

(54) **APPARATUS AND METHODS FOR PHOTOTHERAPY**

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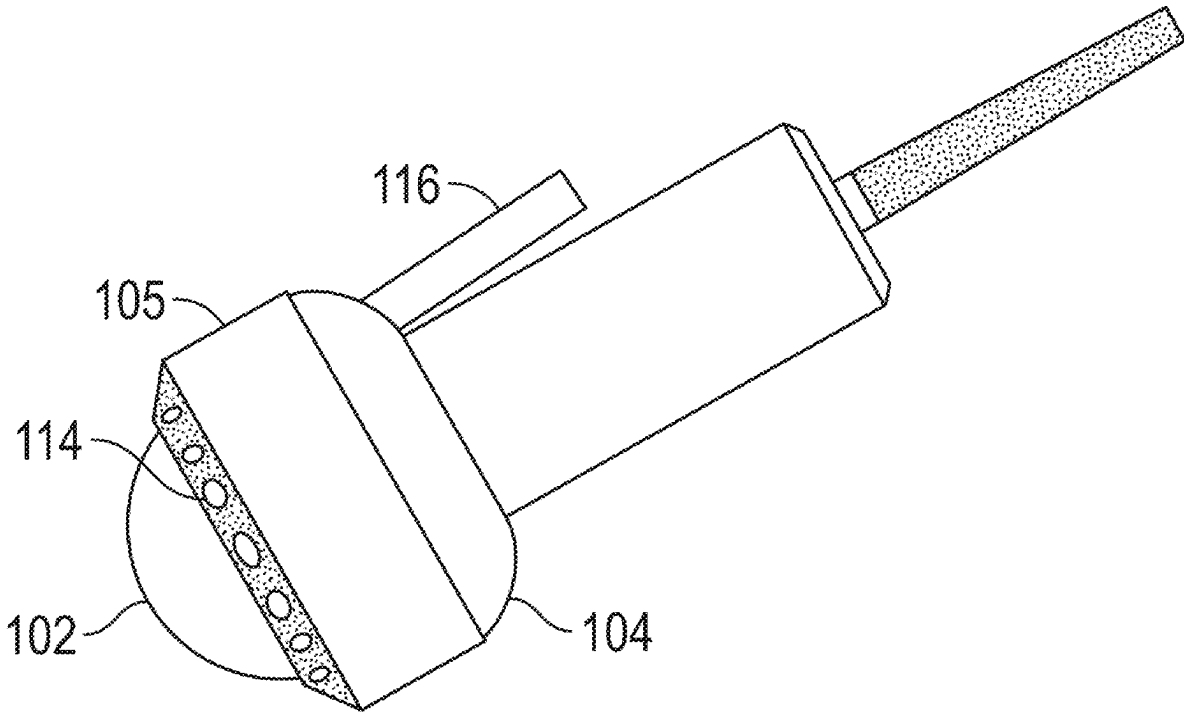
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(57) **ABSTRACT**

There is provided a phototherapy apparatus, in which the therapeutic light is delivered through or in proximity to one or more massage components. The massage component provides mechanical massage to the subject biological tissue and modifies the properties of the subject tissue in thickness, density, etc. to facilitate the absorption of the therapeutic light and enhance the effect of the phototherapy procedure.



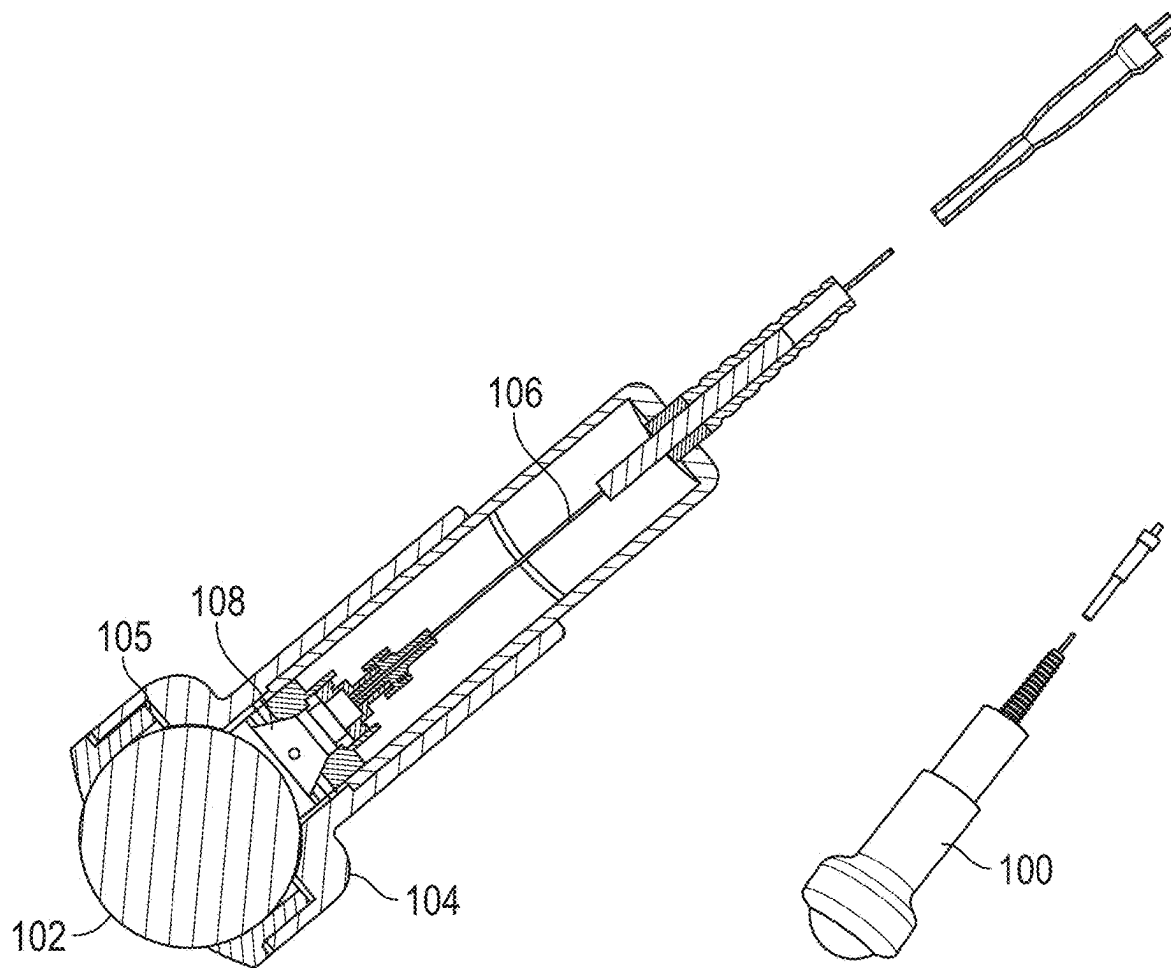


FIG. 1a'

FIG. 1a

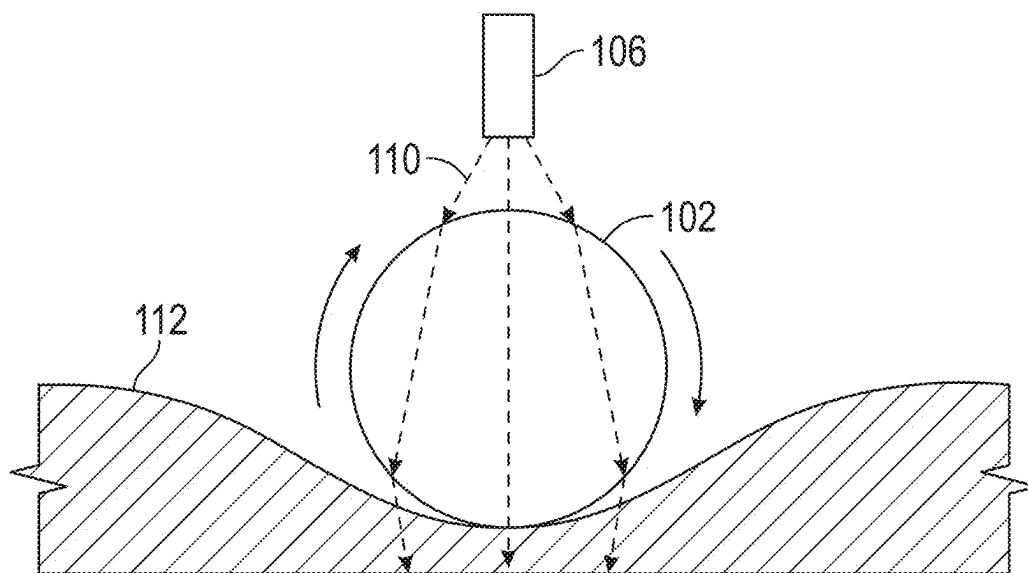


FIG. 1b

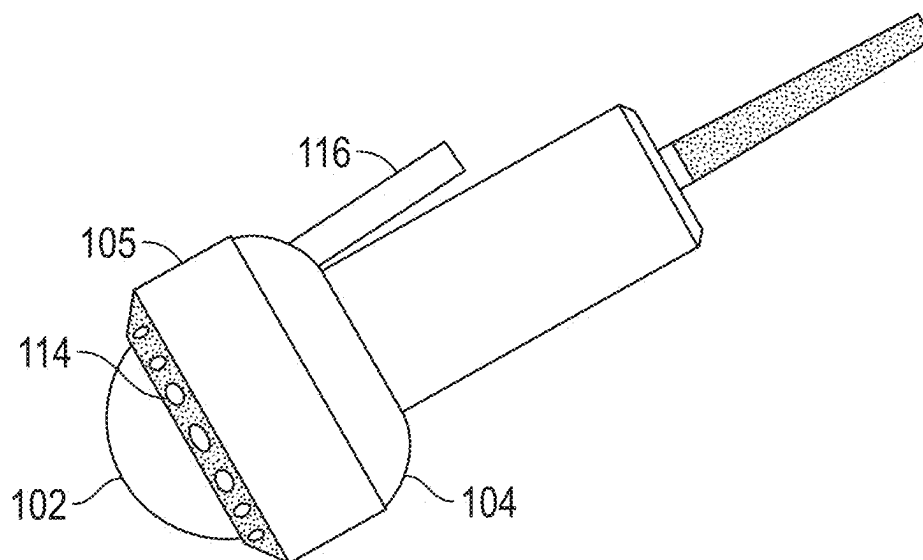


FIG. 2

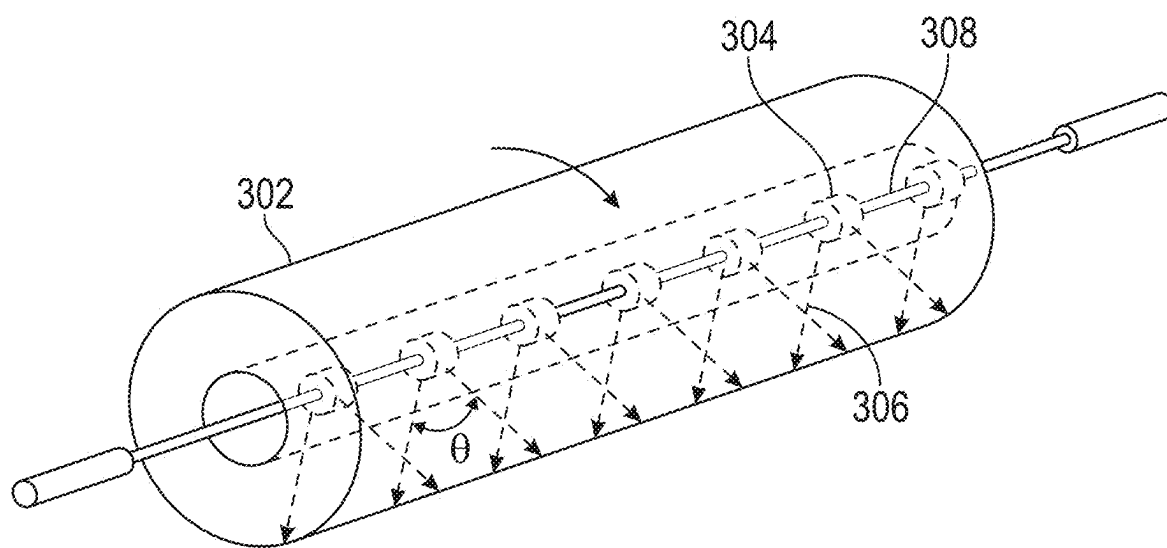


FIG. 3

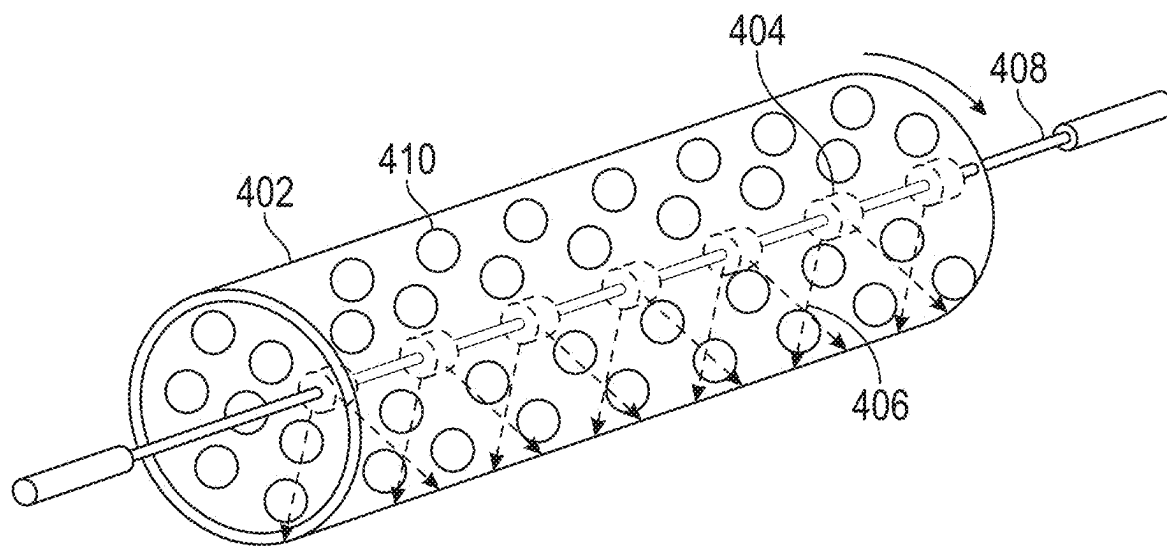


FIG. 4

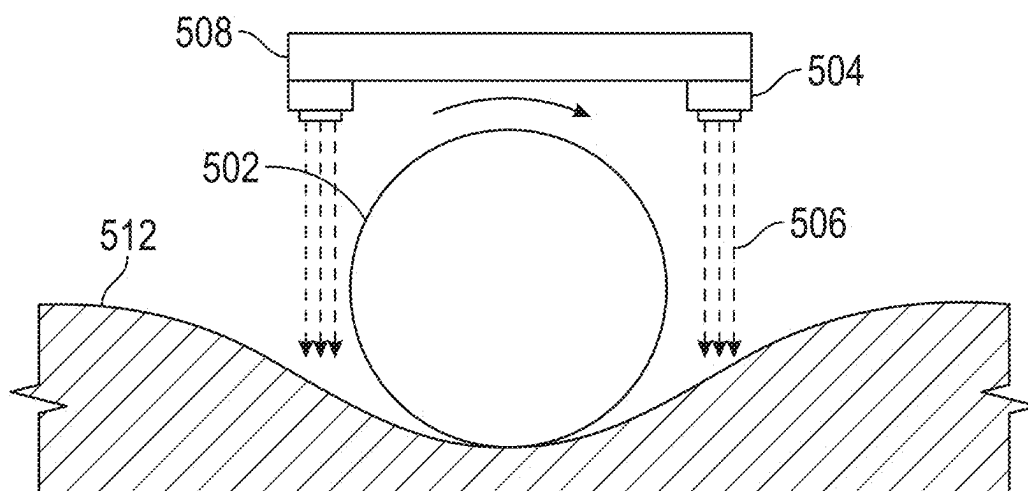


FIG. 5

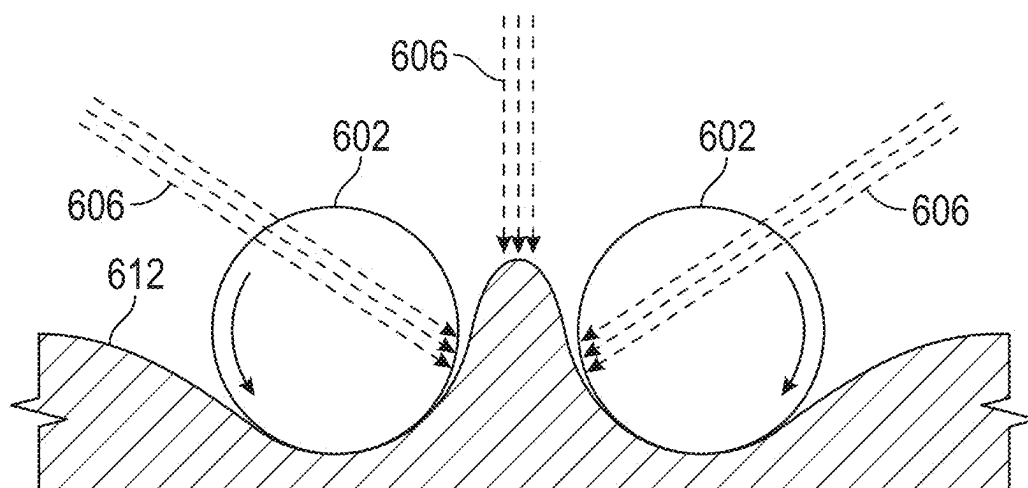


FIG. 6

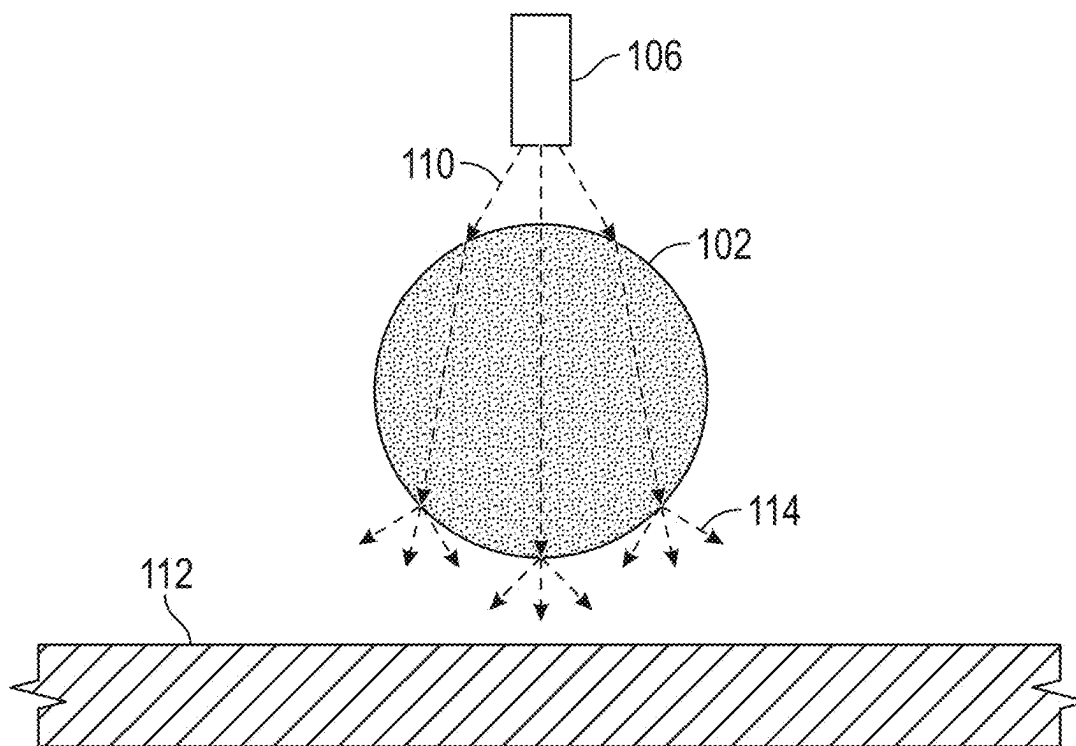


FIG. 7a

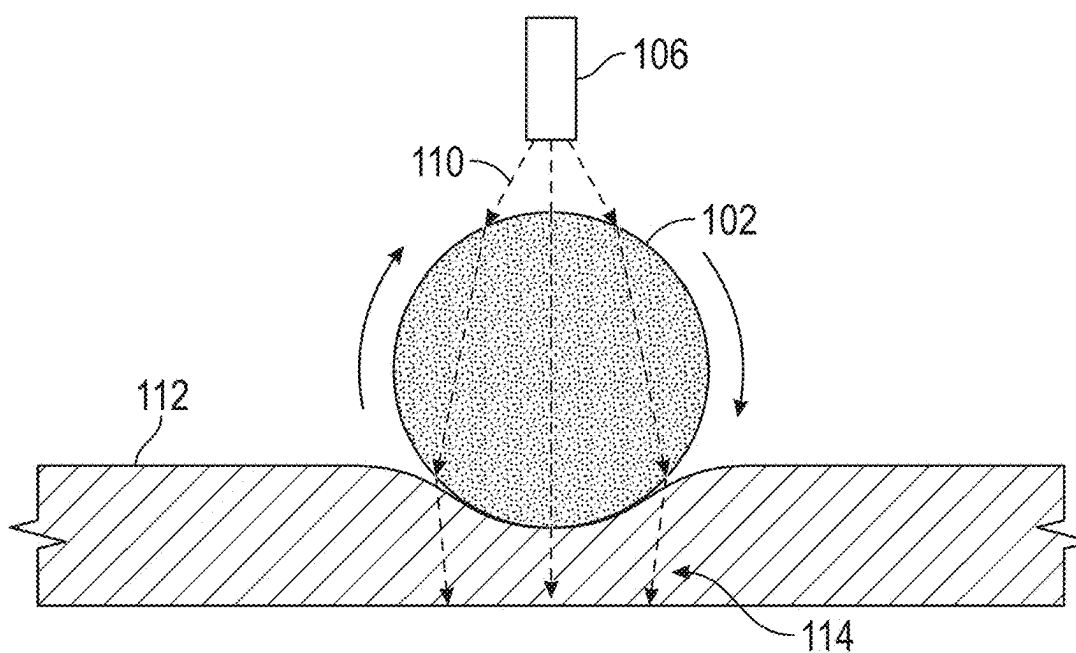


FIG. 7b

## APPARATUS AND METHODS FOR PHOTOTHERAPY

### REFERENCE TO RELATED APPLICATIONS

**[0001]** This application is a continuation of U.S. application Ser. No. 18/321,250, filed May 22, 2023, (U.S. Pat. No. 12,226,648, which is a continuation of U.S. application Ser. No. 16/986,005, filed Aug. 5, 2020, which is a continuation of U.S. application Ser. No. 16/295,677, filed Mar. 7, 2019 (U.S. Pat. No. 11,020,606), which is a continuation of U.S. application Ser. No. 14/635,160, filed Mar. 2, 2015 (U.S. Pat. No. 10,238,889), which is a continuation of U.S. application Ser. No. 12/104,012, filed Apr. 16, 2008 (U.S. Pat. No. 8,968,221), which claims the benefit of U.S. Provisional Nos. 60/912,284 filed Apr. 17, 2007, 60/976,554, filed Oct. 1, 2007, and 60/983,719, filed Oct. 30, 2007. All of the above-listed applications are hereby incorporated herein by reference. Any and all applications for which a foreign or domestic priority claim is identified in the Application Data Sheet as filed with the present application are hereby incorporated by reference under 37 CFR 1.57.

### FIELD OF THE INVENTION

**[0002]** This invention relates to apparatus and methods for phototherapy.

### BACKGROUND

**[0003]** Phototherapy relates to treatment of biological tissues, such as skin tissues, using visible, ultraviolet, and/or infrared lights. The light treatment may be applied solely for sterilization, pain relief, bio-modulation, and photo-rejuvenation. Alternatively, the treatment may be used in combination with certain photo-sensitive drugs or nutrition supplements. In comparison with laser surgery, the light intensity employed in phototherapy is much lower. Thus the light sources used in phototherapy are not limited to lasers but may include light emitting diodes (LEDs) and/or certain types of lamps as well. Typical applications of phototherapy include wound healing, cellulite reduction, skin rejuvenation, pain relief, fat reduction and contouring, laser acupuncture, pressure ulcer treatment, etc.

**[0004]** It is well known in the prior art that phototherapy may be applied in combination with other treatment methods such as local heating/cooling, magnetic therapy, mechanical massage involving rolling, kneading, vibrating components, etc. Some examples can be found in U.S. Pat. No. 7,033,382 to Lach; and U.S. Patent Application Nos. 20060253051 to Milne et al, 20060235494, 20040236252 to Muzzi et al, and 20070073366 to Porco. However, none of the prior art disclosure suggests to apply phototherapy with other treatment methods in a concerted manner, where phototherapy and some or all of the other treatment methods are applied to the same target area and benefit from each other thereby producing significantly improved therapeutic results.

### SUMMARY OF THE INVENTION

**[0005]** There is provided a phototherapy apparatus, wherein the therapeutic light is delivered through or in proximity to one or more massage components. The massage component provides mechanical massage to a subject biological tissue and modifies the properties of the subject tissue in thickness, density, local pressure, micro-circulation, etc. to facilitate the absorption and interaction of the

therapeutic light with the subject tissue and enhance the effect of the phototherapy procedure. Meanwhile, the therapeutic light in its interaction with the illuminated tissue also facilitates and enhances the effect of the mechanical massage.

**[0006]** A phototherapy apparatus for treatment of a biological tissue is provided. The phototherapy apparatus comprising: at least one light source to provide therapeutic light to be absorbed by the biological tissue to produce a first therapeutic effect; and at least one massage component to provide mechanical massage to the biological tissue to produce a second therapeutic effect. The therapeutic light and mechanical massage are applied to the biological tissue in a concerted manner. The mechanical massage modifies a plurality of properties or conditions of the biological tissue to facilitate absorption or interaction of the therapeutic light with the biological tissue to improve the first therapeutic effect. The therapeutic light modifies a plurality of properties or conditions of the biological tissue to improve the second therapeutic effect.

**[0007]** A method for making a phototherapy apparatus for treatment of a biological tissue is provided. The method comprising the steps of: providing at least one light source to provide therapeutic light to be absorbed by the biological tissue to produce a first therapeutic effect; and providing at least one massage component to provide mechanical massage to the biological tissue to produce a second therapeutic effect. The therapeutic light and mechanical massage are applied to the biological tissue in a concerted manner. The mechanical massage modifies a plurality of properties or conditions of the biological tissue to facilitate absorption or interaction of the therapeutic light with the biological tissue to improve the first therapeutic effect. The therapeutic light modifies a plurality of properties or conditions of the biological tissue to improve the second therapeutic effect.

**[0008]** A method for treatment of biological tissue with phototherapy is provided. The method comprising the steps of: providing at least one light source to provide therapeutic light to be absorbed by the biological tissue to produce a first therapeutic effect; and providing at least one massage component to provide mechanical massage to the biological tissue to produce a second therapeutic effect. The therapeutic light and mechanical massage are applied to the biological tissue in a concerted manner. The mechanical massage modifies a plurality of properties or conditions of the biological tissue to facilitate absorption or interaction of the therapeutic light with the biological tissue to improve the first therapeutic effect. The therapeutic light modifies a plurality of properties or conditions of the biological tissue to improve the second therapeutic effect.

### BRIEF DESCRIPTION OF THE DRAWINGS

**[0009]** The accompanying figures, where like reference numerals refer to identical or functionally similar elements throughout the separate views and which together with the detailed description below are incorporated in and form part of the specification, serve to further illustrate various embodiments and to explain various principles and advantages all in accordance with the present invention.

**[0010]** FIG. 1a illustrates one exemplified embodiment of the phototherapy apparatus, in which the therapeutic light is delivered through a transparent massage ball. FIG. 1a illus-

trates one exemplified embodiment of the phototherapy apparatus, in which the therapeutic light is delivered through a transparent massage ball.

**[0011]** FIG. 1*b* illustrates the operation procedure of the phototherapy apparatus of FIG. 1*a*.

**[0012]** FIG. 2 illustrates a slight variation of the phototherapy apparatus of FIG. 1, in which liquid or air can be delivered around the massage ball through an array of holes.

**[0013]** FIG. 3 illustrates a second exemplified embodiment of the phototherapy apparatus, in which the therapeutic light is delivered from inside of a transparent massage roller.

**[0014]** FIG. 4 illustrates a slight variation of the phototherapy apparatus of FIG. 3, in which the massage roller is made of non-transparent material comprising a matrix of holes.

**[0015]** FIG. 5 illustrates a third exemplified embodiment of the phototherapy apparatus, in which the therapeutic light is delivered in proximity to a massage component.

**[0016]** FIG. 6 illustrates a fourth exemplified embodiment of the phototherapy apparatus, in which the therapeutic light is delivered in proximity to two massage rollers rolling in opposite directions.

**[0017]** FIGS. 7*a* and 7*b* illustrate another variation of the phototherapy apparatus of FIG. 2, in which the massage ball has a diffusive or scattering optical surface.

**[0018]** Skilled artisans will appreciate that elements in the figures are illustrated for simplicity and clarity and have not necessarily been drawn to scale. For example, the dimensions of some of the elements in the figures may be exaggerated relative to other elements to help to improve understanding of embodiments of the present invention.

#### DETAILED DESCRIPTION

**[0019]** Before describing in detail embodiments that are in accordance with the present invention, it should be observed that the embodiments reside primarily in combinations of method steps and apparatus components related to phototherapy. Accordingly, the apparatus components and method steps have been represented where appropriate by conventional symbols in the drawings, showing only those specific details that are pertinent to understanding the embodiments of the present invention so as not to obscure the disclosure with details that will be readily apparent to those of ordinary skill in the art having the benefit of the description herein.

**[0020]** In this document, relational terms such as first and second, top and bottom, and the like may be used solely to distinguish one entity or action from another entity or action without necessarily requiring or implying any actual such relationship or order between such entities or actions. The terms “comprises,” “comprising,” or any other variation thereof, are intended to cover a non-exclusive inclusion, such that a process, method, article, or apparatus that comprises a list of elements does not include only those elements but may include other elements not expressly listed or inherent to such process, method, article, or apparatus. An element preceded by “comprises . . . a” does not, without more constraints, preclude the existence of additional identical elements in the process, method, article, or apparatus that comprises the element.

**[0021]** In the first embodiment of the present invention as shown in FIG. 1*a'* and FIG. 1*a*, the phototherapy apparatus 100 comprises a rolling massage ball 102 coupled to a top of a hand piece 104. The massage ball 102 can rotate freely

in all directions (a 360° freedom of movement) in a chamber 105 of the hand piece 104 with controlled friction. The therapeutic light emitted from a laser or a light emitting diode (LED) (both not shown) is first coupled into or carried by an optical fiber 106 and then delivered onto the massage ball 102 through a beam expander 108 wherein the therapeutic light beam is expended therefore. The massage ball 102 is transparent at the wavelength of the therapeutic light. Thus the subject therapeutic light will transmit through the massage ball 102 to the biological tissue for treatment purposes. In a slight variation of the embodiment, the therapeutic light can be delivered onto the massage ball via free space optics or other types of light guides all of which are contemplated by the present invention.

**[0022]** Referring now to FIG. 1*b*, the phototherapy apparatus 100 is utilized to treat a skin tissue 112, where the therapeutic light 110 is delivered through the transparent massage ball 102. When a force is applied onto the hand piece (not shown), the massage ball 102 will roll on the skin tissue 112 and deliver a pressure on the skin tissue in contact with the massage ball 102. On one hand, this rolling and kneading action causes an increase in blood circulation and fluid mobilization of the subcutaneous tissue, smoothes and firms the subject anatomy. Thus lipolysis is restored and fat cell metabolism is reactivated, resulting in the reduction of fat tissue and smoothing of cellulite. It also can help for the relief of muscle aches and pain. On the other hand, the action also causes a reduction in skin thickness and an increase in skin density. This change in skin tissue property helps to reduce the overall absorption and scattering loss of the therapeutic light 110 and allows the therapeutic light 110 to penetrate deeper under the skin and induce stronger photochemical processes, e.g. increase of ATP (adenosine triphosphate), triggering of photo neurological response and activation of enzymes, changes in local pressure, increases in temperature and permeability of cellular membranes. Since the massage ball 102 is in contact with the skin tissue 112, the therapeutic light 110 will penetrate into the skin tissue 112 directly with no air interface. This feature allows the practitioner to control the intensity of the delivered therapeutic light in a more accurate manner. The photo bio-modulation in turn helps to enhance the effect of the mechanical massage by stimulating inter or intra cellular response, increasing micro-circulation, etc.

**[0023]** In a slight variation of the present embodiment as shown in FIG. 2, the ball chamber 105 of the hand piece 104 comprises an array of holes 114 formed adjacent to the massage ball 102. Through these holes, cooling/warming air/liquid, or massage oil/lubricant with specific therapeutic effects may be delivered to the skin tissue during the treatment process. The cooling/warming air/liquid may be used for thermal therapy, while the massage oil/lubricant may help to soften/soothe the skin tissue and maintain its moisture level. The combined mechanical massage and photo bio-stimulation can enhance the response of the skin tissue to the massage oil/lubricant and allow same to penetrate deeper so as to be absorbed by inner skin tissues. The effect of such enhancements include, but are not limited to, increased micro-circulation, elevated temperature, and stimulated inter or intra cellular response. As another possibility, a gap can be introduced between the massage ball 102 and the chamber 105 for delivering cooling/warming air/liquid, or massage oil/lubricant to the subject tissue. The



cooling/warming air/liquid, or massage oil/lubricant can be injected into the chamber **105** through a tube **116** connected to the hand piece **104**.

**[0024]** In another variation of the present embodiment as shown in FIG. **7a** and FIG. **7b**, the massage ball **102** may have a diffusive or scattering optical surface, which is capable of spreading the transmitted light into various angles and directions. The diffusive surface can be prepared by forming some type of micro-structures on the surface of the massage ball, or by coating a layer of diffusive optical material on the massage ball. Referring to FIG. **7a**, when the massage ball **102** is not in contact with the skin tissue **112**, the therapeutic light **110** is diffused by the diffusive surface as it transmits through the massage ball into air. Thus the transmitted light **114** has an increased spread angle and hence a reduced light intensity when viewed from a distance away. This reduction in viewed light intensity enhances the safety level of the phototherapy apparatus. In comparison, when the massage ball **102** is in contact with the skin tissue **112** as shown in FIG. **7b**, the transmitted light **114** is much less distorted or spread. This is due to the fact that the skin in contact with the surface of the massage ball serves as an optical index matching medium which effectively reduces diffusing or scattering cause by the massage ball surface. Hence, the light beam is effectively delivered into the tissue with desired direction, angle, power density, depth, and intensity distribution. As another variation, certain optical index matching liquids, gels, suspension particles, powders may be applied between the massage ball **102** and the skin tissue **112** to further enhance light transmittance and reduce the light distortion caused by the massage ball surface. Those optical index matching media may also have therapeutic or pharmaceutical effect to further improve the effect of phototherapy.

**[0025]** In yet another variation of the present embodiment, the massage ball (or simply an optical window with curved surface) **102** is rigidly affixed to the chamber **105** and moves together or in unison with the hand piece **104**. In this variation, the mechanical massage is performed by kneading the subject tissue **112** with the massage ball **102** without the rolling action.

**[0026]** In yet another variation of the present embodiment, a motor is installed in the hand piece **104** and mechanically coupled to massage ball **102** to generate rolling, kneading, and/or vibration movements of the massage ball **102**.

**[0027]** One application of the phototherapy apparatus **100** is relieving the pain associated with migraine headaches, in which therapeutic light is delivered through the transparent massage ball to the forehead, temples, paranasal sinus, and/or neck of the patient. The optical properties of the massage ball, such as its refractive index, diameter or curvature, etc. can be utilized to shape the light beam to an ideal spot size or value. The phototherapy apparatus **100** may further comprise a touch sensor (not shown) or a pressure sensor (also not shown), such as a spring loaded device feature to control the on/off status of the light source in such a way that the light source can only be turned on when the massage ball touches the skin tissue. This helps to improve the safety of laser treatments around the eye by limiting the chance of laser exposure to the eye directly. Other applications of the phototherapy apparatus **100** comprise cellulite reduction, skin rejuvenation, pain relief, fat reduction and/or contouring, laser acupuncture, wound healing, and/or pressure ulcer treatment.

**[0028]** As can be seen, a variety of embodiments are possible within the scope of the present invention.

**[0029]** Referring to FIG. **3**, the second embodiment of the phototherapy apparatus comprises a hollow massage roller **302** with an array of therapeutic laser diodes or LEDs **304** mounted along an inner axis **308** within the roller **302**. Each of the laser diodes or LEDs **304** is designed to emit therapeutic light **306** with a predetermined divergence angle (**0**) as shown in the figure. The roller **302** is made of material transparent to the wavelength of the therapeutic light **306**. Correspondingly, when the roller **302** is applied to roll across a subject tissue surface to provide mechanical massage, the therapeutic light **306** simultaneously induce photo bio-modulation in the massaged tissue to produce enhanced phototherapy results.

**[0030]** In a slight variation of the present embodiment as shown in FIG. **4**, the phototherapy apparatus comprises a hollow massage roller **402** made of material not transparent at the wavelength of the therapeutic light **406**, where the therapeutic light **406** is produced by an array of therapeutic laser diodes or LEDs **404** mounted along the inner axis **408** of the massage roller **402**. The massage roller **402** comprises a matrix of holes **410** which can let the therapeutic light **406** pass through to produce a patterned illumination onto the surface of the subject tissue. This kind of spatially modulated illumination pattern can further enhance the photo bio-modulation effect. In this embodiment, a positive or negative air pressure from a pressure source (not shown) may be applied through the matrix of holes as an added way to manipulate the treatment area. Either cooled or warm/hot air can be blown through the holes for decreasing or increasing the temperature of the skin. Alternatively, the massage roller **402** can be made of material transparent to the wavelength of the therapeutic light **406** except part of the roller surface is covered by patches of non-transparent materials to produce a patterned illumination.

**[0031]** In the third embodiment of the present invention as shown in FIG. **5**, the therapeutic light sources **504** are mounted on a fixture **508** mechanically coupled to a massage component **502**.

**[0032]** The therapeutic light **506** produced by the light source **504** is delivered to the subject tissue **512** along a path proximal to the massage component **502**. As the massage component **502** rolls across the tissue **512**, the therapeutic light **506** induces photochemical reaction in the massaged tissue **512** before the tissue restores to its original state. Thus similar enhancement in phototherapy result is produced. In this embodiment, the massage component **502** needs not to be transparent to the therapeutic light **506**.

**[0033]** Referring to FIG. **6**, the fourth embodiment of the phototherapy apparatus comprises two massage rollers **602** rolling in opposite directions, or with different rolling speeds or different surface frictions. Those rolling movements cause a portion of the tissue **612** between the two rollers **602** to be squeezed and therefore increasing in height. By illuminating the raised tissue with the therapeutic light **606**, either through, or in proximity to the two rollers **602**, the inner layer of the tissue, which is hard to reach when illuminated from top of the tissue, can be treated with the phototherapy procedure. The height of the raised tissue can be further increased by employing a vacuum sucker (not shown) on top of the rollers and mechanically coupled thereto.

**[0034]** The disclosed phototherapy apparatus can be used on animal subjects as well. For these veterinarian applica-

tions, a comb or comb-like component (not shown) can be integrated in front of the massage/phototherapy component to part the hair of the animal before massage/phototherapy treatment of the skin underneath is performed.

**[0035]** In the foregoing specification, specific embodiments of the present invention have been described. However, one of ordinary skill in the art appreciates that various modifications and changes can be made without departing from the scope of the present invention as set forth in the claims below. For example, the therapeutic light source and the massage component are not limited to the presently disclosed forms. Accordingly, the specification and figures are to be regarded in an illustrative rather than a restrictive sense, and all such modifications are intended to be included within the scope of present invention. The benefits, advantages, solutions to problems, and any element(s) that may cause any benefit, advantage, or solution to occur or become more pronounced are not to be construed as a critical, required, or essential features or elements of any or all the claims. The invention is defined solely by the appended claims including any amendments made during the pendency of this application and all equivalents of those claims as issued.

What is claimed is:

1. A phototherapy apparatus for treatment of a biological tissue, the phototherapy apparatus comprising:

at least one light source to provide therapeutic light to be absorbed by the biological tissue to produce a first therapeutic effect; and

at least one massage component to provide mechanical massage to the biological tissue to produce a second therapeutic effect;

wherein said therapeutic light and mechanical massage are applied to the biological tissue in a concerted manner, wherein the mechanical massage modifies a plurality of properties or conditions of the biological tissue to facilitate absorption or interaction of the therapeutic light with the biological tissue to improve said first therapeutic effect, and the therapeutic light modifies a plurality of properties or conditions of the biological tissue to improve said second therapeutic effect.

2. The phototherapy apparatus of claim 1, wherein the therapeutic light is delivered through the massage component.

3. The phototherapy apparatus of claim 2, wherein the massage component has a diffusive optical surface capable of increasing a spread angle of the therapeutic light.

4. The phototherapy apparatus of claim 1, wherein the therapeutic light is delivered along a path proximal to the massage component.

5. The phototherapy apparatus of claim 1, wherein the light source comprises a laser, a light emitting diode, or a lamp.

6. The phototherapy apparatus of claim 1, wherein the massage component comprises a rolling component, a kneading component, or a vibrating component.

7. The phototherapy apparatus of claim 1, further comprising a touch sensor to monitor a contact/pressure between the massage component and the biological tissue and to obtain a contact/pressure signal, wherein the contact/pressure signal is utilized to control the light source.

8. The phototherapy apparatus of claim 1, further comprising a means for delivering fluid substance along the massage component to improve said first and second therapeutic effect.

9. A method for making a phototherapy apparatus for treatment of a biological tissue, the method comprising the steps of:

providing at least one light source to provide therapeutic light to be absorbed by the biological tissue to produce a first therapeutic effect; and

providing at least one massage component to provide mechanical massage to the biological tissue to produce a second therapeutic effect;

wherein said therapeutic light and mechanical massage are applied to the biological tissue in a concerted manner, wherein the mechanical massage modifies a plurality of properties or conditions of the biological tissue to facilitate absorption or interaction of the therapeutic light with the biological tissue to improve said first therapeutic effect, and the therapeutic light modifies a plurality of properties or conditions of the biological tissue to improve said second therapeutic effect.

10. The method of claim 9, wherein the therapeutic light is delivered through the massage component.

11. The method of claim 10, wherein the massage component has a diffusive optical surface capable of increasing a spread angle of the therapeutic light.

12. The method of claim 9, wherein the therapeutic light is delivered along a path proximal to the massage component.

13. The method of claim 9, wherein the light source comprises a laser, a light emitting diode, or a lamp.

14. The method of claim 9, wherein the massage component comprises a rolling component, a kneading component, or a vibrating component.

15. The method of claim 9, further comprising the step of providing a touch sensor to monitor a contact/pressure between the massage component and the biological tissue and to obtain a contact/pressure signal, wherein the contact/pressure signal is utilized to control the light source.

16. The method of claim 9, further comprising the step of providing a means for delivering fluid substance along the massage component to improve said first and second therapeutic effect.

17. A method for treatment of biological tissue with phototherapy, the method comprising the steps of:

providing at least one light source to provide therapeutic light to be absorbed by the

biological tissue to produce a first therapeutic effect; and

providing at least one massage component to provide mechanical massage to the biological tissue to produce a second therapeutic effect;

wherein said therapeutic light and mechanical massage are applied to the biological tissue in a concerted manner, wherein the mechanical massage modifies a plurality of properties or conditions of the biological tissue to facilitate absorption or interaction of the therapeutic light with the biological tissue to improve said first therapeutic effect, and the therapeutic light modifies a plurality of properties or conditions of the biological tissue to improve said second therapeutic effect.

**18.** The method of claim **17**, further comprising a step of providing a touch sensor to monitor the contact/pressure between the massage component and the biological tissue and obtain a contact/pressure signal, wherein the contact/pressure signal is utilized to control the light source.

**19.** The method of claim **17**, further comprising a step of delivering fluid substance along the massage component to improve said first and second therapeutic effect.

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