8/11　ATLAセミナー

理化学研究所
放射光科学研究センター　先端光源開発研究部門
レーザー駆動電子加速技術開発グループ　基盤開発チーム

辻 明宏

Contents

⑯波長1.5mmの極限波長に出力10mJまでの変換(担当:理化学研究所)

Summary

・DFCチップを用いた1064nm５Ｊレーザーを開発し、LA-MgLNと水晶のQPMを経て波長1.5mm、出力>10mJのTHz波を発生
・同時開発するUVレーザーによる電子発生と、上記テラヘルツ波による誘電体加速の基礎研究
・Develop a 1064nm 5J laser with DFC-chip, and generate 1.5mm and >10mJ THz laser by LA-MgLN /quarts QPM.
・Study about electron generation by developed UV laser and electron acceleration by THz laser.

Stage gate(2022/10)

・THz波で1mJ発生させるとともに、10mJの準備と社会連携への展開の確認
・マイクロチップレーザによる超小型１mJ THz波レーザの検証
・Generate >1mJ THz laser and prepare 10mJ THz and social partnership.
・Develop the tiny 1mJ THz laser system using micro chip.

Goal(2025/3)

・パルスエネルギー：5J以上、パルス幅：約500ps、ピーク出力：10GW以上の1064nmレーザーの開発
・ブレッドボードサイズで出力10mJ以上のTHz波発生(輝度温度：$>10^{20}$K)
・プラットホーム整備を目標とした1mJパルス出力小型高輝度THz波レーザの仮作検証
・Develop 1064nm laser system; Pulse energy: >5J, Pulse width: about 500ps, Peak power: >10GW.
・Generate >1mJ THz laser and prepare 10mJ THz.
・Develop the tiny 1mJ THz laser system using micro chip.

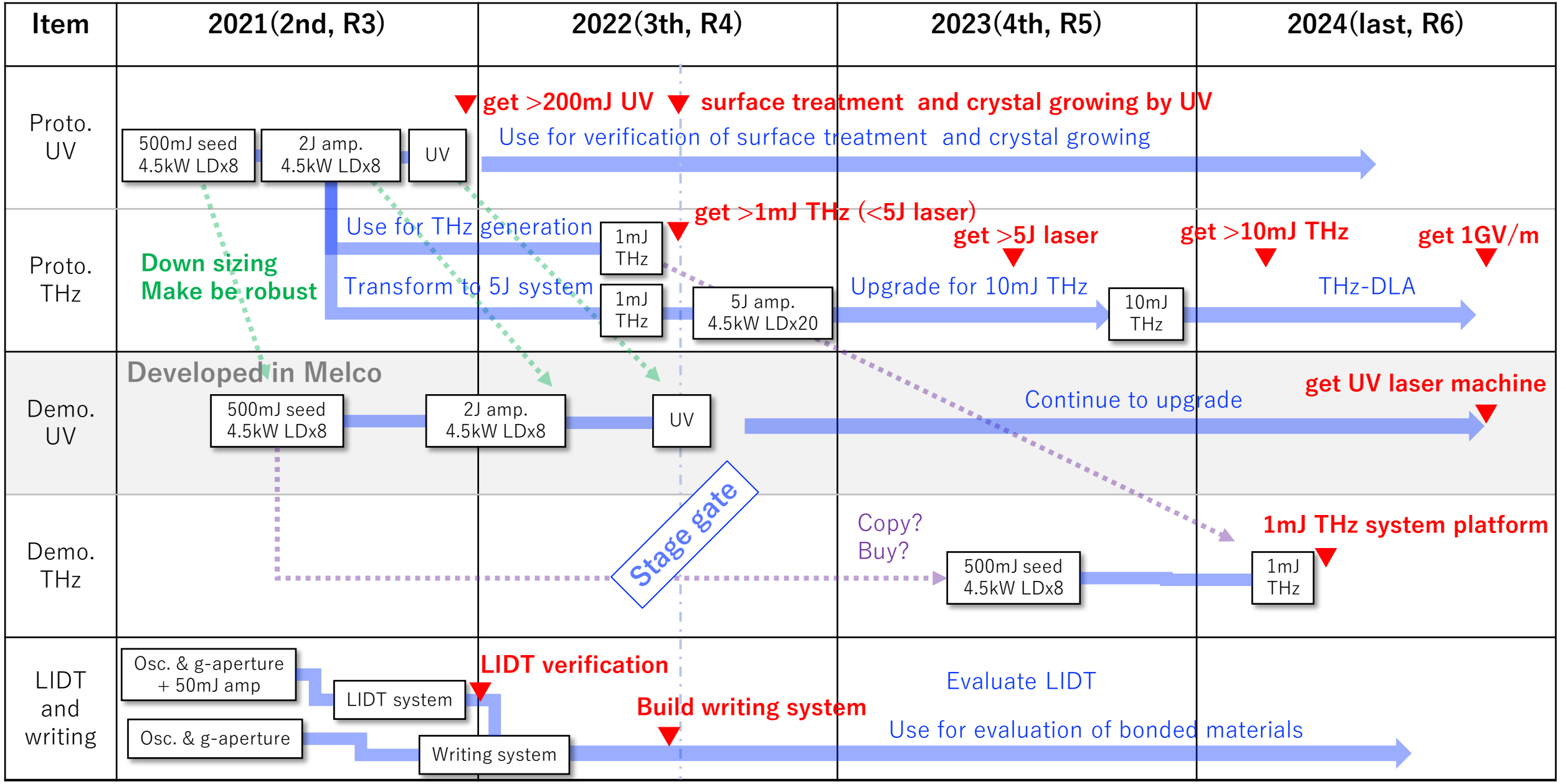
⑳プロジェクトの総合的推進(担当:理化学研究所)

進捗状況を確認し、年に二回以上複数名による進捗報告会や外部有識者を招聘した意見交換会を開き推進を図る。
Check the progress and hold a progress report meeting and an opinion exchange meeting inviting outside experts.

→プロジェクト全体の進捗、調達状況を説明　Today, I will talk about progress and purchase.

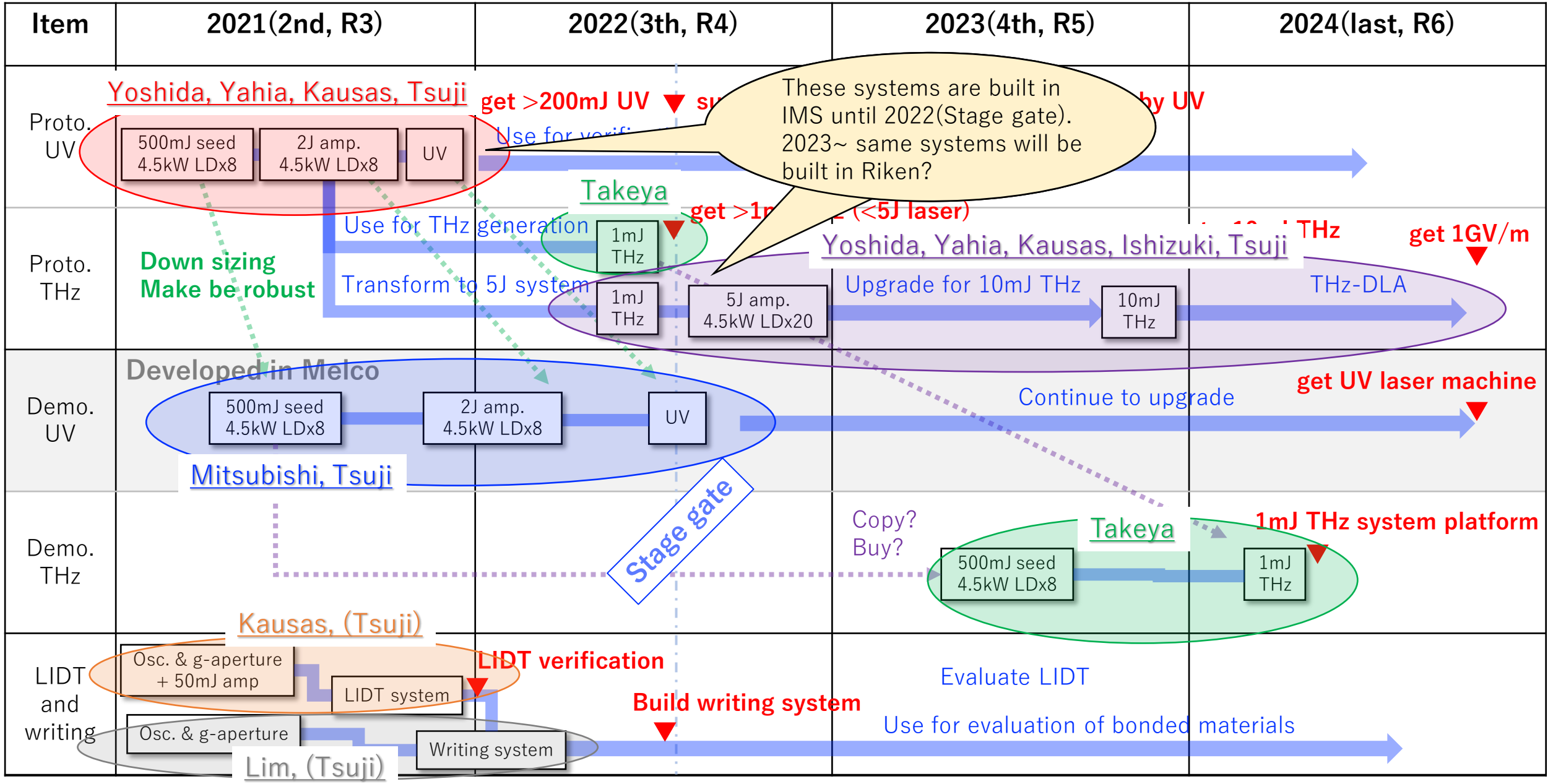
Building plan(2021/8/11) ※Regarding laser

▼：Stage gate and Goal

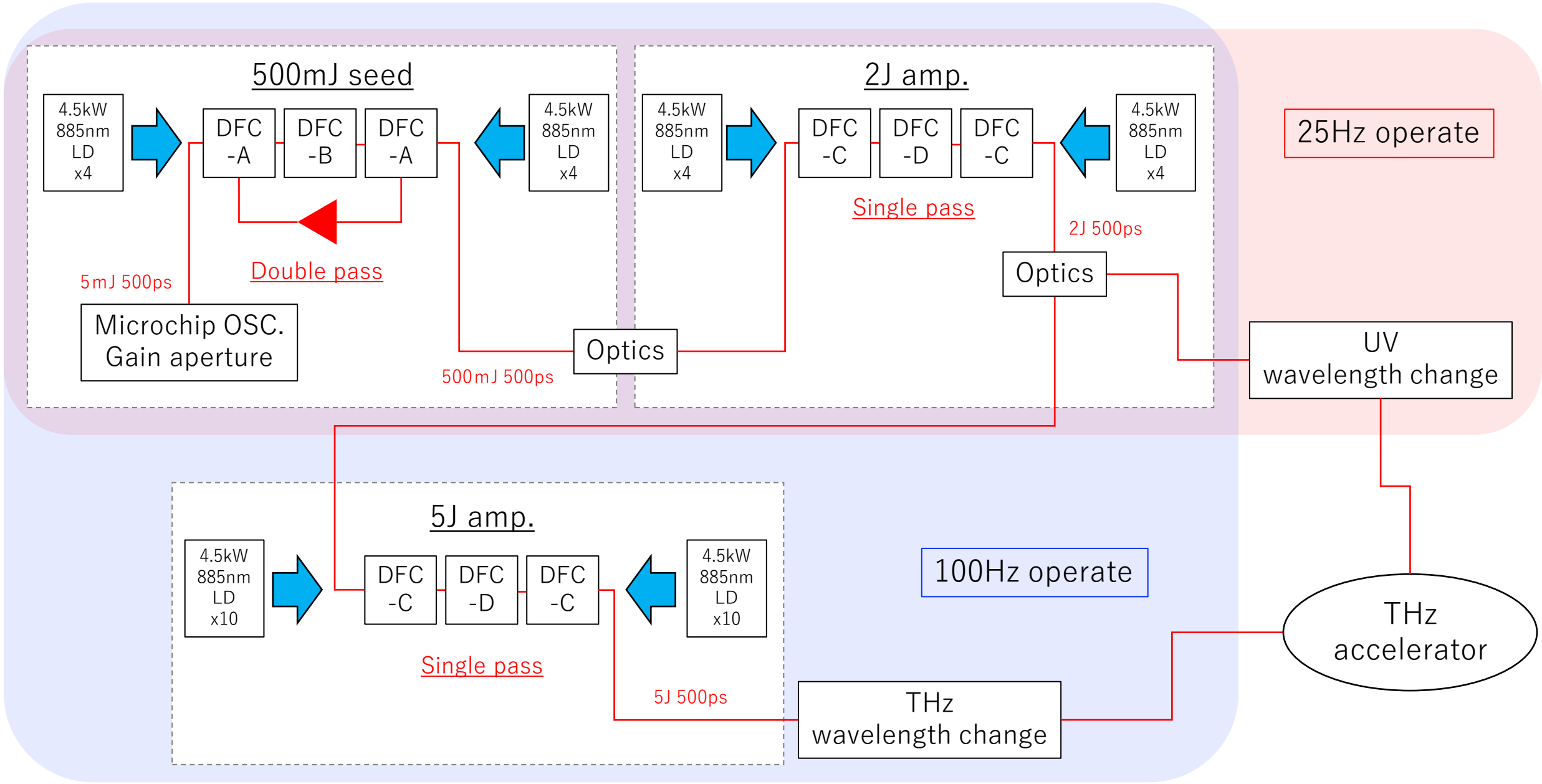


Building plan(2021/8/11) ※Regarding laser

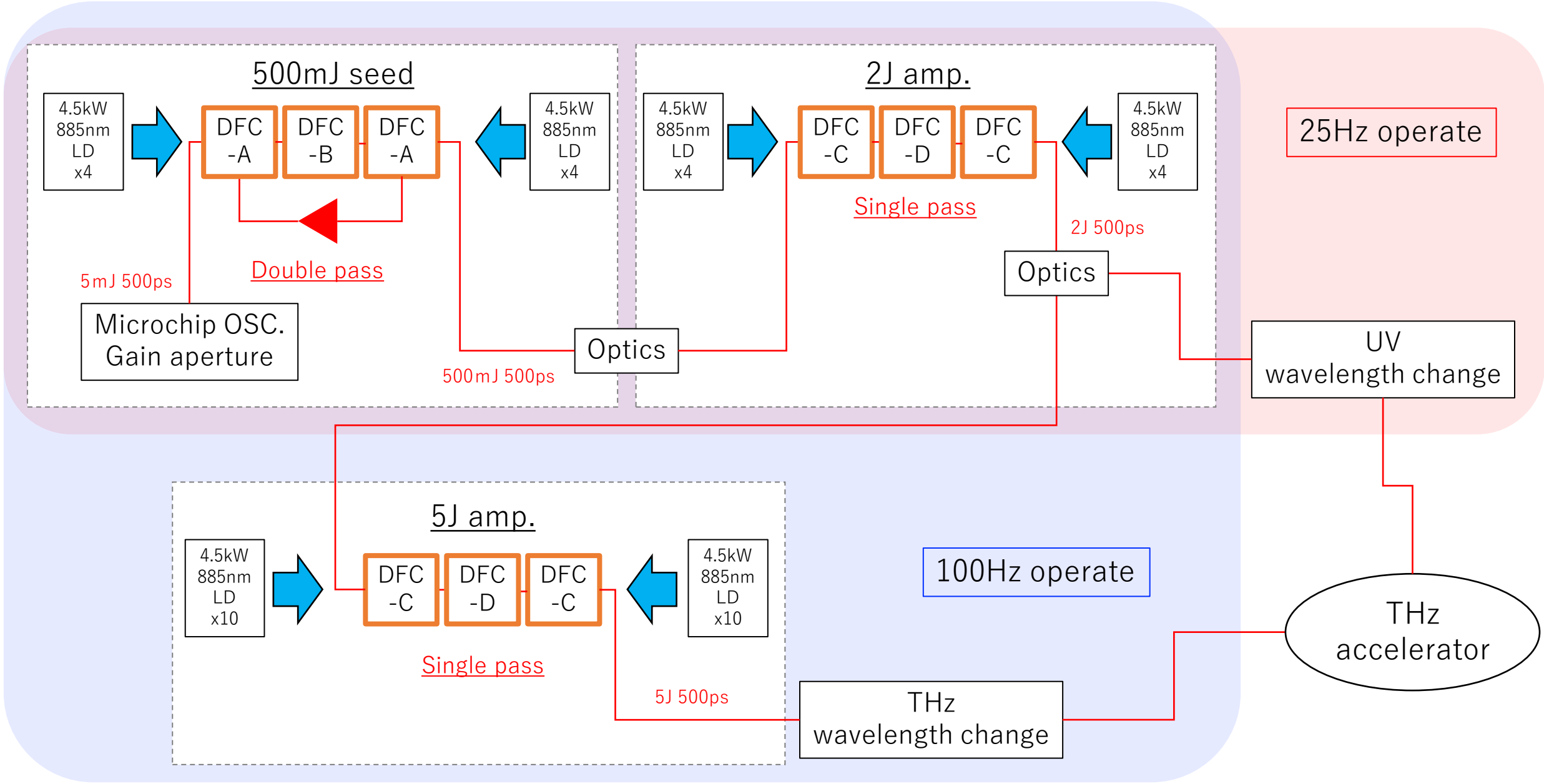
▼：Stage gate and Goal



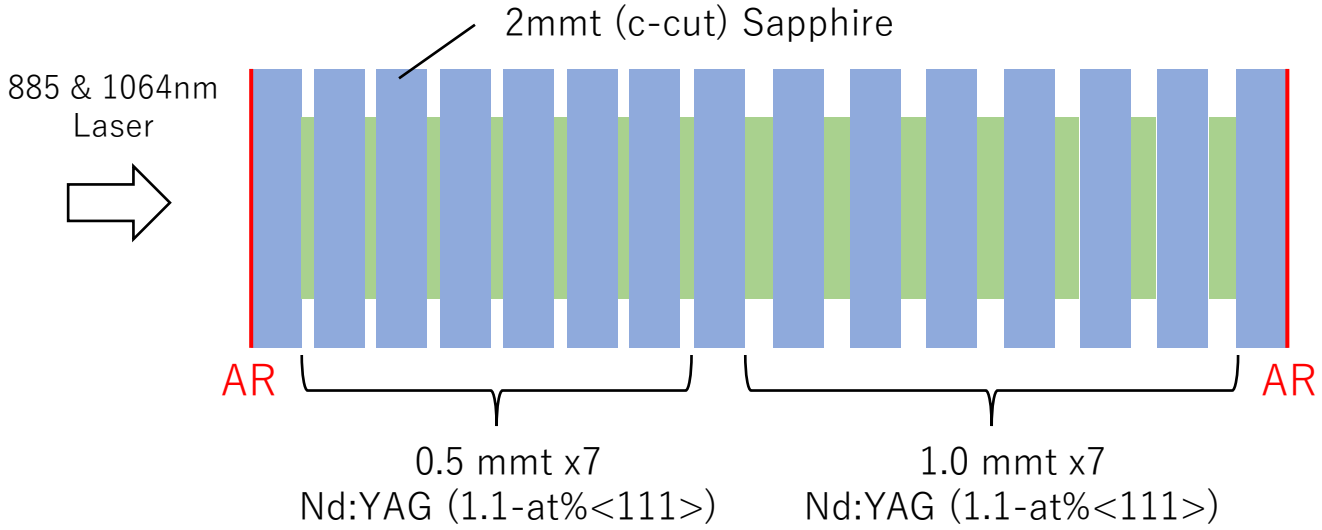
Outline onf 500mJ seed laser and 2J/5J amp. system



Amplifier in 500mJ seed laser and 2J amp. system



DFC design for ATLA

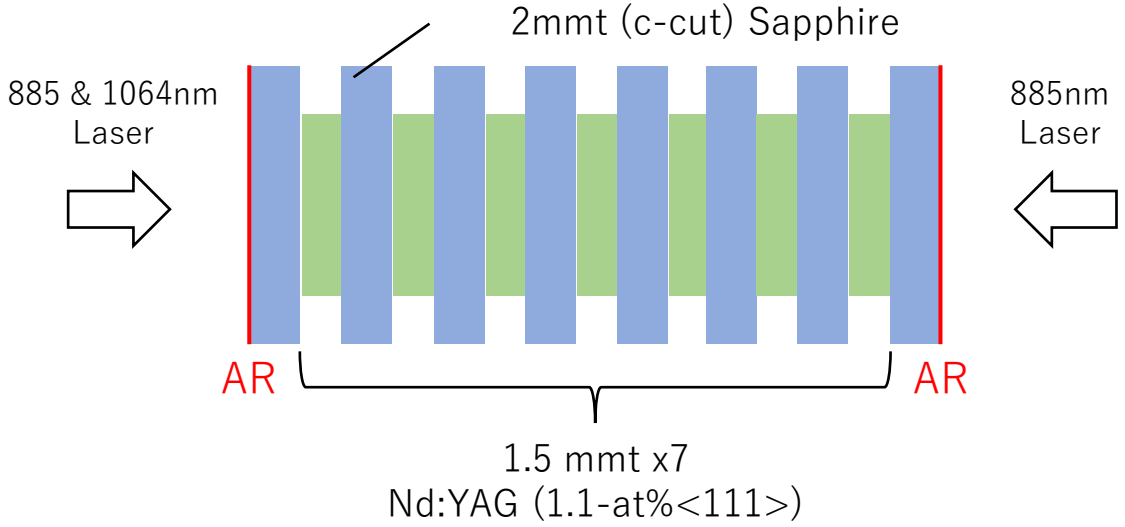


DFC-A … for 500mJ seed

□**10mm** Nd:YAG+ϕ25.4mm Sapphire

DFC-C … for 2J amp.

□**15mm** Nd:YAG+ϕ25.4mm Sapphire



DFC-B … for 500mJ seed

□**10mm** Nd:YAG+ϕ25.4mm Sapphire

DFC-D … for 2 J amp.

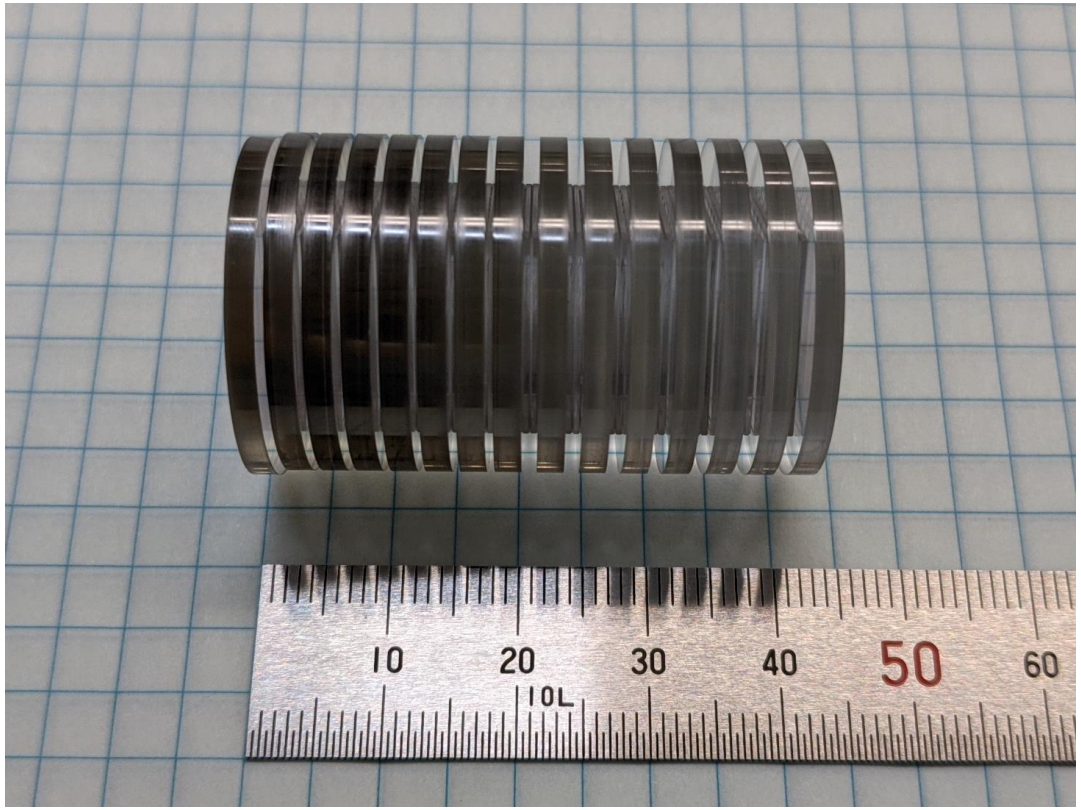
□**15mm** Nd:YAG+ϕ25.4mm Sapphire

Same DFC will be made by Nd:YAG ceramics.

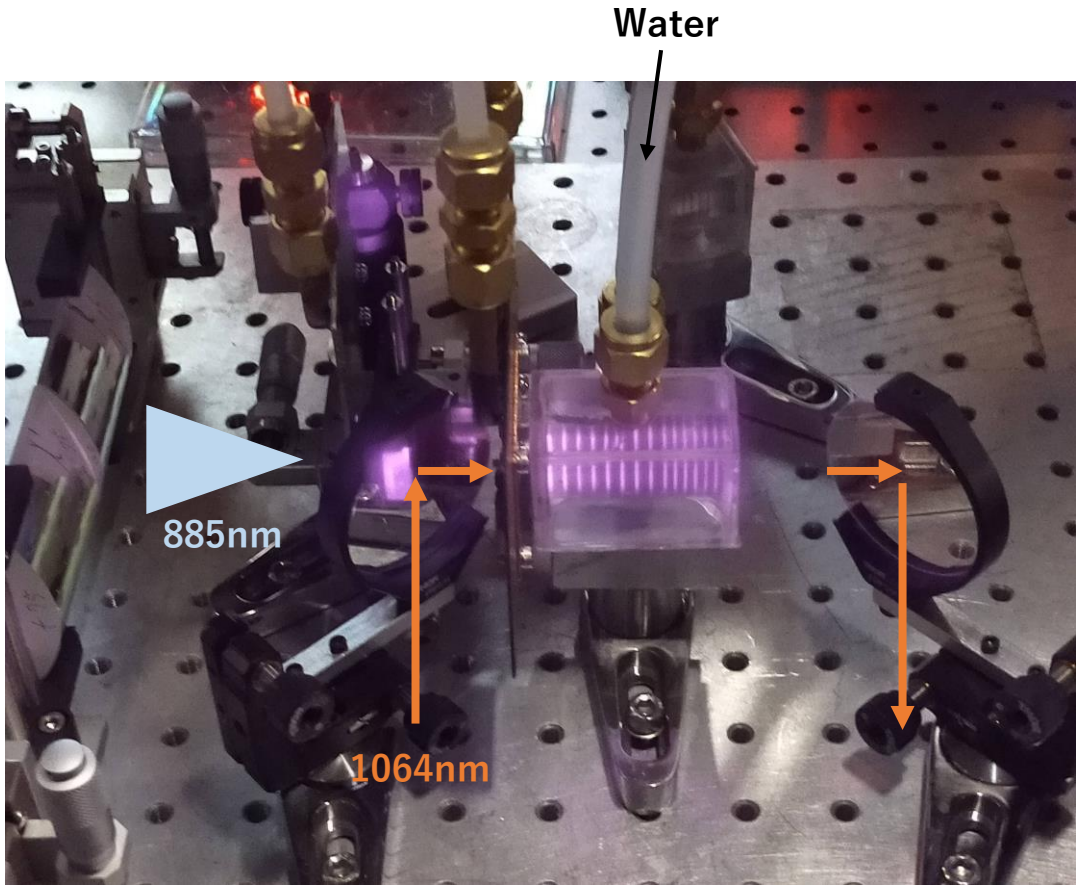
Avoid thermal concentration by using thin Nd:YAG(1.1%).

※Low dope Nd:YAG(0.5%) is three times expensive.

DFC design for ATLA

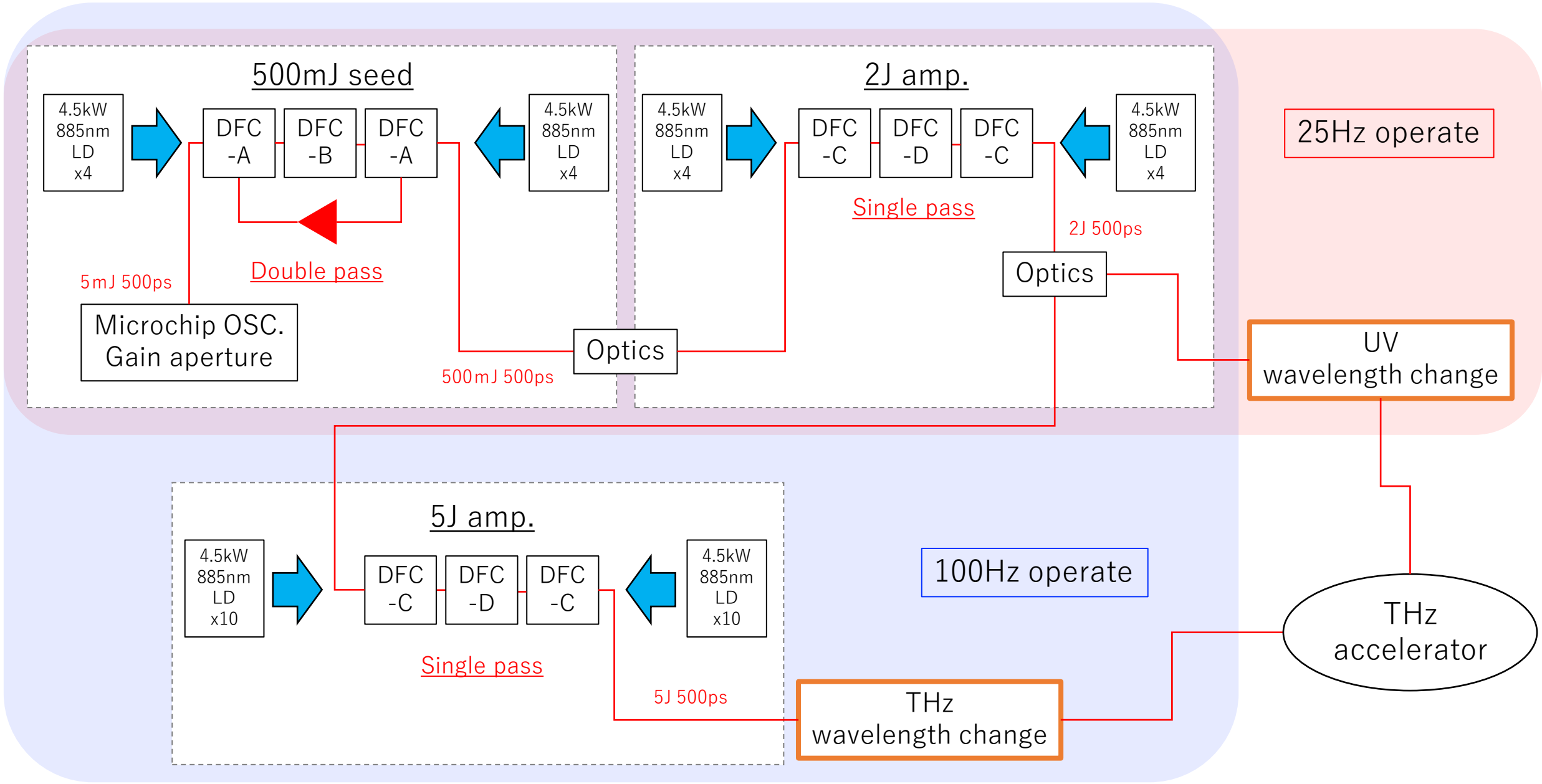


DFC-Type A (by Kobayashi san)



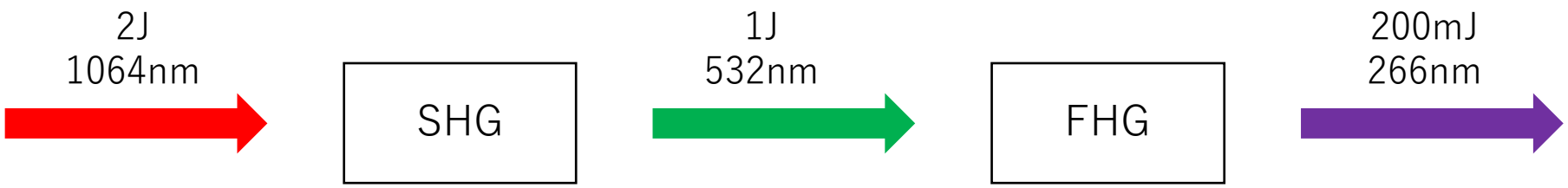
DFC testing

Amplifier in 500mJ seed laser and 2J amp. system



UV and THz wavelength change

UV



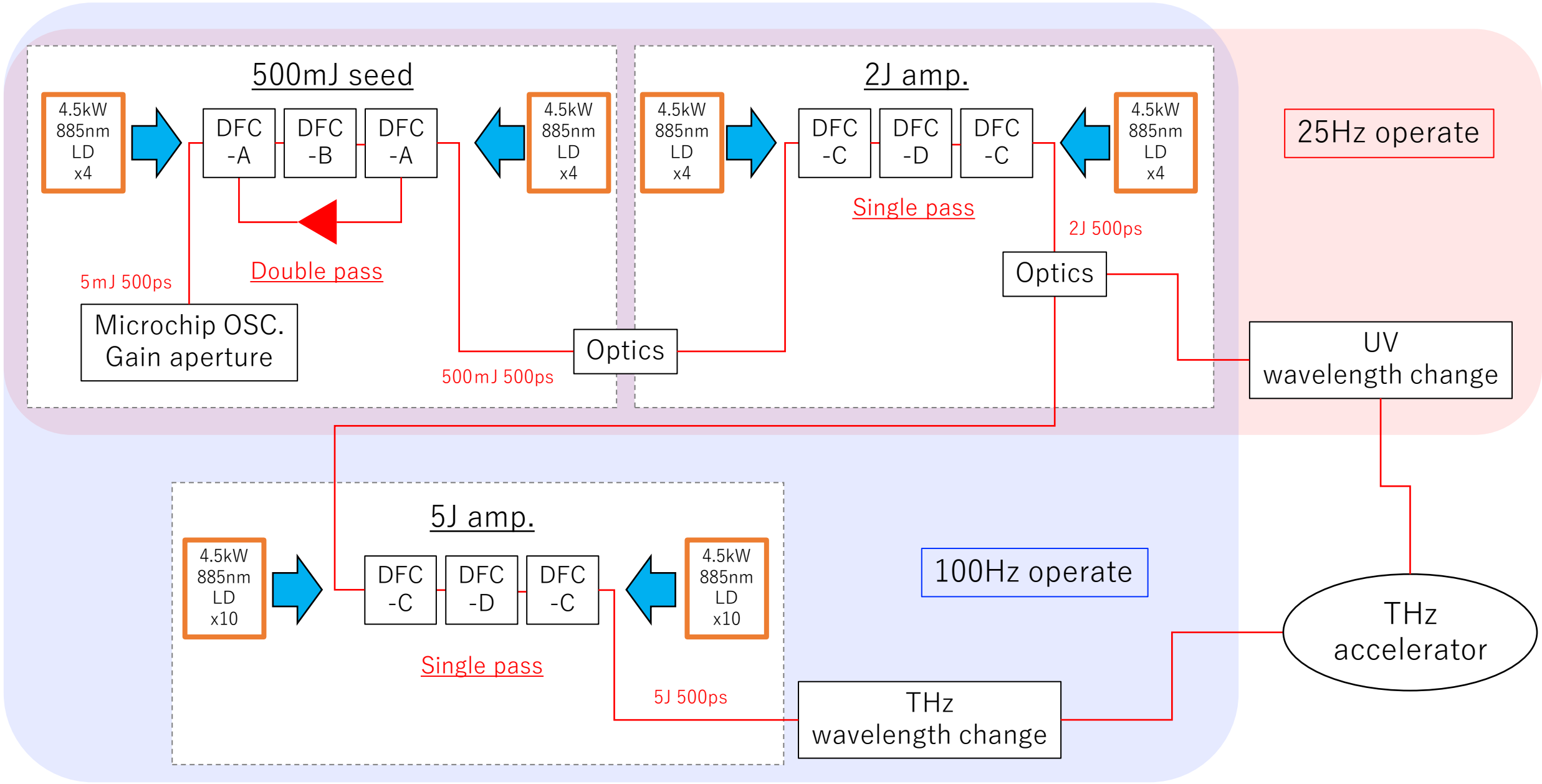
Material	Purpose	Size	Coating	Spec	Manufacture
LBO	SHG	□10mm x 20mmt	AR coating	Theta=90deg Phi=11.4deg	EKSMA
LBO	SHG	□10mm x 20mmt	AR coating	Theta=90deg Phi=11.4deg	Castech
BBO	FHG	□10mm x 7.0mmt	AR coating	Theta=47.6deg Phi=90deg	Castech
KD*P	FHG	□10mm x 15mmt	AR coating	Theta=90deg Phi=45deg	Castech

THz

Purchase
- PPLN
- Quartz
- Temp. controller

Detail is under consideration.

Amplifier in 500mJ seed laser and 2J amp. system



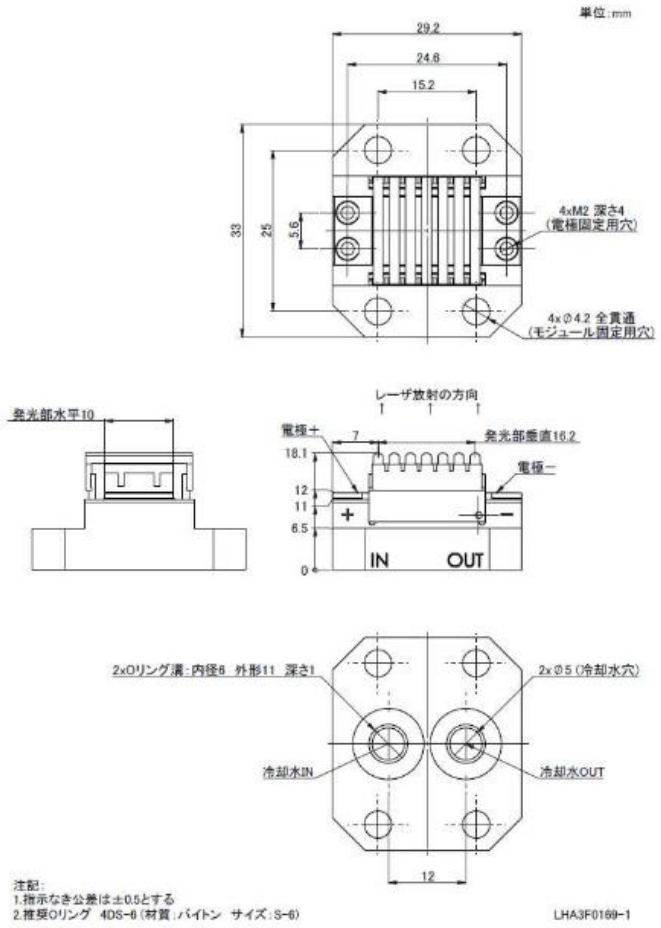
4.5kW 885nm LD

LD

Hamamatsu photonics
LE1598MOD

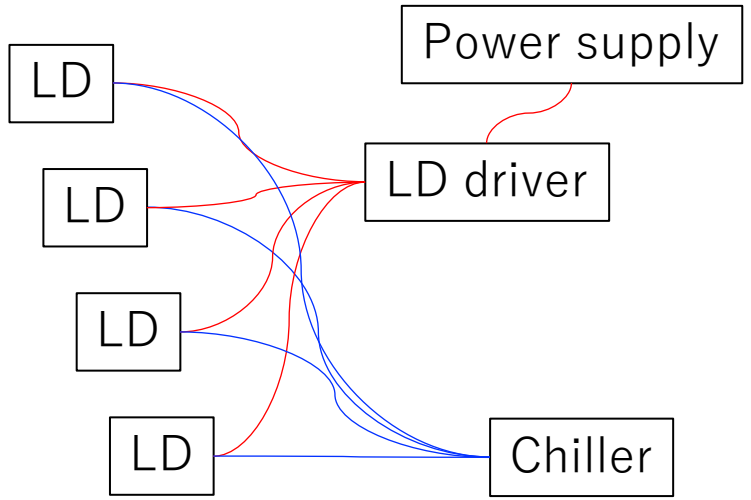
項目	最小値	標準値	最大値
動作電流(A)	-	725	745
中心波長(nm)	882	885	888
半価幅(nm)	-	4	6
動作電圧(V)	-	14	17.5

4.5kW, Duty 1.5%
Temperature25°C, Water flow1L/min



Assembly

Power supply: PWX1500ML



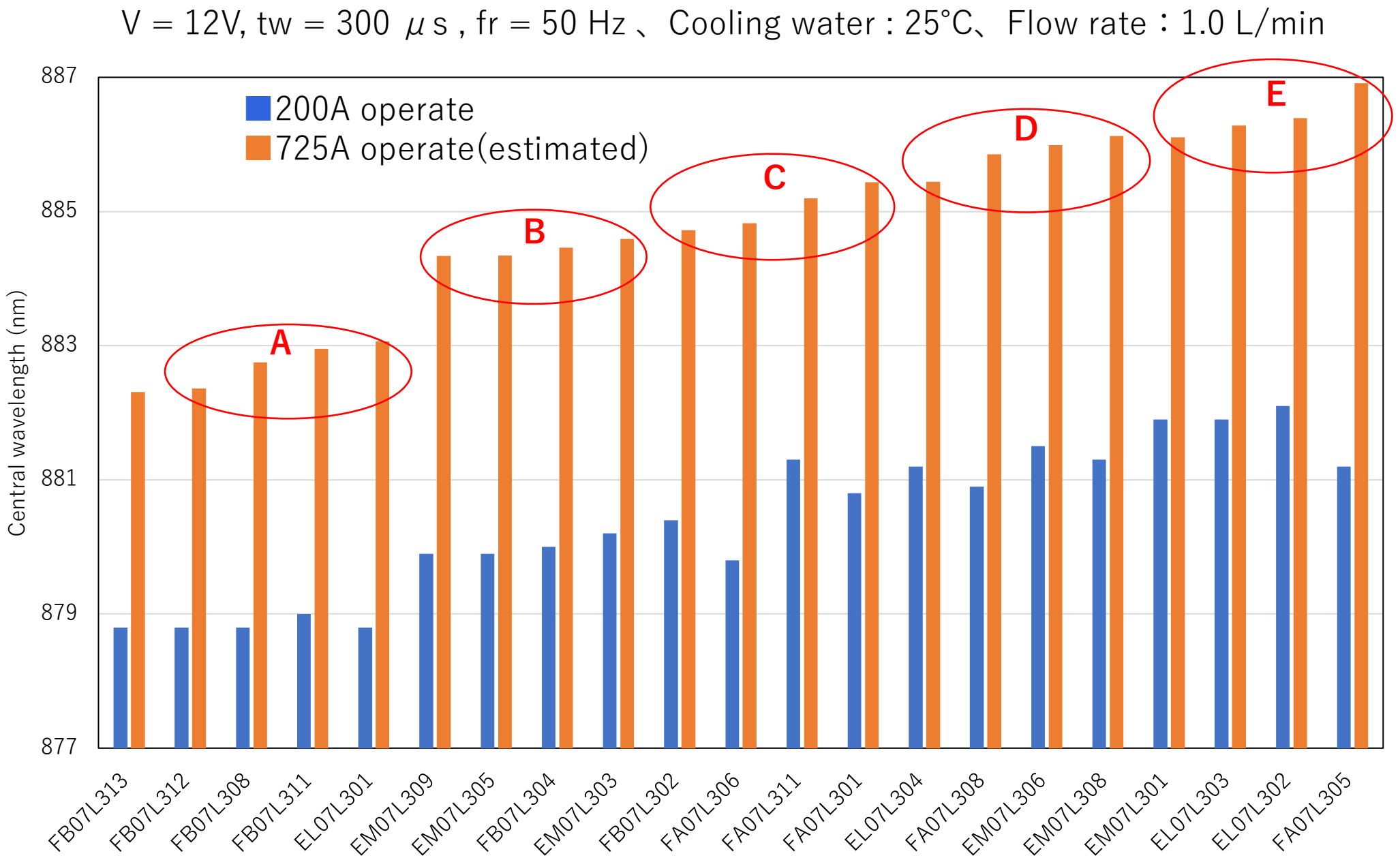
SMC

4 LDs are operated in same conditions.
(Water temperature, Current, Pulse width)

LD data

	Measured (200A operate)			Estimated from two measured data			Measured (4.5kW operate)		
SN	Current [A]	λ c [nm]	FWHM [nm]	Current [A]	λ c [nm]	FWHM [nm]	Current [A]	λ c [nm]	FWHM [nm]
EL07L301	200	878.8	2.3	**725**	883.1	3.9	705	882.9	3.8
EL07L302	200	882.1	1.9	725	886.4	3.8	677	886	3.6
EL07L303	200	881.9	2	725	886.3	3.8	667	885.8	3.6
EL07L304	200	881.2	1.7	725	885.4	3.8	707	885.3	3.7
EM07L301	200	881.9	2.3	725	886.1	3.7	699	885.9	3.6
EM07L303	200	880.2	2	725	884.6	3.9	726	884.6	3.9
EM07L305	200	879.9	2.2	725	884.3	3.8	720	884.3	3.8
EM07L306	200	881.5	2.4	725	886.0	3.8	703	885.8	3.7
EM07L308	200	881.3	2	725	886.1	3.8	711	886	3.8
EM07L309	200	879.9	1.9	725	884.3	3.8	709	884.2	3.7
FA07L301	200	880.8	1.6	725	885.4	4.0	687	885.1	3.8
FA07L305	200	881.2	2.5	725	886.9	4.1	687	886.5	4
FA07L306	200	879.8	1.9	725	884.8	3.9	733	884.9	3.9
FA07L308	200	880.9	1.9	725	885.9	3.9	698	885.6	3.8
FA07L311	200	881.3	1.8	725	885.2	4.3	685	884.9	4.1
FB07L302	200	880.4	1.9	725	884.7	4.0	698	884.5	3.9
FB07L304	200	880	2.9	725	884.5	4.1	694	884.2	4
FB07L308	200	878.8	2.4	725	882.8	4.2	705	882.6	4.1
FB07L311	200	879	1.7	725	883.0	4.1	718	882.9	4.1
FB07L312	200	878.8	2.2	725	882.4	4.5	642	881.8	4.1
FB07L313	200	878.8	2.1	725	882.3	4.8	649	881.8	4.4

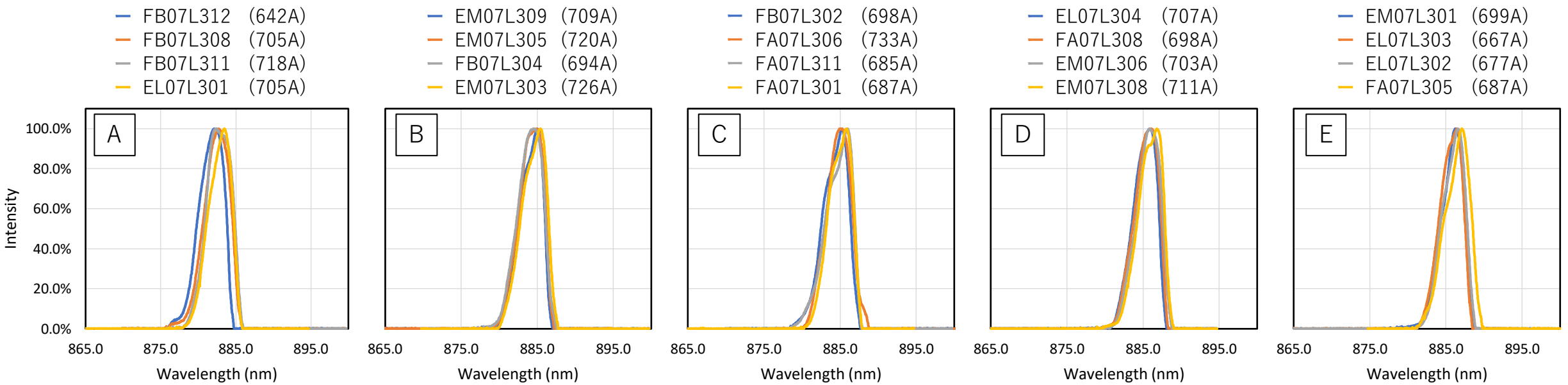
LD combination



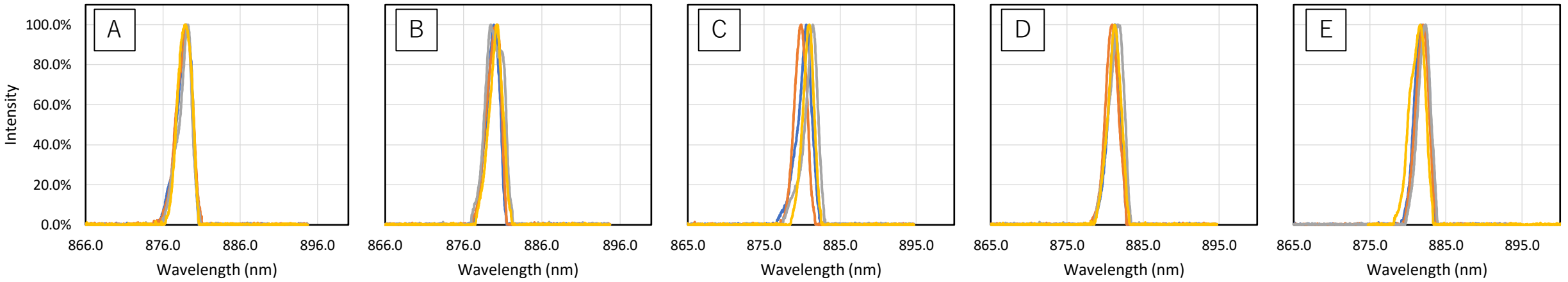
Wavelength distribution

4.5kW operation

※V = 12V, tw = 300 μs , fr = 50 Hz 、 Cooling water : 25°C、 Flow rate : 1.0 L/min



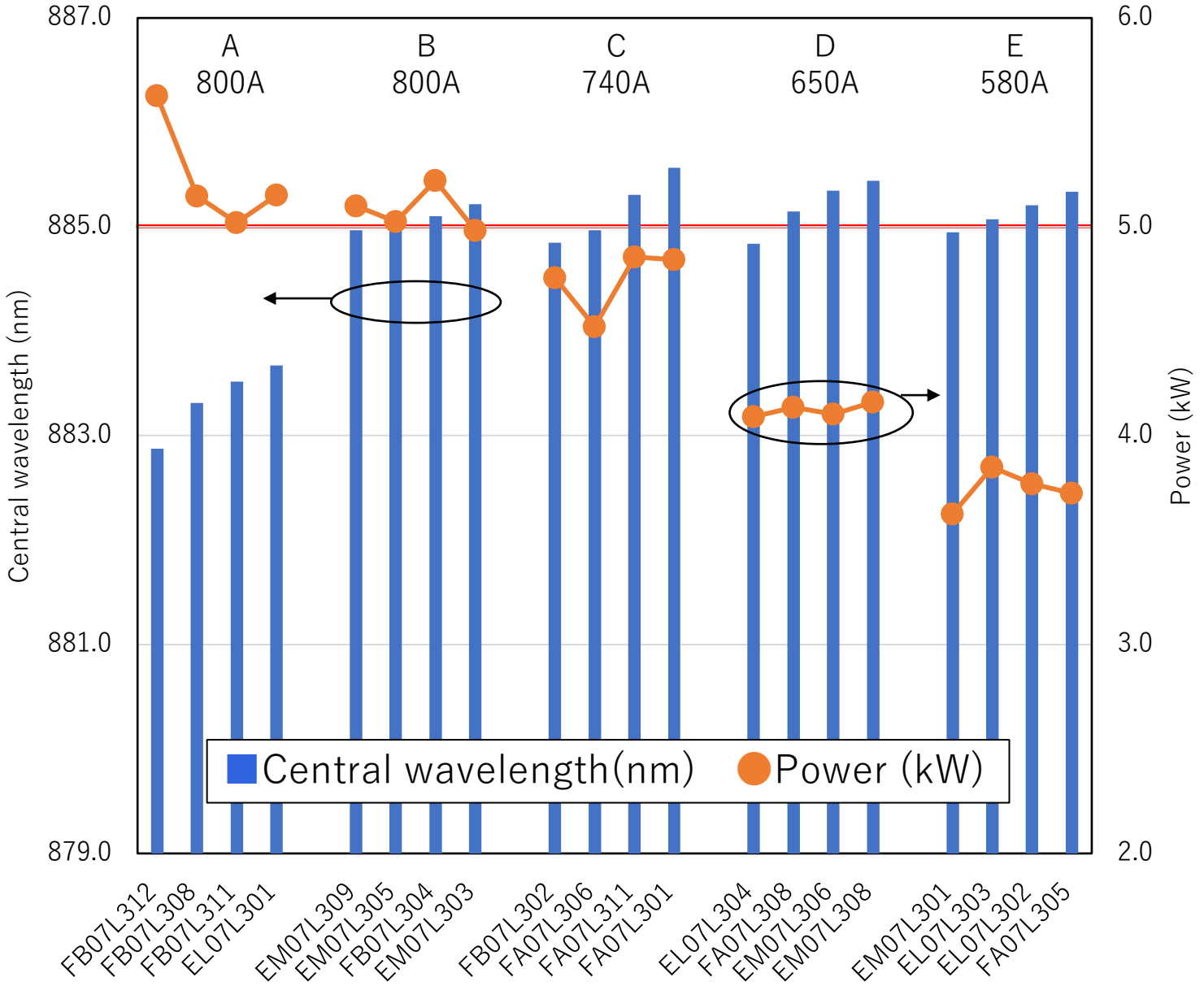
200A operation



Wavelength distributions are same in each group.

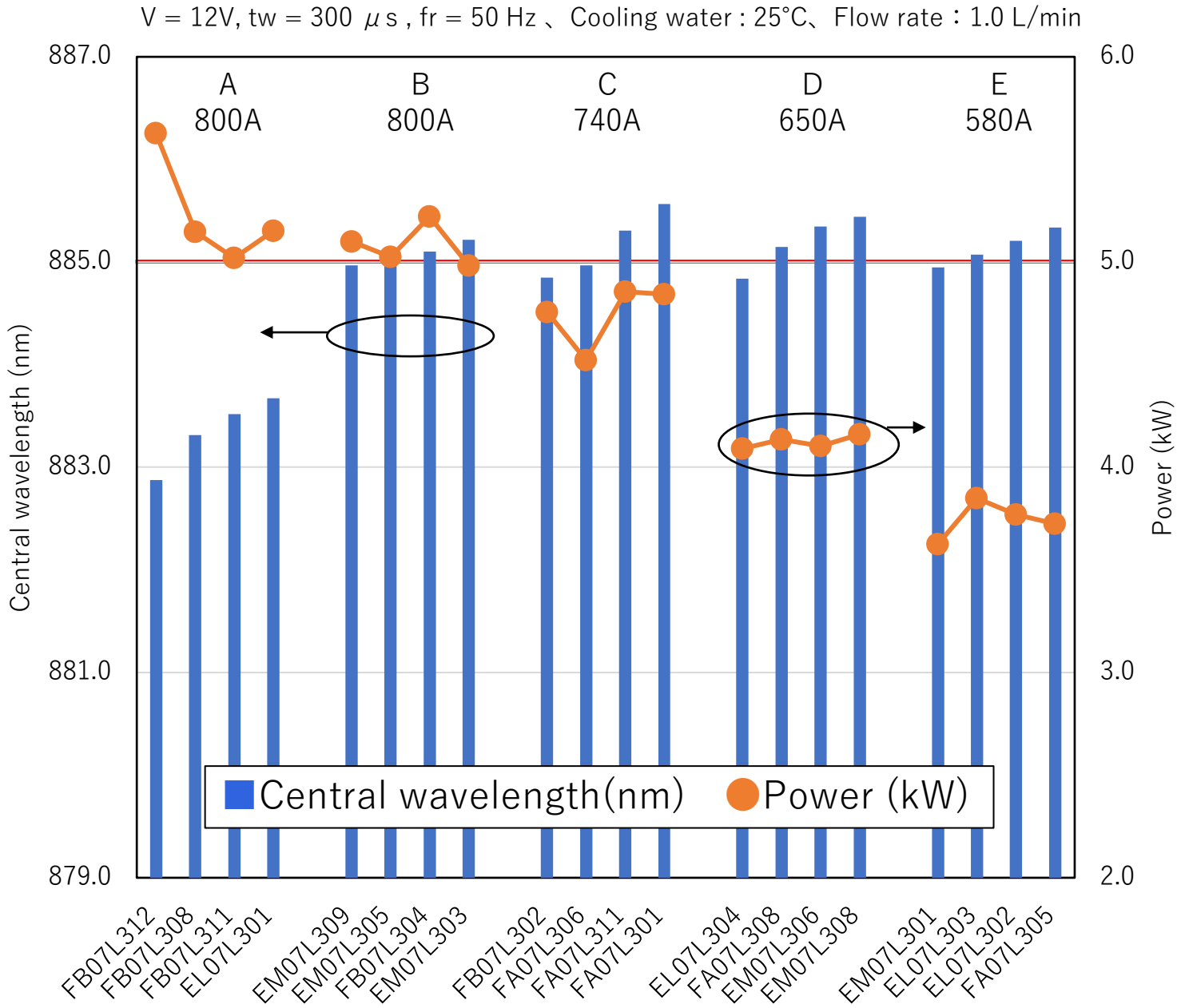
LD power under adjusting to get 885nm laser

V = 12V, tw = 300 μs , fr = 50 Hz 、 Cooling water : 25°C、 Flow rate：1.0 L/min



	SN	Current [A]	λc [nm]	FWHM [nm]	Power [kW]
A	FB07L312	800	882.9	4.8	5.6
	FB07L308	800	883.3	4.4	5.1
	FB07L311	800	883.5	4.5	5.0
	EL07L301	800	883.7	4.1	5.2
B	EM07L309	800	885.0	4.0	5.1
	EM07L305	800	885.0	4.0	5.0
	FB07L304	800	885.1	4.2	5.2
	EM07L303	800	885.2	4.2	5.0
C	FB07L302	740	884.8	4.1	4.8
	FA07L306	740	885.0	3.9	4.5
	FA07L311	740	885.3	4.4	4.9
	FA07L301	740	885.6	4.0	4.8
D	EL07L304	650	884.8	3.5	4.1
	FA07L308	650	885.1	3.6	4.1
	EM07L306	650	885.3	3.6	4.1
	EM07L308	650	885.4	3.6	4.2
E	EM07L301	580	884.9	3.3	3.6
	EL07L303	580	885.1	3.3	3.8
	EL07L302	580	885.2	3.3	3.8
	FA07L305	580	885.3	3.7	3.7

LD power under adjusting to get 885nm laser



Under 50Hz operation

Group A

Change water temperature warmer to make 885nm laser.

Group D and E

Change water temperature cooler and current higher to get more power.

Under 100Hz operation

Group B and C

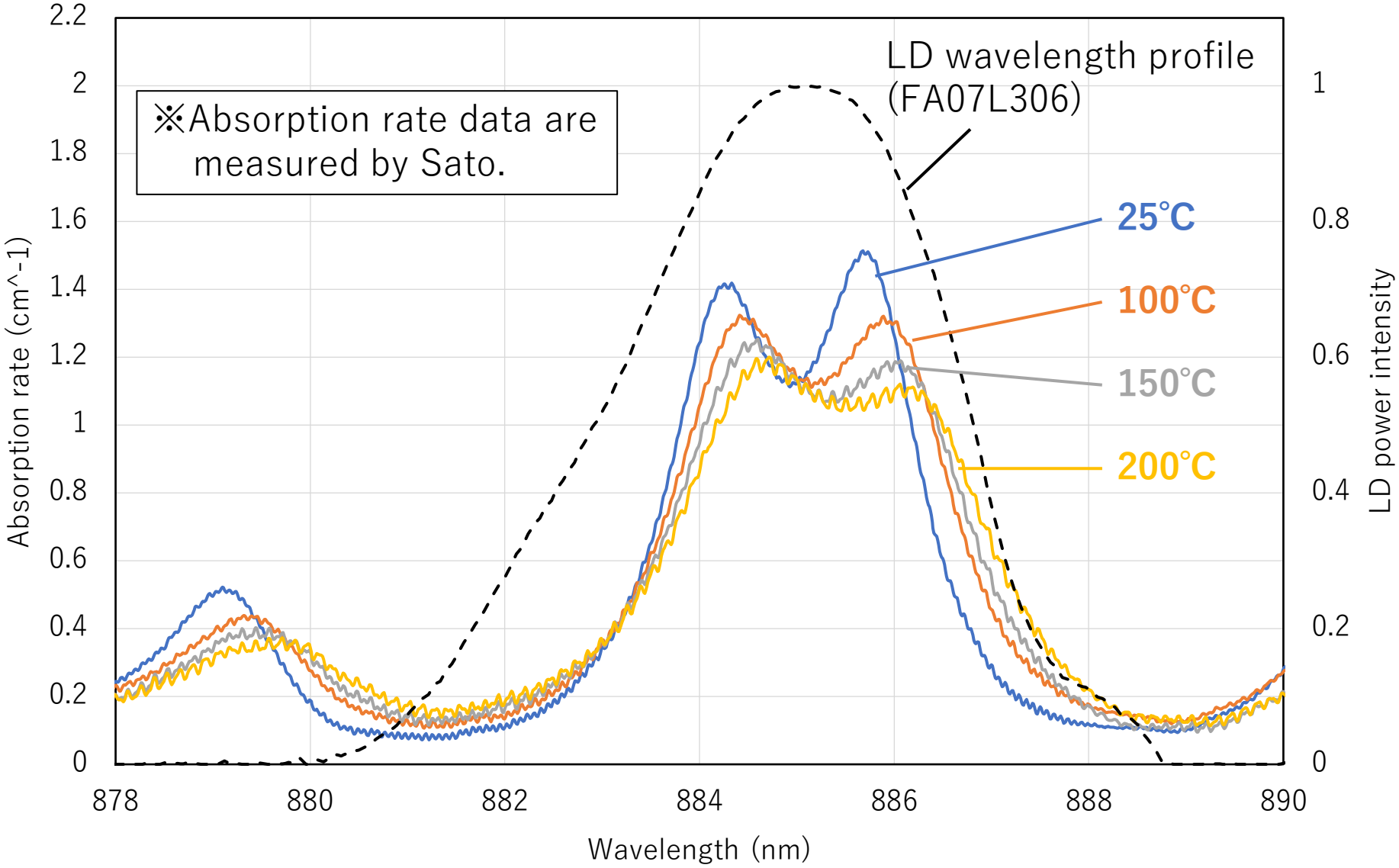
Change water temperature cooler to make 885nm laser.

Group D and E

Change water temperature **much** cooler and current higher to get more power.

Group A … Spare
Group B,C … for Riken (100Hz operate)
(Strong for heat)
Group D E … for Melco (25Hz operate)
(Weak for heat)

LD wavelength and absorption rate profile



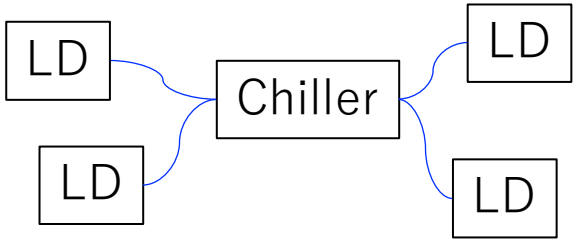
LD wavelength wide is bigger than absorption wide.
Temperature control is so important.

Chiller

2．2．1 基本特性

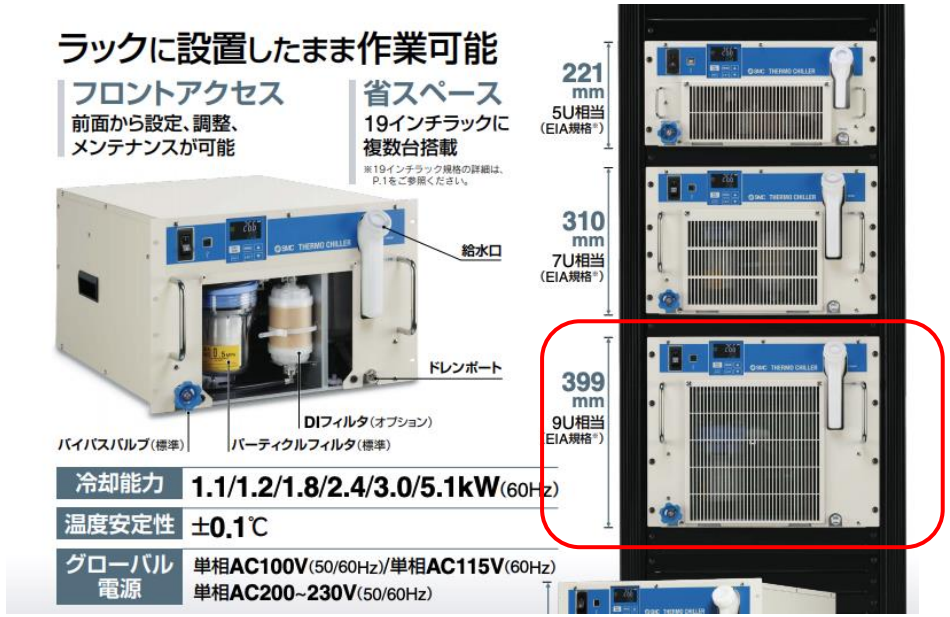
〔規定がない限り t_w = 300 μs，f_r[注1] = 50 Hz，冷却水温度(冷却水 IN 側)：25 ℃、冷却水流量 1.0 L/min〕

項目	記号	条件	最小値	標準値	最大値	単位
動作電流	I_{op}	Φ_{ep} = 4.5 kW	—	725	745	A
中心発振波長	λ_c	Φ_{ep} = 4.5 kW	882	885	888	nm
スペクトル半値幅	$\Delta\lambda$	半値全幅、Φ_{ep} = 4.5 kW	—	4	6	nm
動作電圧	V_{op}	Φ_{ep} = 4.5 kW	—	14	17.5	V
しきい値電流	I_{th}	—	—	65	80	A



Power consumption of each LD

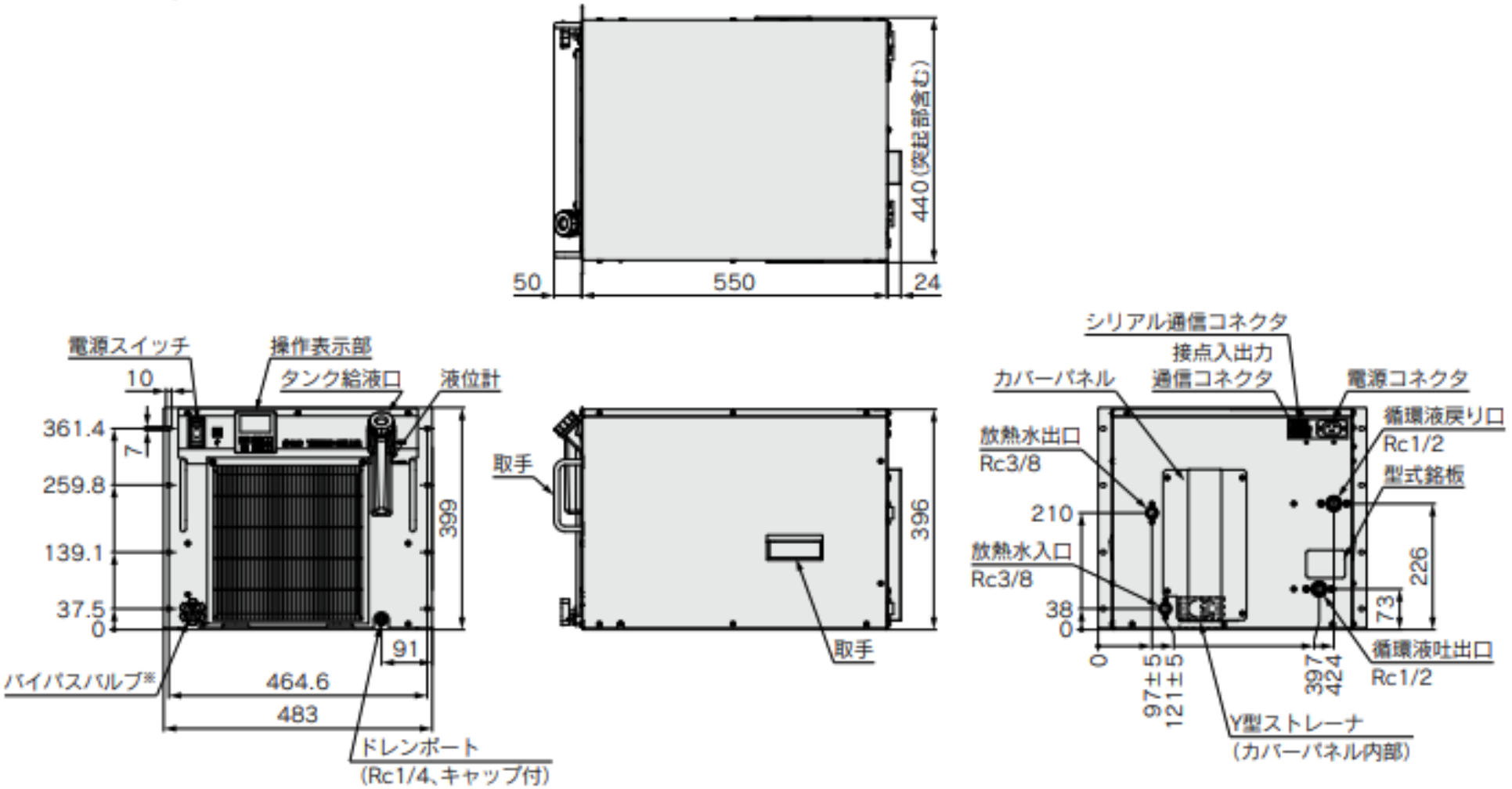
725A x 14V x 50Hz x 300us x 4台=609W
725A x 14V x 100Hz x 300us x 4台=1218W
800A x 17.5V x 100Hz x 300us x 4台=1680W



	HRR024-W-20-TUY
Cooling method	Water
Power(50/60Hz)	2000/2400W
Size	W440xL550xT396
Weight	45kg
Power supply	単相AC200V
Colling medium	清水、エチレングリコール15%水溶液
Other	SUS熱交換機器+銅ブレージング、ポンプケーシ

HRR024-W-20-TUY

HRR024-W, HRR030-W



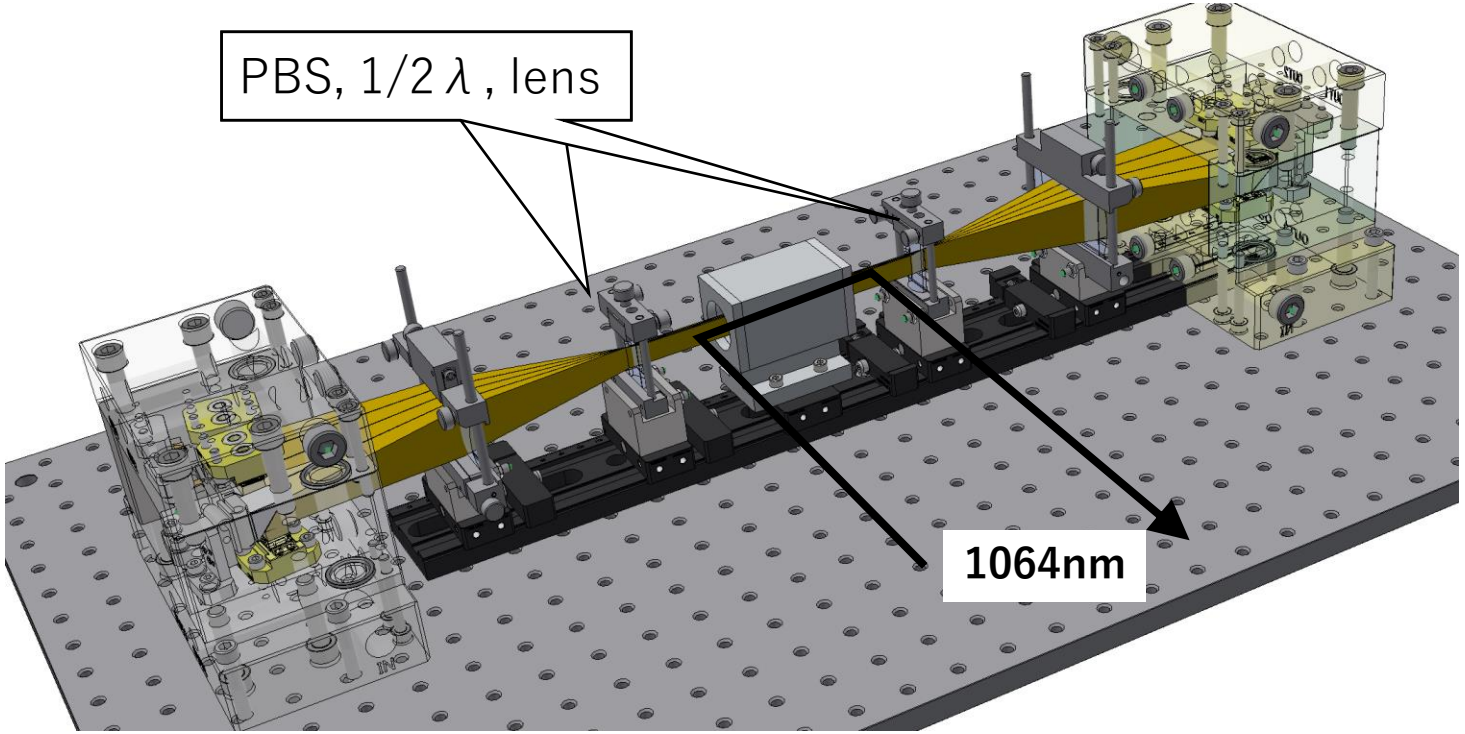
※オプションZの場合、バイパスバルブは除きます。

LD and other equipment allotment

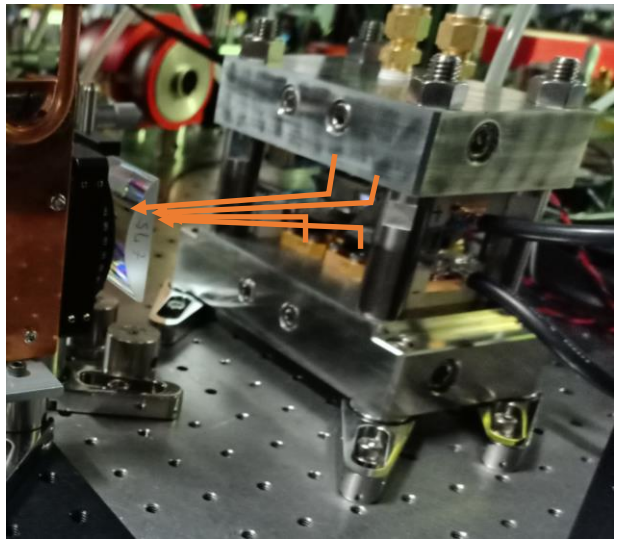
	LD No	Allotment	Purpose
Bought in 2020 21 set	1	stock	
	2~5(Group A)	stock→Melco?	2J amp
	6~13(Group B & C)	Riken	500mJ seed
	14~21(Group D & E)	Melco	500mJ seed
New in 2021 12 set	22~29(Group F & G)	Riken?	2J amp.
	30~37(Group H)	Melco?	2J amp.

	Item	Number	Purpose
Bought in 2020	Power supply	2	500mJ seed
	LD Driver	2	500mJ seed
	Power supply	2	2J amp
	LD Driver	2	2J amp
New in 2021	Chiller	2	500mJ seed.
	Chiller	2	2J amp.

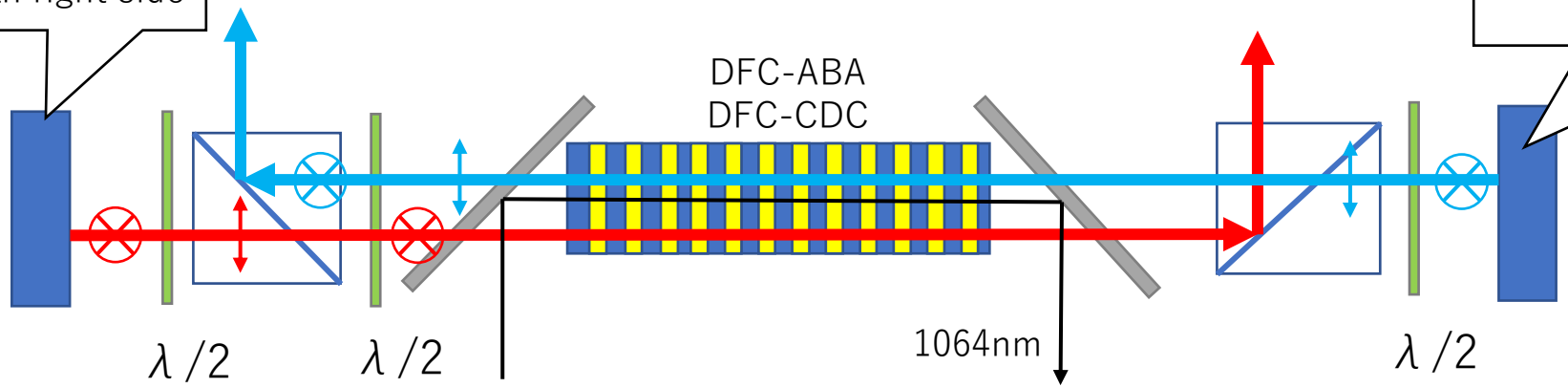
Amplifier design in 500mJ seed laser and 2J amp. system



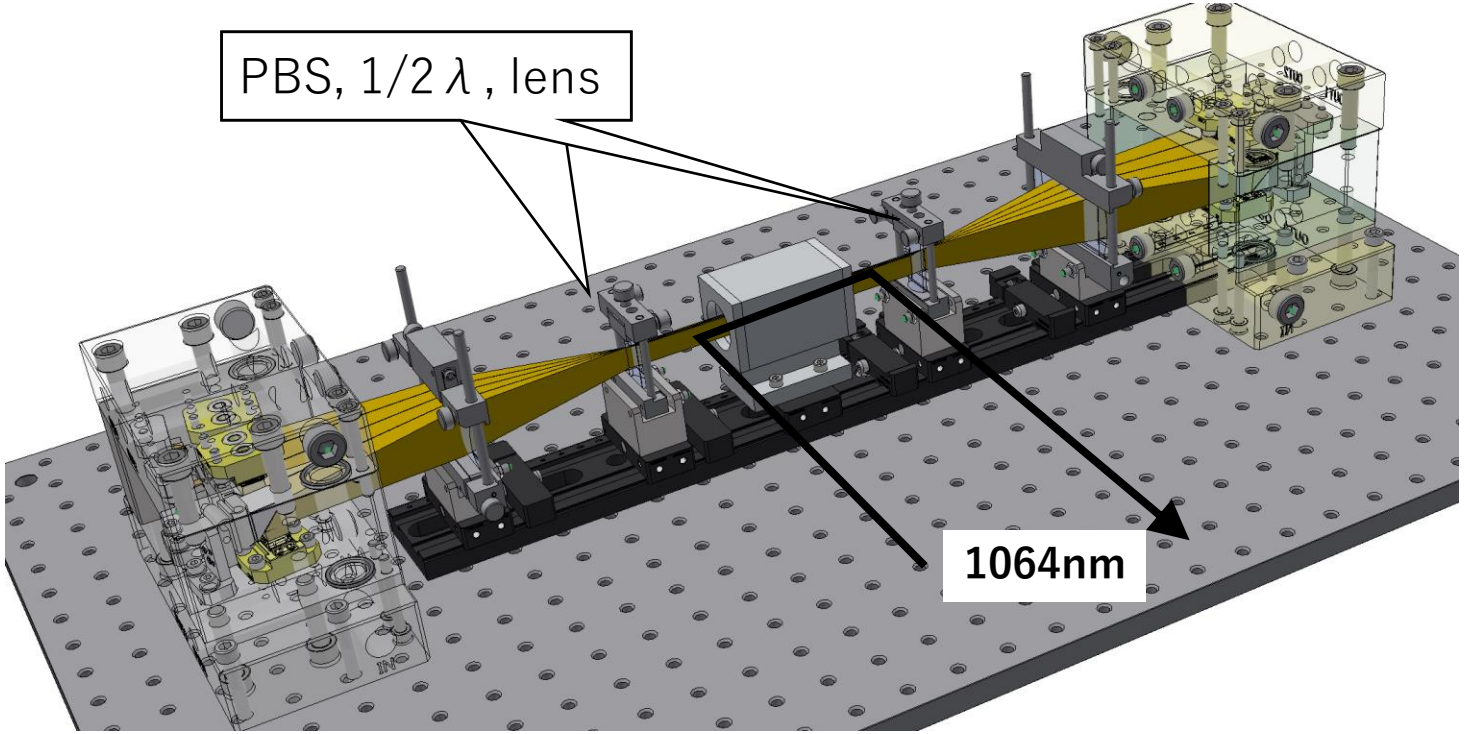
Synthesize the 885nm laser



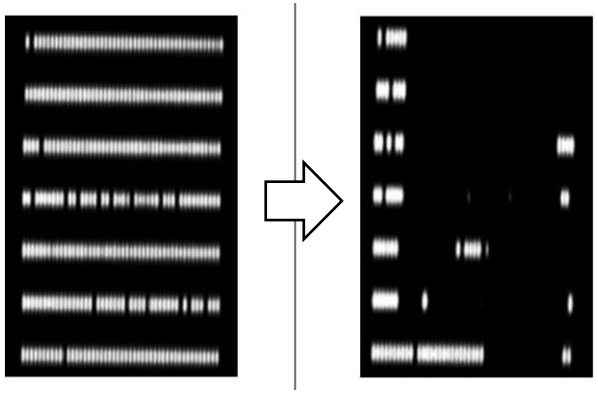
Same with right side



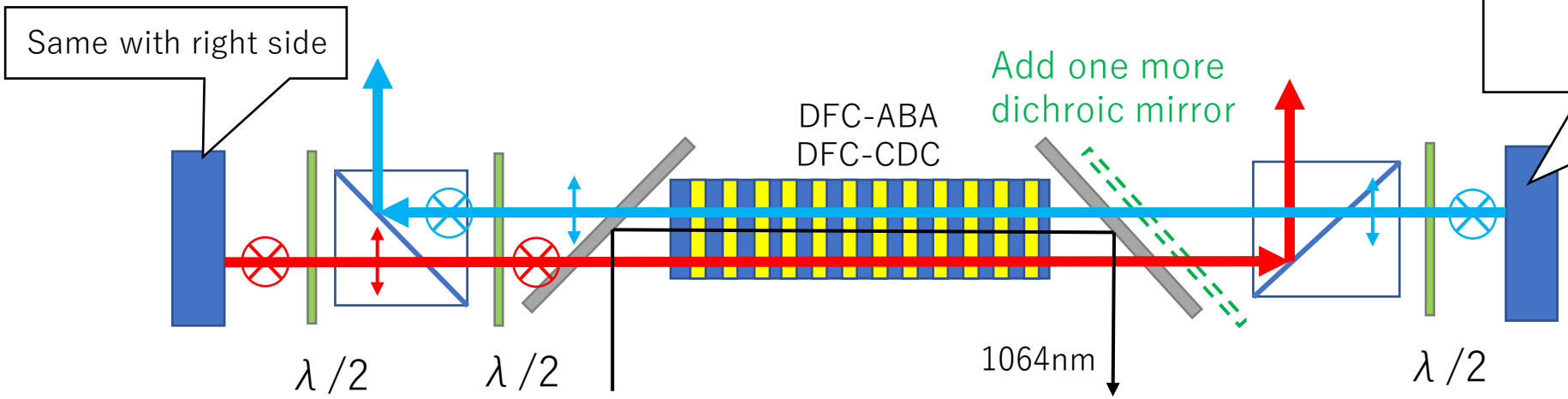
Amplifier design in 500mJ seed laser and 2J amp. system



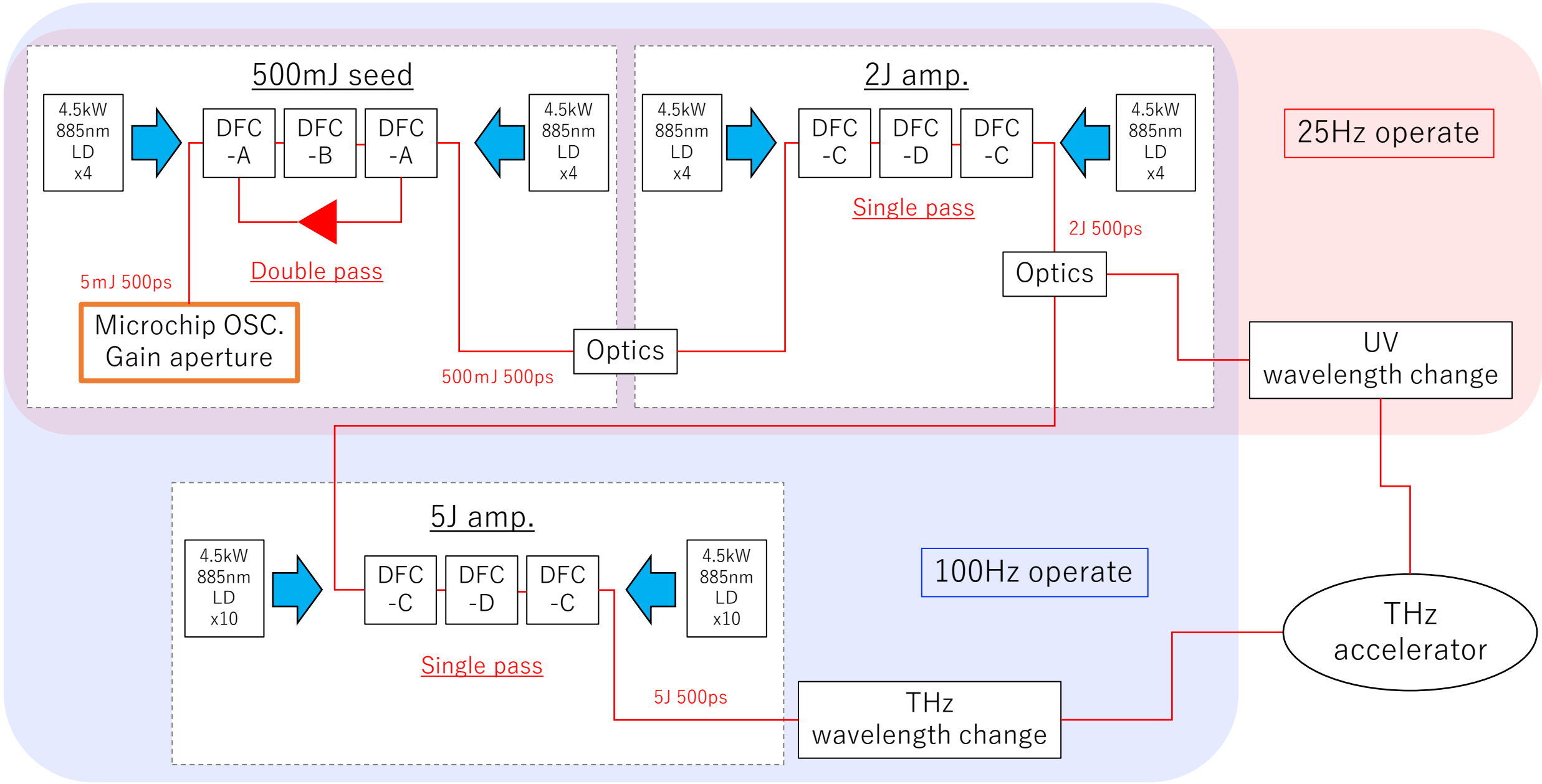
LD in the downstream-side was damaged by 1064nm.



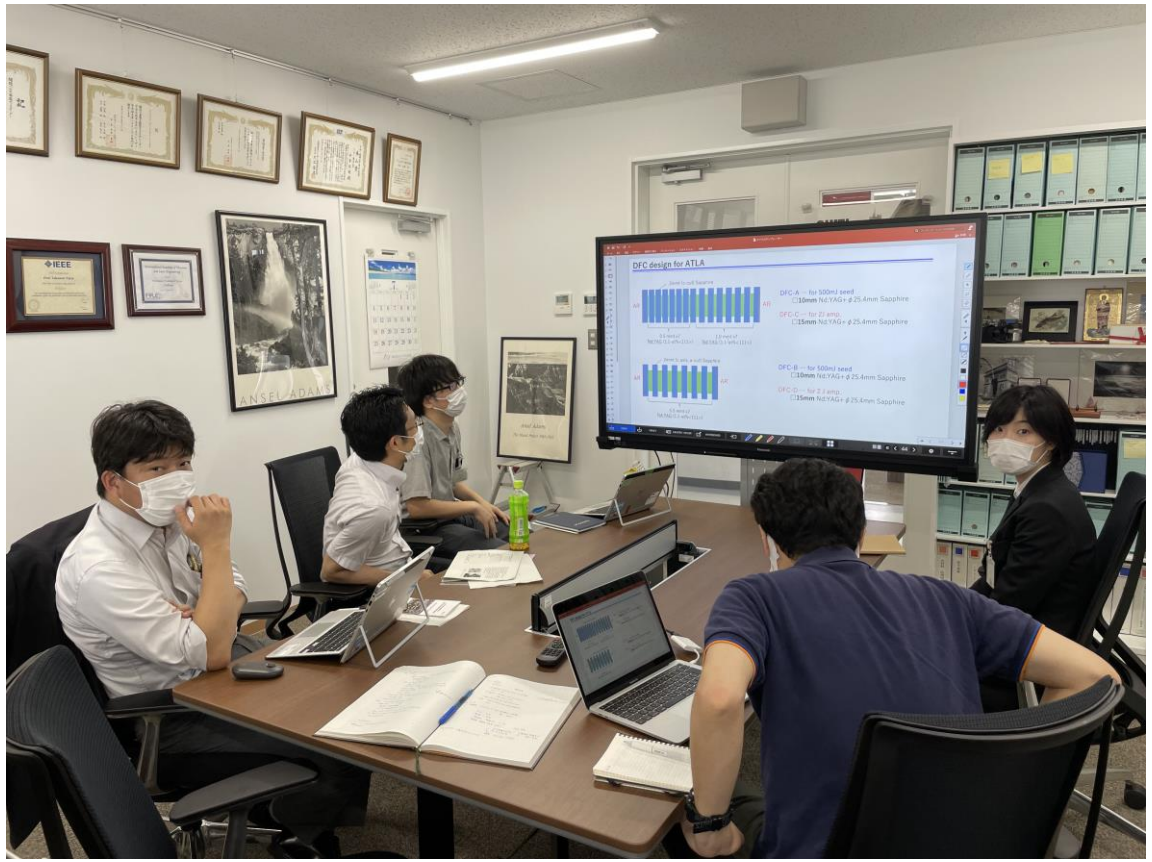
Normal Damaged

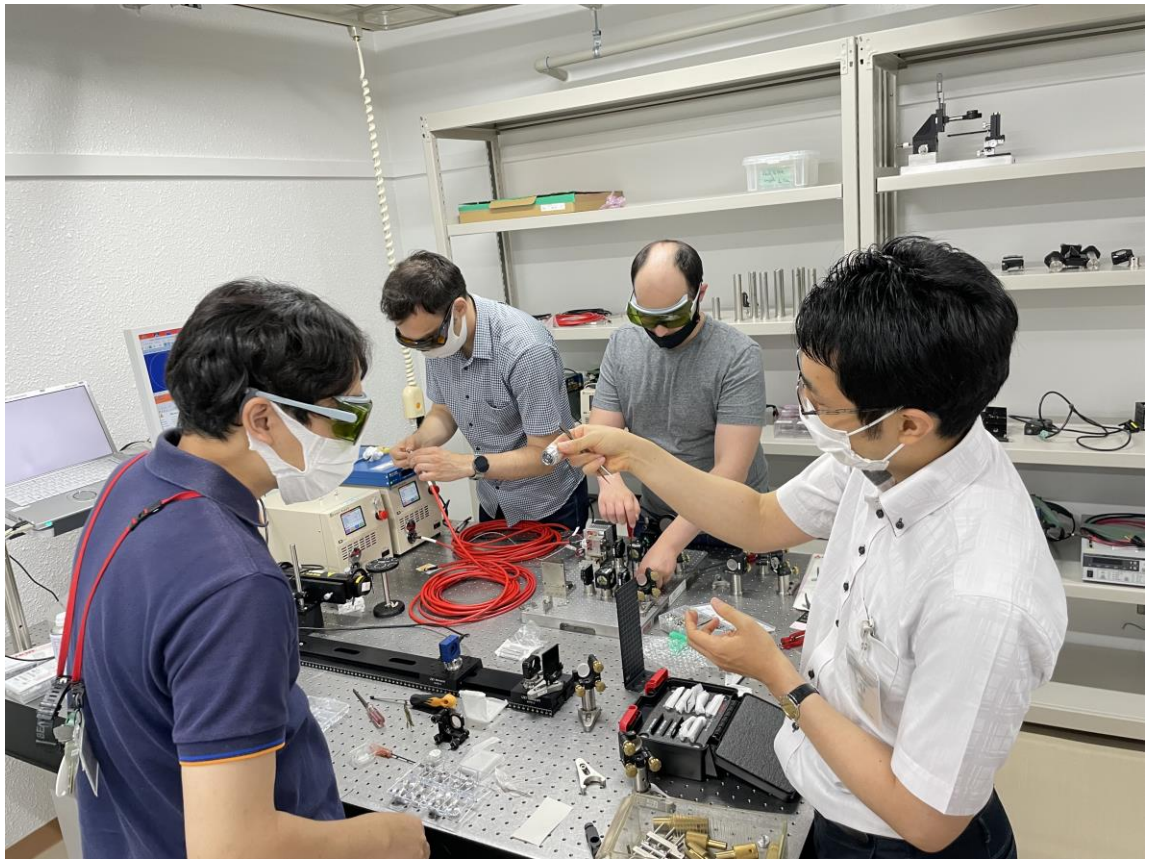


Amplifier in 500mJ seed laser and 2J amp. system



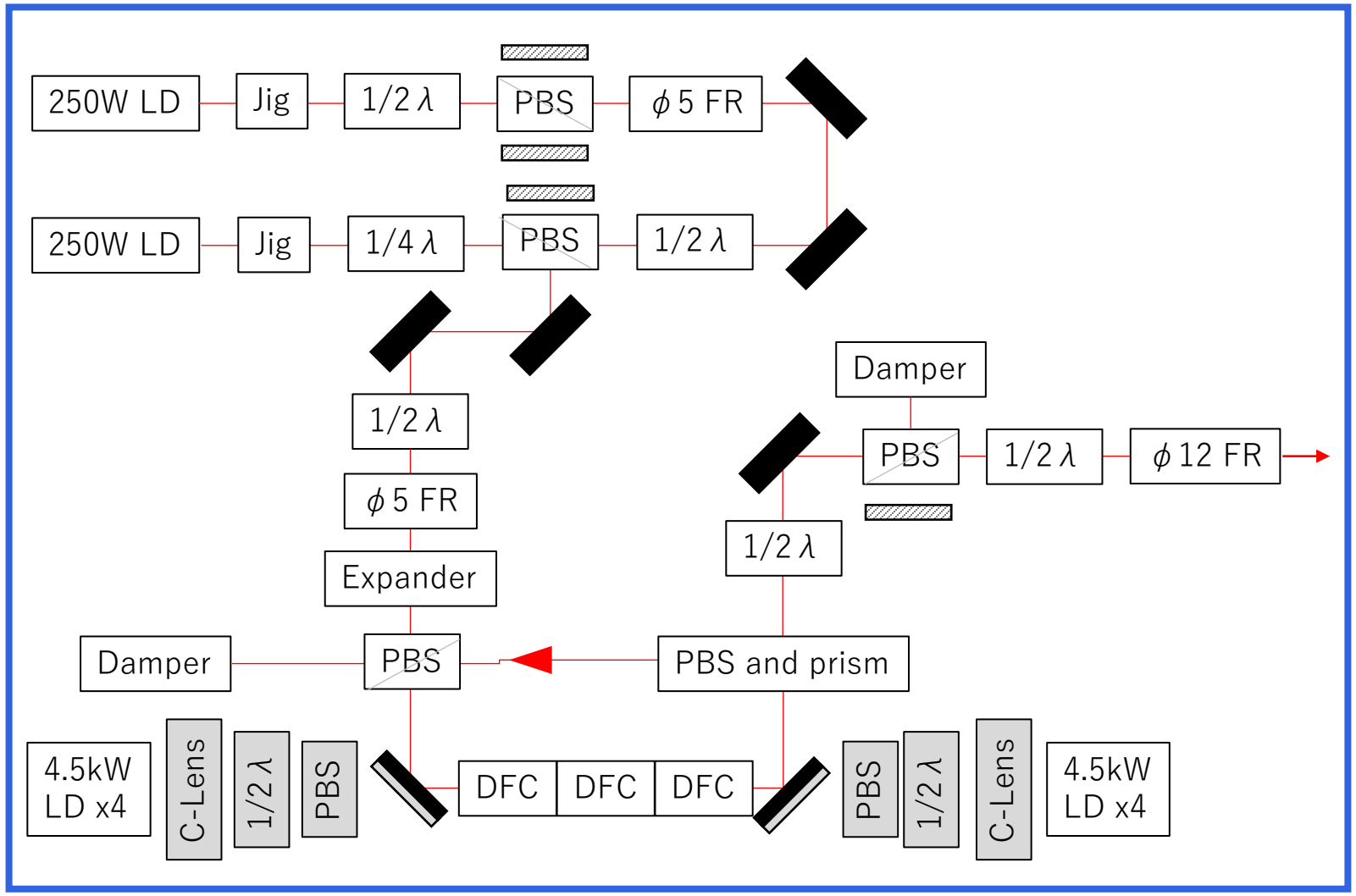
Workshop with Melco　※Regarding UV laser





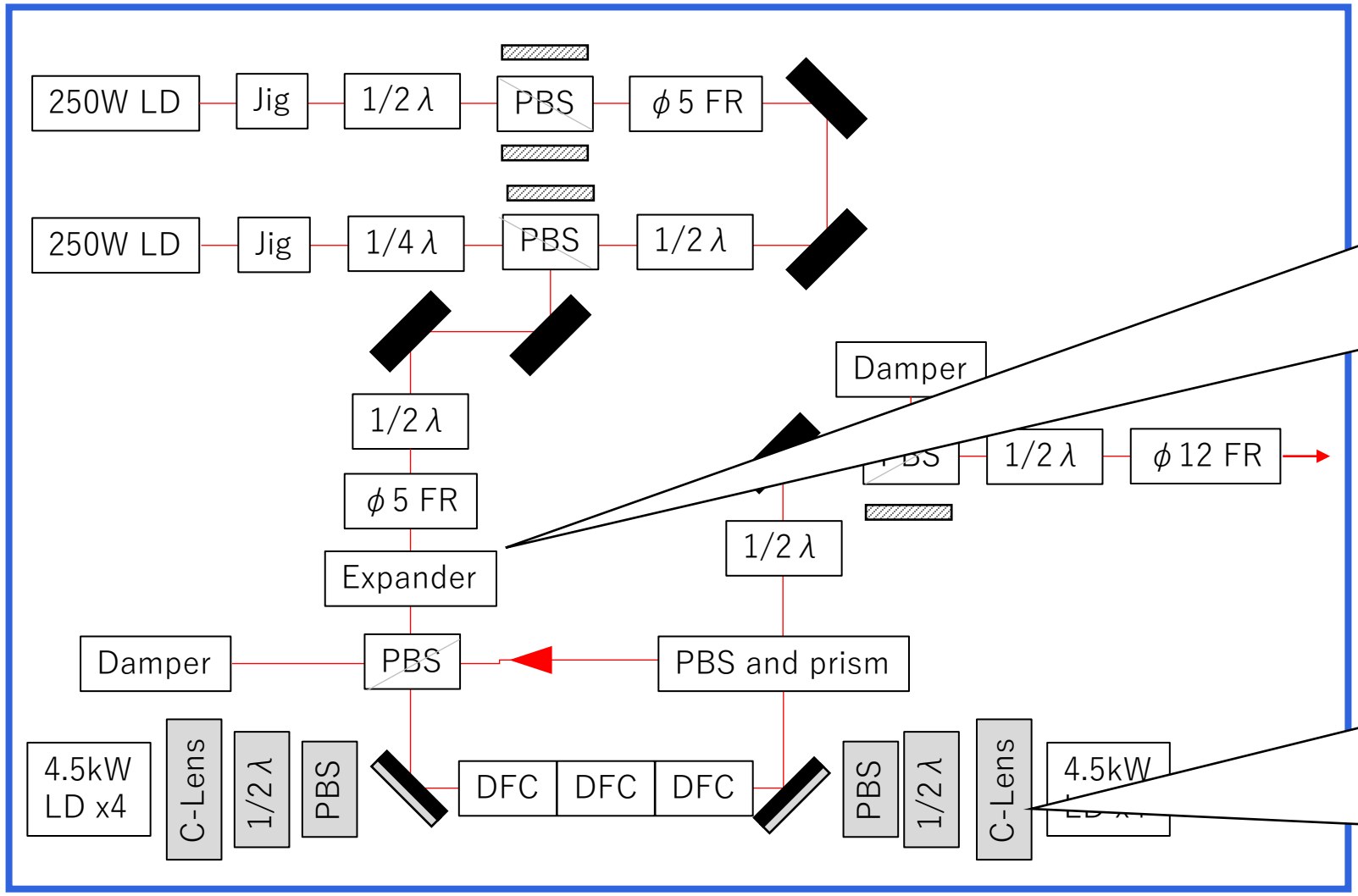
Items for ATLA laser system

450mm x 750mm x 17.5mmt



Expander and Cylindrical lens

450mm x 750mm x 17.5mmt



Thorlabs lens set+gage＋CT1

＋

Spec

＞7.5 J/cm² (10 ns, 10 Hz)

Thorlabs cylindrical lens

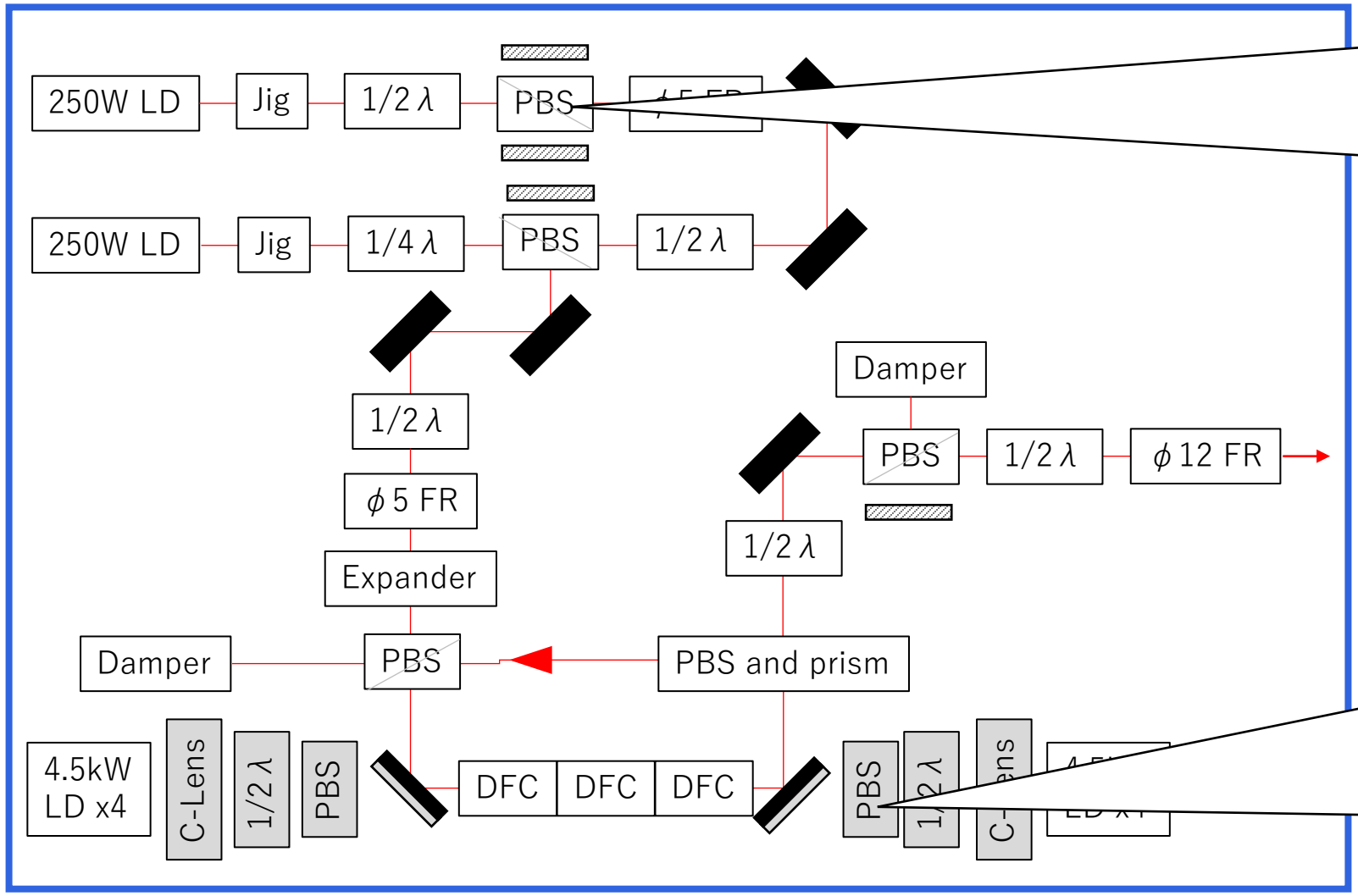
＋

Spec

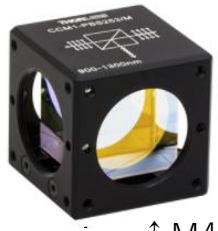
＞7.5 J/cm² (10 ns, 10 Hz)

PBS

450mm x 750mm x 17.5mmt



High power 1 inch PBS with 30mm gage



↑ M4

CCM1-PBS25-1064-HP/M

with gage

Spec

>10 J/cm^2(1064nm, 10ns,10Hz)

Transmission: P>98.8%, S<0.05%

Broadband 1 inch PBS with 30mm gage

PBS253
(900nm~1300nm用)

without gage

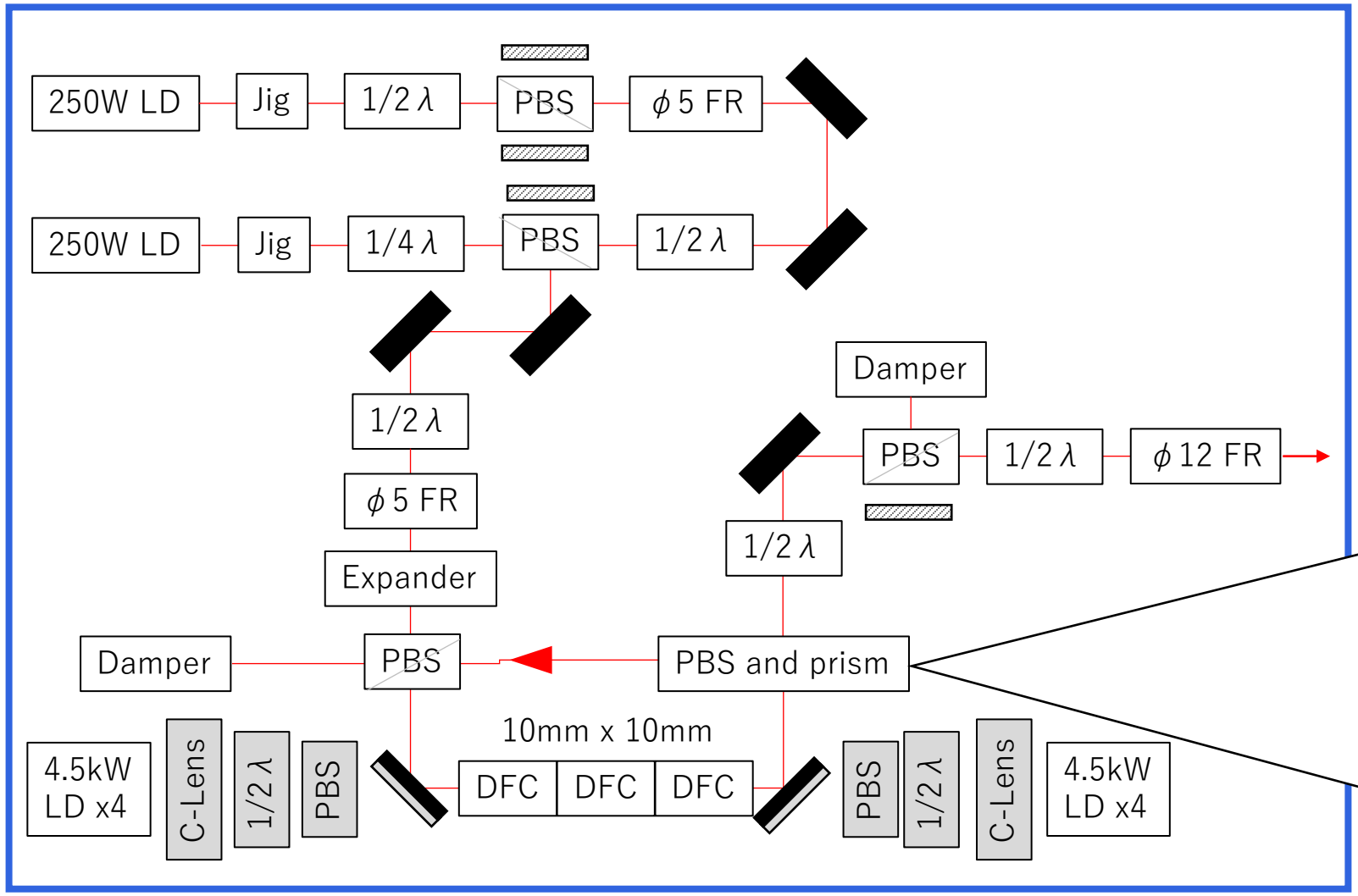
Spec

>2 J/cm^2(1064nm, 10ns,10Hz)

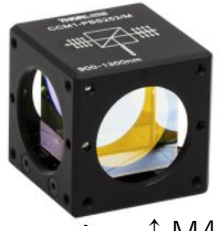
Transmission: P>98.0%, S<0.07%

PBS

450mm x 750mm x 17.5mmt



High power 1 inch PBS with 30mm gage



CCM1-PBS25-1064-HP/M

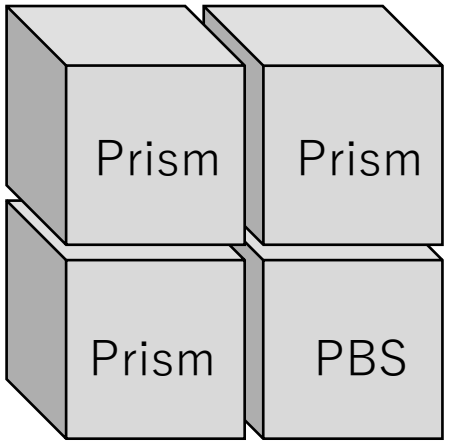
with gage

↑ M4

Spec

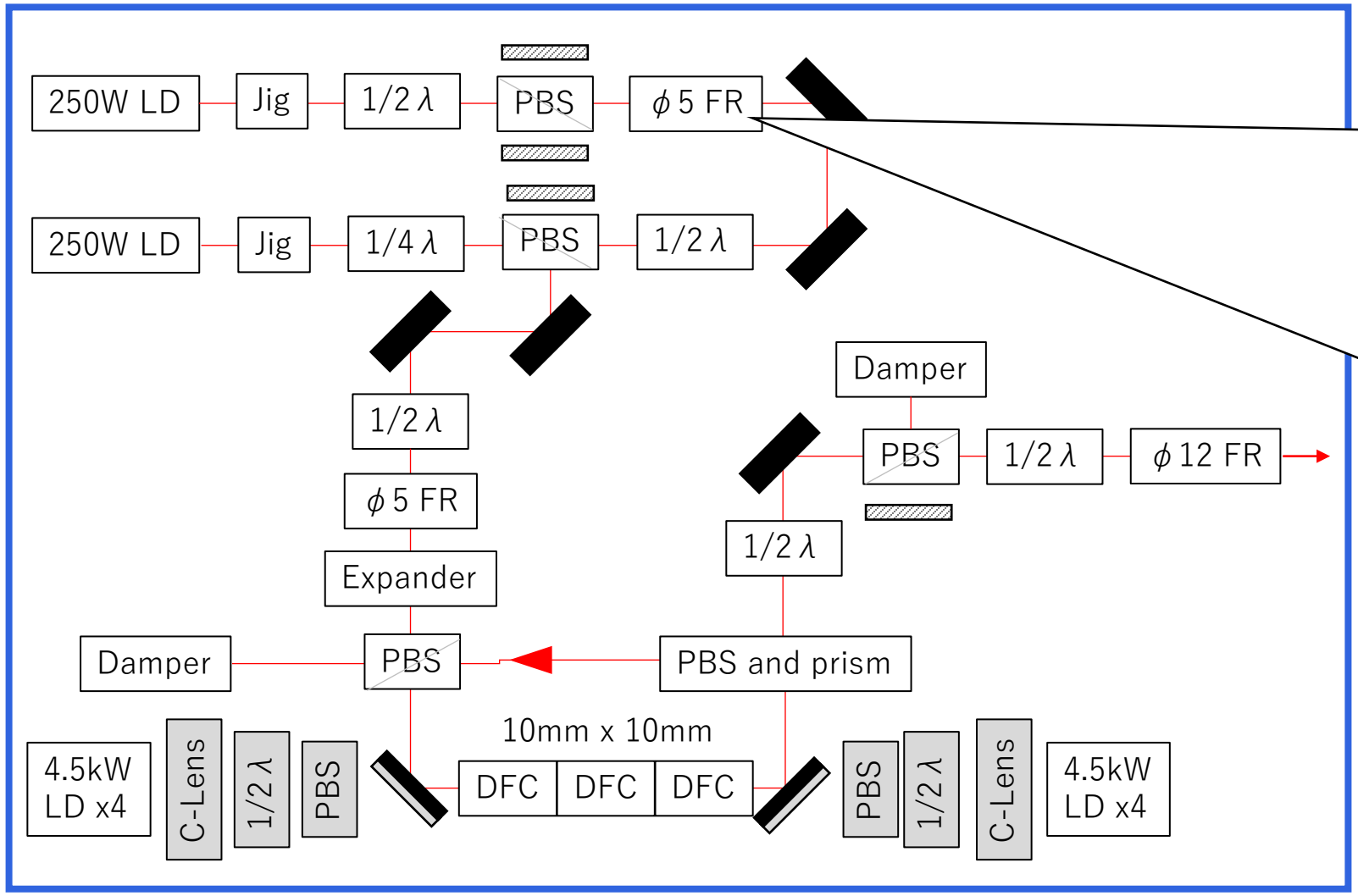
>10 J/cm^2(1064nm, 10ns,10Hz)

Transmission: P>98.8%, S<0.05%



Faraday rotator

450mm x 750mm x 17.5mmt



ϕ 20mm aperture
Faraday rotator (PAVOS)

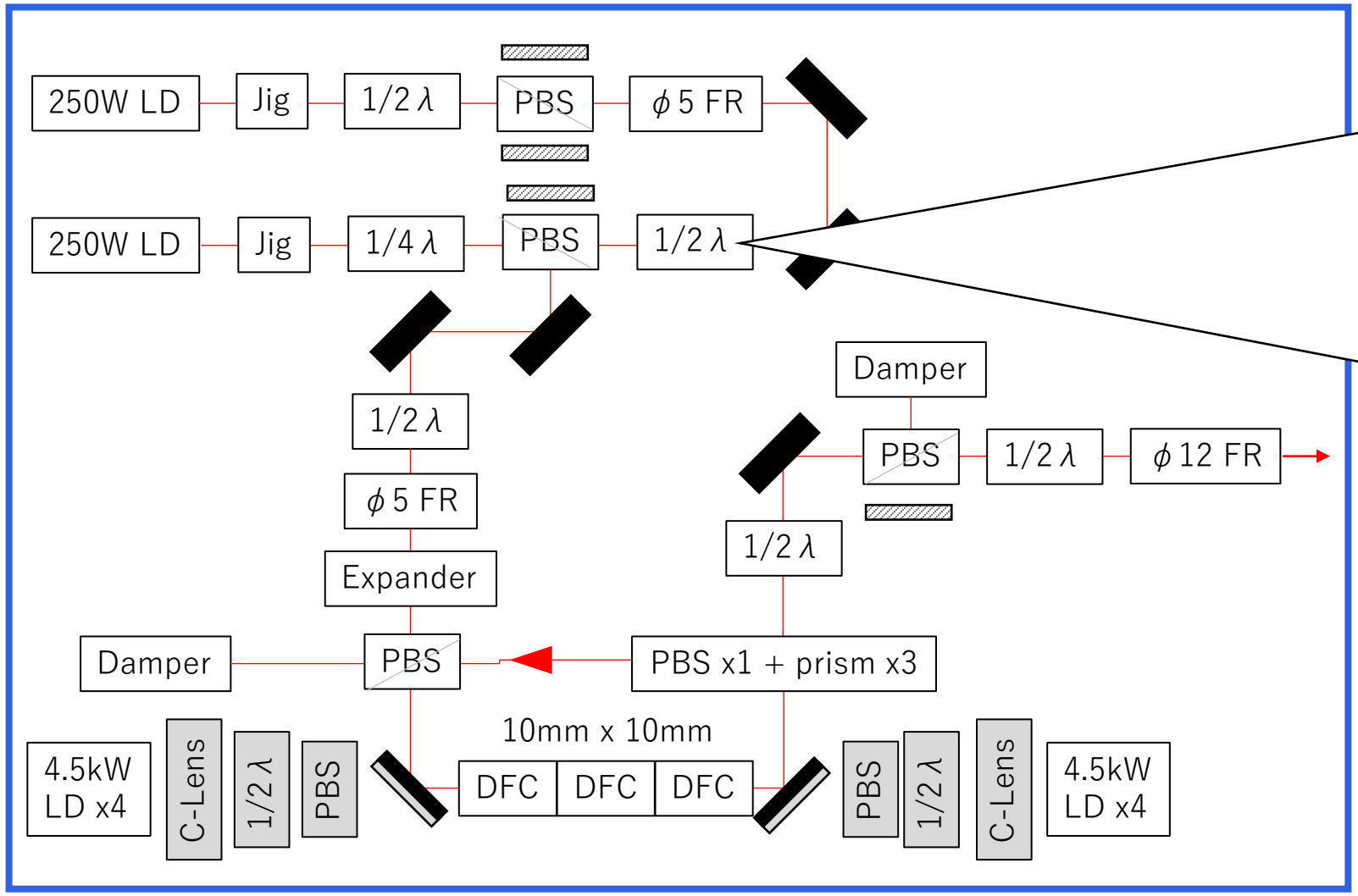
PAVOS Faraday Rotators - 1010 nm to 1080 nm

Spec

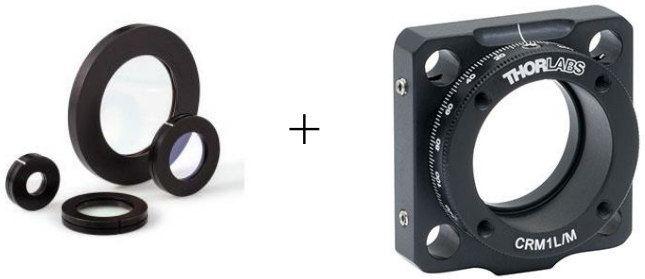
>10 J/cm^2(1064nm?, 10ns)
>1 J/cm^2(1064nm?, 5ps)
Transmission >98%

Wavelength plate

450mm x 750mm x 17.5mmt



1/2 λ and 1/4 λ plate (CVI)



CRM1L/M

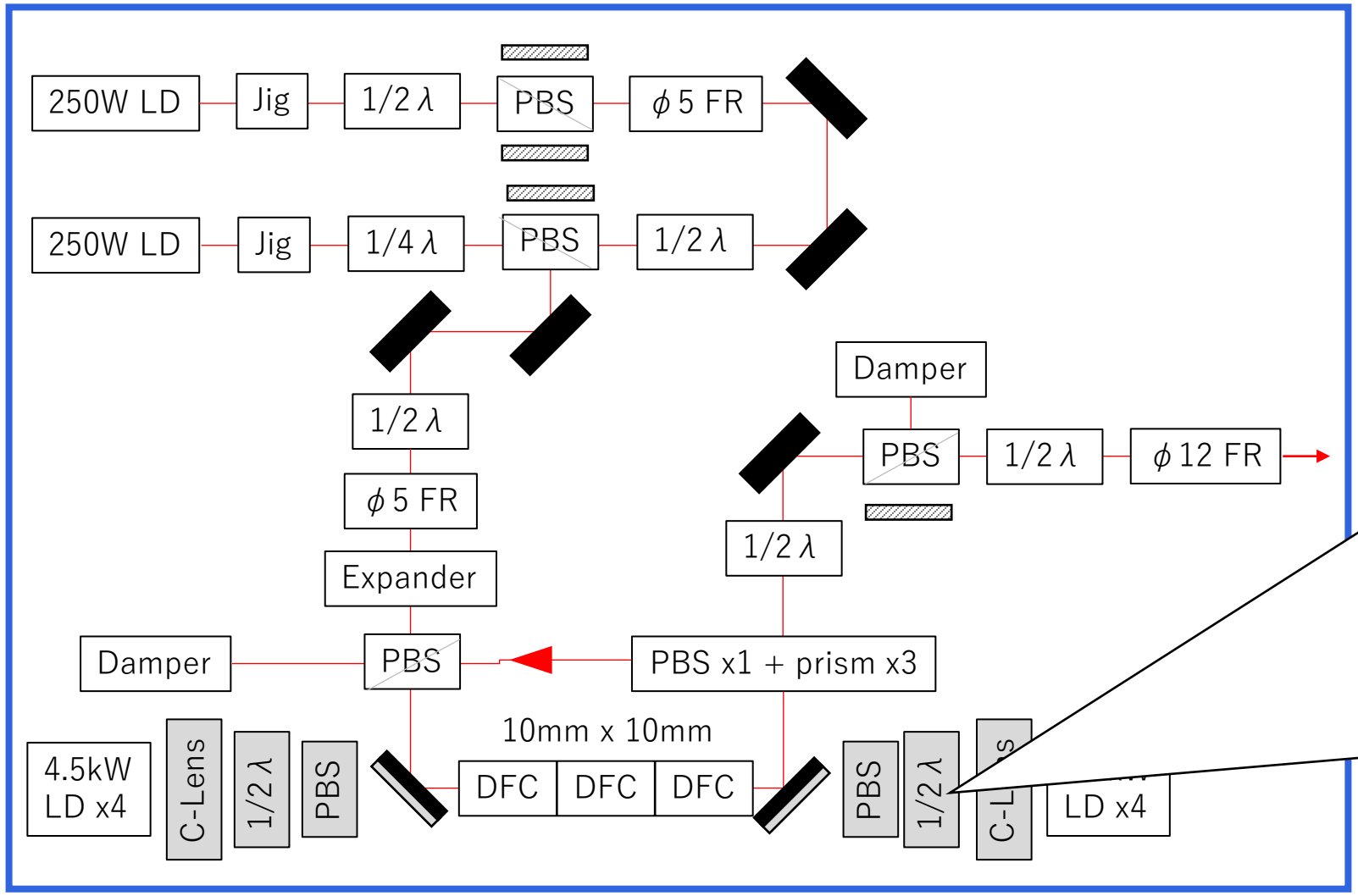
Spec

>17.5 J/cm^2(1064nm, 20ns,20Hz)

Reflect <0.2%

Wavelength plate

450mm x 750mm x 17.5mmt



2inch 1/2 λ (for amplifier LD)

CRM1L/M

Crylight　0 order Ramda plate

Type 1

Full length: 50.8mm

Aperture: 35mm

Type

Full length: 76.2mm

Aperture: 50.8mm

System composition @2J amp

450mm x 750mm x 17.5mmt

500mJ seed

500mJ, ϕ 12mm, M^2 ?

Thorlabs lens and gage OK

Expander

500mJ, ϕ 12mm, M^2 ?

Damper

PBS

1/2 λ

ϕ 20 FR

Expander

1/2 λ

1/2 λ

2J, ϕ 12mm, M^2 ?

10mm x 10mm
or
15mm x 15mm

4.5kW LD x4

C-Lens

1/2 λ

PBS

DFC

DFC

DFC

PBS

1/2 λ

C-Lens

4.5kW LD x4

ϕ 20mm apertureFaraday rotator (PAVOS)

Spec

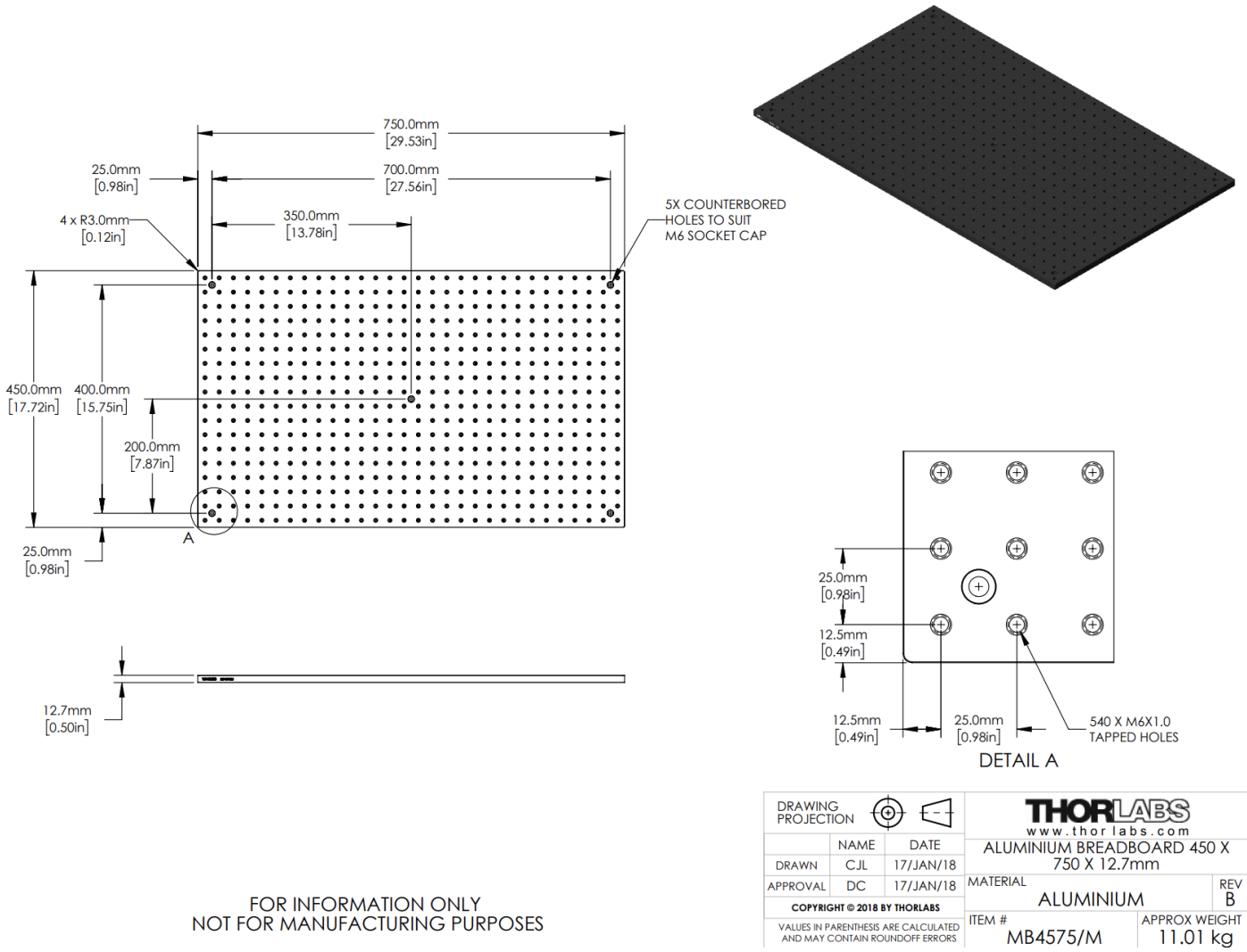
>10 J/cm^2(1064nm?, 10ns)

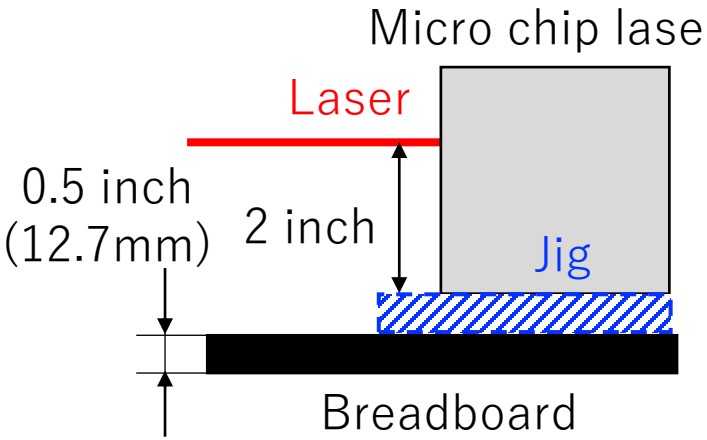
>1 J/cm^2(1064nm?, 5ps)

Transmission >98%

Breadboard and new jig(spacer) for micro chip laser

Breadboard for ATLA…(MB4575/M @ thorlabs)





New jig
to adjust high
to attach on breadboard
(M4→M6)

Laser high is 3 inch from base(optical bench).

Power meter

L100(500)A-PF-120

- 吸収体：PF型
- 有効口径：Ø120mm
- 波長帯域：0.15 – 20μm
- パワーレンジ：1W-500W
- エネルギレンジ：6J-6000J
- 寸法：φ200 W x 35 D (mm)
- 最大パルスエネルギ：6000J
- 最大平均パワー密度：2kW/cm²
- 応答時間：7 s
- 最大エネルギ密度(<100ns)1.5J/cm²
- 最大エネルギ密度(2ms)15J/cm²
- 最大平均パワー500W

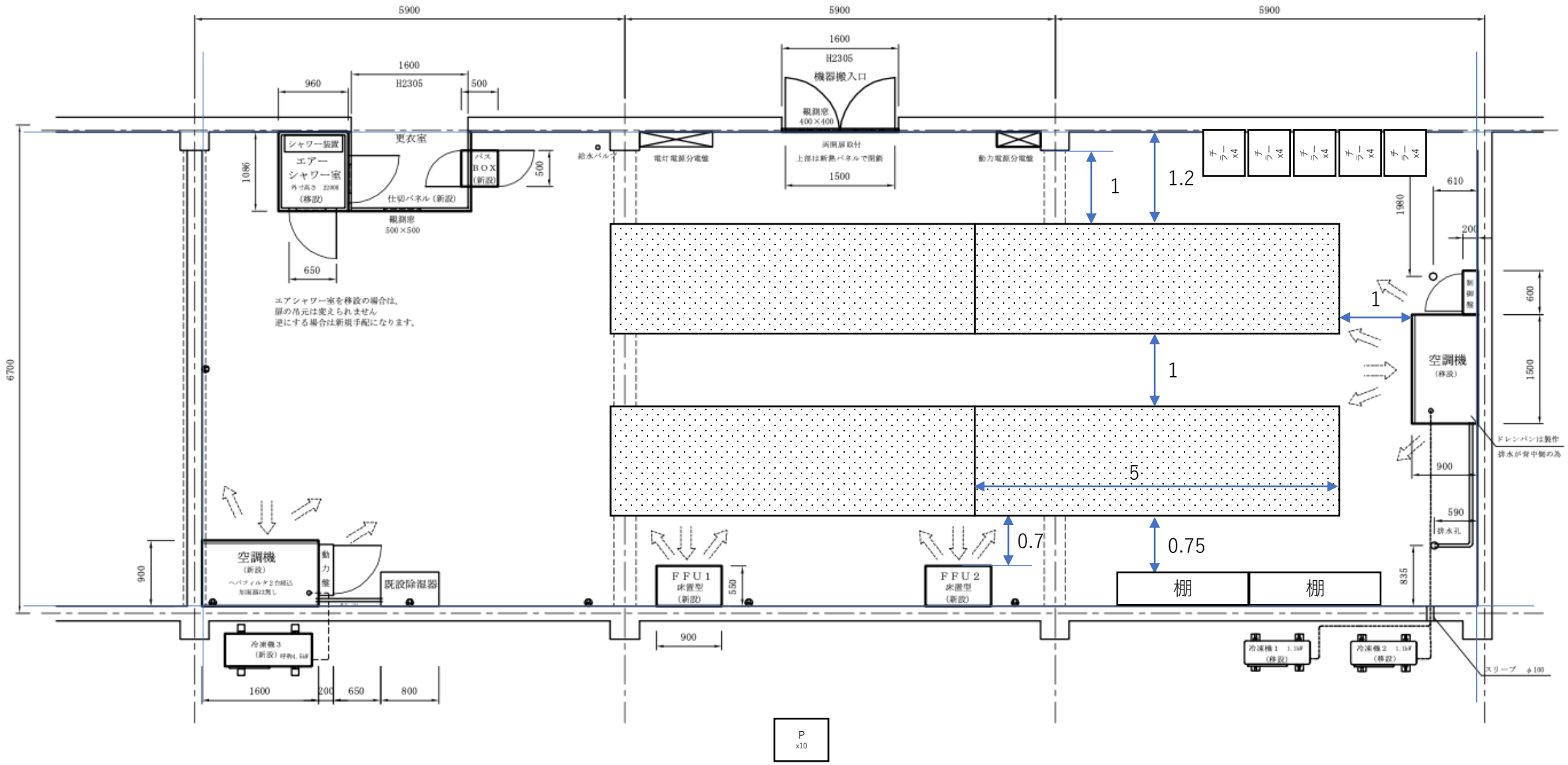
Bought in 2020

F100A-PF-DIF-33

- 吸収体PF型＋ディフューザー
- 有効口径Ø33mm
- 波長帯域0.24 – 2.2μm
- パワーレンジ50mW-100W
- エネルギレンジ60mJ-200J
- 寸法90 L x 90 W x 111 D (mm)
- 最大パルスエネルギ200J
- 最大平均パワー密度0.5kW/cm²
- 応答時間2.5 s
- 最大エネルギ密度(<100ns)4J/cm²
- 最大エネルギ密度(2ms)35J/cm²
- 最大平均パワー100W

Buy in 2021

Layout of new laser system room



Bench：5000mm x 1500mm
Shelf：1800mm 450mm

Purchase plan

Status	Item	Person	Number	Total price	Sum
Used	高温雰囲気焼成炉(high temp furnace)	佐藤	1	12,100,000	
	LDドライバー(LD driver)	Kausas(辻)	1	1,130,800	
	フェムト秒MHzレーザ(fs laser)	杉本(辻)	1	34,980,000	
	引張試験装置(Tensile test machine)	Kausas(辻)	1	9,044,420	
	LD用チラー(Chiller for LD)	辻	4	1,980,000	
	4.5 kW LD	辻	12	21,120,000	
	Optics(Lens, Mirror, Holder)	辻	many	4,932,524	
	Farraday rotator(φ5, 12, 20mm)	辻	6	3,240,820	
	Ramda plate(104nm, 885nm)	辻	17	999,548	
	Optical bench	辻	2	4,840,000	
	Dichroic mirror	辻	20	654,500	
	None dope YAG	杉本(辻)	1	165,000	**95,187,612**
Waiting	溶媒回収装置(Spray dryer)	佐藤	1	14,322,000	
	フォトリソシステム(Photoriso)	石月	1	5,662,074	
	4.5 kW LD	辻	12	21,120,000	
	Nd:YAG(Single crystal for DFC)	Kausas(辻)	50 x 6	5,464,800	
	Sapphire(for DFC)	Kausas(辻)	300 + 20	4,888,400	
	DFC用チラー(Chiller for DFC)	辻	2	915,200	
	チラー用棚など(Items for chiller)	辻		1,588,070	
	薬品、粉末(Chemicals)	佐藤		1,011,353	
	UV crystal(LBO, BBO, KD*P)	辻		3,306,600	
	高速オシロ(33GHz oscilloscope)	辻	1	35,000,000	**93,278,497**
Keeping	低温接合装置(Bonding machine)	Kausas		3,080,000	
	LIDT測定装置(LIDT)		1	11,000,000	
	レーザ描画装置(Writing)		1	11,000,000	
	THz関連①(for 1mJ THz)	竹家		5,000,000	
	THz関連②(for 10mJ THz)	吉田 石月 辻		7,000,000	
	結晶関連(for ceramics)	佐藤		1,000,000	
	装置関連(for mechanics)			5,000,000	
	光学素子追加購入(for optics)			2,000,000	
	Laser for LIDT and Writing			6,561,000	
	杉本Gr(残り)			1,335,000	**52,976,000**
Other	人件費(Labor cost)			23,327,645	
	No plan			**1,453,577**	
			Total	266,223,331	
Original plan	予算(謝金、旅費除く)(Budget)		Total	266,223,331	
	設備費(Equipment cost)			180,234,714	
	消耗品費(Consumables cost)			22,802,216	
	外注費(Order)			5,110,715	
	人件費(Labor cost)			58,075,686	

Item	Person	Price	
真空チェンバー	吉田(辻)	4,890,000	Canceled
電子源	吉田(辻)	908,000	Canceled
THzカメラ	竹家	7,260,000	Transfer to ATLA-Minamide
パルス電源	吉田(辻)	3,632,000	Canceled
充電電源	吉田(辻)	596,700	Canceled
チラー	吉田(辻)	909,000	Canceled
プラズマ洗浄装置	Kausas(辻)	14,091,000	Canceled
スペクトロメータ	Lim	3,510,000	Buy another budged?
低温接合装置周辺機器	Kausas	40,000,000	Transfer ¥40,000,000 to next term.

Item	Total price
Xeフラッシュアナライザー	14,916,000
線膨張計測装置	12,223,200
Total	27,139,200

Item	Total price
辻 & 市井	10,650,000
事務補佐員(佐々木さん)	2,469,145
技術補佐員(チョン・ピョンフさん)	3,208,500
ポスドク	7,000,000
Total	23,327,645

Canceled some items.
Transfer ¥40 million to next term.
Buy Xe flash analyzer instead of oscilloscope?

Status	Item	Person	～7月 ～July	8月 August	9月 September	10月 October	11月 November	12月 December	1月 January	2月 Fabray	3月 Mach
Used	高温雰囲気焼成炉	佐藤								2/28	
	LDドライバー	Kausas(辻)				10/29					
	フェムト秒MHzレーザ	杉本(辻)									3/15
	引張試験装置	Kausas(辻)				10/29					
	LD用チラー	辻		8/31							
	4.5 kW LD	辻							1/14		
	Optics(Lens, Mirror, Holder)	辻	Completed								
	Farraday rotator(φ5, 12, 20mm)	辻			9/30						
	Ramda plate(104nm, 885nm)	辻	Completed								
	Optical bench	辻		8/21, 8/27							
	Dichroic mirror	辻	Completed								
	None dope YAG	杉本(辻)	Completed								
Waiting	溶媒回収装置	佐藤									
	フォトリソシステム	石月									
	4.5 kW LD	辻									3/18
	Nd:YAG	Kausas(辻)								2/18	
	Sapphier	Kausas(辻)							1/14		
	DFC用チラー	辻			9/30						
	チラー周辺機器(棚、マニホールド)	辻									
	薬品、粉末	佐藤									
	UV crystal(LBO, BBO, KD*P)	辻					11/30				
	高速オシロスコープ	辻									3/18
Other	人件費(labor cost)										
	事務員(佐々木さん)				9/1~						
	技術員(チョンさん)					10/1~					