An apparatus for bio-stimulating phototherapy of a subjects body portion is herewith provided, which comprises a light source for providing light with a phototherapeutic wavelength and an optical filter for modifying at least a portion of the light emitted by the light source. The apparatus is arranged for illuminating a skin portion of the body portion with the modified light. The apparatus is formed for conforming to at least part of the body portion, e.g. being a human wearable object such as a deformable or flexible patch or bandage, which may be pliable. The filter has a modification function corresponding to the skin type of the subject's skin portion. A method and a filter are also provided.
Improvements in phototherapy

TECHNICAL FIELD OF THE INVENTION

The present disclosure relates to phototherapy, in particular to apparatus and methods for dermatological phototherapy. The apparatus and methods may be used both in professional and domestic use, and for curative, cosmetic and wellness purposes.

BACKGROUND OF THE INVENTION

In the field of phototherapy, treating a patient with light, it is known that optical absorption of the skin may affect treatment efficiency. Further, both ultraviolet (UV) and/or infrared (IR) treatments can cause damage to the skin when the radiation absorbed by the skin exceeds a threshold.

Infrared (IR) phototherapy is often used in the context of hair removal (depilation), where a sufficient amount of heat energy is needed near the hair shaft and hair bulb to 'burn' the hair. Such treatment should be performed without damaging the skin through energy absorption. The correct amount of energy deposition is generally determined by trial and error.

UV treatment is often used in treatment of various dermatological diseases such as e.g. psoriasis. The main problem of UV treatment is that the absorbed UV radiation can cause DNA damage and skin cancer when the irradiation dose is too high. Often a MED value (minimum erythematic dose) is used as a guide to determine a safe UV dose. The MED is the smallest dose to produce visible reddening of the skin, which is indicative of a skin irritation. The MED indicates an upper dose limit but provides no useful information for doses below the MED, reducing usefulness of the parameter.

E.g. EP 1 797 923 discloses a phototherapy apparatus using excimer radiation in which, by skillful use of the individual peak wavelength of 308 nm and of the emission range of shorter wavelengths than 308 nm, the therapy effect is enhanced, and in which, at the same time, harm can be reduced. This is achieved using a XeCl excimer lamp and diseased sites of skin disorders are irradiated with UV-B radiation with an optical filter being used for changing the spectral shape of the UV-B radiation with which the diseased sites are irradiated.
EP 1 797 923 teaches to determine the strength of the filter to be used by trial and error, oscillating between ineffective therapy due to too low dosage and hurting the patient by too high dosage. A presently increasingly relevant field - and being the field of the present disclosure - is that of bio-stimulation of living tissue. Bio-stimulating skin phototherapy may be applied for treating jaundice and psoriasis and may comprise curative phototherapy like wound healing or cosmetic phototherapy like rejuvenation. A particular branch of bio-stimulating phototherapy is known as Low Level Light Therapy (or: LLLT). In the field of bio-stimulation of living tissue, any damage to the tissue must be prevented. This poses significantly stricter requirements on the applied dose, since doses which are considered acceptable for the earlier-referenced fields of phototherapy may in fact already exceed stimulatory effective thresholds. On the other hand, reducing the applied illumination doses for safety reasons can easily lead to administration of a dose which is therapeutically ineffective. The concept of bio-stimulating phototherapy, be it for curative or cosmetic purposes, is generally incompatible with determination of a correct dosage through trial and error. Consequently, there is a desire for equipment and methods for providing both safe and effective bio-stimulation phototherapy, in particular for domestic use.

SUMMARY OF THE INVENTION

An apparatus for bio-stimulating phototherapy of a subject's body portion is herewith provided, which comprises a light source for providing light with a phototherapeutic wavelength and an optical filter for modifying at least a portion of the light emitted by the light source. The apparatus is arranged for illuminating a skin portion of the body portion with the modified light. The apparatus is formed for conforming to at least part of the body portion, e.g. being a human wearable object such as a deformable or flexible patch or bandage, which may be pliable. The filter has a modification function corresponding to the skin type of the subject's skin portion.

The apparatus being formed for conforming to at least part of the body portion to be treated improves user comfort and allows prolonged treatment. Such apparatus, in particular in the form of a patch or bandage, may be worn inconspicuously under clothing. Such apparatus allows improved and predictable illumination of the body portion since shifted illumination portions and/or shadows caused by relative movement of the apparatus
and the body portion are prevented. Further, illumination at an oblique angle may be prevented which may otherwise cause undesired reflection of the light and inaccurate dosing.

The skin type determines the response of the skin to known illumination factors, such as tanning or sunburn in daylight. Providing a modification filter function corresponding to the skin type reduces chances of over- or underdosing the phototherapy light. The modification function may be wavelength dependent.

The skin type may be defined according to the Fitzpatrick scale. For more accurately determining the skin type, the skin type may be determined by the melanin index M and/or the lightness L* of the skin portion.

Melanin absorbs radiation, hindering attaining an intended treatment dose in the body portion. The melanin index M indicates the melanin content in the skin considered and the lightness L* is defined in 1976 by the Commission International d'Eclairage (CIE) and is a measure of how the human eye perceives the lightness of the skin, see M.D. Shriver and E.J. Parra, "Comparison of Narrow-band reflectance spectroscopy and tristimulus colorimetry for measurements of skin and hair color in persons of different biological ancestry", Amer. J Phys Anthropology 112:17-27 (2000). In humans, melanin is almost exclusively located in the epidermis. It has been found that by determination of the melanin index or the lightness the irradiation losses in the epidermis may be correctly assessed, and that for deeper-lying tissue (e.g. dermis, hypodermic tissue) absorption losses due to melanin are of little to no influence. Hence, the actually administered phototherapeutic dose into these deeper-lying tissues can be reliably assessed. Determining the melanin index or the lightness of the skin portion provides quantitative information on, and determination of, the effective filtering function of the skin due to the melanin. The melanin index M may be measured by apparatus commonly used in cosmetic industry, e.g. the Skin Pigmentation Analyzer © SPA 99 of CK electronic GmbH, or the DSM II ColorMeter by Cortex Technology, which latter apparatus can measure both the melanin index M and the lightness L*.

Measurement of the melanin index is preferred over measuring the lightness since it has been found that the melanin index is a more reliable parameter for quantifying the melanin content of the skin, see Shriver and Parra cited above.

Bio-stimulating phototherapy may comprise inter alia pain reduction, growth promotion, tissue restoration, treatment of (infantile) jaundice, for curative and/or substantially cosmetic treatments.
The apparatus, and in particular the filter may be arranged in close contact with the subject's skin portion to minimize light leakage and reduce protruding portions. In such case the material should be substantially bio-compatible.

The modification function may be wavelength dependent, e.g. transmitting or blocking one or more predetermined wavelength ranges, to accommodate a phototherapeutic wavelength range and/or sensitivity of the skin portion to a particular wavelength range, in particular when the light source produces light with a relatively broad emitted spectrum and/or when the light source provides high-intensity light at one or more wavelengths, compared to desired values of wavelength range and/or spectral intensity.

The filter may comprise an optically active portion which may shift at least a portion of the wavelength range emitted by the light source and incident on the filter to another wavelength range, which may be within and/or outside of the wavelength range emitted by the light source, so as to illuminate the skin portion of the body portion with the modified and wavelength shifted light. Suitable materials are phosphors and fluorescent materials. The optically active portion may comprise the entire filter.

Also or alternatively, the optically active material may change one or more of its properties as a function of the incident light, which may be substantially irreversible, e.g. coloring, bleaching, opacification, and/or otherwise aging. In particular when the change is at least partially reversible, it may be used to adapt the modification function to (the duration of) the administered treatment, e.g. to increase or decrease the transmitted modified light and/or modified shifted light.

The apparatus may comprise an optical redistribution portion, which may be comprised at least partially in the filter, for distributing and/or redistributing the light from the light source into a desired direction. The redistribution portion may comprise a reflector and/or diffuser. Such apparatus may improve homogeneity of the illumination.

To enable use of the apparatus for subjects with different skin types, the apparatus may be formed for facilitating exchanging the filter to provide a modification function corresponding to the skin type of other subject's skin portion. Further, due to sun tanning, the exposure to chemicals, treatment effects such as subsided inflammation or improved psoriasis conditions, and the like, the melanin index of the subject's body portion may vary. Exchanging the filter allows adapting to such varying circumstances and thus improving treatment for the same subject. The filter may be attachable to and detachable from other portions comprised in the apparatus by using one or more adhesive materials, one or more fasteners and/or clamps, one or more hook-and-loop type fasteners, etc.
In an advantageous embodiment, the filter is disposable which improves hygiene. The above-described optically active portion may be used to indicate (the end of) a characteristic lifetime of the filter.

The apparatus may comprise an input system for determining a skin type and/or a filter type associated with a particular modification function, and the apparatus may comprise a controller for controlling operation of the apparatus, in particular the light source, as a function of the input skin type and/or modification function. At least one of the inputs may comprise a user interface, e.g. with a selector switch having one or more settings, a keypad, or any other user interface. Also, or alternatively, the apparatus may comprise a sensor for non-invasively determining the skin type of a subject's skin portion and/or a sensor for determining the modification function of the filter, to provide at least partly automated determination of these aspects. Advantageously, the apparatus comprises a sensor for non-invasively determining the melanin index and/or the lightness of the subject's skin portion, to objectively determine and quantify the skin type.

The operation of the apparatus may comprise indicating information relating to the determined skin type and/or modification function, respectively, for which one or more indicators may be provided. A signal may be provided when the combination of the detected skin type and modification function fulfils, or does not fulfill, one or more predetermined criteria, e.g. a warning signal if an attenuation of the filter for one or more wavelength ranges is too weak or too strong for the skin type, or an "OK" signal if the skin type and the filter function correspond to each other. This facilitates selection of a filter with a modification function correctly corresponding to the skin type of the subject's skin portion and it prevents inappropriate, possibly ineffective or rather harmful use of the apparatus.

A filter sensor may be configured to detect a marking or code contained in or on the filter and/or its packaging, e.g. a bar code or a matrix code; the sensor may also be configured to measure transmittance of the filter at one or more wavelengths, with respect to one or more reference values, e.g. comparing modified light reflected off an object with unmodified light reflected off that object.

The skin type indicator and/or filter indicator may be separate or combined and may have any suitable form, e.g. a display indicating one or more alphanumeric indications, a series of light emitting diodes wherein one or more number of the diodes lights up corresponding to a certain skin type or modification function, respectively, a sound system, etc. or combinations thereof. The filter indicator may also indicate that a filter has
been used and/or changed to a predetermined extent, e.g. due to exposure or aging, e.g. for suggesting replacement of the filter.

A filter for use in such apparatus comprising a filter sensor may suitably comprise at least one marking corresponding to the modification function of the filter, wherein the at least one marking is readable by the input system for determining the modification function of the filter.

One or more filter markings may comprise expiry time/date information and the apparatus may comprise a clock and a controller for comparing the filter marking(s) with the clock for determining age of the filter. The clock and controller may also be used for timing and/or controlling a treatment or treatment protocol.

A method of bio-stimulating phototherapy of a subject's body portion is further provided herewith, comprising non-invasively determining the skin type of a skin portion of the subject's body portion, providing an optical filter with a modification function corresponding to the determined skin type and providing light in a phototherapeutic wavelength from a light source through the optical filter. Advantageously, the skin type is determined and defined by the melanin index M and/or the lightness L* of the skin portion.

The method applied with the apparatus may comprise the steps of selecting a bio-stimulating wavelength range to be used; determining a first phototherapeutic dose to be administered to the subjects body portion; determining the melanin index or the lightness at least at or near a skin portion of the body portion; calculating a second phototherapeutic dose as a function of the first dose, the selected wavelength range and the determined melanin index or lightness, respectively, of the skin portion; providing a filter with a modification function for modifying an emitted dose provided by the light source to the second phototherapeutic dose; and providing the second phototherapeutic dose to the body portion by illuminating at least the skin portion with modified light in the selected wavelength range.

The first and second phototherapy doses may comprise a full treatment dose or a predetermined portion thereof. The melanin index and lightness may, and generally will be, dependent on the body portion, the skin portion (e.g. outside or inside of an upper arm) and the tanning of the skin portion. Further, the absorption of melanin and therewith the modification function are dependent on the wavelength of the phototherapy light. Taking such features into account allows providing an accurate prediction of the attenuation of an applied dose so that a second dose of phototherapeutic radiation may reliably be determined for achieving a desired first dose phototherapeutic radiation.
The function for calculating a phototherapy dose to be administered to
the skin, e.g. for calculating the second phototherapy dose as described above, may comprise a
wavelength and melanin-index dependent irradiance correction factor \( I_{cf} = I_{cf}(M, \lambda) = \exp(C_m \mu(\lambda) d) \), wherein \( C_m \) is a measure of the concentration of melanosomes in the
epidermis of the skin portion which may be stated in terms of the melanin index \( M \) as \( C_m = (M-20)/150 \) and may be approximated in terms of the lightness \( L^* \) as \( C_m = 1.925 - 0.44 \ln(L^*) \), \( \mu(\lambda) \) describes the wavelength dependent absorption of the melanin and may be
approximated as \( \mu(\lambda) = \mu_0 \lambda^{-3.33} = 6.6 \times 10^{11} \lambda^{-3.33} \) in units of \( \text{cm}^{-1} \) with \( \lambda \) in units of nm and
wherein \( \mu_0 \) is the average absorption coefficient of a single melanosome, and wherein \( d \)
accounts for the optical path in the epidermis. The thickness of the epidermis generally varies
between about 0.4 mm to about 1.2 mm, taking scattering into account \( d \) may be in a range
from about 0.004 to about 0.024 cm, averaging over thickness variations and scattering
provides a generally applicable range of about 0.008-0.016 cm, and a practical approximation
is \( d = 0.012 \) cm. This function \( I_{cf} \) corresponds to the inverse of the attenuation of the
radiation by melanin absorption and it provides an approximation of the modification
function of the skin under consideration. The function is applicable to usefully provide
correction factors over a large wavelength range, from UV to near IR wavelengths, and for
substantially all skin types, ranging from light Caucasian type skin to dark negroid type skin.

Advantageously, the melanin index or the lightness, respectively, is
determined in a wavelength range between approx. 400 nm and approx. 2000 nm, in
particular between approx. 500 nm and approx. 1500 nm, more in particular between approx.
600 nm and approx. 900 nm, and the body portion is illuminated with a phototherapy
wavelength in that wavelength range.

It has been found than in the wavelength range between ca. 400-2000 nm
several phototherapeutic treatments may be provided. From ca 450 nm, absorption of light by
haemoglobin and oxyhaemoglobin generally decays with increasing wavelength. A local
maximum is located between ca 550-600 nm with a steep decrease for longer wavelengths.
On the other hand, absorption by water generally increases from ca 450 nm to 2000 nm with
a number of absorption peaks near particular wavelengths, in particular around ca 1600 nm.

Melanin has a generally decreasing absorption over the wavelength range 400-2000 nm.
Between ca 500-1500 nm absorption of (oxy-) haemoglobin and water is reduced and in the
wavelength range of ca 600-900 nm the main absorber is melanin. However, since the
wavelength dependent absorption profile of melanin is known and rather smooth, correction
may also be effectively employed in wavelength ranges where (oxy-) haemoglobin and water have a significant absorption influence.

These and other aspects will hereafter be elucidated with reference to the figures of the drawings, which indicate examples for explanatory purposes only. Various other embodiments may be conceived within the scope of the appended claims.

BRIEF DESCRIPTION OF THE DRAWINGS

In the drawings:

Fig. 1 is a schematic representation of a skin portion;

Fig. 2 indicates typical irradiance correction factors for different skin types;

Fig. 3 is a block scheme of an embodiment of a method of bio-stimulating phototherapy of a subject's body portion;

Fig. 4 is a schematic side view of a phototherapy apparatus;

Figs. 5-7 are schematic side views of different phototherapy apparatus.

DETAILED DESCRIPTION OF EMBODIMENTS

It is noted that in the drawings, like features may be identified with like reference signs. It is further noted that the drawings are schematic, not necessarily to scale and that details that are not required for understanding the present invention or the particular embodiment may have been omitted. The terms "upward", "downward", "below", "above", and the like relate to the embodiments as oriented in the drawings. Further, elements that are at least substantially identical or that perform an at least substantially identical function are denoted by the same numeral.

Fig. 1 illustrates illumination of a human body portion 1, showing a skin portion 3, and illumination light 5. The skin 3 comprises an epidermis layer 7 of ca 0.1 mm thickness, a ca 1-4 mm thick dermis layer 9 covering hypodermic tissue 11. A fraction of the illumination light 5 penetrates into the dermis 9, and another fraction may penetrate into the hypodermic tissue 11 indicated with the arrows 13 and 15, respectively.

In the epidermis 7, the main optical absorbers are melanin and water. In the dermis 9 and hypodermic tissue 11, the main optical absorbers are water and blood. These absorbers are the most important factors determining the skin type. The skin type may be usefully classified in six skin types using the Fitzpatrick scale, which mainly relates to tanning and sunburn (erythema, or even blistering), and thus to the skin's response to UV radiation. For some therapies, in particular using longer visible or (near) infrared wavelength
ranges, it has been found that such classification is insufficient, since within one Fitzpatrick skin type, significant deviations in response to an optical stimulus may still occur.

It has now been found that, in accordance with the distribution of melanin in the skin, the absorbing or filtering effect of melanin is concentrated in the epidermis 7, and that, once the reduction in optical energy by the epidermis 7 is known, the fraction of the energy available for deposition in the dermis 9 and hypodermic tissue 11 can be calculated. It has further been found that determining the melanin index of the skin portion 3 in fact substantially returns the melanin index of the epidermis 7 and thus provides a reliable quantification of the filtering effect of the epidermis 7 and determination of the dose available for deeper-lying tissue. Similarly, the absorption of the illumination light 5 by the melanin can be readily determined and therewith heating of the epidermis 5 can be predicted to prevent overheating or hurting.

The filtering effect of the melanin in the epidermis can be substantial. The resulting correction factor Icf for different skin types are indicated in Fig. 2: light Caucasian skin with M = 26 (full lines), Asian skin with M = 42.5 (dotted lines) and dark Negroid skin with M = 80 (dashed lines). From Fig. 2 it becomes clear that the irradiance dose to be applied onto the skin may be a large multiple of the dose to be deposited in the dermis or hypodermic tissue, in particular for phototherapy with blue light for Asian or Negroid skin types. E.g. for blue phototherapy light at a wavelength near 450 nm, e.g. for treating (neonatal) jaundice or psoriasis, the correction factor Icf for dose administration may differ by a factor of 20 between a light Caucasian skin type and a dark negroid skin type. As a corollary, the correction factor Icf also indicates the relative energy absorption in the epidermis 3, and therewith the chances of overheating that skin part, risking pain and damage.

The dose is a combination of illumination irradiance and illumination time. Adapting the irradiance and the dose to the local melanin index of the subject's skin will significantly affect and improve the effectiveness of the phototherapy. Also, safety of phototherapy is improved since irritation, damage and/or pain are substantially prevented. Phototherapy may therefore be made available for domestic use with little to no risk of damage or maltreatment.

An operating scheme of an embodiment of the method is provided in Fig. 3. A phototherapeutic wavelength (range) λ is selected and a suitable dose D1 to be administered to the body portion 1 are determined in step 17, e.g. by a practitioner. As an example, D. Barolet, "Light-emitting diodes (LEDs) in dermatology", Semin Cutan Med Surg 27:227-238
(2008), elucidates on the existence of suitable wavelengths and optimal doses or fluences for different phototherapies, dependent on the tissue and condition to be treated. An overview of conditions which may be treated with bio-stimulating phototherapy, the mechanism believed to underlie the treatment effect and the associated wavelengths is provided in the following table:

<table>
<thead>
<tr>
<th>Condition</th>
<th>Mechanism</th>
<th>Wavelength [nm]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Neonatal jaundice</td>
<td>Bilirubin-Lumirubin conversion</td>
<td>460</td>
</tr>
<tr>
<td>Acne</td>
<td>Reactive Oxygen + Anti-inflammatory</td>
<td>415 + 630, 660</td>
</tr>
<tr>
<td>Psoriasis</td>
<td>Inhibit DNA synthesis</td>
<td>311</td>
</tr>
<tr>
<td></td>
<td>NO-mediated decreased proliferation^1</td>
<td>450</td>
</tr>
<tr>
<td></td>
<td>(in vitro test)</td>
<td></td>
</tr>
<tr>
<td>Wound healing</td>
<td>ATP-up-regulation and tissue</td>
<td>660</td>
</tr>
<tr>
<td></td>
<td>repair(inconclusive clinical evidence)</td>
<td>(620, 670, 760, 830)</td>
</tr>
<tr>
<td>Rejuvenation</td>
<td>ATP-up-regulation</td>
<td>660</td>
</tr>
<tr>
<td></td>
<td>(limited clinical evidence)</td>
<td>(620, 670, 760, 830)</td>
</tr>
<tr>
<td>Pain of muscles and joints</td>
<td>Heat induced vasodilatation</td>
<td>IR-A</td>
</tr>
<tr>
<td></td>
<td>ATP-up-regulation and tissue</td>
<td>660</td>
</tr>
<tr>
<td></td>
<td>repair(limited clinical evidence)</td>
<td>(620, 670, 760, 830)</td>
</tr>
<tr>
<td></td>
<td>NO-mediated vasodilatation and/or pain signalling^1,2</td>
<td>UV-A or 450</td>
</tr>
</tbody>
</table>


The skin type S or the melanin index M of the skin portion 3 of the body portion 1 is determined in step 19. The melanin index M may be determined by measuring light reflectance of the skin portion 3 at one or more wavelengths and deducting the skins absorbance at the used wavelength(s). Using plural wavelengths facilitates removing contribution to the absorption by (oxy-) haemoglobin and/or water.
In step 21 the absorption of light at the phototherapeutic wavelength (range) $\lambda$ to be used is determined and a correction factor $I_{cf}$ is calculated based on the skin type $S$ to give $I_{cf}(S, \lambda)$ or based on the melanin index $M$, e.g. according to the above-reference formula to give $I_{cf}(M, \lambda)$.

In step 23 a phototherapy dose $D_2$ to be applied onto the skin portion 3 is calculated based on the dose $D_1$ to be administered. This may comprise straightforward multiplication with the correction factor $I_{cf}$, or: $D_2(D_1, I_{cf}) = D_2(D_1, \{S \text{ or } M\}, \lambda) = I_{cf}(\{S \text{ or } M\}, \lambda) \times D_1(\lambda)$. More complicated calculation is also conceivable. The phototherapy dose $D_2$ may be applied by suitable selection of illumination intensity and duration, which may comprise illumination in one or more pulses of which the pulse intensity, duration and interval may be selected.

In step 25 the thus calculated phototherapy dose $D_2$ and an emitted dose $D_3$ from the light source is used to determine a modification function $F$ of the filter corresponding to the skin type of the subject's body portion 1 and the emitted dose $D_3$.

In step 26 the second phototherapy dose is applied to the body portion 1 by illuminating the skin portion 3 through the filter, resulting in administering the suitable dose $D_1$.

In calculating the phototherapy dose $D_2$ to be applied, the effect of heating of the epidermis by the absorbed radiation may be included, so as to determine a maximum applied irradiance in order not to overheat the skin. A skin temperature of below 42°C is considered suitable, higher temperatures, in particular during prolonged periods, are undesired and temperatures of ca 45°C and higher are painful.

The method may be employed in separate stages, wherein the skin type or melanin index is determined at one moment and later on used for determining the function for operation of the light source. However, since the melanin index may, and generally will, depend inter alia on the particular location of the skin portion and on its tanning, it is preferred to (re-)determine the melanin index shortly before applying a phototreatment.

A phototherapy apparatus 27 for use in the above described method comprises a light source 29 for providing light at a bio-stimulating phototherapeutic wavelength, here comprising a plurality of sub-light sources 31 mounted to a carrier 33, an optical filter 34, a sensor 35 for determining the melanin index of a subjects skin portion 3, and a sensor 36 for determining the modification function of the filter 34. The sub-light sources 31 may provide light at different wavelengths. The apparatus is arranged for illuminating the subject's skin portion 3 with light 30 emitted by the light source 29 and modified by the filter 34. The
apparatus further comprises a controller 37 for controlling operation of the light source 29 as a function of the determined melanin index. The apparatus 27 may be powered from any suitable power source 39, for portability powering from a battery is preferred.

The controller 37 may comprise one or more user operable input systems e.g. with selectable settings. The input system(s) may comprise one or more user interfaces and may be arranged for inputting skin type data and/or modification function data of a filter 34. Also or alternatively, the controller may be configured to take additional input, e.g. for determining parameters of a therapy, user settings, timing, driving schemes for different skin colors etc. Such additional input may be provided in machine readable format on a suitable data carrier, e.g. a disk, a memory card, a flash-drive, etc, as well as via transmission systems from a remote data storage medium, such as wired or wireless data transmission from a computer and/or via the internet. The apparatus may suitably comprise a memory for storing one or more settings and/or programs, which may be user-selectable via a user interface.

Advantageously, the controller is arranged, programmable or programmed for controlling operation of the light source 29 with a function based on the Icf discussed above.

The controller 37 may be configured for controlling operation of the light source 29 during use, possibly automated, e.g. for adaptation to skin heating, tanning, increased or decreased blood perfusion etc.

The phototherapy apparatus 27 may be a human wearable patch or bandage, such as an apparatus conforming to human physique, preferably being deformable or even pliable, indicated in Fig. 5. The patch may be maintained in position with any suitable means such as one or more adhesive portions, hook-and-loop-type fastener and/or a strap 41 closable around the body portion.

Alternatively (not shown) a phototherapy apparatus may be an assembly comprising the light source, the sensor and/or the controller as separate objects, which may be interconnected for communicating with each other, e.g. with cables or via wireless communication.

A phototherapy apparatus 27 may comprise plural sensors 35 for determining the melanin index of the subject’s skin portion 3 to detect local variations of the skin portion. As shown, the light source 29 may comprise plural sub-light sources 31. Advantageously, the light source 29 comprises one or more Light Emitting Diodes or LEDs, which are available for numerous suitable wavelengths, provide significant optical output power per watt input power and generate little heat. Incoherent LEDs are considered particularly advantageous, since lasers require additional control, increasing complexity and cost of the apparatus 27 and
relatively narrowband radiation poses a high risk of overheating skin. Laser radiation may also present a danger to users eyes.

The sensor 35 may comprise at least one light source and at least one detector for detecting light, the sensor being configured to illuminate a subject's skin portion 3 and detect light reflected off the subject's skin portion 3, wherein the sensor 35 is configured for determining a reflectivity of the subject's skin portion 3 at a plurality of wavelengths. This allows accurate determination of the reflectance of the skin portion 3 and thus of determining the melanin index M.

As another embodiment, Fig. 6 shows a patch 27 comprising surface-emitting LEDs 29 for emitting light with a wavelength of approx. 450 nm. The patch 27 further comprises a tapered optically active filter 34 having a first end 43 with a relatively small surface area and a second end 45 with a relatively large surface area. The filter 34 comprises a material mixed with one or more photoluminescent materials which is (are) excitable by the light of the first light sources 29. The first light sources 29 and the filter 34 are arranged such that the light sources 29 illuminate the first end 43 of the filter 34. A first portion of the light of the first light sources 29 received in the filter 34 is emitted redistributed over the surface area of the second end 45. A second portion of the light of the first light sources 29 received in the filter 34 excites the photoluminescent material, which subsequently fluoresces at one or more longer wavelengths, e.g. in a range between approximately 550 and 1500 nm, e.g. between about 600 and 700 nm, and/or between about 800 and 1500 nm, depending on the chosen photoluminescent material(s). Note that the use of photoluminescent material(s) may provide a relatively broad useful spectrum which would otherwise require plural narrowband light sources, e.g. LEDs. This light is also emitted distributed over the surface area of the second end 45. Thus, the filter 34 serves the plural purposes of filtering a portion of the light emitted by the first light sources 29, being a redistributing light guide and being a light source for a second wavelength, i.e. a second light source. The first light (here: blue) and the second light (here: IR) may be substantially homogeneously mixed, depending on the distribution of the photoluminescent material in the filter 34. The relative intensities of the light with different wavelengths (blue and IR) may be determined by selecting the (relative) amount of photoluminescent material in the filter 34 and possibly its location, during manufacturing of the filter.

In an alternative embodiment, the filter 34 is not optically active, but has an intensity redistributing shape, as illustrated in Fig. 6.
Fig. 7 illustrates a patch 27 comprising side-illumination of a flexible, optically active, filter 34 by blue or UV light sources 29 via opposite first ends 43A, 43B. The filter 34 comprises a material mixed with a photoluminescent material which is excitable by the light of the light sources 29, emitting red, and near-IR light. The resultant light of different wavelengths is scattered within the filter 34, possibly being reflected by an optional reflector 47, to be emitted substantially homogeneously from the filter 34 via second end 45 (see the open white arrows).

Instead of being mixed through the filter material, a photoluminescent material may also be provided as a coating on a surface of the filter 34.

The filter may comprise ridges, bumps or lens portions. Also or alternatively, the filter may comprise one or more fiberoptic portions, e.g. one or more fiber bundles for redistributing the light, wherein at least part of the fiberoptic portion comprises a predetermined modification function. The filter may comprise silicone incorporating absorption or reflection particles, fabrics or any other filter material. An intensity redistributing filter may improve homogeneity of the illumination and/or assist illuminating a relatively large skin surface area from a relatively small light emitting surface.

Other variations to the disclosed embodiments can be understood and effected by those skilled in the art in practicing the claimed invention, from a study of the drawings, the disclosure, and the appended claims. Features from different embodiments may be suitably combined within the scope of the appended claims, unless explicitly mentioned otherwise. "Light emitting diode" or LED includes "organic light emitting diode" or OLED. In the claims, the word "comprising" does not exclude other elements or steps, and the indefinite article "a" or "an" does not exclude a plurality. Options presented with the conjunction "or" may be provided in combination unless stated otherwise. A single processor or other unit may fulfill the functions of several items recited in the claims. The mere fact that certain measures are recited in mutually different dependent claims does not indicate that a combination of these measured cannot be used to advantage. A computer program may be stored and/or distributed on a suitable medium, such as an optical storage medium or a solid-state medium supplied together with or as part of other hardware, but may also be distributed in other forms, such as via the Internet or other wired or wireless telecommunication systems. Any reference signs in the claims should not be construed as limiting the scope.
CLAIMS:

1. An apparatus (27) for bio-stimulating phototherapy of a subject's body portion (1), comprising a light source (29) for providing light with a phototherapeutic wavelength, and an optical filter (34) for modifying at least a portion of the light emitted by the light source, wherein the apparatus is arranged for illuminating a skin portion (3) of the body portion with the modified light; wherein the apparatus is formed for conforming to at least part of the body portion; and wherein the filter has a modification function corresponding to the skin type of the subject's skin portion.

2. The apparatus (27) of claim 1, wherein the skin type is determined by at least one of the melanin index (M) and the lightness (L*) of the skin portion.

3. The apparatus (27) of claim 1, wherein the modification function is wavelength dependent.

4. The apparatus (27) of claim 1, wherein the filter (34) comprises an optically active portion.

5. The apparatus (27) of claim 1, wherein the apparatus comprises an optical redistribution portion.

6. The apparatus (27) of claim 1, wherein the apparatus is configured to facilitate exchanging the filter (34).

7. The apparatus (27) of claim 1, comprising at least one of: an input system for determining the skin type of the subject's skin portion, and an input system (36) for determining the modification function of the filter; and further comprising:
a controller (37) for controlling operation of the apparatus as a function of the determined skin type or modification function, respectively.

8. The apparatus (27) of claim 7, comprising a sensor (35) for non-invasively determining at least one of the melanin index (M) and the lightness (L*) of the subject's skin portion (3).

9. The apparatus (27) of claim 1, wherein the light source (29) comprises at least one light emitting diode (31).

10. A filter (34) adapted for use in the phototherapy apparatus (27) of any preceding claim.

11. The filter (34) of claim 10, being disposable.

12. The filter (34) of claim 10, adapted for use in the phototherapy apparatus (27) of claim 7, wherein the filter comprises at least one marking corresponding to the modification function of the filter, wherein the at least one marking is readable by the input system (36) for determining the modification function of the filter.

13. A method of bio-stimulating phototherapy of a subject's body portion (1) comprising: non-invasively determining the skin type of a skin portion (3) of the subject's body portion; providing an optical filter (34) with a modification function corresponding to the determined skin type; and providing light in a phototherapeutic wavelength from a light source through the optical filter.

14. The method of claim 13, wherein the skin type is defined by at least one of the melanin index (M) and the lightness (L*) of the skin portion.
FIG. 1

FIG. 2
FIG. 3
**INTERNATIONAL SEARCH REPORT**

**International application No**
PCT/IB2011/053026

**A. CLASSIFICATION OF SUBJECT MATTER**

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

**B. FIELDS SEARCHED**

Minimum documentation searched (classification system followed by classification symbols)

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

**C. DOCUMENTS CONSIDERED TO BE RELEVANT**

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<th>Citation of document, with indication, where appropriate, of the relevant passages</th>
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1 5 September 2011 28/12/2011

Rodriguez Cossio, J

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

**See patent family annex.**

**Date of the actual completion of the international search**

15 September 2011

**Date of mailing of the international search report**

28/12/2011

**Name and mailing address of the ISA/**

European Patent Office, P.O. 5618 Patentlaan 2 NL-2280 HV Rijswijk
Tel. (+31-70) 340-2040, Fax (+31-70) 340-3018

**Authorized officer**

Rodriguez Cossio, J

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Form PCT/ISA/210 (second sheet) (April 2009)
### DOCUMENTS CONSIDERED TO BE RELEVANT

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## INTERNATIONAL SEARCH REPORT

**Box No. II**  Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. **Claims Nos.:** 13, 14
   - because they relate to subject matter not required to be searched by this Authority, namely:
     
     Rule 39.1(iv) PCT - Method for treatment of the human or animal body by therapy

2. □ Claims Nos.:
   - because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

3. □ Claims Nos.:
   - because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 64(a).

**Box No. III**  Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This international Searching Authority found multiple inventions in this international application, as follows:

- see additional sheet

1. □ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.

2. □ As all searchable claims could be searched without effort justifying an additional fee, this Authority did not invite payment of additional fees.

3. □ As only some of the required additional search fees were timely paid by the applicant, this international search report covers the invention(s) in the claims Nos.:

4. □ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

   1-11

### Remark on Protest

- The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.
- These additional search fees were accompanied by the applicant's protest but the applicable protest was not received before the time limit specified in the invitation.
- No protest accompanied the payment of additional search fees.

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Form PCT/ISA/21 0 (continuation of first sheet (2)) (April 2005)
This International Searching Authority found multiple (groups of) inventions in this international application, as follows:

1. claims: 1-11
   
   phototherapy apparatus comprising light source and optical filter modifying the light from the source.

2. claim: 12
   
   optical filter having a readable marking corresponding to its modification function
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