

DESCRIPTION

TITLE OF THE INVENTION: N₂O ANALYSIS DEVICE AND ANALYSIS METHOD

TECHNICAL FIELD

[0001]

The invention relates to an N₂O analysis device and analysis method.

BACKGROUND ART

[0002]

Dinitrogen monoxide (hereinafter referred to as N₂O) is known to be one of greenhouse gases. However, since it is not subject to a flue gas regulation, the concentration of N₂O in flue gas discharged from sludge incinerators and circulating fluidized bed boilers has not been measured, or control based on the measured concentration of N₂O has not been performed. Since N₂O has about 310 times as much greenhouse effect as carbon dioxide, the reduction of N₂O greatly contributes to the reduction of the total amount of greenhouse gases. Accordingly, it is strongly desired to reduce N₂O discharged from sludge incinerators and circulating fluidized bed boilers as much as possible.

[0003]

Conventionally, the measurement and analysis of N₂O have been performed with analysis equipment such as a non-dispersive infrared spectrometer, a gas chromatography mass spectrometer (GC-MS), or a gas chromatography electron capture detector (GC-ECD) after gas is sampled and pretreated to remove dust and coexisting gases (H₂O/CO₂/CO/SO₂/CH₄ and so on).

[0004]

In addition, nowadays, a gas analysis device capable of continuously analyzing NO, NO₂, N₂O and NH₃ simultaneously using

multiple quantum cascade lasers (hereinafter referred to as QCLs) after gas is sampled and pretreated to remove only dust/H₂O, is being developed and researched (for example, refer to Patent Document 1 below).

PRIOR ART DOCUMENT

PATENT DOCUMENT

[0005]

Patent Document 1: WO2012/120957

NON-PATENT DOCUMENT

[0006]

Non-Patent Document 1: O. Tadanaga et al., "Efficient 3- μ m difference frequency generation using direct-bonded quasi-phase-matched LiNbO₃ ridge waveguides", 2006, APPLIED PHYSICS LETTERS, Vol.88, No.6, 061101-1-061101-3

SUMMARY OF THE INVENTION

PROBLEMS TO BE SOLVED BY THE INVENTION

[0007]

However, even the gas analysis device described in Patent Document 1 requires dust removal and dehumidification, and the analysis is performed under a reduced pressure to reduce interference of other coexisting gases. Thus, this gas analysis device has problems of requiring much cost and time. For this reason, it has been strongly desired to directly measure the concentration of N₂O in flue gas without pretreatment.

Moreover, for a QCL utilizing long-wavelength mid-infrared (8 μ m), only a material having a high deliquescent property such as CaF₂ or MgF₂ can be used for window material, which makes it impossible to directly measure combustion flue gas containing a large amount of H₂O.

[0008]

In view of the above, the present invention is made to solve the problems described above, and an object thereof is to provide an N₂O analysis device and analysis method capable of directly measuring the concentration of N₂O in flue gas without pretreatment.

MEANS FOR SOLVING THE PROBLEMS

[0009]

To solve the above problems, an N₂O analysis device according to a first aspect of the invention comprises light emission means for emitting laser light to flue gas containing N₂O, H₂O, and CO₂; light reception means for receiving the laser light emitted to the flue gas; wavelength control means for performing control such that a wavelength of the laser light emitted by the light emission means is in a 3.84 to 4.00 μm band; and N₂O concentration calculation means for calculating a concentration of N₂O by means of infrared spectroscopy, using the laser light received by the light reception means and the laser light controlled by the wavelength control means.

[0010]

To solve the above problems, an N₂O analysis device according to a second aspect of the invention is the N₂O analysis device according to the first aspect of the invention, wherein the wavelength control means performs control such that the wavelength of the laser light is 3.9034 to 3.9060 μm , 3.9090 to 3.9116 μm , or 3.9122 to 3.9148 μm .

[0011]

To solve the above problems, an N₂O analysis device according to a third aspect of the invention is the N₂O analysis device according to the first or second aspect of the invention, wherein the wavelength control means performs control such that

the wavelength of the laser light is 3.9047 μm , 3.9103 μm , or 3.9135 μm .

[0012]

To solve the above problems, an N_2O analysis device according to a fourth aspect of the invention is the N_2O analysis device according to any one of the first to third aspects of the invention, wherein the light emission means includes a nonlinear optical crystal, generates, by means of difference frequency generation using inputs of laser light with a wavelength of λ_1 and laser light with a wavelength of λ_2 , laser light with a wavelength of λ_3 satisfying $1/\lambda_3 = 1/\lambda_1 - 1/\lambda_2$, and outputs the laser light with the wavelength of λ_3 .

[0013]

To solve the above problems, an N_2O analysis device according to a fifth aspect of the invention is the N_2O analysis device according to any one of the first to fourth aspects of the invention, further comprising temperature measurement means for measuring a temperature of the flue gas, wherein the N_2O concentration calculation means calculates the concentration of N_2O by means of the infrared spectroscopy, using also the temperature of the flue gas measured by the temperature measurement means.

[0014]

To solve the above problems, an N_2O analysis device according to a sixth aspect of the invention is the N_2O analysis device according to any one of the first to fifth aspects of the invention, further comprising sampling means for sampling the flue gas, wherein the light emission means emits the laser light to the flue gas sampled by the sampling means.

[0015]

To solve the above problems, an N₂O analysis device according to a seventh aspect of the invention is the N₂O analysis device according to the sixth aspect of the invention, further comprising heating means for heating the flue gas sampled by the sampling means.

[0016]

To solve the above problems, an N₂O analysis method according to an eighth aspect of the invention comprises emitting, by light emission means, laser light with a wavelength of 3.84 to 4.00 μm to flue gas containing N₂O, H₂O, and CO₂;

receiving the laser light emitted to the flue gas; and calculating a concentration of N₂O by means of infrared spectroscopy, using the received laser light and the laser light which is controlled to be 3.84 to 4.00 μm .

[0017]

To solve the above problems, an N₂O analysis method according to a ninth aspect of the invention is the N₂O analysis method according to the eighth aspect of the invention, wherein the wavelength of the laser light emitted by the light emission means is controlled to be 3.9034 to 3.9060 μm , 3.9090 to 3.9116 μm , or 3.9122 to 3.9148 μm .

[0018]

To solve the above problems, an N₂O analysis method according to a tenth aspect of the invention is the N₂O analysis method according to the eighth or ninth aspect of the invention, wherein the wavelength of the laser light emitted by the light emission means is controlled to be 3.9047 μm , 3.9103 μm , 3.9135 μm .

[0019]

To solve the above problems, an N₂O analysis method

according to an eleventh aspect of the invention is the N₂O analysis method according to any one of the eighth to tenth aspects of the invention, wherein equipment including a nonlinear optical crystal is used for the light emission means, the equipment generating, by means of difference frequency generation using inputs of laser light with a wavelength of λ_1 and laser light with a wavelength of λ_2 , laser light with a wavelength of λ_3 satisfying $1/\lambda_3 = 1/\lambda_1 - 1/\lambda_2$, and outputting the laser light with the wavelength of λ_3 .

[0020]

To solve the above problems, an N₂O analysis method according to a twelfth aspect of the invention is the N₂O analysis method according to any one of the eighth to eleventh aspects of the invention, further comprising: measuring a temperature of the flue gas; and calculating the concentration of N₂O by means of the infrared spectroscopy, using also the measured temperature of the flue gas.

[0021]

To solve the above problems, an N₂O analysis method according to a thirteenth aspect of the invention is the N₂O analysis method according to any one of the eighth to twelfth aspects of the invention, wherein the flue gas to which the laser light is emitted is sampled.

[0022]

To solve the above problems, an N₂O analysis method according to a fourteen aspect of the invention is the N₂O analysis method according to the thirteenth aspect of the invention, wherein the sampled flue gas is heated.

EFFECT OF THE INVENTION

[0023]

The present invention makes it possible to measure the concentration of N_2O in the flue gas accurately and promptly without pretreatment.

BRIEF DESCRIPTION OF THE DRAWINGS

[0024]

[Fig. 1] Fig. 1 is a schematic configuration diagram of a sludge incinerator including an N_2O concentration analysis device according to a first embodiment of the present invention.

[Fig. 2] Fig. 2 is a schematic configuration diagram of an example of laser light source and a wavelength control device included in the N_2O concentration analysis device.

[Fig. 3] Fig. 3 is a graph illustrating the absorbance of N_2O in a wavelength band of $4.5\ \mu\text{m}$ at room temperature.

[Fig. 4A] Fig. 4A is a graph illustrating the absorbance of H_2O in the wavelength band of $4.5\ \mu\text{m}$ at 800°C .

[Fig. 4B] Fig. 4B is a graph illustrating the absorbance of CO_2 in the wavelength band of $4.5\ \mu\text{m}$ at 800°C .

[Fig. 4C] Fig. 4C is a graph illustrating the absorbance of N_2O in the wavelength band of $4.5\ \mu\text{m}$ at 800°C .

[Fig. 5] Fig. 5 is a graph illustrating the absorbance of N_2O in a wavelength band of $3.9\ \mu\text{m}$ at room temperature.

[Fig. 6A] Fig. 6A is a graph illustrating the absorbance of H_2O in the wavelength band of $3.9\ \mu\text{m}$ at 800°C .

[Fig. 6B] Fig. 6B is a graph illustrating the absorbance of CO_2 in the wavelength band of $3.9\ \mu\text{m}$ at 800°C .

[Fig. 6C] Fig. 6C is a graph illustrating the absorbance of N_2O in the wavelength band of $3.9\ \mu\text{m}$ at 800°C .

[Fig. 7] Fig. 7 is a graph illustrating the absorbance of H_2O , CO_2 , N_2O around the wavelength $3.9\ \mu\text{m}$ at 800°C .

[Fig. 8] Fig. 8 is a graph illustrating the relationship

between the measurement time and the measurement result of the N₂O concentration analysis device.

[Fig. 9] Fig. 9 is a schematic configuration diagram of an N₂O concentration analysis device according to a second embodiment of the present invention.

MODE FOR CARRYING OUT THE INVENTION

[0025]

Descriptions will be provided for embodiments of an N₂O concentration analysis device and analysis method according to the present invention based on the drawings. However, the present invention is not limited only to the following embodiments described based on the drawings.

[0026]

[First Embodiment]

Descriptions will be provided using Figs. 1, 2, 3, 4A to 4C, 5, 6A to 6C, and 7 for an application of an N₂O concentration analysis device according to a first embodiment of the present invention to N₂O measurement in a sludge incinerator.

[0027]

As illustrated in Fig. 1, a sludge incinerator 100A according to this embodiment is a fluidized bed incinerator in which sludge (fuel) 1 is supplied into a sludge incinerator main body 101 by a sludge feeder (feeder) 111, and inside the sludge incinerator main body 101, a fluidized bed 102 is formed by sand grains (fluidized material) as a heating medium together with the sludge 1 and combusts. Combustion air 2 with its temperature adjusted is introduced from a bottom 101a of the sludge incinerator main body 101 by means of a combustion air supply pipe 112a and a combustion air supply flow rate adjustment valve 112b, and auxiliary fuel 3 is introduced into the fluidized bed

102 in the sludge incinerator main body 101 by means of an auxiliary fuel supply pipe 113a and an auxiliary fuel supply flow rate adjustment valve 113b, and then combusts. The sand grains in the heated fluidized bed 102 are moved and combusted together with the supplied sludge 1 by the combustion air 2 and generated combustion gas. Further, while the combustion gas of sludge moves up in a freeboard 103 above the fluidized bed 102, combustion of the combustion gas is completed with secondary air 4 supplied by means of a secondary air supply pipe 114a and a secondary air supply flow rate adjustment valve 114b. Then, flue gas 5 after the combustion passes through a flue 105 at an upper portion of the sludge incinerator main body 101 and is discharged to a flue gas treatment device.

[0028]

The sludge incinerator 100A includes an N_2O concentration analysis device 10A for analyzing the concentration of N_2O in the flue gas 5 passing through the flue 105.

As illustrated in Fig. 1, the N_2O concentration analysis device 10A includes a light source 11, windows 12a and 12b, a light receiver 13, a control device 14, a temperature measurement instrument 15a, and a signal generator 15b. The control device 14 includes a light source control unit 14a and a signal analyzing unit 14b which calculates the concentration of N_2O based on a light reception signal from the light receiver 13, a temperature signal from the signal generator 15b, and a reference signal from the light source control unit 14a.

[0029]

Here, descriptions will be provided for an example of the light source 11 and the light source control unit 14a, using Fig. 2.

As illustrated in Fig. 2, the light source 11 includes the two near-infrared semiconductor lasers (hereinafter referred to as NIR-LDs) 11a and 11b having different oscillation wavelengths, a mirror (reflection mirror) 11c, a multiplexer 11d, and a nonlinear optical crystal 11e. In the light source 11 thus configured, laser light having a wavelength λ_1 generated from the first (one) NIR-LD 11a is inputted into the nonlinear optical crystal 11e via the mirror 11c and the multiplexer 11d, and at the same time, laser light having a wavelength λ_2 ($\lambda_2 > \lambda_1$) generated from the second (the other) NIR-LD 11b is inputted into the nonlinear optical crystal 11e via the multiplexer 11d. As a result, the light source 11 emits laser light having a short-wavelength mid-infrared wavelength λ_3 ($1/\lambda_3 = 1/\lambda_1 - 1/\lambda_2$), which is the difference-frequency light. This difference frequency generation is based on the second order nonlinear optical effect and occurs in a second order nonlinear optical crystal. As second order nonlinear optical crystals, lithium niobate (LN), lithium tantalate (LT), and potassium titanyl phosphate (KTP) which have large nonlinear constants are well known.

[0030]

In addition, to utilize the nonlinear constant efficiently, the phases of the wavelengths λ_1 , λ_2 , and λ_3 of the incident and outgoing laser lights need to be matched, and the angle matching method or the quasi phase matching method are used for it. For example, as shown in Non-Patent Document 1, LN is used as a nonlinear optical crystal, a periodic polarization reversal structure is adopted to achieve the quasi phase matching, and a waveguiding structure is further adopted to generate a mid-infrared light in a 3 μm band with high

efficiency. Although in Non-Patent Document 1, light of a 3 μm band is generated, for example, it is possible to generate a short-wavelength mid-infrared light with a desired wavelength λ_3 in a 2 to 5 μm range, by appropriately selecting the wavelength λ_1 and the wavelength λ_2 , which are in the near-infrared range.

[0031]

In this case, the stability/robustness of the device is guaranteed by using NIR-LD light sources, which have been used for many applications for communication or the like, for the original light sources. In addition, in a QCL that oscillates and generates a long-wavelength mid-infrared light, since the wavelength line width of the generated laser light is wide, the measurement tends to be affected by coexisting gases. On the other hand, since in this embodiment, the NIR-LDs, the wavelength line widths of which are extremely narrow, are used as origins, the wavelength line width of the generated short-wavelength mid-infrared laser light is as narrow as the NIR-LDs, and this embodiment has a characteristic of being hardly affected by coexisting gases.

[0032]

Note that although the incident lights from the two NIR-LDs 11a and 11b enter the nonlinear optical crystal 11e through the spatial optical system in Fig. 2, optical fibers can be used for the incidence.

[0033]

The light source 11 is controlled by the light source control unit 14a, which performs temperature control for the two NIR-LDs 11a and 11b and the nonlinear optical crystal 11e, and electric current control for the two NIR-LDs 11a and 11b. Appropriate setting of the temperature allows for precise

control of the oscillation wavelengths at the NIR-LDs 11a and 11b, and precise control of combinations of wavelengths that can be efficiently generated by the difference frequency generation, at the nonlinear optical crystal 11e.

[0034]

Further, in this embodiment, utilizing short-wavelength mid-infrared (around 4 μm) for the measurement wavelength allows sapphire window plates having high strength/corrosion resistance to be utilized for the windows 12a and 12b. On the other hand, since, in a QCL utilizing long-wavelength mid-infrared (8 μm), only CaF_2 , MgF_2 , or the like having a high deliquescent property can be used for window material, it is impossible to directly measure combustion flue gas containing a large amount of H_2O .

[0035]

Meanwhile, strong basic absorption of N_2O exists at a wavelength of 4.50 μm (absorption intensity 1×10^{-18} cm/molecule), and typically, N_2O is observed as a target in a wavelength region where such strong absorption exists. However, in the application described above, for example, where gases such as 50% of water and 12% of carbon dioxide coexist, for example, even though a strong absorption of N_2O exists, it is impossible to measure the absorption line accurately because the absorption of N_2O is small compared to the coexisting gases and the coexisting gases obstruct (interfere) the measurement.

[0036]

After diligent studies in this respect, it was found that absorption of N_2O can be observed at around 3.9 μm while avoiding influence of the coexisting gases, even though the absorption intensity is 2.5×10^{-20} cm/molecule, which is a small absorbance

compared to the basic absorption. The situation will be described using Figs. 3, 4A to 4C, 5, 6A to 6C, and 7.

[0037]

Fig. 3 illustrates the absorbance of N_2O around $4.5\text{ }\mu\text{m}$. Fig. 3 illustrates the case where the concentration of NO_2 is 100 ppm, the pressure is 1 atmospheric pressure, the path length is 6 m, and the temperature is room temperature. Fig. 3 shows that, depending on the wavelength in this region, there is strong absorption the absorbance of which exceeds 1. Figs. 4A to 4C show the absorbance around a $4.5\text{ }\mu\text{m}$ band for the case where the temperature is 800°C , which is an example of a temperature assumed to be inside the incinerator, and where 50% of water and 12% of CO_2 coexist. According to Figs. 4A to 4C, it was confirmed that in the high temperature condition at 800°C , the absorbance of N_2O reduces while the absorption of CO_2 , which is a coexisting gas, is very strong, which makes it difficult to observe N_2O . Note that according to Fig. 4B, the absorbance of CO_2 is larger than 1 at wavelengths of $4.52\text{ }\mu\text{m}$ or less.

[0038]

Meanwhile, Fig. 5 shows the absorbance of N_2O around $3.9\text{ }\mu\text{m}$ for the case where the concentration of N_2O is 100 ppm, the pressure is 1 atmospheric pressure, the path length is 6 m, the temperature is room temperature. It is shown that the absorbance of N_2O is only about one fortieth of the absorbance around $4.5\text{ }\mu\text{m}$. In the same way as in Figs. 4A to 4C, Figs. 6A to 6C show the absorbance around a $3.9\text{ }\mu\text{m}$ band for the case where the temperature is 800°C , which is an example of a temperature assumed to be inside the incinerator, and where 50% of water and 12% of CO_2 coexist. From Figs. 6A to 6C, it was confirmed that unlike the vicinity of $4.5\text{ }\mu\text{m}$, this region is less

susceptible to the absorption of CO_2 . Fig. 7 illustrates the case where Figs. 6A to 6C are superimposed and the scale of the vertical axis is changed. According to Fig. 7, it was confirmed that although the absorption of water exists around $3.9\text{ }\mu\text{m}$, the positions of its absorption lines are sparse and the influence of the absorption lines of water is small, and it is possible to observe N_2O .

[0039]

From this result, the light source 11 is a mid-infrared semiconductor laser capable of emitting laser light with, for example, a vibrational-rotational absorption wavelength of N_2O in a wavelength band of 3.84 to $4.00\text{ }\mu\text{m}$, preferably a wavelength region A1 (wavelengths of 3.9034 to $3.9060\text{ }\mu\text{m}$), a wavelength region A2 (wavelengths of 3.9090 to $3.9116\text{ }\mu\text{m}$), or a wavelength region A3 (wavelengths of 3.9122 to $3.9148\text{ }\mu\text{m}$), or more preferably a wavelength of $3.9047\text{ }\mu\text{m}$, a wavelength of $3.9103\text{ }\mu\text{m}$, or a wavelength of $3.9135\text{ }\mu\text{m}$.

[0040]

The windows 12a and 12b are arranged to face each other at the flue 105 and can be passed through by the laser light. It is preferable that the windows 12a and 12b are made of, for example, sapphire. This is because that sapphire does not have a deliquescent property and eliminates the need of maintenance such as replacing the windows.

[0041]

The light receiver 13 receives the laser light emitted by the light source 11 and having passed through the window 12a, the flue 105, and the window 12b. A light intensity signal (light reception signal) obtained by the light receiver 13 is outputted to the signal analyzing unit 14b to be described in detail later

of the control device 14.

[0042]

The temperature measurement instrument 15a is disposed so as to measure the temperature at generally the same position as the laser measurement position in the flue 105, and capable of measuring the temperature of the flue gas 5 flowing inside the flue 105. The temperature measurement instrument 15a measures the temperature of the flue gas 5, and the temperature signal generated by the signal generator 15b is outputted to the signal analyzing unit 14b.

[0043]

The light source control unit 14a transmits a control signal to the light source 11 to control the wavelength of the laser light emitted by the light source 11, and transmits the reference signal to the signal analyzing unit 14b. The reference signal is a signal having the wavelength information of the laser light emitted by the light source 11 based on the control signal.

[0044]

The signal analyzing unit 14b calculates the concentration of N_2O and outputs a signal corresponding to this concentration of N_2O . The signal analyzing unit 14b calculates the concentration of N_2O by means of infrared spectroscopy based on the reference signal transmitted from the light source control unit 14a, the light reception signal obtained at the light receiver 13, and the temperature signal transmitted from the temperature measurement instrument 15a via the signal generator 15b.

[0045]

The measurement time of the N_2O concentration analysis

device 10A described above and the measurement result of the concentration of N_2O will be described using Fig. 8. In Fig. 8, the test specimen indicates a case of the N_2O concentration analysis device according to this embodiment, and the comparative specimen indicates a case of a conventional N_2O concentration analysis device that measures the concentration of N_2O after flue gas is sampled and pretreated to remove dust and coexisting gases. In Fig. 8, the thin line indicates the measurement result of the test specimen, and the thick line indicates the measurement result of the comparative specimen. The measured gas contained 50% of water, 12% of CO_2 , several% of O_2 , and the temperature of the gas was 800 to 850°C.

[0046]

As illustrated in Fig. 8, for the maximum peaks of the concentrations of N_2O around 30 minutes, it was found that the test specimen was able to be measured 1 minute and 38 seconds before the case of the comparative specimen. It was also found that the concentration of N_2O of the test specimen was higher than that for the case of the comparative specimen. For the minimum values of the concentrations of N_2O around 40 minutes, it was found that the test specimen was able to be measured 1 minute and 25 seconds before the case of the comparative specimen. It was also found that the concentration of N_2O of the test specimen is lower than that for the case of the comparative specimen. In other words, it was confirmed that the N_2O concentration analysis device 10A according to this embodiment makes it possible to analyze the concentration of N_2O promptly and accurately compared to a conventional N_2O concentration analysis device regardless of the maximum value and the minimum values of the concentration of N_2O .

[0047]

Thus, the N_2O concentration analysis device 10A according to this embodiment, having the equipment described above, can directly measure the concentration of N_2O in the flue gas 5 without pretreatment of removing dust and coexisting gases other than N_2O in the flue gas 5, which makes it possible to measure the concentration of N_2O in the flue gas 5 promptly and accurately.

[0048]

In addition, changing the attachment positions of the windows 12a and 12b allows for the measurement at an upstream portion such as the inside of the freeboard 103 where the concentration of particles is high, or a position directly above the fluidized bed where flames cross and the concentration of N_2O is high. Moreover, in the measurement at a downstream portion, the concentration of N_2O measured by the N_2O concentration analysis device 10A according to this embodiment shows an average value on the laser light path. For this reason, although conventional sampling measurement requires traverse measurement or the like to find a representative value when the concentration is not constant inside the flue, the N_2O concentration analysis method in accordance with the N_2O concentration analysis device 10A according to this embodiment makes it possible to always measure the average concentration of N_2O in the flue 105.

[0049]

[Second Embodiment]

Descriptions will be provided for an application of the measurement of N_2O in a sludge incinerator in accordance with a N_2O concentration analysis device according to a second

embodiment of the present invention using Fig. 9.

In this embodiment, a sampling device is added to the N₂O concentration analysis device according to the first embodiment described above, and except for it, this embodiment is generally the same as the first embodiment.

[0050]

As illustrated in Fig. 9, a sludge incinerator 100B according to this embodiment includes the same equipment as in the sludge incinerator 100A according to the above first embodiment, and also includes an N₂O concentration analysis device 10B.

[0051]

The N₂O concentration analysis device 10B includes the same equipment as in the N₂O concentration analysis device 10A according to the above first embodiment, and further includes a sampling device 16. The sampling device 16 includes a sampling pipe 16a, a delivery pipe 16b, a sampling cell 16c, a discharge pipe 16d, and a blower 16e.

[0052]

The sampling pipe 16a is disposed with its distal end side protruded into the flue 105, and samples the flue gas 5 flowing through the flue 105.

[0053]

The proximal end side of the delivery pipe 16b is connected to the proximal end side of the sampling pipe 16a, and the distal end side of the delivery pipe 16b is connected to the proximal end side (the end side connected to the light receiver 13) of the sampling cell 16c.

[0054]

The distal end of the sampling cell 16c is coupled to the

light source 11 through a window 12c, and the proximal end of the sampling cell 16c is coupled to the light receiver 13 through a window 12d. Note that it is preferable that the windows 12c and 12d be made of, for example, sapphire in the same way as in the windows 12a and 12b.

[0055]

The proximal end of the discharge pipe 16d is connected to the distal end side (the end side connected to the light source 11) of the sampling cell 16c, and the distal end of the discharge pipe 16d is connected to the flue 105 downstream of the sampling pipe 16a in the flowing direction of the flue gas. The blower 16e is disposed in the middle of the discharge pipe 16d. With the operation of this blower 16e, a part of the flue gas 5 flowing through the flue 105 will be introduced through the sampling pipe 16a and the delivery pipe 16b into the sampling cell 16c, and the flue gas 5 having flowed through the sampling cell 16c will be returned through the discharge pipe 16d to the flue 105.

[0056]

The sampling device 16 further includes a heater 16f that heats the sampling cell 16c to keep the temperature of the flue gas 5 inside the sampling cell 16c at a desired temperature. This allows the inside of the sampling cell 16c to be kept at a predetermined constant temperature, and makes it possible to measure the concentration of N_2O in the flue gas 5 without measuring the temperature.

[0057]

Here, the main operation of the above N_2O concentration analysis device 10B will be described. Note that the main operation of the sludge incinerator 100B is the same as that of the above sludge incinerator 100A, and descriptions thereof

are omitted.

[0058]

First, the heater 16f is activated to heat the sampling cell 16c. This keeps the inside of the sampling cell 16c at a constant temperature, making it possible to keep a temperature correction constant when directly measuring the concentration of N_2O in the flue gas 5 flowing through the flue 105, and thereby eliminating the need for a temperature measurement instrument and its signal generator.

[0059]

Then, the blower 16e is activated. This will cause a part of the flue gas 5 flowing through the flue 105 to flow into the sampling cell 16c through the sampling pipe 16a and the delivery pipe 16b.

[0060]

Next, the light source 11 emits laser light with a wavelength of a predetermined range (for example, 3.84 to 4.00 μm) based on a control signal from the light source control unit 14a of the control device 14. The laser light is received by the light receiver 13 through the window 12c, the flue gas 5 inside the sampling cell 16c, and the window 12d. The light receiver 13 transmits the light reception signal corresponding to the received laser light to the signal analyzing unit 14b of the control device 14. The signal analyzing unit 14b also receives the reference signal from the light source control unit 14a.

[0061]

The signal analyzing unit 14b calculates the concentration of N_2O in the flue gas by means of infrared spectroscopy based on the light reception signal and the

reference signal.

[0062]

Thus, even in the case where the flue gas 5 is sampled, the N_2O concentration analysis device 10B according to this embodiment including the above equipment makes it possible to directly measure the concentration of N_2O in the flue gas without removing dust and coexisting gasses other than N_2O in the flue gas 5, which makes it possible to measure the concentration of N_2O in the flue gas 5 promptly and accurately.

[0063]

Moreover, the N_2O concentration analysis device 10B allows for the installment without a large-scale modification work such as attaching measurement windows to a furnace.

[0064]

[Other Embodiments]

In the above, descriptions have been provided for the case where the concentration of N_2O in the flue gas containing 100 ppm of N_2O , 50% of H_2O , and 12% of CO_2 is measured. However, the concentration of N_2O in the flue gas is not limited to 100 ppm. When the concentration of N_2O is higher than 100 ppm, the absorbance of laser is high, and accordingly, it is possible to obtain the same operation effect as described above.

[0065]

In addition, although in the above, descriptions have been provided for the case where the concentration of N_2O in the flue gas containing 100 ppm of N_2O , 50% of H_2O , and 12% of CO_2 is measured, the concentration of H_2O in the flue gas is not limited to 50%. When the concentration of H_2O is lower than 50%, the absorbance of laser is lower than in the case where the concentration of H_2O is 50%, and the influence on the

measurement of the concentration of N_2O is small. Accordingly, it is possible to obtain the same operation effect as described above.

[0066]

Moreover, although in the above, descriptions have been provided for the case where the concentration of N_2O in the flue gas containing 100 ppm of N_2O , 50% of H_2O , and 12% of CO_2 is measured, the concentration of CO_2 in the flue gas is not limited to 12%. When the concentration of CO_2 is lower than 12%, the absorbance of laser is lower than in the case where the concentration of CO_2 is 12%, and the influence on the measurement of the concentration of N_2O is small. Accordingly, it is possible to obtain the same operation effect as described above.

INDUSTRIAL APPLICABILITY

[0067]

Since the N_2O analysis device and analysis method according to the present invention can measure the concentration of N_2O in the flue gas accurately and promptly without pretreatment, it can be utilized extremely usefully in industrial applications.

REFERENCE SIGNS LIST

[0068]

- 1 sludge (fuel)
- 2 combustion air
- 3 auxiliary fuel
- 4 secondary air
- 5 flue gas
- 10A, 10B N_2O concentration analysis device
- 11 light source (light emission means)
- 12a, 12b window

- 13 light receiver (light reception means)
- 14 control device
- 14a light source control unit (wavelength control means)
- 14b signal analyzing unit (N_2O concentration calculation means)
- 15a temperature measurement instrument (temperature measurement means)
- 100A, 100B sludge incinerator
- 101 incinerator main body
- 102 fluidized bed
- 103 freeboard
- 105 flue

Claims

[Claim 1]

An N₂O analysis device comprising:

light emission means for emitting laser light to flue gas containing N₂O, H₂O, and CO₂, the flue gas being at normal pressures and being not treated with anyone of a dust removal and a dehumidification and a pressure reduction;

light reception means for receiving the laser light emitted to the flue gas;

wavelength control means for performing control such that a wavelength of the laser light emitted by the light emission means is in a 3.84 to 4.00 μm band; and

N₂O concentration calculation means for calculating a concentration of N₂O by means of infrared spectroscopy, using the laser light received by the light reception means and the laser light controlled by the wavelength control means.

[Claims 2]

The N₂O analysis device according to claim 1, wherein the wavelength control means performs control such that the wavelength of the laser light is 3.9034 to 3.9060 μm , 3.9090 to 3.9116 μm , or 3.9122 to 3.9148 μm .

[Claim 3]

The N₂O analysis device according to claim 1 or 2, wherein the wavelength control means performs control such that the wavelength of the laser light is 3.9047 μm , 3.9103 μm , or 3.9135 μm .

[Claim 4]

The N₂O analysis device according to any one of claims 1 to 3, wherein

the light emission means includes a nonlinear optical crystal, generates, by means of difference frequency generation using inputs of laser light with a wavelength of λ_1 and laser light with a wavelength of λ_2 , laser light with a wavelength

of λ_3 satisfying $1/\lambda_3 = 1/\lambda_1 - 1/\lambda_2$, and outputs the laser light with the wavelength of λ_3 .

[Claim 5]

The N₂O analysis device according to any one of claims 1 to 4, further comprising

temperature measurement means for measuring a temperature of the flue gas, wherein

the N₂O concentration calculation means calculates the concentration of N₂O by means of the infrared spectroscopy, using also the temperature of the flue gas measured by the temperature measurement means.

[Claim 6]

The N₂O analysis device according to any one of claims 1 to 5, further comprising

sampling means for sampling the flue gas, wherein

the light emission means emits the laser light to the flue gas sampled by the sampling means.

[Claim 7]

The N₂O analysis device according to claim 6, further comprising

heating means for heating the flue gas sampled by the sampling means.

[Claim 8]

An N₂O analysis method comprising:

emitting, by light emission means, laser light with a wavelength of 3.84 to 4.00 μm to flue gas containing N₂O, H₂O, and CO₂, the flue gas being at normal pressures and being not treated with anyone of a dust removal and a dehumidification and a pressure reduction;

receiving the laser light emitted to the flue gas; and

calculating a concentration of N₂O by means of infrared spectroscopy, using the received laser light and the laser light which is controlled to be 3.84 to 4.00 μm .

[Claim 9]

The N₂O analysis method according to claim 8, wherein the wavelength of the laser light emitted by the light emission means is controlled to be 3.9034 to 3.9060 μm , 3.9090 to 3.9116 μm , or 3.9122 to 3.9148 μm .

[Claim 10]

The N₂O analysis method according to claim 8 or 9, wherein the wavelength of the laser light emitted by the light emission means is controlled to be 3.9047 μm , 3.9103 μm , 3.9135 μm .

[Claim 11]

The N₂O analysis method according to any one of claims 8 to 10, wherein

equipment including a nonlinear optical crystal is used for the light emission means, the equipment generating, by means of difference frequency generation using inputs of laser light with a wavelength of λ_1 and laser light with a wavelength of λ_2 , laser light with a wavelength of λ_3 satisfying $1/\lambda_3 = 1/\lambda_1 - 1/\lambda_2$, and outputting the laser light with the wavelength of λ_3 .

[Claim 12]

The N₂O analysis method according to any one of claims 8 to 11, further comprising:

measuring a temperature of the flue gas; and

calculating the concentration of N₂O by means of the infrared spectroscopy, using also the measured temperature of the flue gas.

[Claim 13]

The N₂O analysis method according to any one of claims 8 to 12, wherein the flue gas to which the laser light is emitted is sampled.

[Claim 14]

The N₂O analysis method according to claim 13, wherein the sampled flue gas is heated.