LASER Summary

Amita Das

IPR

Overwhelming participation

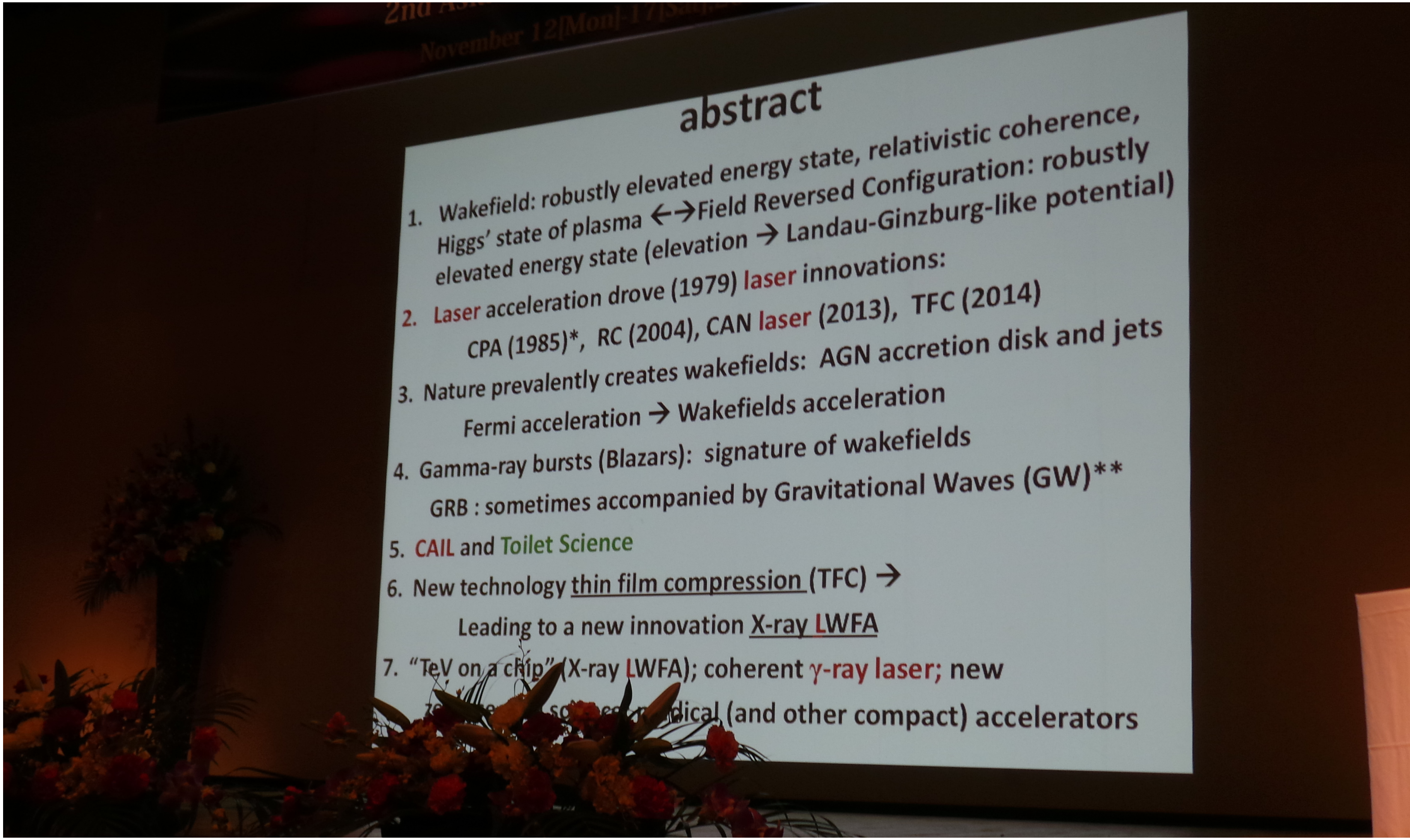
- Plenary talks: 4
- Semi Plenary talks: 12
- Invited talks:24
- Oral Talks:12
- Evening lectures: 2
- Posters: 28

This year’s attraction:

Chandrasekhar Prize Lecture – (Prof. Tajima)

[Nobel Prize – Lasers (Prof Gerard Mourou)]

Chandrasekhar lecture by Prof. Tajima



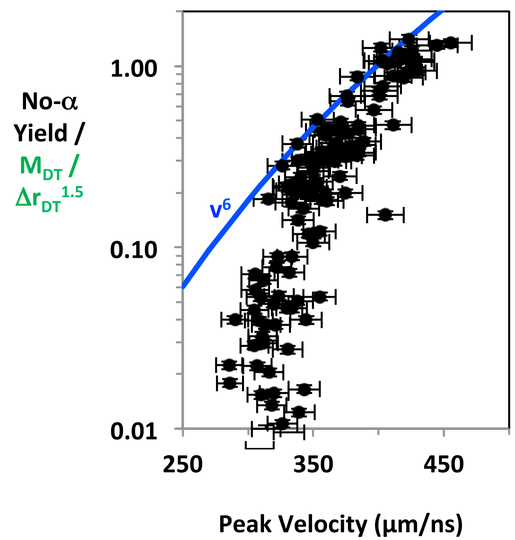
Broad Themes

1. Laser Applications: Fusion, Particle acceleration and heating, absorption, REB propagation, magnetic field generation, Radiation sources, Shocks, WDM, etc;
2. Pushing the physics frontiers: QED, Radiation reaction, Particle production cascades, laboratory astrophysics.
3. Facility development

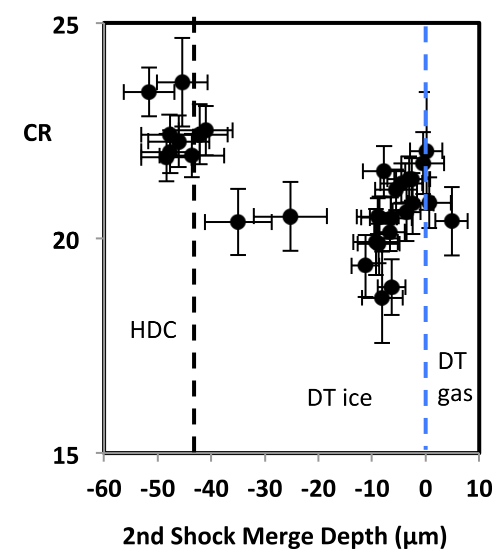
Laser Fusion: Ignition

- NIF developments: Landen
- FIREX in Japan: Fujioka
- Key achievements in IFE: Peter Norreys.
- Counterbeam configuration : Y. Mori. GPL Hamamatsu.
- Other issues: kinetic effects(Yuqui Gu); fast isochoric heating (S. sakata), neutron creation (Minqing He).
- Importance and difficulties due to parametric instabilities recognised back then in 60s – and they play an important role even now – Bob Bingham.

Status of NIF indirect-drive implosion research



- Best yields (2e16 yields with 3x alpha heating) increase with velocity and smaller filltube and tent support area
- Yields drop by 1.5-2x for the largest mode 1 and 2 asymmetries present - fixable



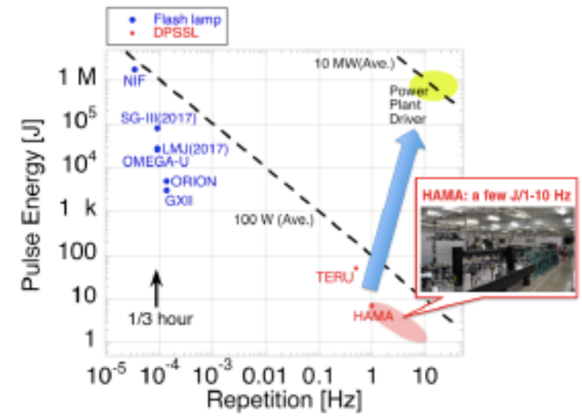
- Compression ratio is sensitive to shock merge depths
  - Unexpected: Compression can drop for lower adiabat designs – ablator/fuel mix?
- New techniques are being applied to study fuel compression, uniformity and mix

Summary

Counterbeam configuration offers a promising rote to Fast Ignition Inertial Confinement Fusion (ICF)

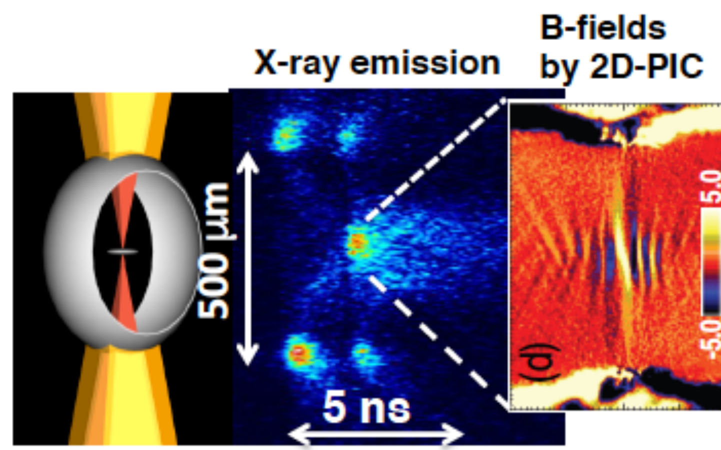
Presenter: Y. MORI
GPI, Hamamatsu, JA

- **Laser system HAMA[1] is a unique ICF driver; compact (joule-class) & repetitive (1-10 Hz) system applies for**
  1. Technology R&D for power plant
     ex) Pellet injection[2]
  2. Plasma exp. with flexible beam config.
     ex) Counterbeam FI;



- **Counterbeam fast ignition is a promissing scheme expecting**
  1. High Coupling eff.; 10±2%(exp.), 28% (sim.) upto 7% (one-direction scheme)
  2. MG-class Weibel Mag. fields in the core leading an anomalous heating[4]

[1] *MORI:* NF 53, 073011 (2013)
[2] *KOMEDA*: Sci. Rep. 3, 2561 (2013), *MORI:* FST 75 (2018)
[3] *KITAGAWA:* PRL 108, 155001(2012),
MORI: PRL 117, 005001 (2016), *MORI:* NF 57, 116031 (2017)
[4] *SENTOKU:* PRL 90, 155001 (2003)



L-I3 “Compact Fast Ignition experiments using Joule-class drive pulse under conterbeam configuration”
Y. Mori, 2nd Asia-Pacific Conference on Plasma Physics,12 Nov.2018, Kanazawa, Japan

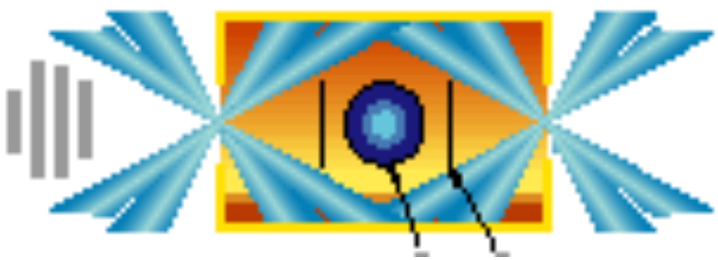
Bingham: Cross Beam Energy Transfer in ICF

CBET

Lasers or X-rays
symmetrically
irradiate pellet

Direct drive

Energy transfer between incoming and refracted laser beams enhances beam loss



Indirect drive

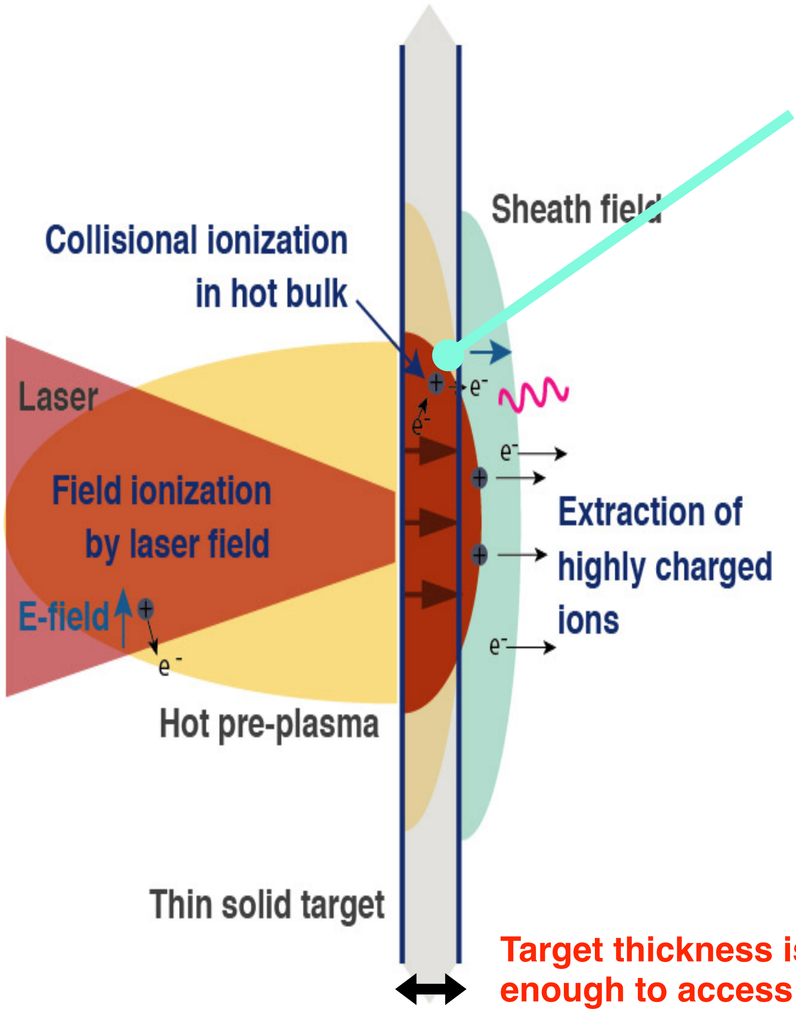
Energy transfer between inner and outer beams.

In Direct and indirect Drive laser fusion the laser drives parametric instabilities.
In indirect drive use is made of cross beam energy transfer between inner and outer beams. Good effect
Other instabilities eg Raman, 2 plasmon decay responsible for fast electrons.
Brillouin and Raman responsible for anomalous scattering.

Particle Acceleration and heating

- Ion and High Z acceleration: Sentoku (high Z), M. Nishiuchi (J- Karen),, Tatiana Pikuz (Plasma properties); Hata (theory and simulations) Hazel Lowe (X ray characterization in TNSA).
- Ion acceleration in the presence of external magnetic field: Atul Kumar and Ayushi Vashishta.
- Proton beam by cluster explosion: Y Fukuda
- Optimization through Target design: Microplasma and Clusters (Jorg Schreiber, Ramgopal), layered targets (B. Ramakrishna), Lihua Cao- laser propagation through capilaries.

Y. Sentoku@ILE, Osaka U
Propose a scheme for heavy ion acceleration by a short PW laser



1) keV plasma driven by fast electron current (resistive heating)

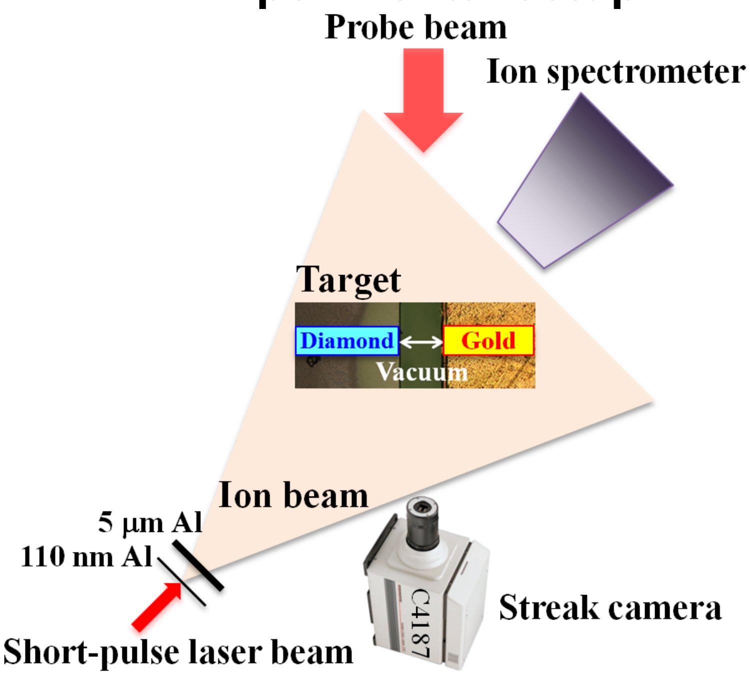
2) Heavy ions via collisional ionization

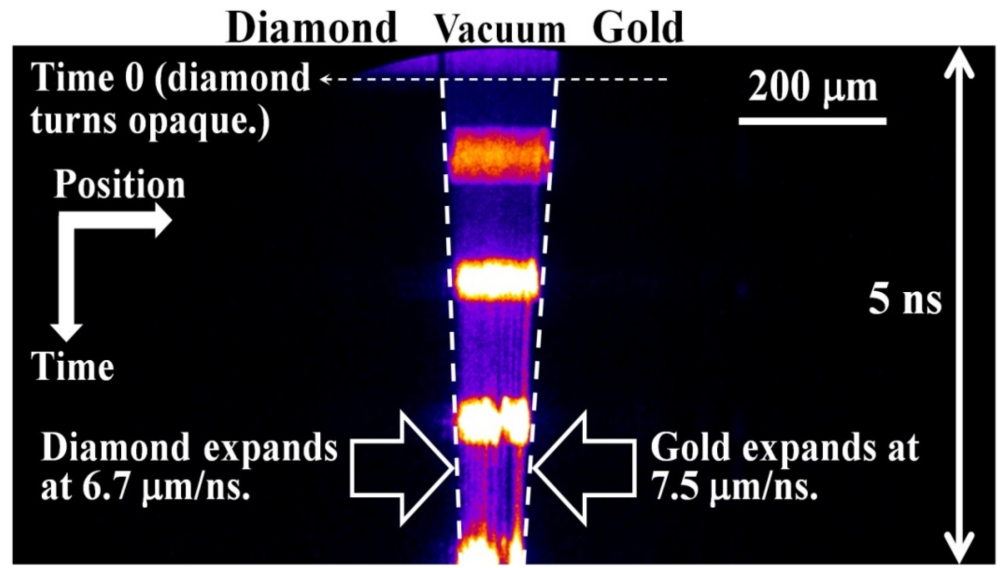
3) Extract ions by sheath field & accelerate them!

Target thickness is thin enough to access the hot region

Rapid and uniform heating of matter with a laser-driven ion beam

Experimental setup





Streak camera image shows the expansion of gold at 60,000 K and diamond at 20,000 K.

- **A laser-driven ion beam* on Trident laser facility heats gold and diamond in 20 ps very uniformly.****

* S. Palaniyappan *et al.*, Nature Communications **6**, 10170 (2015).

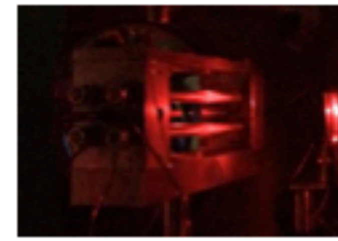
** W. Bang *et al.*, Scientific Reports **5**, 14318 (2015); W. Bang *et al.*, Phys. Rev. E **92**, 063101 (2015);
W. Bang *et al.*, Scientific Reports **6**, 29441 (2016).

Los Alamos NATIONAL LABORATORY

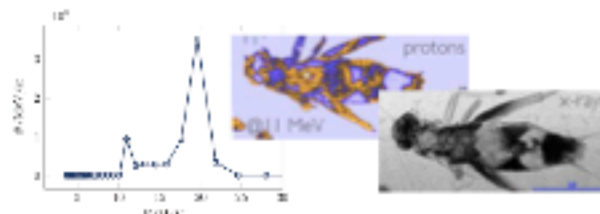
Jörg Schreiber L-I24 – Relativistic laser interaction with isolated micro-plasma

Stay tuned at
www.alpa.physik.uni-muenchen.de

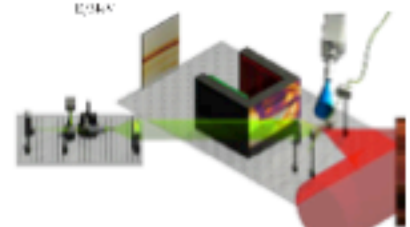
Desirable **Applications of Laser Particle Acceleration** rely on distinct features that the laser-driver can offer.



The high-intensity laser compatible Paul-trap based positioning of nano- and micro-targets allows studying plasmas with parameters otherwise inaccessible.
Ostermayr+, RSI 89, 013302 (2018).



Coulomb explosion provides narrow energy spread proton emission in 4π (and simultaneous emission of X-rays), an interesting aspect for imaging applications.
Ostermayr+, PRE 94, 033208 (2016).



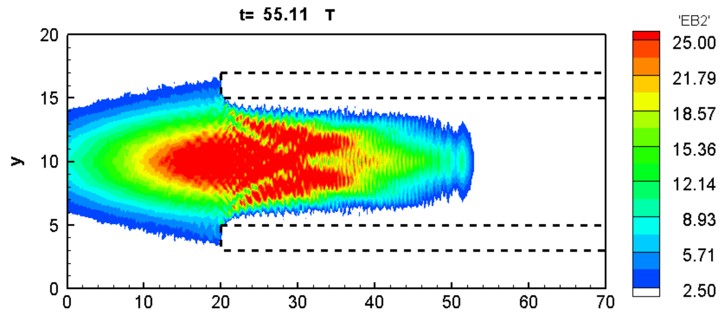
3-dimensional microscopic near-critical plasmas can be achieved by targeted pre-expansion and will guide optimization of **coherent acceleration** processes.
Hilz+, Nat Comm 9, 423 (2018).

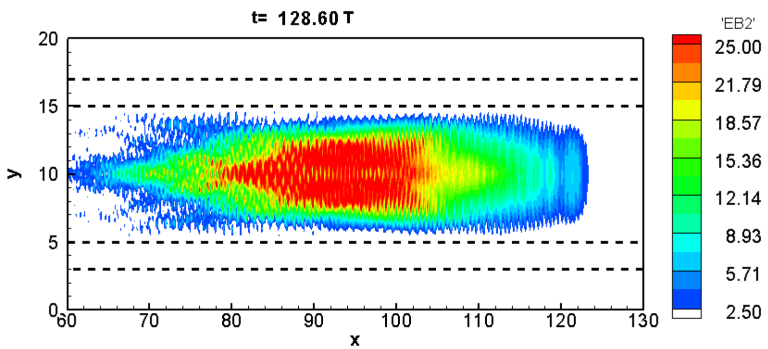
ATLAS 3 PW
www.cala-laser.de/en/instruments/light-sources.html#c2

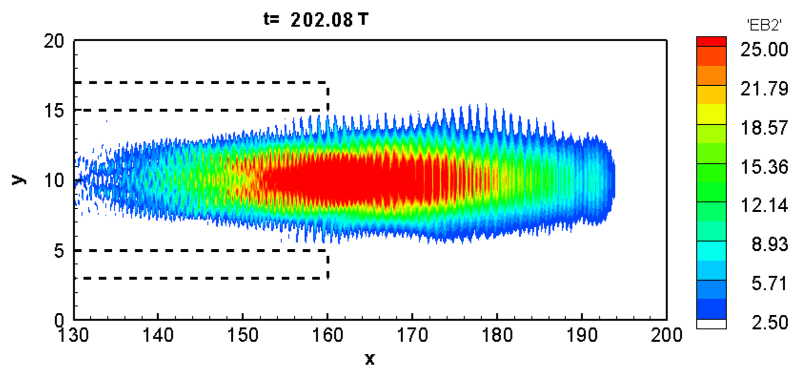
Commissioning experiments at the LMU-operated **3 Petawatt** ATLAS system at the **Centre for Advanced Laser Applications (CALA)** start.

Joerg.Schreiber@lmu.de

EM field energy density







Typical snapshots of EM field energy density at three moments when the laser pulse

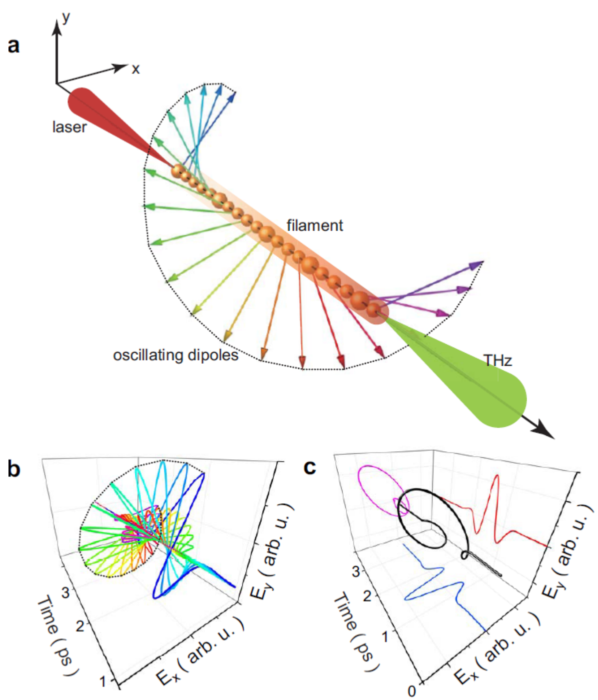
- **at the entrance when t=55.11T**
- **in the middle part of capillary**
- **at the exit when t=202.08T.**

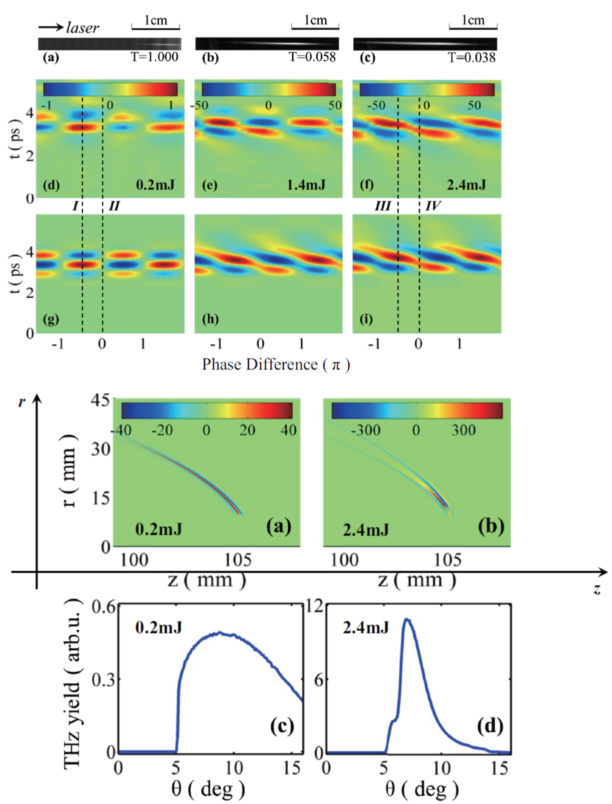
Radiation sources

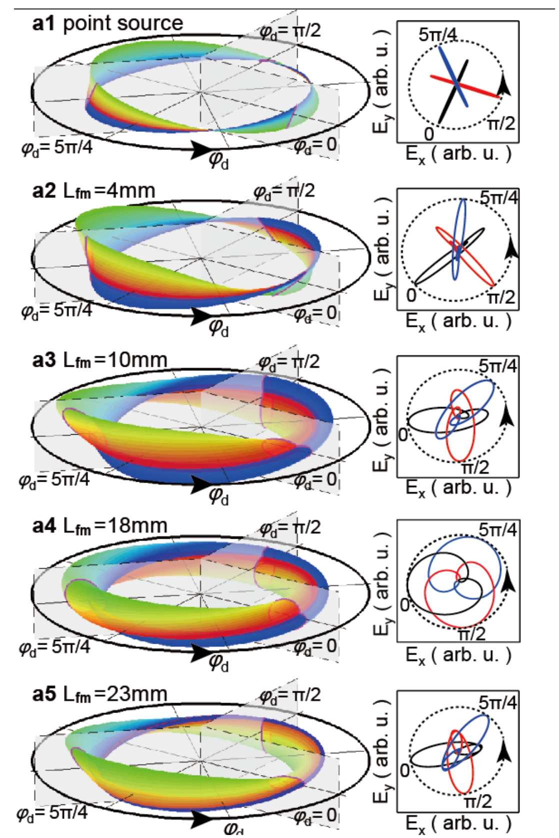
- THz emmision: Both U30(Zhelin Zhang) and U40(Wei Min Wang) awards on THz works. Yutong Li (novel large energy THZ source).
- Gamma ray emmision: Liming Chen, Alexey, Arefiev.

Controllable broadband terahertz radiations from laser driven air plasmas

- We demonstrate an effective control on the carrier-envelope phase and angular distribution as well as the polarization state, including the ellipticity and the azimuthal angle of a nearly single-cycle terahertz pulse emitted from a plasma filament formed by two-color laser pulses propagating in air.
- A linear-dipole-array model, including the descriptions of both the generation (via laser field ionization) and propagation of the emitted terahertz pulse, is proposed to present a quantitative interpretation of the observations.





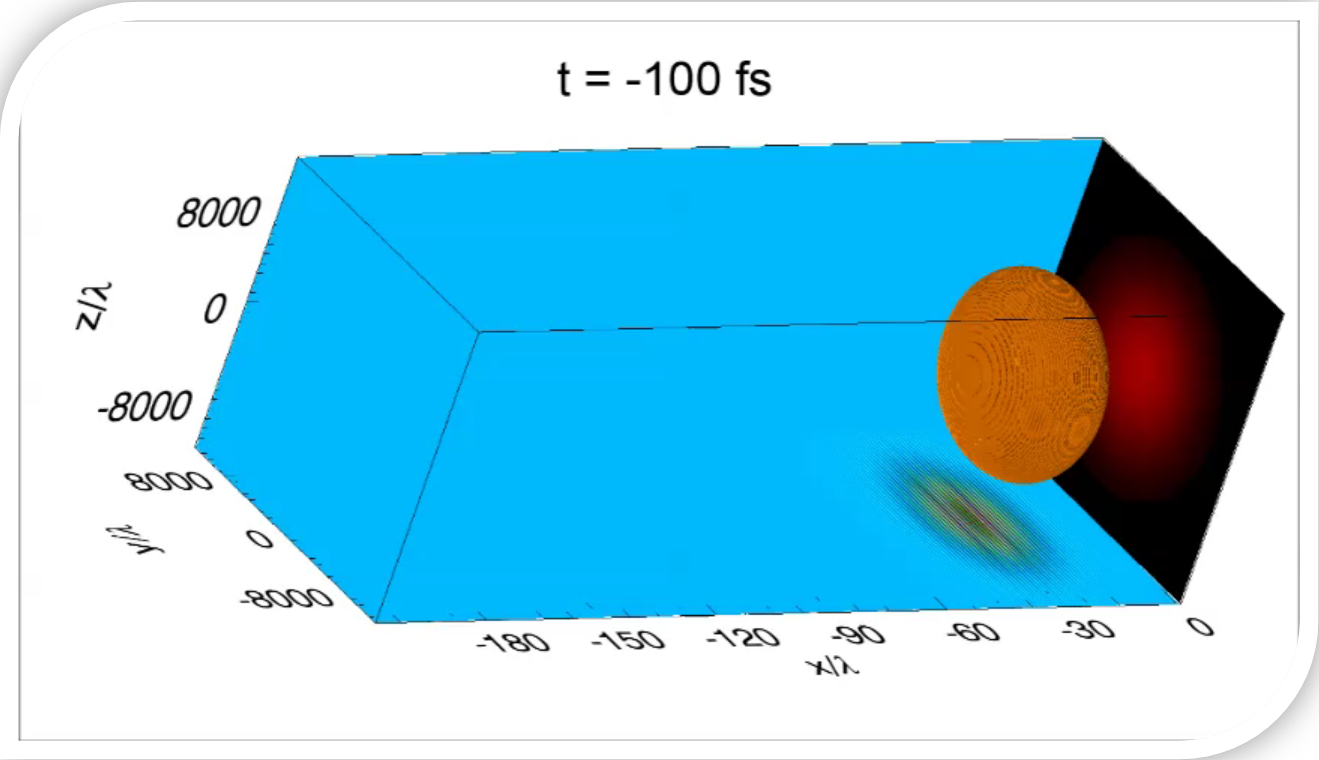


Phys. Rev. Lett., **117**, 243901 (2016).

Nat. Photon., **12**, 554 (2018).

Novel concepts: Plasma Polarizers: Extreme case of Faraday effect

Splitting of ultrashort laser pulses in a magnetized plasma



t_p=50 fs
($\Delta\omega/\omega_0 \sim 0.029$)
B= 1000 T
($\omega_c/\omega_0 \sim 0.1$)

a=0.1
w_0=6800λ
10 PW

1st sub-pulse (LCP): the endpoint of E rotates anti-clockwise.

2nd sub-pulse (RCP): the endpoint of E rotates clockwise.

S. M. Weng *et al.*, Optica 4, 1086 (2017).

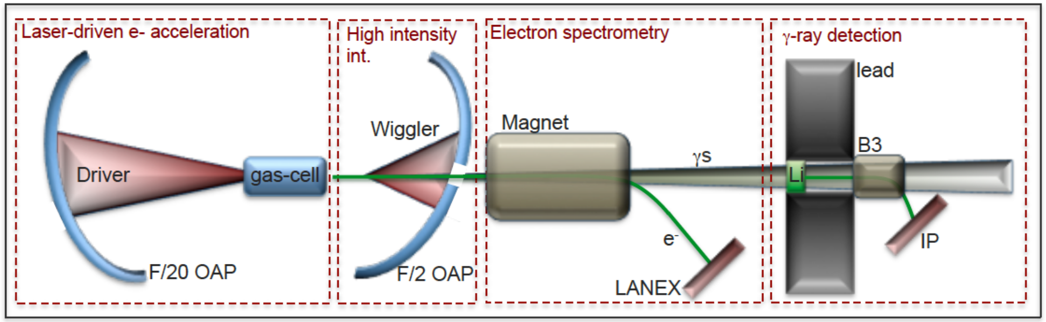
Interesting reviews on ongoing activities

- R. Kodama (Japanese programs), G. R. Kumar (India), Landen and Bruce Remington(NIF),

Kodama: Japanese Program Osaka Univ, Gekko laser etc. Miniariazation and better beam quality in laser acceleration, the HED Science, Elucidated challenging frontier problems, Vacuum quantum optics, EPOCh millenium goals, achievement of strong magnetic fields.

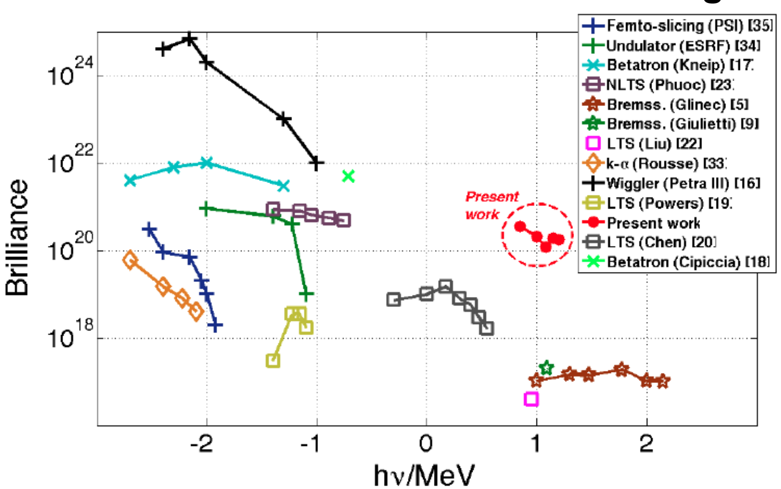
Radiation Reaction in a purely optical setup

Studied the interaction between an electron beam and a high-intensity laser



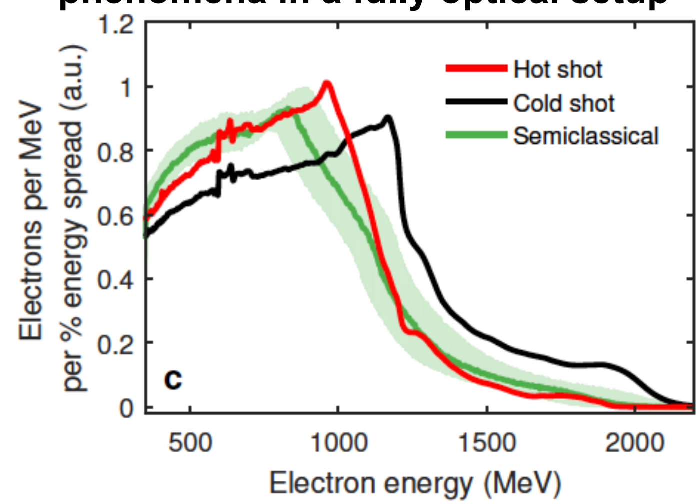
Main findings:

Gamma Ray Source from Non-Linear Thomson Scattering



A large flux of high-energy photons is emitted due to NLTS with a quality of interest for applications

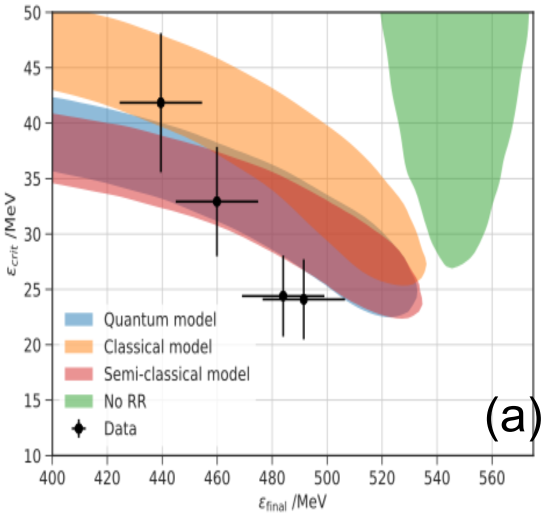
First experimental observation of high-field QED phenomena in a fully optical setup



Radiation reaction directly measured in the laboratory will allow to test theoretical models and predictions

a.alejo@qub.ac.uk / g.sarri@qub.ac.uk

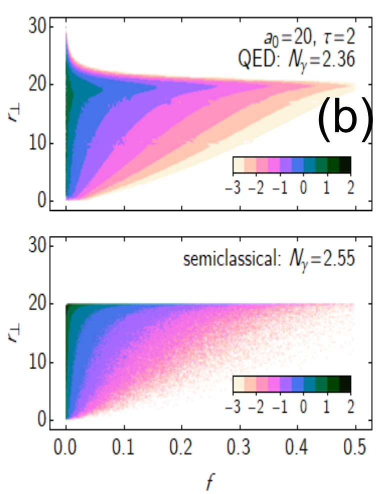
Radiation reaction in laser-electron-beam interactions
Tom Blackburn, Chalmers University of Technology

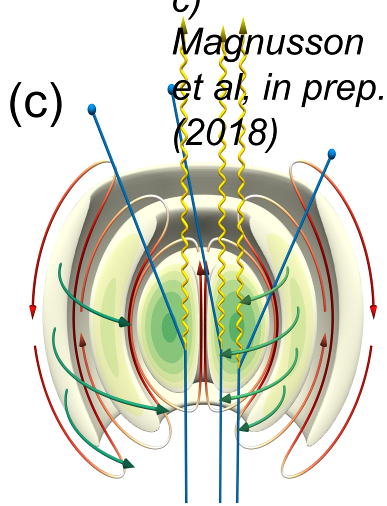


a) Cole et al, PRX 8, 011020 (2018)

b) Blackburn et al, PoP 25, 083108 (2018)

c) Magnusson et al, in prep. (2018)

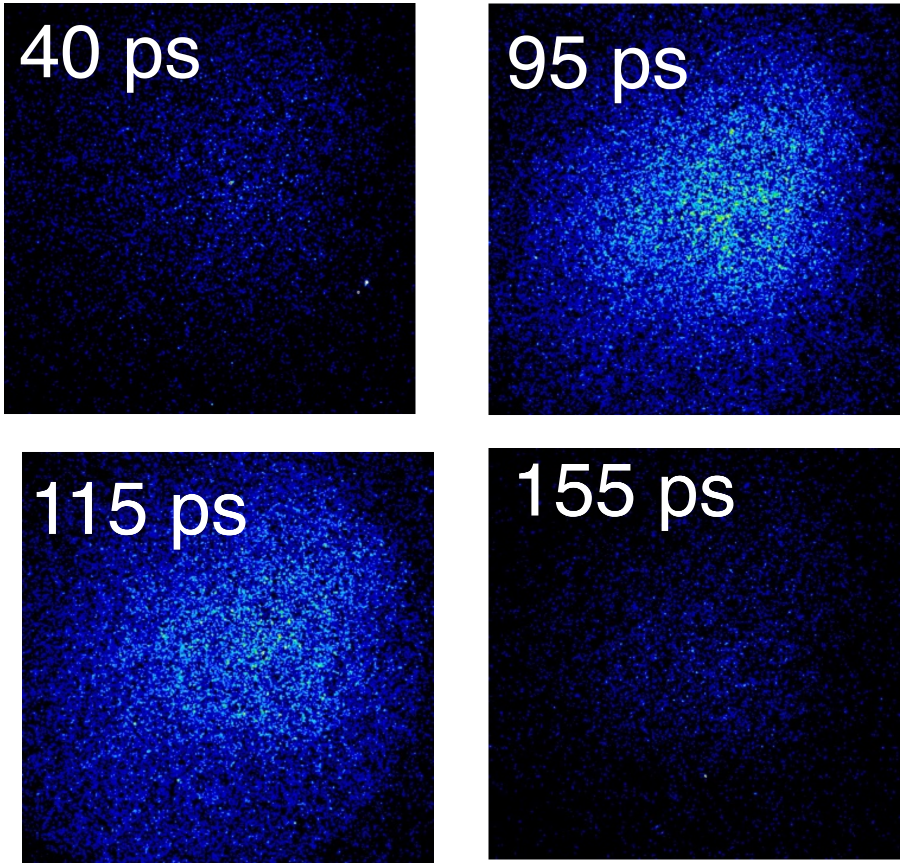


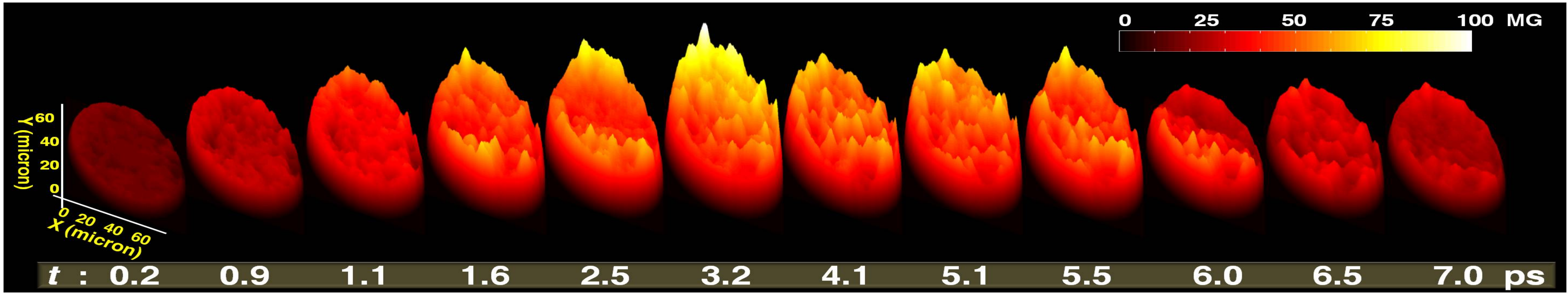


- Experimental exploration of radiation reaction with high-intensity lasers is underway, investigating the same nonlinear QED effects that will be prolific in next-generation laser facilities.
- While there is evidence of radiation reaction, at present the uncertainties prevent differentiation between quantum models.
- Comparison between exact QED results and the "semiclassical" Monte Carlo algorithm in PIC codes indicate the latter works

Indian exptal program by GRK

- Tracking REBs : Cherenkov emission using appropriate gating scheme.
- Magnetic field generation and turbulence. Lab astrophysics explorations.
- THz acoustics, shocks etc.



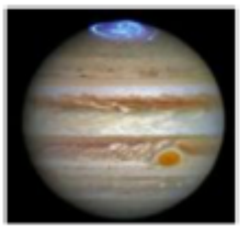


The NIF Discovery Science program allows scientists (external and internal) to pursue basic science on NIF

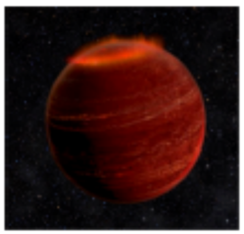
We are currently executing the Discovery Science NIF shots for the 11 teams allocated time in the Nov. 2017 TRC review

EOS

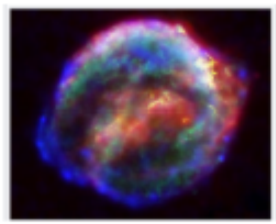
Jeanloz (UCB), gas giant planets



Falcone (UCB), EOS of WDM relevant to brown dwarfs

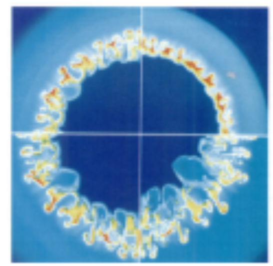


Kuranz (U. Mich.), radiative supernova remnant shocks



Hydrodynamics

Kline (LANL), turbulent RT in cylindrical geometry

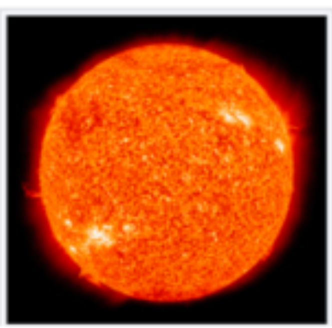


Casner (Univ. Bordeaux and CEA), Landau-Darrius flame instability

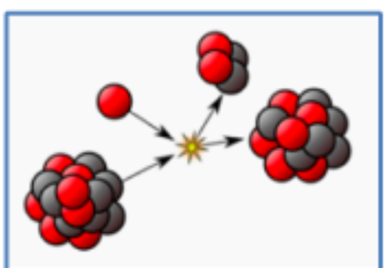
Meyers (UCSD), extreme materials science

Nuclear

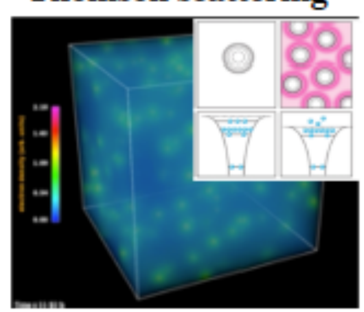
Gatu-Johnson (MIT), stellar nuclear reactions



Berzak-Hopkins (LLNL), plasma nuclear reactions

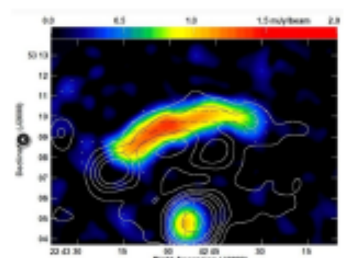


Doeppner (LLNL), dense plasmas, x-ray Thomson scattering

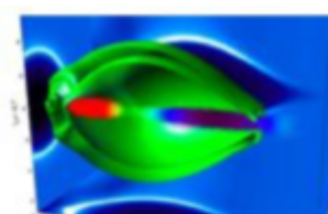


Plasma

Pollock (LLNL) magnetic fields in the universe



Albert (LLNL), plasma wake-field particle acceleration



The NIF Discovery Science program issues a call for proposals annually

Proposals for experiments in many facility

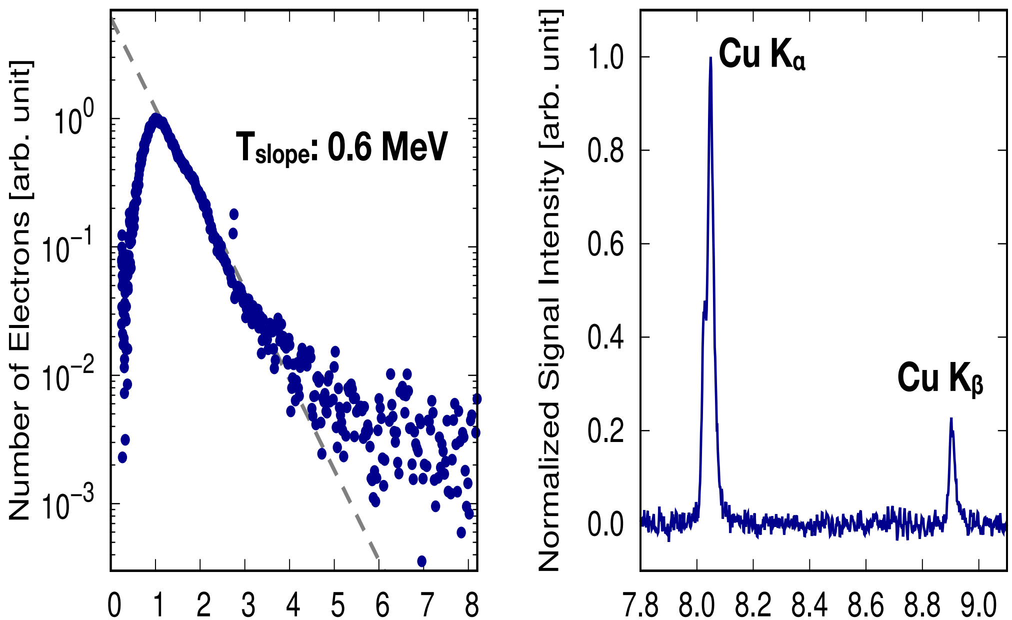
- SACLA XFEL system: T. Yabuuchi
- Gekko XII, LFEX: Mitsuo Nagai
- NIF : Remington

experiments in combinative use with XFEL at SACLA

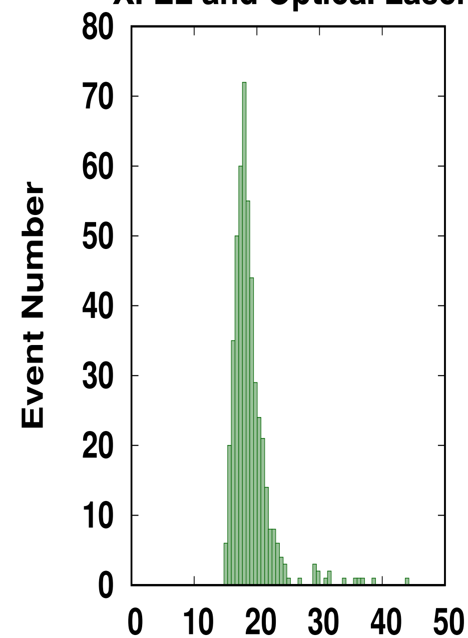
- Experimental platform using high intensity laser and x-ray free electron laser (XFEL) is now open for international users from 2018 at SACLA in Japan.

- High-intensity laser is currently operated for early users' experiments at the power of ~200 TW (~8 J/~ 40 fs) in combination with XFEL. The timing synchronization is achieved with a jitter of ~20 fs (rms).

Electron and X-ray Spectra produced by High-intensity Laser



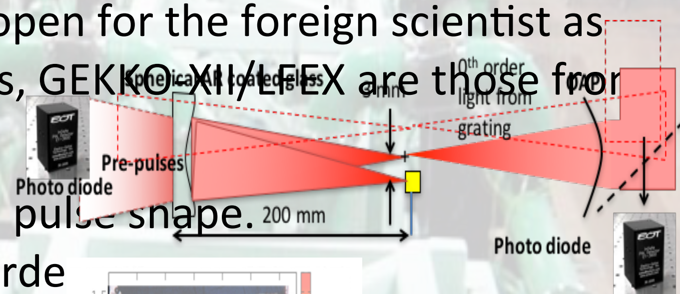
Timing Jitter Between XFEL and Optical Laser



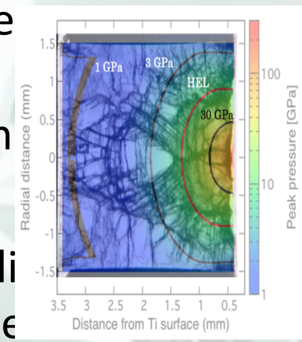
Joint usage / joint research program of GEKKO-XII/LFEX at ILE, Osaka University

Mitsuo Nakai

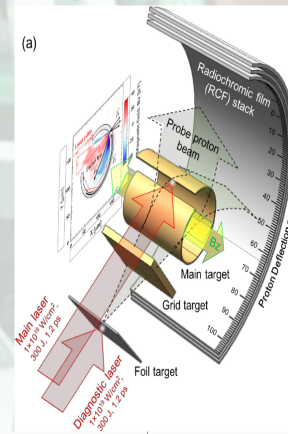
- The institute of Laser Engineering, Osaka University is a national users facility in Japan as a Joint usage / Research center, but is internationally open for the foreign scientist as well. About 1/4 to 1/3 of the projects using large lasers, GEKKO-XII/LFEX are those for abroad.



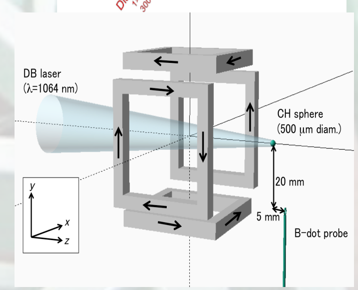
- Recent improvements on lasers
  1) A new fiber oscillator was installed to get an arbitrary pulse shape.
  2) Shperical plasma mirror was adapted for the LFEX in orde increase the contrast ratio and to change the illumination direction



- Example and progress of planned subjects
  1) Laser Earth & Planetary Science :
     Two types of recovery target sets were successfully utili
  2) Plasma Sciences with Laser-Produced Strong Magnetic Fie
     "Capacitor-Coil Target " was revisited to generate the magnetic field of 1 kT
     and demonstrate the "Magnetized fast isochoric laser heating ".
     A new scheme to generate the B field as high as 10 kT was demonstrated and
     the generation of 6 kT B field was inferred by proton deflection imaging.



- Example of general subject
  Establishment of Thrust vector control technique by using a multiple-coil magnetic nozzle.



- Future perspective J-EPoCH was proposed as the future high power laser facility for the high energy density science

The NIF Discovery Science program issues calls for proposals once a year in May, with proposals due in September, decisions made by the end of November, and shots start ~1 yr later

Calls for NIF Discovery Science proposals are issued annually in May

Letters of intent are due in June

Feedback is provided in July

Full proposals are due at the beginning of September

Oral presentations are in late Oct. or early Nov.

Decisions are communicated by late November or early December

For the successful teams, experiments start typically in 1 - 2 years, depending on the complexity and requirements

Awards are for 1, 2, or 3 days, with 1 day corresponding to 1-3 shots

The cost of the targets and shots is covered by NIF

More info. at the NIF User Office website: https://lasers.llnl.gov/for_users/

Experiments start about ~1 yr after the allocations are announced, and it usually takes ~1.5 yrs to complete an allocation of 1-3 days

The NIF Users Meeting in Feb. would be useful to attend, if you are interested

My impressions

- Importance of fundamental plasma issues - highlighted by many speakers – Bob Bingham, Kodama.
- Discovery science at NIF

My take

- On strong magnetic field generated in lab – Is very important and will soon open up a new area of interest- heating and absorption of laser energy in magnetized plasma experimentally – (in tokamaks the geometry has been complicated). The magnetic fields at such scales in future may lead to bringing MCF and ICF concepts together in future for smarter devices for confining plasma using the best of both designs.

Thank You!

High-M_A-number collisionless magnetized shock generated by the interaction of a laser-driven plasma flow with a magnetized ambient plasma

- Magnetized ambient plasma made possible at OMEGA EP using MIFEDS
- Shock formation is reproduced in particle-in-cell simulations appropriately initialized and constrained by measured density profiles.
- Shocks form within $\sim 1\ \omega_{ci}^{-1}$, as indicated by density and magnetic field compressions, reflected ions, and a hot downstream region

D.B. Schaeffer, W.Fox, D. Haberberger, et al. PRL (2017)

Particle velocity distributions measured in developing magnetized collisionless shock

- Direct observation of interaction between piston and ambient plasmas
- Deformation of piston and ambient ion flows, magnetic compressions indicate onset of shock formation

D.B. Schaeffer, W.Fox, R.K. Follett, et al. arXiv:1811.01528

Outlook

- Laboratory experiments now allow detailed measurements of magnetized shocks
- Can address questions of particle acceleration, energy partition, etc. and complement spacecraft observations and remote sensing.

PPPL

Conclusions (Bob Bingham)

Parametric instabilities are as important as ever.

New applications eg. Raman/Brillouin amplification. Will Raman amplification succeed soon?

Model for Cross beam energy transfer demonstrates complexity.

White light effects:

- Reduces Brillouin significantly, RBS reduces
- Growth rates for RFS and RMI can increase.
- Range of unstable wavenumbers increases with increasing bandwidth for RFS and RBS.