# Conceptual design of sub-exa-watts OPCPA system


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# Outline

**1. Conceptual design of sub-exa-watts laser -“GEKKO – EXA”-**

1-1 Concept of Sub-EW Laser

**2. Pump source of OPCPA**

2-1 Repeatable DPSSL at 100 J

2-2 Single shot glass laser at 10 kJ

**3. Broadband OPCPA**

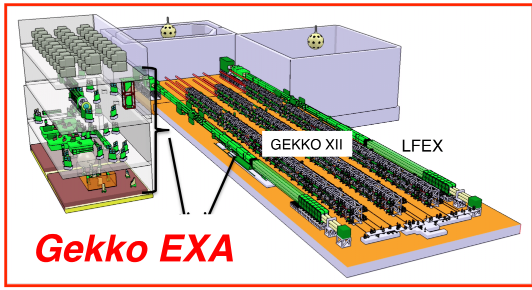
3-1 Randam-phase pumped OPCPA

3-2 Partially-deuterated DKDP

**4. Summary**

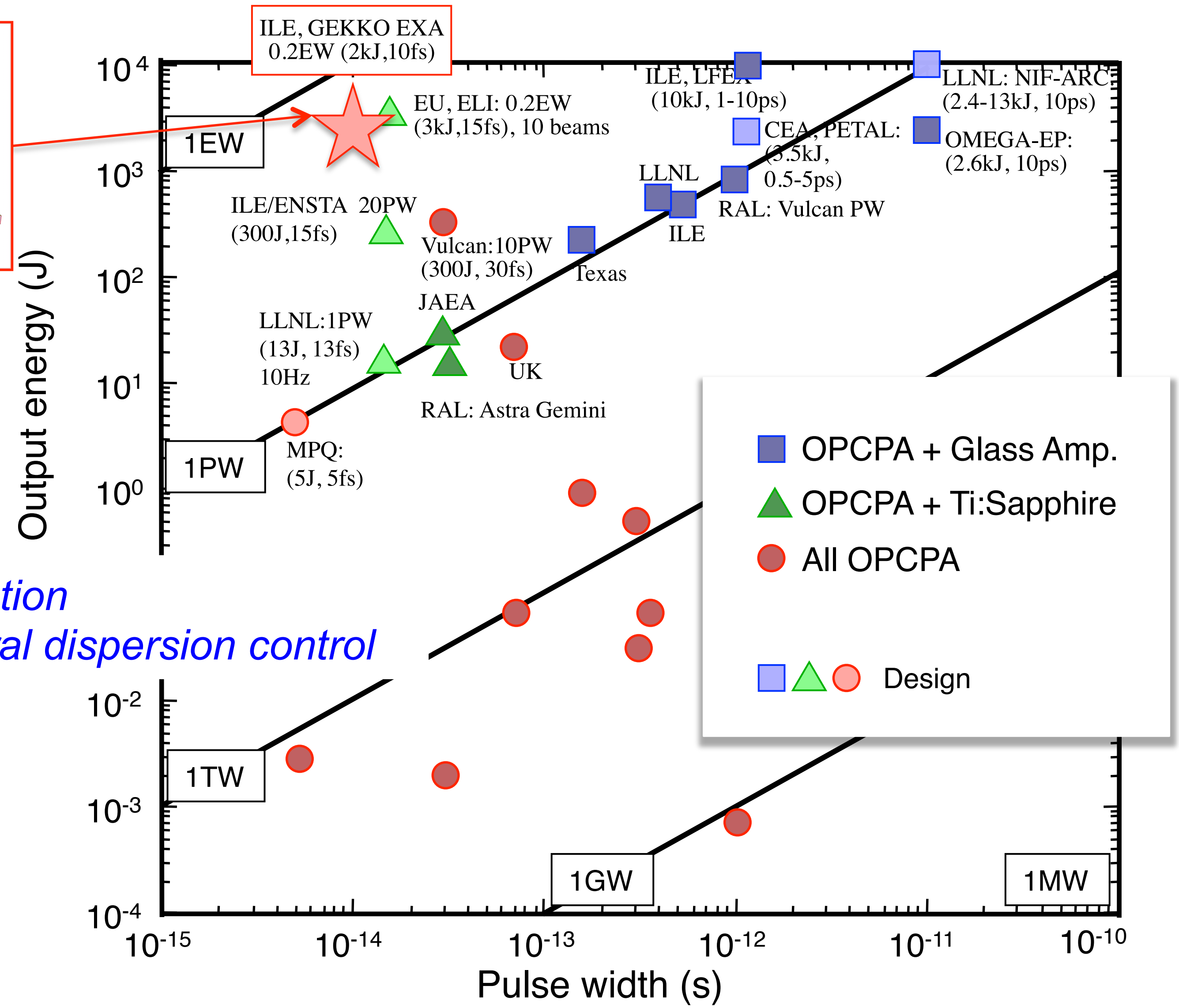
# 1. Conceptual design of sub-exa-watts laser -GEKKO-EXA-

# Ultra-intense lasers over the world




✓ Sub-EW
✓ Few cycle

☀ *Broadband amplification*
☀ *Temporal and spectral dispersion control*



# Basic concept of sub-EW laser

Key technologies

- All **OPCPA** System

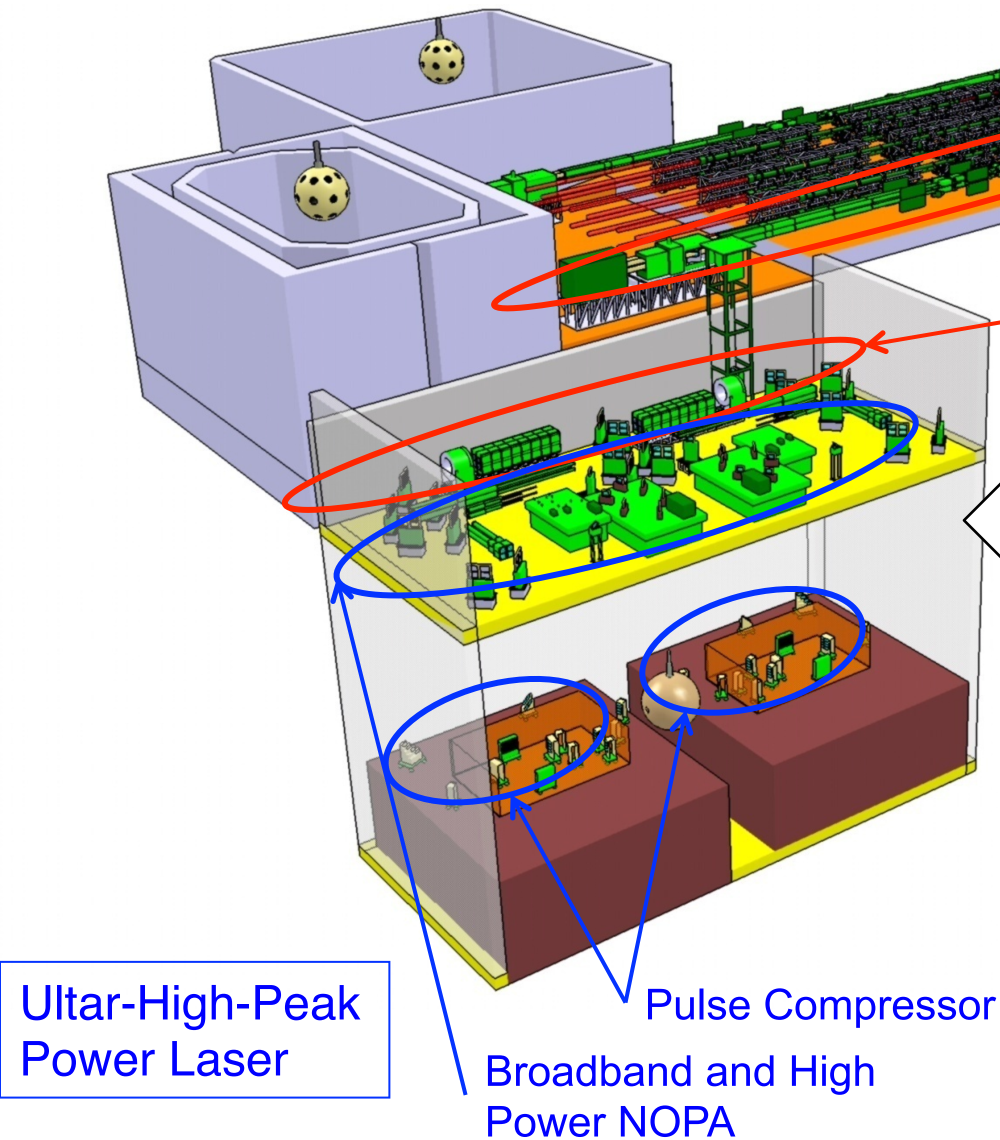
Front End + **DPSSL-pumped OPCPA** + Glass-laser-pumped OPCPA

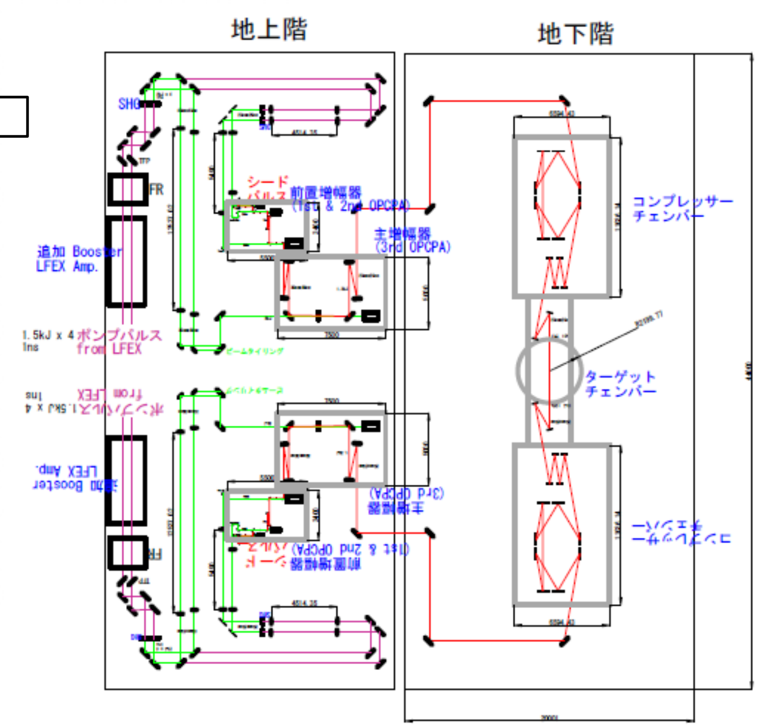
OPA pump source

- Specification

| | | | |
|---|---|---|---|
| Peak power | : > 1 PW | 0.1 EW / beam | |
| Beam size | : 30 x 30 mm$^2$ | 300 x 300 mm$^2$ | Large-aperture, ultra-broad-band crystal |
| Rep. rate | : 100 Hz | Single shot | |
| Beams | : 1 beam | 1~2 beams | |
| Bandwidth | : 750 ~ 1250 nm | | |
| Pulse duration | : ~ 10 fs (CEP stabilied) | | CEP and Dispersion control |

# GEKKO – EXA Layout



# 2. Pump source of OPCPA

# Advantages of cryogenically cooled Yb:YAG

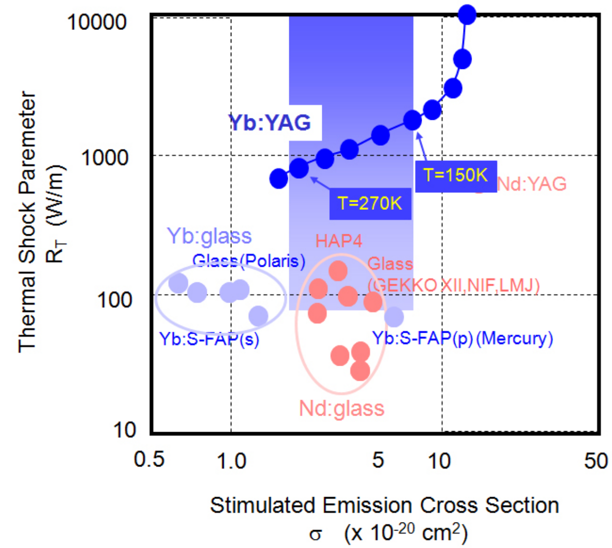
## Advantages

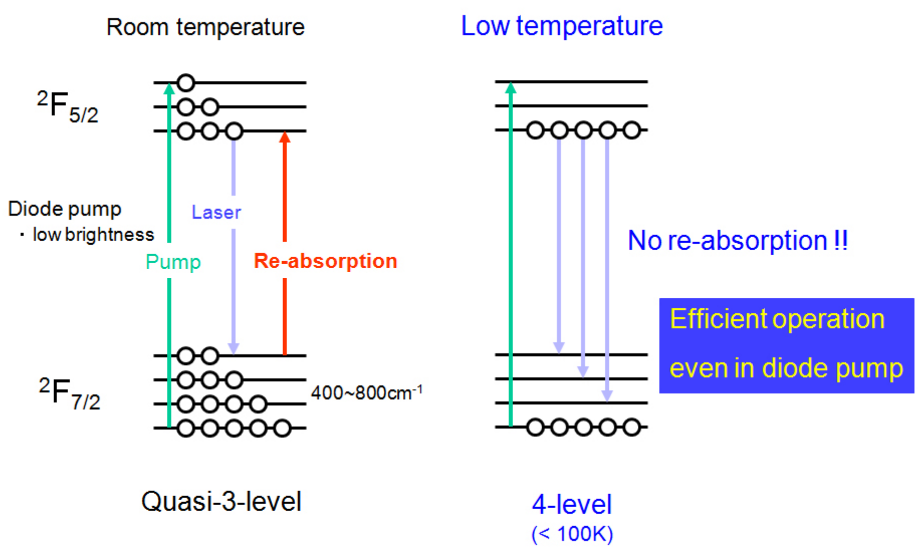
1. Wide Tunability of Stimulated Emission Cross Section

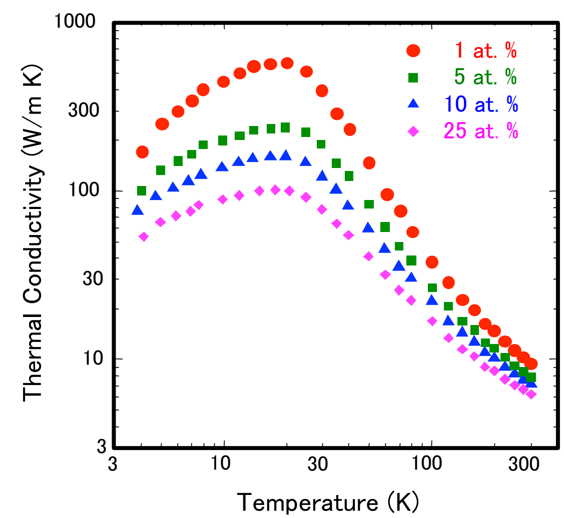
2. Improved Thermal Strength

| | |
|---|---|
| Thermal conductivity | κ, |
| Thermal expanstion | 1/L(dL/dT), |
| Thermal refrative index | dn/dT |

3. Efficient Laser Operation without Re-absorption

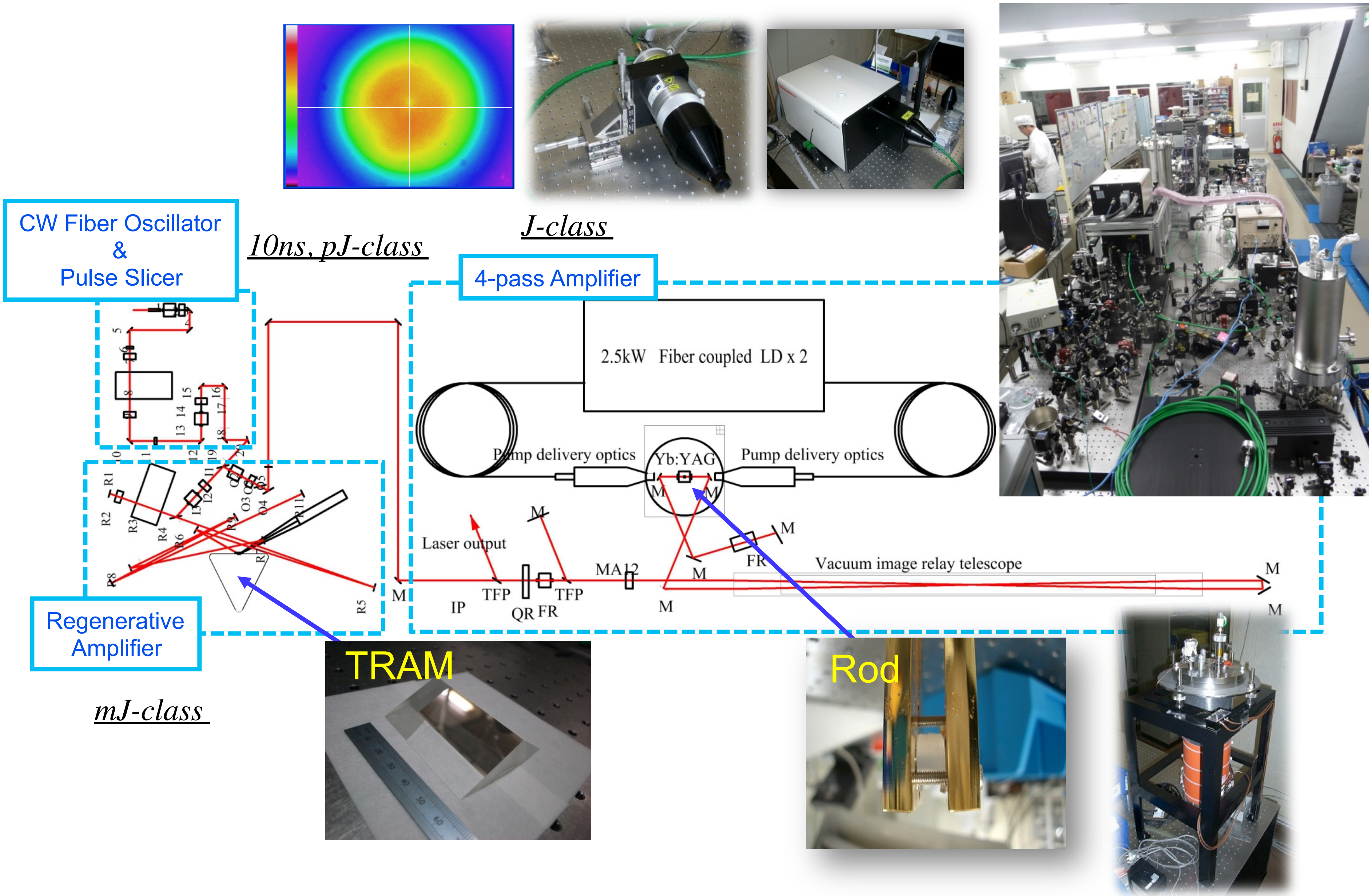


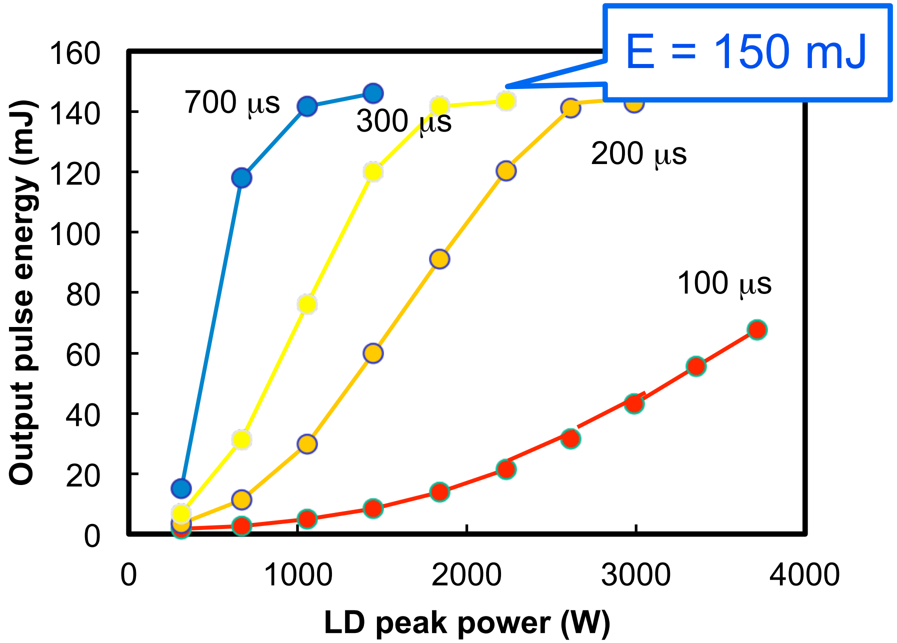



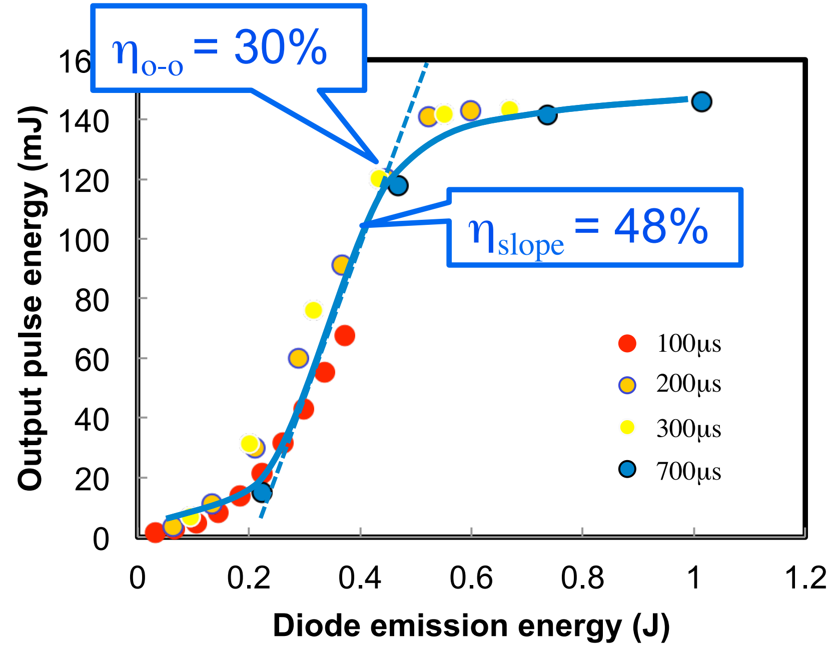

J. Kawanaka et. al, Laser Physics 15, pp. 1306-1312 (2005).

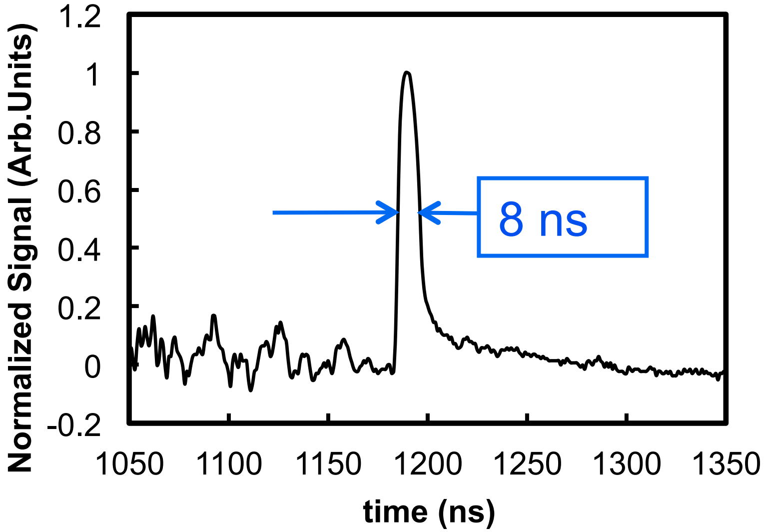
# 1 J, 100Hz laser system as a test bench of pre-amp.



# Experimental results of cryogenic Yb:YAG laser **at 100Hz**



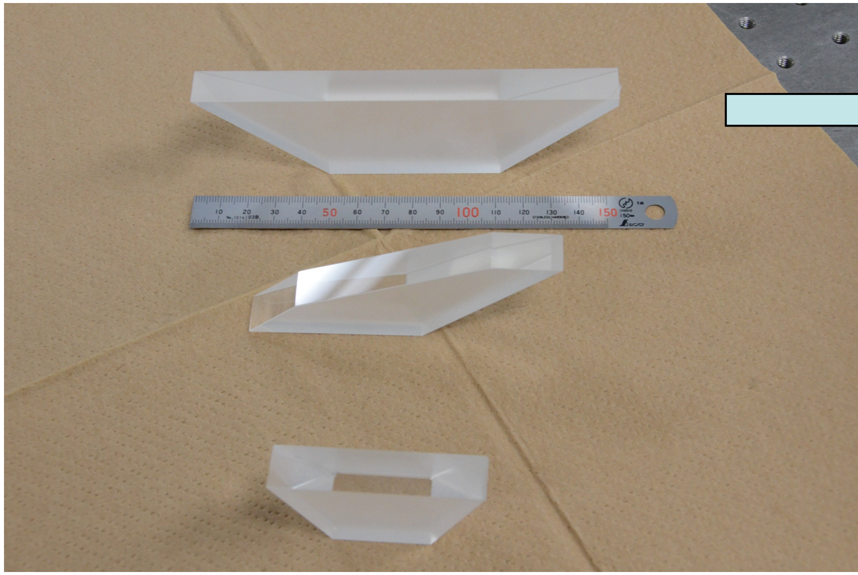



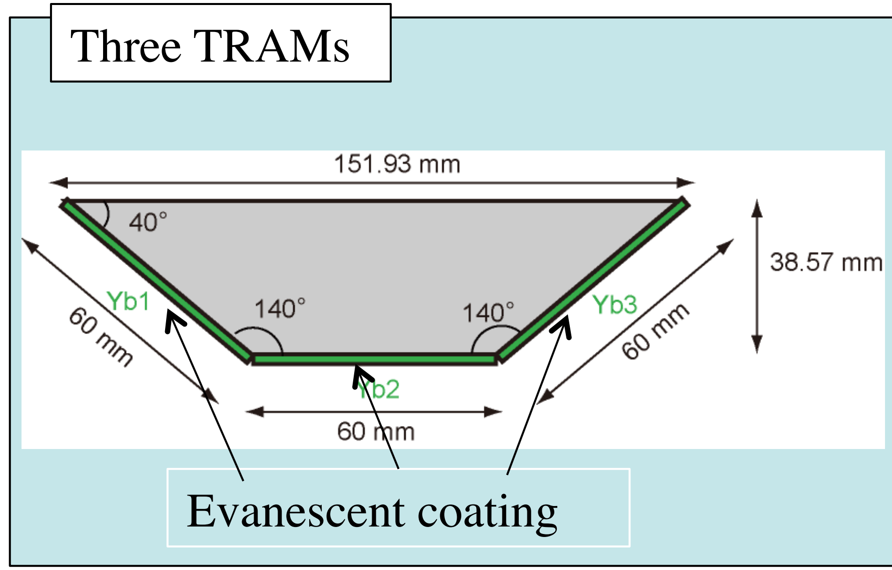

$G_0$ = 13/pass
I = 7.8 kW/cm$^2$ @700μs (5.5 J/cm$^2$)
Transmission loss = 0.3/pass

We need more TRAMs for higher pulse energy.
Pump source power is enough high for 1 J.

S. Pearce, et. al., *Optics Communications* **282** 2199 (2009).

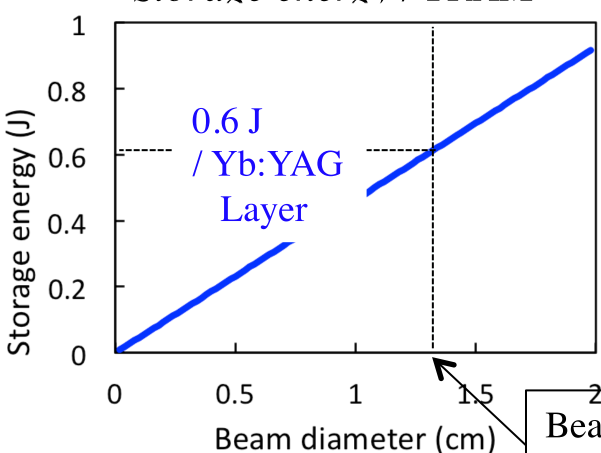
# Output Pulse Energy and Temporal Waveform at 100Hz



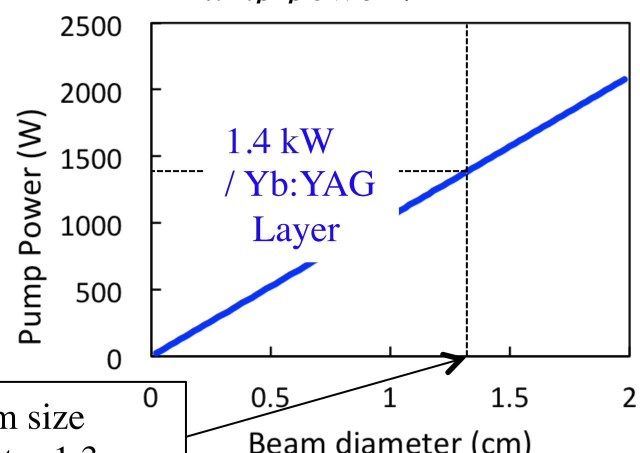



## Numerical calculation

*Storage energy / TRAM*




*Pump power / TRAM*



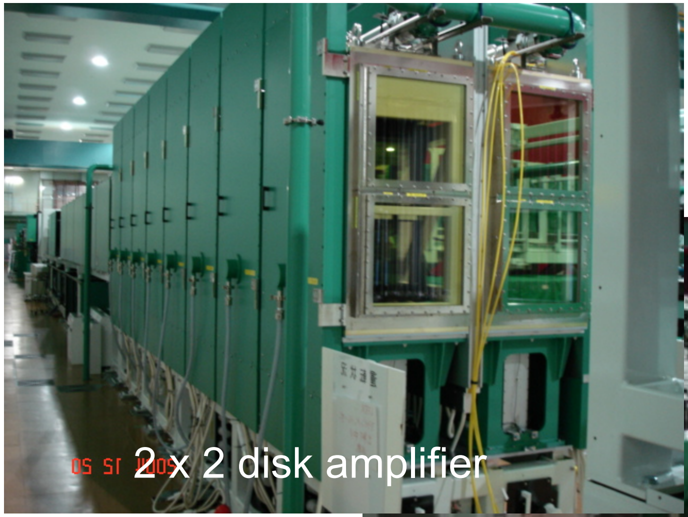

Beam size
Limit ~ 1.3 cm

Storage energy
0.6 x 3 = 1.8 J

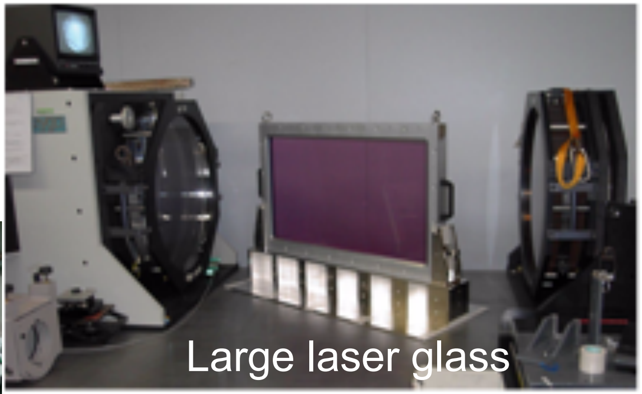
Required pump power
1.4 kW x 3 = 4.2 kW < 5 kW

**1 J, 100Hz ps pulses**

# kJ-pump source based on LFEX-Laser technologies

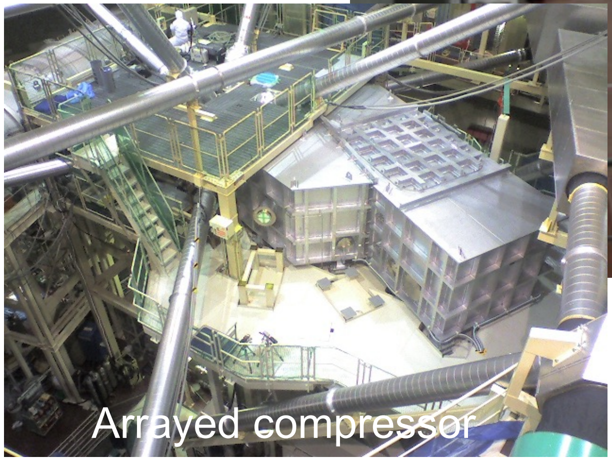


2 x 2 disk amplifier

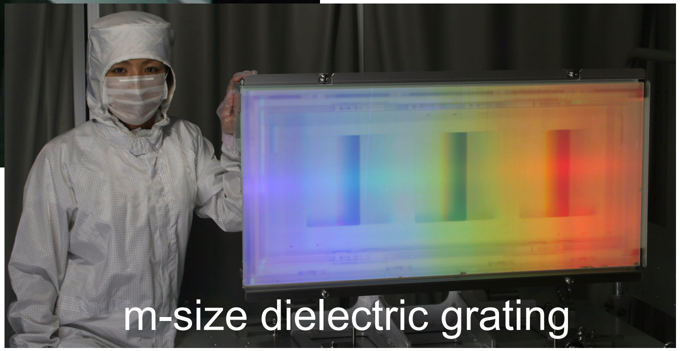


Large laser glass

10 kJ / ps~ns / 4-beams

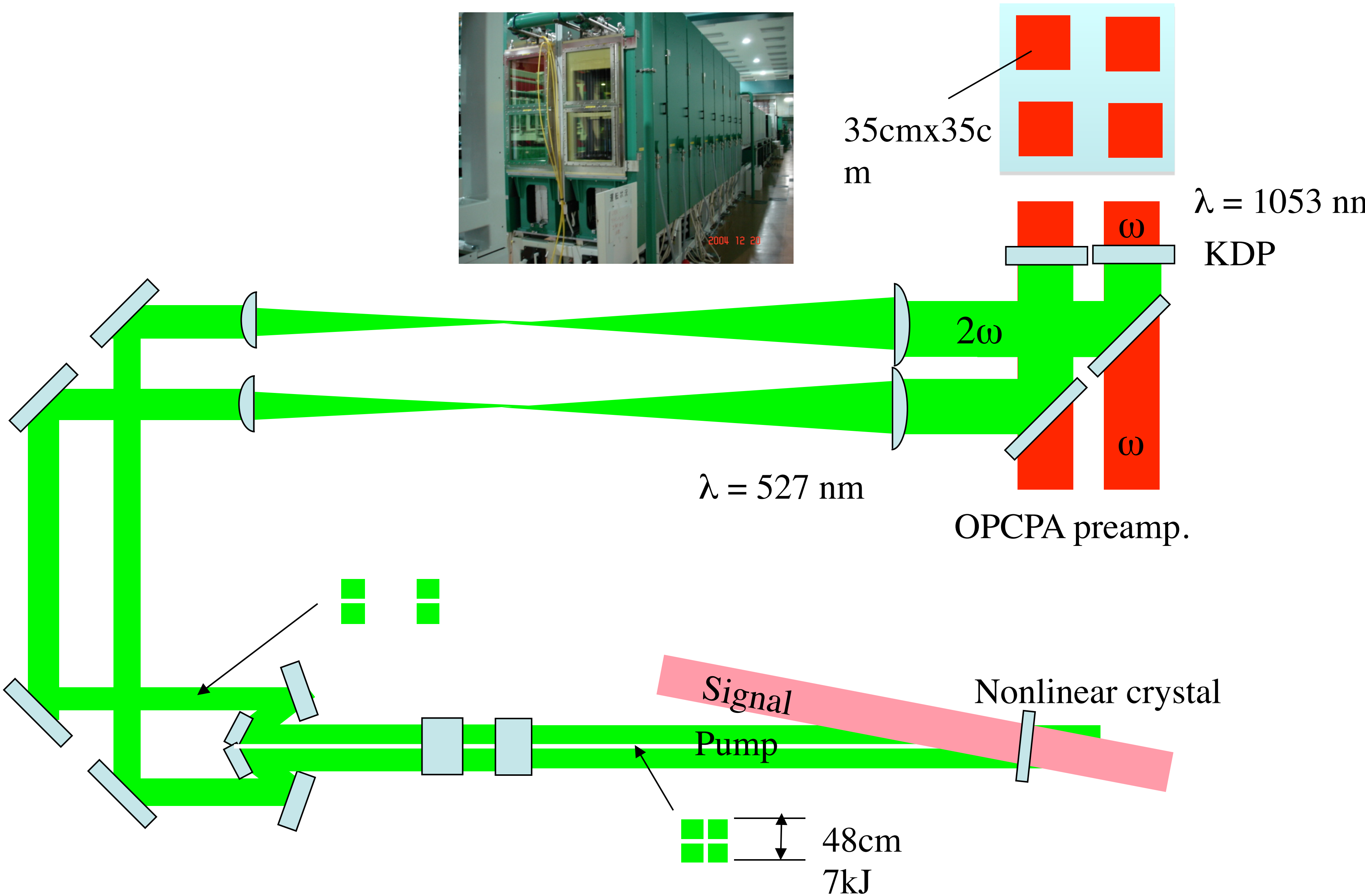


Arrayed compressor



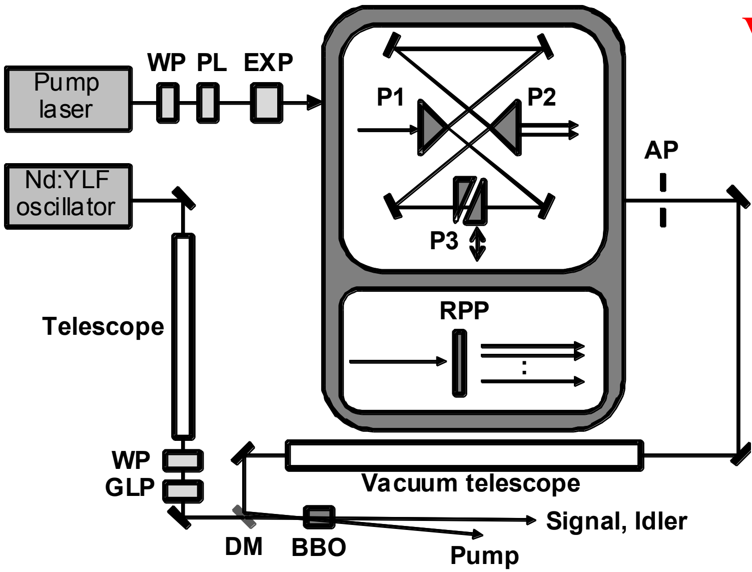
m-size dielectric grating

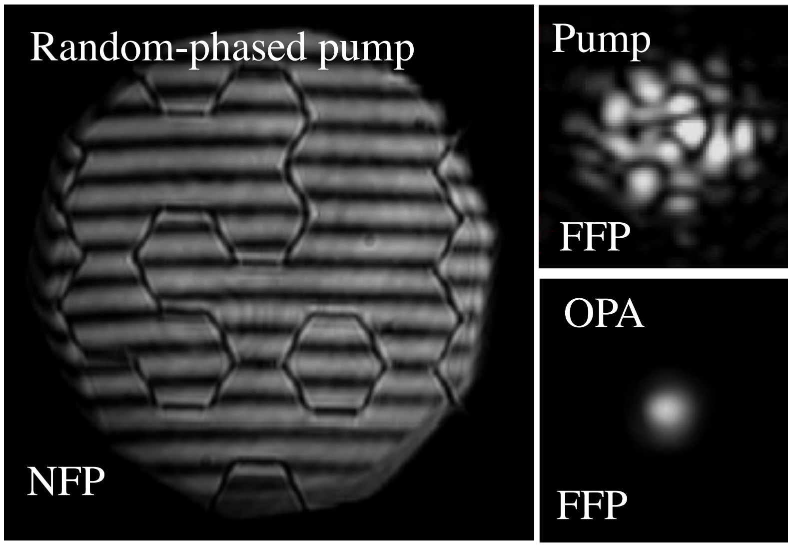
# Large-aperture OPCPA pumped by arrayed beams

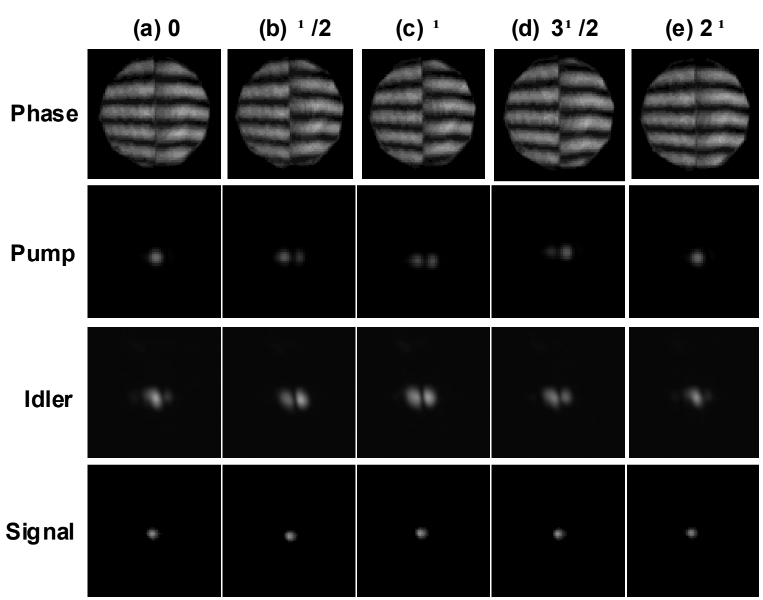


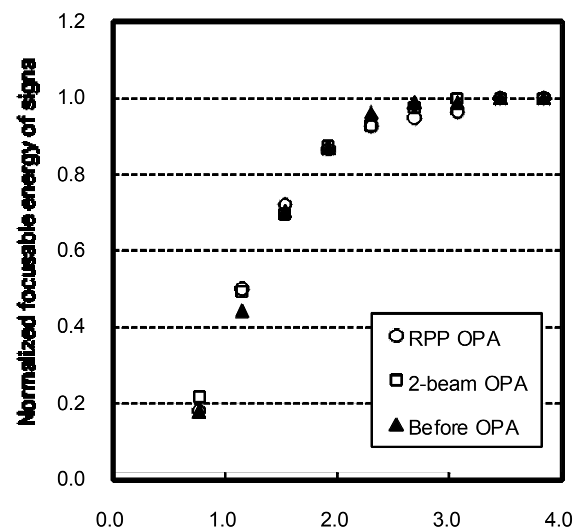
# Proof-of-principle of OPA with random-phased pump

Virtually alignment free for beam combination ?



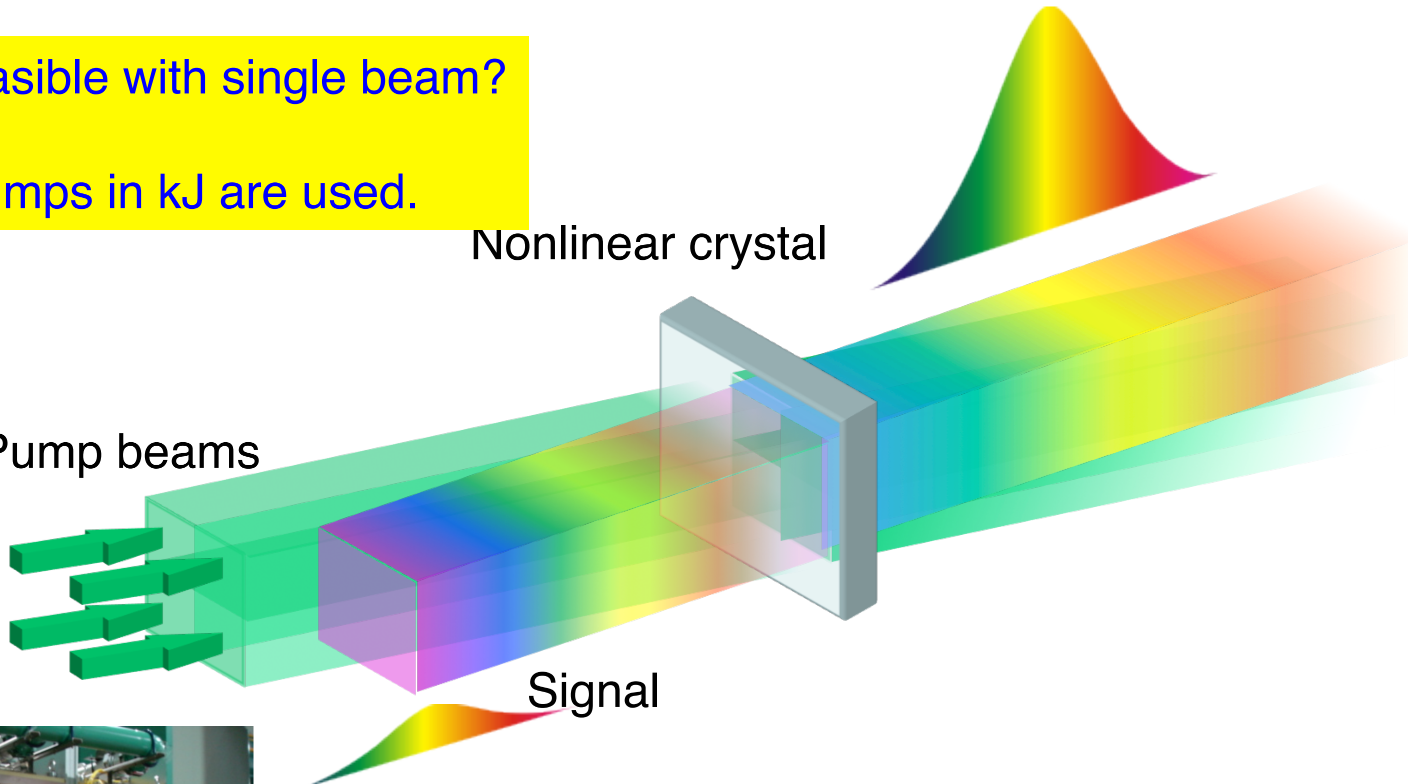



# Large-aperture, ultra-broadband OPCPA with arrayed pumps

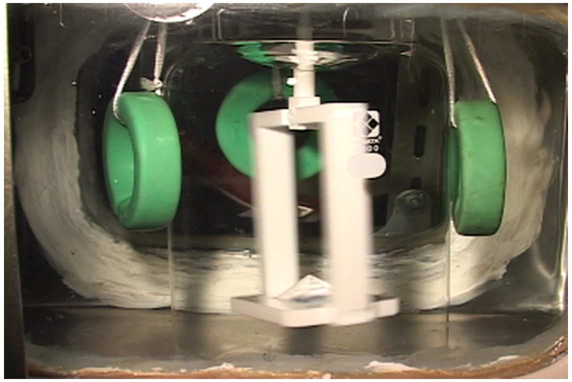
Is sub-EW feasible with single beam?

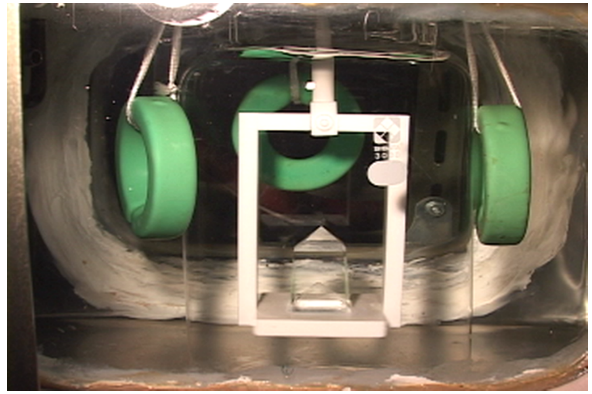
→ Arrayed pumps in kJ are used.

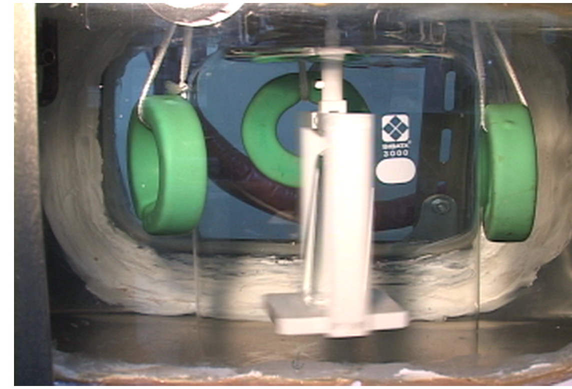


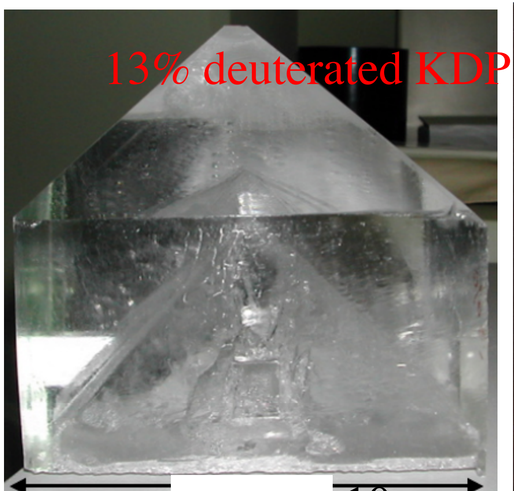

# 3. Broadband OPCPA in kilo-joule

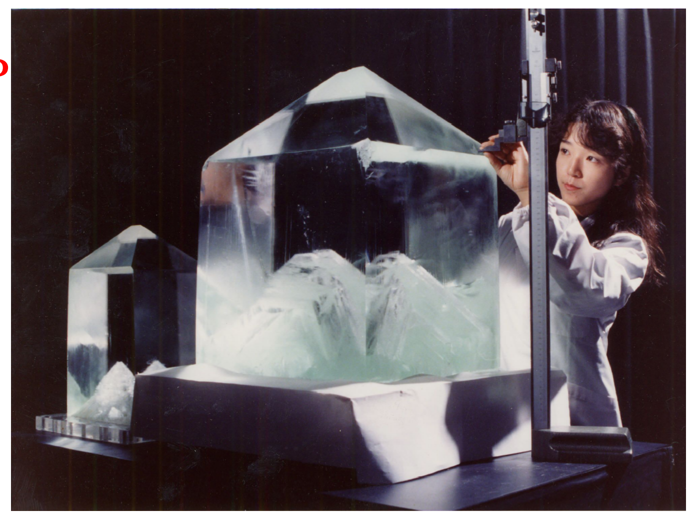
# Partially deuterated KDP crystal for broadband OPA





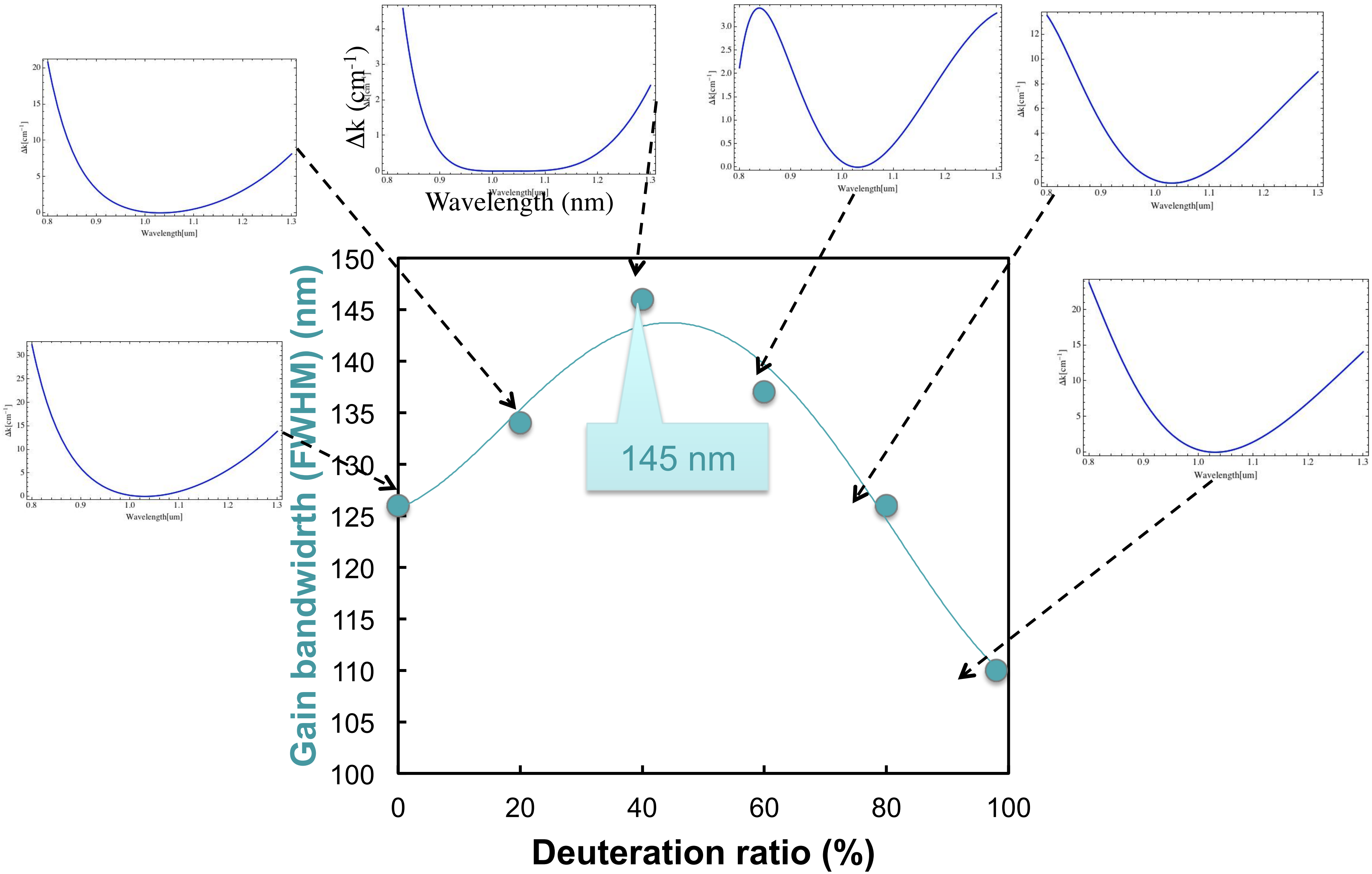




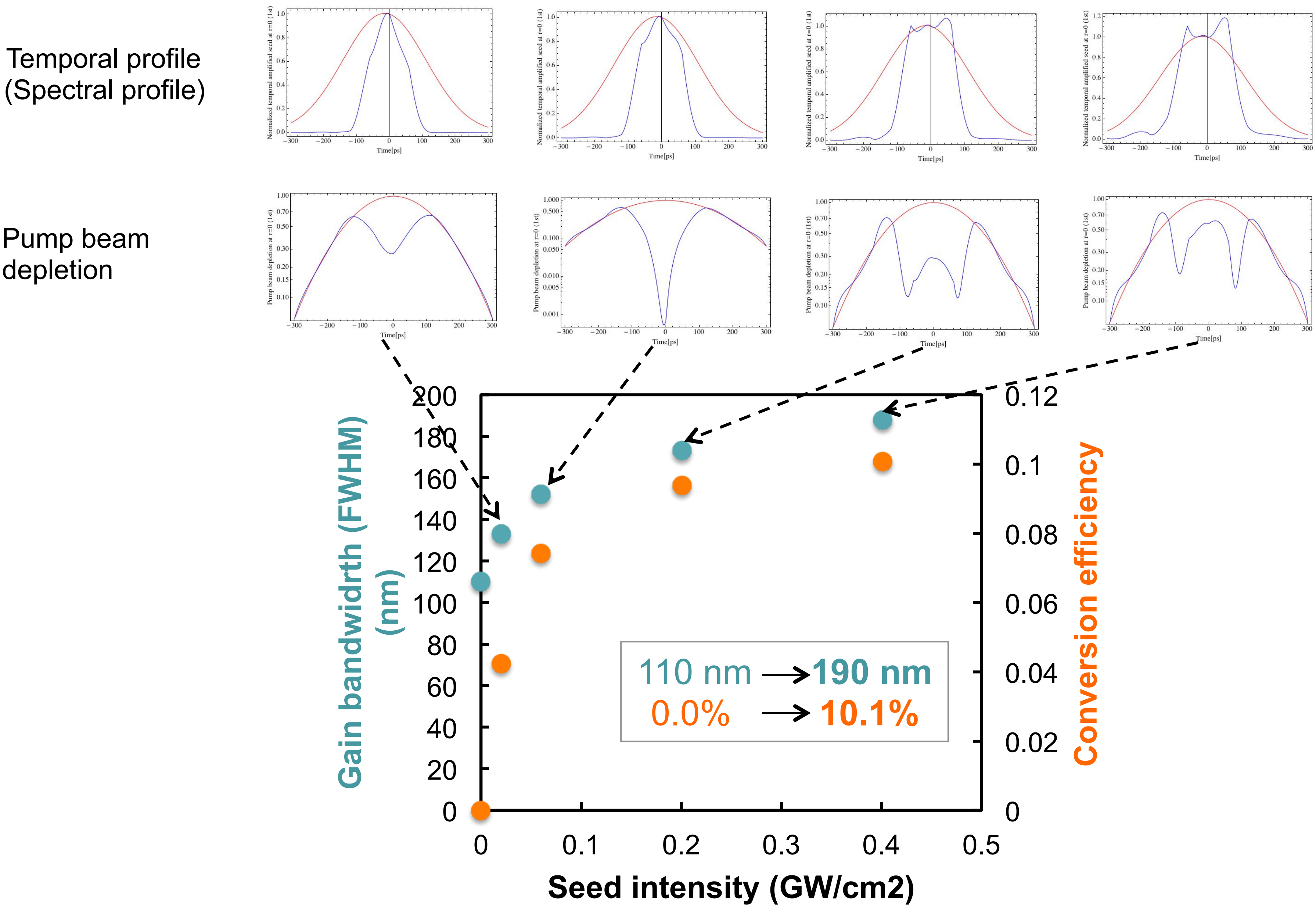



Pumping
  Energy: 8.4 kJ
  Pulse width: 1 ns
  Beam size: 32 cm
  Energy fluence: 10 J/cm$^2$
OPCPA output
  Energy: ~1.2 kJ
  Pulse width: 0.5 ns

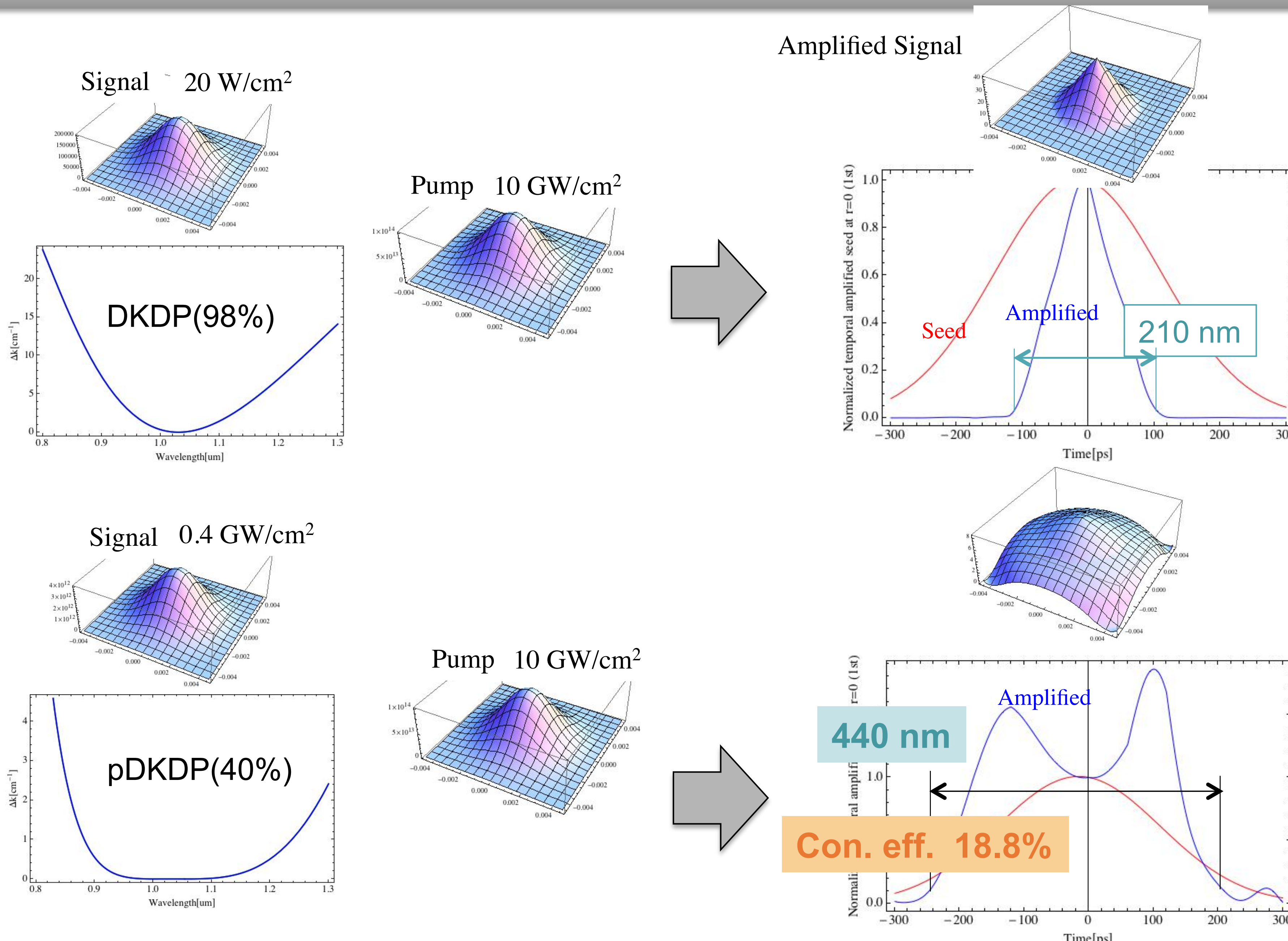
# Deuteration dependence of gain bandwidth (515 nm-pump)



# Gain bandwidth broadening due to gain saturation



# pDKDP(40%) + Gain Saturation in collinear OPCPA



# Summary

We are starting to design “Gekko – EXA” laser system conceptually.

## 1. OPCPA –based sub-EW laser

- Pre – Amp. *DPSSL-pumped OPCPA* ~1 PW @100 Hz
- Main Amp. *Nd:glass-pumped OPCPA* 0.1 EW @ single shot

## 2. Pump source

- DPSSL *Cryogenic Yb:YAG ceramic* 150 mJ @ 100Hz
  $\eta_{o\text{-}o}$=30%
  Upgrade to joule-class
- Nd:glass *Arrayed-beam based on “LFEX” technology*

## 3. Broadband OPCPA in kilo-joule

- p-DKDP *40%-deuteration (515 nm)* 440 nm
  *Non-collinear OPCPA* 18.8%
  *Gain saturation*
- Randam-phase pumped OPCPA

# Collaborators

HAMAMATSU

***GEKKO – EXA design team***

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