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Large aperture tapered fiber phase conjugate mirror in MOPA laser systems with high repetition rate and high pulse energy

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ABSTRACT

A large aperture tapered fused silica fiber phase conjugate mirror with a maximum 50.7% stimulated Brillouin scattering (SBS) reflectivity is presented, which is operated with 400 Hz pulse repetition rate and 36.5 mJ input pulse energy. To the best of our knowledge, it is the first time that over 50% SBS reflectivity is achieved by using solid-state phase conjugate mirror under such high pulse repetition rate and high pulse energy. With much higher pulse repetition rate of 500 and 1000 Hz, the maximum SBS reflectivity is 41.2% and 33.3%, respectively. A single-longitudinal-mode Nd:YAG laser is experimentally studied with master oscillator power amplifier (MOPA) scheme using such a tapered fiber as a phase conjugate mirror. A 101 mJ pulse energy is achieved at 400 Hz repetition rate, with a pulse width of 6 ns and a M^2 factor of less than 2. The corresponding peak power reaches 16.8 MW.

1. Introduction

Since it was demonstrated that the aberrations of laser beam could be eliminated by using the characteristics of phase conjugation via stimulated Brillouin scattering (SBS) [1], various kinds of SBS phase conjugate mirrors (SBS-PCM) have been realized, including gaseous, liquid and solid materials [2].

Solid SBS-PCMs are nontoxic, free of high pressure and easily manufactured compared with gaseous and liquid counterparts [3]. Among various solid SBS-PCMs [4], optical fibers and bulk fused silica are two kinds of promising candidate because of their commercial availability and high damage threshold. For optical fiber SBS-PCMs, the reflectivity ranges from 50% [5] to 80% [6]. But both of the systems in references 5 and 6 were operated with a low pulse energy, typically on the order of a few millijoules. For bulk fused silica, more than 90% reflectivity could be obtained with input pulse energy of hundreds of millijoules to a few joules. Unfortunately, it could be operated only with less than 10 Hz repetition rate [7,8]. Therefore, it is of great importance to develop a solid SBS-PCM operated with high repetition rate and high pulse energy simultaneously. In 2006, L. Tong et al. [9] reported a bulk fused silica PCM with 35% reflectivity at 100 Hz repetition rate and 22% reflectivity at 400 Hz repetition rate. In 2007, S. Wang et al. [3] demonstrated a PCM combining a fused silica rod and a fiber, which showed 42% SBS reflectivity with maximum input energy of 42 mJ at 100 Hz repetition rate, but only 11.6% reflectivity with input energy of 55 mJ at 400 Hz repetition rate. It seems that one has to make a compromise between high repetition rate and high input pulse energy in upgrading SBS reflectivity.

Tapered fiber PCM was first demonstrated by A. Heuer and R. Menzel [10], which showed SBS threshold of 15 μJ and as high as 92% SBS reflectivity with 10 Hz repetition rate. The maximum input pulse energy is 2 mJ. Afterward, J. Chen and C. Liu et al. continued some theoretical and experimental investigations on this kind of PCM [11–13], improving the repetition rate to 100 Hz and pulse energy to 4 mJ but not so remarkably.

In this paper, we demonstrated a novel large aperture tapered fiber PCM, which showed high SBS reflectivity exceeding 50% with repetition rate of 400 Hz and input pulse energy of about 40 mJ simultaneously. To the best of our knowledge, it is the first time that over 50% SBS reflectivity is achieved using solid-state phase conjugate mirror under such high pulse repetition rate and high pulse energy. With much higher pulse repetition rate of 500 and 1000 Hz, its maximum SBS reflectivity is 41.2% and 33.3%, respectively. We applied this tapered fiber PCM to a master oscillator power amplifier (MOPA) laser system and obtained the laser output with 101 mJ pulse energy and M^2 factor of less than 2 at 400 Hz repetition rate. In addition, some ordinary fiber PCMs are tested for comparison.

2. Experimental setup and results

The schematic diagram of the experimental setup for verifying the large aperture tapered fiber PCM is shown in Fig. 1. To test the tapered fiber PCM, a MOPA laser system is developed to provide high pulse energy laser output with high repetition rate. The master oscillator is an EO Q-switched single-longitudinal-mode (SLM) Nd:YAG laser pumped by pulsed laser diodes. Its average output power is 0.5 W at

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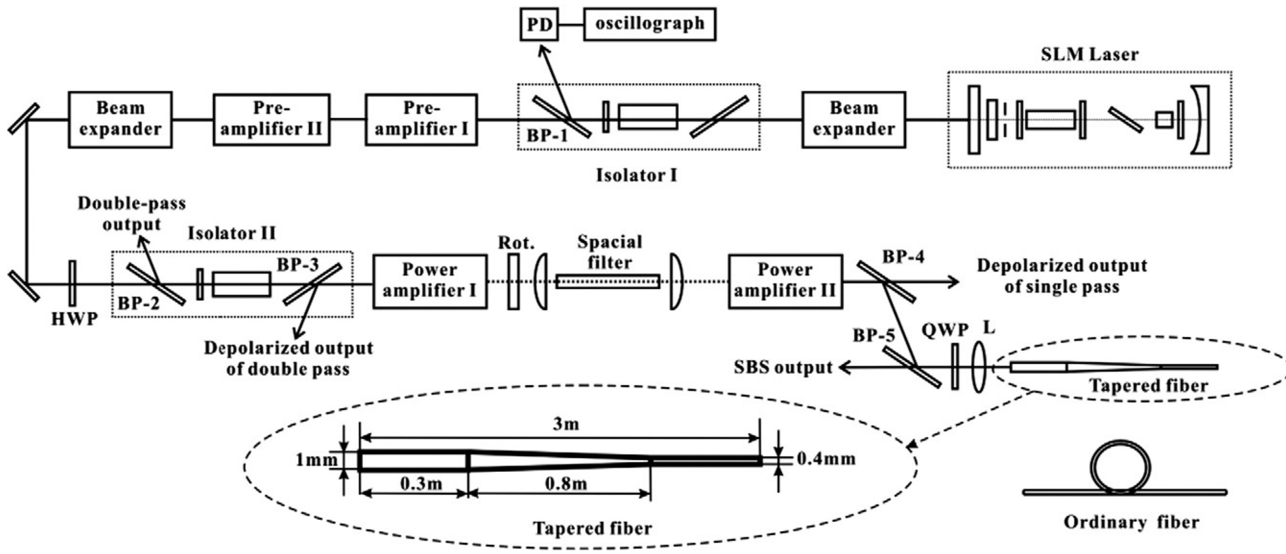

Fig. 1. Schematic diagram of the experimental setup. SLM laser, single-longitudinal-mode laser; PD, photodiode; HWP, half-wave plate; BP, Brewster plate; Rot., 90° quartz rotator; QWP, quarter-wave plate; L, lens.

400 Hz repetition rate and 1.2 W at 1000 Hz repetition rate. The laser beam from the master oscillator is expanded, isolated and then amplified by two pre-amplifiers. The isolator is composed of two pieces of symmetrically-placed thin film polarizer, a Faraday rotator and a $\lambda/2$ plate. The pre-amplifiers are two diodes-side-pumped Nd:YAG laser heads with peak pump power of 700 W. An ultra-fast photo diode (Alphalas UPD-40-UVIR-P) with bandwidth of 7.5 GHz is used to receive the very weak laser beam reflected by Brewster plate (BP-1). The pulse shape is shown by an oscilloscope (Tektronix DPO7104) with bandwidth of 1 GHz. One can monitor the pulse shape in real time to know whether the laser is operated in single-longitudinal-mode or not. Modulation of the pulse shape means that there is a beat effect between multi longitudinal modes. Fig. 2 shows the typical pulse shape of the laser from the oscillator. It has a FWHM pulse width of 24 ns. The pulse shape is rather smooth and free of modulation, which means the laser is in SLM operation.

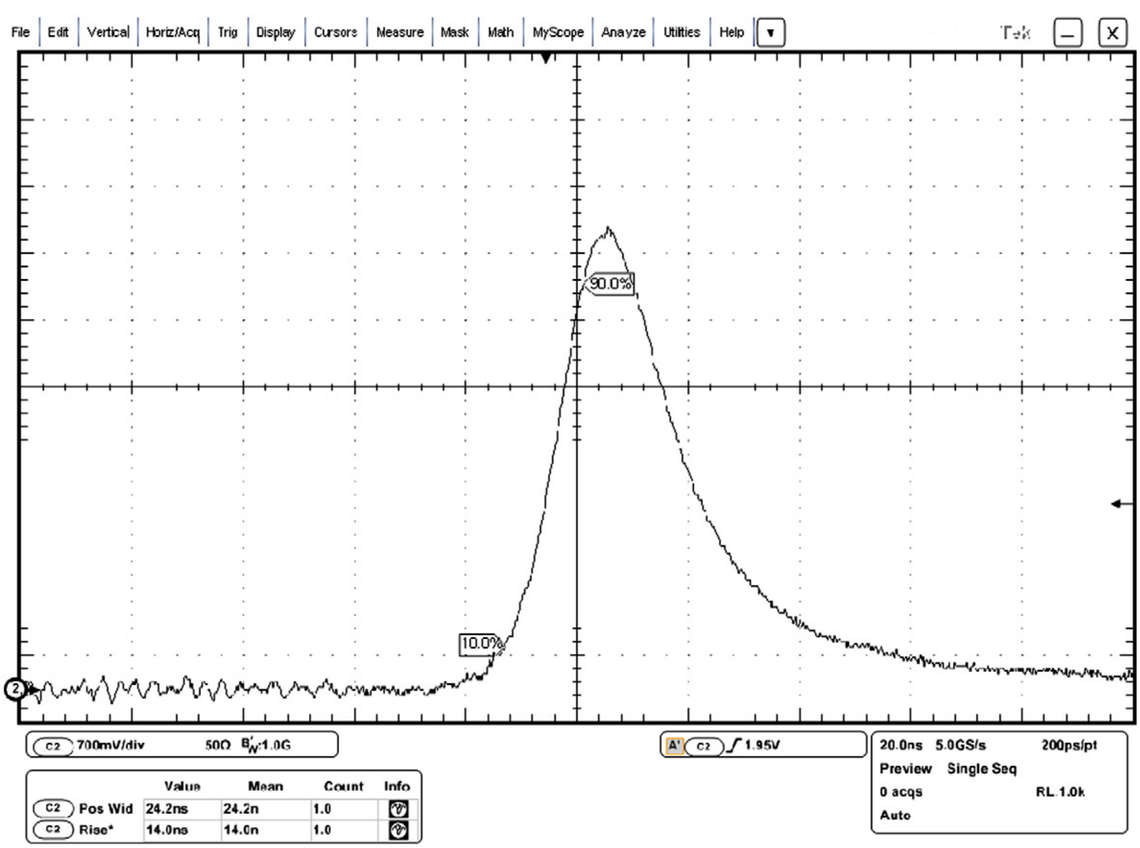

Fig. 2. Typical pulse shape of the single-longitudinal-mode Nd:YAG laser.