Report on fabricated plant-grow-targeted LEDs based on near-UV and blue-semiconductor chip WP2 (D2.1)

LEDtech-GROW

LED TECHNOLOGY BASED ON BISMUTH-SENSITIZED Eu^{3+} LUMINESCENCE FOR COST-EFFECTIVE INDOOR PLANT GROWTH

PROGRAM-PROMIS-2024-2025

Grant Agreement: 10412

This project is supported by the Science Fund of the Republic of Serbia, Grant No. 10412,
LED technology based on bismuth-sensitized Eu^{3+} luminescence for cost-effective indoor plant growth – LEDtech-GROW

Deliverable 2.1

Report on fabricated plant-grow-targeted LEDs based on near-UV and blue-semiconductor chip

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Project Deliverable Information Sheet

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	Abstract: The report includes a description of the design and fabrication of LEDs for plant growth applications that combine (*i*) near-UV semiconductor chips and triple-wavelength emitting single-component phosphors based on Bi^{3+} and Eu^{3+} activators, and (*ii*) blue semiconductor chips and representative red and far-red double-wavelength emitting phosphors. This report is a result of a joint effort between subactivities **2.1 -** A novel strategy for fabrication of plant-grow-targeted LEDs based on a near-UV chip and **2.2** - Common strategy for fabrication of double-wavelength emitting pc-LEDs based on a blue chip.

Document Control Sheet

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Executive Summary

The presented document constitutes Deliverable D2.1 – *Report on fabricated plant-grow-targeted LEDs based on near-UV and blue semiconductor chips,* of the LEDtech-GROW project. It is a public document, delivered in the context of **WP2** - *Design, fabrication, and LEDs performance,* ***Subactivity 2.1*** - *A novel strategy for fabrication of plant-grow-targeted LEDs based on a near-UV chip [month: 12-24] and* ***Subactivity 2.2 -*** *Common strategy for fabrication of double-wavelength emitting pc-LEDs based on a blue chip [month: 12-24]*. This document presents a description of the design and fabrication process for LEDs used in plant growth applications, intended for sharing and distributing information related to the LEDtech-GROW project.

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Abbreviations and Acronyms

	Explanation
[BYF]	$BaYF_5$
[EDTA-2Na]	Disodium ethylenediaminetetraacetic acid
[ET]	Energy transfer
[FWHM]	Full width at half-maximum
[LED]	Light-emitting diode
[LEDtech-GROW]	Acronym of the Project Titled "*LED technology based on bismuth-sensitized Eu^{3+} luminescence for cost-effective indoor plant growth*"
[PAR]	Photosynthetically Active Radiation
[PL]	Photoluminescence emission spectra
[PXRD]	Powder X-ray diffraction
[RE]	Rare earth
[SEF]	Sr_2EuF_7
[SGF]	Sr_2GdF_7
[SLF]	Sr_2LaF_7
[near-UV]	near-ultraviolet
[VinaR]	VinaR, i.e., Vinca Repository, is a joint digital repository of all laboratories and departments at Vinča Institute of Nuclear Sciences, University of Belgrade.
[VINS]	"Vinča" Institute of Nuclear Sciences – National Institute of the Republic of Serbia, University of Belgrade
[WP]	Work package

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1. The list of selected phosphors for LED fabrication

A novel LED fabrication strategy for plant growth applications combines near-UV or UV semiconductor chips and representative triple-wavelength emitting single-component phosphors based on Bi^{3+} and Eu^{3+} activators and their efficient energy transfer (ET). This strategy offers broadband blue emission that may sensitize the various cryptochrome and phototropin photoreceptors (pterin (380), flavin (447 nm), Phototropin, and Zeitlupes, LOV (390, 457, and 480 nm). The list of two selected phosphors coated on the 278 nm LED chip is as follows:

- SrF_2: Bi^{3+}, Eu^{3+}
- $BaYF_5$: Bi^{3+}, Eu^{3+}

The list of six selected phosphors coated on the 395 nm LED chip includes a representative red and far-red double-wavelength emitting Eu^{3+}-activated single-component phosphor is as follows:

- SrF_2: Bi^{3+}, Eu^{3+}
- $BaYF_5$: Bi^{3+}, Eu^{3+}
- $SrGdF_7$: Eu^{3+}
- $SrGdF_7$: Bi^{3+}, Eu^{3+}
- $SrLaF_7$: Eu^{3+}
- RbY_3F_{10}:Eu^{3+}

The conversion of UV light into blue and red light using inorganic phosphors in LEDs is crucial for enhancing photosynthesis in greenhouse-grown plants. Red light, for instance, supports flowering and fruiting in crops such as tomatoes, peppers, and orchids, while also promoting improved fruit production in strawberries and cucumbers. Meanwhile, blue light encourages healthy leaf development in leafy greens like lettuce, spinach, and kale, and strengthens the early growth of seedlings by fostering robust leaves and stems. The tunable red/blue light properties of the synthesized phosphors could ensure plants receive the optimal light spectrum needed at each stage of their growth cycle.

2. LED fabrication *via* triple-wavelength emitting single-component SrF_2:Bi^{3+}, Eu^{3+} phosphors

Since the commercially available blue LED chips based on indium-gallium-nitride ($In_xGa_{1-x}N$, adding indium to the *GaN* of the semiconductor lowers the bandgap to achieve a higher emission wavelength, in this case, blue) have a narrow full width at half-maximum - FWHM (λ_{em}=420 nm, λ_{em}=460 nm) that cannot sensitize several blue-sensitive cryptochrome and phototropin

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photoreceptors, a novel UV based LED chips with broad blue emission originated from Bi^{3+} ions meet the requirements of blue light for plant growth. Firstly, we synthesized two sets of samples: a) SrF_2 doped with different europium concentrations: 1, 5, 10, 15, and 20 mol% ($Sr_{1-x}Eu_xF_2$ (x= 0.01, 0.05, 0.1, 0.15, 0.2) and b) SrF_2 doped with constant europium (10 mol%) and various bismuth concentrations (5, 10, 15, 20, 30, 40, and 50 mol%; $Sr_{0.9-y}Eu_{0.1}Bi_yF_2$ (y= 0.05, 0.1, 0.15, 0.2, 0.3, 0.4, 0.5)). Tunable blue/red-emitting Eu^{3+}-activated, Bi^{3+}-sensitized SrF_2 phosphors with sphere-like particles of ~20 nm were obtained utilizing a solvothermal-microwave method. The optimized sample, SrF_2:10%Eu^{3+},20%Bi^{3+}, that showed the best luminescent properties and matched a Photosynthetically Active Radiation (PAR) spectrum of plant photoreceptors, was used for further LED fabrication based on different wavelength LED chips. Balancing blue and red-light components is vital for optimizing plant health and maximizing yield in controlled environments. The integrated photoluminescence (PL) area in the 380–500 nm (blue) and 575–725 nm (orange-red/far-red) wavelength range was used to determine the red-to-blue emission ratio. The optimized sample, SrF_2:10%Eu^{3+},20%Bi^{3+}, exhibited the highest red-to-blue emission ratio of 40.8:59.2.

<u>*LED fabrication*</u>

The SrF_2:10%Eu^{3+},20%Bi^{3+} phosphor was separately mixed with high-temperature inorganic binder - *Aremco-CeramabindTM 643-2* before being deposited on the (*i*) 278 nm and (*ii*) 395 nm LED chips (LED accessories purchased on the market). The mixed resin, which contains *Ceramabind* and SrF_2:10%Eu^{3+},20%Bi^{3+} phosphor, was deposited on top of the LED chip using the Doctor blade (tape casting) technique, then dried for 48 hours. Photographs of the fabricated LED device, presented in Figure 1a, display a strong pinkish violet light when the power supply is on. The PL spectrum of the fabricated LED, composed of a 278 nm chip and SrF_2:10%Eu^{3+},20%Bi^{3+} phosphor, reveals strong emissions in the blue, orange/red, and far-red regions (see Figure 1b). Figure 1b (right) presents the emission of the 278 nm LED chip before the red phosphor was applied. Owing to its intense blue, orange/red, and far-red emissions, this LED holds great promise for indoor horticultural applications. Accordingly, our next phase of work will focus on assessing its performance. Figure 1c shows the PL spectrum of the fabricated LED, composed of a 395 nm chip and SrF_2:10%Eu^{3+},20%Bi^{3+} phosphor, which reveals strong emissions in near-UV, orange/red, and far-red regions. Figure 1c (right) presents the emission of the 395 nm LED chip before the red phosphor was applied. A noticeable dip at 391 nm confirms the absorption of UV light by Eu^{3+} ions.

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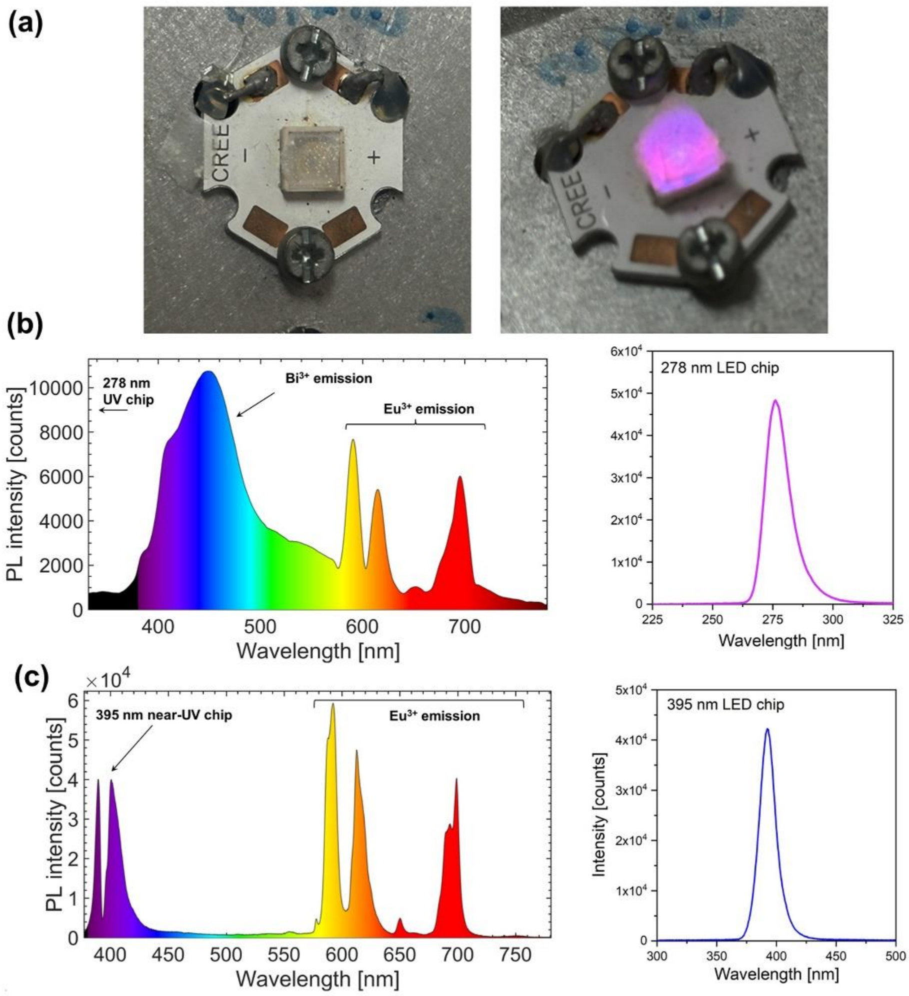

***Figure 1**. (a) Photograph of the fabricated LED device emitting pinkish-violet light, using a 278 nm LED chip combined with SrF_2:10%Eu^{3+},20%Bi^{3+} phosphor; (b) PL spectrum of the LED based on 278 nm chip, with the emission of the bare chip (without phosphor) shown on the right for comparison; (c) PL spectrum of the LED based on 395 nm chip, with the corresponding emission from the bare chip (without phosphor) shown on the right.*

3. LED fabrication *via* triple-wavelength emitting single-component $BaYF_5$: Bi^{3+}, Eu^{3+} phosphors

We explore the sensitization of Eu^{3+} emission with Bi^{3+} in $BaYF_5$:Eu^{3+},Bi^{3+} (BYF:Eu,Bi) nanophosphors. Three sets of nanophosphors were synthesized using the solvothermal method: 1. $BaYF_5$: xEu, where x = 1, 10, 20 mol%; 2. $BaYF_5$: 10Eu, yBi, where y = 0, 5, 10, 20, 30, 50 mol%; and 3. $BaYF_5$: xEu, 20Bi where x = 1, 5, 10, 20 mol%. From the first set, we selected the sample with 10 mol% Eu^{3+} as a representative for further co-doping with Bi^{3+}, as it exhibited the most intense emission. The emission spectra feature Eu^{3+} peaks corresponding to transitions from the $^5D_0$ excited to ^7F_J (J = 1, 2, 3, 4) lower levels with two dominant emissions positioned in the orange-red (~ 592 nm, $^5D_0 \rightarrow {}^7F_1$) and deep-red (~ 697 nm, $^5D_0 \rightarrow {}^7F_4$) regions. Upon 265 nm excitation, the concentration-dependent luminescence properties reveal that the luminescence of a representative BYF:10Eu^{3+},20Bi^{3+} phosphor is 216% enhanced compared to the Bi-free sample due to energy transfer from Bi^{3+} to Eu^{3+}. Our findings indicate that BYF: Eu^{3+} nanophosphor with a unique feature of intense emission at around 700 nm could be used in various applications, particularly sustainable agriculture.

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LED fabrication

The $BaYF_5$:10%Eu^{3+},20%Bi^{3+} phosphor was separately mixed with high-temperature inorganic binder - *Aremco-CeramabindTM 643-2* before being deposited on the (*i*) 278 nm and (*ii*) 395 nm LED chips. The mixed resin was deposited on top of an LED chip using the Doctor blade (tape casting) technique and then dried for 48 hours. Figure 2a shows photographs of the fabricated LED device emitting a violet light, primarily originating from the LED chip when powered on. Figure 2b shows the PL spectrum of the LED, which incorporates a 278 nm chip and $BaYF_5$:10%Eu^{3+},20%Bi^{3+} phosphor, demonstrating a dominant far-red emission, with noticeably weaker red and blue components. Figure 1b (right) presents the emission of the 278 nm LED chip before the red phosphor was applied. Our next phase of work will focus on modifying the phosphor layer to obtain a more intense blue emission, and then we will analyze the performance of improved LEDs. Figure 2c shows the PL spectrum of the fabricated LED, composed of a 395 nm chip and $BaYF_5$:10%Eu^{3+},20%Bi^{3+} phosphor, which reveals strong emissions in near UV, with noticeably weaker orange/red, and far-red components. Figure 2c (right) presents the emission of the 395 nm LED chip before the red phosphor was applied. A minor dip at 391 nm indicates low absorption of near-UV light by Eu^{3+} ions. Therefore, the insufficient intensity of red and far-red emissions makes this LED unsuitable for effective indoor horticultural use.

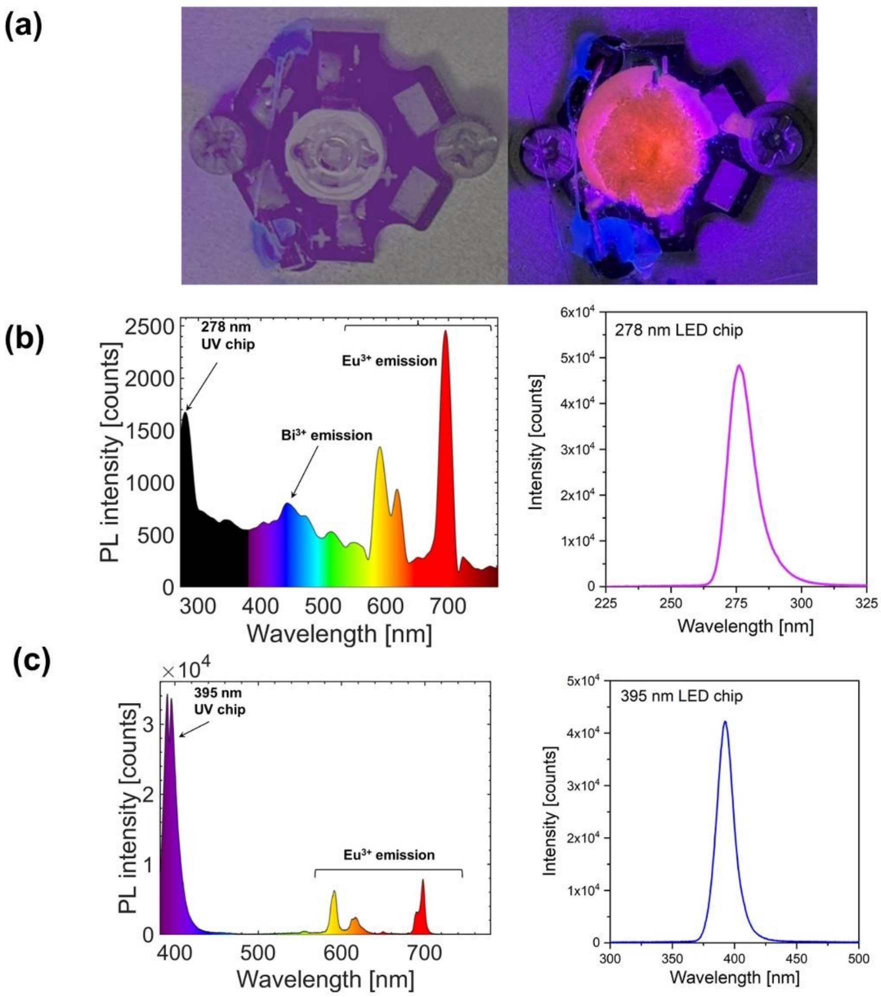

Figure 2. *(a) Fabricated LED device displaying violet light (LED based on 395 nm LED chip and $BaYF_5$:10%Eu^{3+},20%Bi^{3+} phosphor); (b) PL spectrum of the LED based on 278 nm chip, with the emission of the bare chip (without phosphor) shown on the right for comparison; (c) PL spectrum of the LED based on 395 nm chip, with the corresponding emission from the bare chip (without phosphor) shown on the right.*

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4. LED fabrication *via* double-wavelength emitting single-component $SrGdF_7$: Bi^{3+}, Eu^{3+} phosphors

The powders of $Sr_2Gd_{0.2-x}Eu_{0.8}Bi_xF_7$ (x = 0, 0.25, 1, 5, 10 mol%) were prepared using the hydrothermal method. EDTA-2Na was used as a stabilizing agent by forming Sr- and Gd-complexes to prevent particle aggregation during reaction. The precursor solutions were combined, and then the pH was adjusted to ~6 by adding 25 % ammonium hydroxide solution dropwise. A hydrothermal reaction was conducted in an autoclave at 180 °C for 20 hours. The Eu^{3+} concentration was chosen as the one that enables maximal emission intensity in Sr_2GdF_7:Eu^{3+} nanopowders (Eu^{3+} content 80 mol%). The samples' PL spectra upon 391 nm-excitation expose the *4f–4f* transitions of Eu^{3+}, located around 593 nm ($^5D_0 \rightarrow {}^7F_1$), 613 nm ($^5D_0 \rightarrow {}^7F_2$), 650 nm ($^5D_0 \rightarrow {}^7F_3$), 698 nm ($^5D_0 \rightarrow {}^7F_4$ transition), with intense deep-red emission peaks. Also, it was shown that Bi^{3+} co-doping of the $Sr_2Gd_{0.2}Eu_{0.8}F_7$ nanophosphor causes emission intensity increase for all examined concentrations, while for 1 mol% of co-doped Bi^{3+}, the integral emission intensity enhances by a factor of 2.5, compared to the Bi-free sample. The temperature stability of the representative sample is exceptional – 99% of the room temperature emission is maintained at 100 °C and 93% at the temperature of 200 °C. After a detailed investigation, we conclude that ET from Bi^{3+} to Eu^{3+} was minimal, while this PL enhancement occurred due to the lattice distortion by Bi^{3+} co-doping that further leads to the breaking of the partially forbidden transitions of Eu^{3+} ions. All these results point out that Bi^{3+}-co-doped $Sr_2Gd_{0.2}Eu_{0.8}F_7$ nanophosphors, especially $Sr_2Gd_{0.19}Eu_{0.8}Bi_{0.01}F_7$, are suitable for horticulture LEDs based on near-UV semiconductor chips.

<u>*LED fabrication*</u>

The $Sr_2Gd_{0.19}Eu_{0.8}Bi_{0.01}F_7$ phosphor was separately mixed with high-temperature inorganic binder - *Aremco-CeramabindTM 643-2* before being deposited on the near-UV LED chip. The mixed resin was deposited on top of a 395 nm LED chip using the Doctor blade (tape casting) technique, then dried for 48 hours. Photographs of the fabricated LED device, presented in Figure 3a, display a strong red light when the power supply is on. The PL spectrum of the fabricated LED, composed of a 395 nm chip and $Sr_2Gd_{0.19}Eu_{0.8}Bi_{0.01}F_7$ phosphor, reveals strong emissions in the near-UV, orange/red, and far-red regions (see Figure 3b). Figure 3b (right) presents the emission of the 278 nm LED chip before the red phosphor was applied. A noticeable dip at 391 nm confirms the strong absorption of UV light by Eu^{3+} ions. Due to its strong emissions in the near-UV, orange/red, and far-red regions, this LED shows significant potential for indoor horticultural applications. As a result, the next phase of our work will focus on evaluating its performance in this context.

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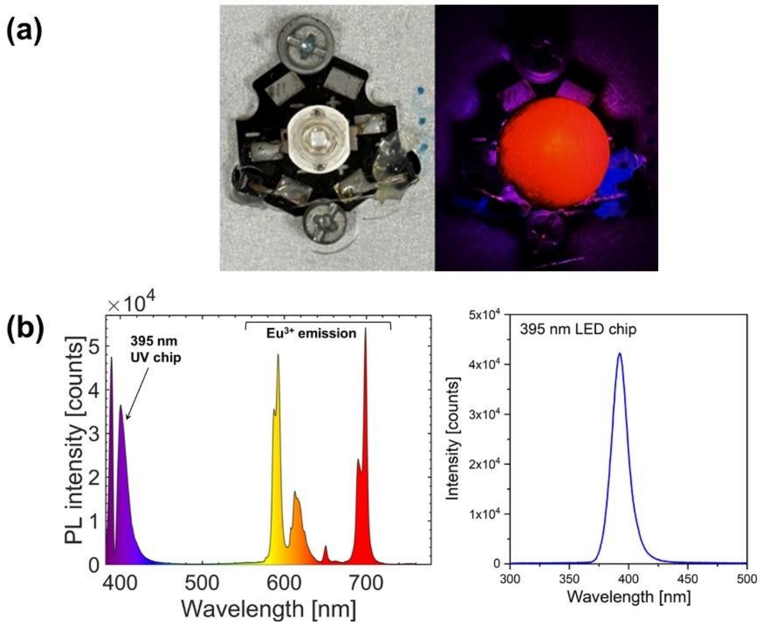

Figure 3. *(a) A fabricated 395nm-chip-based LED device comprising a semiconductor chip and $Sr_2Gd_{0.19}Eu_{0.8}Bi_{0.01}F_7$ nanopowders displays a red light when the electrical power supply is on; and (b) PL spectrum of the LED based on 395 nm chip, with the corresponding emission from the bare chip (without phosphor) shown on the right.*

5. LED fabrication *via* double-wavelength emitting single-component $SrGdF_7$: Eu^{3+} phosphors

A series of multifunctional $Sr_2Gd_{1-x}Eu_xF_7$ (x = 0, 0.05, 0.10, 0.40, 0.60, 0.80, and 1.00) phosphors in stable colloidal form and as nanopowders with an average particle size of ~24 nm have been prepared using a hydrothermal method. PL measurements show highly efficient red emission in both colloids and nanopowders, with intensity continually increasing up to 80 mol% of Eu^{3+} content without concentration quenching. The most prominent emission peaks are around 600 nm (orange/red) and 700 nm (deep red), with the latter more pronounced. Quantum efficiency follows a similar trend and reaches 60% for the sample with 80 mol% Eu^{3+}. The temperature-dependent steady-state and time-resolved PL measurements demonstrate high stability of nanopowders' emission up to 100 °C. The combination of temperature stability and high emission efficiency, as well as the untypical dominant deep-red emission at 700 nm, labels these nanoparticles as potential nanophosphors for various applications.

LED fabrication

The Sr_2GdF_7:80%Eu^{3+} nanophosphor was separately mixed with high-temperature inorganic binder - *Aremco-CeramabindTM 643-2* before being deposited on a 365 nm LED chip. The mixed resin was deposited on top of the LED chip using the Doctor blade (tape casting) technique, then dried for 48 hours. Photographs of the fabricated LED device, presented in Figure 4a, display a strong red light when the power supply is on. The PL spectrum of the fabricated LED, composed of a 365 nm chip and SGF:80Eu nanophosphor, reveals strong emissions in the red and far-red regions with noticeably weaker near-UV LED component (see Figure 4b).

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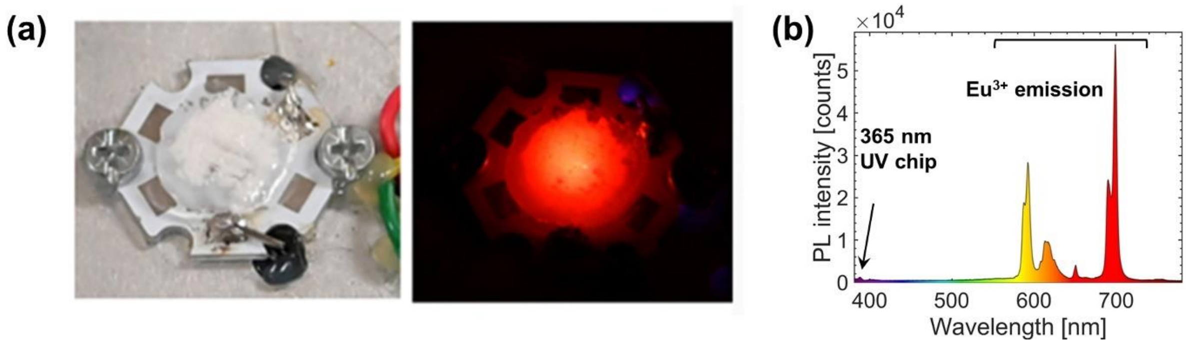

***Figure 4**. (a) A fabricated LED device comprising a 365 nm semiconductor chip and SGF_80Eu nanopowders displays a red light when the electrical power supply is on; and (b) PL spectrum of the fabricated 365nm-chip-based LED.*

6. LED fabrication *via* double-wavelength emitting single-component $SrLaF_7$: Eu^{3+} phosphors

The nanophosphors of Sr_2LaF_7 doped with various concentrations of Eu^{3+} ions (5, 10, 15, 20, 30, 40, 50, 60, and 80 mol%) were prepared using the hydrothermal method with EDTA-2Na as a stabilizing agent, in a 100-mL Teflon-lined autoclave at 180°C for 20 hours. Transmission electron micrographs of the representative Sr_2LaF_7 powder (50 mol% Eu^{3+}) showed nanoparticles of a similar quasi-spherical shape with the average particle size ~ 24 nm.
PL spectroscopy was conducted to assess the optical performance of these nanophosphors. The emission spectra, recorded with 391 nm excitation, reveal the specific orange-red and deep-red peaks, corresponding to intra-*4f* transitions of Eu^{3+}, located around 591 nm ($^5D_0 \rightarrow {}^7F_1$), 612 nm ($^5D_0 \rightarrow {}^7F_2$), 650 nm ($^5D_0 \rightarrow {}^7F_3$), 698 nm ($^5D_0 \rightarrow {}^7F_4$ transition). All Eu^{3+} concentrations produce strong emission peaks; however, the sample with 50 mol% Eu^{3+} is optimal for LED fabrication, as it exhibits the highest integrated emission intensity.

LED fabrication

The Sr_2LaF_7:50Eu^{3+} nanophosphor was separately mixed with high-temperature inorganic binder - *Aremco-CeramabindTM 643-2* before being deposited on the 395 nm LED chip. The mixed resin, which contains *Ceramabind* and SLF:50Eu phosphor, was deposited on top of the LED chip using the Doctor blade (tape casting) technique, then dried for 48 hours. Photographs of the fabricated LED device, presented in Figure 5a, display a strong red light when the power supply is on. The PL spectrum of the fabricated LED, composed of a 395 nm chip and SLF:50Eu phosphor, reveals strong emissions in the near-UV, orange/red, and far-red regions. Figure 5b (right) presents the emission of the 395 nm LED chip before the red phosphor was applied. A noticeable dip at 391 nm confirms the absorption of UV light by Eu^{3+} ions. Therefore, this LED shows considerable potential for use in indoor horticulture.

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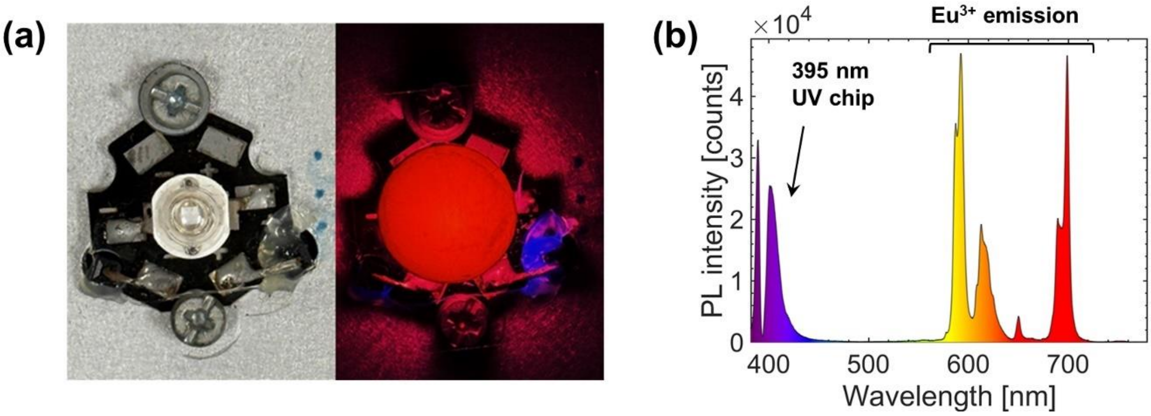

Figure 5. *A fabricated LED device comprising a semiconductor chip and Sr_2LaF_7:50mol%Eu^{3+} nanopowders displays a red light when the electrical power supply is on; PL spectrum of the fabricated 395nm-chip-based LED.*

7. LED fabrication via double-wavelength emitting single-component RbY_3F_{10}: Eu^{3+} phosphors

Using the microwave-assisted solvothermal method, we synthesized the fluoride host material RbY_3F_{10} doped with Eu^{3+}. By varying the chelating agents (EDTA, Na_2EDTA, citric acid) and pH, we controlled the coordination environment around the metal ions, resulting in different products. The optimized RbY_3F_{10}:Eu^{3+} phosphor was obtained using a molar ratio of 1:6 (EDTA:RE) and pH=9. Nanoparticles are spherical as well as have a high degree of crystallinity. The average crystalline size of RbY_3F_{10} nanoparticles was estimated to be in the range between 50 and 90 nm. The PL spectra of all RbY_3F_{10}:$x$$Eu^{3+}$($x$ = 1, 5, 10, 30, and 50 mol%) samples were recorded at room temperature under 405 nm excitation. All emissions correspond to 4f–4f transitions of Eu^{3+} are located at ~594 nm ($^5D_0 \rightarrow {}^7F_1$), ~613 nm ($^5D_0 \rightarrow {}^7F_2$), ~650 nm ($^5D_0 \rightarrow {}^7F_3$), and ~700 nm ($^5D_0 \rightarrow {}^7F_4$). Europium ions' emission intensity monotonically increases in the co-doped samples up to 50 mol% of Eu^{3+}. These findings suggest that highly doped RbY_3F_{10}:Eu^{3+} nanophosphors, exhibiting strong orange/red and deep-red emissions, are promising candidates for plant-targeted LEDs.

LED fabrication

The RbY_3F_{10}:50Eu^{3+} nanophosphor was separately mixed with high-temperature inorganic binder - *Aremco-CeramabindTM 643-2* before being deposited on the 395 nm LED chip. The mixed resin, which contains *Ceramabind* and RbY_3F_{10}:50Eu^{3+} phosphor, was deposited on top of the LED chip using the Doctor blade (tape casting) technique, then dried for 48 hours. Photographs of the fabricated LED device, presented in Figure 6a, display a strong violet/pinkish light when the power supply is on. The PL spectrum of the fabricated LED, composed of a 395 nm chip and RbY_3F_{10}:50Eu^{3+}phosphor, reveals strong emissions in the near-UV, orange/red, and far-red regions (see Figure 6b). A minor dip at 391 nm indicates low absorption of near-UV light by Eu^{3+} ions. The insufficient intensity of red and far-red emissions makes this LED unsuitable for effective indoor horticultural use. Our upcoming research will focus on the improvement of red and far-red light components.

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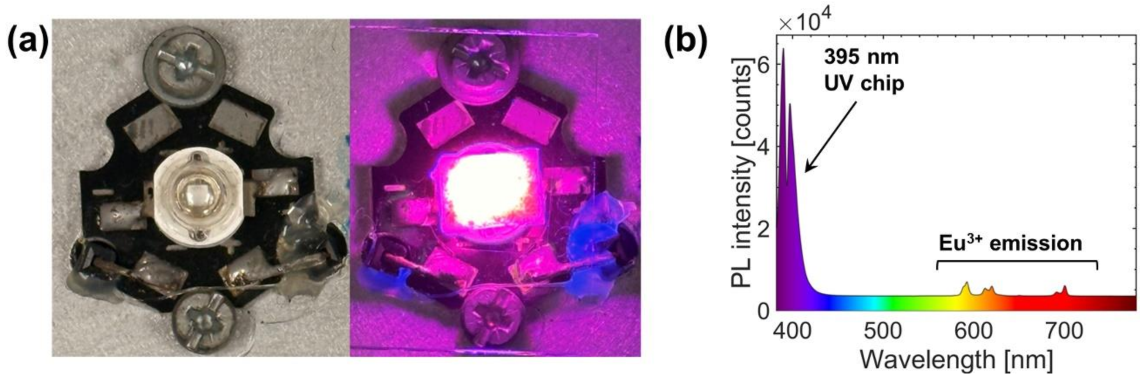

Figure 6. *A fabricated LED device comprising a semiconductor chip and RbY_3F_{10}:50mol%Eu^{3+} nanopowders displays a violet/pinkish light when the electrical power supply is on; and (b) PL spectrum of the fabricated 395nm-chip-based LED.*

8. Scientific Publications and Peer-Reviewed Journals

During the project implementation, the LEDtech-GROW team achieved the following: four papers were published in peer-reviewed journals, all of which are Open Access as per the grant agreement (with more in preparation); four poster presentations were delivered at international conferences, and one invited talk was given at a domestic conference.

1. B. Milićević, A. Ćirić, K. Milenković, Z. Ristić, J. Periša, Ž. Antić, M. D. Dramićanin. "*Pr^{3+}-Activated Sr_2LaF_7 Nanoparticles as a Single-Phase White-Light-Emitting Nanophosphor". Nanomaterials 15(10) (2025) 717;* https://doi.org/10.3390/nano15100717

2. B. Milićević, A. Ćirić, Z. Ristić, M. Medić, A. N. Alodhayb, I. Radosavljević Evans, Ž. Antić, M. D. Dramićanin. "*Eu^{3+}- activated Sr_2GdF_7 colloid and nano-powder for horticulture LED applications". Journal of Alloys and Compounds 1010 (5) (2025) 177820.* https://doi.org/10.1016/j.jallcom.2024.177820

3. K. Milenković, Lj. Đačanin Far, S. Kuzman, Ž. Antić, A. Ćirić, M. D. Dramićanin, B. Milićević. "Red emission enhancement in $BaYF_5:Eu^{3+}$ phosphor nanoparticles by Bi^{3+} co-doping". *Optics Express* 32 (23) (2024) 41632-41643 https://doi.org/10.1364/OE.542685

4. J. Periša, S. Kuzman, A. Ćirić, Z. Ristić, Ž. Antić, M. D. Dramićanin, B. Milićević. "Tuneable Red and Blue Emission of Bi^{3+}-Co-Doped $SrF_2:Eu^{3+}$ Nanophosphors for LEDs in Agricultural Applications". *Nanomaterials* 14(20), 1617. https://doi.org/10.3390/nano14201617

5. K. Milenković, V. Đorđević, I. Zeković, Z. Ristić, J. Periša, B. Milićević, M. D. Dramićanin: "Microwave-assisted solvothermal method for RbY_3F_{10} doped with Eu^{3+}"- The 7th International Conference on the Physics of Optical Materials and Devices & The 4th International Conference on Phosphor Thermometry (ICOM&ICPT 2024), August 26-30, 2024, Bečići, Budva Montenegro, P-50, (pp 165).

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6. S. Kuzman, B. Milićević, J. Periša, A. Ćirić, Z. Ristić, Ž. Antić, M. D. Dramićanin: "Synthesis and photoluminescent properties of Bi^{3+}-codoped $SrF_2:Eu^{3+}$ phosphor nanoparticles"- The 7th International Conference on the Physics of Optical Materials and Devices & The 4th International Conference on Phosphor Thermometry (ICOM&ICPT 2024), August 26-30, 2024, Bečići, Budva Montenegro, P-51, (pp 166).

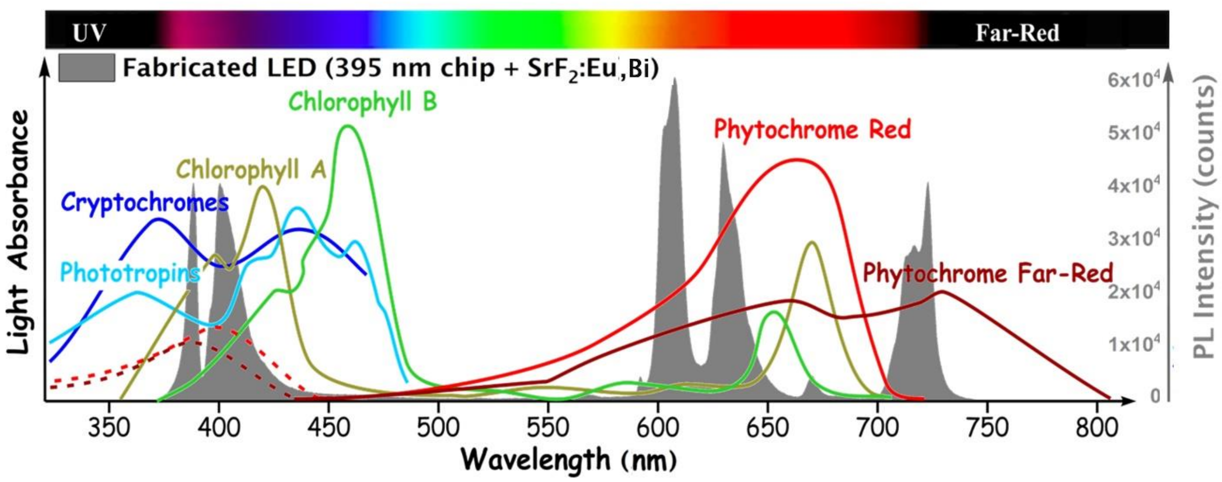
7. B. Milićević, A. Ćirić, Z. Ristić, M. Medić, I. Radosavljevic Evans, Ž. Antić, M. D. Dramićanin: "Synthesis, luminescent properties, and thermal stability of Eu^{3+}-doped Sr_2GdF_7 red-emitting nanophosphor for horticulture LEDs"- The 7th International Conference on the Physics of Optical Materials and Devices & The 4th International Conference on Phosphor Thermometry (ICOM&ICPT 2024), August 26-30, 2024, Bečići, Budva Montenegro, P-53, (pp 168).

8. K. Milenković, V. Đorđević, S. Kuzman, J. Periša, B. Milićević, Miroslav D. Dramićanin: "Three-fold enhancement of Eu^{3+} emission intensity in $BaYF_5$ nanoparticles by Bi^{3+} co-doping", -12th International Conference on Luminescent Detectors and Transformers of Ionizing Radiation (LUMDETR), June 16-21, 2024, Riga, Latvia, PA13, (pp 89).

9. S. Kuzman, B. Milićević, K. Milenković, J. Periša, M. D. Dramićanin: "Bizmuth-sensitized Eu^{3+} luminescent LED technology for effective indoor plant growth"- The 3rd Serbian Conference on Materials Application and Technology (SCOM2024), October 16-18, Belgrade, Serbia, I-1, (pp 8). *Invited talk*

LEDtech-GROW team members reached **Milestone M2.1 - LEDs fabricated** (verification: LED emission matches the PAR spectrum of plant photoreceptors (see below)).

SrF_2:10%Eu^{3+},20%Bi^{3+}



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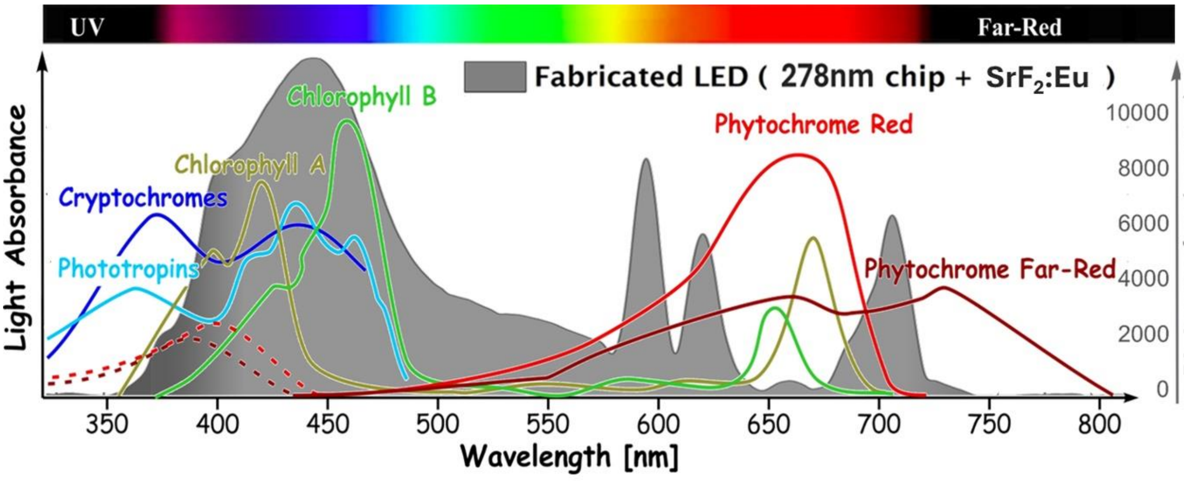
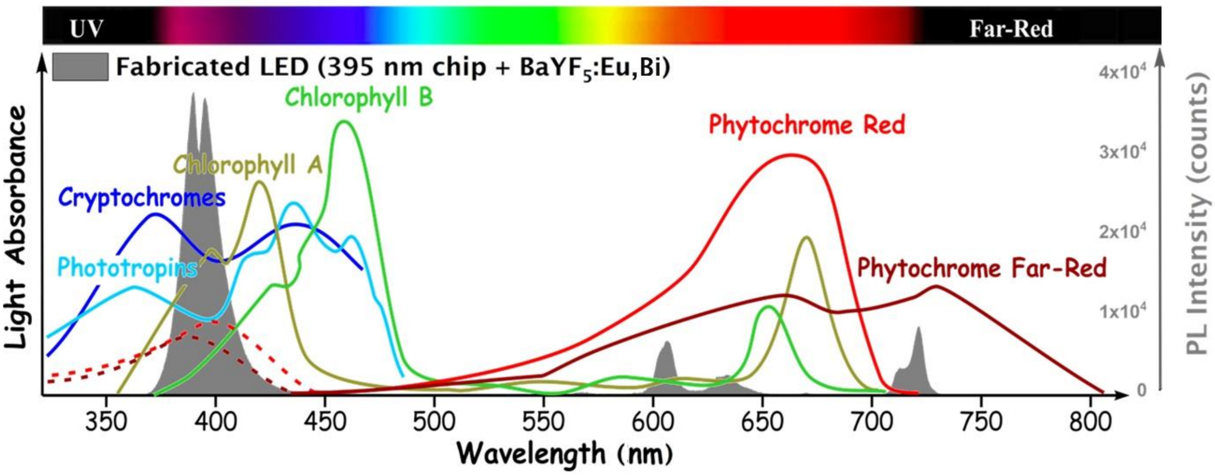
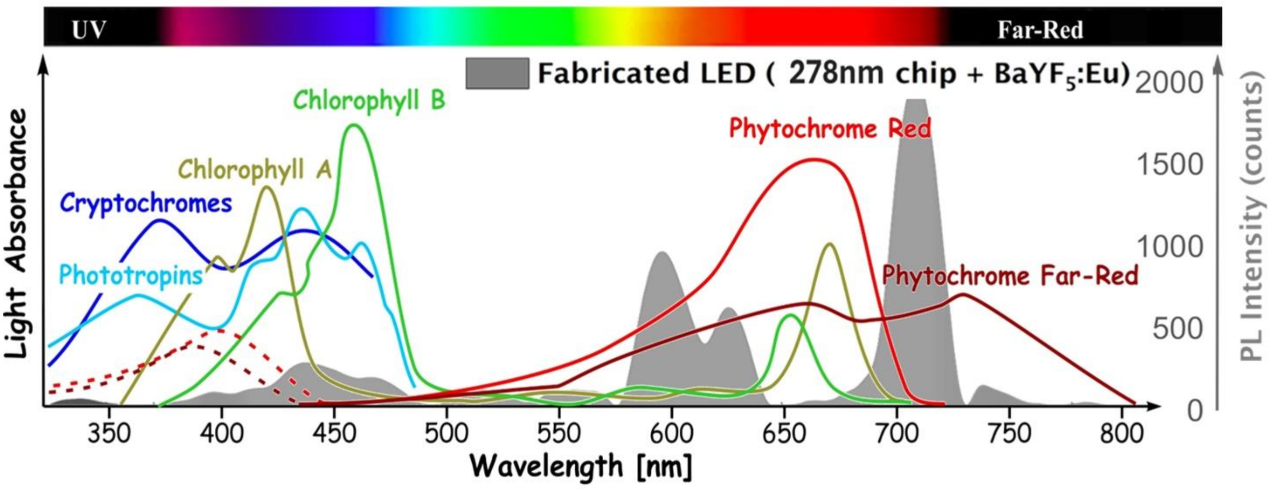
SrF_2:10%Eu^{3+},20%Bi^{3+}



$BaYF_5$:10Eu^{3+},20Bi^{3+}



$BaYF_5$:10Eu^{3+},20Bi^{3+}



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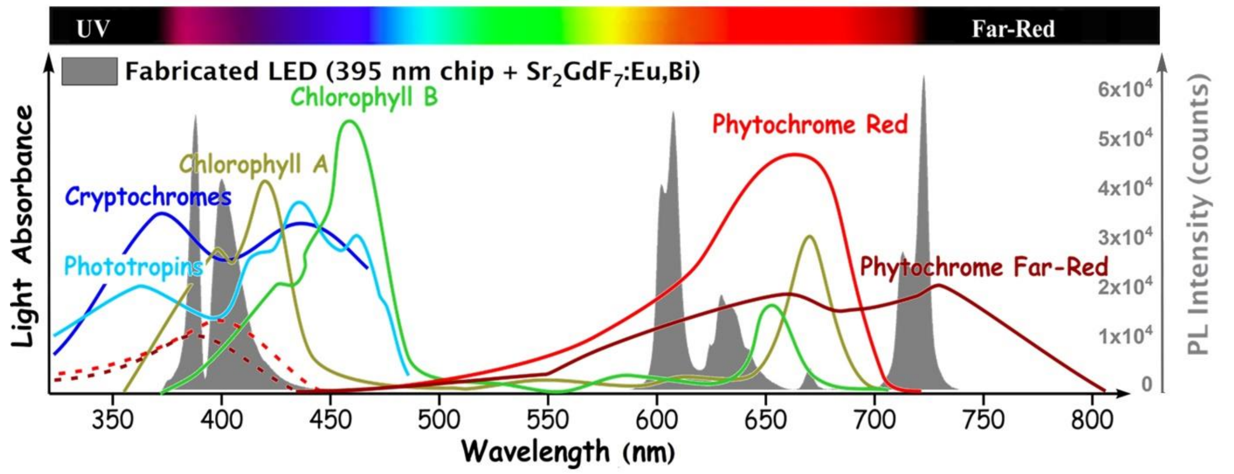
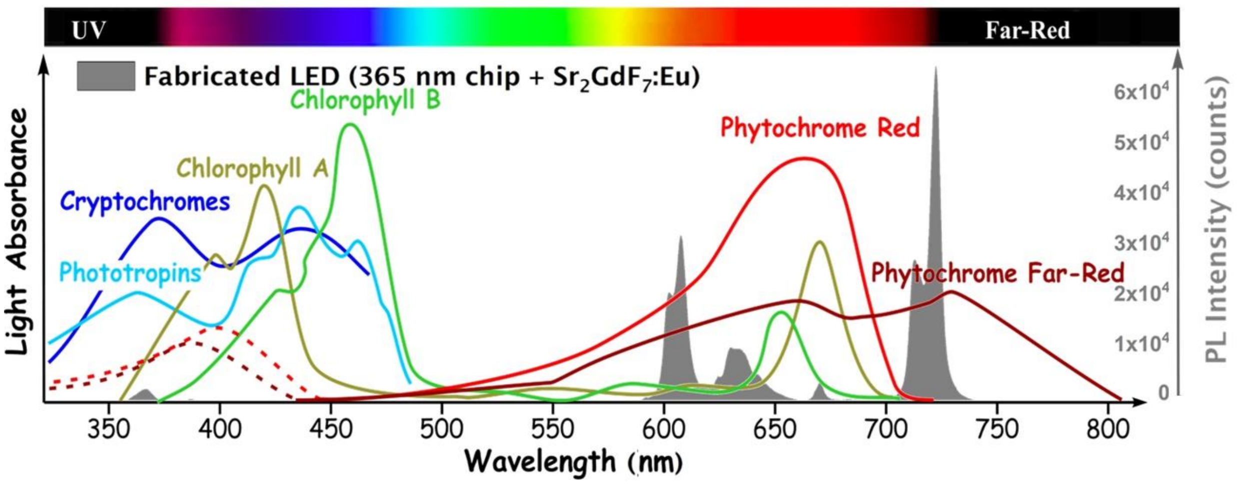
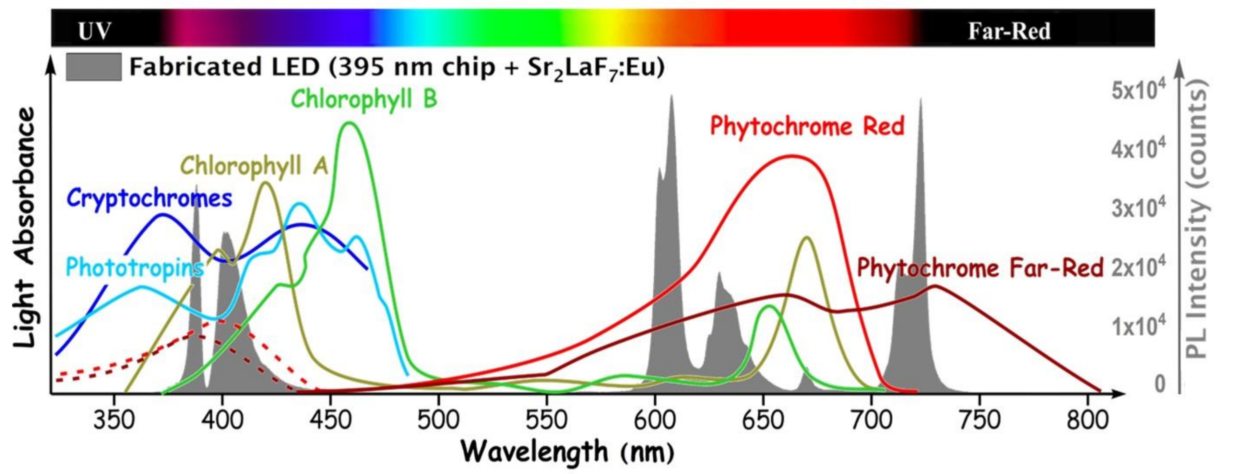
$SrGd_{0.19}F_7$: 80%Eu^{3+},1%Bi^{3+}



$SrGdF_7$: 80%Eu^{3+}



Sr_2LaF_7:50mol%Eu^{3+}



RbY_3F_{10}:50mol%Eu^{3+}

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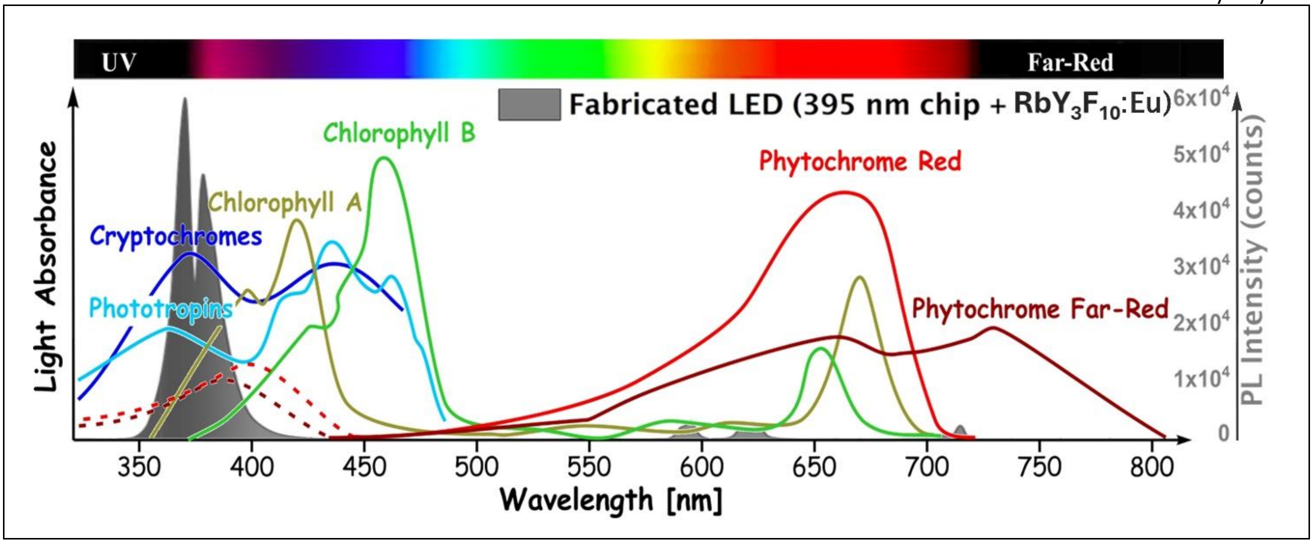

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