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Pulse shape tuning for 1064 nm nanosecond MOPA fibre laser

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Abstract

For a high power 1064 nm nanosecond MOPA pulse fibre laser, the seeding pulse shape is distorted after amplified by pre-amplifier and power-amplifier stages under the effect of gain saturation. As the pulse shape is crucial for some industrial applications, the distortion of eight different shapes of seeding pulses is experimentally studied, and the Stimulated Raman Scattering (SRS) for several shapes is also investigated.

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Keywords: MOPA; pulse shape tuning;

1. Introduction

High power nanosecond pulse Ytterbium-doped fibre laser with emitting wavelength at 1064 nm has been widely used in many areas such as research, medical treatment, industry and military because of the merits (compact structure, lower heat dissipation comparing to other types of laser, good beam quality etc) associated with it [1-3]. As the peak power of a nanosecond pulse laser can easily reach more than 10 KW, it causes several nonlinearity effects during propagation in the waveguide of thin fiber. At the same time the shape of the pulse suffers severe distortion because of the gain saturation effect [4, 5]. For many industrial applications especially for metal engraving, a stable high peak power pulse with square-shape is desirable. In this paper study of the distortion for

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eight different shapes of seeding pulses, and the Stimulated Raman Scattering (SRS) of several shapes in a master oscillation power amplifier (MOPA) fiber laser has been done.

2. Experiment and analyses

An MOPA Ytterbium-doped fibre laser with central wavelength at 1064 nm is shown in Fig. 1, and the seed laser diode is current modulated to produce nanosecond pulse with tunable pulse width and repetition rate. The seed laser diode (LC96A1064BBFBG-20R) is from Oclaro with 1 W peak power output at 2 A current driver. The core/cladding diameter of the double cladding gain Ytterbium-doped fibre used in pre-amplifier and power-amplifier stages is 6.6/128 μm and 21.7/128 μm with length of 6 meters and 4.4 meters respectively. In between seed diode, pre-amplifier stage and power-amplifier, there is an isolator to prevent the reflecting light. A coupler (1/1000 coupling ratio) is used to monitor the backward light from the power-amplifier cavity via TP1. The laser emits from the final isolator and collimator. The laser peak power increases dramatically when the pulses travelling through the pre-amplifier and power-amplifier stage sub sequentially. In the following experiment, the pulse width is 200 nanoseconds and only the distortion of the pulse shape in power-amplifier stage is focused as this effect is implicit in pre-amplifier stage.

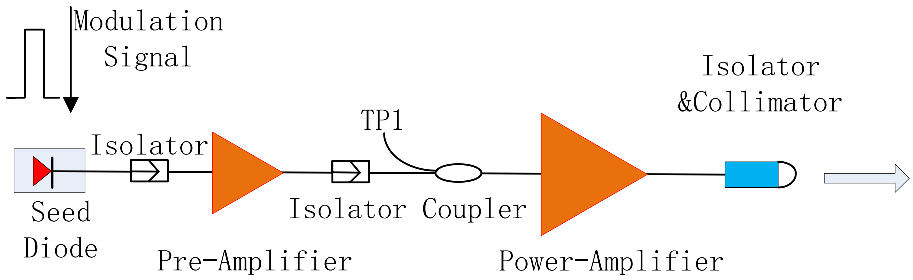

Fig. 1. Structure of MOPA fibre laser system.

One advantage of MOPA fibre laser system is that the pulse shape can be tuned arbitrary by changing the driving current waveform for the seed diode, and this has been drawn the interest of many researchers [6-8]. The average power of the experimental laser is ~20 W with 100 KHz pulse repetition rate. Eight different shapes of seeding pulses have been used to study the distortion at the output. They are: (a) L-shape, (b) triangle-shape, (c) 3-step-shape, (d) convex-shape, (e) reverse-L-shape, (f) rectangle-with-triangle-top-shape, (g) reverse-rectangle-with-triangle-top-shape and (h) rectangle-shape. Fig. 2 shows the different temporal shapes of pulses (a) – (h) after the seed laser diode and the final output. It is easy to see that the pulse distortion becomes more obvious when the output power increases along the way from 10% (~2 W) to 100% (~20 W). All the leading edge of the pulses at the final output grows higher than the falling edge because of the gain saturation which means the front part of the pulse gets more amplification. There is more distortion when coming to shapes (a), (g) and (h) as the rising edge is higher or equal to falling edge at seeding stage. For shapes of (b), (c), (e) and (f), the difference between the rising and falling edge is smaller as the rising edge is lower than the falling edge for their seeding pulse. From the point view of industry material processing, especially for deep engraving on metal, the desired laser pulse is the one that has more energy above the material ablation threshold thus to have higher processing efficiency, ie. square-shape pulse. For this kind of application, the shapes of (b), (c) and (f) are better than the rest.

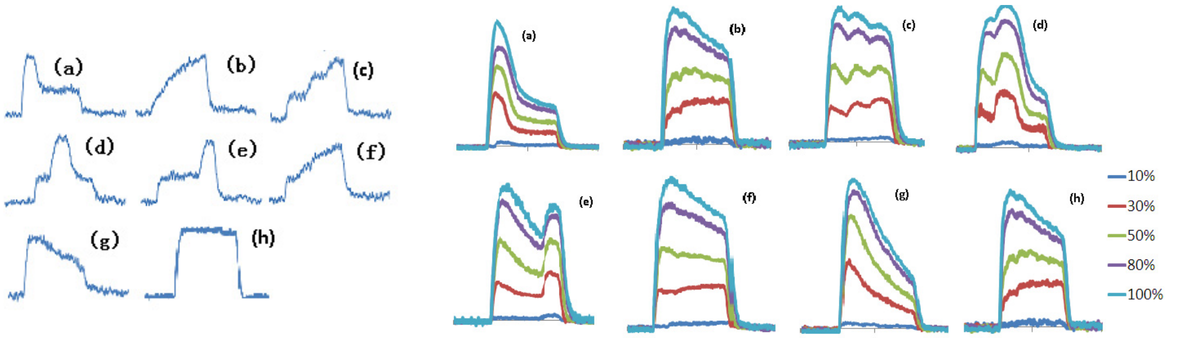

Fig. 2. The (a) – (h) shapes of the seed pulse (left) and final output laser at different power level (right).

The SRS effect is a killing factor for the MOPA fibre laser. Fig. 3 shows the SRS component for the four different shapes of pulses, rectangular-shape (h), 3-step-shape (c), rectangle-with-triangle-top-shape (f) and triangle-shape (b). The experiment setup is the same as previous one except that the pulses repetition rate has been changed to 35 KHz and the average power has been tuned to ~20.3 W. When the peak power of the pulse reaches the threshold of the SRS, the Raman spectrum comes out. Because of the different peak power levels for the four different shapes of pulses, the SRS is also not the same. From Fig. 3, the seeding pulse with rectangular-shape has the highest SRS peak at both the final output and TP1 monitor port. From the final output (left of Fig. 3), the SRS level of the other three shapes is very similar and the biggest amplitude difference between the four shapes is ~2.5 dB at 1115 nm. From the optical spectrum at TP1, it's clear that the Rectangle-with-triangle-top-shape pulse generates just less SRS than rectangle-shape pulse, 2.2 dB difference between them. The third one is the 3-step-shape pulse, the SRS difference between it and rectangle-shape pulse is 4.5 dB. And the lowest SRS is produced by triangle-shape pulse, ~5.7 dB lower than the rectangle one. The difference of the SRS at the final output and the TP1 is because of the backward pumping scheme used for the power-amplifier stage. From the SRS experiment, 3-step-shape and triangle-shape pulses are better than the other two as less SRS is better for the MOPA laser. However, the threshold of Stimulated Brillion Scattering (SBS) for triangle-shape pulse is much lower than the 3-step-shape pulse, because the leading edge of it rises more smoothly which means the frequency spectrum is narrow for the triangle-shape pulse. The narrow frequency spectrum leads to lower threshold for SBS [9].

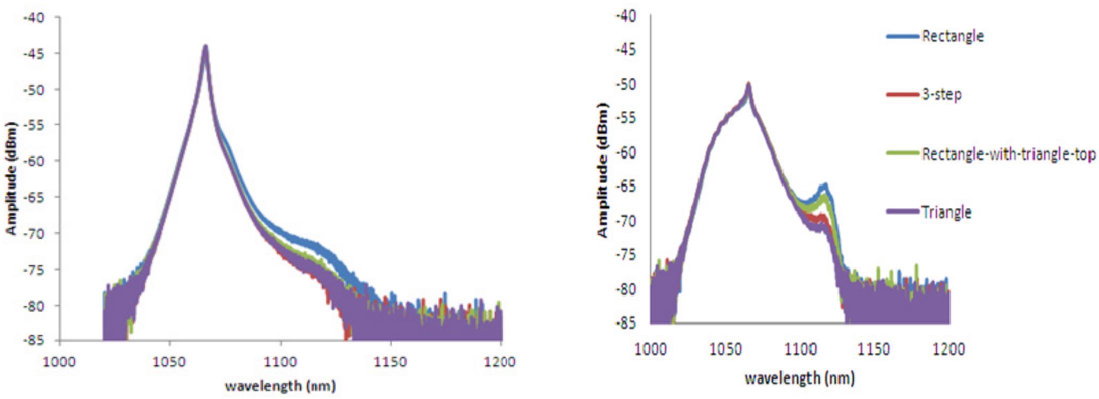

Fig. 3. Spectrums of the final output (left) and monitored at TP1 (right) for different pulse shapes.

3. Conclusion

The distortion of the different shapes of seeding pulse in a nanosecond MOPA fiber laser has been experimentally investigated. The SRS associated with several shapes has also been studied. Base on the experiments result and taking into account of the SBS effect, the 3-step-shape of pulse is an ideal choice for the specific application requiring square-like pulse comparing with the other seven shapes of pulses.

Acknowledgements

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