Next-Generation High-Repetition-Rate Lasers for Laser–Plasma Accelerators and Secondary Sources

EAAC 2025 (Elba) -September 2025

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A Laser Bright Future

01

Amplitude Laser Group

Amplitude at a glance

Innovative & visionary company, created in 2001

Expert manufacturer in ultrafast laser technology

10+ offices and production plants around the world.

450 + employees worldwide

3 000 M² of production area

5 000 + lasers in the field

Amplitude Laser Group Headquarters, near Bordeaux, France

Amplitude

Global company with a global reach

The most complete and advanced Femtosecond & Nanosecond laser portfolio

High peak power: from TW to multi-PW

Ti:Sa-based solutions
> fs to ps, up to 10s J

High repetition rate

Yb-based solutions
> Hz to kHz, up to J, ps
> MHz, mJ, 100s fs

High Energy

Nd-based solutions
> ns, up to 100s J

Amplitude

Our Expertise: High Energy

1. *Increasing the repetition rate of high peak power systems*

   *Targeting Fundamental physics and **Fusion applications***

2. *Increasing the energy of high repetition rate systems*

   *Targeting Laser Plasma Accelerators applications for **secondary sources***

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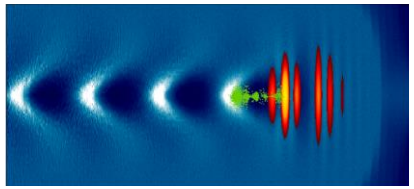
Ultrafast laser-driven secondary sources

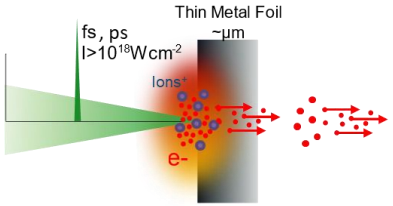
Peak Intensity

Petawatt(Ti:Sa)

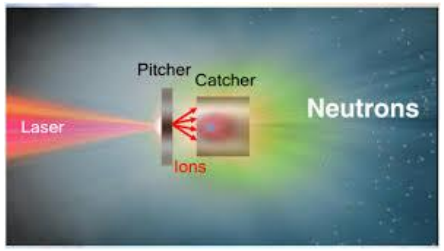
GeV electron sources



MeV proton sources

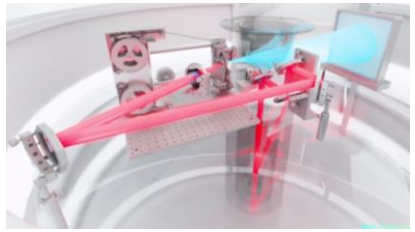


MeV neutron sources

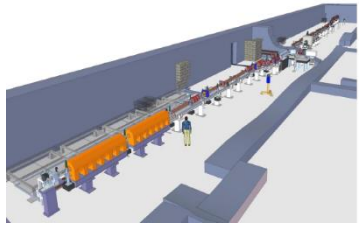


Terawatt (Ti:Sa/Yb)

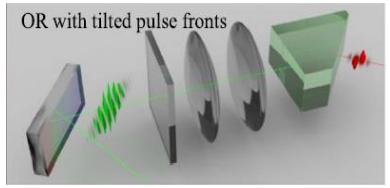
LPP X-ray sources



ICS X/γ-ray sources

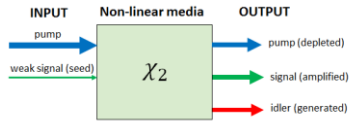


THz sources

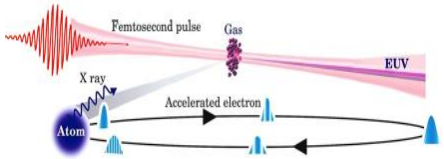


Gigawatt (Yb)

UV-VIS-MIR sources



XUV sources



Average power

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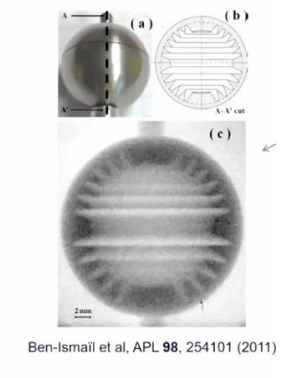
Motivation

> Industry & National Security – NDT with X-ray sources

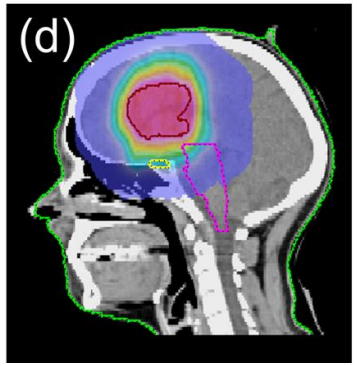


Ben-Ismaïl et al, APL **98**, 254101 (2011)

Motorbike engine
I12 JEEP beamline
Baimpas *et al*, J. Synch. Rad. **20**, 316 (2013)

Aircraft wing
X-ray tube
Xu *et al*, NDT in Aerospace 2010

> **Medical** – VHEE / protontherapy



*Panaino et al, Cancers **17**, 181 (2025)*
https://doi.org/10.3390/cancers17020181

> Improvements needed :

- Stability = fast stabilization on laser parameters
- Flux = higher rep rate

Towards High Energy AND High Average Power Lasers

Amplitude

02

Increasing TiSa drivers repetition rate

Development of « real world »applications requires an Exploration phase followed by an Exploitation phase

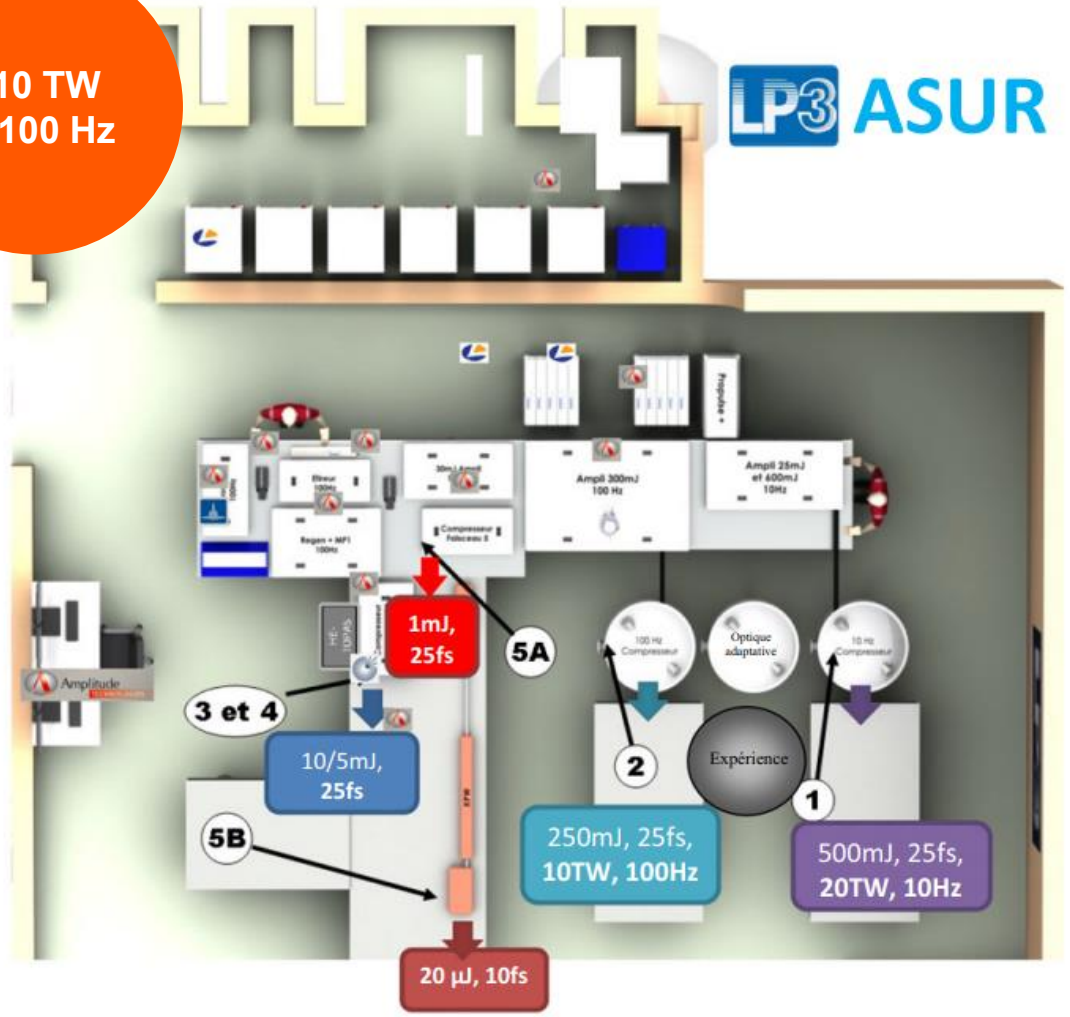
Exploration requires flexible tools. Ti: Sa technology is the best laser technology for developing specific applications

Exploitation requires efficient and optimized tools. Direct Diode pumped Ytterbium technology is the best laser technology exploiting applications

Amplitude

ASUR a multidisciplinary platform since 2013

>10 TW at 100 Hz



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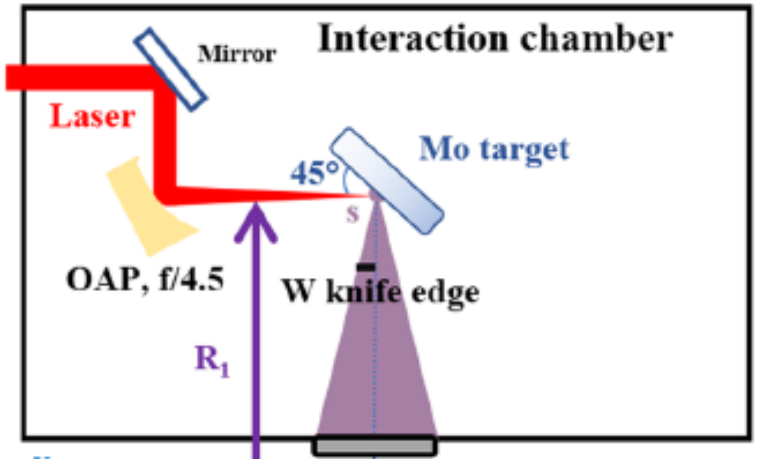
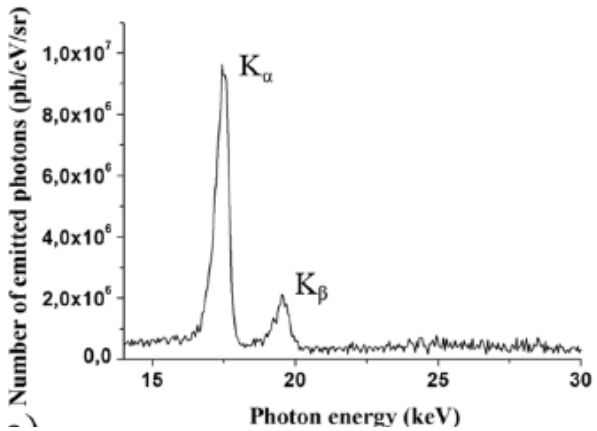
ASUR : driving X-ray sources for 12 years

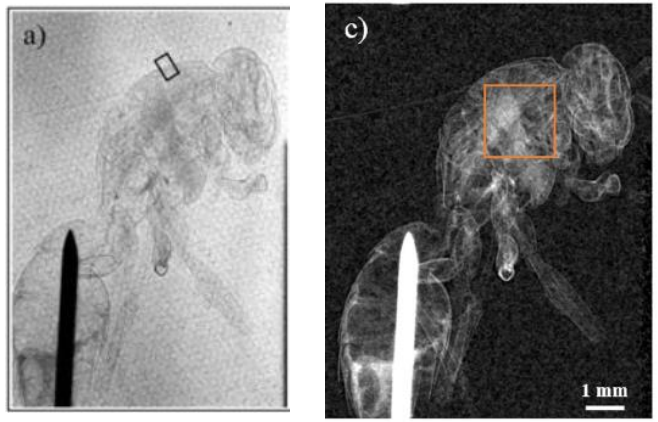
- LPP laser driver : 250mJ 25fs 100Hz



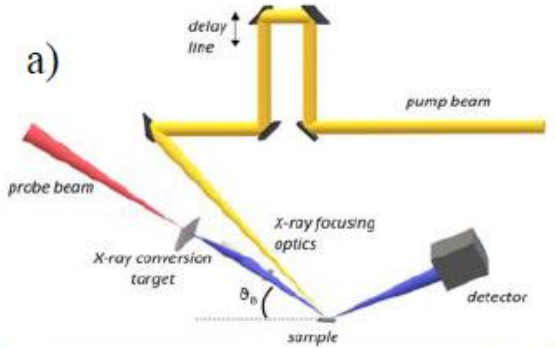


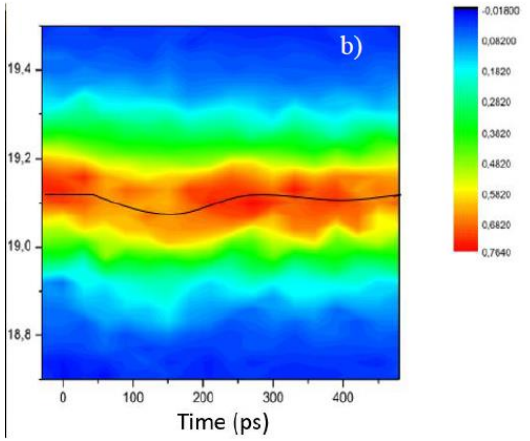
Gambari et al. Sci Rep (2020)
doi.org/10.1038/s41598-020-63614-3

High resolution phase contrast imaging



Time resolved X-ray diffraction





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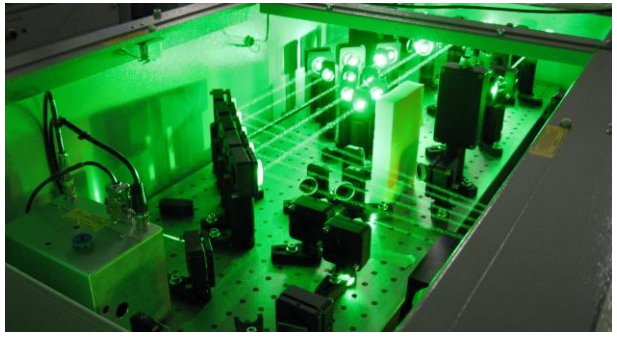
Key Technologies

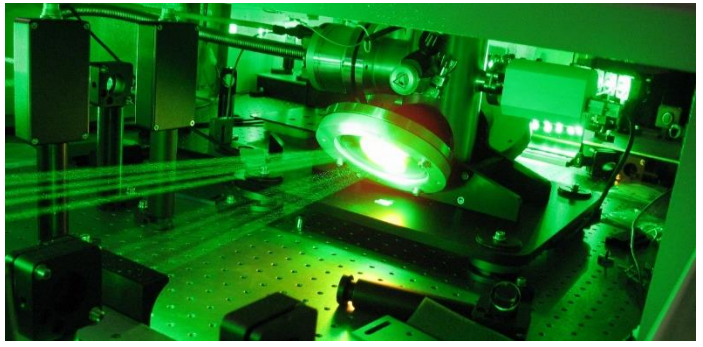
2013

- **High contrast Seeder**
  - Based on XPW and Saturable absorber
- **Pump lasers at 100 Hz**
  - Flashlamp puming : Up to 1J 100Hz @532nm
- **Thermal management of TiSa Amplifiers**
  - Cryogenic cooling : 360mJ 100 Hz output
- **Thermal management of gratings**
  - Passive cooling

2025

- **High contrast Seeder**
  - Based on OPCPA
- **Pump lasers at >100 Hz**
  - Diode puming : 1J up to 10J 100Hz
- **Thermal management of TiSa Amplifiers**
  - Cryocooling up to few J 100Hz
  - Liquid cooling >1kW (10J 100Hz)
- **Thermal management of gratings**
  - Active cooling / MLD gratings





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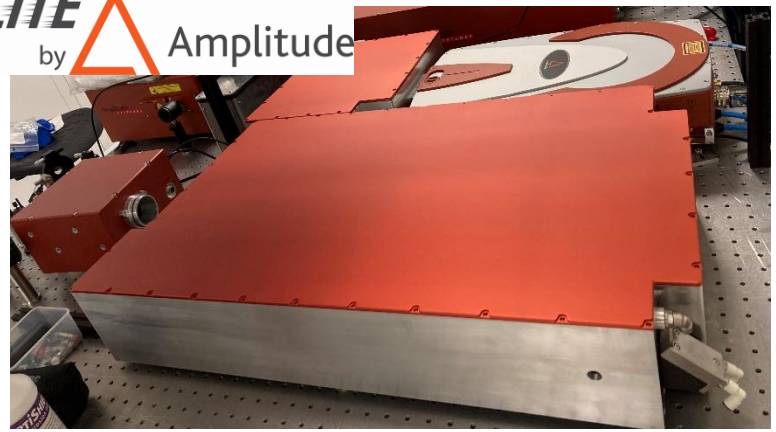
High contrast OPCPA seeder

FASTLITE by Amplitude

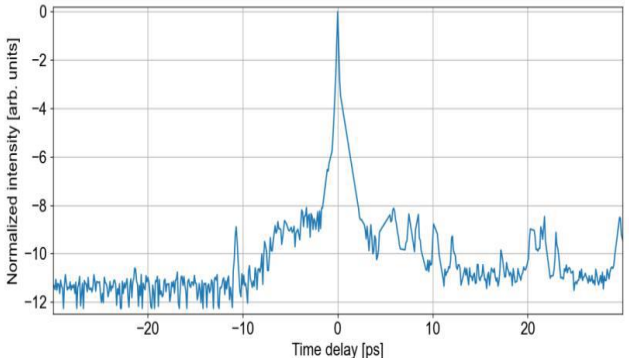
Based on Ytterbium industrial pump

µJ to mJ OPCPA developed for Petawatt TiSa lasers

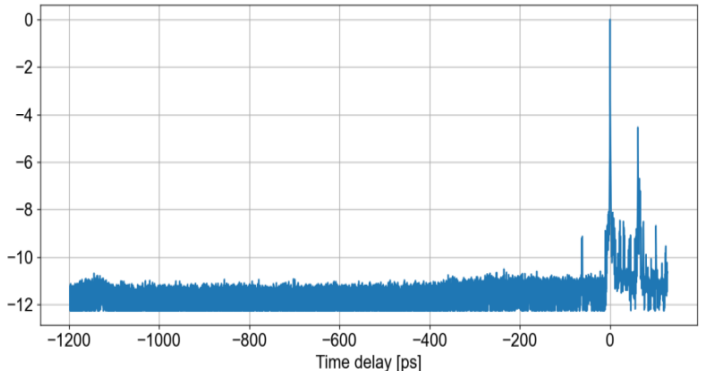
… ready for seeding Nd/Yb CPA lasers



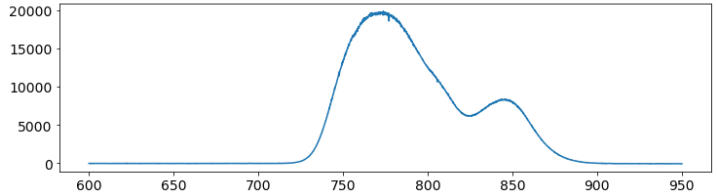
ps contrast



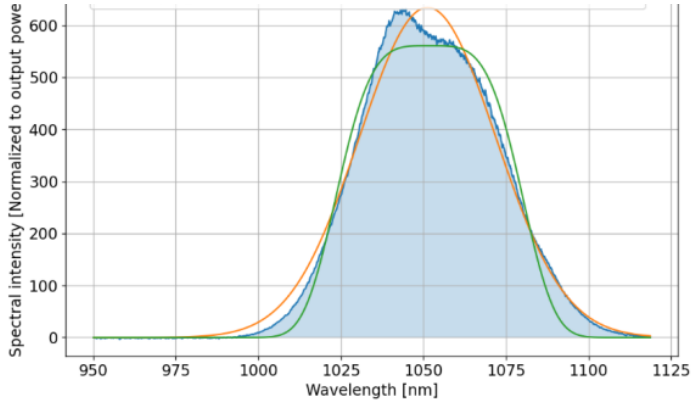
ns contrast



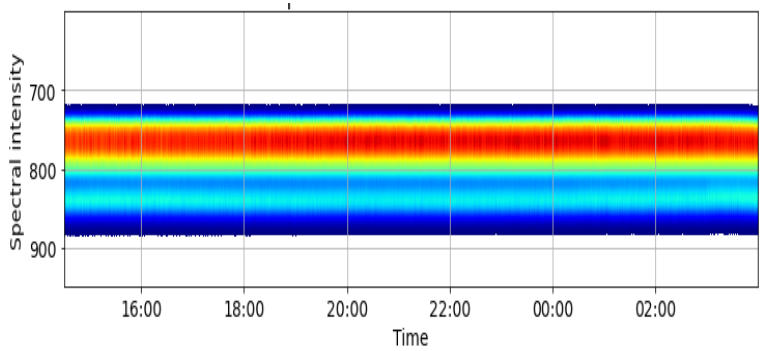
Seeder @800nm



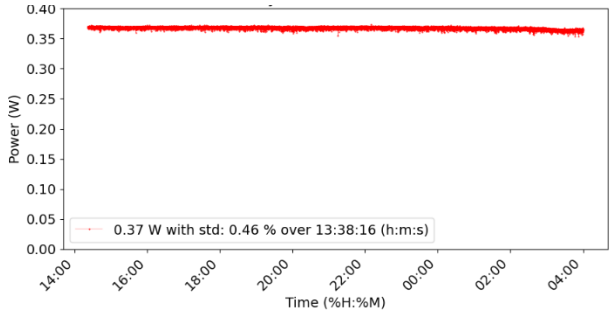
Seeder @1050nm



Spectral stability

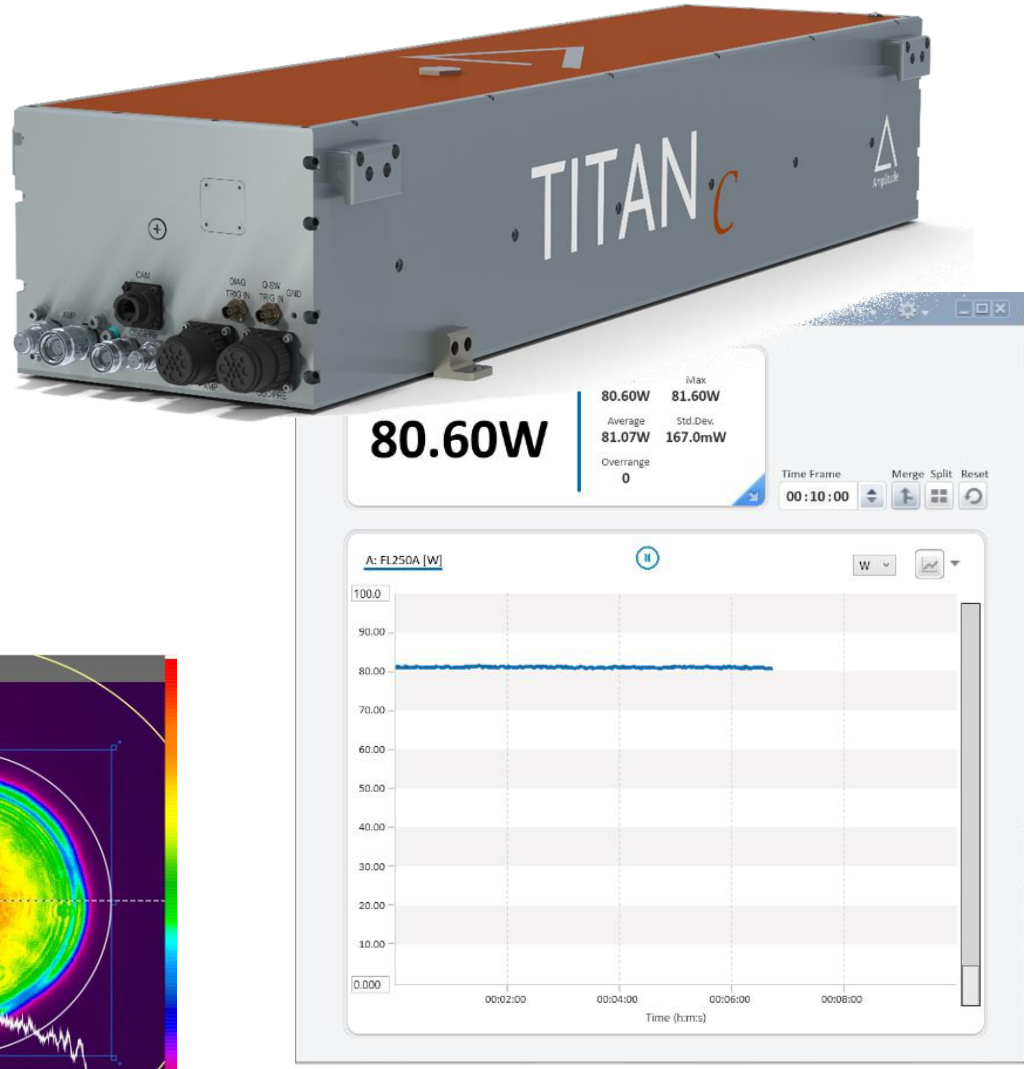


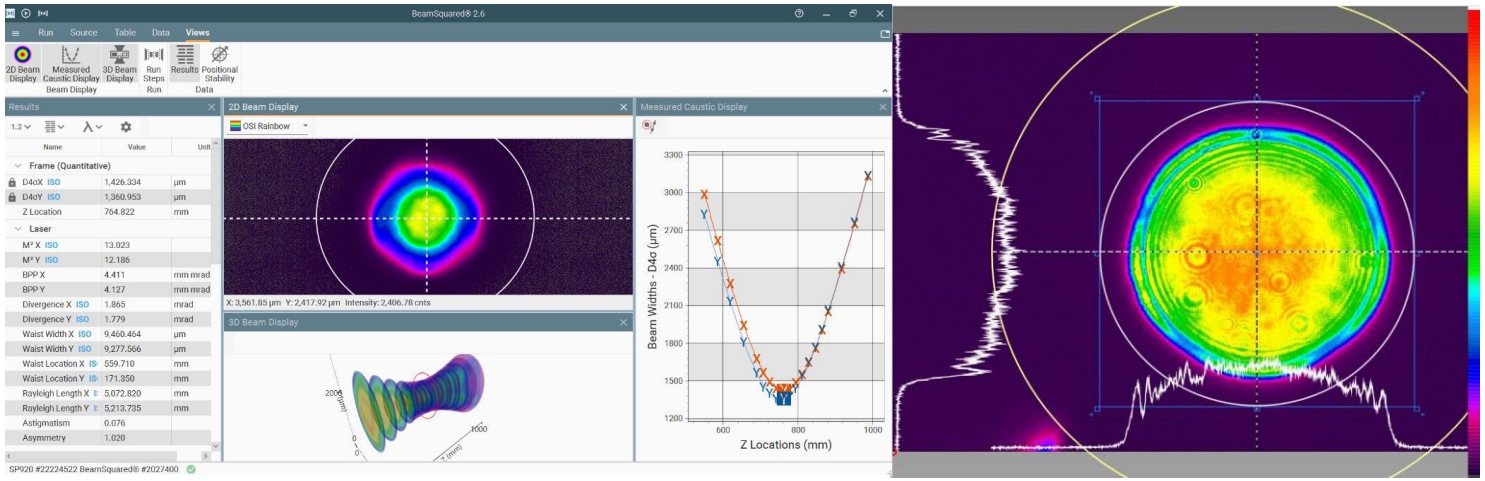
Power stability



DPSS Pump Laser: Titan Century

- Newly developed 100-200 Hz pumping source
  - Diode-pumped
  - > 1.4 J in IR
  - > 0,8 J at 532 nm
  - 100 to 200 Hz
  - Excellent beam properties





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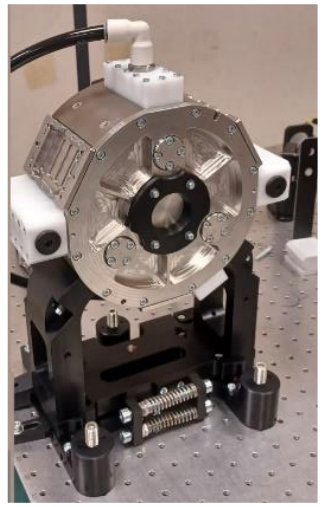
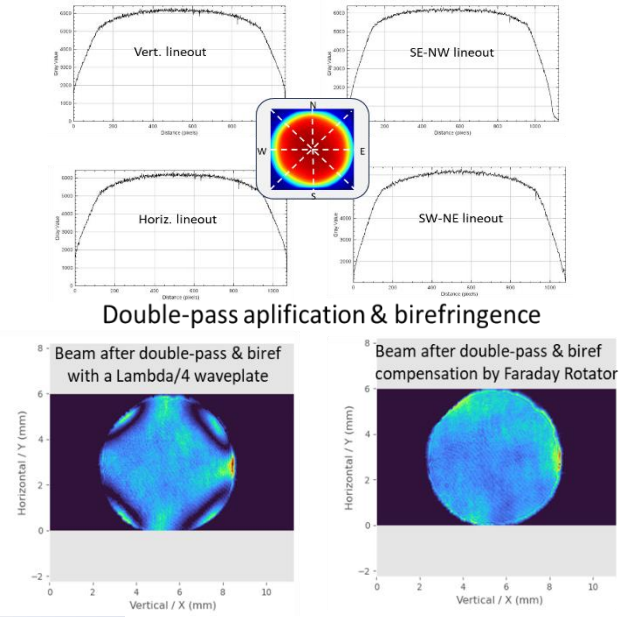
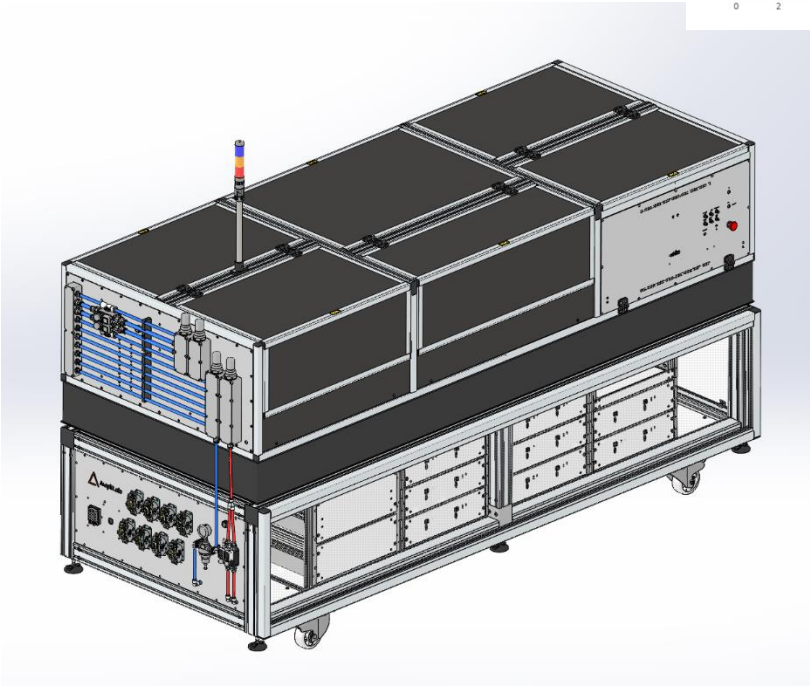
Towards 10J 100Hz pumps

- HE version under development for 4-10J 100Hz
  - Diode-pumped
  - 6-14J in IR
  - 4 - 10J at 532 nm
  - 100 to 200 Hz

- Laser head validated in gain & birefringence
- First version @4J expected summer 2026







Amplitude

Ti:Sa Cryogenic cooling

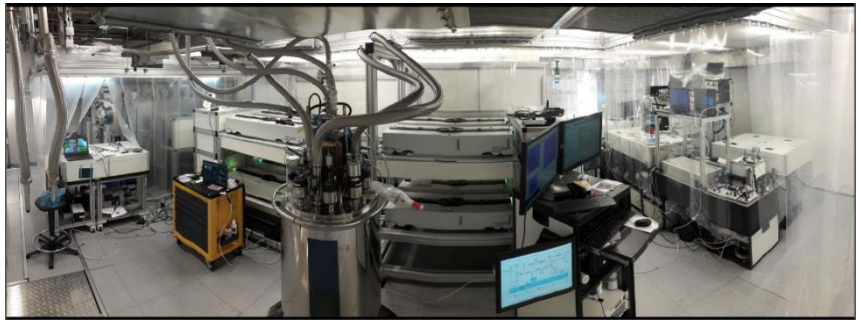
> Cryo temperatures : better conductivity, i.e. lower thermal lensing

> Compatible with multi-kW heat extraction

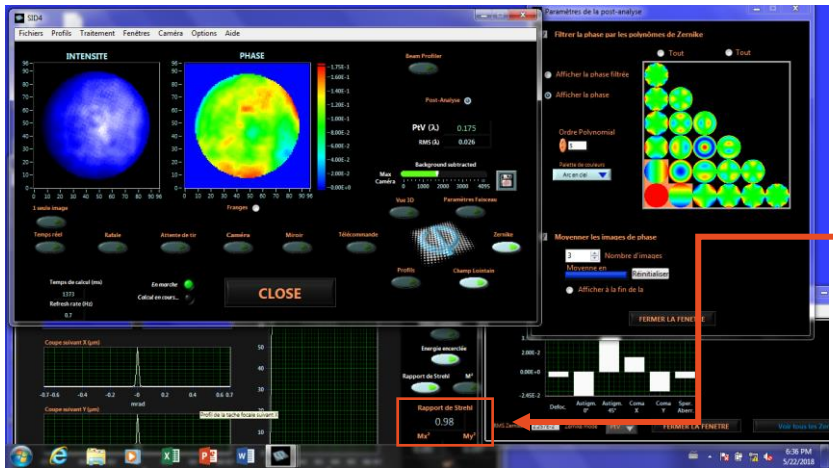
> Use twin architecture (patented solution)

> High beam quality and focus stability

> Already validated on HiBEF Relax laser @ XFEL (500TW@5Hz)



TWIN CryoCooler with the two TiSa crystals

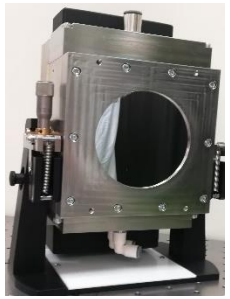


Strehl ratio 98%
With DM

Increasing rep rate: Amplitude roadmap

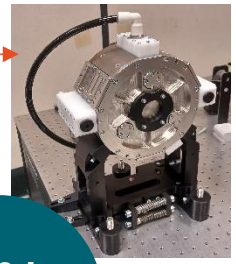
Liquid cooling of multidisks is a key enabling technology for high rep rate PW lasers

Flashlamp Pumped



50J 10Hz

Diode Pumped



>1J 100Hz

>10J 100Hz

2016 2019 2022 2025 2028 2031

750TW 10Hz

> 500TW 100Hz

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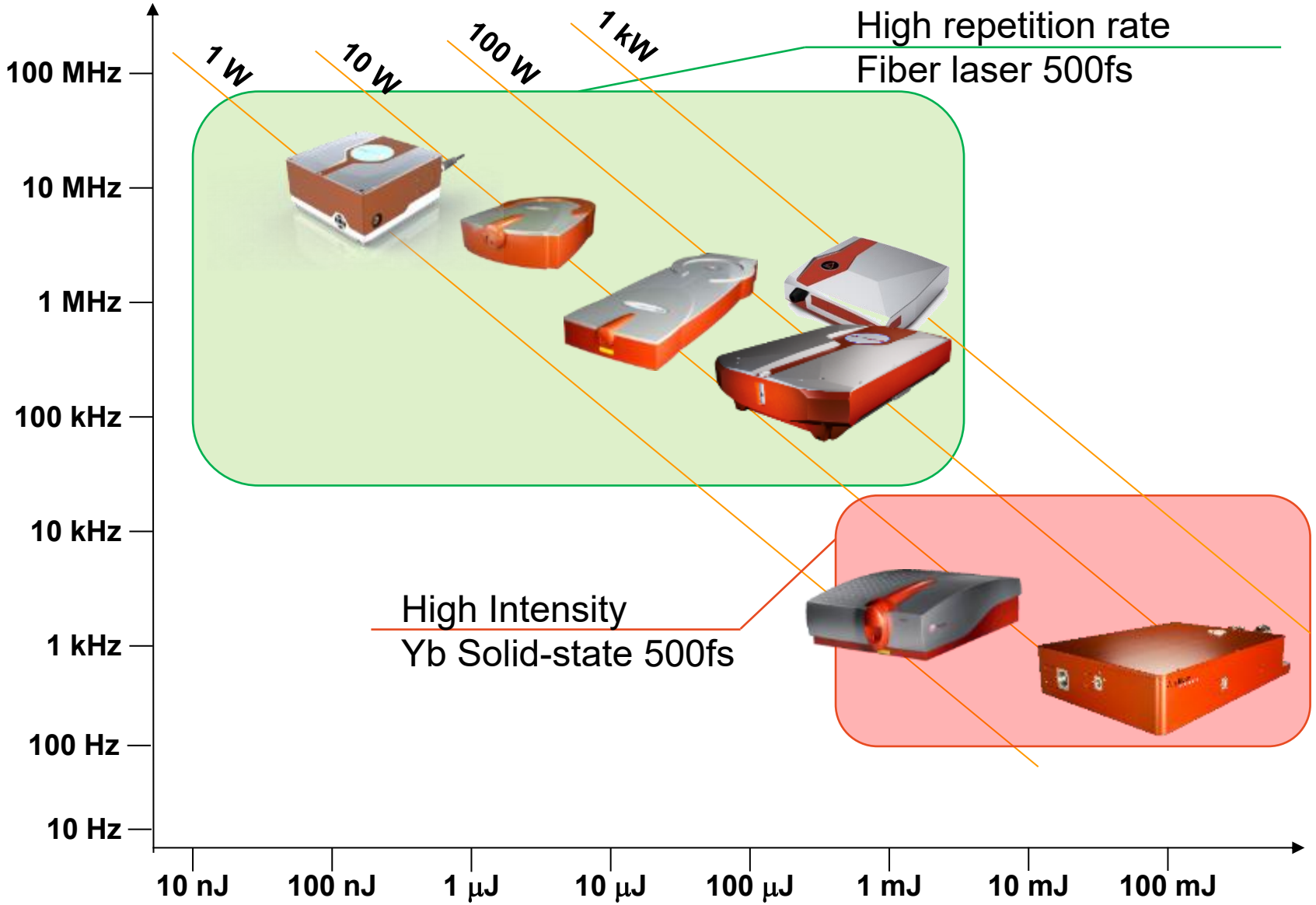
03

Developing Yb lasers for exploitation

Yb Ultrafast laser product range



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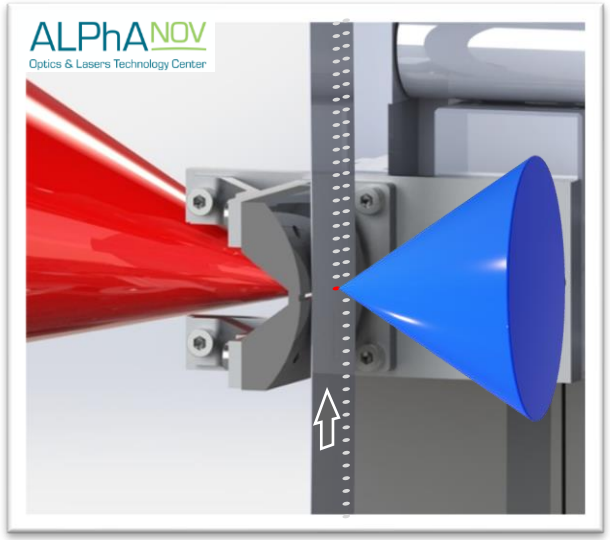
LPP X-ray source with X-Pulse Yb ps laser

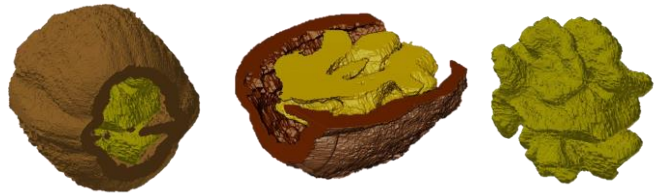
ALPhANOV

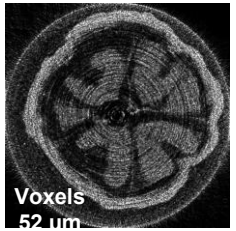
Magma25 Yb laser :
25mJ 1.7ps 1kHz

Mo tape

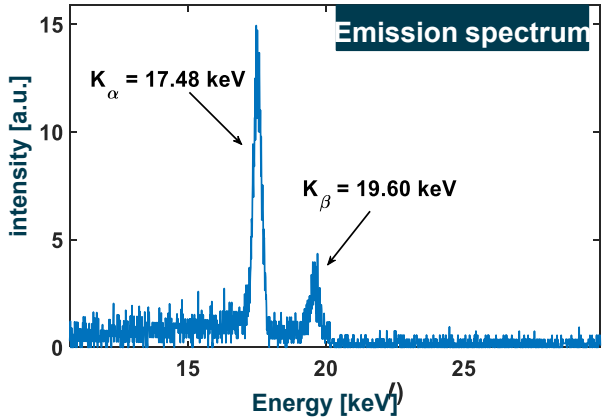


Absorption tomography





- 5. 10^7 phot/pulse – 5.10^{10} ph/s
- Average Flux : 10^{10} ph.s^{-1} .sr^{-1}
- Spot size : 20x20µm FWHM
- Brightness : 10^{13} ph.s^{-1}.sr^{-1}.mm^{-2}



Amplitude

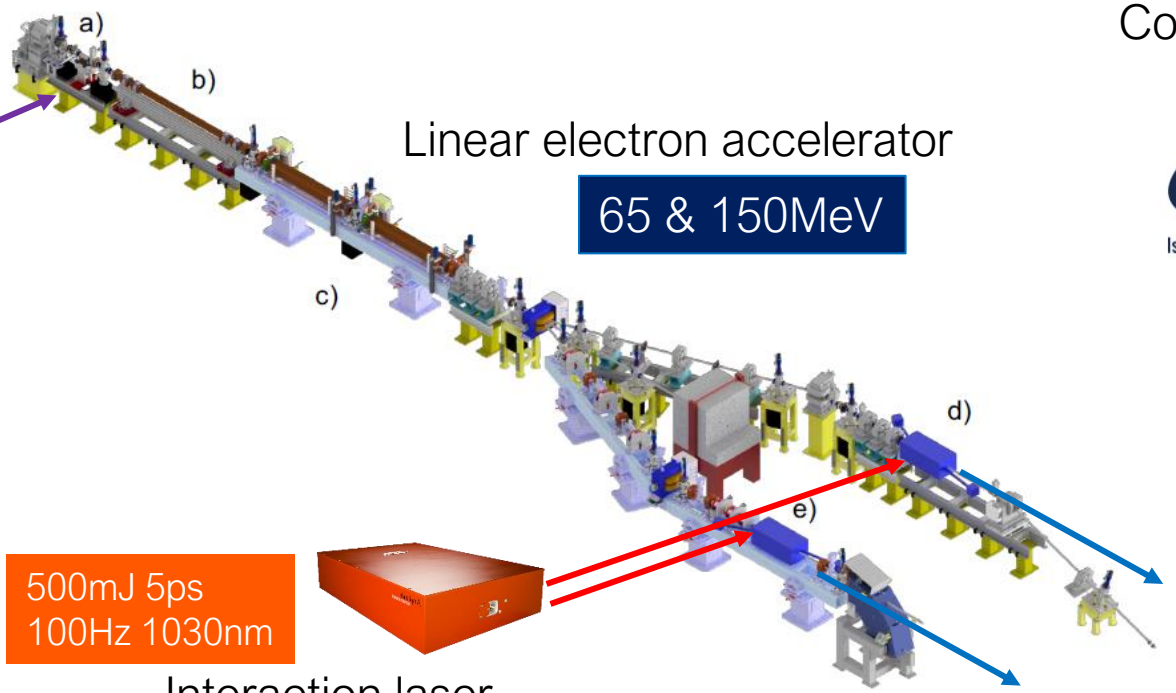
STAR : a unique X-ray ICS source

Collaboration with

INFN
Istituto Nazionale di Fisica Nucleare

Photocathode laser

300µJ 5ps
100Hz 258nm



Linear electron accelerator

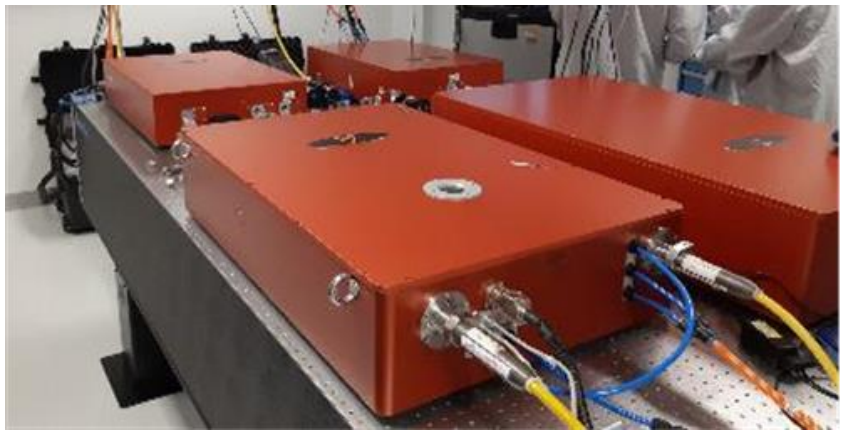
65 & 150MeV

500mJ 5ps
100Hz 1030nm

Interaction laser

32-350keV

17-85keV



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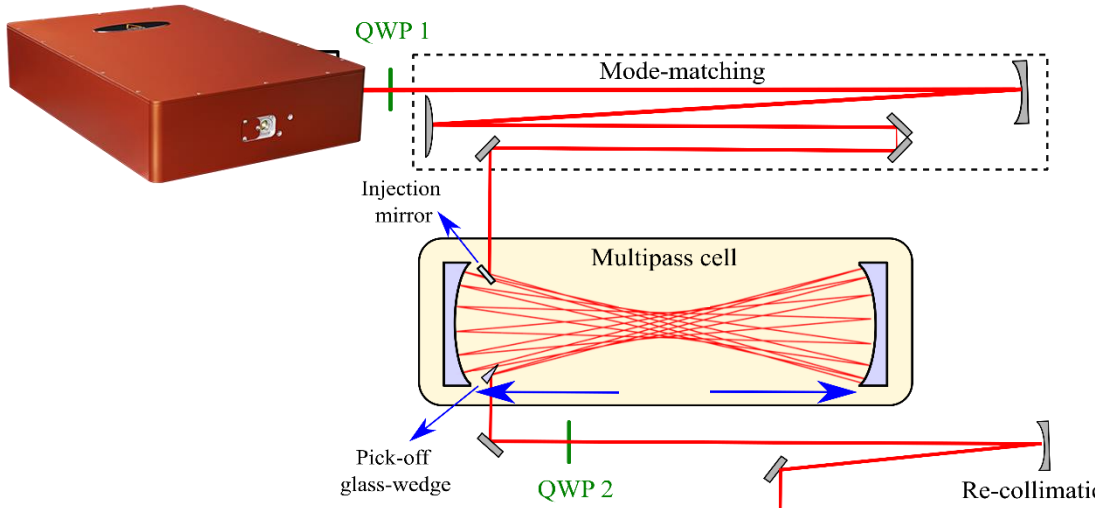
MeV X-ray source wih Yb laser at LOA

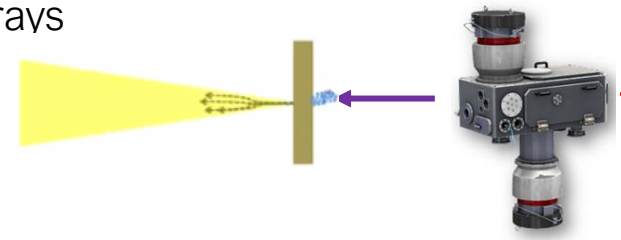
Collaboration with LOA SourceLAB

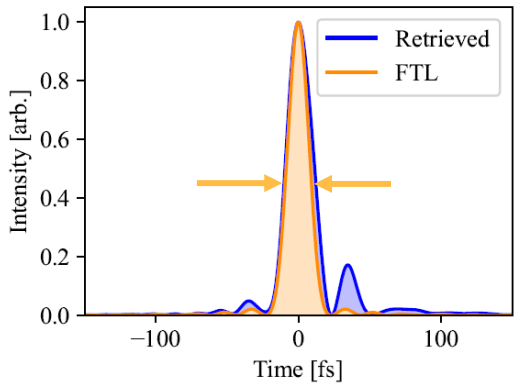
Magma25 Yb laser :
~20mJ 350fs 1kHz

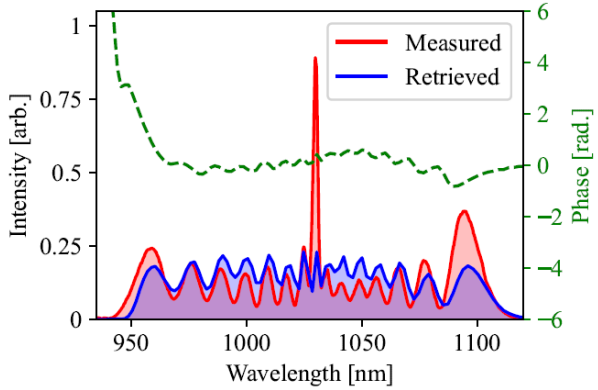


- 18W input – 14W output
- 23fs compressed – 0,6TW

Target :
MeV X-rays







Measured with TipToe

Amplitude

Conclusion & perspectives

> New key-enabling technologies are ready for modern TiSa laser drivers for accelerators

  > OPCPA high contrast seeders

  > Diode-pumping for J-class 100Hz pumps

  > Thermal management at kW power with cryo cooling

> Yb lasers are promising for dedicated secondary sources & applications

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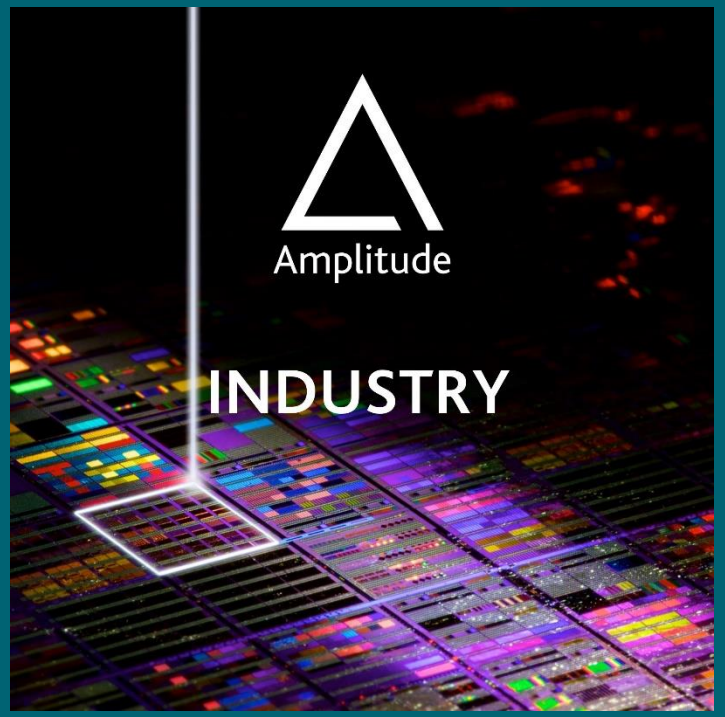
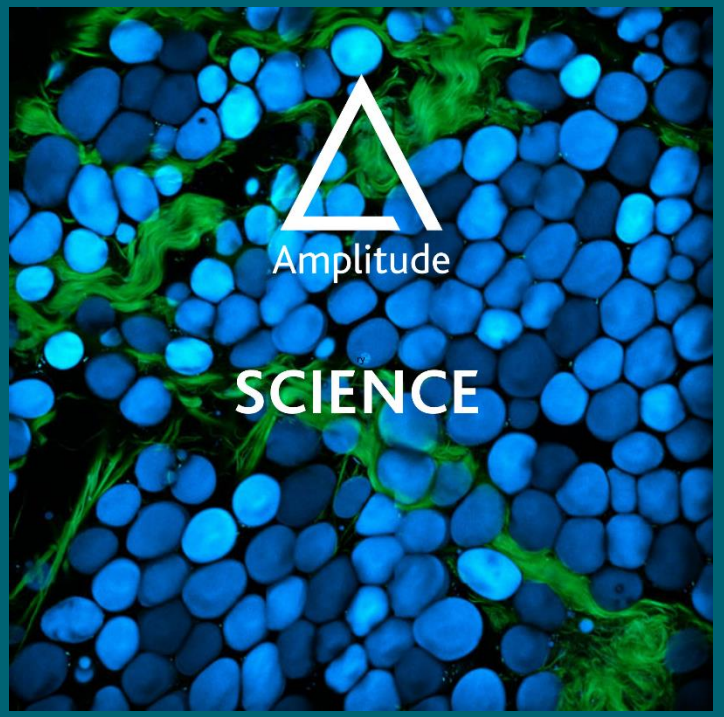
A Laser Bright Future





*Sparking a **brighter future** with our laser **solutions**: excellence, **innovation**, **purpose***

Continuum® by Amplitude

FASTLITE by Amplitude