총회초청강연 I

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Topics on Power Photonics for High-Power Solid-state Laser

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The inertial fusion research at ILE, Osaka moves to the fast ignition scheme with using PW laser system to achieve hot core plasma of keV-temperature by heating additionally the dense plasma imploded by the multi-beam Gekko laser system. The solid-state lasers have been developed of the peak-power from TW to PW region with the chirped pulse amplification (CPA) and optical parametric amplification (OPA) technology. Fig. 1 shows a history of development of sub-ps laser systems including Nd:glass and Ti:sapphire lasers. Broadband amplification at a solid-state laser is a key issue for amplification stage of CPA system. Also, OPA scheme (see Fig.2) gives high gain amplification with a very low pre-pulse level keeping easily 5-nm bandwidth. Also the thermal-distortion-free 10-ns-class repetitive peak-power laser is requested as a pumping source of Ti:sapphire laser.

Average power operation of solid-state laser is strongly affected by the thermal problems in the laser material. A nonlinear optical technology using the stimulated Brillouin scattering (SBS) is promising to compensate thermal difficulties caused at a strongly pumped material. The SBS is well known as a phase conjugation mirror (PCM) used in an average power output with high reflectivity over 95%. (Fig. 3) A liquid fluorocarbon with a special treatment works as PCM at 10-ns duration, 50-Hz repetition delivering 6-J, 300-W average power (Fig. 3). A liquid flowing system in an SBS cell realized the PCM behavior up to over kW-class average power.

The new average-power-laser materials such as doped silica and ceramic YAG for a scalable solid-state laser will be reviewed. In these ten years, Japanese researchers have investigated new transparent silica and ceramic YAG materials for industry application that have a lot of advantage for an average power laser. The output energy of peak power laser is limited by a volume(stored energy) and diameter(fluence) of the laser materials. A quartz glass has high thermal shock parameter due to its low expansion coefficient. In general, there is a difficulty to dope oxide ions to silica glass because the clustering results in fluorescence quenching. We invented a new doping process of ions to silica glass.

High-rate doping of fluorescence emitting ions to silica glass had been achieved with zeolite powder that has a cage-like structure. A silica-rich zeolite can be doped over 30% concentration of Nd oxide. The uniform dispersion of doped zeolite power to silica glass was made without clustering of Nd-oxide in the silica glass. In this research process, there are some inventions of new fluorescent lines of bismuth and copper. Bi ion in silica glass delivers 1.25 μm in wavelength with very broad band emission of 150 nm having a life time of 600 μs, that is useful for an amplifier of the 1.3μm optical communication. Copper ion in silica glass has strong and broad fluorescence at 0.55 μm with absorption bands at 0.3and 0.4μm, which is available as a sensitizing ion absorbing ultra-violet components of flash lamp light or solar light. (Fig.4)

YAG is an excellent host crystal, but its size is limited by fabrication process. The ceramic media have a lot of advantage for average power laser, such as high doping rate, co-doping potentials, large size fabrication, and composite structure. A ceramic YAG co-doped with Cr and Nd shows good excitation property of 1.06μm fluorescence. (Fig. 5) Cr ions have two absorbing band at 0.44 and 0.55μm, and its fluorescence at 0.78μm(lifetime of 1.8ms) matched to Nd absorption band. Emission efficiency pumped by a flash lamp is enlarged so much.

The ceramics has a wide design potential by using the ensemble property of small crystals such as an emission spectrum control, emission/absorption mixing material, layered composite structure, functional nano-size structure, so on.

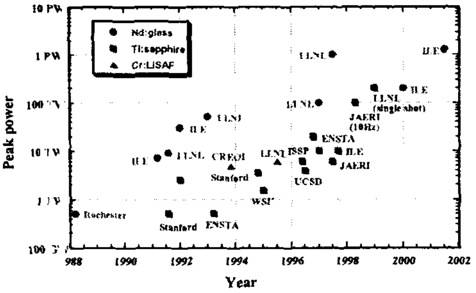


Fig. 1 History of under-ps lasers (left). Abbreviations show institutes.

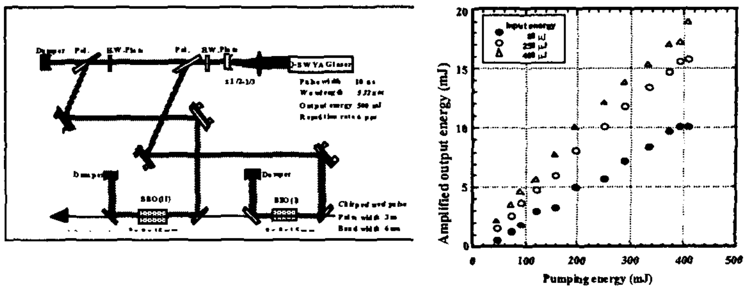
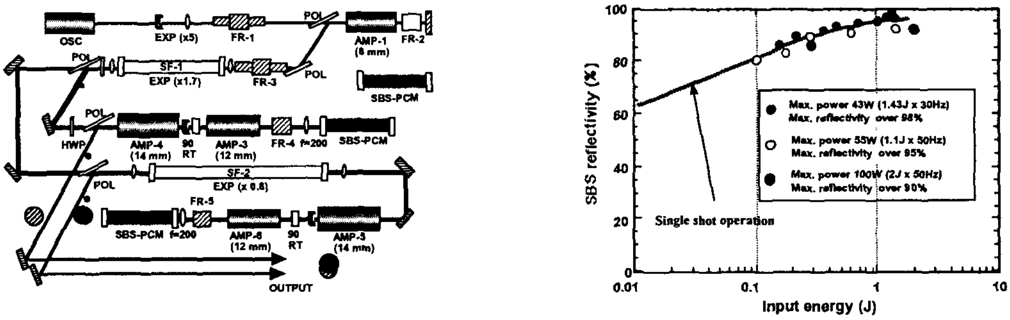
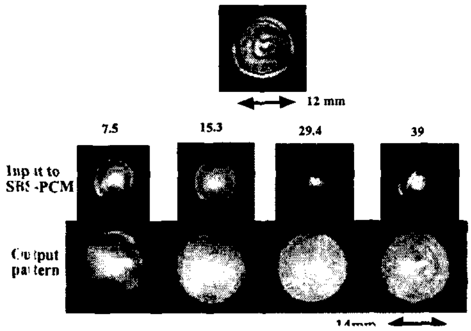


Fig. 2 Typical OPA system at ILE, Osaka (center) and its output characteristics (right).





ical system of 6J/50Hz YAG laser (left, up), with SBS reflectivity (up) and beam pattern recovery from the effects of diffraction & thermal deformation (left)

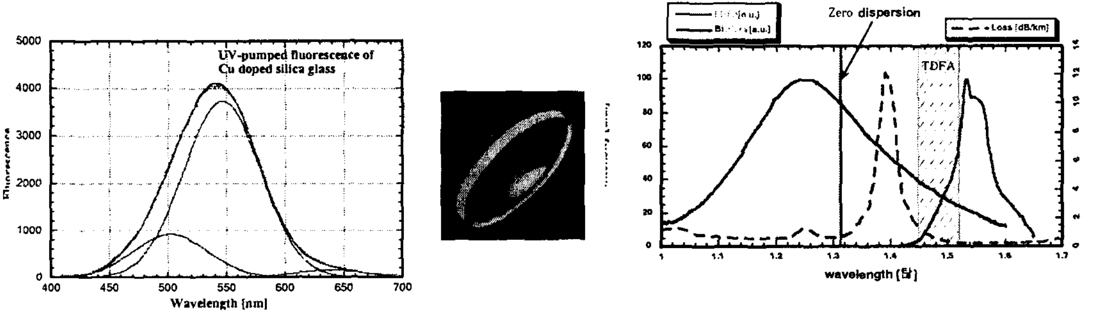


Fig. 4 Green fluorescence of Cu-doped silica glass (left), and 1.3μm emission from Bi-doped silica glass compared with Er-doped silica (right).

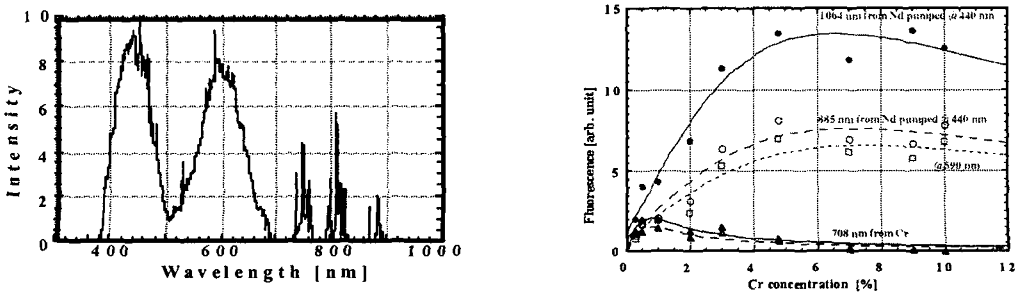


Fig. 5 (left, excitation spectrum), Cr;Nd:YAG ceramics shows an broad excitation property of 1.06μm emission from Nd, (right) Cr doping dependence of 1.06μm emission with enhancement factor over 15.