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Editors
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Towards an Integrated Fiber-To-The-Home Transceiver on a Silicon Nanophotonics platform

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We discuss the advancements in realizing a fully integrated Fiber-To-The-Home transceiver on a Silicon-On-Insulator (SOI) platform. Special attention will be given to solving the fiber/chip coupling problem with a grating duplexer. Furthermore we propose to integrate the laser and photodetectors by using a heterogeneous III/V Silicon DVS-BCB bonding technique.

Introduction

Current broadband services such as copper-based access technologies, i.e., the asymmetrical digital subscriber line (ADSL) and cable modem (CM), have reached there limits and the growing demand for bandwidth is driving the deployment of optical networks. Without a doubt, Fiber-To-The-Home is the most impressive technology for realizing very high symmetrical bandwidths. Due to the rising demand, optical fibers become cheaper every year and many advances have made optical fiber networks much less costly than they once were.

Still, the use of discrete optical components for fabricating FTTH transceivers makes these devices not suitable for mass production. The key to solve this problem is integrating the optical functionalities on a single chip. Through integration of FTTH transceivers it is possible to significantly reduce the installation costs of FTTH optical networks. Furthermore the maintenance cost en power consumption will decrease. It is believed that integrated optical equipment will stimulate in the near future the deployment of FTTH networks. [1]

Schematic Overview of a FTTH Transceiver

Point-to-point Fiber-to-the-Home optical access networks require large volume and low-cost optical transceivers, both at the subscriber and the central office side. From the perspective of the transceiver at the subscriber side, 1310nm is the upstream channel and 1490nm and 1550nm are the downstream channels for data and CATV. In Figure 1, an integrated FTTH transceiver is schematic illustrated. Starting from the fiber, we can distinguish five functionalities:

1. Interface between the fiber and the optical chip
2. Splitting of the downstream and upstream channels
3. Splitting of the downstream wavelengths (CATV and data)
4. Detection of the downstream wavelengths
5. Transmission of the upstream wavelength

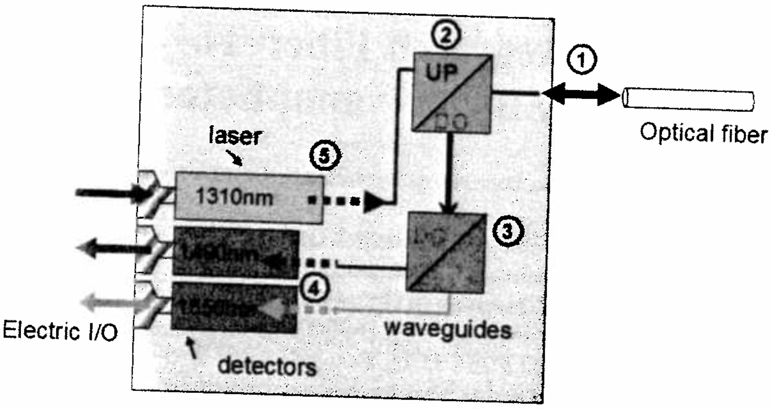

Figure 1: Schematic overview of an integrated FTTH transceiver.

Silicon-On-Insulator

Silicon-on-insulator technology has many advantages for the realization of photonic integrated circuits. First of all the platform is CMOS-compatible and due to the high refractive index contrast, the designs are very compact. Furthermore, out-of-plane coupling can be realized by the use of a diffractive grating [2]. This makes wafer scale testing feasible. By unifying these advantages it is possible to fabricate nanophotonic integrated circuits in large volumes at a low cost.

Fiber/Chip Coupling

In order to couple and at the same time split the upstream and downstream wavelength bands, we use a 1-dimensional grating duplexer [3]. The working principle is shown in Figure 2. Under a certain angle of the optical fiber, the Bragg condition is fulfilled for both wavelengths λ1 and λ2 and the 2 wavelength bands will couple in opposite directions. The grating period, duty cycle and number of periods have been optimized using a particle swarm optimization algorithm, in order to achieve maximum coupling efficiency for both the upstream and downstream wavelength bands.

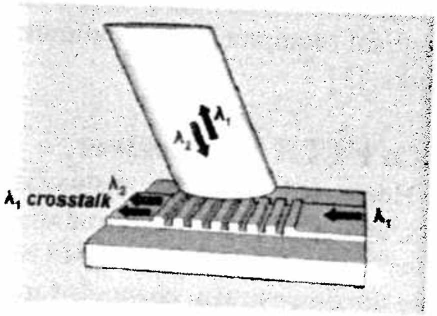

Figure 2: Operation principle of a grating duplexer. λ1 represents the upstream wavelength band, λ2 represents the downstream wavelength band.

The duplexer has been designed in a way that the upstream band around 1310 nm is coupled in the forward direction and the downstream band around 1520 nm is coupled backwards. The measurement results of the grating duplexer are plotted in Figure 3. The period of the grating is 520 nm and the grating duty cycle is 40%. The etch depth is 70nm. The number of grating periods is 20. Index matching fluid was applied between the optical fiber facet and the grating duplexer to avoid reflections at the fiber facets and the fiber was tilted under an angle of 10 degrees. Standard single mode fiber was used for the experiments. The experiments were performed using TE polarized light. Making the grating duplexer polarisation independent can be done by using a two dimensional grating structure [3].

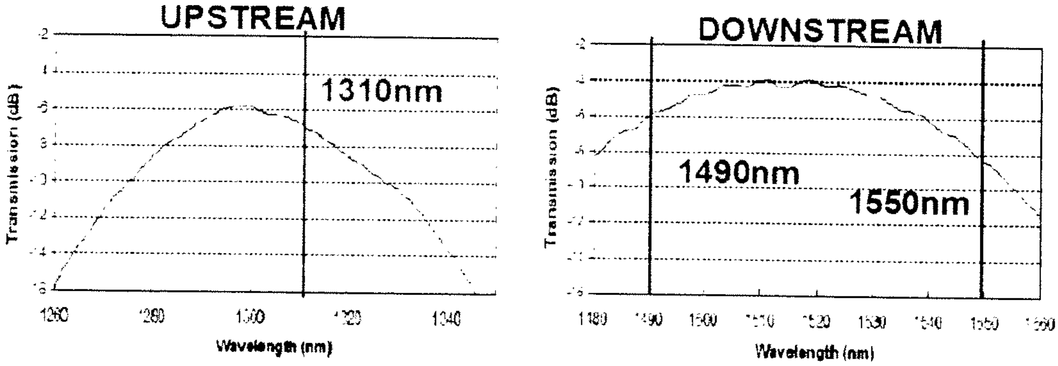

Figure 3: Transmission spectrum of the grating duplexer for the upstream band (left graph) and the downstream band (right graph).

The coupling efficiencies of the central wavelengths are -6 dB for 1300 nm and -4 dB for 1520 nm. At the communication wavelengths 1310 nm, 1490 nm and 1550 nm the coupling efficiencies are respectively -7 dB, -6 dB and -8 dB. Decreasing these losses can be done by first depositing an extra silicon layer prior to defining the grating [4]. Simulations show that efficiencies of -1.9 dB are possible for both central wavelengths.

Demultiplexing the 1490nm and 1550nm wavelengths

Demultiplexing the downstream band is accomplished by using a planar concave grating demultiplexer (PCG) [5]. In order to avoid possible crosstalk from the grating duplexer as shown in Figure 2, we also have to filter the 1310 nm wavelength in both downstream channels. This was done by adjusting the free spectral range of the grating demultiplexer. Measurements of the grating demultiplexer are shown in Figure 4. The maxima of the transmission efficiencies are -5.4 dB for 1485 nm and -7.6 dB for 1542 nm and are limited by the Fresnel reflection at the Silicon/Air interface. The crosstalk at these maxima is about -30 dB and -40 dB respectively. Filtering of the 1310 nm channel is as good as -40 dB. Several techniques to reduce the insertion loss of this demultiplexer exist; for example with high reflectivity Bragg reflectors, as described in [6], the insertion loss can be reduced by 4 dB.

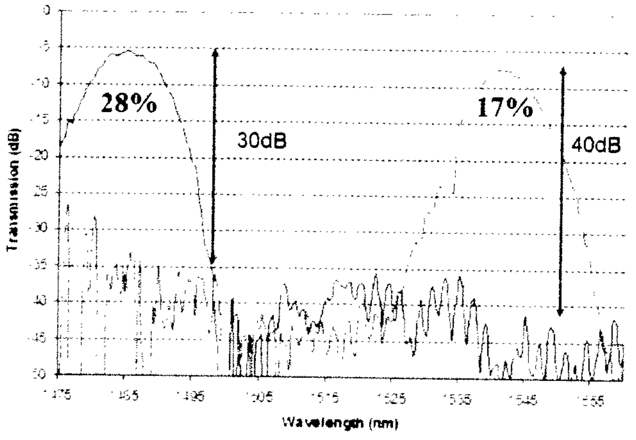

Figure 4: Transmission spectrum of the planar concave grating demultiplexer.

Prospects for a fully integrated FTTH transceiver

In Figure 5 we have combined the grating duplexer, which couples the light and splits the upstream/downstream bands, and the PCG demultiplexer which separates the 1490 nm and 1550 nm while filtering 1310 nm. These two components thus take care of the whole passive section (numbers 1 to 3 in Figure 1) of a FTTH transceiver. As mentioned these structures need to be optimized in order to satisfy the FTTH specifications. With a silicon overlay we can enhance the coupling efficiencies and with a 2D grating the light coupling can be made polarisation independent. Using high reflectivity Bragg reflectors, the PCG efficiency can be greatly increased.

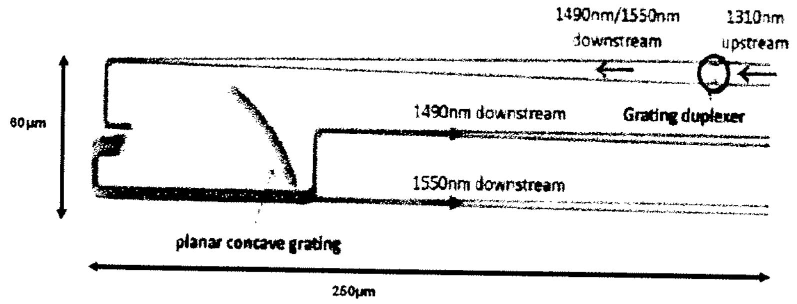

Figure 5: Microscope·image of a grating duplexer in combination with a Planar Concave Grating (PCG) demultiplexer for FTTH applications.

Integrating the photodetectors and laser can be done with a heterogeneous III/V Silicon DVS-BCB bonding technique. In [7] compact and efficient InAlAs–InGaAs metal–semiconductor–metal photodetectors integrated on silicon-on-insulator (SOI) waveguides have been reported and these are an excellent candidate for future FTTH transceivers. For the laser diode, we propose to integrate a VCSEL. This laser type has a high efficiency and a low threshold current, which makes that the VCSEL has a very low power consumption.

Acknowledgement

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