Three-State Optical Memory Based on Coupled Ring Lasers

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Abstract: A three-state optical memory is demonstrated, with a compact configuration and low switching power. It is presented that the memory has an extinction ratio of 40 dB and a large wavelength range of set pulses.

OCIS codes: (210.4680) Optical memories; (190.1450) Bistability; (200.4560) Optical data processing

1. Introduction

All optical packet switching is expected to play an important role in the future photonic network. In the last few years, optical bi-stability has been extensively investigated due to its potential application in optical packet switches [1], and several approaches to two-state optical memories have been proposed and demonstrated [2-4].

In principle, multi-state memories could extend 1×2 optical packet switches to a large dimension of 1×N, which depends on the states of the memory. However, so far as we know, fewer papers are related to multi-state optical memories. In [5], a three-state optical memory using fiber Bragg gratings is demonstrated, where high switching power is required and the interconnection is not easy. In [6], a five-state optical memory based on serially connected Fabry-Parot cavities is presented, in which it is hard to let the wavelength of the set pulse same as the state. Here, we propose a novel approach to three-state optical memories and demonstrated it experimentally. The main benefits of this approach are (1) compact configuration; (2) lower switching power; (3) set pulse with large wavelength range and (4) good extinction ratio.

2. Proposed approach and operation principle

The configuration of the three-state optical memory is shown in Fig.1, which consists of three coupled unidirectional ring lasers at three different wavelengths.

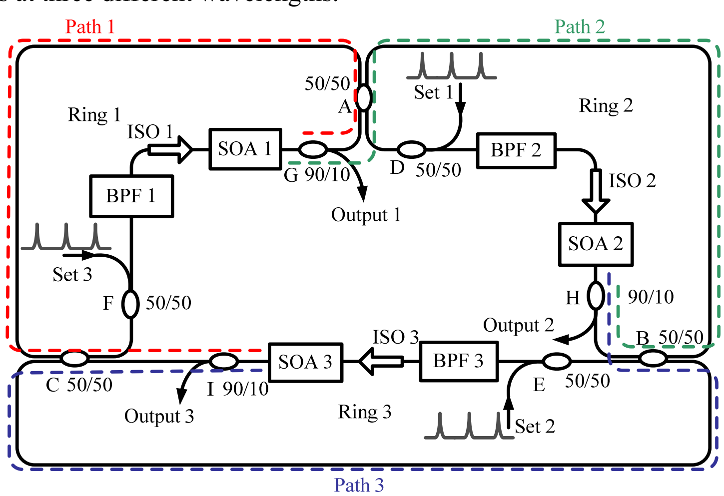


Fig.1 Experimental setup of the three-state optical memory; SOA: semiconductor optical amplifier; ISO: isolator; BPF: band pass filter

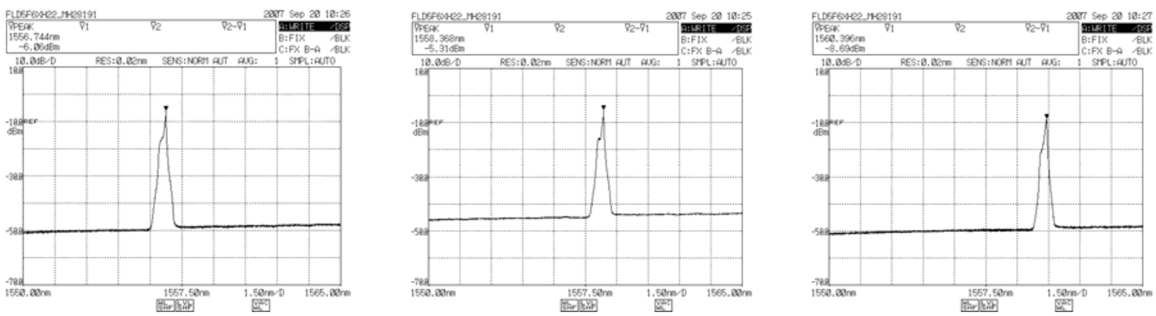
When ring 1 is lasing, the output light of SOA 1 is splitted into two portions. One portion of the light passes through Path 1 (the dashed red line) and then saturates SOA 3; the other portion of the light passes through Path 2 (the dashed green line) and then saturates SOA 2. Both ring 2 and ring 3 are suppressed because the gain of SOA 2 and SOA 3 are quenched. The state is called "state 1" when only ring 1 is lasing. Similarly, in state 2, when only ring 2 is lasing, the output light of SOA 2 saturates SOA 1 (through Path 2) and SOA 3 (through Path 3, the dashed blue line) respectively, and ring 1 and ring 3 are both suppressed; in state 3, when only ring 3 is lasing, both ring 1 and ring 2 are suppressed. In other words, for each state of the memory, only one ring cavity is lasing at one wavelength.

As shown in Fig.1, each of the three set ports corresponds to a particular state. When one pulse is injected into the port of set 1, after coupler A, one half of the pulse saturates SOA 3 through Path 1, and the other half saturates SOA 2 through Path 2; but for SOA 1, however, the pulse could not reach. So when ring 2 and ring 3 are suppressed by the pulse from set 1 port, ring 1 begins to lase, thus the memory is set to state 1. Similarly, the pulse injected from set 2 port is splitted by coupler B, then saturates SOA 1 (through Path 2) and SOA 3 (through Path 3), and sets the memory to state 2; the pulse from set 3 port saturates SOA 1 (through Path 1) and SOA 2 (through Path 3), and sets the memory to state 3.

By injecting a regular pulse sequence into each of the three set ports, we obtain the dynamic flip-flop operation of the optical memory. Since the bandwidth of SOA gain spectrum is large, and the flip-flop behavior in our setup is based on gain quenching of SOA, there is no specific requirement for the wavelength of the set pulse as soon as it could saturate SOA, so there is a large wavelength range for the input pulses.

3. Experimental results

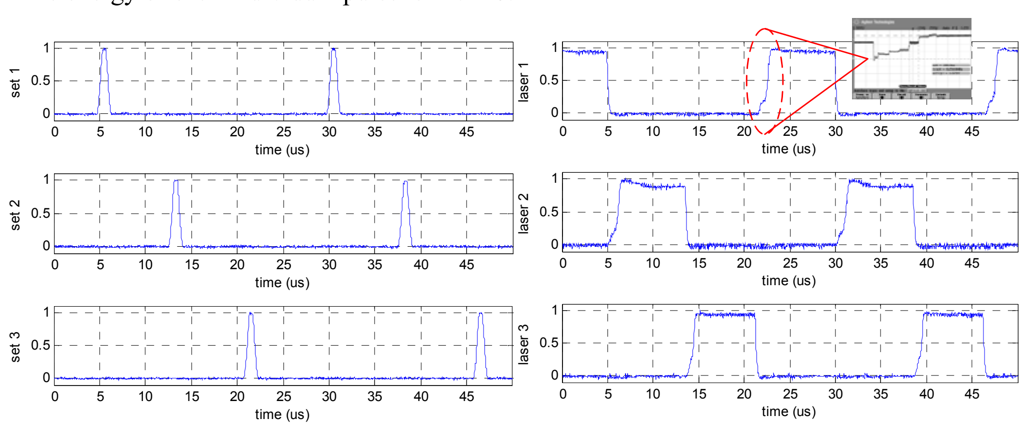
The optical spectrum of each state is investigated by an optical spectrum analyzer, shown in Fig.2. The central wavelengths of the three states are 1556.7 nm, 1558.4 nm and 1560.4 nm, respectively. Each state has an extinction ratio of 40 dB.



a. state 1 (1556.7 nm) b. state 2 (1558.4 nm) c. state 3 (1560.4 nm)

Fig.2 Optical spectrum of the three states of the memory

By injecting a regular pulse sequence into each of the three set ports, a stable flip-flop operation of the memory is demonstrated, shown in Fig.3. The central wavelength of the set pulse is 1554.9 nm. The set pulse has a repetition rate of 40 kHz and a duration of 1 us. The minimum mean power of the pulse for switching is -2.64 dBm, which means that the energy of each individual pulse is 13.6 nJ.



a. set pulses b. output of the three lasers

Fig.3 Flip-flop operation of the optical memory

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The memory's switching speed between two states is determined by the falling-down time of the original state and building-up time of the new state. The falling-down time depends on the edge time of the pulse which switches off the original state, and in our case, the edge time is 500 ns. The building-up time of the new state depends on the cavity length and the distances between SOAs, where the cavity length of each ring is about 42 m and the fiber length between two SOAs is 10 m. For state 1, 2 and 3, the building-up time is 1.5 us, 1.7 us and 1.2 us respectively. As shown in the inset of Fig.3.b, the building-up process of state 1 is taken step by step, and each step corresponds to one round trip, 210 ns. The memory is set to state 1 within 7 round trips, which coincides with the building-up time of 1.5 us. Device integration could help to improve the switching speed due to the short cavity length.

4. Conclusion

A three-state all optical memory is demonstrated. The memory has a stable flip-flop operation with an extinction ratio of 40 dB for each state. Due to the simplicity and compactness of the configuration, only -2.64 dBm mean power of set pulse is required for switching. The wavelength range of input pulse is large as soon as the pulse could be amplified by the SOA. Finally, to apply this setup in ultra-fast optical packet switching, photonic integration would be helpful to increase the switching speed.

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