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(54) **SYSTEMS FOR TREATING SKIN LAXITY**

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(Continued)

(56) **References Cited**

U.S. PATENT DOCUMENTS

2,427,348 A 9/1947 Bond et al.

2,792,829 A 2/1952 Calosi

(Continued)

FOREIGN PATENT DOCUMENTS

CN 104027893 9/2014

DE 4029175 3/1992

(Continued)

OTHER PUBLICATIONS

Delon Martin, C., et al., "Venous Thrombosis Generation By Means
of High-Intensity Focused Ultrasound" *Ultrasound in Med. & Biol.*,
vol. 21, No. 1, pp. 113-119 (1995).

Agren, Magnus S. et al., Collagenase in Wound Healing: Effect of
Wound Age and Type. *The Journal of Investigative Dermatology*,
vol. 99/No. 6, (Dec. 1992).

Alster, Tinas S., Tanzi, Elizabeth L., "Cellulite Treatment using a
Novel Combination Radiofrequency, Infrared Light, and Mechanical
Tissue Manipulation Device," *Journal of Cosmetic & Laser
Therapy*, Jun. 2005, vol. 7, Issue 2, pp. 81-85.

(Continued)

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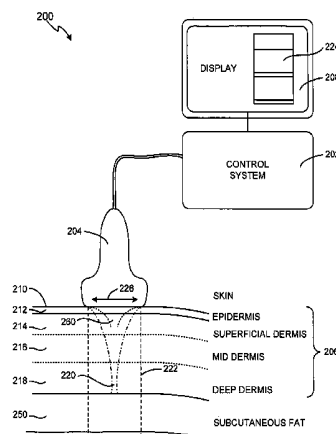
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(57)

ABSTRACT

A system and method for ultrasound treatment of skin laxity
are provided. Systems and methods can include ultrasound
imaging of the region of interest for localization of the
treatment area, delivering ultrasound energy at a depth and
pattern to achieve the desired therapeutic effects, and/or
monitoring the treatment area to assess the results and/or
provide feedback. In an embodiment, a treatment system and
method can be configured for producing arrays of sub-
millimeter and larger zones of thermal ablation to treat the
epidermal, superficial dermal, mid-dermal and deep dermal
components of tissue.

20 Claims, 22 Drawing Sheets



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See application file for complete search history.

(56) References Cited

U.S. PATENT DOCUMENTS

3,913,386 A 10/1975 Saglio
 3,965,455 A 6/1976 Hurwitz
 3,992,925 A 11/1976 Perillhou
 4,039,312 A 8/1977 Patru
 4,059,098 A 11/1977 Murdock
 4,101,795 A 7/1978 Fukumoto et al.
 4,151,834 A 5/1979 Sato et al.
 4,166,967 A 9/1979 Benes et al.
 4,211,948 A 7/1980 Smith et al.
 4,211,949 A 7/1980 Brisken et al.
 4,213,344 A 7/1980 Rose
 4,276,491 A 6/1981 Daniel
 4,315,514 A 2/1982 Drewes et al.
 4,325,381 A 4/1982 Glenn
 4,343,301 A 8/1982 Indech
 4,372,296 A 2/1983 Fahim
 4,379,145 A 4/1983 Masuho et al.
 4,381,007 A 4/1983 Doss
 4,381,787 A 5/1983 Hottinger
 4,397,314 A 8/1983 Vaguine
 4,409,839 A 10/1983 Taenzer
 4,431,008 A 2/1984 Wanner et al.
 4,441,486 A 4/1984 Pounds
 4,452,084 A 6/1984 Taenzer
 4,484,569 A 11/1984 Driller

4,507,582 A 3/1985 Glenn
 4,513,749 A 4/1985 Kino
 4,513,750 A 4/1985 Heyman et al.
 4,527,550 A 7/1985 Ruggera et al.
 4,528,979 A 7/1985 Marchenko
 4,534,221 A 8/1985 Fife et al.
 4,566,459 A 1/1986 Umemura et al.
 4,567,895 A 2/1986 Putzke
 4,586,512 A 5/1986 Do-Huu
 4,601,296 A 7/1986 Yerushalmi
 4,620,546 A 11/1986 Aida et al.
 4,637,256 A 1/1987 Sugiyama et al.
 4,646,756 A 3/1987 Watmough
 4,663,358 A 5/1987 Hyon
 4,668,516 A 5/1987 Duraffourd et al.
 4,672,591 A 6/1987 Breimesser et al.
 4,680,499 A 7/1987 Umemura et al.
 4,697,588 A 10/1987 Reichenberger
 4,754,760 A 7/1988 Fukukita et al.
 4,757,820 A 7/1988 Itoh
 4,771,205 A 9/1988 Mequio
 4,801,459 A 1/1989 Liburdy
 4,803,625 A 2/1989 Fu et al.
 4,807,633 A 2/1989 Fry
 4,817,615 A 4/1989 Fukukita et al.
 4,858,613 A 8/1989 Fry
 4,860,732 A 8/1989 Hasegawa et al.
 4,865,041 A 9/1989 Hassler
 4,865,042 A 9/1989 Umemura
 4,867,169 A 9/1989 Machida
 4,874,562 A 10/1989 Hyon
 4,875,487 A 10/1989 Seppi
 4,881,212 A 11/1989 Takeuchi
 4,891,043 A 1/1990 Zeimer et al.
 4,893,624 A 1/1990 Lele
 4,896,673 A 1/1990 Rose
 4,900,540 A 2/1990 Ryan et al.
 4,901,729 A 2/1990 Saitoh
 4,917,096 A 4/1990 Englehart
 4,932,414 A 6/1990 Coleman et al.
 4,938,216 A 7/1990 Lele
 4,938,217 A 7/1990 Lele
 4,947,046 A 8/1990 Kawabata et al.
 4,951,653 A 8/1990 Fry
 4,955,365 A 9/1990 Fry
 4,958,626 A 9/1990 Nambu
 4,976,709 A 12/1990 Sand
 4,979,501 A 12/1990 Valchanov
 4,992,989 A 2/1991 Watanabe et al.
 5,012,797 A 5/1991 Liang
 5,018,508 A 5/1991 Fry et al.
 5,030,874 A 7/1991 Saito et al.
 5,036,855 A 8/1991 Fry
 5,040,537 A 8/1991 Katakura
 5,054,310 A 10/1991 Flynn
 5,054,470 A 10/1991 Fry
 5,054,491 A 10/1991 Saito et al.
 5,070,879 A 12/1991 Herres
 5,088,495 A 2/1992 Miyagawa
 5,115,814 A 5/1992 Griffith
 5,117,832 A 6/1992 Sanghvi
 5,123,418 A 6/1992 Saurel
 5,142,511 A 8/1992 Kanai et al.
 5,143,063 A 9/1992 Fellner
 5,143,074 A 9/1992 Dory
 5,149,319 A 9/1992 Unger
 5,150,711 A 9/1992 Dory
 5,150,714 A 9/1992 Green
 5,152,294 A 10/1992 Mochizuki et al.
 5,156,144 A 10/1992 Iwasaki
 5,158,536 A 10/1992 Sekins
 5,159,931 A 11/1992 Pini
 5,163,421 A 11/1992 Bernstein
 5,163,436 A 11/1992 Saitoh et al.
 5,178,135 A 1/1993 Uchiyama et al.
 5,190,518 A 3/1993 Takasu
 5,190,766 A 3/1993 Ishihara
 5,191,880 A 3/1993 McLeod
 5,205,287 A 4/1993 Erbel et al.

(56)

References Cited

U.S. PATENT DOCUMENTS

5,209,720 A	5/1993	Unger	5,575,291 A	11/1996	Hayakawa
5,212,671 A	5/1993	Fujii et al.	5,575,807 A	11/1996	Faller
5,215,680 A	6/1993	D'Arrigo	5,577,502 A	11/1996	Darrow et al.
5,224,467 A	7/1993	Oku	5,577,507 A	11/1996	Snyder et al.
5,230,334 A	7/1993	Klopotek	5,577,991 A	11/1996	Akui et al.
5,230,338 A	7/1993	Allen et al.	5,580,575 A	12/1996	Unger et al.
5,247,924 A	9/1993	Suzuki et al.	5,601,526 A *	2/1997	Chapelon A61N 7/02 601/2
5,255,681 A	10/1993	Ishimura et al.	5,603,323 A	2/1997	Pflugrath et al.
5,257,970 A	11/1993	Dougherty	5,605,154 A *	2/1997	Ries G01S 7/52046 600/444
5,265,614 A	11/1993	Hayakawa	5,609,562 A	3/1997	Kaali
5,267,985 A	12/1993	Shimada	5,615,091 A	3/1997	Palatnik
5,269,297 A	12/1993	Weng	5,617,858 A	4/1997	Taverna et al.
5,282,797 A	2/1994	Chess	5,618,275 A	4/1997	Bock
5,295,484 A	3/1994	Marcus	5,620,479 A	4/1997	Diederich
5,295,486 A	3/1994	Wollschlager et al.	5,622,175 A	4/1997	Sudol et al.
5,304,169 A	4/1994	Sand	5,638,819 A	6/1997	Manwaring et al.
5,305,756 A	4/1994	Entrekin et al.	5,643,179 A *	7/1997	Fujimoto A61N 7/02 600/444
5,321,520 A	6/1994	Inga et al.	5,644,085 A	7/1997	Lorraine et al.
5,323,779 A	6/1994	Hardy et al.	5,647,373 A	7/1997	Paltieli
5,327,895 A	7/1994	Hashimoto et al.	5,655,535 A	8/1997	Frlmel et al.
5,348,016 A	9/1994	Unger et al.	5,655,538 A	8/1997	Lorraine
5,358,466 A *	10/1994	Aida A61B 17/2256 600/439	5,657,760 A	8/1997	Ying
5,360,268 A	11/1994	Hayashi	5,658,328 A	8/1997	Johnson
5,370,121 A	12/1994	Reichenberger	5,660,836 A *	8/1997	Knowlton A61B 18/12 128/898
5,371,483 A	12/1994	Bhardwaj	5,662,116 A	9/1997	Kondo
5,375,602 A	12/1994	Lancee et al.	5,665,053 A	9/1997	Jacobs
5,379,773 A	1/1995	Hornsby	5,665,141 A	9/1997	Vago
5,380,280 A	1/1995	Peterson	5,671,746 A	9/1997	Dreschel et al.
5,380,519 A	1/1995	Schneider et al.	5,673,699 A	10/1997	Trahey et al.
5,383,917 A	1/1995	Desai et al.	5,676,692 A	10/1997	Sanghvi
5,391,140 A	2/1995	Schaetzle et al.	5,685,820 A	11/1997	Riek et al.
5,391,197 A	2/1995	Burdette et al.	5,690,608 A	11/1997	Watanabe
5,392,259 A	2/1995	Bolorforosh	5,694,936 A	12/1997	Fujimoto
5,396,143 A	3/1995	Seyed-Bolorforosh et al.	5,697,897 A	12/1997	Buchholtz
5,398,689 A	3/1995	Connor et al.	5,701,900 A	12/1997	Shehada et al.
5,406,503 A	4/1995	Williams	5,704,361 A	1/1998	Seward et al.
5,413,550 A *	5/1995	Castel A61H 23/0245 601/2	5,706,252 A	1/1998	Le Verrier et al.
5,417,216 A	5/1995	Tanaka	5,706,564 A	1/1998	Rhyne
5,419,327 A	5/1995	Rohwedder	5,715,823 A	2/1998	Wood et al.
5,423,220 A	6/1995	Finsterwald et al.	5,720,287 A	2/1998	Chapelon et al.
5,435,311 A	7/1995	Umemura	5,722,411 A	3/1998	Suzuki
5,438,998 A	8/1995	Hanafy	5,727,554 A	3/1998	Kalend et al.
5,443,068 A *	8/1995	Cline A61B 5/0555 600/411	5,735,280 A	4/1998	Sherman et al.
5,445,611 A	8/1995	Eppstein et al.	5,743,863 A	4/1998	Chapelon
5,458,596 A	10/1995	Lax	5,746,005 A	5/1998	Steinberg
5,460,179 A	10/1995	Okunuki et al.	5,746,762 A	5/1998	Bass
5,460,595 A	10/1995	Hall et al.	5,748,767 A	5/1998	Raab
5,469,854 A	11/1995	Unger et al.	5,749,364 A	5/1998	Sliwa et al.
5,471,988 A	12/1995	Fujio	5,755,228 A	5/1998	Wilson et al.
5,472,405 A	12/1995	Buchholtz et al.	5,755,753 A	5/1998	Knowlton
5,487,388 A	1/1996	Rello et al.	5,762,066 A	6/1998	Law
5,492,126 A	2/1996	Hennige	5,763,886 A	6/1998	Schulte
5,496,256 A	3/1996	Bock	5,769,790 A	6/1998	Watkins
5,501,655 A	3/1996	Rolt	5,779,644 A	7/1998	Eberle et al.
5,503,152 A	4/1996	Oakley et al.	5,792,058 A	8/1998	Lee
5,503,320 A	4/1996	Webster et al.	5,795,297 A	8/1998	Daigle
5,507,790 A	4/1996	Weiss	5,795,311 A	8/1998	Wess
5,511,296 A	4/1996	Dias et al.	5,810,009 A	9/1998	Mine et al.
5,520,188 A	5/1996	Hennige	5,810,888 A	9/1998	Fenn
5,522,869 A	6/1996	Burdette	5,814,599 A	9/1998	Mitragotri et al.
5,523,058 A	6/1996	Umemura et al.	5,817,013 A	10/1998	Ginn et al.
5,524,620 A	6/1996	Rosenschein	5,817,021 A	10/1998	Reichenberger
5,524,624 A	6/1996	Tepper	5,820,564 A	10/1998	Slayton
5,524,625 A	6/1996	Okazaki	5,823,962 A	10/1998	Schaetzle
5,526,624 A	6/1996	Berg	5,827,204 A	10/1998	Grandia et al.
5,526,812 A	6/1996	Dumoulin et al.	5,840,032 A	11/1998	Hatfield et al.
5,526,814 A	6/1996	Cline et al.	5,844,140 A	12/1998	Seale
5,526,815 A	6/1996	Granz	5,853,367 A	12/1998	Chalek et al.
5,529,070 A	6/1996	Augustine et al.	5,869,751 A	2/1999	Bonin
5,540,235 A	7/1996	Wilson	5,871,524 A	2/1999	Knowlton
5,558,092 A	9/1996	Unger	5,873,902 A	2/1999	Sanghvi
5,560,362 A	10/1996	Sliwa et al.	5,876,341 A	3/1999	Wang et al.
			5,879,303 A	3/1999	Averkiou et al.
			5,882,557 A	3/1999	Hayakawa
			5,891,034 A	4/1999	Bucholz

(56)	References Cited		6,241,753 B1 *	6/2001	Knowlton	A61B 18/12 128/898
	U.S. PATENT DOCUMENTS		6,246,898 B1	6/2001	Vesely et al.	
5,895,356 A	4/1999	Andrus et al.	6,251,074 B1	6/2001	Averkiou et al.	
5,899,861 A	5/1999	Friemel et al.	6,251,088 B1	6/2001	Kaufman et al.	
5,904,659 A	5/1999	Duarte	6,268,405 B1	7/2001	Yao	
5,919,219 A	7/1999	Knowlton	6,273,864 B1	8/2001	Duarte	
5,923,099 A	7/1999	Bilir	6,280,402 B1	8/2001	Ishibashi et al.	
5,924,989 A	7/1999	Polz	6,287,257 B1	9/2001	Maticchuk	
5,928,169 A	7/1999	Schatzle et al.	6,287,304 B1	9/2001	Eggers et al.	
5,931,805 A	8/1999	Brisken	6,296,619 B1	10/2001	Brisken	
5,938,606 A	8/1999	Bonnefous	6,301,989 B1	10/2001	Brown et al.	
5,938,612 A	8/1999	Kline-Schoder	6,307,302 B1	10/2001	Toda	
5,948,011 A	9/1999	Knowlton	6,309,355 B1	10/2001	Cain et al.	
5,957,844 A	9/1999	Dekel	6,311,090 B1	10/2001	Knowlton	
5,957,882 A	9/1999	Nita et al.	6,315,741 B1 *	11/2001	Martin	A61B 8/4254 601/3
5,957,941 A	9/1999	Ream	6,322,509 B1	11/2001	Pan et al.	
5,964,707 A	10/1999	Fenster et al.	6,322,532 B1	11/2001	D'Sa	
5,967,980 A	10/1999	Ferre et al.	6,325,540 B1	12/2001	Lounsberry et al.	
5,968,034 A	10/1999	Fullmer	6,325,758 B1	12/2001	Carol et al.	
5,971,949 A	10/1999	Levin	6,325,769 B1	12/2001	Klopotek	
5,977,538 A	11/1999	Unger et al.	6,325,798 B1	12/2001	Edwards et al.	
5,984,881 A *	11/1999	Ishibashi	6,338,716 B1	1/2002	Hossack et al.	
		A61B 17/2256 601/2	6,350,276 B1	2/2002	Knowlton	
5,984,882 A	11/1999	Rosenchein	6,356,780 B1	3/2002	Licato et al.	
5,990,598 A	11/1999	Sudol et al.	6,361,531 B1	3/2002	Hissong	
5,997,471 A	12/1999	Gumb et al.	6,370,411 B1	4/2002	Osadchy et al.	
5,997,497 A	12/1999	Nita et al.	6,375,672 B1	4/2002	Aksan	
5,999,843 A	12/1999	Anbar	6,377,854 B1	4/2002	Knowlton	
6,004,262 A	12/1999	Putz et al.	6,377,855 B1	4/2002	Knowlton	
6,007,499 A	12/1999	Martin et al.	6,381,497 B1	4/2002	Knowlton	
6,013,032 A	1/2000	Savord	6,381,498 B1	4/2002	Knowlton	
6,014,473 A	1/2000	Hossack et al.	6,387,380 B1	5/2002	Knowlton	
6,016,255 A	1/2000	Bolan et al.	6,390,982 B1	5/2002	Bova et al.	
6,019,724 A	2/2000	Gronningsaeter et al.	6,405,090 B1	6/2002	Knowlton	
6,022,308 A	2/2000	Williams	6,409,720 B1	6/2002	Hissong	
6,022,327 A	2/2000	Chang	6,413,216 B1	7/2002	Cain et al.	
6,030,374 A	2/2000	McDaniel	6,413,253 B1	7/2002	Koop	
6,036,646 A	3/2000	Barthe	6,413,254 B1	7/2002	Hissong	
6,039,048 A	3/2000	Silberg	6,419,648 B1	7/2002	Vitek	
6,039,689 A	3/2000	Lizzi	6,423,007 B2	7/2002	Lizzi et al.	
6,042,556 A *	3/2000	Beach	6,425,865 B1	7/2002	Salcudean	
		A61N 7/02 600/437	6,425,867 B1	7/2002	Vaezy	
6,049,159 A	4/2000	Barthe	6,425,912 B1	7/2002	Knowlton	
6,050,943 A	4/2000	Slayton	6,428,477 B1	8/2002	Mason	
6,059,727 A	5/2000	Fowlkes	6,428,532 B1	8/2002	Doukas	
6,071,239 A	6/2000	Cribbs	6,430,446 B1	8/2002	Knowlton	
6,080,108 A	6/2000	Dunham	6,432,057 B1	8/2002	Mazess et al.	
6,083,148 A	7/2000	Williams	6,432,067 B1	8/2002	Martin	
6,086,535 A	7/2000	Ishibashi	6,432,101 B1	8/2002	Weber	
6,086,580 A	7/2000	Mordon et al.	6,436,061 B1	8/2002	Costantino	
6,090,054 A	7/2000	Tagishi	6,438,424 B1	8/2002	Knowlton	
6,093,148 A *	7/2000	Fujimoto	6,440,071 B1	8/2002	Slayton	
		A61N 7/00 600/438	6,440,121 B1	8/2002	Weber	
6,093,883 A	7/2000	Sanghvi	6,443,914 B1	9/2002	Costantino	
6,101,407 A	8/2000	Groezinger	6,447,443 B1	9/2002	Keogh et al.	
6,106,469 A	8/2000	Suzuki et al.	6,451,013 B1	9/2002	Bays et al.	
6,113,558 A	9/2000	Rosenchein	6,453,202 B1	9/2002	Knowlton	
6,113,559 A	9/2000	Klopotek	6,461,304 B1	10/2002	Tanaka et al.	
6,120,452 A	9/2000	Barthe	6,461,378 B1	10/2002	Knowlton	
6,123,081 A	9/2000	Durette	6,470,216 B1	10/2002	Knowlton	
6,126,619 A	10/2000	Peterson et al.	6,488,626 B1	12/2002	Lizzi	
6,135,971 A	10/2000	Hutchinson	6,491,657 B2	12/2002	Rowe	
6,139,499 A	10/2000	Wilk	6,500,121 B1	12/2002	Slayton	
6,159,150 A	12/2000	Yale et al.	6,500,141 B1	12/2002	Irion	
6,171,244 B1	1/2001	Finger et al.	6,506,171 B1	1/2003	Vitek et al.	
6,176,840 B1	1/2001	Nishimura	6,508,774 B1	1/2003	Acker	
6,183,426 B1	2/2001	Akisada	6,511,427 B1	1/2003	Sliwa, Jr. et al.	
6,183,502 B1	2/2001	Takeuchi	6,511,428 B1	1/2003	Azuma	
6,183,773 B1	2/2001	Anderson	6,514,244 B2	2/2003	Pope	
6,190,323 B1	2/2001	Dias	6,517,484 B1	2/2003	Wilk	
6,190,336 B1	2/2001	Duarte	6,524,250 B1	2/2003	Weber	
6,193,658 B1	2/2001	Wendelken	6,540,679 B2	4/2003	Slayton	
6,210,327 B1	4/2001	Brackett et al.	6,540,685 B1	4/2003	Rhoads et al.	
6,213,948 B1	4/2001	Barthe	6,540,700 B1	4/2003	Fujimoto et al.	
6,216,029 B1	4/2001	Paltieli	6,547,788 B1	4/2003	Maguire et al.	
6,233,476 B1	5/2001	Strommer et al.	6,554,771 B1	4/2003	Buil et al.	
6,234,990 B1	5/2001	Rowe et al.	6,569,099 B1	5/2003	Babaev	

(56)

References Cited

U.S. PATENT DOCUMENTS

6,569,108 B2	5/2003	Sarvazyan et al.	7,235,592 B2	6/2007	Muratoglu
6,572,552 B2	6/2003	Fukukita	7,258,674 B2	8/2007	Cribbs
6,575,956 B1	6/2003	Brisken et al.	7,273,459 B2	9/2007	Desilets
6,595,934 B1	7/2003	Hissong	7,294,125 B2	11/2007	Phalen et al.
6,599,256 B1	7/2003	Acker	7,297,117 B2	11/2007	Trucco
6,605,080 B1	8/2003	Altshuler et al.	7,303,555 B2	12/2007	Makin et al.
6,607,498 B2	8/2003	Eshel	7,311,679 B2	12/2007	Desilets et al.
6,618,620 B1	9/2003	Freundlich et al.	7,327,071 B2	2/2008	Nishiyama et al.
6,623,430 B1	9/2003	Slayton	7,331,951 B2	2/2008	Eshel et al.
6,626,854 B2	9/2003	Friedman	7,332,985 B2	2/2008	Larson et al.
6,626,855 B1	9/2003	Weng	7,338,434 B1	3/2008	Haarstad et al.
6,638,226 B2	10/2003	He et al.	7,347,855 B2	3/2008	Eshel
6,645,150 B2	11/2003	Angelsen et al.	RE40,403 E	6/2008	Cho et al.
6,645,162 B2	11/2003	Friedman	7,393,325 B2	7/2008	Barthe
6,662,054 B2	12/2003	Kreindel	7,398,116 B2	7/2008	Edwards
6,663,627 B2	12/2003	Francischelli	7,399,279 B2	7/2008	Abend et al.
6,665,806 B1	12/2003	Shimizu	7,491,171 B2	2/2009	Barthe et al.
6,666,835 B2	12/2003	Martin	7,507,235 B2	3/2009	Keogh et al.
6,669,638 B1	12/2003	Miller	7,510,536 B2	3/2009	Foley et al.
6,685,639 B1	2/2004	Wang et al.	7,517,315 B2	4/2009	Willis
6,685,640 B1	2/2004	Fry	7,530,356 B2	5/2009	Slayton
6,692,450 B1	2/2004	Coleman	7,530,958 B2	5/2009	Slayton
6,699,237 B2	3/2004	Weber	7,532,201 B2	5/2009	Quistgaard et al.
6,716,184 B2	4/2004	Vaezy et al.	7,571,336 B2	8/2009	Barthe
6,719,449 B1	4/2004	Laugharn, Jr. et al.	7,601,120 B2	10/2009	Moilanen et al.
6,719,694 B2	4/2004	Weng	7,615,015 B2	11/2009	Coleman
6,726,627 B1	4/2004	Lizzi et al.	7,615,016 B2	11/2009	Barthe
6,733,449 B1	5/2004	Krishnamurthy et al.	7,652,411 B2	1/2010	Crunkilton et al.
6,749,624 B2	6/2004	Knowlton	7,662,114 B2	2/2010	Seip et al.
6,772,490 B2	8/2004	Toda	7,674,257 B2	3/2010	Pless et al.
6,773,409 B2	8/2004	Truckai et al.	7,686,763 B2	3/2010	Vaezy et al.
6,775,404 B1	8/2004	Pagoulatos et al.	7,694,406 B2	4/2010	Wildes et al.
6,790,187 B2	9/2004	Thompson et al.	7,695,437 B2	4/2010	Quistgaard et al.
6,824,516 B2	11/2004	Batten et al.	7,713,203 B2	5/2010	Lacoste et al.
6,835,940 B2	12/2004	Morikawa et al.	7,727,156 B2	6/2010	Angelsen et al.
6,846,290 B2	1/2005	Lizzi et al.	7,758,524 B2	7/2010	Barthe
6,875,176 B2	4/2005	Mourad	7,766,848 B2	8/2010	Desilets et al.
6,882,884 B1	4/2005	Mosk et al.	7,789,841 B2	9/2010	Huckle et al.
6,887,239 B2	5/2005	Elstrom	7,806,839 B2	10/2010	Mast et al.
6,889,089 B2	5/2005	Behl	7,815,570 B2	10/2010	Eshel et al.
6,896,657 B2	5/2005	Willis	7,819,826 B2	10/2010	Diederich et al.
6,902,536 B2	6/2005	Manna	7,824,348 B2	11/2010	Barthe
6,905,466 B2	6/2005	Salgo	7,828,734 B2	11/2010	Azhari et al.
6,918,907 B2	7/2005	Kelly	7,833,162 B2	11/2010	Hasegawa et al.
6,920,883 B2	7/2005	Besette	7,841,984 B2	11/2010	Cribbs et al.
6,921,371 B2	7/2005	Wilson	7,846,096 B2	12/2010	Mast et al.
6,932,771 B2	8/2005	Whitmore	7,857,773 B2	12/2010	Desilets et al.
6,932,814 B2	8/2005	Wood	7,875,023 B2	1/2011	Eshel et al.
6,936,044 B2	8/2005	McDaniel	7,901,359 B2	3/2011	Mandrusov et al.
6,936,046 B2	8/2005	Hissong	7,905,007 B2	3/2011	Calisti et al.
6,945,937 B2	9/2005	Culp et al.	7,905,844 B2	3/2011	Desilets et al.
6,948,843 B2	9/2005	Laugharn et al.	7,914,453 B2	3/2011	Slayton et al.
6,953,941 B2	10/2005	Nakano et al.	7,914,469 B2	3/2011	Torbati
6,958,043 B2	10/2005	Hissong	7,931,611 B2	4/2011	Novak et al.
6,971,994 B1	12/2005	Young et al.	7,955,262 B2	6/2011	Rosenberg
6,974,417 B2	12/2005	Lockwood	7,955,281 B2	6/2011	Pedersen et al.
6,976,492 B2	12/2005	Ingle	7,967,764 B2	6/2011	Lidgren et al.
6,992,305 B2	1/2006	Maezawa et al.	7,967,839 B2	6/2011	Flock et al.
6,997,923 B2	2/2006	Anderson	7,993,289 B2	8/2011	Quistgaard et al.
7,006,874 B2	2/2006	Knowlton	8,057,389 B2	11/2011	Barthe et al.
7,020,528 B2	3/2006	Neev	8,057,465 B2	11/2011	Sliwa, Jr. et al.
7,022,089 B2	4/2006	Ooba	8,066,641 B2	11/2011	Barthe et al.
7,058,440 B2	6/2006	Heuscher et al.	8,123,707 B2	2/2012	Huckle et al.
7,063,666 B2	6/2006	Weng	8,128,618 B2	3/2012	Gliklich et al.
7,070,565 B2	7/2006	Vaezy et al.	8,133,180 B2	3/2012	Slayton et al.
7,074,218 B2	7/2006	Washington et al.	8,133,191 B2	3/2012	Rosenberg et al.
7,094,252 B2	8/2006	Koop	8,142,200 B2	3/2012	Crunkilton et al.
7,108,663 B2	9/2006	Talish et al.	8,152,904 B2	4/2012	Slobodgian et al.
7,115,123 B2	10/2006	Knowlton	8,162,858 B2	4/2012	Manna et al.
7,122,029 B2	10/2006	Koop et al.	8,166,332 B2	4/2012	Barthe et al.
7,142,905 B2	11/2006	Slayton	8,182,428 B2	5/2012	Angelsen et al.
7,165,451 B1	1/2007	Brooks et al.	8,197,409 B2	6/2012	Foley et al.
7,179,238 B2	2/2007	Hissong	8,206,299 B2	6/2012	Foley et al.
7,189,230 B2	3/2007	Knowlton	8,208,346 B2	6/2012	Crunkilton
7,229,411 B2	6/2007	Slayton	8,211,017 B2	7/2012	Foley et al.
			8,262,591 B2	9/2012	Pedersen et al.
			8,262,650 B2	9/2012	Zanelli et al.
			8,264,126 B2	9/2012	Toda et al.
			8,273,037 B2	9/2012	Kreindel et al.

(56)

References Cited

U.S. PATENT DOCUMENTS

8,282,554 B2	10/2012	Makin et al.	2002/0002345 A1	1/2002	Marlinghaus
8,292,835 B1	10/2012	Cimino	2002/0040199 A1	4/2002	Klopotek
8,298,163 B1	10/2012	Cimino	2002/0040442 A1	4/2002	Ishidera
8,333,700 B1	12/2012	Barthe et al.	2002/0055702 A1	5/2002	Atala
8,334,637 B2	12/2012	Crunkilton et al.	2002/0062077 A1	5/2002	Emmenegger
8,337,407 B2	12/2012	Quistgaard et al.	2002/0062142 A1	5/2002	Knowlton
8,343,051 B2	1/2013	Desilets et al.	2002/0072691 A1	6/2002	Thompson et al.
8,366,622 B2	2/2013	Slayton et al.	2002/0082528 A1	6/2002	Friedman
8,388,535 B2	3/2013	Weng et al.	2002/0082529 A1	6/2002	Suorsa et al.
8,409,097 B2	4/2013	Slayton et al.	2002/0082589 A1	6/2002	Friedman
8,425,435 B2	4/2013	Wing et al.	2002/0087080 A1	7/2002	Slayton
8,444,562 B2	5/2013	Barthe et al.	2002/0095143 A1	7/2002	Key
8,454,540 B2	6/2013	Eshel et al.	2002/0099094 A1	7/2002	Anderson
8,460,193 B2	6/2013	Barthe et al.	2002/0115917 A1	8/2002	Honda et al.
8,480,585 B2	7/2013	Slayton et al.	2002/0128639 A1	9/2002	Pless et al.
8,506,486 B2	8/2013	Slayton et al.	2002/0128648 A1	9/2002	Weber
8,512,250 B2	8/2013	Quistgaard et al.	2002/0143252 A1	10/2002	Dunne et al.
8,523,775 B2	9/2013	Barthe et al.	2002/0156400 A1	10/2002	Babaev
8,535,228 B2	9/2013	Slayton et al.	2002/0161357 A1	10/2002	Anderson
8,570,837 B2	10/2013	Toda et al.	2002/0165529 A1	11/2002	Danek
8,573,392 B2	11/2013	Bennett et al.	2002/0168049 A1	11/2002	Schriever
8,583,211 B2	11/2013	Salomir et al.	2002/0169394 A1	11/2002	Eppstein et al.
8,585,618 B2	11/2013	Hunziker et al.	2002/0169442 A1	11/2002	Neev
8,604,672 B2	12/2013	Toda et al.	2002/0173721 A1	11/2002	Grunwald et al.
8,622,937 B2	1/2014	Weng et al.	2002/0193784 A1	12/2002	McHale et al.
8,636,665 B2	1/2014	Slayton et al.	2002/0193831 A1	12/2002	Smith
8,641,622 B2	2/2014	Barthe et al.	2003/0009153 A1	1/2003	Briskin et al.
8,663,112 B2	3/2014	Slayton et al.	2003/0014039 A1	1/2003	Barzell et al.
8,672,848 B2	3/2014	Slayton et al.	2003/0018255 A1	1/2003	Martin
8,690,778 B2	4/2014	Slayton et al.	2003/0018270 A1	1/2003	Makin et al.
8,690,779 B2	4/2014	Slayton et al.	2003/0023283 A1 *	1/2003	McDaniel A61K 8/02 607/88
8,690,780 B2	4/2014	Slayton et al.	2003/0028111 A1	2/2003	Vaezy et al.
8,708,935 B2	4/2014	Barthe et al.	2003/0028113 A1	2/2003	Gilbert et al.
8,715,186 B2	5/2014	Slayton et al.	2003/0032900 A1	2/2003	Ella
8,726,781 B2	5/2014	Eckhoff et al.	2003/0036706 A1	2/2003	Slayton et al.
8,728,071 B2	5/2014	Lischinsky et al.	2003/0040739 A1	2/2003	Koop
8,753,295 B2	6/2014	Thierman	2003/0050678 A1	3/2003	Sierra
8,758,253 B2	6/2014	Sano et al.	2003/0055417 A1	3/2003	Truckai et al.
8,836,203 B2	9/2014	Nobles et al.	2003/0060736 A1	3/2003	Martin et al.
8,857,438 B2	10/2014	Barthe et al.	2003/0065313 A1	4/2003	Koop
8,858,471 B2	10/2014	Barthe et al.	2003/0066708 A1	4/2003	Allison et al.
8,915,853 B2	12/2014	Barthe et al.	2003/0073907 A1	4/2003	Taylor
8,915,854 B2	12/2014	Slayton et al.	2003/0074023 A1	4/2003	Kaplan
8,915,870 B2	12/2014	Barthe et al.	2003/0083536 A1	5/2003	Eshel
8,920,320 B2	12/2014	Stecco et al.	2003/0092988 A1	5/2003	Makin
8,920,324 B2	12/2014	Slayton et al.	2003/0097071 A1	5/2003	Halmann et al.
8,926,533 B2	1/2015	Bockenstedt et al.	2003/0099383 A1	5/2003	Lefebvre
8,932,224 B2	1/2015	Barthe et al.	2003/0125629 A1	7/2003	Ustuner
8,932,238 B2	1/2015	Weng et al.	2003/0135135 A1	7/2003	Miwa et al.
8,968,205 B2	3/2015	Zeng et al.	2003/0139790 A1	7/2003	Ingle et al.
9,011,336 B2	4/2015	Slayton et al.	2003/0153961 A1	8/2003	Babaev
9,039,617 B2	5/2015	Slayton et al.	2003/0171678 A1	9/2003	Batten et al.
9,039,619 B2	5/2015	Barthe et al.	2003/0171701 A1	9/2003	Babaev
9,095,697 B2	8/2015	Barthe et al.	2003/0176790 A1	9/2003	Slayton
9,114,247 B2	8/2015	Barthe et al.	2003/0191396 A1	10/2003	Sanghi
9,272,162 B2	3/2016	Slayton et al.	2003/0200481 A1	10/2003	Stanley
9,283,409 B2	3/2016	Slayton et al.	2003/0212129 A1	11/2003	Liu et al.
9,283,410 B2	3/2016	Slayton et al.	2003/0212351 A1	11/2003	Hissong
9,320,537 B2	4/2016	Slayton et al.	2003/0212393 A1	11/2003	Knowlton
9,421,029 B2	8/2016	Barthe et al.	2003/0216648 A1	11/2003	Lizzi et al.
9,427,600 B2	8/2016	Barthe et al.	2003/0216795 A1	11/2003	Harth
9,427,601 B2	8/2016	Barthe et al.	2003/0220536 A1	11/2003	Hissong
9,440,096 B2	9/2016	Barthe et al.	2003/0220585 A1	11/2003	Hissong
9,510,802 B2	12/2016	Barthe et al.	2003/0229331 A1	12/2003	Briskin et al.
9,522,290 B2	12/2016	Slayton et al.	2003/0233085 A1	12/2003	Giammarusti
9,533,175 B2	1/2017	Slayton et al.	2003/0236487 A1	12/2003	Knowlton
2001/0009997 A1	7/2001	Pope	2004/0000316 A1	1/2004	Knowlton
2001/0009999 A1	7/2001	Kaufman et al.	2004/0001809 A1	1/2004	Briskin
2001/0014780 A1	8/2001	Martin	2004/0002658 A1	1/2004	Marian, Jr.
2001/0014819 A1	8/2001	Ingle	2004/0002705 A1	1/2004	Knowlton
2001/0031922 A1 *	10/2001	Weng A61B 17/0057 600/439	2004/0010222 A1	1/2004	Nunomura et al.
2001/0039380 A1	11/2001	Larson et al.	2004/0015079 A1	1/2004	Berger et al.
2001/0041880 A1	11/2001	Briskin	2004/0015106 A1	1/2004	Coleman
2002/0000763 A1	1/2002	Jones	2004/0030227 A1	2/2004	Littrup
			2004/0039312 A1	2/2004	Hillstead
			2004/0039418 A1	2/2004	Elstrom
			2004/0041563 A1	3/2004	Lewin et al.
			2004/0041880 A1	3/2004	Ikeda et al.

(56)

References Cited

U.S. PATENT DOCUMENTS

2004/0042168	A1	3/2004	Yang et al.	2006/0074355	A1	4/2006	Slayton
2004/0044375	A1	3/2004	Diederich et al.	2006/0079816	A1	4/2006	Barthe
2004/0049134	A1	3/2004	Tosaya et al.	2006/0079868	A1	4/2006	Makin
2004/0059266	A1	3/2004	Fry	2006/0084891	A1	4/2006	Barthe
2004/0068186	A1	4/2004	Ishida et al.	2006/0089632	A1	4/2006	Barthe
2004/0073079	A1	4/2004	Altshuler et al.	2006/0089688	A1	4/2006	Panescu
2004/0073113	A1	4/2004	Salgo	2006/0094988	A1	5/2006	Tosaya
2004/0073115	A1	4/2004	Horzowski et al.	2006/0111744	A1	5/2006	Makin
2004/0073116	A1	4/2004	Smith	2006/0116583	A1	6/2006	Ogasawara et al.
2004/0073204	A1	4/2004	Ryan et al.	2006/0116671	A1	6/2006	Slayton
2004/0077977	A1	4/2004	Ella et al.	2006/0122508	A1	6/2006	Slayton
2004/0082857	A1	4/2004	Schonenberger	2006/0122509	A1	6/2006	Desilets
2004/0082859	A1	4/2004	Schaer	2006/0161062	A1	7/2006	Arditi et al.
2004/0102697	A1	5/2004	Evron	2006/0184069	A1	8/2006	Vaitekunas
2004/0105559	A1	6/2004	Aylward et al.	2006/0184071	A1	8/2006	Klopotek
2004/0106867	A1	6/2004	Eshel et al.	2006/0189972	A1	8/2006	Grossman
2004/0122323	A1	6/2004	Vortman et al.	2006/0206105	A1	9/2006	Chopra
2004/0122493	A1	6/2004	Ishibashi et al.	2006/0224090	A1	10/2006	Ostrovsky et al.
2004/0143297	A1	7/2004	Ramsey	2006/0229514	A1	10/2006	Wiener
2004/0152982	A1	8/2004	Hwang et al.	2006/0241440	A1	10/2006	Eshel
2004/0158150	A1	8/2004	Rabiner et al.	2006/0241442	A1	10/2006	Barthe
2004/0186535	A1	9/2004	Knowlton	2006/0241470	A1	10/2006	Novak et al.
2004/0189155	A1	9/2004	Funakubo	2006/0241576	A1	10/2006	Diederich et al.
2004/0206365	A1	10/2004	Knowlton	2006/0250046	A1	11/2006	Koizumi et al.
2004/0210214	A1	10/2004	Knowlton	2006/0282691	A1	12/2006	Barthe
2004/0217675	A1	11/2004	Desilets	2006/0291710	A1	12/2006	Wang et al.
2004/0249318	A1	12/2004	Tanaka	2007/0032784	A1	2/2007	Gliklich et al.
2004/0254620	A1	12/2004	Lacoste	2007/0035201	A1	2/2007	Desilets
2004/0267252	A1	12/2004	Washington et al.	2007/0055154	A1	3/2007	Torbati
2005/0033201	A1	2/2005	Takahashi	2007/0055155	A1	3/2007	Owen et al.
2005/0033316	A1	2/2005	Kertz	2007/0055156	A1	3/2007	Desilets et al.
2005/0038340	A1	2/2005	Vaezy et al.	2007/0065420	A1	3/2007	Johnson
2005/0055018	A1	3/2005	Kreindel	2007/0083120	A1	4/2007	Cain et al.
2005/0055073	A1	3/2005	Weber	2007/0087060	A1	4/2007	Dietrich
2005/0061834	A1	3/2005	Garcia et al.	2007/0088245	A1	4/2007	Babaev et al.
2005/0070961	A1	3/2005	Maki	2007/0088346	A1	4/2007	Mirizzi et al.
2005/0074407	A1	4/2005	Smith	2007/0161902	A1	7/2007	Dan
2005/0080469	A1	4/2005	Larson	2007/0166357	A1	7/2007	Shaffer et al.
2005/0091770	A1	5/2005	Mourad et al.	2007/0167709	A1	7/2007	Slayton
2005/0096542	A1	5/2005	Weng et al.	2007/0208253	A1	9/2007	Slayton
2005/0104690	A1	5/2005	Larson et al.	2007/0219604	A1	9/2007	Yaroslavsky et al.
2005/0113689	A1	5/2005	Gritzky	2007/0219605	A1	9/2007	Yaroslavsky et al.
2005/0131302	A1	6/2005	Poland	2007/0238994	A1	10/2007	Stecco et al.
2005/0137656	A1	6/2005	Malak	2007/0239075	A1	10/2007	Rosenberg
2005/0143677	A1	6/2005	Young et al.	2007/0239077	A1	10/2007	Azhari et al.
2005/0154313	A1	7/2005	Desilets	2007/0239079	A1	10/2007	Manstein et al.
2005/0154314	A1	7/2005	Quistgaard	2007/0239142	A1	10/2007	Altshuler
2005/0154332	A1	7/2005	Zanelli	2008/0015435	A1	1/2008	Cribbs et al.
2005/0154431	A1	7/2005	Quistgaard	2008/0027328	A1	1/2008	Klopotek
2005/0187495	A1	8/2005	Quistgaard	2008/0039724	A1	2/2008	Seip et al.
2005/0191252	A1	9/2005	Mitsui	2008/0071255	A1	3/2008	Barthe
2005/0193451	A1	9/2005	Quistgaard	2008/0086054	A1	4/2008	Slayton
2005/0193820	A1	9/2005	Sheljaskow et al.	2008/0086056	A1	4/2008	Chang et al.
2005/0197681	A1	9/2005	Barolet et al.	2008/0097214	A1	4/2008	Meyers et al.
2005/0228281	A1	10/2005	Nefos	2008/0097253	A1	4/2008	Pedersen et al.
2005/0240127	A1	10/2005	Seip et al.	2008/0114251	A1	5/2008	Weymer et al.
2005/0240170	A1	10/2005	Zhang et al.	2008/0139974	A1	6/2008	Da Silva
2005/0251120	A1	11/2005	Anderson et al.	2008/0146970	A1	6/2008	Litman et al.
2005/0251125	A1	11/2005	Pless et al.	2008/0167556	A1	7/2008	Thompson
2005/0256406	A1	11/2005	Barthe	2008/0183077	A1	7/2008	Moreau-Gobard et al.
2005/0261584	A1	11/2005	Eshel	2008/0183110	A1	7/2008	Davenport et al.
2005/0261585	A1	11/2005	Makin et al.	2008/0188745	A1	8/2008	Chen et al.
2005/0267454	A1	12/2005	Hissong	2008/0194964	A1	8/2008	Randall et al.
2005/0288748	A1	12/2005	Li et al.	2008/0195000	A1	8/2008	Spooner et al.
2006/0004306	A1	1/2006	Altshuler	2008/0200810	A1	8/2008	Buchalter
2006/0020260	A1	1/2006	Dover et al.	2008/0200813	A1	8/2008	Quistgaard
2006/0025756	A1	2/2006	Francischelli	2008/0214966	A1	9/2008	Slayton
2006/0042201	A1	3/2006	Curry	2008/0221491	A1	9/2008	Slayton
2006/0058664	A1	3/2006	Barthe	2008/0223379	A1	9/2008	Stuker et al.
2006/0058671	A1	3/2006	Vitek et al.	2008/0242991	A1	10/2008	Moon et al.
2006/0058707	A1	3/2006	Barthe	2008/0243035	A1	10/2008	Crunkilton
2006/0058712	A1	3/2006	Altshuler et al.	2008/0269608	A1	10/2008	Anderson et al.
2006/0074309	A1	4/2006	Bonnefous	2008/0275342	A1	11/2008	Barthe
2006/0074313	A1	4/2006	Slayton et al.	2008/0281206	A1	11/2008	Bartlett et al.
2006/0074314	A1	4/2006	Slayton	2008/0281236	A1	11/2008	Eshel et al.
				2008/0281237	A1	11/2008	Slayton
				2008/0281255	A1	11/2008	Slayton
				2008/0294073	A1	11/2008	Barthe
				2008/0319356	A1	12/2008	Cain

(56)

References Cited

U.S. PATENT DOCUMENTS

2009/0005680 A1	1/2009	Jones et al.	2012/0165848 A1	6/2012	Slayton et al.
2009/0012394 A1	1/2009	Hobelsberger et al.	2012/0191020 A1	7/2012	Vitek et al.
2009/0043198 A1	2/2009	Milner et al.	2012/0197120 A1	8/2012	Makin et al.
2009/0043293 A1	2/2009	Pankratov et al.	2012/0197121 A1	8/2012	Slayton et al.
2009/0048514 A1	2/2009	Azhari et al.	2012/0209150 A1	8/2012	Zeng et al.
2009/0069677 A1	3/2009	Chen et al.	2012/0215105 A1	8/2012	Slayton et al.
2009/0093737 A1	4/2009	Chomas et al.	2012/0271202 A1	10/2012	Wisdom
2009/0156969 A1	6/2009	Santangelo	2012/0271294 A1	10/2012	Barthe et al.
2009/0163807 A1	6/2009	Sliwa	2012/0296240 A1	11/2012	Azhari et al.
2009/0171252 A1	7/2009	Bockenstedt et al.	2012/0302883 A1	11/2012	Kong et al.
2009/0177122 A1	7/2009	Peterson	2012/0316426 A1	12/2012	Foley et al.
2009/0177123 A1	7/2009	Peterson	2012/0330197 A1	12/2012	Makin et al.
2009/0182231 A1	7/2009	Barthe et al.	2012/0330222 A1	12/2012	Makin et al.
2009/0198157 A1	8/2009	Babaev et al.	2012/0330223 A1	12/2012	Makin et al.
2009/0216159 A1	8/2009	Slayton et al.	2012/0330283 A1	12/2012	Hyde et al.
2009/0226424 A1	9/2009	Hsu	2012/0330284 A1	12/2012	Hyde et al.
2009/0227910 A1	9/2009	Pedersen et al.	2013/0012755 A1	1/2013	Slayton
2009/0230823 A1	9/2009	Kushculey et al.	2013/0012816 A1	1/2013	Slayton et al.
2009/0253988 A1	10/2009	Slayton et al.	2013/0012838 A1	1/2013	Jaeger et al.
2009/0281463 A1	11/2009	Chapelon et al.	2013/0012842 A1	1/2013	Barthe
2009/0312693 A1	12/2009	Thapliyal et al.	2013/0018285 A1	1/2013	Park et al.
2009/0318909 A1	12/2009	Debenedictis et al.	2013/0018286 A1	1/2013	Slayton et al.
2009/0326420 A1	12/2009	Moonen et al.	2013/0046209 A1	2/2013	Slayton et al.
2010/0011236 A1	1/2010	Barthe et al.	2013/0051178 A1	2/2013	Rybyanets
2010/0022919 A1	1/2010	Peterson	2013/0060170 A1	3/2013	Lee et al.
2010/0022921 A1	1/2010	Seip et al.	2013/0066208 A1	3/2013	Barthe et al.
2010/0022922 A1	1/2010	Barthe et al.	2013/0066237 A1	3/2013	Smotrich et al.
2010/0030076 A1	2/2010	Vortman et al.	2013/0072826 A1	3/2013	Slayton et al.
2010/0042020 A1	2/2010	Ben-Ezra	2013/0096471 A1	4/2013	Slayton et al.
2010/0049178 A1	2/2010	Deem et al.	2013/0190659 A1	7/2013	Slayton et al.
2010/0056925 A1	3/2010	Zhang et al.	2013/0211293 A1	8/2013	Auboiroux et al.
2010/0100014 A1	4/2010	Eshel et al.	2013/0225994 A1	8/2013	Hsu et al.
2010/0113983 A1	5/2010	Heckerman et al.	2013/0268032 A1	10/2013	Neev
2010/0130891 A1	5/2010	Taggart et al.	2013/0274603 A1	10/2013	Barthe et al.
2010/0160782 A1	6/2010	Slayton et al.	2013/0281853 A1	10/2013	Slayton et al.
2010/0160837 A1	6/2010	Hunziker et al.	2013/0281891 A1	10/2013	Slayton et al.
2010/0168576 A1	7/2010	Poland et al.	2013/0296697 A1	11/2013	Slayton et al.
2010/0191120 A1	7/2010	Kraus et al.	2013/0296700 A1	11/2013	Slayton et al.
2010/0241035 A1	9/2010	Barthe et al.	2013/0303904 A1	11/2013	Barthe et al.
2010/0249602 A1	9/2010	Buckley et al.	2013/0303905 A1	11/2013	Barthe et al.
2010/0249669 A1	9/2010	Ulric et al.	2013/0310714 A1	11/2013	Eshel et al.
2010/0256489 A1	10/2010	Pedersen et al.	2013/0310863 A1	11/2013	Makin et al.
2010/0274161 A1	10/2010	Azhari et al.	2013/0345562 A1	12/2013	Barthe et al.
2010/0280420 A1	11/2010	Barthe et al.	2014/0024974 A1	1/2014	Slayton et al.
2010/0286518 A1	11/2010	Lee et al.	2014/0050054 A1	2/2014	Toda et al.
2010/0312150 A1	12/2010	Mast et al.	2014/0081300 A1	3/2014	Melodelima et al.
2011/0040171 A1	2/2011	Foley et al.	2014/0082907 A1	3/2014	Barthe et al.
2011/0040190 A1	2/2011	Jahnke et al.	2014/0117814 A1	5/2014	Toda et al.
2011/0066084 A1	3/2011	Desilets et al.	2014/0142430 A1	5/2014	Slayton et al.
2011/0087099 A1	4/2011	Eshel et al.	2014/0148834 A1	5/2014	Barthe et al.
2011/0087255 A1	4/2011	McCormack et al.	2014/0180174 A1	6/2014	Slayton et al.
2011/0112405 A1	5/2011	Barthe et al.	2014/0187944 A1	7/2014	Slayton et al.
2011/0144490 A1	6/2011	Davis et al.	2014/0188015 A1	7/2014	Slayton et al.
2011/0178444 A1	7/2011	Slayton et al.	2014/0188145 A1	7/2014	Slayton et al.
2011/0178541 A1	7/2011	Azhari	2014/0194723 A1	7/2014	Herzog et al.
2011/0190745 A1	8/2011	Uebelhoer et al.	2014/0208856 A1	7/2014	Schmid
2011/0251524 A1	10/2011	Azhari et al.	2014/0221823 A1	8/2014	Keogh et al.
2011/0251527 A1	10/2011	Kushculey et al.	2014/0236049 A1	8/2014	Barthe et al.
2011/0270137 A1	11/2011	Goren et al.	2014/0236061 A1	8/2014	Lee et al.
2011/0319793 A1	12/2011	Hynnen	2014/0243713 A1	8/2014	Slayton et al.
2012/0004549 A1	1/2012	Barthe et al.	2014/0257145 A1	9/2014	Emery
2012/0016239 A1	1/2012	Barthe et al.	2014/0276055 A1	9/2014	Barthe et al.
2012/0029353 A1	2/2012	Slayton et al.	2015/0000674 A1	1/2015	Barthe et al.
2012/0035473 A1	2/2012	Sanghvi et al.	2015/0080723 A1	3/2015	Barthe et al.
2012/0035475 A1	2/2012	Barthe et al.	2015/0080771 A1	3/2015	Barthe et al.
2012/0035476 A1	2/2012	Barthe et al.	2015/0080874 A1	3/2015	Slayton et al.
2012/0046547 A1	2/2012	Barthe et al.	2015/0088182 A1	3/2015	Slayton et al.
2012/0053458 A1	3/2012	Barthe et al.	2015/0164734 A1	6/2015	Slayton et al.
2012/0111339 A1	5/2012	Barthe et al.	2015/0165238 A1	6/2015	Slayton et al.
2012/0123304 A1	5/2012	Rybyanets et al.	2015/0165243 A1	6/2015	Slayton et al.
2012/0136280 A1	5/2012	Rosenberg et al.	2015/0174388 A1	6/2015	Slayton
2012/0136282 A1	5/2012	Rosenberg et al.	2015/0202468 A1	7/2015	Slayton et al.
2012/0143056 A1	6/2012	Slayton et al.	2015/0217141 A1	8/2015	Barthe et al.
2012/0143100 A1	6/2012	Jeong et al.	2015/0360058 A1	12/2015	Barthe et al.
2012/0165668 A1	6/2012	Slayton et al.	2015/0374333 A1	12/2015	Barthe et al.
			2015/0375014 A1	12/2015	Slayton et al.
			2016/0027994 A1	1/2016	Toda et al.
			2016/0175619 A1	6/2016	Lee et al.
			2016/0206335 A1	7/2016	Slayton

(56)

References Cited

U.S. PATENT DOCUMENTS

2016/0206341 A1 7/2016 Slayton
 2016/0256675 A1 9/2016 Slayton
 2016/0296769 A1 10/2016 Barthe et al.

FOREIGN PATENT DOCUMENTS

DE 10140064 3/2003
 DE 10219297 11/2003
 DE 10219217 12/2004
 DE 20314479 12/2004
 EP 0142215 5/1984
 EP 0344773 12/1989
 EP 1479412 11/1991
 EP 0473553 4/1992
 EP 670147 2/1995
 EP 0661029 7/1995
 EP 724894 2/1996
 EP 763371 11/1996
 EP 1044038 10/2000
 EP 1050322 11/2000
 EP 1234566 8/2002
 EP 1262160 12/2002
 EP 1283690 2/2003
 EP 0659387 4/2003
 EP 1374944 1/2004
 EP 1028660 1/2008
 EP 1874241 1/2008
 EP 1362223 5/2008
 EP 1750804 7/2008
 EP 1811901 4/2009
 EP 1785164 8/2009
 EP 2230904 9/2010
 EP 1501331 6/2011
 EP 2066405 11/2011
 EP 2474050 7/2012
 FR 2532851 9/1983
 FR 2685872 1/1992
 FR 2672486 8/1992
 FR 2703254 3/1994
 GB 2113099 8/1983
 IL 102516 1/1996
 IL 112369 8/1999
 IL 120079 3/2001
 JP 63036171 2/1988
 JP 03048299 3/1991
 JP 3123559 5/1991
 JP 03136642 6/1991
 JP 4089058 3/1992
 JP 04150847 5/1992
 JP 7080087 3/1995
 JP 07505793 6/1995
 JP 7184907 7/1995
 JP 7222782 8/1995
 JP 09047458 2/1997
 JP 9108288 4/1997
 JP 9503926 4/1997
 JP 11123226 5/1999
 JP 11505440 5/1999
 JP 11506636 6/1999
 JP 10248850 9/1999
 JP 2000126310 5/2000
 JP 2000166940 6/2000
 JP 2000233009 8/2000
 JP 2001170068 6/2001
 JP 2002505596 2/2002
 JP 2002078764 3/2002
 JP 2002515786 5/2002
 JP 2002521118 7/2002
 JP 2002537939 11/2002
 JP 2003050298 7/2003
 JP 2003204982 7/2003
 JP 2004-507280 3/2004
 JP 2004-509671 4/2004
 JP 2004-512856 4/2004
 JP 2004147719 5/2004

JP 2005503388 2/2005
 JP 2005527336 9/2005
 JP 2005323213 11/2005
 JP 2006520247 9/2006
 JP 2008515559 5/2008
 JP 2009518126 5/2009
 JP 2010517695 5/2010
 KR 1020010024871 3/2001
 KR 100400870 10/2003
 KR 1020060113930 11/2006
 KR 1020070065332 6/2007
 KR 1020070070161 7/2007
 KR 1020070098856 10/2007
 KR 1020070104878 10/2007
 KR 1020070114105 11/2007
 KR 1020000059516 4/2012
 WO WO9312742 7/1993
 WO WO9524159 9/1995
 WO WO9625888 8/1996
 WO WO9634568 11/1996
 WO WO9639079 12/1996
 WO WO9735518 10/1997
 WO WO9832379 7/1998
 WO WO9852465 11/1998
 WO WO9933520 7/1999
 WO WO9949788 10/1999
 WO WO0006032 2/2000
 WO WO0015300 3/2000
 WO WO0021612 4/2000
 WO WO0053113 9/2000
 WO WO0128623 4/2001
 WO WO0145550 6/2001
 WO WO0180709 11/2001
 WO WO0182777 11/2001
 WO WO0182778 11/2001
 WO WO0187161 11/2001
 WO WO0209813 2/2002
 WO WO0215768 2/2002
 WO WO0224050 3/2002
 WO WO02092168 11/2002
 WO WO03053266 7/2003
 WO WO03065347 8/2003
 WO WO03070105 8/2003
 WO WO02054018 9/2003
 WO WO03077833 9/2003
 WO WO03086215 10/2003
 WO WO03096883 11/2003
 WO WO03099177 12/2003
 WO WO03099382 12/2003
 WO WO03101530 12/2003
 WO WO04000116 12/2003
 WO WO2004080147 9/2004
 WO WO2004110558 12/2004
 WO WO2005/011804 2/2005
 WO WO2005065408 7/2005
 WO WO2005090978 9/2005
 WO WO2005113068 12/2005
 WO WO2006/042163 4/2006
 WO WO2006036870 4/2006
 WO WO2006042168 4/2006
 WO WO2006042201 4/2006
 WO WO2006065671 6/2006
 WO WO2006082573 8/2006
 WO WO 2006104568 10/2006
 WO WO2007067563 6/2007
 WO WO2008036622 3/2008
 WO WO2008036479 11/2008
 WO WO2009013729 1/2009
 WO WO2009149390 10/2009
 WO WO2008144274 1/2010
 WO WO2012134645 1/2013
 WO WO2014045216 3/2014

(56)

References Cited

FOREIGN PATENT DOCUMENTS

WO	WO2014055708	4/2014
WO	WO2014057388	4/2014

OTHER PUBLICATIONS

Arthur et al., "Non-invasive estimation of hyperthermia temperatures with ultrasound," *Int. J. Hyperthermia*, Sep. 2005, 21(6), pp. 589-600.

Barthe et al., "Ultrasound therapy system and ablation results utilizing miniature imaging/therapy arrays," *Ultrasonics Symposium*, 2004 IEEE, Aug. 23, 2004, pp. 1792-1795, vol. 3.

Bozec, Laurent et al., *Thermal Denaturation Studies of Collagen by Microthermal Analysis and Atomic Force Microscopy*, *Biophysical Journal*, vol. 101, pp. 228-236, (Jul. 2001).

Calderhead et al., "One Mechanism Behind LED Photo-Therapy for Wound Healing and Skin Rejuvenation: Key Role of the Mast Cell" *Laser Therapy* 17.3: 141-148 (2008).

Chen, L. et al., "Effect of Blood Perfusion on the ablation of liver parenchyma with high intensity focused ultrasound," *Phys. Med. Biol.* 38:1661-1673; 1993b.

Coon, Joshua et al., "Protein identification using sequential ion/ion reactions and tandem mass spectrometry" *Proceedings of the National Academy of Sciences of the USA*, vol. 102, No. 27, Jul. 27, 2005, pp. 9463-9468.

Corry, Peter M., et al., "Human Cancer Treatment with Ultrasound", *IEEE Transactions on Sonics and Ultrasonics*, vol. SU-31, No. 5, Sep. 1984, pp. 444, 456.

Damianou et al., "Application of the Thermal Dose Concept for Predicting the Necrosed Tissue Volume During Ultrasound Surgery," 1993 IEEE Ultrasound Symposium, pp. 1199-1202.

Daum et al., *Design and Evaluation of a Feedback Based Phased Array System for Ultrasound Surgery*, *IEEE Transactions on Ultrasonics, Ferroelectrics, and Frequency Control*, vol. 45, No. 2, Mar. 1998, pp. 431-438.

Davis, Brian J., et al., "An Acoustic Phase Shift Technique for the Non-Invasive Measurement of Temperature Changes in Tissues", 1985 Ultrasonics Symposium, pp. 921-924.

Decision of the Korean Intellectual Property Tribunal dated Jun. 28, 2013 regarding Korean Patent No. 10-1142108 (English translation, English translation certification, and Korean decision included).

Dierickx, Christine C., "The Role of Deep Heating for Noninvasive Skin Rejuvenation" *Lasers in Surgery and Medicine* 38:799-807 (2006).

Dong, Yuan-Lin et al., "Effect of Ibuprofen on the Inflammatory Response To Surgical Wounds" *The Journal of Trauma*, vol. 35, No. 3, (1993).

Dvivedi, Sanjay, et al. "Effect of Ibuprofen and diclofenac sodium on experimental wound healing" *Indian Journal of Experimental Biology*, vol. 35, pp. 1243-1245, (Nov. 1997).

Fry, W.J. et al., "Production of Focal Destructive Lesions in the Central Nervous System with Ultrasound," *J. Neurosurg.*, 11:471-478; 1954.

Gliklich et al., *Clinical Pilot Study of Intense Ultrasound therapy to Deep Dermal Facial Skin and Subcutaneous Tissues*, *Arch Facial Plastic Surgery*, Mar. 1, 2007, vol. 9, No. 1.

Greenhalgh, David G., "Wound healing and diabetes mellitus" *Clinics in Plastic Surgery* 30; 37-45, (2003).

Guo, S. et al., "Factors Affecting Wound Healing" *Critical Reviews in Oral Biology & Medicine*, *J Dent Res* 89(3), pp. 219-229, (2010).

Haar, G.R. et al., "Tissue Destruction with Focused Ultrasound in Vivo," *Eur. Urol.* 23 (suppl. 1):8-11; 1993.

Hantash, Basil M. et al., "Bipolar Fractional Radiofrequency Treatment Induces Neocollagenesis and Neocollagenesis" *Lasers in Surgery and Medicine* 41:1-9 (2009).

Hantash, Basil M. et al., "In Vivo Histological Evaluation of a Novel Ablative Fractional Resurfacing Device" *Lasers in Surgery and Medicine* 39:96-107 (2007).

Hassan et al., "Structure and Applications of Poly(vinyl alcohol) Hydrogels Produced by Conventional Crosslinking or by Freezing/Thawing Methods," *advanced in Polymer Science*, 2000, pp. 37-65, vol. 153.

Hassan et al., "Structure and Morphology of Freeze/Thawed PVA Hydrogels," *Macromolecules*, Mar. 11, 2000, pp. 2472-2479, vol. 33, No. 7.

Husseini et al., "The Role of Cavitation in Acoustically Activated Drug Delivery," *J. Control Release*, Oct. 3, 2005, pp. 253-261, vol. 107(2).

Husseini et al. "Investigating the mechanism of acoustically activated uptake of drugs from Pluronic micelles," *BMD Cancer* 2002, 2:20k, Aug. 30, 2002, pp. 1-6.

Jeffers et al., "Evaluation of the Effect of Cavitation Activity on Drug-Ultrasound Synergisms," 1993 IEEE Ultrasonics Symposium, pp. 925-928.

Jenne, J., et al., "Temperature Mapping for High Energy US-Therapy", 1994 Ultrasonics Symposium, pp. 1879-1882.

Johnson, S.A., et al., "Non-Intrusive Measurement of Microwave and Ultrasound-Induced Hyperthermia by Acoustic Temperature Tomography", *Ultrasonics Symposium Proceedings*, pp. 977-982, (1977).

Krischak, G.D., et al., "The effects of non-steroidal anti-inflammatory drug application on incisional wound healing in rats" *Journal of Wound Care*, vol. 6, No. 2, (Feb. 2007).

Lin, Sung-Jan, et al., "Monitoring the thermally induced structural transitions of collagen by use of second-harmonic generation microscopy" *Optics Letters*, vol. 30, No. 6, (Mar. 15, 2005).

Madersbacher, S. et al., "Tissue Ablation in Benign Prostatic Hyperplasia with High Intensity Focused Ultrasound," *Dur. Urol.*, 23 (suppl. 1):39-43; 1993.

Makin et al., "B-Scan Imaging and Thermal Lesion Monitoring Using Miniaturized Dual-Functionality Ultrasound Arrays," *Ultrasonics Symposium*, 2004 IEEE, Aug. 23, 2004, pp. 1788-1791, vol. 3.

Makin et al., "Confirmed Bulk Ablation and Therapy Monitoring Using Intracorporeal Image-Treat Ultrasound Arrays," 4th International Symposium on Therapeutic Ultrasound, Sep. 19, 2004.

Makin et al., "Miniaturized Ultrasound Arrays for Interstitial Ablation and Imaging," *UltraSound Med. Biol.* 2005, Nov. 1, 2005, pp. 1539-1550, vol. 31(11).

Manohar et al., "Photoacoustic mammography laboratory prototype: imaging of breast tissue phantoms," *Journal of Biomedical Optics*, Nov./Dec. 2004, pp. 1172-1181, vol. 9, No. 6.

Mast et al., "Bulk Ablation of Soft Tissue with Intense Ultrasound; Modeling and Experiments," *J. Acoust. Soc. Am.*, Oct. 1, 2005, pp. 2715-2724, vol. 118(4).

Meshkinpour, Azin, et al., "Treatment of Hypertrophic Scars and Keloids With a Radiofrequency Device: A Study of Collagen Effects" *Lasers in Surgery and Medicine* 37:343-349 (2005).

Mitragotri, S., "Healing sound: the use of ultrasound in drug delivery and other therapeutic applications," *Nature Reviews; Drug Delivery*, pp. 255-260, vol. 4 (Mar. 2005).

Mosser, David M. et al., "Exploring the full spectrum of macrophage activation" *Nat Rev Immunol*; 8(12): 958-969, (Dec. 2008).

Murota, Sei-Itsu, et al., "Stimulatory Effect of Prostaglandins on the Production of Hexosamine-Containing Substances by Cultured Fibroblasts (3) Induction of Hyaluronic Acid Synthetase by Prostaglandin" *Department of Pharmacology, Tokyo Metropolitan Institute of Gerontology, Itabashiku, Tokyo-173, Japan.* (Nov. 1977, vol. 14, No. 5).

Murota, Sei-Itsu, et al., "The Stimulatory Effect of Prostaglandins on Production of Hexosamine-Containing Substances by Cultured Fibroblasts" *Department of Pharmacology, Tokyo Metropolitan Institute of Gerontology, Itabashiku, Tokyo-173, Japan.* (Aug. 1976, vol. 12, No. 2).

Paradossi et al., "Poly(vinyl alcohol) as versatile biomaterial for potential biomedical applications," *Journal of Materials Science: Materials in Medicine*, 2003, pp. 687-691, vol. 14.

Rappolee, Daniel A., et al., "Wound Macrophages Express TGF and Other Growth Factors in Vivo: Analysis by mRNA Phenotyping" *Science*, vol. 241, No. 4866 (Aug. 1988).

(56)

References Cited

OTHER PUBLICATIONS

- Reid, Gavin, et al., "Tandem Mass spectrometry of ribonuclease A and B: N-linked glycosylation site analysis of whole protein ions," *Analytical Chemistry*, Feb. 1, 2002, vol. 74, No. 3, pp. 577-583.
- Righetti et al., "Elastographic Characterization of HIFU-Induced Lesions in Canine Livers," 1999, *Ultrasound in Med & Bio*, vol. 25, No. 7, pp. 1099-1113.
- Rosenberg, Carol S. "Wound Healing in the Patient with Diabetes Mellitus" *Nursing Clinics of North America*, vol. 25, No. 1, (Mar. 1990).
- Saad et al., "Ultrasound-Enhanced Effects of Adriamycin Against Murine Tumors," *Ultrasound in Med. & Biol.* vol. 18, No. 8, pp. 715-723 (1992).
- Sandulache, Vlad C. et al., "Prostaglandin E2 inhibition of keloid fibroblast migration, contraction, and transforming growth factor (TGF)—B1—induced collagen synthesis" *Wound Rep Reg* 15 122-133, 2007. (2007).
- Sanghvi, N.T., et al., "Transrectal Ablation of Prostate Tissue Using Focused Ultrasound," 1993 *Ultrasonics Symposium*, IEEE, pp. 1207-1210.
- Sassen, Sander, "ATI's R520 architecture, the new king of the hill?" <http://www.hardwareanalysis.com/content/article/1813>, Sep. 16, 2005, 2 pages.
- Seip, Ralf, et al., "Noninvasive Detection of Thermal Effects Due to Highly Focused Ultrasonic Fields," *IEEE Symposium*, pp. 1229-1232, vol. 2, Oct. 3-Nov. 1993.
- Seip, Ralf, et al., "Noninvasive Estimation of Tissue Temperature Response to Heating Fields Using Diagnostic Ultrasound," *IEEE Transactions on Biomedical Engineering*, vol. 42, No. 8, Aug. 1995, pp. 828-839.
- Simon et al., "Applications of Lipid-Coated Microbubble Ultrasonic Contrast to Tumor Therapy," *Ultrasound in Med. & Biol.* vol. 19, No. 2, pp. 123-125 (1993).
- Smith, Nadine Barrie, et al., "Non-invasive In Vivo Temperature Mapping of Ultrasound Heating Using Magnetic Resonance Techniques", 1994 *Ultrasonics Symposium*, pp. 1829-1832, vol. 3.
- Suh, D.H., et al., "Intense Focused Ultrasound Tightening in Asian Skin: Clinical and Pathologic Results" *American Society for Dermatologic Surgery, Inc.*; 37:1595-1602. (2011).
- Surry et al., "Poly(vinyl alcohol) cryogel phantoms for use in ultrasound and MR imaging," *Phys. Med. Biol.*, Dec. 6, 2004, pp. 5529-5546, vol. 49.
- Syka J. E. P. et al., "Peptide and Protein Sequence Analysis by Electron Transfer Dissociation Mass Spectrometry," *Proceedings of the National Academy of Sciences of USA*, National Academy of Science, Washington, DC, vol. 101, No. 26, Jun. 29, 2004, pp. 9528-9533.
- Talbert, D. G., "An Add-On Modification for Linear Array Real-Time Ultrasound Scanners to Produce 3D Displays," *UTS Int'l 1977 Brighton, England* (Jun. 28-30, 1977) pp. 57-67.
- Tata et al., "Interaction of Ultrasound and Model Membrane Systems: Analyses and Predictions," *American Chemical Society, Phys. Chem.* 1992, 96, pp. 3548-3555.
- Ueno, S., et al., "Ultrasound Thermometry in Hyperthermia", 1990 *Ultrasonic Symposium*, pp. 1645-1652.
- Verhofstad, Michiel H.J. et al., "Collagen Synthesis in rat skin and ileum fibroblasts is affected differently by diabetes-related factors" *Int. J. Exp. Path.* (1998), 79, 321-328.
- Wang, H., et al., "Limits on Focused Ultrasound for Deep Hyperthermia", 1994 *Ultrasonic Symposium*, Nov. 1-4, 1994, pp. 1869-1872, vol. 3.
- Wasson, Scott, "NVIDIA's GeForce 7800 GTX graphics processor Power MADD," <http://techreport.com/reviews/2005q2/geforce-7800gtx/index.x?pg=1>, Jun. 22, 2005, 4 pages.
- White et al "Selective Creating of Thermal Injury Zones in the Superficial Musculoaponeurotic System Using Intense Ultrasound Therapy," *Arch Facial Plastic Surgery*, Jan./Feb. 2007, vol. 9, No. 1 (pp. 22-29).
- White, W. Matthew, et al., "Selective Transcutaneous Delivery of Energy to Porcine Soft Tissues Using Intense Ultrasound (IUS)" *Lasers in Surgery and Medicine* 40:67-75 (2008).
- Zelickson, Brian D. et al., "Histological and Ultrastructural Evaluation of the Effects of a Radiofrequency-Based Nonablative Dermal Remodeling Device, A Pilot Study" *Arch Dermatol*, vol. 140, (Feb. 2004).
- Alam, M., "The future of noninvasive procedural dermatology". *Semin Cutan Med Surg.* Mar. 2013; 32(1):59-61.
- Alam, M., et al., "Ultrasound tightening of facial and neck skin: a rater-blinded prospective cohort study". *J Am Acad Dermatol*, 2010. 62(2): p. 262-9.
- Alexiades-Armenakas, M., "Ultrasound Technologies for Dermatologic Techniques". *J Drugs Derm.* 2014. 12 (11): p. 1305.
- Alster, T.S., et. al., "Noninvasive lifting of arm, thigh, and knee skin with transcutaneous intense focused ultrasound". *Dermatol Surg.* 2012. 38(5): p. 754-9.
- Arosarena, O., "Options and Challenges for Facial Rejuvenation in Patients With Higher Fitzpatrick Skin Phototypes". *JAMA Facial Plastic Surgery*, 2015.
- Brobst, R.W., et. al., "Noninvasive Treatment of the Neck". *Facial Plast Surg Clin North Am*, 2014. 22(2): p. 191-202.
- Brobst, R.W., et., al., "Ulthera: initial and six month results". *Facial Plast Surg Clin North Am*, 2012. 20(2): p. 163-76.
- Casabona, G., et. al., "Microfocused Ultrasound With Visualization and Fillers for Increased Neocollagenesis: Clinical and Histological Evaluation". *Dermatol Surg* 2014;40:S194-S198.
- Chan, N.P., et al., "Safety study of transcutaneous focused ultrasound for non-invasive skin tightening in Asians". *Lasers Surg Med*, 2011. 43(5): p. 366-75.
- Chapelon et al., "Effects of Cavitation in the High Intensity Therapeutic Ultrasound", *Ultrasonics Symposium—1357* (1991).
- Chapelon, et al., "Thresholds for Tissue Ablation by Focused Ultrasound" (1990).
- Dayan, S.H., et al., "Prospective, Multi-Center, Pivotal Trial Evaluating the Safety and Effectiveness of Micro-Focused Ultrasound with Visualization (MFU-V) for Improvement in Lines and Wrinkles of the Décolletage". *Plast Reconstr Surg.* Oct. 2014; 134(4 Suppl 1):123-4.
- Dobke, M.K., et al., "Tissue restructuring by energy-based surgical tools". *Clin Plast Surg*, 2012. 39(4): p. 399-408.
- Fabi, S.G., "Microfocused Ultrasound With Visualization for Skin Tightening and Lifting: My Experience and a Review of the Literature". *Dermatol Surg.* Dec. 2014; 40 Suppl 12: S164-7.
- Fabi, S.G., "Noninvasive skin tightening: focus on new ultrasound techniques". *Clin Cosmet Investig Dermatol.* Feb. 5, 2015; 8:47-52.
- Fabi, S.G., et. al., "A prospective multicenter pilot study of the safety and efficacy of microfocused ultrasound with visualization for improving lines and wrinkles of the décolleté". *Dermatol Surg.* Mar. 2015; 41(3):327-35.
- Fabi, S.G., et. al., "Evaluation of microfocused ultrasound with visualization for lifting, tightening, and wrinkle reduction of the décolletage". *J Am Acad Dermatol*, 2013. 69(6): p. 965-71.
- Fabi, S.G., et. al., "Future directions in cutaneous laser surgery". *Dermatol Clin*, 2014. 32(1): p. 61-9.
- Fabi, S.G., et. al., "Retrospective Evaluation of Micro-focused Ultrasound for Lifting and Tightening the Face and Neck". *Dermatol Surg*, 2014.
- Friedmann D.P., "Comments on evaluation of microfocused ultrasound system for improving skin laxity and tightening in the lower face". *Aesthet Surg J.* Mar. 2015;35(3):NP81-2.
- Friedmann, D.P., et. al., "Combination of intense pulsed light, Sculptra, and Ultherapy for treatment of the aging face". *J Cosmet Dermatol*, 2014. 13(2): p. 109-18.
- Fujimoto, et al., "A New Cavitation Suppression Technique for Local Ablation Using High-Intensity Focused Ultrasound" *Ultrasonics Symposium—1629* (1995).
- Gold, M.H., et. al., "Use of Micro-Focused Ultrasound with Visualization to Lift and Tighten Lax Knee Skin". *J Cosmet Laser Ther*, 2014: p. 1-15.
- Goldberg, D.J., et. al., "Safety and Efficacy of Microfocused Ultrasound to Lift, Tighten, and Smooth the Buttocks". *Dermatol Surg* 2014; 40:1113-1117.

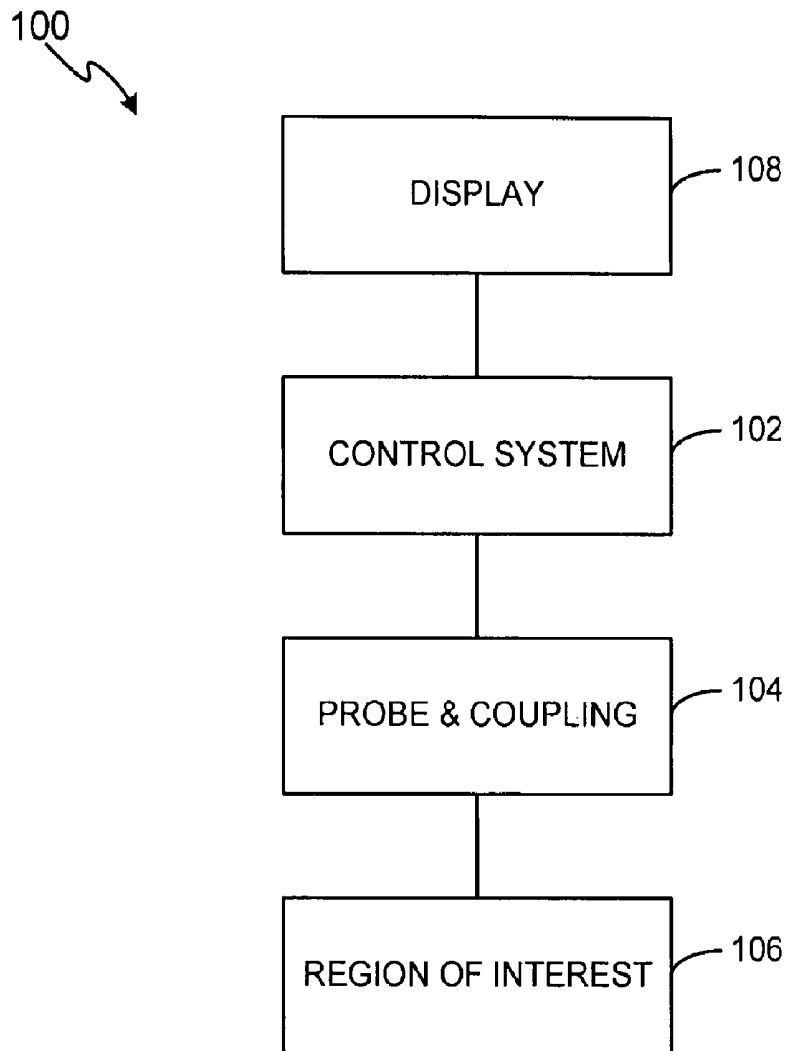
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References Cited

OTHER PUBLICATIONS

- Greene, R.M., et al., "Skin tightening technologies". *Facial Plast Surg.* Feb. 2014; 30(1):62-7.
- Harris, M.O., "Safety of Microfocused Ultrasound With Visualization in Patients With Fitzpatrick Skin Phototypes III to VI". *JAMA Facial Plast. Surg.* 2015.
- Hart, et. al., "Current Concepts in the Use of PLLA: Clinical Synergy Noted with Combined Use of Microfocused Ultrasound and Poly-L-Lactic Acid on the Face, Neck, and Décolletage". *Amer. Soc. Plast. Surg.* 2015. 136; 180-187S.
- Hitchcock, T.M. et. al., "Review of the safety profile for microfocused ultrasound with Visualization". *Journal of Cosmetic Dermatology*, 13, 329-335. (2014).
- Hynynen et al., Temperature Distributions During Local Ultrasound Induced Hyperthermia In Vivo, *Ultrasonics Symposium—745* (1982).
- Jeong, K.H., et al., "Neurologic complication associated with intense focused ultrasound". *J Cosmet Laser Ther.* 2013.
- Kim, H.J., et al., "Coagulation and ablation patterns of high-intensity focused ultrasound on a tissue mimicking phantom and cadaveric skin". *Laser Med Sci.* Sep. 4, 2015.
- Kornstein, A.N., "Ulthera for silicone lip correction". *Plast Reconstr Surg.* 2012. 129(6): p. 1014e-1015e.
- Kornstein, A.N., "Ultherapy shrinks nasal skin after rhinoplasty following failure of conservative measures". *Plast Reconstr Surg.* 2013. 131(4): p. 664e-6e.
- Laubach, H.J., et. al., "Confined Thermal Damage with Intense Ultrasound (IUS)" [abstr.] *American Society for Laser Medicine and Surgery Abstracts*, p. 15 #43 (Apr. 2006).
- Laubach, H.J., et. al., "Intense focused ultrasound: evaluation of a new treatment modality for precise microcoagulation within the skin". *Dermatol Surg.* 2008. 34(5): p. 727-34.
- Lee, H.J., et. al., "The efficacy and safety of intense focused ultrasound in the treatment of enlarged facial pores in Asian skin". *J Dermatolog Treat.* 2014.
- Lee, H.S., et. al., "Multiple Pass Ultrasound Tightening of Skin Laxity of the Lower Face and Neck". *Dermatol Surg.* 2011.
- Macgregor J.L., et. al., "Microfocused Ultrasound for Skin Tightening". *Semin Cutan Med Surg* 32:18-25. (2013).
- Minkis, K., et. al., "Ultrasound skin tightening". *Dermatol Clin.* 2014. 32(1): p. 71-7.
- Nestor, M.S. et. al., "Safety and Efficacy of Micro-focused Ultrasound Plus Visualization for the Treatment of Axillary Hyperhidrosis". *J Clin Aesthet Dermatol.* 2014. 7(4): p. 14-21.
- Oni, G., et. al. "Response to 'comments on evaluation of microfocused ultrasound system for improving skin laxity and tightening in the lower face'". *Aesthet Surg J.* Mar. 2015;35(3):NP83-4.
- Oni, G., et. al., "Evaluation of a Microfocused Ultrasound System for Improving Skin Laxity and Tightening in the Lower Face". *Aesthet Surg J.* 2014. 38:861-868.
- Pak, C.S., et. al., "Safety and Efficacy of Ulthera in the Rejuvenation of Aging Lower Eyelids: A Pivotal Clinical Trial". *Aesthetic Plast Surg.* 2014.
- Pritzker, R.N., et. al., "Updates in noninvasive and minimally invasive skin tightening". *Semin Cutan Med Surg.* Dec. 2014;33(4):182-7.
- Pritzker, R.N., et. al., "Comparison of different technologies for noninvasive skin tightening". *Journal of Cosmetic Dermatology*, 13, 315-323. (2014).
- Rokhsar, C., et. al., "Safety and efficacy of microfocused ultrasound in tightening of lax elbow skin". *Dermatol Surg.* 2015; 41(7):821-6.
- Sabet-Peyman, E.J. et. al., "Complications Using Intense Ultrasound Therapy to Treat Deep Dermal Facial Skin and Subcutaneous Tissues". *Dermatol Surg* 2014; 40:1108-1112.
- Sasaki, G.H. et. al., "Clinical Efficacy and Safety of Focused-Image Ultrasonography: A 2-Year Experience". *Aesthet Surg J.* 2012.
- Sasaki, G.H. et. al., "Microfocused Ultrasound for Nonablative Skin and Subdermal Tightening to the Periorbitum and Body Sites: Preliminary Report on Eighty-Two Patients". *Journal of Cosmetics, Dermatological Sciences and Applications*, 2012, 2, 108-116.
- Sklar, L.R., et. al., "Use of transcutaneous ultrasound for lipolysis and skin tightening: a review". *Aesthetic Plast Surg.* 2014. 38(2): p. 429-41.
- Suh, D.H., et. al., "A intense-focused ultrasound tightening for the treatment of infraorbital laxity". *J Cosmet Laser Ther.* 2012. 14(6): p. 290-5.
- Suh, D.H., et. al., "Comparative histometric analysis of the effects of high-intensity focused ultrasound and radiofrequency on skin". *J Cosmet Laser Ther.* Mar. 24, 2015:1-7.
- Suh, D.H., et. al., "Intense focused ultrasound tightening in asian skin: clinical and pathologic results". *Dermatol Surg.* 2011. 37(11): p. 1595-602.
- Weiss, M., "Commentary: noninvasive skin tightening: ultrasound and other technologies: where are we in 2011?" *Dermatol Surg.* 2012. 38(1): p. 28-30.
- White, W. M., et al., "Selective Transcutaneous Delivery of Energy to Facial Subdermal Tissues Using the Ultrasound Therapy System" [abstr]. *American Society for Laser Medicine and Surgery Abstracts*, p. 37 #113 (Apr. 2006).
- Woodward, J.A., et. al. "Safety and Efficacy of Combining Microfocused Ultrasound With Fractional CO2 Laser Resurfacing for Lifting and Tightening the Face and Neck". *Dermatol Surg.* Dec. 2014 40:S190-S193.
- Ulthera, Inc., Petition for Inter Partes Review filed Jul. 19, 2016 in Re U.S. Pat. No. 6,113,559; IPR2016-01459; 63 pages.
- Ulthera Exhibit 1001, U.S. Pat. No. 6,113,559 to Klopotek, filed Jul. 19, 2016 in re IPR2016-01459.
- Ulthera Exhibit 1002, Patent file history of U.S. Pat. No. 6,113,559 Klopotek.
- Ulthera Exhibit 1003, Declaration of Expert Witness Mark E. Schafer, Ph.D.
- Ulthera Exhibit 1004, Curriculum Vitae of Mark E. Schafer, Ph.D.
- Ulthera Exhibit 1005, International PCT Publication WO96/34568 Knowlton.
- Ulthera Exhibit 1006, French Patent No. 2,672,486, Technomed patent.
- Ulthera Exhibit 1007, English translation of French Patent No. 2,672,486, Technomed.
- Ulthera Exhibit 1008, International PCT Publication WO93/12742, Technomed PCT.
- Ulthera Exhibit 1009, English translation of International PCT Publication WO93/12742, Technomed PCT.
- Ulthera Exhibit 1010, U.S. Pat. No. 5,601,526, which claims priority to Technomed PCT.
- Ulthera Exhibit 1011, Patent file history for European Patent Application No. 98964890.2, Klopotek.
- Ulthera Exhibit 1012, Translator Declaration.
- Ulthera Exhibit 1013, U.S. Pat. No. 5,230,334 to Klopotek.
- Ulthera Exhibit 1014, U.S. Pat. No. 5,755,753 to Knowlton.
- Ulthera Exhibit 1015, Excerpts from The American Medical Association Encyclopedia of Medicine (1989).
- Ulthera Exhibit 1016, The Simultaneous Study of Light Emissions and Shock Waves Produced by Cavitation Bubbles, G. Gimenez, J. Acoust. Soc. Am. 71(4), Apr. 1982, pp. 839-847.
- Ulthera Exhibit 1017, Excerpts from Gray's Anatomy (1995).
- Ulthera Exhibit 1018, Anatomy of the Superficial Venous System, Comjen G.M., *Dermatol. Surg.*, 1995; 21:35-45.
- Ulthera Exhibit 1019, Section 2.6 from Ultrasonics Theory and Application, by G.L. Gooberman (Hart Publishing Co., 1969).
- Ulthera Exhibit 1020, Deep Local Hyperthermia for Cancer Therapy: External Electromagnetic and Ultrasound Techniques, A.Y. Cheung and A. Neyzari, *Cancer Research (Suppl.)*, vol. 44, pp. 4736-4744 (1984).

* cited by examiner

**FIG. 1**

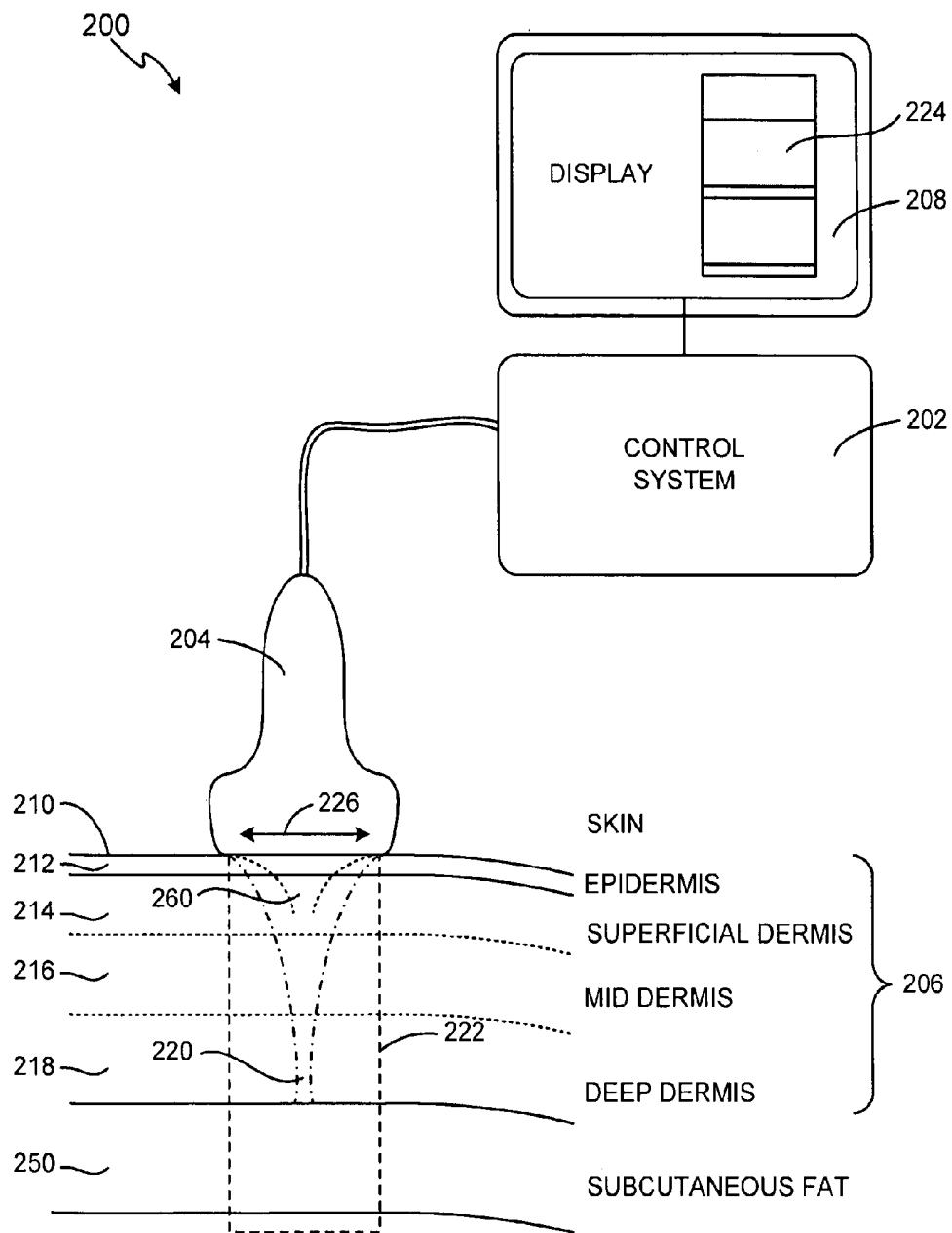


FIG. 2A

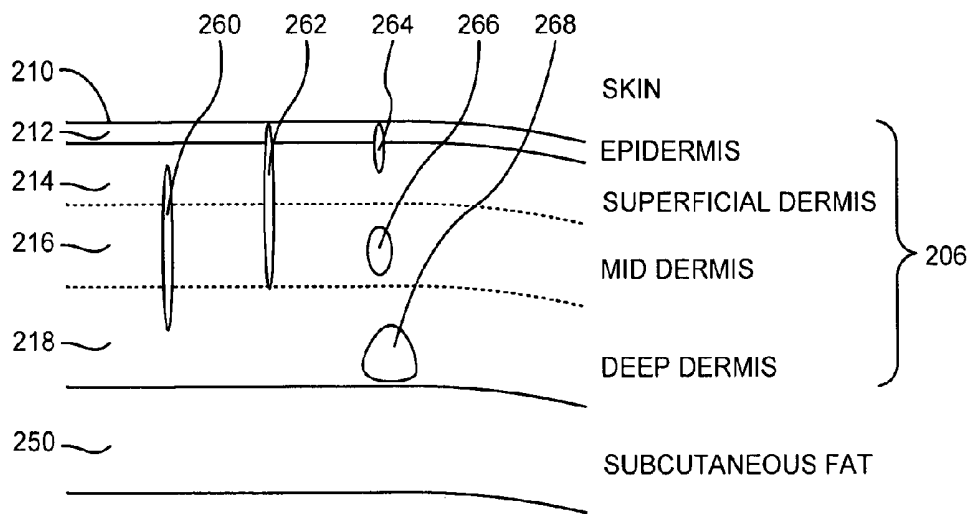


FIG. 2B

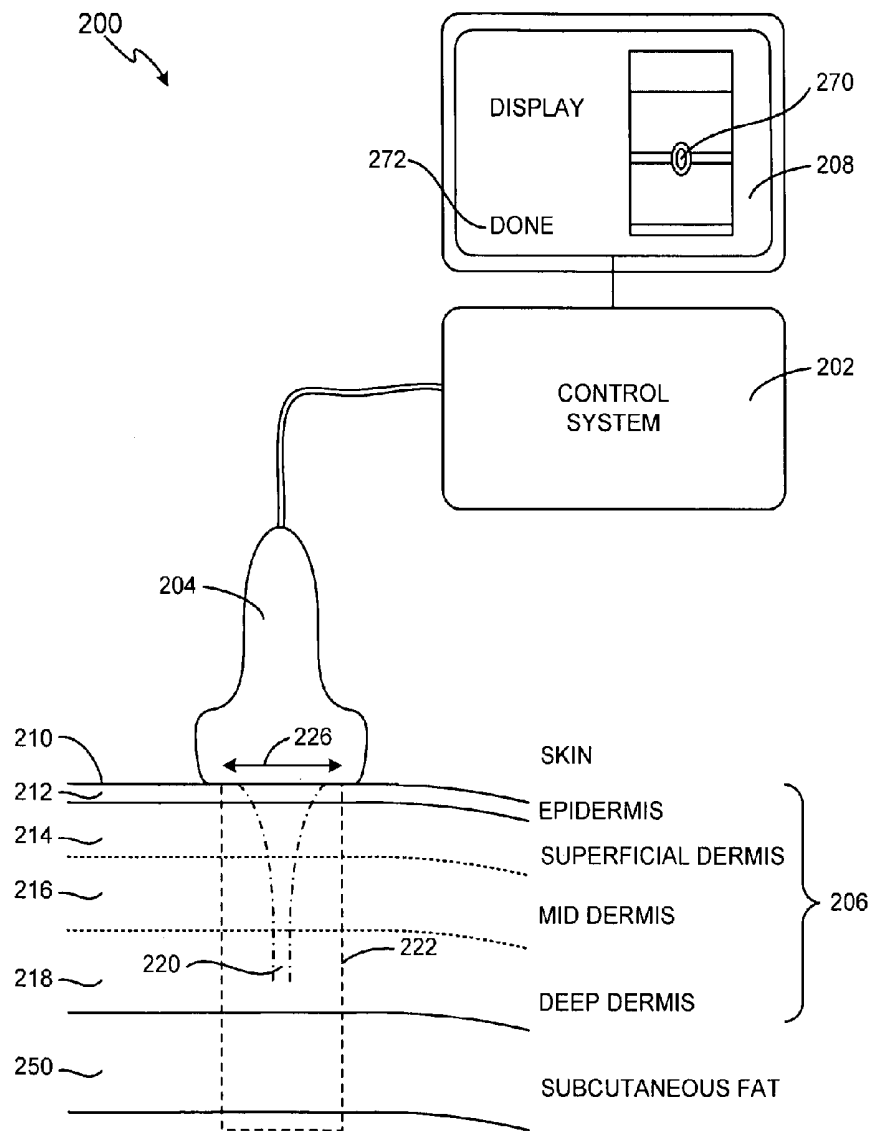


FIG. 2C

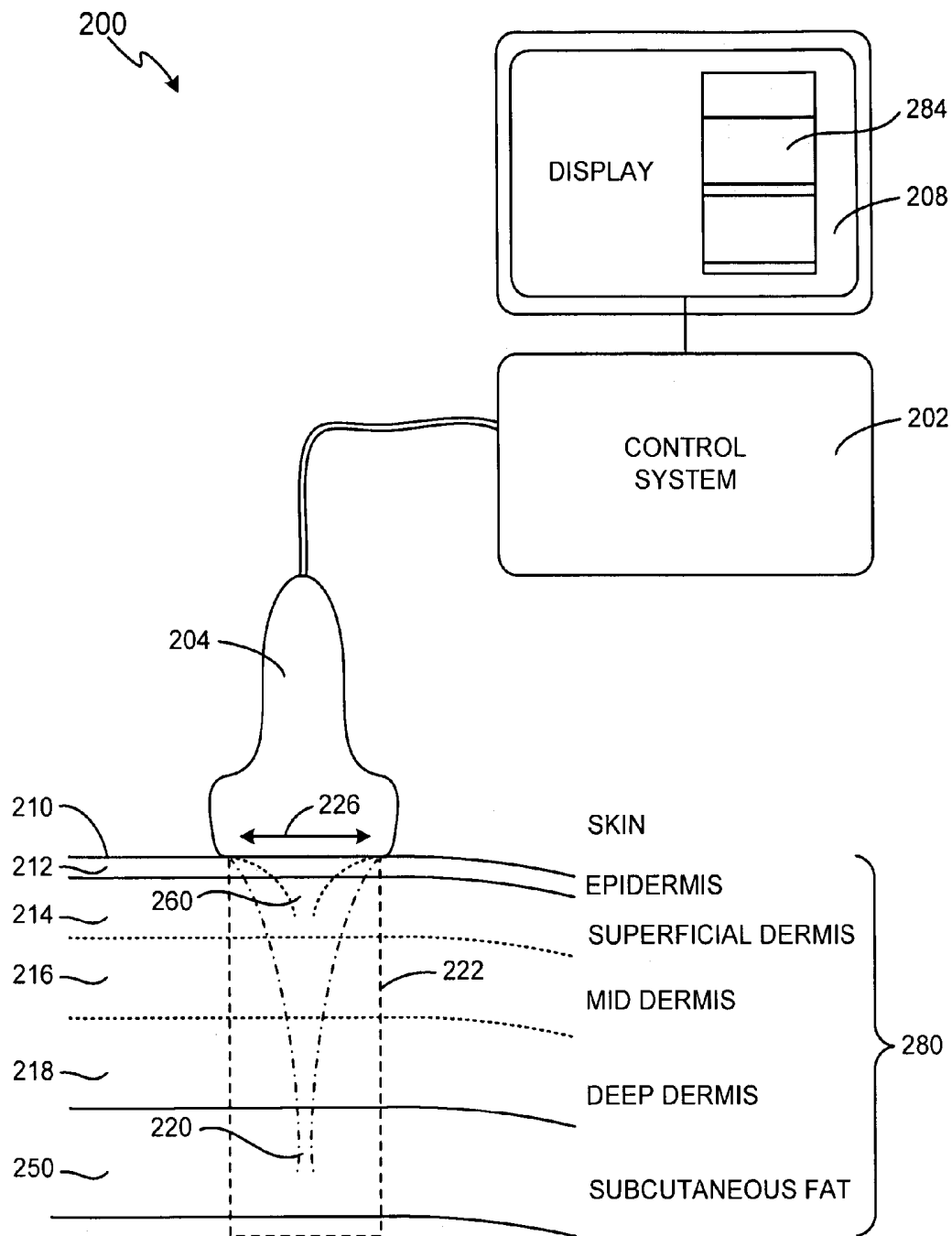
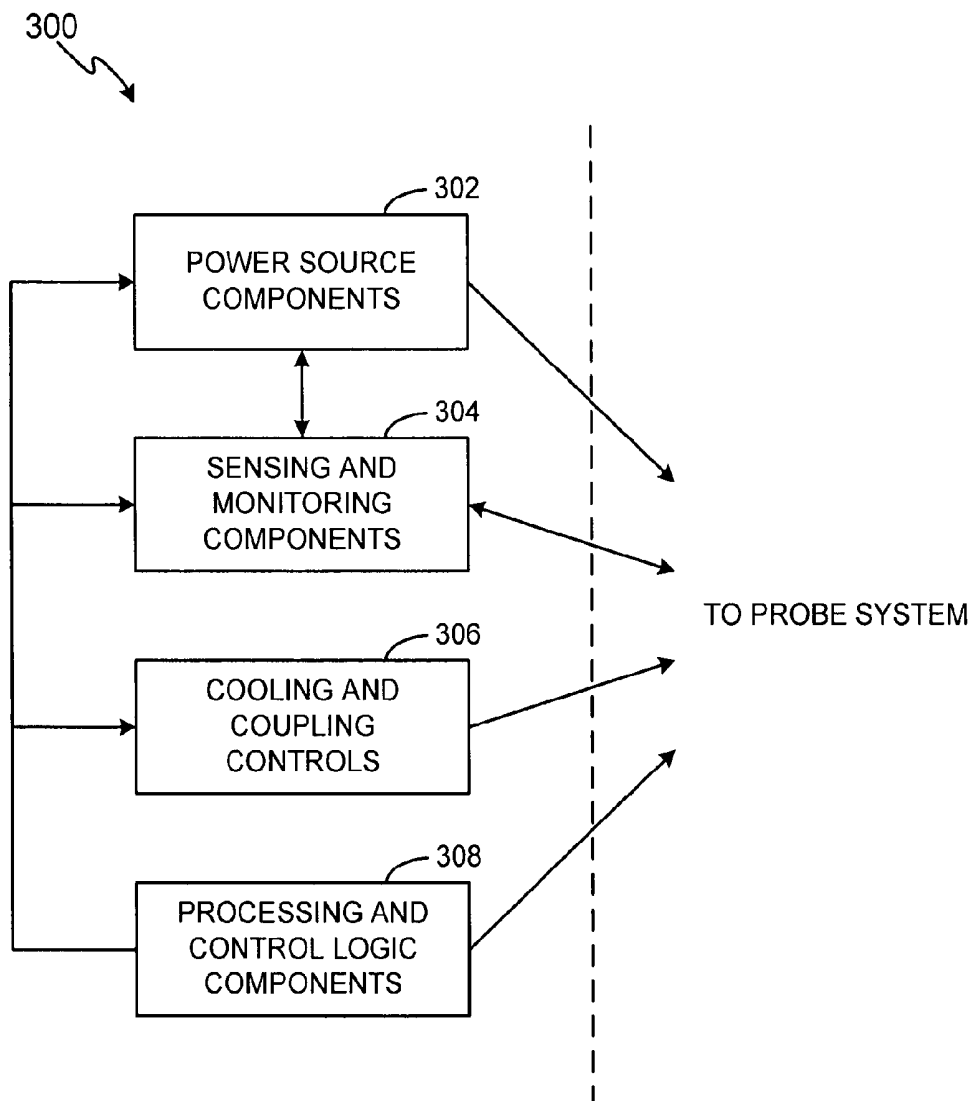
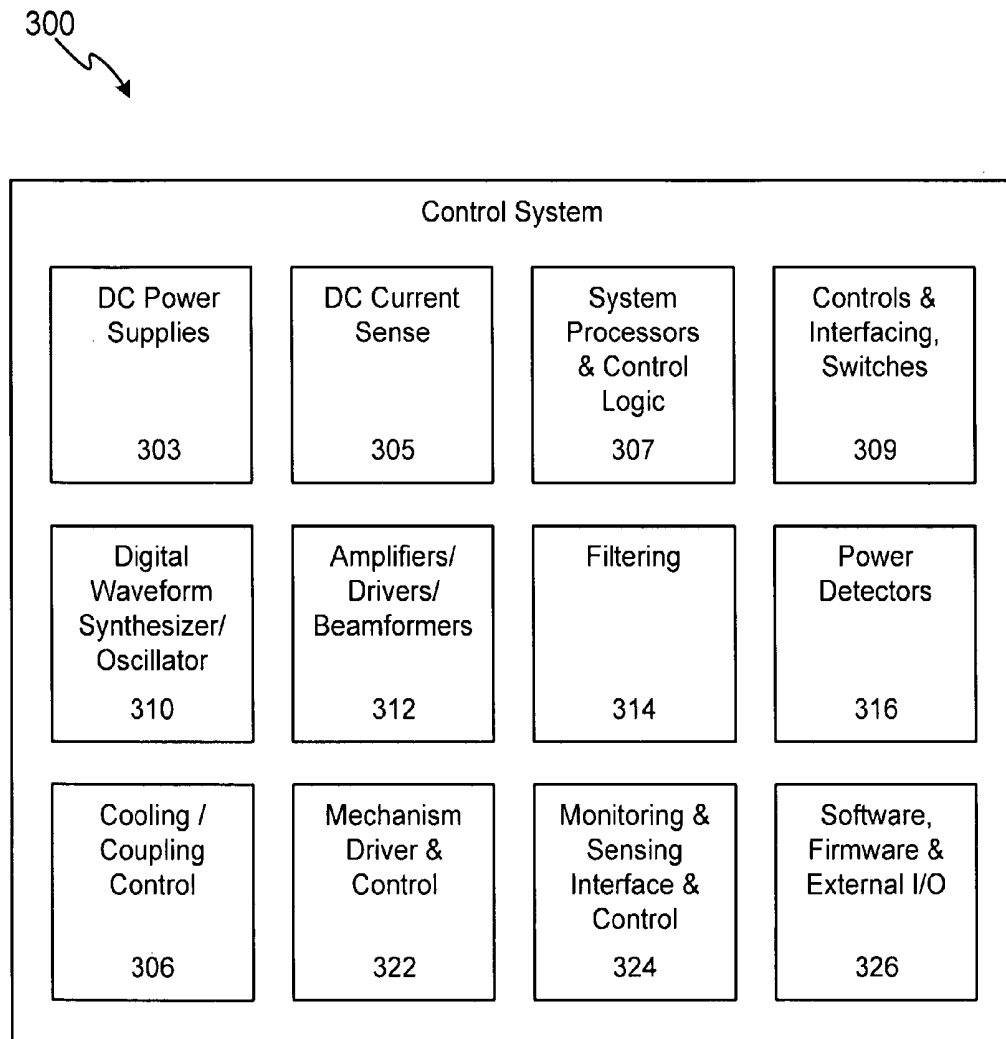
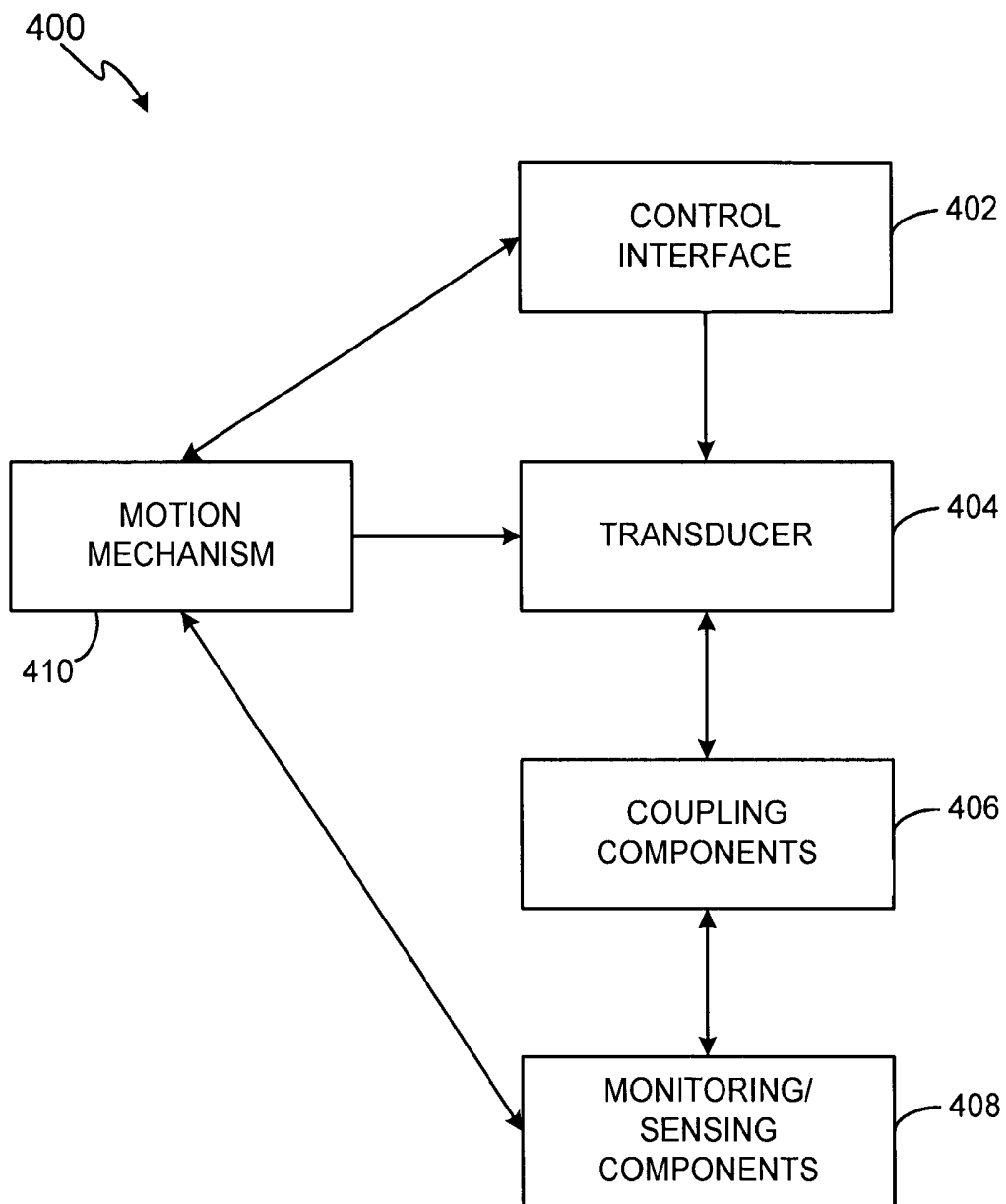


FIG. 2D

**FIG. 3A**

**FIG. 3B**

**FIG. 4A**

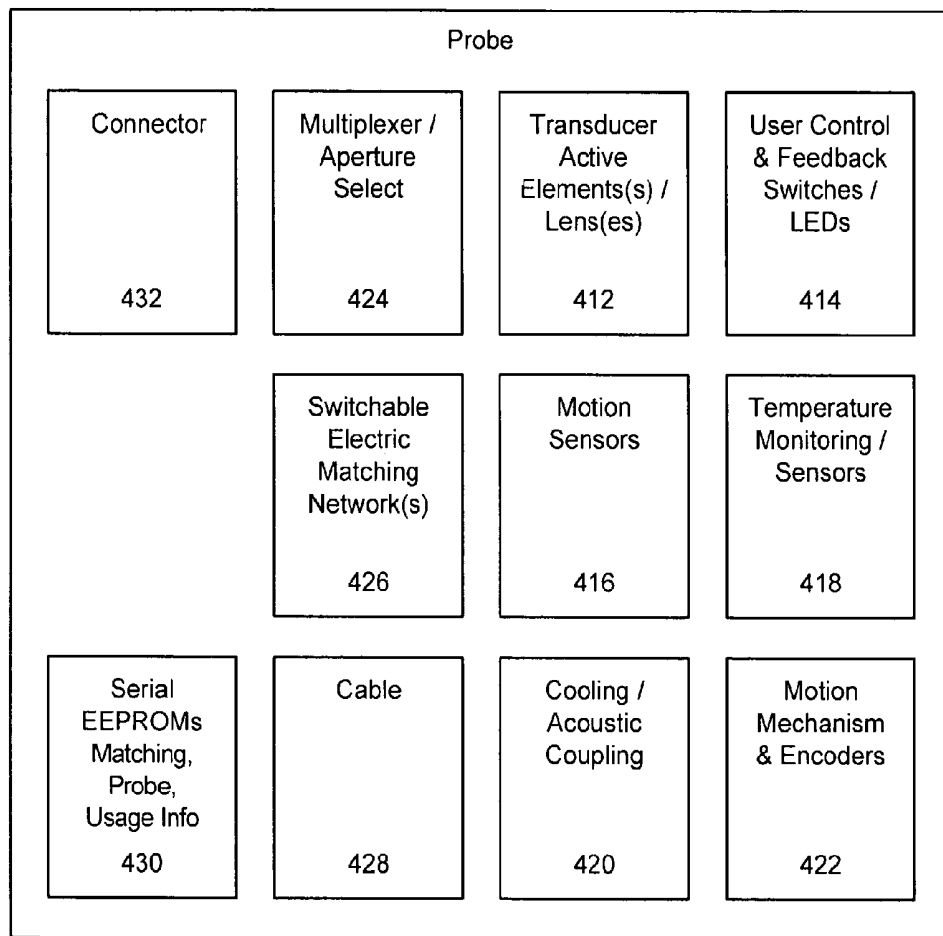
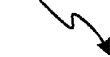
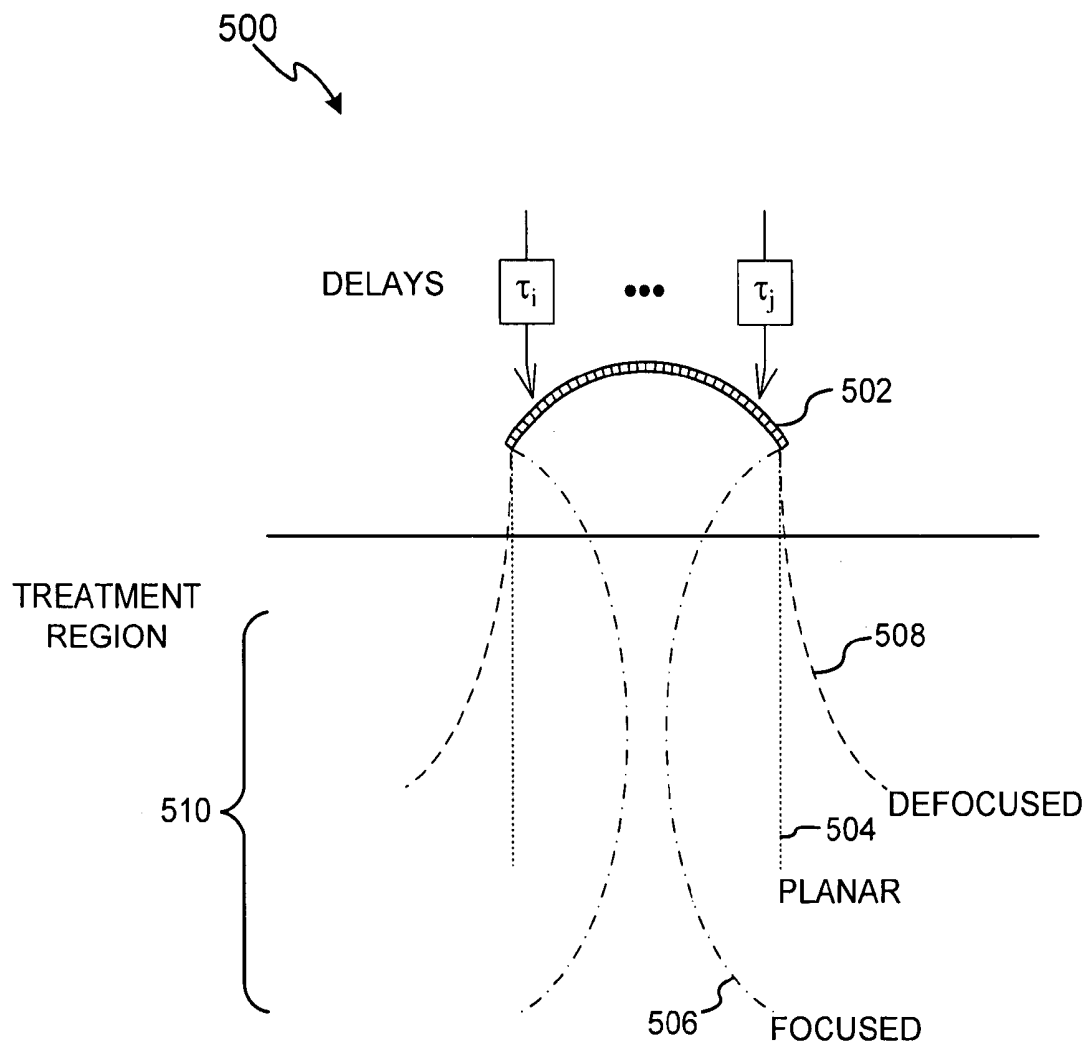
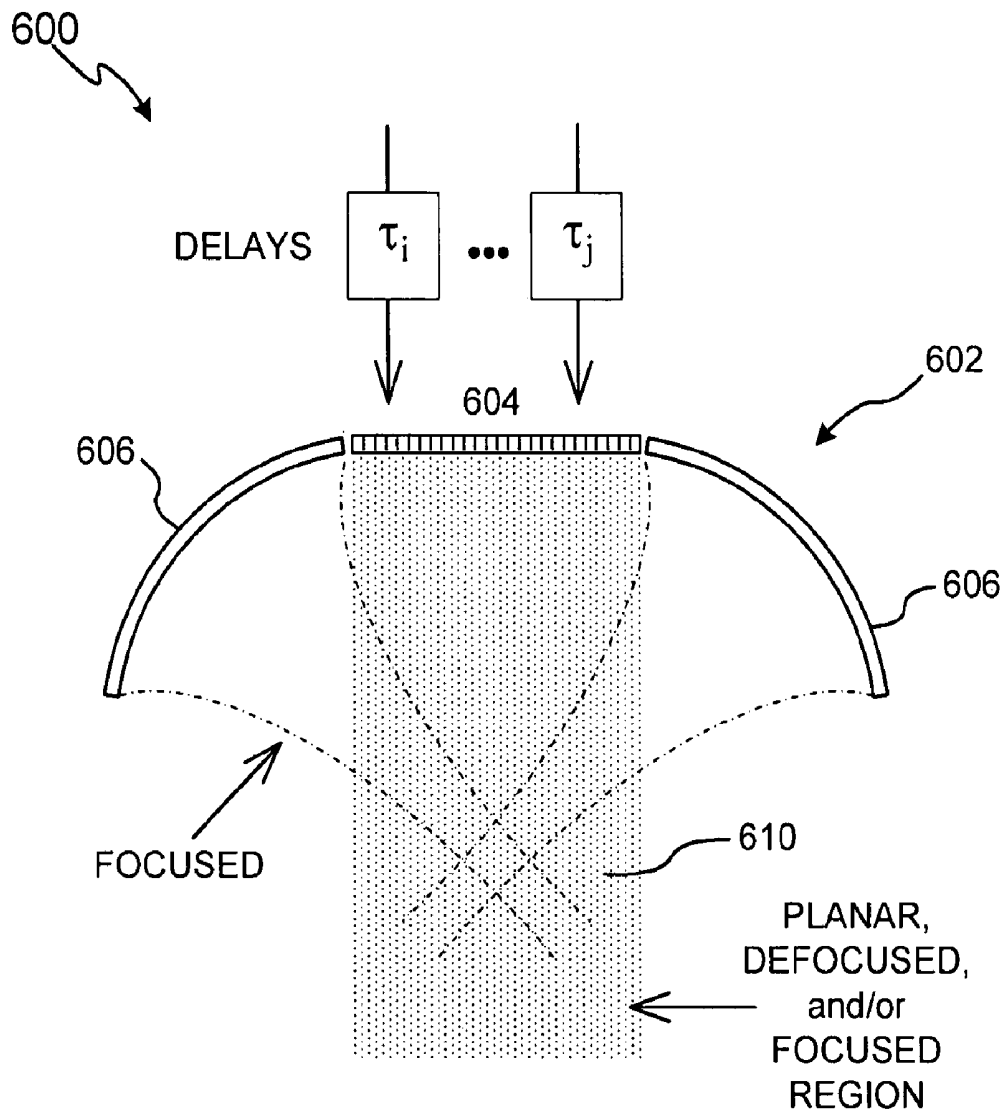
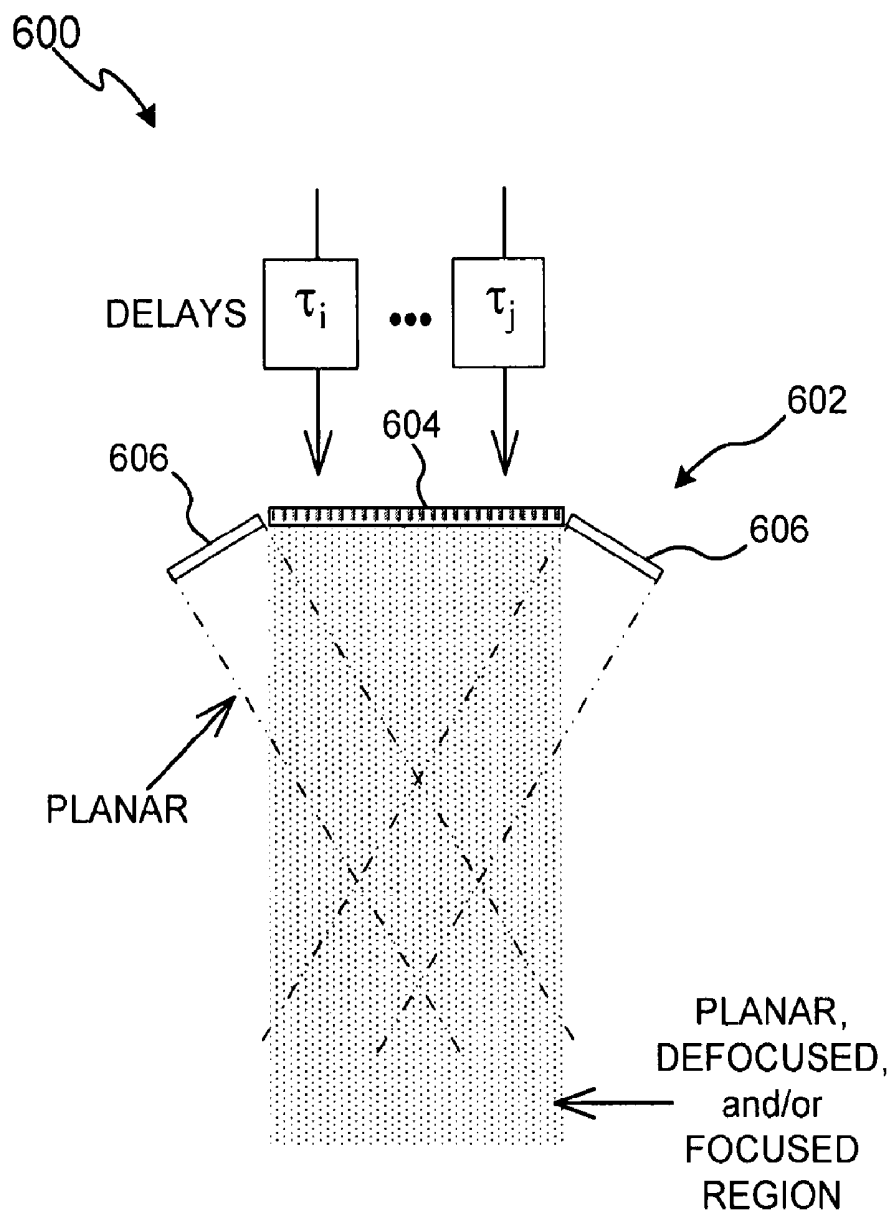
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FIG. 4B

**FIG. 5**

**FIG. 6A**

**FIG. 6B**

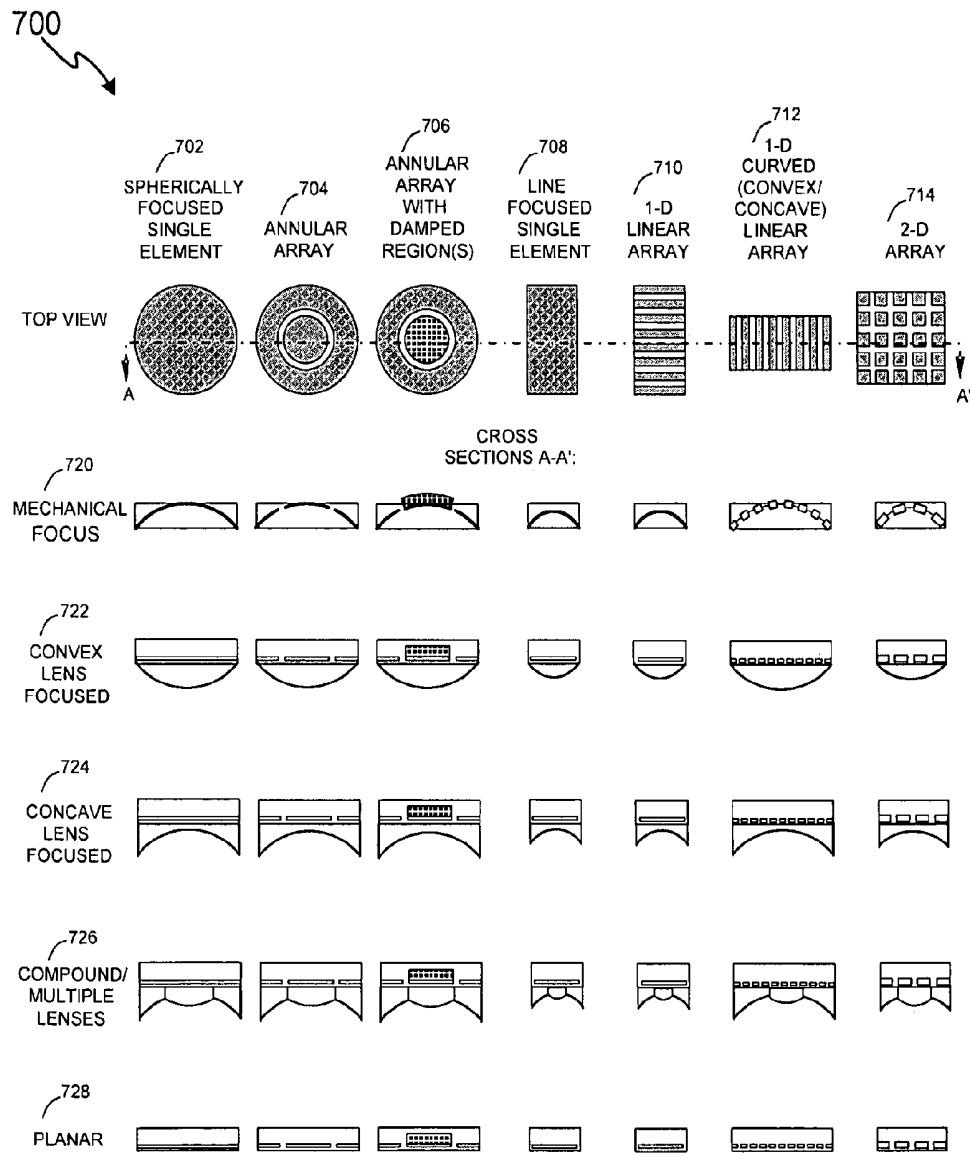


FIG. 7

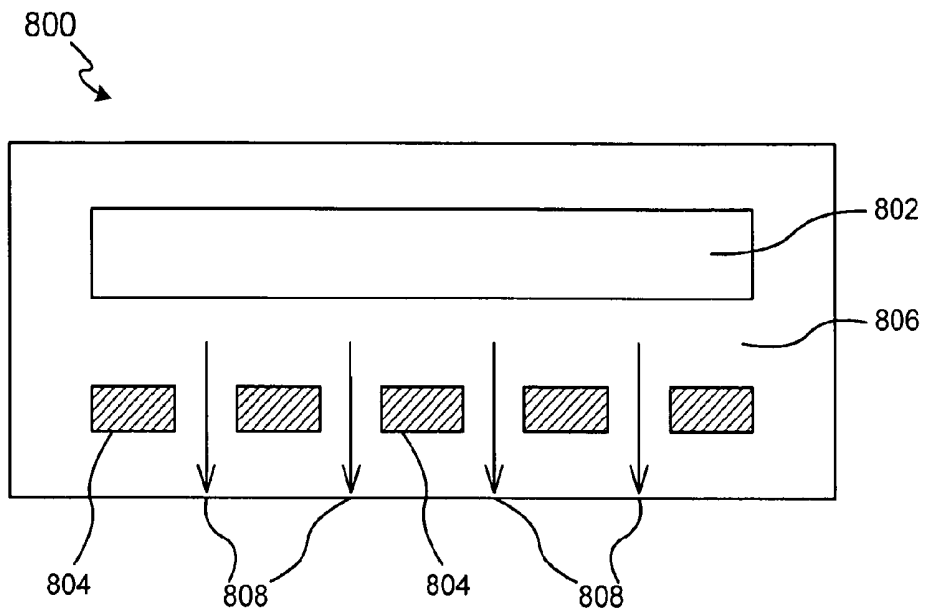


FIG. 8A

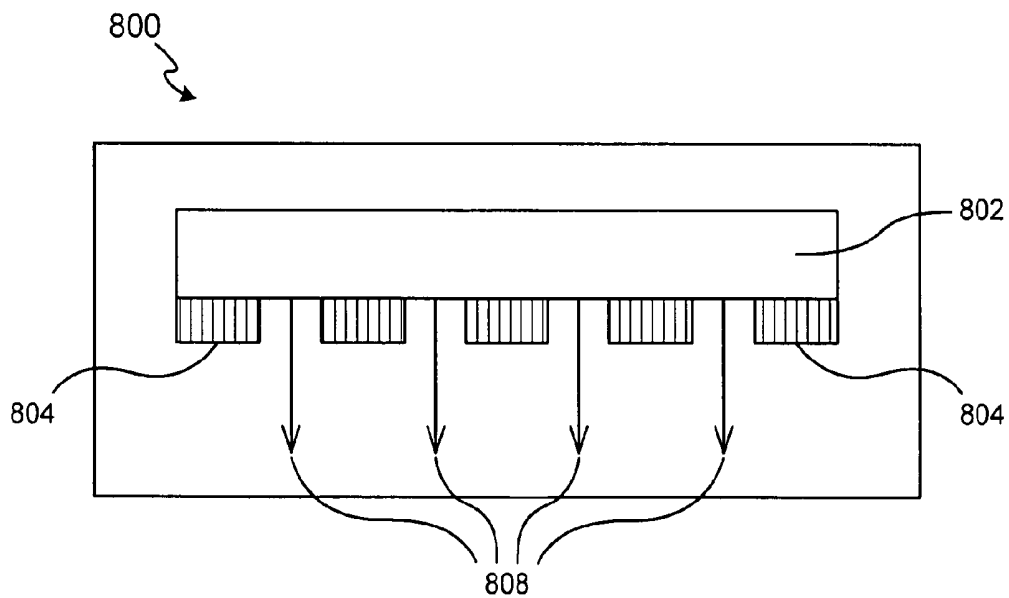


FIG. 8B

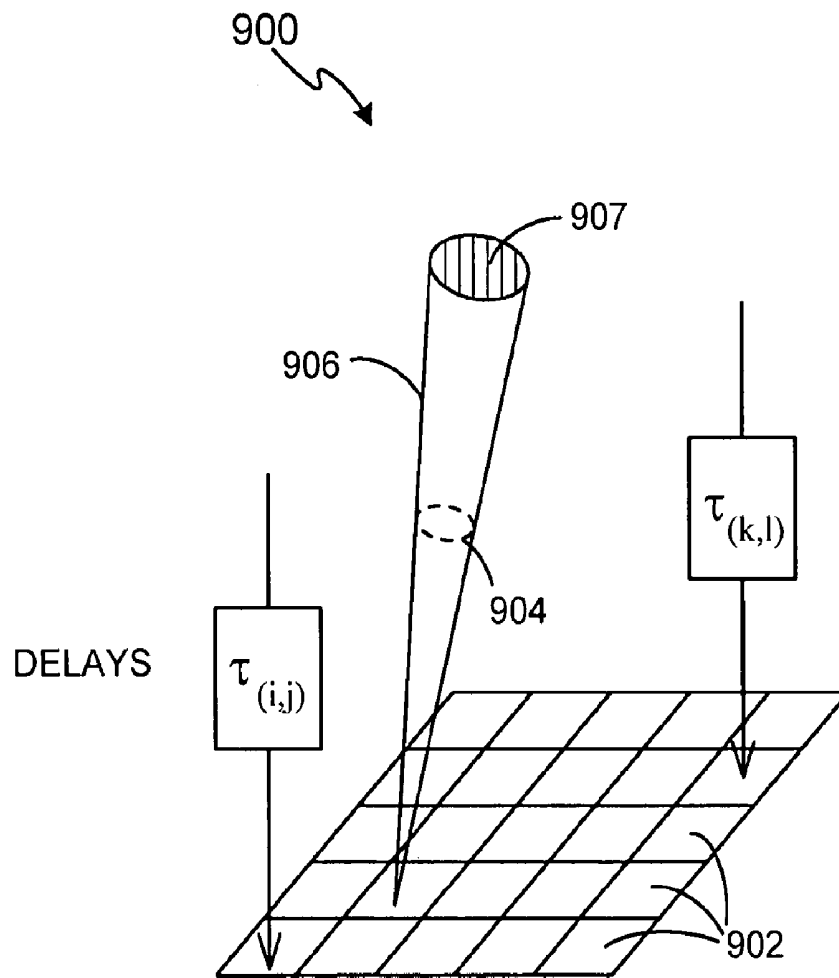


FIG. 9

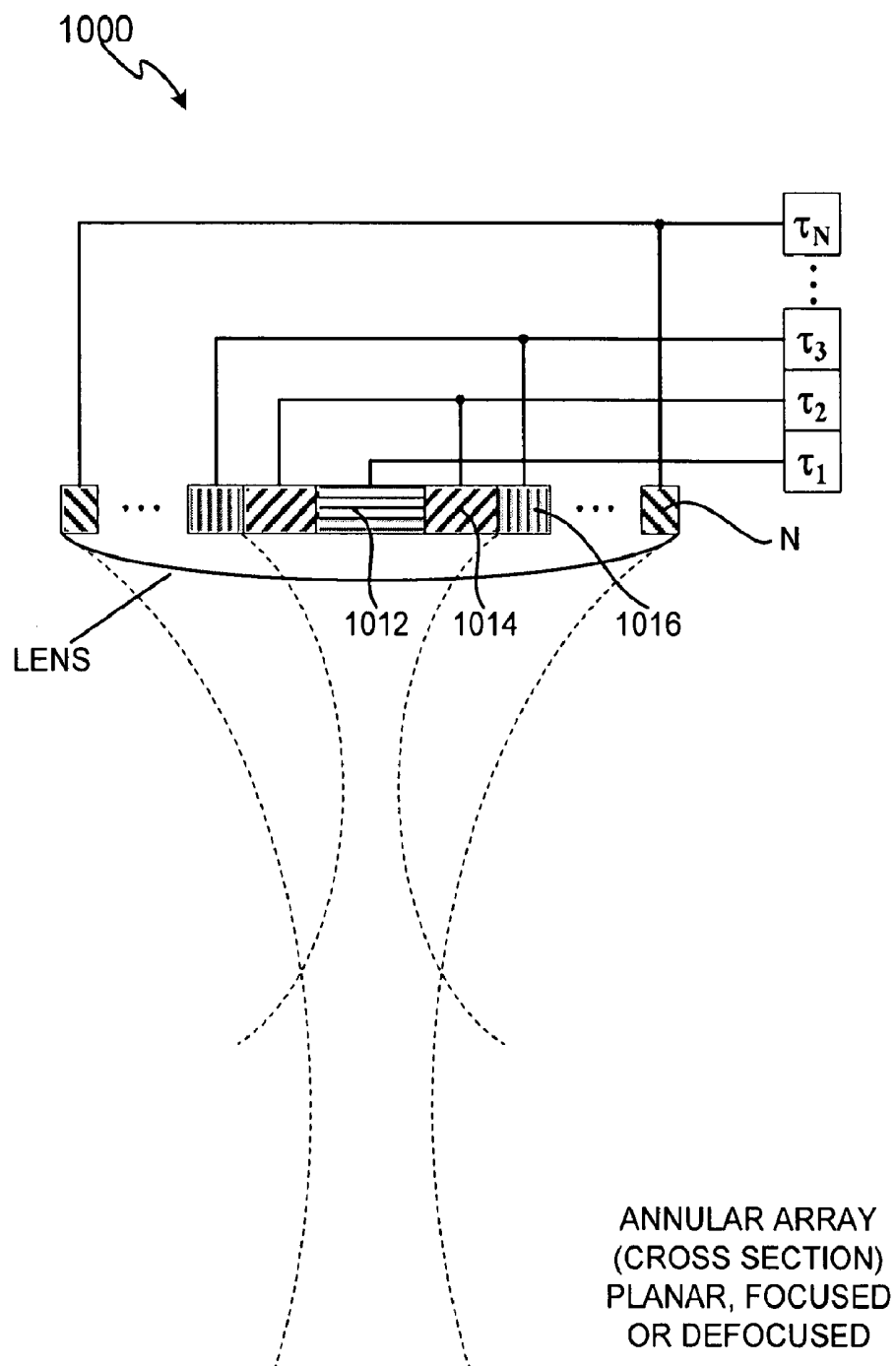
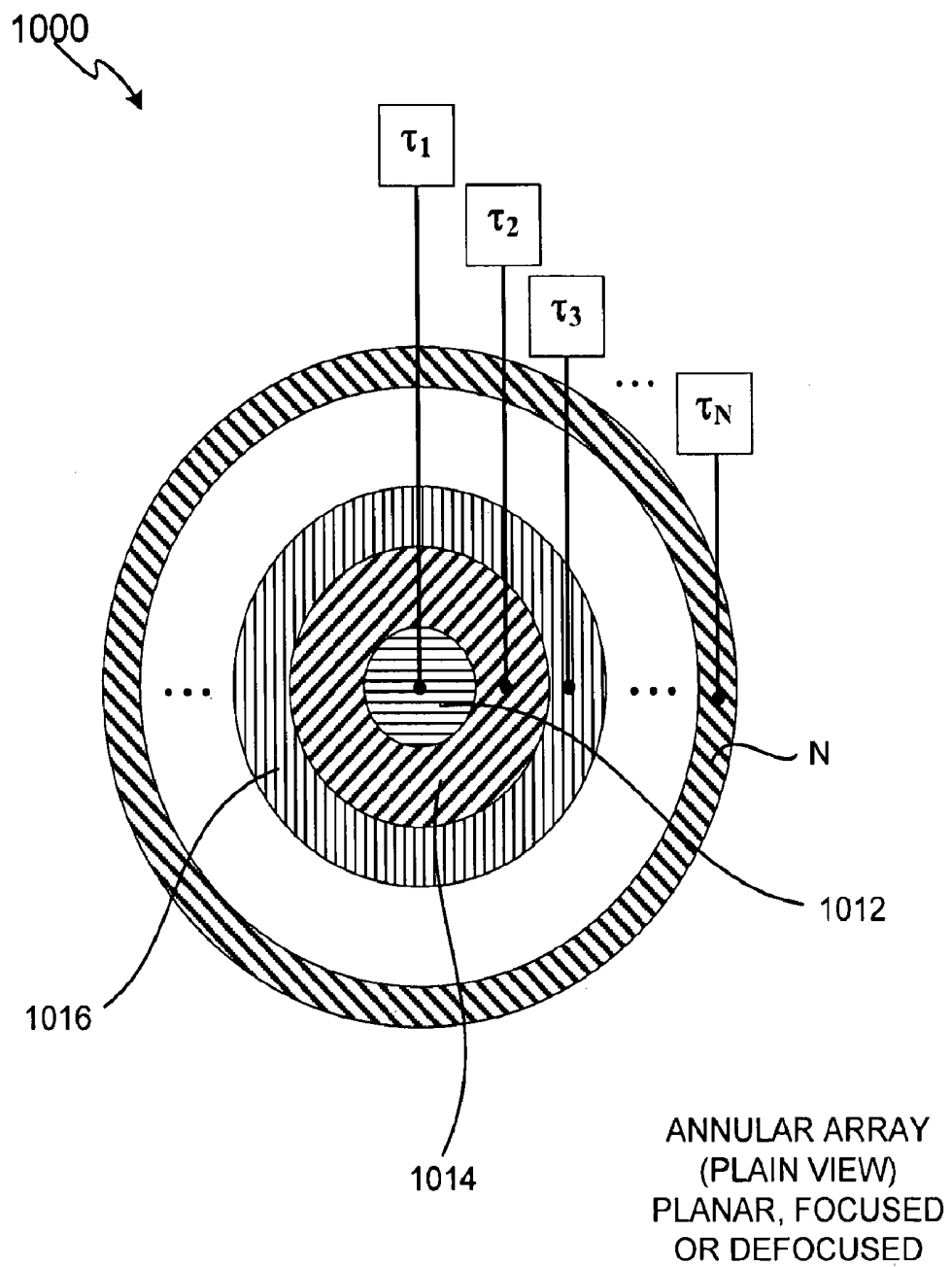


FIG. 10A

**FIG. 10B**

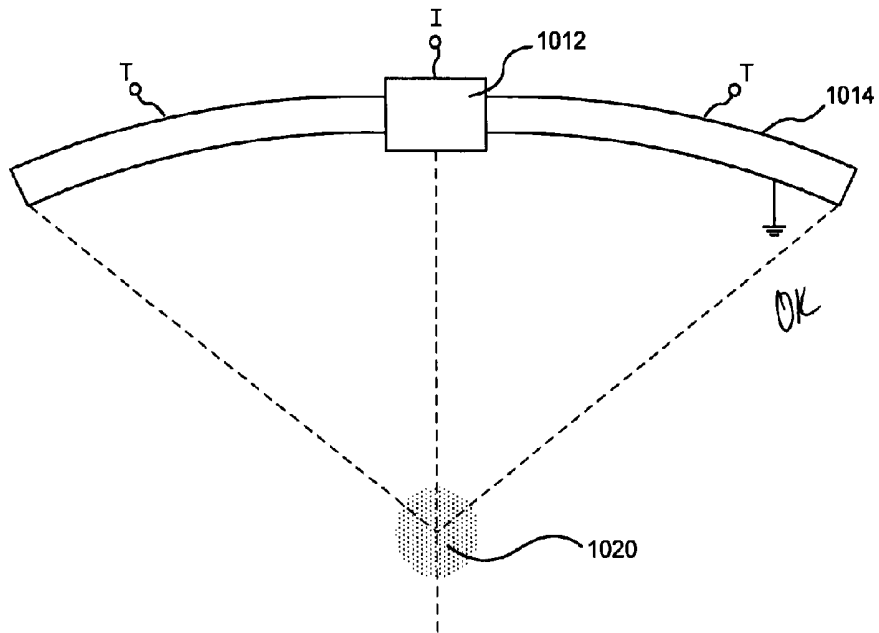


FIG. 10C

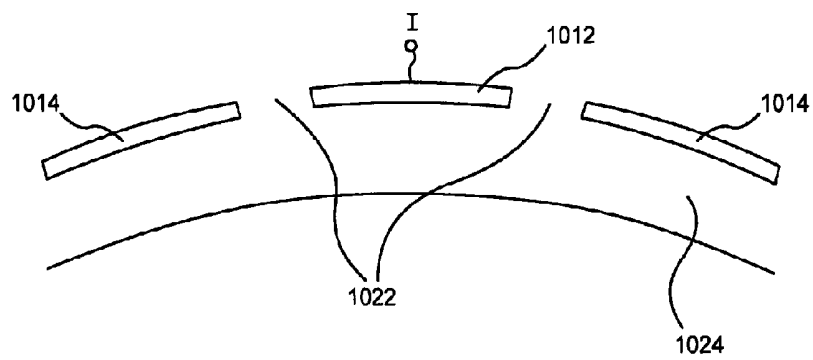


FIG. 10D

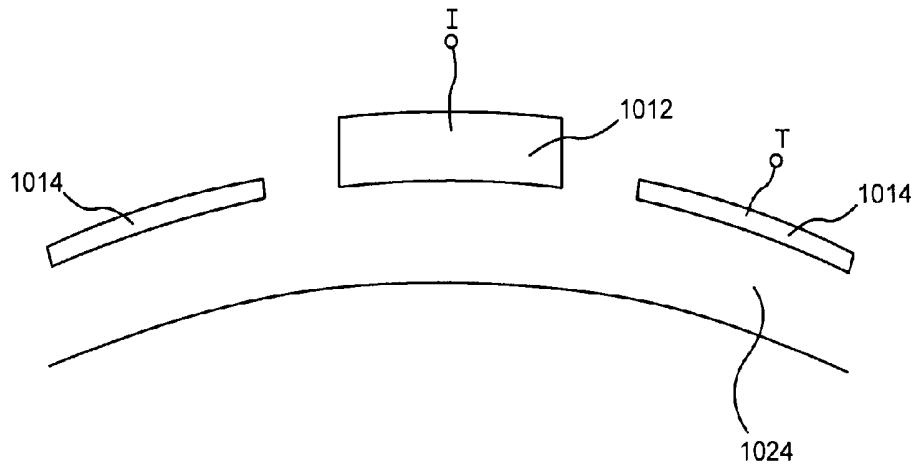


FIG. 10E

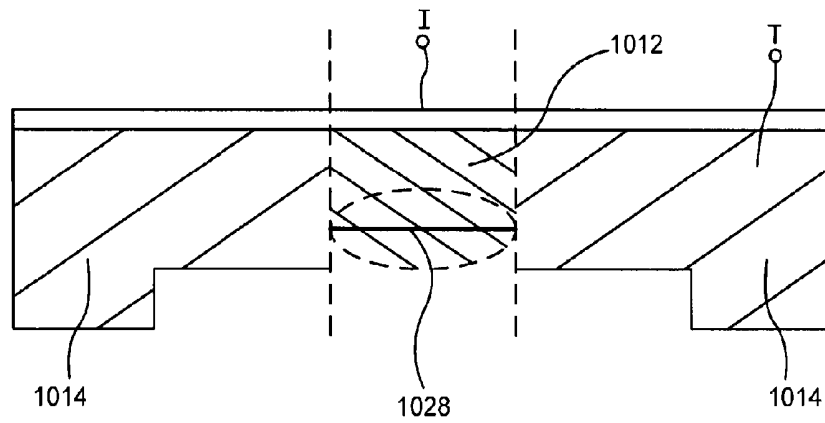


FIG. 10F

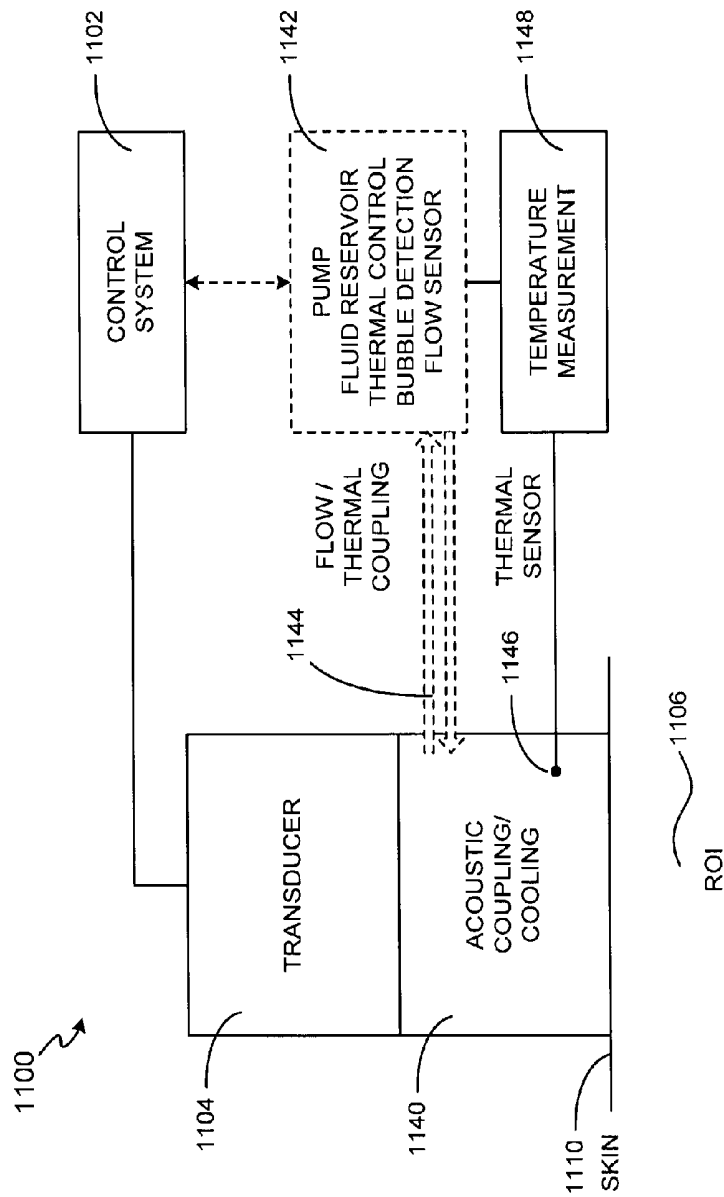
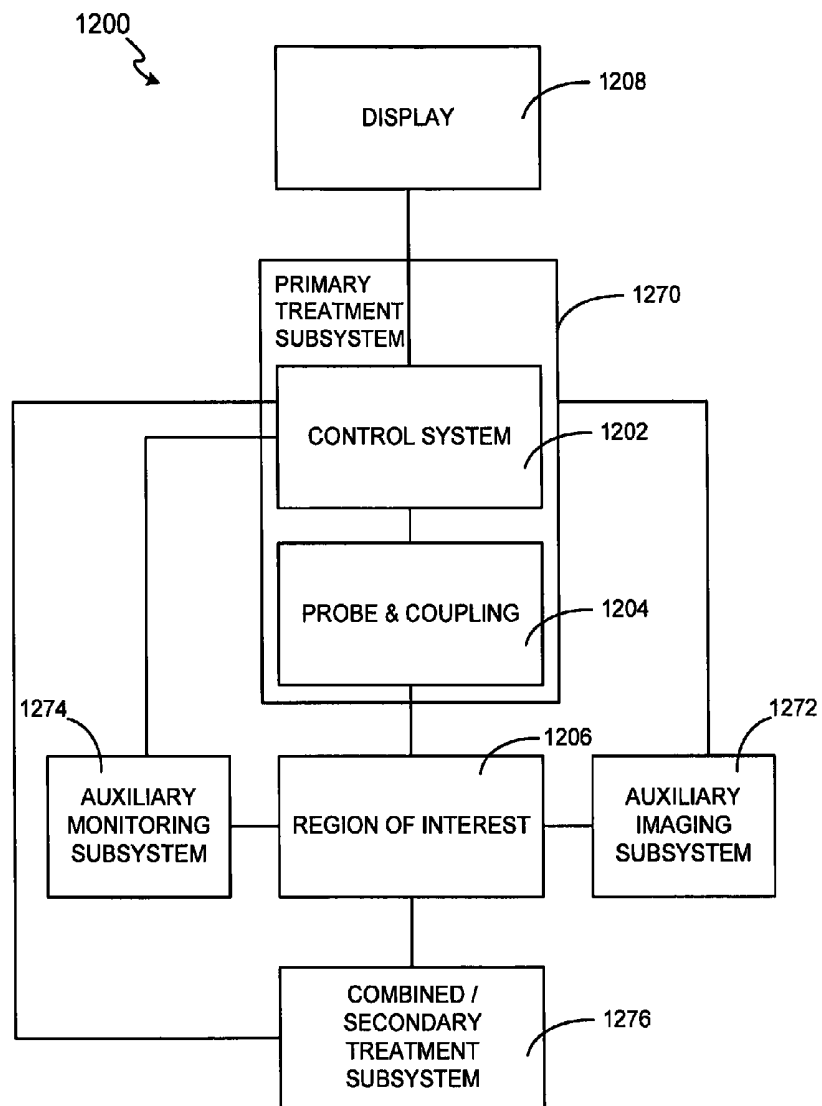
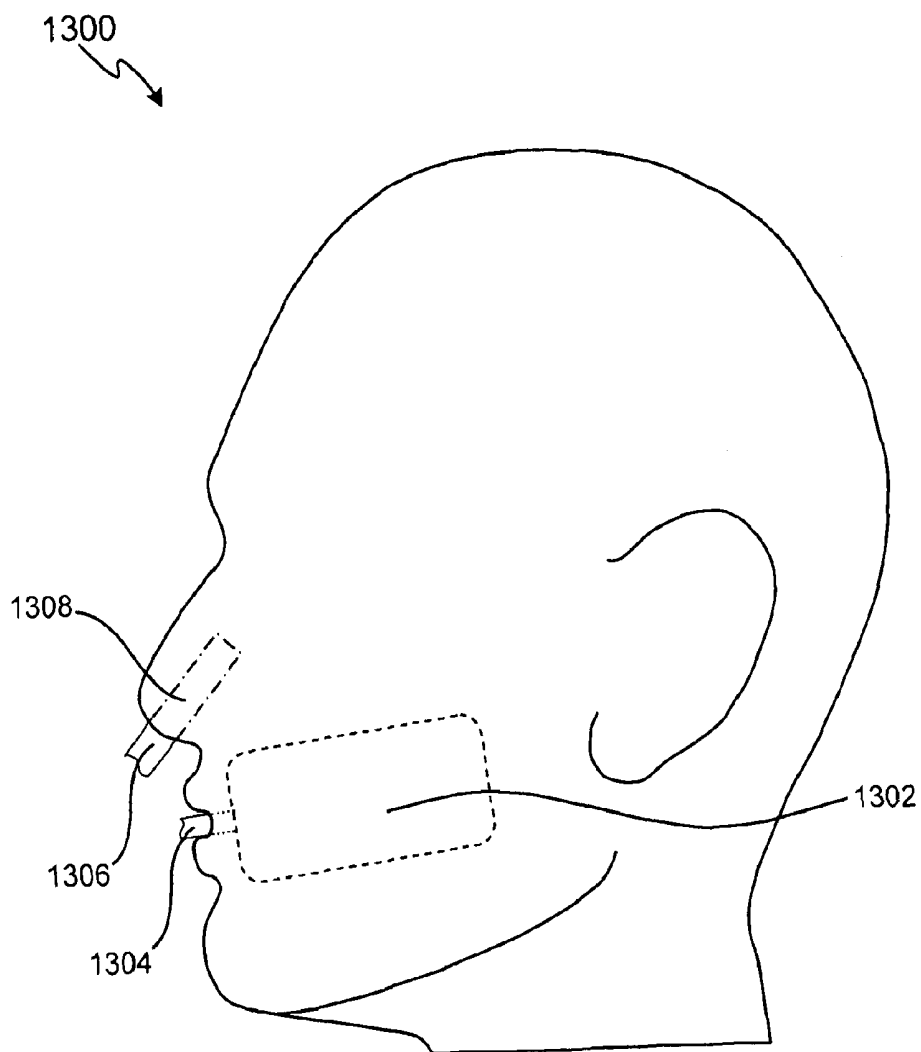


FIG. 11

**FIG. 12**

**FIG. 13**

SYSTEMS FOR TREATING SKIN LAXITY

INCORPORATION BY REFERENCE TO ANY
PRIORITY APPLICATIONS

This application is a continuation of U.S. patent application Ser. No. 14/692,114, issued as U.S. Pat. No. 9,427,600, which is a continuation of U.S. patent application Ser. No. 14/169,709, issued as U.S. Pat. No. 9,039,619, which is a continuation of U.S. patent application Ser. No. 13/230,498, issued as U.S. Pat. No. 8,641,622, which is a continuation of U.S. patent application Ser. No. 11/163,150, issued as U.S. Pat. No. 8,066,641, which claims the benefit of priority to U.S. Provisional Application No. 60/617,295, each of which is incorporated in its entirety by reference herein. 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.

BACKGROUND

The present invention relates to ultrasound therapy and imaging systems, and in particular to a method and system for treating photoaged tissue.

Photoaging of human skin is a complex response due to inflammation, oxidative injury, cellular and extracellular changes induced by decades of sunlight exposure. UV wavelengths are thought to be mainly responsible. Both of the primary skin layers, epidermis and dermis, are affected. Epidermal photoaging includes pigmentary lesions called ephelides (freckles) and solar lentigines (larger pigmented spots), plus precancerous clonal lesions of keratinocytes called actinic keratoses. Thermal destruction of part or all of the epidermis, the outermost cellular layer of skin about 0.1 mm thick, is an effective treatment for epidermal photoaging. For example, lasers that vaporize epidermis are highly effective in a treatment called laser resurfacing. However laser resurfacing creates a significant skin wound with risk of infection, and prolonged healing. Dermal changes of photoaging include solar elastosis (an accumulation of abnormally-formed elastin fibers in the upper reticular layer of the dermis), laxity, loss of elasticity, fine and coarse wrinkles. Laser resurfacing to a depth below the dermoepidermal junction can be highly effective for improving dermal photoaging, through a process of stimulated wound healing. Deep chemical peels, dermabrasion and other methods of destruction of epidermis and/or dermis are also effective, and also produce a significant open skin wound with risk of infection and delayed healing.

Patterns of stimulated thermal damage to epidermis and/or dermis are also effective for treatment of photoaging. Recently, "fractional photothermolysis" using mid-infrared lasers to produce a microscopic array of thermal injury zones that include both epidermis and dermis was reported to be effective and well-tolerated for treatment of photoaging (D. Manstein et al. "Fractional Photothermolysis: a new concept for cutaneous remodeling using microscopic patterns of thermal injury." *Lasers Surg Med* 34:426-438, 2004). A primary advantage of fractional photothermolysis is that each zone of thermal injury is smaller than can be easily seen with the unaided eye, and surrounded by a zone of healthy tissue that initiates a rapid healing response. As described Manstein, the epidermis is stimulated to heal rapidly and without creating an open wound. The microscopic zones of thermally injured epidermis slough harm-

weeks, leaving a rejuvenated epidermis with less photoaging changes. Repeat treatments, which are well tolerated, can be performed until a desired result is obtained. The microscopic zones of thermal injury with fractional photothermolysis extend well into the dermis, as well. Dermis does not heal as rapidly as epidermis, in general. Over weeks to months following treatment, some of the abnormal dermis due to photoaging is remodeled, however, leading to improvement in laxity, wrinkles and skin texture.

Fractional photothermolysis (FP) is intrinsically limited to regions of approximately the upper 1-millimeter of skin. The basic concept of producing well-controlled arrays of thermal injury is therefore limited with fractional photothermolysis, to superficial aspects of photoaging. Aging, which also causes laxity of the skin, and photoaging involve deeper layers of the dermis. Solar elastosis can extend throughout the dermis, to approximately 3 mm deep or more. Laxity and loss of elasticity due to aging are bulk problems of the dermis.

A fundamental requirement for producing arrays of small thermal injury zones using a source of radiant energy that propagates and is absorbed within tissue, is that the source of radiant energy be capable of being adequately delivered to the tissue depth for which the array is desired. Near the skin surface, light can be used, as in fractional photothermolysis. However, light that propagates more than about 1 mm through skin has been multiplied scattered, and can no longer be focused or delivered.

SUMMARY

A method and system for ultrasound treatment of photoaged tissue are provided. An exemplary method and system are configured for first, ultrasound imaging of the region of interest for localization of the treatment area, second, delivery of ultrasound energy at a depth and pattern to achieve the desired therapeutic effects, and third to monitor the treatment area during and after therapy to assess the results and/or provide feedback. The exemplary treatment method and system can be configured for producing arrays of sub-millimeter and larger zones of thermal ablation to treat the epidermal, superficial dermal, mid-dermal and deep dermal components of photoaged tissue.

In accordance with an exemplary embodiment, the treatment method and system use focused, unfocused, and/or defocused ultrasound for treatment of epidermal, superficial dermal, dermal, mid-dermal, and/or deep dermal components of photoaged tissue by adjusting the strength, depth, and/or type of focusing, energy levels and timing cadence. For example, focused ultrasound can be used to create precise arrays of microscopic thermal damage much deeper into the skin or even into subcutaneous structures. Detection of changes in the reflection of ultrasound can be used for feedback control to detect a desired effect on the tissue and used to control the exposure intensity, time, and/or position.

In accordance with an exemplary embodiment, an exemplary treatment system comprises an imaging/therapy probe, a control system and display system. The imaging/therapy probe can comprise various probe and/or transducer configurations. For example, the probe can be configured for a combined dual-mode imaging/therapy transducer, coupled or co-housed imaging/therapy transducers, a separate therapy probe and imaging probe, or a single therapy probe. The control system and display system can also comprise various configurations for controlling probe and system functionality, including for example a microprocessor with software and a plurality of input/output and communication

devices, a system for controlling electronic and/or mechanical scanning and/or multiplexing of transducers, a system for power delivery, systems for monitoring, systems for sensing the spatial position of the probe and/or temporal parameters of the transducers, and systems for handling user input and recording treatment input and results, among others.

BRIEF DESCRIPTION OF THE DRAWINGS

The subject matter of the invention is particularly pointed out in the concluding portion of the specification. The invention, however, both as to organization and method of operation, may best be understood by reference to the following description taken in conjunction with the accompanying drawing figures, in which like parts may be referred to by like numerals:

FIG. 1 illustrates a block diagram of a treatment system in accordance with an exemplary embodiment of the present invention;

FIGS. 2A-2D illustrates a schematic diagram of an ultrasound treatment system including therapy, imaging and/or monitoring and treating photoaged tissue in accordance with various exemplary embodiments of the present invention;

FIGS. 3A and 3B illustrate block diagrams of an exemplary control system in accordance with exemplary embodiments of the present invention;

FIGS. 4A and 4B illustrate block diagrams of an exemplary probe system in accordance with exemplary embodiments of the present invention;

FIG. 5 illustrates a cross-sectional diagram of an exemplary transducer in accordance with an exemplary embodiment of the present invention;

FIGS. 6A and 6B illustrate cross-sectional diagrams of an exemplary transducer in accordance with exemplary embodiments of the present invention;

FIG. 7 illustrates exemplary transducer configurations for ultrasound treatment in accordance with various exemplary embodiments of the present invention;

FIGS. 8A and 8B illustrate cross-sectional diagrams of an exemplary transducer in accordance with another exemplary embodiment of the present invention;

FIG. 9 illustrates an exemplary transducer configured as a two-dimensional, array for ultrasound treatment in accordance with an exemplary embodiment of the present invention;

FIGS. 10A-10F illustrate cross-sectional diagrams of exemplary transducers in accordance with other exemplary embodiments of the present invention;

FIG. 11 illustrates a schematic diagram of an acoustic coupling and cooling system in accordance with an exemplary embodiment of the present invention;

FIG. 12 illustrates a block diagram of an ultrasound treatment system combined with additional subsystems and methods of treatment monitoring and/or treatment imaging as well as a secondary treatment subsystem in accordance with an exemplary embodiment of the present invention; and

FIG. 13 illustrates a schematic diagram with imaging, therapy, or monitoring being provided with one or more active or passive oral inserts in accordance with an exemplary embodiment of the present invention.

DETAILED DESCRIPTION

The present invention may be described herein in terms of various functional components and processing steps. It should be appreciated that such components and steps may

be realized by any number of hardware components configured to perform the specified functions. For example, the present invention may employ various medical treatment devices, visual imaging and display devices, input terminals and the like, which may carry out a variety of functions under the control of one or more control systems or other control devices. In addition, the present invention may be practiced in any number of medical contexts and that the exemplary embodiments relating to a method and system for treating photoaged tissue as described herein are merely indicative of exemplary applications for the invention. For example, the principles, features and methods discussed may be applied to any medical application. Further, various aspects of the present invention may be suitably applied to other applications.

In accordance with various aspects of the present invention, a method and system for treating photoaged tissue are provided. For example, in accordance with an exemplary embodiment, with reference to FIG. 1, an exemplary treatment system 100 configured to treat a region of interest (ROI) 106 comprises a control system 102, an imaging/therapy probe with acoustic coupling 104, and a display system 108. Control system 102 and display 108 can comprise various configurations for controlling functionality of probe 104 and system 100, including for example a micro-processor with software and a plurality of input/output and communication devices, a system for controlling electronic and/or mechanical scanning and/or multiplexing of transducers, a system for power delivery, systems for monitoring, systems for sensing the spatial position of the probe and/or temporal parameters of the transducers, and/or systems for handling user input and recording treatment input and results, among others. Imaging/therapy probe 104 can comprise various probe and/or transducer configurations. For example, probe 104 can be configured for a combined dual-mode imaging/therapy transducer, coupled or co-housed imaging/therapy transducers, a separate therapy probe and separate imaging probe, or a single therapy probe. In accordance with exemplary embodiments, imaging transducers may operate at frequencies from approximately 2 to 75 MHz or more, while therapy energy can be delivered at frequencies from approximately 2 to 50 MHz, with 2 MHz to 25 MHz being typical.

For the treatment of photoaged tissue, it is desirable to be able to produce well controlled arrays of microscopic zones of thermal injury not only near the surface of skin, but in the mid-dermis, and/or in the deep dermis. Thermal ablation of dermis at temperatures greater than about 60° C., capable of producing denaturation of tissue, is also desirable in such arrays of thermal lesions. Shrinkage of dermis due to thermal action results from tightening of the skin.

In contrast to optical or RF approaches, ultrasound energy propagates as a wave with relatively little scattering, over depths up to many centimeters in tissue depending on the ultrasound frequency. The focal spot size achievable with any propagating wave energy, depends on wavelength. Ultrasound wavelength is equal to the acoustic velocity divided by the ultrasound frequency. Attenuation (absorption, mainly) of ultrasound by tissue also depends on frequency.

In accordance with an exemplary embodiment, the use of focused, unfocused, or defocused ultrasound for treatment of epidermal, superficial dermal, dermal, middermal, and deep dermal components of photoaged tissue through adjustment of the strength, depth, and type of focusing, energy levels and timing cadence. For example, focused ultrasound can be used to create precise arrays of microscopic thermal ablation

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zones which have several advantages over fractional photothermolysis (FP). At high frequency and with superficial focusing or diffraction pattern, ultrasound ablation can mimic FP but utilize a simpler ablation device. Unlike fractional photothermolysis, ultrasound can produce an array of ablation zones much deeper into the skin or even into subcutaneous structures. Detection of changes in the reflection of ultrasound can be used for feedback control to detect a desired effect on the tissue and used to control the exposure intensity, time, and/or position.

To further illustrate the use of ultrasound for the treatment of photoaged tissue, with reference to FIG. 2A, an exemplary method and system are configured for initially imaging a region 222 of a region of interest 206 and displaying that region 224 during the localization of the treatment area and surrounding structures. After localization, delivery of ultrasound energy 220 at a depth, distribution, timing, and energy level to achieve the desired therapeutic effect of thermal ablation to treat an epidermis layer 212, superficial dermis layer 214, mid-dermis layer 216, and/or deep dermis layer 218 can be provided. Before, during, and after therapy, i.e., before, during, and after the delivery of ultrasound energy 220, exemplary method and system 200 can suitably monitor the treatment area and surrounding structures to plan and assess the results and/or provide feedback to control system 202 and/or a system user.

While an imaging function may be configured within control system 202 to facilitate imaging a region of interest, in accordance with another exemplary embodiment, an exemplary treatment system 200 may also be configured for therapy only or therapy and monitoring, without imaging functions. In such a case prior known depth of the region of interest, approximately 0 to 5 mm or less, is employed to achieve treatment zones in photoaged skin.

Probe 204 and/or transducers within can be mechanically and/or electronically scanned in a direction 226 to place treatment zones 260 over an extended area, such as a line to generate a matrix of closely spaced treatment spots. Treatment depth 220 can be adjusted between a range of approximately 0 to 5 mm, or otherwise until the depth of the deep dermis. Treatment may be confined to a fixed depth or a few discrete depths, or can be adjustment limited to a fine range, e.g. from approximately between 0 to 5 mm or the greatest depth of the deep dermis, or can be dynamically adjusted during treatment, to the treat region of interest 206 that lies above subcutaneous fat region 250.

In accordance with another exemplary embodiment of the present invention, with reference to FIG. 2B, a treated zone 260 may extend throughout regions of the dermis, and may even extend to the epidermis, 262. In addition, as a treated zone increases in depth its cross section may increase from small size 264 (sub millimeter) in a shallow region near or at the epidermis, to medium size 266 (sub millimeter to millimeter sized) in a middle zone near or at the mid dermis, to large size 268 (millimeter sized) in deep zones near or at the deep dermis. Furthermore a. single treated zone can have a shape expanding in cross section with depth, and/or be composed of the fusion of several smaller treatment zones. Spacing of treatment zones can be on the order of the treatment zone size. The ultrasound beam can be spatially and/or temporally controlled by changing the position of the transducer, its frequency, treatment depth, drive amplitude, and timing via the control system. For example, the ultrasound beam can be controlled as set forth in U.S. patent application Ser. No. 11/163,148, filed Oct. 6, 2005, and entitled METHOD AND SYSTEM FOR COTROLLED

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THERMAL INJURY OF HUMAN SUPERFICIAL TISSUE, and hereby incorporated by reference.

In accordance with another exemplary embodiment of the present invention, with reference to FIG. 2C, an exemplary treatment method and system 200 may be configured to monitor the temperature profile or other tissue parameters of region of interest 206, such as attenuation or speed of sound of the treatment region and suitably adjust the spatial and/or temporal characteristics and energy levels of the ultrasound therapy transducer. The results of such monitoring techniques may be indicated on display 208, such as through display of one-, two-, or three-dimensional images of monitoring results 270, or may comprise an indicator 272, such as a success, fail and/or completed/done type of indication, or combinations thereof. Additional treatment monitoring methods may be based on one or more of temperature, video, profilometry, strain imaging and/or gauges or any other suitable sensing method.

In accordance with another exemplary embodiment, with reference to FIG. 20, an expanded region of interest 280 can suitably include a combination of tissues, such as subcutaneous fat/adipose tissue 250. A combination of such tissues includes at least one of epidermis 212, superficial dermis 214, mid dermis 216, or deep dermis 218, in combination with at least one of muscle tissue, adipose tissue, or other tissues useful for treatment. For example, treatment 260 of superficial dermis may be performed in combination with treatment 220 of subcutaneous fat 250 by suitable adjustment of the spatial and temporal parameters of transducers in probe 204.

An exemplary control system 202 and display system 208 may be configured in various manners for controlling probe and system functionality for providing the various exemplary treatment methods illustrated above. For example, with reference to FIGS. 3A and 3B, in accordance with exemplary embodiments, an exemplary control system 300 can be configured for coordination and control of the entire therapeutic treatment process for producing arrays of sub-millimeter and larger zones of thermal ablation to treat the epidermal, superficial dermal, mid-dermal and deep dermal components of photoaged tissue. For example, control system 300 can suitably comprise power source components 302, sensing and monitoring components 304, cooling and coupling controls 306, and/or processing and control logic components 308. Control system 300 can be configured and optimized in a variety of ways with more or less subsystems and components to implement the therapeutic system for controlled thermal injury of photoaged tissue, and the embodiments in FIGS. 3A and 3B are merely for illustration purposes.

For example, for power sourcing components 302, control system 300 can comprise one or more direct current (DC) power supplies 303 configured to provide electrical energy for entire control system 300, including power required by a transducer electronic amplifier/driver 312. A DC current sense device 305 can also be provided to confirm the level of power going into amplifiers/drivers 312 for safety and monitoring purposes.

Amplifiers/drivers 312 can comprise multi-channel or single channel power amplifiers and/or drivers. In accordance with an exemplary embodiment for transducer array configurations, amplifiers/drivers 312 can also be configured with a beamformer to facilitate array focusing. An exemplary beamformer can be electrically excited by an oscillator/digitally controlled waveform synthesizer 310 with related switching logic.

The power sourcing components can also include various filtering configurations **314**. For example, switchable harmonic filters and/or matching may be used at the output of amplifier/driver **312** to increase the drive efficiency and effectiveness. Power detection components **316** may also be included to confirm appropriate operation and calibration. For example, electric power and other energy detection components **316** may be used to monitor the amount of power going to an exemplary probe system.

Various sensing and monitoring components **304** may also be suitably implemented within control system **300**. For example, in accordance with an exemplary embodiment, monitoring, sensing and interface control components **324** may be configured to operate with various motion detection systems implemented within transducer probe **204** to receive and process information such as acoustic or other spatial and temporal information from a region of interest. Sensing and monitoring components can also include various controls, interfacing and switches **309** and/or power detectors **316**. Such sensing and monitoring components **304** can facilitate open-loop and/or closed-loop feedback systems within treatment system **200**.

Cooling/coupling control systems **306** may be provided to remove waste heat from an exemplary probe **204**, provide a controlled temperature at the superficial tissue interface and deeper into tissue, and/or provide acoustic coupling from transducer probe **204** to region-of-interest **206**. Such cooling/coupling control systems **306** can also be configured to operate in both open-loop and/or closed-loop feedback arrangements with various coupling and feedback components.

Processing and control logic components **308** can comprise various system processors and digital control logic **307**, such as one or more of microcontrollers, microprocessors, field-programmable gate arrays (FPGAs), computer boards, and associated components, including firmware and control software **326**, which interfaces to user controls and interfacing circuits as well as input/output circuits and systems for communications, displays, interfacing, storage, documentation, and other useful functions. System software and firmware **326** controls all initialization, timing, level setting, monitoring, safety monitoring, and all other system functions required to accomplish user-defined treatment objectives. Further, various control switches **308** can also be suitably configured to control operation.

An exemplary transducer probe **204** can also be configured in various manners and comprise a number of reusable and/or disposable components and parts in various embodiments to facilitate its operation. For example, transducer probe **204** can be configured within any type of transducer probe housing or arrangement for facilitating the coupling of transducer to a tissue interface, with such housing comprising various shapes, contours and configurations. Transducer probe **204** can comprise any type of matching, such as for example, electric matching, which may be electrically switchable; multiplexer circuits and/or aperture/element selection circuits; and/or probe identification devices, to certify probe handle, electric matching, transducer usage history and calibration, such as one or more serial EEPROM (memories). Transducer probe **204** may also comprise cables and connectors; motion mechanisms, motion sensors and encoders; thermal monitoring sensors; and/or user control and status related switches, and indicators such as LEDs. For example, a motion mechanism in probe **204** may be used to controllably create multiple lesions, or sensing of probe motion itself may be used to controllably create multiple lesions and/or stop creation of lesions, e.g. for safety reasons

if probe **204** is suddenly jerked or is dropped. In addition, an external motion encoder arm may be used to hold the probe during use, whereby the spatial position and attitude of probe **104** is sent to the control system to help controllably create lesions. Furthermore, other sensing functionality such as profilometers or other imaging modalities may be integrated into the probe in accordance with various exemplary embodiments.

With reference to FIGS. **4A** and **4B**, in accordance with an exemplary embodiment, a transducer probe **400** can comprise a control interface **402**, a transducer **404**, coupling components **406**, and monitoring/sensing components **408**, and/or motion mechanism **410**. However, transducer probe **400** can be configured and optimized in a variety of ways with more or less parts and components to provide ultrasound energy for controlled thermal injury of photoaged tissue, and the embodiments in FIGS. **4A** and **4B** are merely for illustration purposes.

Control interface **402** is configured for interfacing with control system **300** to facilitate control of transducer probe **400**. Control interface components **402** can comprise multiplexer/aperture select **424**, switchable electric matching networks **426**, serial EEPROMs and/or other processing components and matching and probe usage information **430** and interface connectors **432**.

Coupling components **406** can comprise various devices to facilitate coupling of transducer probe **400** to a region of interest. For example, coupling components **406** can comprise cooling and acoustic coupling system **420** configured for acoustic coupling of ultrasound energy and signals. Acoustic cooling/coupling system **420** with possible connections such as manifolds may be utilized to couple sound into the region-of-interest, control temperature at the interface and deeper into tissue, provide liquid-filled lens focusing, and/or to remove transducer waste heat. Coupling system **420** may facilitate such coupling through use of various coupling mediums, including air and other gases, water and other fluids, gels, solids, and/or any combination thereof, or any other medium that allows for signals to be transmitted between transducer active elements **412** and a region of interest. In addition to providing a coupling function, in accordance with an exemplary embodiment, coupling system **420** can also be configured for providing temperature control during the treatment application. For example, coupling system **420** can be configured for controlled cooling of an interface surface or deeper region between transducer probe **400** and a region of interest and beyond by suitably controlling the temperature of the coupling medium. The suitable temperature for such coupling medium can be achieved in various manners, and utilize various feedback systems, such as thermocouples, thermistors or any other device or system configured for temperature measurement of a coupling medium. Such controlled cooling can be configured to further facilitate spatial and/or thermal energy delivery control of transducer probe **400**.

In accordance with an exemplary embodiment, with additional reference to FIG. **11**, acoustic coupling and cooling **1140** can be provided to acoustically couple energy and imaging signals from transducer probe **1104** to and from the region of interest **1102**, to provide thermal control at the probe to region-of-interest interface **1110** and deeper into tissue, and to remove potential waste heat from the transducer probe at region **1144**. Temperature monitoring can be provided at the coupling interface via a thermal sensor **1146** to provide a mechanism of temperature measurement **1148** and control via control system **1106** and a thermal control system **1142**. Thermal control may consist of passive cool-

ing such as via heat sinks or natural conduction and convection or via active cooling such as with peltier thermoelectric coolers, refrigerants, or fluid-based systems comprised of pump, fluid reservoir, bubble detection, flow sensor, flow channels/tubing 1144 and thermal control 1142.

With continued reference to FIG. 4, monitoring and sensing components 408 can comprise various motion and/or position sensors 416, temperature monitoring sensors 418, user control and feedback switches 414 and other like components for facilitating control by control system 300, e.g., to facilitate spatial and/or temporal control through open-loop and closed-loop feedback arrangements that monitor various spatial and temporal characteristics.

Motion mechanism 410 can comprise manual operation, mechanical arrangements, or some combination thereof. For example, a motion mechanism 422 can be suitably controlled by control system 300, such as through the use of accelerometers, encoders or other position/orientation devices 416 to determine and enable movement and positions of transducer probe 400. Linear, rotational or variable movement can be facilitated, e.g., those depending on the treatment application and tissue contour surface.

Transducer 404 can comprise one or more transducers configured for treating of SMAS layers and targeted regions. Transducer 404 can also comprise one or more transduction elements and/or lenses 412. The transduction elements can comprise a piezoelectrically active material, such as lead zirconate titanate (PZT), or any other piezoelectrically active material, such as a piezoelectric ceramic, crystal, plastic, and/or composite materials, as well as lithium niobate, lead titanate, barium titanate, and/or lead metaniobate. In addition to, or instead of, a piezoelectrically active material, transducer 404 can comprise any other materials configured for generating radiation and/or acoustical energy. Transducer 404 can also comprise one or more matching layers configured along with the transduction element such as coupled to the piezoelectrically active material. Acoustic matching layers and/or damping may be employed as necessary to achieve the desired electroacoustic response.

In accordance with an exemplary embodiment, the thickness of the transduction element of transducer 404 can be configured to be uniform. That is, a transduction element 412 can be configured to have a thickness that is substantially the same throughout. In accordance with another exemplary embodiment, the thickness of a transduction element 412 can also be configured to be variable. For example, transduction element(s) 412 of transducer 404 can be configured to have a first thickness selected to provide a center operating frequency of approximately 2 kHz to 75 MHz, such as for imaging applications. Transduction element 412 can also be configured with a second thickness selected to provide a center operating frequency of approximately 2 to 50 MHz, and typically between 2 MHz and 25 MHz for therapy application. Transducer 404 can be configured as a single broadband transducer excited with at least two or more frequencies to provide an adequate output for generating a desired response. Transducer 404 can also be configured as two or more individual transducers, wherein each transducer comprises one or more transduction element. The thickness of the transduction elements can be configured to provide center-operating frequencies in a desired treatment range.

Transducer 404 may be composed of one or more individual transducers in any combination of focused, planar, or unfocused single-element, multi-element, or array transducers, including 1-D, 2-D, and annular arrays; linear, curvilinear, sector, or spherical arrays; spherically, cylindrically,

and/or electronically focused, defocused, and/or lensed sources. For example, with reference to an exemplary embodiment depicted in FIG. 5, transducer 500 can be configured as an acoustic array 502 to facilitate phase focusing. That is, transducer 500 can be configured as an array of electronic apertures that may be operated by a variety of phases via variable electronic time delays. By the term "operated," the electronic apertures of transducer 500 may be manipulated, driven, used, and/or configured to produce and/or deliver an energy beam corresponding to the phase variation caused by the electronic time delay. For example, these phase variations can be used to deliver defocused beams 508, planar beams 504, and/or focused beams 506, each of which may be used in combination to achieve different physiological effects in a region of interest 510. Transducer 500 may additionally comprise any software and/or other hardware for generating, producing and/or driving a phased aperture array with one or more electronic time delays.

Transducer 500 can also be configured to provide focused treatment to one or more regions of interest using various frequencies. In order to provide focused treatment, transducer 500 can be configured with one or more variable depth devices to facilitate treatment. For example, transducer 500 may be configured with variable depth devices disclosed in U.S. patent application Ser. No. 10/944,500, entitled "System and Method for Variable Depth Ultrasound", filed on Sep. 16, 2004, having at least one common inventor and a common Assignee as the present application, and incorporated herein by reference. In addition, transducer 500 can also be configured to treat one or more additional ROI 510 through the enabling of sub-harmonics or pulseecho imaging, as disclosed in U.S. patent application Ser. No. 10/944,499, entitled "Method and System for Ultrasound Treatment with a Multi-directional Transducer," filed on Sep. 16, 2004, having at least one common inventor and a common Assignee as the present application, and also incorporated herein by reference.

Moreover, any variety of mechanical lenses or variable focus lenses, e.g. liquid-filled lenses, may also be used to focus and/or defocus the sound field. For example, with reference to exemplary embodiments depicted in FIGS. 6A and 6B, transducer 600 may also be configured with an electronic focusing array 604 in combination with one or more transduction elements 606 to facilitate increased flexibility in treating ROI 610. Array 604 may be configured in a manner similar to transducer 502. That is, array 604 can be configured as an array of electronic apertures that may be operated by a variety of phases via variable electronic time delays, for example, T1, T2 . . . Tj. By the term "operated," the electronic apertures of array 604 may be manipulated, driven, used, and/or configured to produce and/or deliver energy in a manner corresponding to the phase variation caused by the electronic time delay. For example, these phase variations can be used to deliver defocused beams, planar beams, and/or focused beams, each of which may be used in combination to achieve different physiological effects in ROI 610.

Transduction elements 606 may be configured to be concave, convex, and/or planar. For example, in an exemplary embodiment depicted in FIG. 6A, transduction elements 606 are configured to be concave in order to provide focused energy for treatment of ROI 610. Additional embodiments are disclosed in U.S. patent application Ser. No. 10/944,500, entitled "Variable Depth Transducer System and Method", and again incorporated herein by reference.

In another exemplary embodiment, depicted in FIG. 68, transduction elements 606 can be configured to be substantially flat in order to provide substantially uniform energy to ROI 610. While FIGS. 6A and 68 depict exemplary embodiments with transduction elements 604 configured as concave and substantially flat, respectively, transduction elements 604 can be configured to be concave, convex, and/or substantially flat. In addition, transduction elements 604 can be configured to be any combination of concave, convex, and/or substantially flat structures. For example, a first transduction element can be configured to be concave, while a second transduction element can be configured to be substantially flat.

With reference to FIGS. 8A and 8B, transducer 404 can be configured as single-element arrays, wherein a single-element 802, e.g., a transduction element of various structures and materials, can be configured with a plurality of masks 804, such masks comprising ceramic, metal or any other material or structure for masking or altering energy distribution from element 802, creating an array of energy distributions 808. Masks 804 can be coupled directly to element 802 or separated by a standoff 806, such as any suitably solid or liquid material.

An exemplary transducer 404 can also be configured as an annular array to provide planar, focused and/or defocused acoustical energy. For example, with reference to FIGS. 10A and 10B, in accordance with an exemplary embodiment, an annular array 1000 can comprise a plurality of rings 1012, 1014, 1016 to N. Rings 1012, 1014, 1016 to N can be mechanically and electrically isolated into a set of individual elements, and can create planar, focused, or defocused waves. For example, such waves can be centered on-axis, such as by methods of adjusting corresponding transmit and/or receive delays, T1, T2, T3 . . . TN. An electronic focus can be suitably moved along various depth positions, and can enable variable strength or beam tightness, while an electronic defocus can have varying amounts of defocusing. In accordance with an exemplary embodiment, a lens and/or convex or concave shaped annular array 1000 can also be provided to aid focusing or defocusing such that any time differential delays can be reduced. Movement of annular array 800 in one, two or three-dimensions, or along any path, such as through use of probes and/or any conventional robotic arm mechanisms, may be implemented to scan and/or treat a volume or any corresponding space within a region of interest.

Transducer 404 can also be configured in other annular or non-array configurations for imaging/therapy functions. For example, with reference to FIGS. 10C-10F, a transducer can comprise an imaging element 1012 configured with therapy element(s) 1014. Elements 1012 and 1014 can comprise a single-transduction element, e.g., a combined imaging/transducer element, or separate elements, can be electrically isolated 1022 within the same transduction element or between separate imaging and therapy elements, and/or can comprise standoff 1024 or other matching layers, or any combination thereof. For example, with particular reference to FIG. 10F, a transducer can comprise an imaging element 1012 having a surface 1028 configured for focusing, defocusing or planar energy distribution, with therapy elements 1014 including a stepped-configuration lens configured for focusing, defocusing, or planar energy distribution.

In accordance with various exemplary embodiments of the present invention, transducer 404 may be configured to provide one, two and/or three-dimensional treatment applications for focusing acoustic energy to one or more regions of interest. For example, as discussed above, transducer 404

can be suitably diced to form a one-dimensional array, e.g., transducer 602 comprising a single array of sub-transduction elements.

In accordance with another exemplary embodiment, transducer 404 may be suitably diced in two-dimensions to form a two-dimensional array. For example, with reference to FIG. 9, an exemplary two-dimensional array 900 can be suitably diced into a plurality of two-dimensional portions 902. Two-dimensional portions 902 can be suitably configured to focus on the treatment region at a certain depth, and thus provide respective slices 904, 907 of the treatment region. As a result, the two-dimensional array 900 can provide a two-dimensional slicing of the image plane of a treatment region, thus providing two-dimensional treatment.

In accordance with another exemplary embodiment, transducer 404 may be suitably configured to provide three-dimensional treatment. For example, to provide three-dimensional treatment of a region of interest, with reference again to FIG. 1, a three-dimensional system can comprise a transducer within probe 104 configured with an adaptive algorithm, such as, for example, one utilizing three-dimensional graphic software, contained in a control system, such as control system 102. The adaptive algorithm is suitably configured to receive two-dimensional imaging, temperature and/or treatment or other tissue parameter information relating to the region of interest, process the received information, and then provide corresponding three-dimensional imaging, temperature and/or treatment information.

In accordance with an exemplary embodiment, with reference again to FIG. 9, an exemplary three-dimensional system can comprise a two-dimensional array 900 configured with an adaptive algorithm to suitably receive 904 slices from different image planes of the treatment region, process the received information, and then provide volumetric information 906, e.g., three-dimensional imaging, temperature and/or treatment information. Moreover, after processing the received information with the adaptive algorithm, the two-dimensional array 900 may suitably provide therapeutic heating to the volumetric region 906 as desired.

In accordance with other exemplary embodiments, rather than utilizing an adaptive algorithm, such as three-dimensional software, to provide three-dimensional imaging and/or temperature information, an exemplary three-dimensional system can comprise a single transducer 404 configured within a probe arrangement to operate from various rotational and/or translational positions relative to a target region.

To further illustrate the various structures for transducer 404, with reference to FIG. 7, ultrasound therapy transducer 700 can be configured for a single focus, an array of foci, a locus of foci, a line focus, and/or diffraction patterns. Transducer 700 can also comprise single elements, multiple elements, annular arrays, one-, two-, or three-dimensional arrays, broadband transducers, and/or combinations thereof, with or without lenses, acoustic components, and mechanical and/or electronic focusing. Transducers configured as spherically focused single elements 702, annular arrays 704, annular arrays with damped regions 706, line focused single elements 708, 1-D linear arrays 710, 1-D curvilinear arrays in concave or convex form, with or without elevation focusing, 2-D arrays, and 3-D spatial arrangements of transducers may be used to perform therapy and/or imaging and acoustic monitoring functions. For any transducer configuration, focusing and/or defocusing may be in one plane or two planes via mechanical focus 720, convex lens 722, concave lens 724, compound or multiple lenses 726, planar form 728, or stepped form, such as illustrated in FIG. 10F. Any

transducer or combination of transducers may be utilized for treatment. For example, an annular transducer may be used with an outer portion dedicated to therapy and the inner disk dedicated to broadband imaging wherein such imaging transducer and therapy transducer have different acoustic lenses and design, such as illustrated in FIG. 1 OC-1 OF.

Moreover, such transduction elements **700** may comprise a piezoelectrically active material, such as lead zirconate titanate (PZT), or any other piezoelectrically active material, such as a piezoelectric ceramic, crystal, plastic, and/or composite materials, as well as lithium niobate, lead titanate, barium titanate, and/or lead metaniobate. Transduction elements **700** may also comprise one or more matching layers configured along with the piezoelectrically active material. In addition to or instead of piezoelectrically active material, transduction elements **700** can comprise any other materials configured for generating radiation and/or acoustical energy. A means of transferring energy to and from the transducer to the region of interest is provided.

In accordance with another exemplary embodiment, with reference to FIG. 12, an exemplary treatment system **200** can be configured with and/or combined with various auxiliary systems to provide additional functions. For example, an exemplary treatment system **1200** for treating a region of interest **1202** can comprise a control system **1206**, a probe **1204**, and a display **1208**. Treatment system **1200** further comprises an auxiliary imaging modality **1272** and/or auxiliary monitoring modality **1274** may be based upon at least one of photography and other visual optical methods, magnetic resonance imaging (MRI), computed tomography (CT), optical coherence tomography (OCT), electromagnetic, microwave, or radio frequency (RF) methods, positron emission tomography (PET), infrared, ultrasound, acoustic, or any other suitable method of visualization, localization, or monitoring of epidermal, superficial dermal, mid-dermal and deep dermal components within the region-of-interest **1202**, including imaging/monitoring enhancements. Such imaging/monitoring enhancement for ultrasound imaging via probe **1204** and control system **1206** could comprise M-mode, persistence, filtering, color, Doppler, and harmonic imaging among others; furthermore an ultrasound treatment system **1270**, as a primary source of treatment, may be combined with a secondary source of treatment **1276**, including radio frequency (RF), intense pulsed light (IPL), laser, infrared laser, microwave, or any other suitable energy source.

In accordance with another exemplary embodiment, with reference to FIG. 13, treatment composed of imaging, monitoring, and/or therapy to a region of interest **1302** and/or **1308** may be aided, augmented, and/or delivered with passive or active devices **1304** and/or **1306** within the oral and/or nasal cavity, respectively. For example, if passive or active device **1304** and/or **1306** are second transducers or acoustic reflectors acoustically coupled to the mucous membranes it is possible to obtain through transmission, tomographic, or round-trip acoustic waves which are useful for treatment monitoring, such as in measuring acoustic speed of sound and attenuation, which are temperature dependent; furthermore such transducers could be used to treat and/or image. In addition an active, passive, or active/passive object **1304** and/or **1306** may be used to flatten the skin, and/or may be used as an imaging grid, marker, or beacon, to aid determination of position. A passive or active device **1304** and/or **1306** may also be used to aid cooling or temperature control. Natural air in the oral cavity and/or nasal cavity may also be used as passive device **1304** and/or

1306 whereby it may be utilized to as an acoustic reflector to aid thickness measurement and monitoring function.

The present invention has been described above with reference to various exemplary embodiments. However, those skilled in the art will recognize that changes and modifications may be made to the exemplary embodiments without departing from the scope of the present invention. For example, the various operational steps, as well as the components for carrying out the operational steps, may be implemented in alternate ways depending upon the particular application or in consideration of any number of cost functions associated with the operation of the system, e.g., various of the steps may be deleted, modified, or combined with other steps. These and other changes or modifications are intended to be included within the scope of the present invention, as set forth in the following claims.

What is claimed is:

1. An ultrasound system for treatment of skin laxity, the system comprising:

an ultrasound probe comprising a housing, wherein the housing comprises a motion mechanism and an ultrasound transducer,

wherein the ultrasound transducer comprises a therapy component,

wherein the therapy component consists of:

a single active focused ultrasound therapy element, wherein the ultrasound therapy element is configured to provide a single mechanical focus,

wherein the single mechanical focus is configured to provide ultrasound therapy energy in a form of a single thermal focus in a tissue at a depth below a skin surface,

wherein the depth is a single, fixed depth in a range of up to 5 mm below the skin surface to treat the tissue,

wherein the tissue comprises a combination of any of the group consisting of: an epidermal tissue, a superficial dermal tissue, a mid-dermal tissue, a deep dermal tissue, a muscle tissue, and an adipose tissue,

wherein the single thermal focus is formed without electronic focusing and without a lens,

wherein a portion of the ultrasound probe is configured for acoustic coupling to the skin surface;

a control system connected to the motion mechanism and the ultrasound therapy element;

an input device connected to the control system; and

a power supply connected to the control system;

wherein the ultrasound therapy element is configured for delivery of energy at a temperature sufficient to tighten at least a portion of the tissue at the depth under the skin surface,

wherein the ultrasound therapy element is connected to the motion mechanism,

wherein the motion mechanism moves the ultrasound therapy element to form a plurality of thermal lesions at the depth for tighten at least a portion of the tissue for reducing an appearance of skin laxity.

2. The system of claim 1, wherein the ultrasound therapy element is configured to increase the temperature of the tissue in the region of interest to greater than 60° C.

3. The system of claim 1, further comprising a monitoring system,

wherein the monitoring system is configured to monitor a treatment parameter, wherein the treatment parameter measured comprises a temperature of the tissue below the skin surface,

wherein the housing further comprises a temperature monitoring sensor,

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wherein the therapy element is a single element that delivers ultrasound energy at a frequency of between 2 MHz to 25 MHz.

4. The system of claim 1, wherein the housing contains a temperature monitoring sensor,

wherein the control system comprises a processor, software, and a communication device,
wherein the ultrasound probe is connected to the control system via a cable,

wherein the processor relays data from the temperature monitoring sensor via the communication device.

5. The system of claim 1,

wherein the motion mechanism comprises an encoder and the ultrasound therapy energy is configured to deliver an energy level for causing at least one of shrinking collagen and denaturing the tissue in the region of interest under a wrinkle,

wherein the therapy element delivers the ultrasound therapy energy at a frequency of between 2 MHz to 25 MHz.

6. The system of claim 1, wherein the control system comprises a spatial control and a temporal control,

wherein the spatial control and the temporal control are configured for controlling the delivery of energy at a temperature sufficient to cause denaturation of at least the portion of the tissue at the depth under the skin surface,

wherein the spatial control and the temporal control are configured for controlling the delivery of energy at a frequency of between 2 MHz to 25 MHz.

7. An ultrasound system for treatment of skin laxity, the system comprising:

an ultrasound probe configured for delivery of an ultrasound therapy energy at a temperature sufficient to heat at least a portion of a tissue at a depth under a skin surface,

wherein the tissue comprises a combination of any of the group consisting of: an epidermal tissue, a superficial dermal tissue, a mid-dermal tissue, a deep dermal tissue, a muscle tissue, and an adipose tissue; and a control system;

wherein the ultrasound probe comprises a housing, wherein the housing comprises an ultrasound transducer,

wherein the ultrasound transducer comprises a therapy component,

wherein the therapy component consists of:

a single active ultrasound therapy element,

wherein the single active ultrasound therapy element is configured to provide a single mechanical focus,

wherein the single mechanical focus is configured to provide ultrasound therapy energy in the form of a single thermal focus in the tissue at a depth below a skin surface,

wherein the single thermal focus is formed without electronic focusing and without a lens,

wherein the ultrasound therapy element is in communication with the control system,

wherein the ultrasound therapy element is configured for delivery of the ultrasound therapy energy at the temperature sufficient to heat the at least a portion of the tissue at the depth under the skin surface,

wherein the ultrasound probe forms a plurality of thermal lesions at the depth for reducing the appearance of skin laxity.

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8. The system of claim 7, wherein the region of interest comprises the tissue, wherein the skin surface comprises a wrinkle, and wherein the plurality of thermal lesions tightens the tissue.

9. The system of claim 7, further comprising a monitoring system,

wherein the monitoring system is configured to monitor a treatment parameter, wherein the treatment parameter measured comprises a temperature of the tissue below the skin surface,

wherein the housing further comprises a temperature monitoring sensor, wherein the ultrasound therapy element delivers the ultrasound therapy energy at a frequency of between 2 MHz to 75 MHz.

10. The system of claim 7, wherein the ultrasound probe is connected to the control system via a cable, and wherein the control system comprises:

a communication device;

a processor, software, an input device, and a power supply.

11. The system of claim 7,

wherein the ultrasound therapy element is a single element that delivers the ultrasound therapy energy at a frequency of between 2 MHz to 25 MHz, wherein the ultrasound therapy element is configured to increase the temperature of the tissue in the region of interest to greater than 60° C.

12. An ultrasound system for treatment of skin laxity, the system comprising:

an ultrasound probe comprising a housing, wherein the housing comprises an ultrasound transducer, wherein the ultrasound transducer comprises a therapy component,

wherein the therapy component consists of:

a single active focused ultrasound therapy element, wherein the ultrasound therapy element is configured to provide a single mechanical focus,

wherein the single mechanical focus is configured to provide ultrasound therapy energy in the form of a single thermal focus in a tissue at a depth below a skin surface,

wherein the depth is up to 5 mm below the skin surface, wherein the tissue comprises a combination of any of the group consisting of: an epidermal tissue, a superficial dermal tissue, a mid-dermal tissue, a deep dermal tissue, an adipose tissue, and a muscle tissue, wherein the single thermal focus is formed without electronic focusing and without a lens, and

a control system comprising a processor and power supply;

wherein the ultrasound therapy element is in communication with the control system,

wherein the ultrasound therapy element is configured for delivery of the ultrasound therapy energy at a temperature sufficient to denature at least a portion of the tissue in the region of interest at a depth under the skin surface,

wherein the ultrasound therapy element forms a plurality of thermal lesions at the depth for tightening the tissue for reducing skin laxity.

13. The system of claim 12,

wherein the ultrasound probe is connected to the control system via a cable,

wherein the skin surface comprises a wrinkle.

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14. The system of claim 12, further comprising an acoustic coupler between the ultrasound probe and the skin surface,

wherein the therapy element is a single element that delivers ultrasound energy at a frequency of between 2 5 MHz to 25 MHz,

wherein the housing further comprises a temperature monitoring sensor.

15. The system of claim 12, wherein the ultrasound therapy element is configured to increase the temperature of the tissue in a region of interest to greater than 60° C. 10

16. The system of claim 12, further comprising an ultrasound imaging element co-housed with the ultrasound therapy element in the probe.

17. The system of claim 12, further comprising a monitoring system, 15

wherein the monitoring system is configured to monitor a treatment parameter, wherein the treatment parameter measured comprises a temperature of the tissue below the skin surface.

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18. The system of claim 12,

further comprising a motion mechanism for movement of the ultrasound therapy element to form a plurality of thermal lesions at the depth in the region of interest.

19. The system of claim 12,

further comprising a motion mechanism configured for any one of the group consisting of linear, rotational, and variable movement of the ultrasound therapy element.

20. The system of claim 12,

further comprising a motion mechanism with an encoder for monitoring a position of the ultrasound therapy element,

wherein the therapy element is a single element that delivers the ultrasound therapy energy at a frequency of between 2 MHz to 25 MHz,

wherein the ultrasound therapy element is configured to deliver the ultrasound therapy energy at the depth below the skin surface.

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专利名称(译)	治疗皮肤松弛的系统		
公开(公告)号	US9694211	公开(公告)日	2017-07-04
申请号	US15/248407	申请日	2016-08-26
申请(专利权)人(译)	引导治疗系统 , L.L.C.		
当前申请(专利权)人(译)	引导治疗系统 , L.L.C.		
[标]发明人	BARTHE PETER G SLAYTON MICHAEL H MAKIN INDER RAJ S		
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IPC分类号	A61N7/02 A61B17/32 A61B8/13 A61N7/00 G01S15/89 A61H23/02 A61B8/12 A61B8/08 A61B5/00 A61B8/00		
CPC分类号	A61N7/02 A61B5/682 A61B5/6842 A61B8/08 A61B8/0858 A61B8/12 A61B8/13 A61B8/4483 A61B8/461 A61B8/483 A61B8/546 A61B17/320068 A61H23/0245 A61N7/00 G01S15/8909 A61H2201/5007 A61N2007/0008 A61N2007/0034 A61N2007/0052 A61N2007/027 A61B8/4209 A61B8/4281 A61B8/4455 A61B2017/320069		
优先权	14/169709 2015-05-26 US 13/230498 2014-02-04 US 11/163150 2011-11-29 US 60/617295 2004-10-07 US		
其他公开文献	US20160361573A1		
外部链接	Espacenet USPTO		

摘要(译)

提供了一种用于皮肤松弛的超声治疗的系统和方法。系统和方法可以包括感兴趣区域的超声成像，用于治疗区域的定位，以深度和模式递送超声能量以实现期望的治疗效果，和/或监测治疗区域以评估结果和/或提供反馈。在一个实施例中，治疗系统和方法可以被配置用于产生亚毫米和更大的热消融区域的阵列，以治疗组织的表皮，浅表真皮，中真皮和深真皮组件。

