

High-energy laser source of RF gun

Xiangyu Zhou



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Requirement of laser system for RF-Gun

- Laser energy
 - 500 μ J for Ir₅Ce cathode
 - 50 μ J for Ce₂Te cathode
- 50 Hz, 2-bunch (96ns spacing)
- Temporal pulse shaping to reduce energy spread
 - => Broadband laser crystal (Yb or Ti:Sapphire)
- Continuous operation
 => High power pump LD
 (Yb or Nd)



- \circ Wide bandwidth => pulse shaping
- Long fluorescent time => High power
- Fiber laser oscillator => Stable
- Small state difference
- × ASE
- × Absorption

$\underline{\mathbf{Nd-doped}} \bigtriangleup$

- \circ 4-state laser is easy to operate.
- $^{\rm O}$ High power pump LD is available.
- $^{\circ}$ Large crystal is available
- × Pulse width is determined by SESAM. (Gaussian)



- No laser system company in Japan.
- Support cost for commercial product is very high.

<u>Ti-doped</u> ×

- \circ Very wide bandwidth
- High breakdown threshold
- \times Low cross section
- × Q-switched laser is required for pumping



Yb-doped Solid-state laser





Fiber amplifier

- Long gain media
- $\circ \text{ Compact}$
- \circ No need cooling
- \circ Good beam quality
- × Pulse energy



Thin-disk amplifier

- × Thin gain media (low gain)
- × Cooling system
- × Thermal lens effect
- High pulse energy





Underground laser system





Fiber Oscillator & Amplification



Yb:YAG thin-disk amplifier





Temperature of the Yb:YAG thindisk amplifier

• 10% dope, α =12/cm, 5kW/cm², 25Hz

0.5t

1t



Repetition rate limitation of 25 Hz is reached!



Spectral Range Adjustment

For chirped pulse, the pulse shaping in the time domain can be controlled by adjusted the spectral shaping of the pulse.





Optimized pulse shape by streak camera (After adjustment 2015.12.17)



ω :~10 mJ, 2 ω : ~2 mJ, 4 ω : 230 μ J

Due to the Non-linear effect was occurred, Output power limitation is reached!



Layout of A1 laser room





Laser line underground



Energy loss of the UV in the air: >50%

Laser line to RF-Gun



SHG for the 4ω





Stability of lasers (3 days)





Elevator maintenance

Laser off





No signal, LD work on

Summary of the underground laser

- Yb-doped fiber & Thin-disk Yb:YAG hybrid system @ 1030 nm
- Development of Underground Laser is finished.
- The stability of laser is improved.
- The laser is employed for the Phase-I study.
- The limitation of the output power (10 mJ) and repetition rate (25 Hz) is reached.



Laser line on the ground







Yb fiber laser system on the ground





New System











Issue of the underground laser

- Complex structure (Stability, Maintenance)
- ◆ 50 Hz double bunch repetition rate
 - 10 MHz oscillator
 - High energy fiber amplifier
 - Yb: YAG & Nd: YAG Regenerate amplifier
- Amplifier efficiency & Non-linear effect
 - Chirped Pulse Amplification (CPA) system



Oscillator of 10 MHz repetition rate









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Repetition rate	Cavity length	Fiber length
114.24 MHz	2.6 m	~1 m
10.38 MHz	28.9 m	~20 m



HIGH ENERGY ACCELERATOR RESEARCH ORGANIZATION

Chirp Pulse Amplification (CPA)

Under ground Yb laser system



On the ground Yb laser system





Grating pair compressor

Canon transmission grating

Size: 180mm × 50mm Groove density: 1740 lines/mm Diffraction efficiency: 95%





Vacuum Chamber





Yb:YAG thin disk regenerative amplifier

- For picosecond and nanosecond laser pulse, the regenerative amplifier is very powerful
- Strong amplification factor can help relieve stress of multi-pass amplifier stages and reduce thermal effect
- New dichroic mirror with high optical quality and high damage threshold





Low temperature Yb:YAG thin disk laser

- Low temperature laser operation feasibility analysis
 - Available high gain is possible
 - Low amplified spontaneous emission (ASE)
 - Simpler and more stable (compare with cryogenic laser)
- Current low temperature laser operation
 - Peltier cooling plates: 23 °C $\leftarrow \rightarrow$ -36 °C
 - Small vacuum chamber
 - Home made laser soldering laser head
 - 50 Hz repetition rate test









Yb fiber and Nd:YAG multi-stage laser @ 3-2



- •Laser energy 4.0mJ@1064nm 550uJ@532nm 120uJ@226nm
- Under beam comissioning







Nd:YAG Diode-pumped solid-state (DPSS) Regenerative amplifier





○ 4-state laser is easy to operate.

- High power pump LD is available.
 808nm : Commercial product
- High gain efficiency.
- Large crystal is available
- × Small gain bandwidth. (Gaussian)



1.1% Dia. 4 × 93mm AR/AR@1064nm







Plan B

Yb fiber + Nd:YAG





Summary

Laser system, underground

- Yb-doped fiber & Thin-disk Yb:YAG @ 1030 nm
 - Development of Underground Laser is finished.
 - The stability of laser is improved.
 - The limitation of the output power and repetition rate is reached.
 - The laser is employed for the Phase-I study.
- ◆ New laser system, on the ground
 - Yb-doped fiber & Rod Nd:YAG @ 1064 nm
 - Fiber parts are finished.
 - Nd regenerative amplifier for the Phase-II stable injection.
 - Yb-doped fiber & Thin-disk Yb:YAG @ 1030 nm
 - 10 MHz oscillator to simplify the laser system
 - High-energy fiber ROD amplifier $\mu J \rightarrow mJ$
 - CPA system to avoid non-linear effect
 - Yb regenerative amplifier for the Phase-III