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(54) Title: LAMP FOR STIMULATING VITAMIN D PRODUCTION AND METHOD OF MAKING THE SAME

(57) Abstract: Disclosed are discharge lamps that stimulate the production of vitamin D in a person exposed thereto, and more specifically, to discharge lamps which over a predetermine exposure period stimulate a person's production of vitamin D without causing significant facultative pigmentation or melanin oxidization. Moreover, the present invention is also directed to discharge lamps that in addition to stimulating a person's production of vitamin D, emit photons that rejuvenate the collagen/elastin matrix that supports the person's skin, cartilage and bone.

LAMP FOR STIMULATING VITAMIN D PRODUCTION AND METHOD OF MAKING THE SAME

BACKGROUND OF THE INVENTION

1. Field of the Invention

[0001] The present invention relates generally to discharge lamps that stimulate the production of vitamin D in a person exposed thereto, and more specifically, to discharge lamps which over a predetermine exposure period stimulate a person's production of vitamin D without causing significant facultative pigmentation or melanin oxidization. Moreover, the present invention is also directed to discharge lamps that in addition to stimulating a person's production of vitamin D, emit photons that rejuvenate the collagen/elastin matrix that supports the person's skin, cartilage and bone.

2. Background of the Related Art

[0002] As few as ten years ago, there were only a small trickle of articles being published in scientific journals that discussed the health and welfare benefits of vitamin D. But what started as a small stream of articles about this nutrient five or six years ago, has become a torrent of information in the last few years. Today vitamin D is considered to be a beneficial nutrient for bone-related conditions, such as rickets and osteoporosis. Additionally, it is now appreciated that diverse diseases including cancer, diabetes, multiple sclerosis, and coronary heart disease are also vitamin D mediated.

[0003] Vitamin D is a nutrient most people get though exposure to sunlight. When a person's skin is exposed to ultraviolet radiation (UVR) from the sun, 7-dehydrocholestrol is produced and metabolizes into cholecalciferol (vitamin D_3).

Then cholecalciferol is processed by the liver to create 25-dihydroxyvitamin D_3 which is later transformed by the kidneys to 1,25 dihydroxyvitamin D_3. The nutrient 1,25 dihydroxyvitamin D_3 is known to improve calcium absorption in the small intestines, improve urinary calcium re-absorption in the kidneys and improve bone mineralization.

[0004] Typically those at greatest risk of having too little vitamin D include: elderly people; babies who are exclusively breast-fed; people with dark skin (darker-skinned people need more sun exposure to produce vitamin D); people who don't get any sun exposure (those who are housebound or who cover their bodies with clothing for religious or cultural reasons); people who live in the northern U.S. and Canada (e.g., above 37 degrees latitude) during the winter.

[0005] The vitamin D-effective photons (photons = packets of light energy), i.e., those responsible for stimulating the cutaneous production of pro-vitamin D, are found in the wavelengths between 250 nm and 320 nm, with 296 nm being the "peak" wavelength. (See Figure. 1). The utility of the action spectra illustrated in Fig. 1 will be discuss in more detail hereinbelow.

[0006] Due to atmospheric pollutants, very few of the photons emitted by sunlight (i.e., "terrestrial" vitamin D-effective photons) which have a wavelength below 301 nm reach the earth. Moreover, the T-50 wavelength (i.e., the wavelength range wherein 50% of the vitamin D-effective energy is found) is between 306 nm and 307 nm. Therefore, sunlight is not a very "efficient" source of vitamin D-effective photons.

[0007] Moreover, because vitamin D occurs naturally in only a few food products and is added to just a handful of others, many experts worry that Americans

get too little vitamin D to reap these potential benefits. Yet few are willing to encourage sun exposure with its well-known dangers and therefore, advocated vitamin supplements as a means for addressing vitamin D deficiencies.

[0008] However, the inventors of the present application believe that supplements alone can not maintain the desired level (i.e., greater than 75 nmol/L) of vitamin D in the blood. Therefore, the answer lies in balancing UVR induced vitamin D production obtained from a discharge lamp with supplements.

[0009] Most UVR producing lamps emit a spectrum of ultraviolet light which is similar to that of the sun. The sun emits three kinds of ultraviolet (UV) rays, UVA, UVB and UVC. UVC, at 100 nanometers (nm) to 280 nm, is the shortest and widely considered to be the most harmful wavelength of UV rays, but it is virtually blocked by the Earth's ozone layer and pollution. UVB is the medium wavelength, from 280-320 nm, and although overexposure to UVB has been found to cause erythema (sunburn), a controlled amount is necessary to initiate tanning in the skin. UVA is the longest wavelength, from 320-400 nm, and has been found to be responsible for the completion of the tanning process (*i.e.*, via oxidation or darkening of the pigment (melanin), as discussed in further detail herein). Notably, Short-wavelength UVB (280-315 nm) has been recognized for some time as carcinogenic in experimental animals, and there is some evidence that longer-wavelength UVA (315-400 nm), which penetrates more deeply into the skin, also contributes to the induction of cancer.

[00010] As you will note, the beneficial wavelengths (i.e., those that stimulate the production of vitamin D) and the harmful wavelengths (those that damage the skin and cause Cutaneous Malignant Melanoma (CMM) are found so close together that

the electromagnetic spectrum has been described as "Mother Nature's little joke." As a result, dermatologist have resisted recommending any exposure to sunlight or UVR due to their position that UVR induces CMM.

[00011] It is well known in the field of dermatology that collagen and elastogen (i.e., the proteins that provide the "matrix" that supports our skin, cartilage and bone) breaks down as we age. The wavelengths associated with the biological reactions that stimulate the production of these protein are found between 580nm and 680nm and these wavelengths are also immunostimulatory (i.e., they stimulate our immune defense system).

[00012] Thus, there is a need for a discharge lamp adapted for stimulating the production of vitamin D in human skin being exposed thereto, and more specifically, to discharge lamps which over a predetermine exposure period stimulate the production of Vitamin D without causing significant oxidation of a melanin or facultative pigmentation. Moreover, there is a need for a novel discharge lamp that in addition to stimulating a person's production of vitamin D, emits photons that rejuvenate the collagen/elastin matrix that supports the person's skin, cartilage and bone.

SUMMARY OF THE INVENTION

[00013] The subject invention is directed to new and useful discharge lamps that solve the problems described above. In particular, the present invention relates generally to mercury vapor discharge lamps of the fluorescent type having a particular phosphor coating(s) that is/are adapted to emit radiation having a preferred spectra when excited by the UV radiation generated from the mercury vapor discharge. Lamps constructed in accordance with the present disclosure stimulate the production

of Vitamin D without causing significant oxidation of a melanin or facultative pigmentation.

[00014] The present invention is also directed to lamps for stimulating vitamin D and methods of making the same. An embodiment of the novel lamp construction disclosed herein includes, *inter alia*, a vitreous tube having an outer periphery and axially opposed first and second ends which define an axial length for the tube therebetween.

[00015] The lamp further includes a first electrode assembly associated with the first end of the tube and a second electrode assembly associated with the second end of the tube. Moreover, a coating is applied on an interior of the tube which is adapted for delivering an effective dose of vitamin D photons to a person's skin during a predetermined exposure period, wherein the coating delivers an insufficient amount of UVB and UVA photons during the exposure period to cause significant facultative pigmentation and/or melanin oxidization.

[00016] Those skilled in the art will readily appreciate that the lamp of the present invention does not need to be elongated or axial in construction and can be formed in various shapes and sizes, such as circular or U-shaped, without departing from the inventive aspects of the present disclosure.

[00017] It is presently preferred that the exposure time required to deliver an effecting dose of vitamin D photons to a person's skin is less than T_e and T_m.

[00018] In a preferred embodiment, the ultraviolet radiation emitted from the lamp in a range of about 320 nm to about 340 nm is less than or equal to about 10 percent of the ultraviolet radiation emitted from the lamp in a range of about 280 nm to about 400 nm.

[00019] In a preferred embodiment, the lamp of the present invention is adapted for stimulating the production of collagen through emission of optimal energy in the 580nm to 680nm wavelengths. In certain embodiments, it is preferred that the phosphor coating is also adapted for emitting photons that rejuvenate the collagen/elastin matrix that supports the person's skin, cartilage and bone.

[00020] In certain constructions, the lamp of the present invention emits energy having a peak spectrum of 296 nm and a band with of 5nm.

BRIEF DESCRIPTION OF THE DRAWINGS

[00021] Fig. 1 is a graphical comparison of two vitamin D-effective action spectra that illustrates a peak wavelength for both spectra occurring at 296nm;

[00022] Fig. 2 is a graphical comparison of the spectral distribution for three UVR sources;

[00023] Fig. 3 provides a graphical representation of the an action spectrum for skin rejuvenation;

[00024] Figs. 4a-4f provides in tabular form the irradiance data for the Vitamin D and GTX65 Blue lamps.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

[00025] Exemplary lamps constructed in accordance with the present invention provide a controlled amount of UVB radiation in the approximate 280 nm to 320 nm UV region of the spectrum, dramatically reduce the amount of UVA radiation in the approximate 340 nm to 400 nm UV region of the spectrum (hereinafter referred to as being "UVA1"), and virtually eliminate the amount of UV radiation in the

approximate 320 nm to 340 nm UV region of the spectrum (hereinafter referred to as being "UVA2") in comparison with prior UVR emitting discharge lamps.

[00026] Lamps constructed in accordance with the teachings of the present invention provide light of an appropriate spectrum to induce the production of Vitamin D in the skin of the person being exposed to the light source. Light between the wavelengths of 250 and 320 nm and particularly between 290 and 310 nm are those that stimulate the production of vitamin D in the skin. (See Fig. 1) This is also in the part of the spectrum that causes the skin to redden and sunburn so it is essential that the exposure be controlled. If a pure UVB phosphor were used in this application the person being exposed to the light would be overexposed in a matter of seconds. To control this, the UVB phosphor is diluted with a non-UV emitting substance, such as a phosphor that gives off only visible light. By controlling the ratio of the UVB output to the non-UV output (e.g. visible spectrum) the exposure time can be lengthened and controlled.

[00027] To ensure that the lamp does not cause significant facultative pigmentation the UVA1 (340 – 400 nm) photons are be kept to a minimum and the UVA2 (320 – 340 nm) kept near zero. In a preferred embodiment, the phosphor combination has a peak spectrum of 296 nm and have a total band width of five nanometers and a visible phosphor that has no output below 420 nm.

[00028] To date, lamps which achieve the desired spectral characteristics have been constructed using $(Ca,Zn)_3(PO_4)_2$:Tl (NP803) as the UVB source and $Ca_5(F,CL)(PO_4)_3$:Sb:Mn (Cool White and Daylight) or $(Sr,Mg)_3(PO_4)$:Sn (Type 283) as the visible source. The redder phosphors give better results because they have no output below 420 nm. The NP803 peaks at 319 nm which is really too high but this

phosphor has a tail that reaches below 290 nm so it has an output in the desired range of 290 to 310 nm. Other UVB phosphors that work well in this application are $MgSrAl_{11}O_{17}$:Ce (Type 2096), $Sr(BO_2)_6$:Pb (Type 2061) or (Ba,Zn,Mg)SiO_2:Pb (Type 2071).

Formula	OSRAM	NICHIA
$Sr(BO_2)_6$:Pb	2061	
(Ba,Zn,Mg)SiO_2:Pb	2071	
$(Ca,Zn)_3(PO_4)_2$:Tl		NP803
$MgSrAl_{11}O_{17}$:Ce	2096	
$Ca_5(F,CL)(PO_4)_3$:Sb:Mn	4300, 4450, 5650	NP10, NP20, NP40
$CaSiO_3$:Pb,Mn	290C	NP370
$(Sr,Mg)_3(PO_4)$:Sn	282, 283	NP330
$Y(P,V)O_4$:Eu		NP310
$Gd(Zn,Mg)B_5O_{10}$:Ce,Mn	L165	

[00029] Preferably the visible phosphor does not have an output below 420nm. This cab be achieved using any of the green or red phosphors. Another criterion is that the visible phosphor must have little or no absorption above 290nm. In certain embodiments, it is desired to have the lamp emit radiation in the 633nm range in order to get the benefit of skin rejuvenation (improve collagen). The present inventors have determined that red phosphors are best suited for these applications, such as $Y(P,V)O_4$:Eu (NP310), $Gd(Zn,Mg)B_5O_{10}$:Ce,Mn (L165), $(Sr,Mg)_3(PO_4)$:Sn (Type 283), $CaSiO_3$:Pb,Mn (Type 290C), $(Sr,Mg)_3(PO4)_2$:Sn (Type 282), $Ca_5(F,CL)(PO_4)_3$:Sb:Mn (Type 4300).

[00030] In certain representative embodiments, for example a Daylight phosphor (Type 5650 – NP803) the ratio of visible light emitting phosphor to UVB emitting phosphor is 93:7 In alternative constructions, the ratio can be 92.5:7.5 (e.g. Warm White phosphor (Type 4300 – NP803), or 76:24 (e.g., Orange (Type 283 –

NP803)). Those skilled in the art will readily appreciate that the amount of non-UV or visible light emitting phosphor added to the phosphor composition is based on the particular UVB emitting phosphor used and the proportions are adjusted in order to achieve the desired spectral irradiance for the lamp.

[00031] Fig. 2 provides a graphical comparison of the spectral distribution patterns of three UVR sources; a lamp constructed in accordance with the teachings of the present application (identified as, "Rxd-Orange"); a traditional 100W sunlamp and natural sunlight at noon on a typical Midwestern summer day. As can be readily observed, the phosphors used in the Rxd-Orange lamp have shifted a large portion of the photons to the left in the irradiance spectrum (to a lower wavelength) and into the vitamin D target range (i.e., Region 1: 250 nm to 320nm). Moreover, many of the tanning photons (Region 2: 340nm to 430nm) that are typically within the Region 2 on the graph, have been virtually eliminated.

[00032] Table 2 below compares the UV irradiance data of the RxD lamp to a traditional sunlamp, identified as "GTX65 Blue." As can be seen from this table, in the RxD lamp, a larger percentage of the total UV irradiance (UVA & UVB) is emitted in the UVB spectrum (i.e., the photos have been shifted from the UVA spectrum to the UVB spectrum). Moreover, the percentage of UV irradiance (UVA & UVB) as compared to the total spectral irradiance of the lamp has been dramatically reduced, as compared to a traditional sunlamp. It should be noted that the irradiance data used to created Table 2 is provided in Figures 4a-4f.

	Irradiance [W/(cm^2 nm)]		Percent of UV		Percent of Total	
	Vitamin D	GTX65 Blue	Vitamin D	GTX65 Blue	Vitamin D	GTX65 Blue
Total	3.246E-04	5.625E-04			100%	100%
Total UV	4.307E-05	5.081E-04	100%	100%	13%	90%
UVA1	1.394E-05	3.571E-04	32%	70%	4%	63%
UVA2	1.227E-05	1.190E-04	28%	23%	4%	21%
UVB1	1.403E-05	3.087E-05	33%	6%	4%	5%
UVB2	2.827E-06	1.192E-06	7%	0%	1%	0%

TABLE 2

[00033] As illustrated in Tables 3 and 4 below, as compared to the "traditional" sunlamp, the RxD(orange) sunlamp shows an increase in vitamin D-eff photons of 122% and 330% over sunlight at noon on a typical Midwestern summer day. Regarding the tanning power, the RxD sunlamp, reduces the tanning power by 91.5% as compared to traditional sunlamps and by 87.2% as compared to sunlight. Thus, the RxD lamp is more efficient stimulator of vitamin D then either of the other sources and has virtually removed all of the photons associated with facultative pigmentation.

Source		Te (4.0 MED)* ** (time-mins.)	vD-eff (time-mins.)	Tt-eff * ** (time-mins.)
Sunlight		40.4	15.0	45.4
Traditional lamp		14.3	6.2	25.0
RxD(orange)		12.6	4.3	351.9

* For skin type 2A
** persons with darker skin type will have proportional, but longer times.

TABLE 3

Source			vD-eff (mW/m^2)	Tt-eff * ** (mW/m^2)
Sunlight			233.0	27538.0
Traditional lamp			630.0	41975.0
RxD(orange)			769.0	3553.0

* For skin type 2A
** persons with darker skin type will have proportional, but longer times.

TABLE 4

[00034] Those skilled in the art of UVR lamp construction will readily appreciate how the Te and Tt-eff are calculated. More specifically, skilled artisans in the field of UV discharge lamps will readily understand how the "source" readings/spectral irradiance for a discharge lamp, measured for example by a scanning double-beam spectroradiaometer, are converted into Te and Tt-eff. The vitamin D effective (vD-eff) value is determined in a similar manner.

[00035] First, the irradiance at each wavelength is multiplied by a corresponding weighing factor provided by the appropriate action spectrum, such as Fig. 1 for vitamin D stimulation and Fig. 3 for collagen rejuvenation, to determine "weighted" or "effective" values. Once the weighted values have been determined for a specific wavelength range (i.e., 250nm –405nm in the case of Te), a total effective irradiance is obtained through integration of the data using the FDA EAS formula.

[00036] Then, a "calculation matrix" which has been developed through empirical testing is used to covert the total effective value to a dose (AS-eff-dose) or time (AS-eff-time) value. It should be noted that the action spectra (AS) and calculation matrices have been developed and validated through actual patient testing.

[00037] Table 5 compares the RxD sunlamp to a "traditional" sunlamp and sunlight at noon on a Midwestern summer day in several important parameters (in both absolute (mW/m^2) and percentage).

	RxD (mW/m^2)	Traditional (mW/m^2)	Sunlight (mW/m^2)
Total Irradiance (280-400nm)	0.0009547	0.0149409	0.0042841
UVB (280-320nm)	0.0003048	0.000535	0.0002206
UVA (320-400nm)	0.0006499	0.0144104	0.0040635
UVA1 (340-400nm)	0.0003833	0.0115042	0.0033147
UVA2 (320-340nm)	0.0002666	0.0029062	0.0007488
	%	%	%
Total Irradiance (280-400nm)	100	100	100
UVB (280-320nm)	31.9	3.6	5.1
UVA (320-400nm)	68.1	96.4	94.9
UVA1 (340-400nm)	40.1	77	77.4
UVA2 (320-340nm)	27.9	19.5	17.5
Ultraviolet Index (UVI)	23.1	19.8	6.4
MED/hour (FDA EAS)	19.1	16.7	5.9
MED/min (FDA EAS)	0.318	0.279	0.099

TABLE 5

[00038] The total irradiance in the UVA/UVB range for RxD lamp is much less than the other two sources and many of the photons that would normally be found in the UVA1 and UVA2 ranges have been shifted into the UVB range.

[00039] When we speak of a "vitamin D-effective" (usually shortened to vitamin D-eff or vD-eff) dose, we are referring to a level (Wm^2 or mW/m^2) that is determined after the "source (i.e., sunlight or a sunlamp) irradiance (that has been determined by a scanning double beam spectroradiometer such as our Optronics

Laboratory 752/754/756 has been convoluted (i.e., multiplied by) with a vitamin D AS (action spectrum).

[00040] A mentioned above, over the past five years, the present inventors have developed a calculation matrix that makes it possible, for the first time, to (a) calculate the does of vitamin D-eff photons; (b) calculate the time (minutes) (it takes to stimulate that dose; and in addition, (c) estimate the blood level (nmol/L) of vitamin D (25-OH) that will result from this dose/time for both the WMH (Webb, MacLaughlin & Holick) and our own (SPI) vitamin D-eff AS.

[00041] This information will make it possible for a medical doctor to "prescribe" a specific set of conditions (i.e., the time of exposure, the distance from the lamps and the frequency of exposure) that will allow the patient to attain/maintain a specific blood level (nmol/L) of vitamin D (25-OH).

[00042] In order to determine the degree of vitamin D stimulation, the present inventors use both the WMH and their own (SPI) vitamin D-eff AS. (Shown in Fig. 1) The primary difference between the two spectra is that the (SPI) AS "weights" the wavelengths below 290 nm more strongly than does the SMH AS because several scientific studies going back to 1938 provide that the wavelengths below this level stimulate pro-vitamin D. When measuring sunlight, both action spectra provide almost identical results but when measuring solar simulators, like lamps constructed in accordance with the teachings of the present invention, there is a significant difference between the two and, therefore, the SPI action spectrum more accurately measures the dose/time/blood level than does the WMH AS. Moreover, the SPI action spectrum results in a more conservative exposure time, thus reducing the chance of any ill effects on the person exposed to the lamp.

[00043] As noted above, the wavelengths associated with the biological reactions that stimulate the production of collagen and elastogen (i.e., the proteins that provide the "matrix" that supports our skin, cartilage and bones (that makes possible younger looking skin) and that breaks down as we age are found between 580 nm and 680 nm. (See Fig. 3) and these wavelengths are also immunostimulatory (i.e., they stimulate our immune defense system). Therefore, the present inventors have added a phosphor to the phosphor blend in certain embodiments which emits photons in the 580 nm and 680 nm range. (e.g. Osram Type 283, Type 290 & Type L165 or Nichia NP310).

[00044] Although certain phosphor combinations are disclosed herein above, those skilled in the art will readily appreciated that alternative compositions of the listed phosphors can be used without departing from the inventive aspects of the present disclosure.

[00045] The elongated tubes used the present invention are filled with a rare gas, such as argon, and a drop of mercury. The vitreous tubes can have an outer periphery which is smooth or include a helical groove path formed therein over at least a portion of its axial length, similar to the lamps disclosed in U.S. Patent Nos. 6,943,361 and 6,777,702, which are herein incorporated by reference in their entirety. Moreover, the phosphor coating can be applied to the lamp in a single coating with the desired chemical composition or a multi-layer coating, as know to those skilled in the art. Additionally, the coating(s) can be applied along the entire length of the lamp or over a portion of the length, as described in U.S. Patent 6,919,676, which is herein incorporated by reference in its entirety.

[00046] These and other aspects of the system and method of the subject invention will become more readily apparent to those having ordinary skill in the art from the following detailed description of the invention taken in conjunction with the figures and appended material.

What is Claimed is:

1. A lamp for stimulating vitamin D production comprising:

a) a vitreous tube having an outer periphery and axially opposed first and second ends which define an axial length for the tube therebetween;

b) a first electrode assembly associated with the first end of the tube;

c) a second electrode assembly associated with the second end of the tube; and

d) a coating on an interior of the tube which is adapted for delivering an effective dose of vitamin D photons to a person's skin during a predetermined exposure period, wherein the coating delivers an insufficient amount of UVB and UVA photons during the exposure period to cause significant facultative pigmentation and/or melanin oxidization.

2. A lamp as recited in claim 1, wherein an exposure time required to deliver an effecting dose of vitamin D photons to a person's skin is less than T_e and T_m.

3. A lamp as recited in claim 1, wherein the ultraviolet radiation emitted from the lamp in a range of about 320 nm to about 340 nm is less than or equal to about 10 percent of the ultraviolet radiation emitted from the lamp in a range of about 280 nm to about 400 nm.

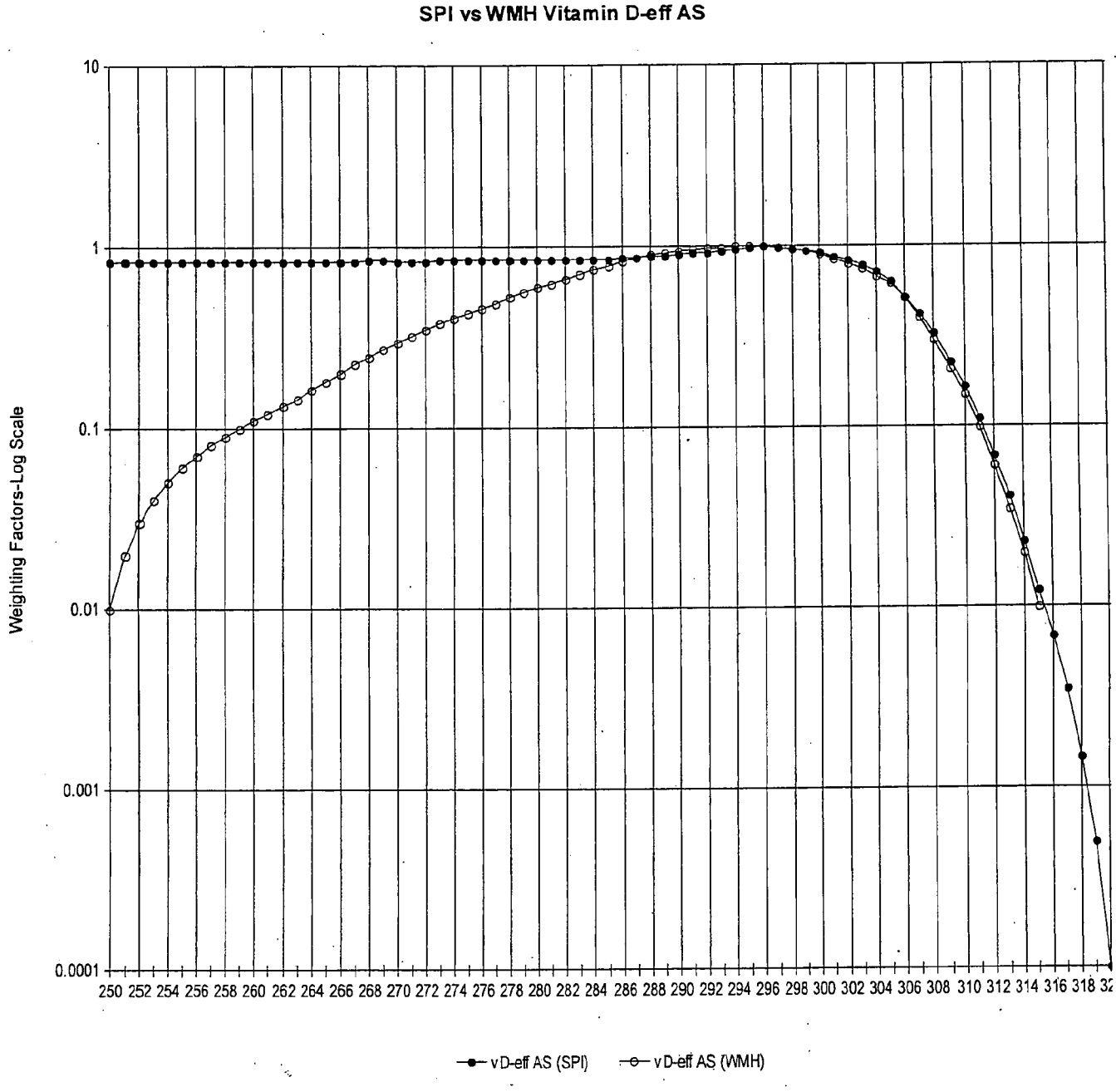
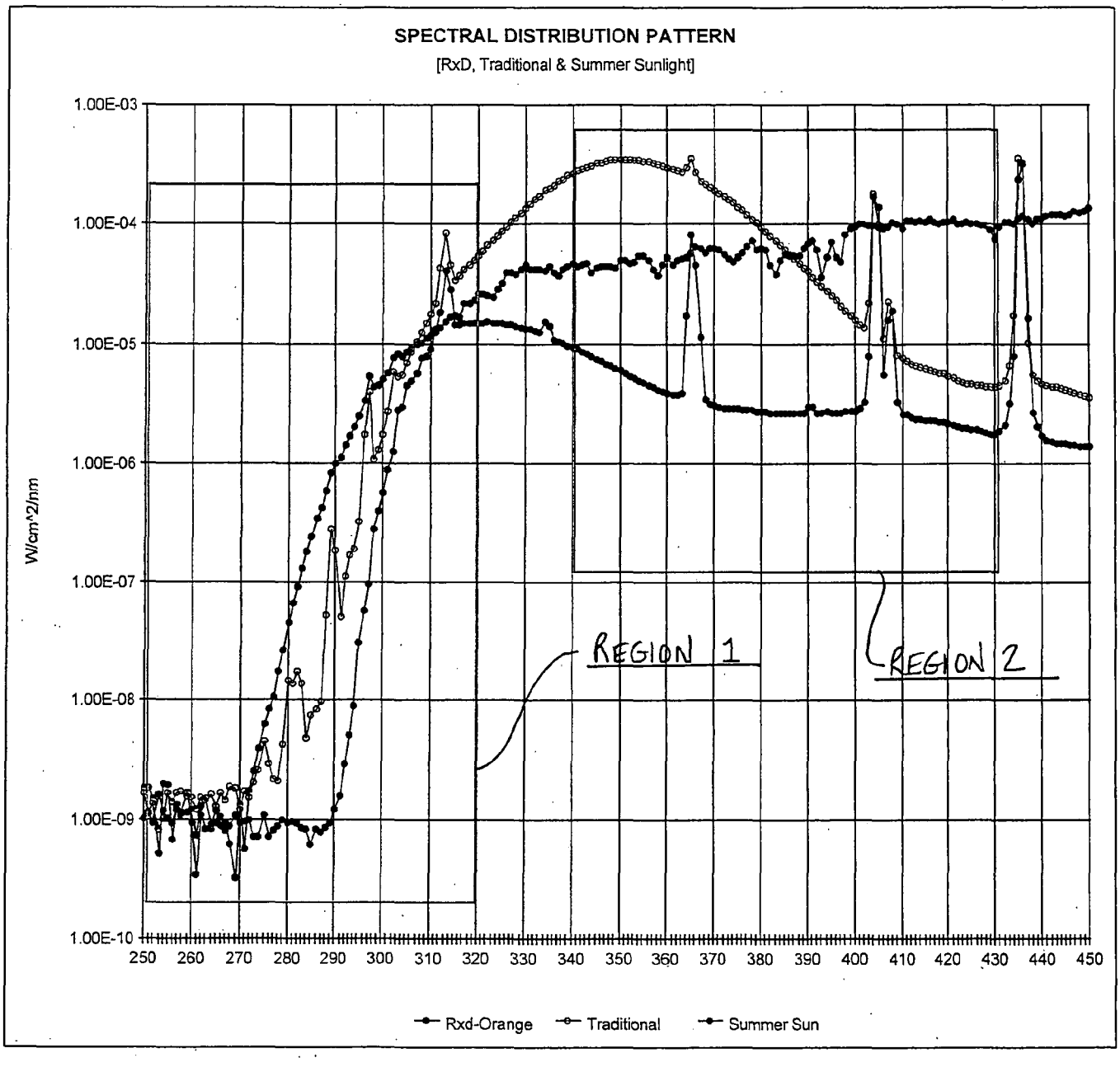

SPI vs WMH Vitamin D-eff AS
Weighting Factors-Log Scale
10
1
0.1
0.01
0.001
0.0001
250 252 254 256 258 260 262 264 266 268 270 272 274 276 278 280 282 284 286 288 290 292 294 296 298 300 302 304 306 308 310 312 314 316 318 32
vD-eff AS (SPI)
vD-eff AS (WMH)

FIG. 1


SPECTRAL DISTRIBUTION PATTERN
[RxD, Traditional & Summer Sunlight]
W/cm^2/nm
1.00E-03
1.00E-04
1.00E-05
1.00E-06
1.00E-07
1.00E-08
1.00E-09
1.00E-10
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REGION 1
REGION 2
Rxd-Orange
Traditional
Summer Sun

FIG. 2

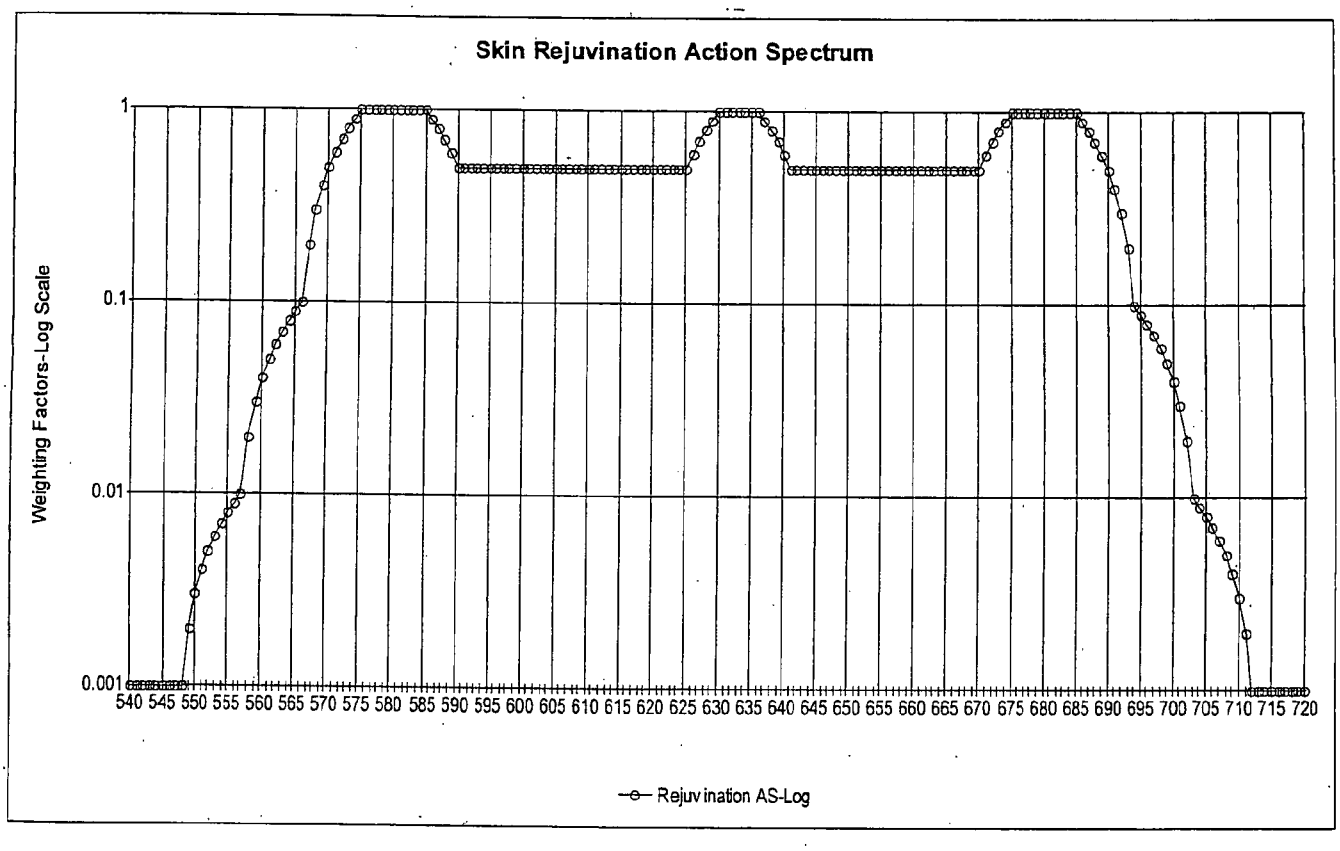
Skin Rejuvination Action Spectrum
Weighting Factors-Log Scale
1
0.1
0.01
0.001
540 545 550 555 560 565 570 575 580 585 590 595 600 605 610 615 620 625 630 635 640 645 650 655 660 665 670 675 680 685 690 695 700 705 710 715 720
Rejuvination AS-Log

FIG. 3

WAVELENGTH	Irradience [W/(cm^2 nm)]		WAVELENGTH	Irradience [W/(cm^2 nm)]	
(nm)	Vitamin D	GTX65 Blue	(nm)	Vitamin D	GTX65 Blue
250	2.6036E-11	5.70341E-10	300	3.1944E-07	1.50372E-07
251	3.57957E-11	5.55241E-10	301	3.67839E-07	2.11238E-07
252	1.60327E-11	6.57204E-10	302	4.62778E-07	3.63863E-07
253	1.55508E-10	8.26367E-10	303	4.57833E-07	4.20309E-07
254	1.51938E-10	1.26124E-09	304	4.66832E-07	4.2883E-07
255	0	7.99108E-10	305	5.03492E-07	5.27671E-07
256	0	5.59391E-10	306	5.36154E-07	6.51719E-07
257	0	5.48474E-10	307	5.73275E-07	7.93645E-07
258	0	6.04205E-10	308	6.08152E-07	9.38917E-07
259	0	5.42374E-10	309	6.39407E-07	1.09031E-06
260	0	5.60131E-10	310	6.68288E-07	1.25662E-06
261	0	5.73309E-10	311	7.7564E-07	1.49272E-06
262	0	5.38852E-10	312	1.48899E-06	2.5703E-06
263	0	5.59859E-10	313	1.93157E-06	3.94682E-06
264	0	5.2182E-10	314	9.31507E-07	2.63837E-06
265	4.25214E-11	5.92359E-10	315	7.61778E-07	2.14052E-06
266	4.83664E-12	6.06517E-10	316	7.67545E-07	2.31801E-06
267	0	4.74744E-10	317	7.69409E-07	2.48551E-06
268	3.82E-12	4.70456E-10	318	7.69451E-07	2.65006E-06
269	0	4.78769E-10	319	7.69837E-07	2.8314E-06
270	8.04112E-12	4.85154E-10	320	7.6344E-07	3.0162E-06
271	5.17665E-12	4.61531E-10	321	7.5812E-07	3.18975E-06
272	6.02306E-11	4.64071E-10	322	7.48054E-07	3.31943E-06
273	1.20588E-10	3.81674E-10	323	7.38143E-07	3.60348E-06
274	2.0993E-10	4.11536E-10	324	7.22692E-07	3.85816E-06
275	4.16397E-10	7.5741E-10	325	7.06061E-07	4.09607E-06
276	5.05986E-10	7.07061E-10	326	6.87255E-07	4.41266E-06
277	7.48989E-10	4.66028E-10	327	6.6926E-07	4.69082E-06
278	1.10004E-09	4.51993E-10	328	6.47757E-07	5.0336E-06
279	1.72015E-09	5.42545E-10	329	6.31211E-07	5.36007E-06
280	2.80297E-09	1.03164E-09	330	6.08965E-07	5.7057E-06
281	3.78113E-09	1.47448E-09	331	5.87932E-07	6.10093E-06
282	5.42586E-09	1.04067E-09	332	5.64717E-07	6.516E-06
283	7.84083E-09	1.05173E-09	333	5.97816E-07	6.94144E-06
284	1.07537E-08	7.3909E-10	334	6.96037E-07	7.50931E-06
285	1.45498E-08	6.96401E-10	335	5.23621E-07	7.77784E-06
286	1.98573E-08	1.07936E-09	336	4.78545E-07	8.10722E-06
287	2.69321E-08	1.00621E-09	337	4.60566E-07	8.46475E-06
288	3.74473E-08	2.91248E-09	338	4.38844E-07	8.83918E-06
289	5.18409E-08	1.19573E-08	339	4.20172E-07	9.20809E-06
290	6.25848E-08	1.56572E-08	340	3.98403E-07	9.54698E-06
291	7.56149E-08	4.9201E-09	341	3.82253E-07	9.84622E-06
292	9.51705E-08	9.96064E-09	342	3.60618E-07	1.0131E-05
293	1.15536E-07	1.37897E-08	343	3.42306E-07	1.03539E-05
294	1.35447E-07	1.62743E-08	344	3.23602E-07	1.05746E-05
295	1.6739E-07	3.03992E-08	345	3.10013E-07	1.07741E-05
296	2.4786E-07	1.13354E-07	346	2.89935E-07	1.09433E-05
297	2.8889E-07	2.1516E-07	347	2.73885E-07	1.09904E-05
298	2.54569E-07	9.79219E-08	348	2.5844E-07	1.10559E-05
299	2.83894E-07	1.08417E-07	349	2.45893E-07	1.10568E-05

FIG. 4a

WAVELENGTH	Irradience [W/(cm^2 nm)]		WAVELENGTH	Irradience [W/(cm^2 nm)]	
(nm)	Vitamin D	GTX65 Blue	(nm)	Vitamin D	GTX65 Blue
350	2.31405E-07	1.10573E-05	400	8.87547E-08	4.47641E-07
351	2.18292E-07	1.09766E-05	401	9.66235E-08	4.16764E-07
352	2.04856E-07	1.08736E-05	402	1.06799E-07	3.8964E-07
353	1.96014E-07	1.07802E-05	403	5.76778E-07	4.83395E-07
354	1.85797E-07	1.06505E-05	404	4.5754E-06	3.30305E-06
355	1.76918E-07	1.03994E-05	405	3.98067E-06	6.02212E-06
356	1.68375E-07	1.02128E-05	406	2.2481E-07	1.0212E-06
357	1.62703E-07	9.9876E-06	407	4.44959E-07	4.4497E-07
358	1.54356E-07	9.74946E-06	408	3.97918E-07	6.62333E-07
359	1.48426E-07	9.46609E-06	409	9.76337E-08	2.62912E-07
360	1.44309E-07	9.17254E-06	410	7.83926E-08	1.70123E-07
361	1.42134E-07	8.88615E-06	411	7.56206E-08	1.55047E-07
362	1.41308E-07	8.56194E-06	412	7.11109E-08	1.3536E-07
363	1.72986E-07	8.17475E-06	413	7.08029E-08	1.23189E-07
364	9.66575E-07	8.21377E-06	414	6.89343E-08	1.13029E-07
365	2.75885E-06	1.00237E-05	415	6.74474E-08	1.02938E-07
366	1.3446E-06	9.34418E-06	416	6.59171E-08	9.39351E-08
367	3.19236E-07	7.20225E-06	417	6.46738E-08	8.61502E-08
368	1.23084E-07	6.37134E-06	418	6.33905E-08	8.00686E-08
369	1.14492E-07	6.02442E-06	419	6.2395E-08	7.36912E-08
370	1.09812E-07	5.67165E-06	420	6.05038E-08	6.78989E-08
371	1.05205E-07	5.27473E-06	421	5.93567E-08	6.26546E-08
372	1.02817E-07	4.93465E-06	422	5.79368E-08	5.8668E-08
373	9.95748E-08	4.63302E-06	423	5.55743E-08	5.35268E-08
374	9.95841E-08	4.34291E-06	424	5.474E-08	4.95129E-08
375	9.75665E-08	4.00713E-06	425	5.33162E-08	4.72514E-08
376	9.65408E-08	3.73779E-06	426	5.21414E-08	4.37941E-08
377	9.54462E-08	3.4985E-06	427	5.09025E-08	4.10178E-08
378	9.34993E-08	3.27599E-06	428	4.9481E-08	3.80733E-08
379	9.34008E-08	3.02013E-06	429	4.9002E-08	3.62811E-08
380	9.29218E-08	2.78551E-06	430	4.92052E-08	3.53769E-08
381	9.24615E-08	2.59136E-06	431	5.30058E-08	3.67952E-08
382	9.08593E-08	2.39441E-06	432	6.66015E-08	4.96109E-08
383	9.06793E-08	2.18456E-06	433	1.0992E-07	8.26708E-08
384	9.02651E-08	2.00679E-06	434	7.70949E-07	3.07838E-07
385	9.03738E-08	1.84502E-06	435	9.38925E-06	6.18927E-06
386	9.0418E-08	1.68691E-06	436	7.77091E-06	1.21356E-05
387	8.88206E-08	1.5299E-06	437	5.75626E-07	1.9577E-06
388	8.94602E-08	1.39244E-06	438	7.69648E-08	7.62677E-08
389	9.15636E-08	1.28145E-06	439	5.35739E-08	4.49353E-08
390	9.85845E-08	1.18778E-06	440	4.23828E-08	2.92412E-08
391	9.42559E-08	1.06892E-06	441	3.91732E-08	2.3556E-08
392	8.80054E-08	9.5417E-07	442	3.77523E-08	2.19141E-08
393	8.82285E-08	8.74986E-07	443	3.71483E-08	2.13413E-08
394	8.7497E-08	7.97966E-07	444	3.67847E-08	2.074E-08
395	8.70251E-08	7.19068E-07	445	3.6303E-08	2.04139E-08
396	8.66468E-08	6.51809E-07	446	3.65324E-08	2.0049E-08
397	8.66054E-08	5.97536E-07	447	3.62848E-08	1.94768E-08
398	8.7699E-08	5.48382E-07	448	3.58683E-08	1.89083E-08
399	8.66036E-08	4.93535E-07	449	3.59704E-08	1.87514E-08

FIG. 4b

WAVELENGTH	Irradience [W/(cm^2 nm)]		WAVELENGTH	Irradience [W/(cm^2 nm)]	
(nm)	Vitamin D	GTX65 Blue	(nm)	Vitamin D	GTX65 Blue
450	3.57992E-08	1.84598E-08	500	1.44853E-07	1.0835E-08
451	3.59446E-08	1.84217E-08	501	1.49405E-07	1.08345E-08
452	3.61373E-08	1.81397E-08	502	1.5574E-07	1.09561E-08
453	3.64364E-08	1.76406E-08	503	1.60391E-07	1.12311E-08
454	3.66103E-08	1.77093E-08	504	1.65506E-07	1.04998E-08
455	3.72249E-08	1.73162E-08	505	1.71704E-07	1.00398E-08
456	3.74511E-08	1.68883E-08	506	1.76624E-07	1.03141E-08
457	3.85205E-08	1.68754E-08	507	1.83263E-07	1.01815E-08
458	3.84824E-08	1.66195E-08	508	1.90672E-07	9.8236E-09
459	3.92079E-08	1.65952E-08	509	1.96843E-07	9.91041E-09
460	3.99409E-08	1.63819E-08	510	2.01455E-07	9.9464E-09
461	4.08652E-08	1.61577E-08	511	2.0891E-07	9.81189E-09
462	4.18417E-08	1.59265E-08	512	2.15808E-07	9.88662E-09
463	4.26126E-08	1.55904E-08	513	2.22181E-07	9.62343E-09
464	4.29544E-08	1.61571E-08	514	2.30792E-07	9.61914E-09
465	4.47308E-08	1.55953E-08	515	2.38053E-07	9.50417E-09
466	4.53924E-08	1.49514E-08	516	2.44884E-07	9.49504E-09
467	4.74337E-08	1.48828E-08	517	2.52704E-07	9.45789E-09
468	4.7839E-08	1.50934E-08	518	2.59768E-07	9.18584E-09
469	5.00831E-08	1.45501E-08	519	2.68143E-07	9.22287E-09
470	5.14172E-08	1.46617E-08	520	2.77729E-07	8.84707E-09
471	5.27417E-08	1.46373E-08	521	2.85518E-07	8.97284E-09
472	5.41501E-08	1.44219E-08	522	2.94143E-07	8.7325E-09
473	5.6243E-08	1.40202E-08	523	3.05104E-07	8.98697E-09
474	5.82476E-08	1.40735E-08	524	3.15278E-07	8.85025E-09
475	6.05532E-08	1.38575E-08	525	3.247E-07	8.66008E-09
476	6.20123E-08	1.39432E-08	526	3.31566E-07	8.37122E-09
477	6.37038E-08	1.38376E-08	527	3.43973E-07	8.5227E-09
478	6.50272E-08	1.35926E-08	528	3.522E-07	8.19126E-09
479	6.83119E-08	1.36015E-08	529	3.63015E-07	8.21055E-09
480	7.09484E-08	1.34195E-08	530	3.74015E-07	8.48679E-09
481	7.19706E-08	1.34357E-08	531	3.83652E-07	8.38099E-09
482	7.51846E-08	1.3618E-08	532	3.94782E-07	8.36459E-09
483	7.80879E-08	1.27165E-08	533	4.07942E-07	7.9586E-09
484	8.2429E-08	1.30372E-08	534	4.19054E-07	8.07641E-09
485	8.4493E-08	1.28273E-08	535	4.33322E-07	8.39199E-09
486	8.63013E-08	1.29106E-08	536	4.41423E-07	8.31828E-09
487	9.06948E-08	1.27373E-08	537	4.53687E-07	7.58721E-09
488	9.35178E-08	1.24045E-08	538	4.65914E-07	7.97506E-09
489	9.70432E-08	1.2647E-08	539	4.79881E-07	8.08751E-09
490	1.04952E-07	1.38502E-08	540	4.90986E-07	7.8879E-09
491	1.46623E-07	4.56564E-08	541	5.05659E-07	8.6911E-09
492	1.23435E-07	4.43154E-08	542	5.20168E-07	1.20614E-08
493	1.12005E-07	1.44293E-08	543	5.43361E-07	2.05922E-08
494	1.15423E-07	1.17471E-08	544	6.51554E-07	4.09479E-08
495	1.21562E-07	1.18212E-08	545	4.19358E-06	1.49209E-06
496	1.24728E-07	1.14339E-08	546	7.31003E-06	7.55509E-06
497	1.29329E-07	1.13674E-08	547	1.38507E-06	2.33963E-06
498	1.34215E-07	1.12644E-08	548	6.18787E-07	5.68881E-08
499	1.39214E-07	1.10281E-08	549	6.23586E-07	1.76682E-08

FIG. 4c

WAVELENGTH	Irradience [W/(cm^2 nm)]		WAVELENGTH	Irradience [W/(cm^2 nm)]	
(nm)	Vitamin D	GTX65 Blue	(nm)	Vitamin D	GTX65 Blue
550	6.28558E-07	1.08242E-08	600	1.3709E-06	4.69528E-09
551	6.46959E-07	7.63275E-09	601	1.39266E-06	4.63054E-09
552	6.57349E-07	6.92741E-09	602	1.40442E-06	4.71616E-09
553	6.74807E-07	6.8029E-09	603	1.41513E-06	4.65289E-09
554	6.90452E-07	6.62618E-09	604	1.41967E-06	4.39412E-09
555	7.08617E-07	6.77786E-09	605	1.43335E-06	4.30484E-09
556	7.2387E-07	6.42028E-09	606	1.44578E-06	4.58756E-09
557	7.38742E-07	6.55076E-09	607	1.45195E-06	5.19281E-09
558	7.53833E-07	6.35891E-09	608	1.45692E-06	4.86389E-09
559	7.71617E-07	6.53724E-09	609	1.47213E-06	4.31404E-09
560	7.82823E-07	6.52313E-09	610	1.47216E-06	4.25764E-09
561	7.97168E-07	6.36599E-09	611	1.48153E-06	4.94458E-09
562	8.15797E-07	6.20234E-09	612	1.49135E-06	7.17988E-09
563	8.34483E-07	6.23341E-09	613	1.49947E-06	5.42831E-09
564	8.44207E-07	6.15481E-09	614	1.50461E-06	4.2537E-09
565	8.64141E-07	6.08843E-09	615	1.51307E-06	3.97973E-09
566	8.75814E-07	6.01886E-09	616	1.50503E-06	3.97773E-09
567	8.94809E-07	6.75586E-09	617	1.51536E-06	3.92426E-09
568	9.14524E-07	6.87468E-09	618	1.51039E-06	4.06904E-09
569	9.29992E-07	6.22453E-09	619	1.52379E-06	3.78121E-09
570	9.41913E-07	6.00149E-09	620	1.52391E-06	3.91997E-09
571	9.64619E-07	5.83503E-09	621	1.52513E-06	3.9225E-09
572	9.7757E-07	6.08014E-09	622	1.52366E-06	3.96797E-09
573	9.95062E-07	6.5275E-09	623	1.52452E-06	5.58165E-09
574	1.01438E-06	7.70527E-09	624	1.52204E-06	5.25499E-09
575	1.07668E-06	1.58988E-08	625	1.52157E-06	3.95614E-09
576	1.88775E-06	5.60752E-07	626	1.5253E-06	3.66811E-09
577	1.99022E-06	1.19732E-06	627	1.52714E-06	3.61144E-09
578	1.7336E-06	6.25684E-07	628	1.52304E-06	3.59345E-09
579	2.0421E-06	1.16577E-06	629	1.52475E-06	3.6299E-09
580	1.2793E-06	4.11151E-07	630	1.51772E-06	3.64968E-09
581	1.12833E-06	2.7429E-08	631	1.51704E-06	3.48581E-09
582	1.1346E-06	7.42789E-09	632	1.50816E-06	3.51081E-09
583	1.15327E-06	6.28531E-09	633	1.50777E-06	3.52752E-09
584	1.16439E-06	5.66175E-09	634	1.50908E-06	3.5485E-09
585	1.18681E-06	5.65938E-09	635	1.50225E-06	3.69707E-09
586	1.19518E-06	5.6789E-09	636	1.49674E-06	3.25321E-09
587	1.21804E-06	5.83986E-09	637	1.49442E-06	3.42924E-09
588	1.22516E-06	5.55301E-09	638	1.483E-06	3.57046E-09
589	1.24603E-06	5.1992E-09	639	1.48408E-06	3.32825E-09
590	1.25003E-06	5.05967E-09	640	1.47506E-06	3.4744E-09
591	1.27109E-06	5.32786E-09	641	1.47346E-06	3.37485E-09
592	1.28709E-06	5.08989E-09	642	1.46579E-06	3.27409E-09
593	1.29835E-06	5.10991E-09	643	1.46031E-06	3.39455E-09
594	1.30594E-06	5.09518E-09	644	1.44544E-06	3.36438E-09
595	1.32537E-06	4.94682E-09	645	1.44368E-06	3.14242E-09
596	1.33101E-06	4.86948E-09	646	1.43398E-06	3.37269E-09
597	1.34791E-06	4.85388E-09	647	1.42999E-06	3.49726E-09
598	1.35304E-06	4.7963E-09	648	1.42534E-06	3.36098E-09
599	1.36975E-06	4.829E-09	649	1.41197E-06	3.33798E-09

FIG. 4d

WAVELENGTH	Irradience [W/(cm^2 nm)]	
(nm)	Vitamin D	GTX65 Blue
650	1.4055E-06	3.31574E-09
651	1.39153E-06	3.48068E-09
652	1.37561E-06	3.49024E-09
653	1.37079E-06	3.39543E-09
654	1.35788E-06	3.43452E-09
655	1.34818E-06	3.42066E-09
656	1.33348E-06	3.49237E-09
657	1.32524E-06	3.4678E-09
658	1.31664E-06	3.50963E-09
659	1.31599E-06	3.52986E-09
660	1.29643E-06	3.68207E-09
661	1.29407E-06	3.60012E-09
662	1.27836E-06	3.65051E-09
663	1.26149E-06	3.86483E-09
664	1.24467E-06	3.45468E-09
665	1.24014E-06	3.71087E-09
666	1.22634E-06	3.85814E-09
667	1.21188E-06	3.72074E-09
668	1.20691E-06	3.66099E-09
669	1.18989E-06	3.85189E-09
670	1.18427E-06	3.86225E-09
671	1.16099E-06	5.35628E-09
672	1.14786E-06	6.29331E-09
673	1.14219E-06	4.37155E-09
674	1.12651E-06	3.67247E-09
675	1.11243E-06	4.03935E-09
676	1.08917E-06	4.15196E-09
677	1.07495E-06	4.27663E-09
678	1.0731E-06	3.79956E-09
679	1.06347E-06	4.06119E-09
680	1.04239E-06	4.22892E-09
681	1.03264E-06	4.24401E-09
682	1.02016E-06	4.05413E-09
683	1.00191E-06	4.44746E-09
684	9.87194E-07	4.11752E-09
685	9.68959E-07	4.26519E-09
686	9.60118E-07	4.735E-09
687	9.43281E-07	4.62287E-09
688	9.30136E-07	4.73978E-09
689	9.26447E-07	5.0084E-09
690	9.30283E-07	1.92315E-08
691	9.12251E-07	3.81816E-08
692	8.76653E-07	9.43271E-09
693	8.70961E-07	4.93504E-09
694	8.5887E-07	5.04294E-09
695	8.43094E-07	4.6469E-09
696	8.34114E-07	8.16326E-09
697	8.31625E-07	8.47541E-09
698	8.15139E-07	5.48213E-09
699	7.93187E-07	5.15541E-09

WAVELENGTH	Irradience [W/(cm^2 nm)]	
(nm)	Vitamin D	GTX65 Blue
700	7.8218E-07	5.11528E-09
701	7.74187E-07	5.28733E-09
702	7.64484E-07	5.24999E-09
703	7.47294E-07	5.36327E-09
704	7.3956E-07	5.87376E-09
705	7.23648E-07	5.51228E-09
706	7.10798E-07	6.62072E-09
707	7.08974E-07	9.61941E-09
708	6.95374E-07	1.43684E-08
709	6.89846E-07	1.24748E-08
710	6.64941E-07	7.90429E-09
711	6.48569E-07	5.76315E-09
712	6.37496E-07	5.52903E-09
713	6.34515E-07	5.81547E-09
714	6.1804E-07	5.62332E-09
715	6.07705E-07	6.199E-09
716	5.92716E-07	5.95086E-09
717	5.86084E-07	6.0792E-09
718	5.75361E-07	5.93684E-09
719	5.61222E-07	6.15816E-09
720	5.58262E-07	5.83585E-09
721	5.44968E-07	6.23939E-09
722	5.29339E-07	6.07072E-09
723	5.24865E-07	6.34383E-09
724	5.10988E-07	6.40927E-09
725	4.97685E-07	6.61694E-09
726	4.92356E-07	6.60915E-09
727	4.81194E-07	7.25095E-09
728	4.72094E-07	7.53479E-09
729	4.68135E-07	6.7469E-09
730	4.47937E-07	6.16102E-09
731	4.43295E-07	6.97134E-09
732	4.36504E-07	6.62764E-09
733	4.32208E-07	6.53544E-09
734	4.18572E-07	6.70202E-09
735	4.08182E-07	7.45043E-09
736	3.98323E-07	7.41721E-09
737	3.977E-07	7.50305E-09
738	3.88079E-07	1.25899E-08
739	3.83433E-07	1.39255E-08
740	3.6083E-07	8.33232E-09
741	3.59677E-07	7.58697E-09
742	3.59576E-07	8.10281E-09
743	3.47392E-07	7.64668E-09
744	3.38844E-07	7.82594E-09
745	3.28102E-07	7.60735E-09
746	3.1656E-07	7.77248E-09
747	3.17861E-07	7.7964E-09
748	3.04002E-07	7.99946E-09
749	3.02659E-07	8.20364E-09

FIG. 4e

WAVELENGTH	Irradience [W/(cm^2 nm)]	
(nm)	Vitamin D	GTX65 Blue
750	2.99609E-07	1.35582E-08
751	2.94591E-07	1.91735E-08
752	2.79633E-07	1.50677E-08
753	2.75398E-07	9.8721E-09
754	2.71512E-07	9.03563E-09
755	2.6223E-07	8.87644E-09
756	2.51099E-07	9.28096E-09
757	2.52417E-07	8.63658E-09
758	2.40045E-07	9.05998E-09
759	2.38802E-07	1.01524E-08
760	2.2838E-07	9.82514E-09
761	2.31423E-07	1.03784E-08
762	2.22675E-07	9.85658E-09
763	2.42879E-07	2.82223E-08
764	2.2575E-07	4.28362E-08
765	2.05315E-07	1.71597E-08
766	2.09531E-07	9.98666E-09
767	1.98234E-07	1.07835E-08
768	1.92624E-07	1.15376E-08
769	1.92256E-07	1.10567E-08
770	1.77814E-07	1.2029E-08
771	1.78559E-07	1.29284E-08
772	1.80867E-07	2.30239E-08
773	1.80728E-07	2.78484E-08
774	1.6563E-07	1.62948E-08
775	1.6383E-07	1.25531E-08
776	1.58111E-07	1.29519E-08
777	1.47718E-07	1.32397E-08
778	1.46366E-07	1.29471E-08
779	1.46437E-07	1.3782E-08
780	1.40538E-07	1.43229E-08
781	1.3981E-07	1.40491E-08
782	1.33926E-07	1.389E-08
783	1.34782E-07	1.44127E-08
784	1.34884E-07	1.41375E-08
785	1.212E-07	1.44807E-08
786	1.21573E-07	1.42307E-08
787	1.16919E-07	1.52752E-08
788	1.17447E-07	1.56984E-08
789	1.14247E-07	1.59071E-08
790	1.10961E-07	1.57849E-08
791	1.06365E-07	1.49553E-08
792	1.07193E-07	1.53156E-08
793	1.02045E-07	1.36107E-08
794	1.06265E-07	1.53005E-08
795	1.05554E-07	2.3831E-08
796	9.57235E-08	1.34635E-08
797	9.53294E-08	8.54305E-09
798	9.03304E-08	8.17497E-09
799	8.66936E-08	7.08884E-09
800	9.02458E-08	8.78622E-09

FIG. 4f