



(12) **United States Patent**  
**Shimizu et al.**

(10) **Patent No.:** **US 7,531,960 B2**  
(45) **Date of Patent:** **May 12, 2009**

(54) **LIGHT EMITTING DEVICE WITH BLUE LIGHT LED AND PHOSPHOR COMPONENTS**

(58) **Field of Classification Search** ..... 313/498-512;  
428/690; 257/103  
See application file for complete search history.

(75) Inventors: **Yoshinori Shimizu**, Tokushima (JP);  
**Kensho Sakano**, Anan (JP); **Yasunobu Noguchi**, Tokushima (JP); **Toshio Moriguchi**, Anan (JP)

(56) **References Cited**  
U.S. PATENT DOCUMENTS  
3,510,732 A 5/1970 Amans

(73) Assignee: **Nichia Corporation**, Anan-shi (JP)

(\* ) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 233 days.

(Continued)  
FOREIGN PATENT DOCUMENTS  
DE 3804293 A1 8/1989

(21) Appl. No.: **11/682,014**

(22) Filed: **Mar. 5, 2007**

(65) **Prior Publication Data**  
US 2007/0159060 A1 Jul. 12, 2007

**Related U.S. Application Data**

(62) Division of application No. 10/609,402, filed on Jul. 1, 2003, now Pat. No. 7,362,048, which is a division of application No. 09/458,024, filed on Dec. 10, 1999, now Pat. No. 6,614,179, which is a division of application No. 09/300,315, filed on Apr. 28, 1999, now Pat. No. 6,069,440, which is a division of application No. 08/902,725, filed on Jul. 29, 1997, now Pat. No. 5,998,925.

(Continued)  
OTHER PUBLICATIONS

Branko et al., Development and applications of highbright white LED lamps, Nov. 29, 1996, The 264th Proceedings of the Institute of Phosphor Society, pp. 4-16 of the English translation.

(Continued)  
*Primary Examiner*—Joseph L Williams  
(74) *Attorney, Agent, or Firm*—Birch, Stewart, Kolasch & Birch, LLP

(30) **Foreign Application Priority Data**

Jul. 29, 1996 (JP) ..... P 08-198585  
Sep. 17, 1996 (JP) ..... P 08-244339  
Sep. 18, 1996 (JP) ..... P 08-245381  
Dec. 27, 1996 (JP) ..... P 08-359004  
Mar. 31, 1997 (JP) ..... P 09-081010

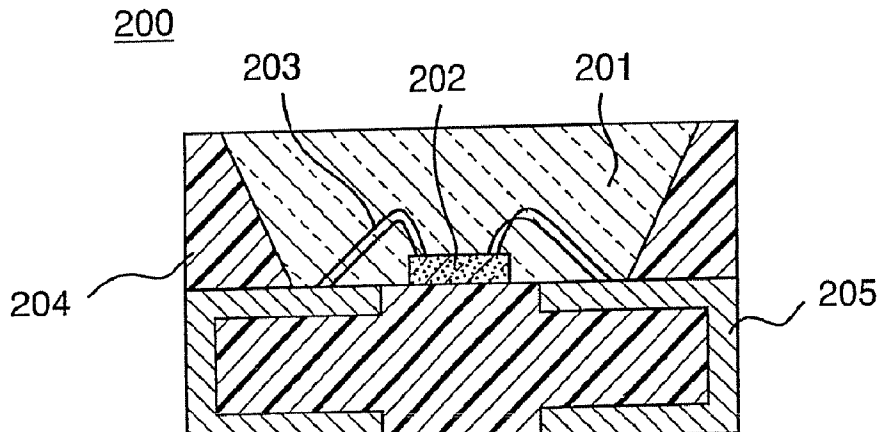
(57) **ABSTRACT**

A light emitting device includes a light emitting component; and a phosphor capable of absorbing a part of light emitted by the light emitting component and emitting light of a wavelength different from that of the absorbed light. A straight line connecting a point of chromaticity corresponding to a peak of the spectrum generated by the light emitting component and a point of chromaticity corresponding to a peak of the spectrum generated by the phosphor is disposed along with the black body radiation locus in the chromaticity diagram.

(51) **Int. Cl.**  
**H05B 33/00** (2006.01)

(52) **U.S. Cl.** ..... 313/512; 257/103; 428/690

**23 Claims, 19 Drawing Sheets**



U.S. PATENT DOCUMENTS						
3,652,956	A	3/1972	Pinnow et al.	JP	01-189695 A	7/1989
3,691,482	A	9/1972	Pinnow et al.	JP	01179471 A	7/1989
3,699,478	A	10/1972	Pinnow et al.	JP	01-257993 A	10/1989
3,819,974	A	6/1974	Stevenson et al.	JP	01-260707 A	10/1989
3,875,456	A	4/1975	Kano et al.	JP	02-111922 A	4/1990
4,298,820	A	11/1981	Bongers et al.	JP	324692	3/1991
4,314,910	A	2/1982	Barnes	JP	03-152898 A	6/1991
4,550,256	A	10/1985	Berkstesser et al.	JP	4-80286 A	3/1992
4,644,223	A	2/1987	de Hair et al.	JP	463162	5/1992
4,716,337	A	12/1987	Huiskes et al.	JP	463163	5/1992
4,727,283	A	2/1988	van Kemenade et al.	JP	4-234481 A	8/1992
4,905,060	A	2/1990	Chinone et al.	JP	5-226676	3/1993
5,006,908	A	4/1991	Matsuoka et al.	JP	05-142424 A	6/1993
5,118,985	A	6/1992	Patton et al.	JP	5152609 A	6/1993
5,202,777	A	4/1993	Sluzky et al.	JP	05152609 A	6/1993
5,257,049	A	10/1993	Van Peteghem	JP	5183189 A	7/1993
5,369,289	A	11/1994	Tamaki et al.	JP	05-63068 U	8/1993
5,471,113	A	11/1995	De Backer et al.	JP	563068	8/1993
5,550,657	A	8/1996	Tanaka et al.	JP	06-027327 A	2/1994
5,578,839	A	11/1996	Nakamura et al.	JP	06-82633 A	3/1994
5,602,418	A	2/1997	Imai et al.	JP	6-115158	4/1994
5,700,713	A	12/1997	Yamazaki et al.	JP	06-139973 A	5/1994
5,798,537	A	8/1998	Nitta	JP	0 599 224 A1	6/1994
5,825,125	A	10/1998	Lighthart et al.	JP	06-160635 A	6/1994
5,847,507	A	12/1998	Butterworth et al.	JP	06-177423 A	6/1994
5,959,316	A	9/1999	Lowery	JP	06177423	6/1994
6,004,001	A	12/1999	Noll	JP	6208845	7/1994
6,066,861	A	5/2000	Hohn et al.	JP	06-231605 A	8/1994
6,538,371	B1	3/2003	Duggal et al.	JP	06260680	9/1994
6,576,930	B2	6/2003	Reeh et al.	JP	06268257	9/1994
6,784,511	B1	8/2004	Kunihara et al.	JP	7-99345 A	4/1995
6,812,500	B2	11/2004	Reeh et al.	JP	07-114904 A	5/1995
2001/0030326	A1	10/2001	Reeh et al.	JP	07-120754 A	5/1995
				JP	7-32638 U	6/1995
				JP	7-42152 U	7/1995
				JP	742152	7/1995
				JP	07176794 A	7/1995
				JP	07-235207 A	9/1995
				JP	07-288341	10/1995
				JP	7-321407	12/1995
				JP	08007614 A	1/1996
				JP	8-78727 A	3/1996
				JP	863119	3/1996
				JP	8170077	7/1996
				JP	09-027642 A	1/1997
				JP	09027642 A	1/1997
				JP	10036835 A	2/1998
				JP	11-500584	1/1999
				JP	2000-512806	9/2000
				JP	2001-320094 A	11/2001
				JP	2002-270020 A	9/2002
				WO	97/50132 A1	12/1997
				WO	98/12757 A1	3/1998

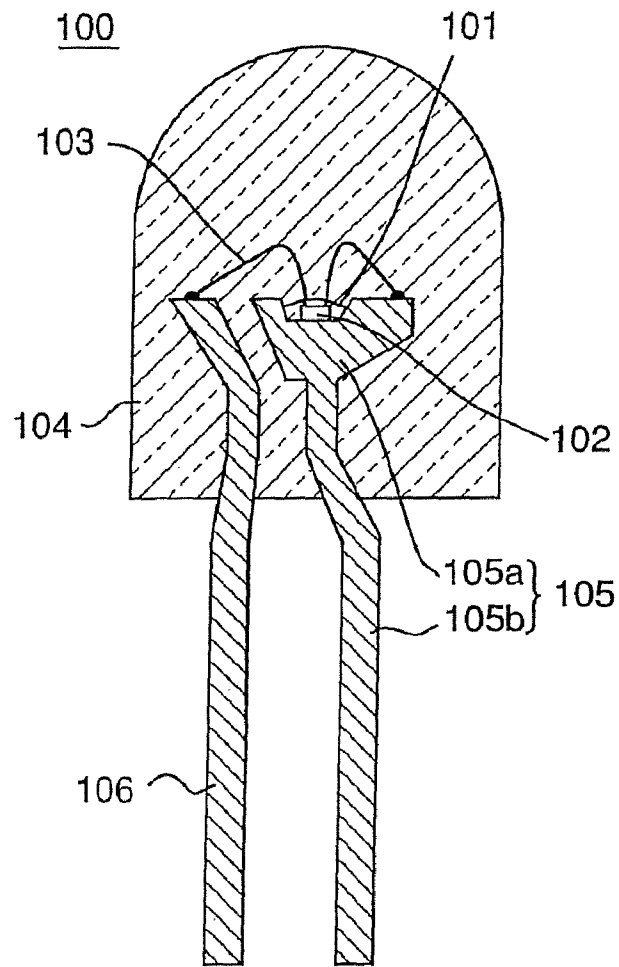
FOREIGN PATENT DOCUMENTS						
DE	9013615	U	1/1991	JP	07176794 A	7/1995
EP	0 209 942	A1	1/1987	JP	07-235207 A	9/1995
EP	0 383 215	A	8/1990	JP	07-288341	10/1995
EP	0 500 937	A1	9/1992	JP	7-321407	12/1995
EP	0 541 373	A2	11/1992	JP	08007614 A	1/1996
EP	0 667 383	A2	8/1995	JP	8-78727 A	3/1996
GB	1 305 111		1/1973	JP	863119	3/1996
GB	2 000 173	A	1/1979	JP	8170077	7/1996
GB	1589964		5/1981	JP	09-027642 A	1/1997
JP	4717684		9/1972	JP	09027642 A	1/1997
JP	49106283		12/1972	JP	10036835 A	2/1998
JP	5079379		11/1973	JP	11-500584	1/1999
JP	491221		1/1974	JP	2000-512806	9/2000
JP	49112577		10/1974	JP	2001-320094 A	11/2001
JP	49-122292		11/1974	JP	2002-270020 A	9/2002
JP	5043913	C1	4/1975	WO	97/50132 A1	12/1997
JP	5245181		10/1977	WO	98/12757 A1	3/1998
JP	53-7153		1/1978			
JP	5331584		3/1978			
JP	5472484		11/1978			
JP	5441660		12/1979			
JP	55-4898	A	1/1980			
JP	55-005533	A	1/1980			
JP	554898	A	1/1980			
JP	59-30107	U	2/1984			
JP	5950445		4/1984			
JP	60144381		7/1985			
JP	60-185457	A	9/1985			
JP	62189770		2/1986			
JP	61-158606		7/1986			
JP	62-20237	A	1/1987			
JP	62167387		7/1987			
JP	621673987		7/1987			

## OTHER PUBLICATIONS

Nikkei Sangyo Shin-bun of Sep. 13, 1996.  
S. Nakaura et al., Japanese Journal of Applied Physics Part 2, vol. 31, No. 10B, 1992, pp. L1457-L1459.  
Mitsubishi Electric Company Technical Report, vol. 48, No. 9, 1974, pp. 1121-1124.  
Proceedings of Illumination National Convention in 1983, p. 12.  
Phosphor Handbook, 1st Edition, 1987, pp. 233-240 and 275-277.  
Journal of the Television Society, vol. 47, No. 5, 1993, pp. 753-764.  
R. W. G. Hunt, Color Research & Application, vol. 16, No. 3, 1991, pp. 146-165.  
Y. Nayatani, Color Research & Application, vol. 20, No. 3, Jun. 1995, pp. 143-155.  
M. Ikeda et al., Color Research & Application, vol. 14, No. 4, Aug. 1989, pp. 198-206.

- H. Shinoda et al., *Color Research & Application*, vol. 18, No. 5, Oct. 1993, pp. 326-333.
- M. Ikeda, *Journal of the Illumination Society*, vol. 71, No. 10, 1987, pp. 612-617 and English Abstract.
- P. Schlouer et al., "Luminescence Conversion of Blue Light Emitting Diodes", *Applied Physics Letter*, vol. 46, p. 417-418, Feb. 1997.
- M.F. Yan et al., Preparation of Y<sub>3</sub>Al<sub>5</sub>O<sub>12</sub>-Based Phosphor Powders, *J. Electrochem. Soc.*, vol. 134, No. 2, Feb. 1987.
- "Proceedings of the Institute of Phosphor Society", Translation of pp. 1, 5 to 14 of the 264th Proceedings of the Institute of Phosphor Society, Nov. 29, 1996.
- Shigeo Shionoya et al. (editors), "Phosphor Handbook", pp. 505-508, CRC Press, 1999.
- E.F. Gibbons et al., "Some Factors Influencing the Luminous Decay Characteristics of Y<sub>3</sub>Al<sub>5</sub>O<sub>12</sub>:Ce<sup>3+</sup>", *J. Electrochem. Soc.*, vol. 120, No. 6, Jun. 1973.
- D.J. Robbins et al., "Lattice Defects and Energy Transfer Phenomena in Y<sub>3</sub>Al<sub>5</sub>O<sub>12</sub>:Ce<sup>3+</sup>", pp. 1004-1013, printed Jun. 19, 2001.
- "White LED lamp: Efficient light-emitting; Manufacture cost half", *Nikkei Sangyo Shimbun*, Sep. 13, 1996, Published by Nihon Keizai Shimbunsha.
- Shuji Nakamura, "InGa<sub>N</sub>/AlGa<sub>N</sub> blue-light-emitting diodes", *J. Vac. Sci. Technol. A* 13(3), May/June. 1995, pp. 705-710.
- Shuji Nakamura et al., "Si-Doped InGa<sub>N</sub> Films Grown on Ga<sub>N</sub> Films", *Jpn. J. Appl. Phys.* vol. 32 (1993), pp. L16-L19, Part 2, No. 1A/B, Jan. 15, 1993.
- Shuji Nakamura et al., "P-GaN/N-InGa<sub>N</sub>/N-GaN Double-Heterostructure Blue-Light-Emitting Diodes", *Jpn. J. Appl. Phys.* vol. 32 (1993), pp. L8-L11, Part 2, No. 1A/B, Jan. 15 1993.
- Shuji Nakamura, "Zn-doped InGa<sub>N</sub> growth and InGa<sub>N</sub>/AlGa<sub>N</sub> double-heterostructure blue-light-emitting diodes", *Journal of Crystal Growth*, 145 (1994), pp. 911-917.
- Shuji Nakamura, "High-Power InGa<sub>N</sub>/AlGa<sub>N</sub> Double-Heterostructure Blue-Light-Emitting Diodes", *IEDM 94* (1994), *IEEE*, pp. 567-570.
- Kozo Osamura et al., "Preparation and optical properties of Ga<sub>1-x</sub>In<sub>x</sub>N thin films", *Journal of Applied Physics*, vol. 46, No. 8, Aug. 1975, pp. 3432-3437.
- Takashi Matsuoka et al., "Growth and Properties of a Wide-Gap Semiconductor InGa<sub>N</sub>", *Optoelectronics-Devices and Technologies*, vol. 5, No. 1, pp. 53-64, Jun. 1990.
- T. Nagatomo et al., "Ga<sub>1-x</sub>In<sub>x</sub>N Blue Light-Emitting Diodes", *Proc. Electrochem. Soc.*, 1993, vol. 93-10, pp. 136-141.
- G. Blasse et al., "Investigation of Some Ce<sup>3+</sup>-Activated Phosphors", *Journal of Chemical Physics*, vol. 47, No. 12, Dec. 15, 1967.
- W.W. Holloway, Jr. et al., "On The Fluorescence of Cerium—Activated Garnet Crystals", *Physics Letters*, vol. 25A, No. 8, Oct. 23, 1967, pp. 614-615.
- E.F. Gibbons et al., "Some Factors Influencing the Luminous Decay Characteristics of Y<sub>3</sub>Al<sub>5</sub>O<sub>12</sub>:Ce<sup>3+</sup>", *J. Electrochem. Soc.*, vol. 120, No. 6.
- W.J. Miniscalco et al., "Measurements of Excited-State Absorption in Ce<sup>3+</sup>:YAGa)", *J. Appl. Phys.* vol. 49, No. 12, Dec. 1978, pp. 6109-6111.
- D.J. Robbins et al., "Lattice Defects and Energy Transfer Phenomena in Y<sub>3</sub>Al<sub>5</sub>O<sub>12</sub>:Ce<sup>3+</sup>", pp. 1004-1013.
- J.M. Robertson, et al., "Colourshift of the Ce<sup>3+</sup> Emission in Monocrystalline Epitaxially Grown Garnet Layers", 1981 *Philips J. Res.* 36, pp. 15-30.
- "Nichia Chemical starts the sample shipment of white light emitting diode", *News Report*, translation of p. 15 of *Nikkei Electronics Sep. 23, 1996* (No. 671).
- Tadao Miura, *Electronics Engineering*, "High-intensity White Backlighting for LCD of Car Audios", *Jul. 1996*, vol. 38, No. 7, pp. 55-58.
- Shigeo Shionoya et al. (editors), "Phosphor Handbook", pp. 505-508, CRC Press.
- M.F. Yan et al., Preparation of Y<sub>3</sub>Al<sub>5</sub>O<sub>12</sub>-Based Phosphor Powders, *J. Electrochem. Soc.*, vol. 134, No. 2.
- "Proceedings of the Institute of Phosphor Society", Translation of pp. 1, 5 to 14 of the 264th Proceedings of the Institute of Phosphor Society.
- "A New Phosphor for Flying-Spot Cathode-Ray Tubes for Color Television: Yellow Emitting . . .", G. Blasse et al., *App. Phys. Lett.* vol. 11, No. 2, pp. 53-55 (1967).
- Glasse et al., *Applied Physics Letters*, vol. 11, No. 2, pp. 53-54 (1967).
- Hoffman, *Journal of les*, pp. 89-91 (1977).
- Nakamura, *SPIE*, vol. 3002, pp. 26-35 (1997).
- "Simens SMT-TOPLED für die Oberflächenmontage" Frank Mollmer et al. *Simens Components*, 29 (1991) *Hfet* 4.
- "Ga<sub>N</sub>p<sub>n</sub> Contact Blue/Ultraviolet light Emitting Diode", H. Amano et al., *Applied Physics*, vol. 20, No. 2, pp. 163-166 (1991).
- "Phosphors Based on Rare-Earths, A New Era in Fluorescent Lighting", B.M.J. Smets, *Materials Chemistry and Physics*, 16 pp. 283-299 (1987).
- W.W. Holloway, Jr. et al., "Optical Properties of Cerium-Activated Garnet Crystals", 1969 *Journal of the Optical Society of America*, vol. 59, No. 1, pp. 60-63.
- Wustlich Mikro-/Opto-Elektronik GMBH (1994/1995).
- Sato et al., *Japanese Journal of Applied Physics*, vol. 35, Jul. 1, 1996, pp. L838-L839.

*Fig. 1*



*Fig. 2*

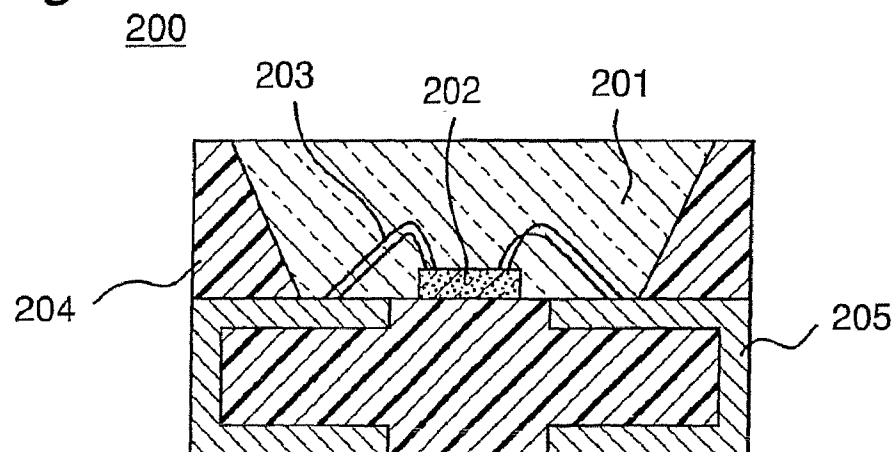


Fig.3A

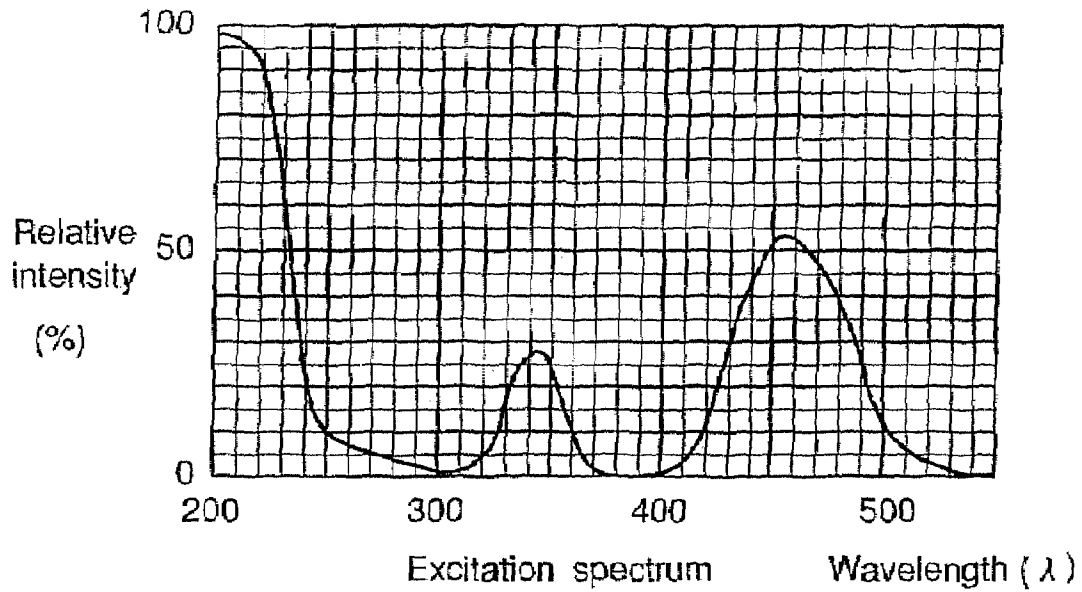
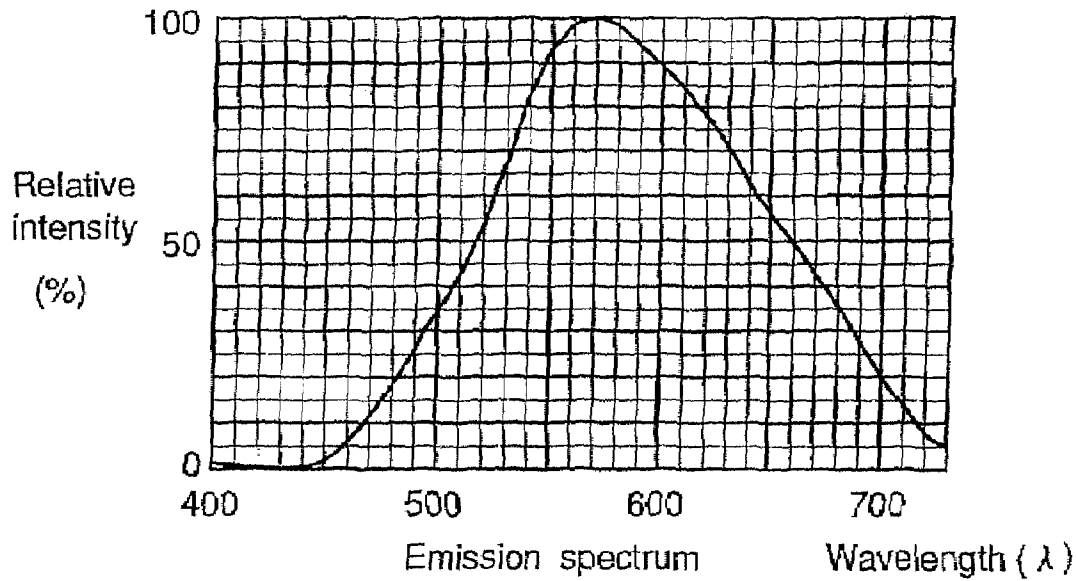


Fig.3B



# Explore Litigation Insights

Docket Alarm provides insights to develop a more informed litigation strategy and the peace of mind of knowing you're on top of things.

## Real-Time Litigation Alerts



Keep your litigation team up-to-date with **real-time alerts** and advanced team management tools built for the enterprise, all while greatly reducing PACER spend.

Our comprehensive service means we can handle Federal, State, and Administrative courts across the country.

## Advanced Docket Research



With over 230 million records, Docket Alarm's cloud-native docket research platform finds what other services can't. Coverage includes Federal, State, plus PTAB, TTAB, ITC and NLRB decisions, all in one place.

Identify arguments that have been successful in the past with full text, pinpoint searching. Link to case law cited within any court document via Fastcase.

## Analytics At Your Fingertips



Learn what happened the last time a particular judge, opposing counsel or company faced cases similar to yours.

Advanced out-of-the-box PTAB and TTAB analytics are always at your fingertips.

## API

Docket Alarm offers a powerful API (application programming interface) to developers that want to integrate case filings into their apps.

## LAW FIRMS

Build custom dashboards for your attorneys and clients with live data direct from the court.

Automate many repetitive legal tasks like conflict checks, document management, and marketing.

## FINANCIAL INSTITUTIONS

Litigation and bankruptcy checks for companies and debtors.

## E-DISCOVERY AND LEGAL VENDORS

Sync your system to PACER to automate legal marketing.