(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
17 October 2024 (17.10.2024)

WIPO | PCT

(10) International Publication Number
WO 2024/213601 A1

(51) International Patent Classification:
G01J 5/00 (2022.01) *G01J 5/08* (2022.01) *G01J 5/04* (2006.01) *G01J 5/80* (2022.01) *G01J 5/06* (2022.01) *G01J 5/20* (2006.01) *G01J 5/0802* (2022.01)

(21) International Application Number: PCT/EP2024/059775

(22) International Filing Date: 11 April 2024 (11.04.2024)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
23167520.8 12 April 2023 (12.04.2023) EP

(71) Applicant: **TRINAMIX GMBH** [DE/DE]; Industriestrasse 35, 67063 Ludwigshafen am Rhein (DE).

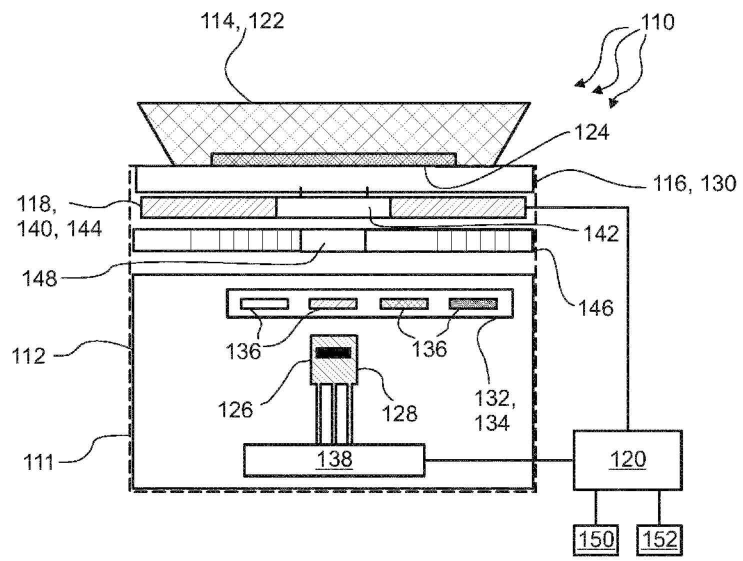
(72) Inventors: **ISLAM, Samiul**; F7 16, 68159 Mannheim (DE). **OEGUEN, Celal Mohan**; Industriestraße 31-35, 67063 Ludwigshafen am Rhein (DE).

(74) Agent: **ALTMANN STÖSSEL DICK PATENTANWÄLTE PARTG MBB**; Matthias Stößel, Theodor-Heuss-Anlage 2, 68165 Mannheim (DE).

(81) Designated States *(unless otherwise indicated, for every kind of national protection available)*: AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CV, CZ, DE, DJ, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IQ, IR, IS, IT, JM, JO, JP, KE, KG, KH, KN, KP, KR, KW, KZ, LA, LC, LK, LR, LS, LU, LY, MA, MD, MG, MK, MN, MU, MW, MX, MY, MZ, NA,

(54) **Title:** CALIBRATION AND OPERATION METHODS FOR DEVICES FOR MONITORING AN EMISSION TEMPERATURE

FIG.1



(57) **Abstract:** The invention refers to a calibration method of assembling a set of items of information for use in a method for operating a measurement device (110) for monitoring an emission temperature of at least one radiation emitting element (114), wherein the measurement device (110) comprises a detector module (112), a transition material (116) and an assembly unit (111), wherein the detector module (112) and the transition material (116) are designated for being integrated into the assembly unit (111) when performing the method for operating a measurement device (110) for monitoring an emission temperature of at least one radiation emitting element (114) in a manner that the transition material (116) is arranged between the detector module (112) and the radiation emitting element (114) such that radiation generated by the radiation emitting element (114) incident onto the detector module (112) is propagating through the transition material (116), wherein the detector module (112) is designated for generating at least one sensor signal

WO 2024/213601 A1

[Continued on next page]

NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SA, SC, SD, SE, SG, SK, SL, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, WS, ZA, ZM, ZW.

(84) Designated States *(unless otherwise indicated, for every kind of regional protection available)*: ARIPO (BW, CV, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SC, SD, SL, ST, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, ME, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, KM, ML, MR, NE, SN, TD, TG).

Declarations under Rule 4.17:

— *as to applicant's entitlement to apply for and be granted a patent (Rule 4.17(ii))*

Published:

— *with international search report (Art. 21(3))*

depending on an intensity of the thermal radiation, the method comprising the following steps: (i) performing a plurality of calibration measurements for determining at least one relationship (352) between at least one sensor signal and at least one temperature of a radiation emitting element (114) by measuring a plurality of sensor signals for at least two different emission temperatures of at least one radiation emitting calibration element when the detector module (112) and the transition material (116) are separate from the assembly unit (111); (ii) performing at least one further calibration measurement for determining at least one correction for the at least one relationship (352) by measuring at least one sensor signal for at least one known emission temperature of at least one radiation emitting calibration when the detector module (112) and the transition material (116) are integrated in the assembly unit (111); (iii) recording the relationship (352) and the correction.

Calibration and operation methods for devices for monitoring an emission temperature

Description

Field of the invention

The present invention refers to a calibration method of assembling a set of items of information, a method for operating a measurement device, a measurement device for monitoring an emission temperature, a computer program, a computer-readable storage medium and a non-transient computer-readable medium. The methods and devices may, in particular, be used for controlling the emission temperature of at least one piece of cookware being heated on a ceramic glass cooktop. However, further applications are conceivable.

Prior art

WO 2022/234074 A1 discloses a device for monitoring an emission temperature of at least one radiation emitting element, a heating system for heating at the least one radiation emitting element to emit thermal radiation at an emission temperature, a method for monitoring an emission temperature of at least one radiation emitting element and method for heating the at least one radiation emitting element to emit thermal radiation at an emission temperature. Herein, the device for monitoring an emission temperature of at least one radiation emitting element comprises at least one light source, wherein the light source is configured to emit optical radiation at least partially towards the at least one radiation emitting element; at least one radiation sensitive element, wherein the at least one radiation sensitive element has at least one sensor region, wherein the at least one sensor region comprises at least one photosensitive material selected from at least one photoconductive material, wherein the at least one sensor region is designated for generating at least one sensor signal depending on an intensity of the thermal radiation emitted by the at least one radiation emitting element and received by the sensor region within at least one wavelength range, wherein the sensor region is further designated for generating at least one further sensor signal depending on an intensity of the optical radiation emitted by the at least one light source and received by the sensor region within at least one further wavelength range, wherein the at least one radiation sensitive element is arranged in a manner that the thermal radiation travels through at least one transition material prior to being received by the at least one radiation sensitive element , wherein at least one of the at least one light source and the at least one radiation sensitive element is arranged in a manner that the optical radiation travels through the at least one transition material and impinges the at least one radiation emitting element prior to being received by the at least one radiation sensitive element; and - at least one evaluation unit, wherein the at least one evaluation unit is configured to determine the emission temperature of the at least one radiation emitting element by using values for the intensity of the thermal radiation and the optical radiation.

WO 2022/234073 A1 discloses a device for monitoring an emission temperature of at least one radiation emitting element, a heating system for heating at the least one radiation emitting element to emit thermal radiation at an emission temperature, a method for monitoring an emission temperature of at least one radiation emitting element and method for heating the at least one radiation emitting element to emit thermal radiation at an emission temperature. Herein, the device for monitoring an emission temperature of at least one radiation emitting element comprises at least one radiation sensitive element, wherein the at least one radiation sensitive element has at least one sensor region, wherein the at least one sensor region comprises at least one photosensitive material selected from at least one photoconductive material, wherein the at least one sensor region is designated for generating at least one sensor signal depending on an intensity of the thermal radiation emitted by the at least one radiation emitting element and received by the sensor region within at least two individual wavelength ranges, wherein the at least one radiation sensitive element is arranged in a manner that the thermal radiation travels through at least one transition material prior to be received by the at least one radiation sensitive element, wherein the at least one transition material is at least partially transparent for the thermal radiation within the two individual wavelength ranges; and at least one evaluation unit, wherein the at least one evaluation unit is configured to determine the emission temperature of the at least one radiation emitting element by comparing values for the intensity of the thermal radiation within the at least two individual wavelength ranges.

EP 3 572 730 A2 discloses a remote temperature measurement of cookware through a ceramic glass plate using an infrared sensor, taking into account the emissivity of the cookware which is continuously evaluated, and taking into account the temperature of the ceramic glass plate.

US 8 049 163 B1 discloses systems and methods directed to calibration techniques for infrared cameras. For example, a method of obtaining calibration information for an infrared device includes providing a calibration target adapted to provide a low-emissivity scene; performing a calibration operation on the infrared device to obtain the calibration information; and storing the calibration information.

WO 2022/234073 A1 discloses a device for monitoring an emission temperature of at least one radiation emitting element, a heating system for heating the at the least one radiation emitting element to emit thermal radiation at an emission temperature, a method for monitoring an emission temperature of at least one radiation emitting element and a method for heating the at least one radiation emitting element to emit thermal radiation at an emission temperature.

Problem to be solved

It is, therefore, an object of the present invention to provide a calibration method of assembling a set of items of information, a method for operating a measurement device, a measurement device for monitoring an emission temperature, a computer program, a computer-readable storage medium and a non-transient computer-readable medium, which may at least partially overcome the above-mentioned technical disadvantages and shortcomings of known.

In particular, it would be desirable to be able to calibrate a measurement device for monitoring an emission temperature for stable and accurate temperature measurement in a short amount of time.

Summary of the invention

This problem is solved by a calibration method of assembling a set of items of information, a method for operating a measurement device, a measurement device for monitoring an emission temperature, a computer program, a computer-readable storage medium and a non-transient computer-readable medium having the features of the independent claims. Preferred embodiments that can be implemented in isolated fashion or in arbitrary combination are listed in the dependent claims and through the specification.

In a first aspect of the present invention, a calibration method of assembling a set of items of information for use in a method for operating a measurement device for monitoring an emission temperature of at least one radiation emitting element is disclosed. The method comprises the following steps that may be performed in the given order. However, a different order may also be possible. In particular, one, more than one or even all of the method steps may be performed once or repeatedly. Further, the method steps may be performed successively or, alternatively, one or more of the method steps may be performed in a timely overlapping fashion or even in a parallel fashion and/or in a combined fashion. The method may further comprise additional method steps that are not listed.

The term “calibration” as used herein is a broad term and is to be given its ordinary and customary meaning to a person of ordinary skill in the art and is not to be limited to a special or customized meaning. The term specifically may refer, without limitation, to at least one process being performed under predetermined standard conditions to establish a relationship between measured quantities and standard quantities.

The term “radiation” as used herein is a broad term and is to be given its ordinary and customary meaning to a person of ordinary skill in the art and is not to be limited to a special or customized meaning. The term specifically may refer, without limitation, to a plurality of photons which are generated by at least one radiation emitting element. At least a portion of the radiation may be “thermal radiation” having at wavelengths that cover at least a portion of the infrared spectral range. As generally used, the term “infrared” refers to a wavelength of 780 nm to 1000 µm, wherein a wavelength of 780 nm to 3 µm is designated as “near infrared” and a wavelength of 3 µm to 8 µm as “mid infrared”, while a wavelength of 8 µm to 15 µm is designated as “far infrared”. Specifically, a wavelength range of 0.8 µm, 1 µm, 1.3 µm, 1.5 µm or 2 µm up to 2.5 µm, 2.8 µm, 3 µm, or 5 µm may, particularly, be preferred for the purposes of the present invention. However, depending on the materials as used in the device, at least one further wavelength may also be feasible.

The term “radiation emitting element” as used herein is a broad term and is to be given its ordinary and customary meaning to a person of ordinary skill in the art and is not to be limited to a special or customized meaning. The term specifically may refer, without limitation, to a source generating radiation, particularly thermal radiation, as defined above. With regard to the present invention, the at least one radiation emitting element may, in particular, be or comprise at least one piece of cookware. The term “cookware” as used herein is a broad term and is to be given its ordinary and customary meaning to a person of ordinary skill in the art and is not to be limited to a special or customized meaning. The term specifically may refer, without limitation, to a receptacle which is designed for being heated in order to transfer the received heat to at least one substance being present in an internal volume as comprised by the receptacle, by which process the receptacle generates and spatially distributes a portion of the thermal radiation to an external volume surrounding the receptacle. In general, the at least one piece of cookware may be selected from a pot or a pan; however a further piece of cookware may also be feasible. In general, the at least one piece of cookware can be used in at least one of a household, a canteen kitchen, or an industrial kitchen; however, it may also be feasible to use them in a further environment, such as in a laboratory. Specifically, at least a partition of the radiation emitting element may emit a predominant portion of the thermal radiation, wherein the partition may, more specifically, be selected from a bottom part of the radiation emitting element being placed at the at least one transition material in an adjacent fashion.

In general, the thermal radiation of the at least one piece of cookware may be determined in an arrangement in which the at least one piece of cookware may be located on top of a cooktop, in particular a ceramic glass cooktop. The cooktop may comprise a transition material. However, the at least one radiation emitting element may, also, be or comprise at least one further object that may, accidentally or deliberately, assume the location of the at least one piece of cookware on top of the cooktop, specifically in order to be able to detect a presence of the at least one further object that may constitute a potential fire hazard on top of the cooktop and to prevent an operation of the cooktop in this event. By way of example, at least one further object may be or comprise a plastic container or a burn stain which is located on the ceramic glass cooktop. However, further objects may also be feasible.

The device according to the present invention is designated for monitoring the emission temperature of the at least one radiation emitting element. The term “emission temperature” as used herein is a broad term and is to be given its ordinary and customary meaning to a person of ordinary skill in the art and is not to be limited to a special or customized meaning. The term specifically may refer, without limitation, to a temperature at which the at least one radiation emitting element is generating the corresponding thermal radiation. As particularly known to the person skilled in the art, a distribution of the intensity of the thermal radiation over a wavelength depends on the emission temperature. In a particular example of the black body emitting the thermal radiation, the spectral radiance of the radiation emitting element for the wavelength at the emission temperature follows Planck’s law. However, for other kinds of radiation emitting elements, the distribution of the intensity of the thermal radiation over the wavelength, in general, also depends on the corresponding emission temperature.

The term “monitoring” as used herein is a broad term and is to be given its ordinary and customary meaning to a person of ordinary skill in the art and is not to be limited to a special or customized meaning. The term specifically may refer, without limitation, to a process of determining at least one piece information from at least one piece of data which may, in particular, be continuously acquired data, without user interaction, wherein the term “measuring” relates to a process of continuously acquiring the data without user interaction. For this purpose, a plurality of sensor signals may be generated and evaluated, from which the at least one piece of information can be determined. In particular, the plurality of sensor signals may be recorded and/or evaluated within at least one of a fixed time interval or a variable time interval or, alternatively or in addition, upon an occurrence of at least one prespecified event, such as a presence of at least one further object that may, accidentally or deliberately, be detected as described below in more detail.

The method is performed on a measurement device. The measurement device comprises a detector module, a transition material and an assembly unit, wherein the detector module and the transition material are designated for being integrated into the assembly unit when performing a method for operating a measurement device for monitoring an emission temperature of at least one radiation emitting element in a manner that the transition material is arranged between the detector module and the radiation emitting element such that radiation generated by the radiation emitting element incident onto the detector module is propagating through the transition material, wherein the detector module is designated for generating at least one sensor signal depending on an intensity of the thermal radiation.

The term “measurement device” as used herein is a broad term and is to be given its ordinary and customary meaning to a person of ordinary skill in the art and is not to be limited to a special or customized meaning. The term specifically may refer, without limitation, refers to a spatial entity which comprises at least the above-listed components. The components of the device may form a physical and/or functional unit.

The measurement device comprises a detector module, a transition material and an assembly unit.

The term “assembly unit” as used herein is a broad term and is to be given its ordinary and customary meaning to a person of ordinary skill in the art and is not to be limited to a special or customized meaning. The term specifically may refer, without limitation, to a unit intended for accommodating components, particularly in a normed fashion. The detector module and/or the transition material may be integrated in the assembly unit at specific positions and/or in specific orientations, particularly when performing the method for operating a measurement device for monitoring an emission temperature of at least one radiation emitting element, described elsewhere herein.

The term “transition material” as used herein is a broad term and is to be given its ordinary and customary meaning to a person of ordinary skill in the art and is not to be limited to a special or customized meaning. The term specifically may refer, without limitation, to a material which is located in the optical path of the thermal radiation to be traversed by the thermal radiation before the thermal radiation irradiates the at least one detector module. The transition material may have an influence on the sensor signals and/or the determined emission temperature of the radiation emitting element, particularly by causing emission radiation by itself. In particular, the at least one transition material may be selected from at least one ceramic material, specifically at least one ceramic material as, typically, used in a ceramic glass cooktop. In particular, the at least one transition material may be mechanically strong to be able carry the at least one piece of cookware. Further, the at least one transition material may be heat-insensitive to be able to sustain repeated and/or rapid temperature alterations. Further, the at least one transition material may have a considerably low heat conduction coefficient to remain at ambient temperature outside a cooking zone designated for receiving the at least one piece of cookware. Further, the at least one transition material may be at least partially transparent for the thermal radiation within the two individual wavelength ranges, it may, however, not be transparent or only “partially transparent for the thermal radiation in at least one further wavelength range, specifically selected from of above 2.8 µm to 3.2 µm. As used herein, the term “partially transparent” refers to a transparency for the thermal radiation of the at least one transition material of, preferably, not more than 10 %, more preferred of not more than 2 %, in particular of not more than 1 %.

The term “detector module” as used herein is a broad term and is to be given its ordinary and customary meaning to a person of ordinary skill in the art and is not to be limited to a special or customized meaning. The term specifically may refer, without limitation, refers to a unit designated for generating the at least one sensor signal depending on the intensity of the radiation, such as thermal radiation, as emitted by the at least one radiation emitting element and received by the sensor region within at least two individual wavelength ranges. The detector module may comprise at least one of: at least one radiation sensitive element, particularly comprising at least one sensor region, such as a sensor region sensitive to the thermal radiation; at least one evaluation unit; at least one wavelength selective element, such as an optical filter, a dispersive element, a grating, a transmission grating, a reflection grating, a prism, a tunable Fabry-Perot filter, a MEMS based Fabry Perot Filter, a Michelson Interferometer and/or a tunable MEMS Michelson interferometer.

The detector module may be sensitive to at least one specific wavelength range. The term “wavelength range” as used herein is a broad term and is to be given its ordinary and customary meaning to a person of ordinary skill in the art and is not to be limited to a special or customized meaning. The term specifically may refer, without limitation, refers to an interval of wavelengths of the radiation from which the at least one sensor signal is generated.

As indicated above, the at least one detector module may be selected from a radiation sensor having at least one sensor region. The term “sensor region” as used herein is a broad term and is to be given its ordinary and customary meaning to a person of ordinary skill in the art and is not to be limited to a special or customized meaning. The term specifically may refer, without limitation, to a portion of the at least one detector module which is designated for receiving the radiation as generated by the radiation emitting element in a manner that a generation of the at least one sensor signal may be triggered, wherein the generation of the sensor signal may depend on a defined relationship between the sensor signal and the manner of the illumination of the sensor region. Herein, the sensor region may be a uniform sensor region or, as an alternative, comprise a radiation sensitive array which may be partitioned into a plurality of radiation sensitive pixels.

As indicated above, the detector module is designated for generating at least one sensor signal depending on an intensity of the thermal radiation. The term “sensor signal” as used herein is a broad term and is to be given its ordinary and customary meaning to a person of ordinary skill in the art and is not to be limited to a special or customized meaning. The term specifically may refer, without limitation, to an electrical signal which is generated by the at least one detector module upon irradiation by the thermal radiation. Herein, the sensor signal may be or may comprise a digital and/or an analog signal. In particular, the sensor signal may be or may comprise a voltage signal and/or a current signal. Additionally or alternatively, the sensor signal may be or may comprise digital data. The sensor signal may comprise a single signal value and/or a series of signal values. The sensor signal may, further, comprise an arbitrary signal which can be generated by combining at least two individual signals, in particular by averaging at least two signals and/or by forming a ration of at least two signals. The at least one sensor signal may be generated in a manner dependent on an intensity of the thermal radiation as emitted by the at least one radiation emitting element and as received by the sensor region, wherein the sensor signal may be an arbitrary signal being indicative of the intensity of the incident thermal radiation illuminating the sensor region.

The term “intensity” as used herein is a broad term and is to be given its ordinary and customary meaning to a person of ordinary skill in the art and is not to be limited to a special or customized meaning. The term specifically may refer, without limitation, to the thermal radiation refers to a power of a radiant flux as emitted per unit area by the radiation emitting element. The intensity may, in a particular for a black radiation emitting element, be represented by a spectrum, wherein the term “spectral radiance” may refers to the radiant flux emitted by the radiation emitting element per unit solid angle, per unit area, and per wavelength. Herein, the spectral radiance indicates how much of a power emitted by the black radiation emitting element can actually be received at a particular wavelength by a detector module viewing the radiation emitting element from a specified angle of view. However, for further kinds of radiation emitting element, a different measure for the intensity of the thermal radiation may be appropriate. As further used herein, the term “value” refers to a numerical representation of the intensity of the thermal radiation.

For a purpose of generating the sensor signal upon illumination, the sensor region comprises a photosensitive material, wherein the photosensitive material is selected from a photoconductive material. The term “photoconductive material” may refer to a material which is capable of sustaining an electrical current, thus exhibiting a specific electrical conductivity, wherein, specifically, the electrical conductivity is dependent on the illumination of the material. In this kind of material, the electrical current may be guided via at least one first electrical contact through the material to at least one second electrical contact, or vive-versa. For this purpose, at least two individual electrical contacts may be applied at different locations of the sensor region, especially in a fashion that the first electrical contact and the second electrical contact are electrically isolated with respect to each other while each of the first electrical contact and the second electrical contact are in direct connection with the sensor layer. For this purpose, the electrical contacts may comprise an evaporated metal layer which can easily be provided by using at least one known evaporation technique. In particular, the evaporated metal layer may comprise at least one of gold, silver, aluminum, platinum, magnesium, chromium, or titanium. Alternatively, the electrical contacts may comprise a layer of graphene.

The at least one photoconductive material may, preferably, comprise at least one chalcogenide, wherein the at least one chalcogenide may, preferably, be selected from a sulfide chalcogenide or a selenide chalcogenide, a solid solution and/or a doped variant thereof. The term “solid solution” may refer to material in which at least one solute is comprised in a solvent, whereby a homogeneous phase is formed and wherein the crystal structure of the solvent is, generally, unaltered by the presence of the solute. By way of example, binary PbSe may be solved in PbS leading to $PbS_{1-x}Se_x$, wherein x can vary from 0 to 1. As further used herein, the term “chalcogenide” may refer to a compound which comprises at least one group 16 element of the periodic table apart from an oxide, i.e. a sulfide, a selenide, and a telluride. In a particularly preferred embodiment, the at least one layer of at least one photoconductive material may, especially, lead sulfide (PbS) for a wavelength of 0.8 µm to 2.8 µm, or lead selenide (PbSe) for a wavelength of 0.8 µm to 5 µm. However, other inorganic photoconductive materials may also be feasible.

The method comprises the following steps:

(i) performing a plurality of calibration measurements for determining at least one relationship between at least one sensor signal and at least one temperature of a radiation emitting calibration element by measuring sensor signals for at least two different emission temperatures when the detector module and the transition material are separate from the assembly unit;

(ii) performing at least one further calibration measurement for determining at least one correction for the at least one relationship by measuring at least one sensor signal for at least one known emission temperature of at least one radiation emitting calibration when the detector module and the transition material are integrated in the assembly unit;

(iii) recording the relationship and the correction.

The term “relationship” as used herein is a broad term and is to be given its ordinary and customary meaning to a person of ordinary skill in the art and is not to be limited to a special or customized meaning. The term specifically may refer, without limitation, to a connection and/or relation between at least two objects. By knowing the relationship between a sensor signal, particularly a strength of a sensor signal, and a temperature of a radiation emitting element, particularly by considering the intensity of the radiation emitted by the radiation emitting element and/or an emissivity of the radiation emitting element, it is possible to conclude from a measured sensor signal to a temperature of the radiation emitting element; or vice versa. The relationship may be determined when the detector module and the transition material are separate from the assembly unit. Any influence caused by the integration of the detector module and the transition material into the assembly unit may thereby not being accounted for in the relation.

The term “separate from the assembly unit” as used herein is a broad term and is to be given its ordinary and customary meaning to a person of ordinary skill in the art and is not to be limited to a special or customized meaning. The term specifically may refer, without limitation, to the calibration measurements involving the detector module only being performed when the detector module is separate from the assembly unit. During these calibration measurements the transition material may be integrated in the assembly unit. Calibration measurements involving the transition material may, further, only be performed when the transition material is separate from the assembly unit. During these calibration measurements the detector module may be integrated in the assembly unit.

The term “correction” as used herein is a broad term and is to be given its ordinary and customary meaning to a person of ordinary skill in the art and is not to be limited to a special or customized meaning. The term specifically may refer, without limitation, to a modification of a measured spectrum, a measured sensor signal and/or a temperature of the radiation emitting element for accounting for influences of integrating the transition material and the detector module into the assembly unit.

The term “recording” as used herein is a broad term and is to be given its ordinary and customary meaning to a person of ordinary skill in the art and is not to be limited to a special or customized meaning. The term specifically may refer, without limitation, to a process wherein data is stored on a storage device. The storage device may be comprised by an evaluation unit of the detector module. Alternatively or in addition, a storage device may be an external device.

The relationship comprises at least one of:

- a first relationship that accounts for a response of the detector module to incident radiation generated by at least one hot body being used as at least one first radiation emitting calibration element;
- a second relationship that accounts for a response of the detector module to incident radiation generated by at least one unit of the transition material being used as at least one second radiation emitting calibration element.

The term “first relationship” as used herein is a broad term and is to be given its ordinary and customary meaning to a person of ordinary skill in the art and is not to be limited to a special or customized meaning. The term specifically may refer, without limitation, to a relation between at least a portion of the radiation incident onto the detector module and the, thereby, temperature of the radiation emitting element. When the detector module and the transition material are integrated in the assembly unit, the first relationship may not directly allow to determine the calibrated temperature of the radiation emitting element as it may be influenced by radiation generated by the transition material.

The term “second relationship” as used herein is a broad term and is to be given its ordinary and customary meaning to a person of ordinary skill in the art and is not to be limited to a special or customized meaning. The term specifically may refer, without limitation, to a relation between a first sensor signal associated with a first wavelength range and a second sensor signal associated with a second wavelength range. The first wavelength range may be dominated by radiation generated by the transition material, wherein the second wavelength range may be evaluated in the method for operating a measurement device for monitoring an emission temperature of at least one radiation emitting element to determine the emission temperature of at least one radiation emitting element. When the detector module and the transition material are integrated in the assembly unit, the second relationship may allow to account for radiation emitted by the transition material in a manner that the first relationship is corrected so that the first relationship may be considered to determine the calibrated temperature on the radiation emitting element. Thereby, the second relationship may consider the temperature of the transition material.

The term “hot body” as used herein is a broad term and is to be given its ordinary and customary meaning to a person of ordinary skill in the art and is not to be limited to a special or customized meaning. The term specifically may refer, without limitation, to an arbitrary object generating radiation. A hot body may generate a known spectrum of radiation, particularly thermal radiation, for a given temperature of the hot body. The emissivity of the hot body may be known. The hot body may specifically be at least one of: a graybody; a blackbody.

The term “blackbody” as used herein is a broad term and is to be given its ordinary and customary meaning to a person of ordinary skill in the art and is not to be limited to a special or customized meaning. The term specifically may refer, without limitation, to at least one idealized physical body that absorbs any incident electromagnetic radiation, regardless of a frequency or an angle of incidence. An energy distribution of emission generated by a blackbody, depending on a temperature of the blackbody, may be described by Planck's law.

The term “graybody” as used herein is a broad term and is to be given its ordinary and customary meaning to a person of ordinary skill in the art and is not to be limited to a special or customized meaning. The term specifically may refer, without limitation, to an imperfect black body that absorbs only a portion of the incident radiation. The ratio of thermal radiation emitted by a gray body to thermal radiation emitted by a black body having the same temperature may be referred to as the “emissivity” of the gray body.

The first relationship and the second relationship may be determined independent from each other. For determine the first relationship and the second relationship independent from each other the separate calibration measurements may be performed, particularly in a manner that calibration measurements may be performed to determine the first relationship and the further and/or different calibration measurements may be performed to determine the second relationship. In the calibration measurements to determine the first relationship and the second relationship different calibration target may be used. In the calibration measurements performed for determining the first relationship, radiation generated by the hot body may be incident on the detector module. No radiation generated by the transition material may be incident on the detector module. In the calibration measurements performed for determining the second relationship, radiation generated by the transition material may be incident on the detector module. No radiation generated by the hot body, particularly the hot body, may be incident on the detector module.

For determining the first relationship, a plurality of hot bodies used as the at least one radiation emitting calibration element, particularly having a known emissivity, more particularly wherein the hot bodies are at least one of: blackbodies; graybodies, may be set to the at least two different known emission temperatures each, wherein the detector module may be illuminated by each hot body, particularly separately, for generating at least one sensor signal assigned to each known emission temperature of the respective hot body, wherein each at least one sensor signal and each known emission temperature may be recorded. The detector module may be arranged at the same distance to each hot body when the detector module is illuminated by the respective hot body. Thereby, influences of the distance on the determined respective relationship may be minimized.

Determining the first relationship may comprise performing a regression by considering the recorded sensor signals and the recorded known temperature to estimate at least one expected sensor signal assigned to an emission temperature, particularly by generating a relationship function interpolating the recorded sensor signals and the recorded known temperatures.

The term “regression” as used herein is a broad term and is to be given its ordinary and customary meaning to a person of ordinary skill in the art and is not to be limited to a special or customized meaning. The term specifically may refer, without limitation, to at least one processes for estimating at least one relationship between a dependent variable and at least one independent variable. For performing the regression, an assumed function may be fitted to the recorded sensor signals and the recorded known temperatures. The, particularly fitted, function may interpolate the recorded sensor signals and the recorded known temperatures. The regression may be used to estimate an expected sensor signal for an assumed emission temperature, particularly based on a model that is considered when performing the regression.

Here, the term “estimating”, or any grammatical variation thereof, as used herein is a broad term and is to be given its ordinary and customary meaning to a person of ordinary skill in the art and is not to be limited to a special or customized meaning. The term specifically may refer, without limitation, to a process of predicting at least one sensor signal based on the regression. Particularly thereby, the expected sensor signal may be generated for an assumed emission temperature.

The first relationship may be considered for determining the strength of at least one sensor signal depending on the temperature of the radiation emitting element having its radiation incident onto the detector module.

For determining the second relationship a plurality of units comprising the transition material bodies used as the at least one radiation emitting calibration element may be set to at least two different emission temperatures each, wherein the detector module is illuminated by each unit for generating at least one sensor signal. The detector module may be arranged at the same distance to each unit when the detector module is illuminated by the respective unit. Thereby, influences of the distance on the determined respective relationship may be minimized.

At least one first sensor signal associated with a first wavelength range and at least one second sensor signal associated with a second wavelength range may be recorded, particularly for each different emission temperature of the respective unit of the transition material, wherein the first wavelength range may be dominated by radiation generated by the transition material, wherein the second wavelength range may be evaluated in the method for operating a measurement device for monitoring an emission temperature of at least one radiation emitting element to determine the emission temperature of at least one radiation emitting element.

Determining the second relationship may comprise performing a regression when considering the recorded first sensor signal and the recorded second sensor signal to estimate an expected second sensor signal, particularly by generating a further relationship function interpolating the recorded first sensor signals and the recorded second sensor signals, wherein the recorded first sensor signals and the recorded second sensor signals are recorded for different temperatures of the hot body. For performing the regression, an assumed function may be fitted to the recorded first sensor signals and the recorded second sensor signals. The, particularly fitted, function may interpolate the recorded first sensor signals and the recorded second sensor signals. The regression may be used to estimate an expected second sensor signal for an assumed first sensor signal, particularly based on a model that is considered when performing the regression.

Here, the term “estimating”, or any grammatical variation thereof, as used herein is a broad term and is to be given its ordinary and customary meaning to a person of ordinary skill in the art and is not to be limited to a special or customized meaning. The term specifically may refer, without limitation, to a process of predicting a second sensor signal based on the regression. Particularly thereby, the predicted second sensor signal may be generated for an assumed first sensor signal.

The radiation emitting element and/or the transition material may be integrated in the assembly unit, when the method for operating a measurement device for monitoring an emission temperature of at least one radiation emitting element to determine the emission temperature of at least one radiation emitting element. Particularly then, the first wavelength range may be dominated by radiation generated by the transition material when the amount of detected radiation within the first wavelength range generated by the transition material is above 80%, preferably above 90%. Alternatively or in addition, the amount of detected radiation within the first wavelength range generated by the radiation emitting element may be below 25%, preferably below 15%.

The first wavelength range may comprise a first interval of wavelengths of the thermal radiation, while the second wavelength range may comprise a second interval of wavelengths of the thermal radiation, wherein the first interval and the second interval differ from each other. As preferred, the first interval and the second interval may be disjoint with respect to each other. In a particular example, the first individual wavelength range may cover a range from 2800 nm to 3000 nm while a second individual wavelength range may cover a range from 1000 nm to 2800 nm.

The measurement device may comprise a single detector module, wherein at least two wavelength ranges, such as the first wavelength range and the second wavelength range, are generated by placing at least one adjustable optical filter in an optical path between the at least one radiation emitting element and the single detector module. Preferably, at least one adjustable optical filter may be selected from a movable optical filter having at least two areas, wherein each area is designed to filter a different wavelength range; and/or an electro-optical filter designed to filter a different wavelength range upon applying a different voltage or current. In particular, the at least one movable optical filter may comprise at least one Micro Electro Mechanical System (MEMS) such as in a MEMS-Fabry-Perot-Interferometer (MEMS-FPI) or in a MEMS-Michaelson-Interferometer.

Alternatively, the device according to the present invention may comprise at least two detector modules, wherein the at least two wavelength ranges are generated by using at least two individual detector modules and/or placing an individual optical filters in each field of view of the detector modules. However, further embodiments may also be feasible.

Determining the correction may comprise determining a deviation between the sensor signal measured for a known emission temperature in the at least one further calibration measurement and an expected sensor signal for the known temperature derived from the relationship. Determining the correction may further comprise compensating the deviation by correcting the relationship, particularly by multiplying each expected sensor signal derived from the relationship with a correction factor.

For determining the correction, the at least one radiation emitting calibration may be at least one of:

- a hot body,
- a cookware, particularly a cookware comprising boiling water;
- a calibrated thermal radiator, particularly an incandescent lamp,

particularly placed on a cooktop, more particularly wherein the cooktop comprises the transition material.

The method may further comprise a step of a determining and recording at least one dark signal of the detector module in at least one further calibration measurement. The term “dark signal”, or any grammatical variation thereof, as used herein is a broad term and is to be given its ordinary and customary meaning to a person of ordinary skill in the art and is not to be limited to a special or customized meaning. The term specifically may refer, without limitation, to at least one sensor signal generated when no radiation is incident on the detector module. The dark signal may be generated by a dark current of the detector module and/or by noise associated with the readout amplifier.

At least one of:

- the relationship, particularly the first relationship and/or the second relationship;
- the correction;
- the dark signal;

may be stored on a storage device, particularly in form of a lookup table. The storage device may be comprised by an evaluation unit of the detector module.

For the calibration method of assembling a set of items of information for use in a method for operating a measurement device for monitoring an emission temperature of at least one radiation emitting element, reference may be made to any further aspect, Embodiment and/or definition as disclosed elsewhere herein.

In a further aspect, a method for operating a measurement device for monitoring an emission temperature of at least one radiation emitting element is disclosed. The method comprises the following steps that may be performed in the given order. However, a different order may also be possible. In particular, one, more than one or even all of the method steps may be performed once or repeatedly. Further, the method steps may be performed successively or, alternatively, one or more of the method steps may be performed in a timely overlapping fashion or even in a parallel fashion and/or in a combined fashion. The method may further comprise additional method steps that are not listed.

The method is performed on a measurement device. The measurement device comprises a detector module and a transition material integrated in an assembly unit, wherein the detector module is designated for generating at least one sensor signal depending on an intensity of the thermal radiation of at least one wavelength range generated by the radiation emitting element incident onto the detector module, wherein the transition material is arranged between the detector module and the radiation emitting element in a manner that radiation generated by the radiation emitting element incident onto the detector module is propagating through the transition material.

The method comprises the following step:

(a) determining, by using an evaluation unit, particularly comprised by the detector module, an emission temperature of at least one radiation emitting element from at least one measurement sensor signal generated by radiation of the radiation emitting element incident onto the detector module by considering the relationship and the correction determined in the calibration method according to any one of the preceding claims.

The term “evaluation unit”, or any grammatical variation thereof, as used herein is a broad term and is to be given its ordinary and customary meaning to a person of ordinary skill in the art and is not to be limited to a special or customized meaning. The term specifically may refer, without limitation, to an arbitrary device which is designed for generating at least one piece of information based on measured data. More particular, the evaluation unit according to the present invention is configured to determine the emission temperature of the at least one radiation emitting element by considering at least one of: the relationship, particularly the first relationship and/or the second relationship; the correction; the dark signal, particularly as determined in the calibration method of assembling a set of items of information for use in a method for operating a measurement device for monitoring an emission temperature of at least one radiation emitting element. For this purpose, the evaluation unit may be or comprise one or more integrated circuits, such as one or more application-specific integrated circuits (ASICs), and/or one or more digital signal processors (DSPs), and/or one or more field programmable gate arrays (FPGAs), and/or one or more data processing devices, such as one or more computers, preferably one or more microcomputers and/or microcontrollers. Additional components may be comprised, such as one or more preprocessing devices and/or data acquisition devices, such as one or more devices for receiving and/or preprocessing of the sensor signals, such as one or more AD-converters and/or one or more filters. Further, the evaluation unit may comprise one or more data storage devices. Further, the evaluation unit may comprise one or more interfaces, such as one or more wireless interfaces and/or one or more wire-bound interfaces.

The method may further comprise a step of compensating an influence of a dark signal on the measurement sensor signal by considering the recorded dark signal, particularly by subtracting the recorded dark signal from of the measurement sensor signal, more particularly and, thereby, updating the measurement sensor signal. The term “compensating”, or any grammatical variation thereof, as used herein is a broad term and is to be given its ordinary and customary meaning to a person of ordinary skill in the art and is not to be limited to a special or customized meaning. The term specifically may refer, without limitation, to accounting for and balancing and/or canceling by counteraction of an influence. The influence may thus be at least partially be canceled.

Considering the relationship may comprise compensating an influence of the transition material on the radiation incident onto the detector by considering the second relationship, particularly and, thereby, updating the measurement sensor signal.

The term “influence of the transition material” as used herein is a broad term and is to be given its ordinary and customary meaning to a person of ordinary skill in the art and is not to be limited to a special or customized meaning. The term specifically may refer, without limitation, to an effect of the transition material on radiation incident onto the detector and, thereby, on the sensor signal, particularly the measurement sensor signal. This effect may be caused by emission radiation related to the temperature of the transition material that adds up to the emission radiation of the radiation emitting element. This effect may be compensated for to improve the accuracy and/or reliability of the determined emission temperature of the radiation emitting element.

For compensating the influence of the transition material to a first measurement sensor signal, particularly used for determining the emission temperature of the at least one radiation emitting element, a second measurement sensor signal may be considered, wherein the first measurement sensor signal and the second measurement sensor signal are associated with different wavelength ranges.

The at least one measurement sensor signal may comprise a first measurement sensor signal associated with the first wavelength range and a second measurement sensor signal associated with the second wavelength range, wherein, by using the second relationship, an expected second sensor signal associated with the second wavelength range is determined by considering the first measurement sensor signal, particularly wherein the expected second sensor signal is subtracted from the second measurement sensor signal, more particularly and, thereby, updating the measurement sensor signal. The emission temperature of at least one radiation emitting element may be determined by considering the second measurement sensor signal.

Considering the correction may comprise compensating an influence on the relationship caused by the integration of the detector module and the transition material into the assembly unit. Compensating the influence on the relationship may be performed by considering a compensated relationship, particularly for determining the emission temperature, and/or a compensated, particularly updated, measurement signal, particularly determined with a not compensated relationship.

The method further may comprise a step of compensating an emissivity of the radiation emitting element and updating the measurement sensor signal, particularly by normalizing the measured sensor signal to the emissivity. The emissivity of the radiation emitting element may be determined as a function of the at least one sensor signal generated by the at least one detector module. The emissivity of the radiation emitting element may determined by providing a ratio of the intensities of the thermal radiation within at least two individual wavelength ranges, thereby determining an emissivity-independent value for the thermal radiation of the radiation emitting element, and by comparing the intensity of the thermal radiation within at least one of the individual wavelength ranges with the emissivity-independent value for the thermal radiation of the at least one radiation emitting element, thereby determining the emissivity of the at least one radiation emitting element.

The temperature of the radiation emitting element from the measurement sensor signal may be determined by using the first relationship.

For the method for operating a measurement device for monitoring an emission temperature of at least one radiation emitting element, reference may be made to any further aspect, Embodiment and/or definition as disclosed elsewhere herein.

In a further aspect, a measurement device for monitoring an emission temperature of at least one radiation emitting element is disclosed. The measurement device comprises a detector module integrated in an assembly unit, wherein the detector module is designated for generating at least one sensor signal depending on an intensity of the thermal radiation of at least one wavelength range generated by the radiation emitting element incident onto the detector module, wherein a transition material is arranged between the detector module and the radiation emitting element in a manner that radiation generated by the radiation emitting element incident onto the detector module is propagating through the transition material, wherein the measurement device comprises an evaluation unit configured for performing the method for operating the measurement device. For the measurement device, reference may be made to any further aspect, Embodiment and/or definition as disclosed elsewhere herein.

In a further aspect, a computer program is disclosed. The computer program comprises instructions which, when the program is executed by the measurement cause the measurement device to perform the method of operating a measurement device. For the computer program, reference may be made to any further aspect, Embodiment and/or definition as disclosed elsewhere herein.

In a further aspect, a computer-readable storage medium is disclosed. The computer-readable storage medium comprises instructions which, when the program is executed by the measurement device cause the spectrometer device to perform the method of operating a measurement device. For the computer-readable storage medium, reference may be made to any further aspect, Embodiment and/or definition as disclosed elsewhere herein.

In a further aspect, a non-transient computer-readable medium is disclosed. The non-transient computer-readable medium included instructions that, when executed by one or more processors of the evaluation unit of the measurement device cause the one or more processors to perform the method of operating a measurement device. For the non-transient computer-readable medium, reference may be made to any further aspect, Embodiment and/or definition as disclosed elsewhere herein.

As used herein, the terms “computer-readable data carrier”, “computer-readable storage medium” and “non-transient computer-readable medium” are broad term and are to be given their ordinary and customary meaning to a person of ordinary skill in the art and are not to be limited to a special or customized meaning. The terms specifically may refer, without limitation, to data storage means, specifically non-transitory data storage means, such as a hardware storage medium having stored thereon computer-executable instructions. The computer-readable data carrier or storage medium or computer-readable medium specifically may be or may comprise a storage medium such as a random-access memory (RAM) and/or a read-only memory (ROM).

As used herein, the terms “have”, “comprise” or “include” or any arbitrary grammatical variations thereof are used in a non-exclusive way. Thus, these terms may both refer to a situation in which, besides the feature introduced by these terms, no further features are present in the entity described in this context and to a situation in which one or more further features are present. As an example, the expressions “A has B”, “A comprises B” and “A includes B” may both refer to a situation in which, besides B, no other element is present in A (i.e. a situation in which A solely and exclusively consists of B) and to a situation in which, besides B, one or more further elements are present in entity A, such as element C, elements C and D or even further elements.

Further, it shall be noted that the terms “at least one”, “one or more” or similar expressions indicating that a feature or element may be present once or more than once typically are used only once when introducing the respective feature or element. In most cases, when referring to the respective feature or element, the expressions “at least one” or “one or more” are not repeated, notwithstanding the fact that the respective feature or element may be present once or more than once.

Further, as used herein, the terms "preferably", "more preferably", "particularly", "more particularly", "specifically", "more specifically" or similar terms are used in conjunction with optional features, without restricting alternative possibilities. Thus, features introduced by these terms are optional features and are not intended to restrict the scope of the claims in any way. The invention may, as the skilled person will recognize, be performed by using alternative features. Similarly, features introduced by "in an embodiment of the invention" or similar expressions are intended to be optional features, without any restriction regarding alternative embodiments of the invention, without any restrictions regarding the scope of the invention and without any restriction regarding the possibility of combining the features introduced in such way with other optional or non-optional features of the invention.

The spectrometer device and the method according to the present invention, in one or more of the above-mentioned embodiments and/or in one or more of the embodiments described in further detail below, provide a large number of advantages over known devices and methods of similar kind. The present invention particularly provides an approach to calibrate a measurement device for monitoring an emission temperature for stable and accurate temperature measurements in a short amount of time.

The time for calibrating a measurement device may be reduced by splitting the calibration process in a plurality of independent steps. This may allow for a quick factory calibration, particularly since by splitting the calibration process in a plurality of steps full heating and cooling cycles of calibration targets are no longer required, which may save a large amount of time. Particularly thereby, it may be avoided having to heat up a radiation emitting calibration element, such as a cookware, and letting it cool down to gather the required calibration data, which may require a lot of time making the approach unsuitable for a factory calibration.

The present invention therefore discloses two steps: A calibration step comprising the calibration of the detector module and the transition material after the components are manufactured and a further calibration step when these components are integrated in the assembly unit.

The first calibration step may account for any desired value and/or tolerance of at least one optical, electrical and/or mechanical property of the respective component. Thereby, even filters, read-out electronics and/or optomechanical setups, may be accounted for.

After the integration into the assembly unit, at least one mechanical and/or optomechanical property of the final assembly, such as the distance of the transition material between the detector module, the size of an aperture or the orientation to the measurement object may be considered by means of a known temperature reference.

Summarizing and without excluding further possible embodiments, the following embodiments may be envisaged:

Embodiment 1: A calibration method of assembling a set of items of information for use in a method for operating a measurement device for monitoring an emission temperature of at least one radiation emitting element, wherein the measurement device comprises a detector module, a transition material and an assembly unit, wherein the detector module and the transition material are designated for being integrated into the assembly unit when performing the method for operating a measurement device for monitoring an emission temperature of at least one radiation emitting element in a manner that the transition material is arranged between the detector module and the radiation emitting element such that radiation generated by the radiation emitting element incident onto the detector module is propagating through the transition material, wherein the detector module is designated for generating at least one sensor signal depending on an intensity of the thermal radiation, the method comprising the following steps:

(i) performing a plurality of calibration measurements for determining at least one relationship between at least one sensor signal and at least one temperature of a radiation emitting element by measuring a plurality of sensor signals for at least two different emission temperatures of at least one radiation emitting calibration element when the detector module and the transition material are separate from the assembly unit;

(ii) performing at least one further calibration measurement for determining at least one correction for the at least one relationship by measuring at least one sensor signal for at least one known emission temperature of at least one radiation emitting calibration when the detector module and the transition material are integrated in the assembly unit;

(iii) recording the relationship and the correction.

Embodiment 2: The calibration method according to the preceding Embodiment, wherein the relationship comprises at least one of:

- a first relationship that accounts for a response of the detector module to incident radiation generated by at least one hot body being used as at least one first radiation emitting calibration element;
- a second relationship that accounts for a response of the detector module to incident radiation generated by at least one unit of the transition material being used as at least one second radiation emitting calibration element.

Embodiment 3: The calibration method according to any one of the preceding Embodiments, wherein the first relationship and the second relationship are determined independent from each other.

Embodiment 4: The calibration method according to any one of the preceding Embodiments, wherein, for determining the first relationship, a plurality of hot bodies used as the at least one radiation emitting calibration element, particularly having a known emissivity, more particularly wherein the hot bodies are at least one of: blackbodies; graybodies, is set to the at least two different known emission temperatures each, wherein the detector module is illuminated by each hot body for generating at least one sensor signal assigned to each known emission temperature of the respective hot body, wherein each at least one sensor signal and each known emission temperature are recorded.

Embodiment 5: The calibration method according to any one of the preceding Embodiments, wherein the detector module is arranged at the same fixed distance to each hot body when the detector module is illuminated by the respective hot body.

Embodiment 6: The calibration method according to any one of the preceding Embodiments, wherein determining the first relationship comprises performing a regression by considering the recorded sensor signals and the recorded known temperature to estimate at least one expected sensor signal, particularly by generating a relationship function interpolating the recorded sensor signals and the recorded known temperatures.

Embodiment 7: The calibration method according to any one of the preceding Embodiments, wherein the first relationship is considered for determining the strength of at least one sensor signal depending on the temperature of the radiation emitting element having its radiation incident onto the detector module.

Embodiment 8: The calibration method according to any one of the preceding Embodiments, wherein, for determining the second relationship a plurality of units comprising the transition material used as the at least one radiation emitting calibration element is set to at least two different emission temperatures each, wherein the detector module is illuminated by each unit for generating at least one sensor signal.

Embodiment 9: The calibration method according to any one of the preceding Embodiments, wherein the detector module is arranged at the same fixed distance to each unit when the detector module is illuminated by the respective unit.

Embodiment 10: The calibration method according to any one of the preceding Embodiments, wherein at least one first sensor signal associated with a first wavelength range and at least one second sensor signal associated with a second wavelength range are recorded, particularly for each different emission temperature of the respective unit of the transition material, wherein the first wavelength range is dominated by radiation generated by the transition material, wherein the second wavelength range is evaluated in the method for operating a measurement device for monitoring an emission temperature of at least one radiation emitting element to determine the emission temperature of at least one radiation emitting element.

Embodiment 11: The calibration method according to any one of the preceding Embodiments, wherein determining the second relationship comprises performing a regression when considering the recorded first sensor signal and the recorded second sensor signal to estimate an expected second sensor signal for a first sensor signal, particularly by generating a further relationship function interpolating the recorded first sensor signals and the recorded second sensor signals, wherein the recorded first sensor signals and the recorded second sensor signals are recorded for different temperatures of the hot body.

Embodiment 12: The calibration method according to any one of the preceding Embodiments, wherein determining the correction comprises determining a deviation between the sensor signal measured for a known emission temperature in the at least one further calibration measurement and an expected sensor signal for the known temperature derived from the relationship.

Embodiment 13: The calibration method according to any one of the preceding Embodiments, wherein determining the correction further comprises compensating the deviation by correcting the relationship, particularly by multiplying each expected sensor signal derived from the relationship with a correction factor.

Embodiment 14: The calibration method according to any one of the preceding Embodiments, wherein, for determining the correction, the at least one radiation emitting calibration is at least one of:

- a hot body,
- a cookware, particularly a cookware comprising boiling water;
- a calibrated thermal radiator, particularly an incandescent lamp,

particularly placed on a cooktop, more particularly wherein the cooktop comprises the transition material.

Embodiment 15: The calibration method according to any one of the preceding Embodiments, wherein the method further comprises a step of a determining and recording at least one dark signal of the detector module in at least one further calibration measurement.

Embodiment 16: The calibration method according to any one of the preceding Embodiments, wherein at least one of:

- the relationship, particularly the first relationship and/or the second relationship;
- the correction;
- the dark signal;

is stored on a storage device, particularly comprised by an evaluation unit of the detector module, more particularly in form of a lookup table.

Embodiment 17: A method for operating a measurement device for monitoring an emission temperature of at least one radiation emitting element, wherein the measurement device comprises a detector module and a transition material integrated in an assembly unit, wherein the detector module is designated for generating at least one sensor signal depending on an intensity of the thermal radiation of at least one wavelength range generated by the radiation emitting element incident onto the detector module, wherein the transition material is arranged between the detector module and the radiation emitting element in a manner that radiation generated by the radiation emitting element incident onto the detector module is propagating through the transition material, wherein the method comprises the following step:

(a) determining, by using an evaluation unit, particularly comprised by the detector module, an emission temperature of at least one radiation emitting element from at least one measurement sensor signal generated by radiation of the radiation emitting element incident onto the detector module by considering the relationship and the correction determined in the calibration method according to any one of the preceding Embodiments.

Embodiment 18: The method according to the preceding Embodiment referring to the method for operating a measurement device, wherein the method further comprises a step of compensating an influence of a dark signal on the measurement sensor signal by considering the recorded dark signal, particularly by subtracting the recorded dark signal from of the measurement sensor signal, more particularly and, thereby, updating the measurement sensor signal.

Embodiment 19: The method according to any one of the preceding Embodiments referring to the method for operating a measurement device, wherein considering the relationship comprises compensating an influence of the transition material on the radiation incident onto the detector by considering the second relationship, particularly and, thereby, updating the measurement sensor signal.

Embodiment 20: The method according to any one of the preceding Embodiments referring to the method for operating a measurement device, wherein the at least one measurement sensor signal comprises a first measurement sensor signal associated with the first wavelength range and a second measurement sensor signal associated with the second wavelength range, wherein, by using the second relationship, an expected second sensor signal associated with the second wavelength range is determined by considering the first measurement sensor signal, particularly wherein the expected second sensor signal is subtracted from the second measurement sensor signal, more particularly and, thereby, updating the measurement sensor signal, wherein the emission temperature of at least one radiation emitting element is determined by considering the second measurement sensor signal.

Embodiment 21: The method according to any one of the preceding Embodiments referring to the method for operating a measurement device, wherein considering the correction comprise compensating an influence on the relationship caused by the integration of the detector module and the transition material into the assembly unit.

Embodiment 22: The method according to any one of the preceding Embodiments referring to the method for operating a measurement device, wherein the method further comprises a step of compensating an emissivity of the radiation emitting element and updating the measurement sensor signal, particularly by normalizing the measured sensor signal to the emissivity.

Embodiment 23: The method according to any one of the preceding Embodiments referring to the method for operating a measurement device, wherein the emissivity of the radiation emitting element is determined as a function of the at least one sensor signal generated by the at least one detector module.

Embodiment 24: The method according to any one of the preceding Embodiments referring to the method for operating a measurement device, wherein the emissivity of the radiation emitting element is determined by providing a ratio of the intensities of the thermal radiation within the at least two individual wavelength ranges, thereby determining an emissivity-independent value for the thermal radiation of the radiation emitting element, and by comparing the intensity of the thermal radiation within at least one of the individual wavelength ranges with the emissivity-independent value for the thermal radiation of the at least one radiation emitting element, thereby determining the emissivity of the at least one radiation emitting element.

Embodiment 25: The method according to any one of the preceding Embodiments referring to the method for operating a measurement device, wherein the temperature of the radiation emitting element from the measurement sensor signal is determined by using the first relationship.

Embodiment 26: A measurement device for monitoring an emission temperature of at least one radiation emitting element, wherein the measurement device comprises a detector module integrated in an assembly unit, wherein the detector module is designated for generating at least one sensor signal depending on an intensity of the thermal radiation of at least one wavelength range generated by the radiation emitting element incident onto the detector module, wherein a transition material is arranged between the detector module and the radiation emitting element in a manner that radiation generated by the radiation emitting element incident onto the detector module is propagating through the transition material, wherein the measurement device comprises an evaluation unit configured for performing the method for operating the measurement device according to any one of the preceding Embodiments referring to a method for operating a measurement device.

Embodiment 27: A computer program comprising instructions which, when the program is executed by the measurement device according to any one of the preceding Embodiments referring to a measurement device cause the measurement device to perform the method of operating a measurement device according to any one of the preceding Embodiments referring to a method of operating a measurement device.

Embodiment 28: A computer-readable storage medium comprising instructions which, when the program is executed by the measurement device according to any one of the preceding Embodiments referring to a measurement device cause the spectrometer device to perform the method of operating a measurement device according to any one of the preceding Embodiments referring to a method of operating a measurement device.

Embodiment 29: A non-transient computer-readable medium including instructions that, when executed by one or more processors of the evaluation unit of the measurement device according to any one of the preceding Embodiments referring to a measurement device cause the one or more processors to perform the method of operating a measurement device according to any one of the preceding Embodiments referring to a method of operating a measurement device.

Brief description of the figures

Further optional details and features of the invention are evident from the description of preferred exemplary embodiments which follows in conjunction with the dependent

Embodiments. In this context, the particular features may be implemented alone or in any reasonable combination. The invention is not restricted to the exemplary embodiments. The exemplary embodiments are shown schematically in the figures. Identical reference numerals in the individual figures refer to identical elements or elements with identical function, or elements which correspond to one another with regard to their functions. In the Figures:

Figure 1 schematically illustrates an exemplary measurement device for monitoring an emission temperature of at least one radiation emitting element;

Figure 2 schematically illustrates a further exemplary measurement device for monitoring an emission temperature of at least one radiation emitting element;

Figure 3 illustrates an exemplary calibration method;

Figure 4 illustrates a typical first relationship;

Figure 5 schematically illustrates an exemplary calibration setup;

Figure 6 illustrates a typical second relationship;

Figure 7 schematically illustrates a further exemplary calibration setup;

Figure 8 illustrates a typical corrected relationship derived by considering a correction; and

Figure 9 illustrates an exemplary method for operating a measurement device.

Exemplary embodiments

Figure 1 illustrates, in a highly schematic fashion, an exemplary embodiment of a measurement device 110 comprising at least one detector module 112 for monitoring an emission temperature of at least one radiation emitting element 114 according to the present invention.

The measurement device 110 further comprises at least one transition material 116 and at least one detector module 112 being integrated in an assembly unit 111. By being integrated in the assembly unit 111, the transition material 116 and/or the detector module 112 are being in at least one of: a respective position; a respective pose required for an intended use, such as performing monitoring an emission temperature of at least one radiation emitting element 114, particularly by performing a method for operating a measurement device 110 for monitoring an emission temperature of at least one radiation emitting element 114.

The detector module 112 may comprise at least one radiation sensitive element 126. The radiation sensitive element 126 may have at least one sensor region 128. The sensor region

128 may comprise at least one photosensitive material selected from at least one photoconductive material. The sensor region may be designated for generating at least one sensor signal depending on an intensity of the thermal radiation emitted by the at least one radiation emitting element 114 and received by the sensor region 128. The radiation sensitive element 126 may be arranged in a manner that the thermal radiation propagates at least one transition material 116 prior to being received by the at least one radiation sensitive element 126. The transition material 116 may be at least partially transparent for the thermal radiation. The transition material 116 may be selected from at least one ceramic material 130 as, typically, used in a ceramic glass cooktop.

As further illustrated in Figure 1, the detector module 112 may specifically comprise a single radiation sensitive element 126. Individual wavelength ranges may be provided by using at least one adjustable optical filter 130 further comprised by the detector module 112. The radiation emitting element 114 may reside on top of the transition material 116, whereas the adjustable optical filter 130 may be positioned underneath the transition material 116, followed by the radiation sensitive element 126. The adjustable optical filter 130 may specifically be or comprise a moveable optical filter 132 having at least two individual areas 134. As shown in Figure 1, the movable optical filter 132 may have four areas 134; however, a different number of areas may also be feasible. Each area may be designed to filter a different wavelength range. The moveable filter 132 may be moveable in a horizontal direction above the radiation sensitive element 126. Additionally or alternatively, the adjustable optical filter 130 may be or may comprise at least one electro-optical filter designed to filter a different wavelength range upon applying a different voltage or current (not depicted here).

The detector module 112 further may comprise at least one evaluation unit 138, particularly having a storage device (not depicted here). The evaluation unit 138 may be configured to determine the emission temperature of the at least one radiation emitting element 114, particularly by considering at least one value of the intensity of the thermal radiation at least one wavelength range. The evaluation unit 138 may further be configured to determine an emissivity of the at least one radiation emitting element 114. The emissivity may relate to an effectivity of the at least one radiation emitting element 114 to emit the thermal radiation, particularly when compared to a blackbody. Specifically, the at least one evaluation unit 138 may be configured to determine the emissivity of the at least one radiation emitting element 114 as a function of the at least one sensor signal generated by the at least one radiation sensitive element 126. The evaluation unit 138 may further be configured to determine the emissivity of the at least one material comprised by the at least one radiation emitting element 114 by providing a ratio of the intensities of the thermal radiation within at least two individual wavelength ranges, thereby determining an emissivity-independent value for the thermal radiation of the at least one radiation emitting element, and by comparing the intensity of the thermal radiation within at least one of the individual wavelength ranges with the emissivity-independent value for the thermal radiation of the at least one radiation emitting element 114, thereby determining the emissivity of the at least one radiation emitting element 114. The evaluation unit 138 may specifically be connected to the radiation sensitive element 126. A connection between the evaluation device 138 and the radiation sensitive element 126 may be wire bound and/or wireless.

The exemplary measurement device 110 that is depicted in Fig. 1 may be used as a heating system. Nevertheless, the invention may not be limited to such a use. Particularly to allow the measurement device 110 to function as a heating system, the exemplary measurement device 110 further may comprise at least one heating unit 118 for heating the radiation emitting element 114 via the transition material 116, and at least one control unit 120. Thus, the measurement device 110 may be configured to heat the at least one radiation emitting element 114 to emit radiation, particularly thermal radiation, at the emission temperature. As shown in Figure 1, the radiation emitting element 114 may specifically be a piece of cookware 122, such as a pot or a pan; however a further piece of cookware 122 may also be feasible. Specifically, at least a partition of the radiation emitting element 114 may emit a predominant portion of the thermal radiation, wherein the partition may, more specifically, be selected from a bottom part 124 of the radiation emitting element 114 which may, preferably, be placed at the at least one transition material 116 in an adjacent fashion.

The measurement device 110 may, further, comprise at least one control unit 120. The control unit 120 may be designated for controlling an output of the at least one heating unit 118 based on the emission temperature of the at least one radiation emitting element 114 determined by the detector module 112 for monitoring the emission temperature of at least one radiation emitting element 114. The heating unit 118 may comprise at least one heating element 140 having at least one opening 142 designated in a manner that the thermal radiation emitted by the at least one radiation emitting 114 element travels through the at least one opening 142. As schematically depicted in Figure 1, the heating unit 118 may comprise an induction coil 144 having a hole in a central area of the induction coil 144. The induction coil 144 may be designed for heating the least one radiation emitting element 114 by using at least one of thermal heat or electromagnetic induction. Additionally or alternatively, the heating element 140 may comprise at least one infrared halogen lamp (not depicted here).

The measurement device 110 may, further, comprise at least one heat shielding 146. The heat shielding 146 may be designated for shielding the at least one detector module 112 for monitoring the emission temperature of the at least one radiation emitting element 114 from the at least one heating unit 118. As illustrated in Figure 1, the heat shielding 146 may comprise at least one aperture 148 designated in a manner that the thermal radiation emitted by the at least one radiation emitting element 114 travels through the at least one aperture 148. Particularly the heating unit 118 and/or the induction coil 144 may further be integrated in the assembly unit 111.

The measurement device 110 may, further, comprise at least one setting element 150. The setting element 150 may be configured to receive at least one piece of information which can be inputted by at least one user of the measurement device 110. As an example, the user may set an emission temperature of the radiation emitting element to a desired value by using the setting element 150. The setting element 150 may, specifically, be connected to the control unit 120 via a wire bound connection and/or a wireless connection.

The measurement device 110 may, further, comprise at least one notification unit 152. The notification unit 152 may be configured to provide at least one further piece of information to the at least one user of the measurement device 110. As an example, the notification unit 152 may be configured to display an actual value and/or a predefined value and/or a desired value of the emission temperature of the radiation emitting element 114. Alternatively or in addition, the notification unit 152 may be configured to display at least one warning, such as a presence of the at least one further object that may, accidentally or deliberately, assume the location of the at least one piece of cookware 122 on top of the transition material 116 used as the cooktop, such as a plastic container or a burn stain, and that may constitute a potential fire hazard; or that an operation of the cooktop is prevented hereby. The notification unit 152 may, specifically, be connected to the control unit 120 via a wire bound connection and/or a wireless connection.

As illustrated in Figure 2, the detector module 112 may specifically comprise two or more radiation sensitive elements 126. In such a case, individual wavelength ranges may be provided by at least two individual optical filters 154, e.g. a first individual optical filter 156 and a second individual optical filter 158, positioned before each one the radiation sensitive elements 126. Each individual optical filter 154 may filter a different wavelength range of the thermal radiation before the thermal radiation is received by the radiation sensitive elements 126. Thus, the first individual optical filter 156 may filter a different wavelength range of the thermal radiation than the second individual optical filter 158, e.g. since they comprise different materials. Additionally or alternatively, the radiation sensitive elements 126 may at least partially be different radiation sensitive elements 126, which may differ with respect to their sensitivity for different wavelengths of the thermal radiation, e.g. since the radiation sensitive elements 126 may at least partially comprise different photosensitive materials.

The detector module 112 may, further, comprise at least one further radiation sensitive element 160. The at least one further radiation sensitive element 160 may be designated for generating at least one further sensor signal depending on the intensity of further thermal radiation emitted by the at least one transition material 116 within at least one further wavelength range. The at least one transition material 116 may not be transparent or only partially transparent for the thermal radiation emitted by the radiation emitting element 114 within the at least one further wavelength range. The at least one evaluation unit 138 may further be configured to take into account the at least one further sensor signal measured by the at least one further radiation sensitive element 160 when determining the emission temperature of the at least one radiation emitting element 114. The at least one evaluation unit 138 may further be configured to correct the intensity of the thermal radiation within the at least two individual wavelength ranges by removing a contribution of the intensity of further thermal radiation emitted by the at least one transition material 116 from the intensity of the thermal radiation emitted by the at least one radiation emitting element 114.

The detector module 112 may, further, comprise at least one temperature sensor 162. The at least one temperature sensor 162 may be designated for monitoring a temperature of the transition material 116. Thus, the temperature sensor 162 may be thermally coupled to the transition material 116. Specifically, the temperature sensor 162 may be attached to the transition material 116. Additionally or alternatively, the temperature sensor 162 may be designated for monitoring a temperature of the radiation sensitive element 114 or further components of the measurement device 110. The at least one evaluation unit 138 may further be configured to take into account the temperature measured by the at least one temperature sensor 162 when determining the emission temperature of the at least one radiation emitting element 114. The at least one temperature sensor 162 may specifically be designated for monitoring the temperature of a portion of the at least one transition material 116 which is passed by an optical path between the at least one radiation emitting element 114 and the at least one radiation sensitive element 126.

The detector module 112 may, further, comprise at least one reference radiation sensitive element 164. The at least one reference radiation sensitive element 164 may have at least one covered sensor region 166. The at least one covered sensor region 166 may comprise the same photosensitive material as the at least one radiation sensitive element 126 but may be covered in a manner to impede that the reference radiation sensitive 164 element receives the thermal radiation emitted by the at least one radiation emitting element 114. The at least one covered sensor region 166 may be designated for generating at least one reference signal. The at least one evaluation unit 138 may, further, be configured to take into account the at least one reference signal when determining the emission temperature of the at least one radiation emitting element 114. The at least one covered sensor region 166 may be covered by a radiation absorptive layer 168 and/or a radiation reflective layer 170. The radiation absorptive layer 168 may be designed to absorb the thermal radiation within the at least two individual wavelength ranges. The radiation reflective layer 170 may be designed to reflect the thermal radiation within the at least two individual wavelength ranges.

The detector module 112 may, further, comprise at least one presence sensor 172. The at least one presence sensor 172 may be configured to determine at least one further object which is located in a manner that the thermal radiation may travel through the at least one further object before it may be received by the at least one radiation sensitive element 126. The at least one further object may be not transparent or partially transparent in at least one of the at least two individual wavelength ranges. The at least one further object may be selected from at least one of a plastic container or a burn stain located on the ceramic material 130. The at least one presence sensor 172 may be selected from at least one of a time-of-flight detector, a presence detector, or a proximity detector.

The detector module 112 may, further, comprise at least one thermoelectric cooler 174. The thermoelectric cooler 174 may be configured to cool at least the at least one radiation sensitive element 126. The at least one radiation sensitive element 126 may be thermally coupled to the thermoelectric cooler 174. Specifically, the at least one radiation sensitive element 126 may be attached to the thermoelectric cooler 174. Further, the thermoelectric cooler 174 may be configured to cool the at least one further radiation sensitive element 160. The at least one further radiation sensitive element 160 may be thermally coupled to the thermoelectric cooler 174. Specifically, the at least one further radiation sensitive element 160 may be attached to the thermoelectric cooler 174.

Figure 3 illustrates a calibration method 210 of assembling a set of items of information, such as a relationship 352, particularly a first relationship 310 and/or a second relationship 326, a correction and/or a dark signal, for use in a method for operating a measurement device 110 for monitoring an emission temperature of at least one radiation emitting element 114.

The method 210 comprises the following steps:

(i) performing a plurality of calibration measurements for determining at least one relationship, in a step 212, between at least one sensor signal and at least one temperature of a radiation emitting element 114 by measuring a plurality of sensor signals for at least two different emission temperatures of at least one radiation emitting calibration element when the detector module 112 and the transition material 116 are separate from the assembly unit 111;

(ii) performing at least one further calibration measurement for determining at least one correction, in a step 214, for the at least one relationship by measuring at least one sensor signal for at least one known emission temperature of at least one radiation emitting calibration when the detector module 112 and the transition material 116 are integrated in the assembly unit 111;

(iii) recording the relationship and the correction, in a step 216.

The relationship 352 may comprise a first relationship 310 that accounts for a response of the detector module 112 to incident radiation generated by at least one hot body 316 being used as at least one first radiation emitting calibration element. A typical first relationship 310 is depicted in Fig. 4 that shows an intensity of a sensor signal on the vertical axis 312 in arbitrary units and the temperature of the radiation emitting element 114 on the horizontal axis 314 in degree Celsius.

For determining the first relationship 310, a plurality of hot bodies 316 may be used as the at least one radiation emitting calibration element. The hot bodies 316 may have a known emissivity and may, particularly, be blackbodies and/or graybodies. The hot bodies 316 may have at least two different known emission temperatures each, such as 0 °C and 100 °C, wherein the detector module 112 may be illuminated by each hot body 316 for generating at least one sensor signal assigned to each known emission temperature of the respective hot body 316, wherein each at least one sensor signal and each known emission temperature are recorded, particularly by using a storage device.

An exemplary calibration setup 315 is illustrated in Fig. 5. The calibration setup 315 comprises a hot body 316, a heat shieling 146 and a detector module 112. The detector module 112 is arranged at a specific distance 318 the hot body 316. Further, the detector module 112 is arranged at a further specific distance 320 to the heat shielding 146. The heat shielding 146 is further arranged at a further specific distance 322 to the hot body 316. At least one of the distances 318, 320, 322, preferably any distance 318, 320, 322, may be selected to be equal to a respective distance when the hot body 316, the heat shieling 146 and the detector module 112 are integrated in the assembly unit 111. The calibration may be repeated for a plurality of different hot bodies 316 being at different temperatures. At least one of the distances 318, 320, 322, preferably any one of the specific distances 318, 320, 322, may be constant in any one of the calibration measurements. Particularly by doing so the first relationship 310 may be established for recorded sensor signals and the recorded known temperatures of the hot bodies 316, as illustrated by the dash-dotted vertical lines 324 in Fig. 4.

The hot bodies 316 used in the calibration measurements may have properties of a typical cookware, such as typical material properties. Alternatively or in addition, hot bodies 316 from an environment generating the ambient radiation may be considered. The hot bodies 316 may be of the same material as a typical cookware, namely at least one metal, at least one ceramic, at least one metal oxide, at least one mixture of silica and metal oxides. At least one hot body 316 may be set to ambient temperature, specifically 22°C. At least one further hot body 316 may be set to a reference temperature, e.g. 100°C. The emissivity of at least one hot body 316 may be determined by using a lamp being integrated in the hot body.

Determining the first relationship 310 may, further, comprise performing a regression by considering the recorded sensor signals and the recorded known temperature to estimate at least one expected sensor signal, particularly by generating a relationship function 325 interpolating the recorded sensor signals and the recorded known temperatures. The first relationship 310 may thus be considered for determining the strength of at least one sensor signal depending on the temperature of the radiation emitting element 114 having its radiation incident onto the detector module 112.

The relationship 352 may, further, comprise a second relationship 326 that accounts for a response of the detector module 112 to incident radiation generated by at least one unit of the transition material 116 being used as at least one second radiation emitting calibration element. The first relationship 310 and the second relationship 326 may be determined independent from each other.

A typical second relationship 326 is depicted in Fig. 6 that shows a sensor signal of a first wavelength interval on the vertical axis 328, such as between 2800 nm to 3000 nm, depending on a sensor signal of a second wavelength interval on the horizontal axis 330, such as between 1000 nm to 2800 nm.

At least one first sensor signal associated with a first wavelength range and at least one second sensor signal associated with a second wavelength range may be recorded, particularly for each different emission temperature of the respective unit of the transition material 116, wherein the first wavelength range may dominated by radiation generated by the transition material 116, wherein the second wavelength range may be evaluated in the method for operating a measurement device 110 for monitoring an emission temperature of at least one radiation emitting element 114 to determine the emission temperature of at least one radiation emitting element 114.

For determining the second relationship 326 a plurality of units comprising the transition material 116 used as the at least one radiation emitting calibration element is set to at least two different emission temperatures each, wherein the detector module 112 is illuminated by each unit for generating at least one sensor signal.

An exemplary further calibration setup 332 is illustrated in Fig. 7. The further calibration setup 332 comprises a unit of the transition material 334, a heat shieling 146 and a detector module 112. The detector module 112 is arranged at a further distance 336 to the unit of the transition material 334. Further, the detector module 112 is arranged at a further distance 338 to the heat shielding 146. The heat shielding 146 is further arranged at a further distance 340 to the unit of the transition material 334. At least one of the distances 336, 338, 340 may be selected to be equal to a respective distance of the transition material 116, the heat shieling 146 and the detector module 112 when integrated in the assembly unit 111. The calibration may be repeated for a plurality of different units of the transition material 334 being at different temperatures. A unit of the transition material 334 may comprise at least one temperature sensor 346 and at least one heating element 348, such as a coil. The temperature sensor 346 and the heating element 348 may be connected to a coil temperature regulator unit 350, particularly to set the unit of the transition material 334 to a calibration temperature. At least one of the distances 336, 338, 340, preferably any one of the distances 318, 320, 322, may be constant in any one of the calibration measurements. Particularly by doing so, the second relationship 326 may be established for recorded first sensor signals and second sensor signals, as illustrated by the dash-dotted vertical lines 342 in Fig. 6.

Determining the second relationship 326 may comprise performing a regression when considering the recorded first sensor signal and the recorded second sensor signal to estimate an expected second sensor signal for a first sensor signal, particularly by generating a further relationship function 344 interpolating the recorded first sensor signals and the recorded second sensor signals, wherein the recorded first sensor signals and the recorded second sensor signals are recorded for different temperatures of the hot body.

Determining the correction may comprise determining a deviation between the sensor signal measured for a known emission temperature in the at least one further calibration measurement and an expected sensor signal for the known temperature derived from the relationship 352, particularly the first relationship 310. As illustrated in Fig. 8, determining the correction may further comprises compensating the deviation by correcting the relationship 352, particularly the first relationship 310, particularly by multiplying each expected sensor signal derived from the relationship 352, particularly the first relationship 310, with a correction factor, particularly wherein a sensor signal is illustrated on the vertical axis 356 and the temperature of the radiation emitting element 114 is illustrated on the horizontal axis 358. Thereby, a corrected relationship 354 may be received.

For determining the relationship 350 and/or the correction, the of at least one radiation emitting calibration may be at least one of:

- a hot body,
- a cookware, particularly a cookware comprising boiling water;
- a calibrated thermal radiator, particularly an incandescent lamp,

particularly placed on a cooktop, more particularly wherein the cooktop comprises the transition material 116.

The method 210 may further comprise a step of a determining and recording at least one dark signal 218 of the detector module 112 in at least one further calibration measurement. At least one of: the relationship 350, particularly the first relationship 310 and/or the second relationship 326; the correction; the dark signal; may be stored on a storage device, particularly comprised by an evaluation unit 138 of the detector module 112, more particularly in form of a lookup table.

Fig. 9 illustrates a method for operating a measurement device 410 for monitoring an emission temperature of at least one radiation emitting element 114. The method 410 may comprise a step of determining at least one measurement sensor signal 420 being selected from at least one of: a first measurement sensor signal associated with the first wavelength range; a second measurement sensor signal associated with the second wavelength range, particularly from radiation generated by the radiation emitting element 114. The method 410 further may comprise a step of compensating an influence of a dark signal 414 on the measurement sensor signal by considering the recorded dark signal, particularly by subtracting the recorded dark signal from of the measurement sensor signal, more particularly and, thereby, updating the measurement sensor signal.

The method 410 comprises the following step:

(a) determining, by using an evaluation unit 138, particularly comprised by the detector module 112, an emission temperature 412 of at least one radiation emitting element 114 from at least one measurement sensor signal generated by radiation of the radiation emitting element 114 incident onto the detector module 112 by considering the relationship 350 and the correction determined in the calibration method according to any one of the preceding claims.

Considering the relationship may comprise compensating an influence of the transition material 416 on the radiation incident onto the detector by considering the second relationship, particularly and, thereby, updating the measurement sensor signal. Particularly therefore, the at least one measurement sensor signal may comprise a first measurement sensor signal associated with the first wavelength range and a second measurement sensor signal associated with the second wavelength range, wherein, by using the second relationship, an expected second sensor signal associated with the second wavelength range may be determined by considering the first measurement sensor signal, particularly wherein the expected second sensor signal may be subtracted from the second measurement sensor signal, more particularly and, thereby, updating the measurement sensor signal. The emission temperature of the at least one radiation emitting element 114 may be determined by considering the second measurement sensor signal.

Considering the correction may comprise compensating an influence on the relationship caused by the integration 422 of the detector module 112 and the transition material 116 into the assembly unit 111.

The method 410 may further comprise a step of compensating an emissivity 418 of the radiation emitting element 114 and updating the measurement sensor signal, particularly by normalizing the measured sensor signal to the emissivity. The emissivity of the radiation emitting element 114 may be determined as a function of the at least one sensor signal generated by the at least one detector module 112. The emissivity of the radiation emitting element 114 may be determined by providing a ratio of the intensities of the thermal radiation within the at least two individual wavelength ranges, thereby determining an emissivity-independent value for the thermal radiation of the radiation emitting element 114, and by comparing the intensity of the thermal radiation within at least one of the individual wavelength ranges with the emissivity-independent value for the thermal radiation of the at least one radiation emitting element 114, thereby determining the emissivity of the at least one radiation emitting element 114.

The temperature of the radiation emitting element 114 from the measurement sensor signal, particularly from the updated measurement signal, more particularly from the updated second measurement sensor signal, may be determined 420 by using the first relationship.

Any one of the methods 210, 410 may be implemented as a computer program, particularly comprised by a computer-readable storage medium and/or a non-transient computer-readable medium.

List of reference numbers

110	measurement device
111	assembly unit
112	detector module
114	radiation emitting element
116	transition material
118	heating unit
120	control unit
122	piece of cookware
124	bottom part
126	radiation sensitive element

128	sensor region
130	ceramic material
132	adjustable optical filter
134	moveable optical filter
136	area
138	evaluation unit
140	heating element
142	opening
144	induction coil
146	heat shielding
148	aperture
150	setting element
152	notification unit
154	individual optical filter
156	first individual optical filter
158	second individual optical filter
160	further radiation sensitive element
162	temperature sensor
164	reference radiation sensitive element
166	covered sensor region
168	radiation absorptive layer
170	radiation reflective layer
172	presence sensor
174	thermoelectric cooler
210	calibration method
212	determining at least one relationship
214	determining at least one correction
216	recording the relationship and the correction
218	recording dark signal
310	first relationship
312	vertical axis
314	horizontal axis
315	calibration setup
316	hot body
318	distance
320	distance
322	distance
324	vertical line
325	relationship function
326	second relationship
328	vertical axis
330	horizontal axis
332	further calibration setup

334	unit of the transition material
336	distance
338	distance
340	distance
342	vertical lines
344	relationship function
346	temperature sensor
348	heating element, coil
350	temperature regulator unit
352	relationship, particularly first relationship
354	corrected relationship, particularly corrected first relationship
356	vertical axis
358	horizontal axis
410	method for operating a measurement device
412	determining an emission temperature
414	compensating an influence of a dark signal
416	compensating an influence of the transition material on the first relationship
418	compensating an emissivity
420	determining the temperature of the radiation emitting element
422	compensating an influence of the integration into the assembly unit

Claims

1. A calibration method (210) of assembling a set of items of information for use in a method for operating a measurement device (110) for monitoring an emission temperature of at least one radiation emitting element (114), wherein the measurement device (110) comprises a detector module (112), a transition material (116) and an assembly unit (111), wherein the detector module (112) and the transition material (116) are designated for being integrated into the assembly unit (111) when performing the method for operating a measurement device (110) for monitoring an emission temperature of at least one radiation emitting element (114) in a manner that the transition material (116) is arranged between the detector module (112) and the radiation emitting element (114) such that radiation generated by the radiation emitting element (114) incident onto the detector module (112) is propagating through the transition material (116), wherein the detector module (112) is designated for generating at least one sensor signal depending on an intensity of the thermal radiation, the method comprising the following steps:
   (i) performing a plurality of calibration measurements for determining at least one relationship (352) between at least one sensor signal and at least one temperature of a radiation emitting element (114) by measuring a plurality of sensor signals for at least two different emission temperatures of at least one radiation emitting calibration element when the detector module (112) and the transition material (116) are separate from the assembly unit (111);
   (ii) performing at least one further calibration measurement for determining at least one correction for the at least one relationship (352) by measuring at least one sensor signal for at least one known emission temperature of at least one radiation emitting calibration when the detector module (112) and the transition material (116) are integrated in the assembly unit (111);
   (iii) recording the relationship (352) and the correction;

   wherein the relationship (352) comprises at least one of:
   - a first relationship (310) that accounts for a response of the detector module (112) to incident radiation generated by at least one hot body being used as at least one first radiation emitting calibration element;
   - a second relationship (326) that accounts for a response of the detector module (112) to incident radiation generated by at least one unit of the transition material (116) being used as at least one second radiation emitting calibration element.

2. The calibration method (210) according to the preceding claim, wherein the first relationship (310) and the second relationship (326) are determined independent from each other.

3. The calibration method (210) according to any one of the preceding claims, wherein, for determining the first relationship (310), a plurality of hot bodies used as the at least one

radiation emitting calibration element, particularly having a known emissivity, more particularly wherein the hot bodies are at least one of: blackbodies; graybodies, is set to the at least two different known emission temperatures each, wherein the detector module (112) is illuminated by each hot body for generating at least one sensor signal assigned to each known emission temperature of the respective hot body, wherein each at least one sensor signal and each known emission temperature are recorded.

4. The calibration method (210) according to any one of the preceding claims, wherein, for determining the second relationship (326) a plurality of units comprising the transition material (116) used as the at least one radiation emitting calibration element is set to at least two different emission temperatures each, wherein the detector module (112) is illuminated by each unit for generating at least one sensor signal.

5. The calibration method (210) according to the preceding claim, wherein for determining the second relationship (326) at least one first sensor signal associated with a first wavelength range and at least one second sensor signal associated with a second wavelength range are recorded for each different emission temperature of the respective unit of the transition material (116), wherein the first wavelength range is dominated by radiation generated by the transition material (116), wherein the second wavelength range is evaluated in the method for operating a measurement device (110) for monitoring an emission temperature of at least one radiation emitting element (114) to determine the emission temperature of at least one radiation emitting element (114).

6. The calibration method (210) according to any one of the preceding claims, wherein determining the correction comprises determining a deviation between the sensor signal measured for a known emission temperature in the at least one further calibration measurement and an expected sensor signal for the known temperature derived from the relationship (352).

7. The calibration method (210) according to the preceding claim, wherein determining the correction further comprises compensating the deviation by correcting the relationship (352).

8. A method (410) for operating a measurement device (110) for monitoring an emission temperature of at least one radiation emitting element (114), wherein the measurement device (110) comprises a detector module (112) and a transition material (116) integrated in an assembly unit (111), wherein the detector module (112) is designated for generating at least one sensor signal depending on an intensity of the thermal radiation of at least one wavelength range generated by the radiation emitting element (114) incident onto the detector module (112), wherein the transition material (116) is arranged between the detector module (112) and the radiation emitting element (114) in a manner that radiation generated by the radiation emitting element (114) incident onto the detector module (112)

is propagating through the transition material (116), wherein the method comprises the following step:

(a) determining, by using an evaluation unit, particularly comprised by the detector module (112), an emission temperature of at least one radiation emitting element (114) from at least one measurement sensor signal generated by radiation of the radiation emitting element (114) incident onto the detector module (112) by considering the relationship (352) and the correction determined in the calibration method according to any one of the preceding claims.

9. The method (410) according to the preceding claim referring to the method for operating a measurement device (110), wherein considering the relationship (352) comprises compensating an influence of the transition material (116) on the radiation incident onto the detector by considering the second relationship (326).

10. The method (410) according to any one of the two preceding claims referring to the method for operating a measurement device (410), wherein considering the correction comprises compensating an influence on the relationship (352) caused by the integration of the detector module (112) and the transition material (116) into the assembly unit (111).

11. A measurement device (110) for monitoring an emission temperature of at least one radiation emitting element (114), wherein the measurement device (110) comprises a detector module (112) integrated in an assembly unit (111), wherein the detector module (112) is designated for generating at least one sensor signal depending on an intensity of the thermal radiation of at least one wavelength range generated by the radiation emitting element (114) incident onto the detector module (112), wherein a transition material (116) is arranged between the detector module (112) and the radiation emitting element (114) in a manner that radiation generated by the radiation emitting element (114) incident onto the detector module (112) is propagating through the transition material (116), wherein the measurement device (110) comprises an evaluation unit configured for performing the method for operating the measurement device (110) according to any one of the preceding claims referring to a method for operating a measurement device (110).

12. A computer program comprising instructions which, when the program is executed by the measurement device (110) according to any one of the preceding claims referring to a measurement device (110) cause the measurement device (110) to perform the method of operating a measurement device (110) according to any one of the preceding claims referring to a method of operating a measurement device (410).

13. A computer-readable storage medium comprising instructions which, when the program is executed by the measurement device (110) according to any one of the preceding claims referring to a measurement device (110) cause the spectrometer device to perform the

method of operating a measurement device (110) according to any one of the preceding claims referring to a method of operating a measurement device (110).

14. A non-transient computer-readable medium including instructions that, when executed by one or more processors of the evaluation unit of the measurement device (110) according to any one of the preceding claims referring to a measurement device (110) cause the one or more processors to perform the method of operating a measurement device (110) according to any one of the preceding claims referring to a method of operating a measurement device (110).

FIG.1

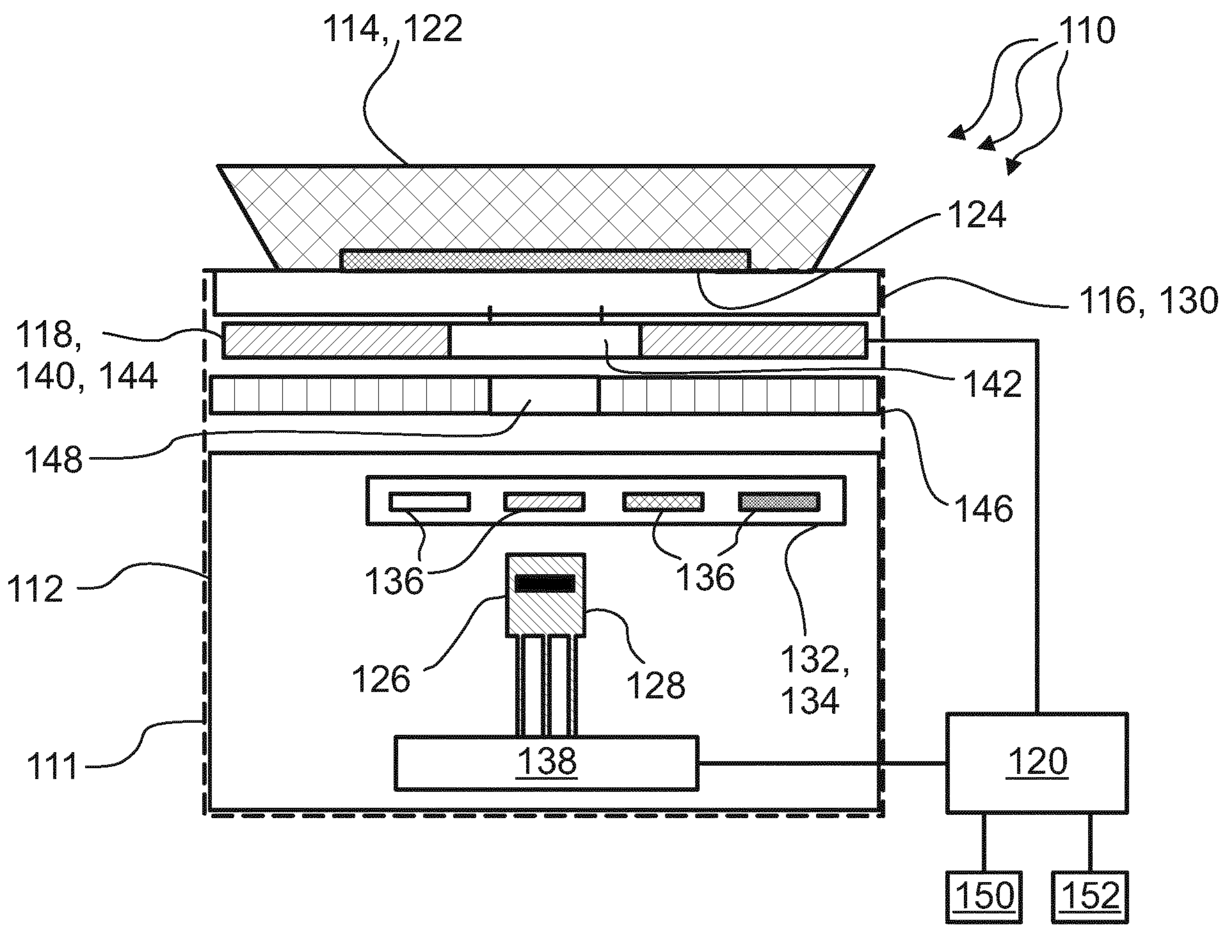

114, 122
110
124
116, 130
118,
140, 144
142
148
146
112
136
136
126
128
132,
134
111
138
120
150
152

FIG.2

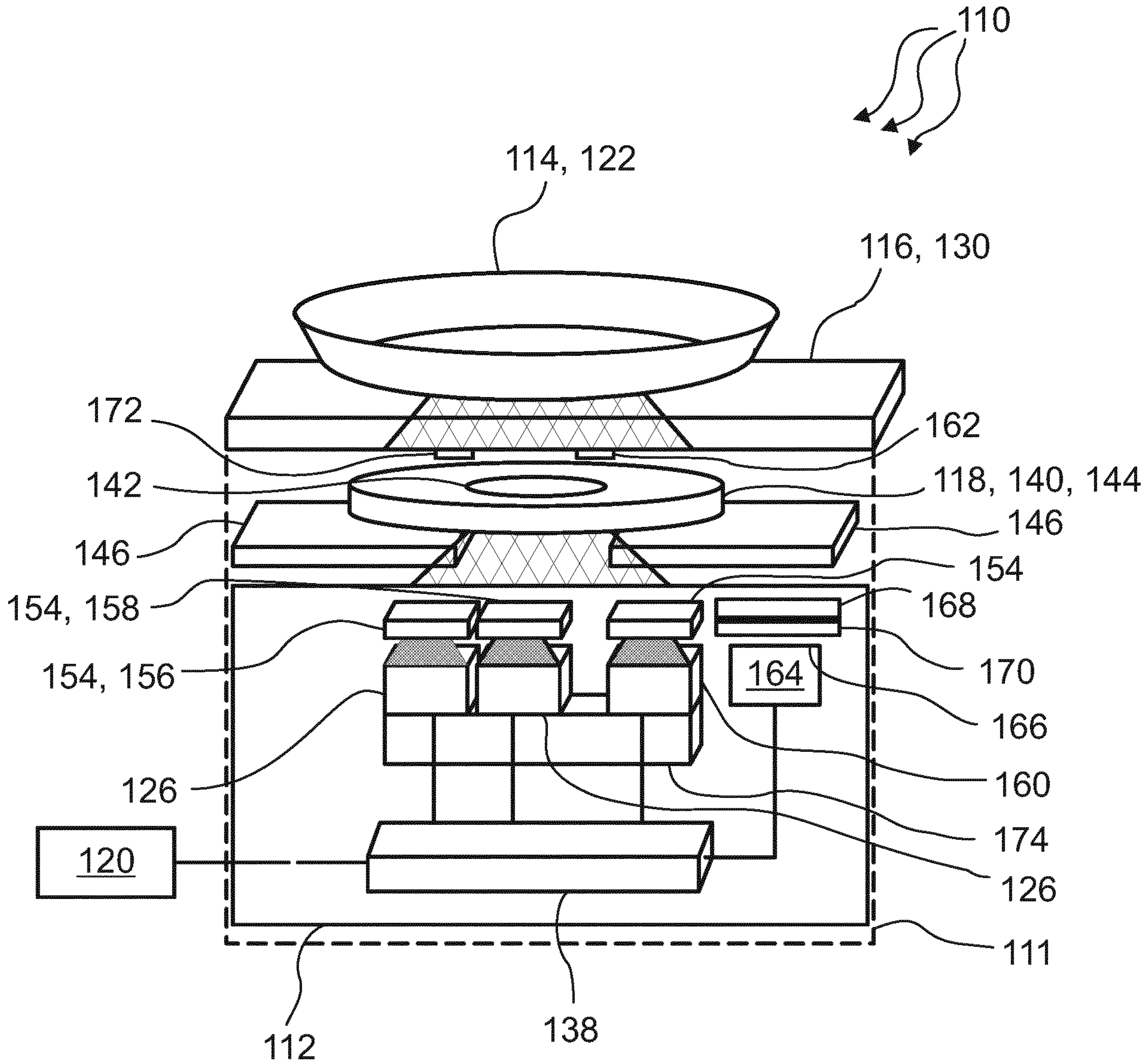

110
114, 122
116, 130
172
162
142
118, 140, 144
146
146
154
154, 158
168
154, 156
170
164
166
126
160
174
120
126
111
112
138

FIG.3

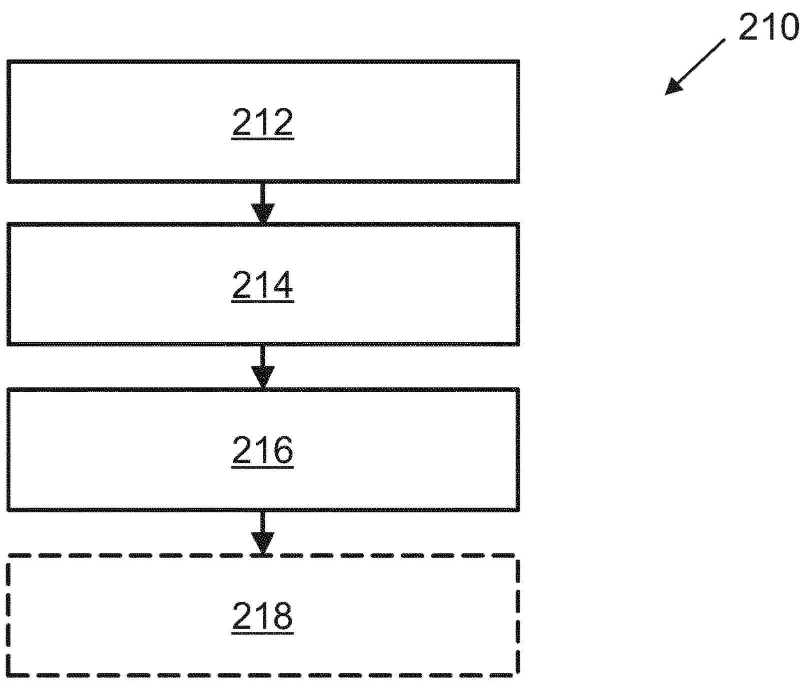


FIG.4

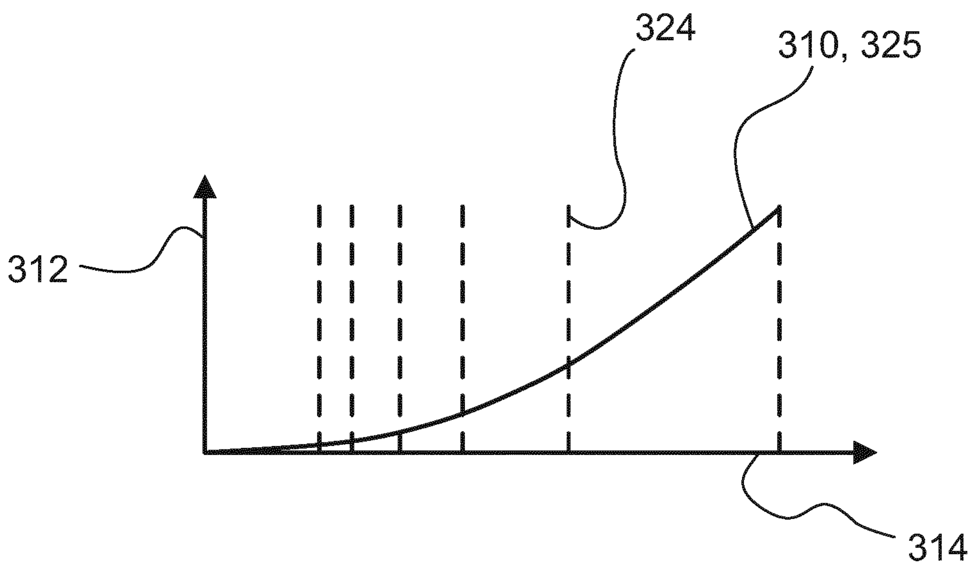


FIG.5

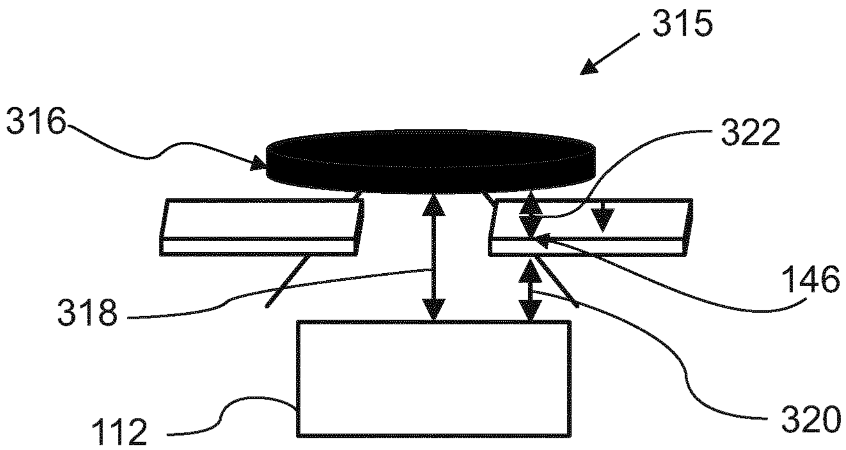


FIG.6

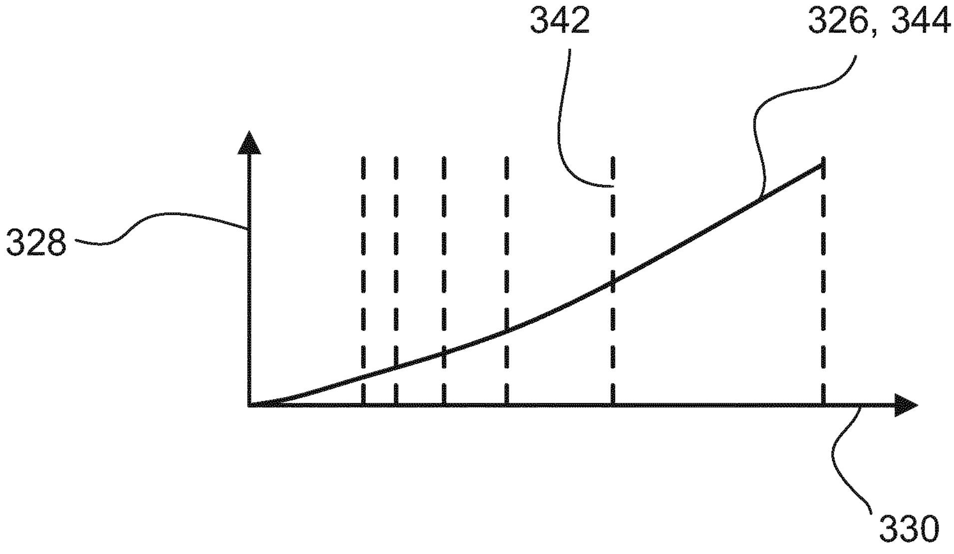


FIG.7

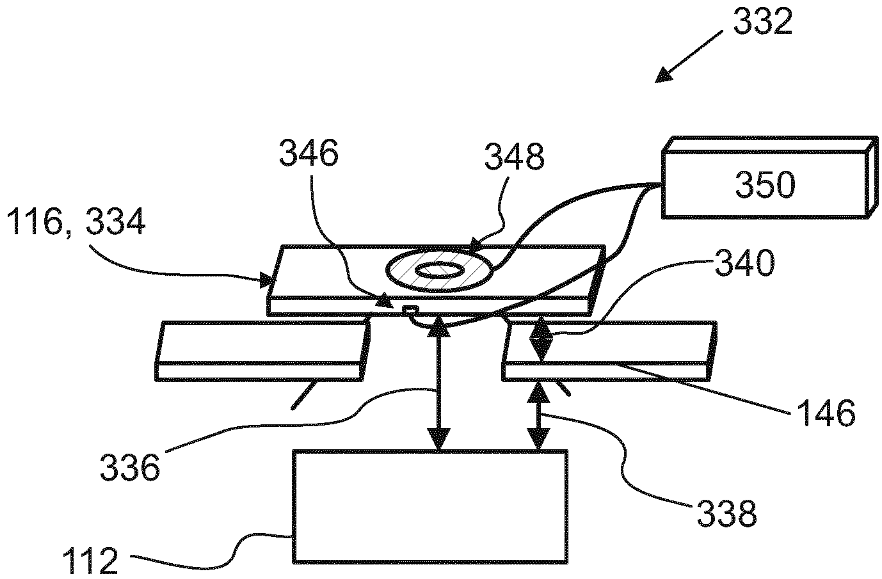


FIG.8

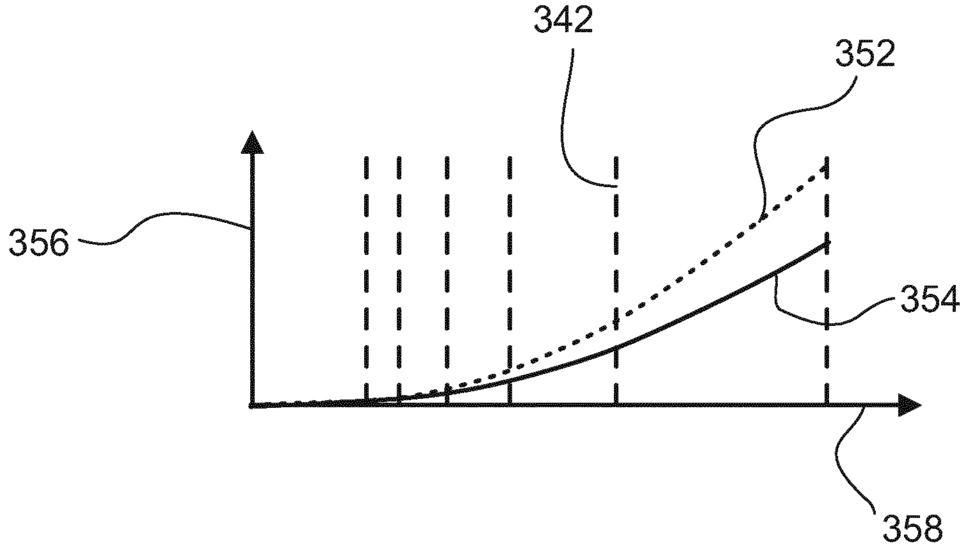
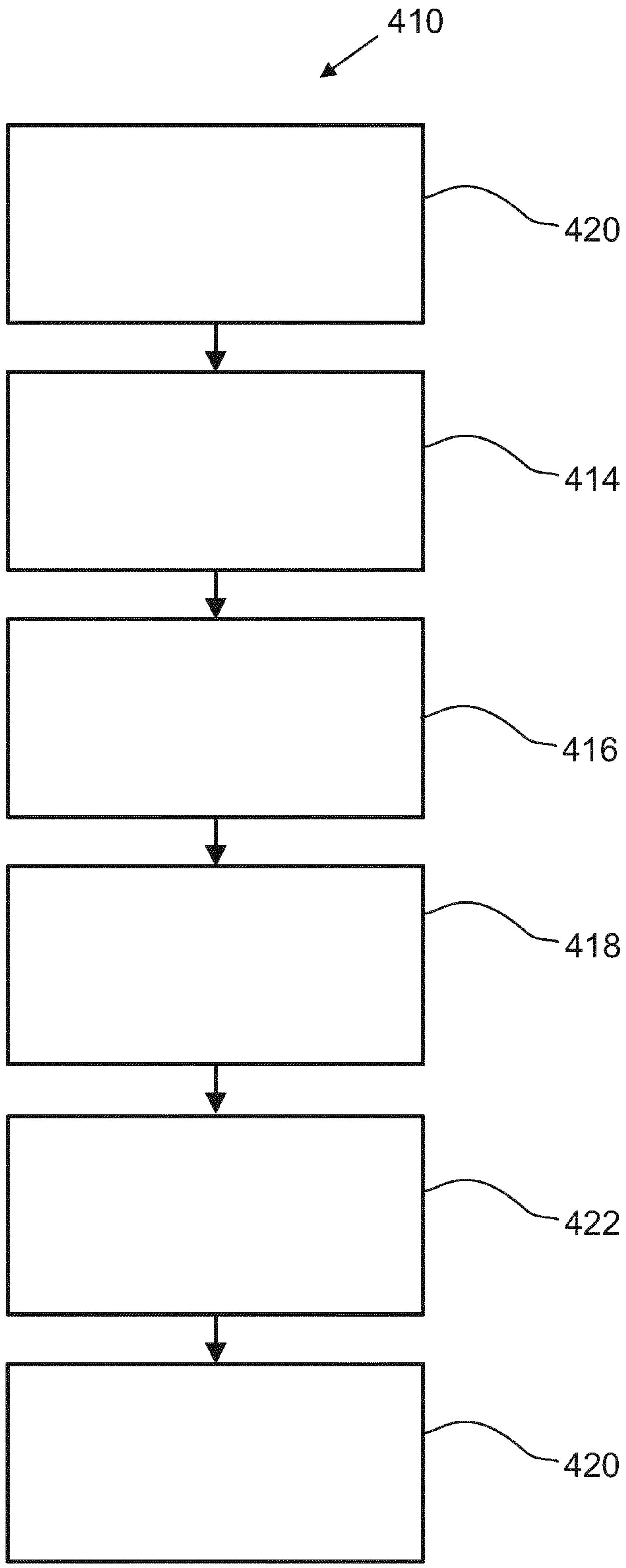


FIG.9



INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2024/059775

A. CLASSIFICATION OF SUBJECT MATTER
INV. G01J5/00 G01J5/04 G01J5/06 G01J5/0802 G01J5/08
G01J5/80 G01J5/20
ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
G01J

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X Y	EP 3 572 730 A2 (ELATRONIC AG [CH]) 27 November 2019 (2019-11-27) paragraph [0027] - paragraph [0044] figures 1-6 -----	1-4,6-14 5
A	US 8 049 163 B1 (GRANNEMAN RUSSELL [US] ET AL) 1 November 2011 (2011-11-01) column 3, line 51 - column 8, line 17 figures 1-6 -----	1,11-14
Y	WO 2022/234073 A1 (TRINAMIX GMBH [DE]) 10 November 2022 (2022-11-10) cited in the application page 33, line 27 - line 40 page 37, line 23 - line 38 figures 2,5 -----	5

☐ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier application or patent but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance;; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance;; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
15 May 2024	24/05/2024

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Haller, Mirjam

1

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/EP2024/059775

Patent document cited in search report		Publication date	Patent family member(s)			Publication date
EP 3572730	A2	27-11-2019	EP	3572730	A2	27-11-2019
			US	2023043515	A1	09-02-2023
US 8049163	B1	01-11-2011	NONE			
WO 2022234073	A1	10-11-2022	CN	117295931	A	26-12-2023
			EP	4334689	A1	13-03-2024
			KR	20240004475	A	11-01-2024
			WO	2022234073	A1	10-11-2022