S8-4 Plasma Diagnostics by Laser with Phase Conjugation Mirror
位相共役鏡支援によるプラズマのレーザー計測

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The phase conjugation effect is described by Stimulated Brillouin Scattering process in a transparent medium. This nonlinear effect was used to compensate a thermal effects occurred in the strongly pumped solid-state YAG laser at Thomson scattering system of JT-60U. Also a new scheme of scattering technology will be presented to improve an energy efficiency of laser system by SBS-PCM, achieving a repetitive use of the laser beam in a scattering optics.

1. Introduction

In the field of *Nonlinear Optics*[1], there is a term, *Stimulated Scattering* in which category an acoustic wave in material works as a grating to scatter a light beam, called as Stimulated Brillouin Scattering (SBS). The scattering rate of a light, wherein it is reflectivity because of a back-scattering process, depends on the incident light energy, reaching near 100% for an intense laser beam. The reflected light has a property of the phase-conjugated wavefront against an incident light. Then this process is usually used for phase compensation during passing through a transparent aberrator.

In this presentation, the principle of SBS process is introduced in detail, and its application will be discussed to compensate a wavefront aberration in the solid-state laser used in the Thomson scattering system at JT-60U, JAERI, and also to present a new scheme of scattering technology for improving an energy-efficiency of the laser utility.

2. Principle of Phase Conjugation Mirror

The phase conjugation effect was discovered in the early 1970s by Zel'dovich *et al.*[2]. SBS process is the three-wave interaction between an intense incident pulse, a reflected wave that builds up from a noise level and an acoustic wave that is pumped by interferometry effect of previous two optical waves. As this acoustic grating has a same shape of wavefront as the incident pulse, the reflected wave has a phase-conjugated wavefront of the incident one. This is one of the most common nonlinear optical processes for achieving a quasi-phase conjugate wave with a small Brillouin frequency shift of 1 GHz. The part of the nonlinear optical medium that causes phase conjugation is called a "phase-conjugate mirror (PCM)" to distinguish it from a standard reflective mirror.

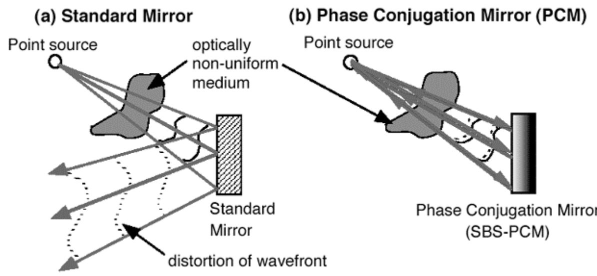

Fig.1 Difference of reflected-beam wave fronts from a) conventional mirror and b) SBS-PCM.

In recent years, several liquid or solid materials, having a very high laser-damage threshold and high reflectivity, were found applicable to the high performance SBS-PCM[3-5]. Heavy fluorocarbon liquids after treatment of severe purification were found to be an ideal medium for the SBS-PCM. For example, fluorinert FC-75 made at 3M, Ltd. shows very high reflectivity ~98% at 14 J of an incident laser energy. For the average peak power laser, a repetitive operation of PCM was also developed up to 20 kW depending on absorbance of liquid.

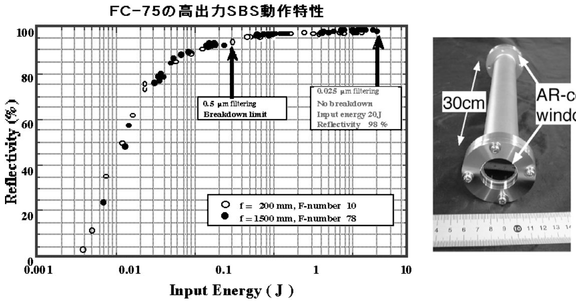

Fig. 2 Reflectivity of SBS cell for 1064-nm, 20-ns YAG pulse.

3. Compensation of Thermal Effect by PCM

The SBS-PCM is a good tool to compensate the thermal lens effect that causes in a heavily pumped YAG laser rod. The thermal load to a laser rod makes strong temperature gradient in a rod that affects a beam transmission by the distribution of an index coefficient as a lens. Figure 3 shows the amplified beam patterns with and without using SBS cell as a reflector in the double pass amplifier. The depolarization effect in the crystal rod gives also a strong loss through a polarized loss in an amplifier system that including many polarizing optics. The phase conjugation mirror reflects a laser beam with very accurate returning path at YAG rod, and then depolarization can be compensated by polarization rotation with a Faraday rotator set in front of a SBS cell.

The far-field patterns are also shown in the figure that makes evidence of phase conjugation effect keeping a diffraction limited beam property.

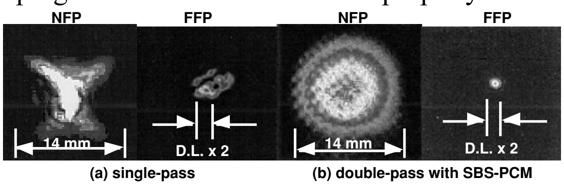

Fig. 3 Near-field and far-field pattern a)without and b) with using SBS-PCM at YAG rod amplifier.

4. Improvement of Thomson-Scattering Laser System

.The phase conjugation mirrors were installed on the YAG laser system in the Thomson scattering diagnostics at JT-60U, JAERI. Without major changes of the components of laser system, a laser staging was changed from a MOPA (master oscillator and power amplifier) configuration to a double-pass amplifier with SBS-PCM as a reflector. After changing a system design to a two-beam staging, the output power level was increased finally 8 times higher than the original design as shown in Fig. 4. The beam brightness is also improved about 10 times by improving the depolarizing property of the beams[6], that was very effective in focusing beams in to the plasma vessel.

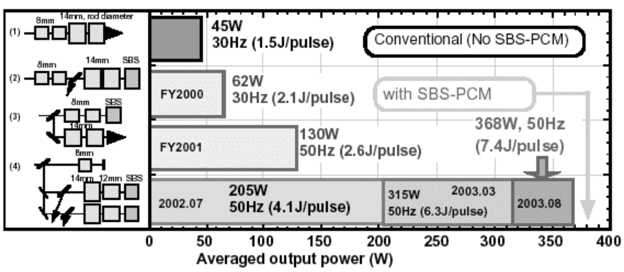

Fig. 4 Improvement of output power of YAG laser system of Thomson scattering diagnostics at JT-60U, JAERI.

5. New Scheme of Scattering Diagnostics

Another proposal at the Thomson scattering system is a double-pass configuration with using a SBS-PCM set at an initial dumper position after through JT-60U plasma (see Fig. 5). The laser beam passing through a plasma is reflected back again to the plasma chamber for a second pass. In the experimental test at JT-60U, a scattering light was increased about 60%.

Figure 5 shows a new scheme of scattering optics for multi-pass system with two SBS cells set both side of a plasma chamber[7]. The laser pulse will be confined in a scattering pass by an large Pockels-cell optical switch and a thin-film polarizer. A simple calculation for designing this optics shows a drastic increase of the scattering light level to 20 times higher than a case of single pass if a system loss is only 5% showed in the insert of Fig. 5. The small frequency shift in SBS cells does not affect a spectral response of Thomson scattering.

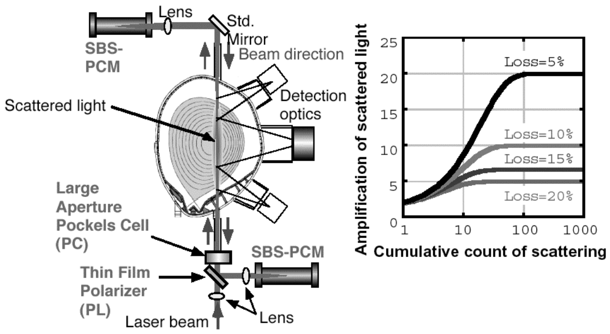

Fig. 5 New scheme of laser transmission into Tokamak plasma increases scattering light by multi-pass configuration.

6. Summary

The phase conjugation method by the stimulated Brillouin scattering is very useful tool to compensate the thermal effects in the YAG rod amplifier, and also to increase the Thomson scattering light from plasma by multi-pass configuration.

The purification of liquid material for SBS process gives a very high laser damage threshold to use a high peak power laser, and a flowing method of liquid in a SBS cell is verified to achieve an availability of over 20-kW average laser power into a cell.

References

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