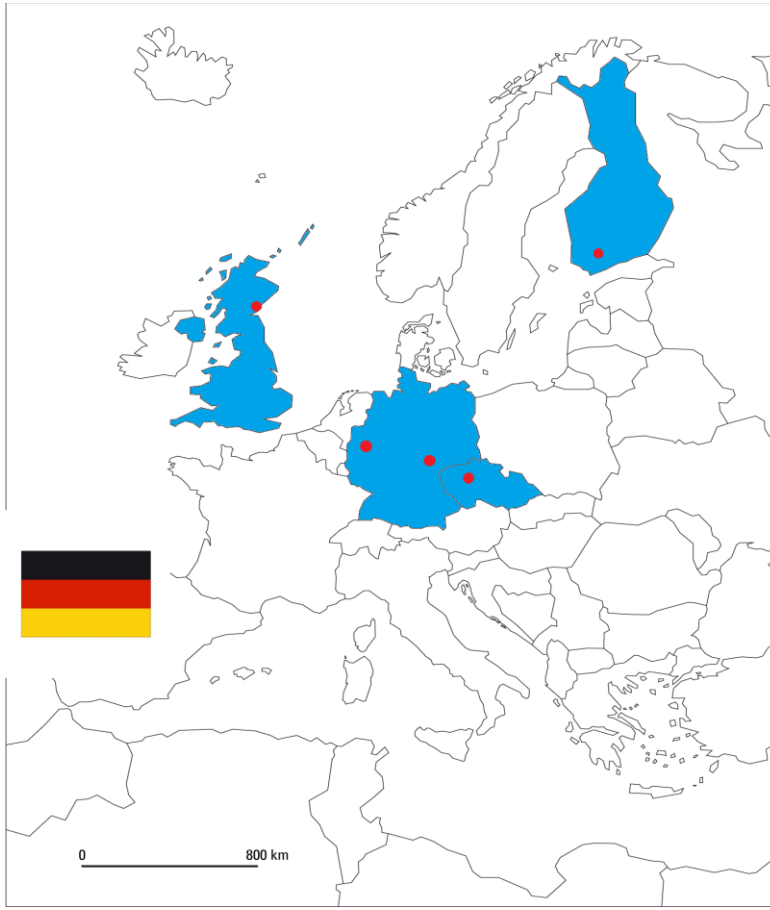
V4F PROJECT

MIROSLAV KRŮS
IN BEHALF OF V4F CONSORTIUM

CONSORTIUM

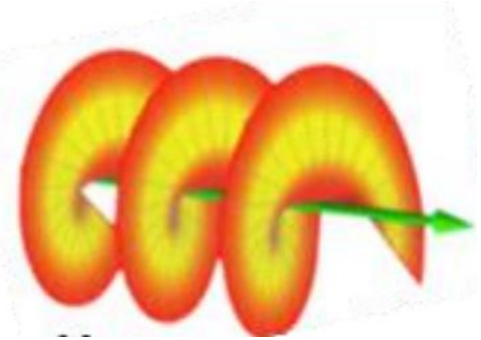
- **Tampere University**
  - Regina Gumenyuk (PI)
- **Institute of Plasma Physics**, Prague
  - Miroslav Krůs
- **Institute of Inorganic Chemistry**, Řež
  - Michael Londesborough
- **Leibniz Institute of Photonic Technology**, Jena
  - Katrin Wondraczek
- **Forschungzentrum Jülich** & Heinrich Heine Universtity Düsseldorf
  - Markus Büscher
- **Ampliconyx OY**, Tampere
  - Valery Filipov
- **MODUS Research & Innovation**, Dundee
  - Bridget Glaysher



- **interdisciplinary project:**
  - laser physics
  - laser chemistry
  - inorganic chemistry
  - computational physics
  - plasma physics

MOTIVATION

- **USE COMPLEX STRUCTURED LASER PULSES FOR NUCLEAR FUSION ENERGY**



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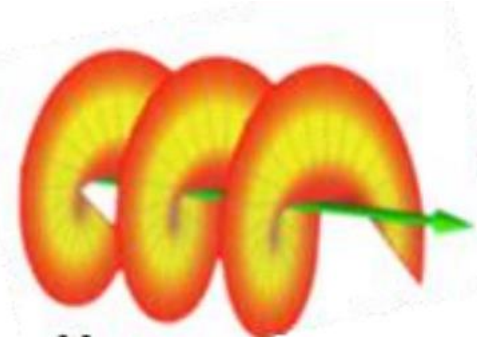
- **USE COMPLEX STRUCTURED LASER PULSES FOR NUCLEAR FUSION ENERGY**
  - WHY?



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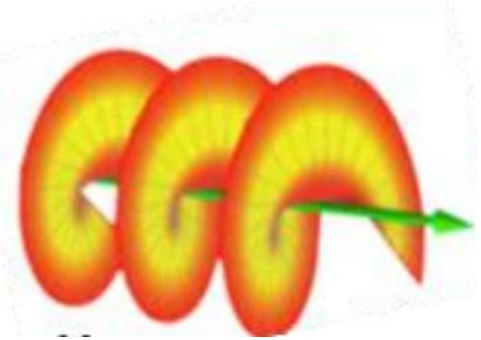

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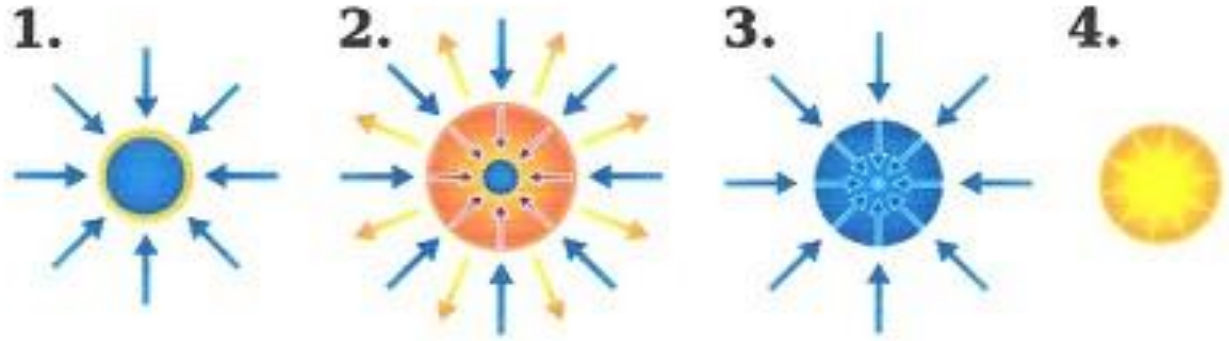
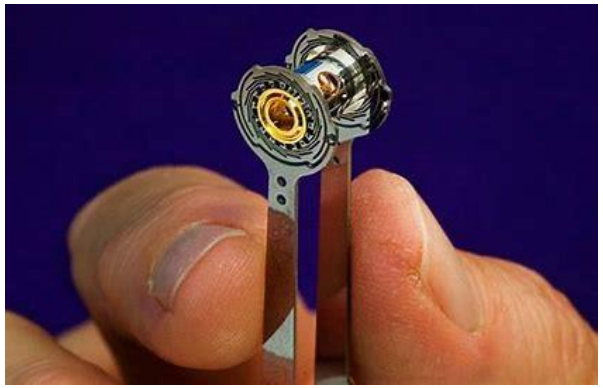
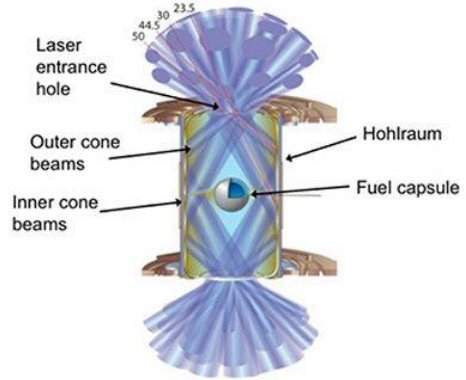


- **NUCLEAR FUSION BY LASERS**
  - direct drive
    - fuel is directly illuminated by high-energy laser(s)
    - difficult mainly due to laser beam profile
  - indirect drive
    - fuel is inside hohlraum
    - haser illuminates hohlraum walls
      - generated X-rays uniformly illuminate fuel

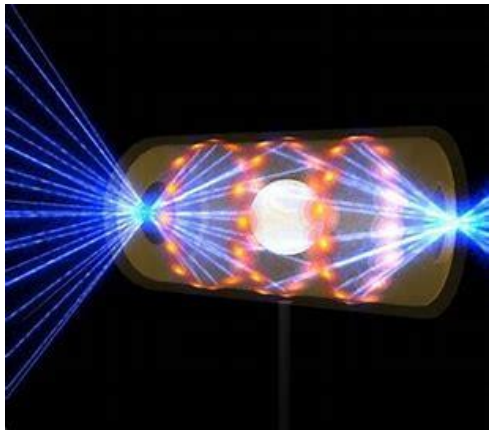


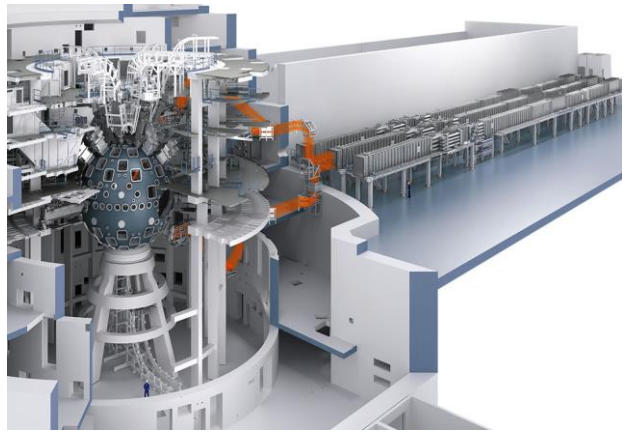


credit: LLNL

MOTIVATION

- **NATIONAL IGNITION FACILITY**
  - indirect drive
  - 2 MJ in light
    - 192 laser beams
    - 400 MJ for one laser shot
    - December 2022
      - produced 3 MJ





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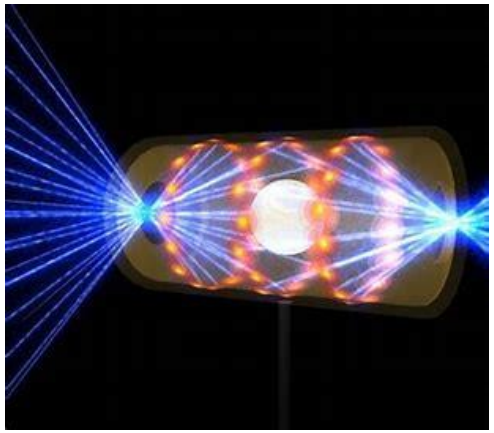
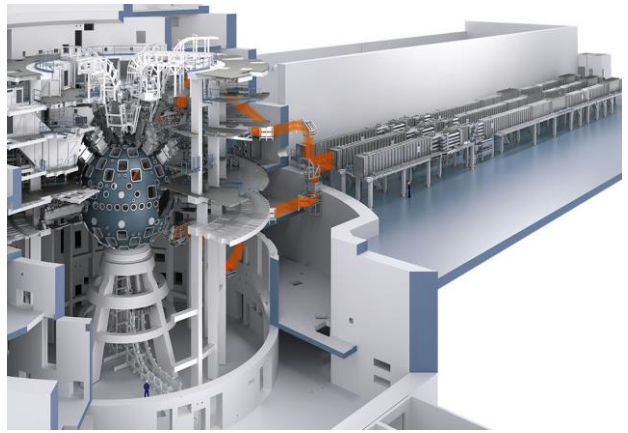

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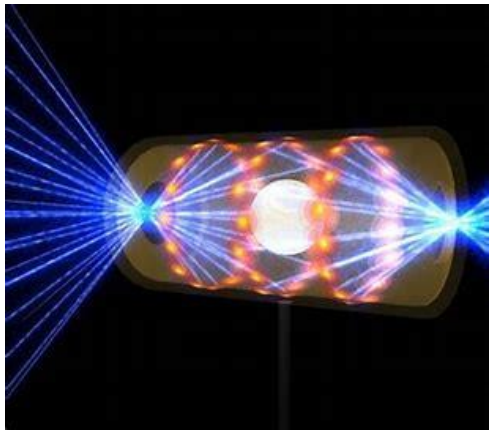

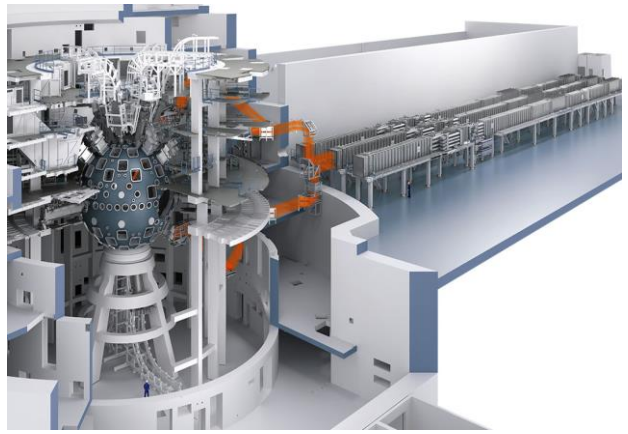

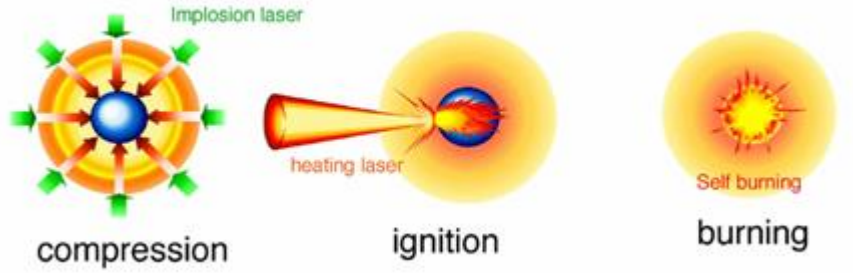

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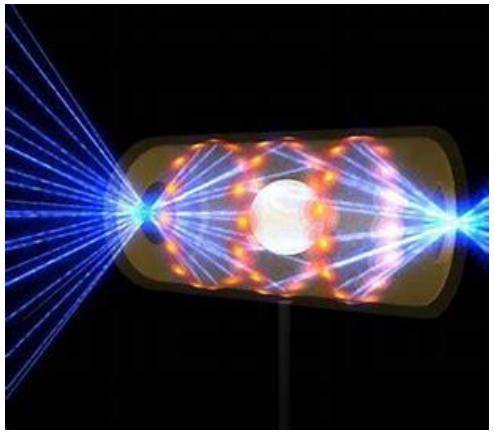

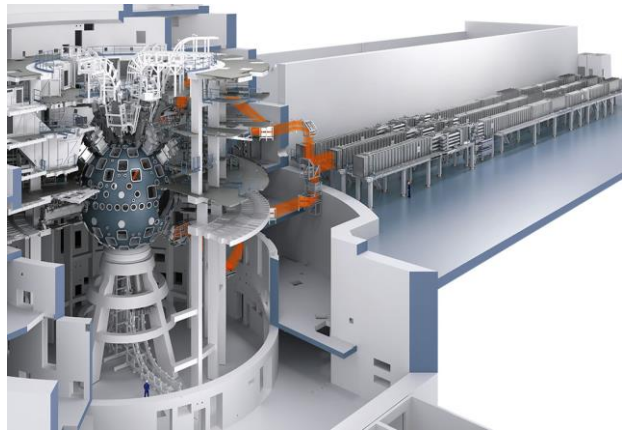

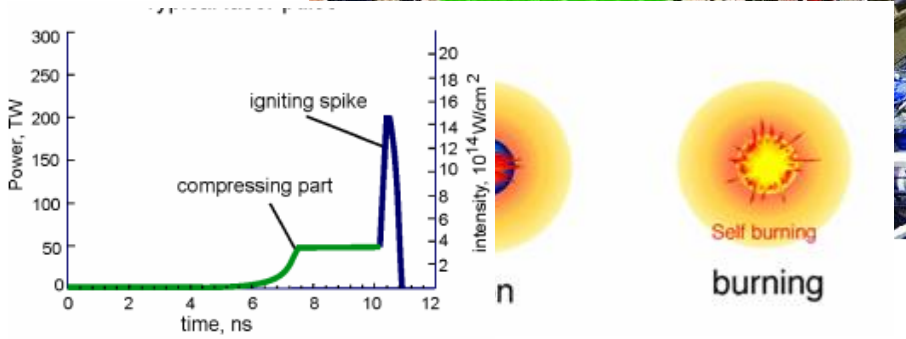

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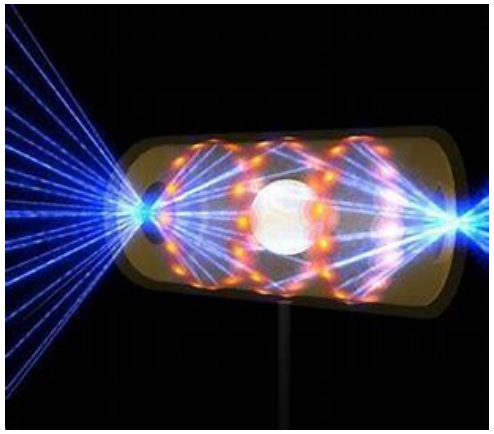

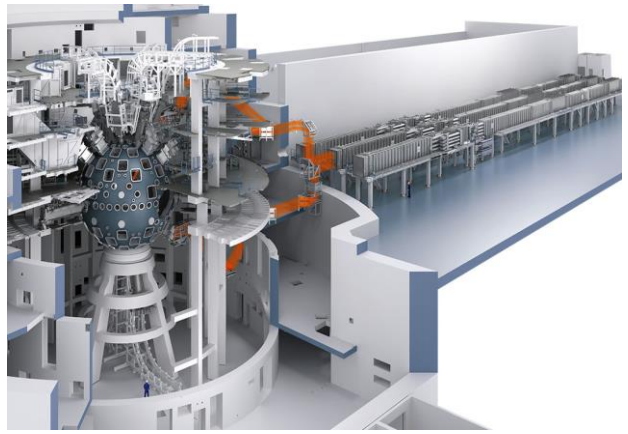

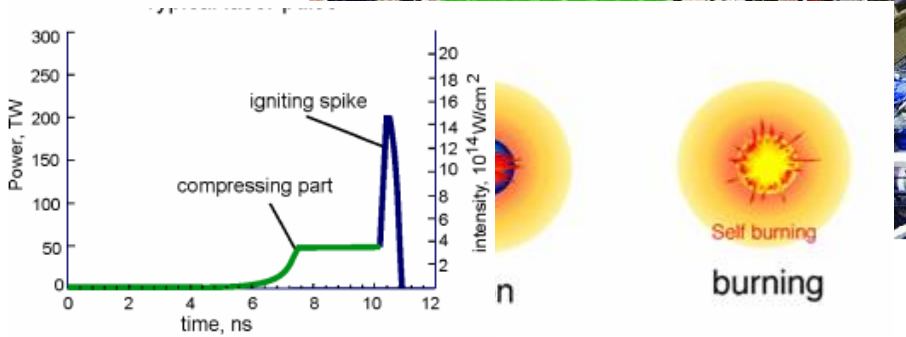

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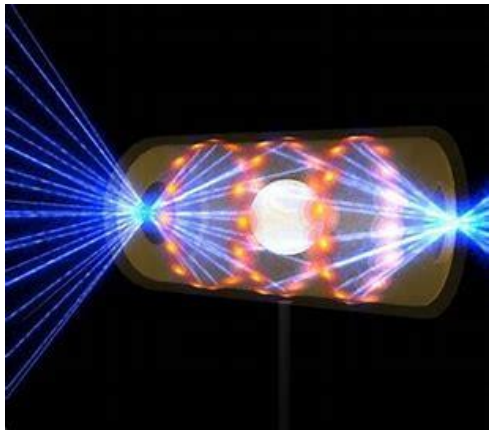

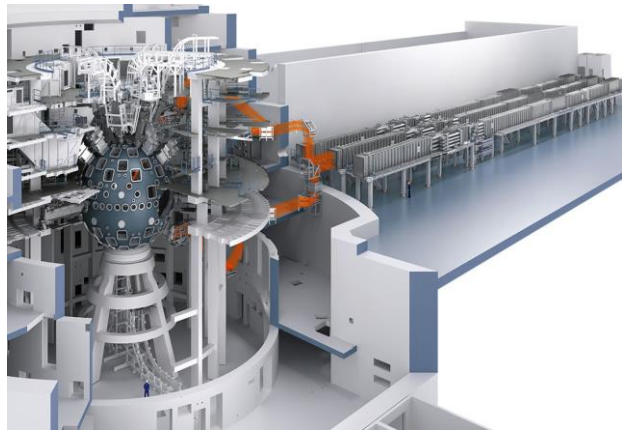

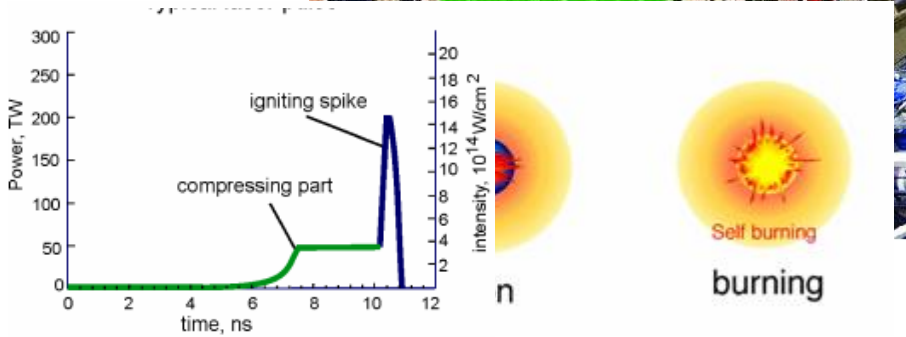

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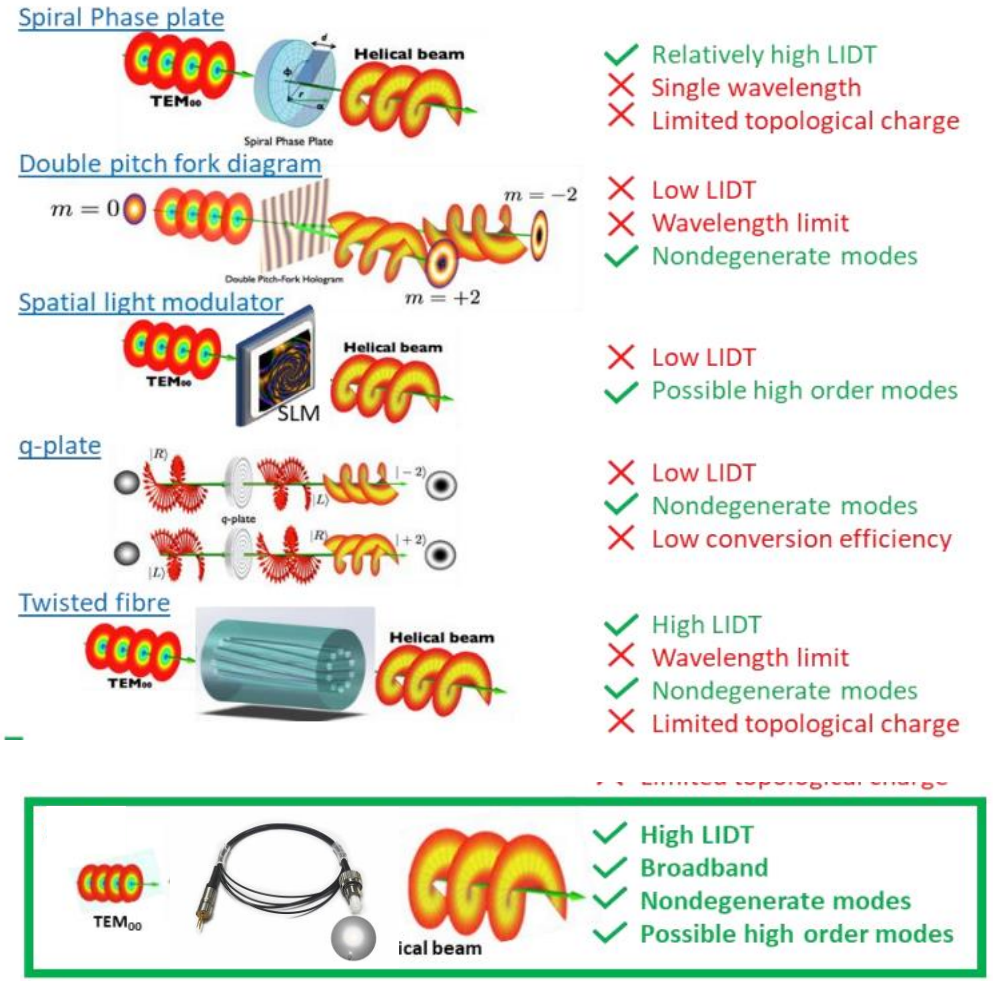
COMPLEX STRUCTURED LASER PULSE GENERATION

- **MAIN PROJECT MISSION**
  - development of highly reliable complex laser
    - specially shaped fiber
    - carrying relatively high energy
      - high damage threshold
    - carrying nondegenerate modes
      - only one mode
    - high order mode generation



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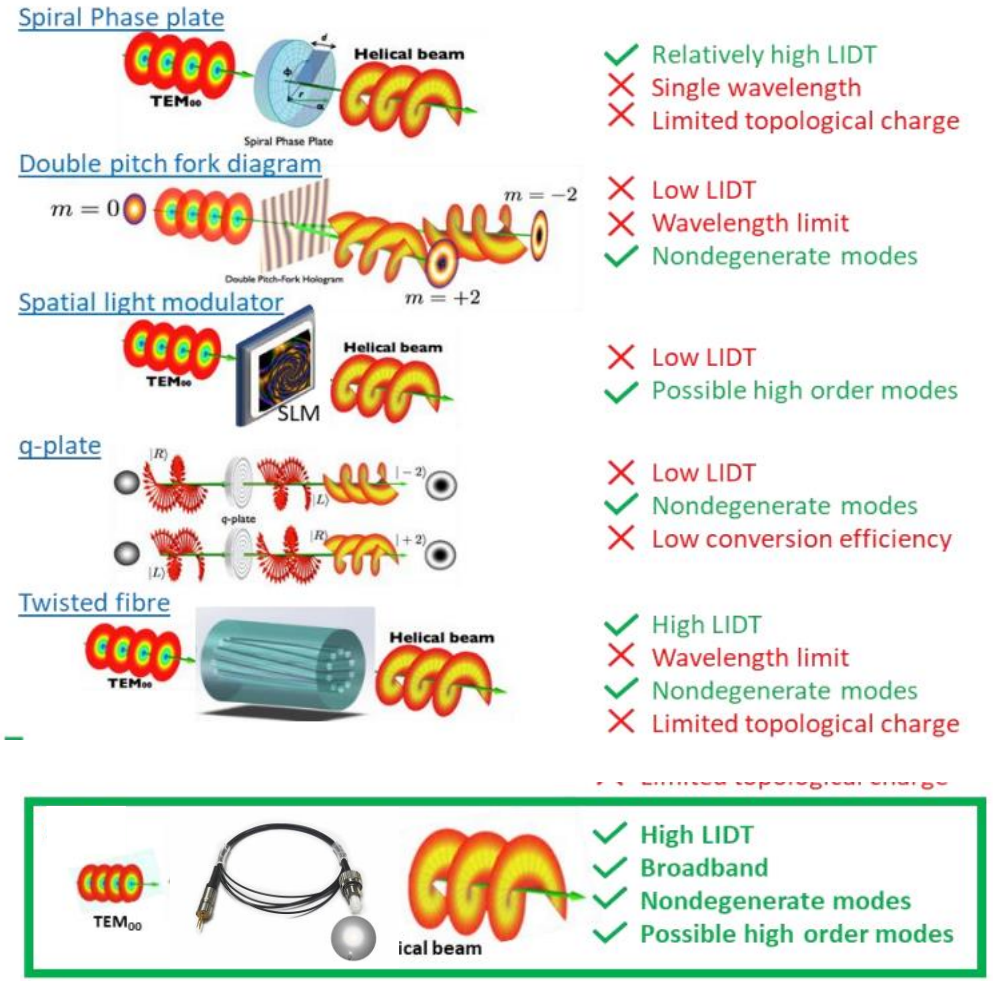
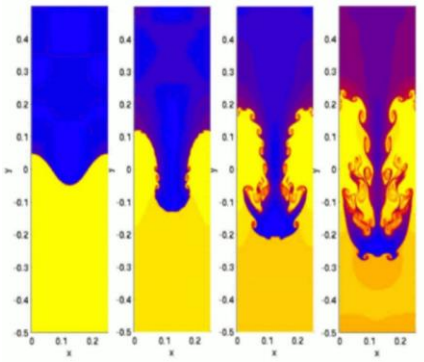
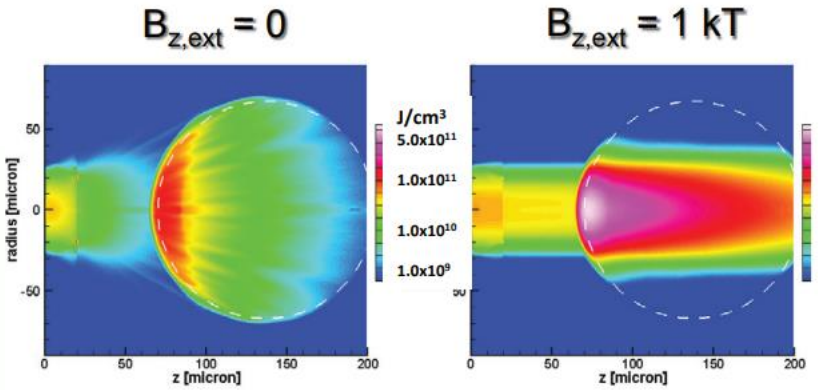
AMPLICONYX, Leibniz Institute & Tampere University



MAGNETIC FIELD GENERATION

- magnetic field varies electron thermal motion in plasma
  - energy deposition and transport
  - electron streams are more collimated

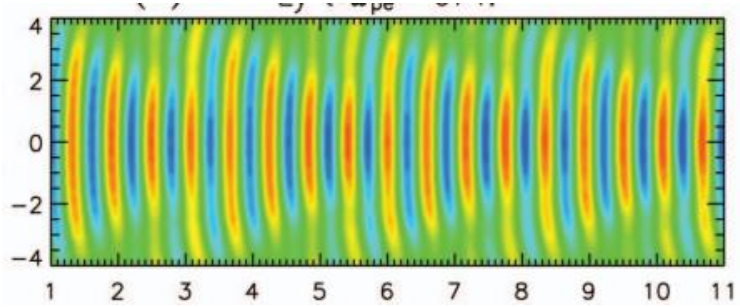




K. Mima et al.: J. Phys. Conf. Series (2016)

  - plasma instability suppression
    - Rayleigh-Taylor instability
    - parametric-instabilities

- allows to lower the compression shock wave velocity
  - 300 km/s → 100 km/s ➔ 3x lower laser light energy needed
  - relax Lawson criterion condition for fusion ignition



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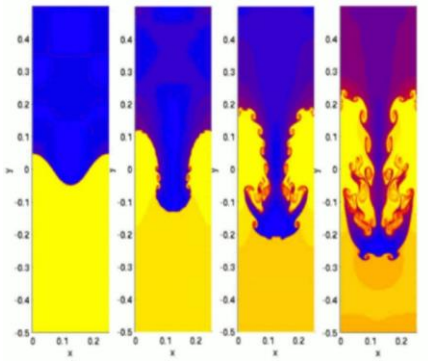

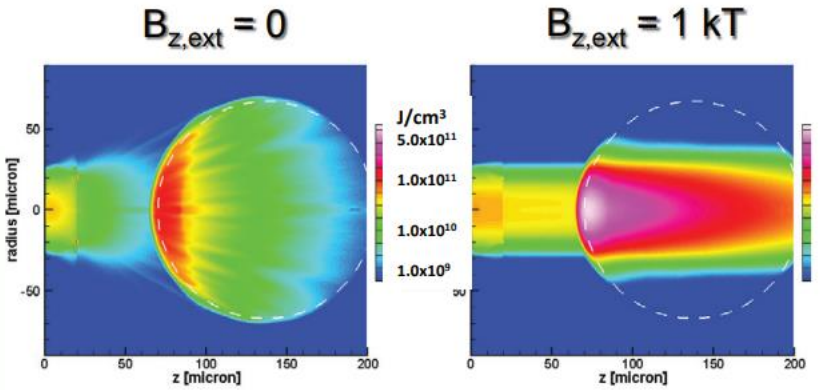

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  - plasma instability suppression
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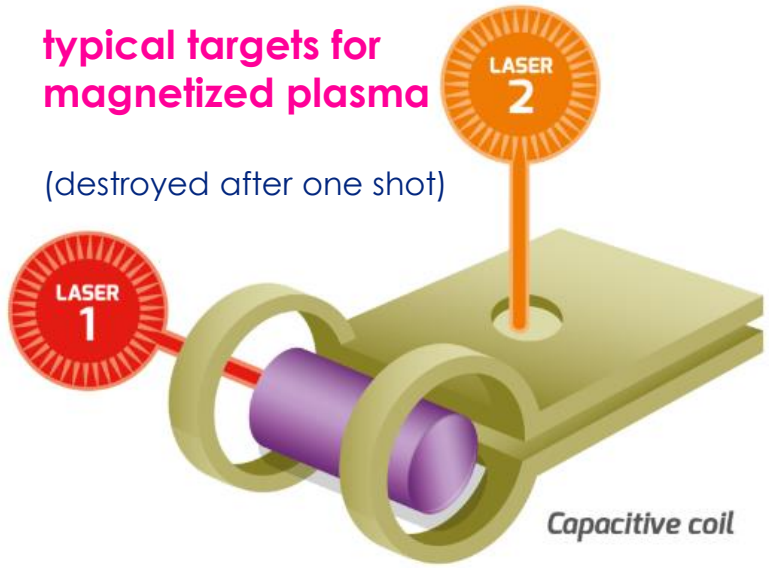
    - p
    - al

typical targets for magnetized plasma

(destroyed after one shot)



hock wave velocity
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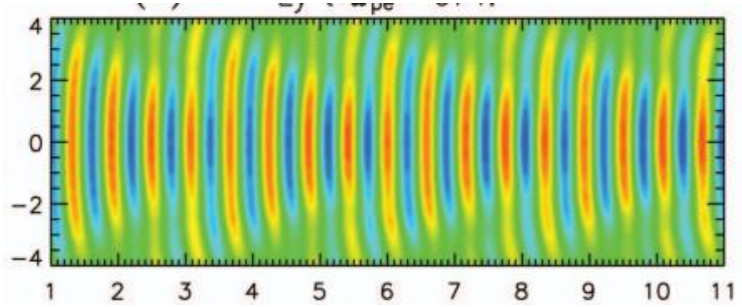
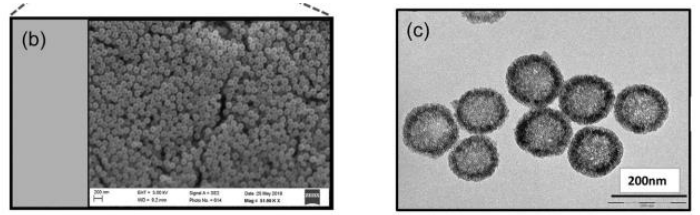
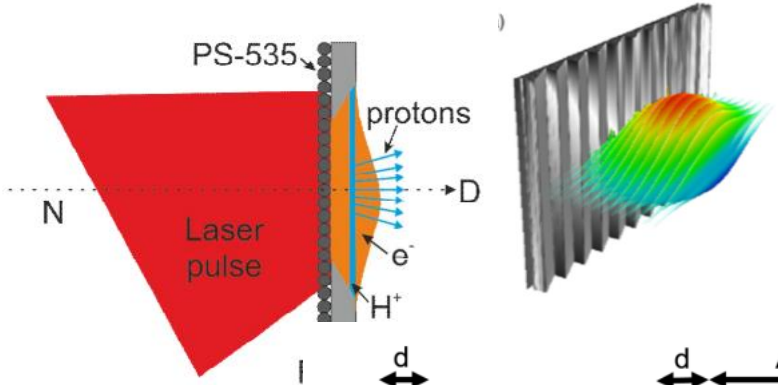


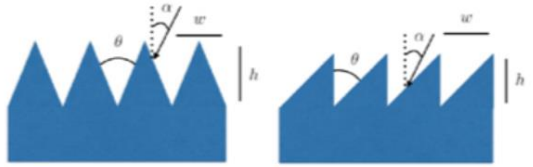
MAGNETIC FIELD GENERATION

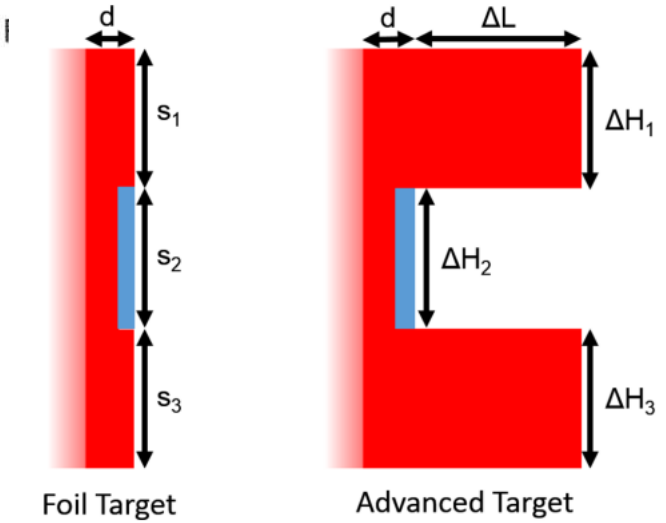
- proton acceleration
  - electron stream collimation → proton beam collimation
  - specially shaped targets
    - nanosphere layer
    - holow-sphere layer
    - grating layer
    - cones
      - low damage threshold
      - destroyed after one laser shot

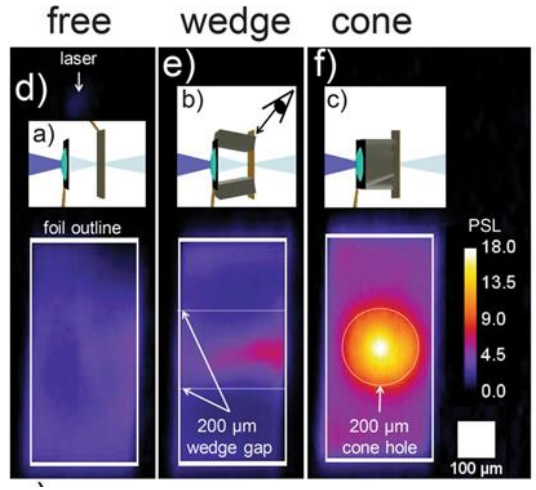
- fast ignition
- proton radiography & radiotherapy











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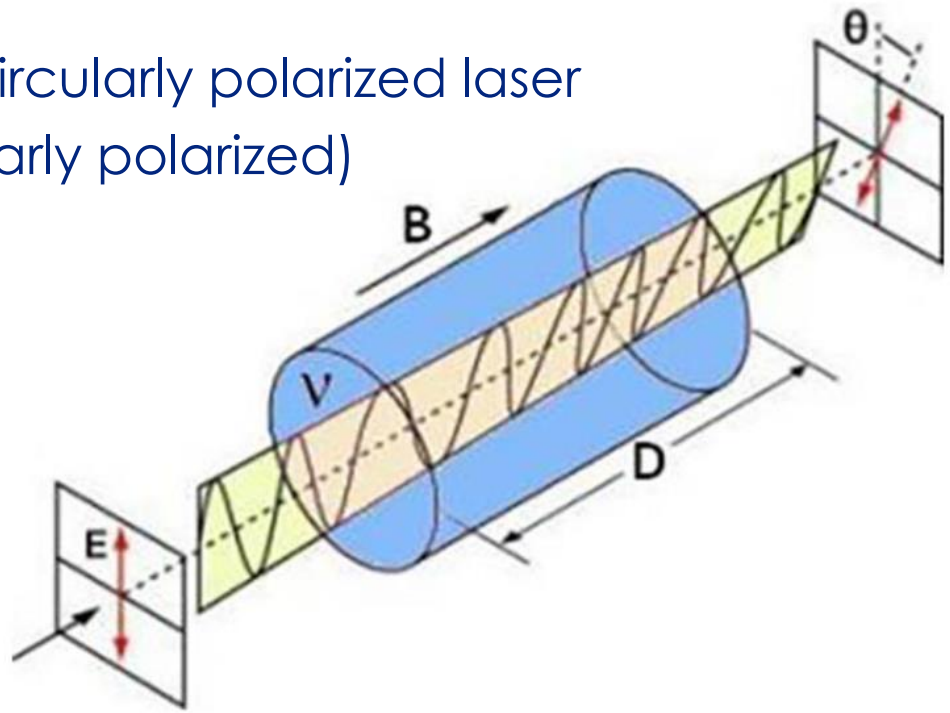
    - magnetic field can be produced by circularly polarized laser
    - or with complex laser (linearly or circularly polarized)
      - can be more than 100x higher
- operation at high repetition rates



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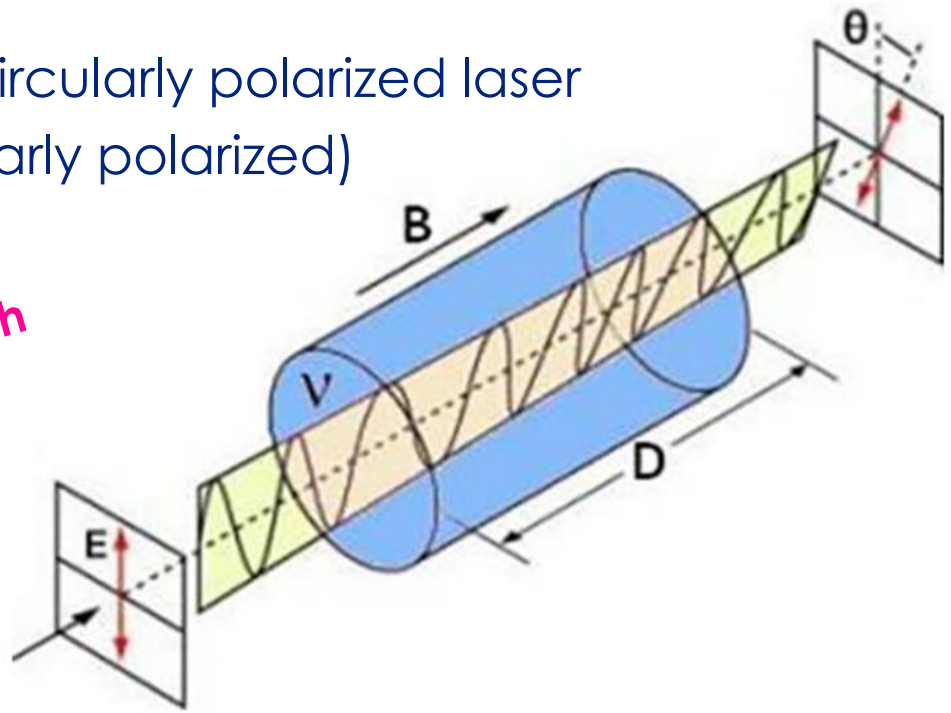
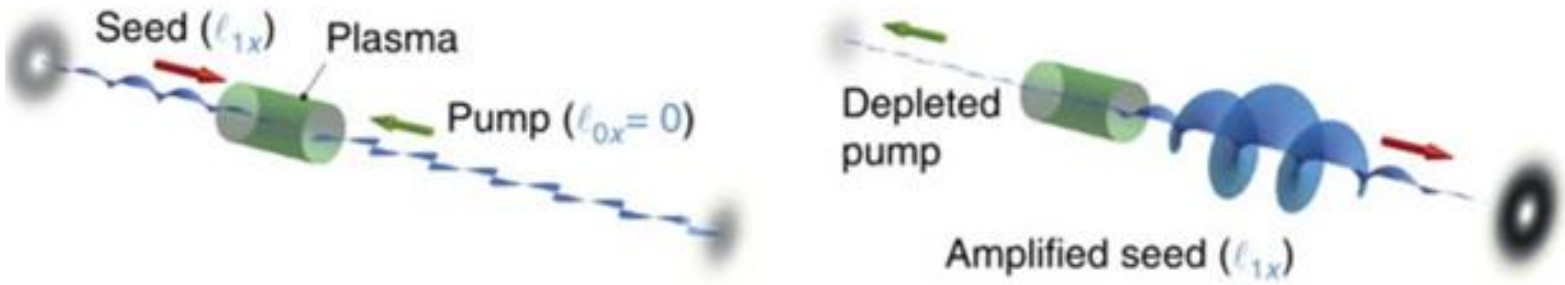


PULSE AMPLIFICATION IN PLASMA

- **Backward Raman Amplification**
  - in plasma (cannot be destroyed as laser or nonlinear crystals, fibers or gases)
    - "unlimited energy" gain
  - three wave mixing
    - seed laser (which is amplified)
      - generates plasma waves
    - pumping laser (high energy)
  - energy is transfered from pumping laser to seed by means of plasma wave
  - 10^8 amplification
    - nJ → J



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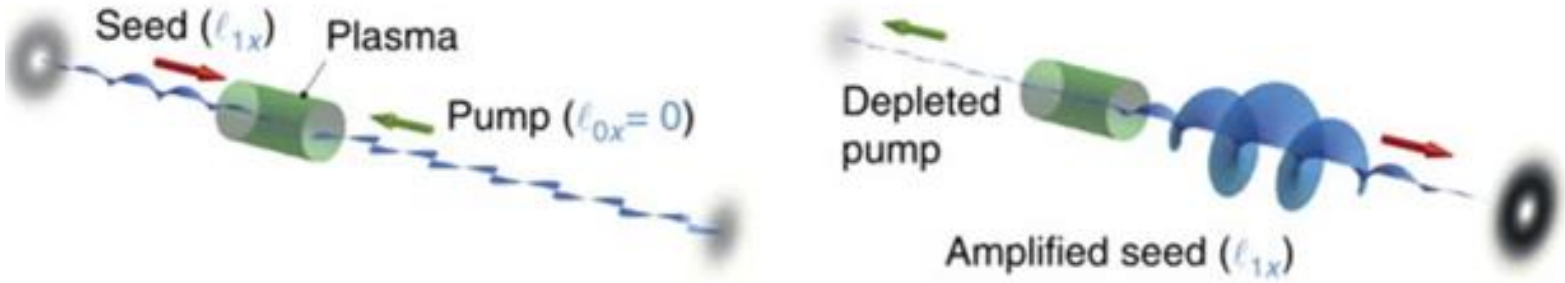
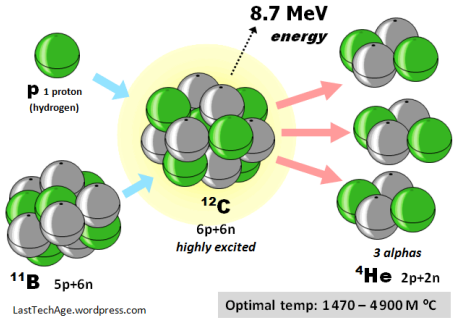


ADVANCED FUELS FOR PROTON-BORON FUSION

- $p + {}^{11}B \rightarrow 3\ {}^{4}He$
  - 8 MeV released (half of conventional DT fusion)
  - no (almost) neutrons
    - secondary reactions may appear producing neutrons (but it is lower amount than in coal combustion)
    - no activation of interaction vessel → no radioactive waste (even no short lived)
  - really clean and almost inexhaustible energy source
    - 0.001% abundancy on Earth surface
      - B^{11} (80%), B^{10} (20%)
  - synthetize optimal ratio between protons and borons in target



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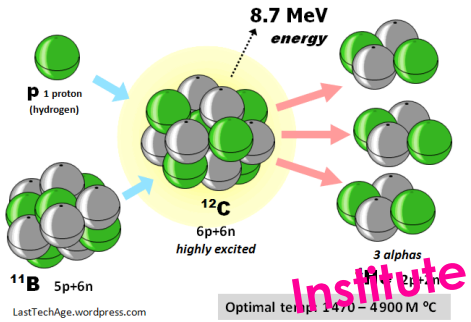

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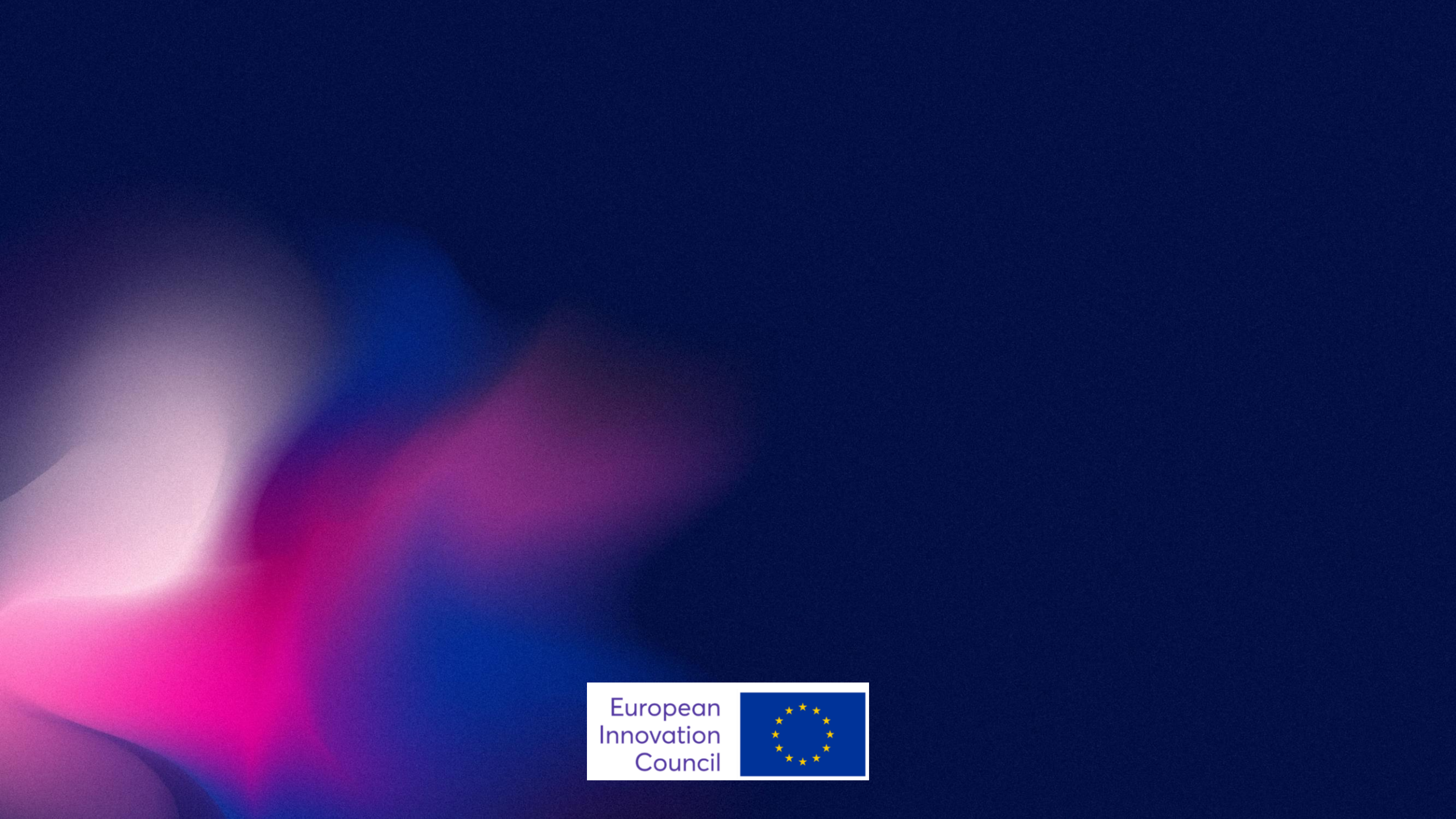
CONCLUSION

- construction of aneutronic (proton-boron) fusion reactor is beyond this project
  - goal:
    - verify potential of complex structured lasers as a feasible lead system for nuclear fusion
    - perform preliminary and critical studies
    - perform proof-of-concept experiments

CONCLUSION

- construction of aneutronic (proton-boron) fusion reactor is beyond this project
  - goal:
    - verify potential of complex structured lasers as a feasible lead system for nuclear fusion
    - perform preliminary and critical studies
    - perform proof-of-concept experiments

THANK YOU FOR YOR ATTENTION!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