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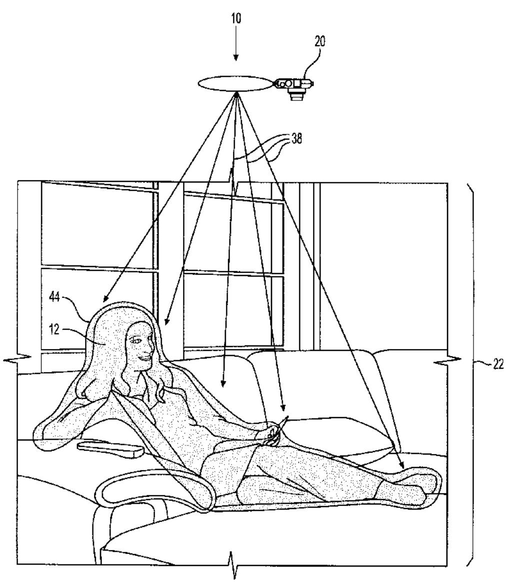

FIG. 1

(57) **Abstract:** A dynamic IR heater for detecting and heating one or more targets by projecting IR radiation includes a camera capturing an image from a field of view and a light source including an array of controllable point sources generating IR radiation. A controller is in communication with the camera to determine a heating profile of each of the targets, including a surface area to be heated and a corresponding radiant power setting, by comparing the captured image to a predetermined characteristic, and generates a distribution map of the IR radiation toward the targets. Each of the controllable point sources are thereby illuminated in accordance with the distribution map to direct the IR radiation substantially toward the targets. A method of operating the dynamic IR heater to detect targets and to project IR radiation thereupon is also disclosed.

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DYNAMIC SPACE HEATER

CROSS REFERENCE TO RELATED APPLICATION

[0001] This PCT Patent Application claims the benefit of U.S. Provisional Patent Application Serial Number 62/471,542 entitled "Dynamic Space Heater", filed March 15, 2017, the entire disclosure of the application being considered part of the disclosure of this application, and hereby incorporated by reference.

BACKGROUND

1. Field of the Invention

[0002] A dynamic space heater for detecting one or more targets and projecting radiant heat thereupon.

2. Discussion

[0003] Several different types of heating are available today for heating occupied or unoccupied spaces such as vehicle interiors and building spaces such as in homes and commercial real estate. Each type of heating and associated energy source has its advantages and disadvantages, which may vary depending on the energy source or sources available, geographic location and climate.

[0004] As for vehicular applications, energy sources for heating have traditionally relied upon the heat generated by the internal combustion engine. Such energy sources have drawbacks in that they take time to warm-up and are not always available, especially with modern electric and hybrid vehicles. Electric resistive heating has been used to replace or to supplement such internal combustion heat, and is generally limited to very specific applications and surfaces such as seat heaters. Electric resistive heating in vehicular applications has its own set of drawbacks, particularly including added weight, and the fact that they must generally be embedded in the surface to be heated.

[0005] As for building spaces, forced air heating using a natural gas energy source is the most common and most economical throughout much of North America, particularly in the northern climates where heating is required most often. However, forced air heating using a natural gas energy source has its drawbacks. It requires expensive infrastructure such as a furnace and ductwork, which must typically be integrated into a building's construction. It is slow to change in heat setting, and is not easily or quickly adjustable, for example in response to a person entering or leaving a particular space. Furthermore, because hot air rises, forced air heating generally does not provide an ideal heating profile for human comfort, with higher air temperature of approximately 70 Deg. F. at about 0.3 ft. above the ground and a gradually decreasing temperature to a lower air temperature of about 67 Deg. F. at 6.0 ft. above the ground.

[0006] Traditionally, other energy sources have been employed to compensate for the shortfalls of forced air heating using natural gas. Such other energy sources include, for example radiant panels, such as those sold under the trade name Ducoterra Solaray II, shown on the website http://www.heatinggreen.com/radiant-heating-panels/, and which may use electrical energy. Electrical radiant heating alone, or in combination with forced air heat, allows for a space which can be quickly adjusted in temperature and which may provide for a heating profile closer to the ideal for human comfort. Electrical radiant heating in combination with a natural gas furnace can allow for the temperature setting of the furnace to be lowered by approximately 5 deg. F, depending on a number of factors. However, electrical radiant heating has drawbacks of its own. A principal drawback is that the cost of electrical space heating is generally approximately 4 times more than the cost to heat with natural gas.

[0007] There exists a need for electrical radiant heating which can narrowly direct heat upon persons and other targets, and therefore providing the advantages of electrical radiant heating without the disadvantages of traditional electrical heating devices. There also exists a need for electrical radiant heating which may be used in vehicular applications where weight and power consumption of such a system must be optimized, and which can remotely heat surfaces which are historically difficult to heat. A dynamic IR heater according to the present invention allows for such a directed heating, which provides all of the advantages of electrical space heating, including fast response and control, and direct heating of a person, allowing for a heating profile closer to the ideal for human comfort, and thereby resulting in higher comfort and lower energy costs.

SUMMARY

[0008] The invention provides for a dynamic infrared (IR) heater for detecting a target and for projecting IR radiation upon the target.

[0009] The invention in its broadest aspect therefore provides for a dynamic IR heater for heating a target using IR radiation projected thereupon using a heating profile of the target which is dynamically adjustable, meaning the surface area and corresponding radiant power setting can be quickly and automatically changed based on the position of the target as detected by a camera, which captures an image from a field of view. The system uses a light source including an array of controllable point sources, each having a corresponding location and each being controllable to generate an adjustable amount of IR radiation. A controller is in communication with the camera, configured to receive the captured image, and to detect a

target, and to determine a heating profile of the target, and to generate a distribution map, which is used to cause each of the controllable light sources to generate IR radiation and to direct the IR radiation substantially toward the target.

[0010] The dynamic IR heater includes only passive devices between the light source and the target. In other words, the dynamic IR heater does not include any active devices, such as a spatial light modulator (SLM), between the light source and the target.

[0011] In an example installation, a system of the present invention may be used in a 15 ft. x 15 ft. room (225 square ft.), which may otherwise use 1500W (6.7 W / square ft.) of supplemental radiant heating panels, allowing a furnace temperature setting for that room to be lowered by approximately 5 deg. F. Assuming a human body has an effective radiation area of 1.24 m^2, or 13.3 square ft., the subject dynamic IR heater system would require approximately 89W per person, or approximately 17 times less power than would be required for a traditional supplemental radiant heating system which heats the entire room instead of the persons directly.

[0012] According to an aspect, the dynamic IR heater according to the present invention may be used to supplement traditional space heating, and may provide for a savings of approximately 2.2 times when compared with natural gas heating in Ontario based on the following assumptions: first, it is approximately 17 times more efficient to heat a person directly, rather than heating the entire room; second, electricity is approximately 4 times more expensive per unit energy than natural gas; third, a natural gas furnace may be up to approximately 95% efficient, while a dynamic IR heater according to the present invention may be approximately 50% efficient at transmitting heat to a person.

BRIEF DESCRIPTION OF THE DRAWINGS

[0013] Other advantages of the present invention will be readily appreciated, as the same becomes better understood by reference to the following detailed description when considered in connection with the accompanying drawings wherein:

[0014] FIG. 1 is an overview diagram of a dynamic IR heater in operation according to an embodiment of the present disclosure;

[0015] FIG. 2 is an overview diagram of a dynamic IR heater in operation according to an alternative embodiment of the present disclosure;

[0016] FIG. 3 is an overview diagram of a dynamic IR heater in operation according to an aspect of the embodiment of Figure 2;

[0017] FIG. 4 is a schematic diagram of liquid crystal cells within a spatial light modulator redirecting IR radiation;

[0018] FIG. 5 is a schematic overview diagram of a dynamic IR heater according to an aspect of the present disclosure;

[0019] FIG. 6A is a schematic diagram of a dynamic IR heater according to another aspect of the present disclosure;

[0020] FIG. 6B is a schematic diagram of a front view of a laser diode array;

[0021] FIG. 7 is a schematic diagram of a dynamic IR heater according to another aspect of the present disclosure;

[0022] FIG. 8 is a schematic diagram of a dynamic IR heater according to another aspect of the present disclosure;

[0023] FIG. 9 is a block diagram of a dynamic IR heater according to another aspect of the present disclosure;

[0024] FIG. 10A is a flow chart of a method of a dynamic IR heater according to the present disclosure;

[0025] FIG. 10B is a continuation of the flow chart of FIG. 10A;

[0026] FIG. 10C is a continuation of the flow chart of FIG. 10B; and

[0027] FIG. 10D is a continuation of the flow chart of FIG. 10C.

DETAILED DESCRIPTION

[0028] Referring to the Figures, wherein like numerals indicate corresponding parts throughout the several views, a dynamic infrared (IR) heater **10** is generally shown for projecting infrared radiation upon a plurality of different targets **12** corresponding to individual persons which may change in position, orientation, or presence, is generally shown. The dynamic IR heater **10** is also referred to as a system for dynamic IR heating **10**, or as "the system" **10**.

[0029] The dynamic IR heater **10** includes a camera **20** capturing an image from a field of view **22** and configured to generate a first signal **24** corresponding to the captured image. The camera **20** may be, for instance, a traditional digital video camera including an image sensor for converting visible light into an electrical signal. The camera **20** may be configured to detect one or more wavelengths of light within the visible and/or invisible spectrum. The camera **20** may be sensitive to IR light, which may allow the dynamic IR heater **10** to determine a temperature map of the temperature of surfaces throughout the field of view **22**, including the temperature of the targets **12**, such as people within a room. The camera **20** may be separate from other components of the dynamic IR heater **10**. For example, the dynamic IR heater **10** may receive the first signal **24** from the camera **20** of a third-party device or system, such as from a home security system and/or from a networked monitoring system, such as those from Nest or Dropcam. The first signal **24** may be communicated from a remote source, such as from a remote server operated by an operator of the home security system. For example, the camera **20** may be used for security purposes and may also be available for use by the dynamic IR heater **10**.

[0030] The dynamic IR heater **10** includes a light source **26** generating IR radiation including a plurality of wavefronts **28**. The light source **26** may include, for example, a laser, one or more light emitting diodes (LEDs), or another suitable source of IR radiation. A source lens or first lens **29** may be provided to direct the IR radiation from the light source **26** along a first path **30** perpendicular to the wavefronts **28**.

[0031] As shown in the embodiments of FIGS. 5, 7, and 8, the dynamic IR heater **10** may also include a spatial light modulator (SLM) **32**, such as a liquid crystal on silicon (LCoS) device including a plurality of liquid crystal cells **34** each having a refractive index **"n"** which is controllably variable to direct the wavefronts **28** in a second direction **36** and to thereby redistribute the IR radiation from the light source **26** into a redistributed light path **38** according to an index of refraction map **40** applied to the spatial light modulator **32**. In other words, the SLM **32** may function as a micro-display, and the index of refraction map **40** may function as the image being shown thereupon. In this way, the cells **34** of the SLM **32** may work in combination to redistribute the IR radiation from the light source **26** which may be directed at or through the SLM **32**. The SLM **32** may be of a type used commercially in projectors, such as, for example, a 1920x1080p device having a two-dimensional array of liquid crystal cells **34** arranged in rows of 1920 cells **34** and columns of 1080 cells **34**.

[0032] The dynamic IR heater **10** also includes a controller **42**, which may also be called a processor or a driver, in communication with the camera **20** for receiving the first signal **24** and for determining a heating profile **44** of each of the targets **12** including a surface area to be heated and a corresponding radiant power setting to be applied to the surface area to be heated by comparing the captured image to a predetermined characteristic, which may be, for example, a signature of an individual person. The predetermined characteristic may include multiple attributes including one or more shapes, the type and degree of movement of the shapes, and connection to other identifying features such as human features (e.g., a face and/or arms/hands, etc.). The surface area to be heated may be a two-dimensional or a three-dimensional surface in three-dimensional space. The **42** may also use the temperature map of the temperature of surfaces within the field of view in determining the heating profile **44**. This may prevent, for example, the dynamic IR heater **10** from over-heating regions or items that are already relatively warm from other sources of heat such as a steam radiator or from sunlight coming through a window. In another example, the heating profile **44** may be altered depending on the temperature of a person's skin. This can prevent the dynamic IR heater **10** from over-exposing a person to IR heating.

[0033] The controller **42** may also consider other factors and/or characteristics as determined by the camera **20**, such as the type and/or color of the surface to be heated, which may impact the degree of heating that may result from a given amount of IR radiation. The controller **42** may then then generate the index of refraction map **40** corresponding to the heating profile **44**. For example, the system **10** may detect and identify two different people as targets **12**, with one person wearing lightly colored clothing, and the other wearing dark clothing. The dynamic IR heater **10** may therefore automatically provide a lower radiant power setting to the person in the dark colored clothing based on a predetermined formulation such that the two persons receive about the same amount of heat at an initial radiant power setting.

[0034] The controller **42** may be a general purpose computer or a controller specifically configured to operate the dynamic IR heater **10**. The controller **42** may include one or more non-transitory computer-readable storage media **45**, such as RAM, ROM, magnetic, optical, and/or electronic storage memory, storing computer-executable instructions that, when executed by one or more processors **43**, instruct a computing device to perform various actions. The controller **42** may be located remotely from the camera **20** and the light source **26**. For example, the controller **42** may, in whole or in part, be located in one or more remote servers that are in communication with other components of the dynamic IR heater **10** via one or more communications channels, such as the Internet. This configuration may allow the first signal **24** from the camera **20**, and possibly other data, such as configuration settings, to be uploaded to the remote server, where the index of refraction map **40** is generated. The dynamic IR heater **10** may, therefore, be provided as a unit comprising at least the camera **20** and the light source **26**, along with a data connection, such as a wired or wireless network connection for communication with the controller **42**, which is located remotely.

[0035] The controller **42** may generate a second signal corresponding to the index of refraction map **40** and be in communication with the spatial light modulator **32** for transmitting the second signal to the spatial light modulator **32**. A projector lens or second lens **46** may be disposed in a path after the spatial light modulator **32** for focusing the redistributed light path **38** of the IR radiation onto the heating profile **44** of each of the targets **12**.

[0036] According to an aspect, the controller **42** may be configured to detect a control gesture corresponding to one of the targets **12** in the first signal **24** and to modify the heating profile **44** of the one of the targets **12** in response to the control gesture. Such gestures could allow, for example, each person to individually increase or lower the radiant power setting, or the amount of power directed at the corresponding one of the targets **12**. In other words, a person could control the heating provided by the system **10** to himself or herself specifically, or to all persons and/or other targets **12** being heated by the system **10**.

[0037] In accordance with an aspect of the invention, and as shown in FIG. 1, the system **10** of the subject invention may be used for heating an interior building space, such as a room of a home or a commercial space. The targets **12** may be individual persons within that space. The heating profile **44** may be determined based upon one or more personal settings associated with the person such as, for example, whether or not to heat the face of the person, whether or not to heat bare skin of the person, and whether or not to heat areas covered by clothing or other coverings such as blankets.

[0038] The system **10** may also be used in other fixed locations including covered or uncovered spaces, such as, for example, pavilions, patios, walkways, or any other fixed area.

[0039] In accordance with another aspect of the invention, and as shown in FIGS. 2-3, the system **10** may be used in the interior space of a vehicle. As shown in FIG. 2, the system **10** may be used to heat one or more targets **12**, which correspond to surfaces which a person may later contact. Those targets **12** may include, for example, seats, gearshift knobs or levers, and one or more portions of a steering wheel. The targets **12** and their corresponding heating profiles **44** may be adjusted automatically based on their actual positions and/or other characteristics as determined by the camera **20**, such as the type and/or color of the surface to be heated, which may impact the degree of heating that results from a given amount of IR radiation. According to an aspect and as shown in Fig. 3, the system **10** may be used to heat different targets **12**, which may include body parts of a person located inside the vehicle. The system **10** may be configured to detect exposed skin and to heat only those areas. The system

10 may be configured to automatically track and avoid heating sensitive areas, such as a person's eyes. The system may automatically switch between different types of targets **12**, such as those shown in FIG. 2 and 3, depending on the presence of a person within the vehicle.

[0040] According to a further aspect, the system **10** may be used to heat other targets **12** on a vehicle, which may include heating surfaces such as windows and/or mirrors to melt snow or ice or to evaporate dew or other condensation therefrom. The system **10** may detect the presence of moisture, snow, or ice and may be configured to automatically activate in response thereto. The system **10** may be used in conjunction with or in place of traditional defroster or defogger devices or HVAC system operating modes. In other words, the system **10**, may provide targeted heating to the windows and/or mirrors when the HVAC system of a vehicle is placed in a defrost mode and/or when a rear window defroster is activated.

[0041] Two or more dynamic IR heaters **10** to may be combined to heat targets **12** from different directions. Furthermore, a dynamic IR heater **10** may use two or more cameras **20** to more accurately identify targets **12** in three-dimensional space and to generate a corresponding three-dimensional heating profile **44**.

[0042] According to an aspect and as shown in FIGS. 6A and 6B, the light source **26** may include a point source array **200** comprising a plurality of individual point sources, which may be, for example, laser diodes, and which may be controlled on or off individually or in groups according to a projection map in order to selectively illuminate one or more regions and thereby project IR radiation onto the target **12**. In other words, the entire projectable area may be subdivided into a plurality of regions, each having an angular width in two dimensions, and each corresponding to a controllable point source or group of point sources such that the region may be selectively illuminated such as with IR radiation, based on the detection of a target **12**

in that region. The point sources may be rapidly cycled on/off, such as with a PWM signal, in order to adjust the intensity of the IR radiation being projected upon the illuminated region. As shown in Fig. 6A, the point source array **200** may be a laser diode array, comprising a plurality of individually controlled laser diodes. Micro-lenses **202** may be provided over individual point sources or groups of point sources to focus or change the angle of the light beams from the point sources. A projector lens **46** may be used to spread the light beam from the point sources to be able reach the entire operating area where targets **12** may be present, such as the entire room. Other devices for spreading out the beams may also be used such as, for example, a parabolic mirror or a combination of multiple lenses and/or mirrors. Figure 6B shows an example of a point source array **200** from a front view showing one possible arrangement pattern of individual point sources, which may be laser diodes.

[0043] In order to effectively utilize the point source array **200** to direct the IR radiation substantially toward the targets **12**, the controller **42** is configured to generate a distribution map, which specifies the relative intensity for each of the individual point sources within the point source array **200**, in accordance with the locations of those individual point sources. By illuminating the point source array **200** in accordance with the distribution map, the IR radiation may be directed substantially toward the target **12** and not in directions away from the **12**. This may provide for an energy savings over a wide-beam light source, and/or allow more IR radiation to be directed directly toward the targets **12**.

[0044] According to an aspect and as shown in the embodiment of FIGS. 6A and 6B, the dynamic IR heater **10** may include only passive devices between the light source **26** and the target **12**. Passive devices include, for example, lenses, mirrors, and filters. In other words, the dynamic IR heater **10** may include no active devices, such as an SLM **32**, directing or redistributing the IR radiation between the light source **26** and the target **12**.

[0045] Alternatively, the dynamic IR heater **10** may include both the point source array **200**, together with an SLM **32**. This is illustrated in the embodiment of FIG. 7, in which the dynamic IR heater **10** includes a point source array **200**, together with a plurality of controllable micromirrors **204** which may each be movable in 2-axes. The micromirrors **204** may operate in combination to focus light to create any pattern desired, such as projecting the heating profile **44** upon a target **12**. The use of controllable micromirrors **204** may allow an array with a fewer number of individual lasers as would otherwise be required to project the heating profile **44** upon the target **12** with sufficient resolution. A liquid cooling channel **206** may be provided adjacent the light source **26** for circulation of a liquid coolant to remove waste heat created by the laser diodes.

[0046] According to an aspect and as shown in FIG. 8, a dynamic IR heater **10** may use a plurality of controllable micromirrors **204** which may each be movable in 2-axes to controllably focus light to create any pattern desired, such as projecting the heating profile **44** upon the target **12**, with the light supplied by a single, wide beam, such as a type which may be provided by a single light source **26** generating IR radiation. The light source **26** may include, for example, a laser, one or more light emitting diodes (LEDs), or another suitable source of IR radiation.

[0047] As shown in FIG. 9, the controller **42** of the dynamic IR heater **10** includes a target recognition module **48**, and a prediction module **50**, a billing module **52**, and a power level control **54**. As also shown in FIG. 9, the controller **42** takes the first signal **24** from the camera **20** as an input and sends the index of refraction map **40** to the spatial light modulator

32. The modules **48, 50, 50, 52** may be software modules, or sequences of instructions present within the storage memory **45** of the controller **42** for execution by the processor **43** order to perform specific actions described in this disclosure. The storage memory **45** of the controller **42** also includes a settings storage region **56** holding a plurality of personal settings **57**, which may each be associated with specific persons.

[0048] According to an aspect, a single target **12** may include two or more surfaces spaced apart from one another. The system **10** may associate those surfaces with a single target **12** to coordinate heating between them. The system **10** may track and store a plurality of personal settings **57**, which may include, for example, a power level setting, which may be applied to two or more separate surfaces of a target **12**. For example, the system **10** may be configured to heat the exposed skin regions, such as the hands and face of a target **12** that is an individual person.

[0049] According to a further aspect, the target **12** may be a person, and the heating profile **44** is determined based upon one or more of the personal settings **57** associated with the person. The personal settings may include, for example, power level, whether or not to heat the face of the person, whether or not to heat bare skin of the person, and whether or not to heat areas covered by clothing or other coverings such as blankets.

[0050] According to another aspect, the target recognition module **48**, is configured to recognize a specific person within the image captured by the camera **20**, and to adjust the heating profile **44** based on the target **12** being a specific person. The target recognition module **48** may use, for example, preset gestures, allowing people to identify themselves to the dynamic IR heater as the specific person. The target recognition module **48** may automatically identify specific persons by characteristics of the specific persons such as habits, clothing, height, weight, voice, and/or facial recognition, or a combination of characteristics. Habits used to identify a specific person may include, for example, how they move, where they go or sit, time they are present in specific locations. The target recognition module **48** may also connect to other systems or services, such as an alarm system, home automation, smart thermostat, or smart speaker for information regarding the location and/or identity of a specific person.

[0051] According to an aspect, the target recognition module **48** may be located, at least in part, remotely from the controller **42**, with the controller **42** being configured to communicate at least a portion of the image from the camera **20** to the target recognition module **48** and to receive information regarding the specific person within the image from the target recognition module **48**. For example, the controller **42** may transmit the image, or a portion thereof containing the face of a person to be identified, to a facial recognition service, which may then identify the specific person and report the identity of the specific person back to the controller **42**.

[0052] According to a further aspect, the dynamic IR heater **10** includes the prediction module **50** which is configured to determine a plurality of settings for heating a specific person including at least a radiant power setting. In order to determine those settings, the predication module **50** uses a plurality of inputs including prior settings used by the specific person, ambient temperature and/or humidity, time of year, weather (e.g. whether it is sunny or cloudy), type of clothing worn by the specific person, percent of exposed bare skin on the specific person, and the type of footwear worn by the specific person, such as shoes, socks, or bare feet.

[0053] According to a further aspect, the dynamic IR heater **10** includes the billing module **52**, which is configured to charge an account associated with the specific person for heating and/or to authorize use of the dynamic IR heater **10** based on a preexisting relationship with the specific person. For example, a specific person may authorize payment for heating at a location such as an outdoor bar patio or other public or private spaces. The billing module **52** may enable use of the dynamic IR heater **10** for specific persons based on a preexisting relationship, such as, for example, members of a club or for specific persons staying at a hotel where the dynamic IR heater **10** is located. Use of the dynamic IR heater **10** may be tied to a specific person based upon a type of ticket purchased for an event, such as a sporting event or other performance at the location where the dynamic IR heater **10** is located.

[0054] According to another aspect, and as illustrated on FIG. 9, the personal settings **57** associated with one or more specific persons may be stored in a cloud storage location **58** remote from the controller **42**, and in communication therewith via a network such as the internet. In practice, the controller **42** may send a request message **59** to the cloud storage location, requesting the personal settings associated with the specific person identified by the controller **42**. Such cloud storage may include accounts associated with the specific person, which may provide portability, allowing one set of personal settings **57** to be used by two or more different dynamic IR heaters **10** at different locations.

[0055] According to a further aspect, the dynamic IR heater **10** includes the power level control **54**, which is configured to adjust the power level of the IR radiation being projected upon one or more of the targets **12**. The power level control **54** may be responsive to one or more different types of control inputs such as gestures by persons within the field of view of the camera **20**, voice commands, or control through a user interface such as an app on a mobile device. Voice commands may be interpreted and communicated via a voice control system such as Siri by Apple, Alexa by Amazon, or Google Assistant. The power level control **54** may be associated with an online account or profile such as is discussed above with reference to the cloud storage location **58**.

[0056] As shown in the flow chart of FIGS. 10A – 10B, the subject invention also includes a method **100** of operating a dynamic IR heater **10** to project IR radiation upon one or more different targets **12** which may change in position, orientation, or presence. In other words, the dynamic IR heater **10** may automatically detect the presence and position/orientation of one or more different targets **12** who may be individual persons, and may then provide radiant heating to each of the targets **12** detected.

[0057] The method **100** includes capturing, by a camera **20**, an image from a field of view **22** at step **102**. The camera **20** may capture a video or one or more still images, and the image is preferably a digital image. The camera **20** may be fixed to a specific location, or it may be moveable, such as where the dynamic IR heater **10** is a temporary installation. This step **102** may be performed by combining two or more different images from different cameras **20**. The image from the field of view **22** may include a temperature map, for example, where the camera **20** is sensitive to IR radiation.

[0058] The method **100** also includes generating by the camera **20** a first signal **24** corresponding to the captured image at step **104**. The first signal **24** is preferably a digital signal, and may be a packet, or digital file having a defined beginning and end. Alternatively, the first signal **24** may be a stream of data having no defined beginning or end.

[0059] The method **100** also includes transmitting, by the camera **20**, the first signal **24** to a controller **42** at step **106**. This step **106** may be accomplished using a wired or a wireless transmission means such as a Wi-Fi connection, particularly where the controller **42** is located remotely from other components of the dynamic IR heater **10**.

[0060] The method **100** also includes receiving, by the controller **42**, the first signal **24** corresponding to the image captured by the camera **20** at step **108**.

[0061] The method **100** also includes detecting a target **12** by the controller **42** by comparing the captured image to a predetermined characteristic at step **110**. The predetermined characteristic may correspond to the target **12** being one or more regions of a specific person. The predetermined characteristic may also be the target **12** being one or more specific surfaces to be heated such as a steering wheel, gear shifter, and/or seat within a vehicle.

[0062] The method **100** also includes determining the presence, position, and geometry of the target **12** within the field of view **22** at step **112**. This step **112** allows for a more precise and even heating of the target **12**. For example, a target **12** including a surface oriented at an oblique angle to the light source **26** and/or spaced further away therefrom, may require a higher amount of IR radiation to be projected thereupon to be heated an equivalent amount as another surface that is oriented perpendicularly and/or is located closer thereto.

[0063] The method **100** may proceed with generating by the controller **42** a heating profile **44** for the target **12** at step **114**. The heating profile **44** may define the intensity of IR radiation to be projected, then angular region in two or three-dimensional space where the IR radiation is to be directed, and/or the distance to the target **12** where the IR radiation is to be focused.

[0064] The method **100** also includes generating an index of refraction map **40** corresponding to the heating profile **24** of the target **12** at step **116**.

[0065] The method **100** also includes transmitting by the controller **42** the index of refraction map **40** to a spatial light modulator **32** at step **118**.

[0066] The method **100** proceeds with generating IR radiation along a first path by an IR light source **26** at step **120**. As described above, this may include energizing one or more light sources **26**, which may include a laser, one or more light emitting diodes (LEDs), or another suitable source of IR radiation. The amount of IR radiation generated may be varied by the controller **42** using, for example, pulse width modulation to control the one or more light sources **26**.

[0067] The method **100** also includes directing the IR radiation in the first path **30** onto the spatial light modulator **32** by a first lens **29** at step **122**. This is illustrated in the diagram of FIG. 5, and allows the spatial light modulator **32** to be evenly illuminated. It also allows the dynamic IR heater **10** to be integrated into a compact package, with the spatial light modulator **32** being located relatively close to the IR light source **26**.

[0068] The method **100** also includes redistributing the IR radiation by the spatial light modulator **32** to a redistributed light path **38** according to the index of refraction map **40** at step **124**.

[0069] The method **100** may also include focusing and directing the redistributed light path **38** upon all of the targets **12** by a second lens **46** at step **126**.

[0070] The method **100** also includes heating the target with the redistributed light path **38** of IR radiation at step **128**.

[0071] According to an aspect, the method **100** may include detecting by the controller **42** a control gesture corresponding to one of the targets **12** in the first signal **24** at step of **130**.

[0072] The method **100** may also include modifying, by the controller **42**, the heating profile **44** of the one of the targets **12** in response to the control gesture at step **132**. For example, the control gesture may allow an individual person to control the radiant power setting directed toward that person individually without impacting the heating of others in who are also being heated by the dynamic IR heater **10** at the same time.

[0073] The method **100** may also include projecting the IR radiation directly from the light source **26** to the target **12** without directing or redistributing the IR radiation by any active devices therebetween at step **133**. In other words, the dynamic IR heater **10** may include no active devices, such as an SLM **32**, directing or redistributing the IR radiation between the light source **26** and the target **12**. The dynamic IR heater **10** may include only passive devices between the light source **26** and the target **12**. Passive devices include, for example, lenses, mirrors, and filters. An example dynamic IR heater **10** practicing this method step **133** is shown in the embodiment of FIGS. 6A and 6B.

[0074] The method **100** may include recognizing, by the target recognition module **48**, a specific person within the image by comparing characteristics of the image with predetermined characteristics associated with one or more individual persons at step **134**. This step is preferably performed by a target recognition module **48**. The predetermined characteristics may include, for example, habits, clothing, height, weight, voice, and/or facial features, or a combination of characteristics. Habits used to identify a specific person may include, for example, how they move, where they go or sit, time they are present in specific locations.

[0075] Step **134** may include identifying, by the target recognition module **48**, a face within the image at sub-step **134A**. For example, target recognition module **48** may recognize the general shape of a face including eyes, nose, mouth, chin, and/or forehead, and may designate the corresponding region of the image as being a person's face. Step **134** may also include identifying, facial features of the face at sub-step **134B**, and comparing the facial features of the face with the facial features of one or more individual persons to identify the specific person within the image at sub-step **134C**. The facial features may include, for example, the general shape of the face, the proportions between the eyes, nose, chin, and cheekbones. These facial features may remain generally unchanged as a person ages, and may be compensated to account for the face being oriented differently from the camera **20**. In short, the target recognition module **48** may recognize the specific person by the predetermined characteristics being aspects of their face. The target recognition module **48** may be located, in whole or in part, remotely from the controller **42**, and may be implemented, for example using a distributed computing service, such as AWS by Amazon or Azure by Microsoft.

[0076] The method **100** may include adjusting, by a power level control **54**, a level of heating applied to the target **12** in accordance with a radiant power setting at step **136**. The power level setting may be associated with a specific target, such as a specific person. The power level setting may be set using gestures, voice commands, control through an app. or other user interface. This step **136** may also allow the user to adjust the boundaries, or physical size of the target **12** to be heated. The user may be able to modify the size and other boundaries of an area associated with the target **12** by the controller **42**. For example, in heating a person covered by a blanket, the dynamic IR heater **10** may default to heating the entire blanket. The user may then adjust the boundaries of the target **12**, using a computer or an app. on a mobile device such as a smartphone or tablet, to designate a more specific area to be heated, such as the lower body area, but not the upper body area.

[0077] The method **100** may include storing, by the controller **42**, one or more personal settings **57** at step **138**. The personal settings **57** may be associated with a specific person. The personal settings **57** may include, for example, whether or not to heat the face of the specific person, whether or not to heat bare skin of the specific person, and whether or not to heat areas covered by clothing or other coverings such as blankets.

[0078] The method **100** may also include using, by the controller **42**, the one or more personal settings **57** in generating the heating profile **44** for the target **12** at step **140**.

[0079] The method **100** may include transmitting, by the controller **42**, a request message **59**, requesting the one or more personal settings **57** stored in a cloud storage location **58** remote from the controller at step **142**. The method **100** may also include receiving, by the controller **42**, the one or more personal settings **57** from the cloud storage location **58**. These steps **142** – **144** are illustrated in the block diagram of FIG. 9, and provides several advantages, such as allowing the personal settings **57** associated with a specific person to be portable and usable with two or more different dynamic IR heaters **10**, which may be at different locations.

[0080] The method **100** may include authorizing, by a billing module **52**, the specific person for heating at step **146** prior to performing step **128**, heating the target **12** with IR radiation. The authorization may include, for example, determining that the specific person has pre-paid for the heating service or is otherwise entitled to receive it, for example, by having a predetermined qualification such as membership or paid admission to the area where the dynamic IR heater **10** is located. The billing module **52** may also change an account, such as a credit card, of the specific person ordering the heating service.

[0081] The method **100** may include generating, by the controller, a distribution map at step **150**. The distribution map define the relative intensity of a plurality of controllable point sources within the light source **26**.

[0082] The method **100** may include transmitting, by the controller, the distribution map to the light source **26** at step **152**.

[0083] The method may further include generating, by each of the plurality of controllable point sources within the light source **26**, IR radiation in accordance with the heating profile for the target, and the position of each of the controllable point sources within the light source at step **154** to direct the IR radiation substantially toward the target. Steps **150** through **154** are applicable where the dynamic IR heater **10** includes a point source array **200** comprising a plurality of individual point sources, such as in the embodiments of FIGS. 6A, and 7.

[0084] The system, methods and/or processes described above, and steps thereof, may be realized in hardware, software or any combination of hardware and software suitable for a particular application. The hardware may include a general purpose computer and/or dedicated computing device or specific computing device or particular aspect or component of a specific computing device. The processes may be realized in one or more microprocessors, microcontrollers, embedded microcontrollers, programmable digital signal processors or other programmable device, along with internal and/or external memory. The processes may also, or alternatively, be embodied in an application specific integrated circuit, a programmable gate array, programmable array logic, or any other device or combination of devices that may be configured to process electronic signals. It will further be appreciated that one or more of the processes may be realized as a computer executable code capable of being executed on a machine readable medium.

[0085] The computer executable code may be created using a structured programming language such as C, an object oriented programming language such as C++, or any other high-level or low-level programming language (including assembly languages, hardware description languages, and database programming languages and technologies) that may be stored, compiled or interpreted to run on one of the above devices, as well as heterogeneous combinations of processors, processor architectures, or combinations of different hardware and software, or any other machine capable of executing program instructions.

[0086] Thus, in one aspect, each method described above and combinations thereof may be embodied in computer executable code that, when executing on one or more computing devices, performs the steps thereof. In another aspect, the methods may be embodied in systems that perform the steps thereof, and may be distributed across devices in a number of ways, or all of the functionality may be integrated into a dedicated, standalone device or other hardware. In another aspect, the means for performing the steps associated with the processes described above may include any of the hardware and/or software described above. All such permutations and combinations are intended to fall within the scope of the present disclosure.

[0087] Obviously, many modifications and variations of the present invention are possible in light of the above teachings and may be practiced otherwise than as specifically described while within the scope of the appended claims.

CLAIMS

What is claimed is:

Claim 1. A dynamic IR heater for heating a target using IR radiation and comprising:

a camera capturing an image from a field of view;

a light source including an array of controllable point sources, each having a corresponding location and each being controllable to generate an adjustable amount of IR radiation;

a controller in communication with said camera, configured to receive said captured image and to detect the target and to determine a heating profile of the target, and to generate a distribution map, and in communication with said light source to cause each of said controllable point sources to generate IR radiation in accordance with said distribution map to direct said IR radiation substantially toward the target; and

wherein the dynamic IR heater includes only passive devices between said light source and said target.

Claim 2. The dynamic IR heater of Claim 1 wherein the target includes two or more surfaces spaced apart from one another.

Claim 3. The dynamic IR heater of Claim 1 wherein the target is a specific person;

wherein the controller stores a plurality of personal settings; and

wherein the controller is configured to adjust the heating profile of the target based upon one or more of said plurality of personal settings associated with the specific person.

Claim 4. The dynamic IR heater of Claim 1 further including a target recognition module configured to recognize a specific person within the image; and

wherein the controller is configured to adjust the heating profile of the target based on the target being a specific person.

Claim 5. The dynamic IR heater of Claim 4 wherein the target recognition module is located remotely from the controller;

wherein the controller is configured to communicate at least a portion of the image to the target recognition module; and

wherein the controller is configured to receive information regarding the specific person within the image from the target recognition module.

Claim 6. The dynamic IR heater of Claim 4, further including a prediction module configured to determine a plurality of settings including at least a radiant power setting for heating the specific person based upon one or more of: prior settings used by the specific person, ambient temperature, ambient humidity, time of year, type of clothing worn by the specific person, percent of exposed bare skin of the specific person, and whether the specific person is wearing shoes, socks, or bare feet.

Claim 7. The dynamic IR heater of Claim 4, further including a billing module configured to charge an account associated with the specific person for heating or configured to authorize use of the dynamic IR heater based on a preexisting relationship with the specific person.

Claim 8. A method of operating a dynamic IR heater comprising:

capturing by a camera an image from a field of view;

detecting by the controller a target within the field of view;

generating by the controller a heating profile for the target;

generating a distribution map corresponding to the heating profile of the target;

transmitting by the controller, the distribution map to the light source;

generating, by each of a plurality of controllable point sources within the light source, IR radiation in accordance with the heating profile and in accordance with a position of each of the controllable point sources within the light source to direct the IR radiation substantially toward the target;

projecting the IR radiation directly from the light source to said target without directing or redistributing the IR radiation by any active devices therebetween; and

heating the target with the IR radiation.

Claim 9. The method of operating a dynamic IR heater according to Claim 8 further including:

detecting by the controller a control gesture corresponding to one of the targets in the first signal; and

modifying by the controller the heating profile of the one of the targets in response to said control gesture.

Claim 10. The method of operating a dynamic IR heater according to Claim 8 further including:

identifying, by a target recognition module, a specific person based upon one or more predetermined characteristics of the specific person.

Claim 11. The method of operating a dynamic IR heater according to Claim 10, wherein the predetermined characteristics include facial features of the specific person, and further including:

identifying, by the target recognition module, a face within the image;

identifying facial features of the face; and

comparing the facial features of the face with the facial features of one or more individual persons to identify the specific person within the image.

Claim 12. The method of operating a dynamic IR heater according to Claim 8 further including:

adjusting, by a power level control, a level of heating applied to the target in accordance with a radiant power setting.

Claim 13. The method of operating a dynamic IR heater according to Claim 8 further including:

storing one or more one or more personal settings, and using, by the controller, the one or more personal settings in generating the heating profile for the target.

Claim 14. The method of operating a dynamic IR heater according to Claim 13 wherein the one or more personal settings stored in a cloud storage location remote from the controller, and further including:

transmitting, by the controller, a request message requesting the one or more personal settings stored in the cloud storage location; and

receiving, by the controller, the one or more personal settings from the cloud storage location.

Claim 15. The method of operating a dynamic IR heater according to Claim 10, wherein the target is associated with a specific person, and further including:

authorizing, by a billing module, the specific person for heating, prior to heating the target with the IR radiation.

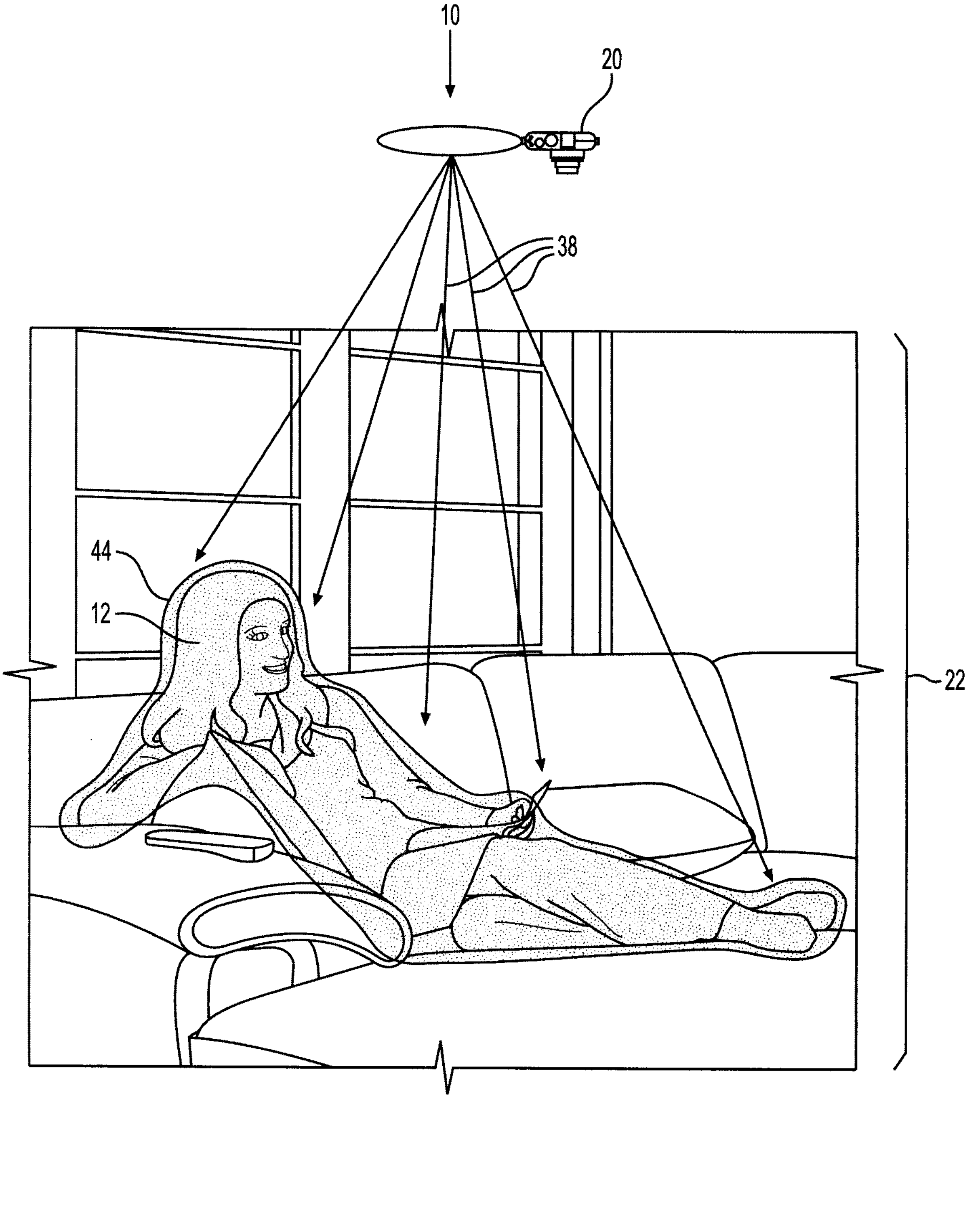

FIG. 1

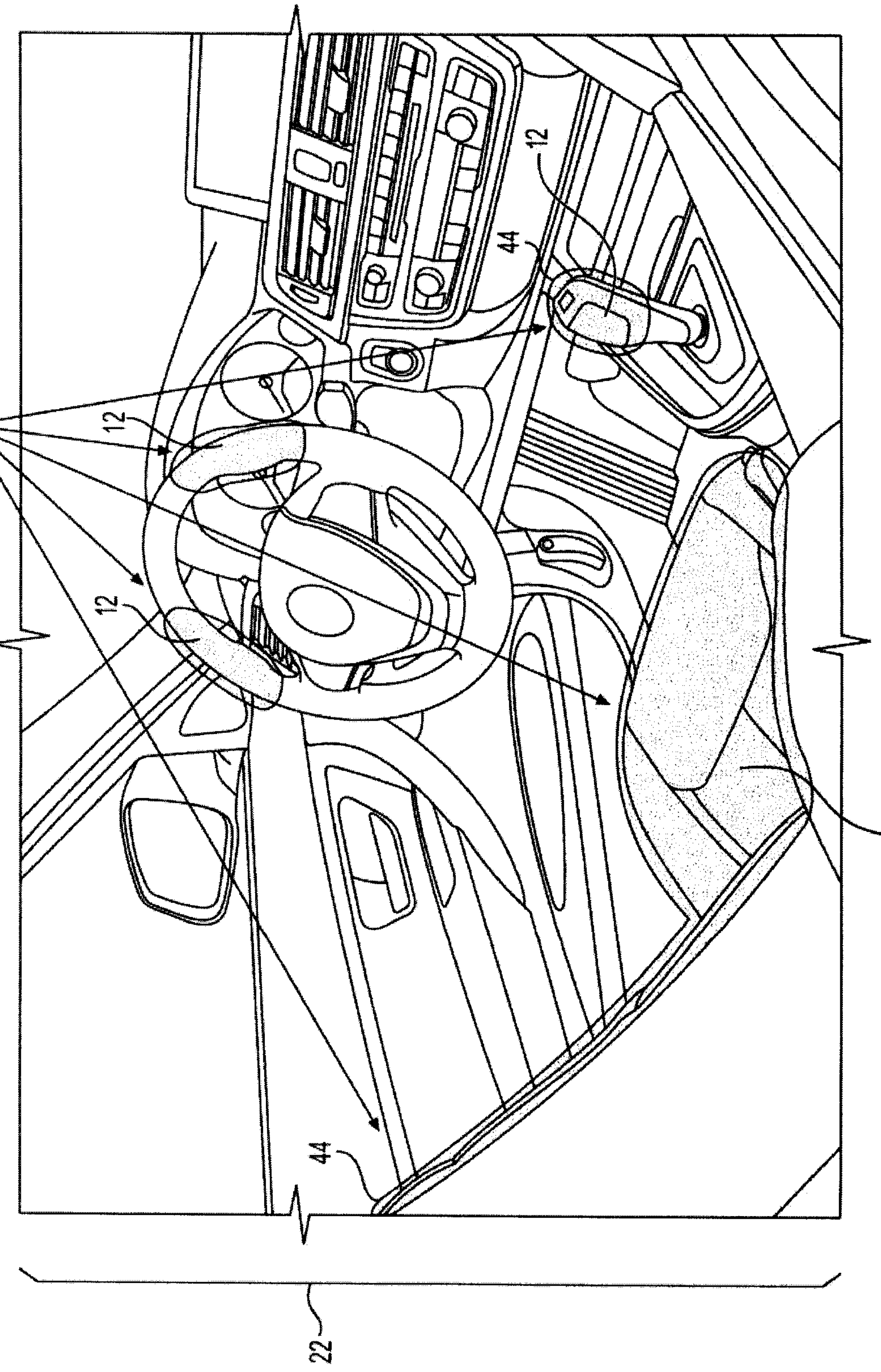

FIG. 2

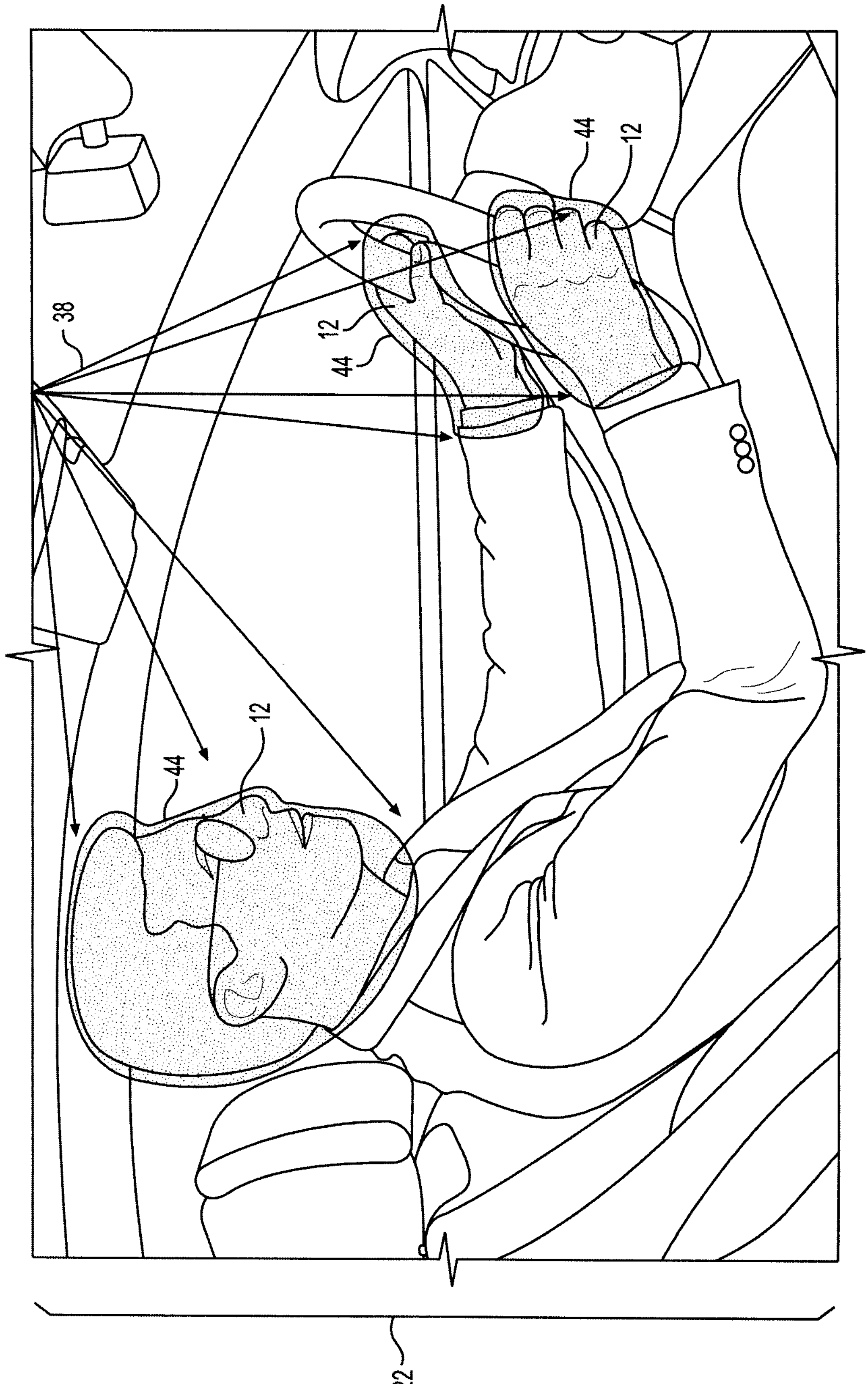

FIG. 3

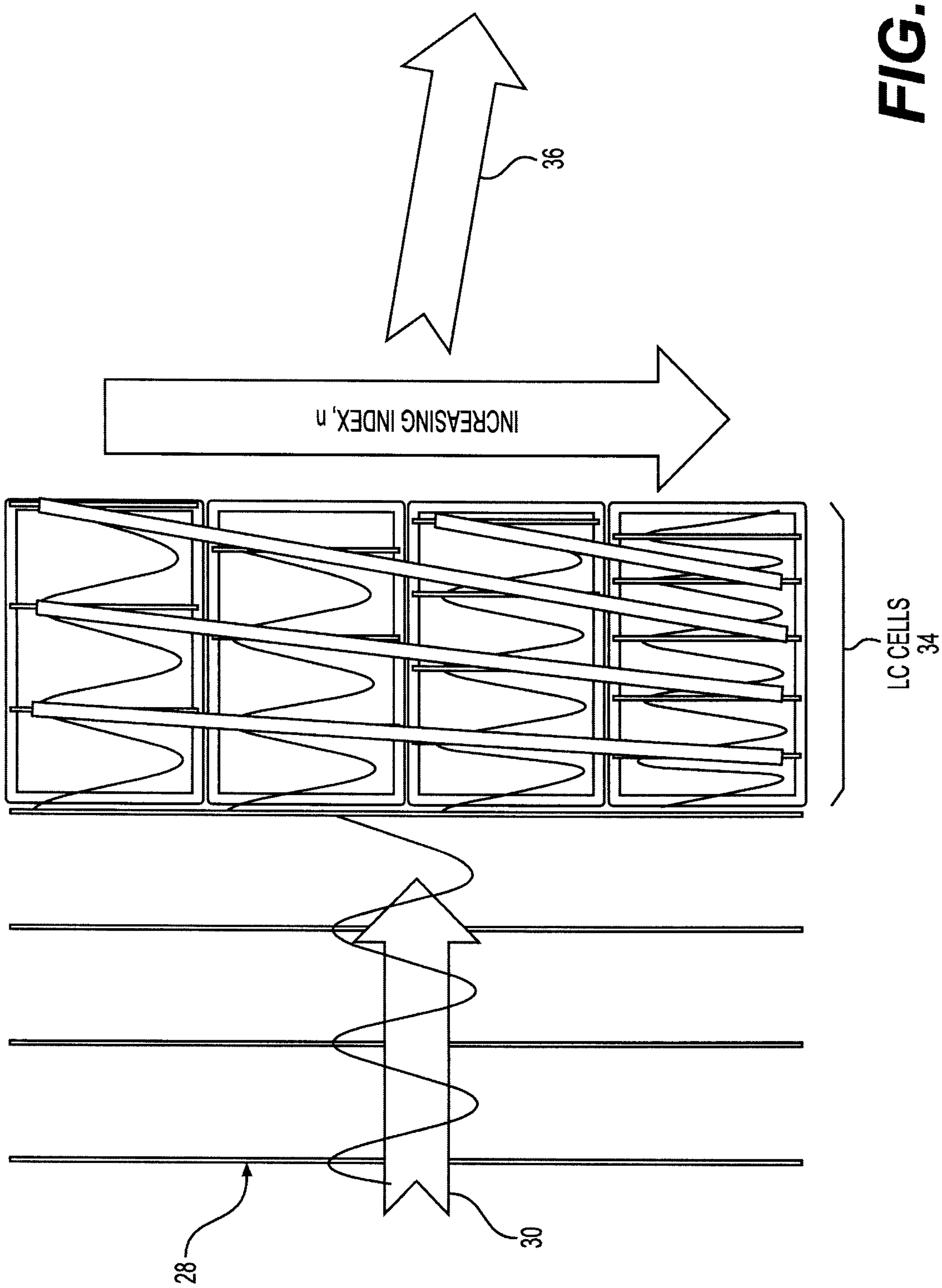

FIG. 4

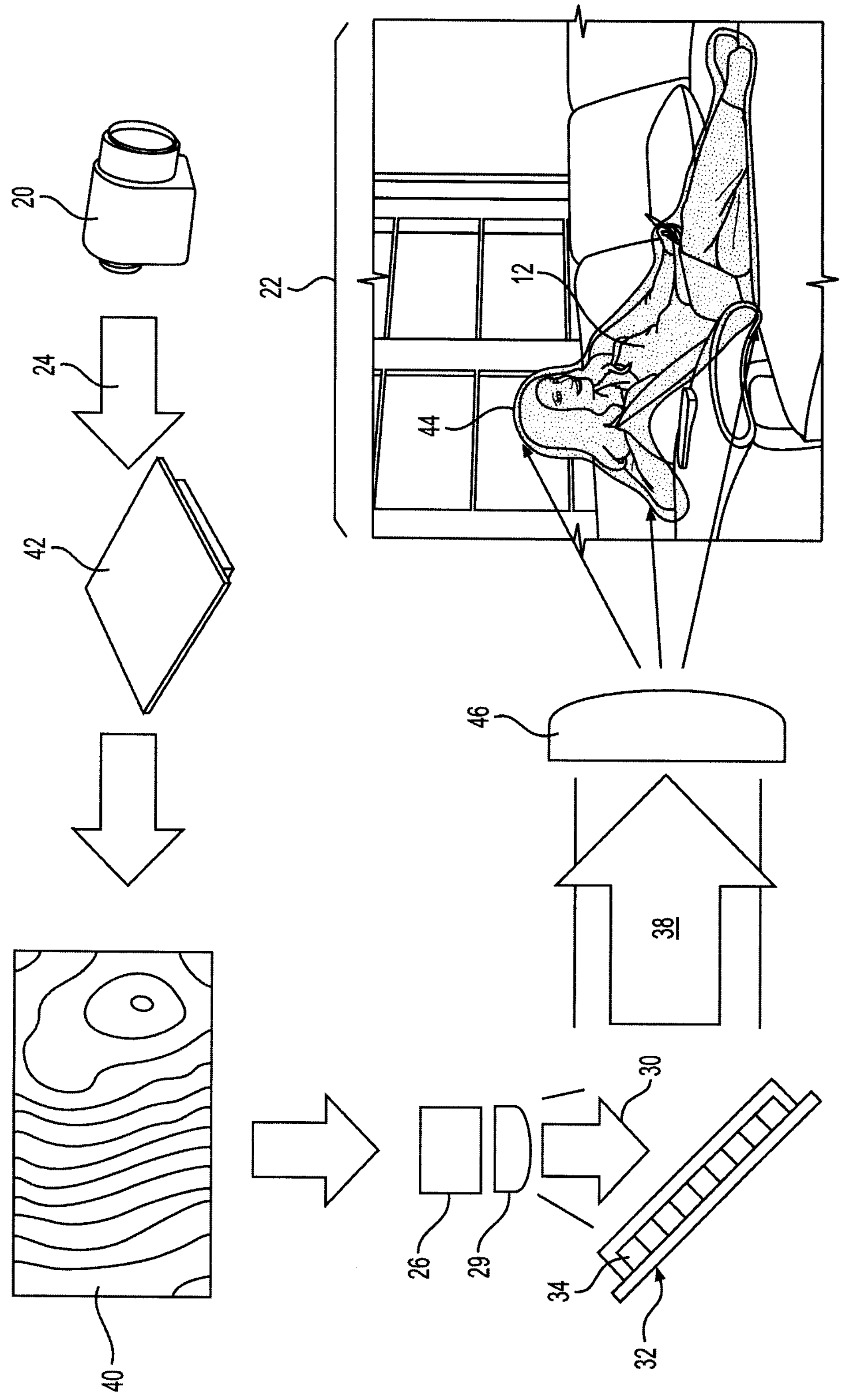

FIG. 5

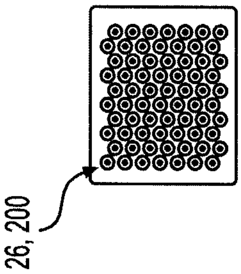

FIG. 6B

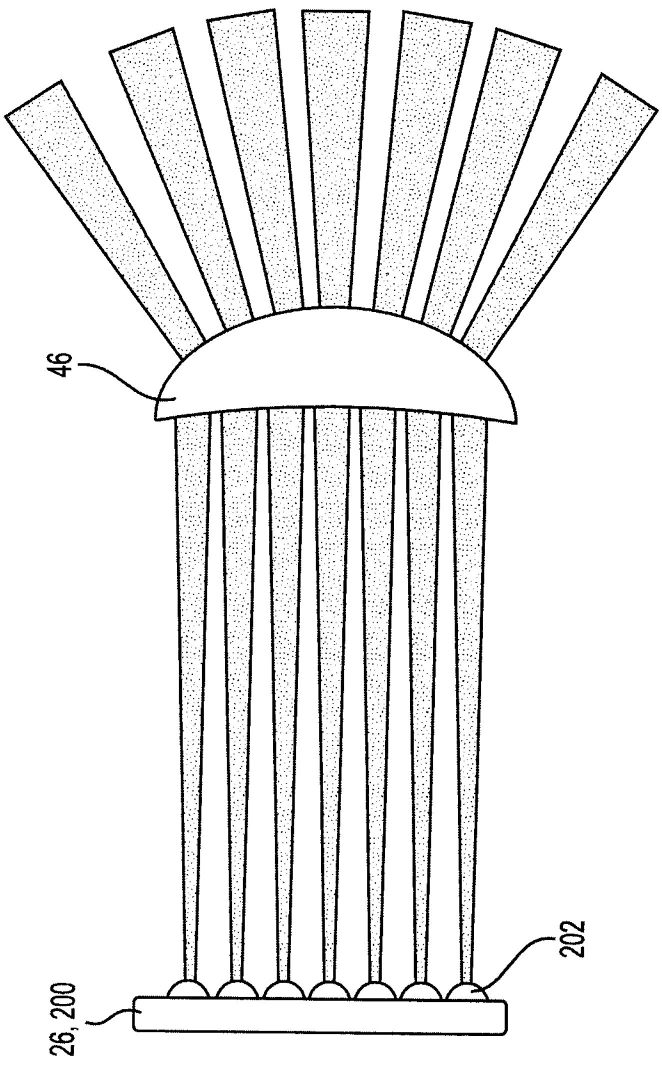

FIG. 6A

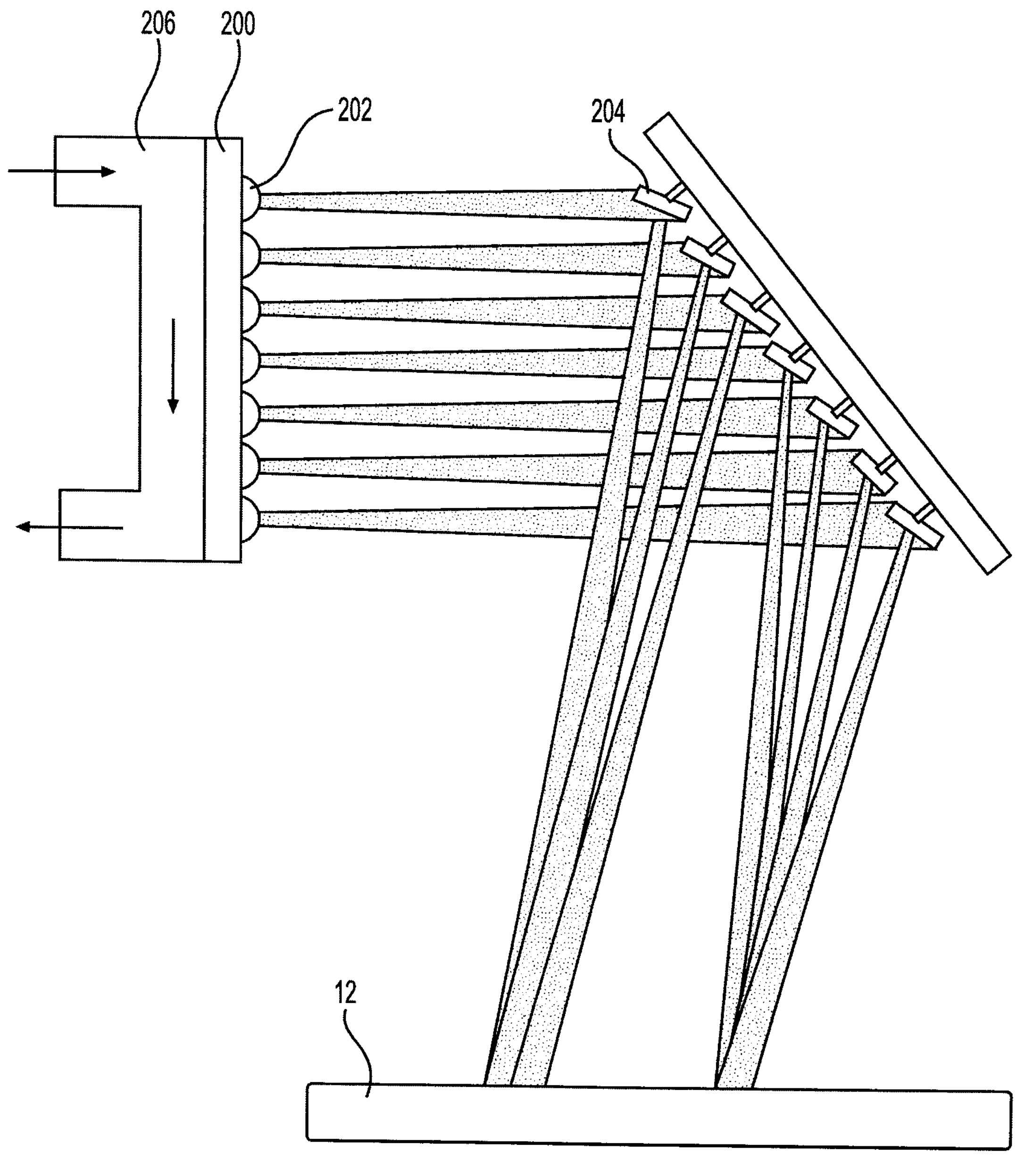

FIG. 7

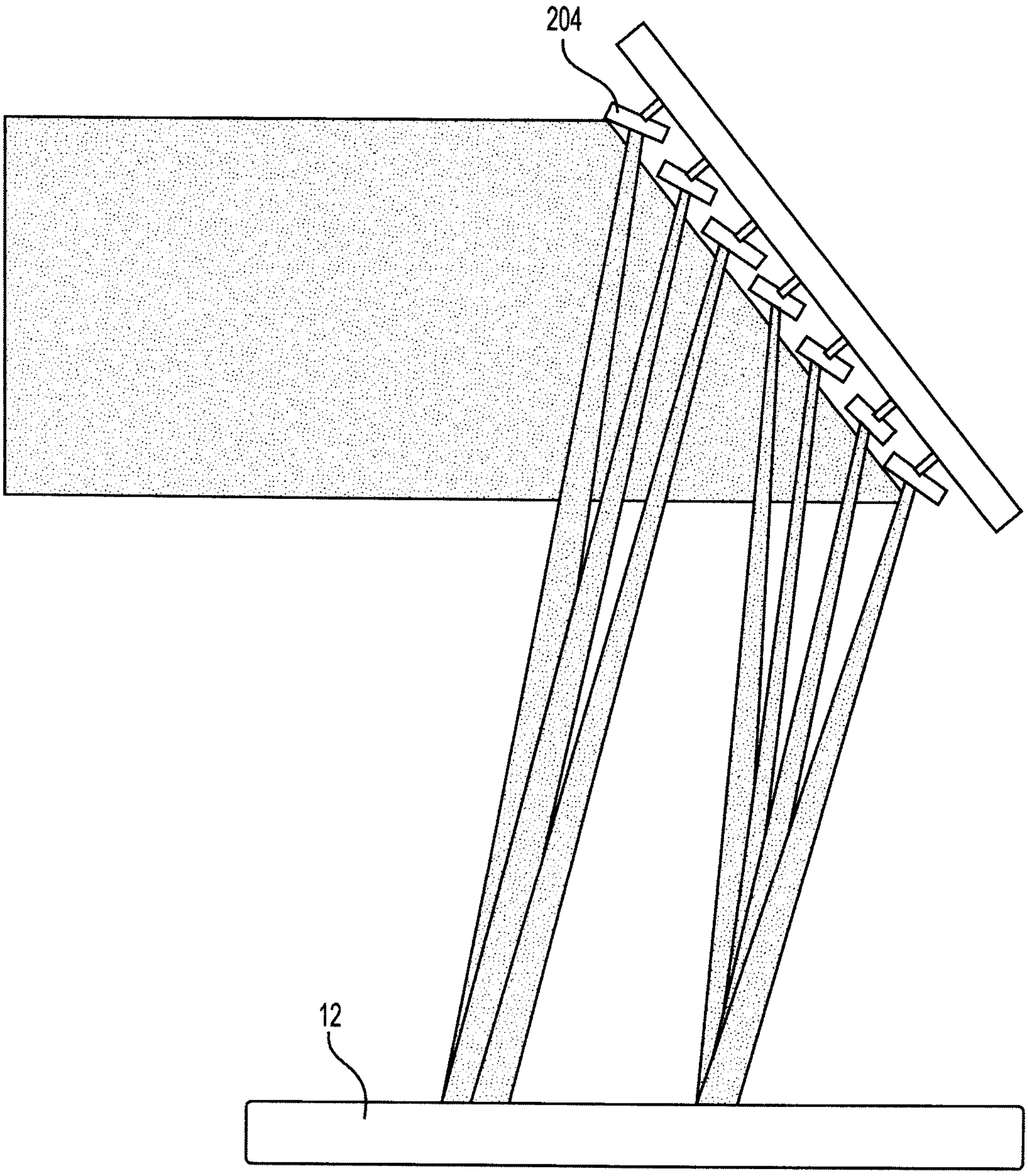

FIG. 8

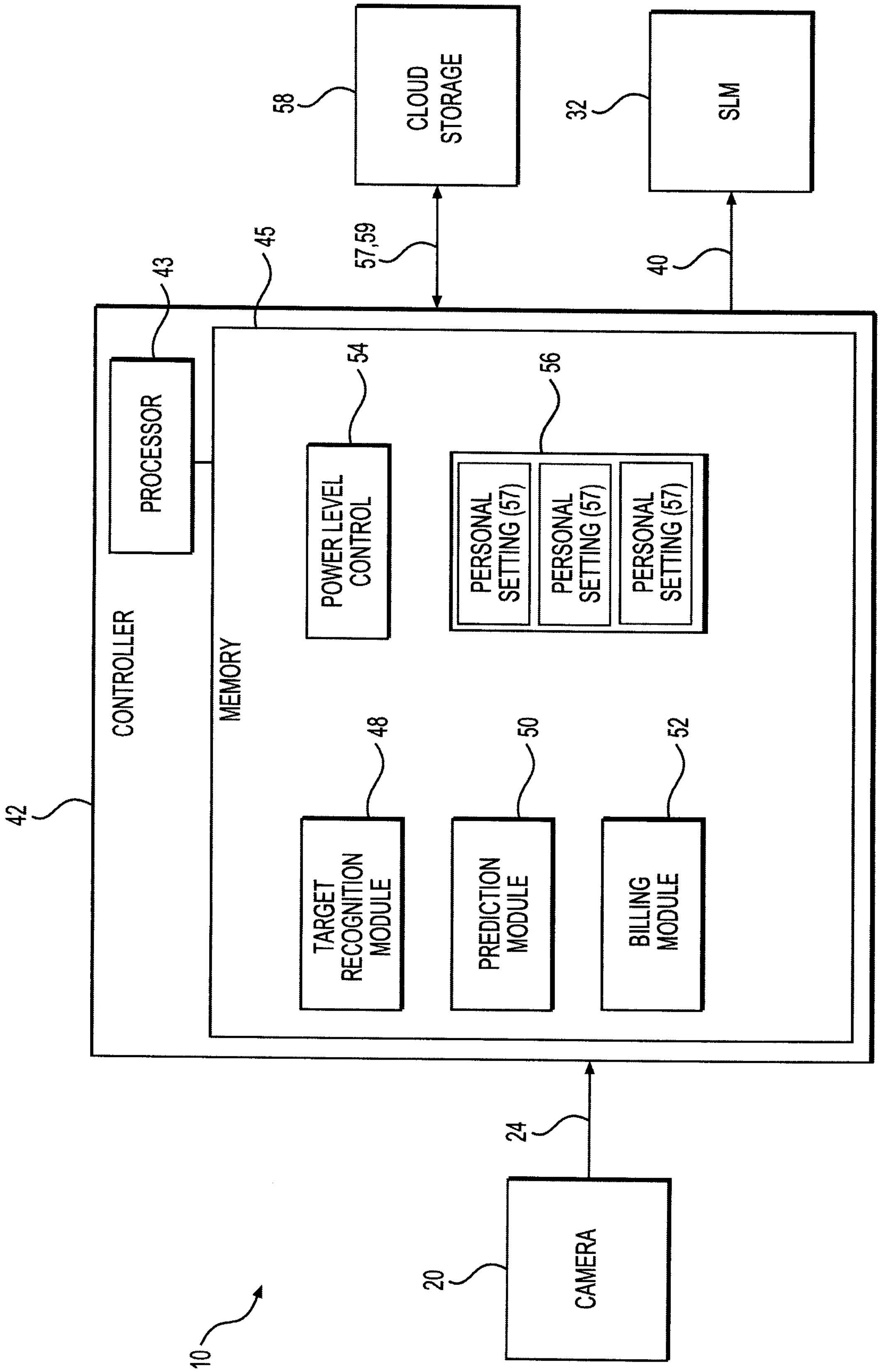
CLOUD STORAGE
58
SLM
32
57,59
40
45
43
PROCESSOR
54
POWER LEVEL CONTROL
56
PERSONAL SETTING (57)
PERSONAL SETTING (57)
PERSONAL SETTING (57)
CONTROLLER
MEMORY
42
48
TARGET RECOGNITION MODULE
50
PREDICTION MODULE
52
BILLING MODULE
24
CAMERA
20
10

FIG. 9

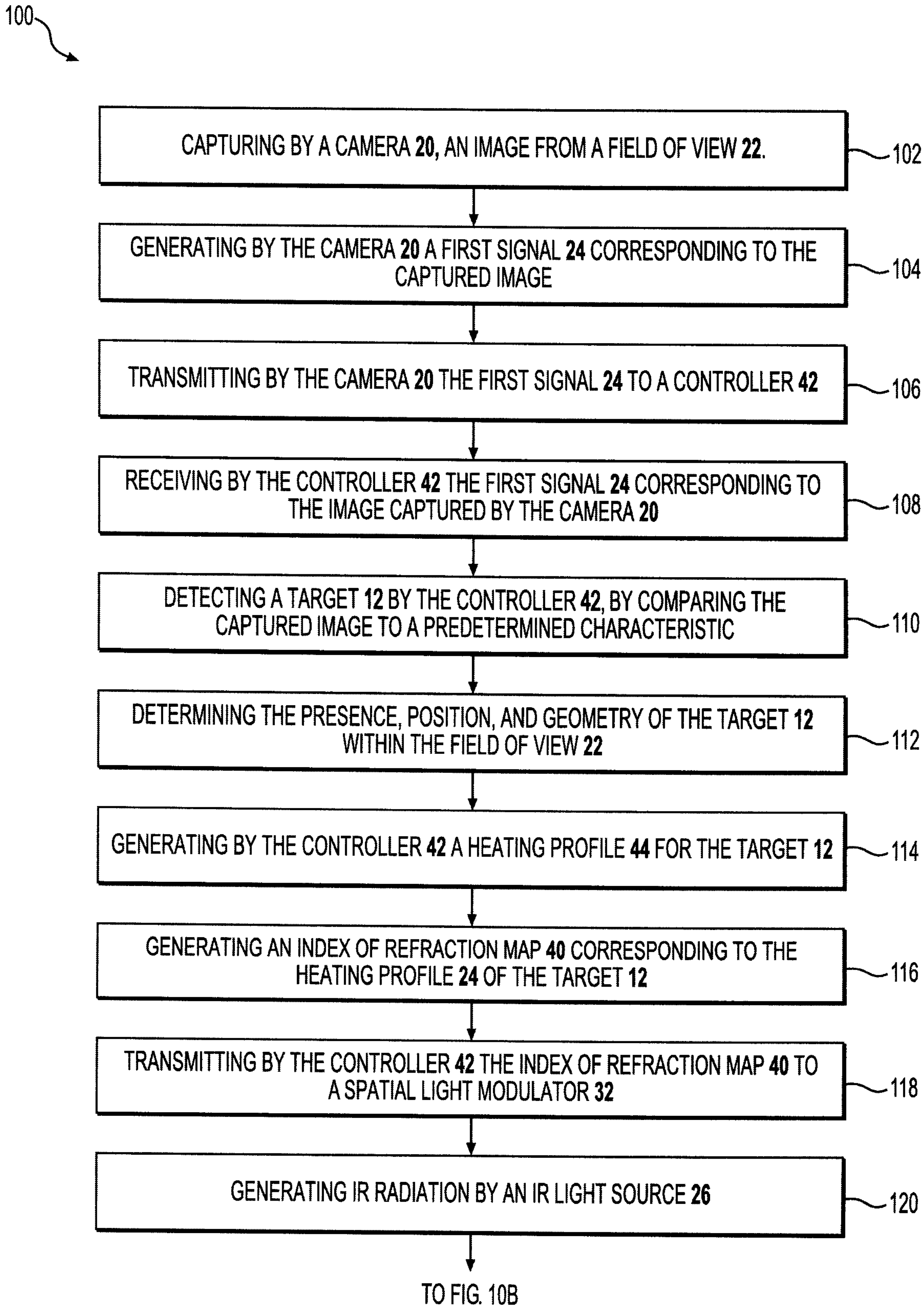
100
CAPTURING BY A CAMERA 20, AN IMAGE FROM A FIELD OF VIEW 22.
102
GENERATING BY THE CAMERA 20 A FIRST SIGNAL 24 CORRESPONDING TO THE CAPTURED IMAGE
104
TRANSMITTING BY THE CAMERA 20 THE FIRST SIGNAL 24 TO A CONTROLLER 42
106
RECEIVING BY THE CONTROLLER 42 THE FIRST SIGNAL 24 CORRESPONDING TO THE IMAGE CAPTURED BY THE CAMERA 20
108
DETECTING A TARGET 12 BY THE CONTROLLER 42, BY COMPARING THE CAPTURED IMAGE TO A PREDETERMINED CHARACTERISTIC
110
DETERMINING THE PRESENCE, POSITION, AND GEOMETRY OF THE TARGET 12 WITHIN THE FIELD OF VIEW 22
112
GENERATING BY THE CONTROLLER 42 A HEATING PROFILE 44 FOR THE TARGET 12
114
GENERATING AN INDEX OF REFRACTION MAP 40 CORRESPONDING TO THE HEATING PROFILE 24 OF THE TARGET 12
116
TRANSMITTING BY THE CONTROLLER 42 THE INDEX OF REFRACTION MAP 40 TO A SPATIAL LIGHT MODULATOR 32
118
GENERATING IR RADIATION BY AN IR LIGHT SOURCE 26
120
TO FIG. 10B

FIG. 10A

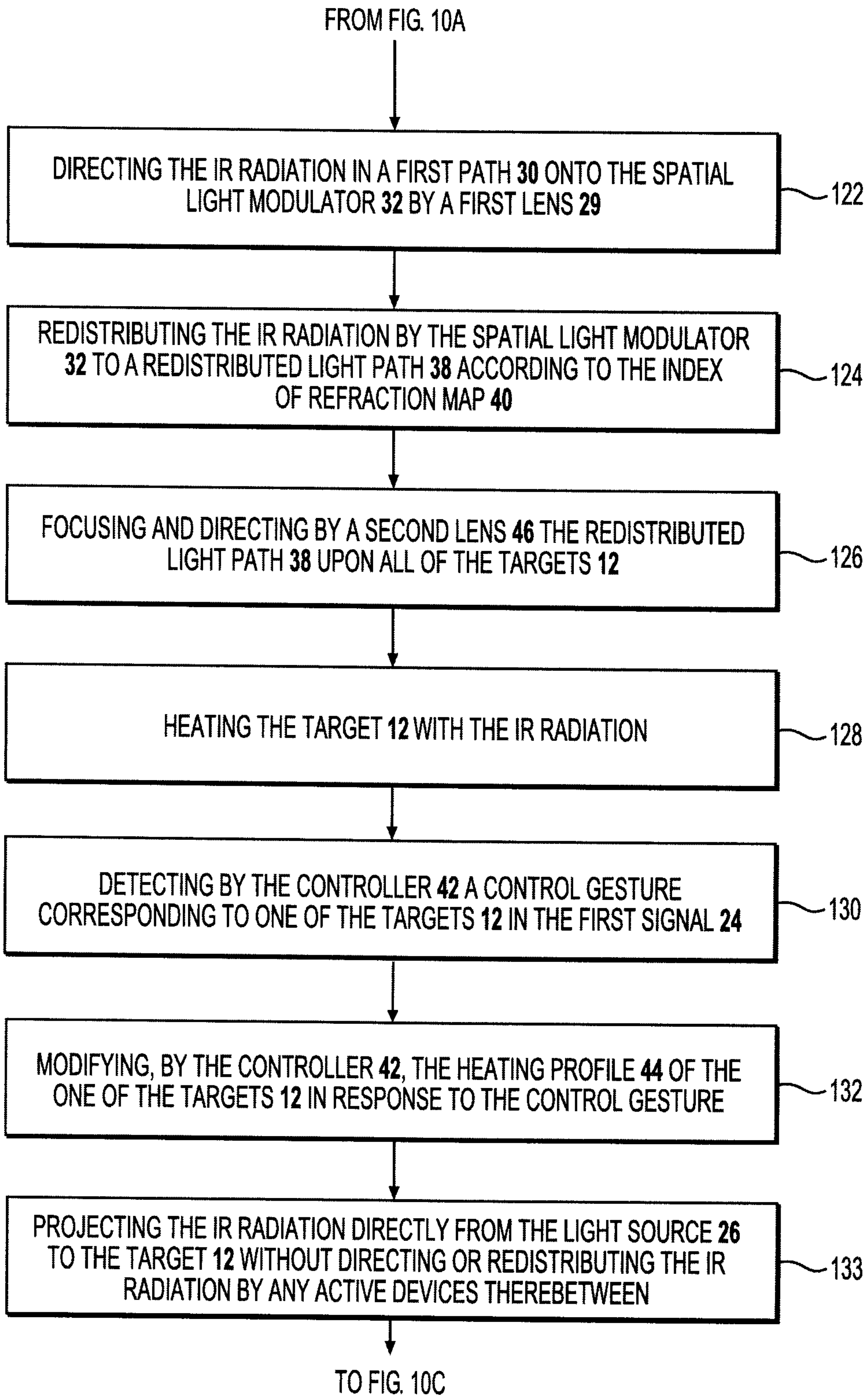
FROM FIG. 10A
DIRECTING THE IR RADIATION IN A FIRST PATH 30 ONTO THE SPATIAL LIGHT MODULATOR 32 BY A FIRST LENS 29
122
REDISTRIBUTING THE IR RADIATION BY THE SPATIAL LIGHT MODULATOR 32 TO A REDISTRIBUTED LIGHT PATH 38 ACCORDING TO THE INDEX OF REFRACTION MAP 40
124
FOCUSING AND DIRECTING BY A SECOND LENS 46 THE REDISTRIBUTED LIGHT PATH 38 UPON ALL OF THE TARGETS 12
126
HEATING THE TARGET 12 WITH THE IR RADIATION
128
DETECTING BY THE CONTROLLER 42 A CONTROL GESTURE CORRESPONDING TO ONE OF THE TARGETS 12 IN THE FIRST SIGNAL 24
130
MODIFYING, BY THE CONTROLLER 42, THE HEATING PROFILE 44 OF THE ONE OF THE TARGETS 12 IN RESPONSE TO THE CONTROL GESTURE
132
PROJECTING THE IR RADIATION DIRECTLY FROM THE LIGHT SOURCE 26 TO THE TARGET 12 WITHOUT DIRECTING OR REDISTRIBUTING THE IR RADIATION BY ANY ACTIVE DEVICES THEREBETWEEN
133
TO FIG. 10C

FIG. 10B

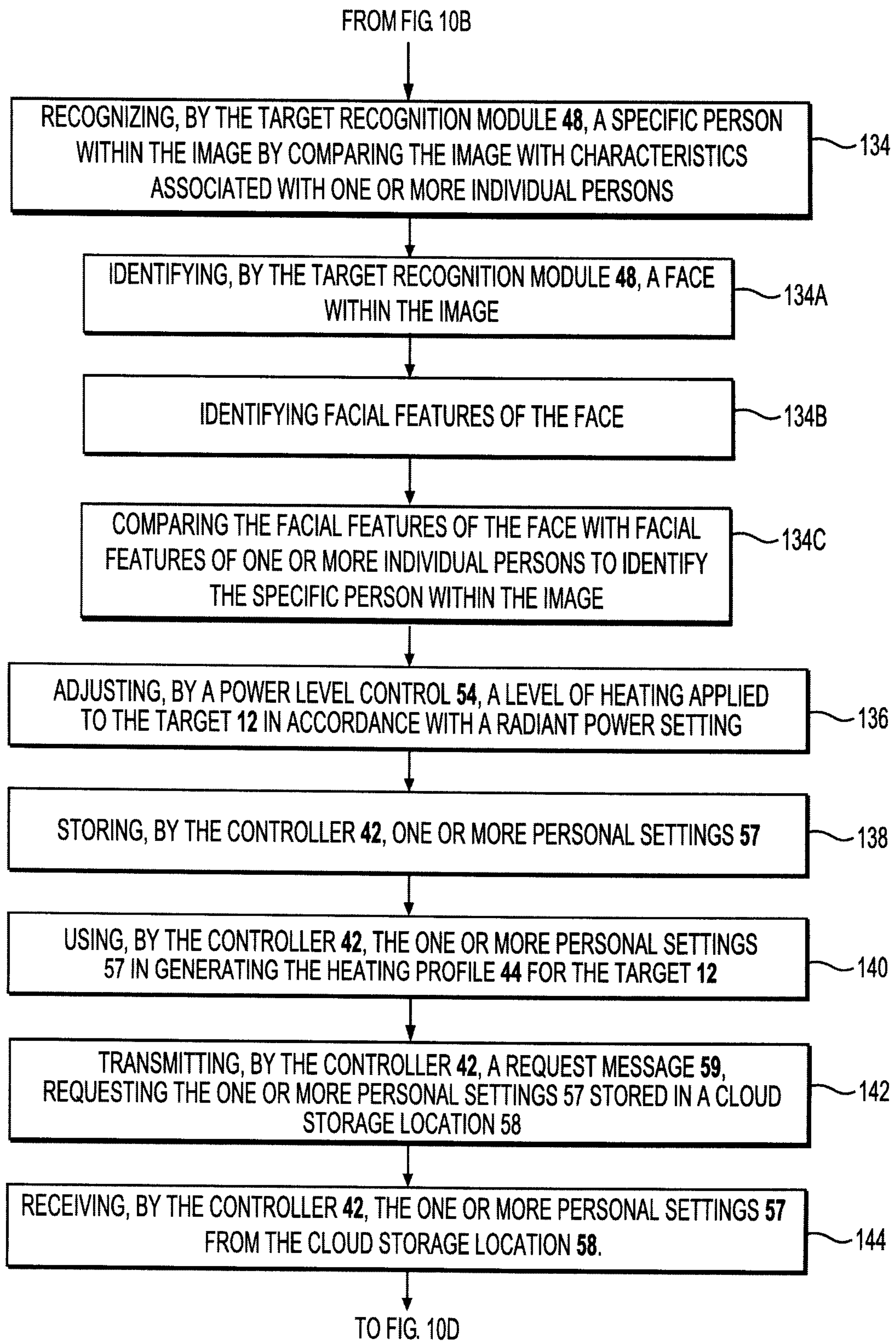
FROM FIG 10B
RECOGNIZING, BY THE TARGET RECOGNITION MODULE 48, A SPECIFIC PERSON WITHIN THE IMAGE BY COMPARING THE IMAGE WITH CHARACTERISTICS ASSOCIATED WITH ONE OR MORE INDIVIDUAL PERSONS
134
IDENTIFYING, BY THE TARGET RECOGNITION MODULE 48, A FACE WITHIN THE IMAGE
134A
IDENTIFYING FACIAL FEATURES OF THE FACE
134B
COMPARING THE FACIAL FEATURES OF THE FACE WITH FACIAL FEATURES OF ONE OR MORE INDIVIDUAL PERSONS TO IDENTIFY THE SPECIFIC PERSON WITHIN THE IMAGE
134C
ADJUSTING, BY A POWER LEVEL CONTROL 54, A LEVEL OF HEATING APPLIED TO THE TARGET 12 IN ACCORDANCE WITH A RADIANT POWER SETTING
136
STORING, BY THE CONTROLLER 42, ONE OR MORE PERSONAL SETTINGS 57
138
USING, BY THE CONTROLLER 42, THE ONE OR MORE PERSONAL SETTINGS 57 IN GENERATING THE HEATING PROFILE 44 FOR THE TARGET 12
140
TRANSMITTING, BY THE CONTROLLER 42, A REQUEST MESSAGE 59, REQUESTING THE ONE OR MORE PERSONAL SETTINGS 57 STORED IN A CLOUD STORAGE LOCATION 58
142
RECEIVING, BY THE CONTROLLER 42, THE ONE OR MORE PERSONAL SETTINGS 57 FROM THE CLOUD STORAGE LOCATION 58.
144
TO FIG. 10D

FIG. 10C

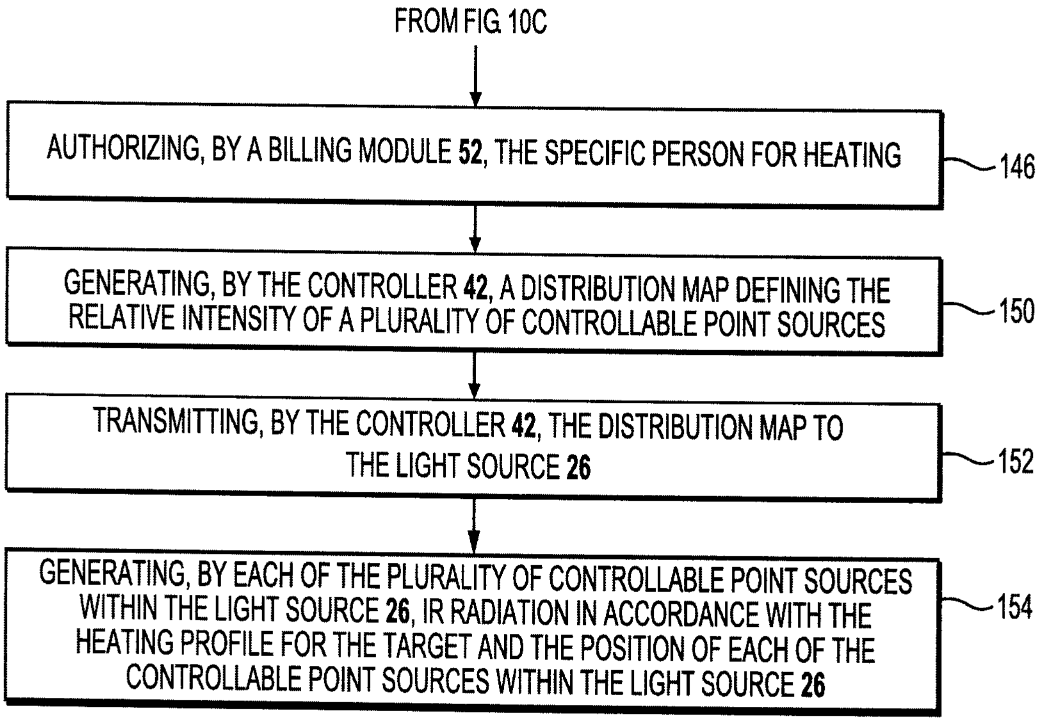
FROM FIG. 10C
AUTHORIZING, BY A BILLING MODULE 52, THE SPECIFIC PERSON FOR HEATING
146
GENERATING, BY THE CONTROLLER 42, A DISTRIBUTION MAP DEFINING THE RELATIVE INTENSITY OF A PLURALITY OF CONTROLLABLE POINT SOURCES
150
TRANSMITTING, BY THE CONTROLLER 42, THE DISTRIBUTION MAP TO THE LIGHT SOURCE 26
152
GENERATING, BY EACH OF THE PLURALITY OF CONTROLLABLE POINT SOURCES WITHIN THE LIGHT SOURCE 26, IR RADIATION IN ACCORDANCE WITH THE HEATING PROFILE FOR THE TARGET AND THE POSITION OF EACH OF THE CONTROLLABLE POINT SOURCES WITHIN THE LIGHT SOURCE 26
154

FIG. 10D

INTERNATIONAL SEARCH REPORT	International application No. **PCT/CA2018/000055**

A. CLASSIFICATION OF SUBJECT MATTER
IPC: ***F24D 15/00*** (2006.01) , ***B60H 1/22*** (2006.01) , ***F24D 13/00*** (2006.01) , ***F24D 19/10*** (2006.01) , ***G02B 26/08*** (2006.01) , ***H04N 21/80*** (2011.01) (more IPCs on the last page)

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)
IPC: F24D 15/00 (2006.01), B60H 1/22 (2006.01), F24D 13/00 (2006.01), F24D 19/10 (2006.01), G02B 26/08 (2006.01), H04N 21/80 (2011.01), H04N 7/18 (2006.01), H05B 1/02 (2006.01), H05B 3/00 (2006.01), G06Q 30/04 (2012.01)

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

Electronic database(s) consulted during the international search (name of database(s) and, where practicable, search terms used)
Databases: Canadian Patent Database, Questel/Orbit, Google Patent

Keywords: heater, infra, image, person, occupant, camera, target, setting, profile, recognition, map, point

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	CA 2899105 A1 (BIESSE, P.) 4 February 2016 (04-02-2016) *Abstract; page 2, line 13; p. 4, l. 9-11, 20; p. 3, l. 5-29 of the Canadian Patent Application* (English translation available with Espacenet)	1, 8
A	CN 104503472 A (ZHOU SIJIA et al.) 8 April 2015 (08-04-2015) *Abstract; page 3, 1st and last paragraphs; page 4; page 5, 1st par.; page 6, 1st par.; page 12* (English translation available with Espacenet, Patent Translate PDF version incl. 16 pages)	1-15
A	US 2013/0259456 A1 (VISWANATHAN, M.) 3 October 2013 (03-10-2013) *Abstract; [0008], [0011], [0014], [0015], [0018], [0049], [0056], [0057], [0060], [0064], [0065], [0066]*	1-15
A	US 2014/0376206 A1 (FISEKOVIC, P.) 25 December 2014 (25-12-2014) *Whole document*	1-15

☑ Further documents are listed in the continuation of Box C. ☑ See patent family annex.

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Date of the actual completion of the international search	Date of mailing of the international search report
11 April 2018 (11-04-2018)	07 June 2018 (07-06-2018)

Name and mailing address of the ISA/CA	Authorized officer
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Information on patent family members

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H04N 7/18 (2006.01) , ***H05B 1/02*** (2006.01) , ***H05B 3/00*** (2006.01) , *G06Q 30/04* (2012.01)