PHOTONICS CHIPS IN MACHINE LEARNING AND IMPLEMENTATION OF FPGA BOARD : REVIEW

1.Abstract:

FPGA plays a significant role in signal processing, embedded systems, and control systems. Nowadays, silicon photonics is used as a primary source for optical transmission. With the drastic change in the digital world, data analytics has become an essential emerging scope where FPGA also has a significant role. Apart from advantages, there are also disadvantages which include computational speed/power efficiency provided by FPGA. FPGA are custom computing machines that have the highest performance implementation.

This paper discusses the growth, application, and societal significance of photonics chips in machine learning and its integration with FPGA boards. We also discuss the challenges and opportunities of photonics chips in the future.

2.Introduction:

Altera was the first industry to introduce reprogrammable logic devices in 1984 -EP300. It has a quartz window package that allows users to know the ultra-violet lamp to erase EPROM cells. After that, Ross Freeman and Bernard Vonderschmitt, co-founders of Xilinx, invented a viable field-programmable gate array in 1985. Field programmable gate could be viewed as a small, slow mask programmable array gate (MPGA) or a sizeable logic device(PLD). FPGA was capable of implementing more than programmable logic. Many FPGA is configured by static RAM cells. In the past 20 years, many changes have been made in the various photonic-assisted signal processing.

To overcome the limitation, the photonics feature includes ultra-wide bandwidth and ultra-fast computational speed with low power. The most system uses photonic solution with discrete fiber-based devices which makes them bulky. FPGA marked their growth in both circuit and volume production. Where Silicon is used as the primary material for producing optical devices. The standard CMOS fabrication process integration of optical and electronic is done on a single chip. For optical communication, the transparency at wavelengths is 1270nm to 1625 nm, and the intrinsic gap of silicon is 1.1ev. There are many scopes in artificial intelligence also where photonic chips have significant roles. Artificial intelligence chips are the borderlines of integrated circuits and artificial intelligence(AI), involving structure design, algorithm analysis, and chip fabrication. Integration size and immense power is the major drawback that is limiting the capacity of the chips. FPGA is used in Microsoft to accelerate high-performance, intensive systems. A basic FPGA architecture consists thousands of fundamental elements called configurable logic blocks(CLBs) surrounded by a system of programmable connects called fabric.

With the rapid advancement of photonic-integrated circuits(PIC), PIC realized on-chip integration of photonic signal processors. However, introducing FPGA into photonics chips will give more open scope to increase the capacity and overall performance of the boards. Nowadays, many practical applications are implemented on task-oriented designs rather than object-oriented designs. Recent studies on an on-chip photonic programmable signal processor consisting of a tunable Mach-Zehnder (MZI) combines a two-dimensional mesh network. We will discuss the modulator used and their impact in society.

3. High-Speed Silicon Modulator:

An optical beam modulator can be used to modulate the beam of light with respect to signal. Many factors determine the performance (1) Modulation depth, (2) modulation speed (3) bandwidth. High-speed silicon modulators prefer large, high modulation speed power. While modulation speeds have progressed, the bandwidth requirements will also increase respectively. Usually, modulator comes in two categories direct absorption and embedded systems, but for FPGA boards we use direct absorption as it is convenient and fast. We use silicon as a photonic material mainly due to the low speed of silicon optical modulators fabricated into the semiconductor. So far, the quickest silicon waveguide optical modulator is in the frequency of 20MHz, and theoretically, it is 1GHz.

4. Hardware structure for linear operations:

ONN is formed by a passive optical waveguide that interconnects the natural advantages of linear operation. The ONN network is classified as feedforward neural network(FNN), convolutional neural networks(CNN), and recurrent neural network. Optical waveguides can implement this network. In SOA(semiconductor optical devices), modulation and amplification are used to control the intensity.

4.1 Semiconductor optical amplifier(SOA):

The idea of SOA, the MAC operation, is realized by single amplifier modules. When the amplifier gets amplified, it enables large-scale MAC operations. This has N*M matric formation multiplication. The FNN based SOA is considered that the variation of the gain coefficient corresponds to the change in transmission. The ring modulator is compact and operates at a sub-voltage level so that it is suitable for high-density and narrow bandwidth applications. In contrast, an Electro absorption modulator (EAM) has a slightly larger footprint and a fair modulation efficiency of up to 16GHz.The Mach-Zehnder modulator (MZM) has higher extensive switch modulation and potential applications as switches and routers inhibiting the future for all-optical communication networks.

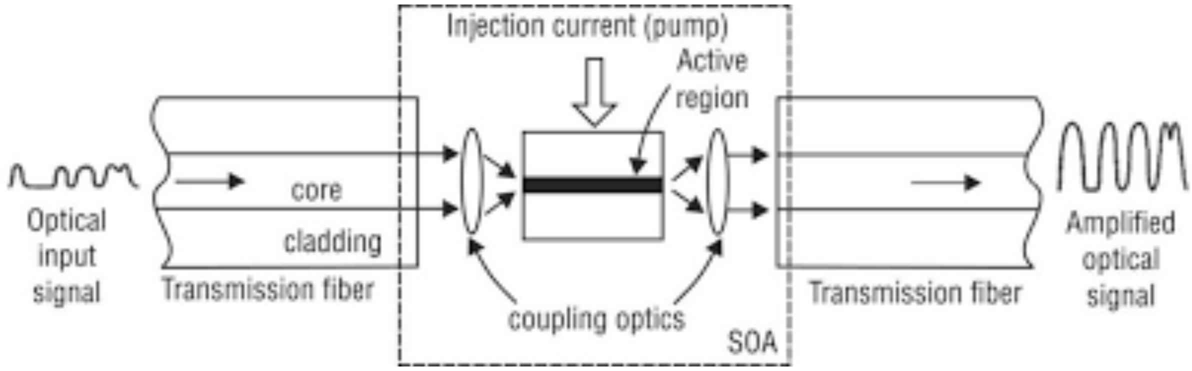

Fig.1 Semiconductor Optical Amplifier diagram

4.2 Photonic Feedforward Neural Network(PFNN):

The feedforward neural network is the accessible one-way neural network having input, hidden, and output layers. This transmits unidirectionally from the information to the output layer. PFNN can be realized by the MZI array, SOA, MRR, and 3D waveguide. The MZI array is cascaded without any type of reflection and forwarding propagation. Whereas in SOA, it is operated in large-scale MAC operations. These vast differences make the network quite complex and time-consuming process. The Micro-ring resonator implementation scheme is similar to SOA, but it works with different wavelengths. It can adjust the waveguide when light is incident on the chips in various methods. Arrayed waveguide grating(AWG) is summated with multiple channels.

5. Metal-oxide Semiconductor (MOS) Capacitor-based silicon modulator:

Modulation can be achieved by driving the MOS capacitor in accumulation mode. The positive voltage VD applied on the gate forms the depletion and inversion layer. The depletion region of silicon charge carriers accumulates in the depletion region. Due to the change in attenuation, there will be a phase shift in both arms of the interferometer. Out of many modulators, ring modulators are compact and operating in low sub-voltage. Due to the plasma dispersion effect, there will be a phase shift change in both magnitude and sign. MOS capacitor also improves the modulation efficiency, but the life depends on the device resistance.

6.Application of this project:

1)Aerospace and defence

2)Medical electronics

3)ASIC prototyping Audio

4)Automotive

5)Broadcast

6)Consumer Electronics

7) Video and image processing

7.Open source research :

Photonics chips in machine learning research is carried by Lightmatter CEO and MIT alumnus Nicholas Harris where they described different way of machine learning works that uses optical interference. These chips needed limited energy because light produces less heat when compared to electricity which benefits reduced latency too. Lightmatter makes great claim about test chip. Nvidia graphics cards, Intel and AMD processors are less when compared to Lightmatter works.

Lightmatter hardware which is designed for standard server or workstation they are not immune to optical processing. Speedy photonic circuits require speedy memory and modulators with optical combiners.

8.References :

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