LIGHT DETECTING SYSTEM AND LIGHT DETECTING METHOD FOR FLOW CYTOMETER

FIELD

[0001] The present disclosure relates to a light detecting system and a light detecting method for a flow cytometer.

BACKGROUND

[0002] Light detecting technology is applied to many fields. For example, the light detecting technology is applied to detect a volume, morphology, a property, and the like of an object. For example, the light detecting technology may be used in a flow cytometry to detect, for example, a volume, morphology, a property and the like of a micro-particle.

SUMMARY

[0003] A brief overview of the present disclosure is given below to provide a basic understanding of certain aspects of the present disclosure. However, it should be understood that the overview is not an exhaustive overview of the present disclosure. The overview is not intended to determine key or important parts of the present disclosure, nor intended to limit the scope of the present disclosure. The purpose is only to give some concepts about the present disclosure in a simplified form as a prelude to a more detailed description given later.

[0004] According to an aspect of the present disclosure, a light detecting system for a flow cytometer is provided. The light detecting system includes a beam separating device and multiple wavelength division multiplexing devices. The beam separating device is configured to separate a beam to be processed by the flow cytometer into multiple first beams having respective wavelength ranges that either do not overlap with each other or partially overlap with each other. Each of the multiple wavelength division multiplexing devices is configured to receive a respective one of the multiple first beams. The multiple first beams are parallel to each other when received by the multiple wavelength division multiplexing devices. Each of the multiple wavelength division multiplexing devices includes multiple light detecting devices being configured to detect a portion of the respective first beam.

[0005] According to another aspect of the present disclosure, a light detecting method for a flow cytometer is provided. The light detecting method includes: separating, by a beam separating device, a beam to be processed by the flow cytometer into multiple first beams having respective wavelength ranges that either do not overlap with each other or partially overlap with each other; and multiplexing and detecting the plurality of first beams by multiple wavelength division multiplexing devices, respectively. Each wavelength division multiplexing device includes multiple light detecting devices configured to detect a respective one of the multiple first beams, and the multiple first beams are parallel to each other when received by the wavelength division multiplexing devices.

[0006] According to other aspects of the present disclosure, computer program codes and a computer program product for implementing the method according to the present disclosure, and a computer-readable storage medium on which the computer program code for implementing the method according to the present disclosure is recorded are further provided.

[0007] Other aspects of embodiments of the present disclosure are given in the following specification. Preferred embodiments for fully disclosing the present disclosure are described in detail without limitation.

BRIEF DESCRIPTION OF THE DRAWINGS

[0008] The present disclosure may be better understood by referring to the detailed descriptions given below in conjunction with the drawings. Same or similar reference numerals are used to represent the same or similar components in the drawings. The drawings, together with the following detail descriptions, are included in the specification and form a part of the specification, to further exemplify preferred embodiments of the present disclosure and to explain principles and advantages of the present disclosure. In the drawings:

[0009] Figure 1 is a block diagram of a configuration example of a light detecting system for a flow cytometer according to an embodiment of the present disclosure;

Figure 2 is a 3D layout showing an implementation of a light detecting system for a flow cytometer according to an embodiment of the present disclosure;

Figure 3 is a top view showing an implementation of a light detecting system for a flow cytometer according to an embodiment of the present disclosure;

Figure 4 is a side view showing an implementation of a light detecting system for a flow cytometer according to an embodiment of the present disclosure;

Figure 5A and Figure 5B are views showing an implementation of a beam separating device according to an embodiment of the present disclosure;

Figure 6A, Figure 6B and Figure 6C are views showing another implementation of a beam separating device according to an embodiment of the present disclosure;

Figure 7 is a top view showing another implementation of a light detecting system for a flow cytometer according to an embodiment of the present disclosure;

Figure 8 is a schematic diagram of an implementation of a wavelength division multiplexing unit according to an embodiment of the present disclosure;

Figure 9A shows an example of a support base included in a wavelength division multiplexing device according to an embodiment of the present disclosure;

Figure 9B is a schematic diagram showing arrangement of a wavelength division multiplexing unit on a support base according to an embodiment of the present disclosure;

Figure 10A shows another example of a support base included in a wavelength division multiplexing device according to an embodiment of the present disclosure;

Figures 10B to 10D are schematic diagrams showing arrangement of a wavelength division multiplexing unit on a support base according to an embodiment of the present disclosure;

Figure 11 is a schematic diagram of another implementation of a wavelength division multiplexing unit according to an embodiment of the present disclosure;

Figure 12 is a schematic diagram of yet another implementation of a wavelength division multiplexing unit according to an embodiment of the present disclosure;

Figure 13 is a flowchart showing an exemplary flow of a light detecting method for a flow cytometry according to an embodiment of the present disclosure; and

Figure 14 is a block diagram of an exemplary structure of a personal computer applicable to the embodiments of the present disclosure.

DETAILED DESCRIPTION OF EMBODIMENTS

[0010] Exemplary embodiments of the present disclosure are described below in conjunction with the drawings. For conciseness and clarity, not all features of an actual embodiment are described in this specification. However, it should be understood that numerous embodiment-specific decisions, for example, in accord with constraining conditions related to system and business, should be made when developing any of such actual embodiments, so as to achieve specific targets of a developer. These constraining conditions may vary with different embodiments. Furthermore, it should be understood that although development work may be complicated and time-consuming, such development work is only a routine task for those skilled in the art benefiting from the present disclosure.

[0011] It should be understood that although terms "first", "second", and the like may be used for describing various elements herein, these elements should not be limited by these terms. These terms are used only for distinguishing one element from another. For example, the first element may be referred to as the second element, and similarly, the second element may be referred to as the first element, without departing from the scope of the present disclosure.

[0012] In addition, in the specification and the drawings, there are also cases where multiple components with basically the same functional configuration are distinguished by adding different letters after a same reference numeral. For example, a wavelength division multiplexing unit 1046 may be referred to as a wavelength division multiplexing unit 1046a, a wavelength division multiplexing unit 1046b, and a wavelength division multiplexing unit 1046c as needs. However, in a case where it is unnecessary to particularly distinguish multiple components having basically the same functional configuration from each other, only the same reference numeral is required to present the components. For example, in a case that it is unnecessary to distinguish the wavelength division multiplexing unit 1046a, the wavelength division multiplexing unit 1046b and the wavelength division multiplexing unit 1046c from each other, the wavelength division multiplexing unit 1046a, the wavelength division multiplexing unit 1046b and the wavelength division multiplexing unit 1046c are simply referred to as the wavelength division multiplexing unit 1046.

[0013] Here, it should also be noted that, in order to avoid blurring the present disclosure due to unnecessary details, only device structures and/or processing steps closely related to

the solution according to the present disclosure are shown in the drawings, and other details not closely related to the present disclosure are omitted.

[0014] The embodiments according to the present disclosure are described in detail below in conjunction with the drawings.

[0015] First, implementation examples of a light detecting system for a flow cytometer according to an embodiment of the present disclosure are described with reference to Figure 1 to Figure 7. Figure 1 is a block diagram of a configuration example of a light detecting system 100 for a flow cytometer according to an embodiment of the present disclosure. Figure 2, Figure 3, and Figure 4 are respectively a 3D layout, a top view, and a side view showing an implementation of the light detecting system 100 for a flow cytometer according to an embodiment of the present disclosure. Figure 5A and Figure 5B are views showing an implementation of a beam separating device according to an embodiment of the present disclosure. Figure 6A, Figure 6B and Figure 6C are views showing another implementation of a beam separating device according to an embodiment of the present disclosure. Figure 7 is a top view showing another implementation of a light detecting system for a flow cytometer according to an embodiment of the present disclosure.

[0016] As shown in Figure 1 to Figure 4, the light detecting system 100 for a flow cytometer according to the embodiment of the present disclosure includes a beam separating device 102 and multiple wavelength division multiplexing devices 104.

[0017] The beam separating device (also referred to as a "spectral band separating device") 102 is configured to separate a beam to be processed by the flow cytometer (which may also be referred to as a "beam to be processed" hereinafter) into multiple first beams having respective wavelength ranges that either do not overlap with each other or partially overlap with each other. For example, the beam to be processed may be transmitted to the beam separating device 102 through an optical fiber. In addition, for example, the beam to be processed may be transmitted to the beam separating device 102 through a free space by means of a coupled lens system.

[0018] As an example, the beam separating device 102 includes a long pass filter or a short pass filter. For example, as shown in Figure 2 and Figure 4, the beam separating device 102 may be arranged at 45 degrees to an optical axis of the beam to be processed to separate the beam to be processed into two first beams propagating along an x-axis direction and a z-axis

direction, respectively. For example, in a case that the beam to be processed has a wavelength range from 350nm to 950nm, the beam separating device 102 separates the beam to be processed into two first beams having a wavelength range from 350nm to A and a wavelength range from A to 950nm, respectively. For example, A is greater than or equal to 400nm and is less than or equal to 900 nm. It should be noted that in Figure 4, the elements framed with dotted frames correspond to the two first beams, respectively.

[0019] As another example, the beam separating device 102 may include a dichroic mirror. For example, as shown in Figure 5A and Figure 5B, the dichroic mirror is capable of reflecting a visible light (Vis) in a certain band and an infrared light (IR) and transmitting an ultraviolet light (UV) and a visible light in another band, so as to separate the beam to be processed into two first beams. In addition, by arranging two or more dichroic mirror with different optical properties, the beam to be processed is separated into three or more first beams. For example, as shown in Figure 6A, by arranging two dichroic mirrors with different optical properties as shown in Figure 6B and Figure 6C, the beam to be processed is separated into three first beams.

[0020] In Figure 2, a gray line represents a beam. In addition, in Figure 5A and Figure 6A, an arrow represents a beam. As can be understood by those skilled in the art, an actual shape of a beam may be different from that shown in the drawings. In addition, relative position between the first beams is not limited by the drawings.

[0021] Each of the wavelength division multiplexing devices 104 is configured to receive a respective one of the multiple first beams. For example, the wavelength division multiplexing devices 104 may correspond to the first beams in one-to-one relationship.

[0022] Each one of the wavelength division multiplexing devices 104 includes multiple light detecting devices 1042 (not shown in Figure 2). The light detecting devices 1042 are configured to detect (for example, to detect light intensity of) a portion of the first beam received by the wavelength division multiplexing device 104. For example, for each wavelength division multiplexing device 104, the wavelength division multiplexing device 104 may perform wavelength division multiplexing on the first beam received by the wavelength division multiplexing device 104 to obtain multiple second beams and transmit the multiple second beams to multiple light detecting devices 1042, respectively. It should be noted that although it is shown in Figure 2 to Figure 4 that the wavelength division

multiplexing device 104 includes a wavelength division multiplexing unit 1046b shown in Figure 11 to perform wavelength division multiplexing on the first beam received by the wavelength division multiplexing device, those skilled in the art may adopt another wavelength division multiplexing unit, for example, a wavelength division multiplexing unit 1046a shown in Figure 8, a wavelength division multiplexing unit 1046c shown in Figure 12, and the like, according to actual needs.

[0023] As an example, the multiple second beams may be focused on the multiple light detecting devices 1042 through multiple second aspheric lenses 122, as shown in Figure 3 and Figure 4.

[0024] The light detecting device 1042 may be, for example, an avalanche photodiode (APD).

[0025] The multiple first beams may be parallel to each other when received by the multiple wavelength division multiplexing devices 104. In this case, for example, the light detecting devices 1042 included in the multiple wavelength division multiplexing devices 104 may be arranged on a same plane, so as to facilitate, for example, temperature control for the light detecting devices 1042 and a layout of a signal processing circuit and wires.

[0026] As an example, in the light detecting system 100a as shown in Figure 4, a transmission path of at least one of the multiple first beams may be changed by a second mirror 118, so that the multiple first beams are transmitted in parallel to the multiple wavelength division multiplexing devices 104. For example, the second mirror 118 may change the transmission path of a first beam by totally reflecting the first beam. The second mirror 118 may be a planar mirror.

[0027] As another example, the multiple first beams may be transmitted to the multiple wavelength division multiplexing devices 104 while not being parallel to each other. For example, in the light detecting system 100b shown in Figure 7, the two beams may be transmitted to respective wavelength division multiplexing devices 104 at an angle of 90 degrees between the two beams. In addition, in practical application, the angle between the beams may be changed by configuring the beam separating device 102 as needed. For example, the angle between the two beams may range from 15 degrees to 165 degrees.

[0028] At present, the flow cytometry is developing from the conventional multi-color

fluorescence channel to the high-channel fluorescence full spectrum. With the fluorescence full spectrum, more fluorescence information is acquired and more (up to 40 or more or more channels of) fluorescein and other information are analyzed at the same time, so as to acquire more sample expression information, thereby achieving a sensitive and accurate test result. In order to achieve this objective, high-density channel acquisition of the fluorescence spectrum is required to reflect a spectral feature of the fluorescence.

[0029] As described above, in the light detecting system 100 according to the embodiment of the present disclosure, the beam to be processed (for example, including a fluorescent light signal) is separated into multiple first beams by the beam separating device 102, and then the first beams are multiplexed and detected by the wavelength division multiplexing devices 104, so that the number of light channels is easily increased (for example, increased to 20 or more) and a good optical property is maintained. In addition, compared with a case that the beam to be processed is multiplexed and detected by the wavelength division multiplexing device directly, with the light detecting system 100, an optical path length of the last one or more channels corresponding to the first beams and the number of optical elements through which the first beams are passed are reduced, thereby improving an optical transmission efficiency of the last one or more channels and reducing a size of the wavelength division multiplexing device 104.

[0030] In addition, the light detecting system 100 may be compatible with a dual-port wavelength division multiplexing structure. Two excitation sources (an example of an object generating the beam to be processed) with a small number (for example, less than or equal to 10) of channels may share one dual-port wavelength division multiplexing structure, which saves a cost.

[0031] As an example, the multiple first beams may be transmitted in a layered layout in a vertical direction (for example, a z-axis direction shown in Figure 2), so that, for example, the size of the wavelength division multiplexing device 104 can be further reduced. According to an embodiment of the present disclosure, the beam to be processed by the flow cytometer may include a side scatter light signal and a fluorescent light signal. In this case, as shown in Figures 3 and 4, the light detecting system may further include multiple side scatter light signal separating devices 106. Each of the multiple side scatter light signal separating devices 106 is configured to separate a side scatter light signal from a respective one of the multiple

first beams (that is, a first beam transmitted to the side scatter light signal separating devices 106) and transmit the separated respective first beam to a respective one of the multiple wavelength division multiplexing devices (for example, a wavelength division multiplexing device configured to multiplex and detect the separated respective first beam), so that the influence of the side scatter light signal on the fluorescent light signal is reduced, thereby improving a signal-to-noise ratio of the fluorescent light signal. For example, the multiple side scatter light signal separating devices 106 may correspond to the multiple first beams in one-to-one relationship.

[0032] As an example, the beam to be processed may include a beam collected from a micro-particle, and a fluorescent light signal may include a fluorescence light signal emitted from the micro-particle.

[0033] According to an embodiment of the present disclosure, each side scatter light signal separating device 106 may include a first side scatter light signal separating unit 1062 and a second side scatter light signal separating unit 1064 (not shown in Figure 2). The first side scatter light signal separating unit 1062 may be configured to separate a side scatter light signal from the respective first beam, and the second side scatter light signal separating unit 1064 may be configured to further separate the side scatter light signal from the respective first beam separated by the first side scatter light signal separating unit 1062 and transmit the separated respective first beam to a respective one of the multiple wavelength division multiplexing devices 104, so that, for example, the signal-to-noise ratio of the fluorescent light signal is further improved.

[0034] For example, the first side scatter light signal separating unit 1062 may include a long bandpass filter. For example, the long bandpass filter may be disposed at 20 degrees to 50 degrees relative to an optical axis of a corresponding first beam to reflect the side scatter light signal and transmit the fluorescent light signal.

[0035] As an example, the second side scatter light signal separating unit 1064 may include a long bandpass filter. For example, the long bandpass filter may be disposed at -5 degrees or 5 degrees relative to the optical axis of a corresponding first beam to deeply isolate a residual side scatter light signal in the multiple first beams from the first side scatter light signal separating unit 1062.

[0036] For example, as shown in Figure 3, Figure 4 and Figure 7, the light detecting system

100 may further include multiple attenuating devices 108, multiple first bandpass filters 110, and multiple first light detecting units 112. Each of the multiple attenuating devices 108 may be configured to attenuate the side scatter light signal separated by the first side scatter light signal separating unit 1062 corresponding to the attenuating device 108 to prevent the side scatter light signal from saturating a first light detecting unit 112. Each of the multiple first bandpass filters 110 may be configured to perform a bandpass filtering on the side scatter light signal attenuated by the attenuating device 108 corresponding to the first bandpass filter 110. Each of the multiple first light detecting units 112 may be configured to detect (for example, detect intensity of) the side scatter light signal filtered by the first bandpass filter 110 corresponding to the first light detecting unit 112, so that, for example, a size of a micro-particle screened by the flow cytometry is detected.

[0037] For example, the multiple attenuating devices 108 may have a same attenuation coefficient, or at least one of the multiple attenuating devices 108 has an attenuation coefficient different from that of other attenuating devices 108. Similarly, the multiple first bandpass filters 110 may have a same optical property, or at least one of the multiple first bandpass filters 110 has an optical property different from that of other first bandpass filters 110.

[0038] As an example, in a case that the beam to be processed is separated into two first beams by the beam separating device 102, an intensity of a side scatter light signal included in one of the two first beams (referred to as "SSC1" hereafter) and an intensity of a side scatter light signal included in the other one of the two first beams (referred to as "SSC2" hereafter) are b% and 1-b% of an intensity of the side scatter light signal included in the beam to be processed (referred to as "SSC" hereafter), respectively, where $1 \leqslant b \leqslant 2$. On one hand, a side scatter light signal generated by small particles (such as particles with nanometer sizes) is weak, so that it is desired to improve an efficiency of collecting the side scatter light signal from small particles as much as possible. On the other hand, a side scatter light signal generated by large particles (such as cells with micron sizes) is strong, which results in that the light detecting device is easily saturated, so that it is desired to reduce an efficiency of collecting the side scatter light signal from large particles. In a case that SSC1 and SSC2 are configured as described above, for example, SSC1 may be used to detect a cell with a size ranging from 1μm to 30μm and SSC2 may be used to detect a small particle with a size ranging from 80nm to 1μm, so that, for example, the accuracy of detecting particles is further

improved. For example, in the light detecting system 100a shown in Figure 4, elements framed with an upper dotted frame and elements framed with a lower dotted frame may correspond to the first beam including SSC1 and the first beam including SSC2, respectively. In addition, for example, in the light detecting system 100b shown in Figure 7, elements framed with a dotted frame indicated by a reference numeral SSC1 may be used for transmission and detection of SSC1, and elements framed with a dotted frame indicated by a reference numeral SSC2 may be used for transmission and detection of SSC2.

[0039] For example, as shown in Figure 2 to Figure 4 and Figure 7, the light detecting system 100 may further include multiple first mirrors 114. Each of the multiple first mirrors 114 is configured to change a transmission path of the side scatter light signal separated by the first side scatter light signal separating unit 1062 corresponding to the first mirror 114 to transmit the side scatter light signal to a respective one of the multiple attenuating devices 108.

[0040] For example, as shown in Figure 3, the first mirror 114 may be disposed at 20 degrees to 50 degrees relative to an optical axis of the side scatter light signal from the first side scatter light signal separating unit 1062 corresponding to the first mirror 114 to reflect the side scatter light signal, so as to change the transmission path of the side scatter light signal, so that, for example, the side scatter light signal and the first beam separated by the first side scatter light signal separating unit 1062 are transmitted in parallel. In this case, for example, the multiple first light detecting units 112 and the multiple light detecting devices 1042 may be disposed on a same plane, so as to, for example, facilitate temperature control for the multiple first light detecting units 112 and the multiple light detecting devices 1042 and facilitate a layout of a signal processing circuit and wires. For example, the multiple first light detecting units 112 and the multiple light detecting devices 1042 may be disposed with reference to a virtual reference plane represented by a dotted line in Figure 3, so that the multiple first light detecting units 112 and the multiple light detecting devices 1042 are accurately disposed on the same plane.

[0041] For example, as shown in Figure 3, Figure 4 and Figure 7, the light detecting system 100 may further include multiple first aspheric lens 120 disposed between the multiple first bandpass filters 110 and the multiple first light detecting units 112. Each of the multiple first aspheric lens 120 is configured to focus the side scatter light signal filtered by the first

bandpass filter 110 corresponding to the first aspheric lens 120 to a respective one of the multiple first light detecting units 112..

[0042] For example, as shown in Figure 3, Figure 4 and Figure 7, the light detecting system 100 may further include an achromatic lens 116 configured to collimate the beam to be processed and transmit the collimated beam to the beam separating device 102. For example, the beam to be processed is collected through coupling by an optical fiber. In addition, for example, the beam to be processed may be transmitted to the achromatic lens 116 through a free space by means of a coupled lens system.

[0043] The wavelength division multiplexing unit according to the embodiments of the present disclosure is described in detail below with reference to Figure 8 to Figure 12.

[0044] Figure 8 is a schematic diagram of an implementation of a wavelength division multiplexing unit according to an embodiment of the present disclosure. As shown in Figure 8, a wavelength division multiplexing unit 1046a may include multiple mirrors 1046-M and multiple second bandpass filters 1046-L disposed opposite to the multiple mirrors 1046-M. Each mirror 1046-M may be configured to reflect a beam transmitted from a respective one of the multiple second bandpass filters 1046-L to the mirror 1046-M. For example, each mirror 1046-M may include a concave portion (for example, a foveate portion) C disposed between a pair of planar portions P. Each concave portion C is configured to reflect a beam transmitted to the concave portion C from a corresponding one of the multiple second bandpass filters 1046-L to collimate the beam. In addition, each second bandpass filter 1046-L may be configured to transmit light having a wavelength within a wavelength range corresponding to the second bandpass filter 1046-L and reflect other light. Therefore, the beam propagates in zigzag between the multiple mirrors 1046-M and the multiple second bandpass filters 1046-L to separate a corresponding light beam (for example, the first beam) into multiple second beams, for example, 10 second beams corresponding to a channel#1 to a channel#10 shown in Figure 8. In addition, by disposing the concave portion C between the planar portions P, a divergent light transmitted over a certain distance is collimated to realize long-distance transmission, which is conducive to detecting more channels. It should be noted that, although Figure 8 shows that adjacent mirrors 1046-M are disposed at intervals, the multiple mirrors 1046-M may be disposed without intervals therebetween as needed. In addition, for example, the multiple mirrors 1046-M may be disposed as a single mirror 1046-M with one or more

planar portions P and concave portions C, and extending the length of wavelength division multiplexing unit 1046a.

[0045] In some examples, directivity of the beam may be adjusted by adjusting a relative position between the second bandpass filter 1046-L and the corresponding mirror 1046-M, for example, a distance between a center of the second bandpass filter 1046-L and a center of the corresponding mirror 1046-M in a direction along which the second bandpass filters 1046-L are arranged, so as to further ensure that the beam propagates in zigzag.

[0046] As an example, the wavelength division multiplexing device 104 may further include a support base 1048a as shown in Figure 9A. For example, as shown in Figure 9B, the multiple mirrors (also referred to as a "mirror array") may be disposed on a first surface SA1 of support base 1048a, and the multiple second bandpass filters (also referred to as a "second bandpass filter array") may be disposed on a second surface SA2 of the support base 1048a that is opposite and parallel to the first surface SA1, ensuring parallelism between the mirror array and the second bandpass filter array and improving the light transmission efficiency.

[0047] For example, as shown in Figure 9B, the multiple mirrors 1046-M and the multiple second bandpass filters 1046-L may be disposed to exceed the first surface SA1 and the second surface SA2 respectively, so that the beam is transmitted without passing through the interior of the support base 1048a, which avoids an interface light loss (Ferrer reflection loss) caused by light transmission through the interior of the support base 1048a, thereby further improving the light transmission efficiency. In addition, light scattering caused by crystallization or bubble in a material of the support base 1048a is avoided, so that light signal crosstalk between different channels is reduced.

[0048] As another example, the wavelength division multiplexing device 104 may further include a support base 1048b with a hollow interior as shown in Figure 10A. For example, as shown in Figure 10B to Figure 10D, the multiple mirrors 1046-M may be disposed on a first surface SB1 of support base 1048b, and the multiple second bandpass filters 1046-L may be disposed on a second surface SB2 of the support base 1048b that is opposite and parallel to the first surface SB1, ensuring parallelism between the multiple mirrors 1046-M and the multiple second bandpass filters 1046-L and improving the light transmission efficiency. In addition, in this case, the beam is transmitted through the hollow interior, which avoids an interface light loss, thereby further improving the light transmission efficiency. Furthermore,

light scattering caused by crystallization or bubble inside a material of the support base 1048b is avoided, so that light signal crosstalk between different channels is reduced. Moreover, the hollow interior greatly reduces the quality of the support base 1048b while ensuring the parallelism and structural strength.

[0049] For example, the same material as the support base 1048b or any other material with a refractive index greater than 1 such as glass, polymer, and fluid may be filled in the hollow interior of the support base 1048b.

[0050] For example, two wavelength division multiplexing devices 104 may share one support base 1048. For example, in the examples shown in Figure 9B and Figure 10B, the upper mirror array and second bandpass filter array correspond to one of the two wavelength division multiplexing devices 104, and the lower mirror array and second bandpass filter array correspond to the other of the two wavelength division multiplexing devices 104, so that, for example, the size and the weight of the wavelength division multiplexing device 104 can be reduced.

[0051] For example, the wavelength division multiplexing units 1046 included in the multiple wavelength division multiplexing devices may be disposed as one body.

[0052] The support base 1068 may be made of a transparent material or a non-transparent material. For example, the support base 1068 may be made of metal, glass, and/or polymer.

[0053] Figure 11 is a schematic diagram of another implementation of a wavelength division multiplexing unit according to an embodiment of the present disclosure. The wavelength division multiplexing unit 1046b shown in Figure 11 is different from the wavelength division multiplexing unit 1046a shown in Figure 8 in that the mirrors 1046-M are replaced with multiple planar mirrors 1046-P and multiple concave mirrors 1046-C that are arranged alternately. Similar to the planar portion P of the mirror 1046-M, each planar mirror 1046-P may be configured to reflect a beam transmitted to the planar mirror 1046-P from a corresponding second bandpass filter 1046-L of the multiple second bandpass filters 1046-L. In addition, similar to the concave portion C of the mirror 1046-M, each concave mirror 1046-C may be configured to reflect a beam transmitted to the concave mirror from a second bandpass filter 1046-L corresponding to the concave mirror of the multiple second bandpass filters 1046-L to collimate the beam. Although Figure 11 shows that one planar mirror 1046-P is disposed between two concave mirrors 1046-C, two or more planar mirrors

1046-P may be disposed between two concave mirrors 1046-C as needed. For example, as shown in Figure 3 and Figure 7, two planar mirrors 1046-P are disposed between two concave mirrors 1046-C.

[0054] Figure 12 is a schematic diagram of still another implementation of a wavelength division multiplexing unit according to an embodiment of the present disclosure. A wavelength division multiplexing unit 1046c may include multiple third bandpass filters 1046-J and multiple fourth bandpass filters 1046-K disposed opposite to the multiple third bandpass filters 1046-J. Each of the third bandpass filters 1046-J and the fourth bandpass filters 1046-K transmits light having a wavelength within a wavelength range corresponding to the bandpass filter and reflects other light. For example, as shown in Figure 12, a concave mirror may be disposed between some of the multiple third bandpass filters 1046-J to collimate a beam transmitted to the concave mirror from a corresponding fourth bandpass filter 1046-K of the multiple fourth bandpass filters 1046-K. Compared with the wavelength division multiplexing units 1046a and 1046b, the wavelength division multiplexing unit 1046c further increases the number of fluorescence channels. It should be noted that, although only one concave mirror is disposed as shown in Figure 12, two or more concave mirrors may be disposed according to actual needs. For example, the third bandpass filters 1046-J and the concave mirrors may be alternately disposed in a same way as that of the planar mirrors 1046-P and the concave mirrors 1046-C as described above with reference to Figure 11. In addition, positions of the concave mirrors are not limited by the drawings.

[0055] For example, the wavelength division multiplexing units 1046b and 1046c may be arranged in a manner similar to the arrangement of the wavelength division multiplexing unit 1046a described with reference to Figure 9A to Figure 10D, which is not repeated herein.

[0056] In the wavelength division multiplexing unit 1046 described above with reference to Figure 8 to Figure 12, the number of fluorescence channels may be easily increased by increasing the number of corresponding elements (for example, the mirrors 1046-M and the second bandpass filters 1046-L shown in Figure 8).

[0057] The above mainly describes the light detecting system for a flow cytometry. However, the light detecting system may be applied to another device such as a sorting device.

[0058] According to an embodiment of the present disclosure, a light detecting method for a

flow cytometry is provided. Figure 13 is a flowchart of a light detecting method 1000 for a flow cytometry according to an embodiment of the present disclosure.

[0059] As shown in Figure 13, the light detecting method 1000 includes a beam separating step S1020 and a beam detecting step S1040.

[0060] In the beam separating step S1020, a beam to be processed by the flow cytometry (which may also be referred to as a "beam to be processed" hereinafter) is separated, by a beam separating device, into multiple first beams having respective wavelength ranges that either do not overlap with each other or partially overlap with each other. For example, the beam to be processed may be separated into multiple first beams by the beam separating device 102 described above.

[0061] In the beam detecting step S1040, the multiple first beams are detected, respectively, by multiple light detecting devices included in multiple wavelength division multiplexing devices (for example, the wavelength division multiplexing devices 104). For example, the multiple first beams are parallel to each other when received by the wavelength division multiplexing devices.

[0062] With the light detecting method 1000 according to the embodiment of the present disclosure, the beam to be processed is separated into multiple first beams by the beam separating device, and then the multiple first beams are multiplexed and detected by the wavelength division multiplexing device, so that the number of light channels is easily increased (for example, increased to 20 or more) and good optical performance is maintained.

[0063] As an example, the beam to be processed may include a side scatter light signal and a fluorescent light signal. In this case, the light detecting method 1000 may further include separating the side scatter light signal from the multiple first beams by a side scatter light signal separating device, and transmitting the separated multiple first beams to the wavelength division multiplexing device. For example, the side scatter light signal may be separated from the multiple first beams by the side scatter light signal separating device 106 described above.

[0064] For example, the beam to be processed may include a beam collected from a micro-particle and the fluorescent light signal may include a fluorescence signal emitted from the micro-particle.

[0065] For example, the light detecting method 1000 may further include: attenuating, by

an attenuating device (for example, the attenuating device 108 as shown in Figure 2 to Figure 4), the side scatter light signal obtained through separation by the side scatter light signal separating device; performing, by a first bandpass filter (for example, the first bandpass filter 110 as shown in Figure 2 to Figure 4), a bandpass filtering on the side scatter light signal attenuated by the attenuating device, and detecting, by a first light detecting unit (for example, the first light detecting unit 112 as shown in Figure 3 and Figure 4), the side scatter light signal filtered by the first bandpass filter, so as to detect, for example, a size of an object which is a source of the side scatter light signal.

[0066] As an example, the light detecting method 1000 may further include: changing a transmission path of at least one of the multiple first beams by a second mirror, so that the multiple first beams are transmitted in parallel.

[0067] It should be noted that though functional configurations of the light detecting system and the light detecting method according to the embodiments of the present disclosure have been described above, the above descriptions are merely illustrative rather than restrictive. Those skilled in the art may modify the above embodiments based on principles of the present disclosure. For example, those skilled in the art may add, delete or combine functional modules and operations in the above embodiments. Such modifications fall within the scope of the present disclosure.

[0068] It should further be noted that, the details described in the system embodiment may be applied to the method embodiment, and similarly, the details described in the method embodiment may be applied to the system embodiment.

[0069] In addition, a storage medium and a program product are further provided according to the present disclosure. It should be understood that machine executable instructions in the storage medium and the program product according to embodiments of the present disclosure may further be configured to perform the above light detecting method. Therefore, details not described here may refer to corresponding parts in the above, and are not repeated here.

[0070] Accordingly, a storage medium for carrying the program product including machine executable instructions is also included in the present disclosure. The storage medium includes but is not limited to a floppy disk, an optical disk, a magneto-optical disk, a memory card, a memory stick and the like.

[0071] In addition, it should further be pointed out that the above series of processing and devices may also be implemented by software and/or firmware. In a case that the above series of processing and apparatuses are implemented by software and/or firmware, a program constituting the software is installed from a storage medium or network to a computer with a dedicated hardware structure, for example, a general-purpose personal computer 1700 shown in Figure 14. The computer can perform various functions when being installed with various programs.

[0072] In Figure 14, a central processing unit (CPU) 1701 executes various processing according to a program stored in a read-only memory (ROM) 1702 or a program loaded from a storage part 1708 to a random access memory (RAM) 1703. Data required when the CPU 1701 performs various processing is also stored in the RAM 1703 as needed.

[0073] The CPU 1701, the ROM 1702 and the RAM 1703 are connected each other via a bus 1704. An input/output interface 1705 is also connected to the bus 1704.

[0074] The following parts are connected to the input/output interface 1705: an input part 1706 including a keyboard, a mouse and the like; an output part 1707 including a display such as a cathode ray tube (CRT) and a liquid crystal display (LCD), a loudspeaker and the like; a storage part 1708 including a hard disk and the like; and a communication part 1709 including a network interface card such as a local area network (LAN) card, a modem and the like. The communication part 1709 performs communication processing via a network such as the Internet.

[0075] A driver 1710 may also be connected to the input/output interface 1705 as needed. A removable medium 1711 such as a magnetic disk, an optical disk, a magneto-optical disk, and a semiconductor memory is mounted on the driver 1710 as needed, so that a computer program read from the removable medium 1711 is installed in the storage part 1708 as needed.

[0076] In a case that the above series of processing is implemented by software, the program constituting the software is installed from the network such as the Internet or the storage medium such as the removable medium 1711.

[0077] Those skilled in the art should understand that the storage medium is not limited to the removable medium 1711 shown in Figure 14 that has the program stored therein and is

distributed separately from the apparatus so as to provide the program to the user. Examples of the removable medium 1711 include a magnetic disk (including a floppy disk (registered trademark)), an optical disk (including a compact disk read only memory (CD-ROM) and a digital versatile disc (DVD)), a magneto-optical disk (including a MiniDisc (MD) (registered trademark)), and a semiconductor memory. Alternatively, the storage medium may be the ROM 1702, a hard disk included in the storage part 1708 or the like. The storage medium has a program stored therein and is distributed to the user together with a device in which the storage medium is included.

[0078] Preferred embodiments of the present disclosure have been described above with reference to the drawings. However, the present disclosure is not limited to the above embodiments. Those skilled in the art may obtain various modifications and changes within the scope of the appended claims. It should be understood that these modifications and changes naturally fall within the technical scope of the present disclosure.

[0079] For example, multiple functions implemented by one unit in the above embodiments may be implemented by separate devices. Alternatively, multiple functions implemented by multiple units in the above embodiments may be implemented by separate devices, respectively. In addition, one of the above functions may be implemented by multiple units. Of course, such configuration is included in the technical scope of the present disclosure.

[0080] In this specification, the steps described in the flowchart include not only processing performed in time series in the described order, but also processing performed in parallel or individually rather than necessarily in time series. Furthermore, the steps performed in time series may be performed in another order appropriately.

CLAIMS

1. A light detecting system for a flow cytometer, comprising:

a beam separating device configured to separate a beam to be processed by the flow cytometer into a plurality of first beams having respective wavelength ranges that either do not overlap with each other or partially overlap with each other; and

a plurality of wavelength division multiplexing devices, each of which is configured to receive a respective one of the plurality of first beams, the plurality of first beams being parallel to each other when received by the plurality of wavelength division multiplexing devices,

wherein each of the plurality of wavelength division multiplexing devices includes a plurality of light detecting devices configured to detect a portion of the respective first beam.

2. The light detecting system according to claim 1, wherein

the beam to be processed by the flow cytometer includes a side scatter light signal and a fluorescent light signal; and

the light detecting system further includes a plurality of side scatter light signal separating devices, each being configured to separate a side scatter light signal from a respective one of the plurality of first beams and transmit the separated respective first beam to a respective one of the plurality of wavelength division multiplexing devices.

3. The light detecting system according to claim 2, wherein each side scatter light signal separating device comprises:

a first side scatter light signal separating unit configured to separate the side scatter light signal from the respective first beam;

a second side scatter light signal separating unit configured to further separate the side scatter light signal from the separated respective first beam and transmit the separated respective first beam to a respective one of the plurality of wavelength division multiplexing devices.

4. The light detecting system according to claim 3, further including:

a plurality of attenuating devices, each being configured to attenuate the side scatter light

signal separated by the first side scatter light signal separating unit included in a respective one of the plurality of side scatter light signal separating devices;

a plurality of first bandpass filters, each being configured to perform a bandpass filtering on the side scatter light signal attenuated by a respective one of the plurality of attenuating devices, and

a plurality of first light detecting units, each being configured to detect the side scatter light signal filtered by a respective one of the plurality of first bandpass filters.

5. The light detecting system according to claim 4, further including:

a plurality of first mirrors, each being configured to change a transmission path of the side scatter light signal separated by the first side scatter light signal separating unit included in a respective one of the plurality of side scatter light signal separating devices, to transmit the side scatter light signal to a respective one of the plurality of attenuating devices.

6. The light detecting system according to claim 5, wherein separating a beam to be processed by the flow cytometer into a plurality of first beams includes separating the beam to be processed by the flow cytometer into two first beams, and

wherein an intensity of a side scatter light signal included in one of the two first beams and an intensity of a side scatter light signal included in the other one of the two first beams are b% and 1-b% of an intensity of the side scatter light signal included in the beam to be processed by the flow cytometer, respectively, $1 \leqslant b \leqslant 2$.

7. The light detecting system according to claim 4, further including a plurality of first aspheric lens disposed between the plurality of first bandpass filters and the plurality of first light detecting units, each being configured to focus the side scatter light signal filtered by a respective one of the plurality of first bandpass filters to a respective one of the plurality of first light detecting units.

8. The light detecting system according to claim 1, further including:

an achromatic lens configured to collimate the beam to be processed by the flow cytometer and transmit the collimated beam to the beam separating device.

9. The light detecting system according to claim 1, further including:

a second mirror configured to change a transmission path of at least one of the plurality

of first beams, such that the plurality of first beams are transmitted in parallel to the plurality of wavelength division multiplexing devices.

10. The light detecting system according to claim 1, further comprising a plurality of second aspheric lenses configured to focus a plurality of second beams, which are obtained by separating the respective first beam by a respective one of the plurality of wavelength division multiplexing devices, on the plurality of light detecting devices in the respective wavelength division multiplexing device.

11. The light detecting system according to claim 1, wherein the beam separating device comprises a long pass filter or a short pass filter.

12. The light detecting system according to claim 1, wherein each wavelength division multiplexing device comprises a wavelength division multiplexing unit including a plurality of mirrors, and a plurality of second bandpass filters disposed opposite the plurality of mirrors,

each mirror is configured to reflect a beam transmitted to the mirror from a respective one of the plurality of second bandpass filters.

13. The light detecting system according to claim 12, wherein each mirror comprises a concave portion disposed between a pair of planar portions, and

each concave portion is configured to reflect a beam transmitted to the concave portion from a corresponding one of the plurality of second bandpass filters, so as to collimate the beam.

14. The light detecting system according to claim 13, wherein the plurality of mirrors are disposed as one body.

15. The light detecting system according to claim 1, wherein each wavelength division multiplexing devices comprises a wavelength division multiplexing unit including a plurality of planar mirrors and a plurality of concave mirrors alternatively disposed, and a plurality of second bandpass filters disposed opposite to the plurality of planar mirrors and the plurality of concave mirrors,

each planar mirror is configured to reflect a beam transmitted to the planar mirror from a corresponding one of the plurality of second bandpass filters, and

each concave mirror is configured to reflect a beam transmitted to the concave mirror from a corresponding one of the plurality of second bandpass filters, so as to collimate the beam.

16. The light detecting system according to claim 12, wherein each wavelength division multiplexing device further comprises a support base,

the plurality of mirrors are disposed on a first surface of the support base, and the plurality of second bandpass filters are disposed on a second surface of the support base that is opposite and parallel to the first surface.

17. The light detecting system according to claim 16, wherein the support base has a hollow interior.

18. The light detecting system according to claim 1, wherein the plurality of light detecting devices are arranged on a same plane.

19. The light detecting system according to claim 1, wherein each wavelength division multiplexing device comprises a wavelength division multiplexing unit including a plurality of third bandpass filters and a plurality of fourth bandpass filters disposed opposite to the plurality of third bandpass filters.

20. The light detecting system according to claim 19, wherein the wavelength division multiplexing device further comprises a support base with a hollow interior,

the plurality of third bandpass filters are disposed on a first surface of the support base, and the plurality of fourth bandpass filters are disposed on a second surface of the support base that is opposite and parallel to the first surface.

21. The light detecting system according to claim 2, wherein:

the beam to be processed by the flow cytometer comprises a beam collected from a micro-particle; and

the fluorescent light signal comprises a fluorescence signal emitted from the micro-particle.

22. A light detecting method for a flow cytometer, comprising:

separating, by a beam separating device, a beam to be processed by the flow cytometer into a plurality of first beams having respective wavelength ranges that either do not overlap

with each other or partially overlap with each other; and

multiplexing and detecting the plurality of first beams by a plurality of wavelength division multiplexing devices, respectively,

wherein each wavelength division multiplexing device comprises a plurality of light detecting devices configured to detect a respective one of the plurality of first beams, and the plurality of first beams are parallel to each other when received by the plurality of wavelength division multiplexing devices .

23. The light detecting method according to claim 22, wherein the beam to be processed by the flow cytometer comprises a side scatter light signal and a fluorescent light signal; and

the light detecting method further comprises: separating a side scatter light signal from the plurality of first beams by a side scatter light signal separating device, and transmitting the separated plurality of first beams to the wavelength division multiplexing device.

24. The light detecting method according to claim 23, further comprising:

attenuating, by an attenuating device, the side scatter light signal separated by the side scatter light signal separating device;

performing, by a first bandpass filter, a bandpass filtering on the side scatter light signal attenuated by the attenuating device, and

detecting, by a first light detecting unit, the side scatter light signal filtered by the first bandpass filter.

25. The light detecting method according to claim 22, further comprising:

changing a transmission path of at least one of the plurality of first beams by a second mirror, such that the plurality of first beams are transmitted in parallel.

26. The light detecting method according to claim 23, wherein

the beam to be processed by the flow cytometry comprises a beam collected from a micro-particle; and

the fluorescent light signal comprises a fluorescence light signal emitted from the micro-particle.