Graphene-based passively *Q*-switched Tm^{3+}:ZBLAN fiber laser at 1480 nm

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***Abstract*—We demonstrate for the first time a graphene-based passively *Q*-switched Tm^{3+}:ZBLAN all-fiber laser at 1480 nm. Pulses with a duration of ~ 9 μs, repetition rate of 29.9 kHz, and energy up to 447.16 nJ are obtained.**

I. Introduction

ZrF_4-BaF_2-LaF_3-AlF_3-NaF (ZBLAN) is an excellent host for rare-earth ions and has become an important material for fiber lasers due to its low phonon energy and long radiative lifetime [1]. Tm-doped (Tm^{3+}) ZBLAN fibers provide a variety of energy transitions to develop fiber lasers operating at a wide range of wavelengths. Especially the $^3H_4 \rightarrow {}^3F_4$ transition with a resulting photon wavelength of ~1480 nm, is of great importance for S-band fiber communication and chemical detection [2, 3].

Q-switched fiber lasers have attracted considerable attention due to their widespread applications in fiber sensing, reflectometry, medicine and telecommunications. Compared with actively *Q*-switched fiber lasers, passively *Q*-switched fiber lasers provide the advantages of low cost, simplicity and compactness. Recently, graphene has attracted considerable interest as a saturable absorber (SA) to develop passively *Q*-switched fiber lasers due to its unique properties of low saturation intensity, ultrabroad operating wavelength range and ease of fabrication [4]. Graphene-based passively *Q*-switched ZBLAN fiber lasers have been demonstrated at 1190 nm and 3 εm by Ho^{3+}-doped ZBLAN fiber [5, 6] and at 2.78 εm by Er^{3+}-

optical spectrum analyzer (YOKOGAWA AQ6375) with a resolution bandwidth of 0.05 nm while the temporal characteristics are monitored by a combination of a 7 GHz photodetector (Newport, 818-BB-51F) and a 60 MHz oscilloscope (Agilent, 54621A). The output power is measured by a power meter (EXFO, FPM-300).

Fig. 1. Graphene-based *Q*-switched Tm^{3+}:ZBLAN fiber laser configuration.

III. Results and Discussion

In our experiment, continuous wave (CW) lasing starts at a pump power of ~390 mW. Stable *Q*-switched pulses are then established when the pump power is increased to ~426 mW and is maintained up to ~527 mW. Note that all the pump power values are measured after 1064/1480 nm WDM. The *Q*-switched pulse trains observed on the oscilloscope are very

duration measured at different pump powers. As the pump power increases from 426 mW to 527 mW, the repetition rate (black dots) increases linearly from 16.9 kHz to 29.9 kHz at a rate of 0.129 kHz/mW, a typical signature of *Q*-switching. On the other hand, the pulse duration (red squares) decreases from 12.25 εs to 8.25 εs and then increases to 8.9 εs. At a lower