

1563 nm Q-Switched Brillouin-Raman fiber laser using Graphene as a saturable absorber

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Abstract. This paper demonstrates a Q-switched Brillouin-Raman fiber laser (BRFL) operating at 1563nm. The BRFL uses a 7.7 km dispersion compensating fiber (DCF) as nonlinear gain medium and graphene as a saturable absorber. As the pump power is increased, the repetition rate increases from 20.80 kHz to 21.99 kHz while the pulse width decreased from 15.45 μ s to 12.34 μ s. The highest pulse energy is 1407.913 nJ. This result shows that the graphene SA has a high potential to be used for pulsed BRFL generation.

1. Introduction

Brillouin-Raman fiber lasers (BRFLs) have gained a tremendous interest in recent years, especially for operation at wavelengths that are difficult to access directly to conventional gain media. They are developed based on Stimulated Raman Scattering (SRS) effect. In the process, the amount of the Stokes frequency shift is intrinsically determined by the irradiated medium in which a quantum conversion increase proportionally with the complex part of the third-order nonlinear permittivity [1]. To date, many Brillouin or Raman fiber lasers have been fabricated and demonstrated using various gain media such as germane-silicate or phosphor silicate glass fiber. Most of the proposed lasers are operating in a CW mode with high output power [2-4]. On the other hand, Q-switched fiber lasers were also intensively investigated for many potential applications such as LIDAR, remote sensing, communication and medicine [5-6]. Compared with the active technique, the passive approach is better regarding simplicity, compactness, and flexibility of implementation [7]. The passive Q-switching generation can be realized by using either nonlinear polarization rotation or passive saturable absorber (SA) techniques.

To date, various SAs have been implemented such as semiconductor saturable absorber mirrors (SESAMs), two-dimensional (2D) materials (graphene, topological insulators, and transitions-metal dichalcogenides) and doped-fiber SA for Q-switching generation in various fiber lasers and cavities [8-11]. However, the applications of these SAs are restricted due to their drawbacks such as complex optical alignments, environmentally sensitive, limited operating bandwidth and complicated in fabrication. Therefore, there are many new attempts in recent years to develop new SAs with better performance for Q-switching laser operation.



In this paper, we have successfully demonstrated a Q-switched BRFL using a Graphene as a passive SA. The Graphene was sandwiched between two fiber ferrules via a fiber connector to form a fiber-compatible SA, which is then incorporated in BRFL cavity to generate Q-switched pulses at 1563 nm. As the pump power is increased, the repetition rate increases from 20.80 kHz to 21.99 kHz while the pulse width decreased from 15.45 μ s to 12.34 μ s. The highest pulse energy is 1407.913 nJ. This result shows that this ring laser cavity capable of generating stable Q-Switched BRFL. Hence, it has great potential to produce pulse laser operation in the next extended research of future employment.

2. Methodology

The experimental setup for Q-switched Brillouin-Raman Fiber Laser pump is depicted in Figure 1. The Graphene is inserted in the RFL cavity to act as SA for Q-switching pulse generation as shown in the figure. The fiber laser cavity employs a 7.7 km long dispersion compensating fiber (DCF) with a dispersion of 584 ps/nm-km as a nonlinear gain medium. The DCF was pumped by a 1455 nm laser via a 1455/1550nm wavelength division multiplexer (WDM). The Graphene SA was incorporated into the ring cavity between the 90/10 coupler and circulator which is connected to the Brillouin pump. The output signal was coupled out using a 90/10 output coupler which 10% of laser for spectrum, pulse, and power measurement and other 90% of the light is kept to oscillate in the cavity for both spectral and temporal diagnostics. The output laser characteristic was measured using an optical spectrum analyzer (OSA) with a spectral resolution of 0.02 nm and optical power meter. The temporal characteristics were measured using a 500 MHz oscilloscope via a 7.8 GHz radio-frequency (RF) spectrum analyzer via a 1.2 GHz InGaAs photodetector to convert photon energy to electrical energy from the output laser.

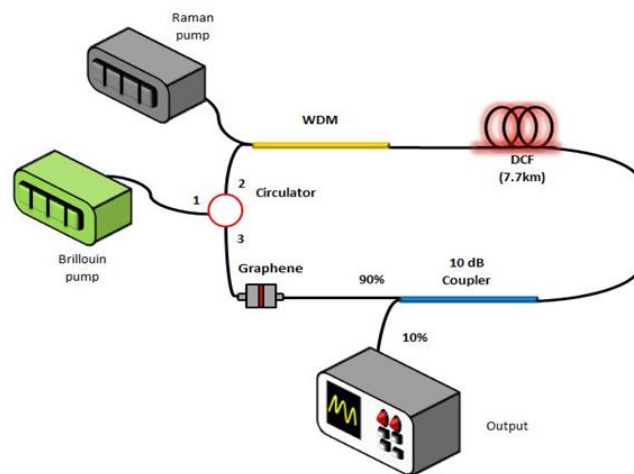


Figure 1. Experimental setup for the Q-Switched BRFL.

3. Results and discussion

The output spectrum generated by the proposed setup is shown in Figure 2(a). The output spectra of Brillouin-Raman fiber laser are obtained between 235 mA to 265 mA pump power. This is to show the results of output power (dBm) versus wavelength. The pulse repetition rate and pulse width of the proposed Q-switched BRFL are investigated as functions of pump power. Figure 2(b) shows the repetition rate of the Q-switching pulse train increased from 20.80 kHz to 21.99 kHz as the pump power is varied from 235 mA to 265 mA. Concurrently, the pulse width also decreased from 15.45 μ s to 12.34 μ s. The narrower pulse width can be achieved by either shortening the laser cavity length. Also, the average output power and the corresponding pulse energy of the laser are investigated at various pump powers. The Figure 2(c) shows the average output power almost linearly increased with the input pump power up to the maximum pump power. The calculated efficiency is around 0.04% corresponding to the output power. One can observe from the figure that the pulse energy fluctuates with the maximum pulse

energy of 1407.913 nJ. The stability of the pulse presence is confirmed by RF spectrum as depicted in Figure 2(d). At maximum pump power, the repetition rate has obtained at 21.99 kHz with signal-to-noise ratio 31.35 dB. Thus, indicates the obtained Q-switching operation is stable and comparable. This Q-switching performance could be improved by further optimizing the cavity design.

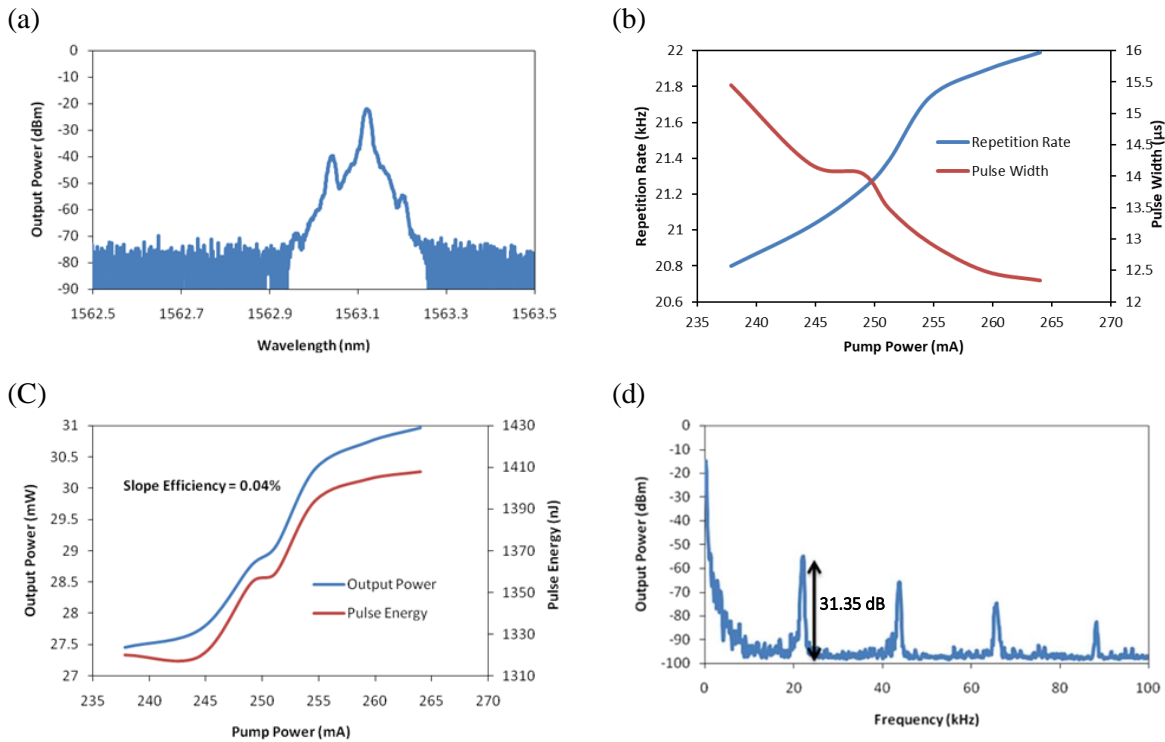


Figure 2. Q-switching performance of the BRFL (a) Output spectrum. (b) Repetition rate and pulse width against pump power (c) Output power and calculated pulse energy against pump power (d) RF spectrum with 100 kHz span.

4. Conclusion

We have successfully demonstrated a Q-switched BRFL using a graphene embedded in polymer film as a passive SA. The graphene film was sandwiched between two fiber ferrules via a fiber connector to form a fiber-compatible SA, which is then incorporated in BRFL cavity to generate Q-switched pulses at 1563 nm. As the pump power is increased, the repetition rate increases from 20.80 kHz to 21.99 kHz while the pulse width decreased from 15.45 μs to 12.34 μs. The highest pulse energy is 1407.913 nJ. This result shows that this ring laser cavity capable of generating stable Q-Switched BRFL with comparable performances.

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