Generation of ENergetic Beam Ultimate (GENBU) Laser
– Main Laser –

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A new diode-pumped laser fusion driver has been conceptually designed at 16-Hz repetition rate, 17% electrical-optical efficiency and less than 3000-m^3 main amplifier size. Output power is 1.2 MJ for a blue compression laser and 0.1 MJ for a heating laser. 1-kJ pulse energy in near infrared is a basic unit to obtain such megajoules energy. We have proposed two new technologies into the system. One is cryogenic Yb:YAG ceramics as a laser material. The other is a large-aperture active-mirror as amplifier architecture. Recently, 1-kJ laser system "GENBU" has been designed in details with these technologies as a milestone for the new driver. A 1-J system "GENBU-Kid" is under construction for power-scaling up to 1 kJ.

Key Words: High Power Laser, Cryogenic Laser Material, Yb:YAG, DPSSL, Fusion Reactor Driver.

1. Introduction

A new diode-pumped laser fusion driver has been conceptually designed at 16-Hz repetition rate, 17% electrical-optical efficiency and less than 3000 m^3 main amplifier size.[1)] Output power is 1.2-MJ for a blue compression laser and 0.1 MJ for a heating laser. 1-kJ pulse energy in near infrared is a basic unit to obtain such mega-joules energy. We have proposed two new technologies into the system. One is cryogenic Yb:YAG ceramics as a laser material.[2)] The other is a large-aperture active-mirror as amplifier architecture.

On the other hand, demands for high power lasers has been investigated in various fields such as space debris remove, cleaning, drilling, welding, peening, plasma diagnostics, laser-driven rays, nuclear reaction and so on, shown in fig. 1. As a result, two goals for high power laser to open novel application fields are shown in table 1, a high power pico-second laser and an ultra high peak power laser, respectively. A repetition rate is 100 Hz. The pulse energy of the high power laser is 1 kJ, which is same as the basic unit of

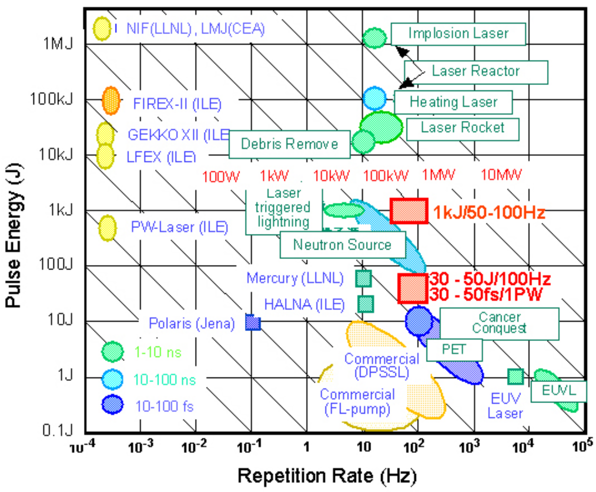

Fig. 1 Pulse energy and repetition rate in applications and recent laser specifications

Table 1 Two goals for the next generation of high power lasers.

Main Laser	1 kJ, 10~100ps, 50~100 Hz, 50~100 kW
Ultra-short pulse Laser	30~50 J, 30~50 fs, 1PW, 100 Hz, > 2 x 10^{21} W/cm^2

the new reactor driver. A “GENBU” laser has been conceptually designed to reach the goals. Also, cryogenic Yb:YAG ceramics and large-aperture active-mirror were adopted in the design, that leads to basic researches of the new reactor driver.

2. “GENBU” Laser - Main Laser -

“GENBU”-laser was conceptually designed for not only reactor driver development but also various industrial applications. Policies on designing “GENBU” laser were set as the followings.

(i) The laser system is attractive for various industrial applications with high power, high efficiency, high repetition rate and compact size.
(ii) Four excellent characteristics mentioned above be reached simultaneously. Challenges to new technologies are, therefore, necessary.
(iii) Power Scalability and true reliability invest the system.
(iv) Technical issues are made clear in designing.

The “GENBU” laser consists of two laser systems, a main laser and an optical parametric chirped-pulse amplification (OPCPA) laser, shown in fig. 2. The main laser generates 1-kJ output pulse energy with 100-Hz repetition rate, which is a milestone in the new reactor driver developments. Specifications of the main laser are shown in table 2. Chirped-pulse amplification is adopted for the final pulse duration of 10~100-ps. A 30-fs pulse from a front end oscillator is temporally stretched at 1 ns. A combination of a fiber amplifier and a regenerative amplifier increase its pulse energy to 1 J. A Yb:YAG ceramics is used between 160 K and 200 K as a laser material in two main amplifier chain.

Table 2 Specifications of main laser.

	100 J	1 kJ
Wavelength	NIR（~1030 nm）	
Pulse Energy	100 J (50J@515nm)	1 kJ
Pulse Duration	20 ps	10 ~ 100 ps
Pulse Waveform	sech, Rectangle	
Beams	1	
Spatial Homogeneity	< 5%	< 10%
Beam Shape	Circle, Rectangle	
Rep. Rate	100 Hz	

Active-mirror amplifier architecture is also tested with large aperture. A rough image of the first amplifier is shown in Fig. 3. A seed pulse is amplified via five active mirrors and reflected for the second pass by a deformable mirror at the end to compensate its wavefront distortion. A Pockels cell is used to prevent amplifying spontaneous emission. The laser pulse energy increases at 200 J with a 50-mm beam diameter. The second amplifier with seven active mirrors gives 2 kJ with 150-mm diameter. After a pulse compressor, a 1-kJ, 10~100-ps pulse is obtained. The main laser is also used as a pump source of the OPCPA laser. A laser pulse is extracted after the first main amplification. By using a pulse compressor and a frequency converter, a 50-J. 20-ps green laser is generated. In the OPCPA laser, a coherent white light is generated by irradiating a femto-second pulse into a sapphire plate and temporally stretched at 8 ps. Via three stages OPCPA with two BBO crystals and a DKDP crystal, a peta-watt peak power is obtained at 5~50-fs after pulse compression. A beam size is 85 mm in diameter. A size of the “GENBU” laser is 12m x 6m.

Several kinds of basic and technical issues are not avoidable in “GENBU” laser development. Higher brightness of laser diodes is strongly desired for intense pump. Decreasing emitter space leads to increasing spatially-averaged emission density. Higher damage-threshold coating makes high photon density operation, resulting in a compact system size with a small beam diameter. Optics as grating, Faraday rotator and Pockels cell with large aperture size and higher thermal strength are useful for improving laser performance. A 1-J, 100-Hz laser system “GENBU-Kid” is under construction to demonstrate a cryogenic Yb:YAG laser ceramic and a

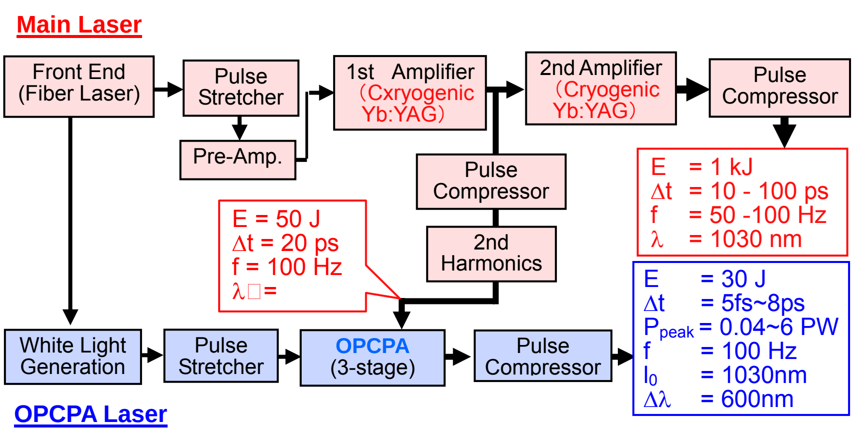

Fig. 2 Systematic diagram of the “GENBU”-laser.

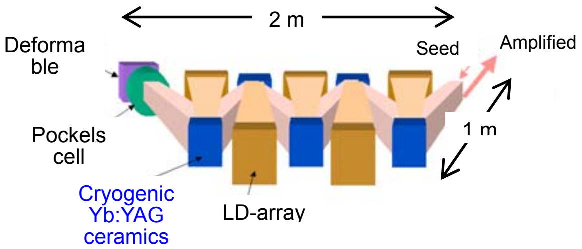

Fig. 3 Brief design of the first main amplifier.

large-aperture active-mirror at joule-class energy and to obtain several parameter for power-scaling.

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