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Infrared Raman device

Abstract

An infrared Raman device is capable of switching and performing Raman measurement and first infrared measurement on a sample. The infrared Raman device includes an objective lens for Raman measurement; a first observation lens for infrared measurement; a laser light source that generates laser light; a first infrared light source that generates first infrared light; and a mirror. The mirror is disposed at time of the Raman measurement to reflect the laser light to cause the laser light to pass through the objective lens for Raman measurement and reflect Raman light generated from the sample by the laser light that passes through the objective lens for Raman measurement and radiated to the sample. The Raman light passes back through the objective lens for Raman measurement.

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Background/Summary

CROSS REFERENCE TO RELATED APPLICATIONS

(1) This nonprovisional application is based on Japanese Patent Application No. 2022-191431 filed on Nov. 30, 2022 with the Japan Patent Office, the entire contents of which are hereby incorporated by reference.

BACKGROUND OF THE INVENTION

Field of the Invention

(2) The present disclosure relates to an infrared Raman device.

Description of the Background Art

(3) For example, WO 2013/132734 describes a device that switches and performs Raman measurement and infrared measurement on a sample.

SUMMARY OF THE INVENTION

(4) Some devices that switch and perform Raman measurement and infrared measurement on a sample may suffer from an increase in size around an objective optical system. In addition, such devices that switch and perform Raman measurement and infrared measurement on a sample may require positional adjustment of the sample in measurement mode switching.

(5) The present disclosure has been made in view of the problems with the conventional technology as described above. More specifically, the present disclosure provides an infrared Raman device that is allowed to decrease in size around an objective optical system and perform measurement mode switching without having the position of a sample adjusted.

(6) An infrared Raman device according to the present disclosure is capable of switching and performing Raman measurement and first infrared measurement on a sample. The infrared Raman device includes an objective lens for Raman measurement; a first observation lens for infrared measurement; a laser light source that generates laser light; a first infrared light source that generates first infrared light; and a mirror. The mirror is disposed at time of the Raman measurement to reflect the laser light to cause the laser light to pass through the objective lens for Raman measurement and reflect Raman light generated from the sample by the laser light that passes through the objective lens for Raman measurement and radiated to the sample. The Raman light passes back through the objective lens for Raman measurement. The objective lens for Raman measurement is switched to the first observation lens for infrared measurement at time of the first infrared measurement to cause an optical axis of the first observation lens for infrared measurement to coincide with an optical axis of the objective lens for Raman measurement at the time of the Raman measurement and the first observation lens for infrared measurement is used. The mirror is disposed at the time of the first infrared measurement to partially reflect the first infrared light to cause the first infrared light to pass through the first observation lens for infrared measurement and transmit the first infrared light that is reflected by the sample after passing through the first observation lens for infrared measurement and passes through the first observation lens for infrared measurement again.

(7) The foregoing and other objects, features, aspects and advantages of the present invention will become more apparent from the following detailed description of the present invention when taken in conjunction with the accompanying drawings.

Description

BRIEF DESCRIPTION OF THE DRAWINGS

(1) FIG. **1**A is a schematic diagram of an infrared Raman device **100** at time of Raman measurement;

(2) FIG. **1**B is a schematic diagram of infrared Raman device **100** at time of first infrared measurement;

(3) FIG. **2** is an enlarged schematic view of a region near a mirror **30** at the time of the first infrared measurement;

(4) FIG. **3**A is a schematic diagram of a first observation lens **42** for infrared measurement;

(5) FIG. **3**B is a schematic diagram illustrating that first infrared light L**2** passes through first observation lens **42** for infrared measurement;

(6) FIG. **4**A is a schematic diagram of an infrared Raman device **200** at the time of the Raman

measurement;
(7) FIG. **4**B is a schematic diagram of infrared Raman device **200** at the time of the first infrared measurement;
(8) FIG. **5** is a schematic diagram of an infrared Raman device **100**A at time of second infrared measurement;
(9) FIG. **6**A is a schematic diagram of a second observation lens **46** for infrared measurement; and
(10) FIG. **6**B is a schematic diagram illustrating that second infrared light L**4** passes through second observation lens **46** for infrared measurement, a sample S, and first observation lens **42** for infrared measurement.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

(11) Embodiments of the present disclosure will be described with reference to the drawings. In the following drawings, the same or corresponding portions will be denoted by the same reference numerals and duplicate description will not be repeated.

First Embodiment

(12) An infrared Raman device (that will be referred to as "infrared Raman device **100**" below) according to a first embodiment will be described.
(13) <Configuration of Infrared Raman Device **100**>
(14) The following describes a configuration of infrared Raman device **100**.
(15) FIG. **1**A is a schematic diagram of infrared Raman device **100** at the time of Raman measurement and FIG. **1**B is a schematic diagram of infrared Raman device **100** at the time of first infrared measurement. As illustrated in FIGS. **1**A and **1**B, infrared Raman device **100** includes a laser light source **11**, a first infrared light source **12**, a beam splitter **21**, a mirror **22**, a mirror **23**, a mirror **24**, a mirror **30**, an objective lens **41** for Raman measurement, a first observation lens **42** for infrared measurement, a revolving nosepiece **43**, a stage **50**, a Raman spectrometer **61**, and an infrared detector **62**.
(16) Laser light source **11** generates laser light L**1**. First infrared light source **12** generates first infrared light L**2**. Infrared Raman device **100** is capable of switching and performing Raman measurement and first infrared measurement. Laser light L**1** is used in the Raman measurement. First infrared light L**2** is used in the first infrared measurement.
(17) Objective lens **41** for Raman measurement and first observation lens **42** for infrared measurement are attached to revolving nosepiece **43**. It is possible to switch objective lens **41** for Raman measurement and first observation lens **42** for infrared measurement by revolving revolving nosepiece **43**. More specifically, revolving revolving nosepiece **43** at the time of first infrared measurement causes the optical axis of first observation lens **42** for infrared measurement to coincide with the optical axis of objective lens **41** for Raman measurement at the time of Raman measurement. Sample S is positioned on the optical axis of objective lens **41** for Raman measurement at the time of Raman measurement and the optical axis of first observation lens **42** for infrared measurement at the time of first infrared measurement. It is to be noted that sample S is disposed on stage **50**.
(18) Laser light L**1** generated by laser light source **11** is reflected by beam splitter **21**. Laser light L**1** reflected by beam splitter **21** is reflected by mirror **22**. First infrared light L**2** generated by first infrared light source **12** is reflected by mirror **23**. First infrared light L**2** reflected by mirror **23** is reflected by mirror **24**.
(19) The position of mirror **30** is movable. Mirror **30** is, for example, an edge mirror. At the time of Raman measurement, mirror **30** is moved to a position at which the whole of laser light L**1** reflected by mirror **22** is reflected. This causes laser light L**1** reflected by mirror **30** to pass through objective lens **41** for Raman measurement. Laser light L**1** passing through objective lens **41** for Raman measurement is condensed and radiated to sample S. The radiation of laser light L**1** causes sample S to generate Raman light L**3**
(20) Raman light L**3** generated from sample S passes through objective lens **41** for Raman

measurement. The whole of Raman light L**3** that is collimated by passing through objective lens **41** for Raman measurement is reflected by mirror **30**. Raman light L**3** reflected by mirror **30** is reflected by mirror **22**. Raman light L**3** reflected by mirror **22** passes through beam splitter **21**. Raman light L**3** passing through beam splitter **21** enters Raman spectrometer **61**. This causes Raman spectrometer **61** to perform Raman measurement.

(21) At the time of first infrared measurement, objective lens **41** for Raman measurement is switched to first observation lens **42** for infrared measurement by revolving revolving nosepiece **43**. In addition, the position of mirror **30** is moved at the time of first infrared measurement. More specifically, at the time of first infrared measurement, mirror **30** is moved to a position at which a portion of first infrared light L**2** reflected by mirror **24** is reflected. This causes first infrared light L**2** reflected by mirror **30** to pass through first observation lens **42** for infrared measurement. First infrared light L**2** passing through first observation lens **42** for infrared measurement is condensed and radiated to sample S.

(22) First infrared light L**2** reflected by sample S passes through first observation lens **42** for infrared measurement. First infrared light L**2** that is collimated by passing through first observation lens **42** for infrared measurement passes through mirror **30**. In other words, first infrared light L**2** that is reflected by sample S and passes through first observation lens **42** for infrared measurement is not reflected by mirror **30**. First infrared light L**2** passing through mirror **30** enters infrared detector **62**. This causes infrared detector **62** to perform first infrared measurement.

(23) FIG. **2** is an enlarged schematic view of a region near mirror **30** at the time of the first infrared measurement. As illustrated in FIG. **2**, first infrared light L**2** reflected by mirror **24** has a first portion L**2***a* and a second portion L**2***b*. First portion L**2***a* is reflected by mirror **30**, but second portion L**2***b* passes through mirror **30** instead of being reflected by mirror **30**. It is to be noted that second portion L**2***b* passing through mirror **30** is absorbed by an appropriate method though not illustrated. This prevents second portion L**2***b* from being stray light.

(24) FIG. **3**A is a schematic diagram of first observation lens **42** for infrared measurement. As illustrated in FIG. **3**A, first observation lens **42** for infrared measurement includes an aspherical mirror **42***a* and spherical mirrors **42***b* and **42***c*. Spherical mirror **42***b* is disposed to be symmetrical to spherical mirror **42***c* with respect to the position of the middle (see the dotted line in FIG. **3**A) of aspherical mirror **42***a* in the direction orthogonal to the optical axis of first observation lens **42** for infrared measurement.

(25) Aspherical mirror **42***a* has a first portion **42***aa* and a second portion **42***ab*. First portion **42***aa* is closer to spherical mirror **42***b* than the position of the middle of aspherical mirror **42***a* in the direction orthogonal to the optical axis of first observation lens **42** for infrared measurement. Second portion **42***ab* is closer to spherical mirror **42***c* than the position of the middle of aspherical mirror **42***a* in the direction orthogonal to the optical axis of first observation lens **42** for infrared measurement.

(26) FIG. **3**B is a schematic diagram illustrating that first infrared light L**2** passes through first observation lens **42** for infrared measurement. As illustrated in FIG. **3**B, first infrared light L**2** (first portion L**2***a*) entering first observation lens **42** for infrared measurement is reflected by only first portion **42***aa*. First infrared light L**2** reflected by first portion **42***aa* is reflected by spherical mirror **42***b* to be condensed on sample S. First infrared light L**2** reflected by sample S is sequentially reflected and collimated by spherical mirror **42***c* and second portion **42***ab*. In this way, first infrared light L**2** reflected by second portion **42***ab* passes through an optical path different from that of first infrared light L**2** that enters first observation lens **42** for infrared measurement. First infrared light L**2** that is reflected by sample S and passes through first observation lens **42** for infrared measurement thus passes through mirror **30** instead of being reflected by mirror **30**.

(27) <Effect of Infrared Raman Device **100**>

(28) The following describes an effect of infrared Raman device **100** in comparison with that of an infrared Raman device (that will be referred to as “infrared Raman device **200**” below) according

to a comparative example.
(29) FIG. **4**A is a schematic diagram of infrared Raman device **200** at the time of Raman measurement and FIG. **4**B is a schematic diagram of infrared Raman device **200** at the time of first infrared measurement. As illustrated in FIGS. **4**A and **4**B, infrared Raman device **200** includes laser light source **11**, first infrared light source **12**, a beam splitter **25**, a mirror **26**, mirror **30**, objective lens **41** for Raman measurement, first observation lens **42** for infrared measurement, a revolving nosepiece **44**, a revolving nosepiece **45**, stage **50**, Raman spectrometer **61**, and infrared detector **62**. Infrared Raman device **200** is capable of switching and performing Raman measurement and first infrared measurement.
(30) In infrared Raman device **200**, laser light L**1** generated by laser light source **11** is sequentially reflected by beam splitter **25** and mirror **26**, passes through objective lens **41** for Raman measurement, and radiated to sample S at the time of Raman measurement. In infrared Raman device **200**, Raman light L**3** generated from sample S passes through objective lens **41** for Raman measurement, is reflected by mirror **26**, and then passes through beam splitter **25** to enter Raman spectrometer **61** at the time of Raman measurement.
(31) In infrared Raman device **200**, first infrared light L**2** generated by first infrared light source **12** is partially reflected by mirror **30** and first infrared light L**2** reflected by mirror **30**, passes through first observation lens **42** for infrared measurement, and radiated to sample S at the time of first infrared measurement. In infrared Raman device **200**, first infrared light L**2** reflected by sample S sequentially passes through first observation lens **42** for infrared measurement and mirror **30** to enter infrared detector **62** at the time of first infrared measurement. In this way, mirror **30** is used in infrared Raman device **200** only at the time of first infrared measurement.
(32) In infrared Raman device **200**, objective lens **41** for Raman measurement and first observation lens **42** for infrared measurement are respectively attached to revolving nosepiece **44** and revolving nosepiece **45**. The optical axis of objective lens **41** for Raman measurement at the time of Raman measurement does not thus coincide with the optical axis of first observation lens **42** for infrared measurement at the time of first infrared measurement. This makes it necessary to adjust the position of sample S at the time of Raman measurement and at the time of first infrared measurement. In addition, mirror **30** is used in infrared Raman device **200** only at the time of first infrared measurement. A different mirror (mirror **26**) is used around the objective optical system at the time of Raman measurement. This causes an increase in size around the objective optical system.
(33) In contrast, objective lens **41** for Raman measurement and first observation lens **42** for infrared measurement are attached to one revolving nosepiece (revolving nosepiece **43**) in infrared Raman device **100**. Revolving the one revolving nosepiece makes it possible to cause the optical axis of first observation lens **42** for infrared measurement at the time of first infrared measurement to coincide with the optical axis of objective lens **41** for Raman measurement at the time of Raman measurement. This makes it unnecessary to adjust the position of sample S at the time of Raman measurement and at the time of first infrared measurement. In addition, mirror **30** is used in infrared Raman device **100** both at the time of Raman measurement and at the time of first infrared measurement. This allows for a decrease in size around the objective optical system.
Second Embodiment
(34) An infrared Raman device (that will be referred to as “infrared Raman device **100**A” below) according to a second embodiment will be described. A difference from infrared Raman device **100** will be chiefly described here and duplicate description will not be repeated.
(35) <Configuration of Infrared Raman Device **100**A>
(36) The following describes a configuration of infrared Raman device **100**A.
(37) FIG. **5** is a schematic diagram of infrared Raman device **100**A at the time of second infrared measurement. As illustrated in FIG. **5**, infrared Raman device **100**A includes laser light source **11**, first infrared light source **12**, beam splitter **21**, mirror **22**, mirror **23**, mirror **24**, mirror **30**, objective

lens **41** for Raman measurement, first observation lens **42** for infrared measurement, revolving nosepiece **43**, stage **50**, Raman spectrometer **61**, and infrared detector **62**. In this respect, the configuration of infrared Raman device **100**A is the same as the configuration of infrared Raman device **100**.

(38) Infrared Raman device **100**A is capable of switching and performing not only Raman measurement and first infrared measurement, but also second infrared measurement in which second infrared light L**4** is used. Infrared Raman device **100**A further includes a second infrared light source **13**, a mirror **27**, and a second observation lens **46** for infrared measurement.

(39) Second infrared light source **13** generates second infrared light L**4**. Second infrared light L**4** generated by second infrared light source **13** is reflected by mirror **27**. In infrared Raman device **100**A, revolving nosepiece **43** is revolved at the time of second infrared measurement to cause the optical axis of first observation lens **42** for infrared measurement to coincide with the optical axis of objective lens **41** for Raman measurement at the time of Raman measurement. At the time of second infrared measurement, the optical axis of second observation lens **46** for infrared measurement coincides with the optical axis of first observation lens **42** for infrared measurement.

(40) Second infrared light L**4** reflected by mirror **27** passes through second observation lens **46** for infrared measurement and is condensed and radiated to sample S. At this time, second infrared light L**4** passes through stage **50**. Second infrared light L**4** passing through sample S is collimated by passing through first observation lens **42** for infrared measurement.

(41) FIG. **6**A is a schematic diagram of second observation lens **46** for infrared measurement. As illustrated in FIG. **6**A, second observation lens **46** for infrared measurement includes an aspherical mirror **46***a* and spherical mirrors **46***b* and **46***c*. Spherical mirror **46***b* is disposed to be symmetrical to spherical mirror **46***c* with respect to the position of the middle (see the dotted line in FIG. **6**A) of aspherical mirror **46***a* in the direction orthogonal to the optical axis of second observation lens **46** for infrared measurement.

(42) Aspherical mirror **46***a* has a first portion **46***aa* and a second portion **46***ab*. First portion **46***aa* is closer to spherical mirror **46***b* than the position of the middle of aspherical mirror **46***a* in the direction orthogonal to the optical axis of second observation lens **46** for infrared measurement. Second portion **46***ab* is closer to spherical mirror **46***c* than the position of the middle of aspherical mirror **46***a* in the direction orthogonal to the optical axis of second observation lens **46** for infrared measurement.

(43) FIG. **6**B is a schematic diagram illustrating that second infrared light L**4** passes through second observation lens **46** for infrared measurement, sample S, and first observation lens **42** for infrared measurement. As illustrated in FIG. **6**B, a portion of second infrared light L**4** entering second observation lens **46** for infrared measurement is reflected by first portion **46***aa* and further reflected by spherical mirror **46***b*. Another portion of second infrared light L**4** entering second observation lens **46** for infrared measurement is reflected by second portion **46***ab* and further reflected by spherical mirror **46***c*. This condenses second infrared light L**4** and second infrared light L**4** is then radiated to sample S. A portion of second infrared light L**4** passing through sample S is sequentially reflected by spherical mirror **42***b* and first portion **42***aa*. Similarly, another portion of second infrared light L**4** passing through sample S is sequentially reflected by spherical mirror **42***c* and second portion **42***ab*. This causes second infrared light L**4** passing through sample S to be collimated by passing through first observation lens **42** for infrared measurement.

(44) As illustrated in FIG. **5**, second infrared light L**4** passing through first observation lens **42** for infrared measurement enters infrared detector **62**. This causes infrared detector **62** to perform second infrared measurement. At the time of second infrared measurement, mirror **30** is detached from the optical path of second infrared light L**4** passing through first observation lens **42** for infrared measurement. This prevents mirror **30** from influencing second infrared light L**4** passing through first observation lens **42** for infrared measurement. In these respects, the configuration of infrared Raman device **100**A is different from the configuration of infrared Raman device **100**.

(45) <Effect of Infrared Raman Device **100**A>
(46) The following describes an effect of infrared Raman device **100**A.
(47) In infrared Raman device **100**A, the optical axis of second observation lens **46** for infrared measurement coincides with the optical axis of objective lens **41** for Raman measurement at the time of Raman measurement and the optical axis of first observation lens **42** for infrared measurement at the time of first infrared measurement. It is thus unnecessary in infrared Raman device **100**A to adjust the position of sample S in switching Raman measurement or first infrared measurement to second infrared measurement. In addition, infrared Raman device **100**A does not request an objective optical system for second infrared observation other than second observation lens **46** for infrared measurement. This allows for a decrease in size around the objective optical system even when it is possible to switch and perform not only Raman measurement and first infrared measurement, but also second infrared measurement in which second infrared light L**4** is used.
(48) (Supplements)
(49) The embodiments of the present disclosure include the following configurations.
(50) <Supplement 1> An infrared Raman device capable of switching and performing Raman measurement and first infrared measurement on a sample, the infrared Raman device including: an objective lens for Raman measurement; a first observation lens for infrared measurement; a laser light source that generates laser light; a first infrared light source that generates first infrared light; and a mirror, in which the mirror is disposed at time of the Raman measurement to reflect the laser light to cause the laser light to pass through the objective lens for Raman measurement and reflect Raman light generated from the sample by the laser light that passes through the objective lens for Raman measurement and radiated to the sample, the Raman light passing back through the objective lens for Raman measurement, the objective lens for Raman measurement is switched to the first observation lens for infrared measurement at time of the first infrared measurement to cause an optical axis of the first observation lens for infrared measurement to coincide with an optical axis of the objective lens for Raman measurement at the time of the Raman measurement and the first observation lens for infrared measurement is used, and the mirror is disposed at the time of the first infrared measurement to partially reflect the first infrared light to cause the first infrared light to pass through the first observation lens for infrared measurement and transmit the first infrared light that is reflected by the sample after passing through the first observation lens for infrared measurement and passes through the first observation lens for infrared measurement again.
(51) <Supplement 2> The infrared Raman device according to Supplement 1, further comprising a revolving nosepiece, in which the objective lens for Raman measurement and the first observation lens for infrared measurement are attached to the revolving nosepiece, and the objective lens for Raman measurement is switched to the first observation lens for infrared measurement at the time of the first infrared measurement by revolving the revolving nosepiece to cause the optical axis of the first observation lens for infrared measurement to coincide with the optical axis of the objective lens for Raman measurement at the time of the Raman measurement and the first observation lens for infrared measurement is used.
(52) <Supplement 3> The infrared Raman device according to Supplement 1 or 2, in which the infrared Raman device is capable of further performing second infrared measurement on the sample by switching to the second infrared measurement, the infrared Raman device further includes a second observation lens for infrared measurement, and a second infrared light source that generates second infrared light, an optical axis of the second observation lens for infrared measurement coincides with the optical axis of the first observation lens for infrared measurement at the time of the first infrared measurement, and the mirror is detached at time of the second infrared measurement from an optical path of the second infrared light that sequentially passes through the second observation lens for infrared measurement, the sample, and the first observation lens for infrared measurement.

(53) <Supplement 4> The infrared Raman device according to any one of Supplements 1 to 3, in which the mirror is an edge mirror.
(54) Although the embodiments of the present invention have been described, it should be understood that the embodiments disclosed herein are examples in all respects, but should not be taken by way of limitation. The scope of the present invention is defined by the claims. The scope of the present invention is intended to include all modifications within the meaning and the scope equivalent to the claims.

Claims

1. An infrared Raman device capable of switching and performing Raman measurement and first infrared measurement on a sample, the infrared Raman device comprising: an objective lens for Raman measurement; a first observation lens for infrared measurement; a laser light source that generates laser light; a first infrared light source that generates first infrared light; and a mirror, wherein the mirror is disposed at time of the Raman measurement to reflect the laser light to cause the laser light to pass through the objective lens for Raman measurement and reflect Raman light generated from the sample by the laser light that passes through the objective lens for Raman measurement and radiated to the sample, the Raman light passing back through the objective lens for Raman measurement, the objective lens for Raman measurement is switched to the first observation Jens for infrared measurement at time of the first infrared measurement to cause an optical axis of the first observation lens for infrared measurement to coincide with an optical axis of the objective lens for Raman measurement at the time of the Raman measurement and the first observation lens for infrared measurement is used, and the mirror is disposed at the time of the first infrared measurement to partially reflect the first infrared light to cause the first infrared light to pass through the first observation lens for infrared measurement and transmit the first infrared light that is reflected by the sample after passing through the first observation lens for infrared measurement and passes through the first observation lens for infrared measurement again.
2. The infrared Raman device according to claim 1, further comprising a revolving nosepiece, wherein the objective lens for Raman measurement and the first observation lens for infrared measurement are attached to the revolving nosepiece, and the objective lens for Raman measurement is switched to the first observation lens for infrared measurement at the time of the first infrared measurement by revolving the revolving nosepiece to cause the optical axis of the first observation lens for infrared measurement to coincide with the optical axis of the objective lens for Raman measurement at the time of the Raman measurement and the first observation lens for infrared measurement is used.
3. The infrared Raman device according to claim 1, wherein the infrared Raman device is capable of further performing second infrared measurement on the sample by switching to the second infrared measurement, the infrared Raman device further comprises a second observation lens for infrared measurement, and a second infrared light source that generates second infrared light, an optical axis of the second observation lens for infrared measurement coincides with the optical axis of the first observation lens for infrared measurement at the time of the first infrared measurement, and the mirror is detached at time of the second infrared measurement from an optical path of the second infrared light that sequentially passes through the second observation lens for infrared measurement, the sample, and the first observation lens for infrared measurement.
4. The infrared Raman device according to claim 1, wherein the mirror is an edge mirror.