Generation and application of a laser driven magnetic field

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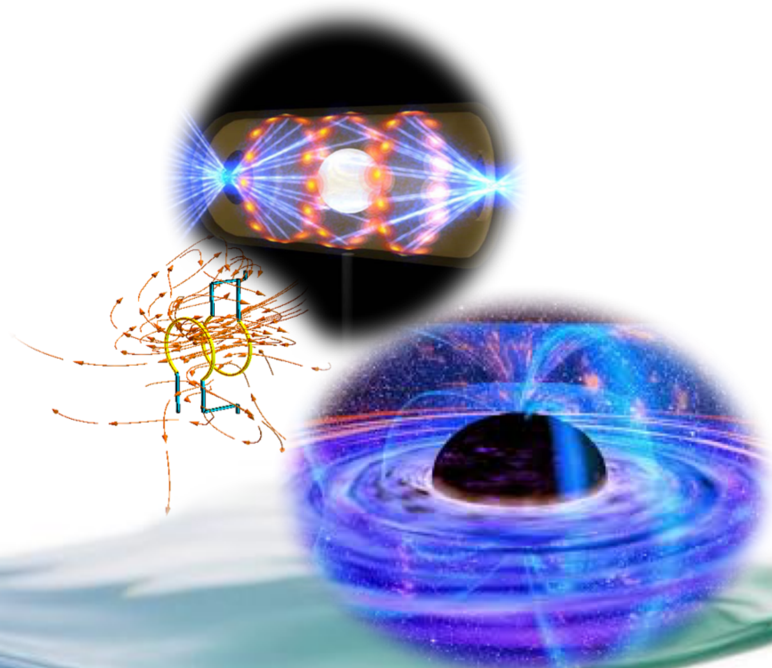

2017.07.23, LaB, Russia

Collaborations

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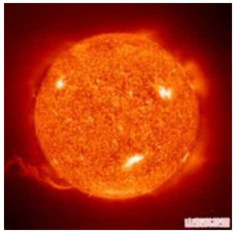
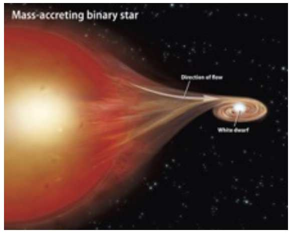
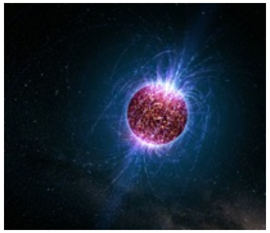
D. Neely, et. al.,

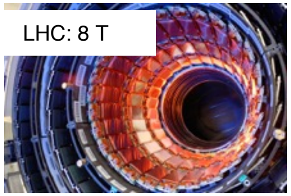
Strength of Magnetic field





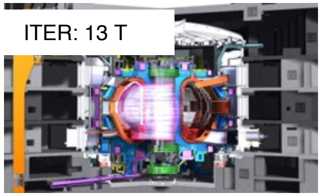


10^{-5} T | $10^{-1\sim1}$ T | $10^{1\sim2}$ T | 10^{3} T | 10^{5} T


LHC: 8 T

~100 T

1000 T?


ITER: 13 T

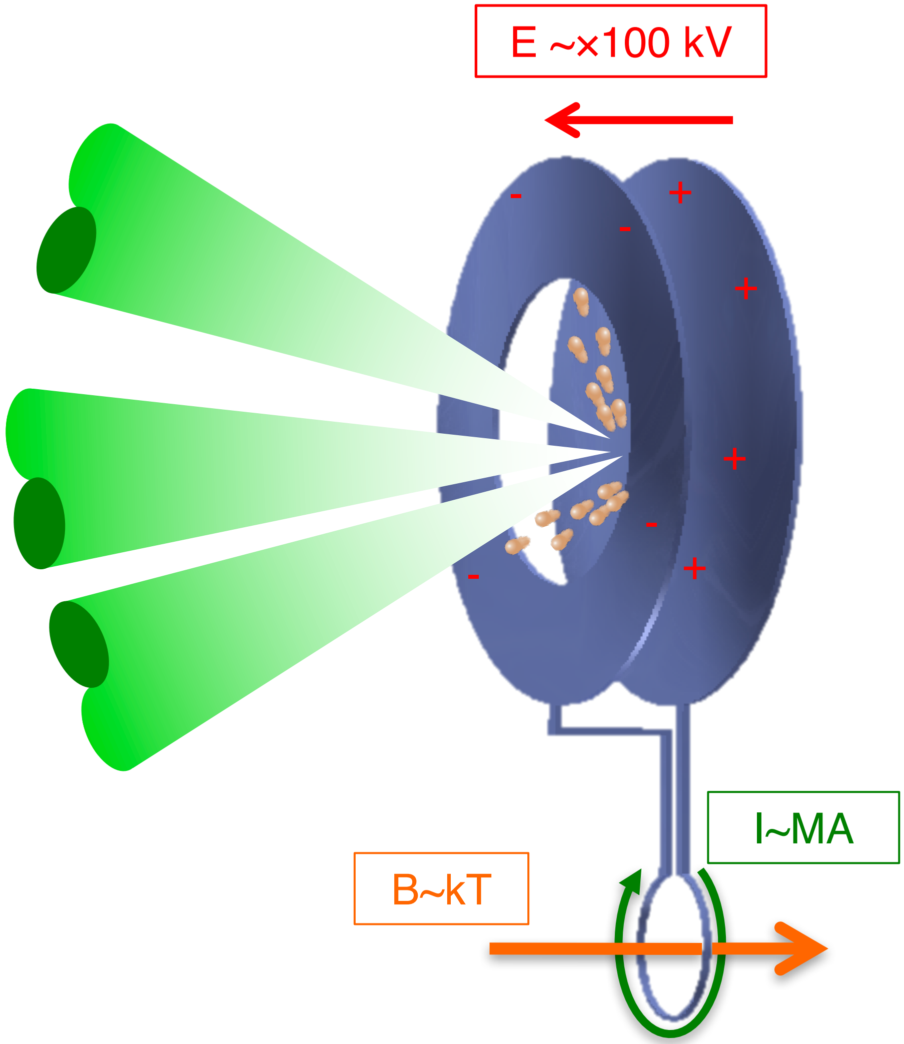

LANL: 45 T

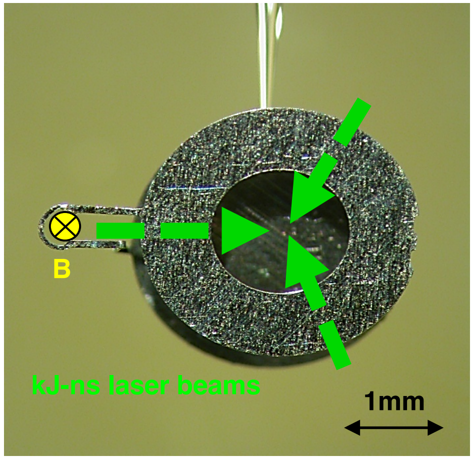
Laser driven B-field in free space.


HUST 90 T


LANL: 100 T/100 ms

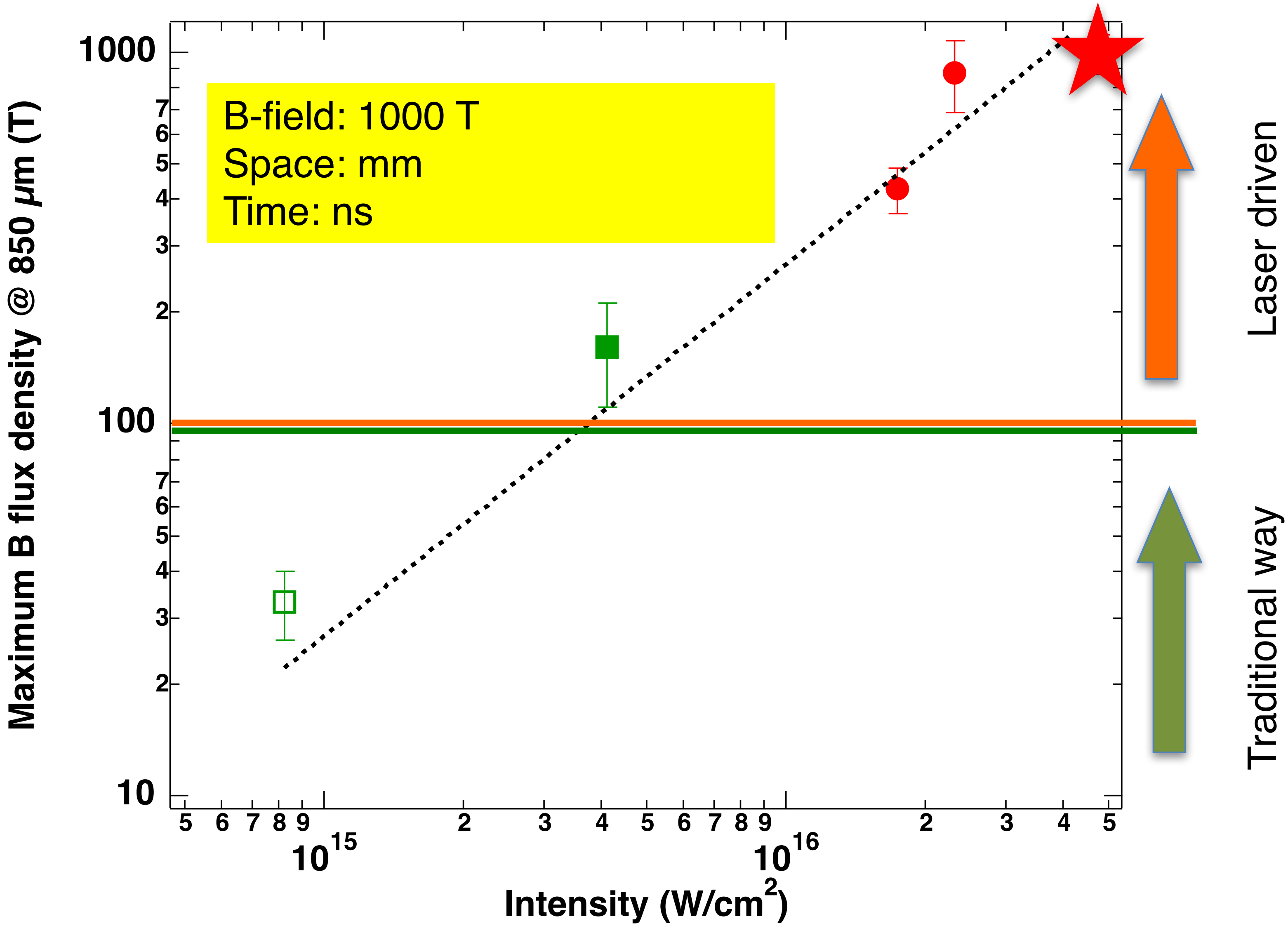
Laser driven magnetic field





H. Daido, et. al., Phys. Rev. Lett. 56 8 (1986)
S. Fujioka, et. al., Sci. Rep. 3 1170 (2013)

Maximum magnetic field with laser



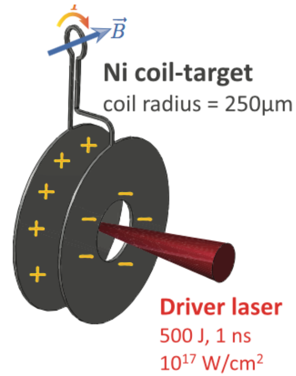
S. Fujioka, Z. Zhang, Scientific Reports, 3:1170 2013

Laser driven magnetic field on ns facility

1 kT

Gekko: 1 kJ, 1 ns

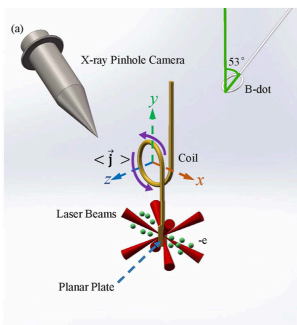
$I\lambda^2 \sim 5\times10^{16}$



0.8 kT

LULI: 0.5 kJ, 1 ns

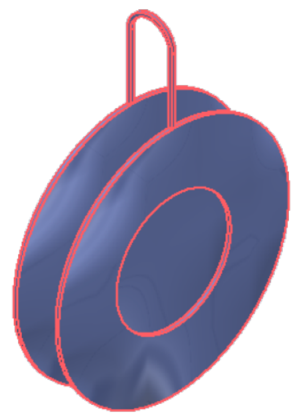
$I\lambda^2 \sim 1\times10^{17}$



200 T

SGII: 2 kJ, 1 ns

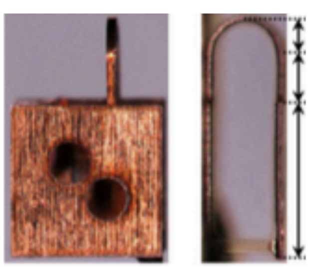
$I\lambda^2 \sim 10^{15}$



50 T

SGII: 1 kJ, 1 ns

$I\lambda^2 \sim 10^{15}$



50 T

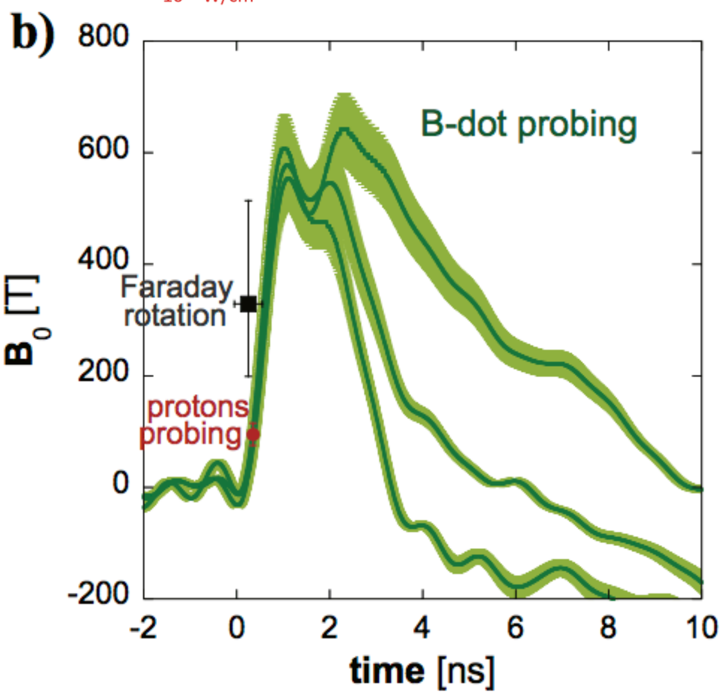
Omega EP: 1.25 kJ, 1 ns

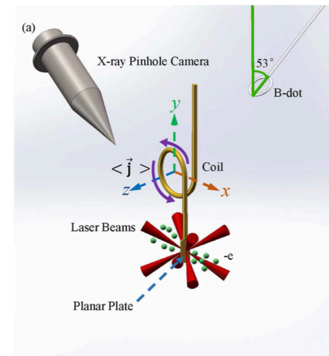
$I\lambda^2 \sim 2\times10^{15}$

L. Gao, et. al., POP, 2016

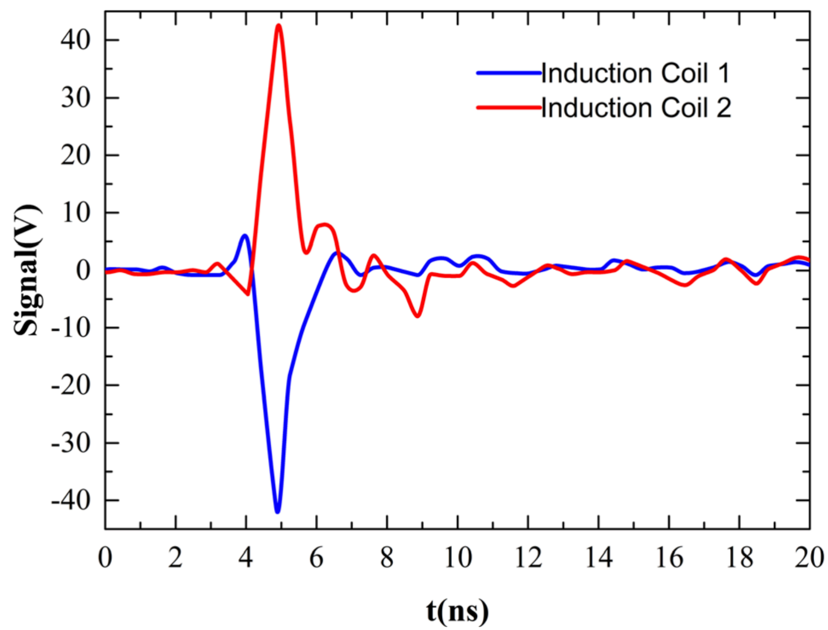
Temporal evolution of the B-field

0.8 kT ~ 2 ns
LULI: 0.5 kJ, 1 ns



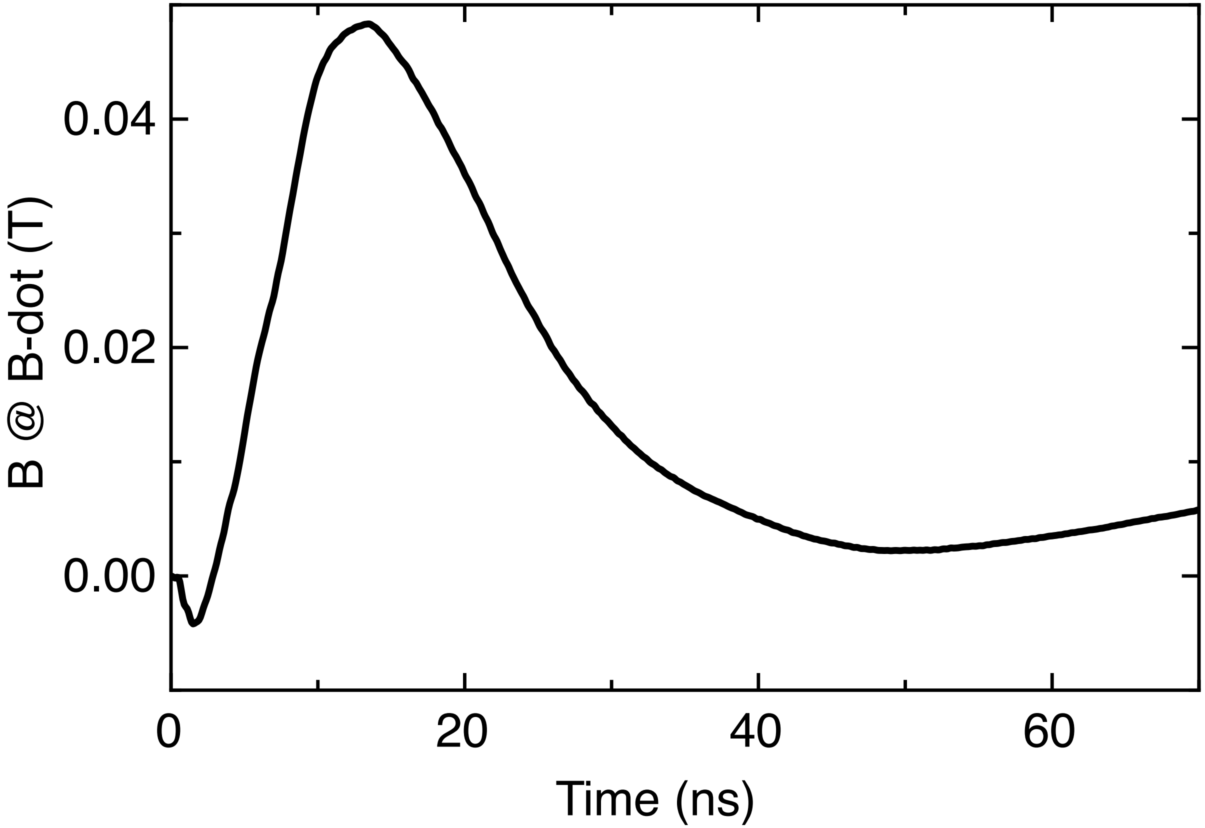


200 T ~ 1 ns
SGII: 2 kJ, 1 ns



Multi-turns coil

25 T ~20 ns
SGII: 2 kJ, 1 ns



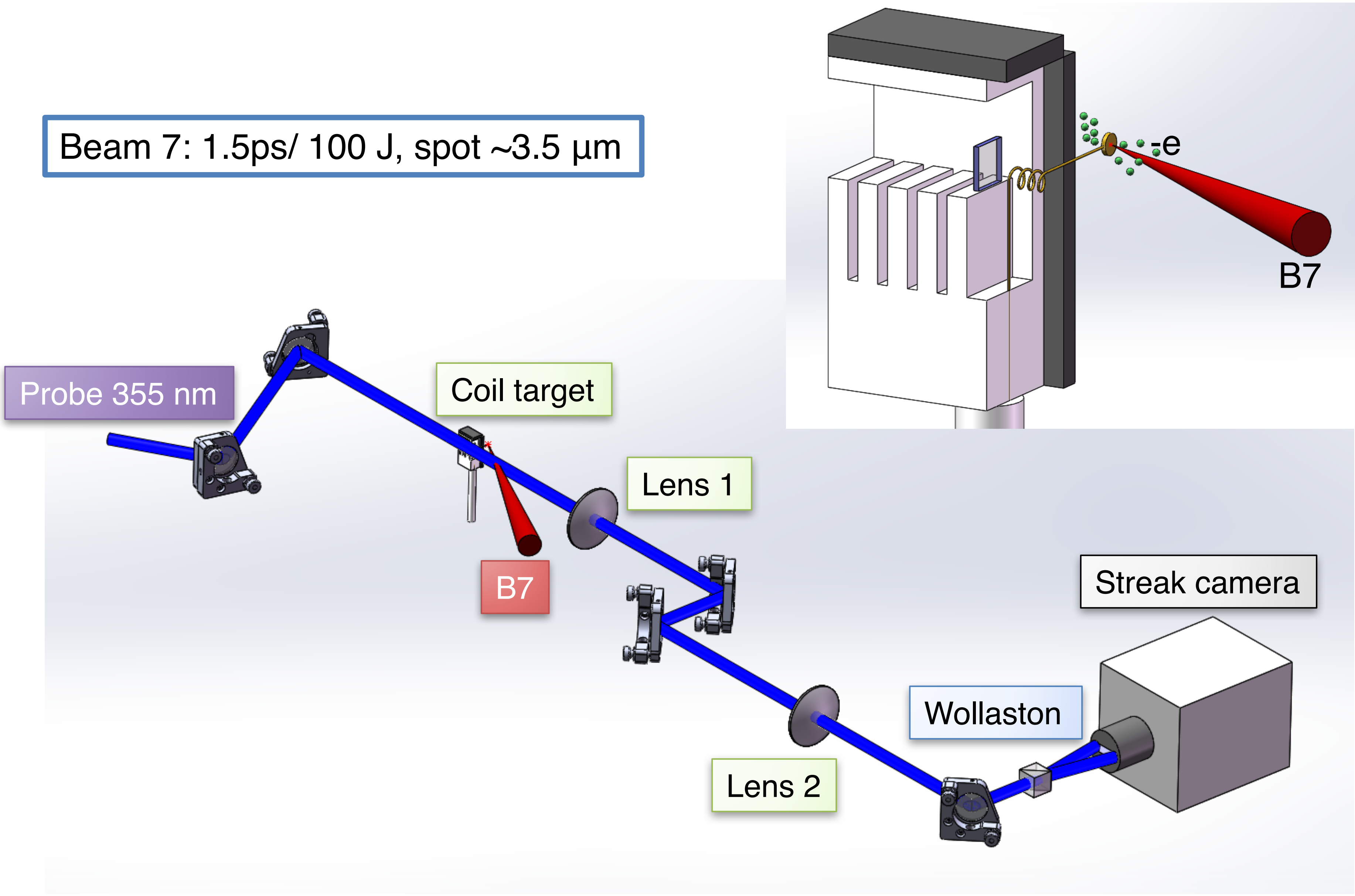
- Not finishied job

How it works with short pulse lasers?

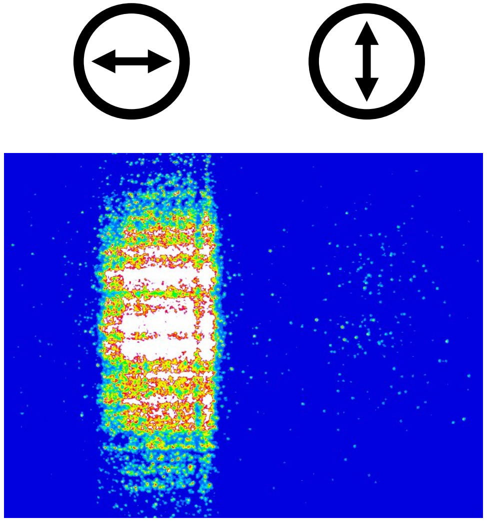
- IOP
  - 500 mJ in 25 fs, 20 TW
  - Spot 6 μm
  - B-field ~ 4 T
- RAL Vulcan TAW
  - 56 J in 8 ps, 8 TW
  - Spot 3 μm
  - B-field ~50 T

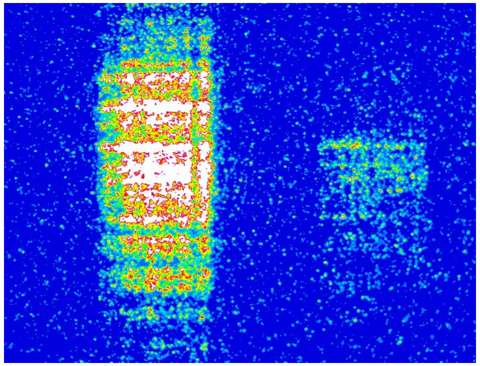
RAL Vulcan experiment

Beam 7: 1.5ps/ 100 J, spot ~3.5 µm

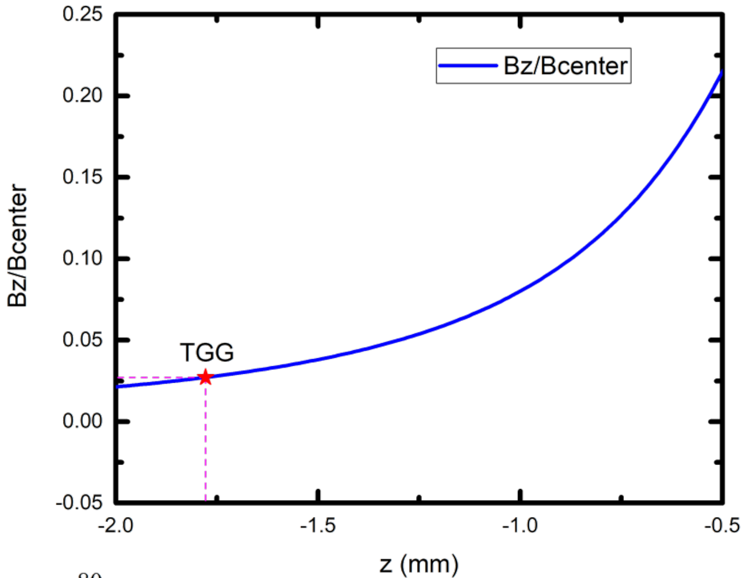


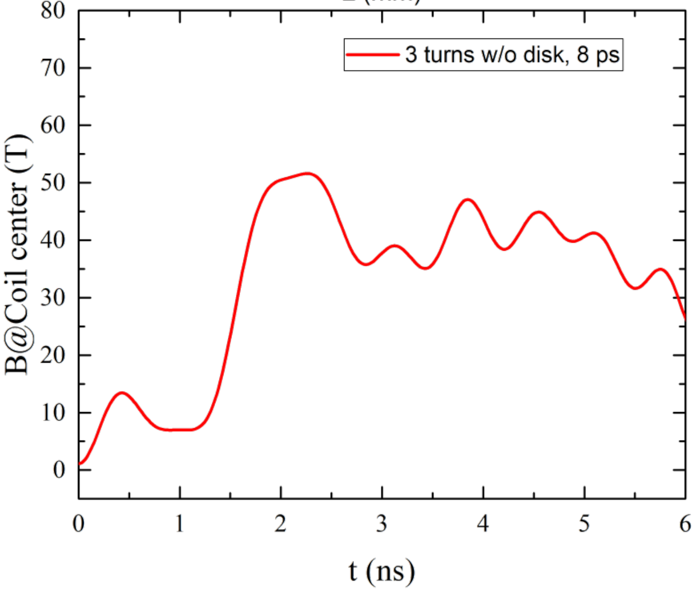
Magnetic field estimation





$$Ratio = \frac{I_p}{I_p + I_s} = Sin^2(\theta)$$





Conclusions

- B-field is generation with high power lasers
  - Maximum ~ 1 kT on Gekko
  - Duration can be extended to tens of ns by multi turns
  - fs
    - 0.5 J~ 4 T
  - ps
    - 60 J ~ 50 T
  - The efficiency
    - $B_{fs} > B_{ps} > B_{ns}$
  - It is possible to further increase the B-field with moderated laser parameters and target geometries

Applications of the magnetic field

- Lab-astrophysics:
  - Low β MR have been demonstrated (Prof. Zhong's talk)
  - Landau Quantization spectroscopy
  - High-order Zeeman splitting
  - Opacity of magnetized plasma
  - …
- Laser-plasma interactions
  - MHD
  - Hydrodynamic instabilities
  - Plasma pinch
  - ...
- Laser Fusion
  - Collimation of escaping electrons
  - Magnetized fast ignition
- Condense matter physics...
- Chemistry...
- ...

- Not finished Job

Summary

Generation

- Target:
  - Capacitor-coil
  - Single-turn coil
  - Multi-turn coils
  - Open coil
  - Snail
- Laser
  - ns: Gekko, SG-II, LULI
  - ps: LFEX
  - fs: L05 20 TW, XL-II 100 TW, LLP 200 TW
- Diagnostics develop
  - Faraday
  - B-dot
  - p+ radiography
  - 3D B-dot
  - Chirp Faraday

Applications

- Relativistic electron beam collimation
- High B-field MHD
- Hydro-instability under high B-field
- Magnetic reconnection
- Compression of B-field for high-order Zeeman splitting spectroscopy
- Plasma pinch
- THz generation
- Magnetized Fast Ignition
- ……