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(54) **SUB MINIATURIZED LASER DOPPLER VELOCIMETER SENSOR**

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(51) **Int. Cl.**[7] **G01P 3/36**

(52) **U.S. Cl.** **356/28**; 356/28.5

(58) **Field of Search** 356/28

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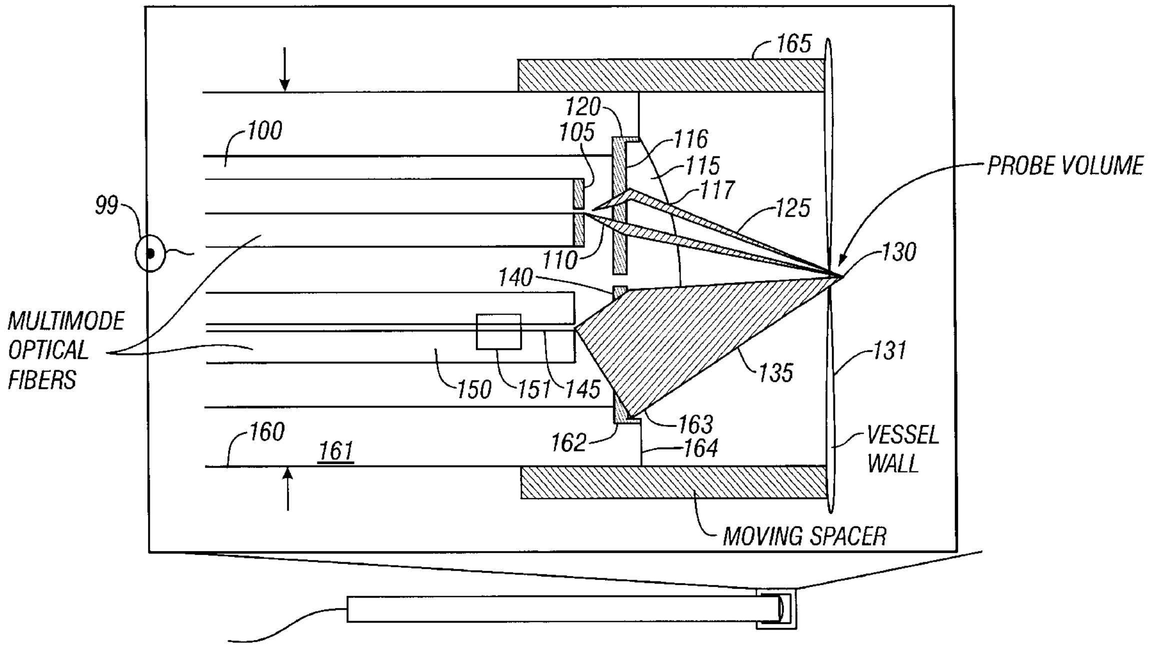
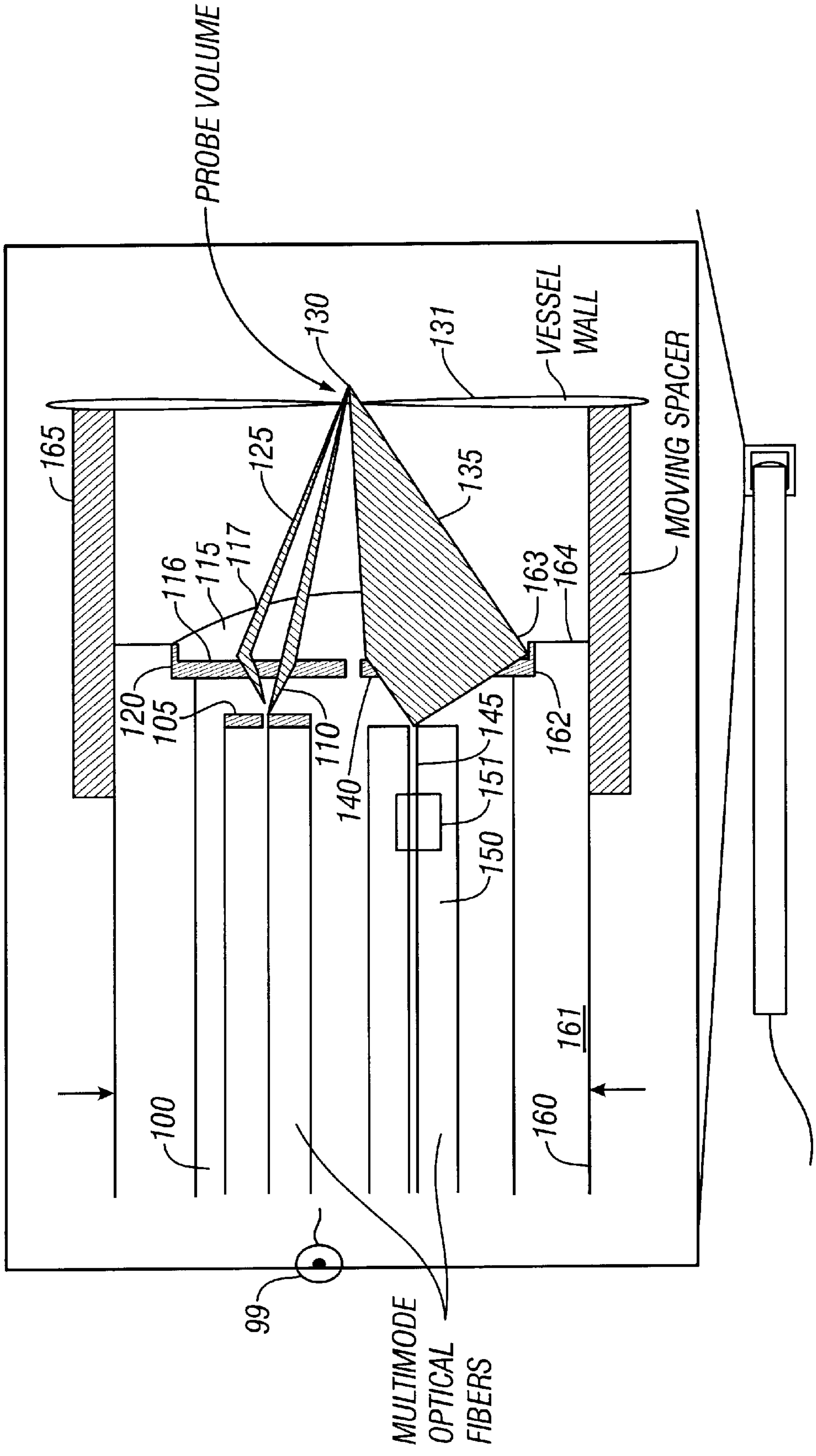
(57) **ABSTRACT**

A miniaturized laser Doppler velocimeter is formed in a housing that is preferably 3 mm in diameter or less. A laser couples light to a first diffractive optical element that is formed on the fiber end. The light is coupled to a lens that also includes a diffractive optical element. The same lens is also used to collect receive light, and receives includes another diffractive optical element to collect that received light.

10 Claims, 1 Drawing Sheet





PROBE VOLUME
130
131
VESSEL WALL
MOVING SPACER
165
125
135
116
115
117
163
164
120
105
110
140
145
151
162
150
161
100
160
99
MULTIMODE OPTICAL FIBERS

FIG. 1

SUB MINIATURIZED LASER DOPPLER VELOCIMETER SENSOR

CROSS REFERENCE TO RELATED APPLICATIONS

The present application claims priority from application Ser. No. 60/224,931, filed Aug. 11th 2000.

The U.S. government has certain rights in this invention pursuant to Grant No. 30821 awarded by NASA NPO and Grant No. N66001-99-1-8902 awarded by Space and Naval Warfare Systems Center.

BACKGROUND OF INVENTION

Non contact particle sensors are known, and have been described in patents and in the literature. A commercially available laser Doppler velocimeter may include a gas laser and discrete optics. This has often resulted in relatively large and nonportable instruments. The instruments may be unsuitable for harsh environments since they are subject to misalignment.

Diode based laser the velocimeters have been suggested. This may result in miniaturization of the probes and better integration of the structure. Existing probes, however, often require beam alignment for the transmitting optics. This may result in complex optical mechanical system design. This may also be prone to misalignment due to vibration and temperature changes.

SUMMARY OF INVENTION

The present system describes a self-contained rugged sensor probe used for measuring the speed of moving particles and objects that are located at a fixed distance from a housing of the probe. The probe may operate properly without moving parts, and with a minimal number of optical components. The inherent design of the system may operate without calibration, allowing it to be used in hostile environments. The probe may also be sealed and self-contained, allowing more flexibility in its use. For example, ultraviolet and other sterilization techniques may be used when the system is used for biomedical applications.

BRIEF DESCRIPTION OF DRAWINGS

These and other aspects will now be described in detail, with reference to the accompanying drawing, wherein FIG. **1** shows a block diagram type embodiment of the structure of the device.

DETAILED DESCRIPTION

An embodiment is shown in FIG. **1**. This embodiment uses optical fibers and diffractive optical elements to carry out the well-known process of two beam laser Doppler anemometry. This system may allow dramatic minimization of dimensions of the probe and specifically the diameter of the probe.

The present application defines a special way of using optical fibers for injection and collection of light. Light is coupled through a transmitting optical fiber **100** which may be a single-mode optical fiber. The transmitting optical fiber **100** may be driven by any laser of any desired wavelengths. Laser wavelengths between 800 and 1000 nm are often used for biomedical applications. A diffractive optical element **105** is directly written on the distal end portion of the transmitting optical fiber **100**. The diffractive optical element can have dimensions and characteristics as disclosed in

conventional laser Doppler velocimeter information. The light output **110** from the transmitting optical fiber **100** is coupled to a lens **115** which may be, for example, of focusing lens. In this embodiment, a single lens is used for both transmitting and receiving. An advantage is that the lens can be housed in the housing in a way which extends all the way from one wall of the housing to the other wall of the housing, thus simplifying the formation. For example, a watertight seal may be formed around the edges of the lens in order to seal the housing.

The lens preferably has a flat surface **116**, and a curved surface **117** use for the focusing. The portion of the lens which receives that transmitted light from the transmitting optical fiber is marked with a diffractive optical element **120**. Therefore, the light output from the transmitting optical fiber **100** is altered by both DOEs. The thus altered light **125** is directed to the probe volume **130**.

As described herein, a moving spacer may adjust the distance between the lens the outer surface, and the probe volume.

For example, the probe volume **130** may be directly below the surface of a vessel wall such as a blood vessel.

The light is reflected back from the probe volume **130** as reflected light **135**. This light is directed to a second region of the optical lens **115**. This second region includes a third diffractive optical element, **140**, written thereon. The combination of the lens and third diffractive optical element may effectively focus reflected light **135** to the area of the core **145** of the receiving optical fiber **150**. The receiving optical fiber **150** may be a multimode optical fiber.

All of the elements are housed within a housing **160**. A housing may be of any shape, and preferably has a maximum outer extent of 3 mm or less. If the housing is cylindrical, which may be preferred, then the housing may have a diameter of 3 mm or less, for example. The outer wall **161** of the housing may be formed from a cylindrical element with a notch **162** that is formed therein. The outer edges of the lens **115** sit within the notch, with of the rear flat surface of the lens also sitting against a surface of the notch **162**. As shown, the edge of the front surface of the lens **163** may be substantially aligned with the front surface **164** of the housing element **161**. This may be advantageous, since it may allow the front surface of the device to have minimal, if any, edge portions. The front surface of the housing is substantially aligned with edges of the lens.

A second housing element **165** forms a moving spacer that is connected to the first housing element. The moving spacer may fit around the outer surface of the first housing element **161**. The connection may be of any type of connection that can allow the moving spacer **165** to move back and forth in the housing. For example, this may be used to tune the location of the probe volume.

The fiber **150** may also optionally include a Bragg grating portion **151** embedded in the fiber optic. This may be used for temperature sensitive measurements as well as reflective, absorption measurements at different wavelengths.

Although only a few embodiments have been disclosed in detail above, other modifications are possible. All such modifications are intended to be encompassed within the following claims, in which:

What is claimed is:

1. An apparatus comprising:

a housing, having a maximum outer dimension extending from one end to the other, of 3 mm or less; and

at least an optical transmitter part, and an optical receiver part, and elements which alter the path of light between said optical transmitter part and said optical receiver part, coupled to said housing, and carrying out laser Doppler velocimetry within said housing, wherein said optical transmitter part and said optical receiver par are each formed from lengths of optical fibers, wherein said optical elements include a single lens coupled to both said optical transmitter part and said optical receiver part,

wherein said lens has at least one diffractive optical element formed thereon, and wherein said lens has a first flat surface and a second curved surface, and wherein said diffractive optical element is formed on said flat surface.

2. An apparatus comprising:

a housing, having a maximum outer dimension extending from one end to the other, of 3 mm or less; and

at least an optical transmitter part, and an optical receiver part, and elements which alter the path of light between said optical transmitter part and said optical receiver part, coupled to said housing, and carrying out laser Doppler velocimetry within said housing

wherein said optical transmitter part and said optical receiver part are each formed from lengths of optical if fliers, wherein said optical elements include only a single lens coupled to receive light from both said optical transmitter part and from said optical receiver part wherein said single lens includes a first diffractive optical element part formed thereon adjacent to said optical transmitter part, and a second diffractive optical element formed thereon adjacent to said optical receiver part further comprising a third diffractive optical element, formed on an end of one of said optical fibers.

3. An apparatus as in claim **2**, wherein said third diffractive optical element is formed on an end of said fiber that carries out said optical transmitter part.

4. An apparatus comprising:

a housing, having a maximum outer dimension extending from one end to the other, of 3 mm or less; and

at least an optical transmitter part, and optical receiver part, and elements which alter the path of light between said optical transmitter part and said optical receiver part, coupled to said housing, and carrying out laser Doppler velocimetry within said housing wherein said optical transmitter part and said optical receiver part are each formed from lengths of optical fibers, wherein said optical transmitter part and said optical receiver part are each formed from lengths of optical fibers, wherein said optical elements include only a single lens coupled to receive light from both said optical transmitter part and from said optical receiver part, further comprising a Bragg element, formed on one of said optical fibers.

5. An apparatus comprising:

a housing;

a first optical fiber within said housing, carrying an optical beam;

a second optical fiber, within said housing, receiving an optical beam that has been reflected from an object of scanning;

a single lens, formed within said housing to cover an entire surface of said housing, to transmit a transmitted optical beam from said first optical fiber, and to receive a reflected optical beam to said second optical fiber, said single lens having a diffractive optical element formed on a surface thereof, wherein said diffractive optical element includes a first portion at an area located to intersect said transmitted optical beam, and a second portion located to intersect a received optical beam, wherein said single lens has a first flat surface facing said first and second optical fibers, and a second curved surface, facing away from said first and second optical fibers.

6. An apparatus as in claim **5**, wherein said diffractive optical element is formed on said flat surface of said lens.

7. An apparatus as in claim **6**, further comprising another diffractive optical element, formed on a distal surface of said first optical fiber, to intersect said optical beam being carried by said first optical fiber.

8. An apparatus as in claim **7**, wherein said housing is substantially cylindrical in shape, and has an outer diameter of approximately 3 mm or less.

9. An apparatus as in claim **7**, further comprising a spacer element, coupled around an outside of said optical housing, and holding a front surface of said lens at a specified distance from said object of scanning.

10. An apparatus as in claim **7**, further comprising a Bragg optical element, formed as part of said fiber.

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