Feasibility Study of the High Power Laser System with Beam Combination Method Using Phase Conjugation Mirrors of Stimulated Brillouin Scattering for Generating an Ultra High Power Output with High Repetition Rate over 10 Hz

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Abstract

The feasibility of a new high power laser system for producing an ultra high power output with high repetition rate over 10 Hz will be studied in this work. Phase conjugation mirrors using a stimulated Brillouin scattering will be used to accomplish it and the main goal of this work will be focused in how to get the phase locking of many beams (>10) in the beam combination using the stimulated Brillouin scattering phase conjugation mirrors. The author suggests three new methods to phase lock. If one of them is proved practically useful to lock many beams over 10 up to millions, the high power laser with unlimited output energy with high repetition rate over 10 Hz will be possible to realize and it will enhance the commercial IFE in near future.

1. Introduction

For realization of IFE for commercial application, ICF using a high power laser needs a laser driver with an ultra high output power over MJ and its repetition rate over 10 Hz. The main barrier of the realization of such a high power laser is the cooling efficiency. The laser rod or discs should be cooled efficiently for the laser system operationable over 10 Hz. The laser rod whose diameter is over 3cm is almost unable to operate over 10Hz due to the thermal stress problem. To solve this thermal stress problem, the beam combination methods have been developed using an SBS-PCM (Stimulated Brillouin Scattering Phase Conjugation Mirror). The beam combination method splits the wavefront of the laser beam and amplifies them separately, and then combines them again as shown in FIG. 1. Each amplifier arms has a gain medium and Faraday rotator and phase conjugation mirror such as SBS-PCM. The main problem in this method is to lock the phases of the beams. The phases of the beams reflected by SBS-PCM are random due to the characteristics of the stimulated Brillouin scattering, which occur from the acoustic noise. It is necessary to lock those phases to get a good beam combination result. If the phases are random, the beam combination gives a speckle pattern in the boundary area between the combined beams. To lock the phases, 2 ways were suggested, one of them is overlapping the focal points [1]-[5] and the other is back seeding method [5]-[7], as shown in FIG.2 (a) and (b), respectively. The former method becomes impractical if the number of beams are over 10, for the alignment is to be very difficult and also the overlapped focal point will be break down due to the high power laser beams focused in one point. The latter method looks like makes the total system very complicated if the number of beams large over 10. For example, to get a mega-joules output energy using a beam combination technique by 2cm diameter laser rod, 1,000 X 1,000 laser rod array should be built up. In this case, we must develop an innovative method to lock the phases, which must be easy to align and maintain the system.

For this purpose, the author suggests two innovative methods, self-phase locking and acoustic injection locking, and will study its feasibility to apply it to the fusion driver in this project.

2. Suggestion of the innovative system

The author suggested an ultra high power laser system which can operates with the repetition rate over 10 Hz by beam combination technique [8]-[11]. FIG. 1 shows the basic idea of the suggested system. The system is composed of the symmetric cross type which has great advantages; insensitive to the misalignment of the optical components as shown in FIG. 3 and gives perfect optical isolation between the neighboring amplifiers and compensate any thermally or optically induced birefringence of the in-between the optical components. The cross type system having two symmetric SBS-PCM in each arm compensates any misalignment of optical components shown in FIG. 3(a). The left side of it has no gain medium but SBS-PCM only acts as a perfect optical isolator, which blocks off perfectly the back reflection from a post amplifier system. These two advantages give the many beams combination practically possible, especially over 10. The main problem remained is how to lock the phases of the beams. The suggested methods by the previous works [1]-[7], the overlapping focal points and the back seeding (FIG. 2 (a) and (b)), are not suitable for many beams case. In general, the Brillouin grating is produced from a spontaneous noise [12]. Controlling the background acoustic wave by some means, we can lock the phase of the reflected SBS wave as we want. The main idea to control the phase of the background acoustic wave is to generated a background noise artificially, whose phase can be controlled. We will test three locking techniques newly suggested by the author, the self generated standing wave (self phase locking), the injection of external acoustic wave (acoustic injection locking), and the back seeding by optical fibers. Through this contract work, the author will test the newly suggested ideas for the phase locking, the self phase locking, the acoustic injection, and back seeding by using optical fibers as shown in FIG. 4 (a) to (c) [11]-(3).

For the self phase locking method shown in FIG. 4 (a), the concave mirror reflects the pumping beam and it produce a standing wave by interfering with the incoming beam, which produce the induced standing acoustic wave whose position can be controlled by positioning the concave mirror and it will determine the phase of the Brillouin grating. In this case the background acoustic wave is a standing wave which is different from the traveling wave of the Brillouin grating. This fact might be a reason of not locking the phase. The decay time of the Brillouin grating is less than 1 ns and the propagation velocity of the hypersonic sound is 563m/s [13], and to get the phase control better than tenth of wavelength the locking should occur within 0.1ns between the beams. This is the main issue for this method. If it is proved possible, this method is the most feasible for our purpose for this is very simple and cheapest one.

For the acoustic injection as shown in FIG. 4 (b), we will use external PZT acoustic modulator to inject the acoustic wave whose frequency is harmonics of the Brillouin wave and the position of the PZT is controlled to control the phase. This externally injected acoustic wave acts as a seed of the Brillouin grating of the SBS and it will lock the phases of the beams. This method is expected to work surely and it will be proved through the experimental work. If it is proved to be possible, it is also very simple but expensive than the previous one, self phase locking.

In the case of the failure of both methods, the back seeding can be applied by using optical fiber for the back seeding to simplify the optics as shown in FIG. 4 (c), which method was proved to be effective to lock the phases by several previous works [5]-[7]. In this case, the mechanical vibration of the optical fiber may introduce phase retardation inside the optical fiber, but removing this effect will be minor problem to solve.

3. Conclusion

In conclusion, the phase locking in the suggested beam combination for the next generation high power laser system producing an ultra high power output with high repetition rate over 10 Hz is expected to be feasible to work. It will be shown through this work theoretically and/or experimentally.

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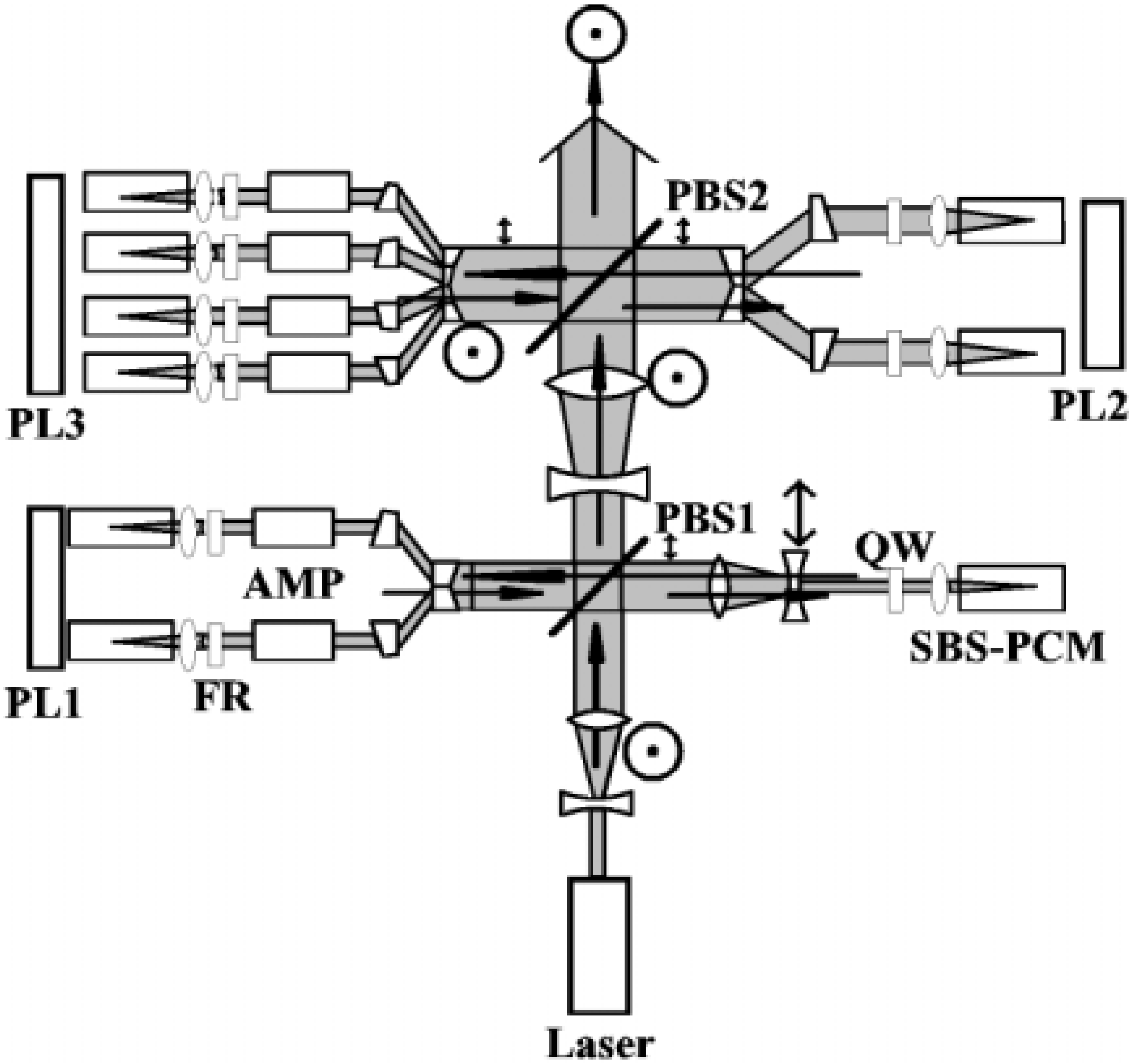

FIG.1 Beam combination method to get a high power laser output with high repetition rate.

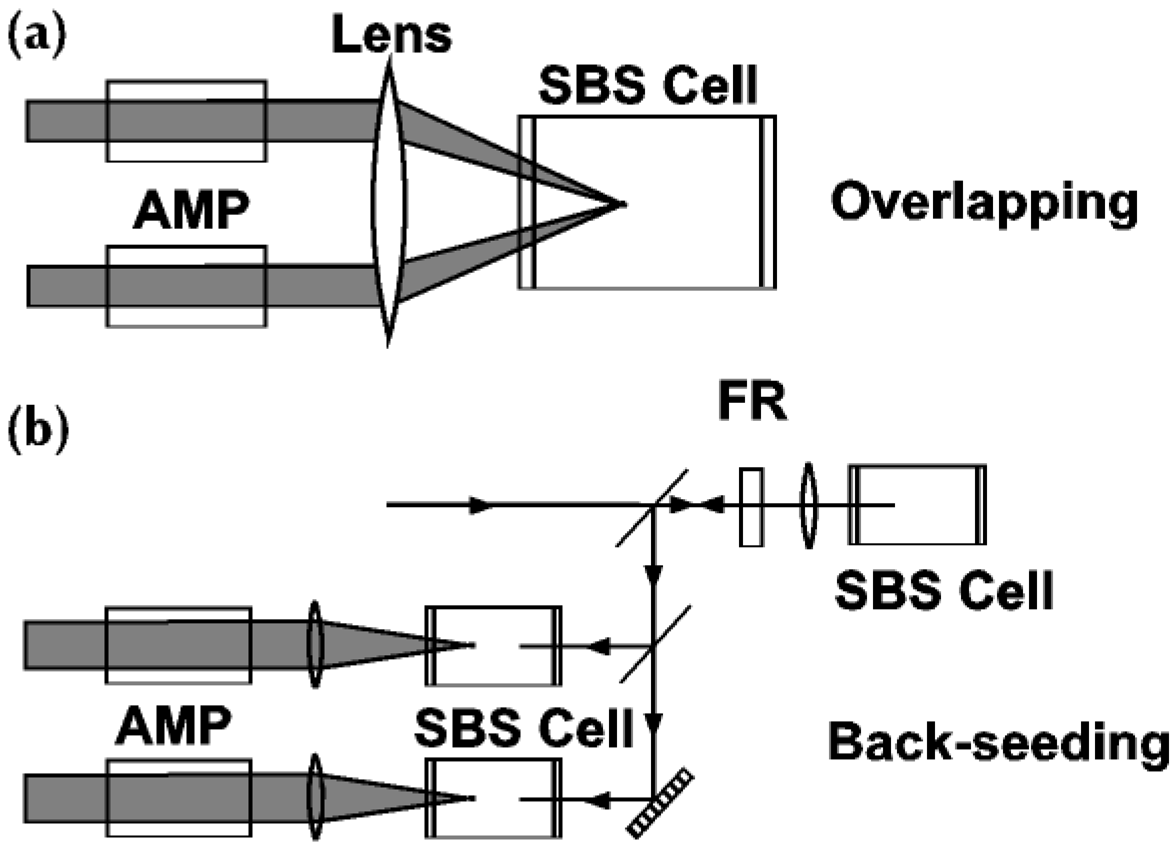

FIG.2 Two conventional phase locking methods; (a) overlapping the focal points and (b) back seeding.

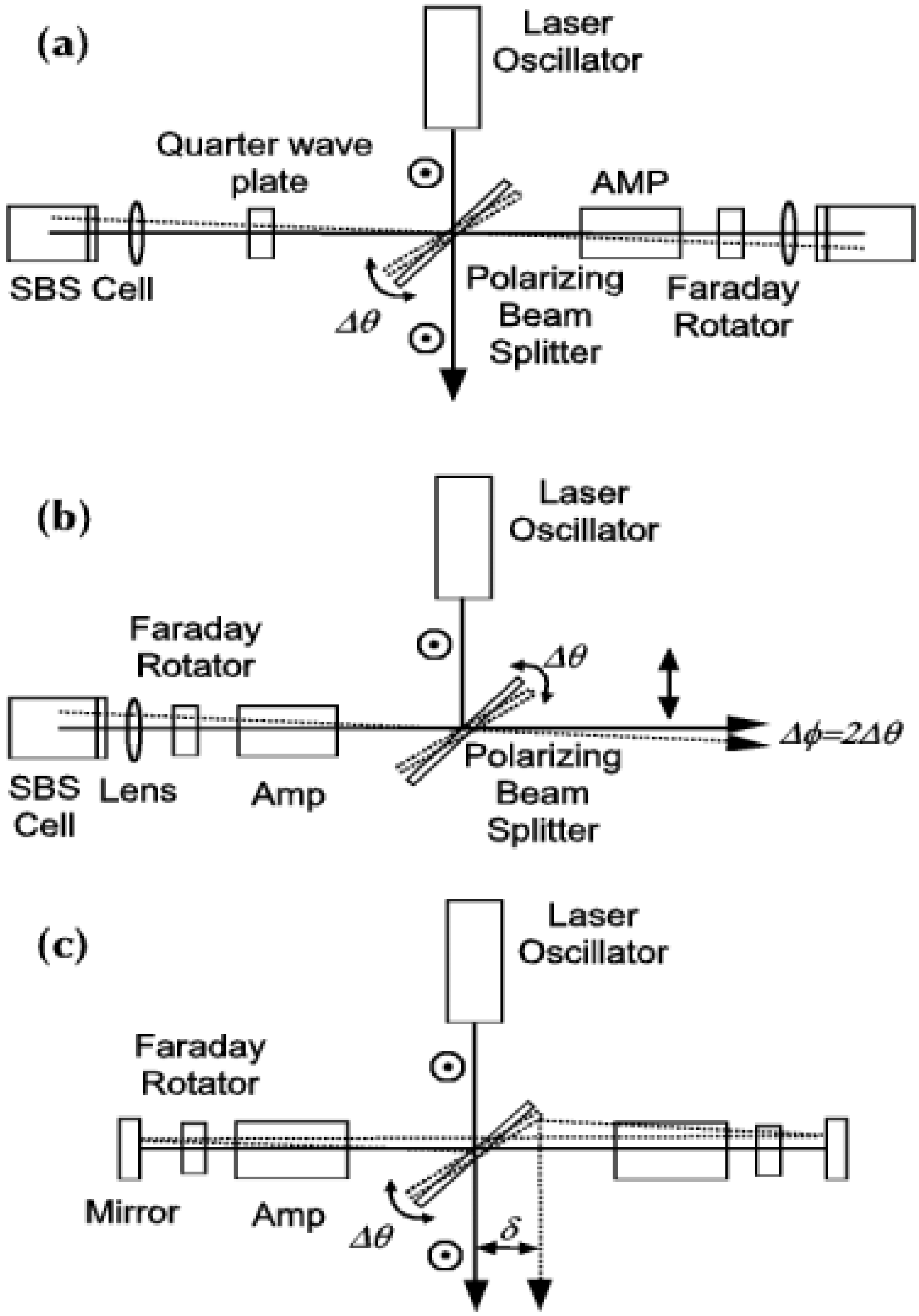

FIG.3 (a) The cross type laser system with symmetric SBS-PCM insensitive to the misalignment of the optical components, (b) and (c) the one arm SBS MOPA system and the symmetric conventional mirror system sensitive to the misalignment.

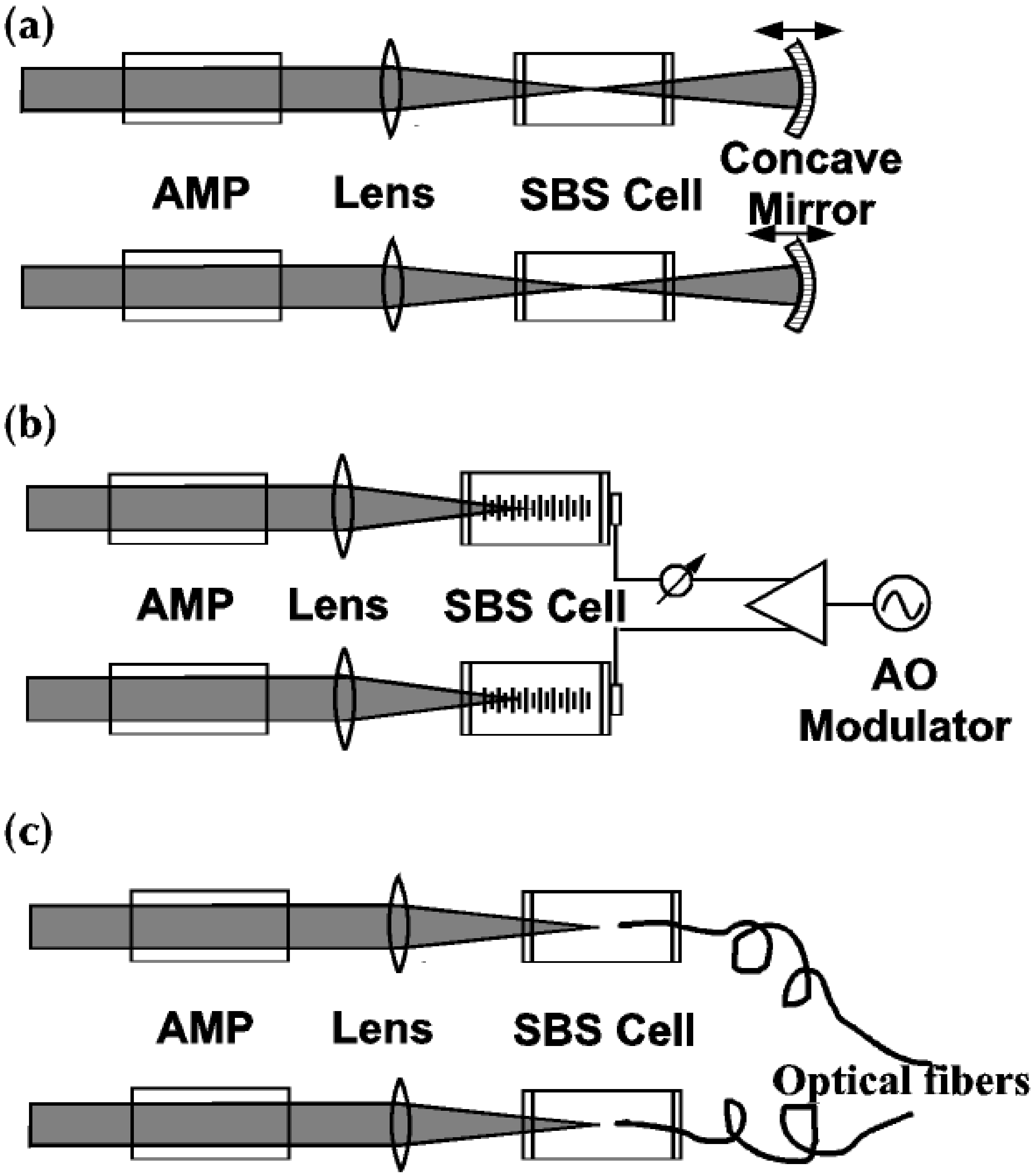

FIG.4 Three suggested phase locking methods; (a) self phase locking, (b) acoustic injection locking, and (c) back seeding by optical fibers.