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(54) **COLOR COMPENSATION FOR OPTICAL MODIFICATION**

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F21Y 115/10 (2016.01)

(52) **U.S. Cl.**

CPC ***H05B 45/20*** (2020.01); ***F21V 14/06*** (2013.01); *F21Y 2115/10* (2016.08)

(58) **Field of Classification Search**

CPC H05B 45/20; F21V 14/06; F21V 23/0442; F21Y 2115/10; F21Y 2113/13; F21W 2131/406

See application file for complete search history.

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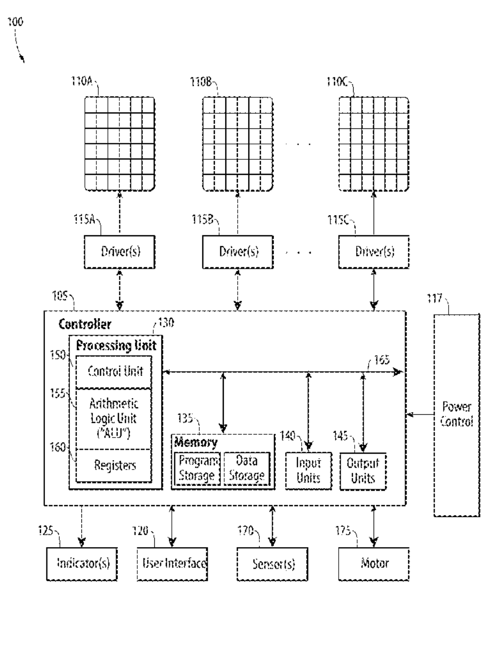
(57) **ABSTRACT**

A light fixture includes an array of light-emitting diode ("LED") light sources, a driver circuit that drives the array of LED light sources, and a controller. Controlling the light fixture includes receiving a first output color spectrum for the array of LED light sources that corresponds to a fixture color output spectrum, performing an optical modification of the fixture output color spectrum, determining, based on the optical modification, a compensation value to modify the first output color spectrum to a second output color spectrum that compensates for changes to the fixture output color spectrum resulting from the optical modification, generating, based on the compensation value, a first control signal to drive the array of LED light sources at the second output color spectrum, and controlling the driver circuit using the first control signal.

22 Claims, 7 Drawing Sheets



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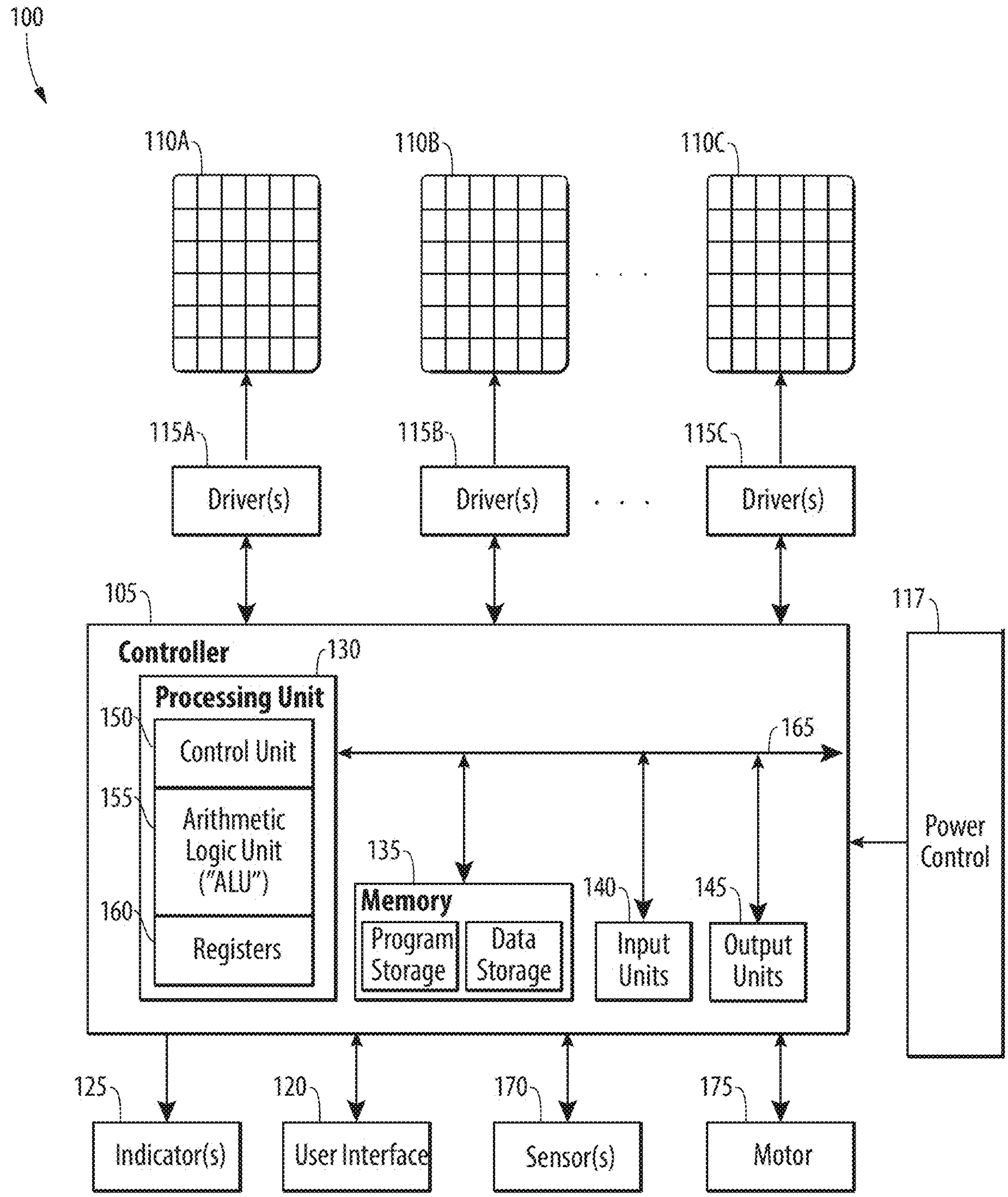

100
110A
110B
110C
115A
115B
115C
Driver(s)
Driver(s)
Driver(s)
105
117
Controller
130
Processing Unit
150
Control Unit
165
155
Arithmetic Logic Unit ("ALU")
160
Registers
135
Memory
Program Storage
Data Storage
140
Input Units
145
Output Units
Power Control
125
120
170
175
Indicator(s)
User Interface
Sensor(s)
Motor

Fig. 1

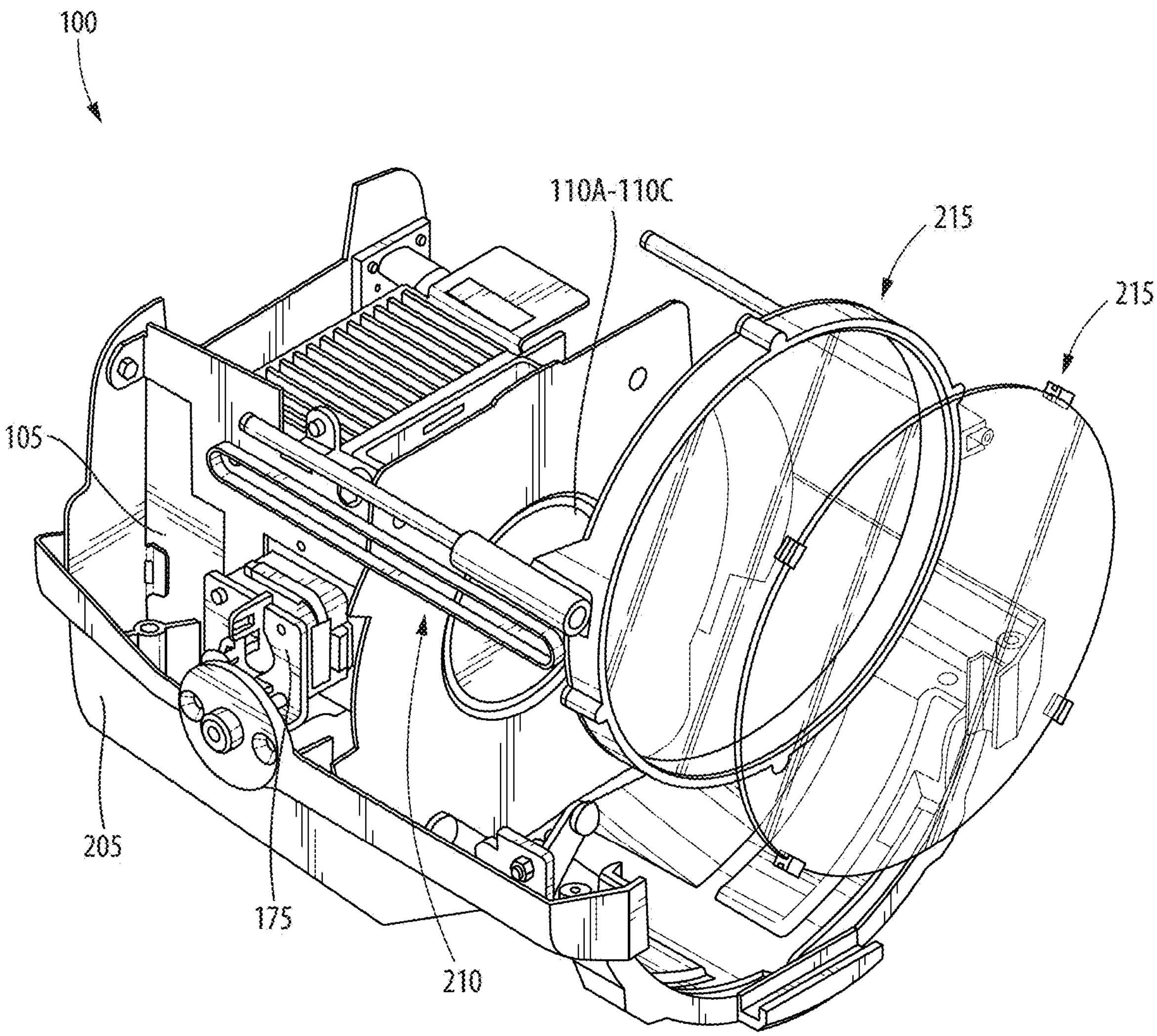


Fig. 2

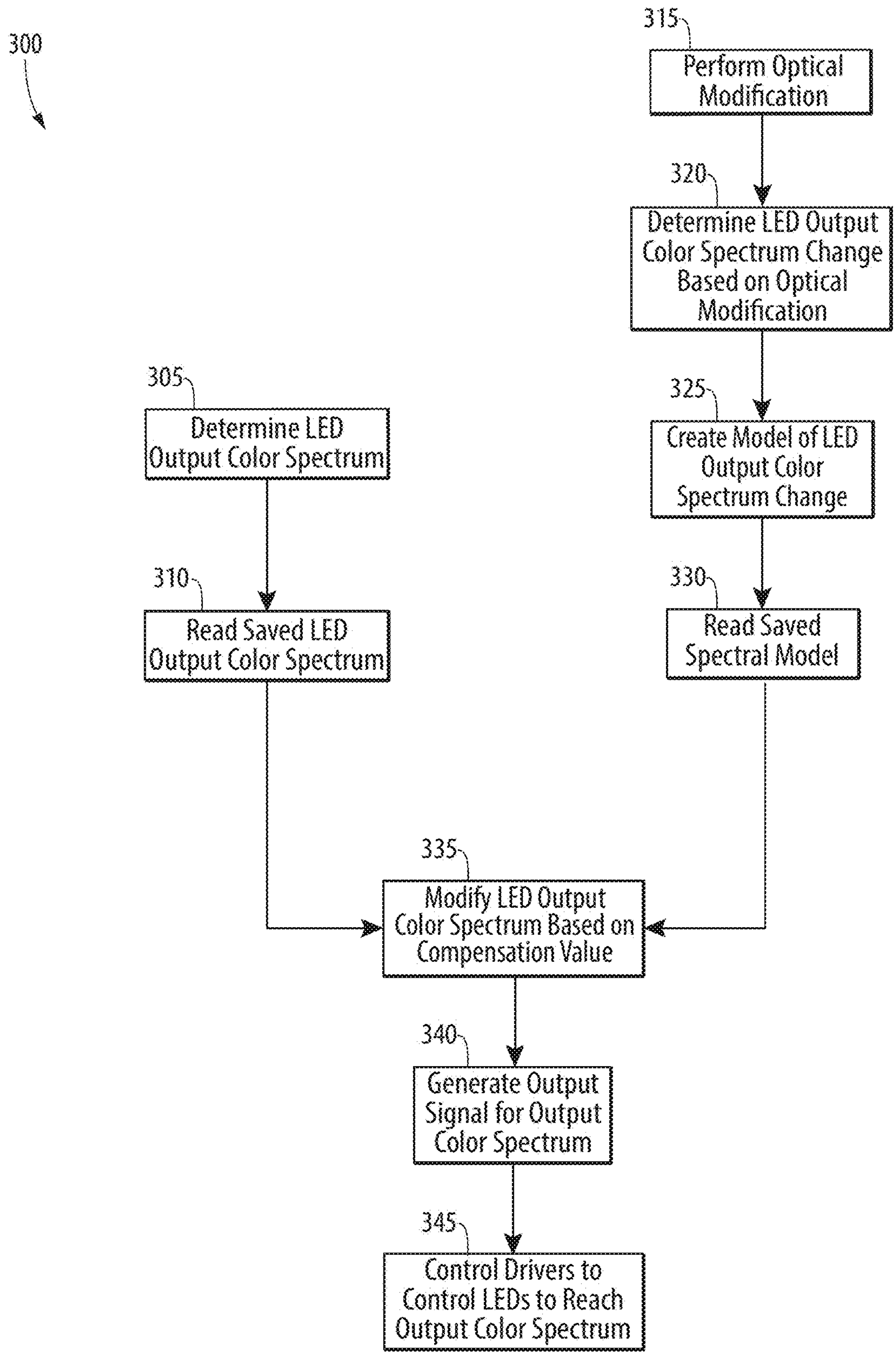

300
315
Perform Optical Modification
320
Determine LED Output Color Spectrum Change Based on Optical Modification
325
Create Model of LED Output Color Spectrum Change
330
Read Saved Spectral Model
305
Determine LED Output Color Spectrum
310
Read Saved LED Output Color Spectrum
335
Modify LED Output Color Spectrum Based on Compensation Value
340
Generate Output Signal for Output Color Spectrum
345
Control Drivers to Control LEDs to Reach Output Color Spectrum

Fig. 3

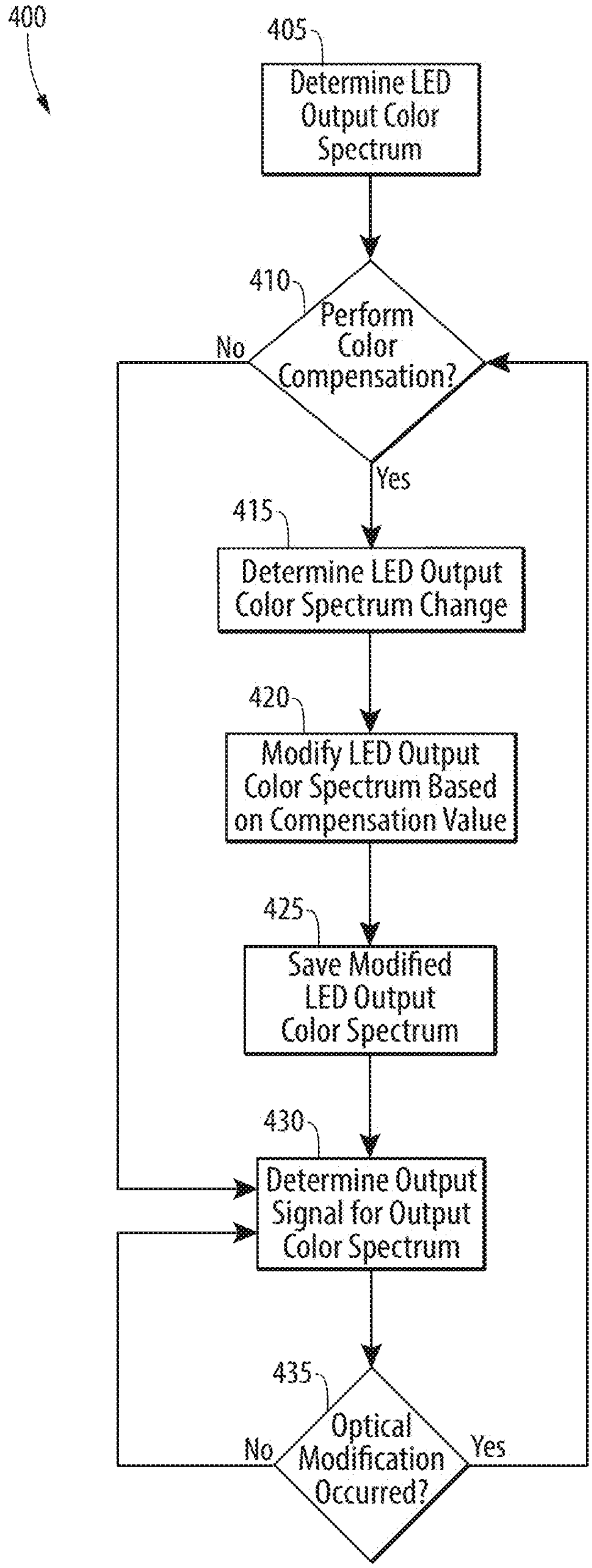

400
405
Determine LED Output Color Spectrum
410
Perform Color Compensation?
No
Yes
415
Determine LED Output Color Spectrum Change
420
Modify LED Output Color Spectrum Based on Compensation Value
425
Save Modified LED Output Color Spectrum
430
Determine Output Signal for Output Color Spectrum
435
Optical Modification Occurred?
No
Yes

Fig. 4

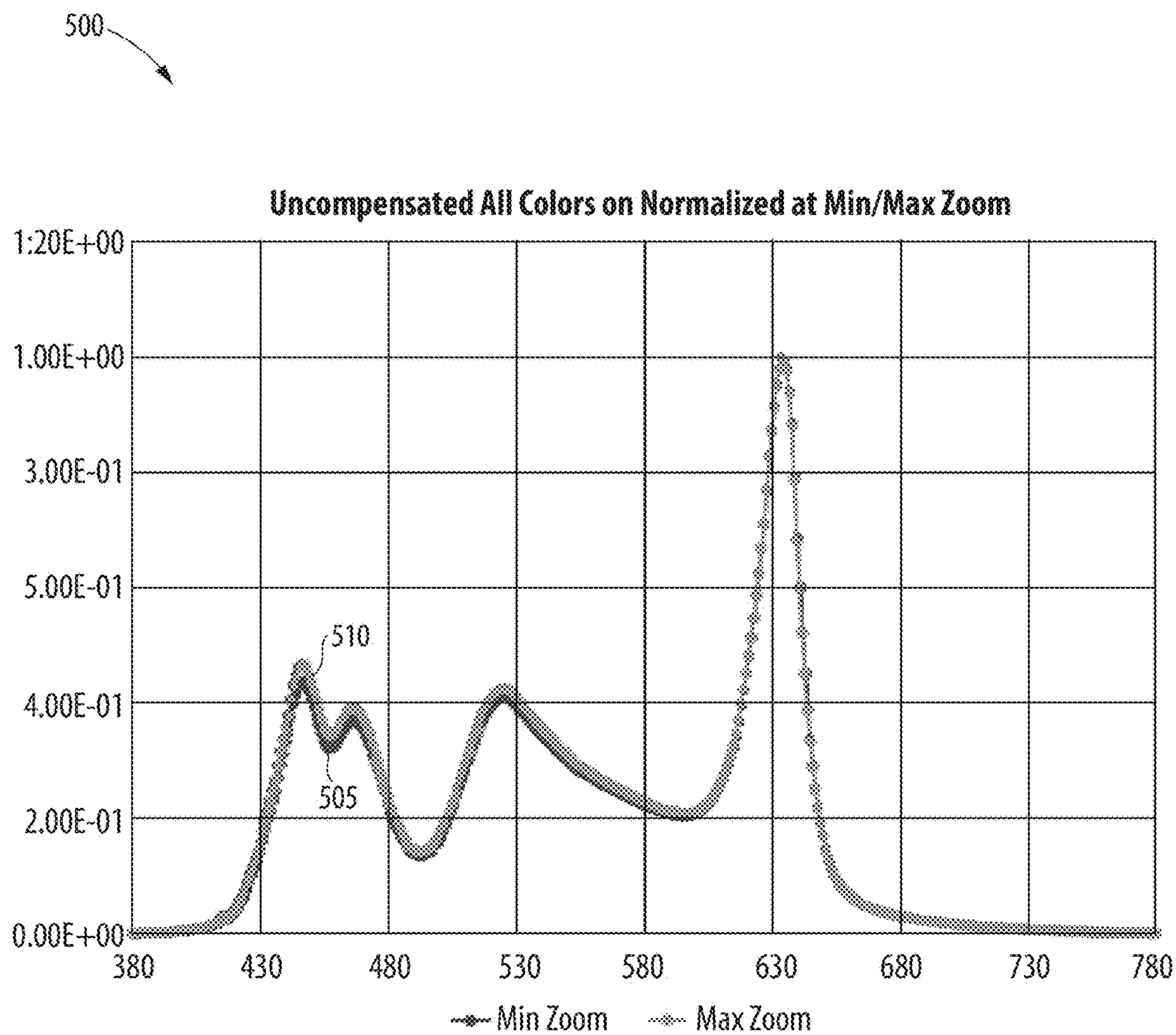
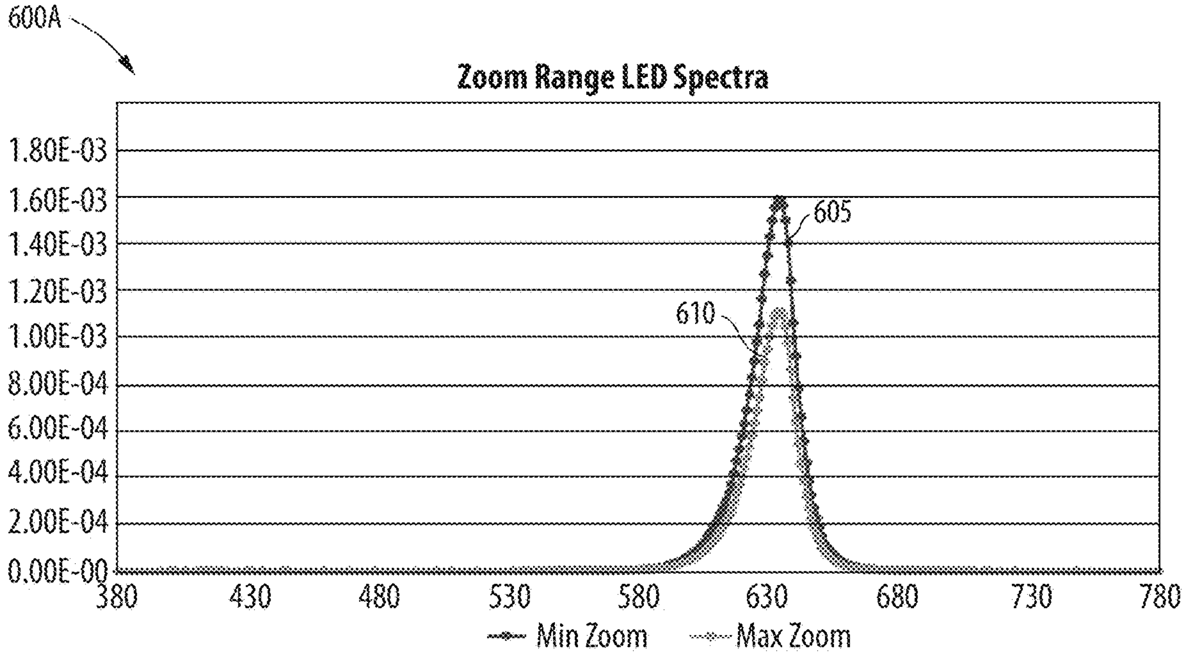

500
Uncompensated All Colors on Normalized at Min/Max Zoom
1:20E+00
1.00E+00
3.00E-01
5.00E-01
4.00E-01
2.00E-01
0.00E+00
380
430
480
530
580
630
680
730
780
510
505
Min Zoom
Max Zoom

Fig. 5


600A
Zoom Range LED Spectra
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1.60E-03
1.40E-03
1.20E-03
1.00E-03
8.00E-04
6.00E-04
4.00E-04
2.00E-04
0.00E-00
380
430
480
530
580
630
680
730
780
605
610
Min Zoom
Max Zoom

Fig. 6A

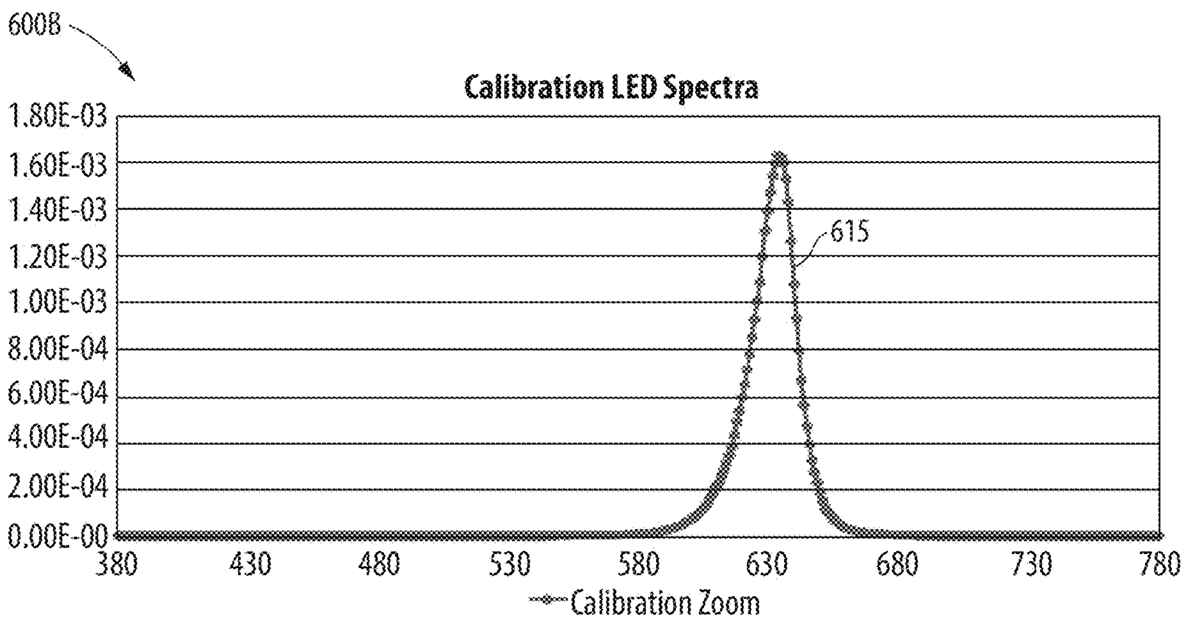
600B
Calibration LED Spectra
1.80E-03
1.60E-03
1.40E-03
1.20E-03
1.00E-03
8.00E-04
6.00E-04
4.00E-04
2.00E-04
0.00E-00
380
430
480
530
580
630
680
730
780
615
Calibration Zoom

Fig. 6B

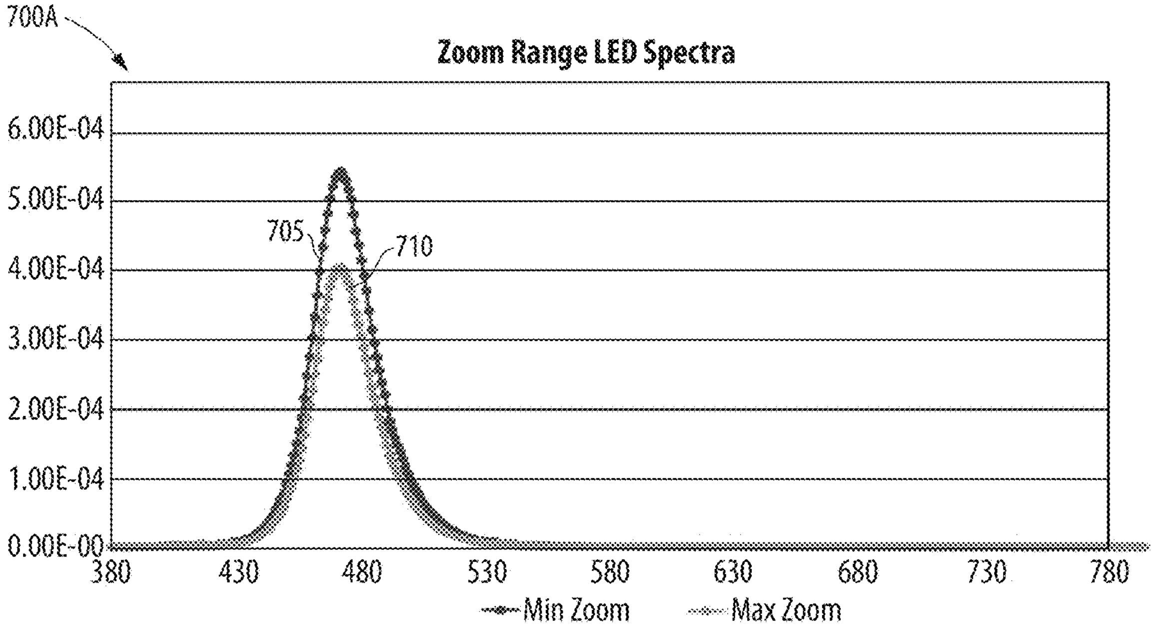
700A
Zoom Range LED Spectra
6.00E-04
5.00E-04
4.00E-04
3.00E-04
2.00E-04
1.00E-04
0.00E-00
705
710
380
430
480
530
580
630
680
730
780
Min Zoom
Max Zoom

Fig. 7A

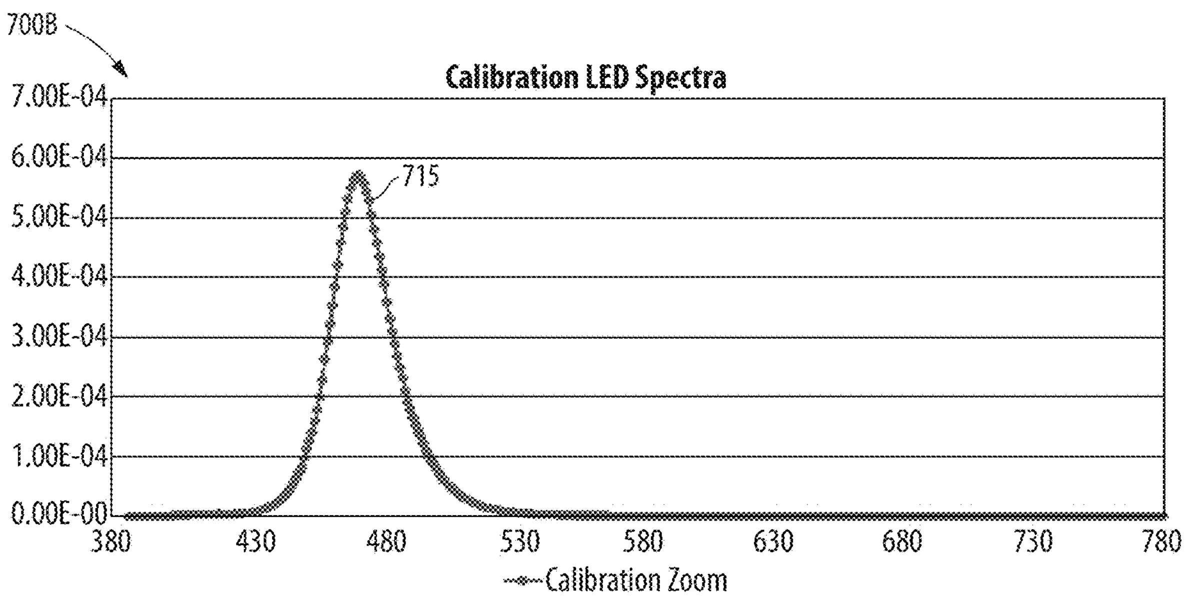
700B
Calibration LED Spectra
7.00E-04
6.00E-04
5.00E-04
4.00E-04
3.00E-04
2.00E-04
1.00E-04
0.00E-00
715
380
430
480
530
580
630
680
730
780
Calibration Zoom

Fig. 7B

COLOR COMPENSATION FOR OPTICAL MODIFICATION

FIELD

Embodiments described herein relate to controlling an output of a light fixture.

BACKGROUND

The lens assembly (e.g., lenses, diffusers, filters, or other optical components) of a light fixture allows the light fixture to manipulate light emitted from light sources (e.g., light-emitting diodes or LEDs) within the light fixtures. Advanced lighting systems include light fixtures capable of performing optical modifications to the light emitted from the LEDs via the lens assembly. LEDs are capable of emitting white light or colored light, commonly referred to as the visible light spectrum. The visible light spectrum typically includes wavelengths of light between 380 to 700 nanometers. Optical modification of the visible light spectrum is typically accomplished by bending or changing the direction of the light emitted from light sources using a lens assembly.

SUMMARY

Optical modifications are convenient for manipulating emitted light, but can cause the spectrum of the emitted light to shift. Different wavelengths of light within the visible light spectrum can be shifted by the optical modifications at different rates. This can be the result of the location of each LED relative to the lens assembly being different. As an optical modification occurs, a direction that rays of the emitted light are deflected when exiting the lens assembly can also change. This can result in a shift of the light emitted from the lens assembly.

Embodiments described herein provide systems, devices, and methods for controlling an output of a light fixture. The light fixture includes a plurality of light sources. The light fixture is configured to produce an output that achieves a desired output color spectrum having different wavelengths of light. A controller performs an optical modification corresponding to a change in the desired output color spectrum. A relationship between the optical modification and the output color spectrum is then used to determine a color compensation value. The color compensation value is used to determine a control signal at which the light sources will be driven. As the optical modification is performed, the controller is configured to modify the control signal at which the light sources are driven based on the color compensation value.

According to some embodiments, a light fixture that produces an output includes an array of light-emitting diode ("LED") light sources, a driver circuit, and a controller. Each LED light source defines a color channel of the light fixture. The driver circuit drives the array of LED light sources. The controller includes a non-transitory computer readable medium and processing unit, the controller also including computer executable instructions stored in the non-transitory computer readable medium for controlling operation of the light fixture. Controlling operation of the light fixture includes receiving a first output color spectrum for the array of LED light sources that corresponds to a fixture color output spectrum (e.g., a CIE 1931 chromaticity diagram, an LAB color space, or any other representation of color range). Controlling operation of the light fixture also includes performing an optical modification of the fixture output color spectrum. Controlling operation of the light fixture also includes determining, based on the optical modification, a compensation value to modify the first output color spectrum to a second output color spectrum that compensates for changes to the fixture output color spectrum resulting from the optical modification. Controlling operation of the light fixture also includes generating, based on the compensation value, a first control signal to drive the array of LED light sources at the second output color spectrum. Controlling operation of the light fixture also includes controlling the driver circuit using the first control signal.

According to some embodiments, a system controls an output of a light fixture. The system includes the light fixture and a controller. The light fixture includes an array of light-emitting diode ("LED") light sources and a driver circuit. Each LED light source emits a color channel of the light fixture. The driver circuit drives the array of LED light sources. The controller generates a direct drive signal for one or more arrays of LED light sources. The controller includes a non-transitory computer readable medium and a processing unit, the controller including computer executable instructions stored in the non-transitory computer readable medium for controlling operation of the light fixture. Controlling operation of the light fixture includes receiving a first fixture output color spectrum emitted by the array of LED light sources. Controlling operation of the light fixture also includes performing an optical modification of the first fixture output color spectrum. Controlling operation of the light fixture also includes determining, based on the optical modification, a compensation value to compensate for changes to the first fixture output color spectrum, the changes to the first fixture output color spectrum resulting from the optical modification. Controlling operation of the light fixture also includes generating, based on the compensation value, a first control signal to drive the array of LED light sources to emit a second fixture output color spectrum. Controlling operation of the light fixture also includes controlling the driver circuit using the first control signal.

According to some embodiments, a method is used to control the light fixture. The method includes determining a first fixture output color spectrum for the light fixture, the light fixture having an array of LED light sources. The method also includes performing an optical modification of the fixture output color spectrum. The method also includes determining, based on the optical modification, a compensation value to compensate for changes to the fixture output color spectrum resulting from the optical modification. The method also includes generating, based on the compensation value, a first control signal to drive the array of LED light sources to emit a second fixture output color spectrum. The method also includes controlling the driver circuit using the first control signal.

According to some embodiments, a light fixture includes a lens, a first LED, a second LED, a driver circuit, and a controller. The first LED has a first LED output color spectrum. The second LED has a second LED output color spectrum, the first and second output color spectrums are mixed and passed through the lens to generate a fixture output color spectrum. The driver circuit drives the first and second LEDs. The controller includes a non-transitory computer readable medium and processing unit, the controller includes computer executable instructions stored in the non-transitory computer readable medium for controlling operation of the light fixture. Controlling operation of the light fixture includes receiving the fixture output color spectrum. Controlling operation of the light fixture also includes modifying the position of the lens relative to the

first and second LEDs. Controlling operation of the light fixture also includes determining, based on the modification of the position of the lens, a value that compensates for changes in the fixture output color spectrum resulting from the modification of the position of the lens. Controlling operation of the light fixture also includes generating, based on the value, a control signal to drive the first LED at a third LED output color spectrum that is different from the first LED output color spectrum. Controlling operation of the light fixture also includes controlling the driver circuit using the first control signal.

Before any embodiments are explained in detail, it is to be understood that the embodiments are not limited in its application to the details of the configuration and arrangement of components set forth in the following description or illustrated in the accompanying drawings. The embodiments are capable of being practiced or of being carried out in various ways. Also, it is to be understood that the phraseology and terminology used herein are for the purpose of description and should not be regarded as limiting. The use of "including," "comprising," or "having" and variations thereof are meant to encompass the items listed thereafter and equivalents thereof as well as additional items. Unless specified or limited otherwise, the terms "mounted," "connected," "supported," and "coupled" and variations thereof are used broadly and encompass both direct and indirect mountings, connections, supports, and couplings.

In addition, it should be understood that embodiments may include hardware, software, and electronic components or modules that, for purposes of discussion, may be illustrated and described as if the majority of the components were implemented solely in hardware. However, one of ordinary skill in the art, and based on a reading of this detailed description, would recognize that, in at least one embodiment, the electronic-based aspects may be implemented in software (e.g., stored on non-transitory computer-readable medium) executable by one or more processing units, such as a microprocessor and/or application specific integrated circuits ("ASICs"). As such, it should be noted that a plurality of hardware and software-based devices, as well as a plurality of different structural components, may be utilized to implement the embodiments. For example, "servers" and "computing devices" described in the specification can include one or more processing units, one or more computer-readable medium modules, one or more input/output interfaces, and various connections (e.g., a system bus) connecting the components.

Other aspects of the embodiments will become apparent by consideration of the detailed description and accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a block diagram of a light fixture, according to embodiments described herein.

FIG. **2** is a perspective view of the light fixture of FIG. **1** with a portion of a housing removed.

FIG. **3** illustrates a flow chart of a method for controlling an output of the light fixture of FIG. **1**.

FIG. **4** illustrates a flow chart of a method for controlling an output of the light fixture of FIG. **1**.

FIG. **5** is a graph of a fixture output color spectrum of the light fixture of FIG. **1** based an optical modification.

FIG. **6**A is a graph of a first LED output color spectrum of the light fixture of FIG. **1** based on an optical modification.

FIG. **6**B is a graph of the calibrated first LED output color spectrum after the optical modification of FIG. **6**A.

FIG. **7**A is a graph of a second LED output color spectrum of the light fixture of FIG. **1** based on an optical modification.

FIG. **7**B is a graph of the calibrated second LED output color spectrum after the optical modification of FIG. **7**A.

DETAILED DESCRIPTION

In some embodiments, light fixtures are used in, for example, a theatre, a hall, an auditorium, a hotel, a cruise ship, or the like. As illustrated in FIG. **1**, each light fixture **100** includes a controller **105**, a plurality of light sources **110**A-**110**C, a plurality of light source drivers or driver circuits **115**A-**115**C, a power control circuit **117**, a user interface **120**, one or more indicators **125**, one or more sensors **170**, and a motor **175**. In some embodiments, the light fixture **100** is separate from the controller **105**. In other embodiments the controller **105** is contained in the light fixture **100** along with the light sources **110**A-**110**C and the driver circuits **115**A-**115**C.

The controller **105** includes a plurality of electrical and electronic components that provide power, operational control, and protection to the components and modules within the controller **105** and/or the fixture **100**. For example, the controller **105** includes, among other things, a processing unit **130** (e.g., a microprocessor, a microcontroller, or another suitable programmable device), a memory **135**, input units **140**, and output units **145**. The processing unit **130** includes, among other things, a control unit **150**, an arithmetic logic unit ("ALU") **155**, and a plurality of registers **160** (shown as a group of registers in FIG. **1**), and is implemented using a known computer architecture (e.g., a modified Harvard architecture, a von Neumann architecture, etc.). The processing unit **130**, the memory **135**, the input units **140**, and the output units **145**, as well as the various modules connected to the controller **105** are connected by one or more control and/or data buses (e.g., common bus **165**). The use of one or more control and/or data buses for the interconnection between and communication among the various modules and components would be known to a person skilled in the art in view of the invention described herein. The control and/or data buses are shown generally in FIG. **1** for illustrative purposes.

The memory **135** is a non-transitory computer readable medium and includes, for example, a program storage area and a data storage area. The program storage area and the data storage area can include combinations of different types of memory, such as a ROM, a RAM (e.g., DRAM, SDRAM, etc.), EEPROM, flash memory, a hard disk, an SD card, or other suitable magnetic, optical, physical, or electronic memory devices. The processing unit **130** is connected to the memory **135** and executes software instructions that are capable of being stored in a RAM of the memory **135** (e.g., during execution), a ROM of the memory **135** (e.g., on a generally permanent basis), or another non-transitory computer readable medium such as another memory or a disc. Software included in the implementation of the light fixture **100** can be stored in the memory **135** of the controller **105**. The software includes, for example, firmware, one or more applications, program data, filters, rules, one or more models (e.g., an output color spectrum, a spectral model, a CIE 1931 chromaticity diagram, or the like), one or more program modules, and other executable instructions. The controller **105** is configured to retrieve from the memory **135** and execute, among other things, instructions related to the control processes and methods described herein. In other embodiments, the controller **105** includes additional, fewer, or different components.

In some embodiments, the user interface **120** is included to receive a user input from a user. The user interface **120** is operably coupled to the controller **105** to provide an input signal indicative of the user input to the controller **105**. The controller **105** receives the input signal from the user interface **120** to control, for example, the output of the light sources **110**A-**110**C, and generate and provide control signals for the driver circuits **115**A-**115**C based on the input signal. The user interface **120** can include any combination of digital and analog input devices required to receive the user input for the fixture **100**. For example, the user interface **120** can include a computer having a display and input devices, a touch-screen display, a plurality of knobs, dials, switches, buttons, faders, or the like. In some embodiments, the user interface **120** is separated from the light fixture **100**. In some embodiments, the controller **105** controls the light fixture **100** independently of the user interface **120**.

The driver circuits **115**A-**115**C include a first driver circuit **115**A, a second driver circuit **115**B, and a third driver circuit **115**C, all of which are operable to drive (e.g., control) the light sources **110**A-**110**C. The first driver circuit **115**A is connected to a first array of light sources **110**A and provides one or more drive signals to the first array of light sources **110**A. The second driver circuit **115**B is connected to a second array of light sources **110**B and provides one or more drive signals to the second array of light sources **110**B. The third driver circuit **115**C is connected to a third array of light sources **110**C and provides one or more drive signals to the third array of light sources **110**C.

The power control circuit **117** supplies a nominal AC or DC voltage to the light fixture **100** or a system of light fixtures. In some embodiments, the power control circuit **117** is powered by one or more batteries or battery packs. In other embodiments, the power control circuit **117** is powered by mains power having nominal line voltages between, for example, 100V and 240V AC and frequencies of approximately 50-60 Hz. The power control circuit **117** is also configured to supply lower voltages to operate circuits and components within the light fixture **100**.

As illustrated in FIG. **1**, the controller **105** is connected to light sources **110**A-**110**C. In some embodiments, each light source **110**A-**110**C is a chip-on-board ("COB") light source. A three light source embodiment is illustrated for exemplary purposes only. In other embodiments, four or more light sources are used to further enhance the light fixture's ability to produce visible light. Conversely, in other implementations, fewer than three light sources are used (i.e., one or two light sources). The light sources **110**A-**110**C are light emitting diode ("LED") arrays, although, in additional embodiments the light source may vary. The first array of light sources **110**A defines, for example, a first color channel of the light fixture **100**. The second array of light sources **110**B defines, for example, a second color channel of the light fixture **100**. The third array of light sources **110**C defines, for example, a third color channel of the light fixture **100**. In some embodiments, each array of light sources includes light sources that correspond to multiple color channels of the light fixture (e.g., both a first color channel and a second color channel of the light fixture **100**). Each color channel of the light fixture **100** (e.g., the first color channel defined by the first array of light sources **110**A, the second color channel defined by the second array of light sources **110**B, the third color channel defined by the third array of light sources **110**C, etc.) includes at least a first output color. In some embodiments, the first color channel of the first light source **110**A includes the first output color, a second output color, and any greater number of output colors. For example, the first array of light sources **110**A may include a first LED light source that emits the first output color and a second LED light source that emits the second output color. The first output color has a first LED output color spectrum and the second output color has a second LED output color spectrum. In some embodiments, the second LED output color spectrum is different than the first LED output color spectrum. In other embodiments, the second LED output color spectrum is the same as the first LED output color spectrum. Each light source of the plurality of light sources **110**A-**110**C is configured to operate similarly to the first array of light sources **110**A as described above. In some embodiments, a light source of the plurality of light sources **110**A-**110**C may operate differently than described above. In combination, the first LED output color spectrum of the first array of light sources **110**A, the second LED output color spectrum of the second array of light sources **110**B, and further LED output color spectrums of the plurality of light sources **110**A-**110**C produce a fixture color output spectrum of the light fixture **100**. In other words, each individual LED output color spectrum is used in combination with further LED output color spectrums to produce the fixture output color spectrum that is emitted from the light fixture **100**.

As illustrated in FIG. **1**, the controller **105** is also connected to the one or more sensors **170** and the motor **175**. In some embodiments, each sensor **170** is a position sensor that senses a position of the motor **175** and provides to the controller **105** one or more signals indicative of the position of the motor **175**. For example, the sensors **170** may include a linear position sensor, a rotary position sensor, or an angular position sensor. The motor **175** drives the movement of various components of the light fixture **100** to perform any number of lighting operations. For example, the controller **105** may provide, based on the signals received from the one or more sensors **170**, one or more control signals to the motor **175**. The motor **175** drives, based on one or more control signals from the controller **105**, the movement of various components of the light fixture **100** (e.g., a lens assembly, a belt drive assembly, or the like, further described in reference to FIG. **2** below). In some embodiments, the motor **175** is a direct-current ("DC") motor that receives power from the power control circuit **117**. For example, the motor **175** may be a brushed DC motor, a brushless DC motor, a stepper motor, a servo motor, or the like. In some embodiments, it is not necessary to sense the position of the motor **175** using the one or more sensors **170**. Instead, the controller **105** may receive one or more output signals indicative of the position of the motor **175** from the motor **175**. The controller **105** determines, based on the one or more output signals from the motor **175**, the position of the motor **175**. For example, the motor **175** may drive the lens assembly to a final position of the belt drive assembly. At the final position of the belt drive assembly, the lens assembly cannot be driven any further and the controller **105** determines the position of the motor **175** based on the lens assembly stopping at the final position of the belt drive assembly.

FIG. **2** illustrates an example embodiment of the light fixture **100** in an assembly view. As illustrated in FIG. **2**, the light fixture **100** includes the controller **105**, the light sources **110**A-**110**C, the motor **175**, a housing **205**, a belt drive assembly **210**, and a lens assembly **215**. For illustrative purposes, a portion of the housing **205** has been removed. In the illustrated embodiment, the components of the light fixture **100** are disposed at least partially within the housing **205**. In some embodiments, some of the components of the light fixture **100** may be disposed outside of the housing **205**. The motor **175** includes a motor shaft. The belt drive assembly **210** is connected to the motor shaft and the lens assembly **215** is connected to the motor shaft via the belt drive assembly **210**. In response to a control signal from the controller **105**, the motor **175** drives the belt drive assembly **210** to move the lens assembly **215** relative to the light sources **110A-110C**. In some instances, the lens assembly **215** is driven away from the light sources **110A-110C**. In other instances, the lens assembly **215** is driven towards the light sources **110A-110C**. The lens may be driven linearly toward and away from the light sources **110A-110C**. Because the motor shaft rotates to reposition the lens assembly **215**, a rotational position of the motor shaft corresponds to a position of the lens assembly **215** relative to the light sources **110A-110C**. The lens assembly **215** may perform an optical modification to alter the light emitted by the light sources **110A-110C** as the emitted light passes through the lens assembly **215**. In some embodiments, the lens assembly **215** may include one or more lenses, diffusers, filters, shutters, or other optical components to perform the optical modification. For example, the optical modification may be one or more of a zoom, a focus, a prismatic shift, a shutter operation, or the like. In some cases, numerous optical modifications can occur simultaneously. In some embodiments, the lens assembly includes two or more lenses that are moveable relative to one another.

FIG. **3** illustrates a flow chart of a method **300** for controlling an output of the light fixture **100** to control color compensation of the fixture output color spectrum based on an optical modification. Various steps described herein with respect to the method **300** are capable of being executed simultaneously, in parallel, or in an order that differs from the illustrated serial manner of execution. Although the method **300** is described below in reference to a single array of light sources (e.g., the first array of light sources **110A**), the method **300** is capable of being executed simultaneously for the plurality of light sources **110A-110C** to achieve the fixture output color spectrum.

At step **305**, the controller **105** determines a first LED output color spectrum of the first array of light sources **110A** that corresponds to the fixture output color spectrum. In some embodiments, step **305** is performed prior to a runtime (e.g., prior to performing an operation) of the light fixture **100**. In other embodiments, step **305** is performed during the runtime (e.g., while performing an operation) of the light fixture **100**. The first LED output color spectrum is a combination of color outputs from the LED light sources of the first array of light sources **110A** that create the fixture output color spectrum. Each color output may have a known value based on a voltage value, a current value, a duty cycle, or the like. The known value is obtained by the controller **105** to determine the color output within a portion of the first LED output color spectrum resulting from the way that each LED light source is driven. In some embodiments, the known value is stored in the memory **135** (e.g., a look-up table of known values). The controller **105** compares the first LED output color spectrum to the look-up table to determine the color output. In some embodiments, the controller **105** compares the color output to the look-up table to determine the first LED output color spectrum. Each LED light source is driven by a pulse-width modulated ("PWM") signal including a duty cycle that corresponds to the color output of each LED light source. For example, the controller **105** receives a position signal from the one or more sensors **170** indicative of the rotational position of the motor shaft. Based on the rotational position of the motor shaft, the controller **105** determines a first position of the lens assembly **215**. The first position of the lens assembly **215** corresponds to the combination of color outputs representative of the fixture output color spectrum. The controller **105** determines the first output color spectrum based on the first position of the lens assembly **215**.

At step **310**, the controller **105** reads a saved LED output color spectrum from the memory **135**. For example, the controller **105** compares the first LED output color spectrum with the saved LED output color spectrum within the memory **135** to determine whether the saved LED output color spectrum matches the first LED output color spectrum. Although step **315** is illustrated as a separate step from step **305** and step **310**, in some embodiments, step **315** is performed concurrently with step **305** and step **310**. In other embodiments, step **315** is performed in succession after the completion of step **310**. At step **315**, the controller **105** performs an optical modification of the fixture output color spectrum. For example, the controller **105** generates a motor command and sends the motor command to the motor **175** to drive the lens assembly **215** to a second position relative to the first array of light sources. The second position is different than the first position. In some embodiments, the optical modification corresponds to one or more of a zoom, a focus, a prismatic shift, a shutter operation, or the like of the light fixture **100**. The fixture output color spectrum can change based on the optical modification. For example, a shift in the fixture output color spectrum can occur based on the optical modification. The shift may be caused by a relative proportion of the visual light emitters changing as a result of the optical modification or a visible shift in the output color of an individual LED light source as a result of the optical modification.

At step **320**, the controller **105** determines the shift of the fixture output color spectrum (e.g., a change in the fixture output color spectrum from the first color output spectrum) based on the optical modification. In some embodiments, step **320** is performed prior to a runtime (e.g., prior to performing an operation) of the light fixture **100** and referenced after step **315**. In other embodiments, step **320** is performed during the runtime (e.g., while performing an operation) of the light fixture **100**. For example, the controller **105** determines a change in one or more wavelengths of the color outputs of the fixture output color spectrum. At step **325**, the controller **105** creates a model of the change in the fixture output color spectrum based on the optical modification. In some embodiments, step **325** is performed prior to a runtime (e.g., prior to performing an operation) of the light fixture **100** and referenced after step **320**. In other embodiments, step **305** is performed during the runtime (e.g., while performing an operation) of the light fixture **100**. At step **330**, the controller **105** reads a saved spectral model (e.g., the CIE 1931 chromaticity diagram or the like) from the memory **135**. For example, the controller **105** determines the change in the fixture output color spectrum caused by the optical modification based on the motor **175** driving the lens assembly **215** to the second position. The controller **105** creates the model (e.g., a spectral model) of the fixture output color spectrum after the optical modification and compares the model to the saved spectral model to determine the change in the fixture output color spectrum from the first color output spectrum.

At step **335**, the controller **105** modifies the fixture output color spectrum by determining a compensation value to achieve a second output color spectrum that compensates for the change in the fixture output color spectrum resulting from the optical modification. For example, after the optical modification the controller **105** determines the rotational position of the motor shaft that drives the lens assembly **215**. Based on the rotational position after the optical modification, the controller **105** determines the position of the lens assembly **215**. The controller **105** determines the compensation value to maintain the fixture output spectrum at or near the output prior to the optical modification occurring based on the position of the lens assembly **215** after the optical modification.

At step **340**, the controller **105** generates, based on the compensation value, a first control signal to drive the first array of light sources **110**A at the second output color spectrum that will result in maintaining the fixture output color spectrum. In some embodiments, the first control signal corresponds to the second position of the lens assembly **215**. For example, the controller **105** determines a value for a PWM signal (e.g., a duty cycle that will be used to drive the first array of light sources **110**A) to achieve the second output color spectrum. The first control signal may include a first command (e.g., a first PWM value) to drive the first LED light source of the first array of light sources **110**A at the first output color. The first control signal may also include a second command (e.g., a second PWM value) to drive the second LED light source of the first array of light sources **110**A at a third output color to achieve (combined with the first LED light source) the second output color spectrum. The third output color has a third LED output color spectrum and the third output color is different from the second output color.

At step **345**, the controller **105** drives (e.g., controls) the first driver circuit **115**A using the first control signal. For example, the controller **105** controls the first driver circuit **115**A to (i) drive the first LED light source of the first array of light sources **110**A using the first command, and (ii) drive the second LED light source of the first array of light sources **110**A using the second command, where (i) and (ii) combine to achieve the second color output spectrum. In some embodiments, in response to the first control signal, the fixture output color spectrum is substantially the same before and after the optical modification.

FIG. **4** illustrates a flow chart of a method **400** for controlling an output of the light fixture **100** to control color compensation of the fixture output color spectrum based on an optical modification. The method of FIG. **4** is combinable with the methods disclosed in the other figures. Various steps described herein with respect to the method **400** are capable of being executed simultaneously, in parallel, or in an order that differs from the illustrated serial manner of execution. Although the method **400** is described below in reference to a single array of light sources (e.g., the first array of light sources **110**A), the method **400** is capable of being executed simultaneously for the plurality of light sources **110**A-**110**C to achieve the fixture output color spectrum.

At step **405**, the controller **105** determines a first LED output color spectrum of the first array of light sources **110**A that corresponds to the fixture output color spectrum. For example, the controller **105** receives a position signal from the one or more sensors **170** indicative of the rotational position of the motor shaft. Based on the rotational position of the motor shaft, the controller **105** determines a first position of the lens assembly **215**. The first position of the lens assembly **215** corresponds to the combination of color outputs representative of the fixture output color spectrum. The controller **105** determines the fixture output color spectrum based on the first position of the lens assembly **215**.

At step **410**, the controller **105** determines whether to perform a color compensation operation. For example, the controller **105** determines whether an optical modification has occurred. When the controller determines that an optical modification has not occurred, the method **400** proceeds to step **430**. At step **430**, the controller **105** determines a first control signal (e.g., an output signal) to drive the first array of light sources **110**A at the first output color spectrum via the first driver circuit **115**A. For example, the controller **105** determines the first output signal to maintain or substantially maintain the fixture output color spectrum and drives (e.g., controls) the first driver circuit **115**A using the first control signal. At step **435**, the controller **105** determines whether an optical modification has occurred. If the controller **105** determines that an optical modification has not occurred, the method **400** returns to step **430** and the first driver circuit **115**A continues to drive the first array of light sources **110**A at the first control signal. If the controller **105** determines that an optical modification has occurred, the method **400** returns to step **410** to determine whether to perform the color compensation operation based on the optical modification. If the controller **105** determines that the color compensation operation should be performed based on the optical modification, the method **400** proceeds to step **415**.

At step **415**, the controller **105** determines the shift of the fixture output color spectrum (e.g., the change in the fixture output color spectrum from the first color output spectrum) based on the optical modification. For example, the controller **105** determines a change in one or more wavelengths of the color outputs of the fixture output color spectrum. The controller **105** creates a model of the change in the fixture output color spectrum based on the optical modification and reads a saved spectral model (e.g., the CIE 1931 chromaticity diagram or the like) from the memory **135**. For example, the controller **105** determines the change in the fixture output color spectrum caused by the optical modification based on the motor **175** driving the lens assembly **215** to the second position. The controller **105** creates the model (e.g., a spectral model) of the fixture output color spectrum after the optical modification occurs and compares the model to the saved spectral model to determine the change in the fixture output color spectrum.

At step **420**, the controller **105** modifies the fixture output color spectrum with a compensation value to achieve a second output color spectrum that compensates for the change in the fixture output color spectrum resulting from the optical modification. The compensation value may be the determined change in the one or more wavelengths of the fixture output color spectrum after the optical modification. For example, the controller **105** determines the rotational position of the motor shaft after the optical modification. Based on the rotational position after the optical modification, the controller **105** determines the position of the lens assembly **215**. The controller **105** determines the compensation value to maintain or substantially maintain the fixture output spectrum based on the position of the lens assembly **215** after the optical modification.

At step **425**, the controller **105** saves the modified fixture output color spectrum (e.g., the second output color spectrum) to the memory **135**. At step **430**, the controller **105** determines, based on the compensation value, a first control signal to drive the first array of light sources **110**A at the second output color spectrum. In some embodiments, the first control signal corresponds to the second position of the lens assembly **215**. For example, the controller **105** generates a value for a PWM signal (e.g., a duty cycle that will be used to drive the first array of light sources **110**A) to achieve the second output color spectrum. The first control signal may include a first command (e.g., a first PWM value) to drive the first LED light source of the first array of light sources **110**A at the first output color. The first control signal may also include a second command (e.g., a second PWM value) to drive the second LED light source of the first array of light sources **110**A at a third output color to (combined with the first output color from the first LED light source) achieve the second output color spectrum. The third output color has a third LED output color spectrum and the third output color is different from the second output color.

The controller **105** drives (e.g., controls) the first driver circuit **115**A using the first control signal. For example, to achieve the second color output spectrum, the controller **105** controls the first driver circuit **115**A to drive the first LED light source of the first array of light sources **110**A using the first command and drive the second LED light source of the first array of light sources **110**A using the second command. In some embodiments, in response to the first control signal, the fixture output color spectrum (e.g., the second output color spectrum) is substantially the same before and after the optical modification.

At step **435**, the controller **105** determines whether an optical modification has occurred. When the controller **105** determines that an optical modification has not occurred, the method **400** returns to step **430** and the first driver circuit **115**A continues to drive the first array of light sources **110**A at the first control signal. When the controller **105** determines that an optical modification has occurred, the method **400** returns to step **410** to determine whether to perform the color compensation operation based on the optical modification. When the controller **105** determines that the color compensation operation should be performed based on the optical modification, the method **400** returns to step **415**.

While embodiments disclosed herein primarily refer to controlling color compensation of a single LED light source of the first array of LED light sources **110**A based on the optical modification, additional LED light sources may be color compensated in response to the optical modification. For example, the light fixture **100** may include the lens assembly **215** (further including a lens), the first LED light source (e.g., a first LED) having the first output color spectrum, the second LED light source (e.g., a second LED) having a second output color spectrum, the first driver circuit **115**A, and the controller **105**. In some embodiments, the first output color spectrum and the second output color spectrum are mixed and passed through the lens to generate the fixture output color spectrum.

The controller **105** receives a position signal from the one or more sensors **170** indicative of the rotational position of the motor shaft. Based on the rotational position of the motor shaft, the controller **105** determines a first position of the lens. The controller **105** determines the fixture output color spectrum based on the first position of the lens. The controller **105** may modify the first position of the lens relative to the first LED and the second LED to achieve a second position of the lens (e.g., an optical modification). The controller **105** determines a value (e.g., a compensation value) that compensates for changes in the fixture output color spectrum based on the modification of the position of the lens to the second position. Based on the determined compensation value, the controller **105** generates a control signal to drive the first LED at a third LED output color spectrum that is different from the first LED output color spectrum. The controller **105** drives (e.g., controls) the first driver circuit **115**A using the first control signal.

In some embodiments, the controller **105** determines the compensation value so that the fixture output color spectrum remains substantially unchanged before and after the modification of the position of the lens relative to the first and second LEDs. In some embodiments, the controller **105** generates, based on the compensation value, a second control signal to drive the second LED at a fourth LED output color spectrum that is different from the second LED output color spectrum. The controller **105** drives the first driver circuit **115**A using the second control signal.

In some embodiments, the controller **105** includes the third LED light source (e.g., a third LED) having a fifth output color spectrum. In some embodiments, the first output color spectrum, the second output color spectrum, and the fifth output color spectrum are mixed and passed through the lens to generate the fixture output color spectrum. The controller **105** generates, based on the compensation value, a third control signal to drive the third LED at a sixth LED output color spectrum that is different from the fifth LED output color spectrum. The controller **105** drives the first driver circuit **115**A using the third control signal. In some embodiments, the first output color spectrum, the second output color spectrum, and the fifth output color spectrum are different.

FIG. **5** illustrates a graph **500** of the fixture output color spectrum of the light fixture **100** based on an optical modification. In the illustrated embodiment, the fixture output color spectrum includes a plurality of LED output color spectrums. Each LED output color spectrum of the plurality of LED output color spectrums corresponds to a respective wavelength (e.g., wavelengths within the visible light spectrum) and includes a relative intensity of the respective LED output color spectrum. The wavelength of each LED output color spectrum corresponds to a color output for each respective LED output color spectrum. The relative intensity is normalized to a peak that occurs at exactly "1" (e.g., a 100% intensity). The relative intensity of each wavelength is illustrated as its relationship to the peak. For example, if a wavelength is half as bright as the brightest wavelength, then the relative intensity of the given wavelength would be displayed as "0.5" (e.g., a 50% intensity). Line **505** depicts the fixture output color spectrum prior to the optical modification. For example, the line **505** depicts the light fixture **100** with the lens assembly **215** in the first position. Line **510** depicts the fixture output color spectrum after the optical modification. For example, the line **510** depicts the light fixture **100** with the lens assembly **215** in the second position. As illustrated by FIG. **5**, the fixture output color spectrum experiences a change in relative intensity after the optical modification, especially in the wavelength range between 430 nm and 480 nm. FIGS. **6**A-**7**B, which are discussed in more detail below, illustrate how the outputs of the individual LED light sources are driven to compensate for the change in the fixture output color illustrated in FIG. **5**.

FIG. **6**A illustrates a graph **600**A of the first LED output color spectrum of the first LED light source based on an optical modification. The first LED output color spectrum of the first LED light source corresponds to a first wavelength and includes a relative intensity of the first LED output color spectrum. The first wavelength of the first LED output color spectrum corresponds to the first color output. Line **605** depicts the first LED output color spectrum prior to the optical modification. For example, the line **605** depicts the output of the first LED from the light fixture **100** with the lens assembly **215** in the first position. Line **610** depicts the first LED output color spectrum after the optical modification. For example, the line **610** depicts the output of the first LED from the light fixture **100** with the lens assembly **215** in the second position. As shown by FIG. **6**A, the first LED output color spectrum experiences a change in relative intensity after the optical modification. In the illustrated embodiment, the relative intensity of the first LED output color spectrum decreases from line **605** to line **610**.

FIG. **6**B illustrates a graph **600**B of a calibrated first LED output color spectrum of the first LED light source after controlling an output of the light fixture **100** to control color compensation. Line **615** depicts the first LED output color spectrum. Line **615** is a plurality of measurements of relative intensities at a known point (e.g., relative intensities based on the first wavelength) that the controller **105** uses to determine a difference from the modeled first LED color spectrum. In effect, this is the target value for the line **610** (i.e., the target for the LED output after the optical modification has occurred). In the illustrated embodiment, the relative intensity of line **615** is substantially the same as the relative intensity of the line **605** of FIG. **6**A. Thus, the first output color spectrum must be compensated to account for the change in the first color output resulting from the optical modification (i.e., the difference between lines **610** and **615**).

FIG. **7**A illustrates a graph **700**A of the second LED output color spectrum of the second LED light source based on an optical modification. The second LED output color spectrum of the second LED light source corresponds to a second wavelength and includes a relative intensity of the second LED output color spectrum. The second wavelength of the second LED output color spectrum corresponds to the second color output. In the illustrated embodiment, the second wavelength is different than the first wavelength of FIG. **6**A. Line **705** depicts the second LED output color spectrum prior to the optical modification. For example, the line **705** depicts the output of the second LED from the light fixture **100** with the lens assembly **215** in the first position. Line **710** depicts the second LED output color spectrum after the optical modification. For example, the line **710** depicts the output of the second LED from the light fixture **100** with the lens assembly **215** in the second position. As shown by FIG. **7**A, the second LED output color spectrum experiences a change in relative intensity after the optical modification. In the illustrated embodiment, the relative intensity of the second LED output color spectrum decreases from line **705** to line **710**.

FIG. **7**B illustrates a graph **700**B of a calibrated second LED output color spectrum of the second LED light source after controlling an output of the light fixture **100** to control color compensation. Line **715** depicts the second LED output color spectrum. Line **715** is a plurality of measurements of relative intensities at a known point (e.g., relative intensities based on the second wavelength) that the controller **105** uses to determine a difference from the modeled second LED color spectrum. Similar to line **615**, above, this is the target value for the line **710** (i.e., the target for the LED output after the optical modification has occurred). In the illustrated embodiment, the relative intensity of line **715** is substantially the same as the relative intensity of the line **705** of FIG. **7**A. Due to the differences between line **710** and **715**, the output of the second LED must be compensated so that the second LED color spectrum after modification (represented by line **710**) must be modified to match the target second LED output color spectrum (represented by calibration line **715**). When the compensated outputs illustrated in FIGS. **6**A-**7**B are combined to result in the compensated fixture output color, the individual LED light sources are thus driven to compensate for the change in the fixture output color illustrated in FIG. **5**.

Thus, embodiments described herein provide, among other things, systems, devices, and methods for controlling an output of a light fixture to control the color compensation of a plurality of light sources based on an optical modification.

What is claimed is:

1. A light fixture, comprising:

an array of light-emitting diode (LED) light sources, each LED light source defining a color channel of the light fixture;

a driver circuit that drives the array of LED light sources;

a lens;

a motor having a motor shaft connected to the lens such that each rotational position of the motor shaft corresponds to a different respective position of the lens relative to the array of LED light sources; and

a controller including a non-transitory computer readable medium and processing unit, the controller including computer executable instructions stored in the non-transitory computer readable medium for controlling operation of the light fixture to:

determine a first output color spectrum for the array of LED light sources that corresponds to a first rotational position of the motor shaft,

perform an optical modification by controlling the motor to rotate the motor shaft from the first rotational position to a second rotational position,

determine, based on the first and second rotational positions, a color compensation value to modify the first output color spectrum to a second output color spectrum that compensates for a spectral change to light emitted by the light fixture due to the optical modification,

generate, based on the color compensation value, a first control signal to drive the array of LED light sources at the second output color spectrum, and

control the driver circuit using the first control signal.

2. The light fixture of claim **1**, wherein the color channels of the light fixture include a first output color and a second output color, and wherein the array of LED light sources comprises:

a first LED light source emitting the first output color, the first output color having a first color spectrum; and

a second LED light source emitting the second output color, the second output color having a second color spectrum, wherein the second color spectrum is different from the first color spectrum.

3. The light fixture of claim **2**,

wherein the first control signal includes a first command to drive the first LED light source at the first output color, and

wherein the first control signal includes a second command to drive the second LED light source at a third output color, the third output color having a third color spectrum, wherein the third output color is different from the second output color.

4. The light fixture of claim **1**, wherein the optical modification is at least one selected from the group consisting of a zoom, a focus, a prismatic shift, and a shutter operation.

5. The light fixture of claim **1**, wherein the controller further controls operation of the light fixture to:

determine the second rotational position of the motor shaft after the optical modification;

determine, based on the second rotational position, a position of the lens relative to the array of LED light sources after the optical modification; and

determine, based on the position of the lens, the color compensation value.

6. The light fixture of claim 5, wherein the first control signal corresponds to the position of the lens.

7. The light fixture of claim 1, wherein a spectrum of the light emitted by the light fixture, as a result of the first control signal, is substantially the same before and after the optical modification.

8. A system for controlling a light fixture, the system comprising:

the light fixture including:

an array of light-emitting diode (LED) light sources, each LED light source defining a color channel of the light fixture,

a driver circuit for driving the array of LED light sources,

a lens,

a motor having a motor shaft connected to the lens such that each rotational position of the motor shaft corresponds to a different respective position of the lens relative to the array of LED light sources; and

a controller configured to generate a direct drive signal for one or more arrays of LED light sources, the controller including a non-transitory computer readable medium and a processing unit, the controller including computer executable instructions stored in the non-transitory computer readable medium for controlling operation of the light fixture to:

determine a first output color spectrum emitted by the array of LED light sources that corresponds to a first rotational position of the motor shaft,

perform an optical modification by controlling the motor to rotate the motor shaft from the first rotational position to a second rotational position,

determine, based on the first and second rotational positions,

a color compensation value to compensate for a spectral change to the first output color spectrum due to the optical modification,

generate, based on the color compensation value, a first control signal to drive the array of LED light sources to emit a second output color spectrum, and

control the driver circuit using the first control signal.

9. The light fixture of claim 8, wherein the array of LED light sources comprises:

a first LED light source emitting a first output color, the first output color having a first color spectrum; and

a second LED light source emitting a second output color, the second output color having a second color spectrum, wherein the second color spectrum is different from the first color spectrum.

10. The light fixture of claim 9,

wherein the first control signal includes a first command to drive the first LED light source at the first output color, and

wherein the first control signal includes a second command to drive the second LED light source at a third output color, the third output color having a third color spectrum, wherein the third output color is different from the second output color.

11. The light fixture of claim 8, wherein the optical modification is at least one selected from the group consisting of a zoom, a focus, a prismatic shift, and a shutter operation.

12. The light fixture of claim 8, wherein the controller further controls operation of the light fixture to:

determine the second rotational position of the motor shaft during the optical modification;

determine, based on the second rotational position, a position of the lens relative to the array of LED light sources during the optical modification; and

determine, based on the position of the lens, the color compensation value.

13. The light fixture of claim 12, wherein the first control signal corresponds to the position of the lens.

14. A method of controlling a light fixture, the method comprising:

determining a first fixture output color spectrum for the light fixture, the light fixture having an array of LED light sources that are driven to emit first fixture output color spectrum,

performing an optical modification of the fixture output color spectrum,

determining, based on the optical modification, a compensation value to compensate for changes to the fixture output color spectrum resulting from the optical modification,

generating, based on the compensation value, a first control signal to drive the array of LED light sources to emit a second fixture output color spectrum, and

controlling the driver circuit using the first control signal,

wherein the light fixture includes a lens,

wherein the method further comprises:

determining a rotational position of a motor shaft that corresponds to a position of the lens during the optical modification;

determining, based on the rotational position, the position of the lens during the optical modification; and

determining, based on the position of the lens, the compensation value.

15. The method of claim 14,

wherein the first control signal includes a first command to drive a first LED light source of the array of LED light sources at the first output color,

wherein the first control signal includes a second command to drive a second LED light source of the array of LED light sources at a second output color, and

wherein the second output color is different than the first output color.

16. The method of claim 14, wherein the optical modification is at least one selected from the group consisting of a zoom, a focus, a prismatic shift, and a shutter operation.

17. The method of claim 14, wherein the first control signal corresponds to the position of the lens.

18. A light fixture comprising:

a lens,

a first LED emitting first light with a first LED output color spectrum,

a second LED emitting second light with a second LED output color spectrum, wherein the first and second emitted lights are mixed and passed through the lens to generate output light with a fixture output color spectrum,

a motor configured to move the lens relative to the first and second LEDs,

a driver circuit for driving the first and second LEDs, and

a controller including a non-transitory computer readable medium and processing unit, the controller including computer executable instructions stored in the non-transitory computer readable medium for controlling operation of the light fixture to:

determine the fixture output color spectrum corresponding to a first position of the lens relative to the first and second LEDs,

operate the motor to move the lens from the first position to a second position relative to the first and second LEDs,

determine, based on the first and second positions of the lens, a color compensation value that compensates for a spectral change in the output light resulting from the move modification,

generate, based on the color compensation value, a first control signal to drive the first LED to cause the first light to have a third LED output color spectrum that is different from the first LED output color spectrum, and

control the driver circuit using the first control signal.

19. The light fixture of claim **18**, wherein the color compensation value is determined such that the fixture output color spectrum remains substantially unchanged before and after the move.

20. The light fixture of claim **19**, wherein the controller further controls operation of the light fixture to generate, based on the color compensation value, a second control signal to drive the second LED to cause the second light to have a fourth LED output color spectrum that is different from the second LED output color spectrum.

21. The light fixture of claim **20**, further comprising a third LED emitting third light with a fifth output color spectrum, wherein the first, second, and third lights are mixed and passed through the lens to generate the fixture output color spectrum, and

wherein the controller further controls operation of the light fixture to generate, based on the color compensation value, a third control signal to drive the third LED to cause the third light to have at a sixth LED output color spectrum that is different from the fifth LED output color spectrum.

22. The light fixture of claim **21**, wherein the first, second, and fifth LED output color spectrums differ from one another.

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