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APPLICATIONS

Status of WP4

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Collaboration Week,

4th July 2018, Liverpool

On behalf of WP4

http://eupraxia-project.eu

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industries (green outline)
laboratories (blue outline)
shaded: major contributors/collaborators

CONTENT

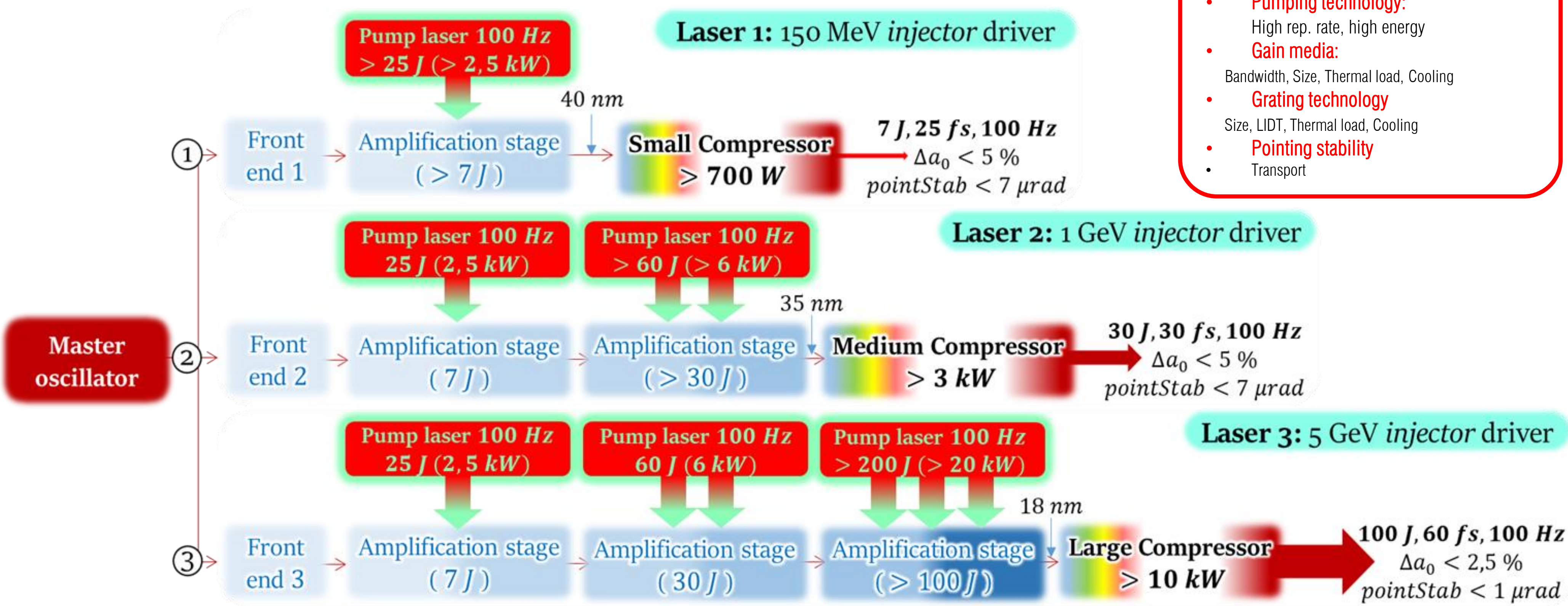
- Main EuPRAXIA laser features
- Needed key developments
- Next phase
- Conclusions

EuPRAXIA Laser Layout

The current EuPRAXIA laser design[1] relies on mature Titanium Sapphire industrial technology to deliver average and peak power as required by the project.
A set of three laser chains are considered, to drive the injectors at 150 MeV and 1 GeV, and the accelerator at 5 GeV.

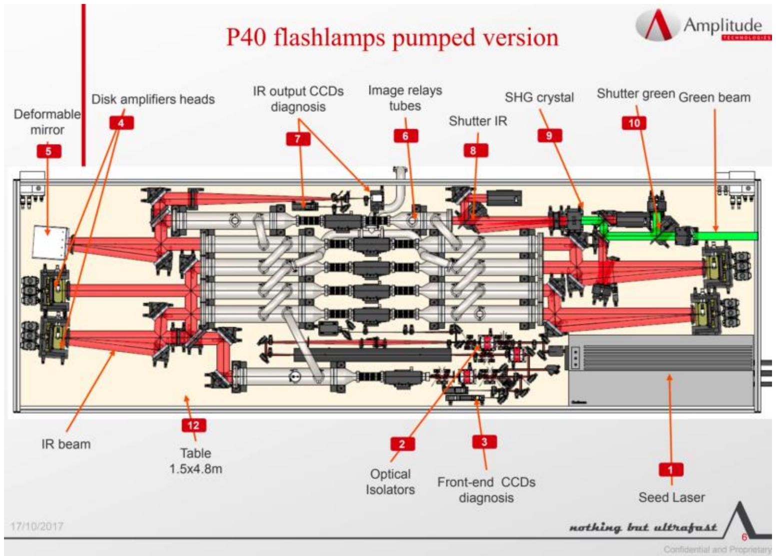
MAIN CHALLENGES

- Pumping technology:
  High rep. rate, high energy
- Gain media:
  Bandwidth, Size, Thermal load, Cooling
- Grating technology
  Size, LIDT, Thermal load, Cooling
- Pointing stability
- Transport



L.A.Gizzi et al., A viable laser driver for a user plasma accelerator., NIM-A, (2018).

Promising developments based on diode pumping technology are in progress at EuPRAXIA industrial and research partners, progressively matching requirements



DIPOLE[(2)] 100

DPSSL cryogenic HE cooling system

100 J @ 10 Hz, @515 nm

Planned developments: 10J @ 100 Hz

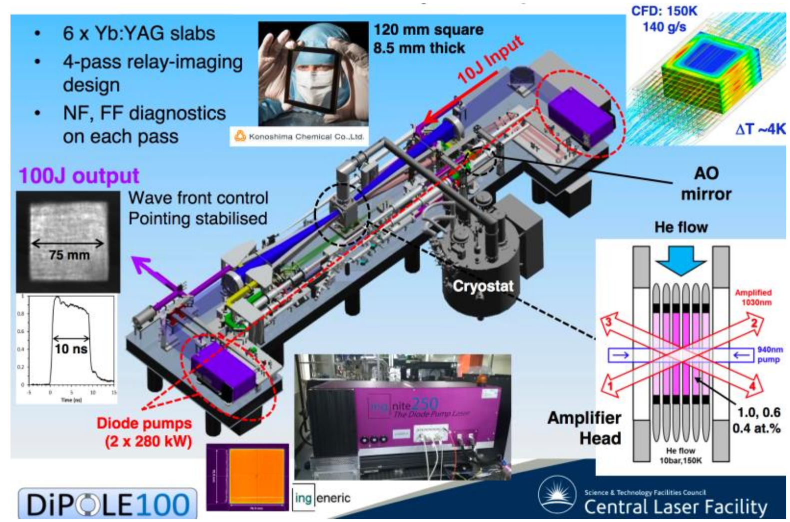
Amplitude P60

Flashlamp pumped Nd:YAG

Design: 60 J @ 10 Hz, 532 nm

<u>Conversion to DPSS fully designed</u>

- Expected rep. rate 50 Hz
- Cost of diode still an issue – currently 5x compared to flashlamps.
- Expected to decrease in 5-10 yrs.
- Maintenance free operation for 25-30 yrs.



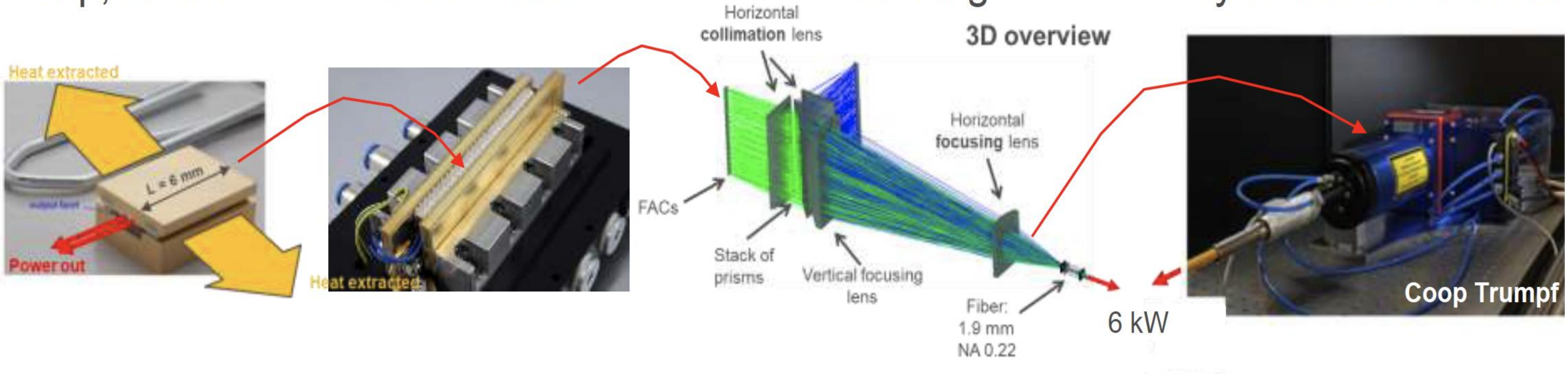
[2])P. Mason et al., Kilowatt average power 100J-level diode pumped solid state laser," Optica 4, 438-439 (2017)

100 Hz pump laser

FBH brilliant high duty cycle pump: small-series prototype

White paper 100 Hz pump trials to assist EuPRAXIA system design (STFC, LLNL, HZDR, FBH), supported by the Institute of Quantum Optics, Friedrich-Schiller-University, Jena in Germany

Novel chip, carrier → Novel passive Side cooler → Custom beam forming → Brilliant, high duty cycle fibered module



130W from 1.2mm
Peak: ~ 245 W
60% efficiency
2x brighter than bars

1…20% DC
1…100ms
Passive cooling

6 kW 60% efficiency
M^2 ~ 300 x 300

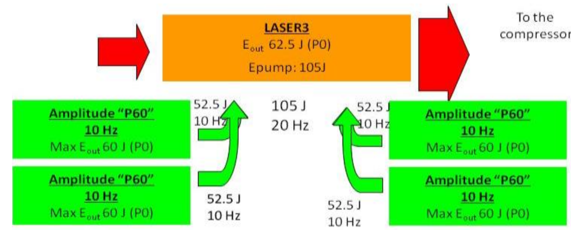
1.4 MW/cm^2-sr
50% efficiency
M^2 ~ 700

6 units delivered to Max Born Institut, Berlin; 2 in build

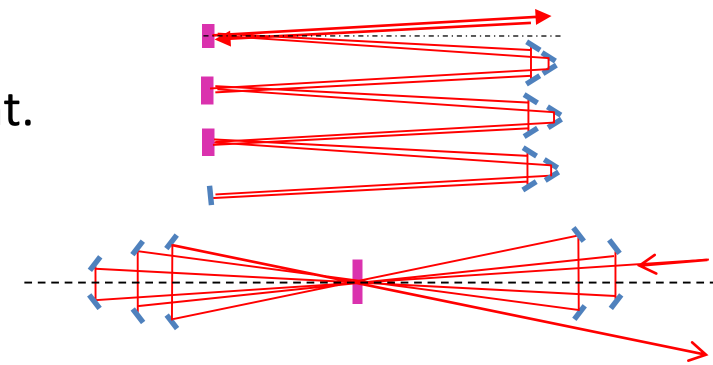
Laser design - Amplifiers

Main recent activities

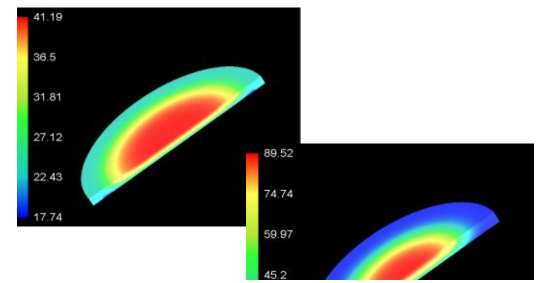
Definition of **pump sources arrays** for the various amplification stages, based on available (SCLF DiPOLE / Amplitude P60) and perspective technologies



Design of **amplifier stages layout** (both for transmission and reflection amplifiers); evaluation of required footprint. Pump delivery /timing schemes for Extraction During Pumping



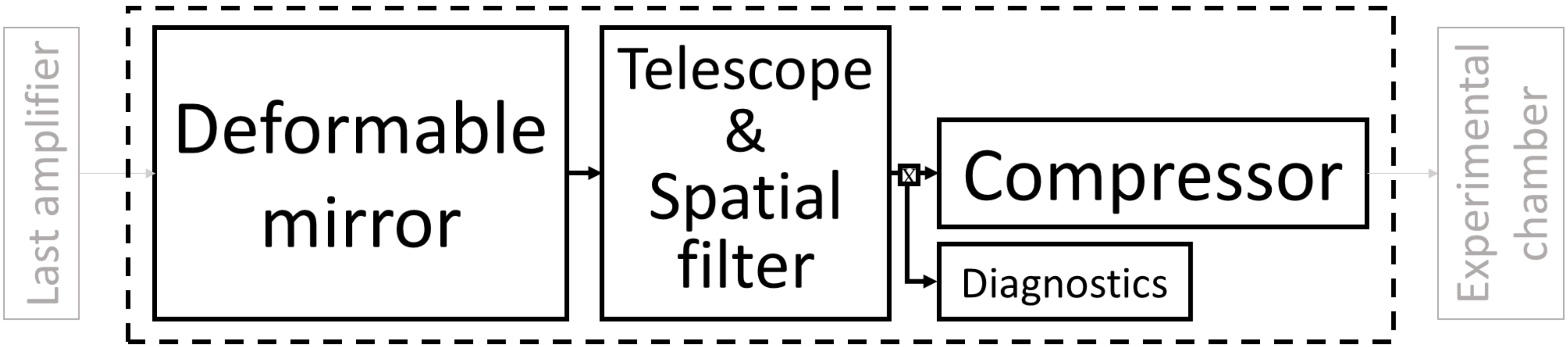
Optimization/simplification of **amplifier design** (reduction of number of stages/passes) and trade-off on thermal design

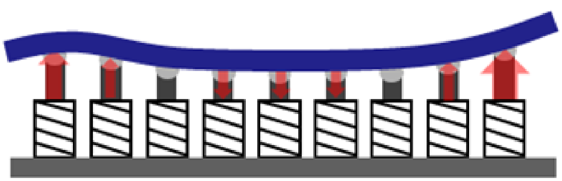


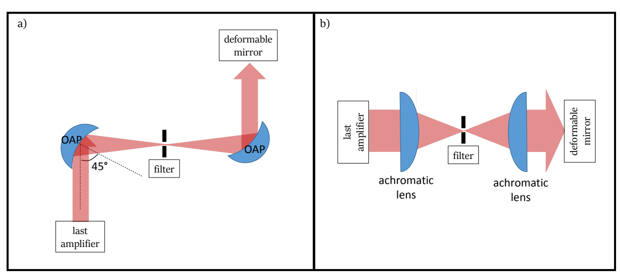
*) Water cooled Ti:Sa amplifier under development at ELI-HU (After V. Cvhykov *et al.* , Opt. Lett, **41**, 3017, 2016)
) Fluid (D_2O) cooled Nd:YAG laser, 20 kW CW pump power, D_2O (After X. Fu *et al.* , Opt. Express, **22, 18421 (2014)
***) Fluid (Siloxane) cooled Nd:YLF laser, 5 kW CW pump power (After Z. Ye *et al.* , Opt. Express, **24**, 1758 (2016)

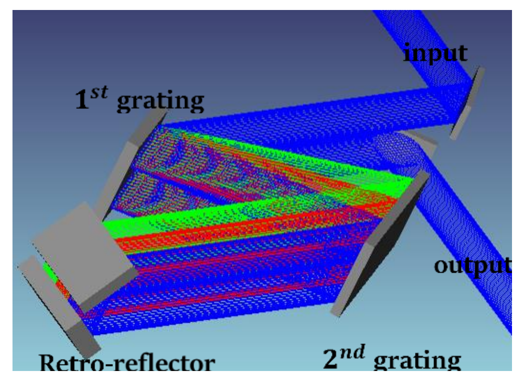
Transport to target

Main challenges: large optics, mechanical stability, cooling of gratings, beam quality control …







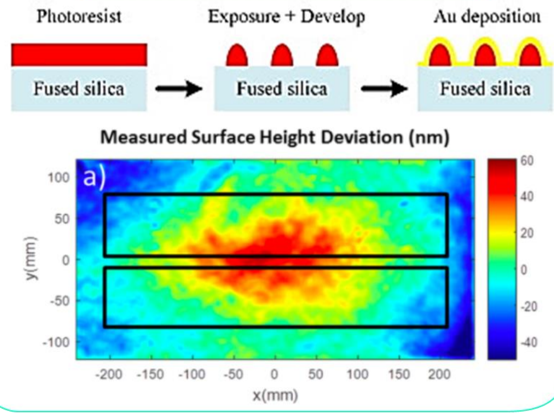


Compressor: grating technology

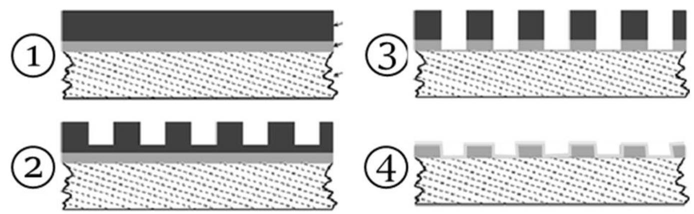
Different technologies under evaluation to address main issues with higher repetition rate. Strategy includes **reduction** of the thermal load at high average power, **cooling** of residual heat and **control** of thermal effects on compression quality.

Lawrence Livermore National Laboratory

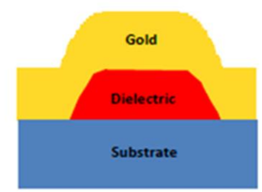
Gold Coated Grating Cooling (BK7 and ULE substrates)
for allowing higher thermal load



Gold Coated Grating without epoxy resin (Photoresist-Free)
for lower thermal stress



MD Gratings
Metal Dielectric Gratings

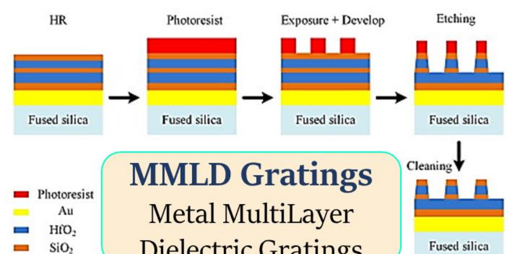


Plymouth Grating Laboratory

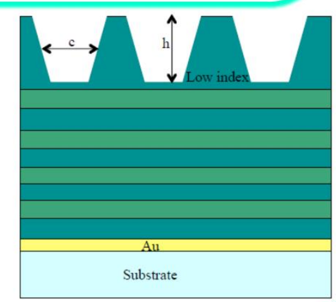
MLD gratings
MultiLayer Dielectric Gratings.

The biggest one is 91*cm x* 42*cm* large

THALES · SAFRAN · HORIBA JOBIN YVON · Cilex · Apollon · INSTITUT FRESNEL



MMLD Gratings
Metal MultiLayer Dielectric Gratings



Summary on developments

- Prototyping of Ti:Sa amplifiers
- Addressing 100 Hz pump lasers developments
- Thermal management of compressor gratings
- Stability (pointing & more) and active control
- Driver pulse temporal shaping and synchronization
- Construction
- Integration Issues
- …

Please fill in excel file (Ralph's message on 28 June) if you can contribute to these items.

SAC Recommendation

Horizon 2020

Rec12. Broaden the dialogue to other WPs (e.g. WP2, WP5, WP14) to inform on design space, specifically on critical parameters (e.g. a0 vs power/focal area). ***Effective interaction with WP2/3***

Rec13. Explore **feasibility** of **timing precision and jitter** requirements provided by WP2 and WP3, and how it can be verified at the target. ***Work in progress at Desy***

Rec14. Develop a better understanding of **pointing requirements** and metrics, specifically how they are coupled to the facility. ***Building DB of pointing performance at facilities***

Rec15. Develop a strategic **technology roadmap** that supports the overarching performance goals of EuPRAXIA. Get guidance on technology demonstrator vs science facility. Maintain perspective of technologies that can scale. ***Work in progress – requires additional funding***

Rec16. Given the timescales on how much technology development is required, how long does it take, and when construction of a system could start, identify **risk reduction experiments** that add credibility to the feasibility of certain technologies. ***Experiments identified***

Rec17. Develop a crisp risk matrix for each technology approach, **identify bottlenecks** and areas where risk reduction experiments are needed. Identify synergetic efforts between technology paths. ***Set of bottlenecks identified and being explored***

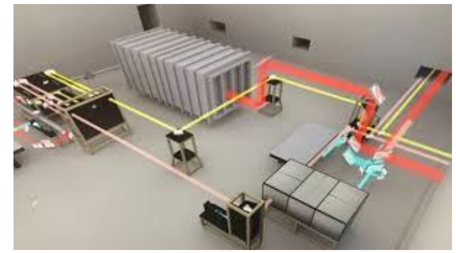
Rec18. Use **technical readiness levels** for the integrated laser system concepts (not individual components) to assess and compare maturity of each solution. ***In progress in collaboration with industry***

PROJECT DELIVERABLES

D4.1 (M12) Benchmarking of existing technologies and comparison with EuPraxia requirements

DELIVERED

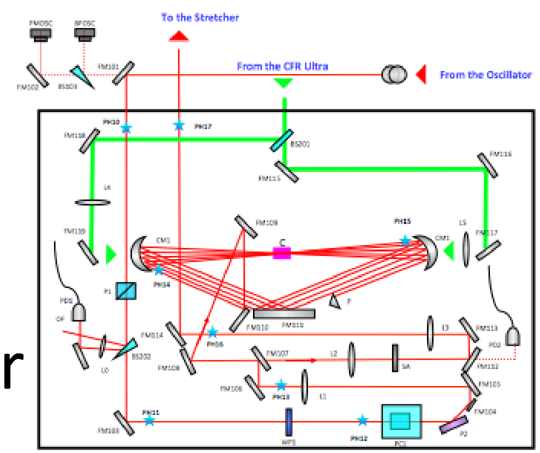
Explore and identify promising technologies



D4.2 (M24) Preliminary laser design

DELIVERED

To be developed with an eye to perspective industrial development



D4.3 (M24) Preliminary design of transverse functions

DELIVERED

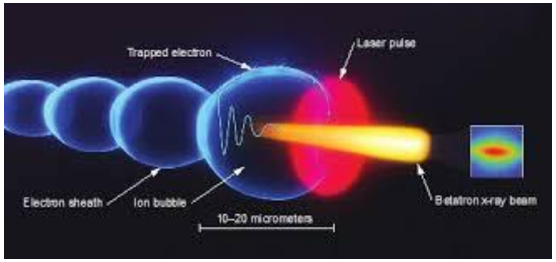
To account for final use of EuPRAXIA (user facility)

PROJECT DELIVERABLES

Horizon 2020

D4.4 (M36) Final requirements of laser system

To comfortably accommodate LWFA design and other laser based activities



D4.5 (M36) Control command design system

To enable turn-key-like operation of the laser system

LABs AND INDUSTRY

EuPRAXIA

Horizon 2020

A wide collaboration is ready to be involved to tackle open issues

Amplitude Technologies

THALES

VCS vacuum components & systems

SAFRAN

VACUUM FAB motion control & optics

HORIBA JOBIN YVON

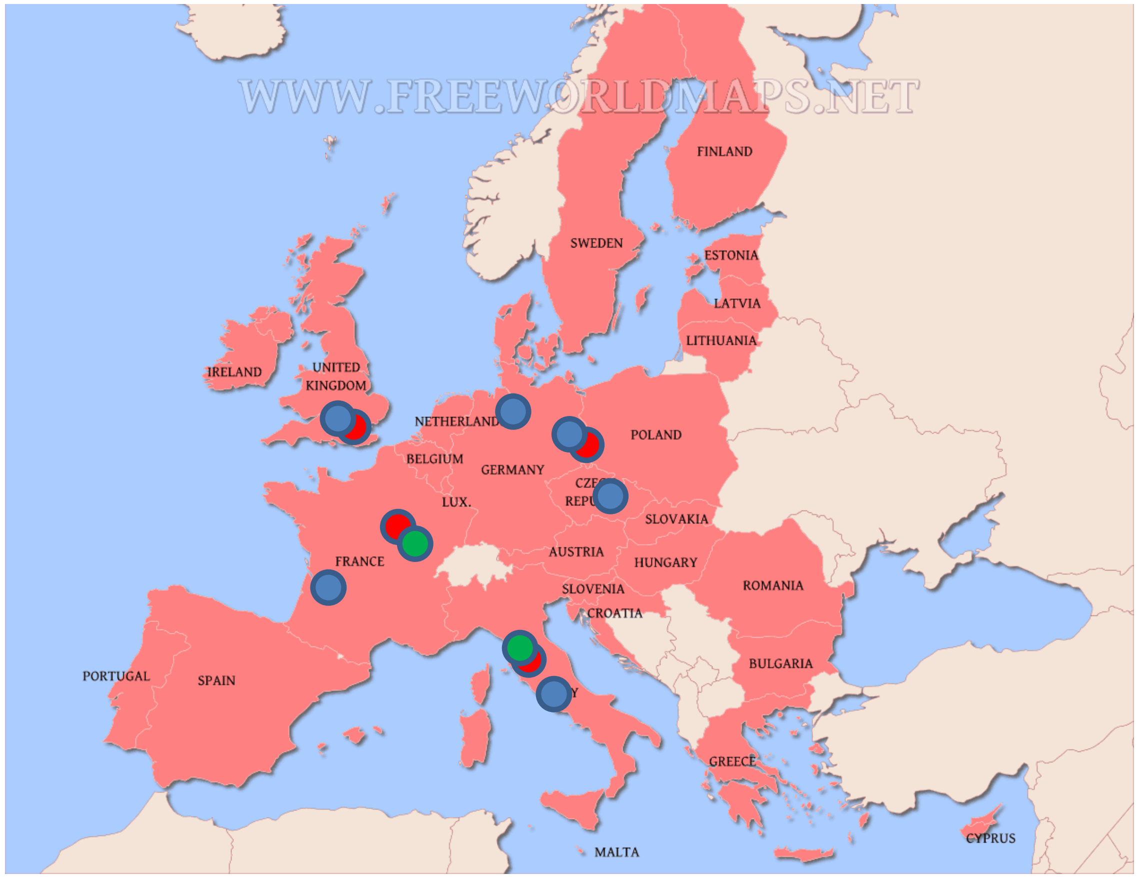
ISP SYSTEM

TRUMPF

imagine optic

DYNAMIC OPTICS

and many more



Consiglio Nazionale delle Ricerche

cnrs centre national de la recherche scientifique

Science & Technology Facilities Council

INFN Istituto Nazionale di Fisica Nucleare

Lawrence Livermore Natl. Lab

Leibniz FBH Ferdinand Braun Institut

SUMMARY

- EuPRAXIA aiming at PW-kW laser system driver, well beyond current state-of-the-art;
- Design phase ongoing: preliminary design going technical;
- Also considering evolution towards higher repetition rate;
- Significant development activities and funding needed to solve standing technical issues;
- Now collecting proposals from contributing groups for next phase.

Consortium

EuPRAXIA

Horizon 2020

16 Participants

DESY
INFN
Consiglio Nazionale delle Ricerche
CNRS
University of Strathclyde Glasgow
IST-ID Associação do Instituto Superior Técnico para a Investigação e Desenvolvimento
Science & Technology Facilities Council
SOLEIL Synchrotron
Manchester 1824 The University of Manchester
University of Liverpool
ENEA Italian National Agency for New Technologies, Energy and Sustainable Economic Development
cea
Sapienza Università di Roma
UHH Universität Hamburg
Imperial College London
University of Oxford

22 Associated Partners

(as of October 2016)

上海交通大學 Shanghai Jiao Tong University
Université de Lille 1 Sciences et Technologies
eli beamlines
HI Jena Helmholtz Institute Jena
清華大學 Tsinghua University
HZDR Helmholtz Zentrum Dresden Rossendorf
LMU Ludwig-Maximilians-Universität München
Wigner
KPSI Kansai Photon Science Institute
JAEA
大阪大学 Osaka University
RIKEN
Stony Brook University CASE
CERN
Lund University
Berkeley Lab
UCLA
KIT Karlsruhe Institute of Technology
Università di Roma Tor Vergata
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ИЯФ РАН
Jülich Forschungszentrum