PJ-2F-3

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100Hz 駆動 10PW/sr/cm^2 級マイクロ MOPA

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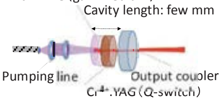
Background

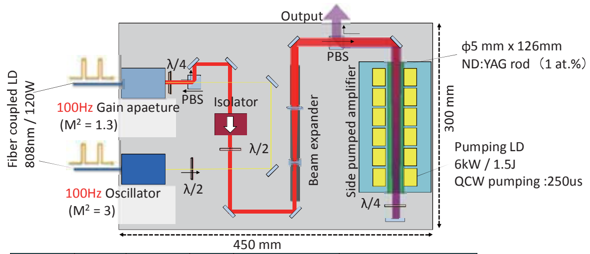
Compact : palm-top - note size -> Portable / Vehicles
Short pulse : sub ns
High peak power : ~ MW
->Ignition, THz generation, particle acceleration, etc.

Higher brightness requirement -> Micro-MOPA



Brightness $B = \frac{P}{A\Omega} = \frac{P}{(\lambda M^2)^2}$ P: power A: mode area Ω: solid angle at far-field

PW/sr/cm^2-class Micro-MOPA

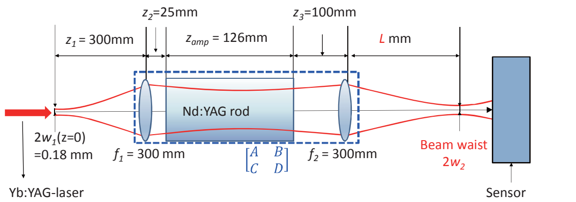


Gain aperture	Energy	Peak power	M²	Brightness	Repetition rate	
					Oscillator Pre-amplifier	Amplifier
No	180 mJ	0.4 GW	>10	418 TW/sr/cm²	100 Hz	100 Hz
Yes	235 mJ	0.34 GW	1.4	18 PW/sr/cm²	100 Hz	10 Hz

Repetition rate limitation
Thermal lens in amplifier can focus high quality beam easily -> **Optics damage**

We evaluated thermal lens effect to avoid the optics damages

Method



$$\begin{bmatrix} A & B \\ C & D \end{bmatrix} = \begin{bmatrix} 1 & 0 \\ -\frac{1}{f_2} & 1 \end{bmatrix} \begin{bmatrix} 1 & z_3 \\ 0 & 1 \end{bmatrix} \begin{bmatrix} \cos(\gamma z_{amp}) & (n_0\gamma)^{-1}\sin(\gamma z_{amp}) \\ -n_{p0}\gamma\sin(\gamma z_{amp}) & \cos(\gamma z_{amp}) \end{bmatrix} \begin{bmatrix} 1 & z_2 \\ 0 & 1 \end{bmatrix} \begin{bmatrix} 1 & 0 \\ -\frac{1}{f_1} & 1 \end{bmatrix}$$

Focal length of thermal Lens f_{th}

$$f_{th} = \frac{1}{n_{p0}\gamma(n_{p2})} \cot(z_{amp}\gamma(n_{p2}))$$

$$\gamma(n_{p2}) \equiv \sqrt{\frac{n_{p2}}{n_{p0}}}$$

n_{p0}: Refractive index at the center of Nd:YAG-rod
n_{p2}: Refractive index divergence of Nd:YAG-rod for radial direction

->f_{th} can be estimated from the beam waist position L

Thermal lens estimation result

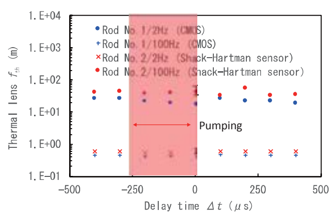
Parameters

Probe beam
Medium : Yb:YAG laser
Wave length : 1030 nm
Effective pulse length 2μs

Nd:YAG rod
Pumping duration : 250 us
Pumping energy : 1.5 J
Pumping rate : variable

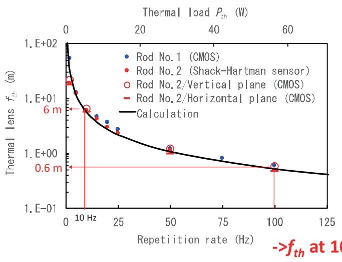
Sensors
CMOS camera
(CMOS-1202, CINOGY)
Shack-Hartman sensor
(HASO 4, IMAGE OPTIC)

Delay time dependence caused by QCW pumping fo Nd:YAG rod



-> f_{th} does not have significant time dependence

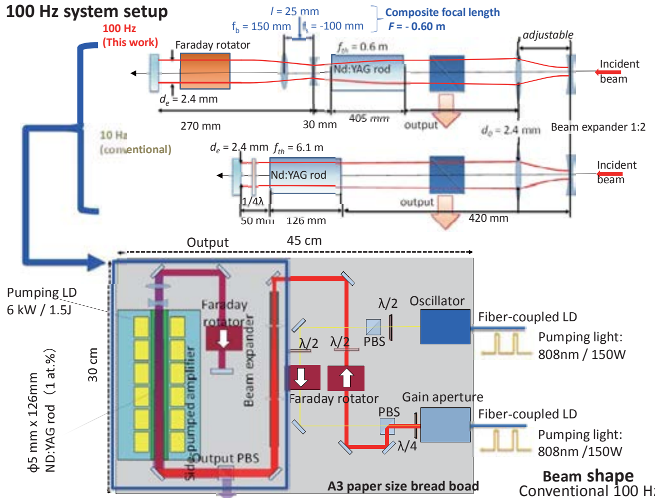
Repetition rate dependence



->f_{th} at 100 Hz operation : 0.6 m

Construction of 100 Hz system

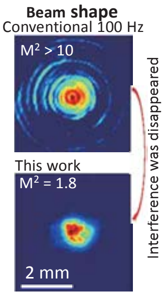
100 Hz system setup



100 Hz operation Result

	Gain aperture	Repetition rate	Energy	Average power	Pulse length	Peak power	M²	Brightness
	No	100 Hz	180 mJ	18 W	430 ps	0.40 GW	>10	0.4 PW/sr/cm²
	Yes	10 Hz	235 mJ	2 W	700 ps	0.34 GW	1.4	18 PW/sr/cm²
This work →	Yes	100 Hz	190 mJ	19 W	470 ps	0.40 GW	1.8	11 PW/sr/cm²

Beam shape



Conclusion
We achieved 100 Hz, 190 mJ and 11 PW/sr/cm^2 operation within A3 size footprint by analyzing thermal lens of the Nd:YAG rod in the amplifier and optimizing optics.