

Simultaneous Q -Switching of a $\text{Tm}^{3+}:\text{ZBLAN}$ Fiber Laser at $1.9\ \mu\text{m}$ and $2.3\ \mu\text{m}$ Using Graphene

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Abstract—We demonstrate a passively Q -switched, dual-band $\text{Tm}^{3+}:\text{ZBLAN}$ fiber laser operating simultaneously around 1895 and 2315 nm using bidirectional pumping at 795 nm and a graphene saturable absorber. The Q -switched pulse trains at 1895 and 2315 nm have a synchronized repetition rate from 10.8 to 25.2 kHz with pulse durations as short as 4.5 and 4.9 μs , respectively.

Index Terms—Thulium-doped ZBLAN fiber, fiber lasers, Q -switched lasers, graphene, mid-infrared lasers.

I. INTRODUCTION

THULIUM-DOPED ZBLAN ($\text{Tm}^{3+}:\text{ZBLAN}$) fiber is an excellent rare-earth doped fiber to generate lasing operation covering from ultra-violet to mid-infrared regions due to its unique advantages such as low phonon energy, high stability, and ultra-broadband transparency [1], [2]. Compared with a silica host, the ZBLAN host has a reduced multiphonon emission rate and a longer radiative lifetime of the upper laser level, especially for the ${}^3\text{F}_4 \rightarrow {}^3\text{H}_5$ transition with resulting emission around 2300 nm [3]. In addition, the ${}^3\text{H}_4 \rightarrow {}^3\text{H}_6$ transition with resulting emission around 1900 nm can be further improved by the simultaneous laser oscillation around 2300 nm to increase the branching ratio from ${}^3\text{F}_4$ to ${}^3\text{H}_4$ [4], [5]. There have been several reports of continuous-wave (CW) co-lasing at 1900 nm and 2300 nm in $\text{Tm}^{3+}:\text{ZBLAN}$ fiber [3], [4], [6], [7] along with demonstrated applications in gas sensing [3].

Q -switching is a technique to modulate the quality factor of a laser cavity for the generation of high energy nanosecond pulses. Compared with actively Q -switched fiber lasers, passively Q -switched configurations have unique advantages such as simplicity, compactness, ease of integration, and low cost. Recently, graphene has emerged as an innovative and promising material as a saturable absorber (SA) for passive pulse generation in fiber lasers due to its remarkable optical properties such as high saturable absorption to

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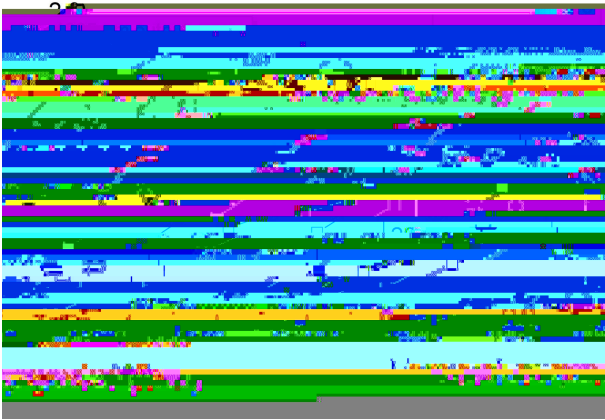


Fig. 7. Output power and pulse energy of the Q -switched pulses at 1895 nm and 2315 nm as a function of forward pump power when the backward pump power is ~ 850 mW.