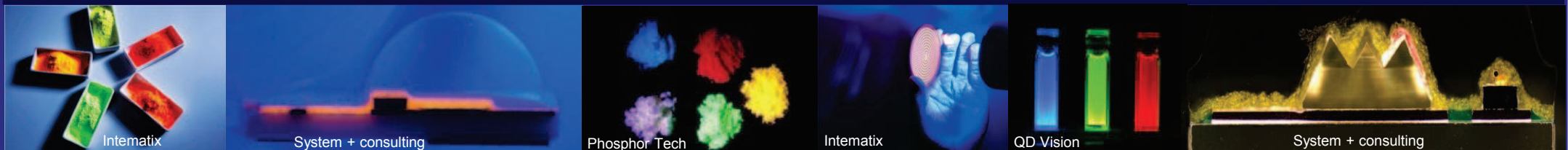


# LED Phosphors and Down-Converters Patent Investigation

Report Sample



Le Quartz  
75 cours Emile Zola, F-69001 Lyon-Villeurbanne, France  
[www.yole.fr](http://www.yole.fr)



2405 route des Dolines  
06902 Sophia Antipolis, France  
[www.knowmade.com](http://www.knowmade.com)

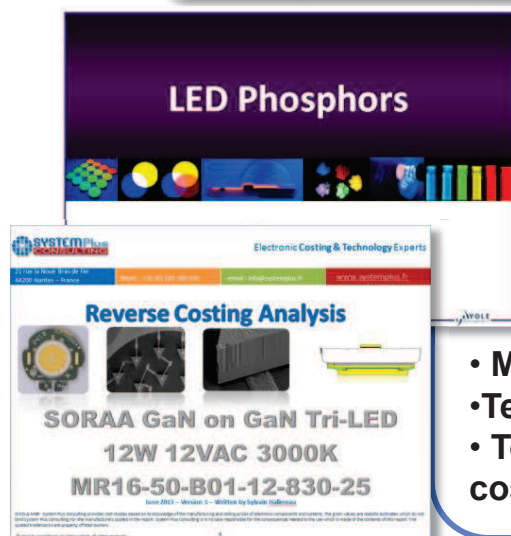
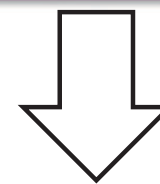
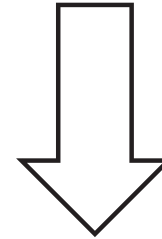
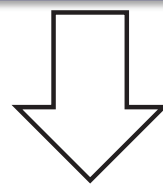
# A New Type of Report Providing a Clear Link between IP Situation and Market Evolutions

More than describing the status of the IP situation, this report provides a missing link between patented technological solutions and market, technological and business trends

- Knowmade has developed a unique methodology to define a technical segmentation of patent landscape and identify key patents.
- By combining their technical knowledge, business understanding and patent search, Yole and Knowmade are able to provide unique analysis and added value you will find in this report
- In-depth technological analysis of patents provided in this report will lead to understanding of strategic decisions and positioning of key players within the value chain

**LED and LED Phosphor Market and Technology analysis and forecast.**

**LED phosphor IP Landscape**

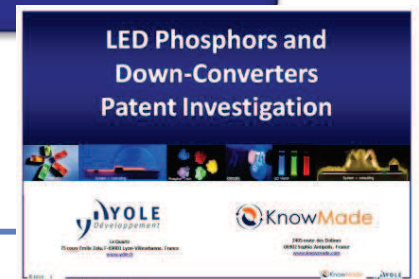


**Yole's Standard Reports:**

- Market Analysis
- Technology Analysis
- Tear down and reverse costing analysis

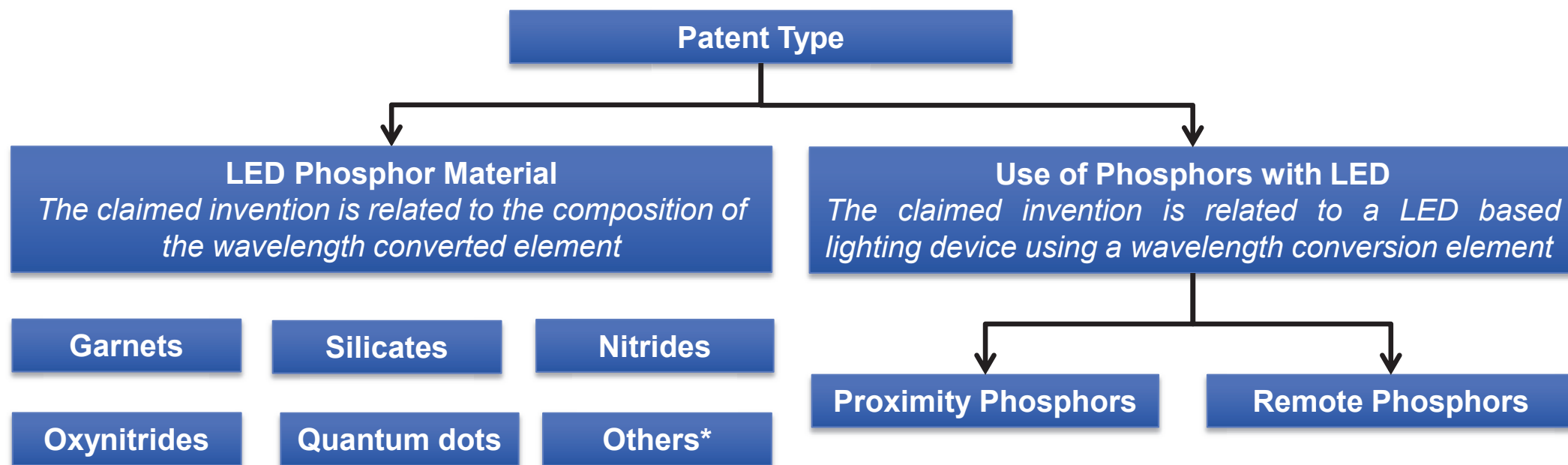
**Yole's / Knowmade New IP Reports:**

- Patent analysis
- Technological segmentations
- Identification of key patents
- Market implication of IP landscape
- Full searchable patent database



# Scope Of the Report

- This report provides a detailed picture of the patent landscape for LED phosphors and other down-converters like quantum dots. This includes statistical analysis by type, compositions, key players and configurations.
- Over the more than 20,000 patent families identified for this project, more than 4,500 relevant to the scope of this report have been analyzed. Those 4500 families have been segmented as follow:



\* Aluminates, Carbidonitrides, Selenides, Phosphates...

# Key Features of the Report:

## What's included and what's not

- The report provide essential market data and forecast for LED Phosphors.
- It identifies more than 50 holders of LED Phosphor related intellectual property. It provides in-depth analysis of technology key segments and key players including:
  - Time evolution of patent filings, priority and publication countries
  - Breakdown and first filing of publication countries
  - Countries of filing for top players
  - Legal status of the patent portfolio
  - Ranking of main patent assignees for both Industry and Academic players.
  - Overview of key patents and collaborations networks between assignees.
  - Patent family citations networks
  - Relative strength of each company IP portfolio.
- A special focus is provided on key composition families and configurations:
  - Garnets
  - Silicates
  - Nitrides, Oxynitrides and Carbidonitrides
  - Quantum Dots
  - Remote Phosphors
- Overview of LED Phosphor related patent litigation and licensing.
- The “Phosphor IP” profiles of more than 15 companies is presented, with key patents, compositions, configurations, IP strategy, litigations, licenses and partnerships.

# Key Features of the Report:

## What's included and what's not

- The report also provides an extensive Excel database with all patents of the company profiled in the report. This database allows multi-criteria searches:
  - **Patent information**
    - Patent publication number
    - Hyperlink to original document
    - Priority date
    - Title
    - Abstract
    - Applicants
  - Technological segments**
    - Garnets
    - Silicates
    - Nitrides/Oxynitrides
    - Quantum Dots
    - Remote Phosphors
- **This report does not:**
  - Provide any insights analyses or counsel regarding legal aspects or the validity of any individual patent: Knowmade and Yole Développement are research firms that provide market and technical analysis and opinions. The research, technical analysis and/or work proposed or provided by Knowmade and contained herein is not a legal opinion and should not be construed as such.
  - Cover phosphor deposition methods or equipments or manufacturing equipments.

# Methodology

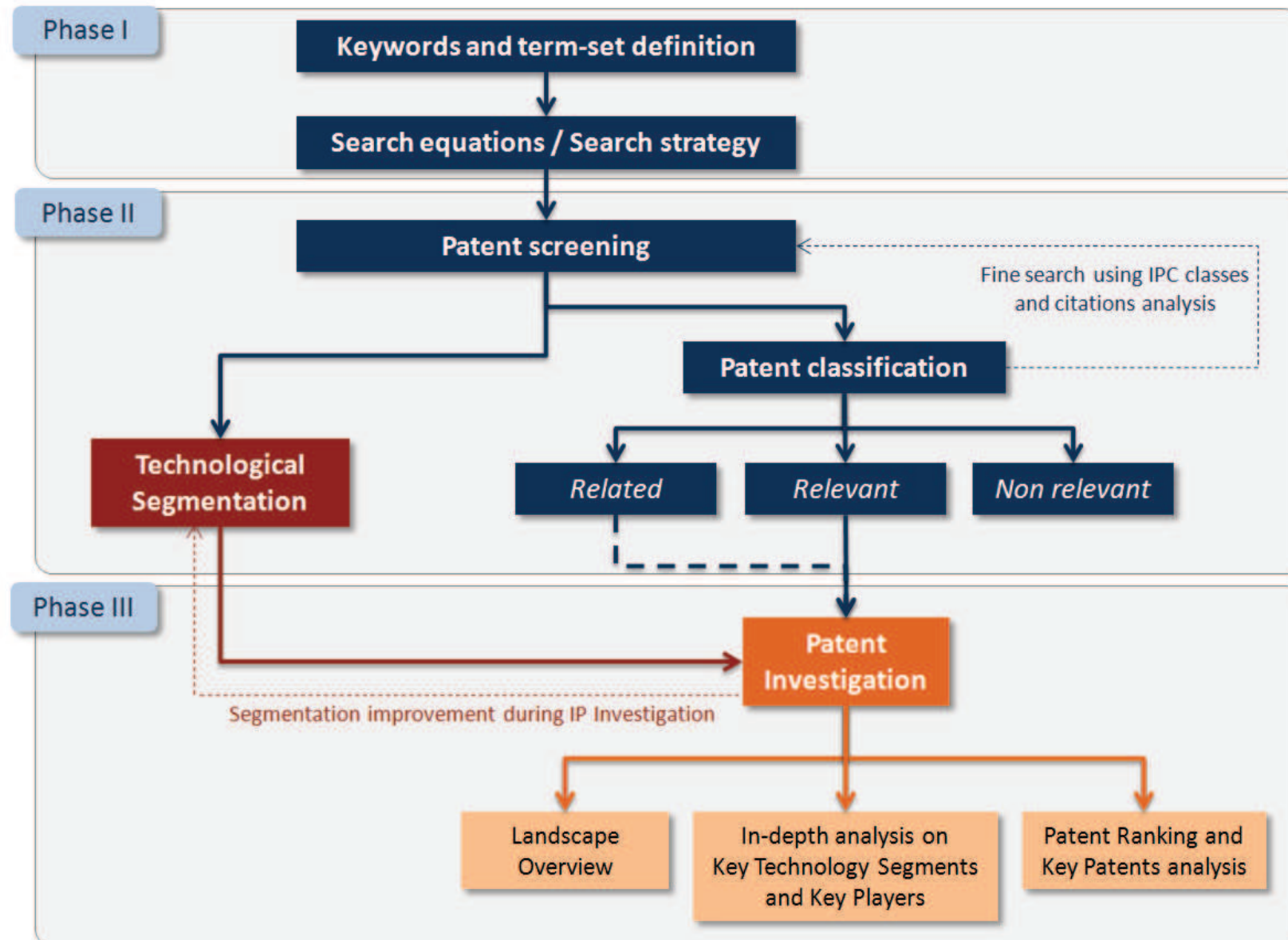
- The data were extracted from the FamPat worldwide database (Questel-ORBIT) which provides 60+ million patent documents from 95 offices.
- The patents search was performed in early June 2013 hence patents published after this date will not be available in this report.
- The patent selection is done both automatically and manually.

Number of selected patent families for the LED Phosphor IP Investigation:  
4,586 over a number of returned results > 20,900

- The statistical analysis was performed with INTELLIXIR System.
- The patents were categorized using keyword analysis of patent title, abstract and claims, in conjunction with expert review of the subject-matter of inventions (details in next slides)
- The patents were organized according to FamPat's family rules (variation of EPO strict family): A *Patent Family* comprises patents linked by exactly same priority numbers (strict family), plus comparison of priority and application numbers, specific rules by country and information gathered from other sources (national files, legal status ...)

**Disclaimer:** Knowmade is a research firm that provides technical analysis and technical opinions. Knowmade is not a law firm. The research, technical analysis and/or work proposed or provided by Knowmade and contained herein is not a legal opinion and should not be construed as such.

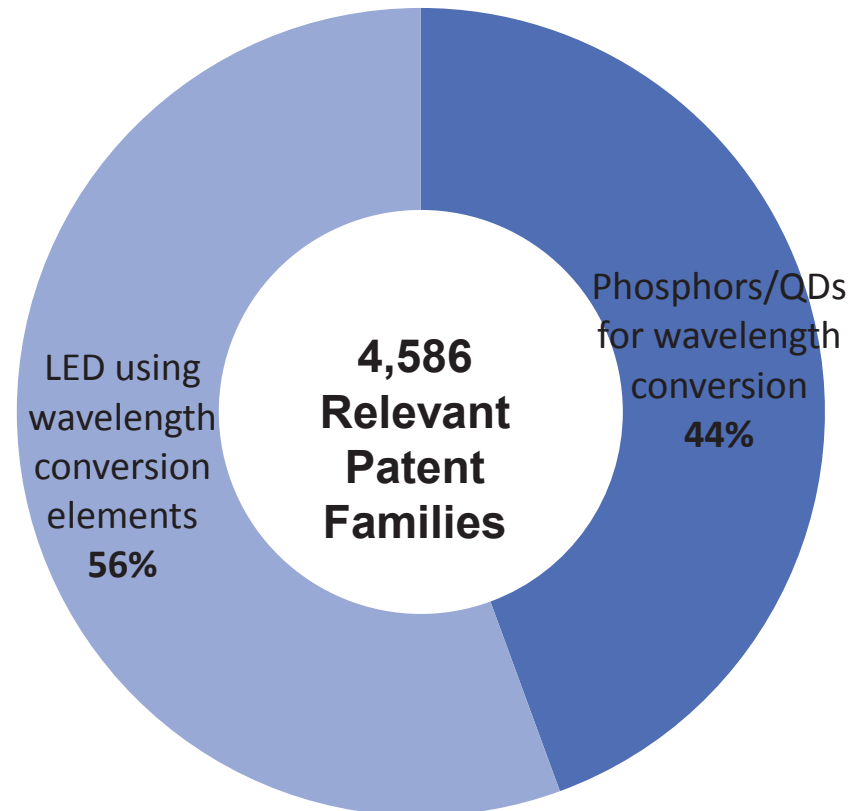
# Methodology





# Search Strategy and Patent Screening

- Note that due to the vast number of patent families related to phosphors in general, we have designed our research equation in order to restrict the results to LED applications. The limit of this strategy is that some composition patents that don't explicitly mention LED related applications might have been filtered out. We believe however this number to be quite low since phosphors used with LED are in most cases, specific to this applications (ie.: different from phosphors used in fluorescent lighting and displays).
- Our search equation and manual filtering resulted in the selection of a total of 4,586 relevant patent families:



## LED with WL conversion Group

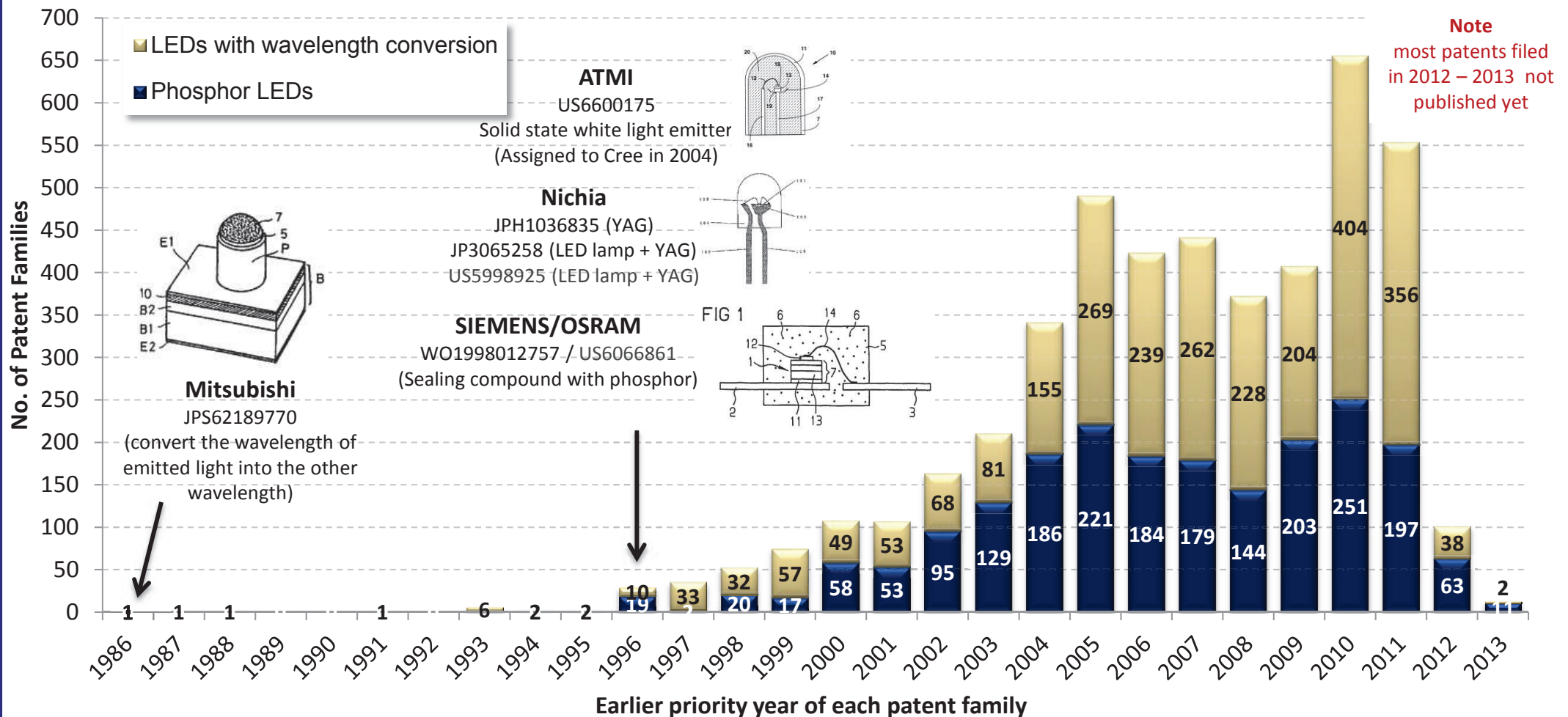
*The claimed invention is related to a LED based lighting device using a wavelength conversion element*

## Phosphor material Group

*The claimed invention is related to the composition of the wavelength conversion element*



# Time Evolution of Patent Filing



- 2,032 patent families were filed from 1996 to 2013 in Phosphor LEDs material technologies. 36% of those were filed over the last 5 years.
- 2,554 patent families were filed from 1986 to 2004 in LED based devices using a wavelength conversion element. 39% of those were filed these last 5 years.

*Note: The data corresponding to the years 2012 and 2013 may not be complete since a significant number of patent applications filed during these years might not have been published yet.*

# Major LED Phosphor Materials



## Currently Dominant Compositions:

Family	Activator	Dominant Color	Main Players
#1: Garnets (YAG)	Ce <sup>3+</sup>	Yellow	Nichia, Osram (IP)
#2: Silicate (BOSE)	Eu <sup>2+</sup>	Yellow	Intematix, Merck/Litec, LWB, Toyoda Gosei / Tridonic
#3: Nitrides (CASN-SCASN) Sulfide (CAS)	Eu <sup>2+</sup>	Red-Orange	Mitsubishi
#4: Oxynitrides (SiALON)	Eu <sup>2+</sup>	Green	Denka

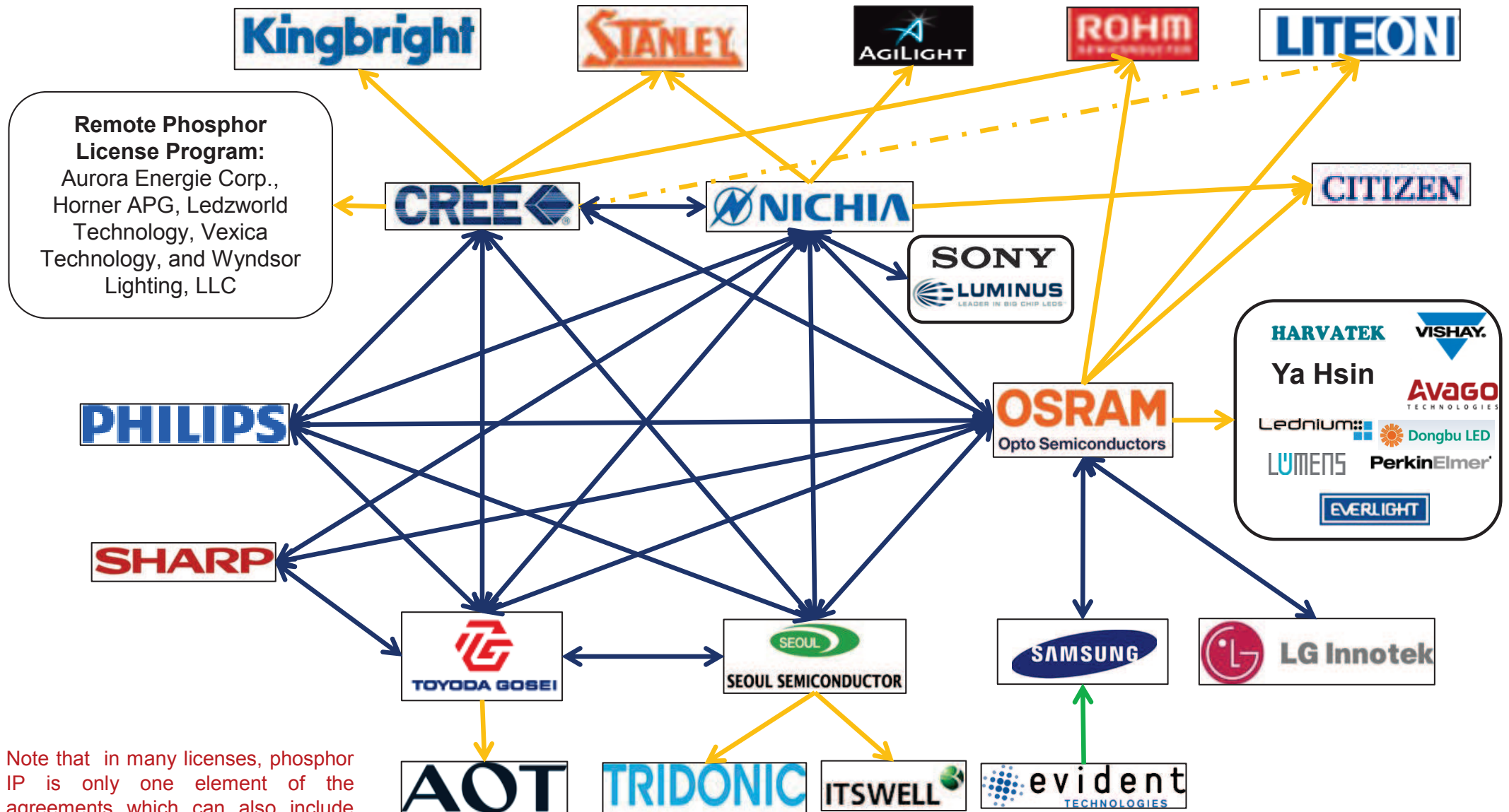
## Emerging Compositions:

Family	Activator	Dominant Color	Main Players
Molybdates, Tungstates	Eu <sup>3+</sup>	Red	Philips
K <sub>2</sub> SiF <sub>6</sub> :Mn <sup>4+</sup>	Mn <sup>4+</sup>	Red	GE (under development)
Quantum Dots	NA	Red	NN Crystal, Nanosys, QD Vision, Nanoco
Alternative Nitrides / Carbido-nitrides	Eu <sup>2+</sup>	Red	Intematix, Nichia, Dow Electronic Materials
Selenides	ZnSeS	Red	Phosphortech
Alternative Oxynitrides	Eu <sup>2+</sup>	Green	Dow Electronic Materials...
Other Garnets LuAG	Ce <sup>3+</sup>	Green	Philips, Misc...
Green Aluminates	Eu <sup>2+</sup>	Green	Intematix

Note: not much activity for new yellow phosphors families: YAG is well established for companies having a license, Silicate for others.

# Phosphor Related Licensing Agreements

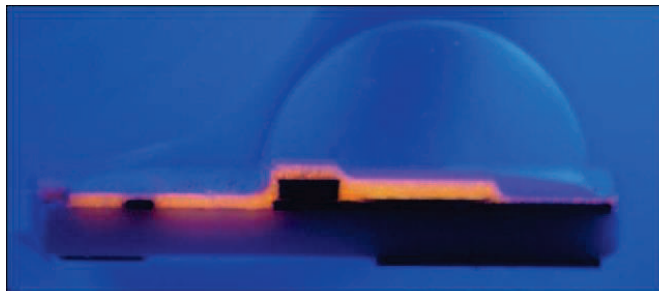
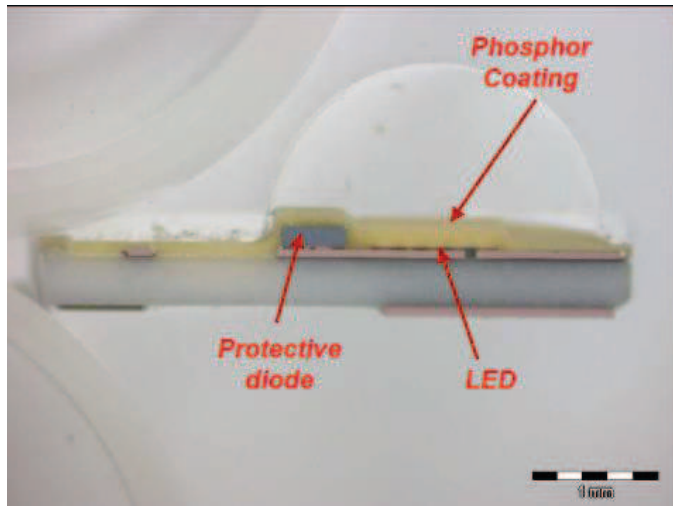
↔ 2-ways licenses  
→ Single way licenses



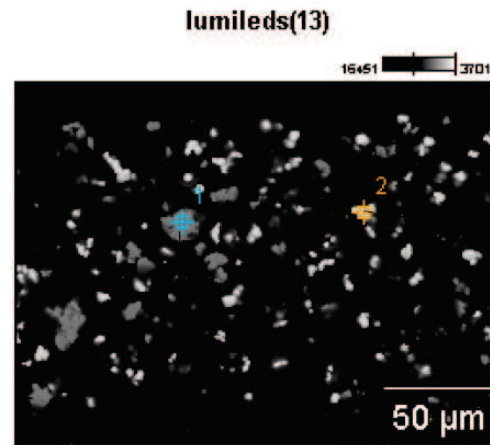
Note that in many licenses, phosphor IP is only one element of the agreements which can also include epitaxial structures, packaging etc...

# Examples

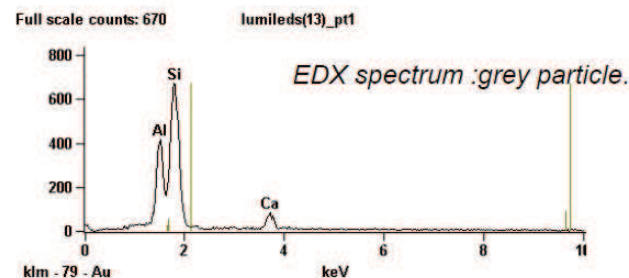
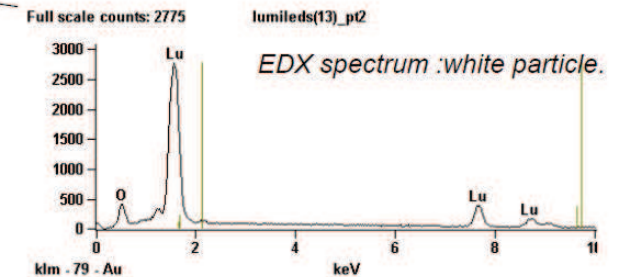
## Conformal Coating – Package Level



Optical view : cross-section under UV light. The yellow phosphor is clearly visible.



EDX spectrum of phosphor material. The Ca and Al are attributed to  $\text{CaAlSiN}_3$ -base particles of red phosphor, the Lutetium particles is attributed to green or yellow phosphor and the Si to silica filler or a silicone matrix.



Source: Lumileds – LXML-PWC1-0100 Luxeon Rebel tear down and reverse costing analysis (System + consulting)

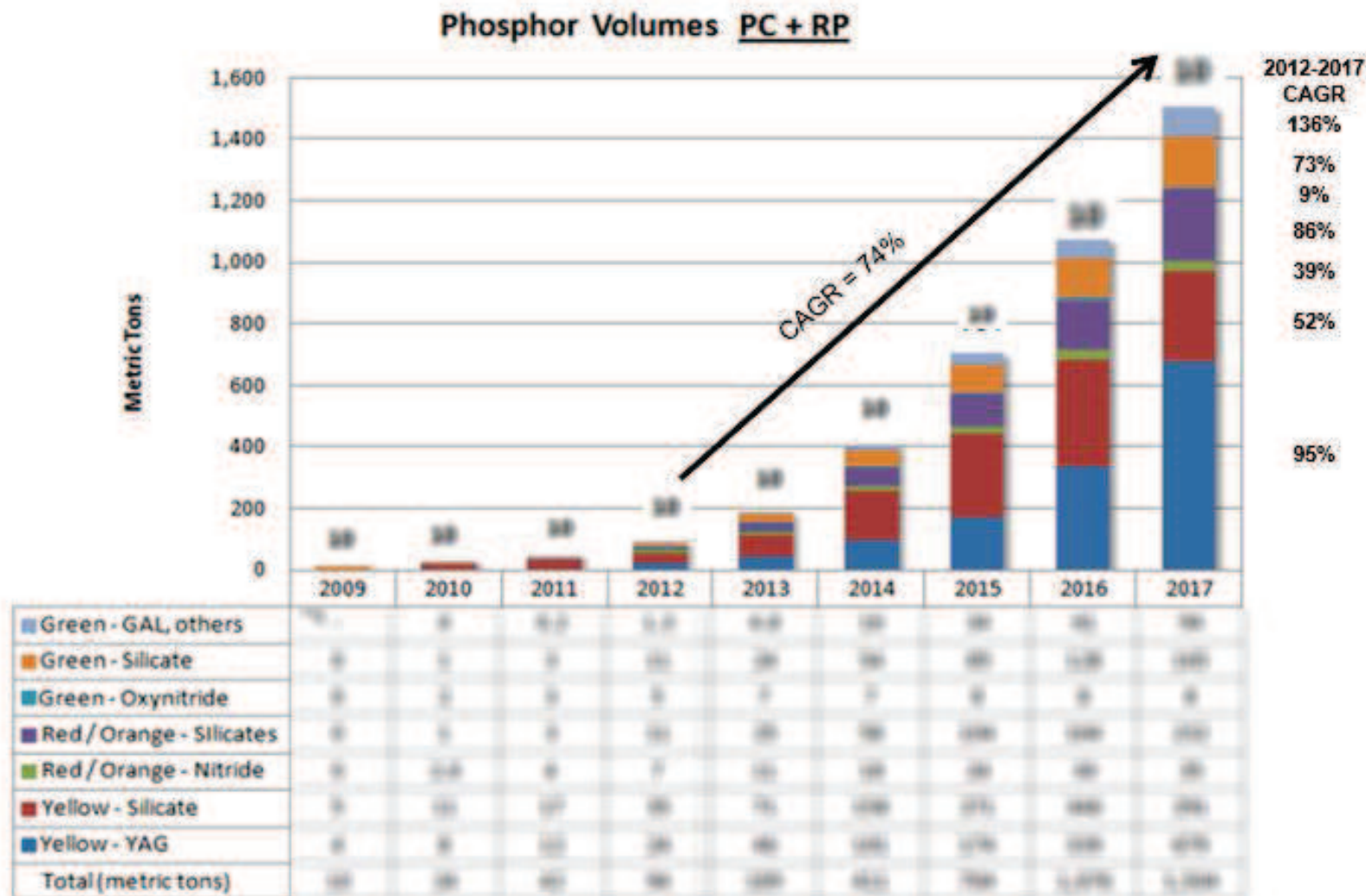


# Market Quantification

## Scenario #2: Volumes with Remote Phosphors



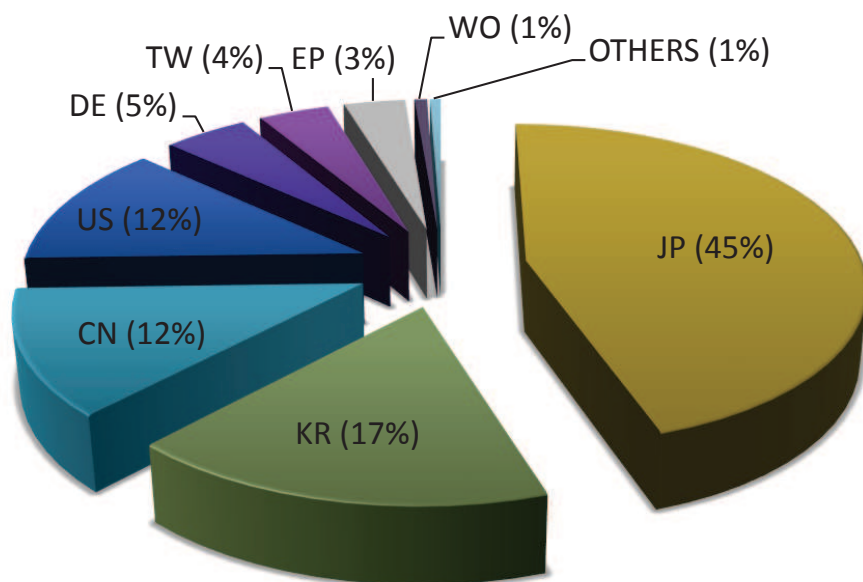
- Under those assumptions, volumes increase significantly and RP related volume rapidly dwarfs that of standard LEDs as illustrated next page.



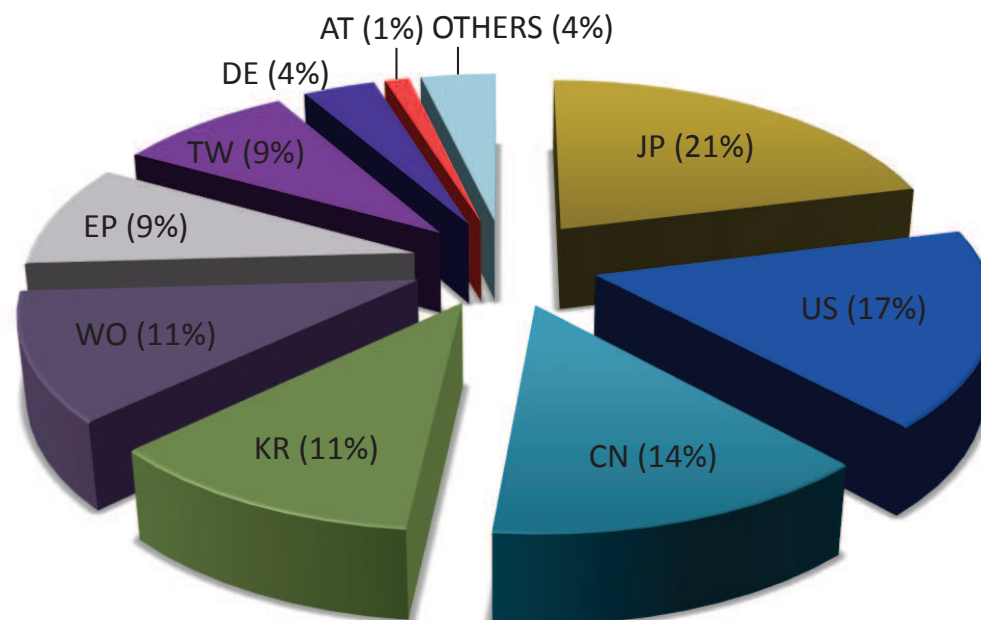
# Geographic Breakdown of Patent Filing: Phosphor Materials



Country of the first filing (priority country)  
for patents related to Phosphor Material



Country of filings (publication countries)  
for patents related to Phosphor Material

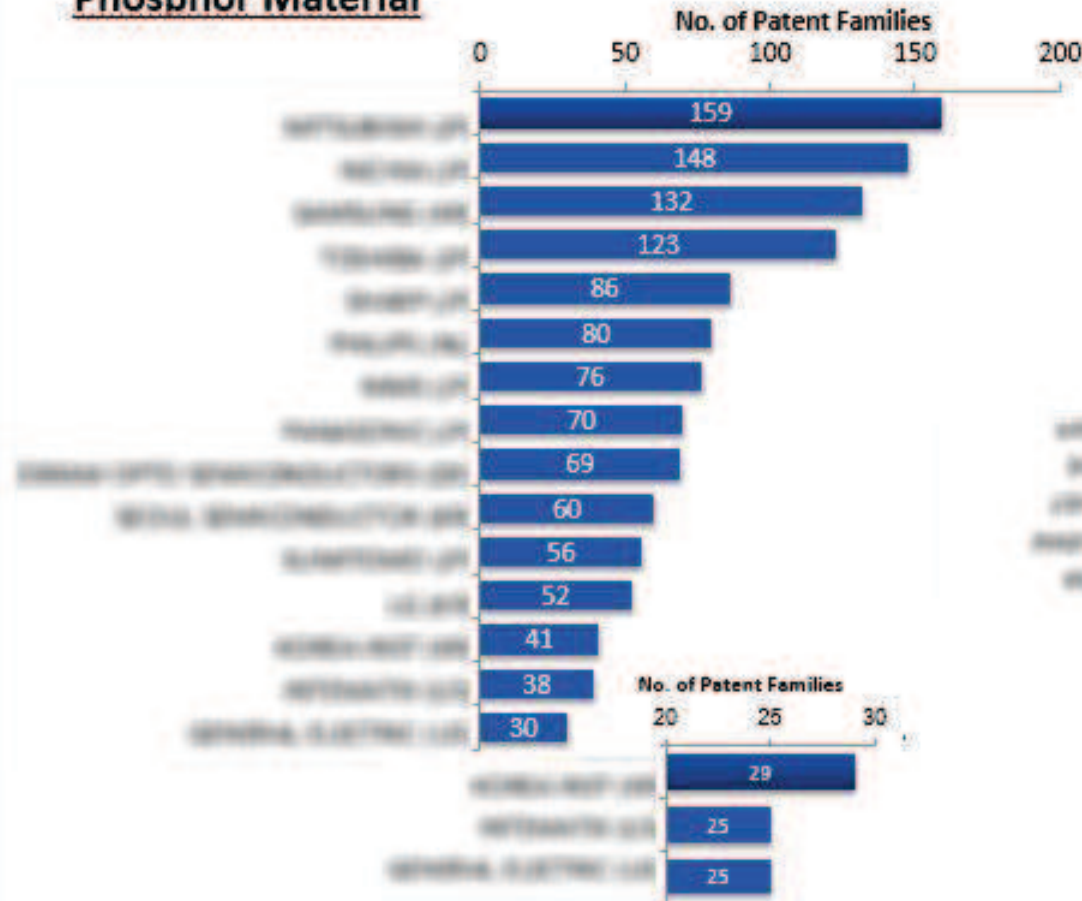


Priority patents are mainly filed in **Japan** (45%). These patents are mainly extended in **Japan, USA, China** and **Korea**. International (WO) and European (EP) applications represent 11% and 9% respectively. Note that they may hide other countries that are not yet published.

# Main Patent Assignees Ranking

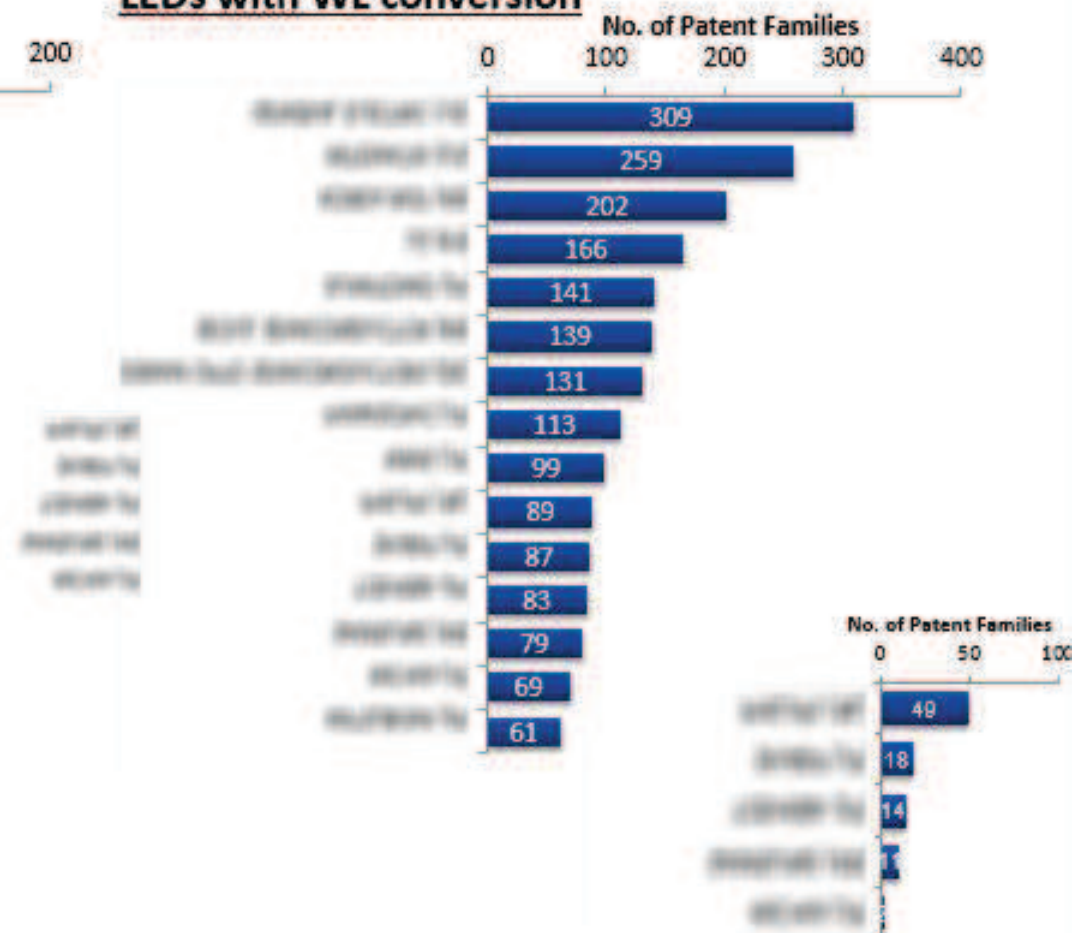


## Phosphor Material



- More than 400 companies are involved in IP related to Phosphor Material. The top-4 assignee represents 28% of patent filings, while xxx alone accounts for 8%.
- Relative newcomer xxx occupies the 3<sup>rd</sup> spot, while xxx and xxx rank 2<sup>nd</sup> and 7<sup>th</sup> respectively.

## LEDs with WL conversion



- More than 150 companies are involved in IP related to LED with WL conversion element.
- From a quantitative point of view, xxx is the leader followed by xxx and xxx.
- The top-3 assignee represents 30% of patent filings. xxx and xxx occupy the 8<sup>th</sup> and 16<sup>th</sup> place respectively.



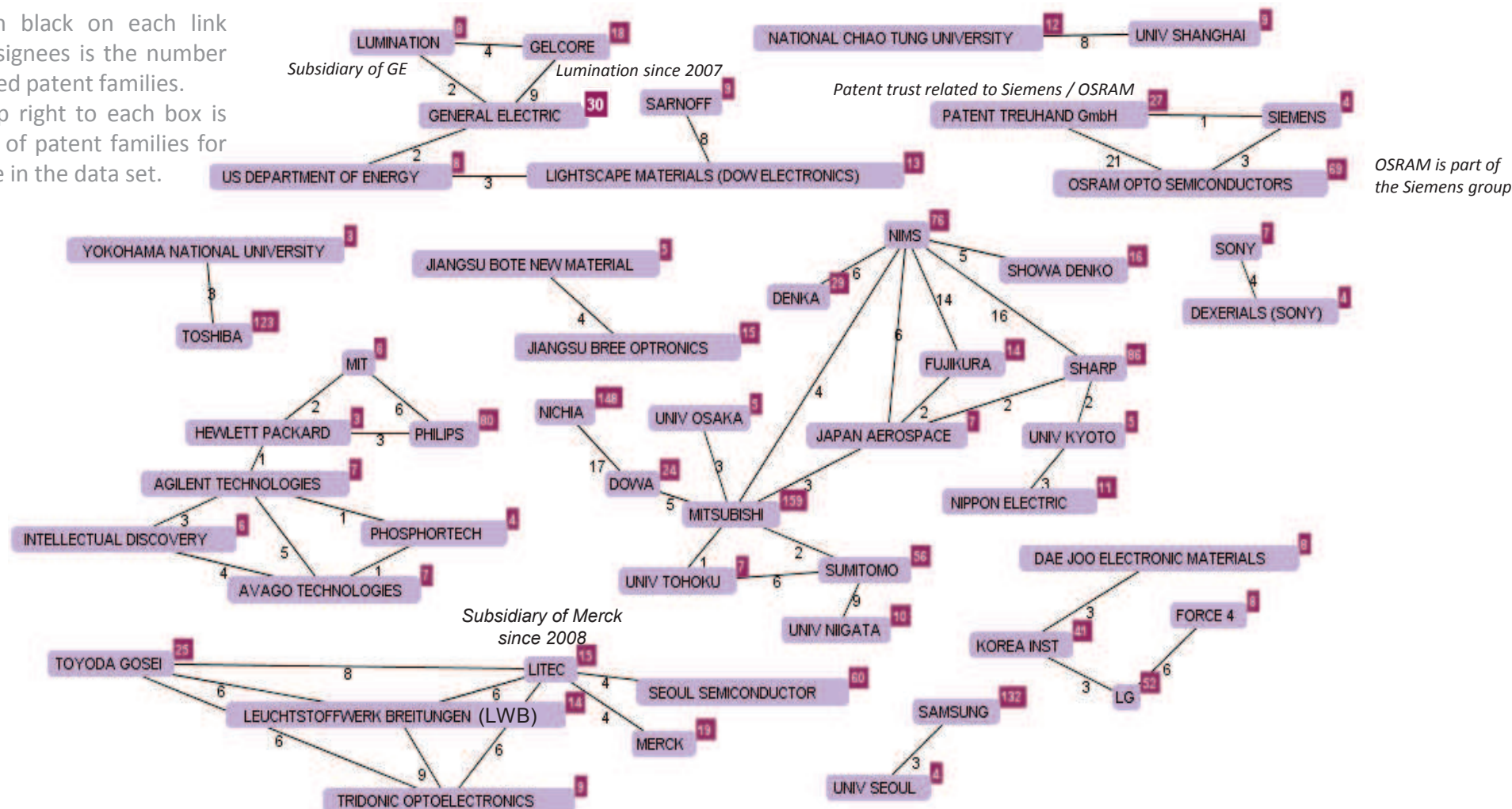
# Patent Assignees IP Network

## Phosphor Materials



### Assignee collaboration network for patents related to Phosphor Material

- Number in black on each link between assignees is the number of co-assigned patent families.
- Number up right to each box is the number of patent families for this assignee in the data set.



- Most assignees collaborate only with players coming from the same originating country. A notable exception is the **BOSE consortium** (= Litec, Merck, LWB, Toyoda Gosei and Tridonic) which holds key Silicate phosphor IP and also has a collaboration with **SEOUL SEMICONDUCTOR** via **LITEC**.
- In the US, the Department Of Energy (DOE) is co-assignee on patents resulting from projects it funded within the frame of its “Solid State Lighting” R&D program.

# Strength of Main Assignee Portfolio

## Phosphor Materials



### Patent portfolio comparison for main patent assignees involved in Phosphor Material

	A	B	C	D	E	F
Assignee (note names available in the full report)	No. of patent families	No. of citing patent families (from FamPat database)	No. of citing patent families / yr (average)	No. of citing patent families / patent family = B/A	Relative Impact Factor of the patent family = D/ 3.44*	Strength of the patent portfolio = A x E
Company A (JP)	159	614	42.8	3.9	1.1	179
Company B (JP)	148	2327	136.9	15.7	4.6	677
Company C (KR)	132	362	33.4	2.7	0.8	105
Company D (JP)	123	395	25.5	3.2	0.9	115
Company E (JP)	86	400	32.7	4.7	1.4	116
Company F (NL)	80	1744	118.2	21.8	6.3	507
Company G (JP)	76	518	42.9	6.8	2.0	151
Company H (JP)	70	838	58.5	12.0	3.5	244
Company I (DE)	69	1530	90.9	22.2	6.4	445
Company J (KR)	60	189	17.6	3.2	0.9	55
Company K (KR)	52	45	3.5	0.9	0.3	13
Company L (US)	39	272	2.4	7.0	2.0	79
Company M (US)	30	984	8.7	32.8	9.5	286
Company N (JP)	29	80	0.7	2.8	0.8	23
Company O (US)	25	324	2.9	13.0	3.8	94
Company P (JP)	25	626	5.5	25.0	7.3	182

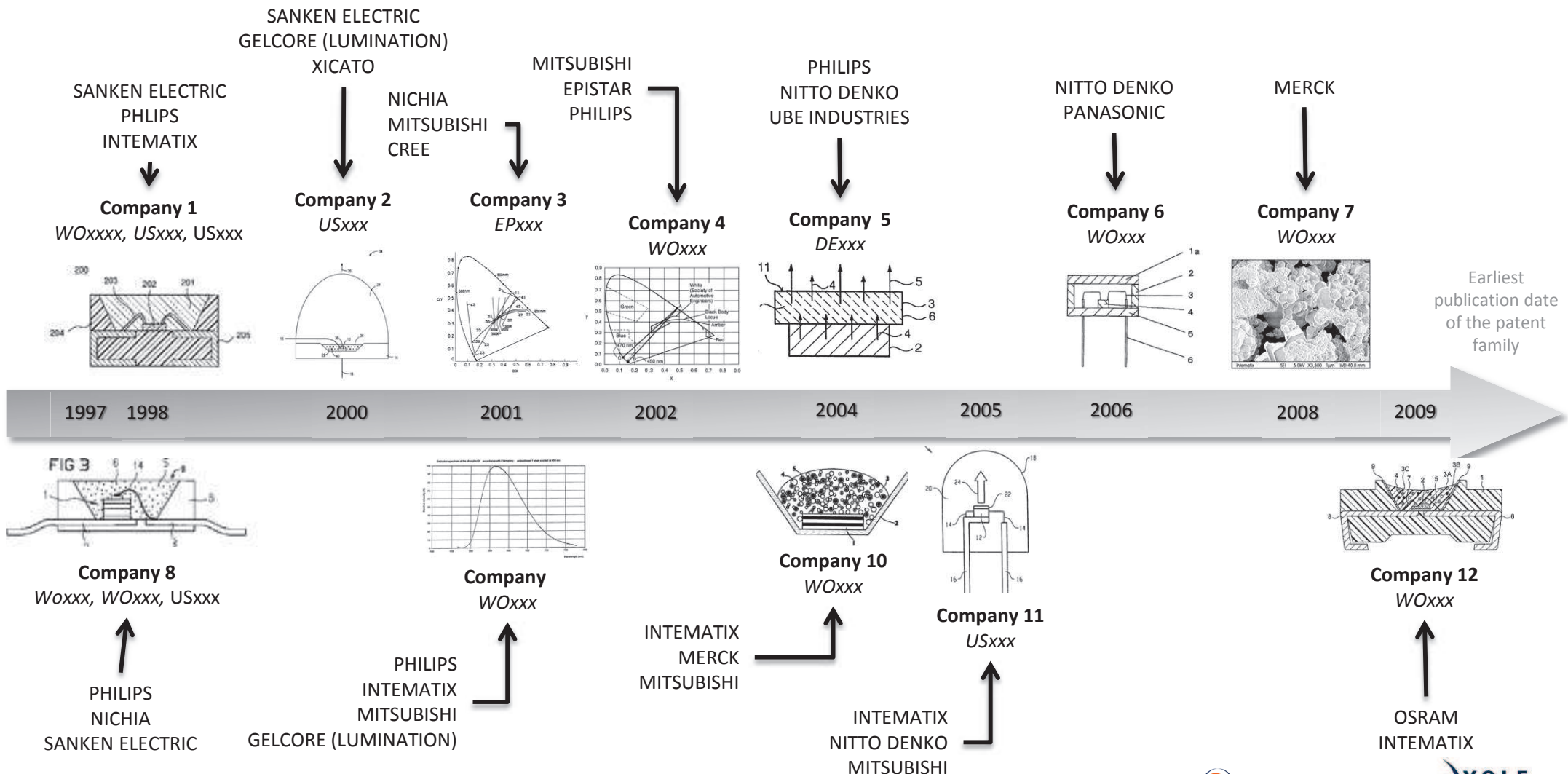
\*: 6,986 patent families cite the whole of the 2,032 patents taken into account for the study, then corresponding to an average of 3.44 citing patent families per patent family.

# Major Reference Patents

**GARNETS**

## Main reference patents for Garnet composition and corresponding main citing applicants

The selection of reference patents is based on both citations analysis and their interest for YAG/TAG technology.



# Key Patents, Citations & Collaborations



General Electric's portfolio	Forward / Backward citations (main citing/cited applicants)	Key Patent Families (representative member and earlier priority date of the patent family)	Collaborations
<b>Garnets</b>	190+ citing patent families (Cree, Philips, Nichia)  120+ cited patent families (Philips, Patent Treuhand, Osram, Panasonic)	<u>EPxxx</u> (number and title in the full report) <u>WOxxx</u> (number and title in the full report) <u>USxxx</u> (number and title in the full report)	No collaboration
<b>Others</b>		Phosphor blends: <u>WOxxx</u> (number and title in the full report), <u>WOxxx</u> (number and title in the full report), <u>WOxxx2</u> (number and title in the full report)  Fluorides: <u>USxxx</u> (2005), <u>USxxx</u> (2007, number and title in the full report), <u>WOxxx1</u> (2008, number and title in the full report)	<b>US Department Of Energy</b> (co-applicant): <u>USxxx</u> (2011, fluoride)
<b>Remote Phosphors</b>	540+ citing patent families (Cree, Philips, Osram)  270+ cited patent families (Philips, Nichia, Cree)	<u>WOxxx</u> (number and title in the full report) <u>WOxxx</u> (number and title in the full report)	No collaboration
<b>LED with wavelength conversion element</b>	740+ citing patent families (Cree, Philips, ABL IP Holding)  360+ cited patent families (Philips, Cree, Panasonic, Nichia)	<u>USxxx</u> (number and title in the full report) <u>USxxx</u> (number and title in the full report) <u>USxxx</u> (number and title in the full report) <u>WOxxx</u> (number and title in the full report)	No collaboration