

A METHOD AND SYSTEM FOR MEASUREMENT OF OPTICAL LOSS IN WAFER LEVEL TESTING VIA WAVELENGTH-ROUTE DIVISION

FIELD OF THE INVENTION

[001] The present invention relates to a field of silicon photonics and optical loss measurement and more particularly to a method and system for measurement of optical loss in wafer level testing via wavelength-route division.

BACKGROUND OF THE INVENTION

[002] Wafer-level loss measurement systems typically use a laser source, a power detector, and two optical fibers. Light is coupled into a photonic circuit on a wafer by using a vertically coupled grating coupler. Routes of different length are used, and the output power varies depending on the length of the route. This allows the optical loss per unit length to be measured.

[003] Current loss measurement systems have a lot of variability in terms of the measured loss. The main variability is due to the grating coupling efficiency: vertical coupling of light is required for wafer level testing setups, but the coupling efficiency depends on the optimization and approach of the fiber array to the wafer. Sometimes, this can be a 6-axis (x , y , z , θx , θy , θz) optimization with low tolerances. If the coupling efficiency is not exactly matched, this will cause the loss measurement to be inaccurate.

[004] Therefore, there remains a need to provide a system that provides high accuracy in optical loss measurement and a method to determine the optical loss in wafer level testing via wavelengths route division.

SUMMARY OF THE INVENTION

[005] In view of the foregoing, a system for measurement of optical loss in wafer level testing via wavelength route division is provided.

[006] In an aspect, the system includes a light source unit that is connected with a first fiber port assembly to provide an input light wavelength, a first grating coupler unit connected

with the first fiber port assembly to couple a respective fiber array (FA), a splitter unit connected with the first grating coupler unit to divert the input light wavelength to a plurality of routes, a combiner module connected with the plurality of route to combine light wavelengths and a second grating coupler unit connected with the combiner module to couple output fiber array, an optical power detector module connected with a second fiber port assembly to collect an output spectrum.

[007] In another aspect the light source unit is a tuneable light source (TLS) and coupled vertically to a silicon photonics wafer.

[008] In another aspect, the second grating coupler unit may be connected with the second fiber port assembly.

[009] In another aspect, the first fiber port assembly collects and couple a vertical light with a multiple port fibre array (FA).

[0010] In another aspect, the first grating coupler unit may be coupled to the respective fiber array.

[0011] In another aspect, splitter unit utilizes a 1:N splitter to split the light into different lengths in the plurality of routes. The value of N can be larger than 2.

[0012] In another aspect, wavelengths (lights) are travelled and traversed in the plurality of routes and their wavelengths are combined via the combiner module.

[0013] In another aspect, a detected power at the second fiber port assembly is calculated via the difference of several variables for instance the output coupling, variable loss, system loss, input coupling and detected power.

[0014] In another aspect, a method for measuring optical loss in wafer level testing via wavelength route division is disclosed. The method comprises providing an input light wavelength, diverting the input light wavelength into a plurality of routes, and combining the input light wavelength with one or more other input light wavelengths. Further, the method comprises collecting an output spectrum in response to combining the input wavelength.

BRIEF DESCRIPTION OF THE DRAWINGS:

[0015] Other objects, features, and advantages of the embodiment will be apparent from the following description when read with reference to the accompanying drawings. In the drawings, wherein like reference numerals denote corresponding parts throughout the several views:

[0016] The diagrams are for illustration only, which thus is not a limitation of the present disclosure, and wherein:

[0017] **FIG. 1** illustrates a block diagram of a system 100 of measurement for optical loss, according to an embodiment herein.

[0018] **FIG. 2** illustrates a schematic view of silicon photonics 200 according to an embodiment herein.

[0019] **FIG. 3** illustrates another block diagram for splitting of wavelength of light, according to an embodiment herein.

[0020] **FIG. 4** illustrates the output spectrum from the system disclosed herein and equations for calculating optical loss.

[0021] To facilitate understanding, like reference numerals have been used, where possible to designate like elements common to the figures.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS:

[0022] The embodiments herein and the various features and advantageous details thereof are explained more fully with reference to the non-limiting embodiments that are illustrated in the accompanying drawings and detailed in the following description. Descriptions of well-known components and processing techniques are omitted so as to not unnecessarily obscure the embodiments herein. The examples used herein are intended merely to facilitate an understanding of ways in which the embodiments herein may be practiced and to further enable those of skill in the art to practice the embodiments herein. Accordingly, the examples should not be construed as limiting the scope of the embodiments herein.

[0023] Throughout the prior art, there remains a need of providing a method and system that provides high accuracy in optical loss measurement in wafer level testing via wavelength-route division.

[0024] In addressing the identified problems of conventional technologies, the present disclosure provides a method and system of measuring loss in a wafer level testing setup, using vertically coupled light. In particular, the method and system disclosed herein can divide light into separate “routes”, based on any property such as wavelength, polarization, or modal properties of the light. Consequently, the light can only be coupled into once, and subdivided by its property. The light can pass through said “routes” of different length and interfere at the output. The output power can be measured against wavelength, polarization, or mode to determine and calculate the optical loss. This removes the issue of coupling efficiency errors. Essentially, the method and system disclosed herein can compare the ratio of powers so that the coupling efficiency is de-embedded. The equation for calculating optical loss is stated in a subsequent paragraph.

[0025] Accordingly, in one embodiment, there is provided a method and system for measurement of optical loss in wafer level testing via wavelength route division, whereby light can be split by one of its property (wavelength, polarization, mode, etc) into separate paths or “routes”, and the subsequent ratio of powers may be compared, to measure the optical loss. This can advantageously remove inaccuracies in the coupling efficiency.

[0026] In one embodiment, the method and system disclosed herein comprises one coupling structure with light being divided into different ‘routes’. Thus, the coupling efficiency is the same for each path. This could remove the inaccuracies in the coupling efficiency. In another embodiment, the method and system disclosed herein comprises at least 3 coupling structures separately. Thus the coupling efficiency in separated ‘routes’ is different. So it could remove the inaccuracies in the coupling efficiency.

[0027] Referring to **FIG. 1**, a block diagram of a system 100 of measurement for optical loss in accordance with the embodiment of the present invention is provided. The system 100 of measurement for optical loss includes a light source unit 102, a first fiber port assembly 104, a first grating coupler unit 106, a splitter unit 108, a plurality of routes 110, a combiner

module 112, a second grating coupler unit 114, a second fiber port assembly 116 and an optical power detector module 118.

[0028] The light source unit **102** may be a laser, a superluminescent diode, or other light emitting device. In another example, the light unit **102** may be for example, a red or green laser diode. The light source unit **102** may be used to emit an electromagnetic radiation in the first fiber port assembly **104**. In an embodiment, the light source unit **102** is a tuneable light source (TLS).

[0029] Each of the first fiber port assembly **104** and the second fiber port assembly **116** may comprise an optical fiber, a reinforcement strand for support, and fiber optic cable connectors. The fiber port assemblies can be made of one of single-mode fibers. The single mode fibers are made of a single strand of glass fiber and ranges between 8.3 and 10 microns in diameter. The single mode fibers has only one mode of transmission in which light moves down the cable in a single direction and have a high bandwidth. The first grating coupler unit **106** and the second grating coupler unit **114**, in an example, are integrated-optic components formed by a refractive index modulation. The refractive index modulation may be performed in a thin layer on a waveguide for coupling a guided wave. The first grating coupler unit **106** and the second grating coupler unit **114** provide output or input coupling of a guided wave. In addition, the first grating coupler unit **106** and the second grating coupler unit **114** may provide functions, such as focusing of light, polarization splitting, switching, and guided-mode selection. In an example, the grating coupler unit **106** and the second grating coupler unit **114** can be placed anywhere on a chip, allowing simple wafer scale testing and providing much wider alignment tolerance. The splitter unit **108** may be an integrated waveguide optical power distribution device that can split an incident light beam into two or more light beams. The combiner module **112** can be used for combining multiple laser or light signals from multiple different paths into a single fiber.

[0030] The optical power detector module **118** can be a device used to measure an output power of an optical signal or average power in fiber optic systems. In an example, the optical power detector module **118** may comprise a calibrated sensor, a measuring amplifier and a display. The calibrated sensor may comprise a photodiode selected for an appropriate range of wavelengths and power levels. On the display, the measured optical power and set wavelengths are displayed.

[0031] In one embodiment, the light source unit **102** may be optically coupled to the first fiber port assembly **104**. The first fiber port assembly **104** may be connected with the first grating coupler unit **106**, and the first grating coupler unit **106** may be connected with the splitter unit **108**. The splitter unit **108** diverts the light to the plurality of routes **110** (**110A**, **110B**..... **110C**). In one embodiment, the plurality of routes **110** may have different lengths. The plurality of routes **110** can be connected with the combiner module **112**. The combiner module **112** is connected with the second grating coupler unit **114**. The second grating coupler unit **114** is connected with the second fiber port assembly **116**. The second fiber port assembly **116** is connected with an optical power detector module **118**. The first fiber port assembly **104** may collect and couple the vertical light from the light source unit **102** with a multiple port fiber array. The first grating coupler unit **106** couples the respective fiber array. The optical loss may be measured by comparing the output power with one or more of wavelength, polarization, or mode of the light. The light source unit **102** and fiber port assembly **104** can be connected by fiber. In continuation, the fiber port assembly **116** and optical power detector module **118** can be connected by fiber. Furthermore, there is no connection between the first fiber port assembly **104**, second fiber port assembly **116** and first grating coupler **106** and second grating coupler **114**. The light coupled from **104** to **106** in free space is called “coupling efficiency”.

[0032] The grating coupler **106**, splitter unit **108**, combiner module **112**, grating coupler **114** can be fabricated on the same chip which is connected by optical waveguide.

[0033] Regarding the plurality of routes, the number of routes can be greater than 2. The light source unit **102** provide optical light with different wavelength and go to fiber port assembly **104**. In free space coupling, optical light is coupled into grating coupler **106** and then it transports in optical waveguide. After the splitter unit **108**, light will split into different paths due to different wavelength. When light arrives at the combiner module **112**, it will combine and propagate in the same optical waveguide. Thus, it is coupled into fiber port assembly **116** and detected by optical power detector module **118**.

[0034] Referring to **FIG. 1**, the splitter unit **108** is connected with the first grating coupler unit **106**. In an embodiment, the 1: N splitter is utilized to split the light into different lengths in the plurality of route **110** (**110A**, **110B**..... **110C**). In another embodiment, the splitter unit

108 is wavelength-based. The splitter unit **108** may use other systems including but not limited to one of a polarization mode and a propagation mode. The wavelengths (lights) are travelled and traversed in the plurality of route **110** (**110A**, **110B**,..... **110C**). Thereafter, the lights are combined via the combiner module **112**. In an embodiment, each wavelength travels in different lengths. The wavelengths undergo with different amount of loss αL . In another embodiment, the relative difference between each wavelength level then determines the loss per unit length. The second grating coupler unit **114** may be connected with the second fiber port assembly **116**. In an aspect, the second grating coupler unit **114** may separately measure and calibrate the light wavelengths. In an embodiment, the lengths are defined in the plurality of route **110** (**110A**, **110B**,..... **110C**). In an embodiment, the channels may be spaced together and configured in another structure with the reverse lengths. Such a configuration provides benefits of characterizing loss against wavelength.

[0035] In another embodiment, the detected power is calculated via the difference of several variables for instance the output coupling, variable loss, system loss, input coupling and detected power. The output spectrum is thus obtained from the second fiber port assembly **116** that is further connected with an optical power detector module **118**.

[0036] In another embodiment, the wavelengths that are partially split are coupled to estimate the propagation loss.

[0037] In an embodiment, the system **100** is not affected from the coupling efficiency error because the ratio of powers is compared to de-embed and measure optical loss.

[0038] In an example, the lengths of different routes **110** are known. Equations (1), (2), and (3) may be used to obtain the result, as shown in **FIG.4**. The equation is given as:

$$P_1 - P_2 = \alpha (L_1 - L_2) \quad (1)$$

$$P_2 - P_3 = \alpha (L_2 - L_3) \quad (2)$$

$$P_1 - P_3 = \alpha (L_1 - L_3) \quad (3)$$

where, P_1 , P_2 , and P_3 denote power levels;

L_1 , L_2 and L_3 denote lengths of each route; and

α denotes absorption coefficient, and α is same for the routes **110A**, **110B**, and **110C**.

Another equation (4) may be used:

$$P_n = P_{in} - G_{in} - S_{ys} - \alpha L_n - G_{out} \quad (4)$$

where, P_n denotes detected power;

P_{in} denotes input power;

G_{in} denotes input coupling;

S_{ys} denotes system loss;

αL_n denotes variable loss; and

G_{out} denotes output coupling.

If there is wavelength independent loss, these equations could be applied to measure the optical loss as below:

For example:

1. Splitter unit 108 splits 3 routes 110 with different wavelength range (1500nm-1510nm, 1510nm-1520nm, 1520nm-1530nm).
2. Router 1-light with the wavelength (1500nm-1510nm) propagate on length L1.
Router 2-light with the wavelength (1510nm-1520nm) propagate on length L2.
Router 3-light with the wavelength (1520nm-1530nm) propagate on length L3.
3. After combiner module 112, the light is combined. The output spectrum is monitored and different wavelength range have different power, such as
 - a. At wavelength (1500nm-1510nm), the power is P1
 - b. At wavelength (1510nm-1520nm), the power is P2.
 - c. At wavelength (152nm-1530nm), the power is P3.
4. After measurement data is collected for different power levels (P1 P2 P3), the loss is calculated based on equations (1-3).

[0039] In another embodiment, if there is a large wavelength dependent loss, these channels can be placed together. The difference in power may be calculated based on equations (5), (6) and (7). These channels are related to different routes 110 with different wavelength after the splitter unit 108.

$$P_1 - P_2 = \alpha_1 L_1 - \alpha_2 L_2 \quad (5)$$

$$P_2 - P_3 = \alpha_2 L_2 - \alpha_3 L_3 \quad (6)$$

$$P_1 - P_3 = \alpha_1 L_1 - \alpha_3 L_3 \quad (7)$$

where:

P1: the power in 110A

P2: the power in 110C

L1: optical waveguide length in 110A

L2: optical waveguide length in 110B

L3: optical waveguide length in 110C

α_1 : absorption coefficient in 110A at wavelength A

α_2 : absorption coefficient in 110B at wavelength B

α_3 : absorption coefficient in 110C at wavelength C

[0040] In another embodiment, the channels can be provided with another structure with the reverse lengths as mentioned herein. The power difference may be calculated based on the equations (8), (9) and (10):

$$P_1 - P_2 = \alpha_1 L_3 - \alpha_2 L_2 \quad (8)$$

$$P_2 - P_3 = \alpha_2 L_2 - \alpha_3 L_1 \quad (9)$$

$$P_1 - P_3 = \alpha_1 L_3 - \alpha_3 L_1 \quad (10)$$

[0041] In the embodiment, α is different for 110A, 110B, and 110C in the equations 8-10.

α_1 : absorption coefficient in 110A at wavelength A

α_2 : absorption coefficient in 110B at wavelength B

α_3 : absorption coefficient in 110C at wavelength C

[0042] In another embodiment, these coupling structures can be grating or edge coupled. For 2-port designs, directional couplers can be used. The case for 2 wavelengths can be simulated, for showing the working of the 2-port designs. For the wavelengths which are partially split, fitting can be performed to also estimate the propagation loss.

[0043] For Multi-port design, Arrayed Waveguide Grating (AWG) or Mach Zehnder Interferometers (MZI) structures may be used. These structures can split the wavelength into

as many channels as required and can have flat tops. Multiple wavelength channels allow multiple path lengths to be measured with a single transmission spectrum (wavelength sweep). Multiple test structures can be formed as a system of linear equations to solve the wavelength-dependent loss. Since all devices are coupled once, the coupling efficiency remains the same, and can be de-embedded from the measurement.

[0044] In an embodiment, the system **100** removes the variabilities associated with vertical light coupling for wafer level optical testing. Here, there is only 1 coupling structure and then light is divided into different “routes”. So the coupling efficiency is the same for each path. Thus it could remove the inaccuracies. Similarly, there can be at least 3 coupling structures separately. Thus the coupling efficiency in separated ‘routes’ is different. So it could remove the inaccuracies in the coupling efficiency.

[0045] Referring to **FIG. 2** illustrates a schematic view of silicon photonics **200** in accordance with an embodiment of the present invention is disclosed. **FIG. 2** describes that a fiber array couples light into grating coupler structures vertically. In one embodiment, the silicon photonics **200** includes a silicon wafer **210**. The fiber array is put above the grating coupler structures on the wafer **210**. To achieve the best coupling efficiency, the fiber is adjusted along X, Y, Z axis.

[0046] The silicon photonics includes a silicon wafer **210** in which various coordinates (x, y, z) are labelled. Vertical light coupling may be performed using a fiber array having two or more ports, such as the first fiber port assembly **104**, which may couple to their respective grating couplers. The Fiber array may be aligned in the spatial XYZ direction. In an example, the fiber array may require θx , the angle of the fiber array, i.e., the relative height of each fiber array port, and θz that denotes an in-plane alignment of the fiber array x-axis.

[0047] In another aspect, the angles may be fixed and non-uniformity in the wafer **210** setup means that each position will have different angles. In yet another aspect, the above-mentioned scenario may be resolved by creating different routes **110** mentioned herein.

[0048] **FIG. 3** illustrates a system **300** comprising a tuneable light source, such as a tuneable laser source **302**, an optical spectrum analyzer **304**, optical fibers **306**, grating couplers **308** and a wavelength splitter **310**. In an embodiment, single device can be measured, where

different lengths are measured all at once. The light is split into different routes, depending upon the wavelength. Each of these routes has a known distance. For instance, a wavelength 1 has distance x , a wavelength 2 has distance $2x$ and a wavelength 3 has distance $3x$, where x is 10 mm distance for each route.

[0049] In an embodiment, a method for measuring the optical loss is disclosed. The optical loss may be measured in wafer level testing via wavelength route division. The method comprises providing an input light wavelength by tunable laser source, diverting the input light wavelength into a plurality of routes by AWG or MZI Demux design, and combining the input light wavelength with one or more other input light wavelengths. Further, the method comprises collecting an output spectrum in response to combining the input wavelength by photodetector. The essential steps of the method is wavelength-based splitter design which splits the light into different lengths and the calculation methods.

[0050] The method removes the variabilities associated with vertical light coupling for wafer level optical testing in accordance with an embodiment. The vertical light coupling may be performed with a two or more port fiber array, which couples to their respective grating couplers mentioned herein.

[0051] As will be readily apparent to those skilled in the art, the present embodiment may easily be produced in other specific forms without departing from its essential characteristics. The present embodiments are therefore, to be considered as merely illustrative and not restrictive, the scope being indicated by the claims rather than the foregoing description, and all changes which come within therefore intended to be embraced therein.

WE CLAIM

1. A system **(100)** for measurement of optical loss in wafer level testing via wavelength route division, the system comprises:
a light source unit **(102)** connected with a first fiber port assembly **(104)** to provide an input light wavelength;
a first grating coupler unit **(106)** connected with the first fiber port assembly **(104)** to couple a respective fiber array (FA);
a splitter unit **(108)** connected with the first grating coupler unit **106** to divert the input light wavelength to a plurality of routes **(110A, 110B..... 110C)**;
a combiner module **(112)** connected with the plurality of route **(110A, 110B..... 110C)** to combine light wavelengths
a second grating coupler unit **(114)** connected with the combiner module **(112)** to couple an output fiber array;
an optical power detector module **(118)** connected with a second fiber port assembly **(116)** to collect an output spectrum.
2. The system **(100)** as claimed in claim 1, wherein the light source unit **(102)** is a tuneable light source (TLS) that is further coupled vertically to a silicon photonics wafer **(210)**.
3. The system **(100)** as claimed in claim 1, wherein the second grating coupler unit **(114)** is connected with the second fiber port assembly **(116)**.
4. The system **(100)** as claimed in claim 1, wherein the first fiber port assembly **(104)** collects and couple a vertical light with a multiple port fibre array (FA).
5. The system **(100)** as claimed in claim 1, wherein the first grating coupler unit **(106)** is coupled to the respective fiber array.
6. The system **(100)** as claimed in claim 1, wherein the splitter unit **(108)** utilizes 1:N splitter to split the light into different lengths in the plurality of routes **(110A, 110B..... 110C)**.

7. The system (**100**) as claimed in claim 1, wherein wavelengths (lights) are travelled and traversed in the plurality of routes (**110A, 110B..... 110C**) and the wavelengths are combined via the combiner module (**112**).
8. The system (**100**) as claimed in claim 1, wherein a detected power at the second fiber port assembly (**116**) is calculated via the difference of several variables for instance the output coupling, variable loss, system loss, input coupling and detected power.
9. A method for measuring optical loss in wafer level testing via wavelength route division, the method comprising:
 - providing an input light wavelength;
 - diverting the input light wavelength into a plurality of routes;
 - combining the input light wavelength with one or more other input light wavelengths;
 - collecting an output spectrum in response to combining the input wavelength.