High energy class second harmonics generation from CLBO by 20-J DPSSL

Takashi Sekine, Hiroshi Sakai, Yasuki Takeuchi,
Yuma Hatano, Toshiyuki Kawashima, Hirofumi Kan

Hamamatsu Photonics K. K.

7th International HEC-DPSSL Workshop

September 14, 2012

Lake Tahoe, California

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Outline

- Introduction of Hamamatsu Photonics K. K.
- HALNA program at ILE, Osaka University
- KURE-I green DPSSL by CLBO at Hamamatsu
- Summary

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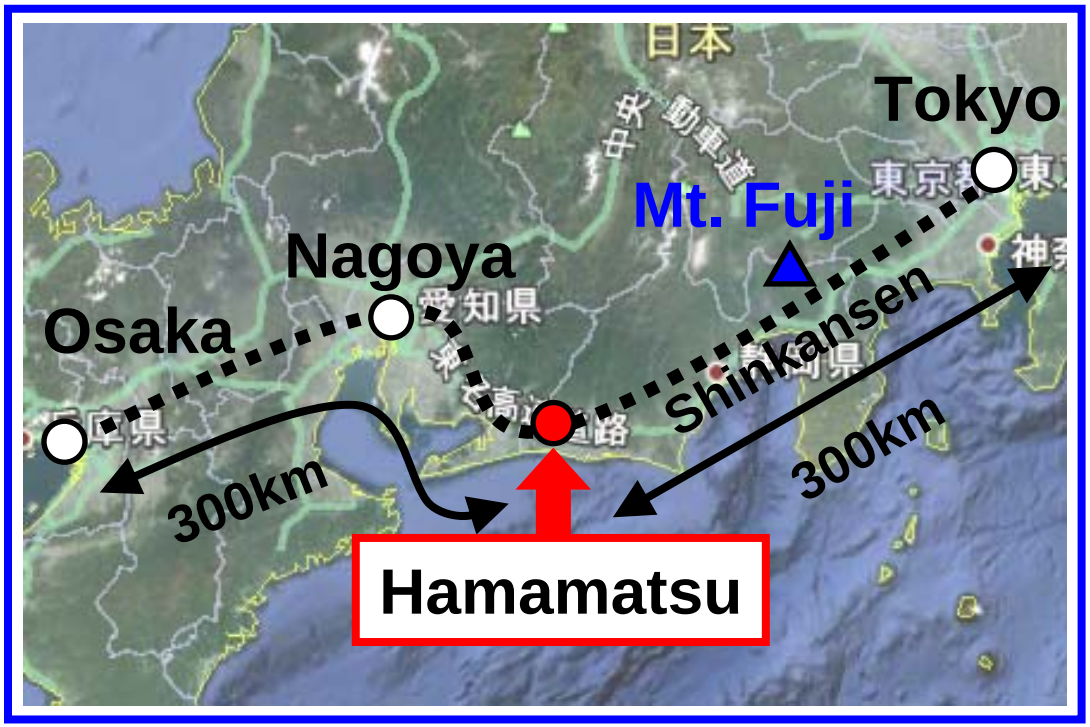
Introduce of Hamamatsu-City



Industries in Hamamatsu

Auto mobile
: SUZUKI, HONDA, Yamaha Motor
Musical instrument
: KAWAI, Roland, YAMAHA
Photonics device
: Hamamatsu Photonics

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Profile of Hamamatsu Photonics group

Established: September, 1953
Capital: 34 billion yen
Sales: 100 billion yen
Employee: 4,100

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Telephone: (1)617-536-6441

Universal Spectrum Corporation
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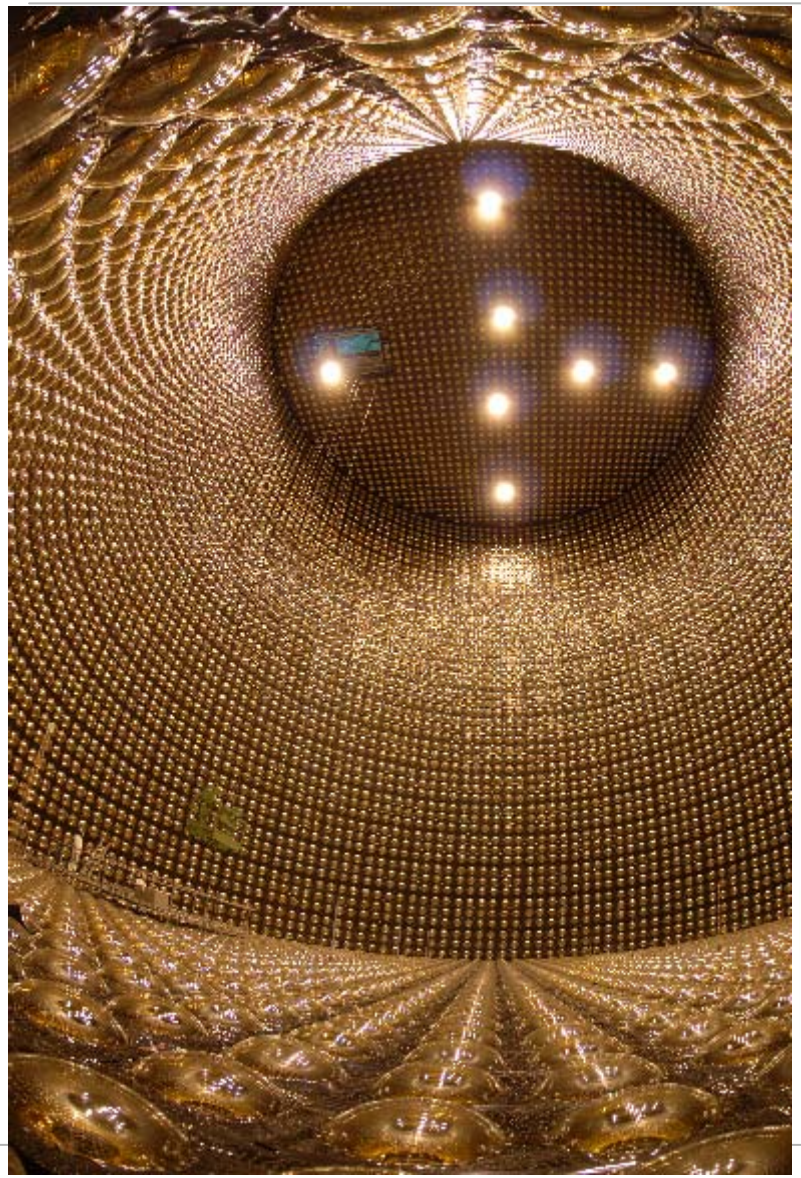
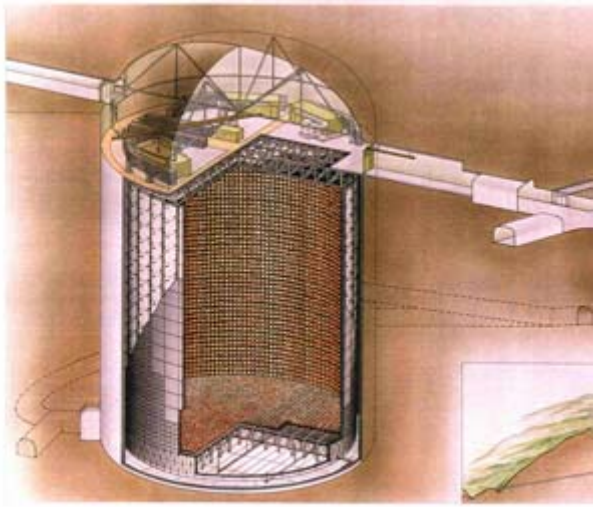
We have played a role in Neutrino Science



The Kamiokande captured the total of 10^{16} neutrinos that passed through the detector. This has led to unexpected discoveries and a new, intensive new field of research, *neutrino-astronomy*.
The Super-Kamiokande, and the consequent KamLAND also equips the improved HAMAMATSU photo-multiplier tubes.



Kamioka Observatory, ICRR（Institute for Cosmic Ray Research）, The University of Tokyo

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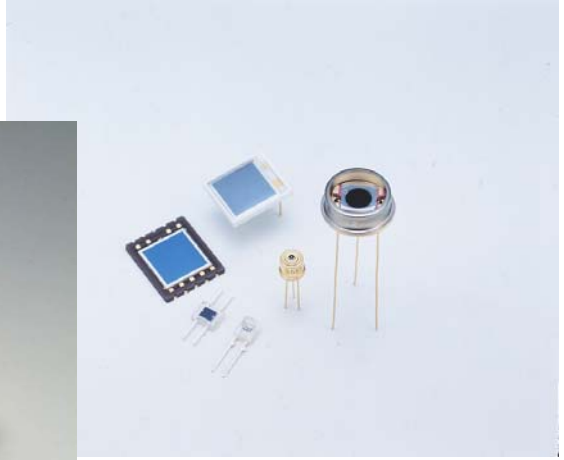
Products of Hamamatsu Photonics

Photo-multipliers

Semiconductor lasers

Photo-sensors



Optical measurement

Medical diagnostics

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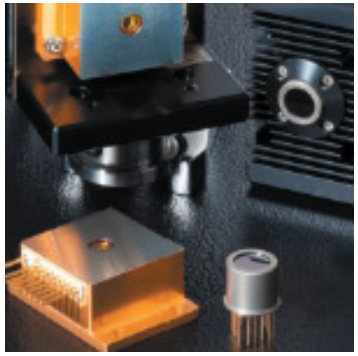
Laser system products

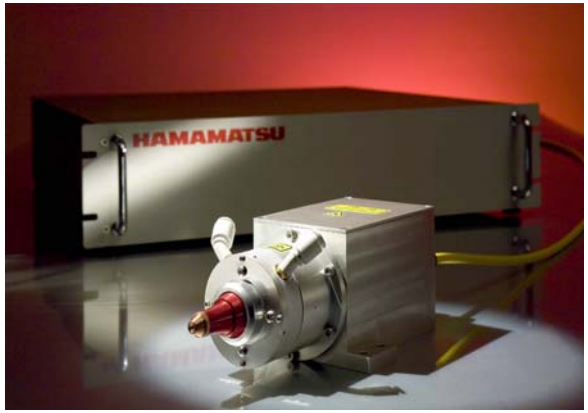
Direct Diode Laser

Fiber out Laser Diode

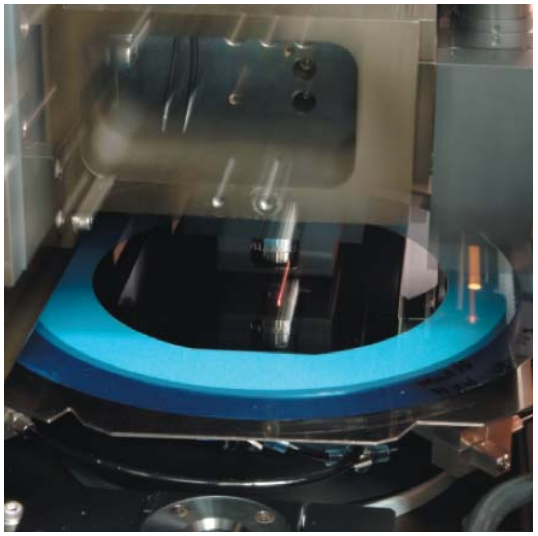
Quantum Cascade Laser



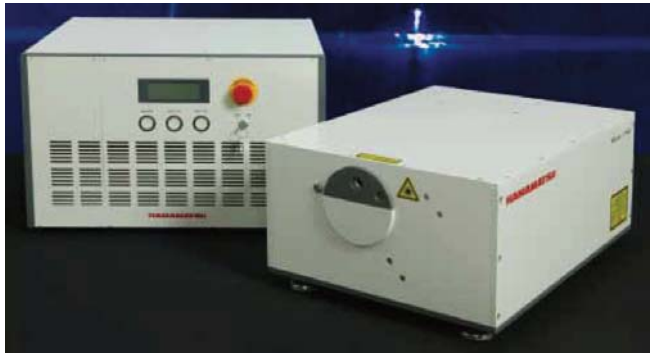
Fiber Disk Laser



Stealth Dicing Laser



Pico-second Laser



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Development of Photonics Industries by DPSSL at Hamamatsu

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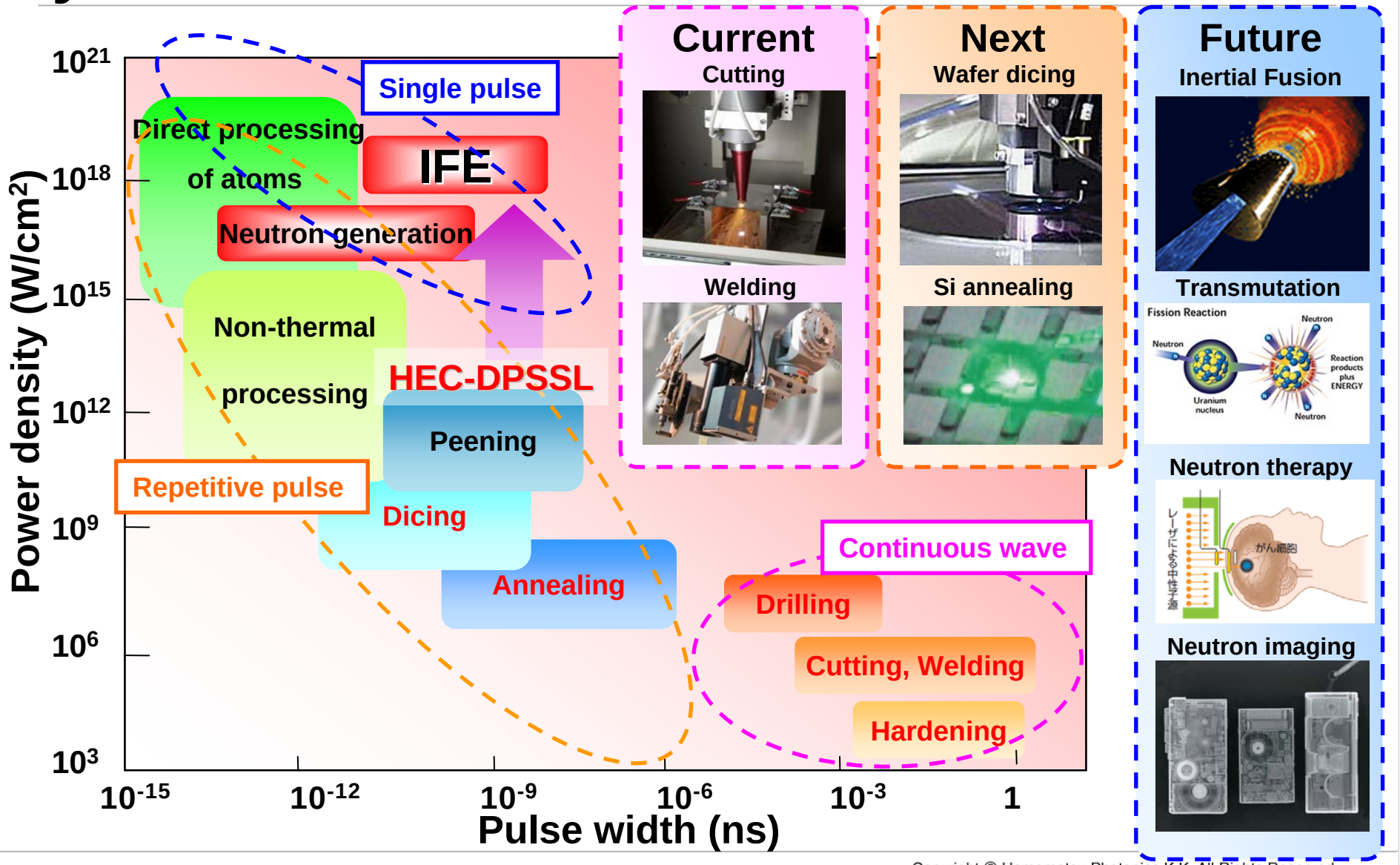

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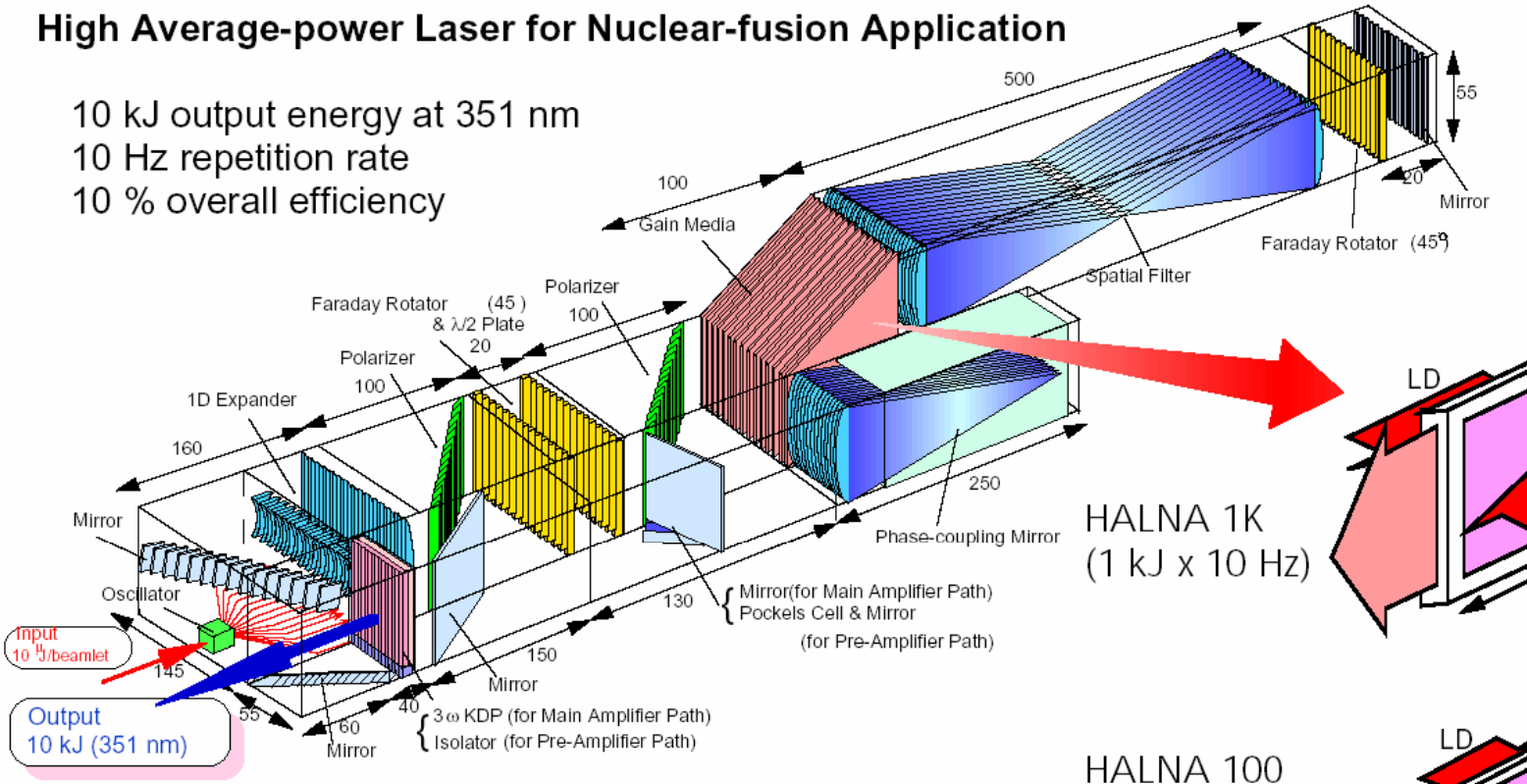
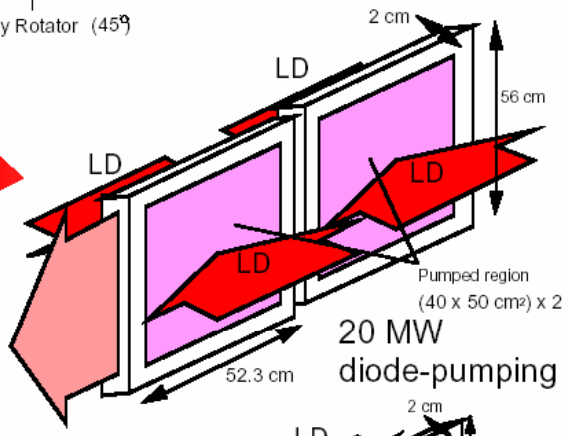
Conceptual design of HALNA

ILE OSAKA

HALNA:
High Average-power Laser for Nuclear-fusion Application

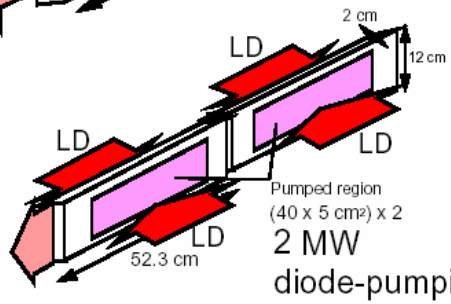
10 kJ output energy at 351 nm
10 Hz repetition rate
10 % overall efficiency





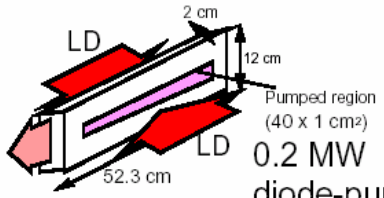
HALNA 1K
(1 kJ x 10 Hz)

20 MW
diode-pumping



HALNA 100
(100 J x 10 Hz)

2 MW
diode-pumping



HALNA 10
(10 J x 10 Hz)

0.2 MW
diode-pumping

- Diode-pumped solid-state laser
- Water-cooled Nd:glass gain medium
- Zig-zag slab geometry
- Multipass amplifier architecture
- Phase-coupled beam combining

Current status of HALNA

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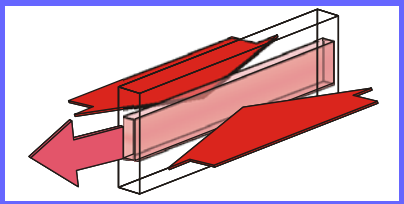
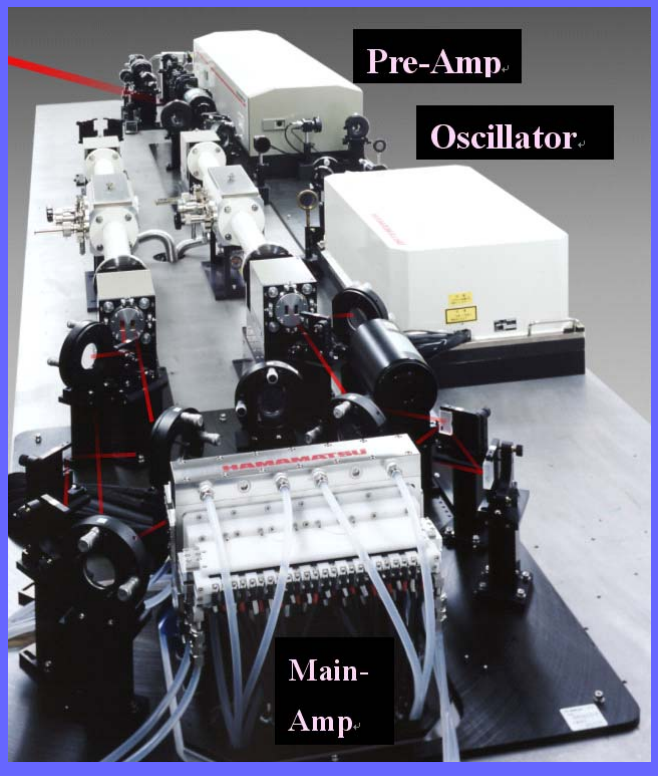
ILE OSAKA

(December 2004)

HALNA 10 (8.4 J in 20 ns at 10 Hz)

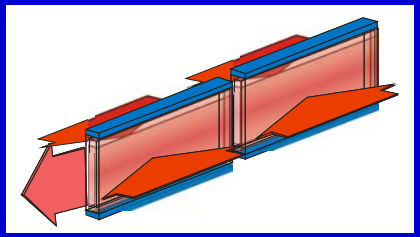


Glass volume:
2.2cm x 1cm x 40cm
(1 slab)
Stored at 0.4 J/cm^3



(Current status)

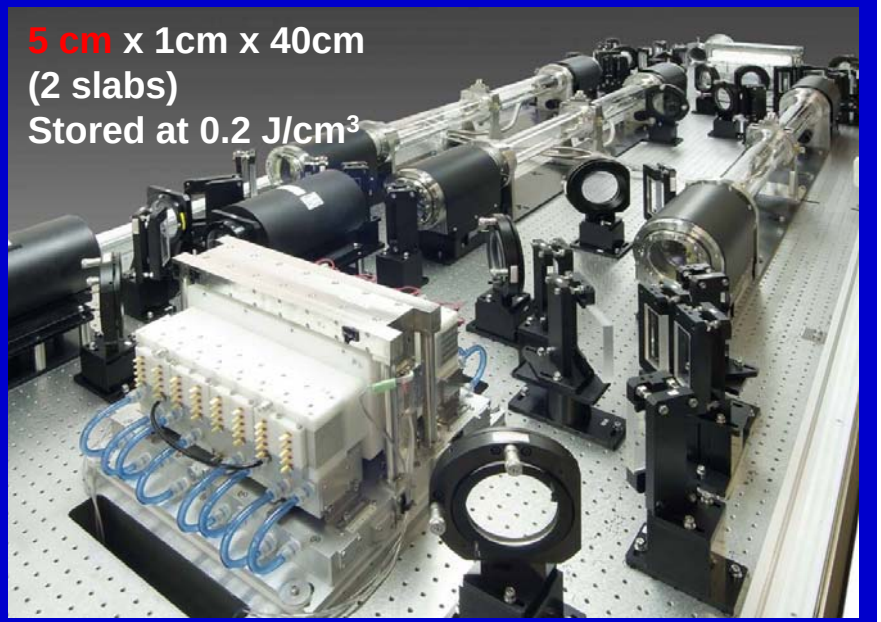
HALNA 100 (100 J in 10 ns at 10 Hz)



Glass volume:
10cm x 1cm x 40cm
(2 slabs)
Stored at 0.4 J/cm^3

Half scale (21.3 J in 8.9 ns at 10 Hz)

5 cm x 1cm x 40cm
(2 slabs)
Stored at 0.2 J/cm^3



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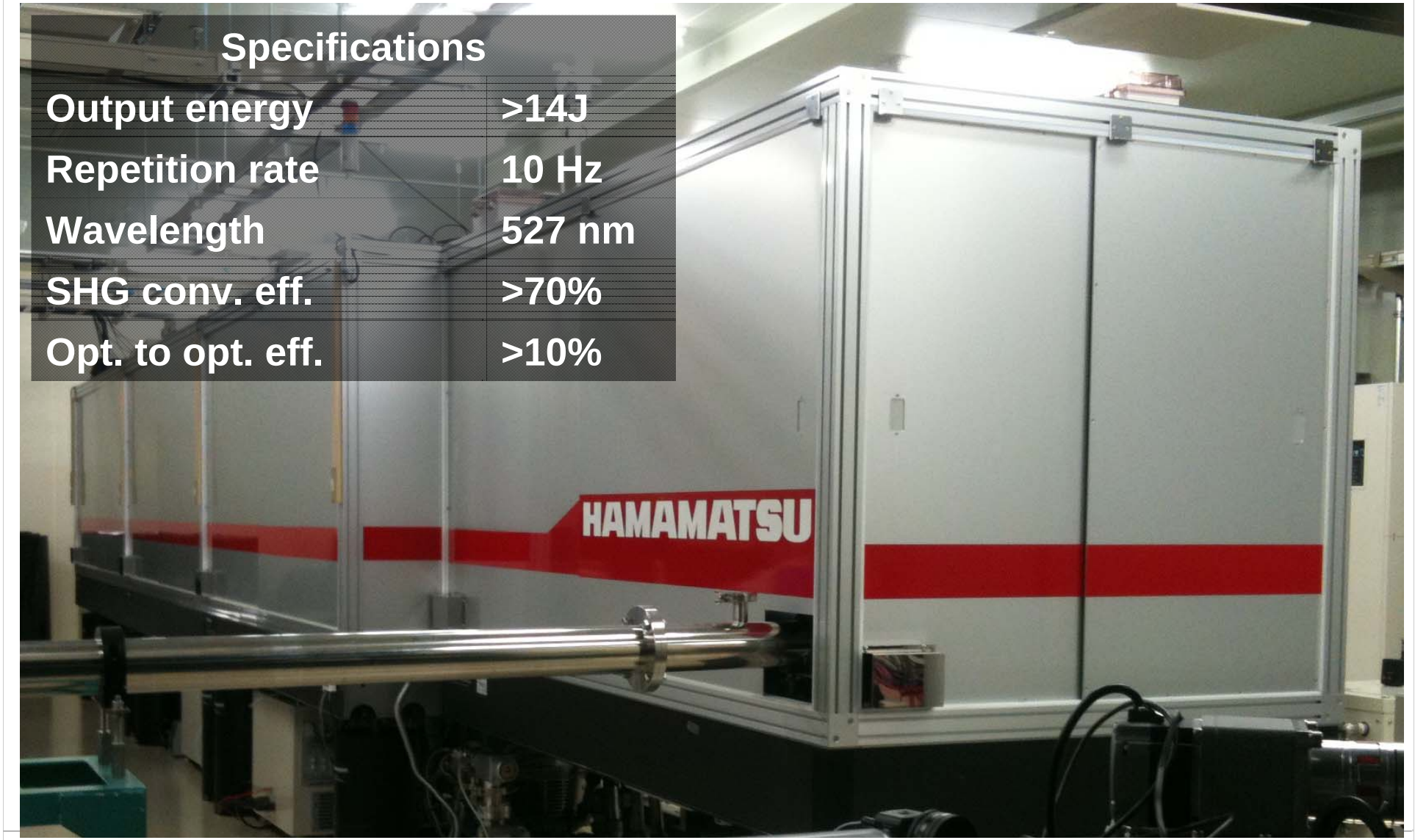
Diode pumped green laser KURE-I



Specifications	
Output energy	>14J
Repetition rate	10 Hz
Wavelength	527 nm
SHG conv. eff.	>70%
Opt. to opt. eff.	>10%

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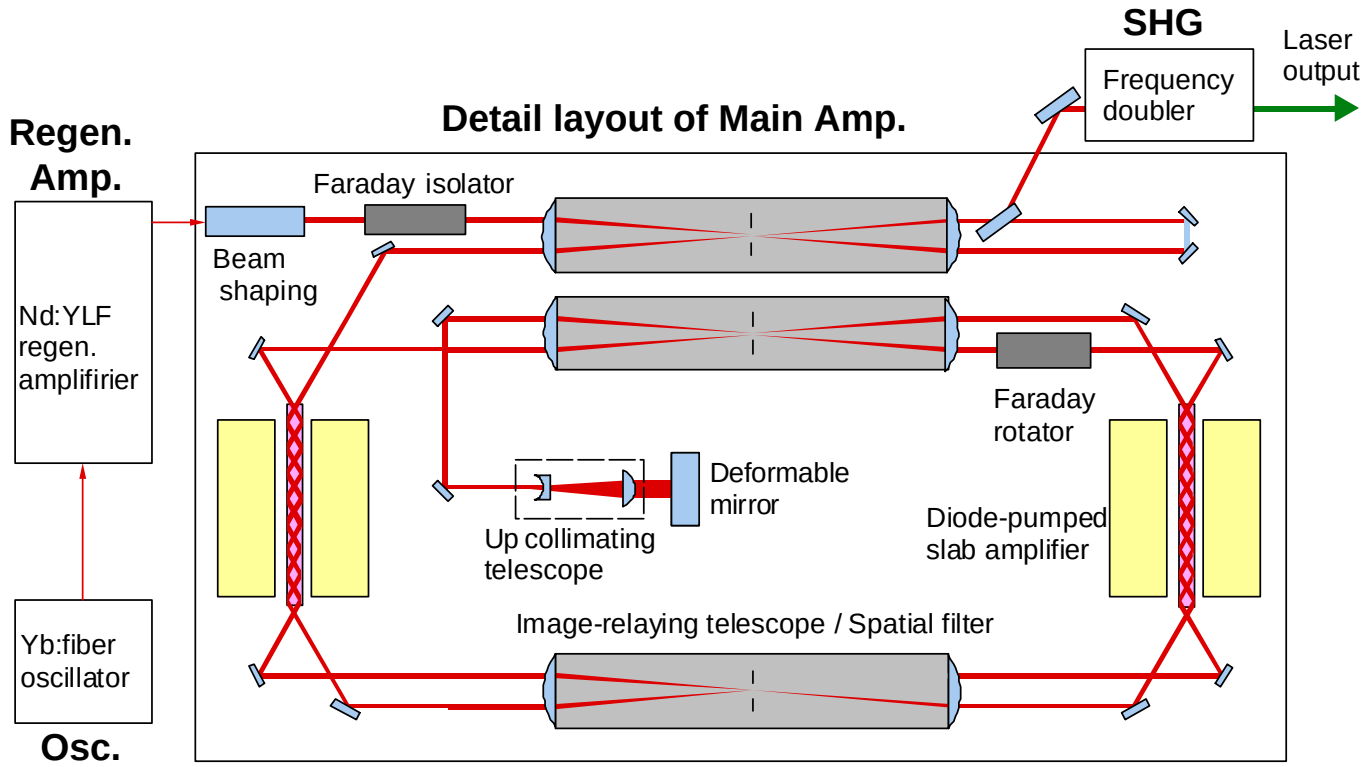
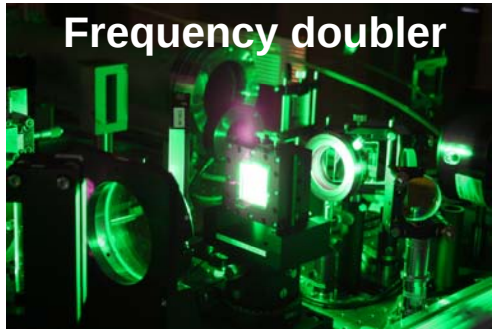
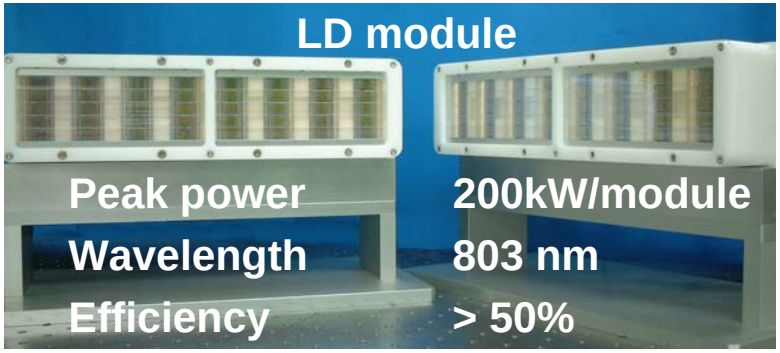
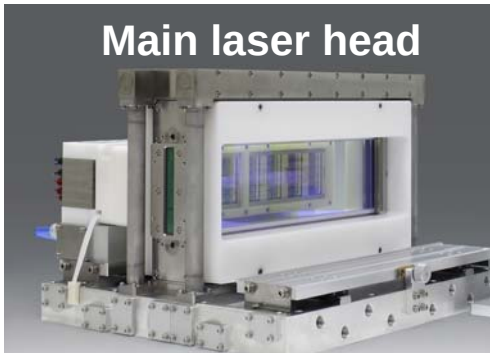
KURE-I system









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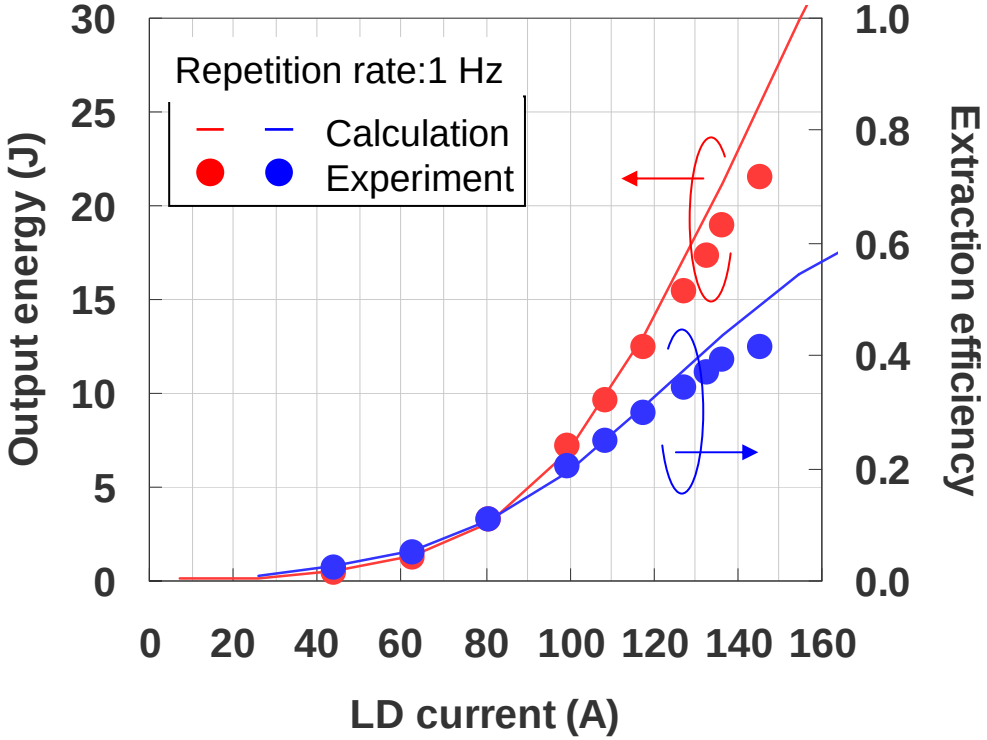
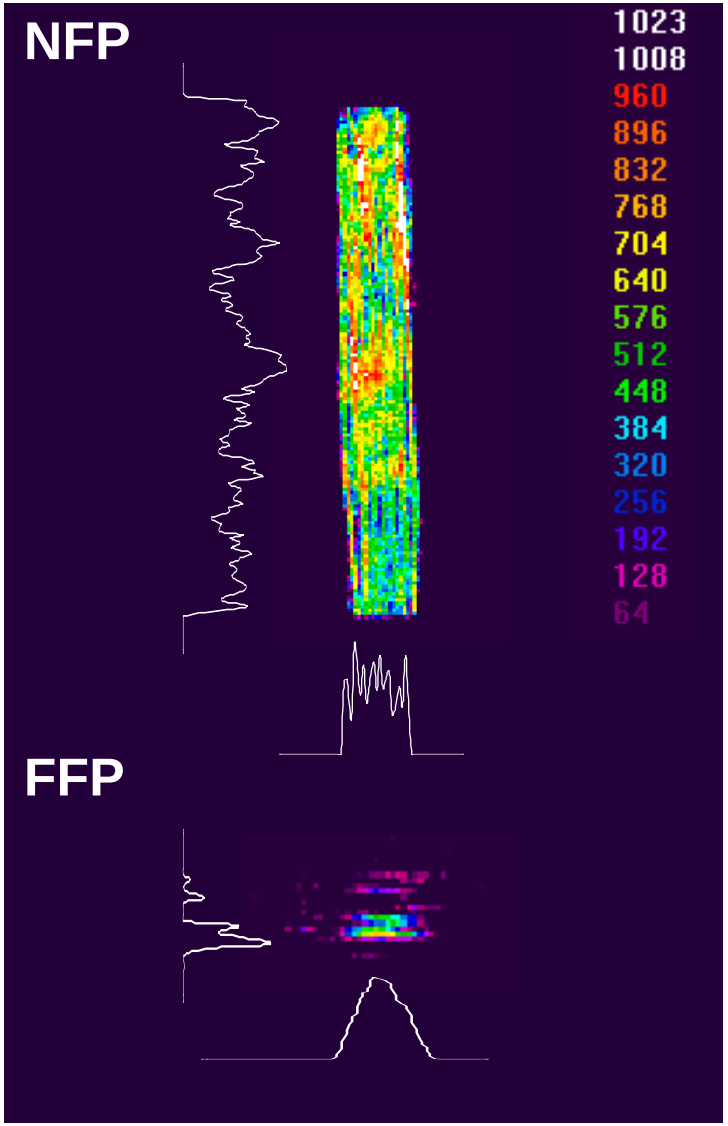
Current status of fundamental output





Output energy	21.4 J
Repetition rate	1 Hz
Extraction eff.	41.6%
Opt. to opt. eff.	14.7%

<u>Design</u>
>20% at 32J output
with 160J pump

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Characteristics of $CeLiB_6O_{10}$ (CLBO) nonlinear crystal

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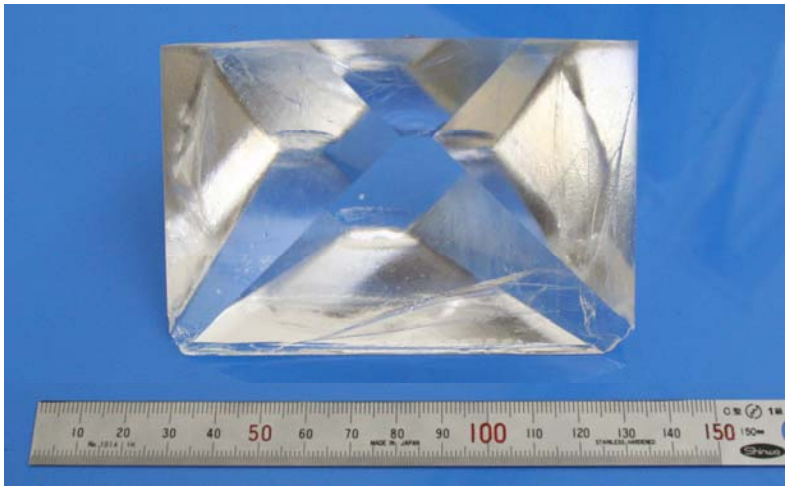
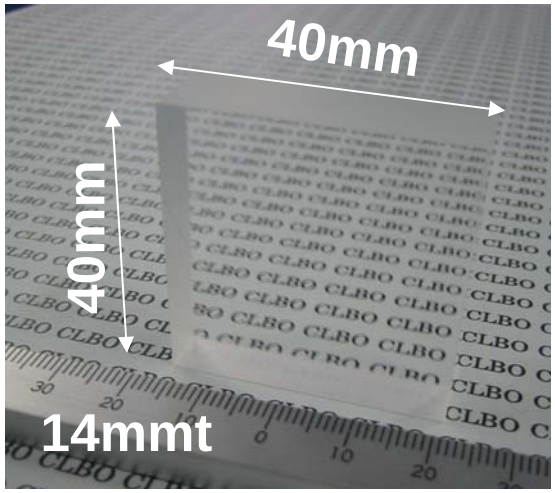
	CLBO	YCOB	BBO	DKDP
Effective nonlinear coefficient (pm/V)	0.95	0.91	1.94	0.4
Maximum aperture (mm)	>50	>80	~30	>400
Temperature bandwidth (deg.C)	43	65	55	6.7
Spectral bandwidth (nm)	5.6	1.3	1.1	5.5
Hygroscopicity	Strong	Non	Slightly	Strong

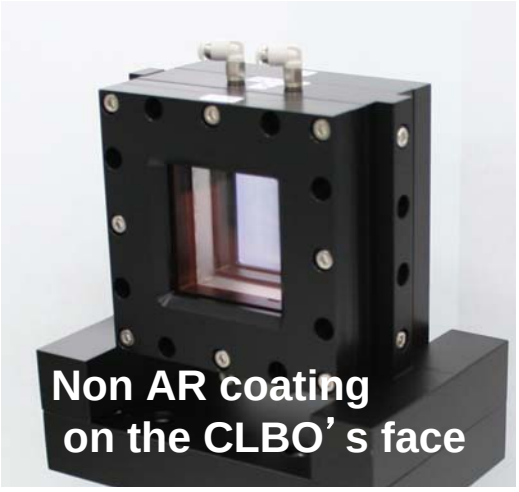
CLBO ingot



Cut and polish



N_2 purged mount



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Design of frequency doubler

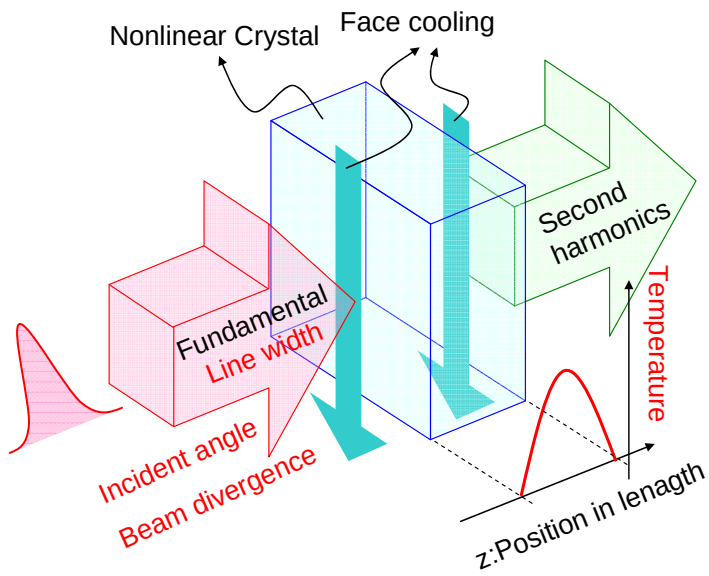
Evaluation of phase mismatch

$$\Delta k = \Delta k0 + \underbrace{\beta_{angl} \cdot \delta T}_{\text{angle}} + \underbrace{\beta_{spec} \cdot \delta\theta}_{\text{spectrum}} + \underbrace{\beta_{themp} \cdot \delta\theta}_{\text{temperature}}$$

Frequency conversion sensitivity

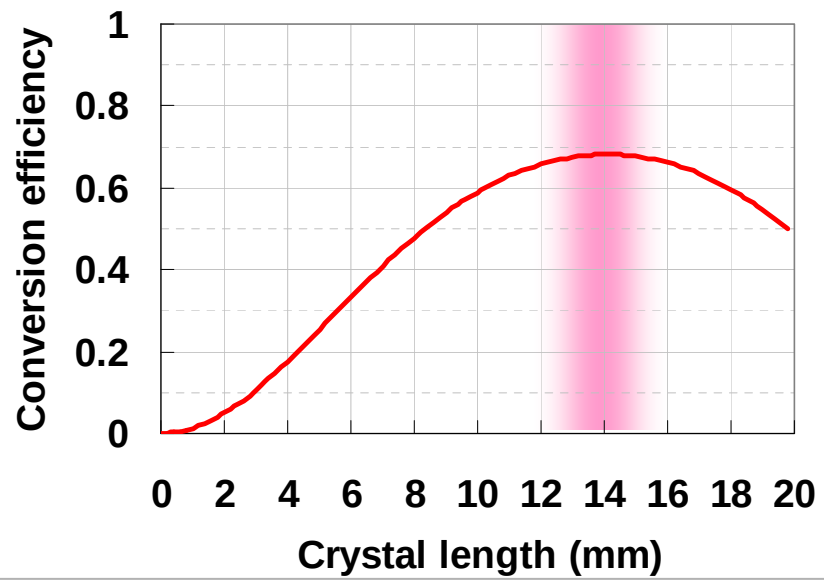
$$\beta = 1.772 \frac{\pi}{L \cdot Bandwidth}$$

V.G.Dimitriev et. al. , "Handbook of Nonlinear Optical Crystals"



Design parameter

Input ω energy	20 J
Repetition rate	10 Hz
Pulse width (Gaussian)	10 ns (FWHM)
Angular mismatch	0.2 mrad
Absorption coefficient	0.001 cm^{-1}
Thermal conductivity	1 W/mK
SHG conv. eff.	70%



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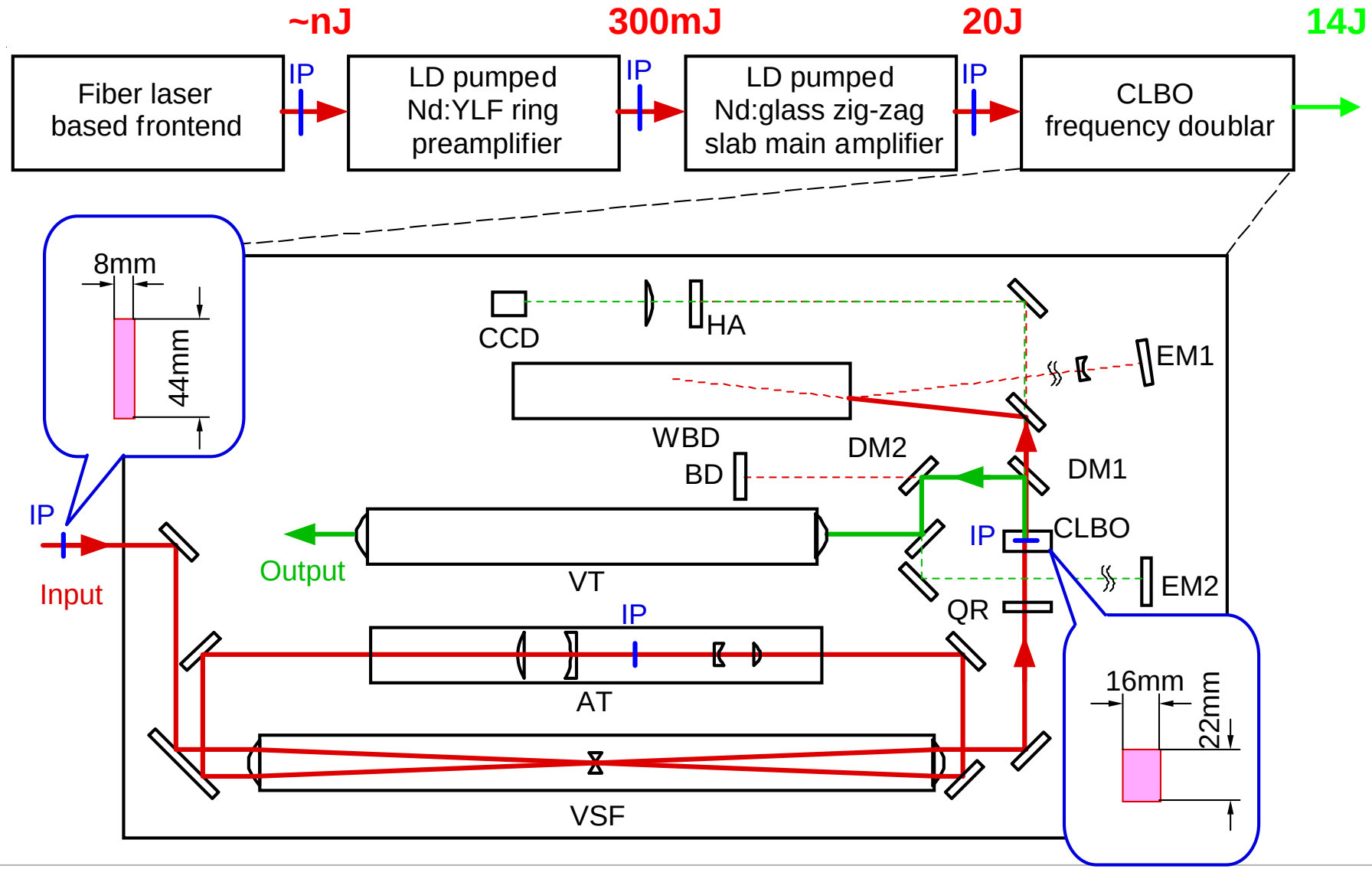
Optical setup of SHG and diagnostics



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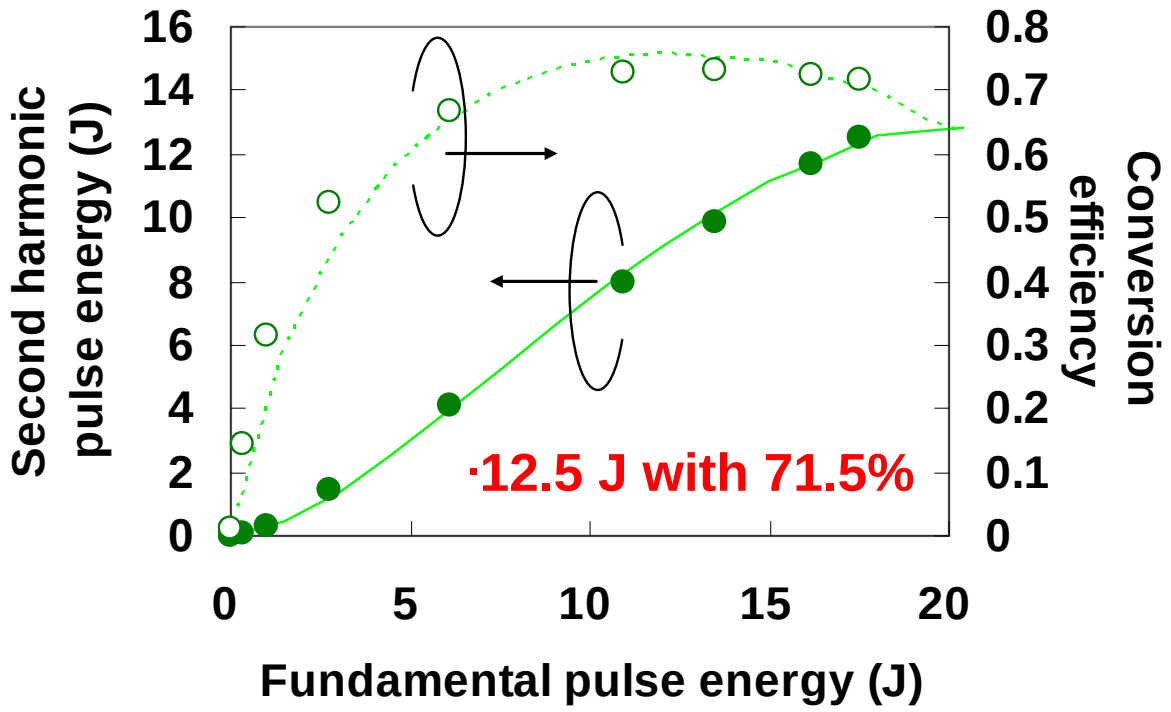
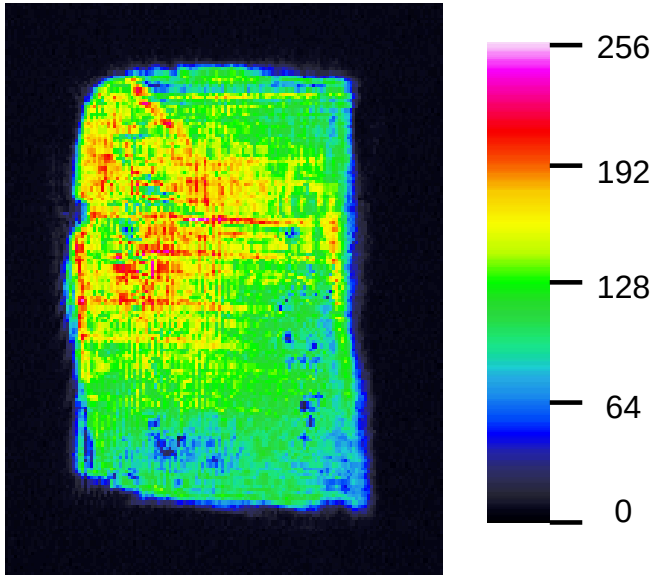
Output characteristics of SHG



·NFP



Filling factor:44.2%

There is no significant reduction of conversion efficiency by exposing over 600,000 shots fpr intermissive experiments during 3 years.

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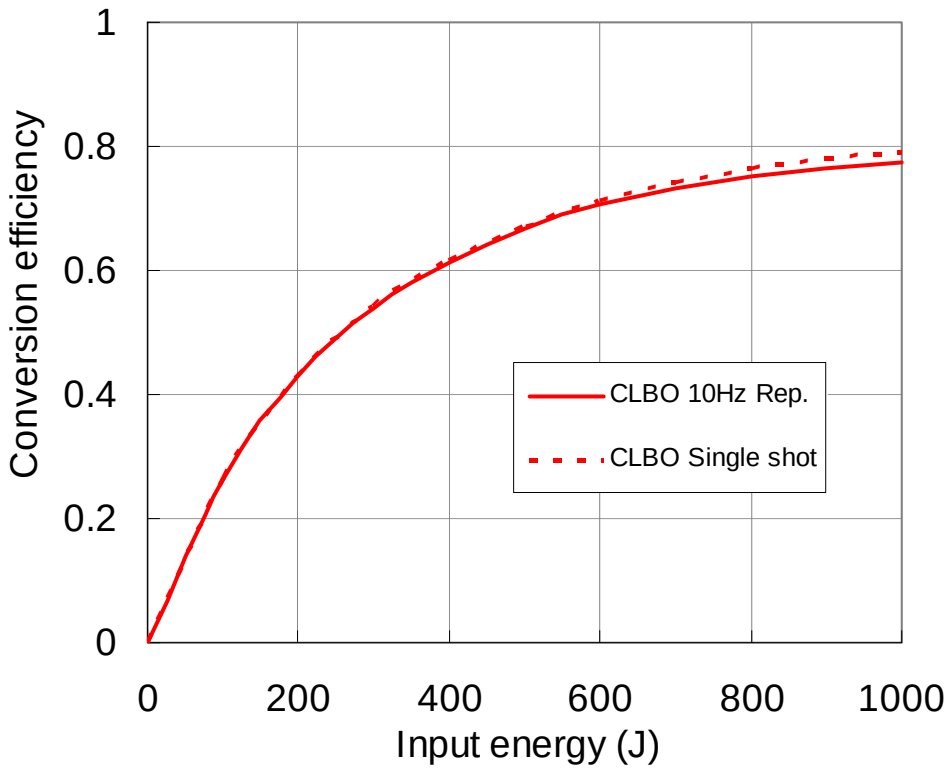
Prospect of kJ class SHG by CLBO

Parameter	CLBO
Phase match type	Type-II
Crystal length	9 mm
Beam size	10 cm x 10 cm
Pulse width (Gaussian)	10 ns (FWHM)
Repetition rate	10 Hz
Longitudinal mode	Single
Angular mismatch	0.1 mrad
Beam divergence	0.1 mrad
Absorption coefficient at 1um	0.0013 cm^{-1} (Assumed same with DKDP)
Thermal conductivity	1.25 W/mK (Assumed same with DKDP)



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Summary

- CLBO frequency doubler has been developed for HEC-DPSSL.
- 12.5 J with 71.5% conversion efficiency has been demonstrated.
- Prospect of frequency converter for 1 kJ x 10Hz by CLBO was evaluated.