ZEUS townhall
November 20, 2023

FACILITY COMMISSIONING, STATUS,
FY25 CALL FOR PROPOSAL
• ZEUS laser system
• ZEUS target areas and science
• ZEUS commissioning & status
• FY2025 capabilities
• Accessing the ZEUS facility
• Proposal process
The team

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Prof Chan Joshi (chair), Prof Stefan Karsch, Prof Ritchie Patterson,
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https://zeus.engin.umich.edu/
Zettawatt \(= 10^{21} \text{ W}\)

Equivalent

Ultrashort pulse laser

System

Critical field \(E_c \sim 10^{18} \text{ V/m}\)

Electric field strength (V/m)

- Vacuum breakdown: spontaneous creation of electron-positron pairs
- Current laboratory record
- Electron accelerated to rest mass energy in 1 µm
- Electric field of hydrogen ground state
- Air breakdown
- Brain wave
Zettawatt Equivalent Ultrashort Pulse Laser System

ZEUS power = $3 \text{ PW} = 3 \times 10^{15} \text{ W}$
(Highest power laser in the USA)

The intensity experienced by a GeV electron beam in the rest frame of reference will be equivalent to a Zettawatt power pulse!

Critical field $E_c \sim 10^{18} \text{ V/m}$

$10^{22} \text{ W/cm}^2$ laser pulse

GeV electron beam

electron

positron

$\gamma$-ray
ZETTAWATT-EQUIVALENT ULTRASHORT PULSE LASER SYSTEM

ZEUS FLOOR PLAN

Target Area 3
Diagnostic preparation
Experimental control room
Target preparation
ISO 7 laser cleanroom
Laser control room
500 TW compressor
3 PW compressor
Target Area 1
Target Area 2

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Mid-scale Research – Award # 2126181
ZEUS FRONT END

Front end supplied by Amplitude Technologies

DPSS CW Pump Laser
  Ti:Sapphire Oscillator

Multi-pass Amplifier A
  Bulk Stretcher

Pulse Picker

Multi-pass Amplifier B
  Dazzler

Compressor

Dazzler

XPW Module

Öffner Stretcher

Mazzler Ring Cavity RGA

20mJ 5Hz

Inlite-10Hz Nd:YAG

Multi-pass Amplifier

1mJ 100Hz 5Hz

Pulse Picker/Cleaner

Regen Ring Module

Tera 50 Nd:YLF

Inlite-10Hz Nd:YAG

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Zettawatt-Equivalent Ultrashort Pulse Laser System (ZEUS)
ZETAWATT-EQUIVALENT ULTRASHORT PULSE LASER SYSTEM

ZEUSS AMPLIFIER CHAIN

- TITAN Nd:YAG
- GAIA Nd:YLF
- ATLAS Nd:Glass
- ATLAS Nd:Glass
- TITAN Nd:YAG

Chain:
- Pockels Cell
- 60 mm 4-pass Amplifier
- Spatial Filter 2
- 90 mm 4-pass Amplifier
- Spatial Filter 3
- 170 mm 4-pass Amplifier
- Compressor (Pass 1)
- (Pass 2)
- (Pass 3)
- (Pass 4)

- 21J
- 9J 5Hz
- 50J 1/min
- 250J

- 1.5J
- 5J 20mJ 5Hz
- 12.5J 140mm
- 75J 305mm
- 25fs 3PW
- To Experiments
- 25fs ½PW

- Motorized Mounts
- Synchronization
- Near Field Camera
- Laser Control
- Spectrometer
- Shutter
- Fluorescence
ZEUS AMPLIFIER CHAIN – YEAR 1

170 mm crystal not yet available
Amplifier chain
ZEUS LASER DIAGNOSTICS

- Shot-ID (time stamps)
- On-shot laser energy (photo-diode)
- On-shot beam profile before and after compressor (leak-through)
- On-shot laser focus (leak-through)
- Off-shot pulse duration with Auto-correlator, Frog and Self-ref spectral interference
- Off-shot laser spectrum
- 2 DMs in air (before and after compressor)
- Off-shot laser focus and wavefront (TA3)
A “shock-driver” laser will be available in TA2 (FY25)
Amplitude Intrepid:
  • Nd:glass system, $\lambda = 1054$ nm (or 527 nm)
  • 1 shot per minute rep rate
    • 110 J (75 J) at 10 ns duration
    • 46 J (35 J) at 1.5 ns duration
ZEUS FACILITY LAYOUT

Target Area 1

Target chamber

Local radiation shielding
Possible Configurations for FY25:
• f/64 for 2PW single beam
• Or 1.5 PW beam for LWFA interaction with 500 TW, focused with f/3 parabola, 75 degrees off axis angle

Semi-permanent diagnostics
• Triple magnet electron spectrometer
• Optical probe beam
TARGET AREA 1 (TA1): SCIENCE

Laser Wakefield Acceleration (LWFA) of electron beams

2.5 PW
f/64

Gas target

Tape drive

Lanex screens

Collision point

2.5 PW
f/64

Gas target

Tape drive

Lanex screens

Collision point

Laser Wakefield Acceleration (LWFA) of electron beams

Single particle detectors

Gamma-ray detector
**TARGET AREA 2 (TA2)**

- 500 TW max for current chamber and upgrading to 3PW chamber in the future
- 2 ft thick concrete shielding
- Double plasma mirrors, deformable mirror and short focusing (f/2) configuration

Semi-permanent diagnostics
- Thompson parabola ion spectrometer
Plasma mirrors give excellent contrast to allow interactions with solid targets (without preplasma). Short-focusing configuration gives the smallest focal spots and highest intensities.

**Proton & ion beams**
- Neutron sources

**Gamma beam generation**

**High-harmonic generation**

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Z Gong, et al., PRE, 102, 013206 (2020)
TARGET AREA 3 (TA3)

- 200 TW @ 1 Hz burst operation
- Or 500 TW @ 1 shot per minute
- 1.5 ft thick concrete shielding
- f/40 and f/20 configurations

Semi-permanent diagnostics
- laser focal spot
- Laser wavefront measurement
- laser pointing
- Magnetic electron spectrometer
- electron beam profile
- X-ray CCD (Andor)
- Optical probe beam (interferometry and shadowgraphy)
Laser wakefield acceleration of electrons & high-energy photon beam generation

Probing applications (including for non-traditional high-power laser users)

Example: Material Science Applications
• Some semi-permanent and a broad selection of movable diagnostic will be available for use.
• Information on each diagnostic will be available from a link on the ZEUS website (this is work in progress).
• The facility will work with external users to integrate their own diagnostics onto the system (assistance from mechanical and electrical engineering staff).
• Please speak with us if you have questions about the specifications or integration.
• The ZEUS target fabrication engineer will assist with target preparation

• A suite of instruments for characterization will be located within the ZEUS facility.

• Basic targets will be available to users:
  • Flat foils
  • Gas jets or gas cells – variety of designs and gas types
    • 2-stage supersonic gas jets
    • 2-stage variable length gas cells
  • (Liquid jet target – but not first year)

• Specialist targets may be fabricated using in-house machining, or outside vendors may supply some of the parts. Cost analysis and assessment will be necessary.
COMMISSIONING STATUS

Front End: 1.5 J; 20 fs; 90 nm; 5Hz continuous

Phase 1 >200 TW:

• 6 J Compressed energy (92% per grating) (measured w/ Gentec-CM160)
• 26 fs FWHM pulse duration (38 fs autocorrelation)
• 80 nm spectral width (1/e^2) (bandwidth measured w/ Ocean Insight-Flame)
• ~80% Strehl ratio with DMs
• <2 fs Computed radial pulse delay
• Pointing jitter ~1 spot diameter
• 1 Hz Burst mode (5, 10, 20 pulses, etc.)
## Capabilities for FY25

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Target area 1 FY24 aim / FY25 aim [eventual]</th>
<th>Target area 2 FY24 aim / FY25 aim [eventual]</th>
<th>Target area 3 FY24 aim / FY25 aim [eventual]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pulse duration</td>
<td>25 fs</td>
<td>25 fs</td>
<td>25 fs</td>
</tr>
<tr>
<td>Rep-rate</td>
<td>1 shot per minute</td>
<td>1 shot per minute</td>
<td>200 TW 1 Hz burst mode / 500 TW 1 shot per minute [5Hz burst mode]</td>
</tr>
<tr>
<td>Split beam option</td>
<td>No / 1.5 PW &amp; 0.5 PW [2.5 PW &amp; 0.5 PW]</td>
<td>No [No]</td>
<td>No</td>
</tr>
<tr>
<td>Plasma Mirror option</td>
<td>No</td>
<td>Yes (double plasma mirror)</td>
<td>No</td>
</tr>
<tr>
<td>Focusing</td>
<td>f/64 / f/64 (2 PW) or f/64 (1.5 PW) and f/3 (0.5 PW) [or (0.5 PW) or f/78 (0.5 PW)]</td>
<td>f/2 [f/2 or f/3]</td>
<td>f/40 / f/40 or f/20</td>
</tr>
<tr>
<td>Long pulse option</td>
<td>No / No [Yes]</td>
<td>No / Yes [Yes]</td>
<td>No / No [Yes]</td>
</tr>
</tbody>
</table>
ACCESSING THE ZEUS FACILITY

• Annual call for proposals
• Proposal Review Panel (PRP) is independent of the facility (No members from ZEUS facility or CUOS)
  • Access will be granted for fundamental research in Physics, medicine and engineering (rather than for industrial or commercial experiments)
  • No classified research will be conducted using ZEUS
• Successful proposals will be passed to the ZEUS facility for scheduling
  • Each experiment assigned a “link” scientist in initiate planning
  • Users connect with ZEUS user office to arrange training before arrival
• Users are expected to provide the facility with constructive feedback
### EXPERIMENTAL PLANNING

**- 3 months**

First planning meeting: Identify elements of experimental design that require development. Order targets.

**- 1 month**

Second planning meeting: Finalize experimental design. Review for conflicts, design or operational problems.

**- 2 weeks**

Third planning meeting: Finalize experimental design.

**Set up weeks**

External users arrive to prepare their experiment. Two weeks of access to the area prior to the beam time would be typical.

Register all users through the MyZEUSPortal.

Coordinate with User office to initiate travel plans and take required safety training before arrival.

Meeting participants: Target area link scientist, PI and User team, Engineers, laser representative.
7 am  – 2 technicians arrive, warmup laser systems, start alignment, maintenance

8 am  – users arrive, morning meeting with TA Link scientist, technical staff

10 am  – laser availability (first alignment beams, then high power beams)

12 pm  – 2 laser technicians arrive

2 pm  – afternoon meeting with TA Link scientist, technical staff

8 pm  – end of laser operations, data available on user web-site

Note that preparatory work (without laser access) for future experiments in two other target areas will also be ongoing.
The 2nd annual call for proposals for access to the ZEUS facility will open this week.

• Announcement to the ZEUS user group email list and on ZEUS website

Proposals are due, through the online submission, by 5pm ET on 31st January 2024. Expected capabilities of the ZEUS facility for the FY2025 cycle will be posted on the ZEUS website.

Approximately equal numbers of experiments will be scheduled in each of the three target areas, 30 weeks in total. Typical experiment would be 4 weeks (longer/shorter possible with justification).

Eligibility criteria: The ZEUS facility welcomes proposals from the whole scientific community, from within the plasma physics community and beyond, no restriction on your funding support. International researchers are welcome to submit proposals for the ZEUS facility.
MyZEUSSPportal is the web-based user interface with the facility.

Here you can submit a proposal, coordinate your experiment, find ZEUS info and resources, and view your experimental data.

MyZEUSSPportal is work-in-progress so please let us know if you encounter bugs or problems.
HOW TO SUBMIT A PROPOSAL

• Register for a user account on the MyZEUSPortal
• Prepare your proposal according to the requested proposal preparation guidelines, available on the ZEUS website.
• Contact ZEUS-users@eecs.umich.edu with any questions regarding the proposals.
• Or attend a Q&A virtual session to speak with the ZEUS team.
• Submit your proposal through the MyZEUSPortal before 31st January 2024, 5pm ET.
The 3-PW ZEUS laser user facility

3 Petawatt power laser user facility

Experiments on:

• Testing extreme field physics
• Unique particle & photon sources
• Applications of sources across STEM

Commissioning late 2023 (now!)

User access through scientific merit-based proposal system

FY25 Call for proposals open
Deadline 31st January 2024

The ZEUS facility construction and operation is supported by the National Science Foundation under award 1935950 and 2126181, as well as by the AFOSR grant number FA9550-22-1-0118 and the University of Michigan.