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

LASERS for Plasma Accelerators, Targets and Focal Spot Stabilisation

Leonida A. GIZZI
CNR, Istituto Nazionale di Ottica, Pisa, Italy

also on behalf of F. MATHIEU and C. THAURY

iFAST 2nd Annual Meeting

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WP6 Task structure and objectives

WP6: Novel particle accelerators concepts and technologies (Objectives)

- Define a roadmap towards low-energy and high-energy physics applications
- Organise the biannual European Advanced Accelerator Concepts workshop (EAAC)
- Build a roadmap for new, efficient laser drivers for laser-plasma accelerators
- Develop innovative targets for laser-plasma acceleration
- Develop a new passive system to improve laser-driver control and quality

Task	Name	Task Leader
6.1	Novel Particle Accelerators Concepts and Technologies (NPACT)	**R. Assmann** (DESY) - WP Leader
6.2	Lasers for Plasma Acceleration (LASPLA)	**L. A. Gizzi** (CNR)
6.3	Multi-scale Innovative targets for laser-plasma accelerators	**C. Thaury** (CNRS)
6.4	Laser focal Spot Stabilization Systems (L3S)	**F. Mathieu** (CNRS)

Participants: CEA, CERN, CNR, CNRS, DESY, INFN, U. OXFORD, THALES, AMPLITUDE Technologies

WP6 Deliverables and Milestones

Deliverables related to WP6	
D6.1: EAAC workshops and strategies. *Report on the EAAC workshops as strategic forums for international accelerator R&D and resulting strategies*	M42
D6.2: LASPLA Strategy. *Report on a strategy for laser drivers for plasma accelerators.*	M46
D6.3: Electron acceleration experiments with new targets. *Report on electron acceleration with micro-scale target at a kHz repetition rate, and with long targets at the multi-Joule level.* **Report being finalized**	M24
D6.4: Improvement of the laser intensity stability on target. *Report showing the stability on two laser facilities before and after improvement.*	M36

MS21: Report on the novel accelerator landscape in Europe, facilities, projects and capabilities at the beginning of the 2020's. Lead – DESY, **M24**, Publication, website (Task 6.1)

MS22: LASPLA Workshop/School. Lead – CNR, **M30**, Report (Task 6.2)

MS23: Target manufacturing and characterization. Lead – CNRS, **M12** Report (Task 6.3) - **Report delivered**

MS24: Hypothesis on the causes of the instabilities of the focal spot profile. Lead – CNRS, **M24** Publication (Task 6.4)

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WP6 - Task 6.2:

LASers for PLAsma accelerators (LASPLA)

Task Leader: Leonida A. GIZZI – CNR-INO

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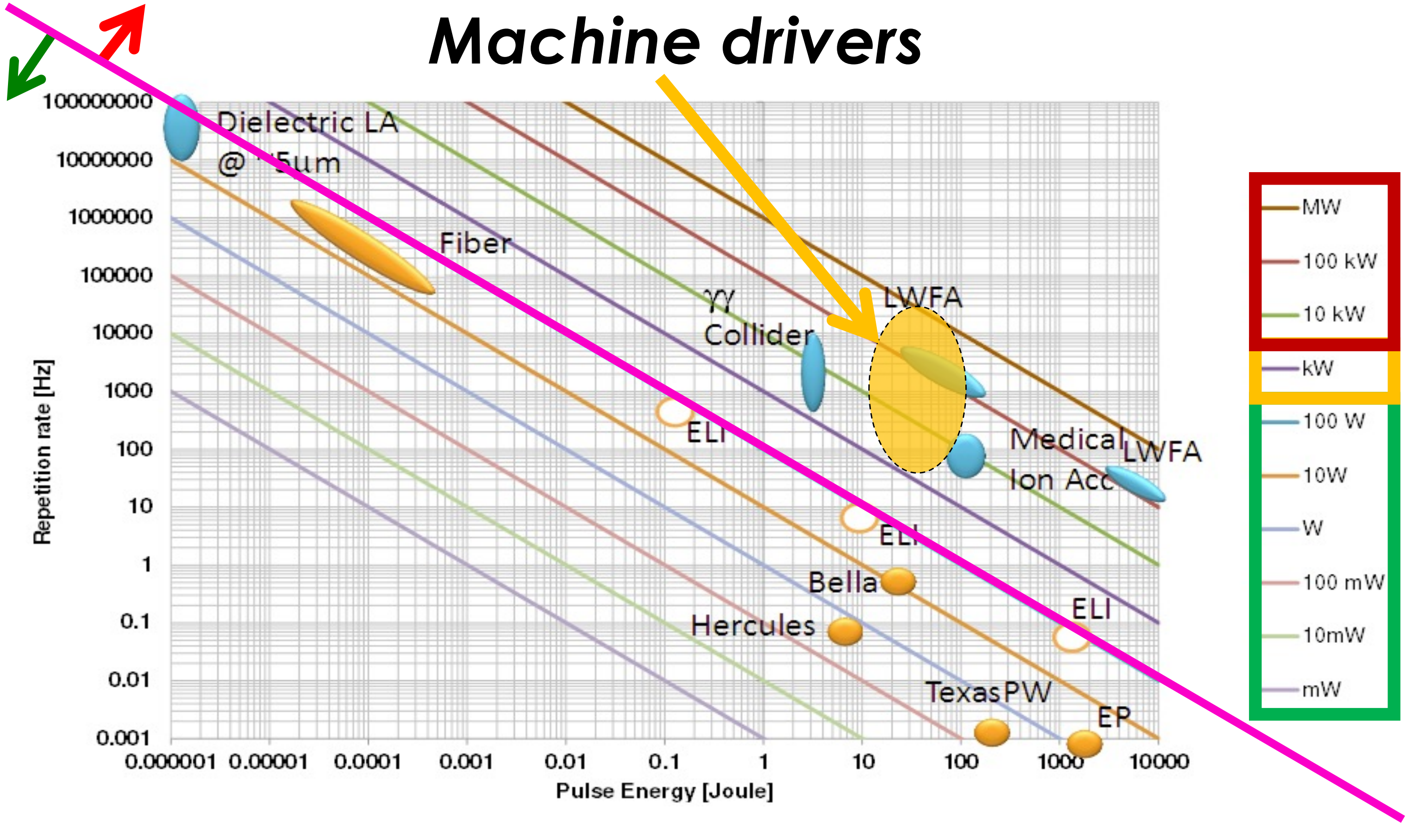
Status of laser driver development for LPA

Current reqirement for LPA driver: PW-class system, with high repetition rate (≈kHz)

Demanding high average power



- **Current industrial technology: ≈ Ti:Sa technology, pumped by flash-lamp pumped lasers**
  - Robust, reliable industrial technology
- **Mature technology: ≈ Ti:Sa technology, pumped by diode-pumped lasers**
  - Strong R&D effort in place (e.g HAPLS@ELI)
  - ≈ 3-5 years to go to first industrial LWFA demonstrator (e.g. Eupraxia) [1]
- **Beyond TiSA: targeting higher wall-plug efficiency and rep. rate, kHz and beyond, stability, control (space, time, spectral)**;
  - **5-10 yrs for first efficient**, multi-kW-scale demonstrator,
  - A strategy is needed to steer effort in the LPA laser driver direction: LASPLA

Major effort required to fill the gap between **existing** and **required** laser technology

[1] 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

EURONNAC Special Topics

18–24 Sep 2022, Hotel Hermitage, La Biodola Bay, Isola d'Elba, Italy

Special Topic S-ST3:
Laser Technology and LPA Results (e-, p+, ion)

Conveners:

Leonida Antonio GIZZI (CNR-INO *also at* INFN, Pisa)

Stefan KARSCH (LMU, München)

- Session conceived to contribute to the objectives of the Task 6.2, aiming at a **roadmap to foster delivery of advanced industrial laser drivers** with high-repetition rate and higher efficiency, for the first user laser-plasma based accelerators.

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Sessions on Laser Technology and LPA

	Sept. Monday 19	Sept. Tuesday 20	Sept. Wednesday 21	Sept. Thursday 22	Sept. Friday 23	Sept. Saturday 24
Morning I 9:00 – 10:30	**S-IN** (RA&MF) News from field - 1 short talk per ST	**S-ST1-b** (EG&PM) Beam driven Plasma Accelerators with focus on proton-driven	**S-ST3-b** (LG&SK) Laser Technology and LWFA Results	**S-ST4-b** (EC&RP) Distributed Plasma Accelerator Landscape in Europe and Technical Progress towards Applications	**S-ST5** (PM&CG&MH&MK &WL) International Landscape: Facilities, projects, initiatives	**NPACT / EuroNNAc Yearly Meeting** (RA&MF)
Coffee Break (20')						
Morning II 10:50 –12:30	**S-IN** (RA&MF) News from field - 1 short talk per ST	**S-ST2** (MT&JV) Simulation tools and roadmap,	**S-ST3-b** (LG&SK) Laser Technology and LWFA Results	**S-ST4-b** (EC&RP) **Special sub-session** (JO&al) Particle physics plasma test facility	**S-ST5** (PM&CG&MH&MK &WL) International Landscape: Facilities, projects, initiatives	**NPACT / EuroNNAc Yearly Meeting** (RA&MF)
Lunch Break (3h30')						
Afternoon I 16:00 –17:30	**S-ST1-a** (EG&PM) Beam driven Plasma Accelerators with focus on proton-driven	**S-ST3-a** (LG&SK) Laser Technology and LWFA Results	**S-ST4-a** (EC&RP) Distributed Plasma Acc. Landscape in Europe and Technical Progress towards Appl.	**S-SP** (BH&RW) Student Talks - Prize Award Session	**S-ST6** (RI&al) Structure-based accelerators and advanced radiation generation schemes	
Coffee Break (20')						
Afternoon II 17:50– 19:15	**S-ST1-a:** (EG&PM) Beam driven Plasma Accelerators with focus on proton-driven	**S-ST3-a** (LG&SK) Laser Technology and LWFA Results	**Special sub-session** (AI&al) Talks and discussion on plasma-based FEL exp.	**S-SP:** (BH&RW) Student Talks - Prize Award Session	**S-SU** (RA&MF) Summary Report from discussions - input to IFAST/NPACT MS21	
Posters 19:15 - 20:15	Participants and student grantees	Participants and student grantees	Participants and student grantees			
Dinner 20:30				**BANQUET**		

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Advanced LinEar collider study GROup

Roadmap for laser driver development

Parto of the **WP6: Novel Particle Accelerators Concepts and Technologies of i.FAST**

- High TRL Ti:Sa, 100 Hz, multi Joule scale (EuPRAXIA-Like) - 1-10 kW
- High TRL – Industrial development in progress at J level

- Short-medium term solution
- Proof-of-principle user laser accelerator
- Needs components testing

"Commercial" Ti:Sa kHz/<100 W front-end (< 100 mJ)

- Diode pumped, direct CPA, kHz, multi-Joule scale
- High efficiency with advanced lasing materials
- Optical parametric chirped pulse amplification (OPCPA) with diode pumping

- Longer term solution
- Scalable, efficient
- Needs high brightness, lower cost diode lasers for pumping
- Needs materials and components R&D

Innovation Fostering in Accelerator Science and Technology (I.FAST) coordinated by CERN https://ifast-project.eu/

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ALEGRO2023 Workshop

Mar 22 – 24, 2023
DESY
Europe/Zurich timezone

Enter your search term

- Overview
- Timetable
- Contribution List
- Registration ALEGRO 2023
- Participant List
- Payment
- Accommodation
- Venue and Transport Information
- Group Photo

Administrative Support: Daniela Koch
alegro2023@desy.de
+49 40 89983899

This workshop is the fourth in the ALEGRO workshop series. Previous workshops: ANAR2017 CERN, ALEGRO2018 Oxford, ALEGRO 2019 CERN

After a four-year hiatus the ALEGRO (Advanced LinEar collider study GROup) Workshop is returning. As in past iterations, the workshop will concentrate on addressing the recent progress and necessary steps towards realising a linear collider for particle physics based on novel-accelerator technology. Unique to this iteration will be two special sessions dedicated to updates on the relevant aspects of the European Strategy for Particle Physics (ESPP) Roadmap Process.

It will be held at the DESY campus from March 22 to 24, 2023.

This workshop is endorsed by the International Committee for Future Accelerators.

ICFA

Laser driver relevant Highlights 1/2

- Development emerged clearly on **industrial scientific laser** development towards the kW regime of Ti:Sa systems.
- Marked progress on **the use of** robust, efficient industrial multi kW, Yb:YAG thin disk laser technology:
  - plasma-modulation resonant wakefield
  - **non-linear spectral broadening** for multi-TW, kW, kHz femtosecond pulse generation with high efficiency (up to 80%)

Nonlinear Compression of a Dira 1000-5 (500fs)

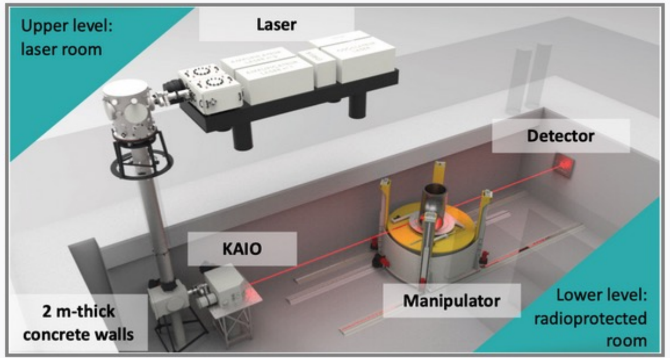
Goal: 200mJ; <50fs; 5kHz

18 Tom Metzger | TRUMPF Scientific Lasers | EuroNNAc S-ST3-b #44

[IPP - CNRS, CNR/INO]

in collaboration with

[SourceLAB + DF Photonics Consult]



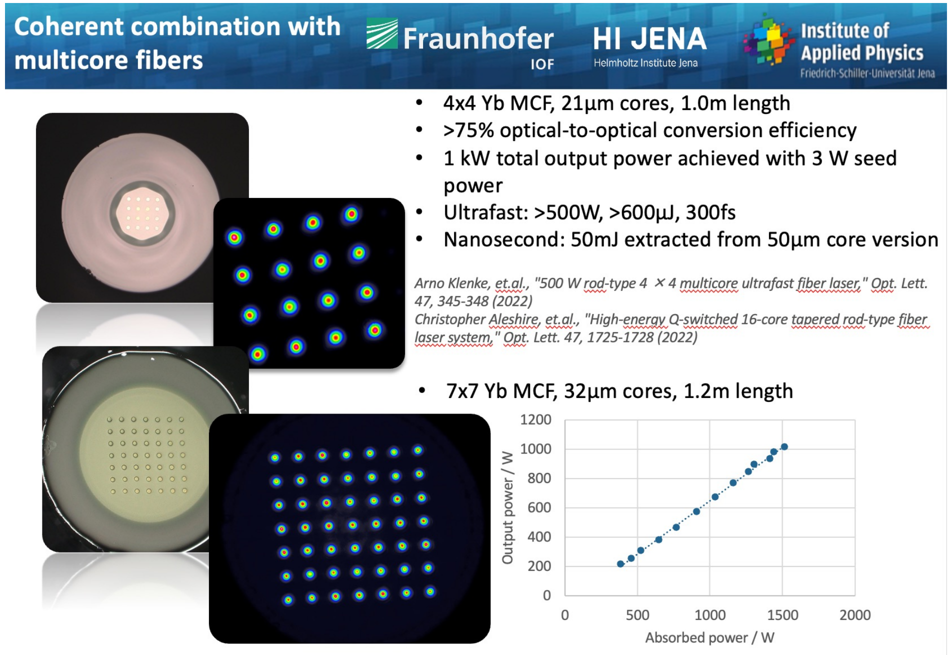
KAIO Accelerator

The project aims to industrially develop a cost-efficient and stable high-power laser technology in kHz class, apt to be used in radiobiology and non-destructive testing applications. It promises to reduce energy requirements for laser-plasma accelerator.

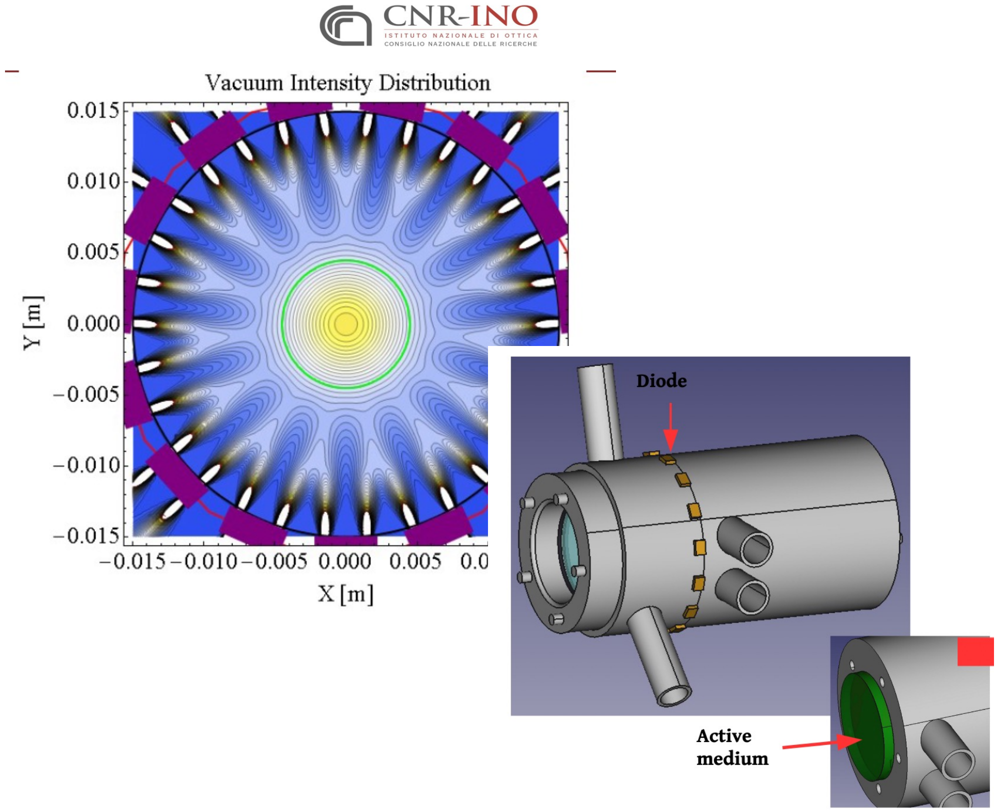
Institutes and partners: CNRS-LOA (France), CNR-INO (Italy), SourceLAB (France).

Laser driver relevant Highlights 2/2

- **Fiber coherent combination** aiming at few cycle, 100 Hz, with self-phase modulation and J-scale pulses with multi-core fibers.
  - Demonstrated wp efficiency of 30% is an extremely valuable result.
- Direct **diode-pumping of Thulium doped** new materials (sesquioxides) is expanding, entering development phase

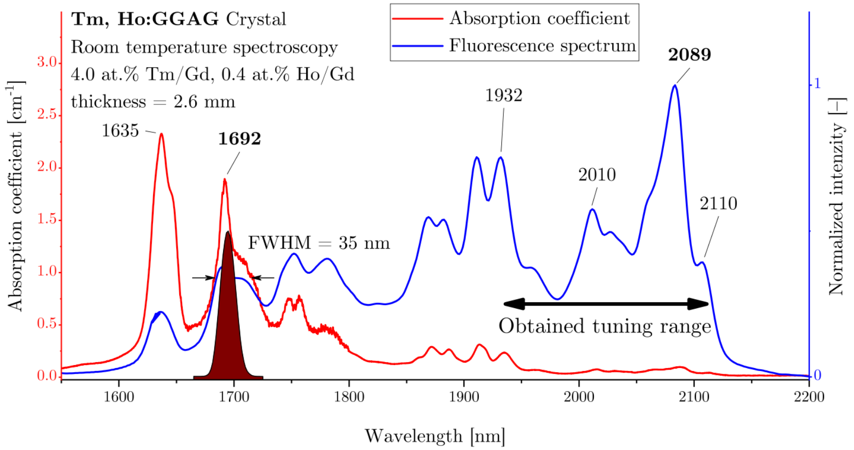


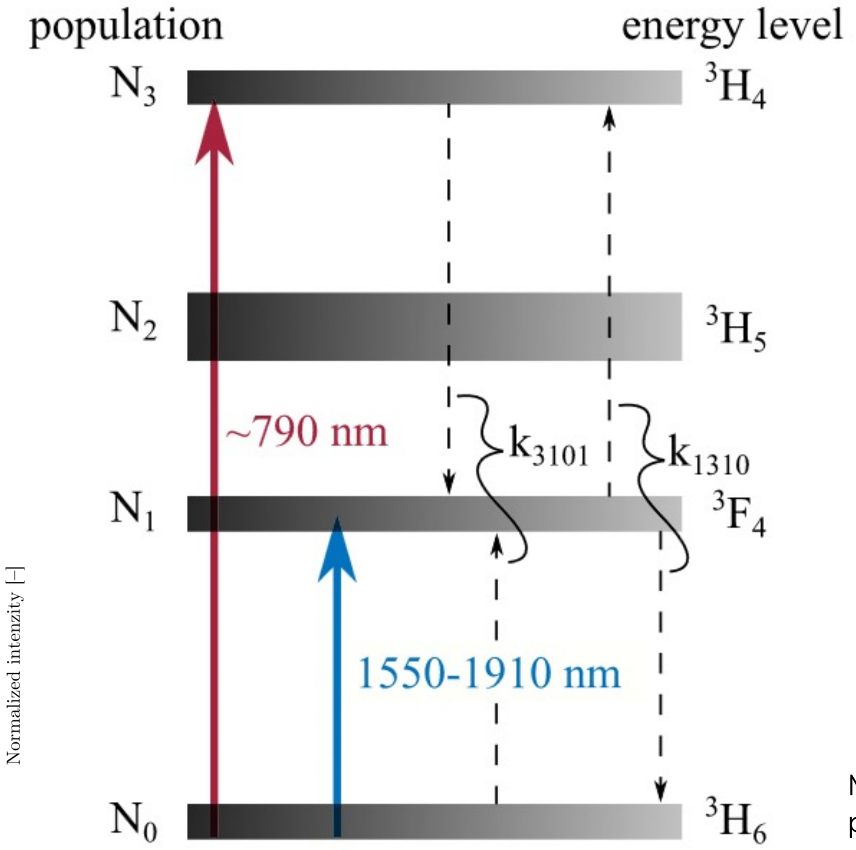
Jens Limpert

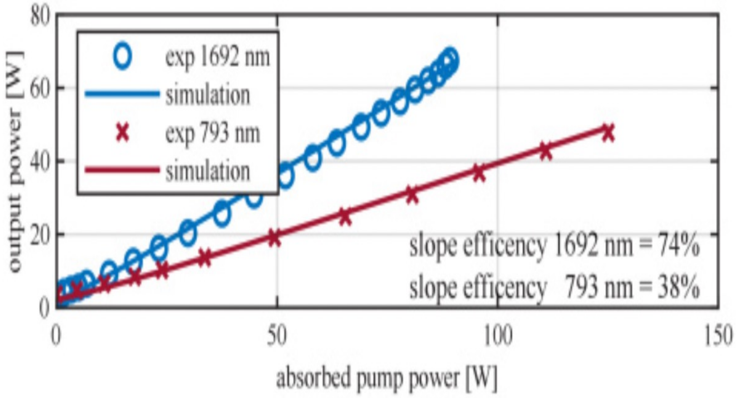


Higher wpe: In-band pumping for low *qd*

Thulium based gain medium can also be pumped with in-band absorption with virtually marginal quantum defect:
High efficiency and lower heat deposition.







>80% slope efficiency demonstrated in fibers

Mathias Lenski et al., "Highly efficient, in-band pumped thulium-doped fibers for high-power ultrafast 2 μm wavelength laser systems," Proc. SPIE 12400, Fiber Lasers XX: Technology and Systems, 124000N (8 March 2023); doi: 10.1117/12.2650475

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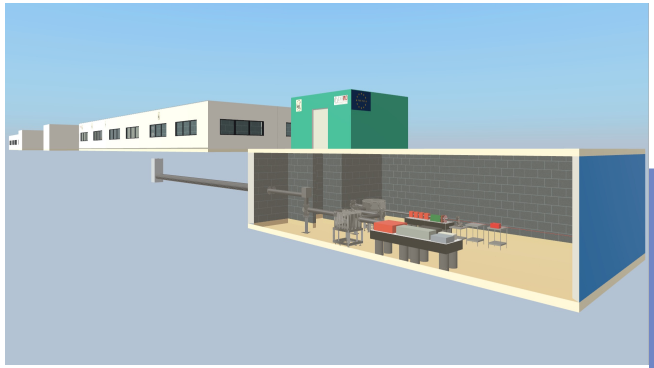
New path for intra-band pumping and marginal quantum defect: step change in wpe?

Establishing 100 Hz Ti:Sa laser driver

Funded by the European Union

- **EuPRAXIA**
- PW class,
- 100 Hz repetition rate,
- multi kW average power,
- diode pumped
- Full therma load transport

Eupraxia laser development is aimed at delivering more efficient, kW-PW laser driver for plasma acceleration at >100 Hz rate



EuPRAXIA Advanced Photon Source

- **EuAPS@CNR-Pisa**
- 30 TW peak power
- 100 Hz repetition rate
- 100 W average power
- Diode pumped
- Thermal load effects

- **CURRENT**
- **PW class,**
- **Hz repetition rate,**
- **≈10 W average power**
- **flashlamp pumped**
- **No thermal load transport**

Multi M€ funding

I-PHOQS INTEGRATED INFRASTRUCTURE INITIATIVE IN PHOTONIC AND QUANTUM SCIENCES

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

WP6 - Task 6.3:

Multiscale innovative targets for laser-plasma acceleration

Task Leader: Cedric THAURY, CNRS-LOA

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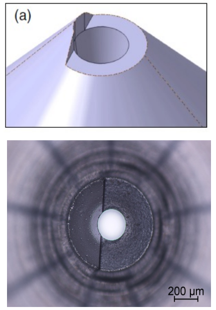
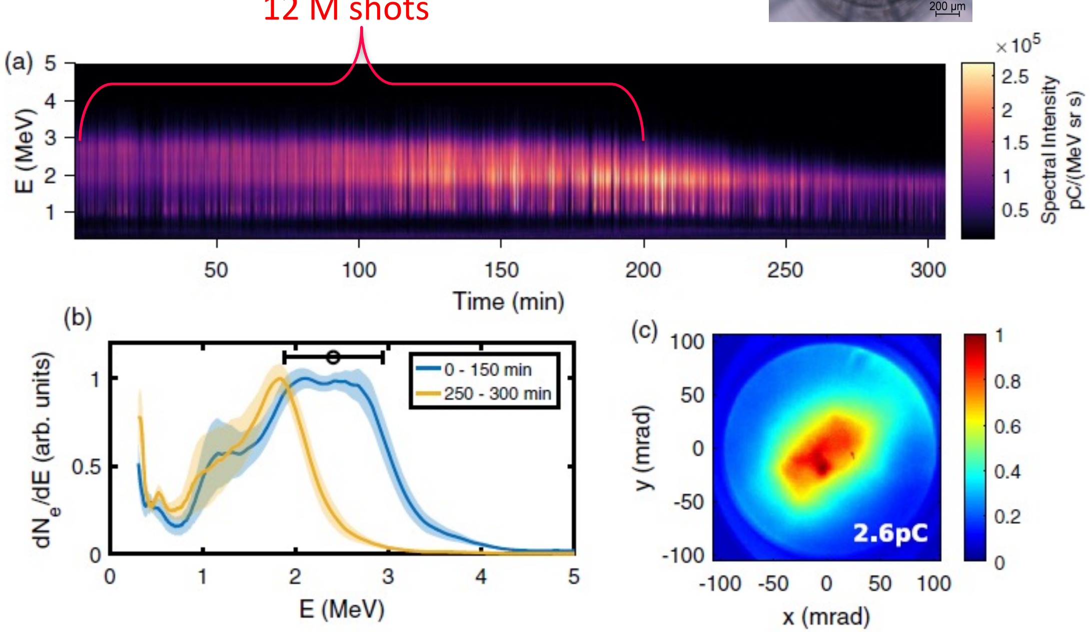
Task 6.3 multi-scale innovative targets for laser-plasma accelerators : *low-energy kHz accelerator*

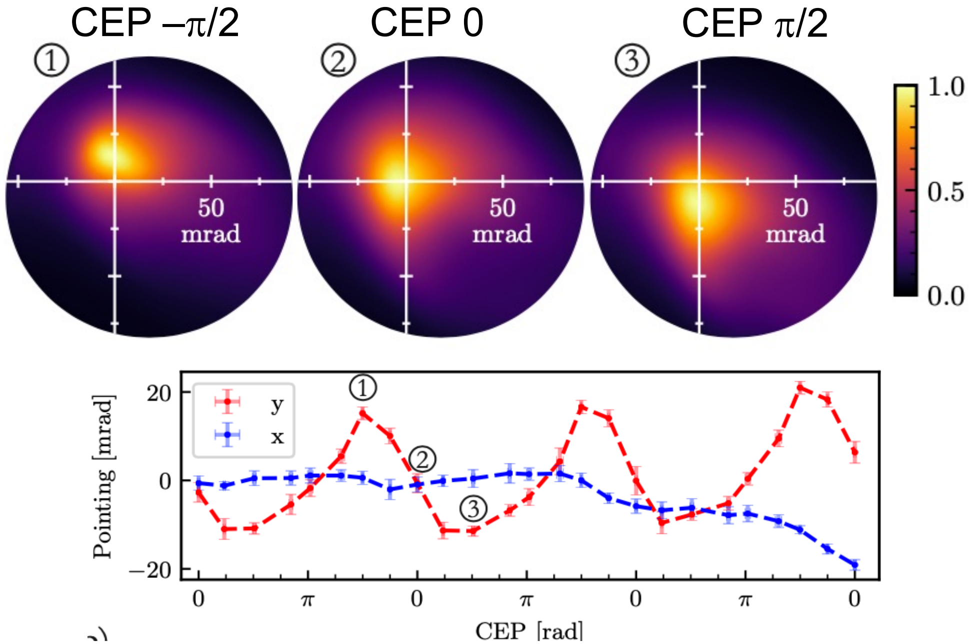
Glass nozzles with shock
→ stable acceleration at a kHz rep. rate





L. Rovige et al., RSI **92**, 083302 (2021)

Control of the laser CEP
→ improved stability and beam stearing



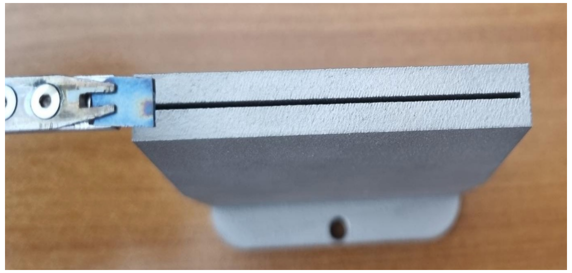
J. Huits et al. Phys. Rev. X 12, 011036 (2022)

Task 6.3 multi-scale innovative targets for laser-plasma accelerators : *high-energy accelerator (also for future laser drivers)*

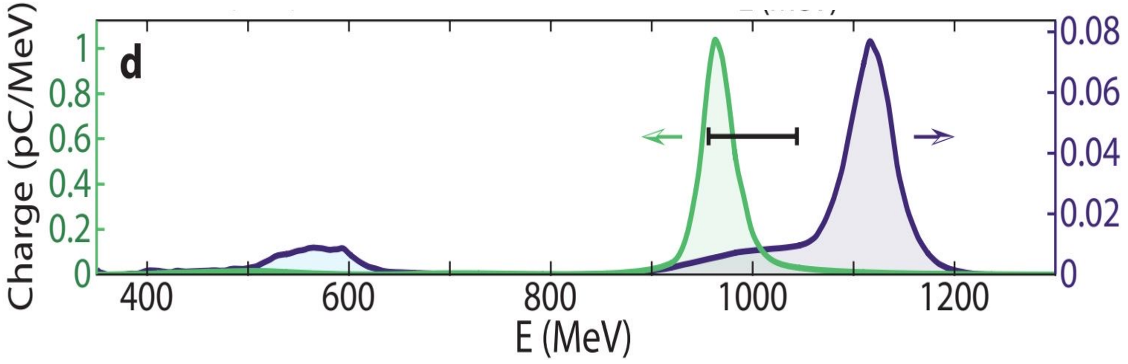
First demonstration of **controlled injection** and acceleration in a **laser-plasma waveguide**

→ High quality GeV beam with a J-class laser (LOA)
→ High quality 2.5 GeV beam with a 10 J laser (Apollon)

6cm long target



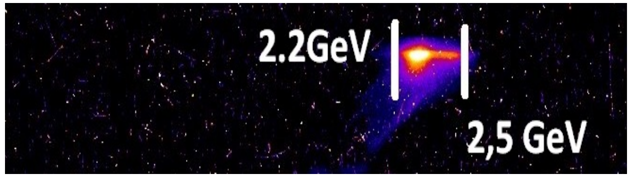
LOA results (1.5 J)



Apollon results (10 J)

Best electron spectrum without guiding

Best electron spectrum with guiding



Oubrerie et al. Light Sci Appl 11, 180 (2022), Oubrerie et al J. Opt. 24 045503 (2022)

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

WP6 - Task 6.4:

Laser focal Spot Stabilization Systems (L3S)

Task Leader: Francois MATHIEU, CNRS-LULI

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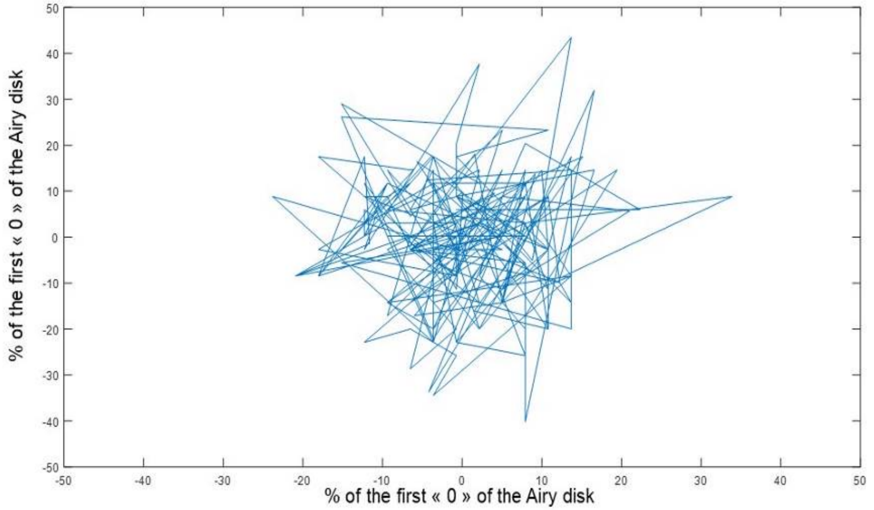
Task 6.4 - Summary of activities in P1

- ***Characterization of beam pointing stability with high sensitivity for accelerator-level performace***



Measurement done over 1 hour in the target chamber

The beam stability is ± 3 µrad PTV

Objective is ± 0,1 µrad PTV

- ***Installation of an active stabilization loop in the amplification stages***

    Beam stability improved by a factor 2

- ***Characterization of the mechanical frame under progress***
- ***Aiming at +/- 0,15 µrad PTV stability requisite for particle beam stability in a laser driven accelerator***

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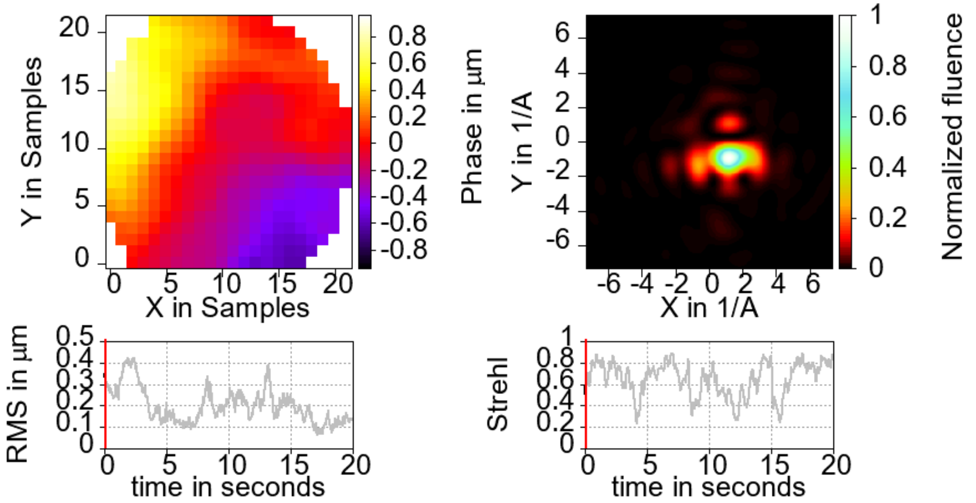
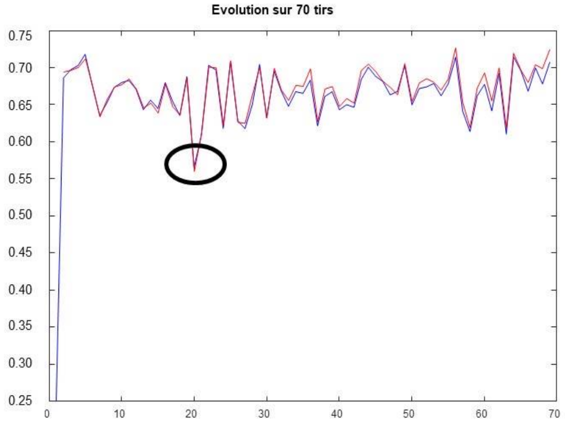
Task 6.4 - Summary of activities in P1

- *Characterization of focal spot stability with most* ***<u>advanced metrology framework</u>***



Measurement done with a **wavefront sensor** running at 200Hz and a cw laser

Strehl rat



- *Installation of new system to* ***minimize airflow***

  Strehl stability improved up to ± 7.8%.

- *Procurement of an 1kHz active loop under progress*
- ***Aiming at +/- 2% PT>V stability on the Strehl ratio, since this impacts beam pointing stability***

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Summary

Year 2 Highlights of Tasks WP6.2-3-4: strong progress on laser driver developments:

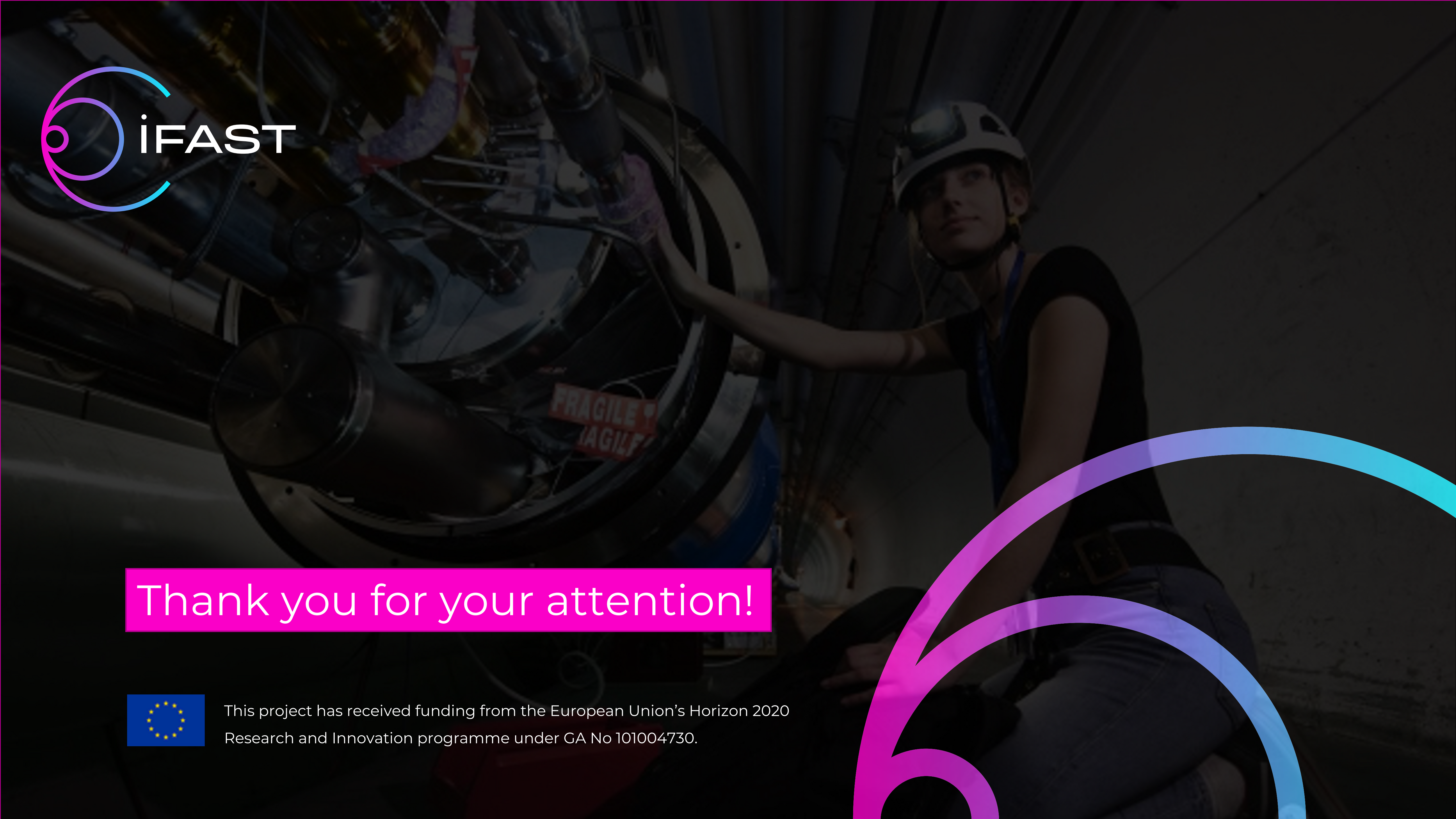
- Increasingly involving industrial partners with new developments for use of robust, commercial Yb:YAG ps, kW, multi-kHz (High TRL): sync with iFAST Innovation Fund (Kaio-accelerator)
- Infrastructure developments pushing industrial femtosecond Ti:Sa laser technology: moving now to kW, 100 Hz (High TRL)
- Fiber and other laser schemes with new materials and for direct diode pumping architectures markedly aiming at high efficiency (low-medium TRL)

Laser stability and quality control progressing to the required specifications for LPA

Target technology including guiding and injection control is developing fast

Milestones and Deliverables on track

Next: Combined WP6 Laser and Target Tasks meeting @ EAAC2023, 18-22 September, Elba, Italy



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