LASERFUSIONX

FUSION POWER ASS0CIATES
45th Annual Meeting and Symposium
Fusion Energy: Progress, Challenges and Promise

SMALLER LOWER-COST LASER-FUSION POWER PLANTS UTILIZING A UNIQUELY CAPABLE LASER TECHNOLOGY

Deep UV light from the argon fluoride (ArF) laser would enable the high gain needed for IFE with much less energy than utilized for NIF ignition.

Presented by Stephen Obenschain

Fusion Power Associates Meeting

Washington DC, Dec 2-3 , 2024

Malcolm McGeoch, PLEX LLC
Matthew Levy, AE Blue Capital

Why IFE with the Argon Fluoride (ArF) Laser using Direct Drive ?

Direct-drive is much more efficient than indirect – approx. 6x with ArF's deep UV light

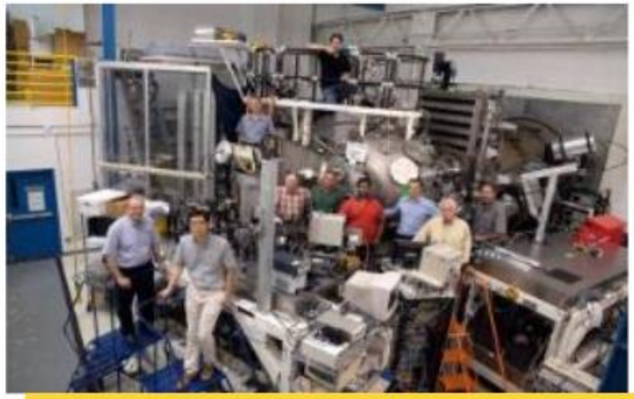
In regard to the similar KrF laser

- ArF has capability for much higher bandwidth – KrF's 2.7 THz FWHM bandwidth demonstrated on Nike vs ArF's 11 THz FWHM bandwidth demonstrated on Electra
- ArF is expected to have 10% electrical efficiency vs KrF's 7 %
- ArF shares capability with KrF for ISI beam smoothing and easy implementation of focal zooming to follow an imploding target.

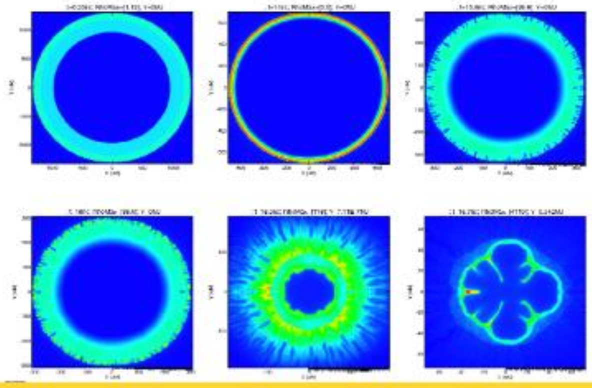
In regard to frequency-tripled solid-state lasers

- ArF's deep UV (193 nm) light results in higher efficiency DD implosions than 351 nm light and also helps suppress LPI.
- Higher ablation pressure with ArF enables more hydrodynamically stable implosions.
- ArF can more easily deploy broad bandwidth and focal zooming.

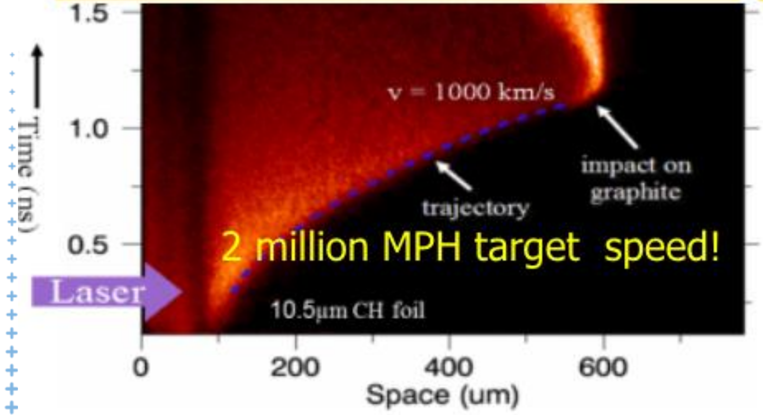
OUR APPROACH IS BASED ON ADVANCES IN ArF LASER TECHNOLOGY AND HIGH-GAIN TARGET DESIGN CONDUCTED AT THE US NAVAL RESEARCH LABORATORY (NRL)

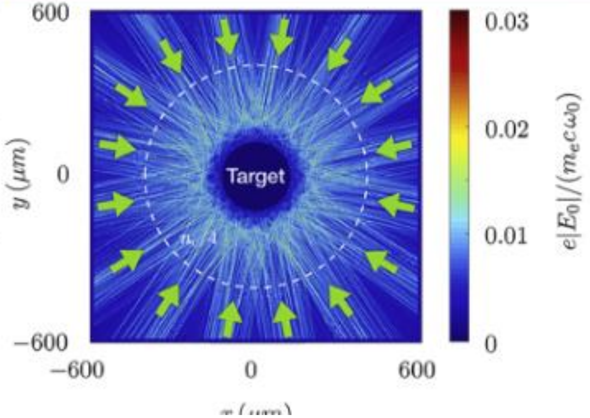


Laser target interaction experiments Nike KrF laser facility



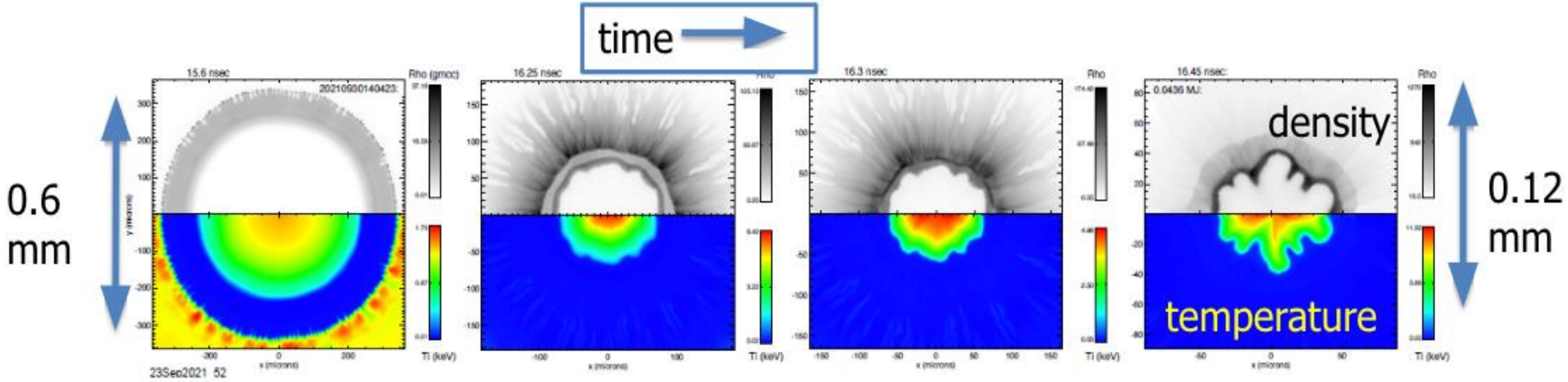
Simulation of a pellet implosion and of a laser-plasma instability





NRL 2D HYDROCODE SIMULATIONS INDICATE AN ArF LASER CAN ACHIEVE TARGET GAINS (>100X) NEEDED FOR LASER FUSION POWER PLANTS WITH MUCH LESS LASER ENERGY THAN USED BY NIF

Sample NRL 2D simulation of a 410 kJ ArF driven shock ignited implosion (20% of NIF's energy)

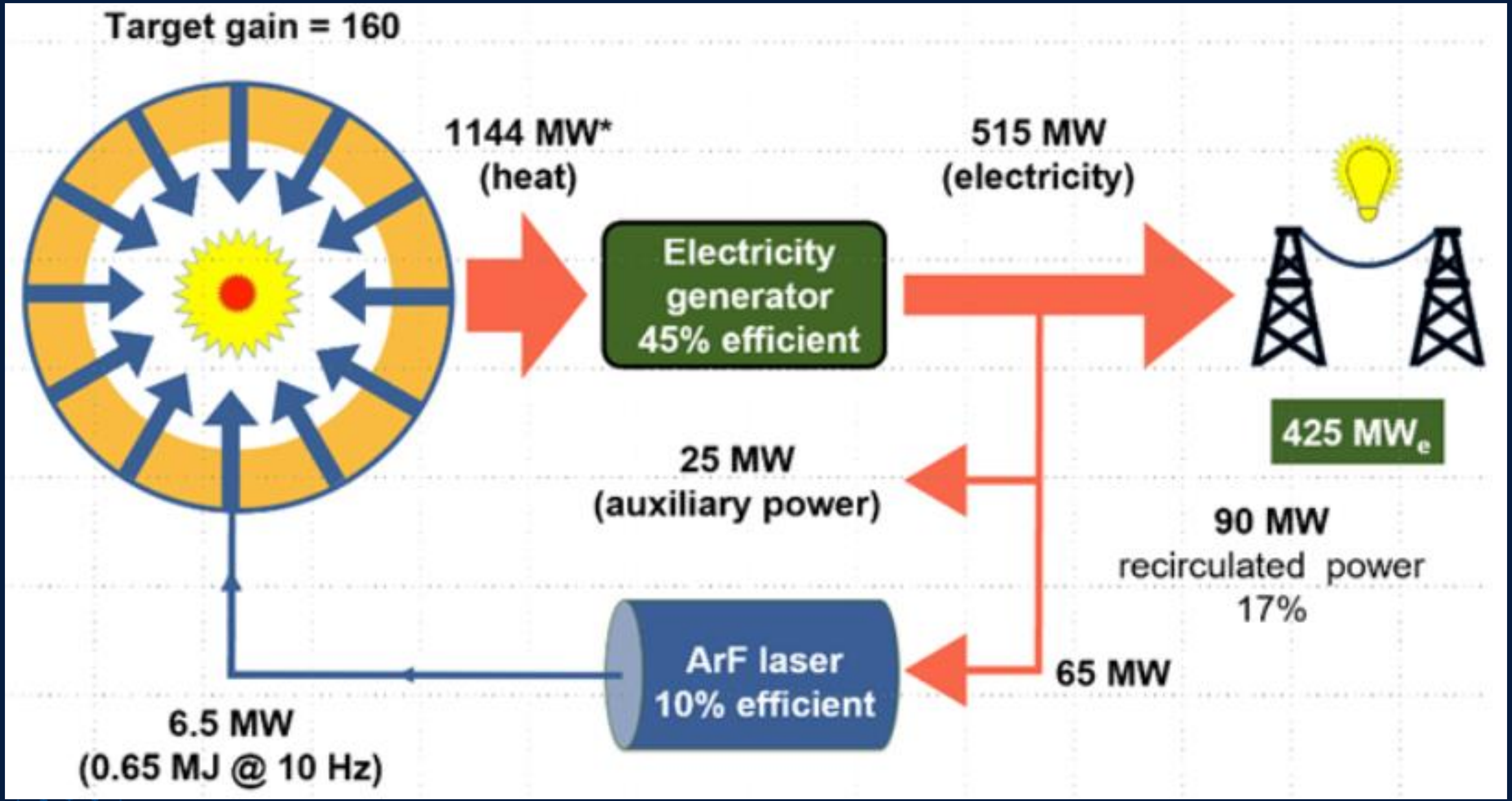


160x energy gain including effects of target imperfection

The importance of laser wavelength for driving inertial confinement fusion targets. II. Target design | Physics of Plasmas | AIP Publishing

POWER FLOW IN A 425 MWe ArF LASER FUSION POWER PLANT USING ONLY 1/3 OF NIF'S ENERGY (0.65* MJ)

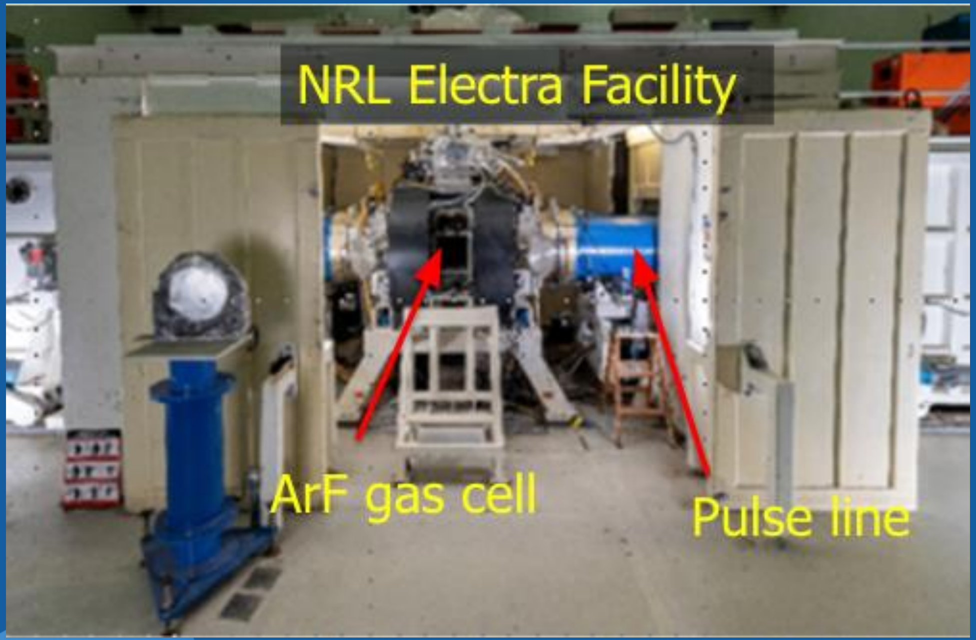
*Gain is from previous slide 2d simulation with 59% energy contingency



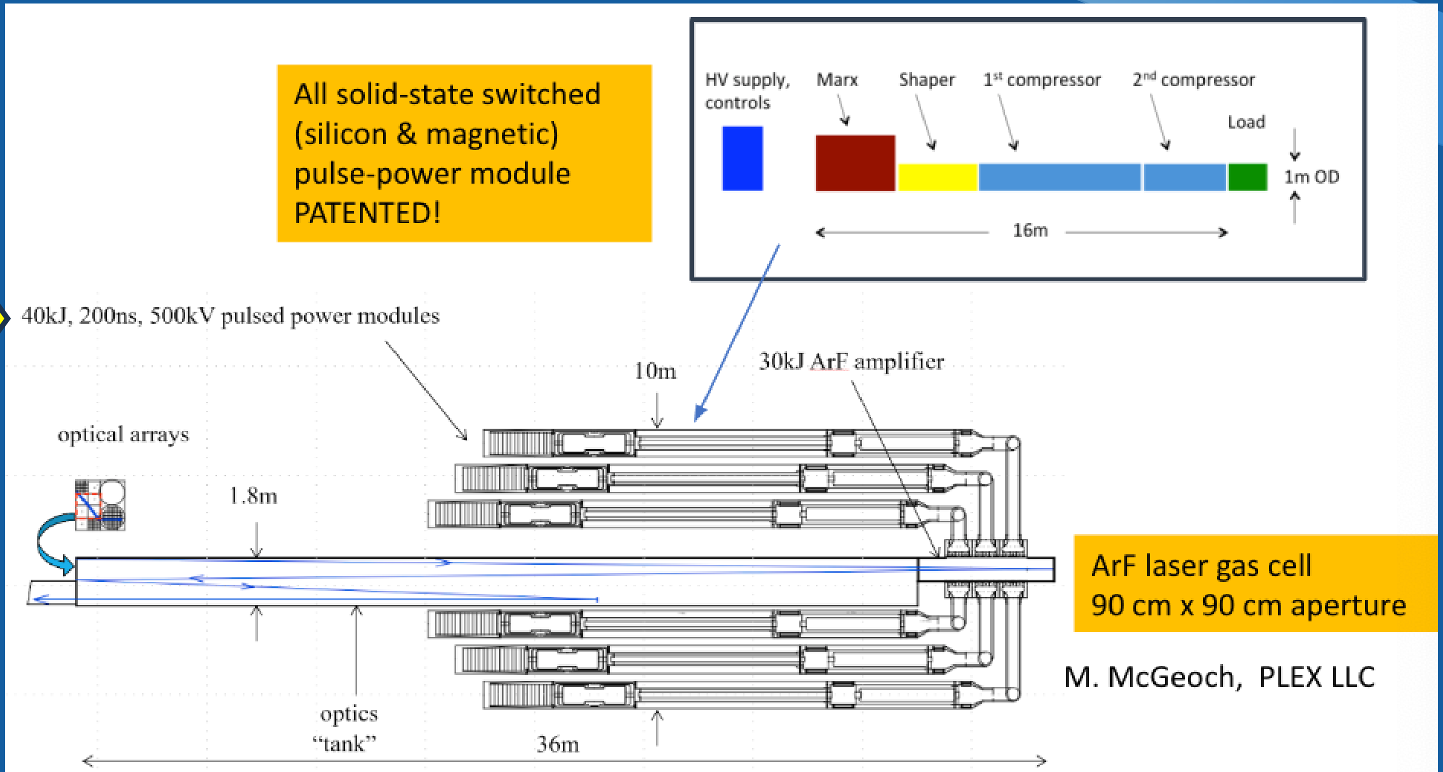
High predicted gain with ArF direct drive allows most of the generated power to go to the grid

*Additional 10% energy from nuclear reactions in the lithium containing "blanket" in the reactor chamber

PATH FROM THE NRL 200-J ELECTRA ELECTRON-BEAM-PUMPED ArF LASER TO A 10-HZ 30-KJ ArF BEAMLINE ADEQUATE FOR IFE IMPLOSION FACILITY



- Demonstrated 5 pulse-per-second operation with similar KrF gas fill
- Converted to ArF to advance the ArF S&T
- World record ArF energy (200 J)
- Demonstrated 11 –THz FWHM bandwidth!



30-kJ 10-pulse-per-second 90-cm aperture ArF amplifier

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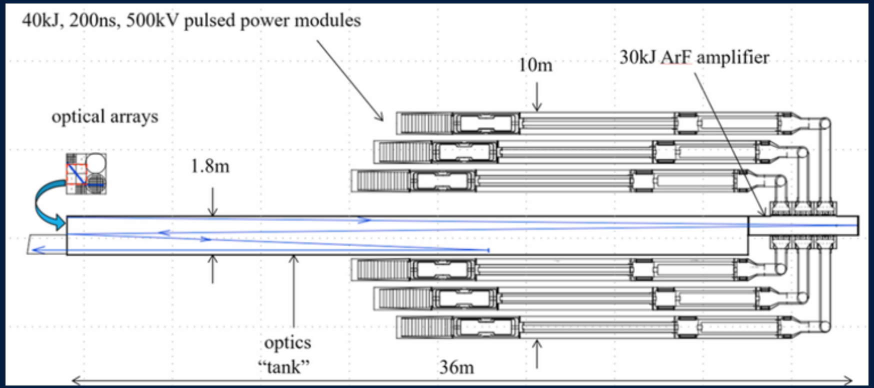
THREE PHASE PATH TO A PILOT ArF LASER-FUSION POWER PLANT

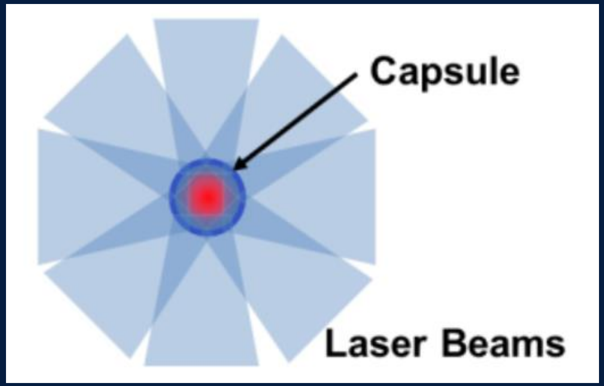
Phase I



Develop and operate 30 kJ ArF laser beamline

- Component for follow-on implosion facilities.
- Test ArF target physics.

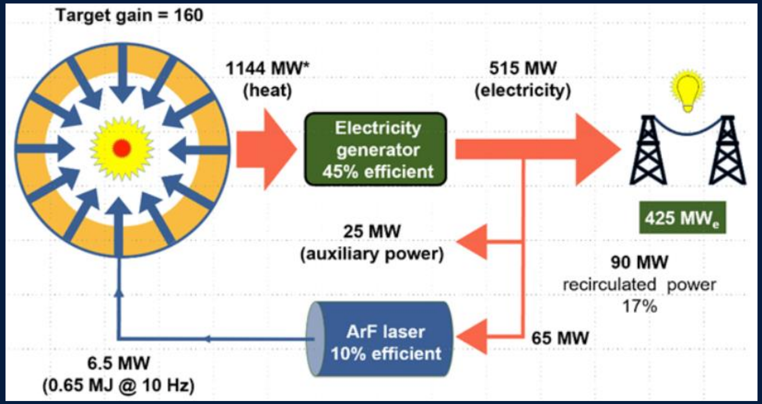
Phase II



High-gain implosion facility operating @ 100 shots/day

- Demo high gain implosions
- Develop components for pilot power plant
- Design pilot power plant

Phase III



ArF laser fusion pilot power plant

- E. g. 650 kJ ArF @ 10 pulses per second
- Test and advance components and procedures
- Generate electrical power 425 MW

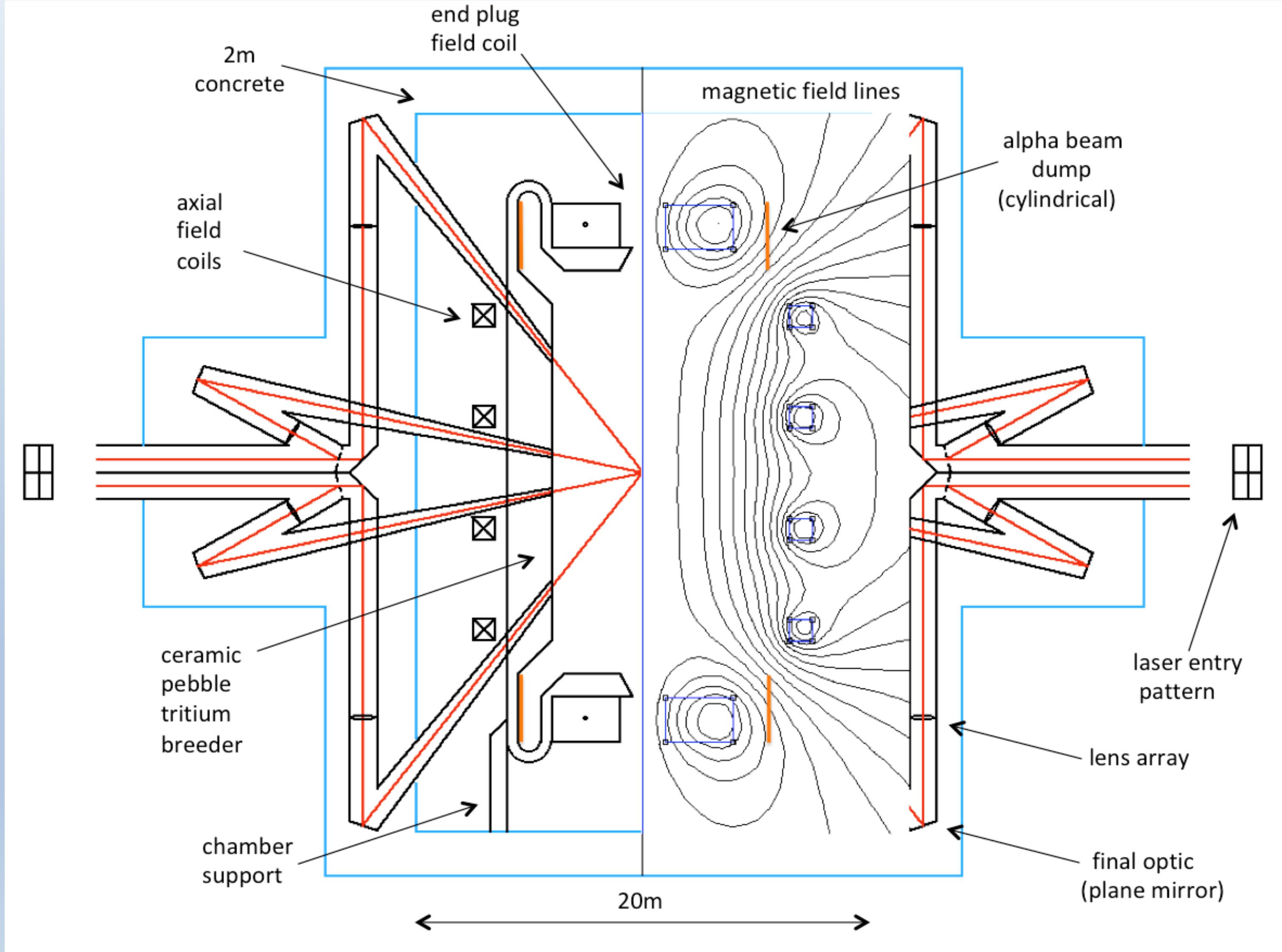
Experience with and advances by the pilot power plant would enable final design & mass deployment of fusion power plants

LaserFusionX Inc.

We plan to emphasize Tritium Breeding Ratio as a goal for the pilot power plant

TBR of the order of 1.3 is anticipated including structure
- neutrons enter blanket with >97% efficiency

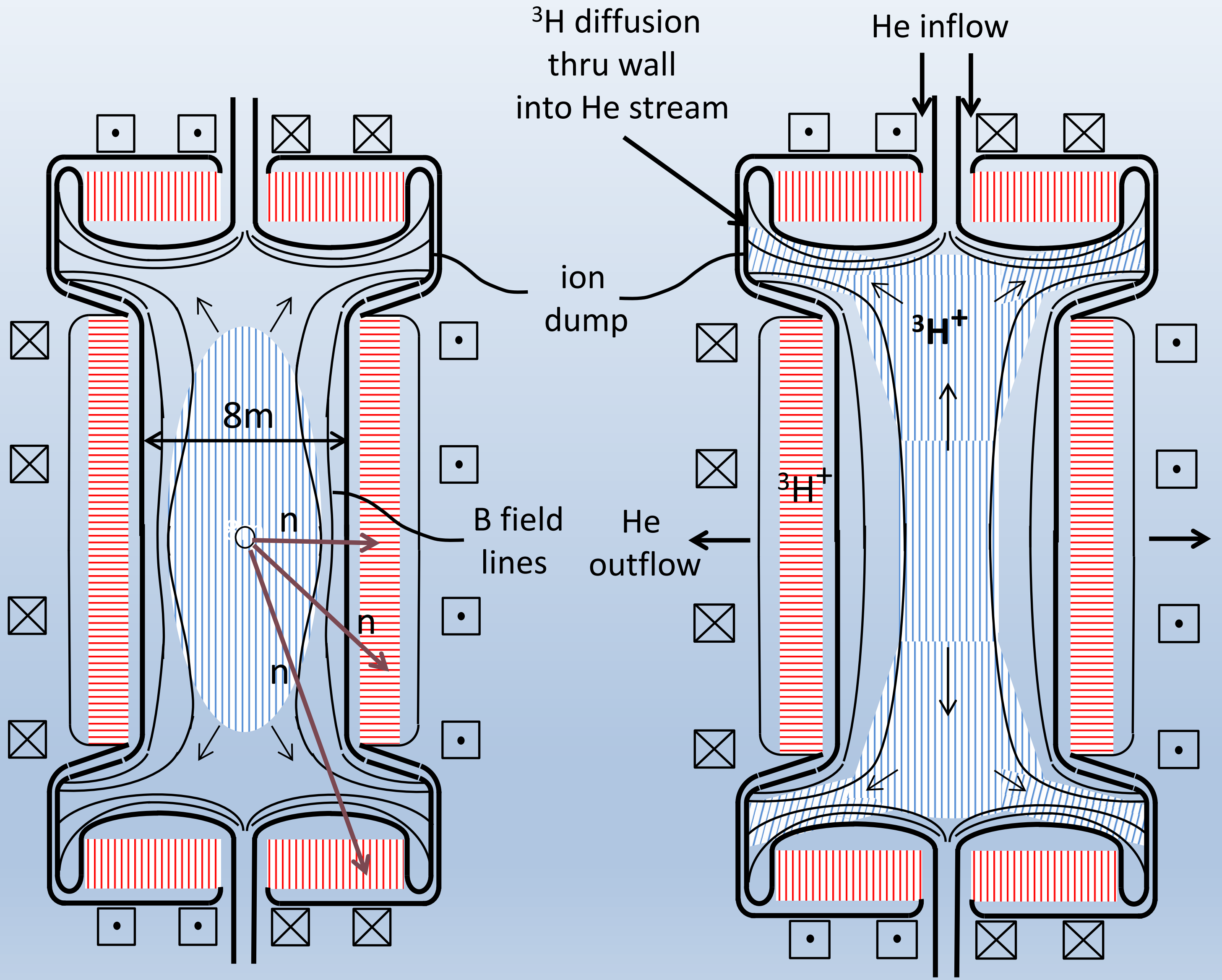
McGeoch and Obenschain
J. Fus. Energy (2024) **43**:23



LaserFusionX Inc.

Direct Tritium recovery should be possible, following up to 30% DT burn-up

Exhaust ^3H is guided to ion dumps followed by super-permeation [3] into He coolant flow



LaserFusionX Inc.

[3] C Li, A. J. Job ..and C. A. Wolden , *J. Nucl. Mater*. (2023) **582** 154484

THE VISION: A PLENTIFUL, SAFE, CLEAN ENERGY SOURCE

Slide by Dr. John Sethian

A 100 ton (4200 Cu ft) COAL hopper runs a 1 GWe Power Plant for 10 min

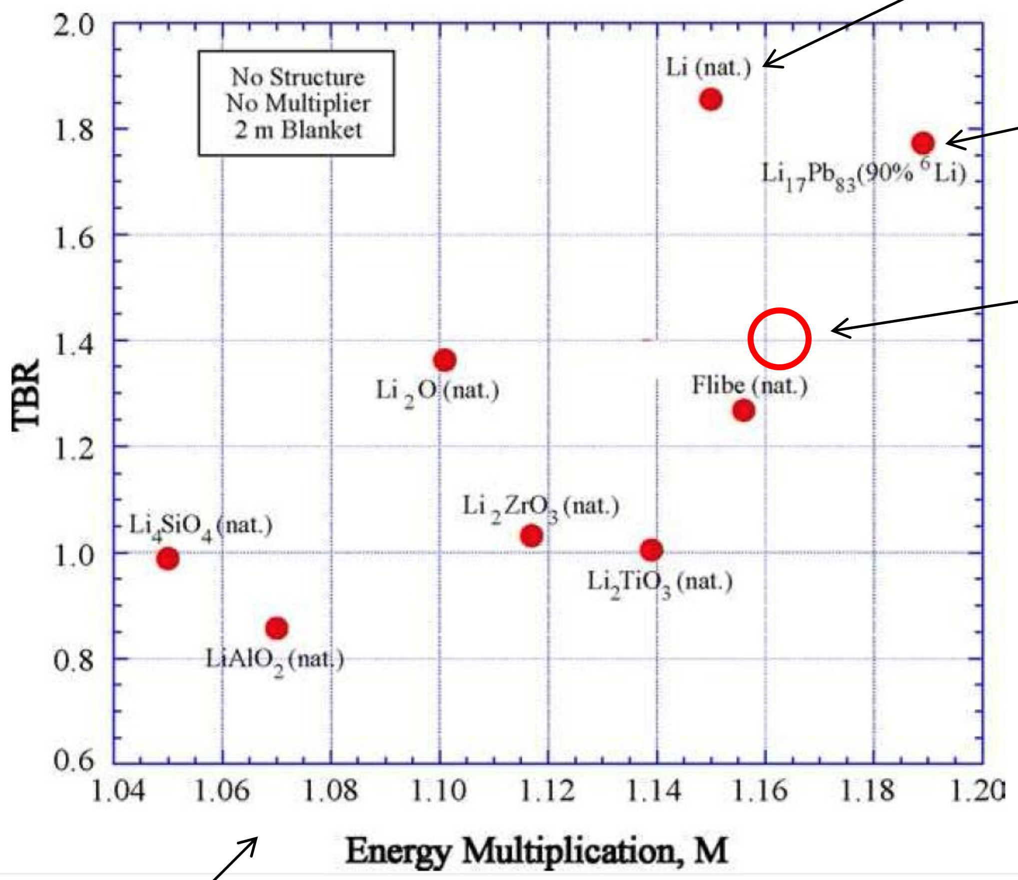
Same hopper filled with laser fusion targets: runs a 1 GWe Power Plant for 7 years

Extra Slides

Idealized 2m blanket Tritium Breeding Ratios, no structure

Li (nat) liquid

$Li_{17}Pb_{83}(90\%^6Li)$ liquid



Li_2PbO_3(nat) [2] ceramic
not optimized (lithium plumbate)

LaserFusionX plans to use He-cooled ceramics in Pb-optimized combinations, incl. Li orthosilicate/ metatitanate and $PbTiO_3$ pellets

>97% interception (LFX design)
<5% structure
<5cm Fe first wall
He pressure 5bar

[1] M. E. Sawan and M. A. Abdou, *Fus. Eng. Des.* (2006) **81** 1131-1144

[2] X. Gao, L. Zhao et al., *Nucl. Matl. Energy* (2024) **38** 101608

THE LASERFUSIONX APPROACH IS SUPPORTED BY A BROAD RANGE OF JOURNAL ARTICLES

target physics, ArF laser technologies, power plant S&T

- High-energy krypton fluoride lasers for inertial fusion, Stephen Obenschain, Robert Lehmberg, David Kehne, Frank Hegeler, Matthew Wolford, John Sethian, James Weaver, and Max Karasik, Applied Optics, Vol. 54, Issue 31, pp. F103-F122 (2015). https://www.osapublishing.org/ao/abstract.cfm?uri=ao-54-31-f103
- Mitigation of cross-beam energy transfer in inertial-confinement-fusion plasmas with enhanced laser bandwidth, J. W. Bates, J. F. Myatt, J. G. Shaw, R. K. Follett, J. L. Weaver, R. H. Lehmberg, and S. P. Obenschain, Phys. Rev. E 97, 061202(R) – Published 18 June 2018. https://journals.aps.org/pre/abstract/10.1103/PhysRevE.97.061202
- Production of radical species by electron beam deposition in an ArF* lasing medium, G. M. Petrov, M. F. Wolford, Tz. B. Petrova, J. L. Giuliani, and S. P. Obenschain, Journal of Applied Physics 122, 133301 (2017); https://aip.scitation.org/doi/10.1063/1.4995224
- J. D. Sethian and 87 other authors, "The Science and Technologies for Fusion Energy With Lasers and Direct-Drive Targets, IEEE Trans on Plasma Science 38, 690-703 (2010).
- Direct drive with the argon fluoride laser as a path to high fusion gain with sub-megajoule laser energy, S. P. Obenschain, A. J. Schmitt, J. W. Bates, M. F.Wolford, M. C. Myers1, M. W. McGeoch, M. Karasik and J. L. Weaver, Phil. Trans. R. Soc. A 378: 20200031. http://dx.doi.org/10.1098/rsta.2020.0031
- Implementation of focal zooming on the Nike KrF laser, D. M. Kehne, M. Karasik, Y. Aglitsky, Z. Smyth, S. Terrell, J. L. Weaver, Y. Chan, R. H. Lehmberg, and S. P.Obenschain, Review of Scientific Instruments 84, 013509 (2013); doi: 10.1063/1.4789313
- Development of a broad bandwidth 193 nanometer laser driver for inertial confinement fusion, M.F. Wolford, M.C. Myers, T. B. Petrova, J.L. Giuliani, T.J. Kessler, M.W. McGeoch, G.M. Petrov, A.J. Schmitt, T.A. Mehlhorn, S.P. Obenschain, High Energy Density Physics 36 (2020) 10080
- The importance of laser wavelength for driving inertial confinement fusion targets. I. Basic physics | Physics of Plasmas | AIP Publishing
- The importance of laser wavelength for driving inertial confinement fusion targets. II. Target design | Physics of Plasmas | AIP Publishing
- Journal of Fusion Energy (6/2024) https://link.springer.com/article/10.1007/s10894-024-00416-9