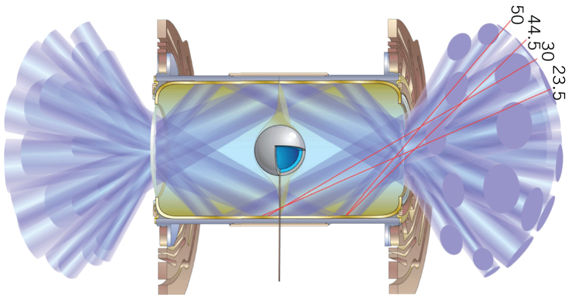
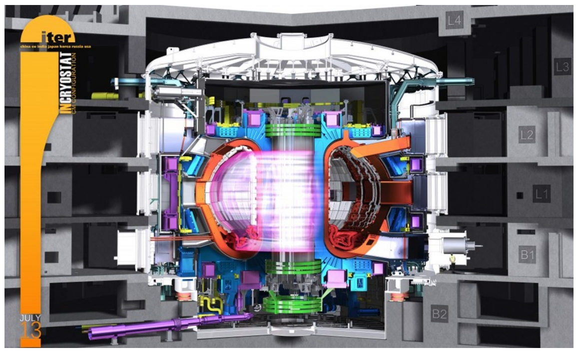
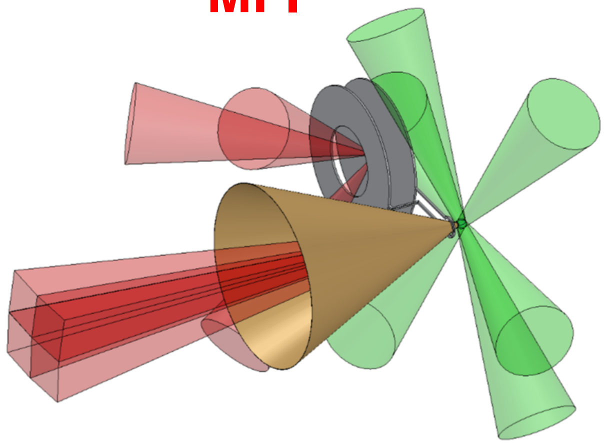
Magnetized fast laser isochoric (MFI) heating for efficient creation of high-energy-density states

Shinsuke FUJIOKA (Institute of Laser Engineering, Osaka Univ.)

ICF + **MCF** = **MFI**

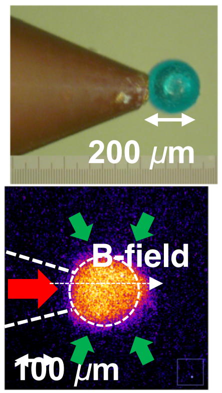


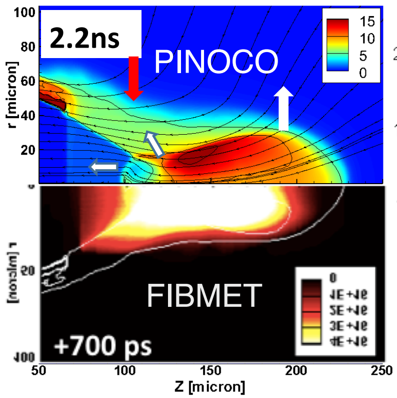


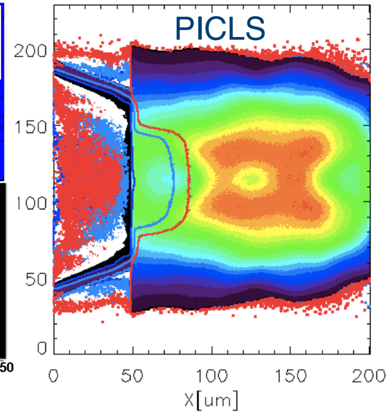


Summary

- Kilo-tesla magnetic field has been generated by using laser-driven capacitor-coil target for magnetized fast isochoric heating (MFI).
- Externally applied magnetic field can penetrate through 7-μm-thick gold cone wall due to decrease of electrical conductivity induced by inductive current.
- ~8% of laser-to-core coupling was obtained by using the MFI scheme even with a small pre-compressed core (ρR = 0.1 g/cm^2) . 15% is achievable with a 0.3 g/cm^2 core.







Guiding of REB by the external B-field

Large divergence of laser-driven electron beam reduces energy coupling efficiency from the heating laser to the fuel core.

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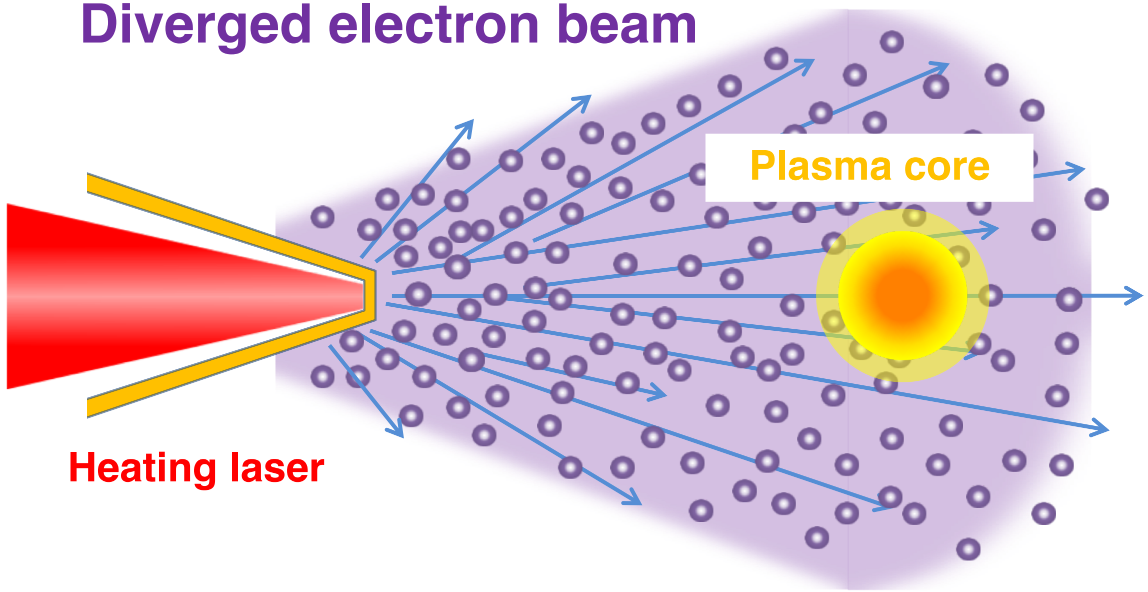
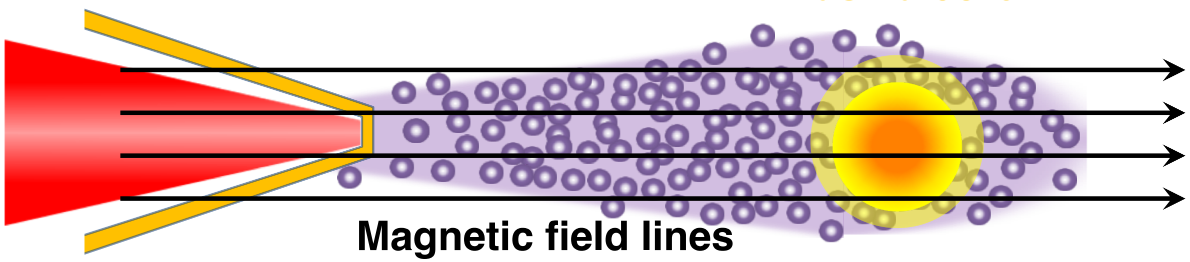
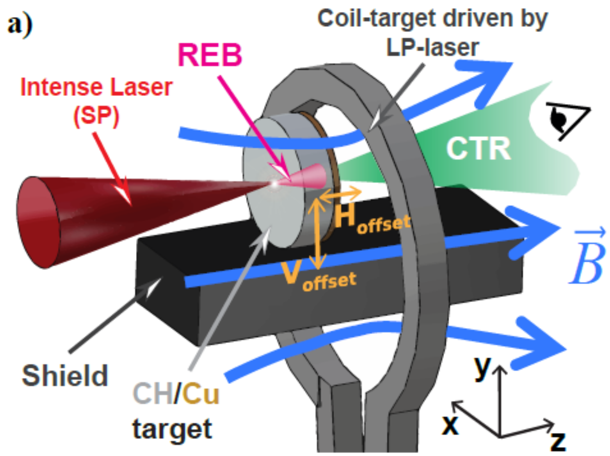
Diverged electron beam



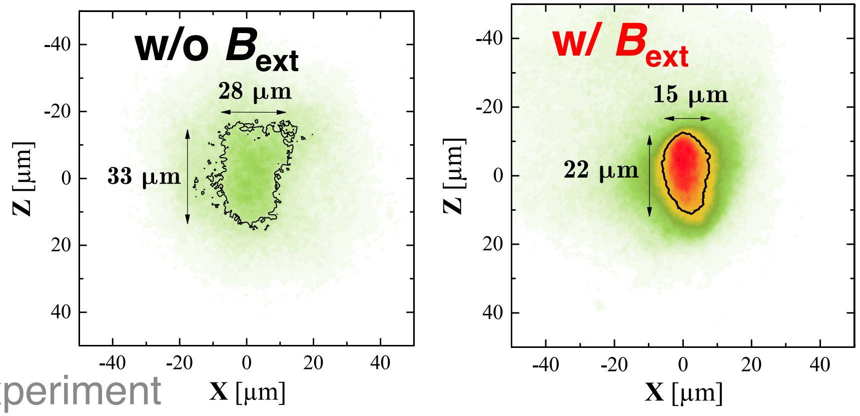
Guided electron beam



M. Bailly-Grandvaux *et al.*, Nat. Comm. 2018.



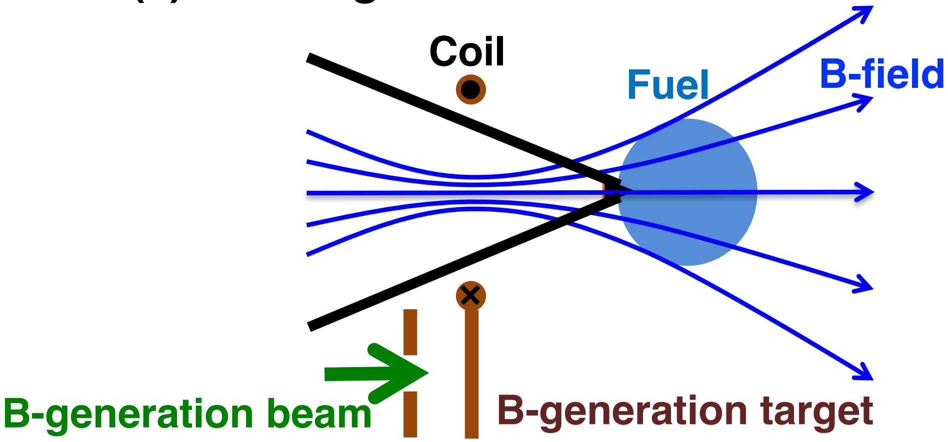
Experimental results



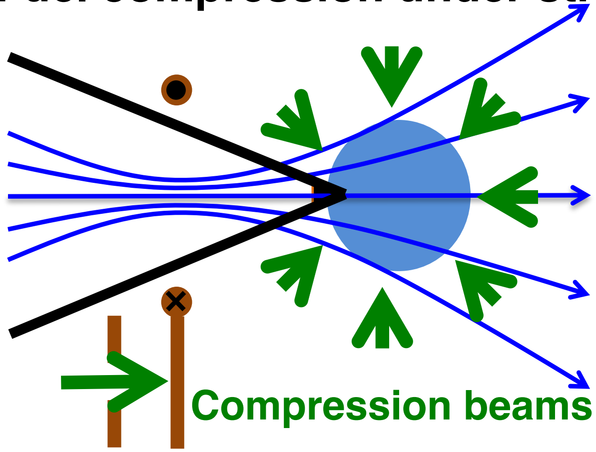
MFI process

The external magnetic field is applied to the “insulator” fuel before the compression beam irradiation.

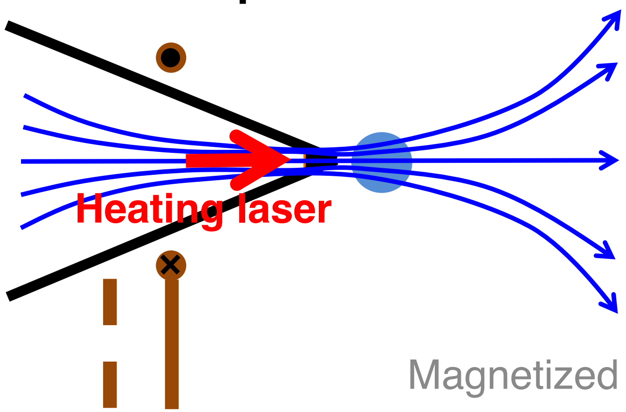
(1) B-field generation and diffusion



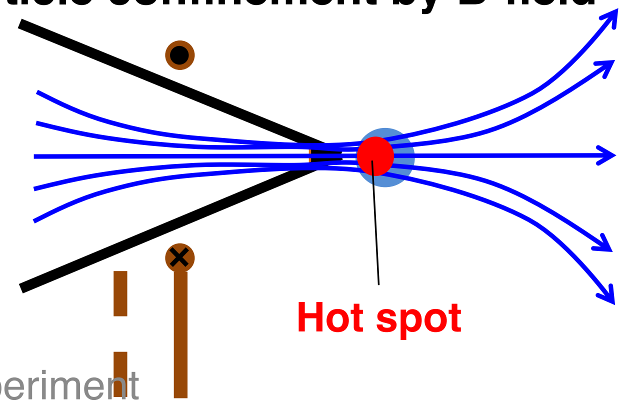
(2) Fuel compression under strong B-field



(3) Laser plasma interactions and REB transport in B-field



(4) Thermal electron and α-particle confinement by B-field



Integrated experiments of MFI scheme

Magnetic field diffusion time in the Au cone depends on electron conductivity and geometry of the cone .

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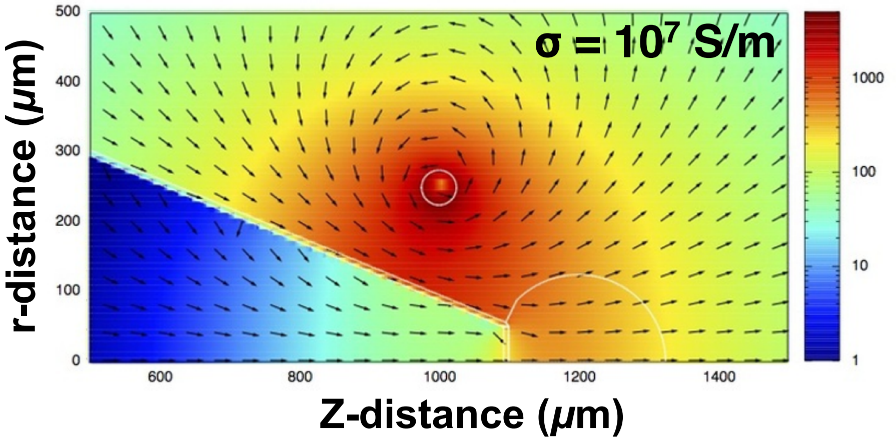
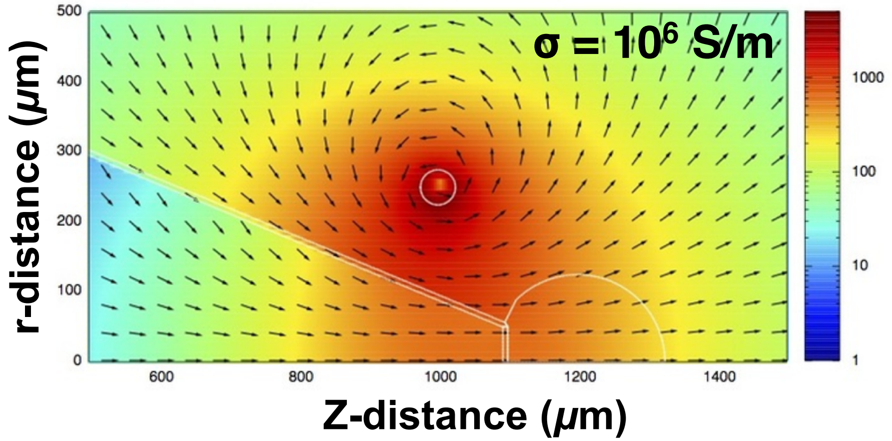
* M. Dharma-wardana *et al.,* Phys. Rev. E (2006).

Calculated 2D magnetic field profile (430 kA)

B-field strength (T)



B-field strength (T)



$$t_{diff} = 1/2\, \mu_0\, \sigma\, r\, L$$

Diffusion time scale	Electrical conductivity	Cylinder radius	Diffusion spatial scale
860 ps	2 x 10^6 S/m (**0.1 eV-gold**)*	50 μm	7 μm cone wall

Integrated experiments of MFI scheme

Magnetic field can penetrate through the 7 μm-thick Au cone wall because the Au cone is heated by inductive current.

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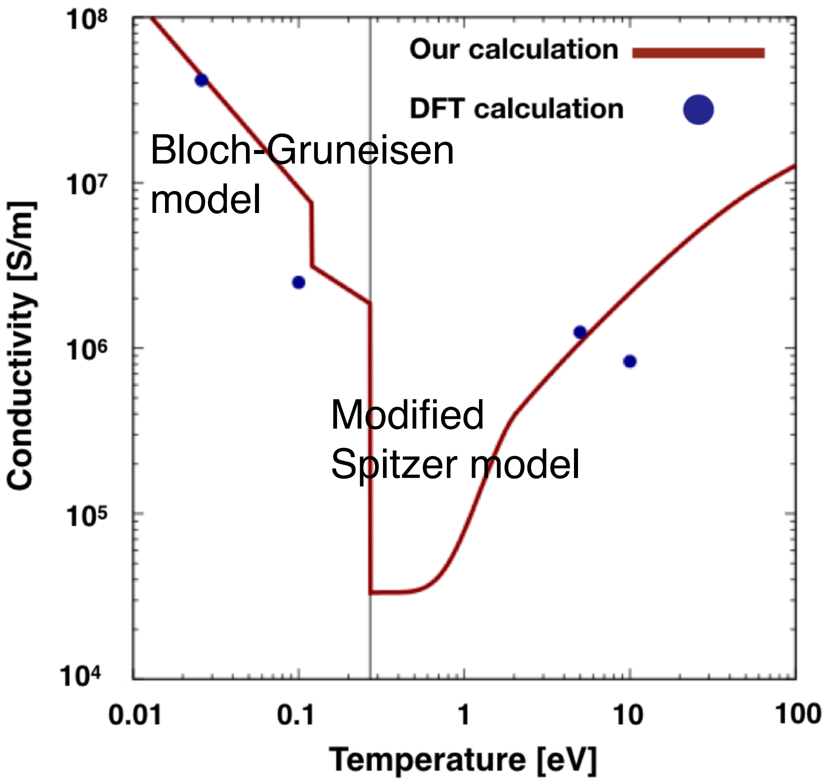
Temperature dependence electrical conductivity



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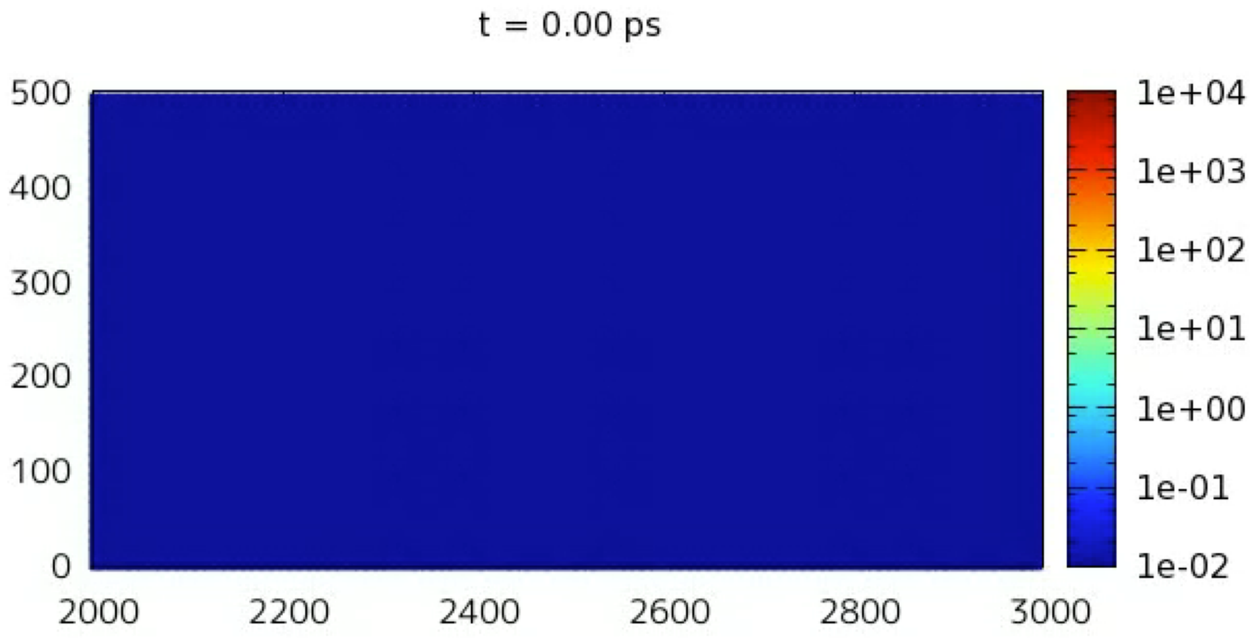
2D magnetic field diffusion dynamics



Integrated experiments of MFI scheme

Cu-doped solid ball were used in integrated experiment
for visualization of energy-deposition and measurement of temperature.

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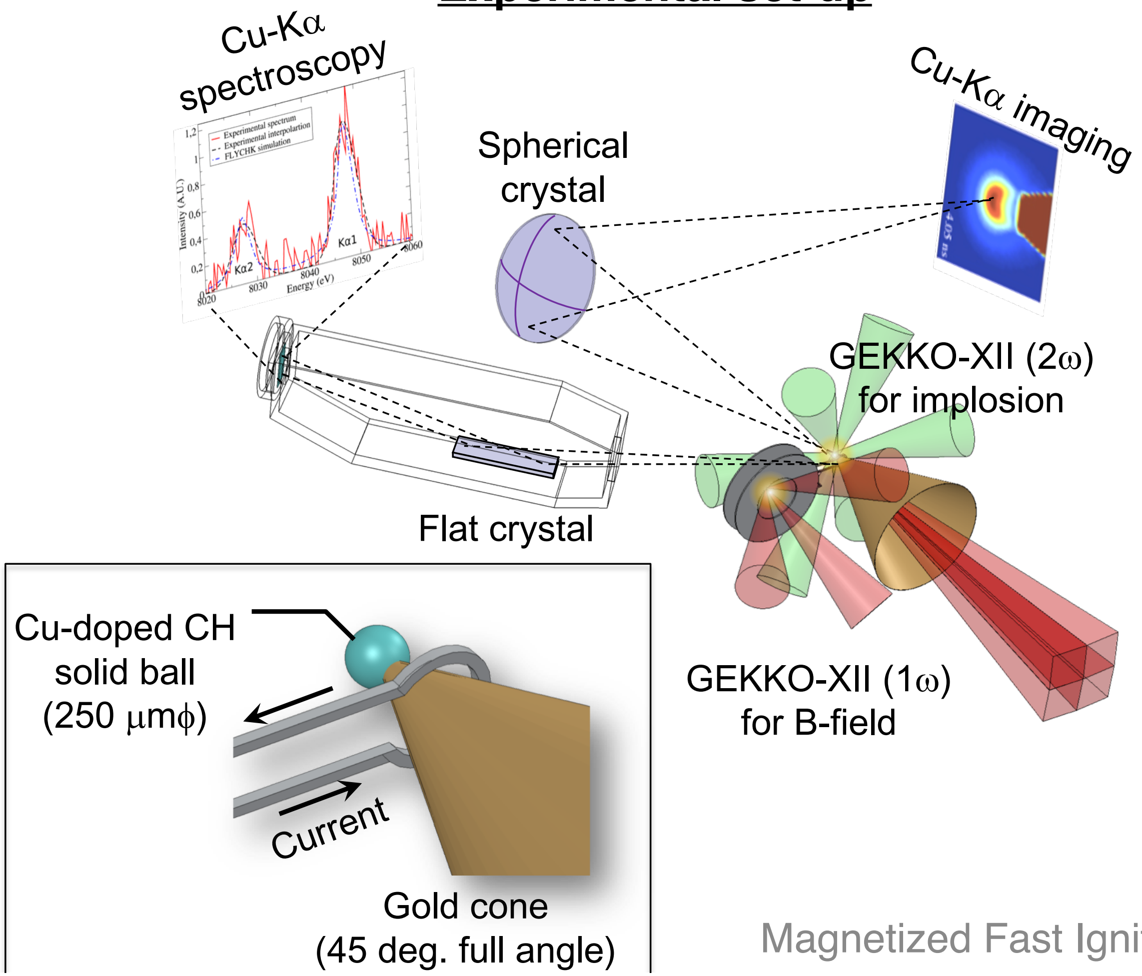
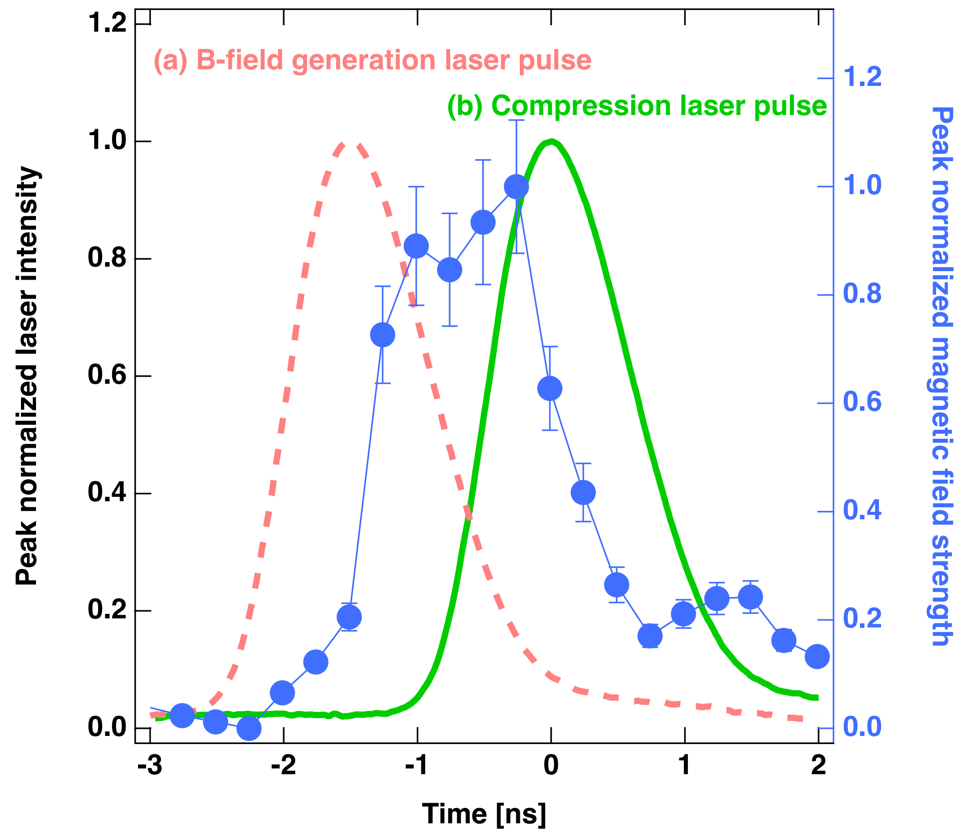
Experimental set-up

S. Sakata *et al.*, submitted.





Integrated experiments of MFI scheme

Temporal change of core compressed under external magnetic field was measured with a flash x-ray backlighting technique.

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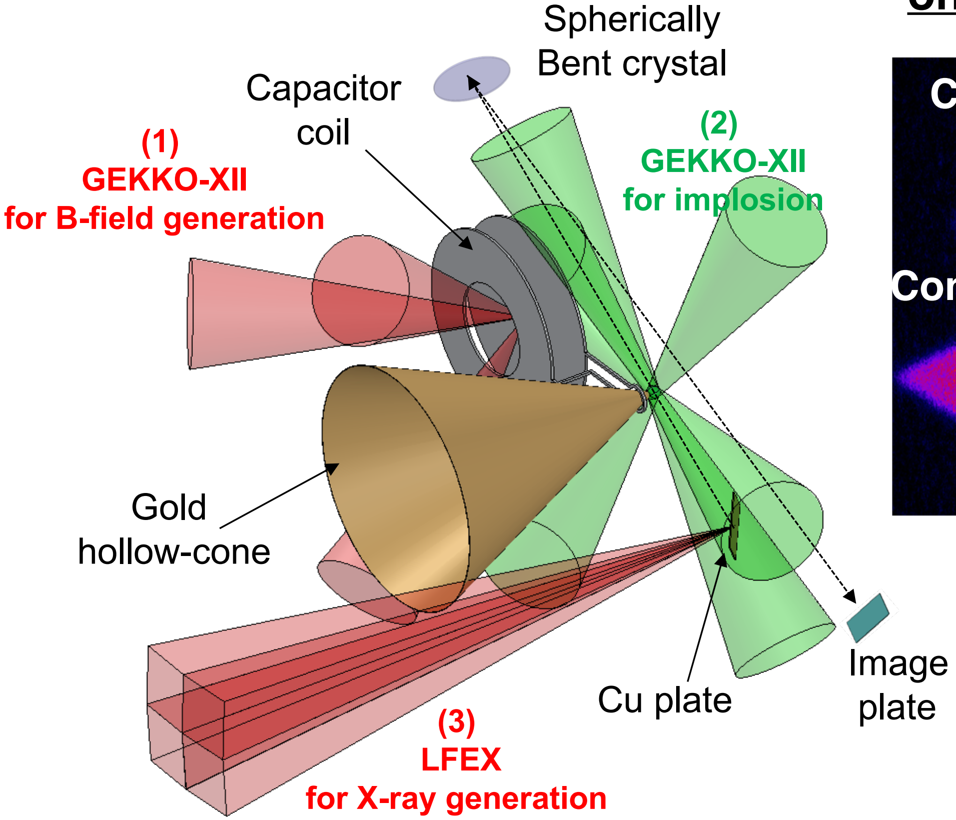
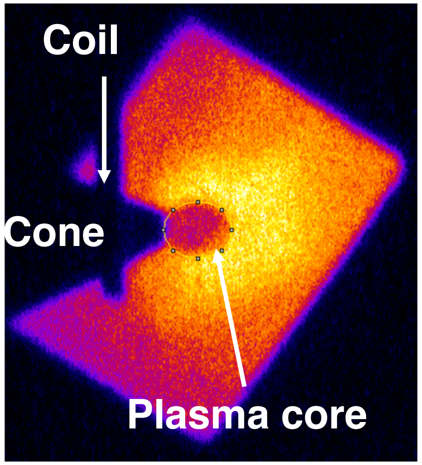
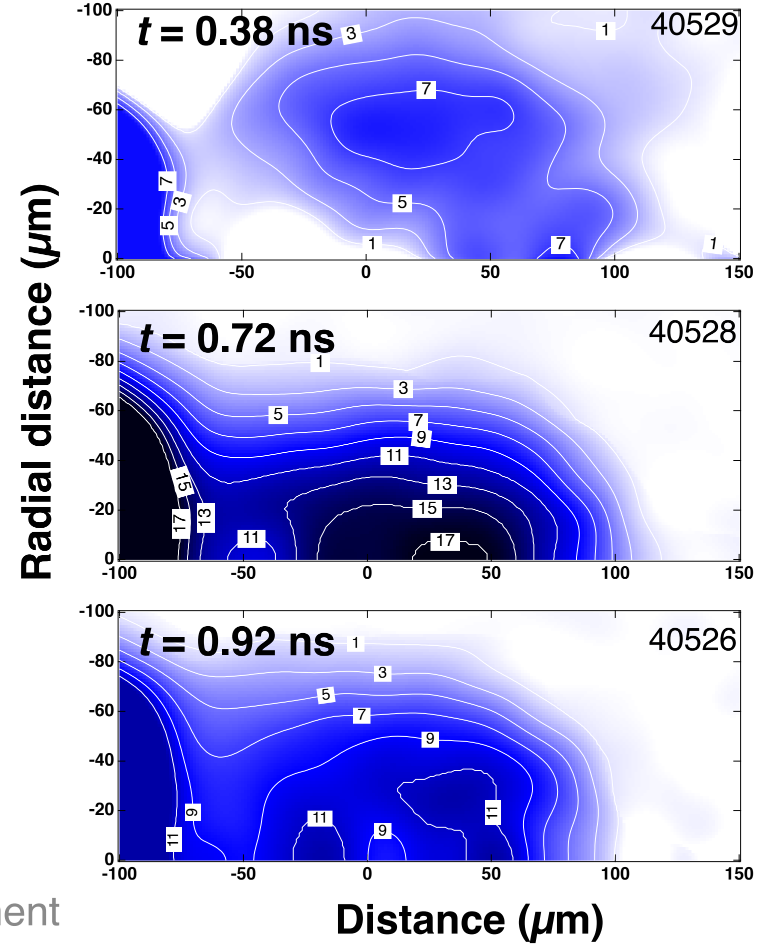
Backlight experiment layout



Cu-$K\alpha$ backlight image on imaging plate



2D density profile



Integrated experiments of MFI scheme

REB energy deposition in the shocked region and the far edge of the core was clearly enhanced in the magnetized core.

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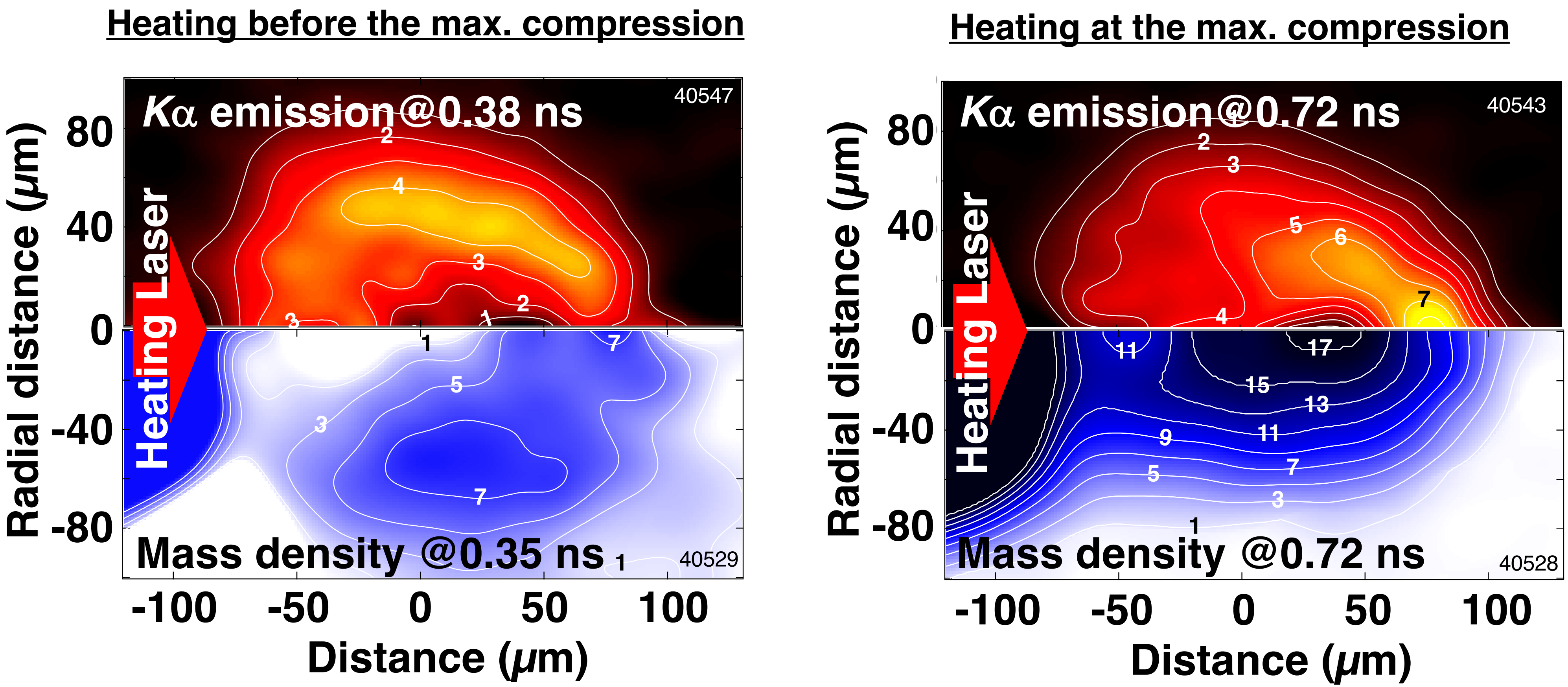

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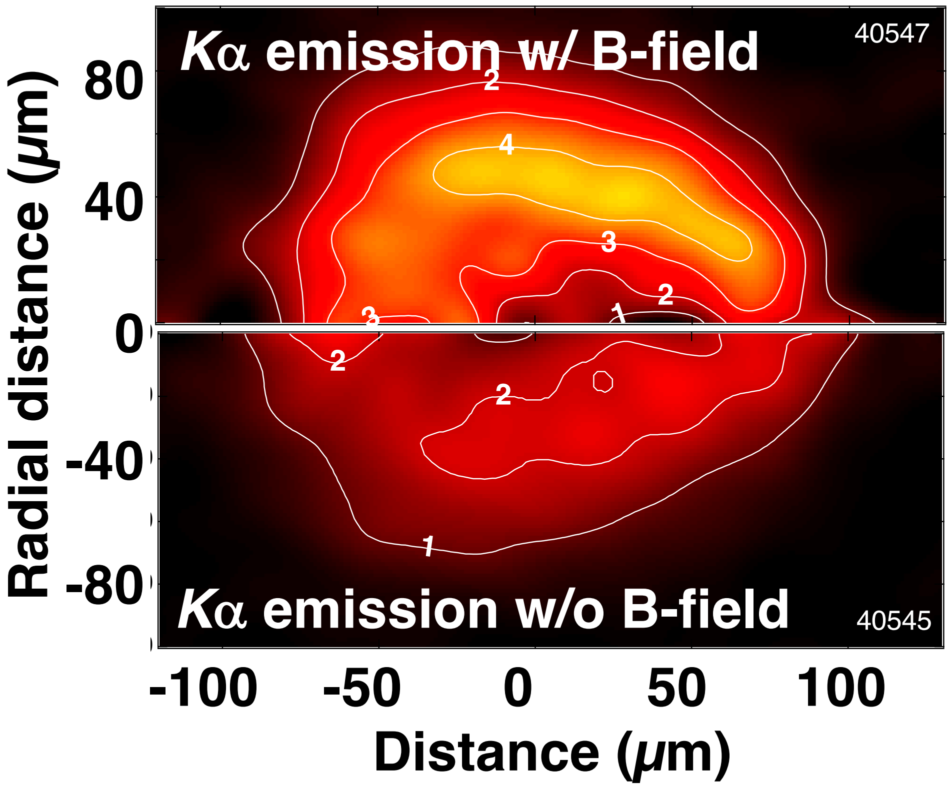
Heating before the max. compression



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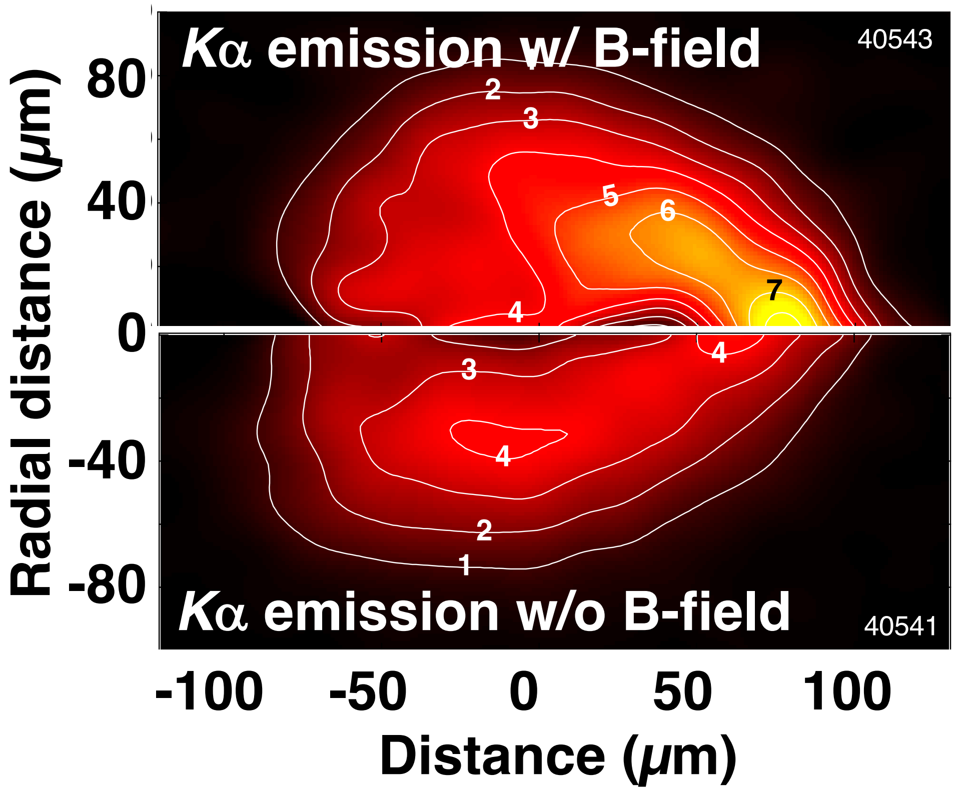

Integrated experiments of MFI scheme

Efficient laser-to-core coupling (~8%) was achieved even with a relatively small ρR core (~ 0.1 g/cm^2) by application of external *B*-field.

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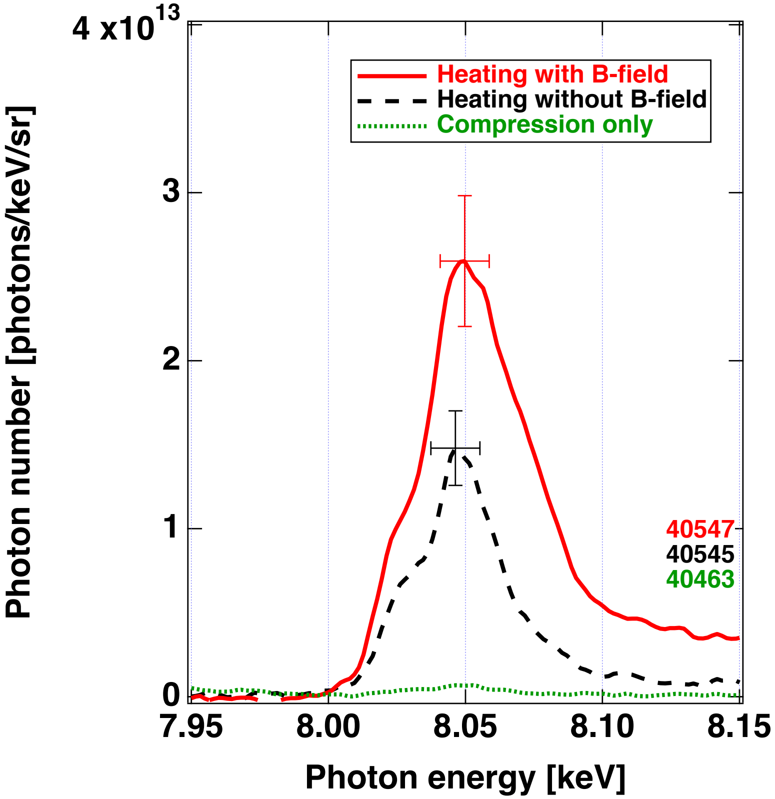
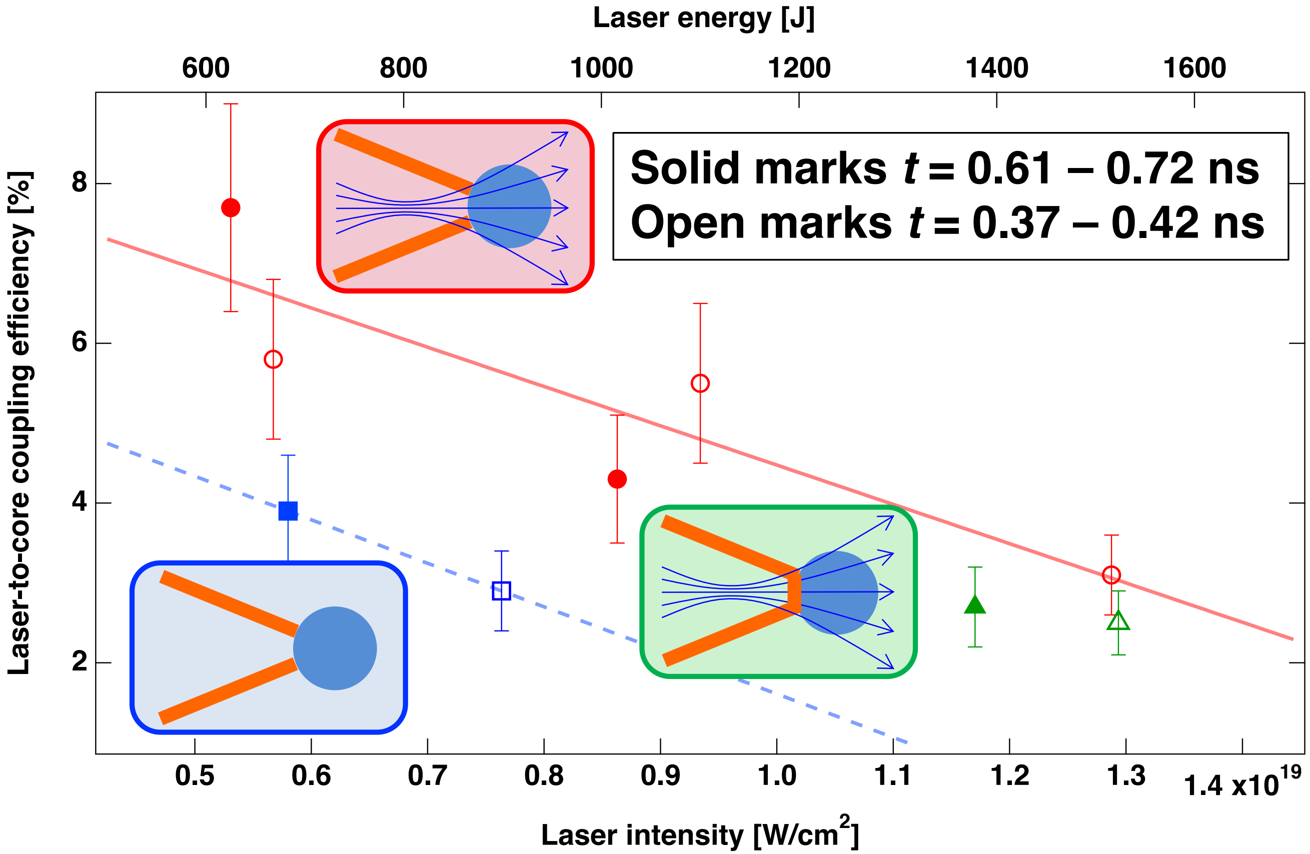
Cu-$K\alpha$ spectra



Dependence of laser-to-core coupling



Heated region imaging of magnetized fast ignition scheme

Fresnel Phase Zone Plate (FPZP) was used to image both Ti-K_α and Ti-He_α emissions from cold and heated regions.

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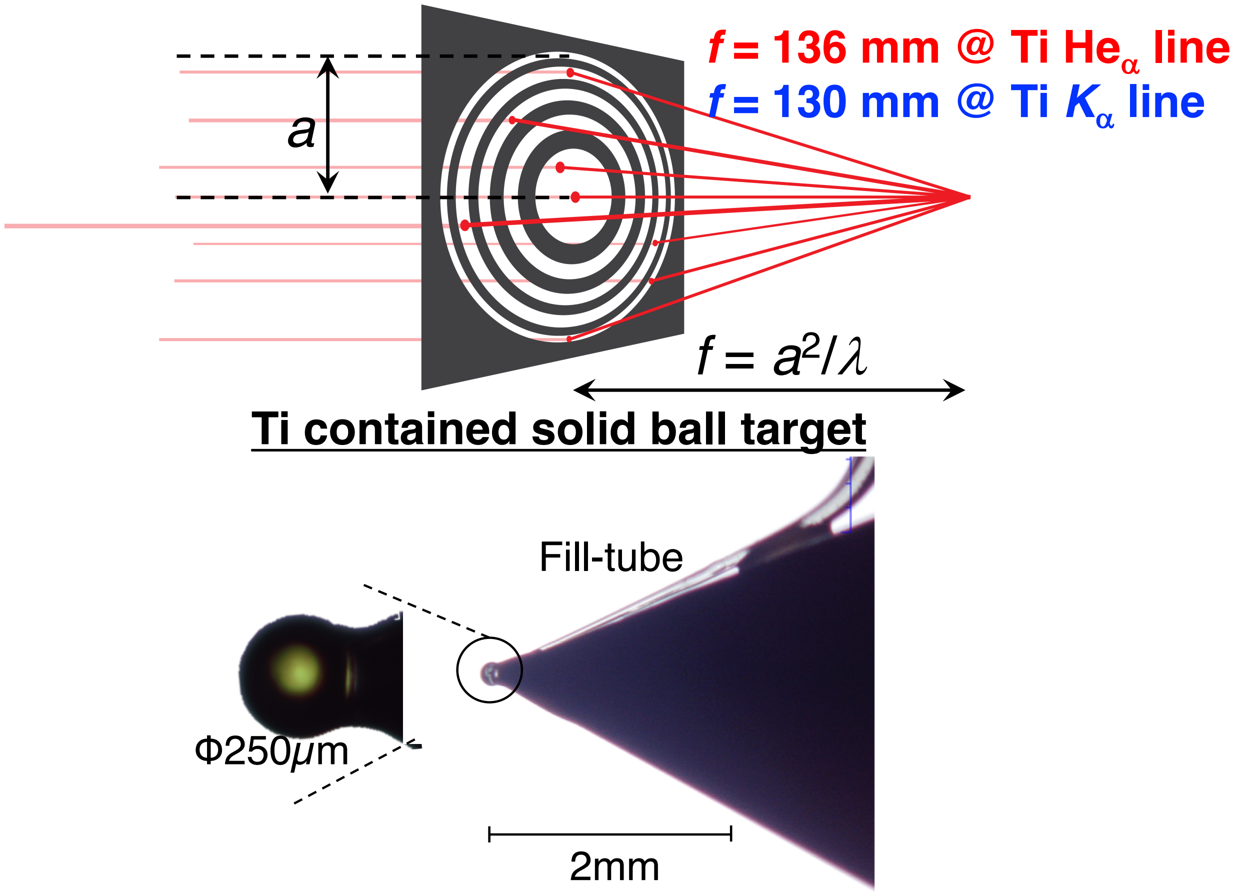
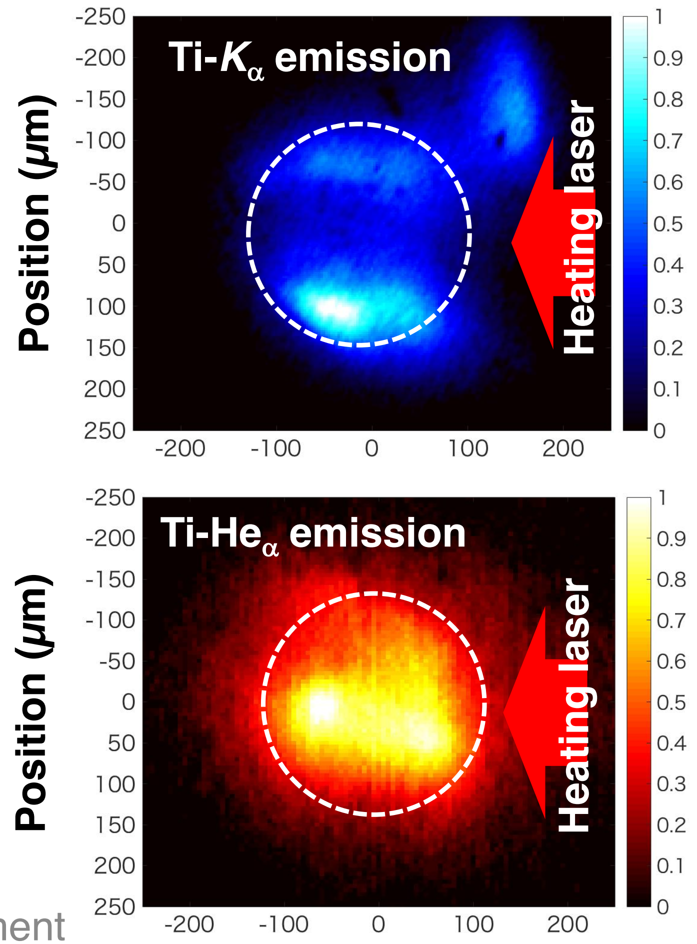
X-ray imaging with FPZP



Visualization of heated region



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