifu, JAPAN December 5-8, 2006

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Motivation

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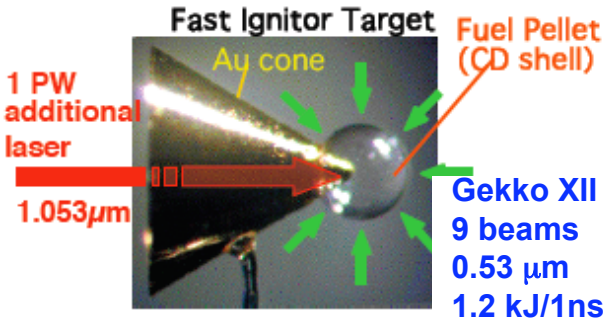
- **Fast ignition scheme**
  - ➢ Highly dense plasma formation
  - ➢ Plasma heating
    - *Core plasma hydrodynamics*
    - *Energy transport and deposition by fast particles*



R. Kodama, et al, Nature 412,798 (2001).

- **Research & Development of x-ray spectroscopy and imaging**
  - ➢ imaging for shadow-graphy ➔ efficient & high energy x-ray source
  - ➢ imaging of self-emission ➔ monochromatic x-ray imaging
- **Development of new x-ray imager for core plasma**
  - ➢ High spatial resolution $\Delta x < 10\ \mu m$
  - ➢ High temporal resolution $\Delta t < 10$ ps

Previous study

Monochromatic X-ray Framing Camera (M-XFC) enabled 35 ps, 10 μm resolutions with a high spectral discrimination.

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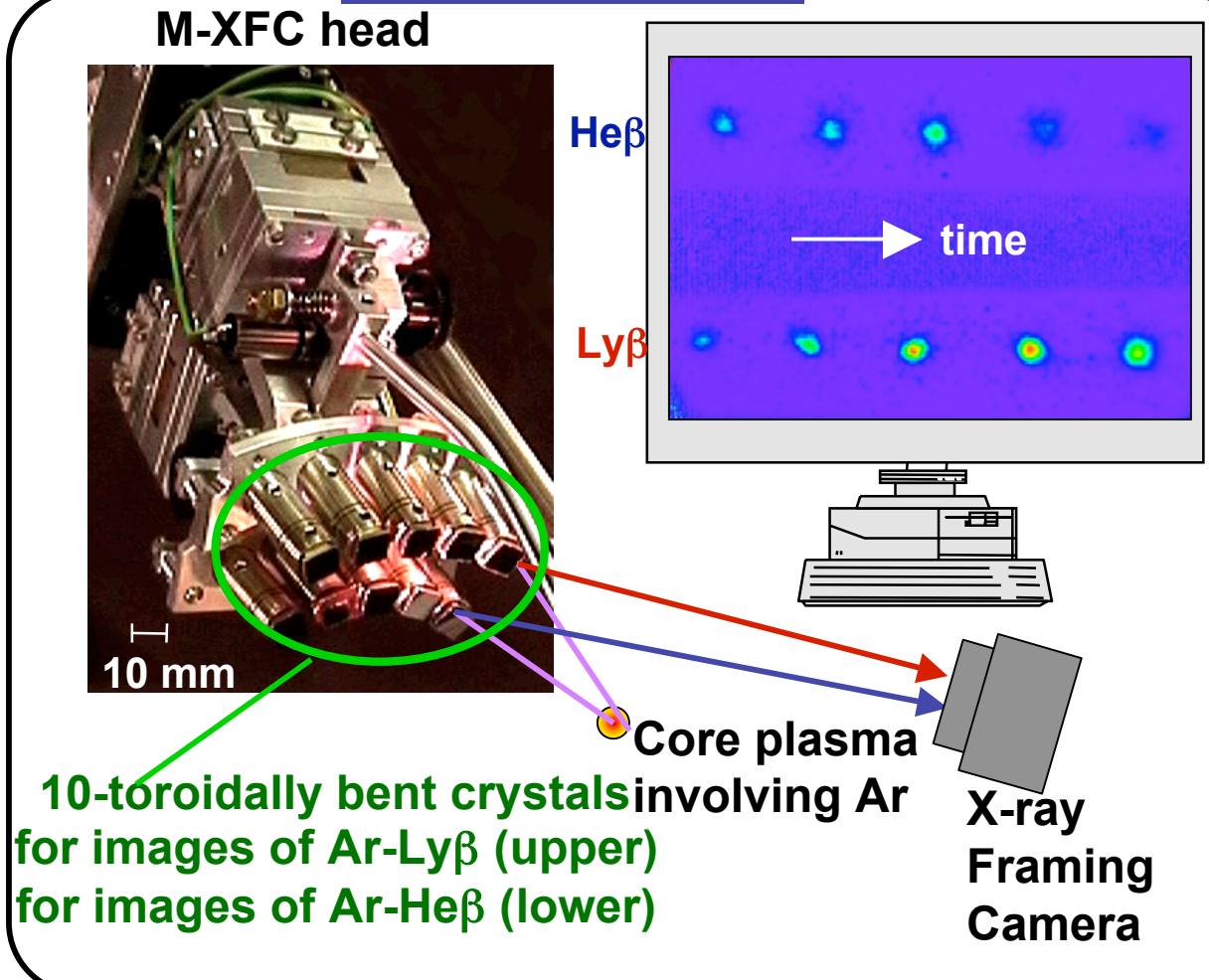
K. Fujita et al. Rev. Sci. Instrum. 72 744 (2001)

Principle of M-XFC



Characteristics of M-XFC

Time resolution	Δt ~ 35 ps
Spatial resolution	Δx ~ 10 μm
Energy resolution	E/ΔE ~ 200

Problems

- Time resolution is not enough for fast ignition.
- Crystal alignment is laborious.

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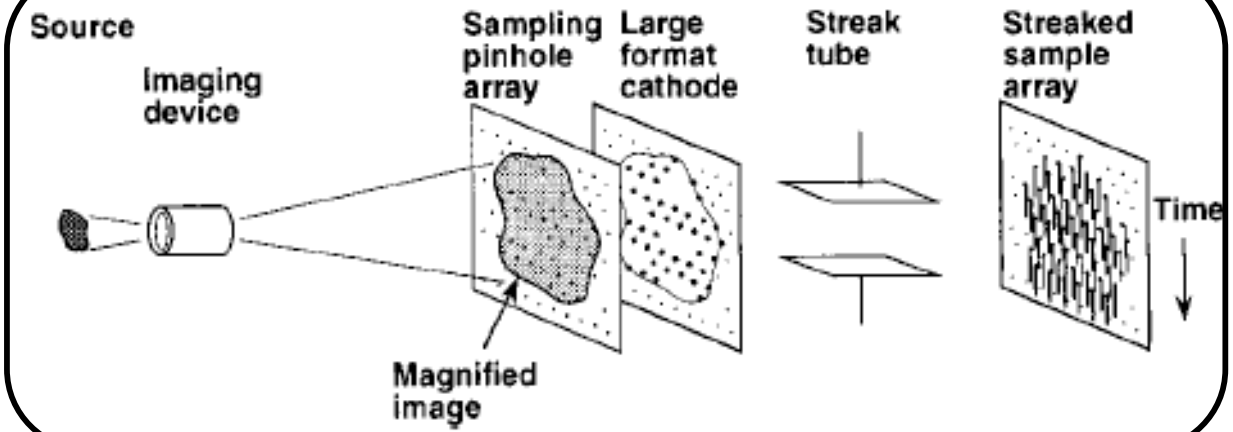
To attain better time resolutions, 2-Demensional Sampling Image X-ray Streak came method has been proposed and its feasibility has been demonstrated

H. Shiraga et al. Rev. Sci. Instrum. 70 620 (1999)

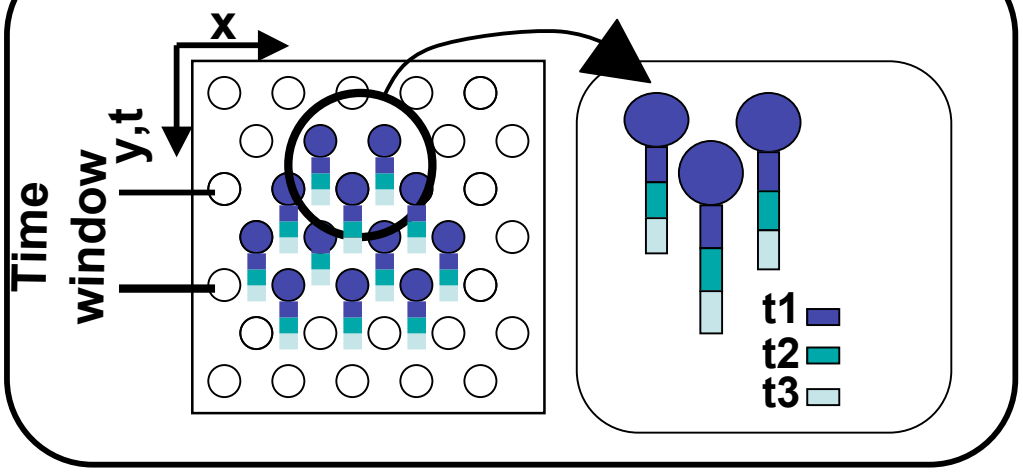
Schematic of 2D-SIXS system



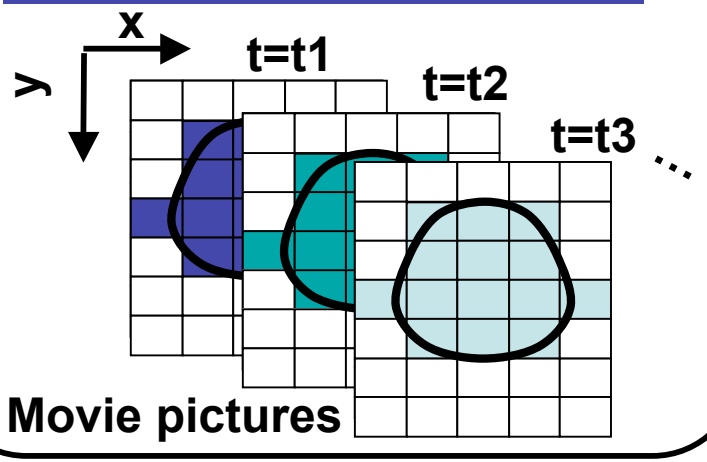
Characteristics of 2D-SIX

Time resolution	$\Delta t < 10$ ps
Spatial resolution	$\Delta x < 10$ μm
Energy resolution	$E/\Delta E \sim 3$

The sampled images on the photocathode swept along time



Reconstructed 2D images for respective time



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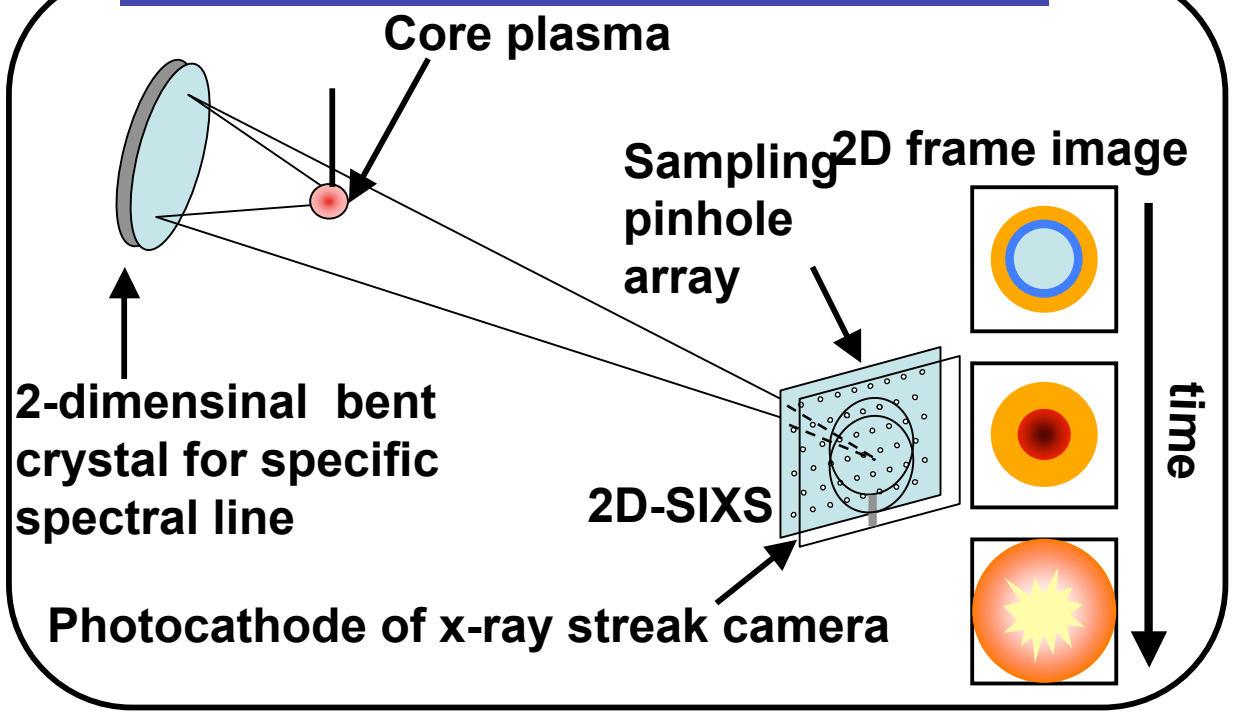
A new scheme of monochromatic x-ray sampling streak camera (Monochro-2D-SIXS) is proposed to satisfy time-, space-, and spectral resolutions simultaneously

Principle of Monochro-2D-SIXS



Goals of Monocro-2D-SIXS

Time resolution	$\Delta t < 10$ ps
Spatial resolution	$\Delta x \sim 10$ μm
Energy resolution	$E/\Delta E \sim 200$

Improvement points

- The number of crystals is limited only one for each spectral line.
  - ➔ Crystal alignment procedure becomes substantially simplified and speedy.
- Comparing to x-ray framing camera, there is no interval of image recording.
  - ➔ Successive images are recorded with a time resolution better than 10 ps.

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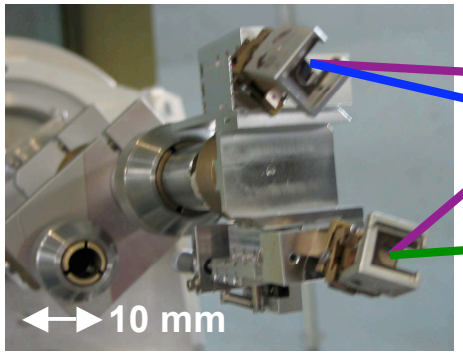
Monochro-2D-SIXS was tested with implosion experiments

Toroidally bent crystal (Si) for Cl-Heβ

Monochro-matic x-ray camera



Chlorinated plastic shell target

2D-SXIS

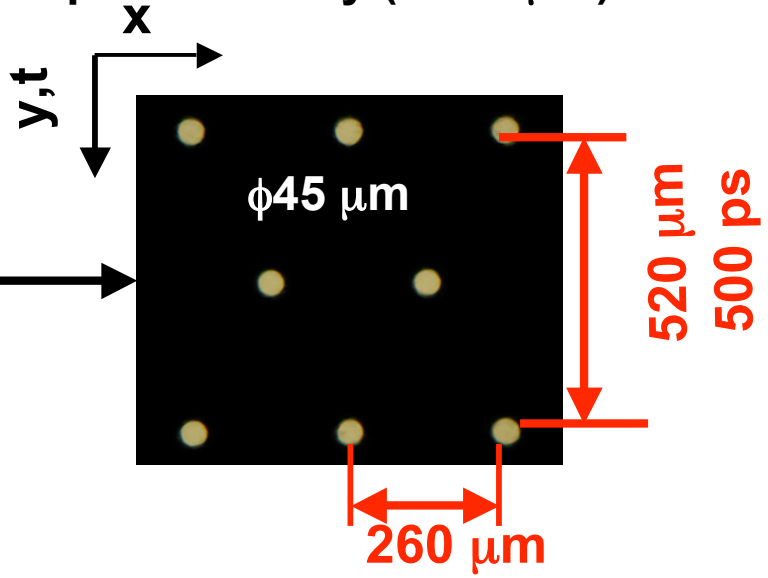
Au cathode 300 Å t

Toroidally bent crystal (Quartz) for Cl-Lyβ

Specification of imaging

Objective	Cl-Heβ	Cl-Lyβ
Crystal	Si (220)	Q(11.2)
Tuning energy (eV)	3272	3508
Energy band (eV)	11.7	20.6
Image magnification	25.8	26.2
Plasma to crystal (mm)	102.5	100.9
Crystal to detector (mm)	2648.2	2640.7

Micrograph of sampling pinhole array (Ni 25 μm)



Implosion experiment was made on Gekko XII in order to address issues of Monochro-2D-SIXS

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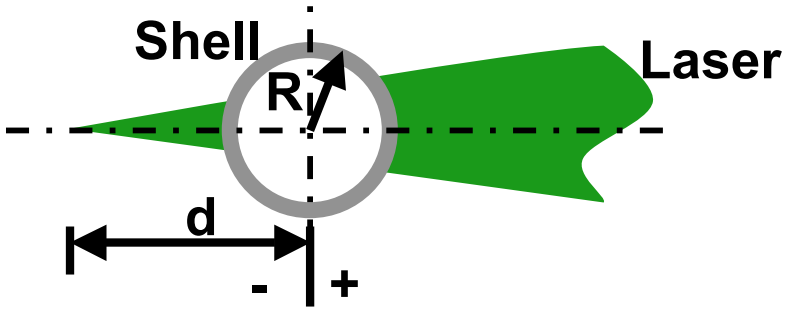
GEKKO XII Laser

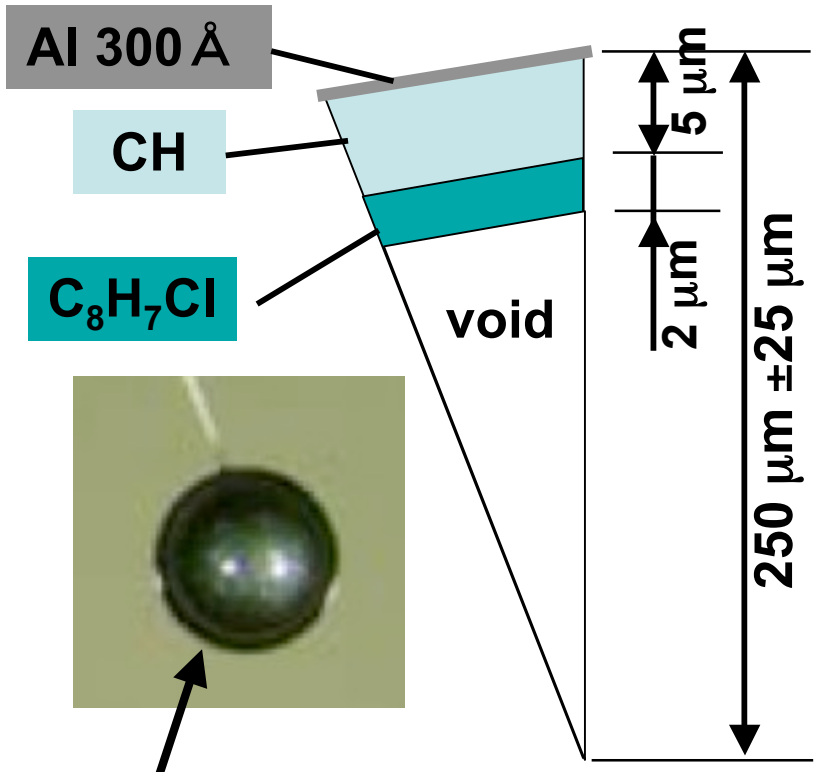
- Wavelength: 526 nm (2ω)
- Total energy: 4.03 kJ (12 beams)
- Wave form: 1.3 ns Gaussian
- Beam smoothing:

  Random Phase Plate (d/R = -5)



- Power imbalance: 5 %

A triple layered chlorinated plastic shell



The aluminum coating prevents the shine-through.

Electromagnetic focus type x-ray streak camera (XSC) has provided the clear pinhole array images.

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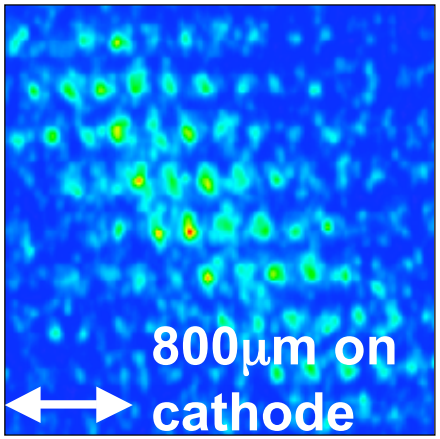
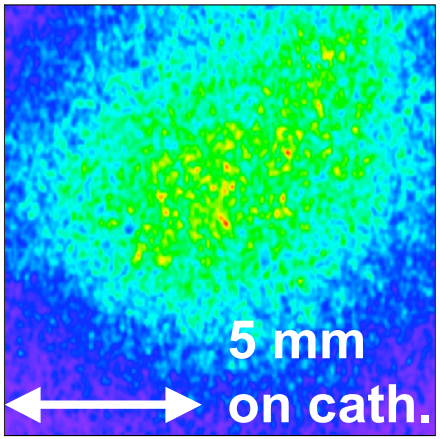
Monochro-2D-SIXS image using an electric focus type XSC

Target : Cl doped target

Static image of Cl-Heβ



Streaked image of Cl-Heβ

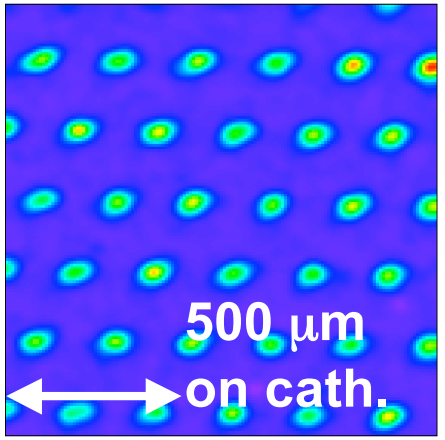


2D-SIXS with pinhole using an electromagnetic focus type XSC

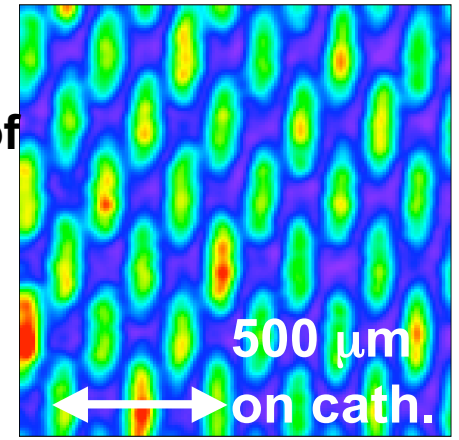
After S. Fujioka

Target : Au coated ball

Static image of continuum line



Streaked image of continuum line



Emission from chlorinated tracer layer appeared earlier than the simulation predicted

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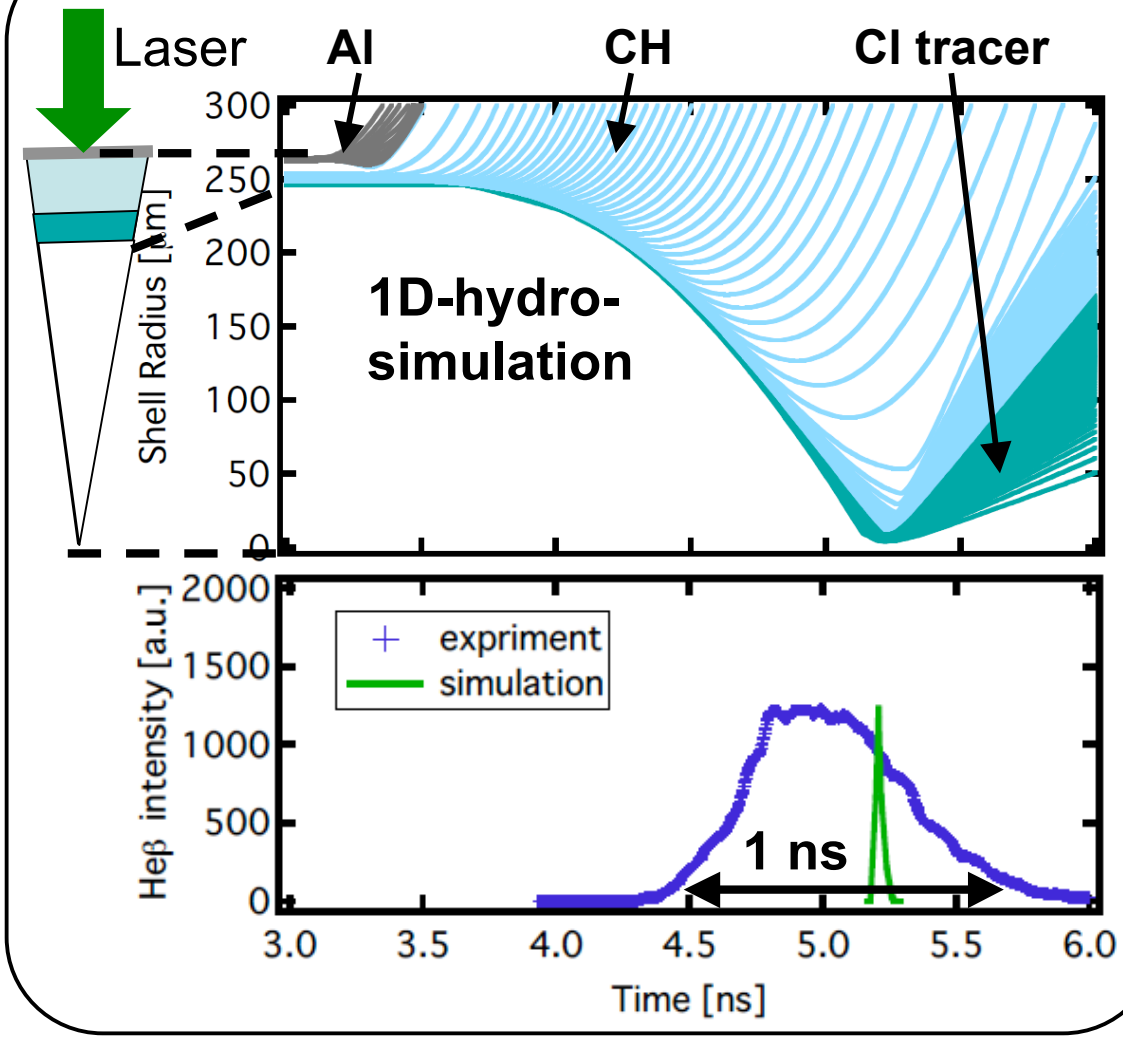
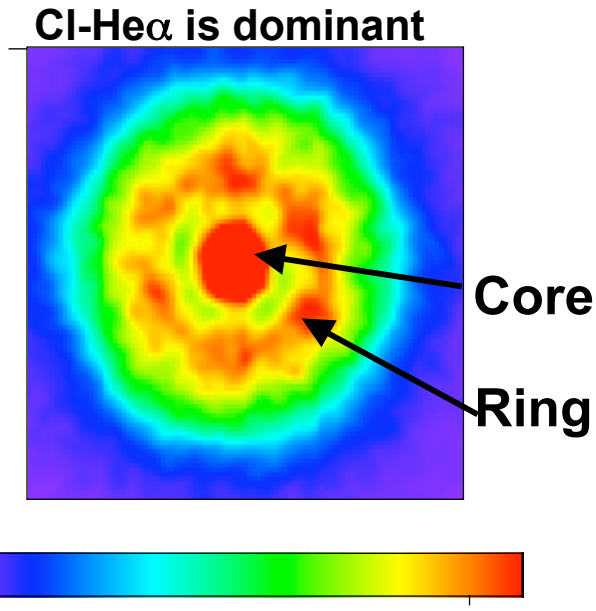
Comparison of Heβ between sim. and exp.



X-ray pinhole image

$CH_2=CCl_2$ filtered image



The ring emission started during the intermediate stage of implosion

Summary & Acknowledgment

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- We have proposed a novel scheme of x-ray monochromatic imager, which allow temporal resolution of 10 ps, spatial resolution of 10 μm, and higher spectral resolution normally obtained with Bragg crystal.

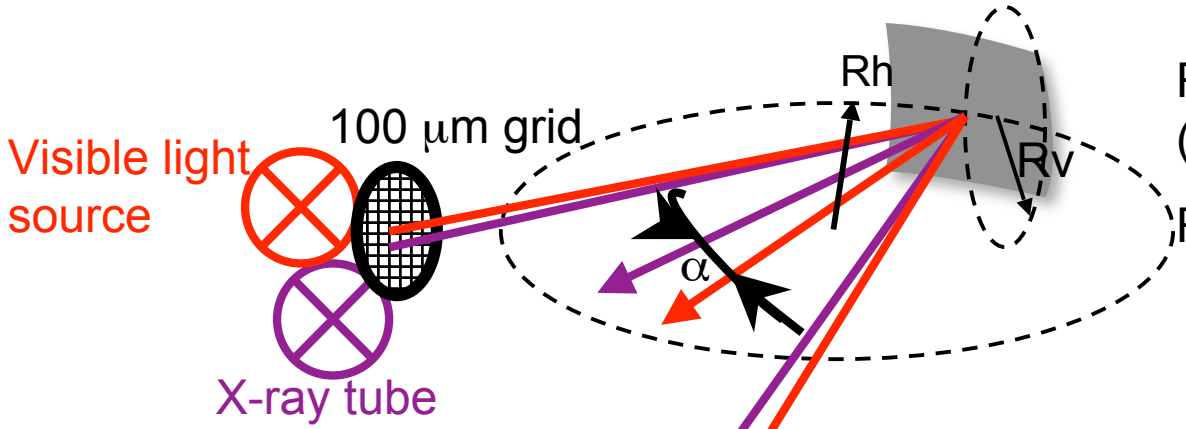
- We made feasibility study using the Gekko XII laser and the chlorinated plastic shell.
  - Further improvement are necessary by using <u>electromagnetic focus type XSC,</u>
    - using Random Phase Plates with partially coherent light, and
    - a new target design to suppress hydrodynamic instabilities; for example gas-fill shell

This work was performed under auspices of MEXT under the project "Advanced Diagnostics for Burning Plasma (code 442)" /the public advertisement research (code 17044005).

Thank you very much for your attention.

Test of Crystals by Dr. I. Uschmann *et al.*

~Misalignment between visible light and x-rays images of a grid with 100 μm period~



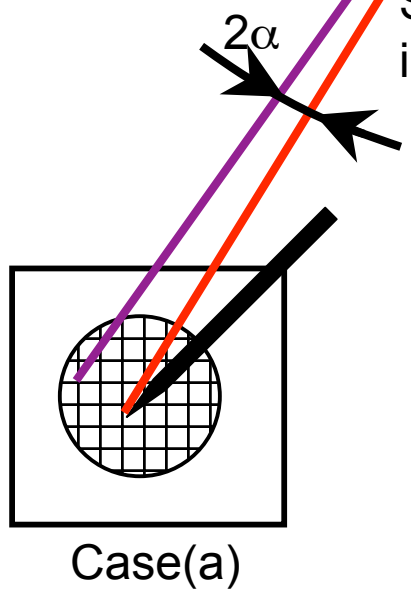
Toroidally bent crystal

Rh : horizontal bending radius (dispersion direction)

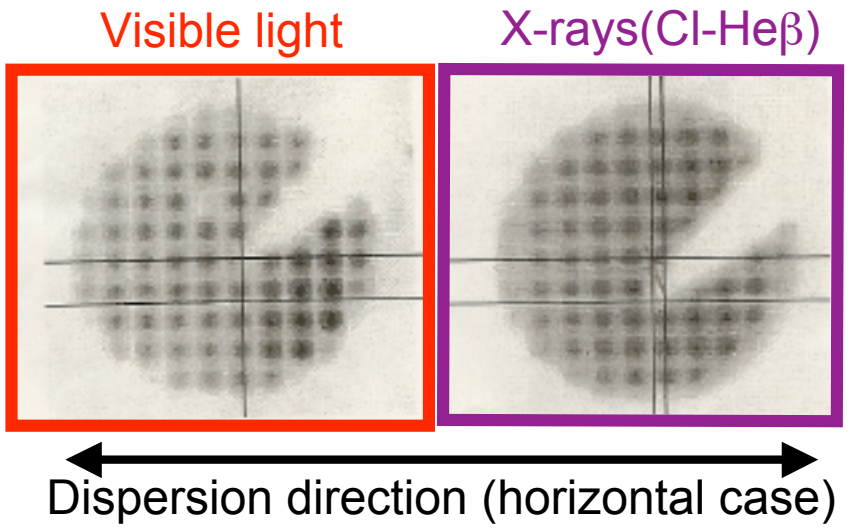
Rv : vertical bending radius

Rh = 200 mm

Rv = 195.8 mm



Shadowgraph of a needle in front of the film



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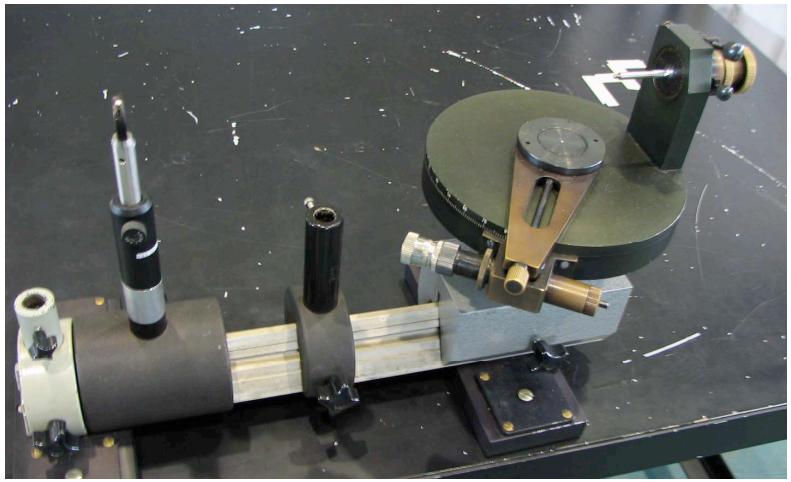
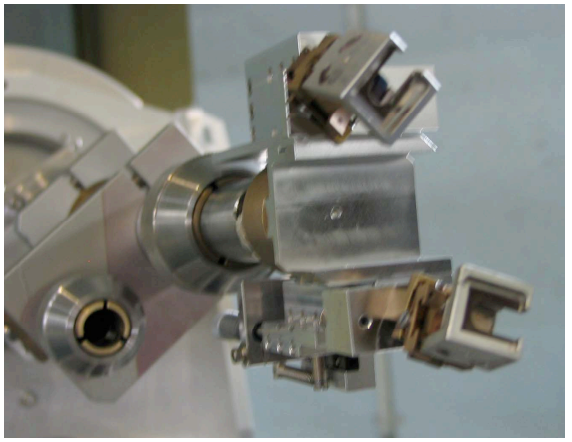
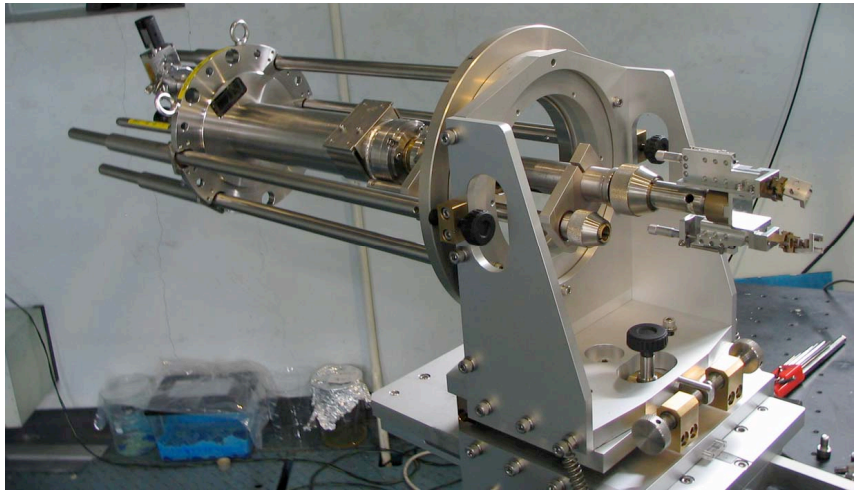
Optical alignment of toroidallybent crystals is very important. (setting accuracy: 0.1 deg., 100 μm)



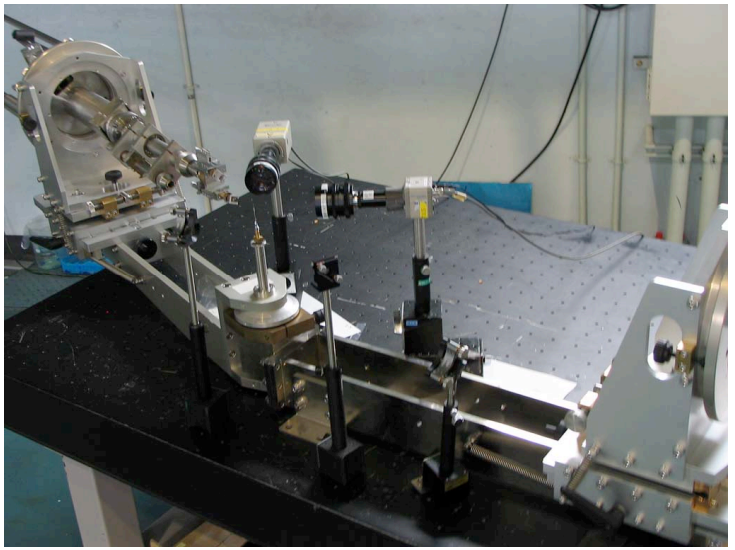
Adjustment of Bragg angle with goniometer



2-color crystal mounts



Crystal mounts supporting instrument with re-creativity of 50 μm



Target chamber dummy skelton

Beam smoothing activities at ILE, Osaka

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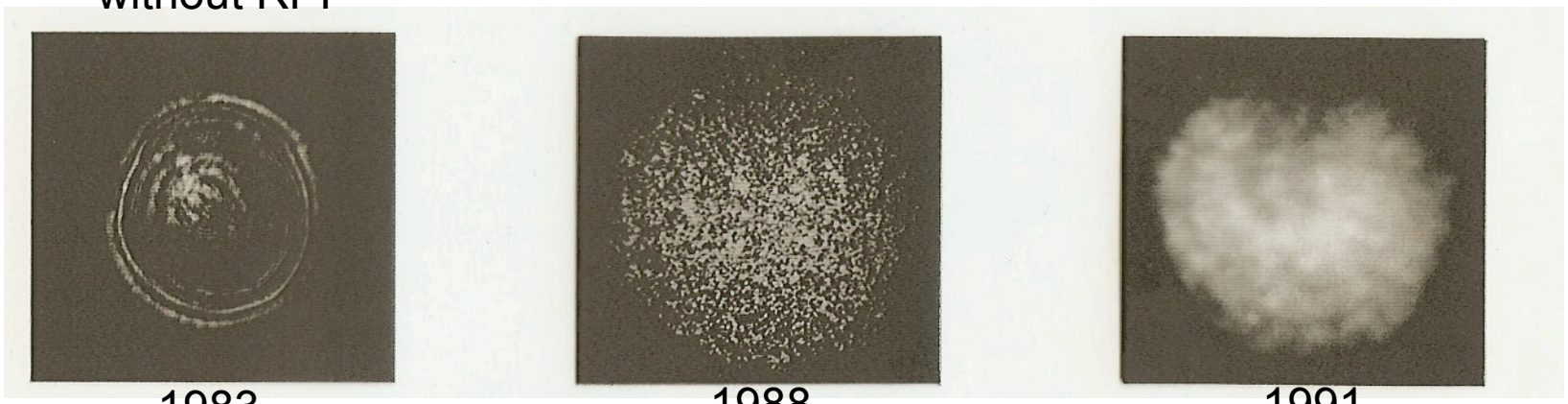

PCL:partially coherent light (ILE,NRL), SSD:smoothing by spectral dispersion(LLE)