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Frequency Shifted Feedback: An Artificial Saturable Absorber for Generation of Passive Q-switch Pulses

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Abstract

Passive Q-switch pulses are generated from an all fiberized cavity in the 1µm wavelength regime. The operation is performed by frequency modulation of the cavity resonant frequencies. The modulation is caused by feedback of shifted frequencies in each cavity round trip. The repetition rate of the generated optical pulses ranges from 40 kHz to 60 kHz with pulse-width tunablity from 6µs to 1.8µs. Maximum pulse energy attained is 1.25µJ with corresponding peak power of 600mW

1. Introduction

Pulsed fiber lasers are permeating in applications reserved for solid state lasers due to their ease of use, compact form, ruggedness and maintenance free operation[1]. Out of the two most employed methods of giant pulse generation i.e. active and passive Q-switching, the latter has mostly been achieved through cavity loss modulation by a saturable absorber. A large part of research today in this field of pulse generation is directed towards improvement of these saturable absorbers[2]. Saturable absorber amplitude modulate the cavity resonant frequencies and if the modulation depth is large with a slow recovery of absorption, it leads to generation of passive Q-switch pulses. In this paper, we approach the generation of passive Q-switch pulses through the process of frequency modulation in form of frequency shifted feedback. Such a system provides an alternative to the production of these giant pulses.

2. Experimental Setup

The experimental setup of the passive Q-switch fiber laser is shown in Figure 1. The cavity comprises of a double-clad (core diameter: 8.9 um, core NA: 0.1) Yb-fiber of length 3 meter, a pair of FBGs of reflectivity 99% (3 dB bandwidth: 3 nm) and 50% (3 dB bandwidth: 1 nm) with center wavelength at 1064nm. A fiber pigtailed acousto-optic modulator (AOM) (operating wavelength: 1030 to 1090 nm) is placed inside the cavity. The AOM driver was supplied a DC waveform from an arbitrary function generator (Agilent81150A). The total cavity length was about 6 m. Active Yb-fiber was pumped by MM 976nm pump diode through a pump combiner.

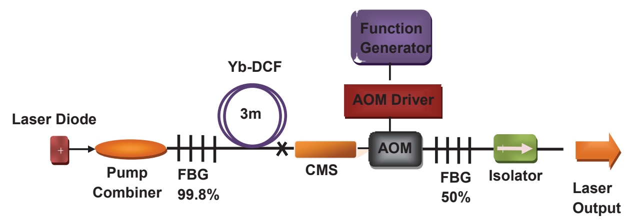

Figure 1. Schematic of the experimental setup.

A cladding mode stripper (CMS) is placed before the AOM to remove the unabsorbed pump light. An isolator was placed at the output end to prevent back-reflection. Temporal characteristics were acquired by an oscilloscope (Tektronix-DPO7254C).

3. Results and Discussions

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Apparently, the same setup generates active Q-switch pulses, the only difference being is the method of operation of the AOM.

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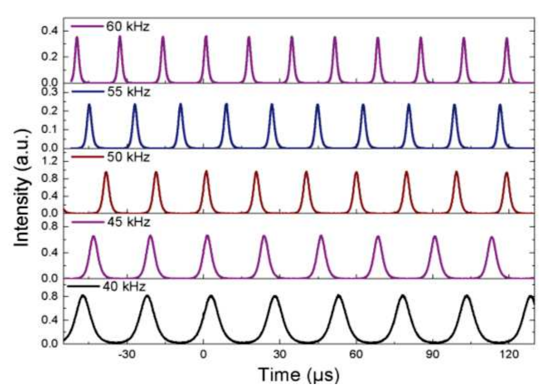

Figure 2. Output pulse train at repetition rate from 40kHz to 60 kHz

The input signal to the AOM is upshifted by 150 MHz (the frequency of 150 MHz is internally generated within the AOM modulator) in a single pass and 300 MHz per cavity round trip. Figure 2 shows the formation of optical pulses tunable from 40 kHz to 60 kHz on increasing pump power. The pump power was increased from a value of 400mW to 800mW. Below 400mW no pulse is generated.

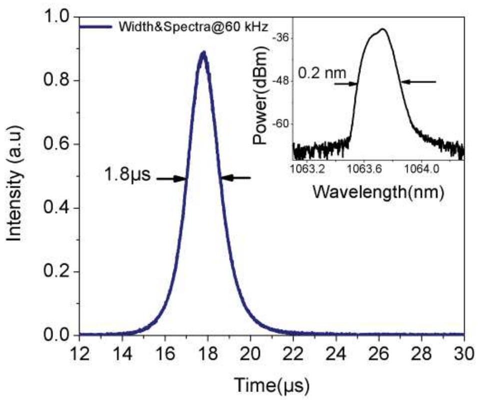

Figure 3. Output pulse-width at 60 kHz (inset: pulse spectrum.

The temporal envelope of 1.8 μs of the output pulse at the repetition rate of 60 kHz is shown in Figure 3 and its corresponding spectra of 0.2nm width in the inset. The spectrum is comparatively narrow and fixed at the central wavelength near 1064nm due the filtering effect of the Fabry-Perot cavity. This shows that the frequency shifted feedback cavity can be functional even in narrowband linear laser cavities. The stability of the Gaussian shaped pulse in terms of time jitter or amplitude fluctuation is equivalent to the ones generated with the active Q-switch method.

The variational trend of the pulse width and its peak power is depicted in Figure 4 that shows an upward growth with increase in the repetition frequency, a signature of passive Q-switch phenomenon.The generation of passive Q-switch pulses is due to loss modulation of the cavity, but not by the much investigated amplitude modulation of a saturable absorber but by frequency modulation occurring through the feedback of shifted frequency. The shifted frequency feedback is an outcome of the moving grating created inside the AOM that both diffracts and up-shifts light that is passed through it.

The frequency displacement per round trip of the cavity results in temporal modulation of laser intensity in a manner similar to the one that occurs in the nonlinear polarization rotation. Movement from cavity resonant to the non-resonant frequencies and vice versa yields the desired characteristics of an artificial saturable absorber.

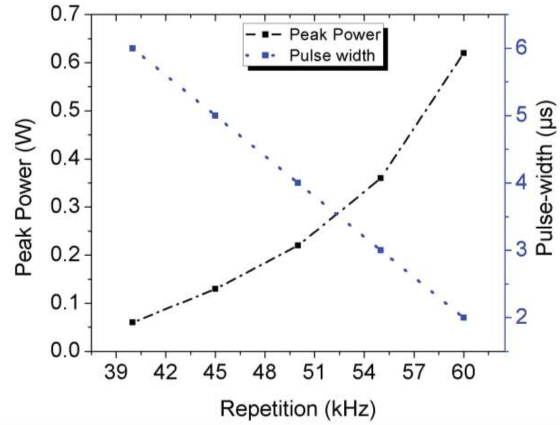

Figure 4. Variation of peak power and pulse-width with repetition frequency.

4. Conclusion

The paper shows the generation of passive Q-switch pulses from a cavity that is well established as an active Q-switch pulse generator. The phenomenon utilized is frequency modulation generated via Doppler generated frequency upshift rather than the more investigated intensity modulation by natural saturable absorbers.

5. Acknowledgements

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6. References

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