

The ARCTURUS Laser Laboratory: Advanced Plasma-Based Acceleration and Ultrabright Beam Applications

Thomas Heinemann

on behalf of **Mirela Cerchez** and ARCTURUS team

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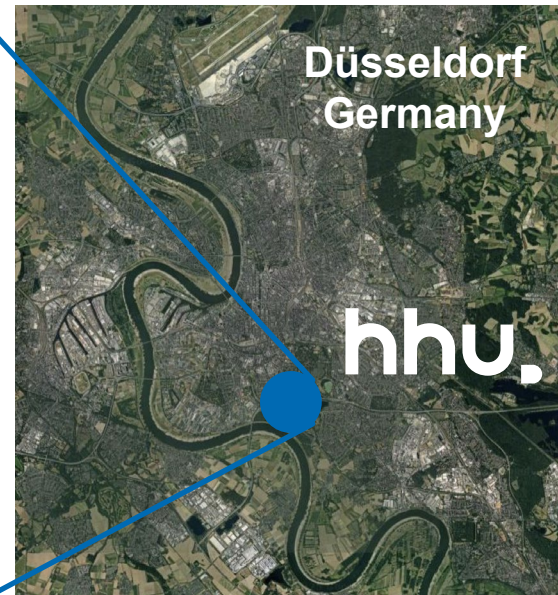
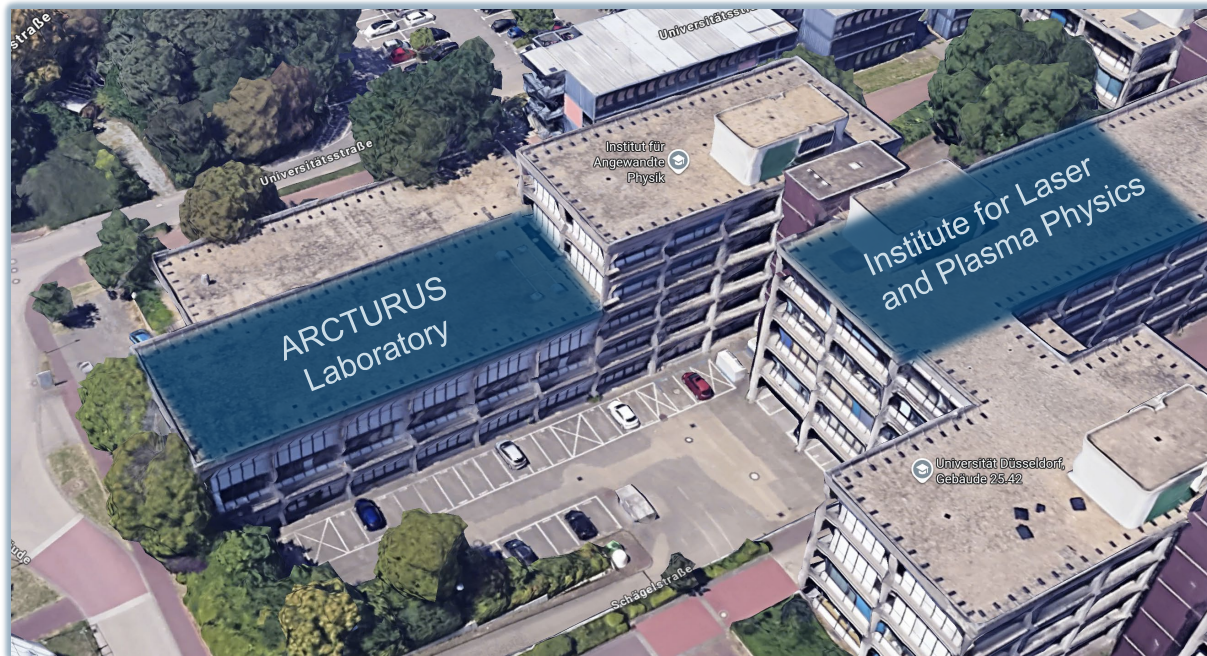
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25/09/2025



ARCTURUS Laser Laboratory

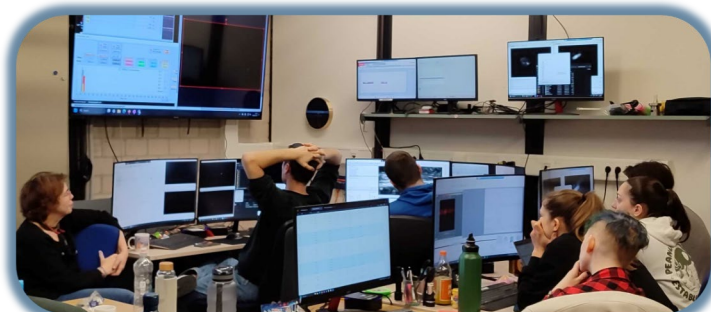
Where we are



Who we are

- University lab!
- Innovation driven by our students!

Team of scientists, post-docs, PhDs, Master and Bachelor students, technicians, administration



Prof. Bernhard Hidding, Mirela Cerchez, Andrew Sutherland, Constantin Aniculaesei, Koen Macken, Marc Osenberg, Edgar Hartmann, Natascha Thomas, Onur Bilen, Paula Sedlatschek, Kamill Naczynski, Antonio Tarzikhan, Imke Wellesen, Nils Hanold, Jesko Wrobel, Katharina Benner, Tobias Kutz, Victor Emde, Christof Bolten, Mario Reinhardt, Helmut Bormann, Andreas Karmann, Kirsten Dittmar & others

Also support from other HHU groups,
Prof. Georg Pretzler,
Prof. Alexander Pukhov,
and more

Hybrid Collaboration partners



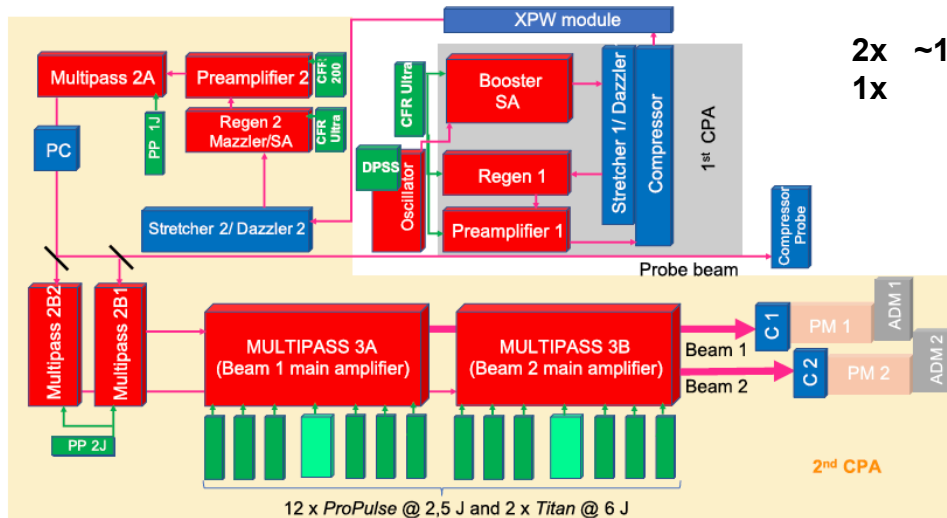
Quick history facts

- Operational since 2007/2008 as 100 TW system
- Continuous evolution and upgrades designed for **multi-beamline, high-contrast operation**

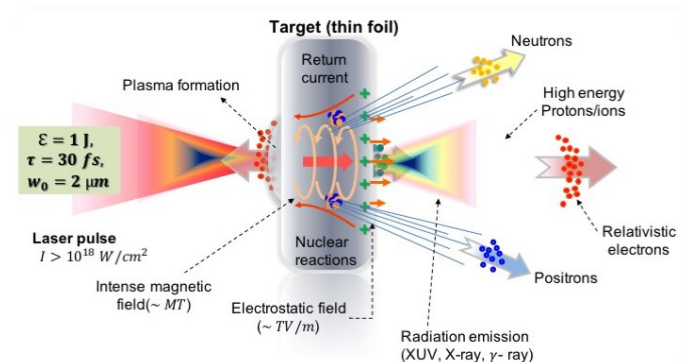
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ARCTURUS laser: a versatile high-contrast, high-power multi-beam laser system

M. Cerchez¹, R. Prasad¹, B. Aurand¹, A. L. Giesecke¹, S. Spickermann¹, S. Brauckmann¹, E. Aktan¹, M. Swantusch¹, M. Tonician², T. Tonician², and O. Willi¹



2x ~150 TW high-power, high-contrast laser beamlines
1x ~1 TW dedicated probe beamline



Since 2023

- Prof. Bernhard Hidding (re-)joins HHU to lead ARCTURUS laboratory



New mission!
Electrons!



Our mission

- **Advance next-generation plasma-based particle accelerators**
development of compact, plasma-based high-brightness electron sources, integrating LWFA and PWFA technologies, explore and develop plasma photocathodes
- **Explore synergistic physics**
explore fundamental physics and interaction mechanisms uniquely accessible in hybrid LWFA-PWFA systems.
- **Innovate experimental techniques and data-driven techniques**
novel diagnostics, injection methods, beam transport and characterisation strategies, interlinked with theory and simulations through integrated controls, data structures and simulation tools
- **Enable innovative applications**
for example, in high-energy physics, ultrafast science, laboratory space applications, medical imaging and radiation therapy through tunable electron beams
- **Drive multidisciplinary collaboration**
unite expertise on plasma accelerator technology through experimental programmes with national and international partners in fundamental physics, photon science, biology and medicine

Building the future at ARCTURUS:

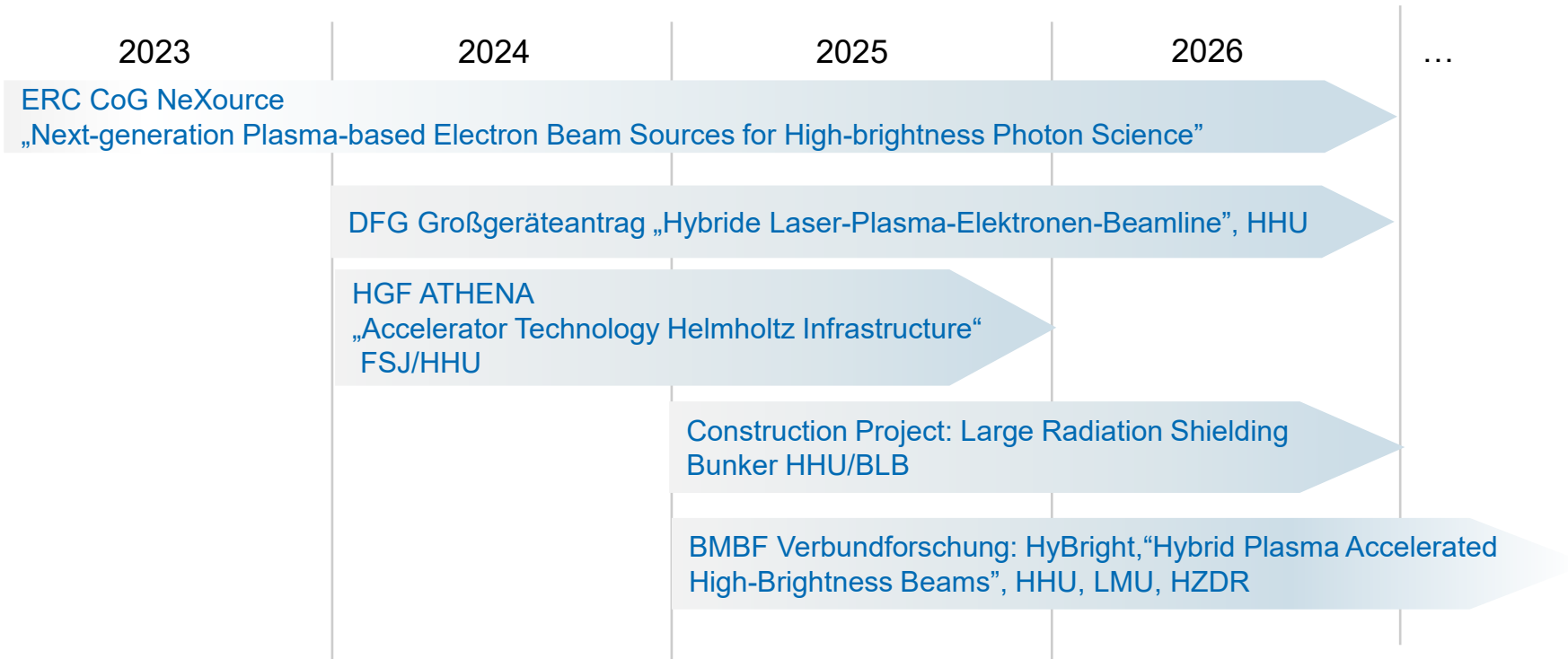
Multi-phase upgrade of the experimental infrastructure

Core goals and activities

- ARCTURUS laser system upgrade
 - Continuous and stable everyday laser operation with multi-k shots per day and **up to 200 TW on target**
 - ~30 NF/FF cameras from oscillator to target
 - integrated control system, active stabilisation
 - comprehensive online and full-power laser metrology
- ARCTURS target area – versatile and flexible R&D platform
 - design, characterisation and optimisation of gas targets (up to 4 independent gas supply lines)
 - LWFA and hybrid LWFA-PWFA operation, plasma photocathodes development
 - electron beams for space radiation and bio-medical applications and compact X-ray light sources
 - R&D platform for advanced diagnostics

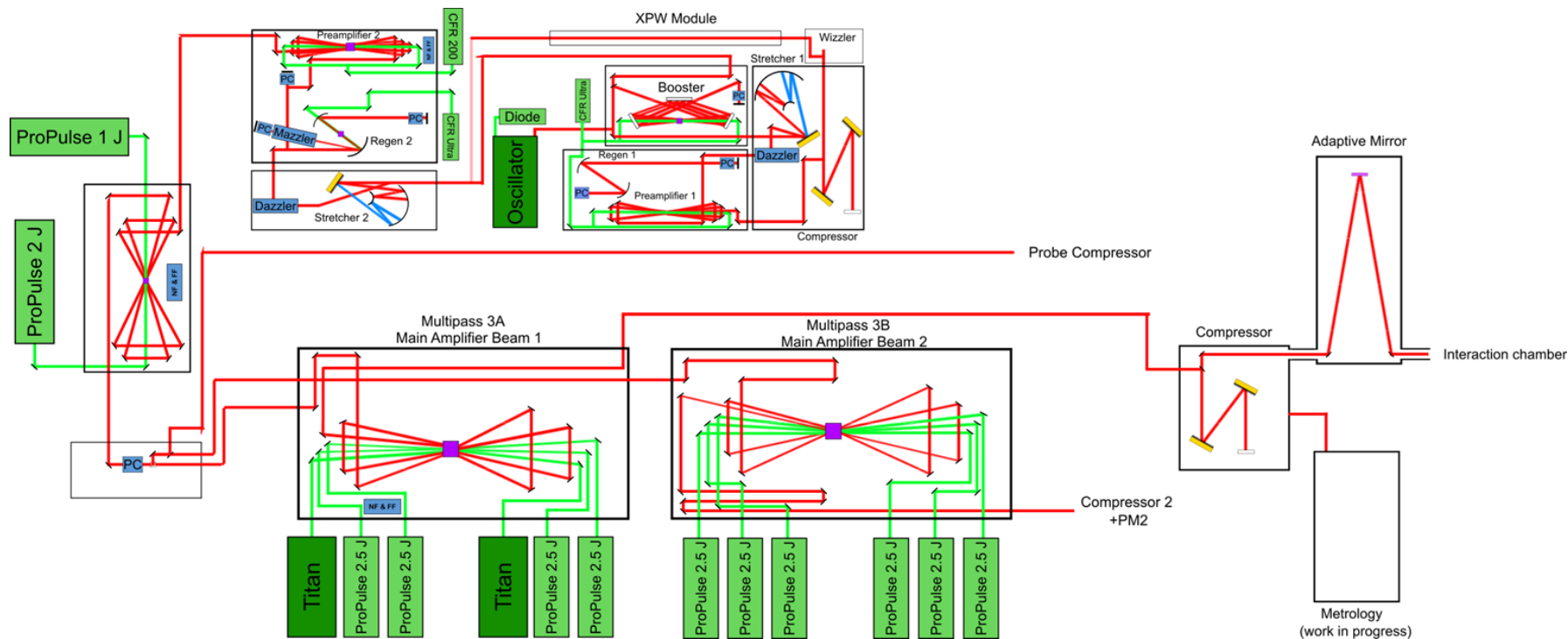
Building the future at ARCTURUS:

Multi-phase upgrade of the experimental infrastructure



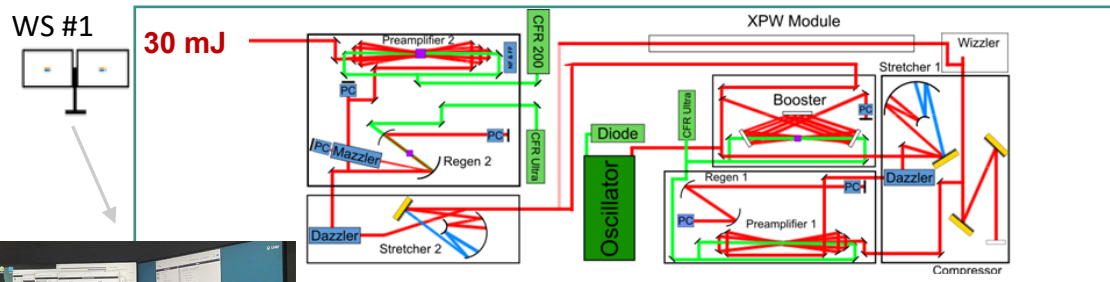
Upgrade of the ARCTURUS Laser System 2024-2025 (ongoing)

- System overview

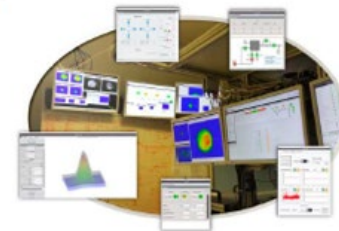


Upgrade of the ARCTURUS Laser System 2024-2025 (ongoing)

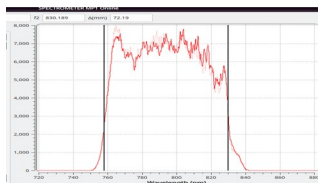
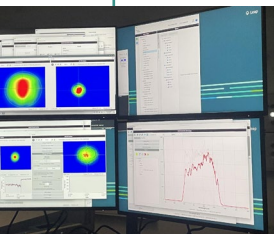
- Front-end and preamplifier



 Amplitude



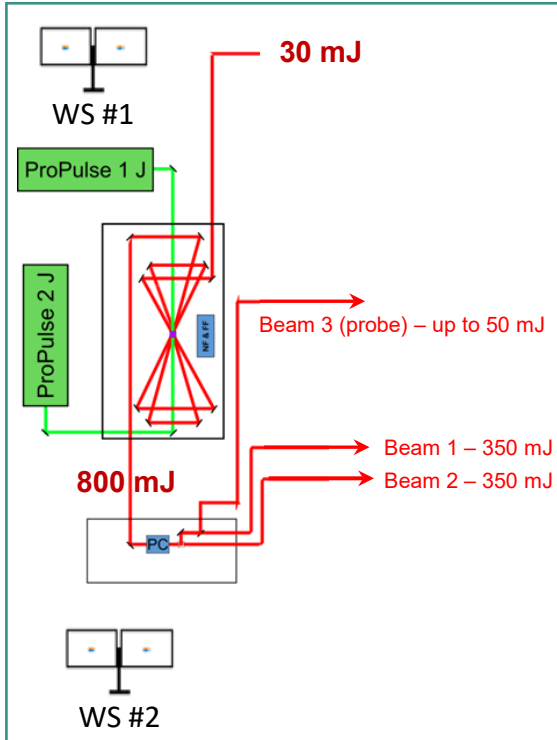
- Implementation of the Laser 4.0 HE system (Control-Command) – 1st working station
- Instruments and diagnostics for:
 - Beam monitoring and/or stabilization (booster, stretcher, regen (CPA1 and CPA2), preamplifier)
 - Pump lasers profile
 - Mazer loop
- New synchronisation architecture of the laser system
- Flexible switch between seeding the regenerative amplifier CPA2 by the booster CPA1 or the XPW



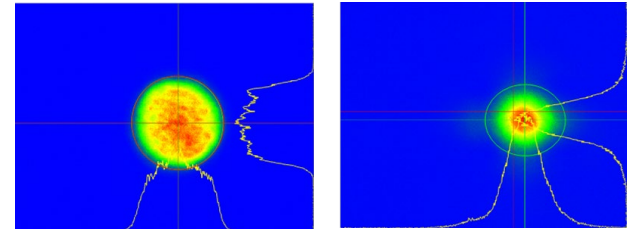
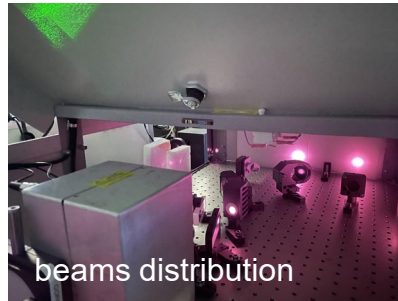
Upgrade of the ARCTURUS Laser System

2024-2025 (ongoing)

- Compact multi pass amplifier and beam distribution



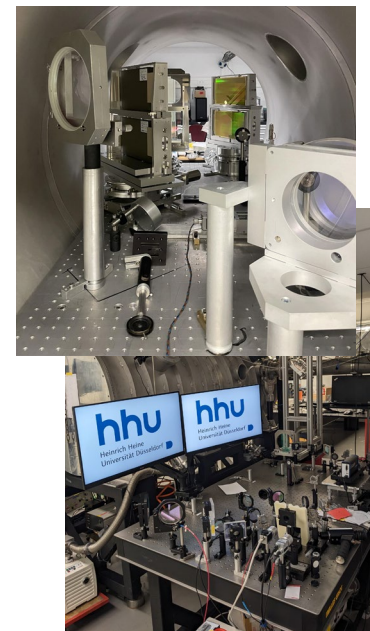
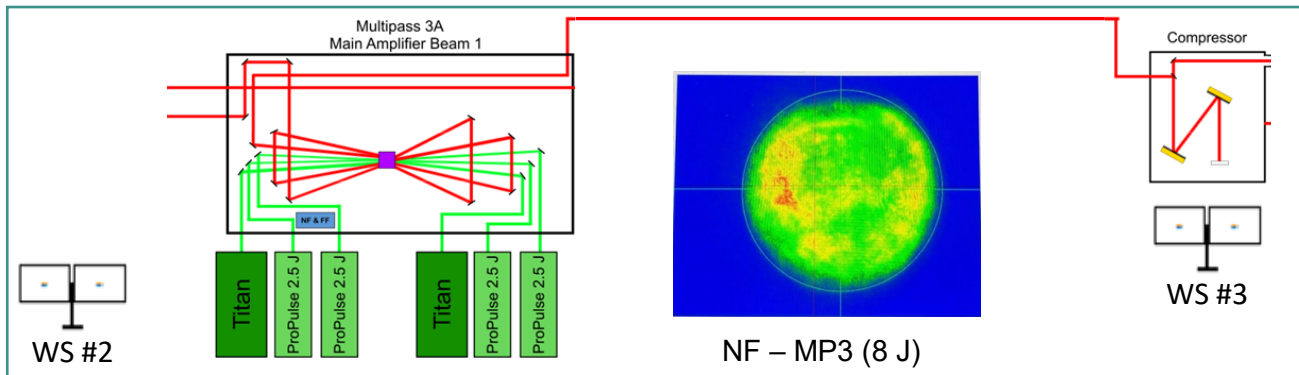
- Further development of CCM architecture (WS #2 - #4)
- Implementation of compact multi pass amplifier MP2 (800 mJ)
- Beam profile via DOEs @ PP MM1&2 pump lasers
- Beam distribution module (45/45/5) for three beam selection + PC
- Optimisation of probe profile for long propagation path (telescopes)



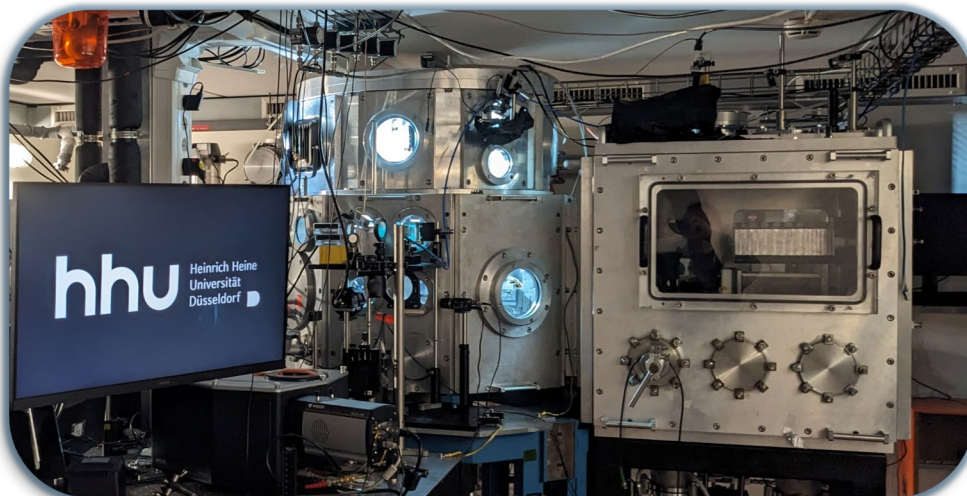
NF and FF – MP2

Upgrade of the ARCTURUS Laser System 2024-2025 (ongoing)

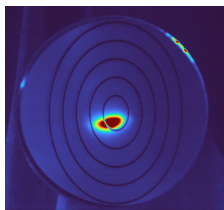
- Main amplifier (beam 1) and compressor
 - Reconfiguration of pumping geometry of the main amplifier (22 J pumping energy = 2 x Titans + 4x Propulses) → beam amplified @ 8J
 - Beam monitorization (Ti:Sa and pump lasers) and beam stabilization module
 - High power beam attenuator
 - Renewed hardware and motorisation of main compressor



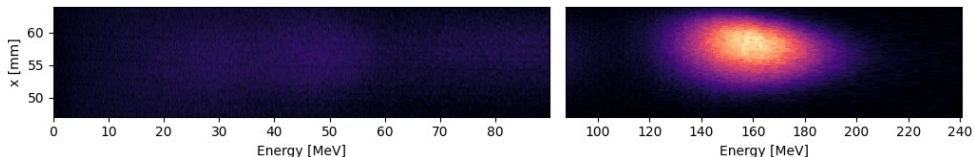
ARCTURUS R&D platform



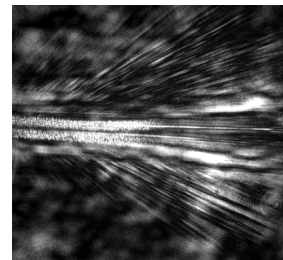
Electron pointing
monitor



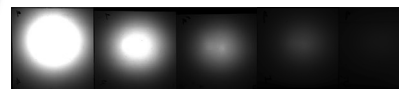
Electron spectrometer



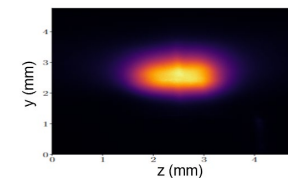
Optical probing



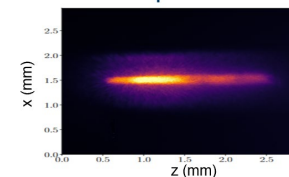
Dosimetry



Plasma light emission



Side view



Top view

Spatially resolved spectroscopy



ARCTURUS Laboratory

- High-power laser system up to 2x ~150-200 TW on target
 - Ongoing upgrades
- Versatile R&D platform (in development)
 - For advanced plasma accelerator concepts and diagnostics development
 - Hybrid LWFA-PWFA
 - Plasma photocathodes
 - Compact X-ray light sources
 - Biomedical and space radiation applications

Thank you!