Review Paper on Optical Random Access Memory

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ABSTRACT-Optical communication has the potential to fulfill the nowadays bandwidth requirements, provided that it can be implemented in a cheap and reliable way. Development of optical communication is hindered by lack of all Optical memory which is essential for storing information, retiming, regeneration, and reshaping. A optical memory can greatly enhance both capacity and flexibility of optical network. Optical Random-Access Memory (o-RAM) has been regarded as one of the most difficult challenges in terms of replacing its various functionalities in electronic circuitry with their photonic counterparts. In optical routing and processing O RAM constitutes as a key device . This Paper provides an overview of various methods, materials, and structures used for constructing optical memory using photonic crystals by taking the advantage of strong confinement of photons and carriers and allowing heat to escape efficiently. This Paper compares the way for constructing a low-power large-scale o-RAM system that can handle high-bit-rate optical signals.

Keywords - ***large-scale o-RAM,*** *Optical Memory*. ***Photonic crystal***

I. INTRODUCTION

In today's Telecommunication scenario, photons have become the main carrier of information. In the earlier systems based on electronics, the data processing at nodes or routers was performed with integrated electronic circuits, this was comparatively slow, consuming high power, and was associated with heat generation during high bit rate operations. These were the real obstacles to further improvements in network speed and traffic capacity.

To improve the networking speed, optical data processing is preferred along with photonic integrated circuits to reduce the power consumption and the heat generation during high bit rate operations while keeping the high-speed properties of optical signals. The progress in optical Network communication, at present, is hindered by absence of an all Optical memory. Future optical routing and switching will require high-speed and low-power optical processing of digital signals[1,2]

PhC are periodic optical nano structures that affect the motion of photons and hence controlling and manipulating the flow of light. PhC dielectric function exhibits spatial periodicity in one, two or three dimensions. photonic crystal has several important advantages, such as small footprint, small energy consumption, high speed, and significant integratability. Thus it may be a promising candidate for all-optical information processing in optical networks.

N. SILICON CHIP BASED OPTICAL FLIP-FLOP MEMORY

The SOI circuit was fabricated with 193 nm DUV lithography using the ePIXfab silicon photonics platform. The SOI structure was designed with a top silicon layer of 220 nm and a buried oxide layer of 2 mm. An unpatterned III–V die was bonded on top of the finished SOI wafer/chip using DVS–BCB[3]. The III–V layer had a total thickness of 583 nm, including three compressively strained InAsP quantum wells for providing transverse electric mode gain and a tunnel junction for a low-loss p-contact. After removing the InP substrate, contact lithography was used to define the microdisk pattern to ensure that the underlying SOI waveguide was well aligned to the edge of the disk. The III–V layer was etched by inductively coupled plasma–reactive ion etching (ICP–RIE) until a thin n-doped InP lateral contact layer (90 nm) was achieved. This InP contact layer was then removed where it was not required, and a titanium/platinum/gold metal layer deposited on top to form the bottom contact. The whole structure was then covered with DVS–BCB. A via was opened through the DVS–BCB layer on the centre of the microdisk, and another titanium/platinum/gold metal layer deposited to form the top contact. The gold layer, which also served as a heat sink, was designed to be thick here (600 nm) to improve heat dissipation under continuous-wave bias. Because the WGM is confined to the edge of the disk, this top metal layer does not result in substantial optical absorption losses. The DVS–BCB was etched away on part of the bottom contact metal to enable it to be contacted electrically.

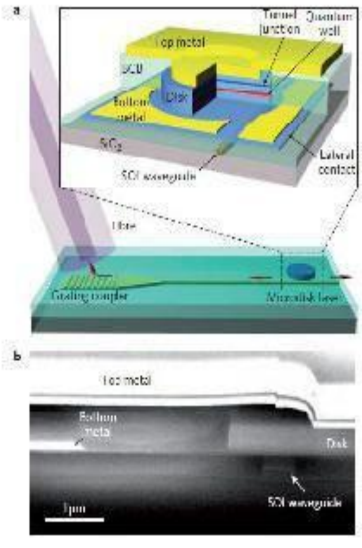

Figure1. Structure of the microdisk laser.

Result: a single microdisk laser with a diameter of 7.5 mm, coupled to a silicon-on-insulator wire waveguide, an all-optical flip-flop working in a continuous-wave regime with an electrical power consumption of a milliwatts, allowing switching in 60ps with 1.8fJ optical energy. The total power consumption of 0.5 mw and the device size are 7.5_ 7.5 μm^2 [4] .

MM. ULTRA HIGH Q InGaAsP PHOTONIC NN.CRYSTAL BASED ON-CHIP OPTICAL BIT MEMORY

The figure below shows a scanning electron micrograph of PhC fabricated on an InGaAsP substrate by a combination of electron beam lithography and ICP dry etching. The air hole size and core thickness are both 200 nm. And adopted a width-tuned line defect cavity so that the air holes surrounding the cavity were shifted away from the center of the line defect.

The cavity mode volume is very small at 0.16 μm3 with a calculated Q-factor of over10 million, and realized a Q-factor of 1,800,000 in a Si-based PhC nanocavity. A light is inputted from a lensed fiber to a PhC-WG with a core of 1.05 W through an input/output waveguide with a 3 μm wide PhC line-defect and a spot size converter with a 15μm long elliptic arc. Here W is the basic line-defect width, which is defined as the distance between the center of adjacent holes of *a (3)* ^{½} and *a* is the lattice constant of the PhC.

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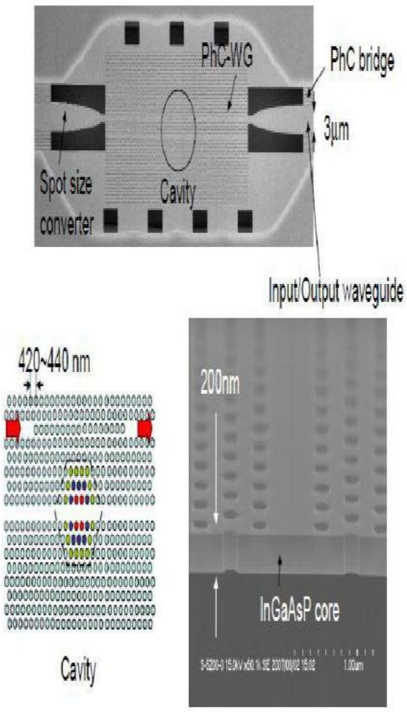

Scanning electron micrograph of fabricated 1.3 m

Figure 2. InGaAsP core PhC on InP substrate.

Result:In this method demonstrated all-optical bit memory operation with photonic crystal (PhC) nanocavities based on an InGaAsP substrate with a band gap at a wavelength of about 1.3 μm. The optical bistability is based on a refractive index modulation caused by carrier-plasma dispersion. The operating energy required for switching is only 30 fJ, and the minimum optical bias power for bistability is 40 μW, which is about one hundred times less than that required for laser based bistable memories[5].

IV ULTRALOW-POWER ALL-OPTICAL RAM BASED ON InP BASED InGaAsP BURIED HETROSRUCTURE

Device structure: Because the band-filling dispersion and linear absorption become strong in the vicinity of an electronic band-edge wavelength, and expect efficient carrier-induced nonlinearity. However, excess absorption degrades the cavity Q and increases the required operating power. Therefore, the composition of the buried InGaAsP should be adjusted to obtain both strong nonlinearity and moderate absorption. In the experiment, the composition was adjusted so that its electronic band-edge wavelength was 1.45 mm for an operation wavelength of 1.55 mm. The buried region was 4 mm long, 0.3 mm wide and 0.15 mm thick. The air hole diameter, lattice period and total thickness of the InP-based photonic crystal slab were 180, 425 and 250 nm, respectively. As shown in Fig. 1a, the photonic crystal waveguide width is increased to 1.1W0 for the guiding region and decreased to 0.98W0 for the barrier region, where W is the basic line defect width defined as the removal of one row of air holes in the G–K direction. The cavity region has a waveguide–width modulation with graded air hole shifts of 5, 10 and 15 nm.A nanocavity is formed by a combination of width modulation and index modulation induced by the buried InGaAsP.

For a 1-bit RAM measurement demonstration, a write pulse, a read pulse, a c.w. bias and a reset pulse are generated and used pulsed light from a tunable wavelength. Mode-locking fibre laser with a pulse width of 12 ps and a 10 MHz repetition rate, and a writing pulse with a 500 kHz repetition rate was picked out with a modulator. A read pulse was generated by splitting from the same laser, but the repetition rate was kept at 10 MHz. The read pulse was sufficiently attenuated that it did not influence the memory state. The c.w. bias light and reset pulse (width, 50 ns; repetition rate, 500 kHz) were obtained with a tunable-wavelength c.w. laser and an electro-absorption modulator. These light sources were merged using an optical coupler and set to a transverse electric polarization, defined as an electric field in the plane of the photonic crystal slab. These lights were then coupled by means of a lensed fibre into a 3-mm-wide photonic crystal waveguide and an intermediate spot size converter so that the light could be input efficiently into the single-line-defect photonic crystal waveguide[6]. The output lights from the sample were amplified by an erbium-doped fibre amplifier (EDFA), and the output waveform of the bias light and read pulse were selectively monitored with a band-pass filter and a sampling oscilloscope. In the measurement, there was an additional loss of 222 dB comprising the coupling loss between the optical fibre and the photonic crystal waveguide, as well as the propagation loss in the waveguide. Because the cavity is placed at the centre of the waveguide, the optical power injected into the cavity is estimated by measuring the power in the fibre and the insertion loss up to the cavityof 211 dB.

In this method demonstrated that photonic crystal nanocavities with an ultrasmall buried heterostructure design can solve most of the problems encountered in o-RAMs. By taking advantage of the strong confinement of photons and carriers and allowing heat to escape efficiently, and realized all-optical RAMs with a power consumption of only 30 nW[6], which is more than 300 times lower than the previous record, and have achieved continuous operation. And also demonstrated their feasibility in multibit integration. This paves the way for constructing a low-power large-scale o-RAM system that can handle high-bit-rate optical signals.

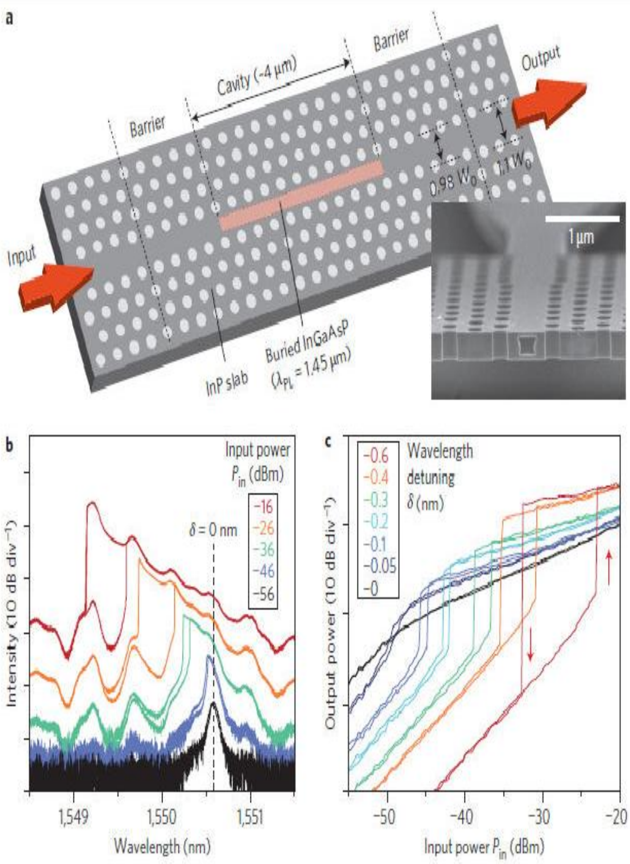

Figure3. Design of the BH–PhC nanocavity, The InGaAsP region was etched to clearly reveal the BH region.

Summary

1 Mbit o-RAMs can be integrated in a footprint of the order of 10 mm^2, and the total power consumption remains less than 100 mW[6]. Although the number of bits is still smaller than that of electric RAMs, o-RAMs may play an important role as high-speed all-optical processing nodes where it is necessary to avoid E–O/O–E conversion.

If we integrate a certain number of bit memories, for certain applications, we may have to reduce the erasing time by sacrificing the carrier lifetime and subsequently the power consumption, but this will be acceptable because large-scale o-RAMs are not required.

The present all-optical bit memory based on a photonic crystal nanocavity is the most promising candidate for an o-RAM in the field of photonic processing circuitry, especially for all-optical packet routers for ultrahigh-speed photonic network processing.

Table 1 | Comparison of performances of various on-chip all-optical memories.

Device	Bias power (mW)	Switching energy (fJ)	Switching speed	Area (μm^2)	Ref.
MMI-BLD	3×10^2 to 5×10^2 (Elec.)	-	240 ps	7,000	8
VCSEL	4 (Elec.)	0.2	50 ps	36	7
Microdisk laser	6 (Elec.)	1.8	60 ps	45	9
Photonic crystal nanolaser	2.5×10^{-2} (Opt.)	-	On: 58 ps Off: 65 ps	<10	24
Photonic crystal nanocavity (all-InGaAsP)	1×10^{-2} (Opt.)	24	Off: 240 ps	<10	6,16
BH-PhC nanocavity	3×10^{-5} (Opt.)	2.5	On: 44 ps Off: ~7 ns	<10	This work

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