

A Radiation Device

TECHNICAL FIELD

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The present disclosure relates broadly to a radiation device and a method of forming a radiation device.

BACKGROUND

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End-stage renal disease (ESRD) typically occurs when a subject's kidneys have deteriorated to a point that requires renal replacement therapy, i.e. dialysis. It is recognised that a dialysis subject may, on average, need to perform dialysis three times a week, with each session lasting from 3 hours to 5 hours.

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Vascular access (VA) is a vital point for dialysis as it is used to connect a subject to a dialyzer or dialysis machine. VA may broadly be understood to be a way of connecting the machine to a blood vessel of the subject. However, it is recognised that native vasculature typically cannot withstand continual cannulation due to the thin walls of veins. As a solution, arteriovenous fistula (AVF) is created surgically by connecting an artery to a vein via anastomosis. Such a procedure may allow a faster blood flow rate in veins with a higher pressure, which strengthens the walls of a vein. It is recognised that AVF is a common VA point for haemodialysis subjects. In current studies, it is recognised that more than 80% of haemodialysis subjects have AVF created on them.

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However, even though AVF may be the most predominant vascular access point for dialysis subjects, a patency rate for AVF is found to be about 60%, which is not desirable. Patency rate is appreciated to be the rate of AVF functioning properly without intervention after implantation. Indeed amongst the AVF created, the primary patency rate is only 60% ($\pm 4\%$, 95% confidence interval, $n = 12,383$) according to a systematic review and meta-analysis.

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Using a radiation device to deliver radiation energy to a subject may improve the blood flow rate in the subject, given that blood flow rate can be a significant indicator of AVF patency. Furthermore, using near- infrared (NIR) radiation may strengthen AVF. For such an application, a control of a radiation target distance, e.g. a penetration depth into
5 a subject surface, may assist to target AVF.

In view of the above, there exists a need for a radiation device and a method of forming a radiation device that seeks to address at least one of the above problems.

10 **SUMMARY**

In accordance with an aspect of the present disclosure, there is provided a radiation device for delivering radiation energy to a surface of a subject, the device comprising a radiation member coupled to a subject-facing side of the radiation device,
15 the radiation member comprising a plurality of radiation emitters; the plurality of radiation emitters having a first radiation emitter disposed at a first position of the radiation member and having a second radiation emitter disposed at a second position of the radiation member; wherein each of the first radiation emitter and the second radiation emitter comprises at least one light-emitting diode (LED) capable of emitting light in the near-
20 infrared (NIR) region; and wherein the second position is angularly displaced from the first position of the radiation member, the angular displacement arranged to cause respective focal points of the first radiation emitter and the second radiation emitter to converge at a predetermined distance from the subject-facing side of the radiation device.

25 The radiation device may further comprise a third radiation emitter, the third radiation emitter being disposed at a third position of the radiation member; wherein the third position is angularly displaced from the first position of the radiation member, the angular displacement arranged to cause respective focal points of the first radiation emitter and the third radiation emitter to converge at the predetermined distance from the
30 subject-facing side of the radiation device; wherein the first radiation emitter is disposed at a centre portion of the radiation member, the second radiation emitter is disposed at a first peripheral wing of the radiation member and the third radiation emitter is disposed at a second peripheral wing of the radiation member; and wherein the first position, the

second position and the third position are disposed along a length-wise direction of the radiation device.

5 The radiation device may further comprise a control unit, the control unit comprising a microcontroller and one or more mechanical control members; wherein the microcontroller is configured to receive a signal from the one or more mechanical control members and to output a frequency signal to the plurality of radiation emitters for the plurality of radiation emitters to deliver the radiation energy in pulses corresponding to the frequency signal.

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The radiation device may further comprise a stability member, the stability member being coupled to the radiation member to stabilise the radiation member when in use; wherein the stability member is coupled to a top side of the radiation device, the top side being opposite the subject-facing side of the radiation device such that, in use, there is no object therebetween the radiation member and the surface of the subject.

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The stability member may comprise a stand that is arranged to be coupled to the top side of the radiation device; wherein the coupling of the stand comprises a ball-joint adjustment knob that is capable of locking the radiation member in position.

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The stability member may comprise a clamp that is arranged to be coupled to the top side of the radiation device; wherein the coupling of the clamp comprises an adjustment knob that is capable of locking the radiation member in position.

25 The radiation device may further comprise a mechanical member for determining a device distance of the radiation member to the surface of the subject, the mechanical member being coupled to an external surface of the radiation device at one end of the mechanical member; wherein the mechanical member comprises another end that is positioned at a second predetermined distance from the radiation device such that the mechanical member is capable of determining the device distance.

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The mechanical member may be arranged to be a collapsible measuring mechanical tool that is movable with respect to the surface of the subject.

The radiation device may further comprise a proximity sensor disposed on the subject-facing side of the radiation device; wherein the proximity sensor is configured to generate an alarm if it is determined that a proximity distance between the proximity
5 sensor and the surface of the subject exceeds a third predetermined distance.

In accordance with another aspect of the present disclosure, there is provided a method of forming a radiation device for delivering radiation energy to a surface of a subject, the method comprising coupling a radiation member to a subject-facing side of a
10 radiation device, the radiation member comprising a plurality of radiation emitters; disposing a first radiation emitter at a first position of the radiation member and disposing a second radiation emitter at a second position of the radiation member, wherein each of the first radiation emitter and the second radiation emitter comprises at least one light-emitting diode (LED) capable of emitting light in the near-infrared (NIR) region; and
15 angularly displacing the second position from the first position of the radiation member to cause respective focal points of the first radiation emitter and the second radiation emitter to converge at a predetermined distance from the subject-facing side of the radiation device.

The method may further comprise disposing a third radiation emitter at a third
20 position of the radiation member, wherein the first radiation emitter is disposed at a centre portion of the radiation member, the second radiation emitter is disposed at a first peripheral wing of the radiation member and the third radiation emitter is disposed at a second peripheral wing of the radiation member; angularly displacing the third position
25 from the first position of the radiation member to cause respective focal points of the first radiation emitter and the third radiation emitter to converge at the predetermined distance from the subject-facing side of the radiation device; and disposing the first position, the second position and the third position along a length-wise direction of the radiation device.

The method may further comprise providing a control unit comprising a
30 microcontroller and one or more mechanical control members; wherein the microcontroller is configured to receive a signal from the one or more mechanical control members and to output a frequency signal to the plurality of radiation emitters for the

plurality of radiation emitters to deliver the radiation energy in pulses corresponding to the frequency signal.

5 The method may further comprise coupling a stability member to a top side of the radiation device to stabilise the radiation member when in use, the top side being opposite the subject-facing side of the radiation device such that, in use, there is no object therebetween the radiation member and the surface of the subject.

10 The stability member may comprise a stand that is arranged to be coupled to the top side of the radiation device; wherein the coupling of the stand comprises a ball-joint adjustment knob that is capable of locking the radiation member in position.

15 The stability member may comprise a clamp that is arranged to be coupled to the top side of the radiation device; wherein the coupling of the clamp comprises an adjustment knob that is capable of locking the radiation member in position.

20 The method may further comprise coupling a mechanical member to an external surface of the radiation device at one end of the mechanical member, the mechanical member for determining a device distance of the radiation member to the surface of the subject; wherein the mechanical member comprises another end that is positioned at a second predetermined distance from the radiation device such that the mechanical member is capable of determining the device distance.

25 The mechanical member may be arranged to be a collapsible measuring mechanical tool that is movable with respect to the surface of the subject.

30 The method may further comprise disposing a proximity sensor on the subject-facing side of the radiation device; configuring the proximity sensor to generate an alarm if it is determined that a distance between the radiation member and the surface of the subject exceeds a third predetermined distance.

BRIEF DESCRIPTION OF THE DRAWINGS

Exemplary embodiments of the present disclosure will be better understood and readily apparent to one of ordinary skill in the art from the following written description, by way of example only, and in conjunction with the drawings, in which:

5 FIG. 1 is a schematic side view drawing for illustrating a radiation device for delivering radiation energy to a surface of a subject in an exemplary embodiment.

 FIG. 2A is a schematic perspective view drawing of a radiation device in an exemplary embodiment.

10 FIG. 2B is a photographic image of a portion of the radiation device taken from direction X of FIG. 2A.

 FIG. 3A is a schematic drawing for illustrating a side view of a radiation member
15 in another exemplary embodiment.

 FIG. 3B is a first schematic drawing of FIG. 3A for illustrating radiant angle as a function of focal point intersection in the exemplary embodiment.

20 FIG. 3C is a second schematic drawing of FIG. 3A for illustrating radiant angle as a function of focal point intersection in the exemplary embodiment.

 FIG. 3D is a third schematic drawing of FIG. 3A for illustrating radiant angle as a function of focal point intersection in the exemplary embodiment.

25 FIG. 4 is a graph showing power distribution and irradiance measured by the photodiode sensor in an example testing.

 FIG. 5 is a schematic drawing showing a comparison between delivery depth of a
30 continuous wave and a super pulsed wave.

 FIG. 6 is a schematic block drawing of a control unit in an exemplary embodiment.

FIG. 7A shows a 10Hz operating voltage pattern as controlled by a microcontroller and sent to a plurality of radiation emitters.

FIG. 7B shows a 10Hz irradiance pattern, with a pulsed wave form, of the plurality
5 of radiation emitters.

FIG. 7C shows a 50Hz operating voltage pattern as controlled by the microcontroller and sent to the plurality of radiation emitters.

FIG. 7D shows a 50Hz irradiance pattern, with a pulsed wave form, of the plurality
10 of radiation emitters.

FIG. 8A is a schematic perspective view of a heatsink in an exemplary
embodiment.
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FIG. 8B is a schematic side view of the heatsink in the exemplary embodiment.

FIG. 9 is a photographic image of a heatsink taken from an underside of the
heatsink in an exemplary embodiment.
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FIG. 10 is a schematic drawing for illustrating a radiation device in an exemplary
embodiment.

FIG. 11 is a schematic drawing for illustrating a radiation device in an exemplary
25 embodiment.

FIG. 12 is a schematic drawing for illustrating a radiation device in an exemplary
embodiment.

FIG. 13 is a photographic image of a radiation device comprising a stand in an
30 exemplary embodiment.

FIG. 14 is a photographic image of a radiation device comprising a clamp in an exemplary embodiment.

FIGs. 15A to 15D show a series of photographic images of a radiation device in
5 an example implementation.

FIG. 16 is a graph illustrating a repeatability of test iterations.

FIG. 17 is a schematic flowchart for illustrating a method of forming a radiation
10 device for delivering radiation energy to a surface of a subject in an exemplary embodiment.

DETAILED DESCRIPTION

15 Exemplary embodiments described herein may provide a radiation device for delivering radiation energy to a surface of a subject. Methods thereof, e.g., a method of forming a radiation device, and a method of delivering radiation energy etc. may also be provided.

20 In exemplary embodiments herein, the inventors recognise that using near-infrared (NIR) radiation delivered to a subject may usefully improve the blood flow rate, recognising that blood flow rate can be a significant indicator of AVF patency.

FIG. 1 is a schematic side view drawing for illustrating a radiation device for
25 delivering radiation energy to a surface of a subject in an exemplary embodiment. The radiation device (100) comprises a body (102) having a subject-facing side (104). The radiation device (100) comprises a radiation member (106) coupled to the subject-facing side (104) of the radiation device (100).

30 The radiation member (106) comprises a plurality of radiation emitters e.g., (108, 110), the plurality of radiation emitters e.g., (108, 110) having a first radiation emitter (108) disposed at a first position (112) of the radiation member (106) and having a second radiation emitter (110) disposed at a second position (114) of the radiation member (106).

Each of the first radiation emitter (108) and the second radiation emitter (110) comprises at least one light-emitting diode (LED) e.g., (116, 118) capable of emitting light in the NIR region. In the exemplary embodiment, the second position (114) is angularly displaced from the first position (112) of the radiation member (106), the angular displacement
5 arranged to cause respective focal points of the first radiation emitter (108) and the second radiation emitter (110) to converge at a predetermined distance (120) from the subject-facing side (104) of the radiation device (100). See for example, convergent point (122).

10 Further, as seen from the configuration of the radiation member (106), it may be considered that first radiation emitter (108) is linearly displaced and angularly displaced from the second radiation emitter (110). The first position (112) and the second position (114) are disposed along a length-wise direction (126) of the radiation device (100). The length-wise direction may be a substantially straight line along which the first position
15 (112) and the second position (114) are disposed along and along which the first position (112) and the second position (114) are adjacent to each other. In some exemplary embodiments, the length-wise direction (126) may be along a breadth of the radiation device (100). In other exemplary embodiments, the length-wise direction (126) may be along a length of the radiation device (100).

20 In the exemplary embodiment, the radiation device (100) is arranged to deliver radiation energy to a subject (not shown), the subject positioned about the subject-facing side (104). The radiation energy may be provided by the LEDs e.g., (116, 118).

25 In the exemplary embodiment, the radiation device (100) may further comprise a control unit (124), the control unit (124) configured to control the functions of the radiation device (100).

30 In some exemplary embodiments, the radiation device (100) may be usefully disposed/positioned such that the convergent point (122) is below a skin surface of a subject.

FIG. 2A is a schematic perspective view drawing of a radiation device in an exemplary embodiment. The radiation device (200) may be used to deliver radiation energy to a subject. The radiation device (200) functions substantially similarly to the radiation device (100) of FIG. 1.

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The radiation device (200) comprises a top side illustrated schematically as top side (202). The radiation device (200) comprises a bottom side or a subject-facing side (204) that is disposed at an opposite side of the top side (202) of the radiation device (200). The radiation device (200) comprises a radiation member (206) coupled to the subject-facing side (204). It will be appreciated that even though a radiation member is described, the exemplary embodiment does not exclude the possibility of having a plurality of radiation members.

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The radiation device (200) may further comprise at least one heatsink (208) coupled to the radiation member (206).

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FIG. 2B is a photographic image of a portion of the radiation device (200) taken from direction X of FIG. 2A. The radiation member (206) comprises a plurality of radiation emitters e.g., (210, 212). In the exemplary embodiment, a first radiation emitter (210) is disposed/located at a first position of the radiation member (206). At least a second radiation emitter (212) is disposed/located at a second position that is angularly displaced from, or with respect to, the first position in an adjacent length-wise direction (218). In the exemplary embodiment, the first radiation emitter (210) and the second radiation emitter (212) are arranged at the first and second positions respectively, i.e., with the angular displacement of the second position with respect to the first position, so that the focal points of the first radiation emitter (210) and the second radiation emitter (212) are caused to intersect or converge at a predetermined distance from the subject-facing side (204) of the radiation device (200).

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In the exemplary embodiment, the length-wise direction (218) corresponds to a breadth of the radiation device (200) when compared to FIG. 2A. In other exemplary embodiments, the length-wise direction (218) may correspond to a length of the radiation device.

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In the exemplary embodiment, a focal point is measured from an emission end of a radiation emitter. FIG. 2B shows the respective emission ends of the plurality of radiation emitters e.g., (210, 212) from the subject-facing side (204) of the radiation device (200).

In the exemplary embodiment, each radiation emitter e.g., (210, 212) comprises at least one LED for emitting light in the NIR region, e.g., light with wavelengths in the range of from about 780 nm to about 2500 nm.

In the exemplary embodiment, with reference to FIG. 2B, the first position may be at a substantially centre portion/location (220) of the radiation member (206) and the second position may be at a first peripheral wing or side portion/location (222) of the radiation member (206). It will be appreciated that the exemplary embodiments are not limited as such. That is, the first position may be at a second peripheral wing or side portion/location (224) of the radiation member (206) while the second position is angularly displaced from the first position in the adjacent length-wise direction (218), with the first radiation emitter (210) and the second radiation emitter (212) arranged so that the focal points of the first radiation emitter (210) and the second radiation emitter (212) intersect or converge at a predetermined distance from the subject-facing side (204) of the radiation device (200).

In other exemplary embodiments, there may be provided more radiation emitters, e.g., (214, 216). The plurality of radiation emitters disposed in an adjacent length-wise direction (comparing to direction (218)), are arranged so that the focal points of the plurality of radiation emitters intersect or converge at a predetermined distance from the subject-facing side (204).

FIG. 3A is a schematic drawing for illustrating a side view of a radiation member in another exemplary embodiment. In the exemplary embodiment, the radiation member (300) functions substantially similarly to the radiation member (206) of FIG. 2B.

The radiation member (300) comprises three radiation emitters (302, 304, and 306). A first radiation emitter (302) is located at a first position of the radiation member (300). The first position is at a substantially centre portion/location (308) of the radiation member (300).

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In the exemplary embodiment, a second radiation emitter (304) is located at a second position of the radiation member (300) and the second position is angularly displaced from the first position of the first radiation emitter (302). The second position is at a first peripheral wing or side portion/location (310) of the radiation member (300).

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In the exemplary embodiment, a third radiation emitter (306) is located at a third position of the radiation member (300) and the third position is angularly displaced from the first position of the first radiation emitter (302). The third position is at a second peripheral wing or side portion/location (314) of the radiation member (300). In the exemplary embodiment, the third position may be at an opposite portion/location of the second position of the radiation member (300).

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In the exemplary embodiment, the radiation emitters (302, 304, and 306) are arranged so that the focal points of the radiation emitters (302, 304, and 306) intersect or converge at a predetermined distance from the subject-facing side of the radiation device comprising the radiation member (300). For example, see convergent point (311).

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Thus, in the exemplary embodiment, the angular displacement between the first and second positions and the angular displacement between the first and third positions are each arranged to cause respective focal points of the first, second and third radiation emitters (302, 304, and 306) to converge at a predetermined distance (at the convergent point (311)) from the subject-facing side of the radiation device.

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In the exemplary embodiment, the first peripheral wing (310) is angularly displaced, see first corner (312), from the centre portion (308) of the radiation member (300) by about 135 degrees. The second peripheral wing (314) is angularly displaced, see second corner (316), from the centre portion (308) of the radiation member (300) by about 135 degrees. In the exemplary embodiment, the centre portion (308), the first

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peripheral wing (310) and the second peripheral wing (314) are disposed along an adjacent length-wise direction (326).

In the exemplary embodiment, the displacements/locations of the radiation
5 emitters (302, 304, and 306) may be varied or determined such that their respective
radiation along the directions (320, 322, and 324) may converge at the convergent point
(311). The convergence at the convergent point (311) at a predetermined distance from
e.g. the first radiation emitter (302) may be a function of the linear and angular
displacement of at least one other radiation emitter (304, 306) from the first radiation
10 emitter (302).

In the exemplary embodiment, a plane (318) is schematically indicated to
represent a possible surface of a subject. In an example, if the radiation member (300) is
disposed for use with a limb of the subject, the limb may be positioned along an axis
15 (328), i.e., the axis (328) extending into the page.

For example, when a subject-facing side of a radiation device (compare the
subject-facing side (204) of FIG. 2A) comprising the radiation member (300) faces a
subject, the first radiation emitter (302) may radiate energy in a direction (320)
20 substantially perpendicularly to a surface of a subject, for example, a subject's arm
surface. The second radiation emitter (304) may radiate energy in a second direction
(322) that is less than 135 degrees with respect to the surface of the subject, for example,
the subject's arm surface, e.g., the example angle being viewed from a side of the second
radiation emitter (304) that is closer to the first radiation emitter (302). The third radiation
25 emitter (306) may radiate energy in a third direction (324) that is less than 135 degrees
with respect to the surface of the subject, for example, the subject's arm surface, e.g., the
example angle being viewed from a side of the third radiation emitter (306) that is closer
to the first radiation emitter (302).

30 In the exemplary embodiment, for example only, the centre portion (308) is
disposed at about 3 cm from both the first corner (312) and the second corner (316). For
example only, the second radiation emitter (304) is disposed at about 2 cm from the first
corner (312) and the third radiation emitter (306) is disposed at about 2 cm from the

second corner (316). As such, it may be considered that first radiation emitter (302) is linearly displaced and angularly displaced from the second radiation emitter (304) and the third radiation emitter (306) respectively.

- 5 With reference to FIG. 3A, using geometry, the intersection of LED radiation at their focal points may be calculated to be:

$$\frac{1}{2}(6) + \frac{2}{\sin(45^\circ)} \approx 5.83\text{cm}$$

- where half of 6 cm is the centre portion (308). The predetermined distance of 5.83 cm is measured from the emission end of the first radiation emitter (302), refer to direction
10 (320).

 Therefore, if radiation may be performed at about 4 cm to about 6 cm away from an LED source, compare the first radiation emitter (302), the radiant intensity may be considered changing with a radiant angle.

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 The inventors recognise that a surface of a subject, for example, the subject's arm surface, may have contours or bumps that may affect a radiant intensity of the second radiation emitter (304) and/or the third radiation emitter (306), due to positioning of the second radiation emitter (304) and/or the third radiation emitter (306) with respect to the
20 surface of the subject. The inventors recognise that even though the radiant intensity of the second radiation emitter (304) and/or the third radiation emitter (306) may vary, the delivery intensity at the convergent focal point (311) remains substantially consistent due to the radiant intensity of the first radiation emitter (302).

- 25 FIG. 3B is a first schematic drawing of FIG. 3A for illustrating radiant angle as a function of focal point intersection in the exemplary embodiment. FIG. 3B is used for explanation with respect to the second radiation emitter (304) and it will be appreciated that the description may apply to the third radiation emitter (306). The focal point intersection is with respect to the intersection of the focal point of the first radiation emitter
30 (302). For example, compare the convergent focal point (311).

 Let θ be the angle away from a focal point of a LED, where NIR waves are emitted:

$$\text{vertical distance, } d, \text{ from LED} = \sqrt{2} + y$$

The parameter d is indicated at numeral 330 and the parameter y is indicated at numeral 332. The angle θ may be viewed from a side of the second radiation emitter (304) that is furthest away from the first radiation emitter (302). The angle θ may also be seen from following FIGs. 3C and 3D.

$$y = h \sin(45^\circ - \theta)$$

$$\text{where } h \text{ is a function of } y: h = \sqrt{(3 + \sqrt{2})^2 + y^2}$$

$$y^2 = [(3 + \sqrt{2})^2 + y^2] \sin^2(45^\circ - \theta)$$

$$y = \sqrt{\frac{(3 + \sqrt{2})^2 \sin^2(45^\circ - \theta)}{1 - \sin^2(45^\circ - \theta)}}$$

$$y = \sqrt{(3 + \sqrt{2})^2 \tan^2(45^\circ - \theta)}$$

It is noted that the exemplary values used above are in cm and illustrated in FIG. 3B in mm.

FIG. 3C is a second schematic drawing of FIG. 3A for illustrating radiant angle as a function of focal point intersection in the exemplary embodiment. FIG. 3D is a third schematic drawing of FIG. 3A for illustrating radiant angle as a function of focal point intersection in the exemplary embodiment.

With the y as a function of θ , the radiant angle may be calculated as between about 4 cm to about 5 cm vertical distance:

$$\theta = 5.9^\circ | d = 5 \text{ cm}$$

$$\theta = 14.6^\circ | d = 4 \text{ cm}$$

FIG. 3C shows the parameter d (330) with a length of 50mm or 5 cm. The radiant angle θ at numeral 334 has a value of 5.9°. FIG. 3D shows the parameter d (330) with a length of 40mm or 4 cm. The radiant angle θ at numeral 336 has a value of 14.6°.

Therefore, there may be provided a tolerance/buffer for the focal point intersection along parameter d (330), and for the positioning of the second radiation emitter (304) and/or the third radiation emitter (306), thereby allowing some tolerance for the radiant angle θ .

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Thus, with the exemplary embodiment, a radiation device that may provide a non-invasive and non-contact radiation process may be provided. As shown in FIGs. 3A and 3B, the location and orientation of the radiation emitters, comprising one or more LEDs, is predetermined so that the focal points of the radiation emitters converge at a distance of about 5.8 cm. For example, in some exemplary embodiments, the focal points may converge at a focal convergent distance of about 4 cm to about 6 cm from the first radiation member (302), e.g., having a buffer of about 2 cm to have substantially the same irradiance effects.

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Thus, in the above exemplary embodiment, the focal points intersect / converge at a distance from the first radiation member (302), e.g. at a predetermined distance relative to a surface of a subject. The inventors recognize that the predetermined distance may be at an area of interest below or at a skin surface of the subject.

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With reference to FIG. 2B, for one exemplary implementation, there may be provided six radiation emitters e.g. (210, 212, 214, 216) with each of the six radiation emitters comprising nine NIR LEDs. Hence, in such an exemplary implementation, when the six radiation emitters e.g. (210, 212, 214, 216) are turned on in operation, fifty-four focal points from the LEDs can be collectively generated on a skin surface of the subject.

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In such an exemplary implementation, a region radiated, or affected by radiation, on the skin surface of the subject may be approximated as a semi-circular area, e.g. a top half of a limb with reference to the axis (328). For example, the plurality of radiation emitters e.g., (210, 212, 214, 216) is selected to provide an array to create an energy pattern at the area of interest below or at a skin surface of the subject.

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In the above exemplary implementation, the arrangement of the six radiation emitters e.g. (210, 212, 214, 216) comprising NIR LEDs is designed to produce sufficient

coverage for a region that may be suitable for a AVF process, as well as maintaining an uniform distribution of energy over the region.

During testing of a setup as shown in FIG. 3A, a photodiode sensor simulating a
5 surface of a subject is used.

In one testing, the photodiode sensor is placed at distances varying between about 4 cm and 6 cm from the radiation member (300), e.g., simulating a process for radiating energy to a surface of a subject.

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FIG. 4 is a graph showing power distribution and irradiance measured by the photodiode sensor in an example testing. The power distribution is measured over a 5 cm by 5 cm region. Compare the two axes. The inventors recognise that irradiance, measured in W/m^2 , is a suitable quantity used to measure power per unit area. Using a
15 setup as shown in FIG. 3A, within the distance range of about 4 cm and 6 cm from the first radiation emitted (302) of the radiation member (300), from the graph (400), it is observed that the irradiance remains relatively consistent due to the specific offset between distance and radiant angle, e.g. as explained above. For example, irradiance of at least about 400 W/m^2 to about 700 W/m^2 may be provided. For example, the offset is
20 deriving from a function of the linear and angular displacement of at least one other radiation emitter (304, 306) from the first radiation emitter (302).

The inventors recognise that a significant useful technical effect may be provided with the arrangement as shown in FIG. 3A. During another testing, when the photodiode
25 sensor is moved closer to the radiation emitters, the amount of light received from the first radiation emitter (302) at the centre portion (308) increases while the amount of light received from the second radiation emitter (304) and the third radiation emitter (306), i.e., from the first and second peripheral wings (310, 314), i.e., from the sides of the first radiation emitter (302), decrease. Such a scenario is if the photodiode sensor moves
30 away from the convergent focal point (311). Consequently, the inventors recognise that the setup as shown in FIG. 3A may usefully ensure that the total amount of light emitted by the radiation device comprising the radiation member (300) may remain substantially and relatively consistent within the range of about 4 cm to about 6 cm, i.e., from the

emission end of the first radiation emitter (302) at the centre portion (308). The results are substantially similar to the results shown in FIG. 4.

The inventors recognise that the above achieved consistency in light intensity is a significant useful effect, for example for a radiation process for AVF, e.g., considering that a subject receiving the radiation energy at a limb may shift position or move during the radiation process. With a setup as shown in FIG. 3A, a buffer zone, e.g., a 2 cm buffer zone as illustrated, may be significantly useful in maintaining a consistent irradiance level for a radiation process, which, in turn, may be significantly useful for achieving a desired radiation/treatment outcome.

With the exemplary embodiment as illustrated with FIG. 3A, for a plurality of radiation emitters (e.g., the first radiation emitter, the second radiation emitter and the third radiation emitter) arranged such that their focal points intersect at a distance from the radiation member, the plurality of radiation emitters are arranged such that the radiation coverage is for a predetermined area or region and such that a uniform distribution of energy is provided over the predetermined area or region. Compare FIG. 4. For example, the predetermined area or region may be below a surface of the subject, e.g. within a subject or below a skin surface of the subject.

Further, a total radiation energy provided by the plurality of radiation emitters is substantially consistent/constant within a buffer/range/tolerance distance from the radiation member. For example, in some exemplary embodiments, a device distance to a surface of the subject may be desired to be about 5 cm. In such exemplary embodiments, a buffer distance of 2 cm may be provided for the device distance, that is, in a range of 4 cm to 6 cm (+/- 1 cm from the desired 5 cm) for the device distance to the surface of the subject, and the radiation energy provided to a predetermined area or region may usefully remain substantially consistent/constant.

The inventors next recognise that penetration depth may be a significant consideration to deliver sufficient radiation energy for the exemplary embodiments, e.g., as AVF is typically conducted or located underneath a skin surface.

FIG. 5 is a schematic drawing showing a comparison between delivery depth of a continuous wave and a super pulsed wave. It may be recognised that a super pulsed wave (502) may deliver energy at a greater penetration depth or distance as compared to a continuous wave (504). For example, the super pulsed wave (502) may reach a dermis layer (506) and a hypodermis layer (508) of a subject.

As such, in an exemplary embodiment, a pulsed wave mode is adopted. For example, the pulsed wave mode may be implemented with the use of a microcontroller.

FIG. 6 is a schematic block drawing of a control unit in the exemplary embodiment. Compare this to the control unit (124) of FIG. 1. The control unit (600) may be provided at e.g., a housing of a radiation device, e.g., accessible by a user to operate the radiation device.

The control unit (600) comprises a processing module such as a microcontroller (602) and one or more mechanical control members e.g. (604, 606). The one or more mechanical control members e.g. (604, 606) are coupled to the microcontroller (602). In the exemplary embodiment, the microcontroller (602) is arranged to receive a signal from the one or more mechanical control members e.g., (604, 606) and to output (608) a frequency signal. The output (608) may be transmitted to the plurality of radiation emitters, (for instance, the radiation emitters 302, 304, and 306 of FIG. 3A), for the plurality of radiation emitters to deliver radiation energy in pulses corresponding to the frequency signal.

In the exemplary embodiment, the control unit (600) may comprise a driver circuit (610) for receiving the output (608) and for controlling the plurality of radiation emitters. In the exemplary embodiment, the one or more mechanical control members e.g., (604, 606) may comprise a potentiometer for a user to control a frequency of the plurality of radiation emitters. In the exemplary embodiment, the one or more mechanical control members e.g., (604, 606) may comprise another potentiometer for a user to control a light intensity/power/brightness of the plurality of radiation emitters.

Therefore, an adjustable control may be provided for a user to control the power of at least one radiation emitter. The adjustable control may further provide brightness control (or irradiance) and/or frequency control of at least one radiation emitter. For example, the control unit (600) may be located at a radiation member.

5

In the exemplary embodiment, a potentiometer e.g. (604, 606) may receive an input signal (e.g., an input signal from a user using the potentiometer) for adjustment of frequency. The potentiometer may provide a feedback signal to the microcontroller (602).

10

In the exemplary embodiment, the microcontroller (602) receives the feedback signal corresponding to "S" and converts it into a digital signal (e.g., 12-bit signal). The microcontroller (602) is arranged to calculate a desired output pulse frequency, i.e., a frequency desired by the user, using the following formula:

$$T = S \cdot 0.01099 + 5, S = \{0 \leq S \leq 4095\}$$

15

where S represents the input signal that the microcontroller (602) reads, and adjustable using a potentiometer e.g., (604, 606). The adjustment is provided to establish a mapping between a period in milliseconds (T) and the input signal (S), enabling the acquisition of frequencies within about 10 to about 100Hz range.

20

Error! Reference source not found. below shows an illustration of example values of mapping input signal S to frequency.

S	T(s)	Frequency(Hz)
0	0.0100	100.00
1000	0.0320	31.27
2000	0.0540	18.53
3000	0.0759	13.17
4000	0.0979	10.21
4095	0.1000	10.00

Table 1

25

The period (T) in Table 1 is shown in seconds. Thus, the microcontroller (602) is arranged to obtain a frequency based on a user adjustment of the potentiometer e.g.,

(604, 606) and with an output signal adjusted to the desired frequency of the user, the output (608) is transmitted to the driver circuit (610). The driver circuit (610) may comprise, for example, a MOSFET to control/regulate a LED of a radiation emitter (e.g., radiation emitters 302, 304, 306 of FIG. 3A).

5

In the exemplary embodiment, the microcontroller (602) may facilitate executing the desired frequency of at least one radiation emitter in radiating energy to a surface of the subject. That is, the at least one radiation emitter may emit radiation energy in the form of a pulsed wave form. With the control unit (600), an adjustable control is provided
10 for a radiation device to radiate energy at a frequency of about 10 Hz to about 100 Hz, as shown in the rightmost column of Table 1.

In the exemplary embodiment, an adjustable control is also provided, e.g., with another potentiometer to adjust the brightness of the plurality of radiation emitters, to
15 allow a radiation device to emit light to provide power in a range of about 150 W/m² to about 1400 W/m². In one example, power may be provided in the range of about 300 W/m² to about 800 W/m². In one example, an NIR wavelength may be about 850nm. It is appreciated that to achieve a desirable radiation output, the exemplary embodiment has the capability to adjust to even higher NIR radiation if needed.

Table 2 below illustrates an example source code for the microcontroller (602).

```
void setup() {
  pinMode(out, OUTPUT);
  pinMode(in, INPUT);
  Serial.begin(115200);

  //setup
  if (!mx.begin(0x5A)) {
    Serial.println("Error connecting to MX sensor.");
  }

  if (!vl.begin()) {
    Serial.println("Failed to connect to Vof sensor.");
  }
  mx.writeEmissivity(new_emissivity);
}

// the loop function runs over and over again forever
void loop() {
  //blinking control
  duration = (analogRead(in)*0.01099+5)/2;
  digitalWrite(out, HIGH);
  delay(duration);
  digitalWrite(out, LOW);
  delay(duration);
}
```

Table 2

- 5
- The equation executed in the microcontroller (602) using the example code of Table 2 is calculating half a period (T) instead of a full period for 50% duty cycle. In brief, the microcontroller (602) reads an input from a potentiometer e.g., (604, 606) for a desired frequency and converts the reading to a time delay which is then used to generate a pulse frequency.
- 10
- FIGs. 7A to 7D are exemplary waveforms that are controlled by a microcontroller of a control unit in an exemplary embodiment. The microcontroller may be the microcontroller (602) of FIG. 6. FIGs. 7B and 7D each show a pulsing pattern used for irradiance by the radiation emitters in the exemplary embodiment. In the exemplary embodiment, the microcontroller is run with a base frequency of 3Hz. In the exemplary embodiment, the microcontroller is arranged to perform the programming e.g. as shown in Table 2, for both the durations of the pulses and pauses of the patterns shown in FIGs. 7B and 7D.
- 15
- FIG. 7A shows a 10Hz operating voltage pattern as controlled by the microcontroller and sent to the plurality of radiation emitters, e.g. via a driver circuit. FIG.
- 20

7B shows a 10Hz irradiance pattern, with a pulsed wave form, of the plurality of radiation emitters.

FIG. 7C shows a 50Hz operating voltage pattern as controlled by the microcontroller and sent to the plurality of radiation emitters, e.g. via a driver circuit. FIG. 7D shows a 50Hz irradiance pattern, with a pulsed wave form, of the plurality of radiation emitters.

From FIGs. 7B and 7D, it is observed that even though the microcontroller may control and vary the frequencies, the power output may remain unaffected. For example, compare the Y-axes of FIGs. 7B and 7D for the irradiance values in W/m^2 .

In the exemplary embodiment, for the example implementation, an ESP32 microcontroller is used. Arduino IDE is used to program the microcontroller for the control of pulsed NIR waves of the radiation emitters. In the exemplary embodiment, a LED of a radiation emitter is model ILR-IO09-85ML-SC201-WIR200. In the exemplary embodiment, the radiation device is observed to be able to comply with the International Commission on Non-ionising radiation protection (ICNIRP) guidelines (for irradiance below $1200W/m^2$). In the exemplary embodiment, the microcontroller receives feedback from a potentiometer and the feedback is utilized to adjust the pulse wave generated by the NIR LEDs of the plurality of radiation emitters within a frequency range of about 10 to about 100Hz.

In exemplary embodiments, the microcontroller (602) may be arranged to control the functions of various components of the radiation device of exemplary embodiments.

In an exemplary embodiment, a heatsink is provided coupled to a radiation member. An example is the heatsink (208) of FIG. 2A. In the exemplary embodiment, the heatsink may be an internal heatsink that is used to circulate heat generated from a radiation device and/or a radiation emitter.

FIG. 8A is a schematic perspective view of the heatsink in the exemplary embodiment. FIG. 8B is a schematic side view of the heatsink in the exemplary

embodiment. In the exemplary embodiment, the heatsink (800) is specifically configured for coupling to a radiation emitter. The heatsink (800) may be coupled to a radiation emitter via direct coupling, e.g., the heatsink (800) is coupled directly to the radiation emitter without intermediate components or layers between the heatsink and the radiation
5 emitter.

In the exemplary embodiment, the coupling may be accomplished by one or more fastening devices, e.g., nuts and screws. In another example, the coupling may be by adhesives, e.g., thermal adhesives.

10

FIG. 9 is a photographic image of a heatsink taken from an underside of the heatsink in an exemplary embodiment. The heatsink (900) may be coupled to six radiation emitters e.g., the radiation emitters as illustrated in FIG. 2B. The heatsink (900) comprises a plurality of docks e.g., (902, 904) for coupling to the plurality of radiation emitters, e.g.,
15 the radiation emitters as illustrated in FIG. 2B.

FIG. 10 is a schematic drawing for illustrating a radiation device in an exemplary embodiment. In the exemplary embodiment, the radiation device (1000) is substantially similar to the radiation device (100) of FIG. 1, the radiation device (200) of FIG. 2A and the radiation device (300) of FIG. 3A. Like features of the radiation device are not
20 described herein for ease of understanding.

The radiation device (1000) comprises a mechanical member (1002) for determining a device distance of a radiation member, compare e.g. radiation member (206) of FIG. 2B, to a surface of a subject. The mechanical member (1002) is coupled to an external surface (1004) of the radiation device (1000) at one end (1006) of the mechanical member (1002). The mechanical member (1002) comprises another end (1008) that is positioned at a second predetermined distance from the radiation device (1000) such that the mechanical member (1002) is capable of determining the device
25 distance of the radiation member, compare e.g., radiation member (206) of FIG. 2B, to the surface of the subject.

30

It will be appreciated that the mechanical member (1002) may take various forms. For example, the mechanical member (1002) may be a permanent immovable mechanical fixture on the radiation device (1000).

5 In the exemplary embodiment, the mechanical member (1002) is arranged to be a collapsible measuring mechanical tool that is movable with respect to the surface of the subject. In the exemplary embodiment, the end (1006) of the mechanical member (1002) is coupled to a rotatable joint (1010) disposed on the external surface (1004) of the radiation device (1000). The mechanical member (1002) may be rotated e.g., in a rotating
10 direction (1012) with respect to the radiation device (1000) such that the mechanical member (1002) is collapsible, e.g., after the device distance of the radiation member, compare e.g. radiation member (206) of FIG. 2B, to the surface of the subject is not needed. Thus, the mechanical member (1002) may be folded and/or moved away from the surface of the subject, e.g., after determination of the device distance between the
15 radiation device / the radiation member and the surface of the subject.

 The mechanical member (1002) may be rotated e.g., opposite to the rotating direction (1012) with respect to the radiation device (1000) such that the mechanical member (1002) is extendable, e.g. to determine the device distance of the radiation
20 member, compare e.g. radiation member (206) of FIG. 2B, to the surface of the subject.

 In some exemplary embodiments, the mechanical member (1002) may be a ruler with a substantially fixed length (e.g., about 5 cm). In such exemplary embodiments, if a convergent point of respective focal points of a plurality of radiation emitters is about 5.83
25 cm, it may be provided that the respective focal points of a plurality of radiation emitters converge under the surface of the subject.

 In some exemplary embodiments, the ruler may further be positioned such that the ruler is substantially parallel to a radiation direction (1014) of a radiation emitter, e.g.,
30 compare radiation emitter (210) of FIG. 2B. Thus, the ruler may be substantially perpendicular to the surface of the subject during use of the radiation device (1000).

FIG. 11 is a schematic drawing for illustrating a radiation device in an exemplary embodiment. In the exemplary embodiment, the radiation device (1100) is substantially similar to the radiation device (100) of FIG. 1, the radiation device (200) of FIG. 2A and the radiation device (300) of FIG. 3A. Like features of the radiation device are not
5 described herein for ease of understanding.

The radiation device (1100) comprises a proximity sensor (1102) disposed on a subject-facing side (1104) of the radiation device (1100). Compare e.g., subject-facing side (204) of FIG. 2A. The proximity sensor (1102) is configured
10 to generate an alarm if it is determined that a proximity distance (1106) between the proximity sensor (1102) and a surface (1108) of a subject exceeds a third predetermined distance.

In the exemplary embodiment, the proximity sensor (1102) may be coupled to and
15 controllable by a microcontroller. Compare e.g., microcontroller (602) of control unit (600) of FIG. 6.

In the exemplary embodiment, the proximity sensor (1102) may be used to provide non-contact detection or determination of a device distance (compare proximity distance
20 (1106)) between the radiation device (1100) or a radiation member and the surface (1108) of the subject. It will be appreciated that the proximity sensor (1102) may take various forms. For example, the proximity sensor (1102) may make use of, for example but not limited to, electromagnetic radiation, infrared radiation, laser light, ultrasonic waves, capacitive variation, etc. for determining the proximity distance (1106).

25

In the exemplary embodiment, the proximity sensor (1102) may be coupled to an alarm system and may be configured to generate an alarm if it is determined that the device distance between the radiation device (1100) and the surface (1108) of the subject exceeds a predetermined distance, for example for a predetermined period of time. For
30 example, the alarm system may be arranged such that an alarm (e.g., a visible alarm, an audible alarm, an alarm signal, a haptic alarm and/or a silent alarm) may be generated if it is determined that the device distance (compare proximity distance (1106)) between

the radiation device (1100) and the surface (1108) of the subject falls out of, or is not within, an optimal or predetermined distance.

For example, the predetermined distance may be a buffer zone of about 1 to about
5 2 cm of a convergent point of respective focal points of a plurality of radiation emitters. For example, compare convergent point (311) of FIG. 3A. For example, the alarm system may be activated by a proximity switch which may close an electrical circuit if the proximity sensor (1102) detects that the device distance (compare proximity distance (1106)) between the radiation device (1100) and the surface (1108) of the subject falls out of, or
10 is not within, an optimal or predetermined range of about 4 cm to about 6 cm. It will be appreciated that the proximity sensor and/or the alarm system may be implemented in a number of different ways and are not limited to the above description.

For example, if the device distance (compare proximity distance (1106)) between
15 the radiation device (1100) and the surface (1108) of the subject is more than the predetermined range, e.g., the device distance is more than about 6 cm, it is recognised that effectiveness of the radiation device (1100) for radiating the subject may be reduced. For example, if the device distance (compare proximity distance (1106)) between the radiation device (1100) and the surface (1108) of the subject is less than the
20 predetermined range, e.g., the device distance (compare proximity distance (1106)) is less than about 4 cm, i.e., determined to be too close to the surface (1108) of the subject, there may be a concern of undesirable / high heat generated on the surface (1108) of the subject by the plurality of radiation emitters.

FIG. 12 is a schematic drawing for illustrating a radiation device in an exemplary
25 embodiment. In the exemplary embodiment, the radiation device (1200) is substantially similar to the radiation device (100) of FIG. 1, the radiation device (200) of FIG. 2A and the radiation device (300) of FIG. 3A. Like features of the radiation device are not described herein for ease of understanding.

30

The radiation device (1200) comprises a stability member (1202). The stability member (1202) is coupled to a top side (1204) of the radiation device (1200), the top side (1204) being opposite to a subject-facing side (1206) of the radiation device (1200). When

the radiation device (1200) is in use, the stability member (1202) is therefore coupled to a radiation member of the radiation device (1200) to stabilise the radiation member, e.g., stabilised and/or immobilised with respect to a subject.

5 In addition, due to the coupling, when the radiation device (1200) is in use, there is no object therebetween the radiation member of the radiation device (1200) and a surface (1208) of the subject. Therefore, the stability member (1202) may allow the radiation device (1200) to be positioned above the surface (1208) of the subject with no other object therebetween the radiation member of the radiation device (1200) and the
10 surface (1208) of the subject.

In some exemplary embodiments, the stability member (1202) may take the form of a stand.

15 FIG. 13 is a photographic image of a radiation device comprising a stand in an exemplary embodiment. The radiation device (1300) is substantially similar to the radiation device (100) of FIG. 1, the radiation device (200) of FIG. 2A and the radiation device (300) of FIG. 3A. Like features of the radiation device are not described herein for ease of understanding.

20 The radiation device (1300) comprises a stability member that is in the form of a stand (1302). The stand (1302) is arranged to be coupled to a top side of the radiation device (1300). In the exemplary embodiment, the coupling of the stand (1302) comprises a ball-joint adjustment knob (1304) that is capable of locking a radiation member of the
25 radiation device (1300) in position. For example, in use, the ball-joint adjustment knob (1304) may be locked so that the radiation device (1300) is locked in position over a surface of a subject and therefore, the radiation member of the radiation device (1300) is also locked in position over the surface of the subject.

30 In some exemplary embodiments, the stand (1302) may be stabilised using anchoring members. In the exemplary embodiments, the stand (1302) comprises a set of tripod legs (1306) to provide stability to the radiation device (1300). For example, the

tripod legs (1306) may be extended with respect to the stand (1302) to provide a stable base for the stand (1302).

In some exemplary embodiments, the stability member (1202) may take the form
5 of a clamp.

FIG. 14 is a photographic image of a radiation device comprising a clamp in an exemplary embodiment. The radiation device (1400) is substantially similar to the radiation device (100) of FIG. 1, the radiation device (200) of FIG. 2A and the radiation
10 device (300) of FIG. 3A. Like features of the radiation device are not described herein for ease of understanding.

The radiation device (1400) comprises a stability member that is in the form of a clamp (1402). The clamp (1402) is arranged to be coupled to a top side of the radiation
15 device (1400).

In the exemplary embodiment, the coupling of the clamp (1402) comprises an adjustment knob (1404) that is capable of locking a radiation member of the radiation device (1400) in position.
20

For example, the clamp (1402) may comprise the adjustment knob (1404) including a locking mechanism (e.g., a vice clamp) to be stably mounted, e.g., over a table top (1406), to provide stability to the radiation device (1400). For example, in use, the adjustment knob (1404) may be locked/clamped so that the radiation device (1400)
25 is locked in position over a surface of a subject and therefore, the radiation member of the radiation device (1400) is also locked in position over the surface of the subject.

FIGs. 15A to 15D show a series of photographic images of a radiation device in an example implementation.
30

At FIG. 15A, a radiation device (1500) comprising a stand (1502) is shown. The radiation device (1500) is substantially similar to the radiation device (100) of FIG. 1, the

radiation device (200) of FIG. 2A and the radiation device (300) of FIG. 3A. Like features of the radiation device are not described herein for ease of understanding.

The radiation device (1500) is positioned with its subject-facing side (1504) facing
5 towards a surface (1506) of a subject (1508). In the example implementation, the surface (1506) is a skin surface. In the example implementation, the stand (1502) comprises a set of tripod legs (1510), e.g., compare tripod legs (1306) of FIG. 13. In the example implementation, the radiation device (1500) comprises a mechanical member (1512) for
10 determining a device distance of a radiation member of the radiation device (1500), compare e.g. radiation member (206) of FIG. 2B, to the surface (1506) of a subject (1508). Compare mechanical member (1002) of FIG. 10.

In the example implementation, the mechanical member (1512) is in the form of a ruler (1512) with a substantially fixed length (e.g., about 5 cm). It may be provided that
15 the respective focal points of a plurality of radiation emitters converge under the surface (1506) of a subject (1508). The ruler may further be positioned such that the ruler is substantially parallel to a radiation direction of a radiation emitter, e.g. compare radiation emitter (210) of FIG. 2B. Thus, the ruler may be substantially perpendicular to the surface (1506) of a subject (1508) during use of the radiation device (1500).

20 As shown in FIG. 15A, the tripod legs (1510) are extended substantially to their fullest extent, thus ensuring that the radiation device (1500) is positioned securely and with optimal stability, e.g., with respect to the surface (1506) of a subject (1508).

25 At FIG. 15B, the radiation device (1500) is aligned at a desired angle so that the plurality of radiation emitters of the radiation device (1500) may be directly positioned over an area of interest at the surface (1506) of a subject (1508). The alignment may include angling the radiation device (1500) at an angle (e.g., relative to the ground or floor). For example, the plurality of radiation emitters of the radiation device (1500) may
30 be positioned substantially perpendicular to the surface (1506) of a subject (1508). After alignment, the adjustment knob (1514) of the radiation device (1500), e.g., compare ball-joint adjustment knob (1304) of FIG. 13, may be firmly tightened to maintain the aligned

position of the radiation device (1500), e.g. to maintain the angle / position of the radiation device (1500).

At FIG. 15C, during the alignment process of FIG. 15B, the ruler (1512) may be
5 used as a guide to determine a suitable device distance for the radiation device (1500) to deliver radiation energy to the subject (1508). The ruler (1512) may be provided as a collapsible measuring mechanical tool that may be moved away or retracted after confirmation/determination of the device distance of the radiation device (1500) to the surface (1506) of the subject (1508).

10

In some other example implementations, additionally or alternatively, a proximity sensor positioned/disposed on the subject-facing side (1504) of the radiation device (1500) may be used to provide a notification or an alarm if the proximity distance between the proximity sensor to the surface (1506) of the subject (1508) exceeds or falls outside
15 an example range of about 4 cm to about 6 cm. Compare proximity sensor (1102) of FIG. 11.

In some example implementations, it is recognised that, with the ruler (1512) and/or the proximity to determine / confirm the device distance, the radiation device may
20 be easily operated by users e.g., by nurses.

At FIG. 15D, after alignment, the radiation device (1500) may be activated. For example, a control unit of the radiation device (1500) may be used to activate the plurality of radiation emitters of the radiation member of the radiation device (1500). Compare
25 control unit (600) of FIG. 6.

In the example implementation, it may be arranged for the radiation device (1500) to deliver radiation energy to the subject (1508) for a pre-determined period of about 30 minutes.

30

In other example implementations, instead of the stand (1502), a clamp for securing directly to e.g., a side of a table may be used. Compare clamp (1402) of FIG. 14.

Therefore, in the example implementation shown above, a NIR radiation device may be provided and it may take the form of a standing lamp. NIR radiation from a plurality of radiation emitters may be used and may converge at a distance between about 4 cm to about 6 cm, from an emission end of a radiation emitter, e.g., to target AVF underneath the surface of the subject, e.g., the skin surface of the subject.

In the example implementation shown above, the measurement of about 4 cm to about 6 cm relates to the distance between an NIR emitter (a radiation emitter emission end) and the area of interest. With the above implementation with the stand and ball-joint adjustment knob, the distance may usefully remain constant and may not be affected by any further adjustments made to the tripod legs. Thus, with the above implementation, the radiation device may have beneficial stability.

In the example implementation shown above, the NIR radiation device incorporates LEDs (comprised with the plurality of radiation emitters) that may provide useful therapeutic effects to the subject. The inventors recognised that the power received by the area of interest (e.g. or the AVF) may align with the power measured in the example testing, e.g., compare FIG. 4.

With the example implementation, the operation of the above device may be made relatively simple such that a user e.g., a nurses may use the radiation device with minimal training.

In relation to the example implementation illustrated above, the inventors have recognised that a subject's limb, e.g., an arm, can have a curved outer surface or skin surface. In some situations, the subject's skin surface may be irregular, e.g., there may be peaks and valleys across the skin surface. Thus, in some situations, the inventors recognise that an angle between an emitted radiation and the skin surface may not be less than 90 degrees for the second and third radiation emitters. Compare e.g. FIG. 3A. In some applications, radiation to be applied may be targeted at any point along a length of a subject's limb. For example, the radiation may be applied to a subject's upper arm, above an elbow, or below an elbow.

In some exemplary implementations, such as illustrated in FIG. 15A, the radiation member is an open design such that a user or observer can visually observe a skin surface of a subject e.g., during radiation. In such exemplary implementations, the subject
5 is allowed to rotate his or her limb for comfort and air can flow easily between the skin surface of the subject and the radiation emitters for a cooling effect.

In one exemplary embodiment, there is provided a method of using a radiation device for delivering radiation energy to a subject, the radiation device being of any of the
10 above-described exemplary embodiments.

In the exemplary embodiment, the method may comprise coupling a radiation member of the radiation device to a stability member and deploying the stability member to immobilize/stabilize the radiation device. For example, the stability member may be
15 coupled to a back surface of the radiation member so as to allow the radiation device to be positioned above the surface of the subject with no other object therebetween the radiation member and the surface of the subject. For example only, the stability member may be in the form of a stand. The stand may be in the form of a tripod stand with legs. In such an example, in use, the method may comprise extending the legs of the tripod
20 stand to ensure that the radiation member coupled to the tripod stand is positioned relatively securely and stably. For another example only, the stability member may be in the form of a clamp. The clamp may be in the form of a locking mechanism such as a vice clamp for a tabletop. In such an example, in use, the method may comprise mounting the radiation device, e.g., over a tabletop, via use of the locking mechanism to ensure that
25 the radiation member coupled to the clamp is positioned relatively stably and securely. For example, the radiation member may be positioned over a surface of a subject. In some examples, it is recognised that the radiation device can have beneficial stability over the surface of the subject and that the radiation device may be easily operated by users e.g., by nurses.

30

In the exemplary embodiment, the method may further comprise aligning / angling the radiation member at an angle (e.g., relative to the ground or floor) so that the at least one radiation emitter is positioned substantially directly over the surface of the subject.

For example, the at least one radiation emitter may be positioned substantially perpendicular to the surface of the subject, for example, the subject's arm surface. For example, the aligning comprises positioning the radiation member at a desired device distance to the surface of the subject. The method may further comprise fixing the
5 radiation member at a chosen angle / in position (in situ), e.g., using one or more adjustment knobs, to maintain the angle / position of the radiation member.

In the exemplary embodiment, the method may further comprise utilising a mechanical / physical element (e.g., a ruler / rule), e.g., coupled to the radiation member
10 and e.g., as a guide, to determine / confirm a device distance of the radiation device / the radiation member to the surface of the subject. In some exemplary embodiments, it is recognised that, with the mechanical element to determine / confirm the device distance, the radiation device can be easily operated by users e.g., by nurses. In some exemplary implementations, after determining the device distance between the radiation device /
15 radiation member to the surface of the subject, the mechanical / physical element may be folded and/or moved away from the surface of the subject. In some other exemplary implementations, the method may alternatively or additionally comprise utilising a proximity sensor to determine / confirm the device distance between the radiation device / radiation member to the surface of the subject. In some exemplary implementations, the
20 proximity sensor may generate an alarm if it is determined that the device distance between the radiation device / the radiation member and the surface of the subject falls out of, or is not within an optimal or predetermined distance, for example for a predetermined period of time. For example, the alarm system may be activated by a proximity switch which may close an electrical circuit when the proximity sensor detects
25 that the device distance between the radiation device / the radiation member and the surface of the subject falls out of, or is not within, an optimal or predetermined range of 4 cm to 6 cm. For example, if the device distance between the radiation device / the radiation member and the surface of the subject is more than the predetermined range, e.g., the device distance is more than about 6 cm, effectiveness of the radiation device
30 for radiating the subject may be reduced. For example, if the device distance between the radiation device / radiation member and the surface of the subject is less than the predetermined range, e.g., the device distance is less than about 4 cm, i.e., determined

to be too close to the surface of the subject, there may be a concern of undesirable / high heat generated on the surface of the subject by the radiation member.

5 In the exemplary embodiment, the method may further comprise utilising an adjustable control to control the power of the at least one radiation emitter. The adjustable control may further provide brightness control (or irradiance) and/or frequency control of the at least one radiation emitter. For example, the adjustable control may be located at a housing of the radiation member.

10 In the exemplary embodiment, the method may further comprise activating the radiation member for a pre-determined time e.g., about 30 minutes. For example, radiation energy is transmitted to the subject (e.g., towards the surface of the subject) over the pre-determined time duration. For example only, the radiation energy provided to the subject may be administered for various purposes, for example but not limited to,
15 delivering radiation energy to a blood vessel in relation to AVF for AVF therapy, wound healing, pain management, vascular health promotion, and cosmetic/aesthetic applications. For example, the radiation energy may be delivered to a varicose vein.

20 With the described exemplary embodiments, the inventors performed test iterations at maximum continuous power output.

FIG. 16 is a graph illustrating a repeatability of test iterations. The graph (1600) shows that with five test sessions, a multivariate anova test shows an appreciably extremely high p-value, i.e., no difference among a sample mean. The x-axis (1602)
25 reflects 100 divisions which correspond to a variable resistor or potentiometer of an exemplary embodiment provided for adjustable control for a user to control the power of at least one radiation emitter. That is, the potentiometer for power adjustment has 100 divisions. It is observed that at about the 35th division mark, the irradiance approaches a constant maximum value (1604). It may also be observed that before about the 35th
30 division mark, the potentiometer may provide a substantially linear control (1606) of irradiance with adjustment of each division of the potentiometer.

With the described exemplary embodiments, the inventors recognise that a radiation device of exemplary embodiments may provide significant advantages. The radiation device or NIR radiation device may provide high adjustability (e.g., referring to the adjustable control of frequency for a pulse wave form and/or control of
5 power/irradiance of the radiation emitters), and enable precise control over the emitted power. In some described exemplary embodiments, the radiation power and pulse frequency are adjustable, while the intersection distance (e.g. the convergent point) and wavelength of radiation may be fixed.

10 With the described exemplary embodiments, the inventors recognise that the radiation device may provide sufficient power to effectively deliver energy through e.g. a skin surface. Such power may ensure that a targeted Area of Interest (e.g., for AVF) may optimally receive a therapeutic energy, making the radiation device suitable for professional therapeutic purposes. The inventors recognise that the radiation device may
15 provide enhanced adjustability and higher power output, making it a more potent and versatile tool e.g., for therapeutic applications.

FIG. 17 is a schematic flowchart (1700) illustrating a method of forming a radiation device for delivering radiation energy to a surface of a subject in an exemplary
20 embodiment.

At step (1702), a radiation member is coupled to a subject-facing side of a radiation device, the radiation member comprising a plurality of radiation emitters. At step (1704), a first radiation emitter is disposed at a first position of the radiation member and
25 a second radiation emitter is disposed at a second position of the radiation member, wherein each of the first radiation emitter and the second radiation emitter comprises at least one LED capable of emitting light in the NIR region. At step (1706), the second position is angularly displaced from the first position of the radiation member to cause respective focal points of the first radiation emitter and the second radiation emitter to
30 converge at a predetermined distance from the subject-facing side of the radiation device.

The method may further comprise a step with a third radiation emitter disposed at a third position of the radiation member, wherein the first radiation emitter is disposed at

a centre portion of the radiation member, the second radiation emitter is disposed at a first peripheral wing of the radiation member and the third radiation emitter is disposed at a second peripheral wing of the radiation member; with the third position angularly displaced from the first position of the radiation member to cause respective focal points
5 of the first radiation emitter and the third radiation emitter to converge at the predetermined distance from the subject-facing side of the radiation device; and with the first position, the second position and the third position disposed along a length-wise direction of the radiation device.

10 The method may further comprise a step with a control unit provided comprising a microcontroller and one or more mechanical control members; with the microcontroller configured to receive a signal from the one or more mechanical control members and to output a frequency signal to the plurality of radiation emitters for the plurality of radiation emitters to deliver the radiation energy in pulses corresponding to the frequency signal.

15 The method may further comprise a step with a stability member coupled to a top side of the radiation device to stabilise the radiation member when in use, the top side being opposite the subject-facing side of the radiation device such that, in use, there is no object therebetween the radiation member and the surface of the subject.

20 The method may further comprise a step with the stability member comprising a stand and coupling the stand to the top side of the radiation device; with the coupling of the stand comprising a ball-joint adjustment knob that is capable of locking the radiation member in position.

25 The method may further comprise a step with the stability member comprising a clamp and coupling the clamp to the top side of the radiation device; with the coupling of the clamp comprising an adjustment knob that is capable of locking the radiation member in position.

30 The method may further comprise a step with a mechanical member coupled to an external surface of the radiation device at one end of the mechanical member, the mechanical member for determining a device distance of the radiation member to the

surface of the subject; with the mechanical member comprising another end that is positioned at a second predetermined distance from the radiation device such that the mechanical member is capable of determining the device distance.

- 5 The method may further comprise a step with the mechanical member arranged to be a collapsible measuring mechanical tool that is movable with respect to the surface of the subject.

- 10 The method may further comprise a step with a proximity sensor disposed on the subject-facing side of the radiation device; with the proximity sensor configured to generate an alarm if it is determined that a proximity distance between the proximity sensor and the surface of the subject exceeds a third predetermined distance. For example, the proximity sensor may be configured to generate an alarm if it is determined that a distance between the radiation member and the surface of the subject exceeds a
15 third predetermined distance.

- The described exemplary embodiments may provide a relatively low-cost radiation device that may be used to e.g., strengthen AVF that may in turn enhance a success rate of AVF and may improve a patency rate using NIR therapy. Such a low-cost radiation
20 device may assist to increase blood flow across an AVF using NIR radiation. The described exemplary embodiments may provide a relatively portable and non-contact radiation device that may be useful for NIR radiation e.g., for a dialysis or pre-dialysis subject.

- 25 The inventors recognise that the NIR radiation device may strengthen AVF by delivering NIR radiation energy to a blood vessel, causing the vessel to dilate and maintain desirable blood flow. In such a radiation process, healthy vascular remodelling may be usefully promoted. Vascular remodelling refers to the homeostatic alteration of blood vessels in response to changes in blood flow rates and conditions.

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 The described exemplary embodiments may provide a radiation device that may assist to maintain a patency rate of AVF after maturation. The designed portable non-

contact device will enhance the AVF blood flow rate using NIR radiation in dialysis and pre-dialysis patients.

In some exemplary embodiments, the radiation device may be specifically configured for enhancing wellbeing of a subject. Such configuration may include, but is not limited to, frequency control of the delivery of radiation energy (with a desired range of values) and/or light intensity/brightness control (with a desired range of values) of the at least one radiation emitter. For example, the delivery of radiation energy may be for, but is not limited to, medical and/or therapeutic use. For example, the radiation device may be configured for AVF therapy, e.g., to deliver radiation energy to a blood vessel in relation to AVF. For example, the radiation device may be configured for wound healing, pain management, vascular health promotion, and cosmetic/aesthetic applications. For example, the radiation device may be configured for radiating a varicose vein.

In the description herein, the terms "coupled" or "connected" as used are intended to cover both directly connected or connected through one or more intermediate means, unless otherwise stated.

The use of "a", "an" or "the" is intended to mean "one or more" unless it is described specifically to the contrary.

The terms "configured to (perform a task/action)", "configured for (performing a task/action)" and the like as used in this description include being programmable, programmed, connectable, wired or otherwise constructed to have the ability to perform the task/action when arranged or installed as described herein. The terms "configured to (perform a task/action)", "configured for (performing a task/action)" and the like are intended to cover "when in use, the task/action is performed", e.g. specifically to and/or specifically configured to and/or specifically arranged to and/or specifically adapted to do or perform a task/action.

The term "and/or", e.g., "X and/or Y" is understood to mean either "X and Y" or "X or Y" and should be taken to provide explicit support for both meanings or for either

meaning. The use of “or” is intended to mean an “inclusive or,” and not an “exclusive or” unless it is described specifically to the contrary.

5 The terms “associated with”, “related to” and the like used herein when referring to two elements refers to a broad relationship between the two elements. The relationship includes, but is not limited to, a physical, a chemical or a biological relationship. For example, when element A is associated with element B, elements A and B may be directly or indirectly attached to each other or element A may contain element B or vice versa.

10 The terms “exemplary embodiment”, “example embodiment”, “exemplary implementation”, “exemplarily” and the like used herein are intended to indicate an example of matters described in the present disclosure. Such an example may relate to one or more features defined in the claims and is not necessarily intended to emphasise a best example or any essentialness of any features.

15 The description herein may be, in certain portions, explicitly or implicitly described as algorithms and/or functional operations that operate on data within a computer memory or an electronic circuit. These algorithmic descriptions and/or functional operations are usually used by those skilled in the information/data processing arts for efficient
20 description. An algorithm is generally relating to a self-consistent sequence of steps leading to a desired result. The algorithmic steps can include physical manipulations of physical quantities, such as electrical, magnetic or optical signals capable of being stored, transmitted, transferred, combined, compared, and otherwise manipulated.

25 Further, unless specifically stated otherwise, and would ordinarily be apparent from the following, a person skilled in the art will appreciate that throughout the present specification, discussions utilizing terms such as “scanning”, “calculating”, “determining”, “replacing”, “generating”, “initializing”, “outputting”, and the like, refer to action and processes of an instructing processor/computer system, or similar electronic
30 circuit/device/component, that manipulates/processes and transforms data represented as physical quantities within the described system into other data similarly represented as physical quantities within the system or other information storage, transmission or display devices etc.

The description also discloses relevant device/apparatus for performing the steps of the described methods. Such apparatus may be specifically constructed for the purposes of the methods, or may comprise a general purpose computer/processor or
5 other device selectively activated or reconfigured by a computer program stored in a storage member. The algorithms and displays described herein are not inherently related to any particular computer or other apparatus. It is understood that general purpose devices/machines may be used in accordance with the teachings herein. Alternatively, the construction of a specialized device/apparatus to perform the method steps may be
10 desired.

In addition, it is submitted that the description also implicitly covers a computer program, in that it would be clear that the steps of the methods described herein may be put into effect by computer code. It will be appreciated that a large variety of programming
15 languages and coding can be used to implement the teachings of the description herein. Moreover, the computer program if applicable is not limited to any particular control flow and can use different control flows without departing from the scope of the invention.

Furthermore, one or more of the steps of the computer program if applicable may
20 be performed in parallel and/or sequentially. Such a computer program if applicable may be stored on any computer readable medium. The computer readable medium may include storage devices such as magnetic or optical disks, memory chips, or other storage devices suitable for interfacing with a suitable reader/general purpose computer. In such instances, the computer readable storage medium is non-transitory. Such storage
25 medium also covers all computer-readable media e.g. medium that stores data only for short periods of time and/or only in the presence of power, such as register memory, processor cache and Random Access Memory (RAM) and the like. The computer readable medium may even include a wired medium such as exemplified in the Internet system, or wireless medium such as exemplified in Bluetooth technology. The computer
30 readable medium may be, for example, cloud storage in the Internet or within an intranet. The computer program when loaded and executed on a suitable reader effectively results in an apparatus that can implement the steps of the described methods, e.g. in a physical

embodiment. The computer readable medium is intended to be transferable and is reproducible in that the computer program if applicable is reproducible..

The exemplary embodiments may also be implemented as hardware modules. A
5 module is a functional hardware unit designed for use with other components or modules.
For example, a module may be implemented using digital or discrete electronic
components, or it can form a portion of an entire electronic circuit such as an Application
Specific Integrated Circuit (ASIC). A person skilled in the art will understand that the
exemplary embodiments can also be implemented as a combination of hardware and
10 software modules.

Additionally, when describing some embodiments, the disclosure may have
disclosed a method and/or process as a particular sequence of steps. However, unless
otherwise required, it will be appreciated that the method or process should not be limited
15 to the particular sequence of steps disclosed. Other sequences of steps may be possible.
The particular order of the steps disclosed herein should not be construed as undue
limitations. Unless otherwise required, a method and/or process disclosed herein should
not be limited to the steps being carried out in the order written. The sequence of steps
may be varied and still remain within the scope of the disclosure.

20 Further, in the description herein, the word "substantially" whenever used is
understood to include, but not restricted to, "entirely" or "completely" and the like. In
addition, terms such as "comprising", "comprise", and the like whenever used, are
intended to be non-restricting descriptive language in that they broadly include
25 elements/components recited after such terms, in addition to other components not
explicitly recited. For an example, when "comprising" is used, reference to a "one" feature
is also intended to be a reference to "at least one" of that feature. Terms such as
"consisting", "consist", and the like, may, in the appropriate context, be considered as a
subset of terms such as "comprising", "comprise", and the like. Therefore, in
30 embodiments disclosed herein using the terms such as "comprising", "comprise", and the
like, it will be appreciated that these embodiments provide teaching for corresponding
embodiments using terms such as "consisting", "consist", and the like. Further, terms such
as "about", "approximately" and the like whenever used, typically means a reasonable

variation, for example a variation of +/- 5% of the disclosed value, or a variance of 4% of the disclosed value, or a variance of 3% of the disclosed value, a variance of 2% of the disclosed value or a variance of 1% of the disclosed value.

- 5 Furthermore, in the description herein, certain values may be disclosed in a range. The values showing the end points of a range are intended to illustrate a preferred range. Whenever a range has been described, it is intended that the range covers and teaches all possible sub-ranges as well as individual numerical values within that range. That is, the end points of a range should not be interpreted as inflexible limitations. For example,
- 10 a description of a range of 1% to 5% is intended to have specifically disclosed sub-ranges 1% to 2%, 1% to 3%, 1% to 4%, 2% to 3% etc., as well as individually, values within that range such as 1%, 2%, 3%, 4% and 5%. It is to be appreciated that the individual numerical values within the range also include integers, fractions and decimals. Furthermore, whenever a range has been described, it is also intended that the range
- 15 covers and teaches values of up to 2 additional decimal places or significant figures (where appropriate) from the shown numerical end points. For example, a description of a range of 1% to 5% is intended to have specifically disclosed the ranges 1.00% to 5.00% and also 1.0% to 5.0% and all their intermediate values (such as 1.01%, 1.02% ... 4.98%, 4.99%, 5.00% and 1.1%, 1.2% ... 4.8%, 4.9%, 5.0% etc.,) spanning the ranges. The
- 20 intention of the above specific disclosure is applicable to any depth/breadth of a range.

- It will be appreciated by a person skilled in the art that other variations and/or modifications may be made to the specific embodiments without departing from the scope of the claimed invention as broadly described. For example, in the description herein,
- 25 features of different exemplary embodiments may be mixed, combined, interchanged, incorporated, adopted, modified, included etc. or the like across different exemplary embodiments. For example, exemplary embodiments are not necessarily mutually exclusive as some may be combined with one or more embodiments to form new exemplary embodiments. Furthermore, it will be appreciated that while the present
- 30 disclosure provides embodiments having one or more of the features/characteristics discussed herein, one or more of these features/characteristics may also be disclaimed in other alternative embodiments and the present disclosure provides support for such

disclaimers and these associated alternative embodiments. The present embodiments are, therefore, to be considered in all respects to be illustrative and not restrictive.

CLAIMS

1. A radiation device for delivering radiation energy to a surface of a subject, the device comprising
- 5 a radiation member coupled to a subject-facing side of the radiation device, the radiation member comprising a plurality of radiation emitters;
- the plurality of radiation emitters having a first radiation emitter disposed at a first position of the radiation member and having a second radiation emitter disposed at a second position of the radiation member;
- 10 wherein each of the first radiation emitter and the second radiation emitter comprises at least one light-emitting diode (LED) capable of emitting light in the near-infrared (NIR) region; and
- wherein the second position is angularly displaced from the first position of the radiation member, the angular displacement arranged to cause respective focal points of
- 15 the first radiation emitter and the second radiation emitter to converge at a predetermined distance from the subject-facing side of the radiation device.
2. The radiation device as claimed in claim 1, further comprising a third radiation emitter, the third radiation emitter being disposed at a third position of the radiation
- 20 member;
- wherein the third position is angularly displaced from the first position of the radiation member, the angular displacement arranged to cause respective focal points of the first radiation emitter and the third radiation emitter to converge at the predetermined distance from the subject-facing side of the radiation device;
- 25 wherein the first radiation emitter is disposed at a centre portion of the radiation member, the second radiation emitter is disposed at a first peripheral wing of the radiation member and the third radiation emitter is disposed at a second peripheral wing of the radiation member; and
- wherein the first position, the second position and the third position are disposed
- 30 along a length-wise direction of the radiation device.
3. The radiation device as claimed in claims 1 or 2, further comprising

- a control unit, the control unit comprising a microcontroller and one or more mechanical control members;
- wherein the microcontroller is configured to receive a signal from the one or more mechanical control members and to output a frequency signal to the plurality of radiation
- 5 emitters for the plurality of radiation emitters to deliver the radiation energy in pulses corresponding to the frequency signal.
4. The radiation device as claimed in any one of claims 1 to 3, further comprising a stability member, the stability member being coupled to the radiation member to
- 10 stabilise the radiation member when in use;
- wherein the stability member is coupled to a top side of the radiation device, the top side being opposite the subject-facing side of the radiation device such that, in use, there is no object therebetween the radiation member and the surface of the subject.
- 15 5. The radiation device as claimed in claim 4, wherein the stability member comprises a stand that is arranged to be coupled to the top side of the radiation device;
- wherein the coupling of the stand comprises a ball-joint adjustment knob that is capable of locking the radiation member in position.
- 20 6. The radiation device as claimed in claims 4 or 5, wherein the stability member comprises a clamp that is arranged to be coupled to the top side of the radiation device;
- wherein the coupling of the clamp comprises an adjustment knob that is capable of locking the radiation member in position.
- 25 7. The radiation device as claimed in any one of claims 1 to 6, further comprising a mechanical member for determining a device distance of the radiation member to the surface of the subject, the mechanical member being coupled to an external surface of the radiation device at one end of the mechanical member;
- wherein the mechanical member comprises another end that is positioned at a
- 30 second predetermined distance from the radiation device such that the mechanical member is capable of determining the device distance.

8. The radiation device as claimed in claim 7, wherein the mechanical member is arranged to be a collapsible measuring mechanical tool that is movable with respect to the surface of the subject.
- 5 9. The radiation device as claimed in any one of claims 1 to 8, further comprising a proximity sensor disposed on the subject-facing side of the radiation device; wherein the proximity sensor is configured to generate an alarm if it is determined that a proximity distance between the proximity sensor and the surface of the subject exceeds a third predetermined distance.
- 10 10. A method of forming a radiation device for delivering radiation energy to a surface of a subject, the method comprising
- coupling a radiation member to a subject-facing side of a radiation device, the radiation member comprising a plurality of radiation emitters;
- 15 disposing a first radiation emitter at a first position of the radiation member and disposing a second radiation emitter at a second position of the radiation member, wherein each of the first radiation emitter and the second radiation emitter comprises at least one light-emitting diode (LED) capable of emitting light in the near-infrared (NIR) region; and
- 20 angularly displacing the second position from the first position of the radiation member to cause respective focal points of the first radiation emitter and the second radiation emitter to converge at a predetermined distance from the subject-facing side of the radiation device.
- 25 11. The method as claimed in claim 10, further comprising
- disposing a third radiation emitter at a third position of the radiation member, wherein the first radiation emitter is disposed at a centre portion of the radiation member, the second radiation emitter is disposed at a first peripheral wing of the radiation member and the third radiation emitter is disposed at a second peripheral wing of the radiation
- 30 member;
- angularly displacing the third position from the first position of the radiation member to cause respective focal points of the first radiation emitter and the third radiation emitter

- to converge at the predetermined distance from the subject-facing side of the radiation device; and
- disposing the first position, the second position and the third position along a length-wise direction of the radiation device.
- 5
12. The method as claimed in claims 10 or 11, further comprising
- providing a control unit comprising a microcontroller and one or more mechanical control members;
- wherein the microcontroller is configured to receive a signal from the one or more
- 10 mechanical control members and to output a frequency signal to the plurality of radiation emitters for the plurality of radiation emitters to deliver the radiation energy in pulses corresponding to the frequency signal.
13. The method as claimed in any one of claims 10 to 12, further comprising
- 15 coupling a stability member to a top side of the radiation device to stabilise the radiation member when in use, the top side being opposite the subject-facing side of the radiation device such that, in use, there is no object therebetween the radiation member and the surface of the subject.
14. The method as claimed in claim 13, wherein the stability member comprises a stand that is arranged to be coupled to the top side of the radiation device;
- wherein the coupling of the stand comprises a ball-joint adjustment knob that is capable of locking the radiation member in position.
- 20
15. The method as claimed in claims 13 or 14, wherein the stability member comprises a clamp that is arranged to be coupled to the top side of the radiation device;
- wherein the coupling of the clamp comprises an adjustment knob that is capable of locking the radiation member in position.
- 25
16. The method as claimed in any one of claims 10 to 15, further comprising
- coupling a mechanical member to an external surface of the radiation device at one end of the mechanical member, the mechanical member for determining a device distance of the radiation member to the surface of the subject;
- 30

wherein the mechanical member comprises another end that is positioned at a second predetermined distance from the radiation device such that the mechanical member is capable of determining the device distance.

5 17. The method as claimed in claim 16, wherein the mechanical member is arranged to be a collapsible measuring mechanical tool that is movable with respect to the surface of the subject.

10 18. The method as claimed in any one of claims 10 to 17, further comprising disposing a proximity sensor on the subject-facing side of the radiation device; configuring the proximity sensor to generate an alarm if it is determined that a distance between the radiation member and the surface of the subject exceeds a third predetermined distance.

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