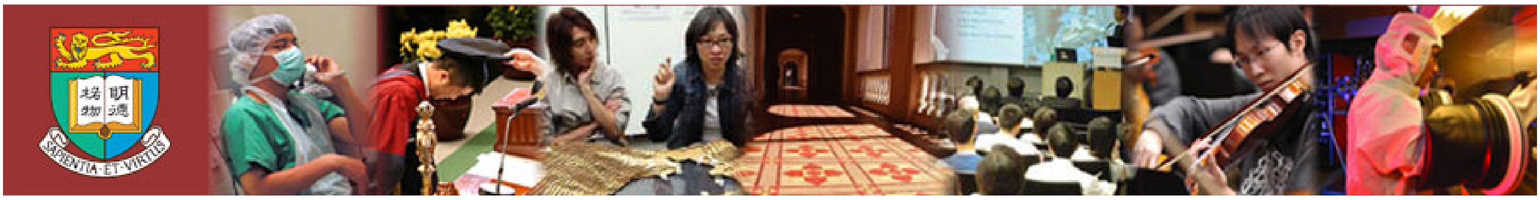

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Addressing a cavity with patterns at ultra-wideband detune

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Abstract: We demonstrate an amplified fiber ring cavity at telecommunication window addressed by optical pattern at 1.0 μm. A storage time longer than 38 μs and an ultra-wideband wavelength conversion of ~500 nm have been obtained.

OCIS codes: (190.4370) Nonlinear optics, fibers; (190.4223) Nonlinear wave mixing

1. Introduction

While dissipative soliton (DS) in fiber laser has already found widespread applications [1], the temporal cavity soliton (TCS, an extended terminology of spatial cavity soliton [2]) in a coherently-driven fiber cavity has been observed recently [3]. The TCS cavities were driven by an external continuous-wave (CW) laser with ultra-narrow linewidth (kHz) instead of a conventional optical amplifier, which compensates the cavity loss. It has been shown that TCS can be excited with an external pulse laser at a nearby wavelength of the fiber cavity [3,4], or even be spontaneously generated without external stimulation in microresonators [5]. As a promising candidate for storing bits in an all-optical buffer, TCS has showcased its multiple telecommunication functions, e.g. all-optical storage and wavelength conversion [3]. This stabilized fiber cavity, however, has to be driven with an ultra-narrow linewidth CW laser at around 1550 nm for coherent gain, and stimulated by an external pulse laser at ~1530 nm for TCS generation. The operation range as a wavelength convertor, in addition, is limited to about 20 nm. As far as the simplicity and cost are concerned, it would be very beneficial to develop a compact and cost-effective design with a larger wavelength conversion range. Here, we demonstrate an all-fiber oscillating cavity at 1.55 μm driven by an off-the-shelf laser diode (LD), which has a spectral width of < 0.2 nm centered at 980 nm. The wavelength conversion and optical storage are realized by addressing the all-fiber cavity with a pulse laser at 1.0 μm. Associated with an ultra-wideband wavelength conversion of 500 nm, this scheme shows promising features over other all-optical delay lines [6].

2. Experimental setup and results

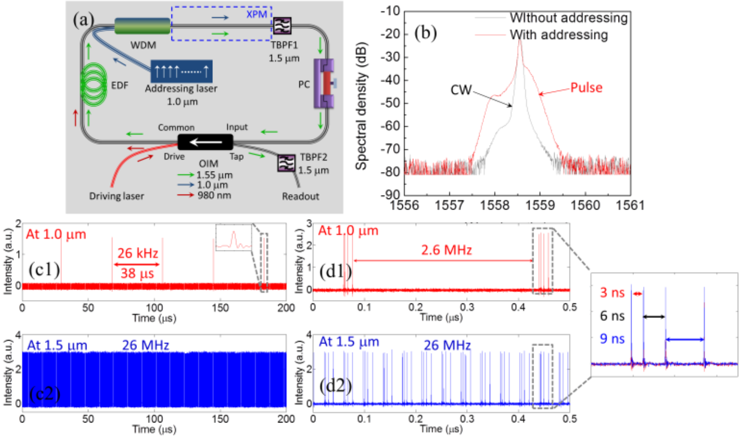

Fig. 1. (a) The experimental setup of the oscillating fiber cavity. (b) The optical spectra of the oscillating fiber cavity with and without addressing beam. (c1) The addressing pulse train at 1.0 μm with an addressing period of 38 μs. (c2) The excited pulse train of the fiber cavity at 1.55 μm with a pulsing period of ~38.1 ns, i.e. the round trip time (RTT). (d1) The addressing pattern with four 1-bit at 1.0 μm. (d2) The excited pattern at 1.55 μm. Inset: the overlapping of the addressing and excited patterns.

The all-fiber cavity, as shown in Fig. 1(a), incorporates the pattern excitation via cross-phase modulation (XPM) and sustaining through an artificial saturable absorber, which was implemented by a fiber-based multi-functional optical integrated module (OIM) [7]. Different from Ref. 3, the fiber cavity in our scheme was driven by a 980-nm LD with a maximum output power of ~300 mW and a spectral width of < 0.2 nm. The 980-nm laser beam, reflected into the common port of OIM via its internal dichroic mirror, would be completely absorbed by a piece of 1-m erbium-doped fiber (EDF) and thus compensated the cavity loss. The output from the EDF would be combined with the addressing beam from an external pulse laser at 1.0 μm through a fiber-based WDM coupler. The combined lightwave at 1.55 μm and addressing beam at 1.0 μm would interact with each other through XPM in a standard single-mode fiber (~3 m in length) between the WDM coupler and a tunable bandpass filter (TBPF1, blocked the 1.0-μm component). Here, the fiber cavity would be deliberately set to only emit CW lightwave at 1.55 μm without the addressing beam, and then the 1.55-μm CW lightwave would be "modulated", via XPM, to be the pulse pattern the same as that of the addressing beam being introduced, as shown in Fig. 1(b).

First, we examined the case that the addressing optical pattern only contained one 1-bit, as shown in the inset of the Fig. 1(c1). With different addressing periods, which were much longer than the round trip time (RTT) of the fiber cavity, the oscillation of the fiber cavity could evolve from CW to pulse pattern exactly the same as that of the addressing beam. Fig. 1(c) shows the results of the addressing case when addressing period was 1000 RTTs. As can be observed, the addressing pattern at 1.0 μm excited the fiber cavity every 38 μs, i.e. 26 kHz. The fiber cavity delivered a pulsed-pattern train at its fundamental repetition rate (26.2 MHz), and no decay between neighboring addressing pulses was observed. With the autocorrelator, the pulsewidth of the excited pulse in the fiber cavity was measured to be ~14 ps, which is comparable with that of the addressing pulse, i.e. 16 ps. The slight discrepancy can be attributed to pulse compression effect of the artificial saturable absorber. The timing jitter of the excited pulse was measured to be < 2 ps. Fig. 1(d) shows the case addressed with four 1-bit pattern. The bit separation between the four 1-bit addressing pulses is about 3 ns, 6 ns and 9 ns, respectively, as shown in the inset of Fig. 1(d). By overlapping both the addressing and excited patterns together, it shows a very good consistency. It is noted that the data bits stored in an all-optical buffer can be interfered by the repulsive interaction between solitons [4]. To study the highest bit-rate (or smallest temporal separation between bits) that can be stored by this fiber cavity, we varied the temporal separation between bits and evaluated the addressing results by real-time oscilloscope and autocorrelator with a temporal resolution of < 10 fs. It was found that the fiber cavity delivered a good consistency between the addressing and excited patterns when the bit separation was longer than 20 ps, while the repulsive interaction for a shorter separation became much stronger [1]. This suggests that the fiber cavity can support a bit-rate of 50 Gbit/s.

3. Conclusion

In conclusion, we have demonstrated the dynamics of a fiber ring cavity at 1.55 μm addressed by external optical pattern at 1.0 μm, and shown that it can be a fruitful platform for studying the nonlinear dissipative dynamics. Addressing by different optical patterns, the amplified fiber ring cavity exhibited a buffering time longer than 38 μs, at an equivalent bit-rate of 50 Gbit/s. With an all-fiber configuration and simple driving-source requirement, together with an effective wavelength conversion with a working range of ~500 nm, this scheme can be a promising candidate for optical buffer over other all-optical delay lines.

4. Acknowledgment

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