This project has received funding from the European Union's Horizon 2020 Research and Innovation programme under GA No 101004730.

WP6 - NPACT-Novel particle accelerators concepts and technologies

Task 6.2 - LASPLA

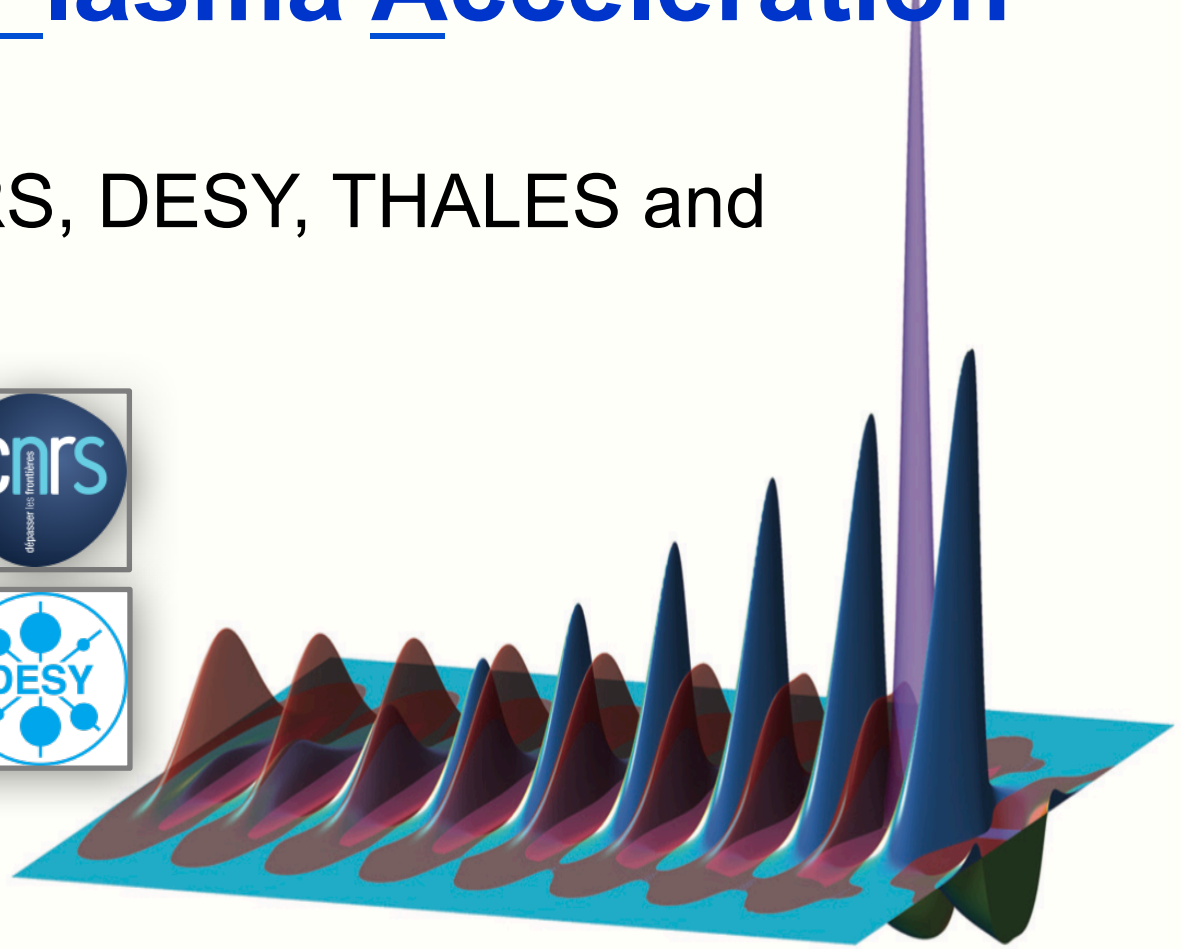
I.FAST Kick-off Meeting

Leonida A. GIZZI, CNR, Italy (Task Leader)

Task 6.2 LASers for Plasma Acceleration

- With CNR, CERN, INFN, CNRS, DESY, THALES and AMPLITUDE Technologies

LASPLA team
L.A.Gizzi (CNR)
F. Mathieu (CNRS),
F. Falcoz (AT),
C. Simon Boisson (Thales)
D. Giove, (INFN-MI)
M.P.Anania (INFN-LNF)
…



P. Tomassini et al., Plasma Physics and Contr. Fusion, **62**, 014010 (2020); https://doi.org/10.1088/1361-6587/ab45c5
R. Assmann et al., EuPRAXIA Conceptual Design Report, EPJST, **229**, 3675–4284 (2020); https://doi.org/10.1140/epjst/e2020-000127-8

Task 6.2: Objectives

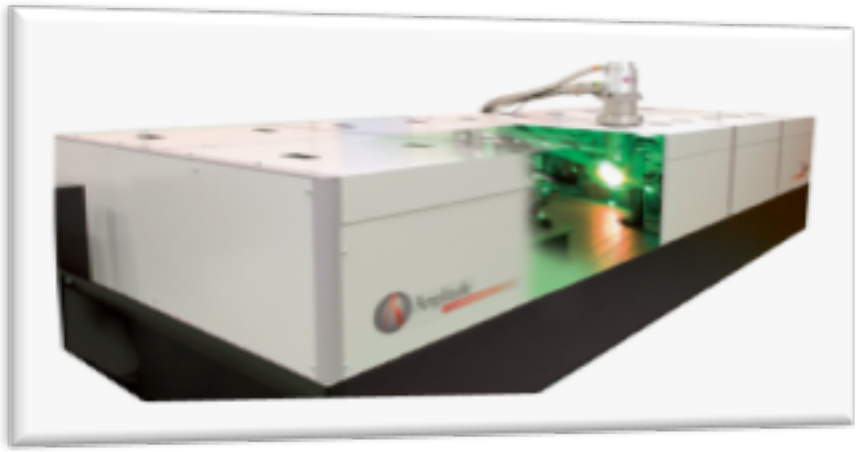
- Establish a roadmap to foster delivery of advanced industrial laser drivers with high-repetition rate and higher efficiency, for the first user plasma-based accelerator.
- Establish a coordination activity with networking and training of main laser labs, focused on laser-driver R&D.
- **D6.2** : LASPLA Strategy [M46] - Strategy for laser drivers for plasma accelerators
- **MS22** - LASPLA Workshop/School [M30] – Report

Leo Gizzi, Task 6.2, I.FAST Kick-off meeting, 4° May 2021, la.gizzi@ino.cnr.it

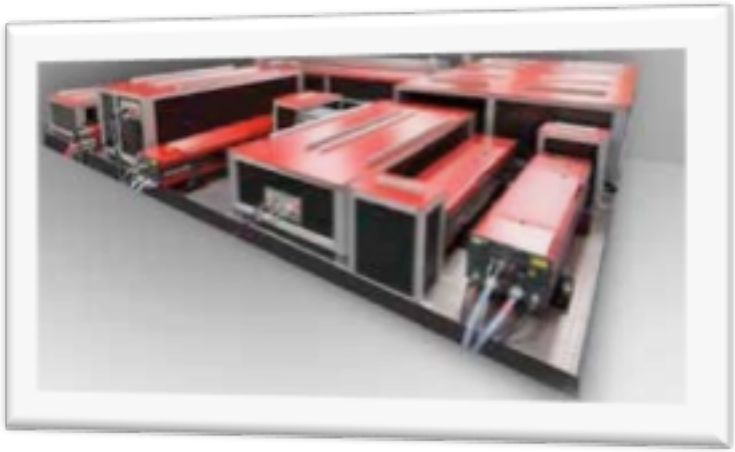
What laser driver for LPA

- Current laboratory LPAs are mostly driven by Ti:Sa lasers, established technology for ultrashort pulse laser technology*

Amplitude Technologies
PULSAR: 5 J, <25 fs, 5-10 Hz
Ti:Sapphire



Thales
ALPHA5/XS: 20 J, 25 fs, 5 Hz
Ti:Sapphire



*Colin N. Danson et al., *Petawatt and exawatt class lasers worldwide*, High Power Laser Sci. and Eng. **7**, e54 (2019); https://doi.org/10.1017/hpl.2019.36

Recent advances at ELI

- Diode-pumping technology for Ti:Sa pump lasers established

Design parameters			
10 Hz	30 J	30 fs	1 PW
Achievement as of March 2020			
3.3 Hz	11.5 J	28 fs	0.4 PW

Latest (April 2021)
0.5 Petawatt (PW)
13.3 Joules (J)
27.3 Femtoseconds (fs),
3.3 Hertz (Hz) repetition rate
44 Watts average power.

The L3-HAPLS at ELI Beamlines Research Center in the Czech Republic. Credit: ELI Beamlines*

*L. Koubíková, LaserFocusWorld, 2020

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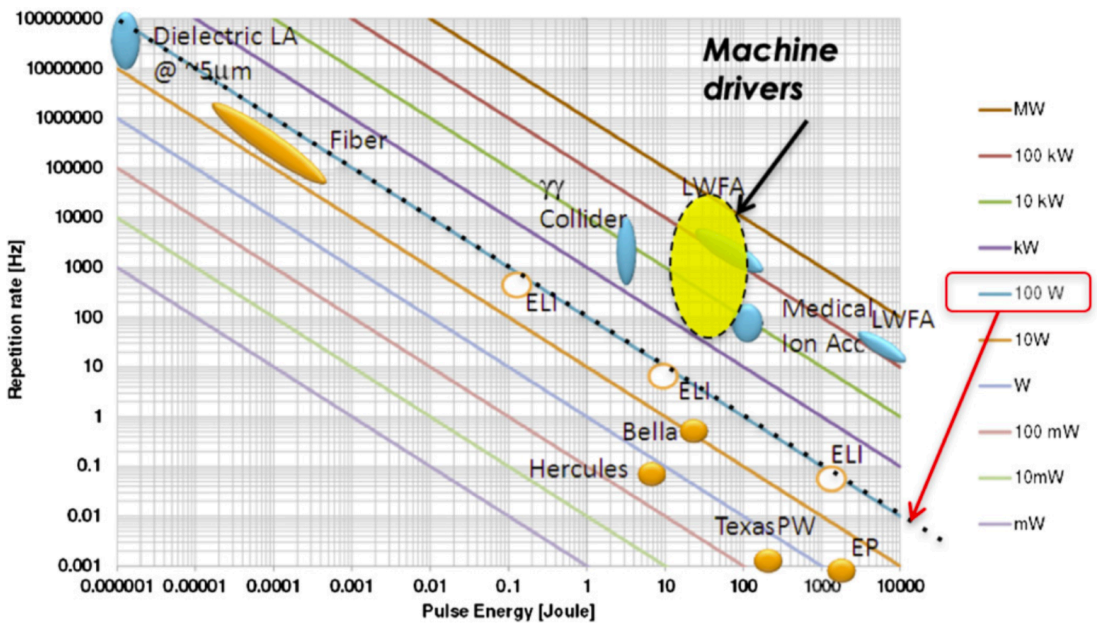
The broader view

- Current technology development mainly driven by **extreme intensity** applications;
- **LASPLA** will focus on the technology required to achieve high-repetition rate at multi-joule (≈100 TW) scale;
- **Key role of industry** to establish turn-key, high average/peak power ultrashort pulse technology;

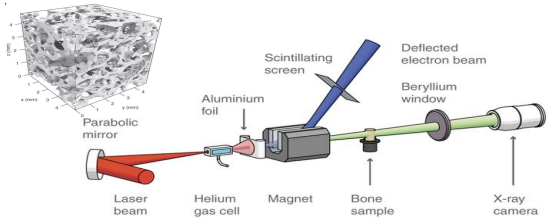


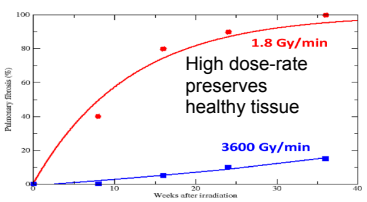
*L.A. Gizzi et al., A viable laser driver for a user plasma accelerator, NIM **A 909** , 58 (2018); https://doi.org/10.1063/1.4984906

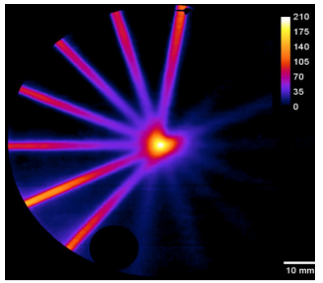
Ready to go applications

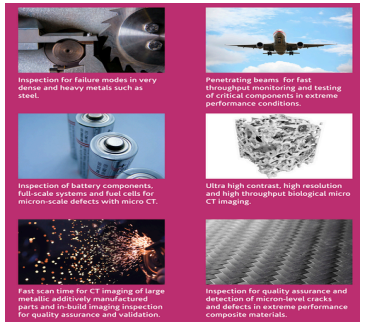
Transition to industrial systems motivated by key societal applications

- **X-ray imaging** for compact, high resolution (phase contrast imaging[1]) bio-medical diagnostics;
  - Address some of the needs of large SR facility users
- **Laser-driven Very High Energy Electron**[2] can provide ultra-high dose-rate to meet requirements of future “FLASH[3]” radiotherapy, currently unaddressed;
- **γ-rays or neutron sources** have been developed[4] for industry and security









The Extreme Photonics Applications Centre (EPAC), CLF, UK

[1]J.M.Cole et al., Sci. Rep. **5**, 13244 (2015); [3]L. Labate et al., Scientific Reports **10**, 17307 (2020); [2]V. Favadoun et al., Sci. Transl. Med. 245ra93 (2014); [4]C. M. Brenner et al, PPCF, 58 014039, (2015)

What laser driver for future LPA

- **Towards the STRATEGY for laser drivers for plasma accelerators:**
- Rapidly evolving scenario for laser technologies relevant for plasma acceleration towards collider design:
- Ultrashort pulses (large bandwidth <50 fs)
- High Repetition rate (100 Hz – 10 kHz)
- High average power (kW -10 kW)
- High wall-plug efficiency

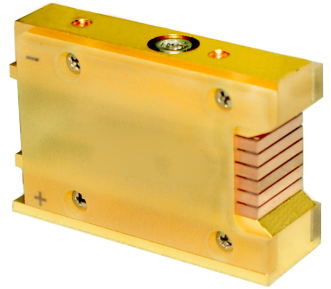
L.A Gizzi, F. Mathieu, P. Mason, P P Rajeev, *Laser drivers for Plasma Accelerators*, in Félicie Albert et al, *2020 roadmap on plasma accelerators*, 2021 New J. Phys. 23 031101, https://doi.org/10.1088/1367-2630/abcc62

More options under development

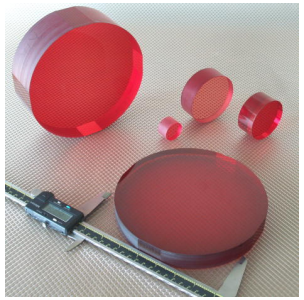
- **Fiber laser technology** offers the best WPE >50% in CW mode and coherent combination is being developed (FSU Jena-Fraunhofer IOF and Ecole Polytechnique-Thales in France).
  - Suited for moderate energy per pulse/high rep-rate (10s of kHz);
  - Now 96 fibers delivering 23 mJ and 674 W in a 235 fs pulse
- **Direct Chirped Pulse Amplification** with lasing media pumped directly by diodes is ideal for higher efficiency and higher rep-rate;
  - several materials under consideration, Yb:CaF2, Tm:YLF, Tm:Lu2O3 …
  - PENELOPE (Jena) 150 J, 1 Hz, at 1030 nm
- **OPCPA** optical parametric amplification within large-aperture lithium triborate (LBO) crystals;
  - ELI-Beamlines facility, L1 ALLEGRA (100 mJ at 1 kHz) and L2 AMOS (100 TW, 2 to 5 J between 10and 50 Hz), and the Shenguang II Multi-PW beamline(SIOM, China) …

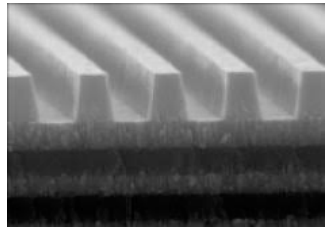
L.A Gizzi, F. Mathieu, P. Mason, P P Rajeev, *Laser drivers for Plasma Accelerators*, in Félicie Albert et al, *2020 roadmap on plasma accelerators*, 2021 New J. Phys. 23 031101, https://doi.org/10.1088/1367-2630/abcc62

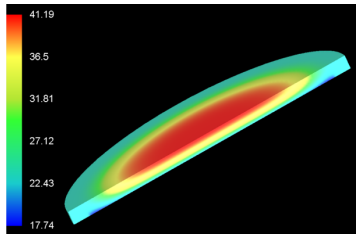
What technologies

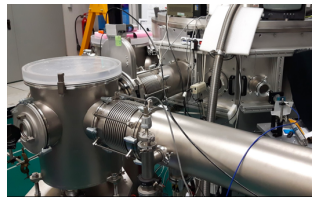


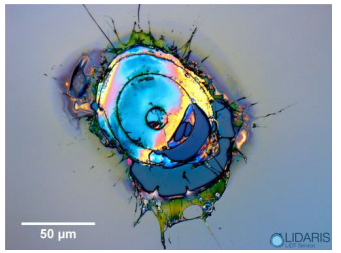
- Enabling technologies include raw materials, components, modelling capabilitied:
  - Gain media (crystals, ceramics, fibers …)
  - Pumping sources (diode lasers)
  - Cryo technology
  - Optical coatings, high damage threshold
  - Gratings technology
  - Materials characterization (optical, thermo-mechanical)
  - Opto-mechanics integration
  - Mechanical stabilization
  - …











Expanding Network

- Irène Joliot-Curie (IJC) Lab, Orsay, France, (Kevin Cassou)
- CEA/DAM, Arpajon, France, (Xavier Davoine)
- Ferdinand Brown Institute, FBH, Berlin (Paul Crump)
- Institut für Optik und Quantenelektronik, Jena, Germany, (Malte Kaluza, Joachim Hein)
- LULI, Ecole Polytechnique, Palaiseau, France, (Bruno Le Garrec)
- FEMTO-ST Institute University of Franche-Comte, Besancon, France, (Francois Courvoisier)
- Institut für Strahlwerkzeuge, Universität Stuttgart (Marwan Abdou Ahmed)
- Lawrence Livermore National Laboratory, (Thomas Spinka et al)
- Center for Physical Sciences and Tech., State Research Institute, Lithuania (Vidmantas Tomkus)
- Institute of Electronics, Bulgarian Academy of Sciences, Sofia, Bulgaria, (Ekaterina Borisova)
- Laboratoire Charles Fabry, CNRS, Université Paris-Saclay, France, (Patric Georges)
- School of Mathematics and Physics, Queen's University of Belfast, UK (Satyabrata Kar)
- …

iFAST

More on network: industry

Amplitude TECHNOLOGIES

THALES

SAFRAN

VACUUM FAB MOTION CONTROL & OPTICS

ISP SYSTEM

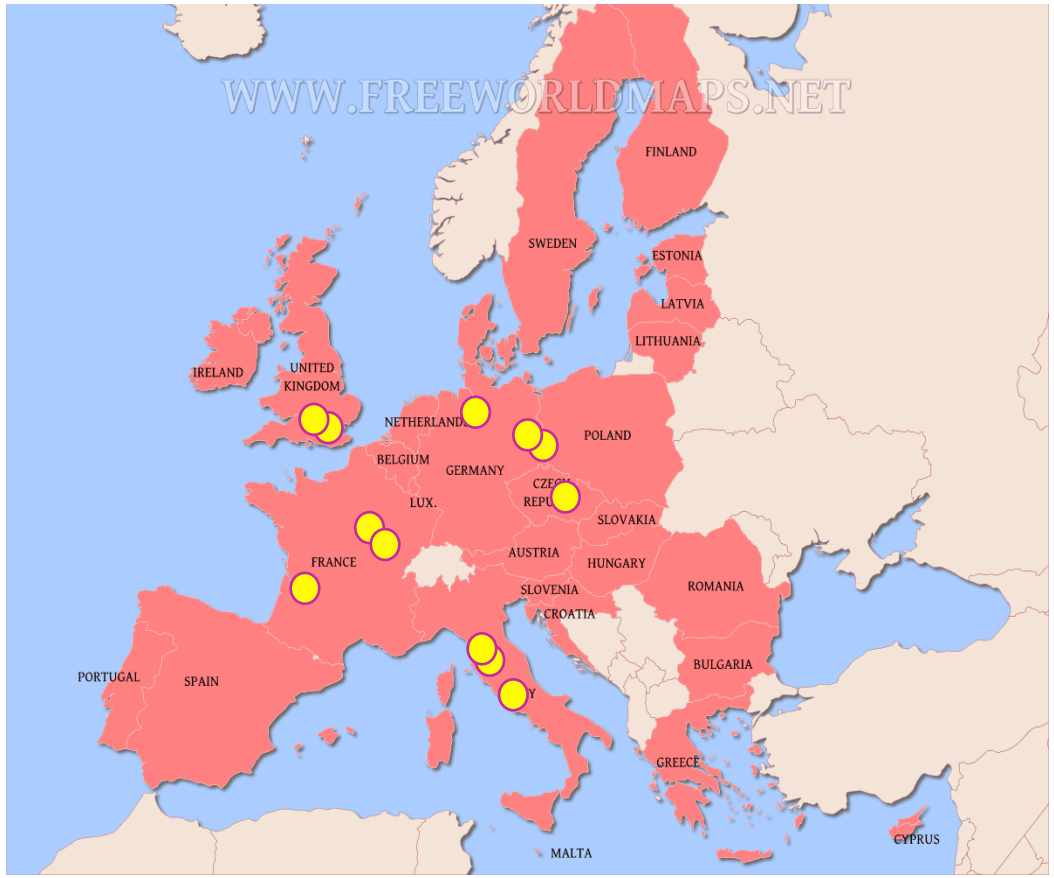
TRUMPF

VCS vacuum components & systems

imagine optic

DYNAMIC OPTICS

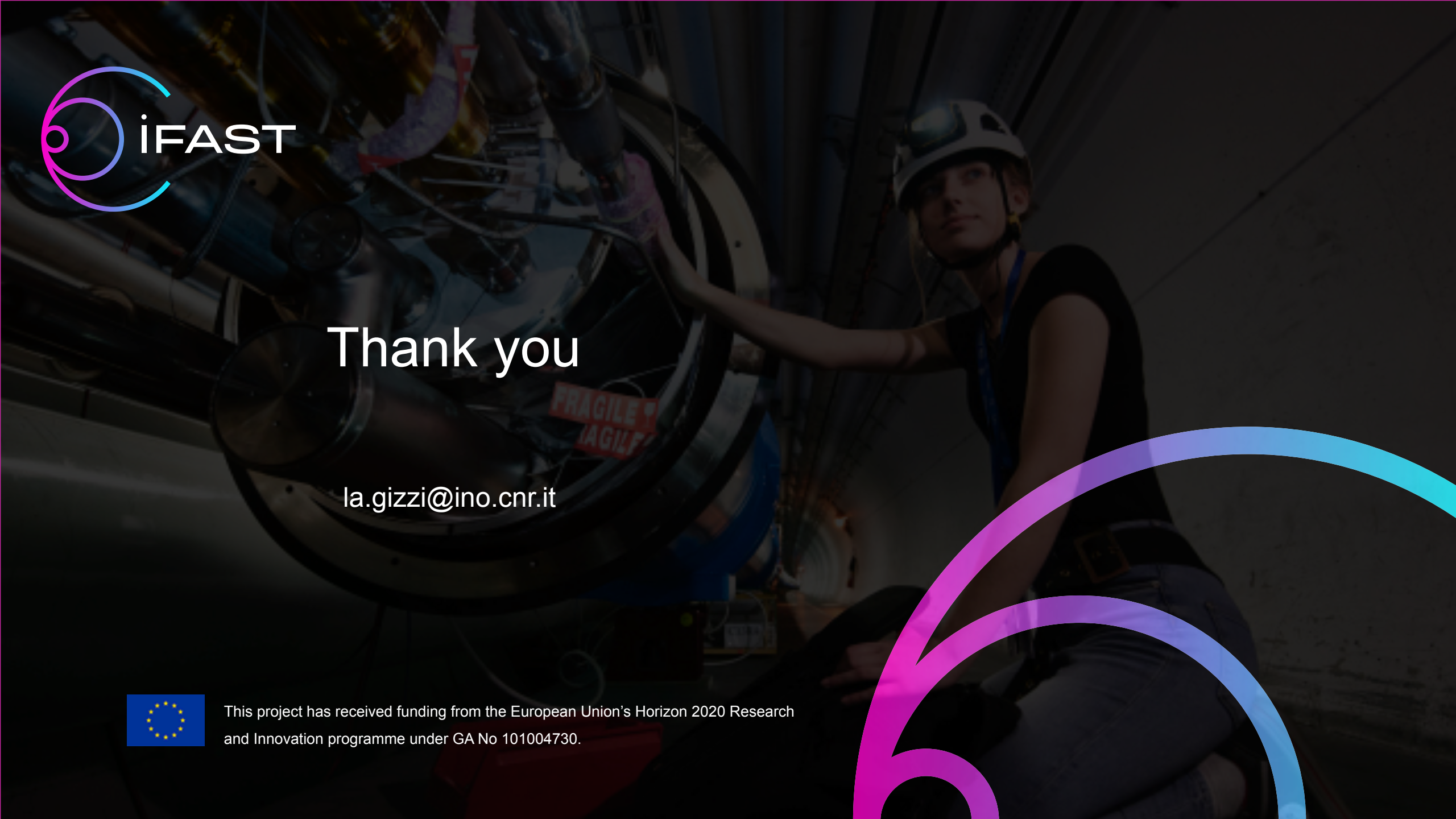
and many more



Leo Gizzi, Task 6.2, I.FAST Kick-off meeting, 4° May 2021, la.gizzi@ino.cnr.it

Forthcoming actions:

- **Towards D6.2 : LASPLA Strategy [M46] - Strategy for laser drivers for plasma accelerators:**
  - Update survey of existing/developing laser technologies, including next-in-line industrial products;
    - List against TRL of components and architectures;
    - Identify key needed collaborative developments;
    - R&D funding opportunities for labs/facilities;
- **Towards MS22 - LASPLA Workshop/School [M30]:**
  - Start preparation of the first LASPLA related workshop (18-22 April, 2022);
  - Secure participation to EAAC 2022
  - Training programme for LPA laser-driver development (Capri Summer School (12-17 Seprember 2021);



Thank you

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