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(54) **LIDAR SYSTEM WITH MULTIPLE CHANNEL COUNT**

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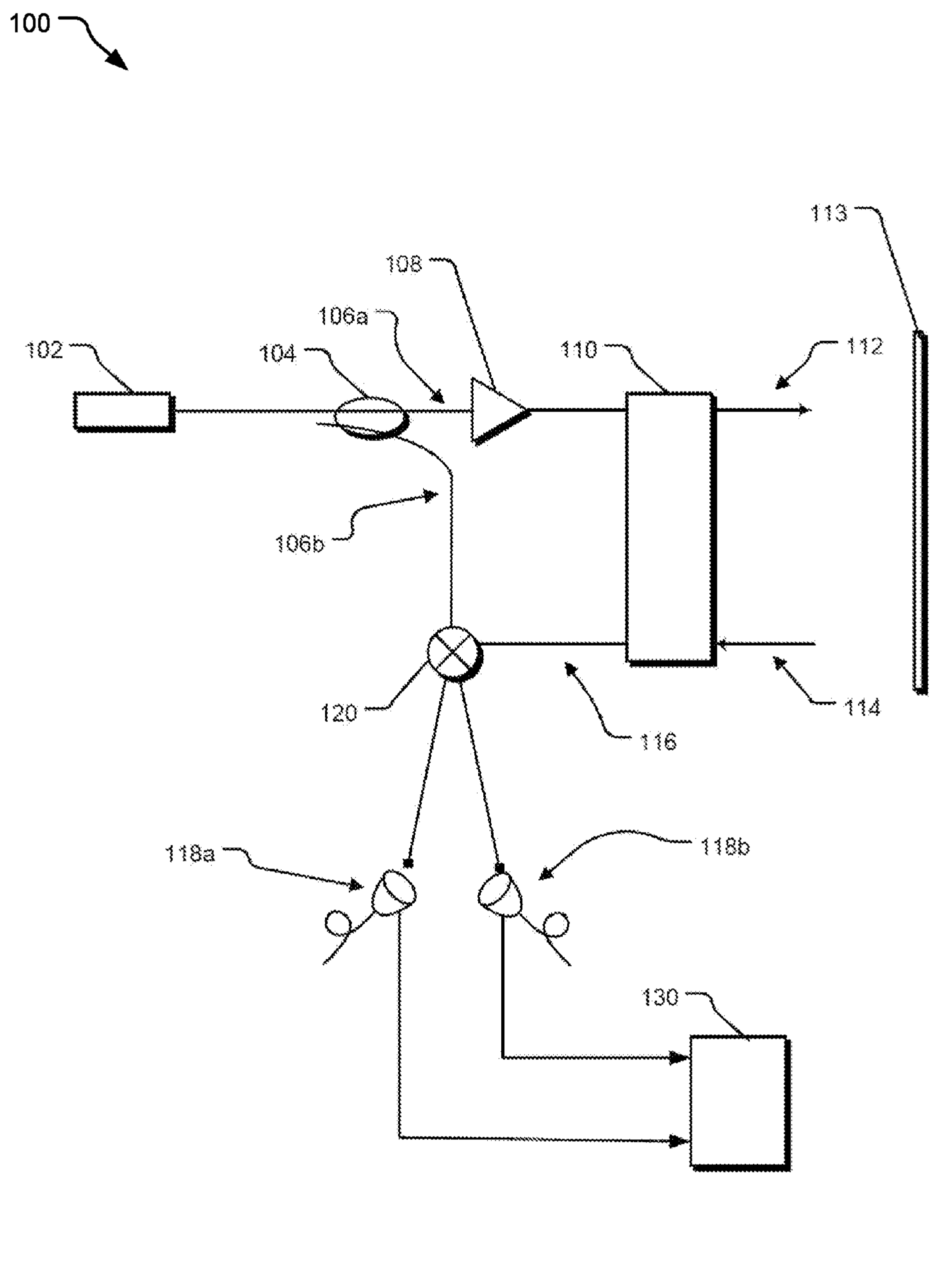
CPC ***G01S 7/4814*** (2013.01); ***G01S 7/4818*** (2013.01)

(57) **ABSTRACT**

Implementations described and claimed herein include a LiDAR system with a semiconductor optical amplifier (SOA) configured to receive a light signal from a master-oscillator laser source, the semiconductor optical source including an optical splitter configured to split the light signal into two or more split light signals and two or more respective semiconductor optical amplifiers (SOAs), each SOA configured to receive one of the split light signals and amplify the split light signal.



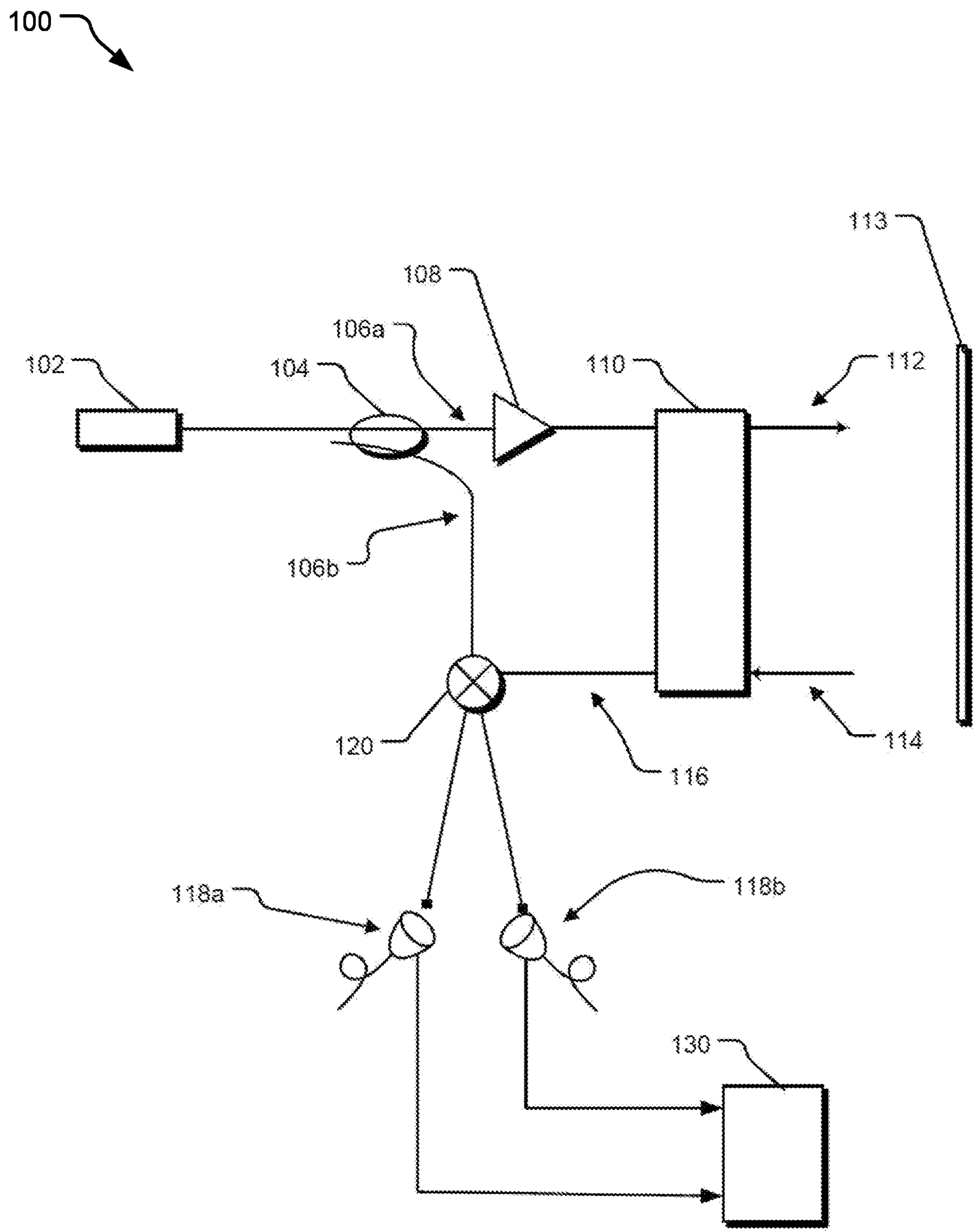
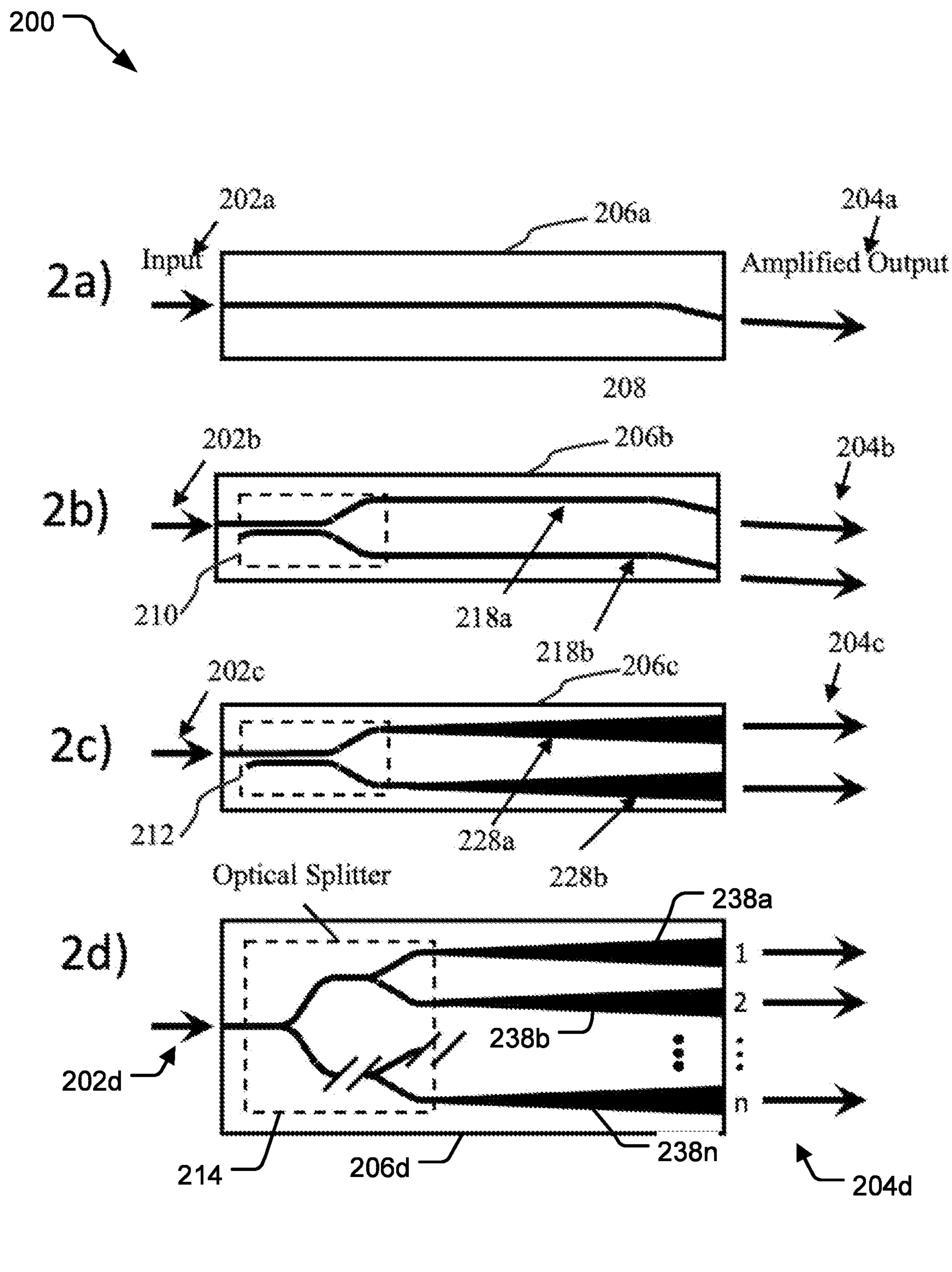
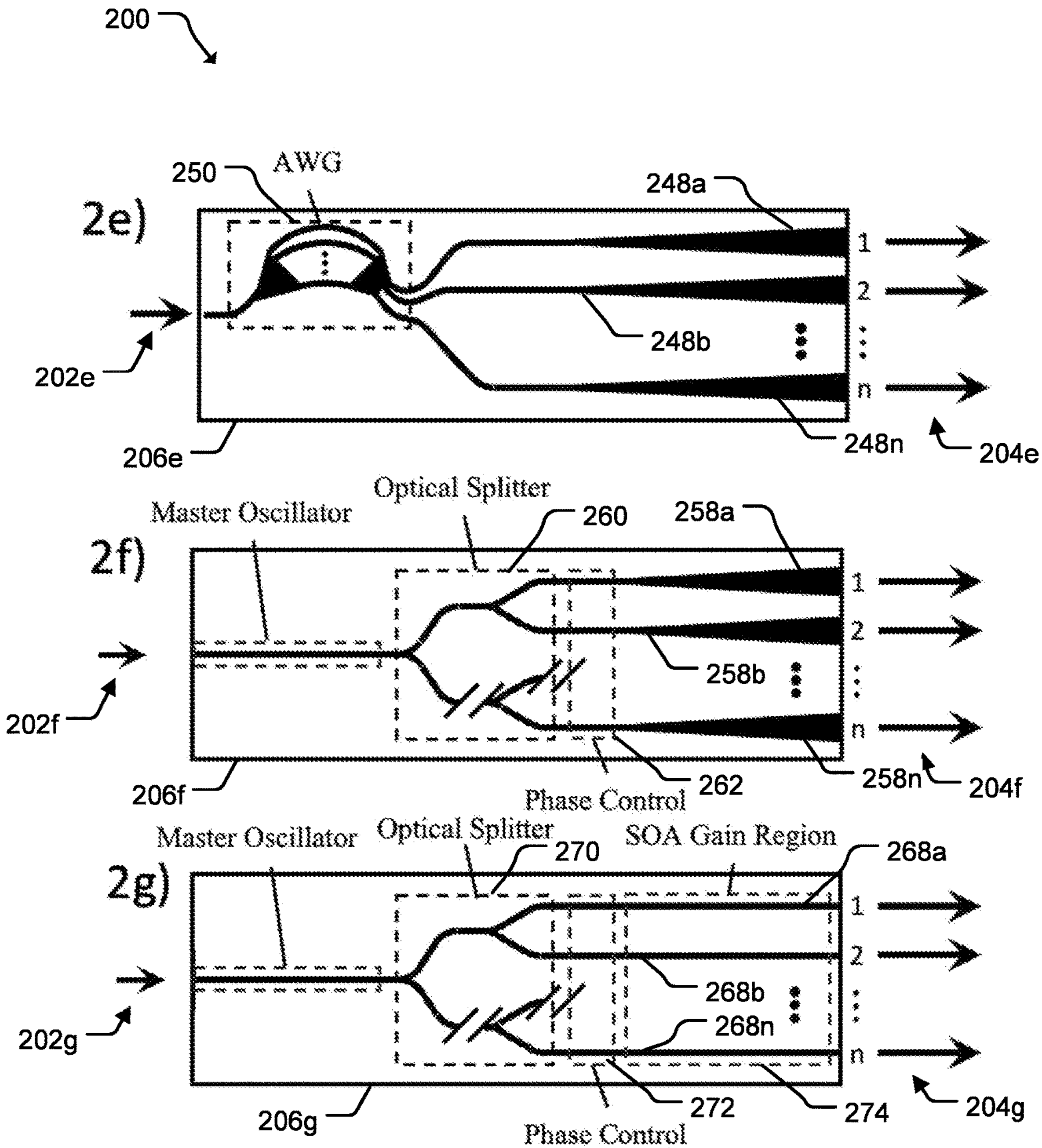


Fig. 1


200
202a
206a
204a
2a)
Input
Amplified Output
208
202b
206b
204b
2b)
210
218a
218b
202c
206c
204c
2c)
212
228a
228b
Optical Splitter
238a
2d)
1
2
238b
n
202d
214
206d
238n
204d

FIGS. 2a-d


200
2e)
250
AWG
248a
1
2
n
248b
202e
206e
248n
204e
Optical Splitter
Master Oscillator
260
258a
2f)
258b
202f
206f
262
258n
204f
Phase Control
Master Oscillator
Optical Splitter
270
SOA Gain Region
268a
2g)
268b
268n
202g
206g
272
274
204g
Phase Control

FIGS. 2e-g

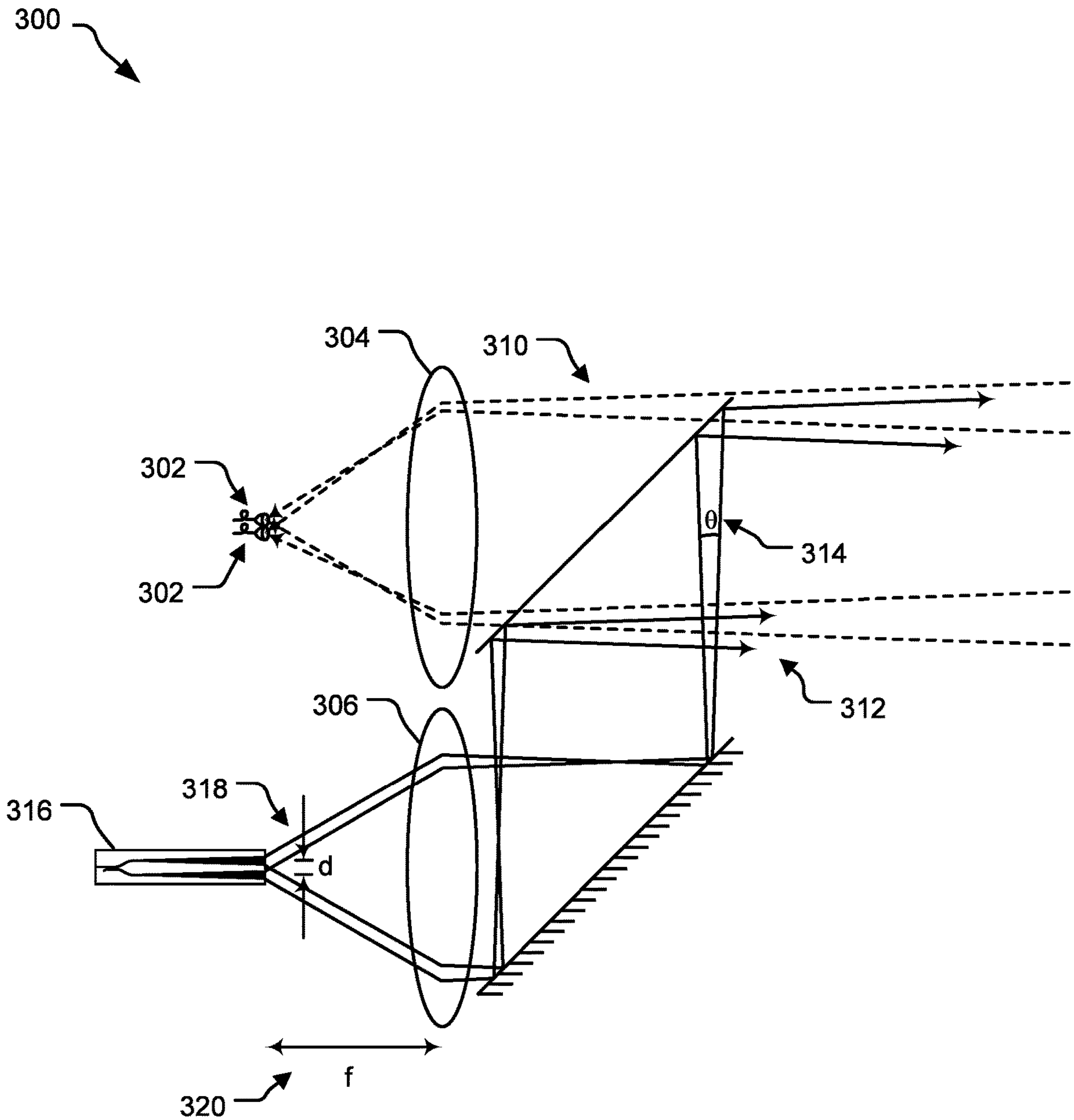


FIG. 3

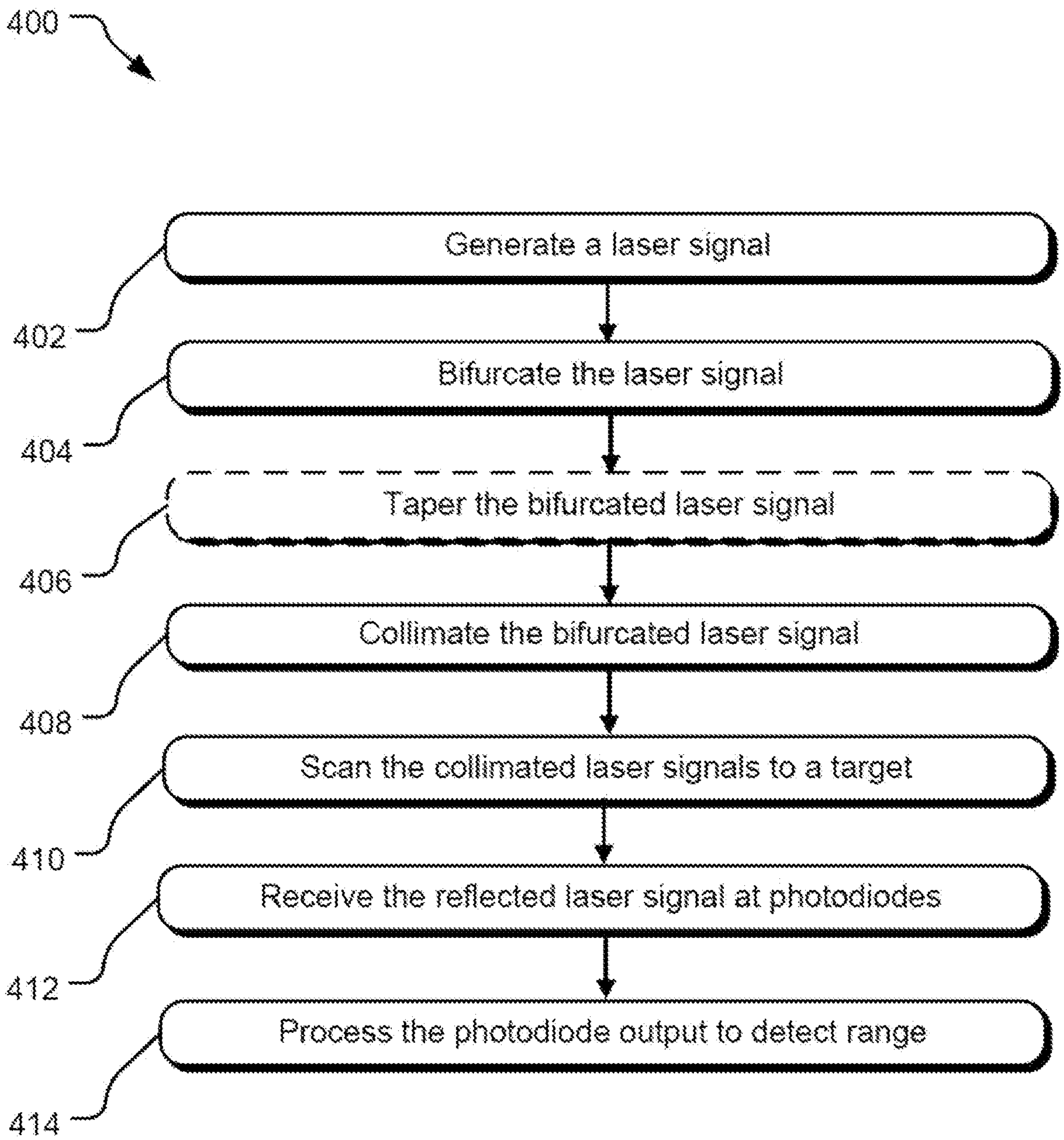

400
Generate a laser signal
402
Bifurcate the laser signal
404
Taper the bifurcated laser signal
406
Collimate the bifurcated laser signal
408
Scan the collimated laser signals to a target
410
Receive the reflected laser signal at photodiodes
412
Process the photodiode output to detect range
414

FIG. 4

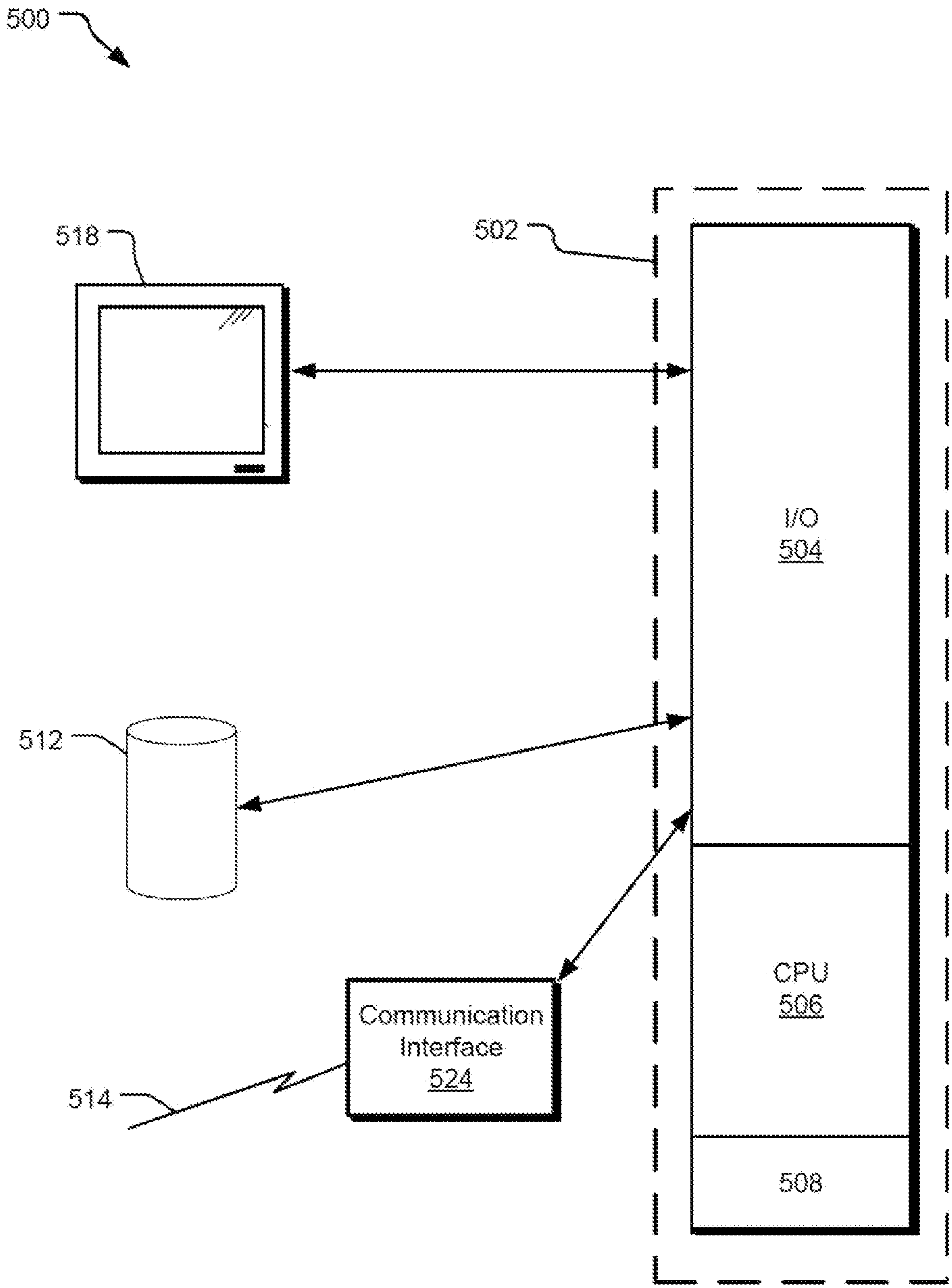

500
518
502
I/O
504
512
CPU
506
Communication
Interface
524
514
508

FIG. 5

LIDAR SYSTEM WITH MULTIPLE CHANNEL COUNT

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application is a non-provisional application based on and takes priority from pending U.S. provisional application Ser. No. 63/385,936, entitled "Lidar System with Multiple Channel Count," which was filed on Dec. 2, 2022. The disclosure set forth in the referenced application is incorporated herein by reference in its entirety.

BACKGROUND

[0002] Light detection and ranging (LiDAR) technology measures a distance to an object by projecting a laser toward the object and receiving the reflected laser. In various implementation of LiDAR systems, a light source illuminates a scene. The light scattered by the objects of the scene is detected by a photodetector or an array of photodetectors. By measuring the time it takes for light to travel to the object and return from it, the distance may be calculated. A LiDAR system may use a number of different ranging methods, including pulsed time of flight, phase shift, and frequency modulation.

SUMMARY

[0003] Implementations described and claimed herein include a LiDAR system with a semiconductor optical amplifier (SOA) configured to receive a light signal from a master-oscillator laser source, the semiconductor optical source including an optical splitter configured to split the light signal into two or more split light signals and two or more respective semiconductor optical amplifiers (SOAs), each SOA configured to receive one of the split light signals and amplify the split light signal.

[0004] This Summary is provided to introduce a selection of concepts in a simplified form that are further described below in the Detailed Description. This Summary is not intended to identify key features or essential features of the claimed subject matter, nor is it intended to be used to limit the scope of the claimed subject matter. These and various other features and advantages will be apparent from a reading of the following Detailed Description.

BRIEF DESCRIPTION OF THE DRAWINGS

[0005] A further understanding of the nature and advantages of the present technology may be realized by reference to the figures, which are described in the remaining portion of the specification. In the figures, like reference numerals are used throughout several figures to refer to similar components.

[0006] FIG. **1** illustrates an example configuration of a coherent LiDAR system using a laser scanner and a coherent receiver.

[0007] FIGS. **2***a*-**2***g* illustrate example implementations of various semi-conductor based amplifiers used in the coherent LiDAR system disclosed herein.

[0008] FIG. **3** illustrates an example illustration of the coherent LiDAR system disclosed herein using a bifurcated semiconductor amplifier.

[0009] FIG. **4** illustrates an example operations disclosing use of the coherent LiDAR system disclosed herein using bifurcated semiconductor amplifier to increase the channel count.

[0010] FIG. **5** illustrates an example processing system that may be useful in implementing the technology described herein.

DETAILED DESCRIPTIONS

[0011] Light detection and ranging (LiDAR) is a process for measuring distances. For example, energy such as laser light can be directed toward a target object, and the energy reflected by the target object can be detected and measured by a sensor or detector. The distance to the target object can be calculated based on the speed of the light and the time it takes for energy to travel to the target object and back to the sensor. In some cases, LiDAR can use ultraviolet, visible, or near-infrared sources to sense, image, identify, or map objects. In some cases, the sensor uses coherent detection, where a portion of the energy from the laser is separated and made to interfere optically with the energy reflected by the target. In other cases, the sensor may use an incoherent detection scheme, where the return light may be measured directly.

[0012] LiDAR systems may include an optical chip or a semi-conductor chip to integrate as much processing as possible so as to reduce cost and complexity of the system. For example, LiDAR systems may include a master oscillator power amplifier (MOPA) style architecture to generate a large amount of power with high optical quality. Here the optical signal may be single mode or narrow linewidth optical signal. An example implementation of MOPA architecture includes a lower power, narrow linewidth laser generator paired with a high-power amplifier stage operated in pulsed, continuous wave (CW), or other mode. An example power amplifier for such implementation may be a semiconductor optical amplifier (SOA). Yet alternatively, the laser generator may be distributed feedback (DFB) laser source of a DFB seed laser source, which for example, may emit laser energy from two ends.

[0013] LiDAR systems may include incoherent (or direct energy detection) LiDAR systems and coherent LiDAR systems. The incoherent LiDAR systems generally measure amplitude changes of reflected light. On the other hand, coherent LiDAR systems may use optical heterodyne detection which is generally more sensitive than direct detection and allows them to operate at much lower power. However, such systems require more complex transceivers.

[0014] For LiDAR systems, including coherent LiDAR system such as that disclosed herein, it is important to increase the sample rate at which the received laser signal is sampled. The maximum sample rate of the LiDAR systems depends on a number of factors, including the number of laser sources or channels, the number of receivers, etc. The LiDAR system disclosed herein provides a method to increase the number of laser sources or channels to increase the sample rate, with a trivial impact on cost and complexity of the LiDAR system.

[0015] LiDAR systems may use an optical amplifier that amplifies an optical signal directly, without the need to first convert it to an electrical signal. Specifically, the LiDAR system disclosed herein may include a bifurcated laser or amplifier system. The amplifier may be a semiconductor optical amplifier SOA or a tapered amplifier (TA). A bifurcated SOA may be an SOA that bifurcates an input laser signal into multiple waveguides to increase the channel count of laser output signals. A TA may be an SOA with a slow, widening, or tapered waveguide to increase gain area and therefore overall output power of the laser signals. A bifurcated TA is an SOA that combines both the bifurcation and the tapering features to increase the channel count of the number of laser signals as well as the output power of the laser signals for each of the output channels.

[0016] FIG. **1** illustrates an example configuration of a coherent LiDAR system **100** using a laser scanner and a coherent receiver. A laser source **102** generates laser signal that is split by a splitter **104**. A portion of the laser signal is split as an amplification stage laser signal **106***a* to be input to an amplifier **108**. Another portion of the laser signal is split as a coherent receiver portion signal **106***b* to be used by an optical mixer **120**. In one implementation of the coherent LiDAR system **100**, the amplifier **108** may be a bifurcated amplifier, a tapered amplifier (TA), or a bifurcated TA as disclosed in further detail below in FIG. **2**. The laser signal **106***a* sent through the amplifier **108** increases in power and scanned throughout the field of view/scene using a scanner **110**. In one implementation, the scanner **110** may be a polygon scanner.

[0017] The scanner **110** projects the scanned laser signal **112** towards a target and **113** de-scans the reflected laser signal **114** that is reflected from the target **113**. The optical mixer **120** may receive a signal generated by a local oscillator and the de-scanned laser signal **116** as inputs and generate frequency differential between the two as output. The optical mixer **120** may output an in-phase or I portion and a quadrature or Q portion of the frequency differential so as to maintain the phase information. The output signal from the optical mixer **120** is received by photodiodes **118***a* and **118***b*, which converts the optical signal into electrical signal for further processing by a digital signal processing unit **130**. The digital signal processing unit **130** processes the input signal received from the photodiodes **118***a* to determine range information of the target **113**.

[0018] FIGS. **2***a*-**2***g* illustrate implementations of various semi-conductor based amplifiers **200** used in the coherent LiDAR system disclosed herein. Specifically, an implementation **2***a* illustrates a semiconductor optical source **206***a* with a bent waveguide **208**. An input laser signal **202***a* may be amplified and bent by the waveguide **208** to send a bent and amplified output **204***a* to a scanner, such as a polygon scanner. An implementation **2***b* discloses another implementation of a semiconductor optical source **206***b* that includes a bifurcated and bent waveguides **218***a* and **218***b*. Specifically, a bifurcation section **210** bifurcates an input laser signal **202***b* into the two waveguides or semiconductor optical amplifiers (SOAs) **218***a* and **218***b* that generates output laser signals **204***b*.

[0019] While the illustrated implementations of semiconductor optical source **206***b* discloses two waveguides or SOAs **218***a* and **218***b* to divide and bend the input laser signal **202***b* into two output signals **204***b*, in alternative implementations, higher number of waveguides may be provided to divide the input laser signal into a larger number of bent output laser signals. The bent waveguides **218***a* and **218***b* may reduce reflections from an end facet on a high-power output side of the semiconductor optical source **206***b*.

[0020] The semiconductor optical source **206***b* may be configured to increase the power of the laser signal traveling through the waveguides or SOAs **218***a* and **218***b*. Cost of SOAs depend on its wafer area, wafer material, and complexity of the SOA. Including a number of waveguides into the SOA **206***b* allows including additional channels for laser signal to travel to a scanner while reducing cost due to wafer material, wafer area, and complexity of the SOA to be lower. For example, a semiconductor wafer used for the semiconductor optical source **206***b* may be 100 s um wide, while the actual SOA region is on the scale of microns wide. The SOAs disclosed herein utilize the additional room on the wafer for bifurcation of waveguides to increase the channel count.

[0021] Another implementation of a semiconductor optical source **206***c* includes bifurcated and tapered waveguides or SOAs **228***a* and **228***b* that bifurcates an input laser signal **202***c* into the two waveguides **228***a* and **228***b* that generates output laser signals **204***c*. A bifurcation section **212** bifurcates an input laser signal **202***c* into the two tapered waveguides or SOAs **228***a* and **228***b* that generates output laser signals **204***c*. Each of the waveguides **228***a* and **228***b* are tapered to increase the output range of the output laser signal **204***c*. While the waveguides **228***a* and **228***b* are tapered but not bent, in an alternative implementation they may also be bent. Furthermore, while the illustrated implementations of SOA **206***c* discloses two waveguides **228***a* and **228***b* to divide and taper the input laser signal **202***c* into two output signals **204***c*, in alternative implementations, higher number of waveguides may be provided to divide the input laser signal into a larger number of tapered output laser signals.

[0022] Another implementation of a semiconductor optical source **2***d* includes an optical splitter that splits the input optical signal **202***d* towards n different waveguides or SOAs **238***a*, **238***b*, . . . **238***n* that generate output laser signals **204***d*. The Optical splitter may be at least one of a y-splitter, Mach-Zehnder splitter, multi-mode interferometer (MMI) splitter, wavelength splitter, or selective switching.

[0023] Another implementation of a semiconductor optical source **2***e* that uses wavelength dependent splitting. For example, arrayed waveguide grating (AWG) **250** can also be used to split input light signal **202***e* between multiple output amplifiers **248***a*, **248***b*, . . . **248***n* to generate output laser signal **204***e*.

[0024] Another implementation of a semiconductor optical source **2***f* discloses the entire chip **206***f* functioning as a master oscillator power amplifier (MOPA) architecture, where a single master oscillator **260** is split by an optical splitter **262** between multiple amplifier sections **258***a*, **258***b*, . . . **258***n*. In this implementation, the entire optical chip **206***f* may act as a coupled laser resonator. In one implementation phase control **264** may be added to the individual arms to ensure optimal coupling performance to generate output laser signals **204***f*. In one implementation, the optical splitter **260** is a waveguide splitter including at least one of a y-splitter, Mach-Zehnder splitter, multi-mode interferometer (MMI) splitter, wavelength splitter, or selective switching.

[0025] Another implementation of a semiconductor optical source **2***g* illustrates using waveguide SOAs (semiconductor optical amplifiers) rather than tapered amplifiers. In such implementation, the input signal **202***g* is split by an optical splitter **270** between multiple waveguide SOAs **268***a*, **268***b*, . . . **268***n* to generate the output laser signals **204***g*. In one implementation, the optical splitter **270** is a waveguide splitter including at least one of a y-splitter, Mach-Zehnder splitter, multi-mode interferometer (MMI) splitter, wavelength splitter, or selective switching.

[0026] FIG. **3** illustrates an example illustration of the coherent LiDAR system **300** disclosed herein using a bifurcated semiconductor amplifier. Specifically, the LiDAR system **300** includes an SOA **316** with bifurcated and/or tapered waveguides to generate two channels of light that are spatially separated by a distance d **318**. A collimation lens **306** having a focal length f **320** collimates the laser signals output from the SOA **316**. The collimation of the laser signals results in having an angular separation of θ **314** in angular space between the laser signals reflected by a scanner **310**. The angular separation of θ is equal to 2*arctan (**1/2***d/f), where fis the focal length of the collimation lens **306** and d is the distance between the two emitting waveguides on the SOA **316**.

[0027] The laser signals may travel to and be reflected from a target. The reflected laser signals (indicated by dotted lines) are focused on photodiodes **302** and **304** using a focusing lens **304**. As the SOA **316** has bifurcated waveguides generating multiple laser signals, these two laser signals are scanned in parallel through the LiDAR system **300**, resulting in the range data/sample points that can be collected by the photodiodes **302** and **304**. While the implementation in FIG. **3** has the SOA **316** bifurcating an input laser signal, in alternative implementations, an input laser signal may be divided into a higher number of output laser signals that are scanned in parallel through the LiDAR system **300**.

[0028] FIG. **4** illustrates an example operations disclosing use of the coherent LiDAR system disclosed herein using bifurcated semiconductor amplifier to increase the channel count. An operation **402** generates a light signal, such as a laser signal. An operation **404** bifurcates the laser signal using an SOA that has bifurcated waveguides. An operation **406** optionally tapers the bifurcated laser signal. The bifurcated laser signal is collimated by a collimation lens at operation **408**. An operation **410** scans the collimated laser signal to a target. For example, the collimated laser signal may be scanned to a target using a polygon scanner. An operation **412** receives the laser signal reflected from the target using photodiodes. The output from the photodiodes is processed by a processing operation **414** to detect range of the target.

[0029] FIG. **5** illustrates an example processing system **500** that may be useful in implementing the described technology. The processing system **500** is capable of executing a computer program product embodied in a tangible computer-readable storage medium to execute a computer process. Data and program files may be input to the processing system **500**, which reads the files and executes the programs therein using one or more processors (e.g., CPUs, GPUs, ASICs). Some of the elements of a processing system **500** are shown in FIG. **5** wherein a processing device **502** is shown having an input/output (I/O) section **504**, a processing unit **506**, and a memory section **508**.

[0030] In some implementations, an operating system (not shown) may reside in the memory **508** and be executed by the processing unit **506**. In other implementations, the processing unit **506** does not execute an operating system during nominal operations. One or more applications (not shown) may reside in the memory **508**, such as the digital signal processing unit **130** of FIG. **1**. In various implementations, the processing unit **506** could be an application-specific integrated circuit (ASIC), digital signal processor (DSP), system on chip (SoC), central processing unit (CPU) of a general-purpose computer, etc. In some implementations, the processing unit **506** comprises more than one processor. The processor(s) may be single core or multi-core processors. The processing device **502** may be a special purpose computing device, a conventional computer, a distributed computer, or any other type of processing device.

[0031] There may be one or more processing devices **502**, such that the processing device **502** of the processing system **500** comprises a single processing unit **506**, or a plurality of processing units. The processors may be single core or multi-core processors. The processing system **500** may be a conventional computer, a distributed computer, or any other type of computer. The described technology is optionally implemented in software loaded in memory **508**, a storage unit **512**, and/or communicated via a wired or wireless network link **514** on a carrier signal (e.g., Ethernet, 3G wireless, 5G wireless, LTE (Long Term Evolution)) thereby transforming the processing system **500** in FIG. **5** to a special purpose machine for implementing the described operations. The processing system **500** may be an application specific processing system configured for supporting the disc drive throughput balancing system disclosed herein.

[0032] The I/O section **504** may be connected to one or more user-interface devices (e.g., a keyboard, a touch-screen display unit **518**, etc.) or a storage unit **512**. Computer program products containing mechanisms to effectuate the systems and methods in accordance with the described technology may reside in the memory section **508** or on the storage unit **512** of such a system **500**.

[0033] A communication interface **524** is capable of connecting the processing system **500** to an enterprise network via the network link **514**, through which the computer system can receive instructions and data embodied in a carrier wave. When used in a local area networking (LAN) environment, the processing system **500** is connected (by wired connection or wirelessly) to a local network through the communication interface **524**, which is one type of communications device. When used in a wide-area-networking (WAN) environment, the processing system **500** typically includes a modem, a network adapter, or any other type of communications device for establishing communications over the wide area network. In a networked environment, program modules depicted relative to the processing system **500** or portions thereof, may be stored in a remote memory storage device. It is appreciated that the network connections shown are examples of communications devices for and other means of establishing a communications link between the computers may be used.

[0034] In an example implementation, a storage controller, and other modules may be embodied by instructions stored in memory **508** and/or the storage unit **512** and executed by the processing device **502**. Further, the storage controller may be configured to assist in supporting the RAIDO implementation. A RAID storage may be implemented using a general-purpose computer and specialized software (such as a server executing service software), a special purpose computing system and specialized software (such as a mobile device or network appliance executing service software), or other computing configurations. In addition, keys, device information, identification, configurations, etc. may be stored in the memory **508** and/or the storage unit **512** and executed by the processing device **502**.

[0035] The processing system **500** may be implemented in a device, such as a user device, storage device, IoT device, a desktop, laptop, computing device. The processing system **500** may be a storage device that executes in a user device or external to a user device.

[0036] In addition to methods, the embodiments of the technology described herein can be implemented as logical steps in one or more computer systems. The logical operations of the present technology can be implemented (1) as a sequence of processor-implemented steps executing in one or more computer systems and/or (2) as interconnected machine or circuit modules within one or more computer systems. Implementation is a matter of choice, dependent on the performance requirements of the computer system implementing the technology. Accordingly, the logical operations of the technology described herein are referred to variously as operations, steps, objects, or modules. Furthermore, it should be understood that logical operations may be performed in any order, unless explicitly claimed otherwise or unless a specific order is inherently necessitated by the claim language.

[0037] Data storage and/or memory may be embodied by various types of processor-readable storage media, such as hard disc media, a storage array containing multiple storage devices, optical media, solid-state drive technology, ROM, RAM, and other technology. The operations may be implemented processor-executable instructions in firmware, software, hard-wired circuitry, gate array technology and other technologies, whether executed or assisted by a microprocessor, a microprocessor core, a microcontroller, special purpose circuitry, or other processing technologies. It should be understood that a write controller, a storage controller, data write circuitry, data read and recovery circuitry, a sorting module, and other functional modules of a data storage system may include or work in concert with a processor for processing processor-readable instructions for performing a system-implemented process.

[0038] The embodiments of the disclosed technology described herein are implemented as logical steps in one or more computer systems. The logical operations of the presently disclosed technology are implemented (1) as a sequence of processor-implemented steps executing in one or more computer systems and (2) as interconnected machine or circuit modules within one or more computer systems. The implementation is a matter of choice, dependent on the performance requirements of the computer system implementing the disclosed technology. Accordingly, the logical operations making up the embodiments of the disclosed technology described herein are referred to variously as operations, steps, objects, or modules. Furthermore, it should be understood that logical operations may be performed in any order, adding, and omitting as desired, unless explicitly claimed otherwise or a specific order is inherently necessitated by the claim language.

[0039] Implementations described and claimed herein include a LiDAR system with a semiconductor optical amplifier (SOA) configured to receive a light signal from a master-oscillator laser source, the semiconductor optical source including an optical splitter configured to split the light signal into two or more split light signals and two or more respective semiconductor optical amplifiers (SOAs), each SOA configured to receive one of the split light signals and amplify the split light signal.

[0040] An apparatus disclosed herein includes a semiconductor optical source configured to receive a light signal from a master-oscillator laser source, the semiconductor optical source including an optical splitter configured to split the light signal into two or more split light signals and two or more respective semiconductor optical amplifiers (SOAs), each SOA configured to receive one of the split light signals and amplify the split light signal, wherein the master-oscillator laser source is integrated into the semiconductor optical source.

[0041] A semiconductor optical source device disclosed herein includes an optical splitter configured to split a light signal from a master-oscillator laser source into two or more split light signals and two or more respective semiconductor optical amplifiers (SOAs), each SOA configured to receive one of the split light signals and amplify the split light signal.

[0042] The above specification, examples, and data provide a complete description of the structure and use of example embodiments of the disclosed technology. Since many embodiments of the disclosed technology can be made without departing from the spirit and scope of the disclosed technology, the disclosed technology resides in the claims hereinafter appended. Furthermore, structural features of the different embodiments may be combined in yet another embodiment without departing from the recited claims.

What is claimed is:

1. A LiDAR system comprising:

a semiconductor optical source configured to receive a light signal from a master-oscillator laser source, the semiconductor optical source comprising:

an optical splitter configured to split the light signal into two or more split light signals; and

two or more respective semiconductor optical amplifiers (SOAs), each SOA configured to receive one of the split light signals and amplify the split light signal.

2. The LiDAR system of claim **1**, wherein the master-oscillator laser source is integrated into the semiconductor optical source.

3. The LiDAR system of claim **2**, wherein the two or more SOAs, the master-oscillator laser source, and the optical splitter form a coupled-laser system.

4. The LiDAR system of claim **1**, wherein the optical splitter is a waveguide splitter comprising at least one of a y-splitter, Mach-Zehnder splitter, multi-mode interferometer (MMI) splitter, wavelength splitter, or selective switching.

5. The LiDAR system of claim **1**, wherein each of the SOAs are tapered waveguides.

6. The LiDAR system of claim **5**, wherein the SOAs are further configured to increase output power of the light signal traveling through the tapered waveguides.

7. The LiDAR system of claim **1**, wherein the master-oscillator laser source is further configured to provide a local oscillator output for use in a coherent detection scheme.

8. The LiDAR system of claim **1**, further comprising a collimating lens configured to collimate the amplified light signal emitted by each of the SOAs and to direct the emitted light signal to a scanner.

9. The LiDAR system of claim **1**, further comprising an optical image collector configured to collect return light associated with each output and to map the collected return light onto an array of one or more light detectors.

10. An apparatus, comprising:

a semiconductor optical source configured to receive a light signal from a master-oscillator laser source, the semiconductor optical source comprising:

an optical splitter configured to split the light signal into two or more split light signals; and

two or more respective semiconductor optical amplifiers (SOAs), each SOA configured to receive one of the split light signals and amplify the split light signal,

wherein the master-oscillator laser source is integrated into the semi-conductor optical source.

11. The apparatus of claim **10**, wherein the two or more SOAs, the master-oscillator laser source, and the optical splitter form a coupled-laser system.

12. The apparatus of claim **10**, wherein the optical splitter is a waveguide splitter comprising at least one of a y-splitter, Mach-Zehnder splitter, multi-mode interferometer (MMI) splitter, wavelength splitter, or selective switching.

13. The apparatus of claim **10**, wherein each of the SOAs are tapered waveguides.

14. The apparatus of claim **10**, wherein the SOAs are further configured to increase output power of the light signal traveling through the tapered waveguides.

15. The apparatus of claim **10**, wherein the master-oscillator laser source is further configured to provide a local oscillator output for use in a coherent detection scheme.

16. The apparatus of claim **10**, further comprising a collimating lens configured to collimate the amplified light signal emitted by each of the SOAs and to direct the emitted light signal to a scanner.

17. A semiconductor optical source device comprising:

an optical splitter configured to split a light signal from a master-oscillator laser source into two or more split light signals; and

two or more respective semiconductor optical amplifiers (SOAs), each SOA configured to receive one of the split light signals and amplify the split light signal.

18. The semiconductor optical source device of claim **17**, wherein the master-oscillator laser source is integrated into the semiconductor optical source.

19. The semiconductor optical source device of claim **17**, wherein each of the SOAs are tapered waveguides.

20. The semiconductor optical source device of claim **17**, wherein the optical splitter is a waveguide splitter comprising at least one of a y-splitter, Mach-Zehnder splitter, multi-mode interferometer (MMI) splitter, wavelength splitter, or selective switching.

* * * * *