Recent Progress of SG-II Laser Facility and its Prototype

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Outline

◆ Introduction
◆ Design of SG-III Laser Facility
◆ Status of SG-III Project
◆ Summary
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Introduction – Plan of developing ICF drivers in China

SG high power laser drivers

Upgrade SG-II
SG-III prototype
SG-Ⅲ laser facility 2012, 200kJ/48beams
SG-II laser facility
SG-I laser facility

Traditional ICF Driver
Single Aperture
MOPA
Low fluence
separate structure

Novel ICF Driver
Combined Aperture
Multi pass
High fluence
Array structure

Fusion Ignition Facility

Fusion Ignition Facility

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Introduction – Prototype of SG-III

Function 1: The main test bed to validate the key technology applied in SG-III.

Function 2: Provide shots for physical experiments.
Specifications:

1. Beam number: 8 (4 × 2)
2. Beam aperture: 290 mm × 290 mm
3. Wavelength: 0.351 μm
4. Energy: 1.2 kJ/1 ns/0.35 μm/beam
   1.8 kJ/3 ns/0.35 μm/beam
5. Temporal shape: 1.0 ns ~ 3.0 ns
6. Beam divergence: 70 μ rad (95% energy enclosed)
7. Pointing: 30 μm (RMS, f=2.2 m)
8. Energy spread: 10% (RMS)
Introduction – Key units in Prototype of SG-III

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Energy bank  Disk amplifier  Spatial filter  Final optical assembly

PDU01  Amp.2  SF.1  FD  IM  L1 L2 L3 L4  PAM  PDU02

CM Amp.1  SF.1  IM  L2  L3  L4  PDU03  Amp.2(6)  SF.2  PDU04

Energy bank  Disk amplifier  Spatial filter  Final optical assembly

PEPC  Deformable mirror  Preamplifier  Front End
Energy

![Graph showing energy vs. efficiency and intensity]

- Efficiencies: 69.8%, 64.4%, 61.0%, 69.4%, 64.7%, 64.4%, 59.7%
- Shot numbers: 62002, 62003, 62004, 62012, 62103, 62201, 62202, 62203
- 100% intensity (GW/cm²)
- 100% Energy (kJ per beam)
- 100% Flence (J/cm²)

Legend:
- 3w energy
- Efficiency

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Introduction – Performance of Prototype of SG-Ⅲ
Beam quality: Far field and near field of $3\omega$

About 30DL (95% energy enclosed) Modulation of near field is about 2.2
Temporal shape

Pulse width: 1.1 ns, Average energy: 939 J
Introduction – Performance of Prototype of SG-Ⅲ

Pointing

Experiment shows the pointing accuracy can reach 25um (RMS, f=2.2m)

Distribution of the 8 focal spots in the LEH captured by X-ray pinhole camera. (100J/0.25ns/beam)
Outline

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Design of SG-III Laser Facility – Overview

Three function area: 1. Laser hall, 2. Optical Assembly Building, 3. Target area

Area size: 172.8m × 76m
Design of SG-III Laser Facility – Overview

1. Front end
2. Preamplifier
3. Cavity Mirror
4. Main Amplifier
5. Cavity Spatial filter
6. Booster Amplifier
7. Transport Spatial Filter
8. Beam Reverser
9. Switchyard
10. Target Chamber
11. Sampling Wedge
12. Sampling shift module
13. Energy Bank

High Power PW Laser System

- ~10J/Shaped pulse at 1.053 μm
- 5~10J/3ns/Beam at 1.053 μm
- 7.5kJ / 3ns/Beam at 1.053 μm
- 3.75kJ / 3ns/Beam at 0.35 μm

Main amplifier (6~4x2 bundles) (Combined 4pass configuration)

Beam control and parameter measurement system
Design of SG-Ⅲ Laser Facility --- Laboratory

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SG lab. is divided into three parts: laser system area, target experiment area and cleaning assembling area.

Lab area: 176m × 76m
Design of SG-III Laser Facility – Specifications

- Beams number: 48 (4×2-6)
- Beam Size: 360mm×360mm
- Wavelength: 351nm
- Energy: 180KJ @3ns flat top pulse
- Temporal shape: arbitrary shape
- Beam quality: 10DL enclosed 95% Energy
- Beam spectrum: 0.1nm~1.2nm
- Power Balance: 10% RMS (foot)
- Pointing: 30μm RMS (f=4,000mm)
SG-III Laser Facility ---- System distribution

Characters:
【basic rule】 “Pulse with same character in one cone and adjustable among different cone”
【Method】 “One bundle corresponding to one cone on target chamber”

Schematic of one of the 48 beamlines in the SG-III facility
SG-III Laser Facility ---- Fluence distribution

SG-III laser facility optimization design and disks distribution.
The multi-pass architecture that is common to all of the 48 beamlines of SG-Ⅲ.

Pulse is injected from CSF and the beam reverser is located in TSF. There are four passes through the main amplifier and three passes through the power amplifier.

Deformable mirror with large aperture located in CM to compensate the wavefront distortion.
### Design of SG-III Laser Facility – Main amplifier

<table>
<thead>
<tr>
<th>Specifications</th>
<th>SG-III</th>
<th>NIF</th>
<th>LMJ</th>
<th>备注</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total disk</td>
<td>16</td>
<td>18</td>
<td>18</td>
<td></td>
</tr>
<tr>
<td>Disk configuration</td>
<td>9+7</td>
<td>11+7</td>
<td>9+9</td>
<td></td>
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<tr>
<td>Equivalent disk</td>
<td>57</td>
<td>58</td>
<td>72</td>
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<tr>
<td>Total gain length of disk</td>
<td>273cm</td>
<td>277cm</td>
<td>344cm</td>
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<tr>
<td>Length of main amplifier</td>
<td>~112m</td>
<td>~123m</td>
<td>~101m</td>
<td>From to CM L4</td>
</tr>
<tr>
<td>Injecting method</td>
<td>CSF farfield injecting</td>
<td>TSF farfield injecting</td>
<td>TSF farfield injecting</td>
<td></td>
</tr>
<tr>
<td>Injecting energy</td>
<td>~1J</td>
<td>~several hundred mj</td>
<td>~several hundred mj</td>
<td></td>
</tr>
<tr>
<td>Beam aperture in main amplifier</td>
<td>275mm,320mm</td>
<td>360mm</td>
<td>360mm</td>
<td></td>
</tr>
<tr>
<td>Beam aperture in booster amplifier</td>
<td>309mm,350mm</td>
<td>360mm</td>
<td>360mm</td>
<td></td>
</tr>
<tr>
<td>Filling factor in booster amplifier</td>
<td>76%</td>
<td>81%</td>
<td>81%</td>
<td></td>
</tr>
<tr>
<td>Beam aperture in reverser</td>
<td>72mm</td>
<td>–</td>
<td>?</td>
<td></td>
</tr>
<tr>
<td>Vignetting allowance*</td>
<td>50mm</td>
<td>35mm</td>
<td>?</td>
<td></td>
</tr>
<tr>
<td>Fluence on Pickoff mirror</td>
<td>~4J/cm²</td>
<td>–</td>
<td>?</td>
<td></td>
</tr>
</tbody>
</table>

*Vignetting allowance refers to the allowance for the vignetting effect in the optical system.
Different beam size in 1-2 pass and 3-4 pass to mitigate effect on beam quality from the static wavefront distortion of the edge of laser glass.

Image relay design

Low fluence on Pick-off mirror to ensure the system work stably.
Rotate the beam in beam reverser before 3-pass the main amplifier, the stigmatism caused by thermal distortion of laser glass can converted to defocus. Therefore beam quality can be improved.
Type I+Type II+Type II design for Frequency converter to match 1.2nm band width of pulse.

Two kind of diffractive element (BSG,CPP) is designed.

BSG: to sample 3w beam for Energy and temporal shape measurement

CPP: to shape the intensity distribution of focal spot.
Design of SG-III Laser Facility – Optical layout of beam smoothing

Beam smoothing

SSD: to eliminate intensity modulation of focal spot (wavelength from 10um to 100um)

CPP: to control the shape of focal spot
Three kind of pulse (fs/ps/ns) can be generated without time jitter.
Realize pulse shaping and long/short pulse synchronizing without time jitter based on optical method
All fiber system.
✓ Energy: 5J/3ns/beam/20min, 100mJ/beam/1Hz
✓ Pulse width: 1.0ns ~ 10.0ns
✓ Beam spatial distribution: super gauss
✓ Modulation: ≤1.4:1
✓ Beam divergence: ≤150 μ rad
✓ Energy stability: ≤4.0% (RMS)
✓ Spectral width: 1.2nm
✓ Beam drift: ≤10 μ rad (RMS) (4 hours)

- Liquid crystal is used to shape the output spatial distribution of beam and compensate the gain non-uniformity of disk amplifier
- Whole image relay design
Clear aperture: 400 × 400mm²
Storage density: ρst~0.24J/cm³
g: 5.0% cm⁻¹ (thickness: 40mm)
Gain uniformity: βpeak / βave ≈ 1.08:1
Storage efficiency: ηst 大于 3.0%
Static wavefront distortion: < λ/3/disk (λ = 632nm)
Shot interval: < 4 hours

Water cooling design is considered.
Performance of disk amplifier is undergoing validated, especially the gain non-uniformity and thermal distortion.
Design of SG-III Laser Facility – PEPC of large aperture

- Clear aperture: 400mm × 400mm
- Wavelength: 1.053 μm
- Static transmission: ≥88%
- Isolation ratio: ≥200:1
- Switch efficiency: ≥99%
- Switch rise time: ≤200ns
- Switch time window: 600ns
Design of SG-III Laser Facility ——— Structure of laser area

【structure characters】

“wall, bridge, cleaning tank + LRU”

SG-III Laser Facility
Structure Design
( laser experiment area)
Design of SG-Ⅲ Laser Facility ——— Structure of beamline

4×1 cavity mirror
4×1 PC
4×1 polarizer
Flash cassette
4×1 Disk cassette
4×1 lens

4×2 beamline with 400mm × 400mm aperture
Design of SG-Ⅲ Laser Facility —— Structure of beamline

4×2 Amp.

Isolator unit

TSF

CSF
Design of SG-III Laser Facility ---- Structure of laser area

- Cavity transfer SF
- Measurement unit
- Pre-amp. system
Design of SG-III Laser Facility ---- Structure of target area
Design of SG-III Laser Facility ---- Structure of switchyard
Design of SG-III Laser Facility ---- Structure of switchyard

Array reflect mirror

Reflect mirror I

Reflect mirror II

Reflect mirror III

300 reflect mirrors
Outline

Introduction

Design of SG-Ⅲ Laser Facility

Status of SG-Ⅲ Project

Summary
The laser house are being constructed and will be completed in the end of June, 2009.
Status of SG-III Project – Engineering design

The detailed engineering design has been finished before May, 2008, the main manufacturer for key unit and vendor for optics material have been selected.
Status of SG-III Project – Performance test of key unit and module

Front end

Rise time less than 100ps

Contrast 1:80

Different kind of shaped pulse

Main units in Front end were validated and can meet the requirement of design.
Installation of 4×2×3 Disk Amplifier Module was completed, and performance experiment including gain measurement are started.
1. Experiment results demonstrated the main specifications of the TIL, the prototype of SG-Ⅲ, have been reached, the first round of physics experiment shows that TIL has the capability to provide shots for experiment.

2. The detailed design of SG-Ⅲ has been finished and the fabrication plan has been started.

3. Experiment to validate performance of key unit such as amplifier, front end, pre-amplifier are being carried out.
Thanks for attention!