Demonstration of High-Contrast, High-Intensity Laser Pulses using an OPCPA Preamplifier in a Double CPA Ti:sapphire Laser System

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Kinkakuji-Temple
40 km
J-KAREN laser
Laboratory
Hawaii
7,000 km
Todaiji-Temple
2 km

Outline

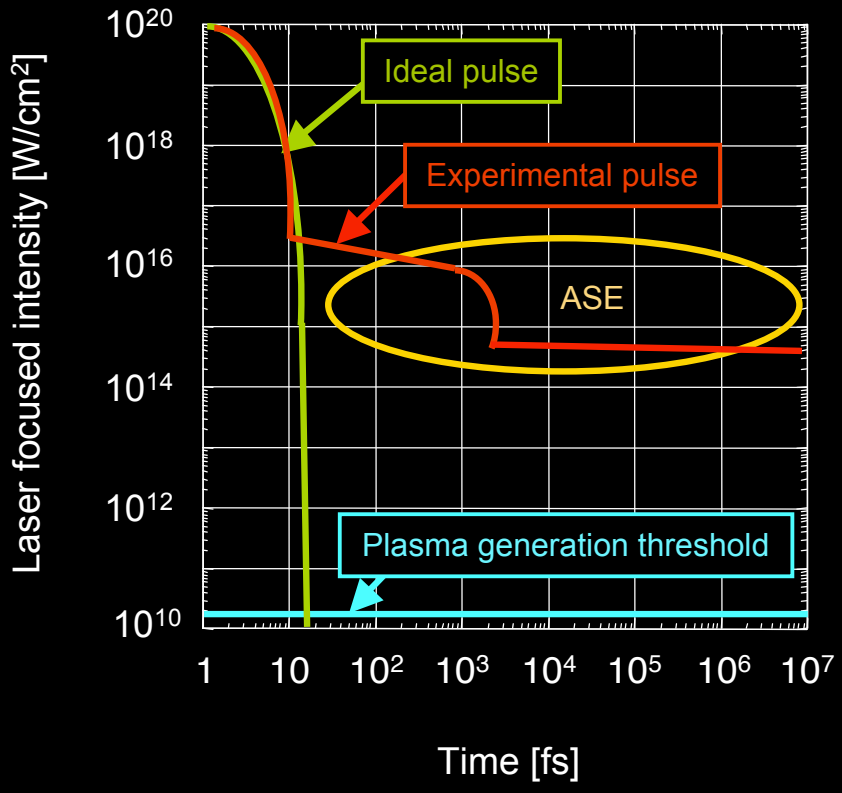
- ✓ Objective
- ✓ “J-KAREN” high intensity laser at APRC, JAEA
- ✓ OPCPA preamplifier
- ✓ Cryogenic-cooled Ti:sapphire power amplifier
- ✓ Results on amplification, compression, and contrast performance
- ✓ Summary

Problem remains to be solved for the application of ultra-high intensity lasers in high-field physics

APR Advanced Photon Research Center

✓ Principal issue with multi-terawatt laser experiments

Modern Ti:sapphire chirped-pulse amplification (CPA) lasers reach intensities greater than 10^{20} W/cm^2. However, in the laser systems, a background of the amplified spontaneous emission (ASE) can generate unwanted plasmas before the main pulse arrives on the target.

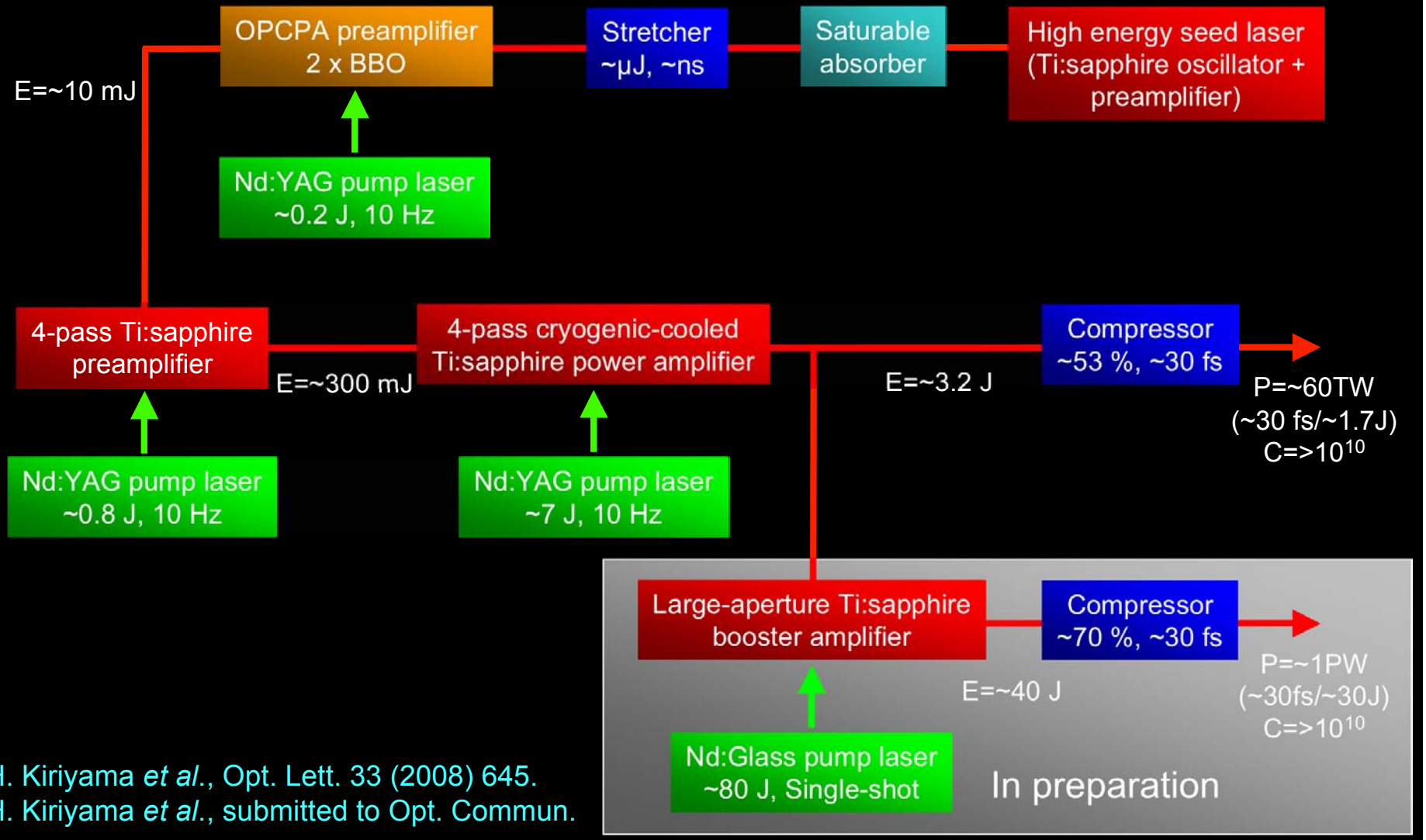


✓ Objective

To develop >10^{10} temporal contrast laser supporting multi-terawatt power level with an OPCPA preamplifier in Ti:sapphire laser system

“J-KAREN” laser schematic

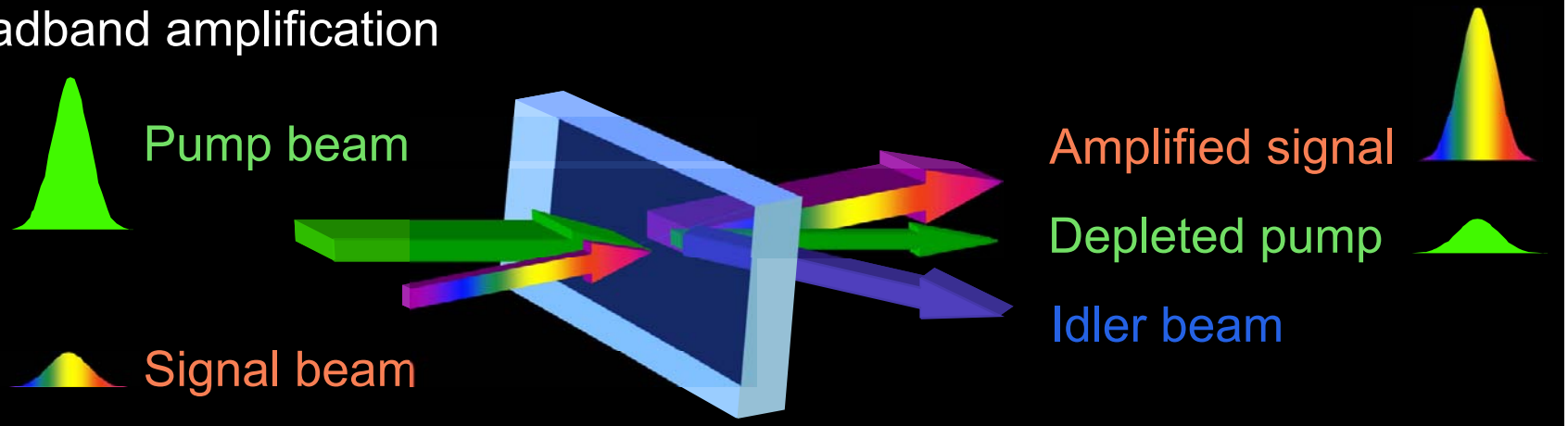
J-KAREN; JAEA Kansai Advanced Relativistic ENgineering



H. Kiriyama *et al.*, Opt. Lett. 33 (2008) 645.
H. Kiriyama *et al.*, submitted to Opt. Commun.

Physics of parametric amplification

✓ Uses a monochromatic laser to provide broadband amplification



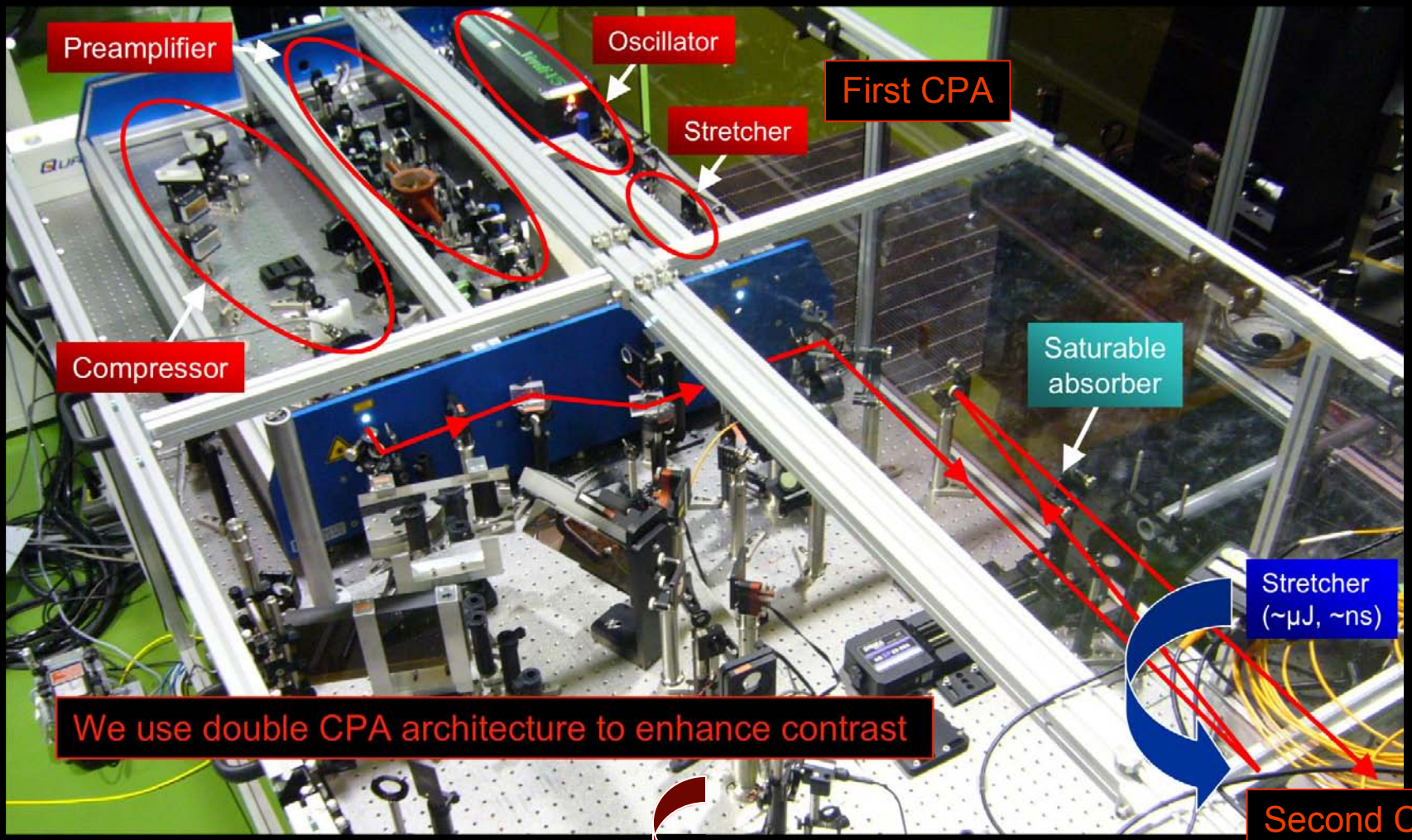
A. Dubietis *et al*., Opt. Commun., 88 (1992) 437.
I. N. Ross *et al*., Opt. Commun., 144 (1997) 125.

Spatial overlap + Synchronized pulses + Phase matching

↓

Energy transfer

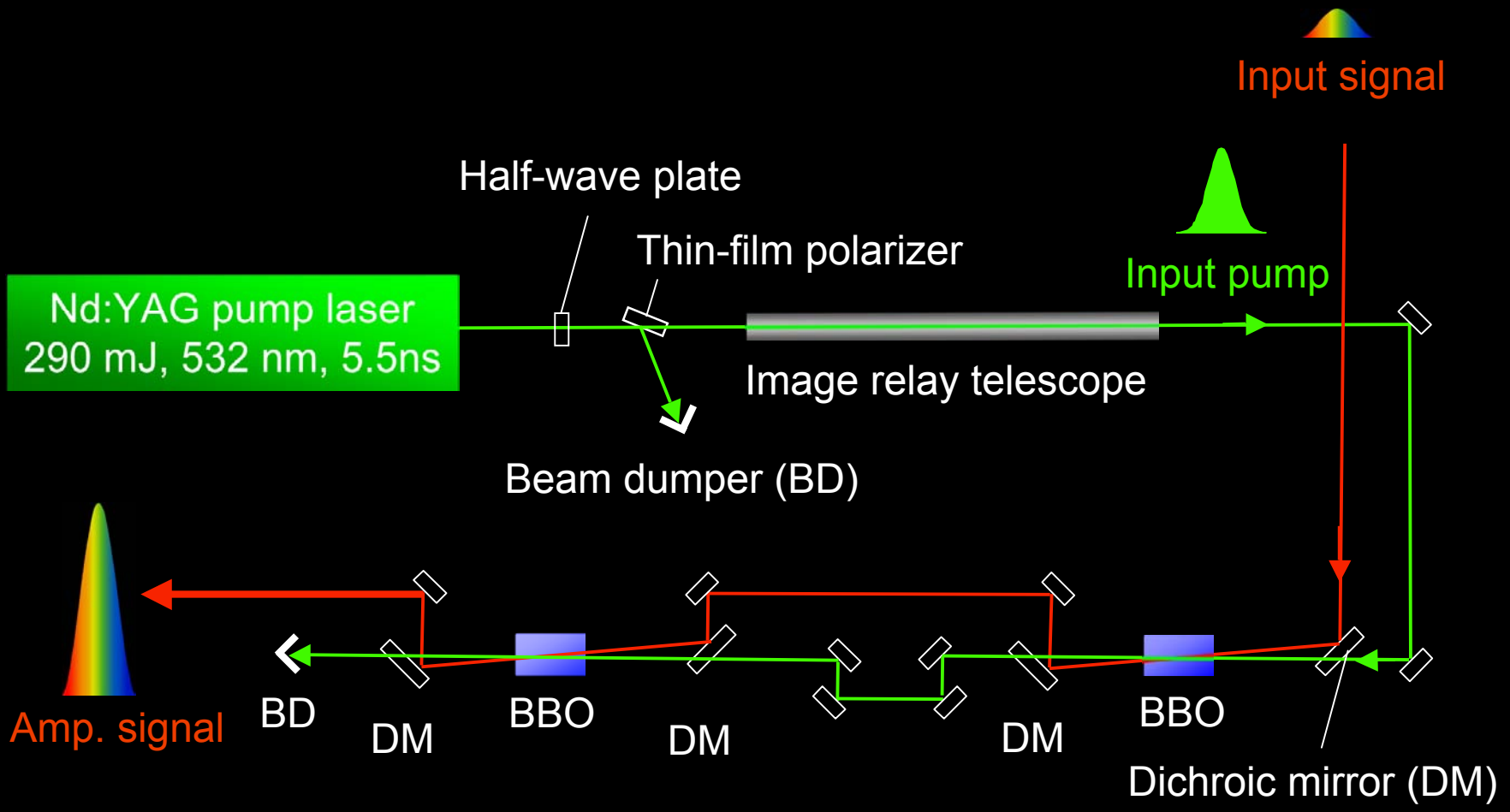
Our front-end can produce cleaned high energy (>μJ) seed pulse for injecting into subsequent amplifiers



M. P. Kalashnikov *et al.*, Opt. Lett., 30 (2005) 923.

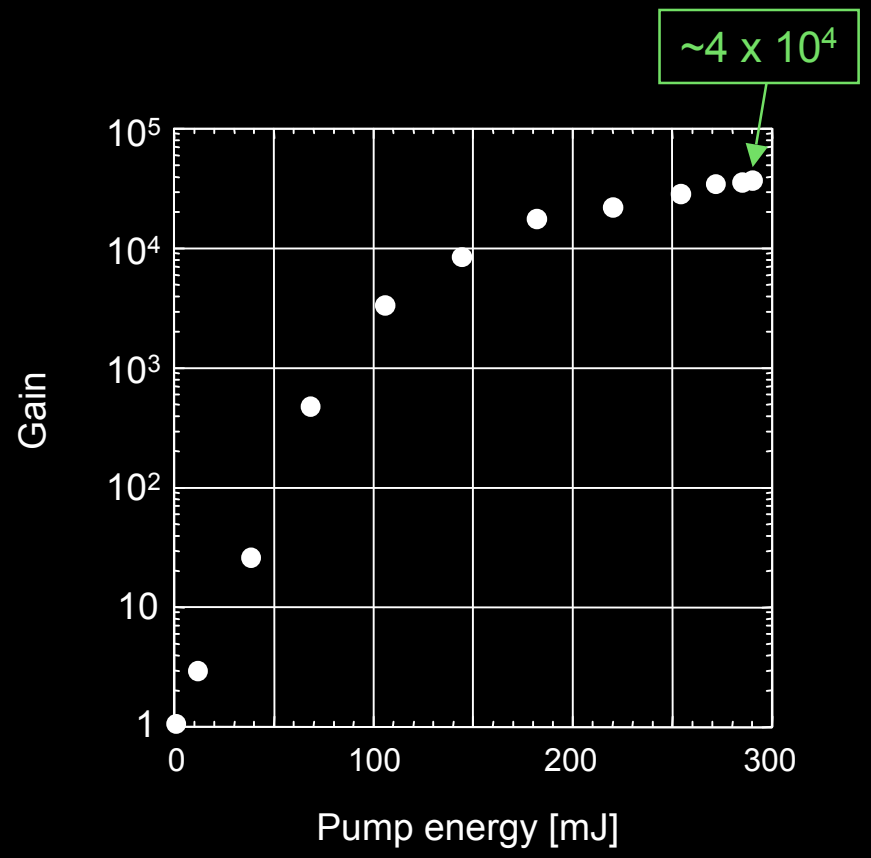
OPCPA technique is used for a high-contrast and broad bandwidth preamplifier

✓ OPCPA preamplifier scheme

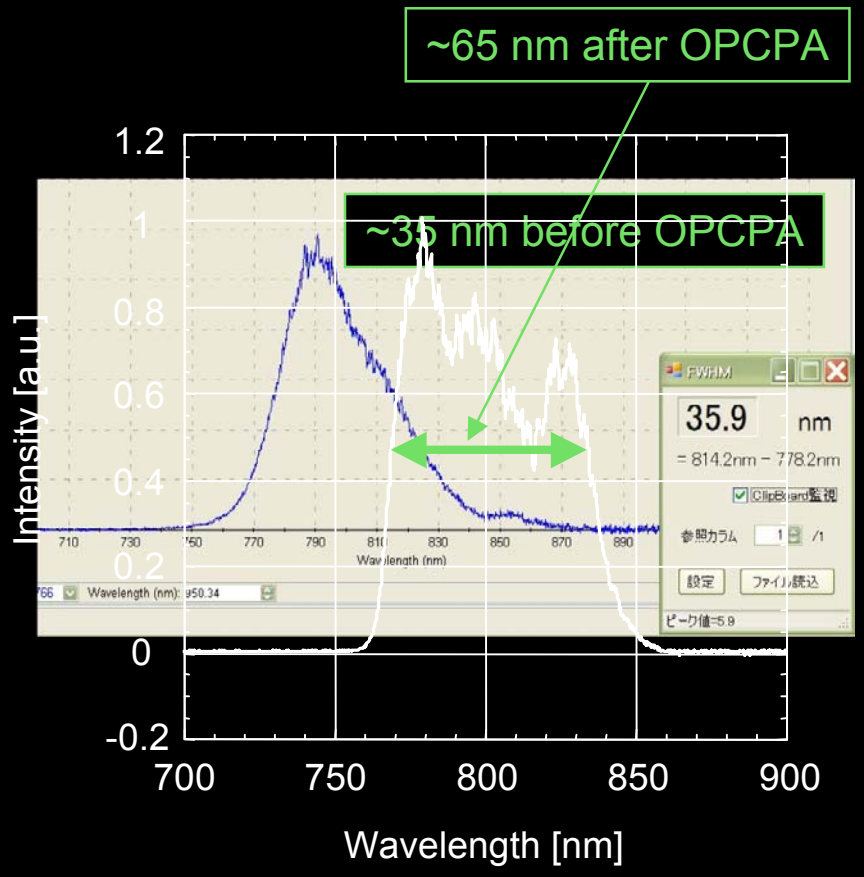


Our OPCPA system amplifies the seed pulse to ~10 mJ with an amplification gain of over 10^4 and is shown to be well suited for broad band amplification

✓ Amplification gain



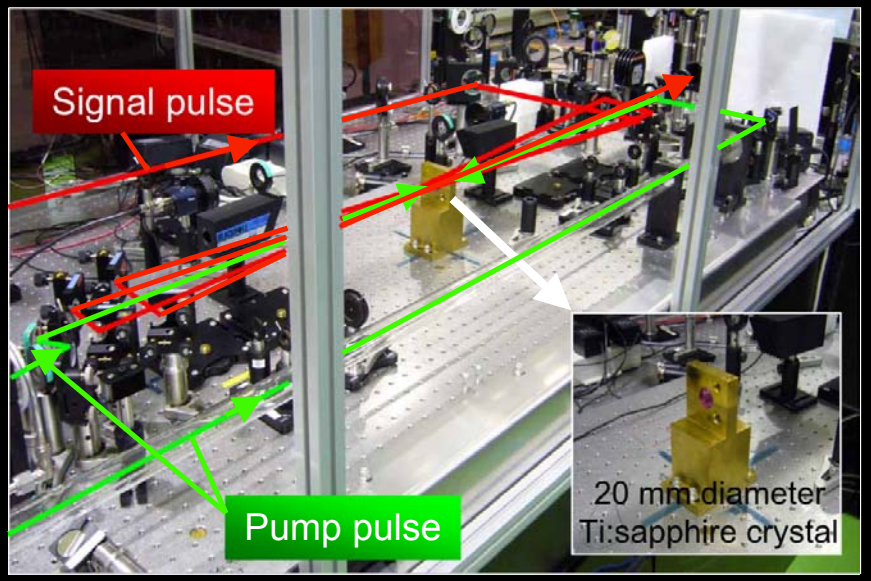
✓ Amplified spectrum



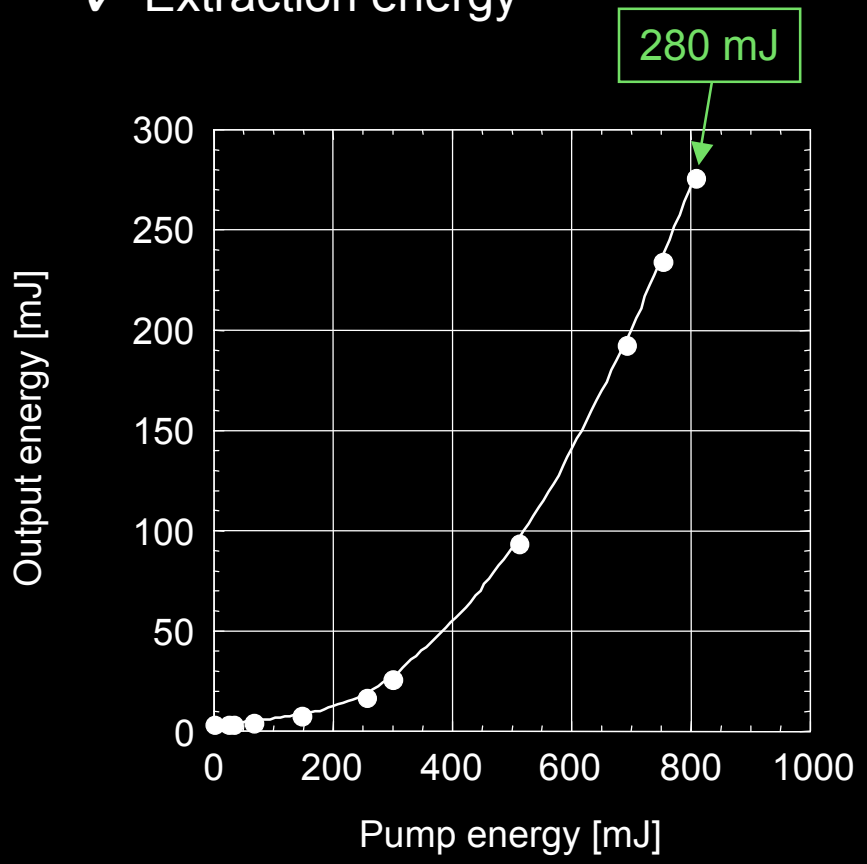
H. Kiriyama *et al*., Opt. Lett. 32 (2007) 2315.

Signal pulse from OPCPA system is amplified to 280 mJ in 4-pass Ti:sapphire preamplifier

✓ View of Ti:sapphire preamplifier



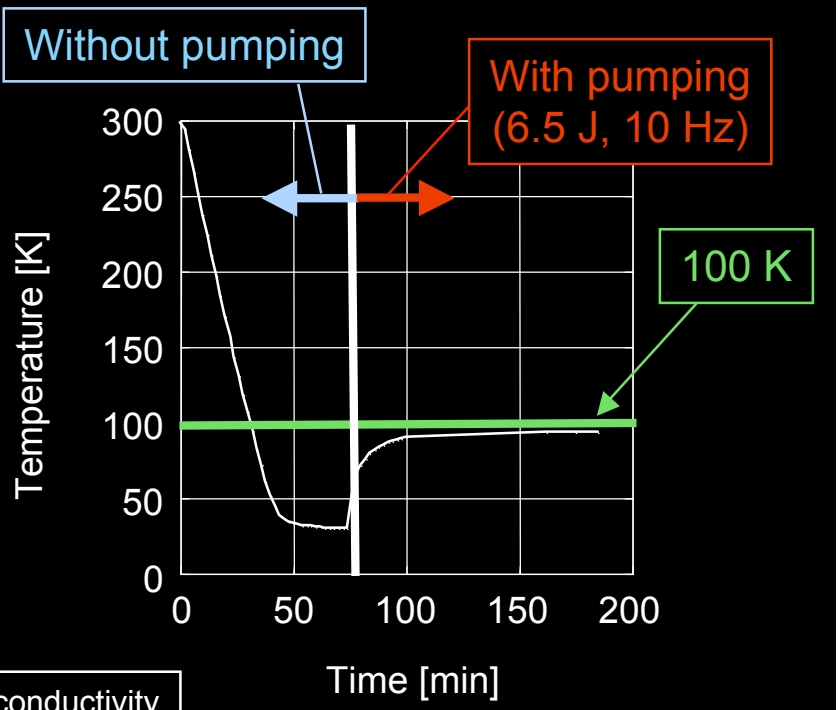
✓ Extraction energy



We cool the Ti:sapphire crystal in power amplifier down to below 100 K, in order to increase its thermal conductivity while reducing the dn/dt, for negligible thermal focusing

✓ View of Ti:sapphire power amplifier

✓ Temperature of the crystal



✓ Thermal focal length

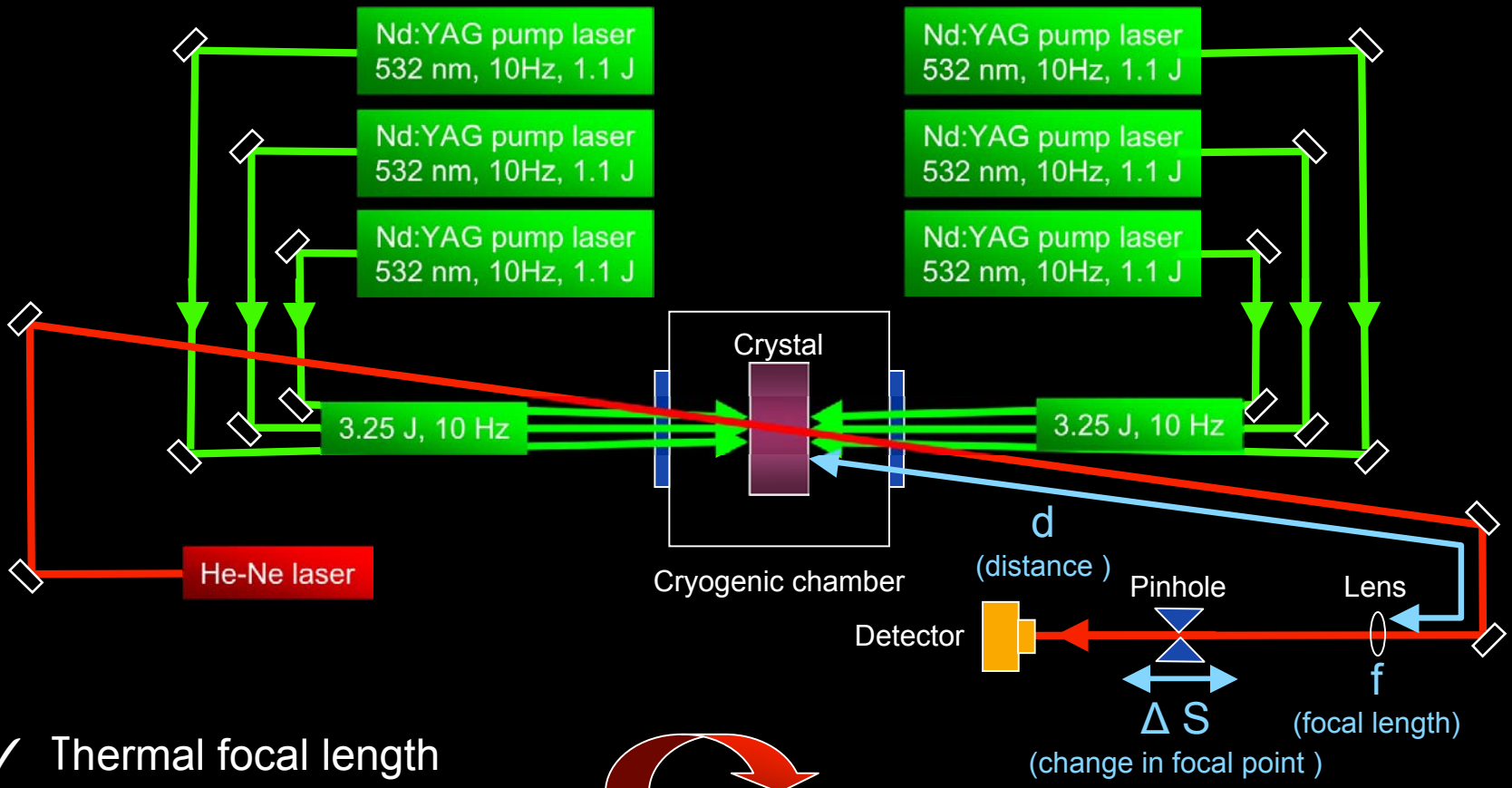
$$f_{th} = \frac{\kappa}{QL}\left(\frac{1}{2}\frac{dn}{dt}\right)^{-1}$$

Thermal conductivity
40 W/mK @ 300K
1000 W/mK @ 100K

dn/dt
1.3×10^{-5} @ 300K
2.5×10^{-6} @ 100K

Thermal focal length is measured to be over 3.8 km at the maximum pumping condition (6.5 J, 10 Hz)

✓ Experimental setup



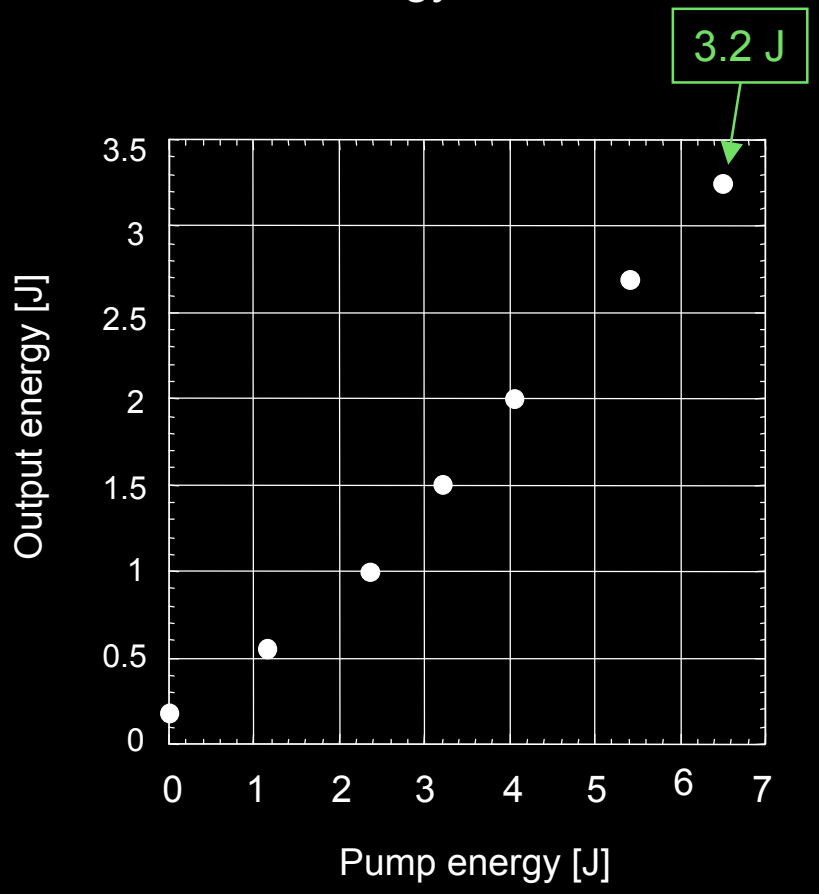
✓ Thermal focal length

$$f_{th} = d - f\left(1 - \frac{f}{\Delta S}\right)$$

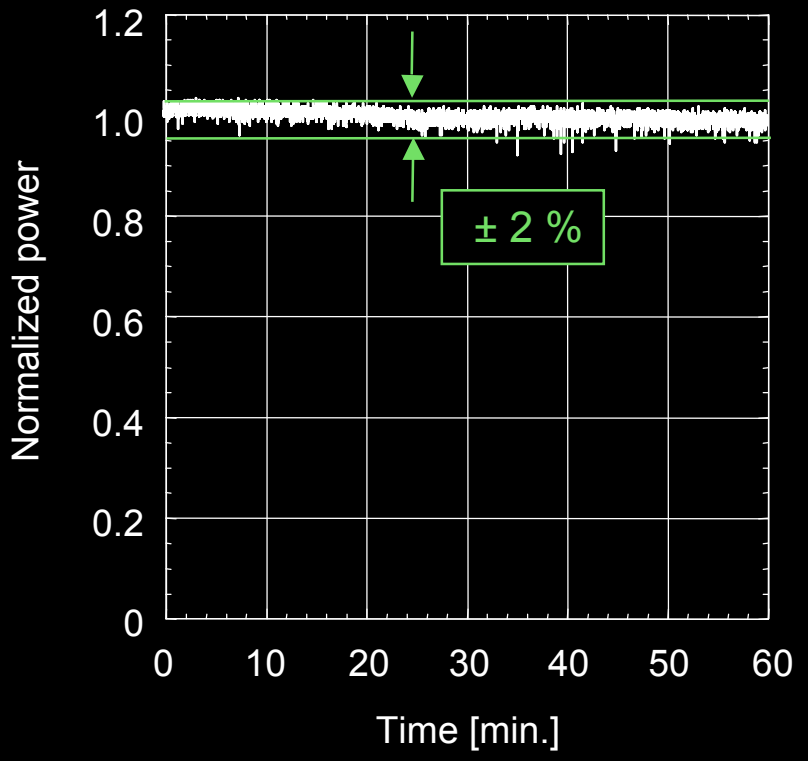
Measured thermal focal length; > 3.8 km !!

Using a cryogenic-cooled Ti:sapphire power amplifier, we amplify further to 3.2 J and obtain good power stability of ± 2 % (36,000 consecutive shots)

✓ Extraction energy

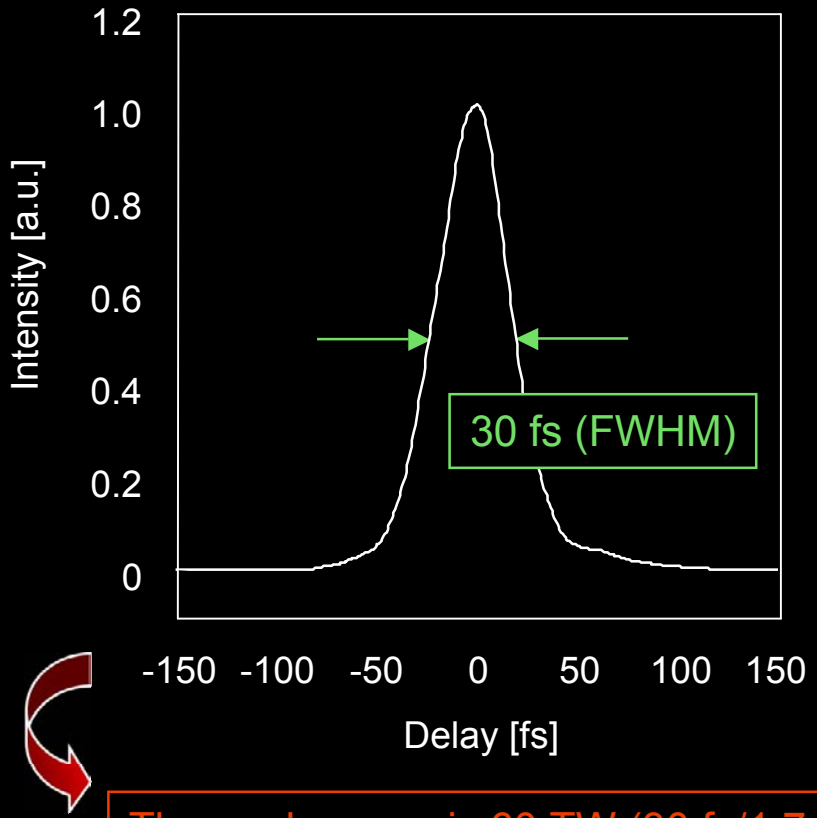


✓ Output power stability



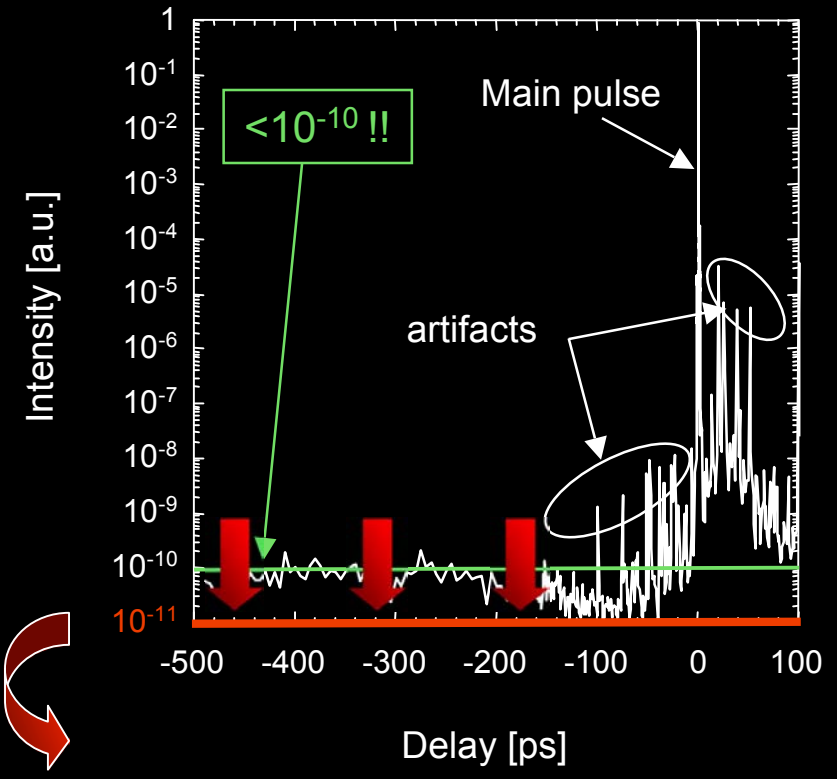
Measured pulse duration is 30 fs with the energy of 1.7 J, corresponding to the peak power of 60 TW and temporal contrast is better than 10^{-10} at 10 Hz

✓ Pulse duration



The peak power is 60 TW (30 fs/1.7 J)

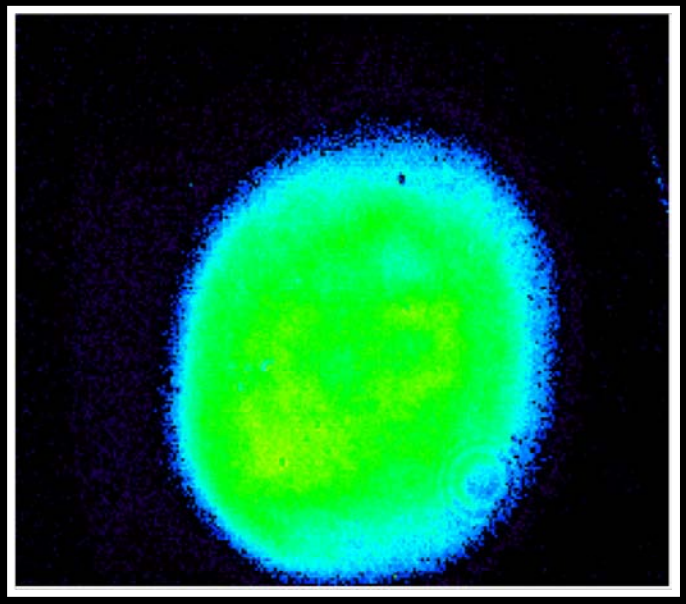
✓ Third order cross correlation



The actual contrast is found to be ~10^{-11} level

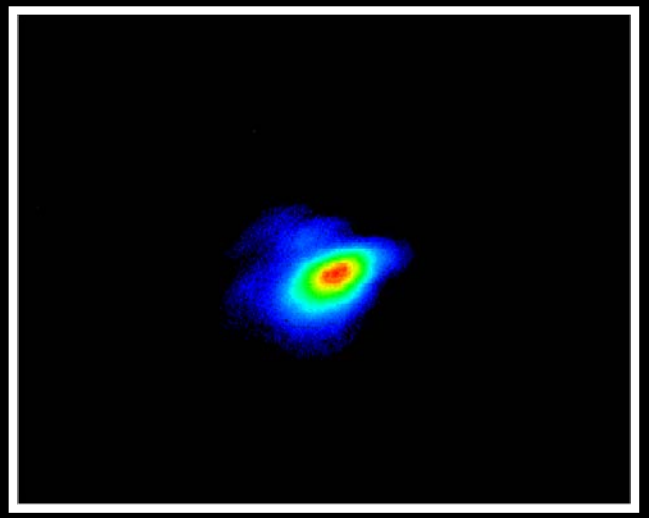
Our J-KAREN laser system generates focused peak intensities in excess of 10^{20} W/cm^2 at 10 Hz

✓ Near-field spatial profile



Homogeneous and uniform spatial distribution

✓ Far-field spatial profile



8 μm x 6 μm (at the 1/e^2 points)

Peak intensity; > 10^{20} W/cm^2

Conclusions

✓ We got over 10^{10} temporal contrast with over 10^{20} W/cm^2 intensity

J-KAREN laser of today;

10^{10} temporal contrast

10^{20} W/cm^2 intensity

10 Hz repetition rate

60 TW peak power

✓ We were encouraged by very successful upgrade

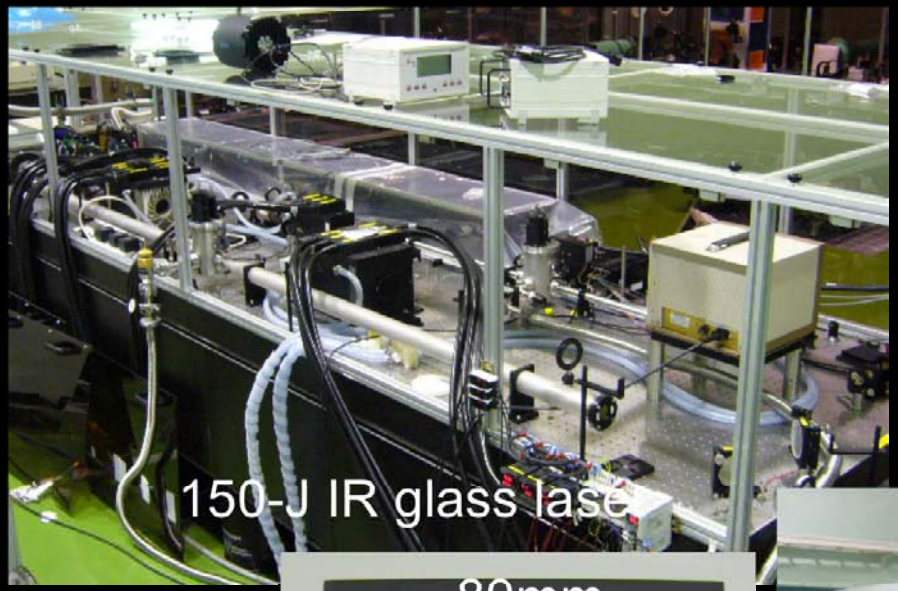
✓ We are currently supplying to laser-plasma accelerator experiments

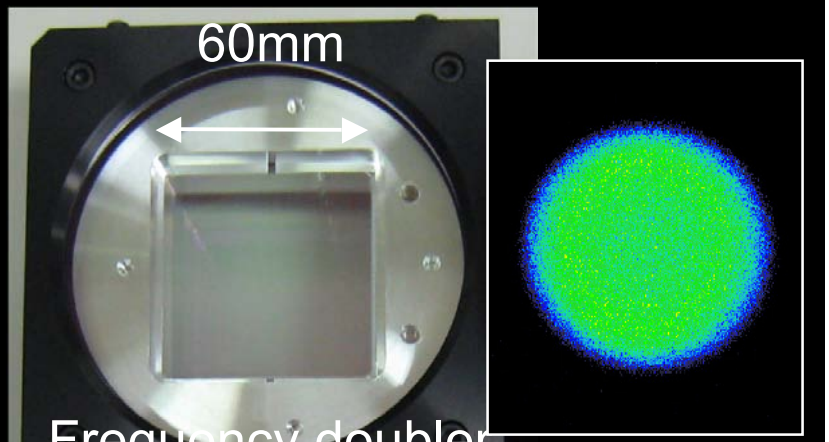
HAMAMATSU HOC USHIO TOSHIBA P M R C photo medical research center NAT PENTAX Fujikura SHIMADZU TOYOTA CENTRAL R&D LABS., INC.

by Prof. P. Bolton, Oct. 31

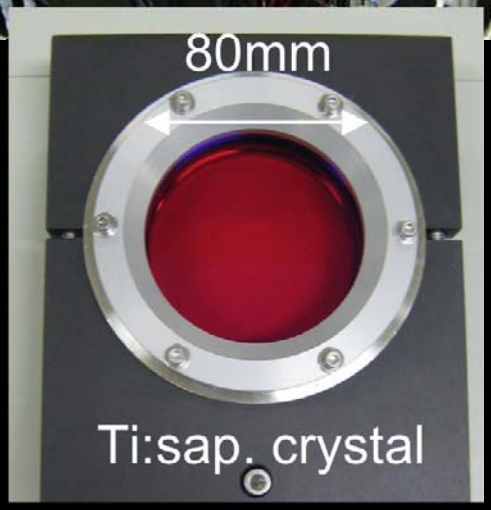
J-KAREN laser of tomorrow ??

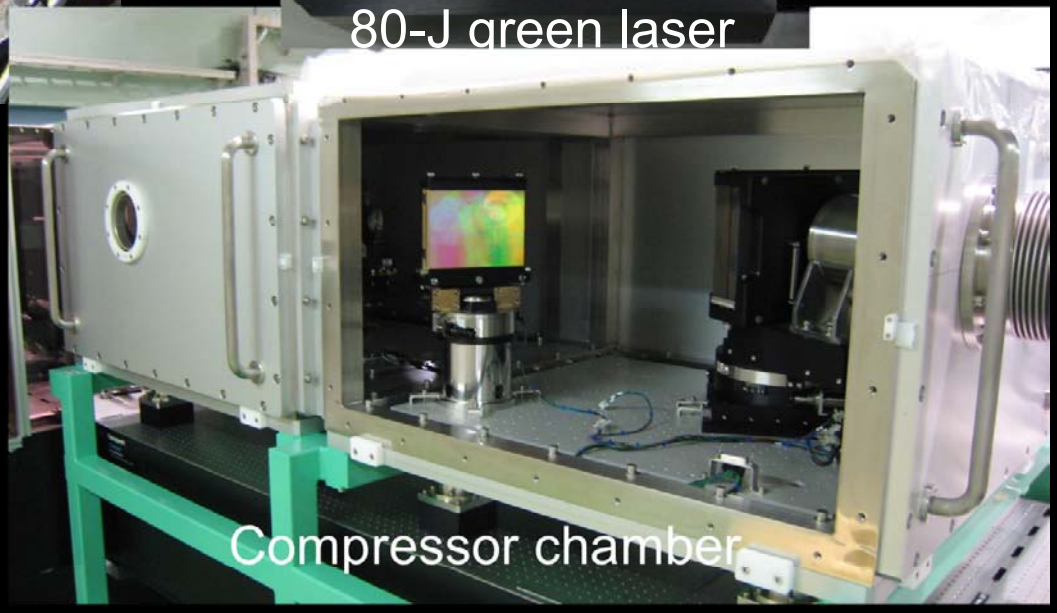
✓ Outstanding issues for supplying PW level pulses -





Frequency doubler
80-J green laser





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✓ Japan Atomic Energy Agency
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