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Efficient Raman pulse generation at 1117nm

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Abstract

Stimulated Raman Scattering (SRS) is a third-order nonlinear optical phenomenon, which plays an important role in wavelength expansion of light source. In this paper, a pulsed Raman optical generator based on Raman effect and a MOPA scheme is developed and its performance is tested in laboratory. This set-up demonstrated a very high conversion from 1064nm seed wavelength into the first order 1117nm wavelength Raman output. The highest optical conversion efficiency achieved from the experiment is 91.5%. Whilst the second-order Raman effect is well suppressed during the process with a 40 dB difference between the first and second order Raman peaks.

Keywords: SRS, non-linear optics, electrical modulation, MOPA;

1. Introduction

The stimulated scattering effect is a third-order nonlinear optical phenomenon. The Raman fiber laser based on the stimulated Raman scattering effect in passive fiber has the advantages of zero amplified spontaneous radiation, simple and stable structure, flexible wavelength selection etc(Agrawal G.P., 2000). A highly efficient Raman conversion device is desired to reduce the cost and to simplify the design for many applications. The MOPA scheme is typical for constructing fiber lasers, its advantage is that it can keep the high quality properties of seed light well and realize the light amplification of seed light. The team at Delphi

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Laser together with Suzhou University has recently achieved high efficiency Raman conversion of over 80% using MOPA scheme and developed a high efficiency Raman pulse generator at 1117nm.

2. Experiment

The schematic diagram of the generator system is shown in Figure.1 The two-stage MOPA structure is adopted in the system. The seed light passes through a 300mW in-line isolator with power output at the milliwatt level. A 9W LD pump was used to inject ytterbium-doped fiber with a core diameter of 10 microns and cladding diameter of 125 microns (10/125) to amplify the seed light to hundreds of milliwatts. Then,use 10W isolator to isolate backward light. The secondary amplifier is a 65W LD injected 15/130 ytterbium-doped fiber to amplify the pulse to the 10W level for stimulated Raman scattering. The filter filters out the Raman pulse, and the fiber used for Raman gain is a 15/130 passive fiber. When the pump power of the second-stage amplifier is increased to 10.86W, the total output power is 8.8W at 1064nm, the output power of the filtered Raman pulse is 8.05W at 1117nm, and the optical conversion efficiency from 1064nm optical power to 1117nm power reaches 91.5%.

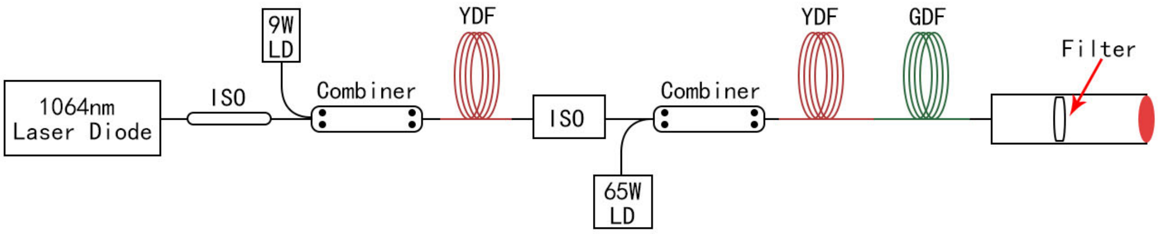

Fig.1. System configuration of a Raman pulse generator

3. Experimental results

3.1. Seed light output characteristics

Because the MOPA structure is used to build the laser, the properties of seed light can be well preserved. Figure. 2 shows the optical properties of seeds measured in the experiment. LD current of seeds is set at 0.9A in the experiment, and the output seed pulse has stable optical properties.

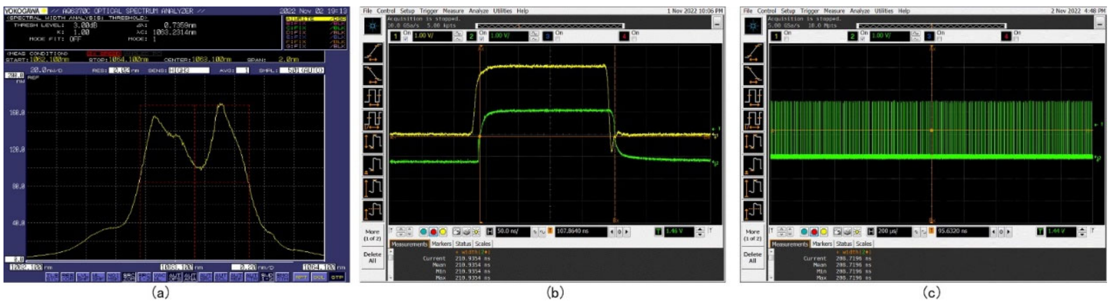

Fig. 2. Seed light experiment results (a) the spectral diagram at 0.9A seed current, with a central wavelength of 1063nm and a 3dB bandwidth of 0.75nm;(b) the seed optical pulse width diagram, the pulse width is about 200ns, and the output power is 5.6mW; (c) the seed light pulse sequence diagram with pulse frequency of 100kHZ

3.2. Power test

The experimental result after two-stage amplification is shown in Figure.3, (a) the variation trend of the total power with the pump power. It is shown in the figure that when the pump power reaches the threshold, the total power presents a linear increase trend with the increase of the pump power. (b) is the variation trend of Raman power with the pump power, and is the power test result after adding the filter. As a result, the actual Raman power also presents a linear increase trend with the increase of the pump power. The experimental results show that the Raman power reaches 8.05W and the optical conversion efficiency is 91.5%.

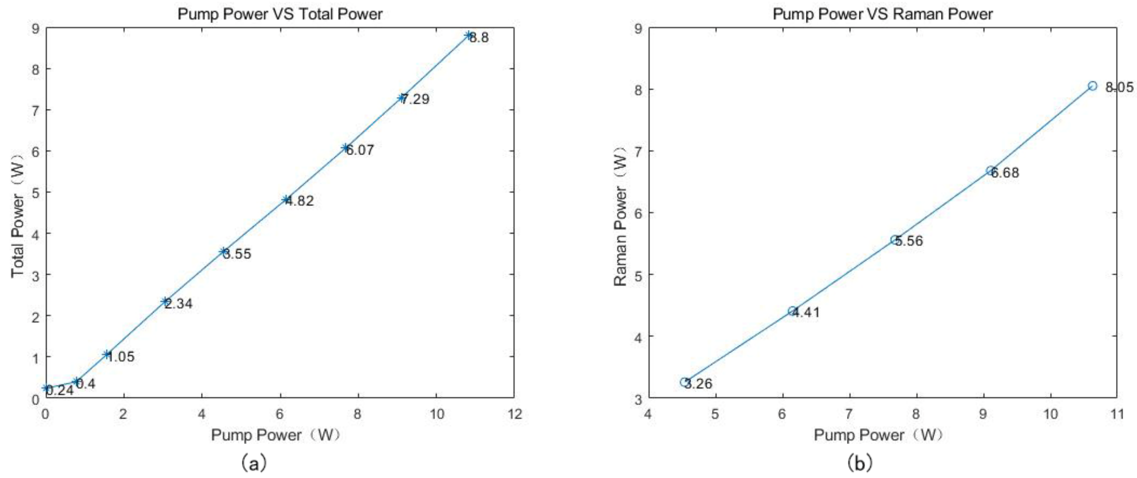

Fig.3 Variation trend of output power with the second stage amplifier pump power

3.3. Time domain output characteristic

The experimental test results of Raman pulse width are shown in Figure.4, (a) ~ (e) are the pulse widths corresponding to pump power 7.68W,8.39W,9.11W,9.99W and 10.86W, which are 30.4ns, 40.8ns, 73ns, 97ns and 112.8ns respectively. (f) is the variation trend of pulse width with pump power. It can be seen that with the increase of pump power, pulse width presents a rising trend. The explanation of this phenomenon is related to the Raman threshold, which can be calculated using this formula(Smith R.G., 1972):

$$\frac{g_R P_0^{cr} L_{eff}}{A_{eff}} \approx 16 \quad (1)$$

When the pump power is low, the pump pulse energy concentrates on the pulse front, and the front reaches the Raman threshold first. With the increase of the pump power, the pulse width rises along the energy until it reaches the Raman threshold, stimulating Stokes light and leading to the broadening of the Raman pulse width.

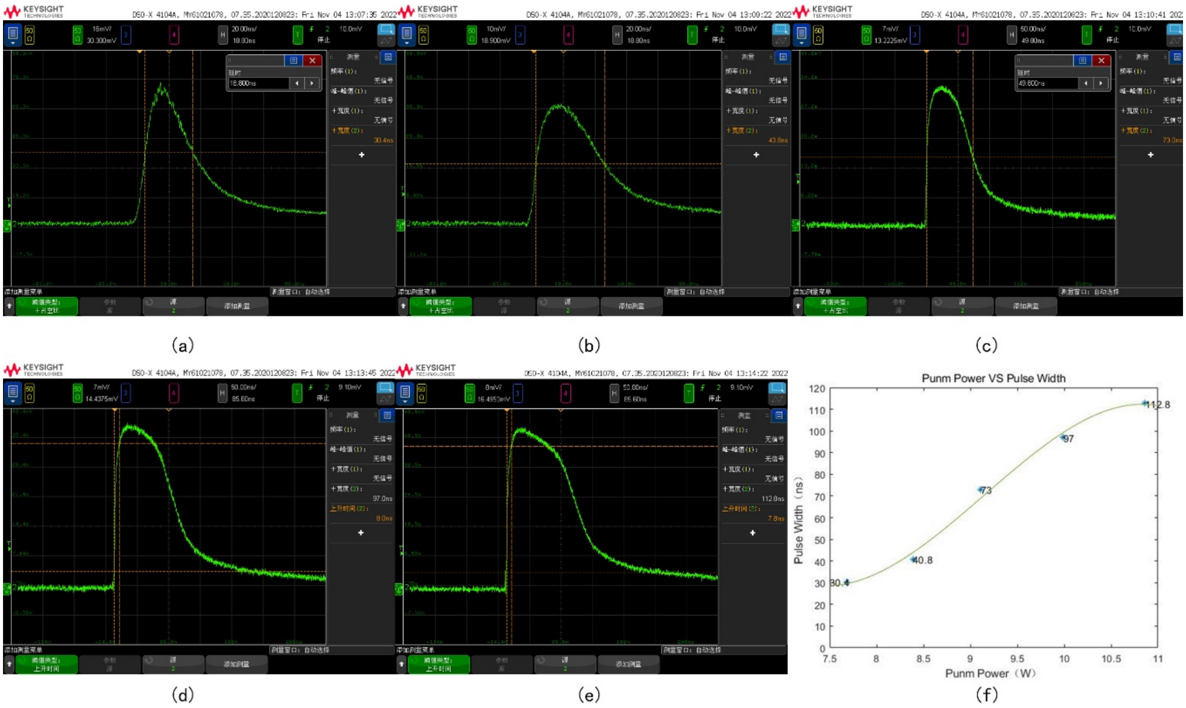

Fig.4 Variation trend of Raman pulse width with pump power

3.4. Frequency domain output characteristics

Raman pulse spectrum test results are shown in Figure 5, (a) is the linear coordinate spectrum measured before the filter is added, and it can be seen that most of the energy has been converted from pump light to first-order Stokes light, (b) is the corresponding logarithmic coordinate spectral diagram, in which there is almost no second-order Stokes light, and the difference between first-order Stokes light and second-order Stokes light is about 40dB, (c) is the Stokes pulse spectrum, the central wavelength is 1117nm, the spectral width (half-height full width) is 7nm, and the first order Stokes light we need is filtered using a filter.

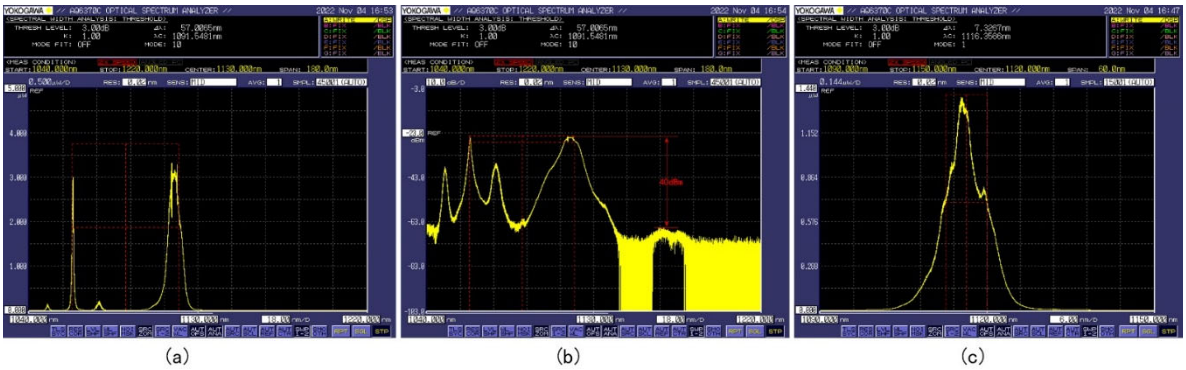

Fig.5 Raman spectra at 10.86W pump power

4. Summary

This paper introduces a Raman pulse generator based on the principle of stimulated Raman scattering in optical fibre. A high efficiency Raman spectrum conversion in a MOPA scheme is realised, with a 40dB second-order suppression.

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