DEVELOPMENT OF Yb LASER FOR HIGH POWER ULTRA-SHORT PULSE

○Yosuke MATSUMURA, Kazuyoshi KOYAMA, Mitsuru UESAKA

Department of Nuclear Engineering and Management School of Engineering, The University of Tokyo

Mitsuhiro YOSHIDA, Xiangyu ZHOU

KEK (High Energy Accelerator Research Organization)

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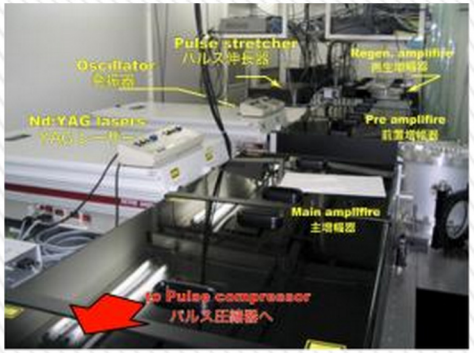
Background

» Ultra-short pulse has been used in many scientific fields.

Ti:Sapphire Laser



Specification for LWPA @ KEK

Central wavelength	780 nm
Pulse duration	60 fs
Pulse energy	600 mJ
Repetition rate	10 Hz
Average power	6 W

Application

High Speed Phenomena
Electron Gun etc.

Thermal Load
Thermal Lens Effect

To increase the average power
~100 W, 1 kW and more

We must solve Thermal Lens Effect.
How should we suppress it? -> Ytterbium

Advantages of Yb laser

Efficiency60～70%

- Laser diode pumping

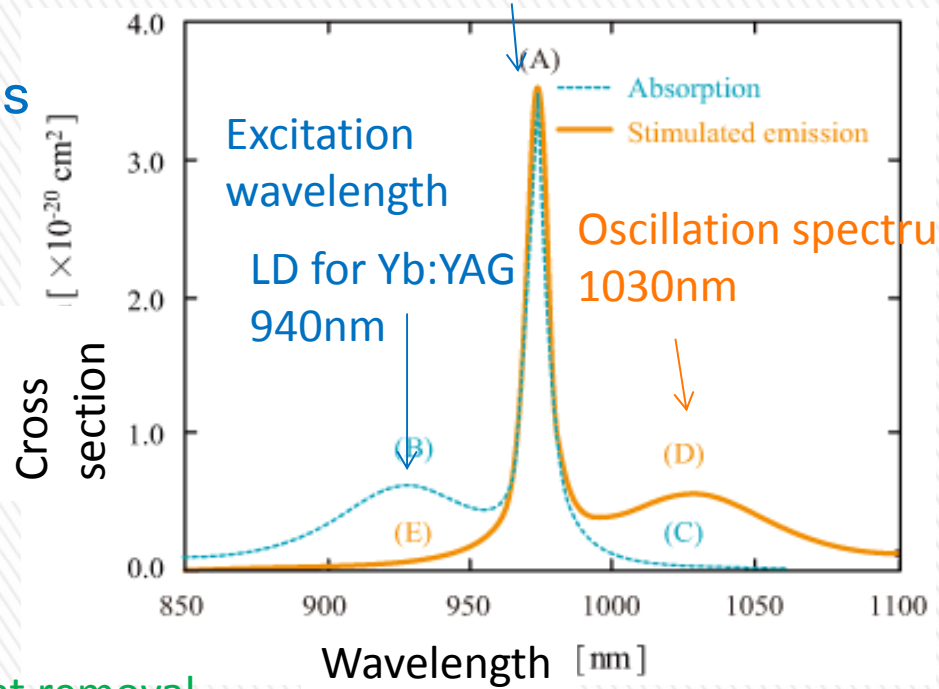
  fluorescence life time: 1ms
- Quantum efficiency

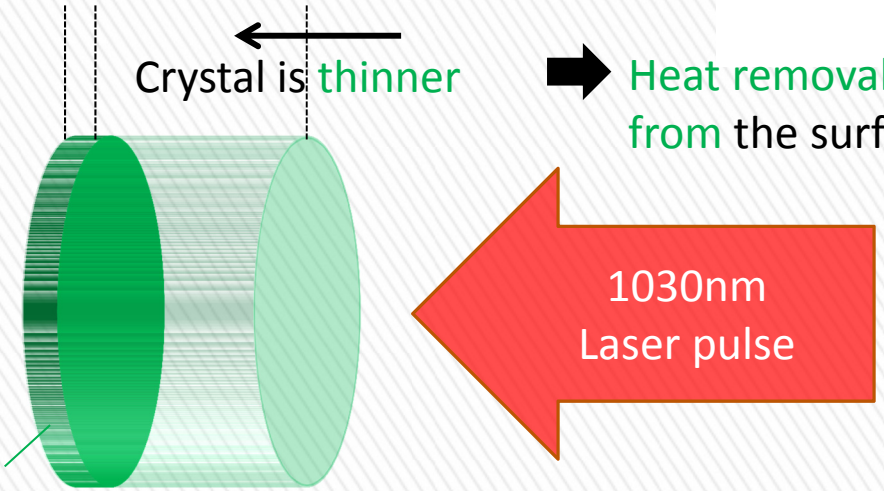
  $\nu_{emission} / \nu_{pump}$ ～90%
- Emission spectrum

  1000～1060nm
- Highly Yb-doped crystal

  ＞10%

LD for fiber pumping
976nm





Our Purpose :

To develop Yb laser for the generation of
500 fs pulse with 500 W average power at 50 Hz.

	Yb laser in this research	Ti:Sapphire laser for LWPA
Central wavelength	1030 nm	780 nm
Pulse duration	500 fs	60 fs
Pulse energy	>10 J	600 mJ
Repetition rate	50 Hz	10 Hz
Average power	>500 W	6 W

New Accelerator Technologies R&D

Advanced Accelerator

DLA (~1 mJ, ~1 kHz)

LPWA(10 J, ~10 Hz)

High Power RF Souce

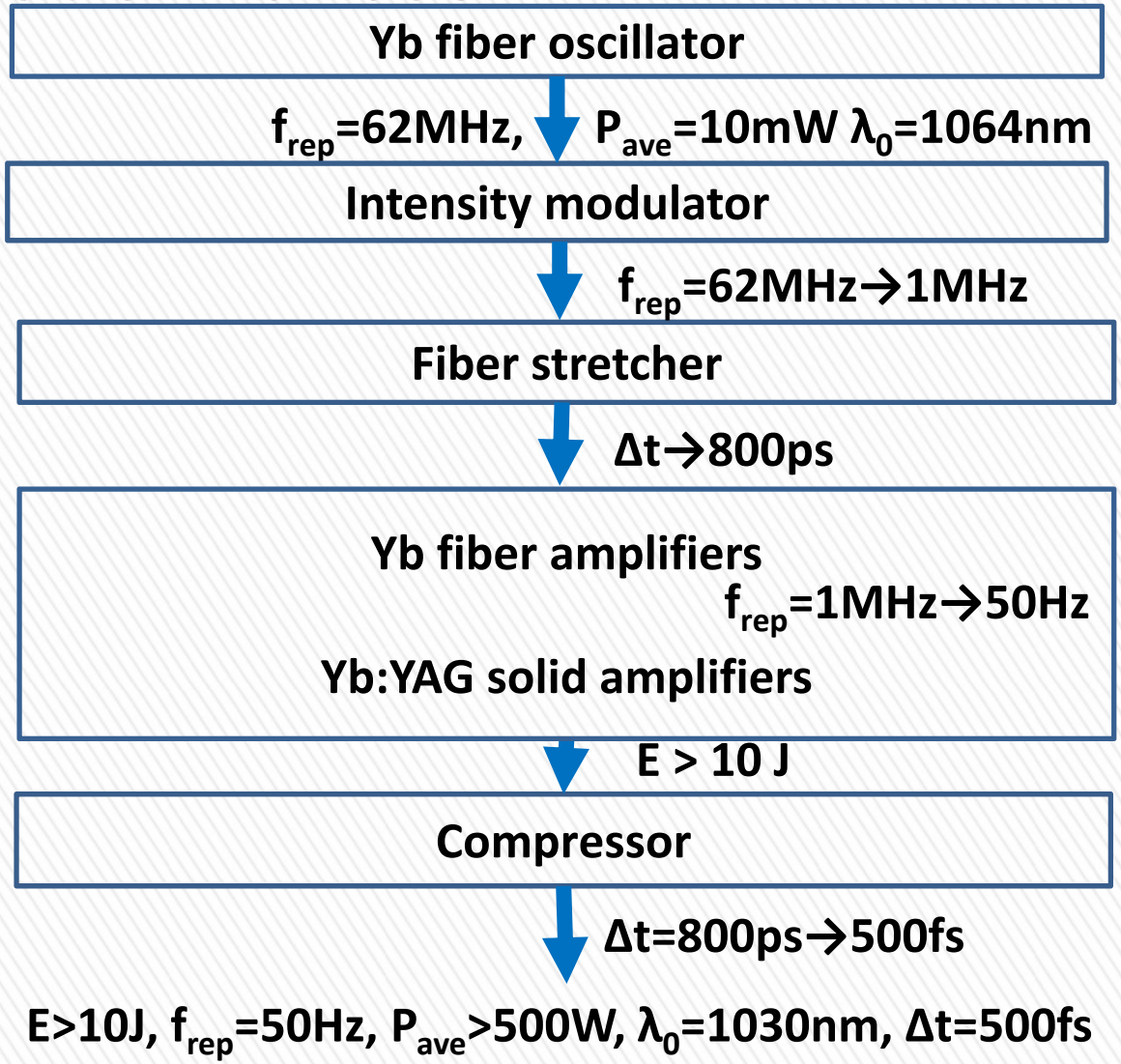
Lasertron(~1J, ~10 Hz)

X-ray Source

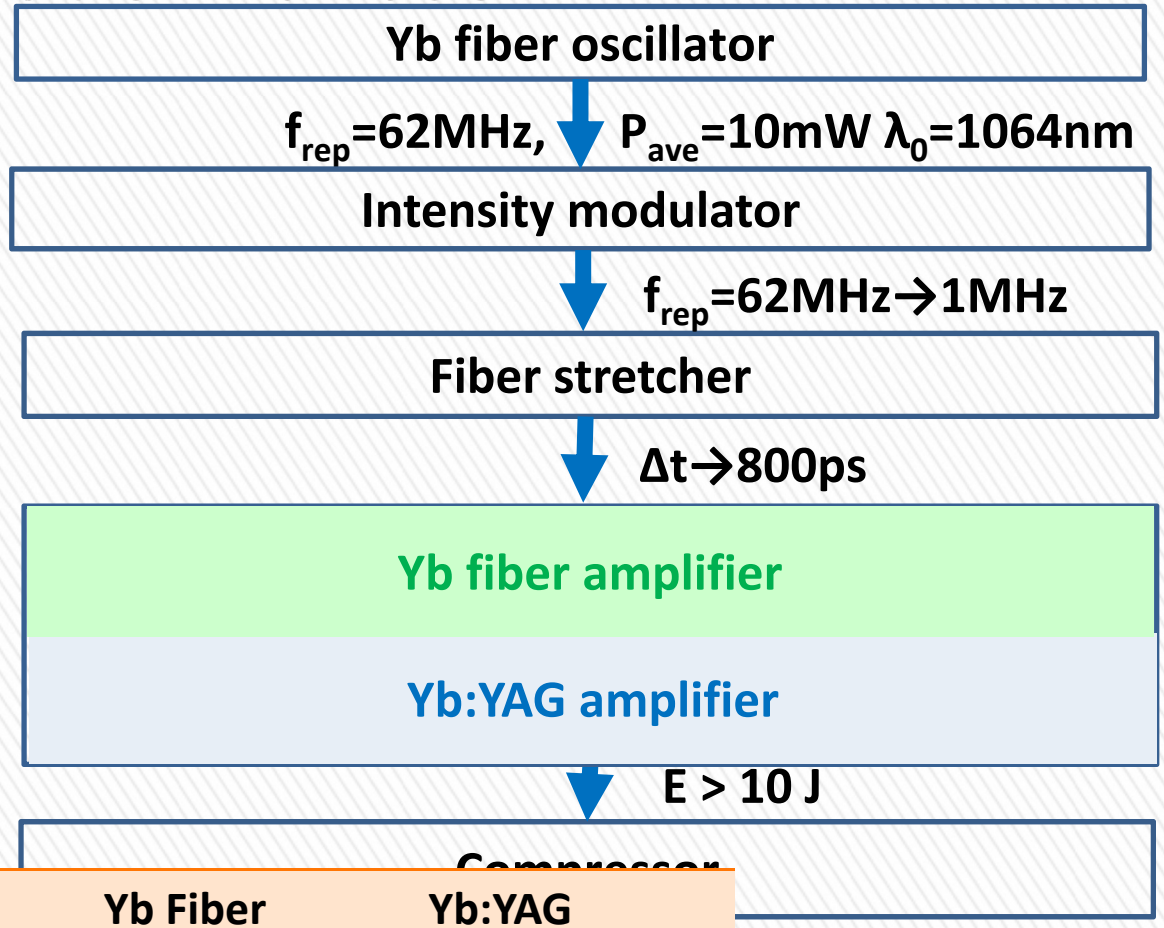
HHG(~1 uJ, ~10 MHz)

Laser Compton Scattering(~1 J, ~1 kHz)

Layout of Yb Laser



Layout of Yb Laser

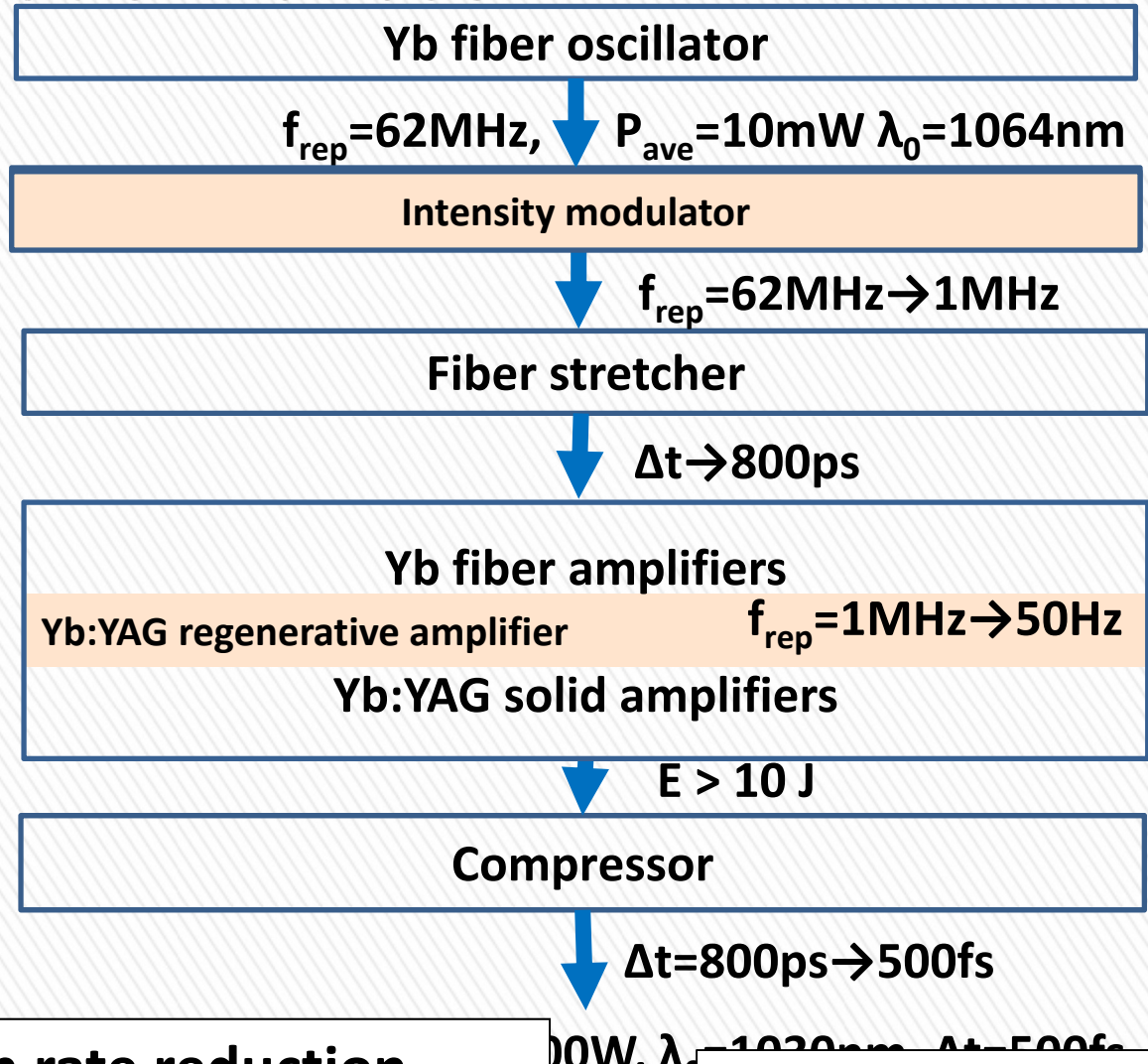


	Yb Fiber	Yb:YAG
Gain	High	Low
Cooling	Air	Water etc.
Amplification	Low Intensity	High Intensit
LD cost	High	Low
Scaling	Impossible	Applied

Yb Fiber Amplifier → First half part

Yb:YAG Amplifier → Second half part

Layout of Yb Laser



repetition rate reduction

To increase pulse energy

To suppress ASE

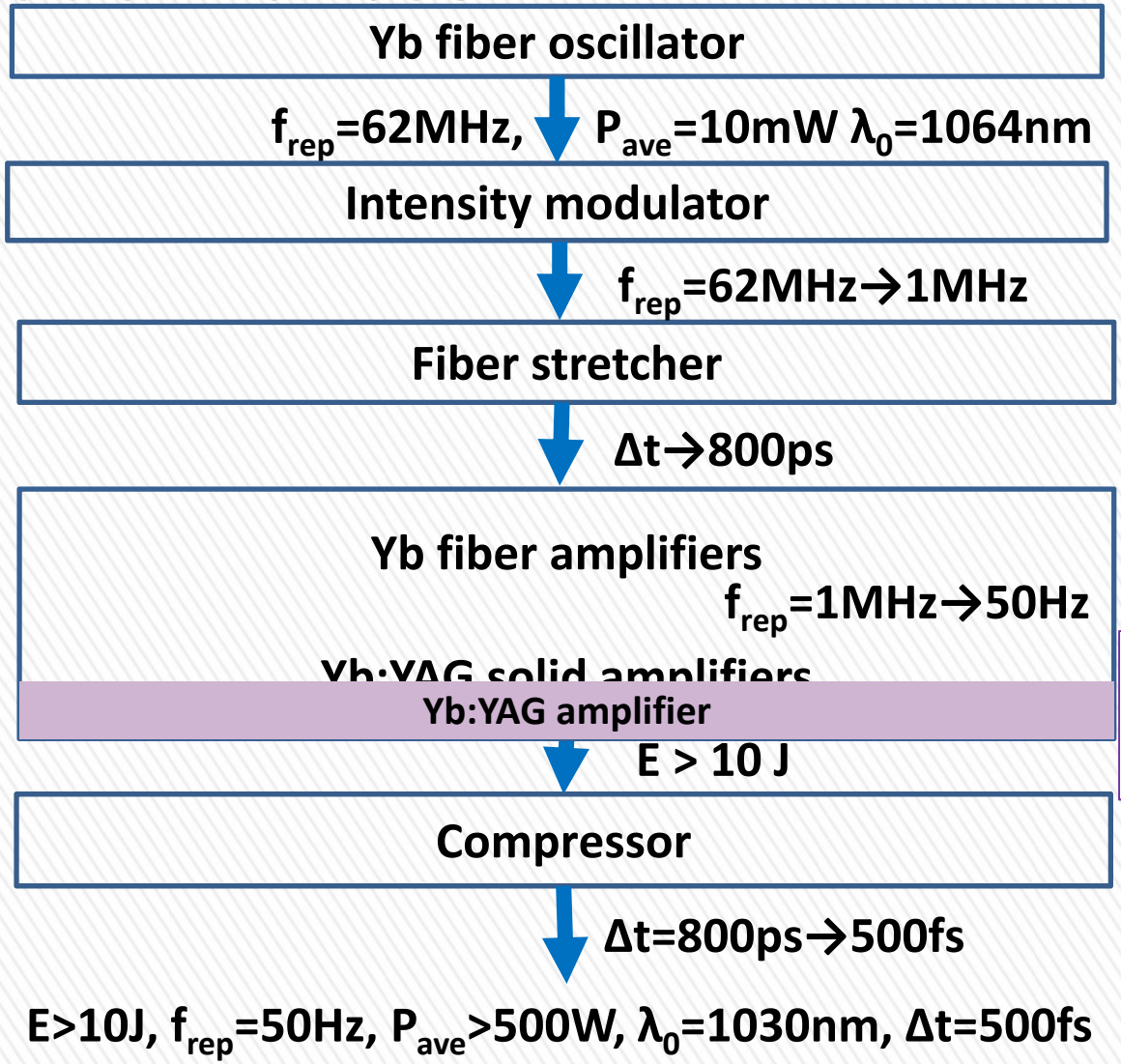
ASE…Amplified Spontaneous Emission

2 steps of rep. rate reduction

1) f_{rep}=62MHz→1MHz

2) f_{rep}=1MHz→50Hz

Layout of Yb Laser



new design of Yb:YAG amplifier

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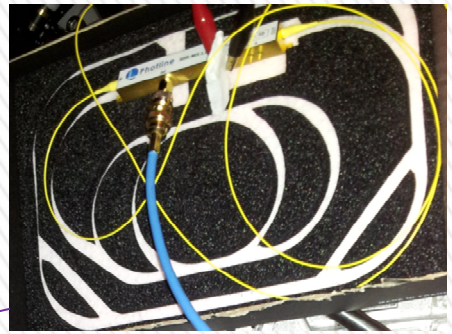
Experimental Results



Red Energy -> Results
Blue Energy -> Plan

f_{rep}=62MHz,
λ_0=1064nm

Yb fiber oscillator

0.2 nJ

Intensity modulator

f_{rep}=62MHz→1MHz

Yb fiber pre-amplifier

0.3 nJ

Δt→800ps

Fiber stretcher

Yb fiber pre-amplifier

0.4 nJ

Yb fiber pre-amplifier

1.4 nJ

10 W pump Yb fiber amplifier

0.7 uJ

70 W pump Yb fiber amplifier

13 uJ

Yb:YAG regenerative amplifier

Yb:YAG amplifier

. . .

100~1000 mJ
= LWPA, Lasertron

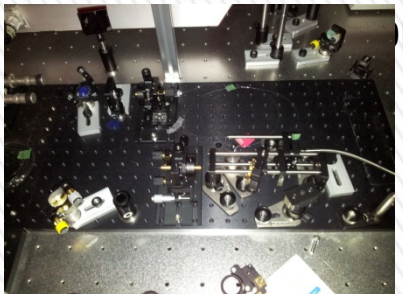
Yb:YAG amplifier

>10 J

Compressor

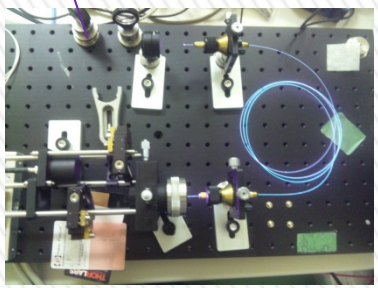
Δt=800ps→500fs

E=10J, f_{rep}=50Hz
P_{ave}=500W, λ_0=1030nm
Δt=500fs

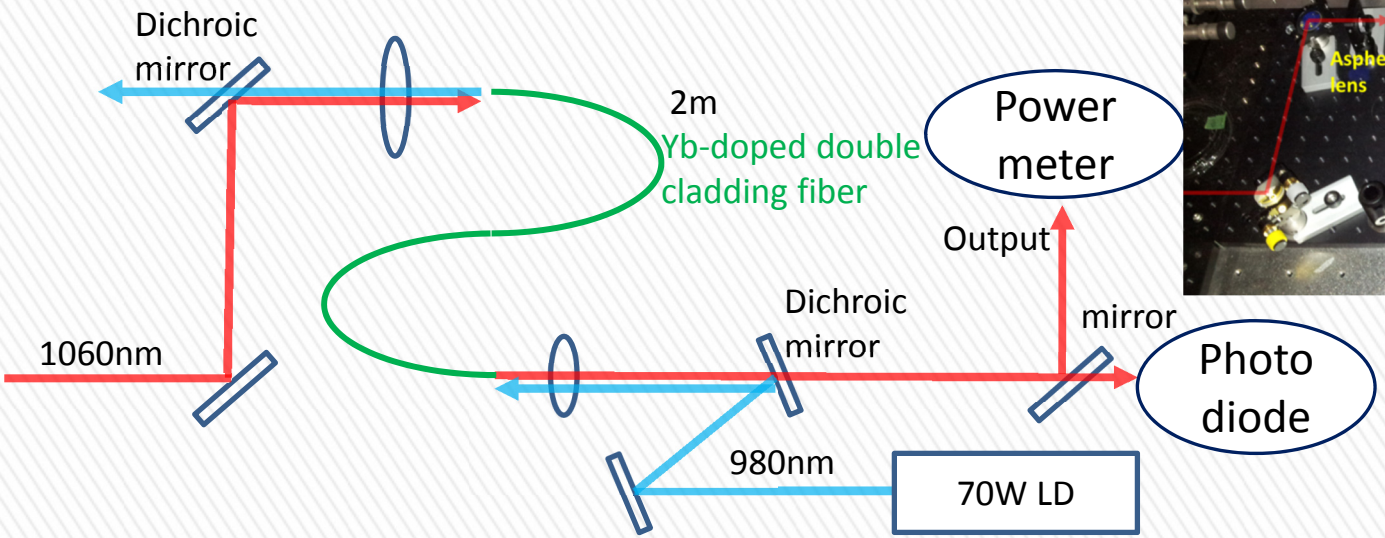


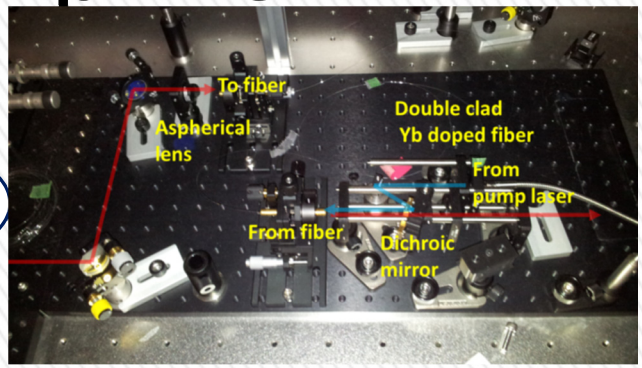
Hz

10 mJ
II
DLA



70 W pump Yb fiber amplifier

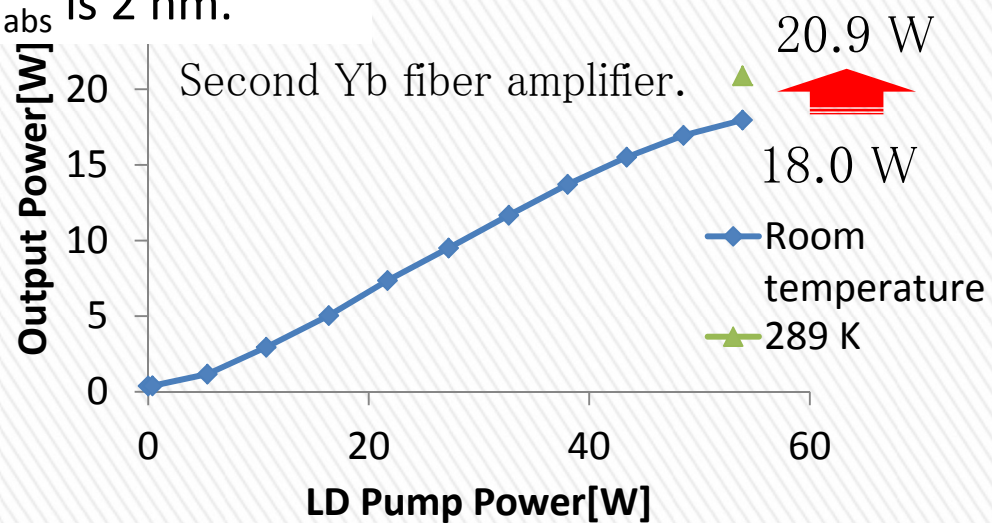




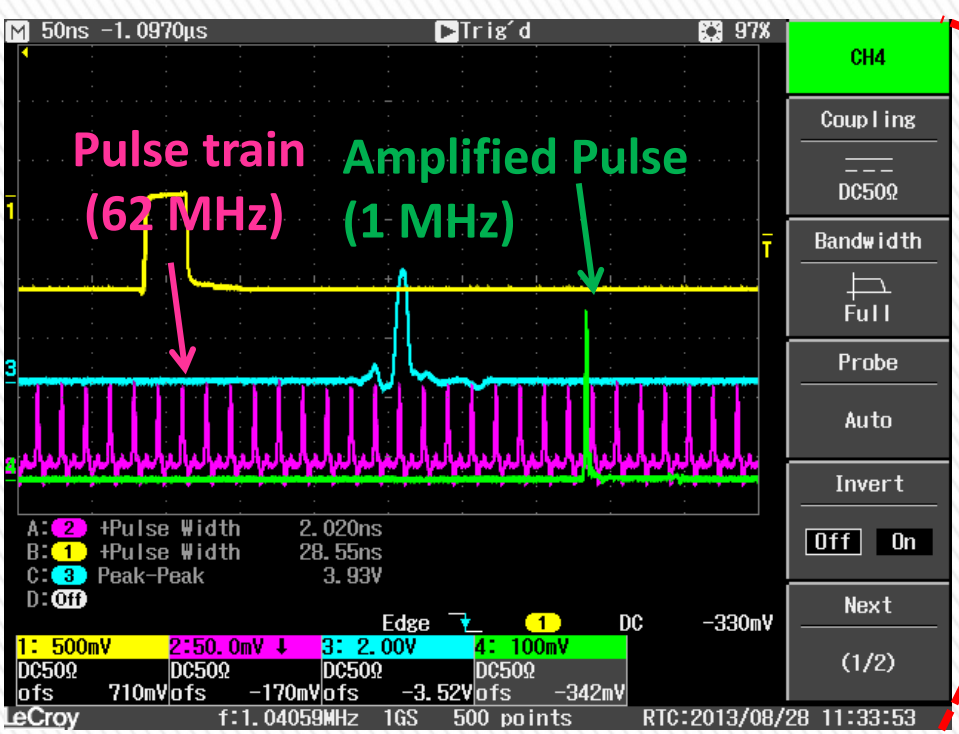
・Wavelength of LD depends on temperature.

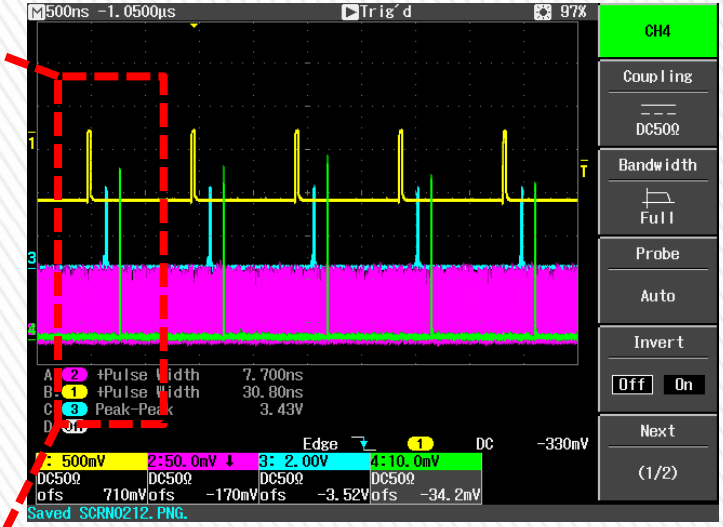
・FWHM of Yb's σ_{abs} is 2 nm.

→ **LD temperature control**



» Behind the mirror, the photodiode monitored the pulse train.





The SN ratio was 100.

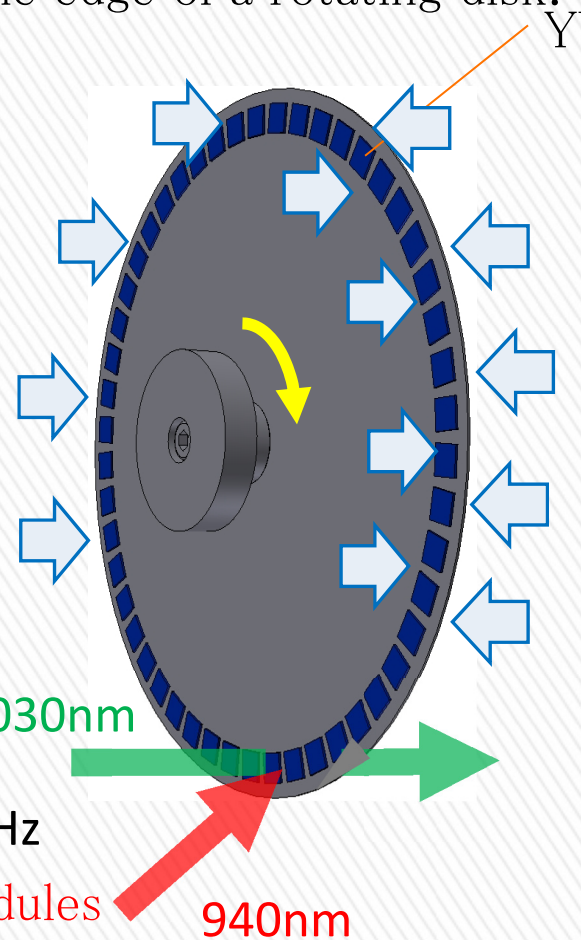
ASE was small.

20.9 W × 100 / (100+1×61) = 13 µJ at 1 MHz was achieved.

Yb:YAG Amplifier at Final Stage

» To realize 50 Hz repetition rate, we are designing Yb:YAG amplifier.

The design of final Yb:YAG amplifier. 50 pieces of Yb:YAG are arraigned on the edge of a rotating disk.



50 pieces Yb:YAG

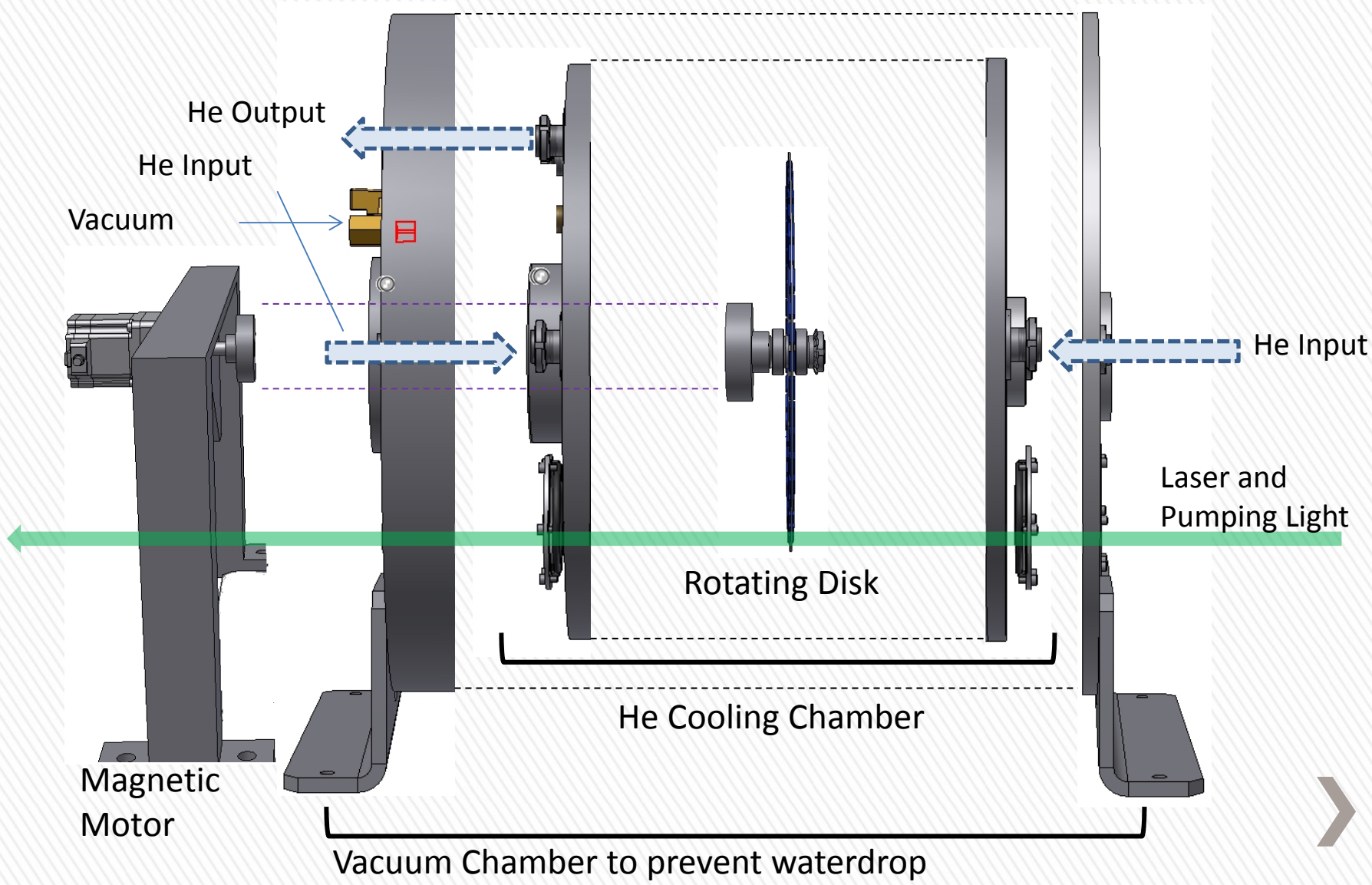
Low Thermal Load

He gas
Cooling from Surface

Small Thermal
Lens Effect

Different Place at cooling

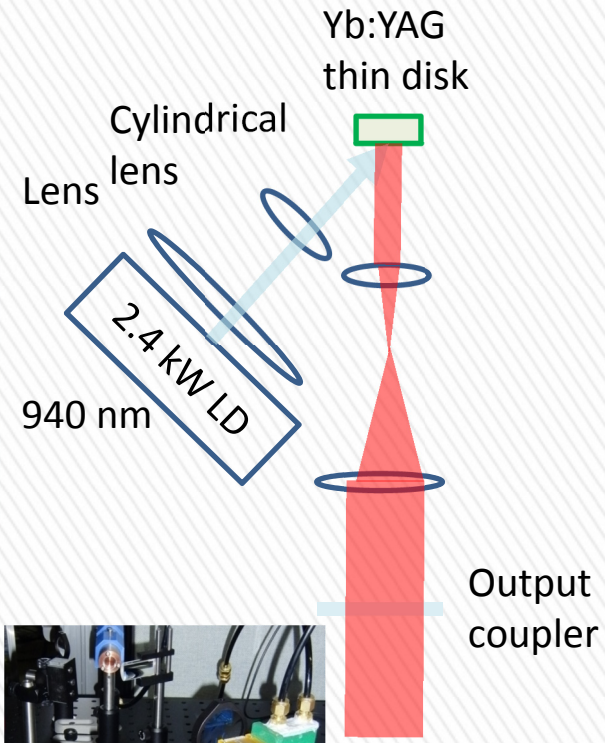
Overview

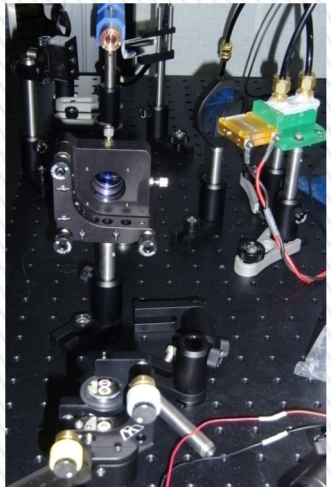

He Output
He Input
Vacuum
He Input
Laser and
Pumping Light
Rotating Disk
He Cooling Chamber
Magnetic
Motor
Vacuum Chamber to prevent waterdrop

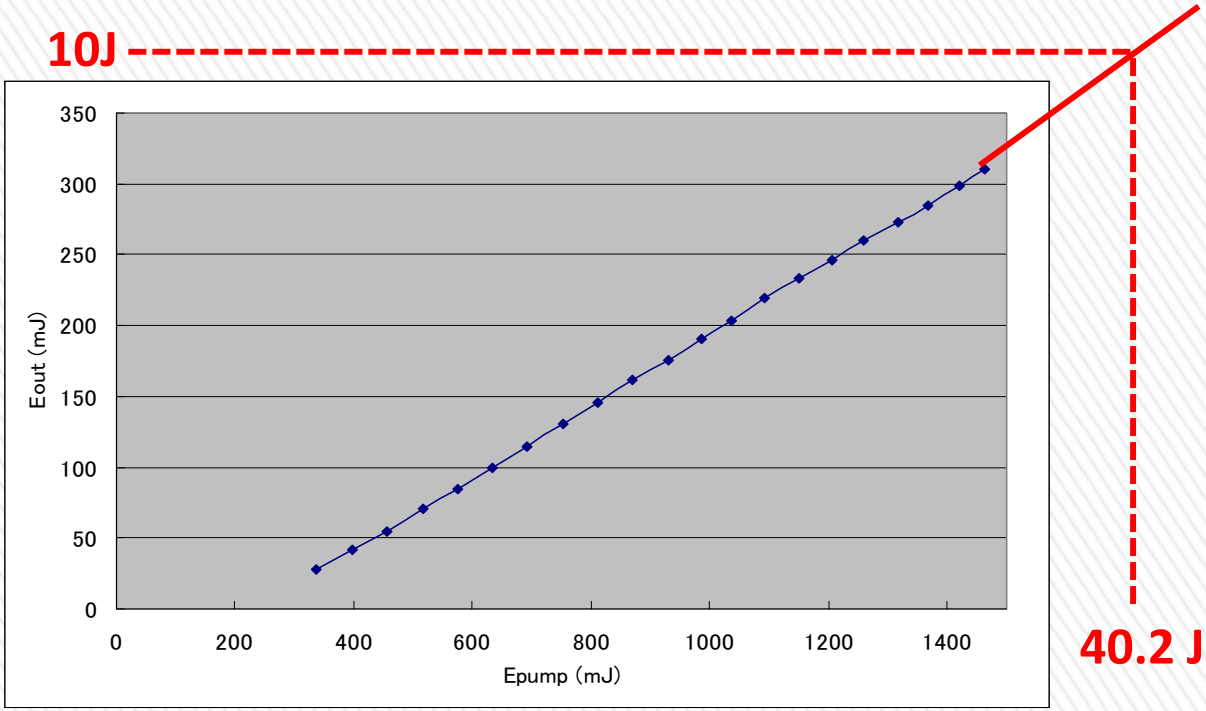
Basic Experiment for Yb:YAG Amplifier

» Yb:YAG thin disk oscillator

2.4 kW×600us=1.44J, Repetition rate 1 Hz.







30 % slope efficiency

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Conclusion

» we reduced repetition rate to 1 MHz, amplified the average power up to 13 W, and achieved 13 uJ pulse energy.

	Present Yb Laser	Yb Laser For DLA	Ti:Sapphire For LWPA	Goal
Pulse Energy	**13 µJ**	**20 mJ**	**600 mJ**	**>10 J**
Repetition Rate	**1 MHz**	**1 kHz**	**10 Hz**	**50 Hz**
Average Power	**13 W**	**20 W**	**600 mW**	**>500 W**
Pulse Duration	**800 ps**	**2 ps**	**60 fs**	**500 fs**

We will go to the stage of the Yb:YAG amplifiers.
In the near future, the generation of 500 fs pulse with 500 W average power at 50 Hz will be achieved!!

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Thank you for your attention !
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