Lambda 421

Ultra-High-Speed Optical Beam Combined 4-Channel Wavelength Switching LED Light Source System

(With Lambda DG-4 External Control Compatibility)

Operation Manual

Rev. 1.02 ((20190531)

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CE EU Declaration of Conformity

Application of Council Directives:
2014/30/EU (EMC), 2014/35/EU (LVD), and 2011/65/EU (RoHS 2)

Manufacturer's Name:	Sutter Instrument Company
Manufacturer's Address:	One Digital Drive Novato, CA. 94949 USA Tel: +1 415 883 0128
Equipment Tested:	**Lambda 421** Optical Beam Combined 4-Channel Wavelength Switching LED Light Source System
Model(s):	LB-421 **Optical Beam Combiner (OBC)** **Low/medium-power LED (up to four)** **Controller for manual and external-control, with power supply**
Conforms to Standards:	EMC Emissions: EN 61326-1:2013, including: EN 55011: 2009 Class A; EN 61000-3-2:2015, & EN 61000-3-3:2014 EMC Immunity: EN 61000-4-2:2009, EN 61000-4-3:2011, EN 61000-4-4:2012, EN 61000-4-5:2014, EN 61000-4-6:2014, EN 61000-4-8:2010, & EN 61000-4-11:2004 LVD (Safety): EN 61010-1:2010 Photobiological Safety of Lamps & Lamp Systems: EN 62471: 2008 / IEC 62471, Ed 1.0 (2006-07)
Tested/Verified (based on LBHPX & LBHPX-L5) By:	ITC Engineering Services, Inc. 9959 Calaveras Road, PO Box 543 Sunol, CA 94586-0543 USA Tel. +1 925 862 2944 Fax: +1 925 862 9013 Email: itcemc@itcemc.com Web: www.itcemc.com Sutter Instrument
Test Report(s):	20150902-01, SI_HPX[-L5]_TF-A_(20150930), SI_EMC_LBHPX[-L5]_20160713

Sutter Instrument Company hereby declares that the equipment specified above was tested and conforms to the EU Directives and Standards listed above, and further certifies conformation to the requirements of the European Union's Restriction on Hazardous Substances in Electronic Equipment Directive 2011/65/EU (RoHS 2).

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DISCLAIMER

The **Lambda 421** is an ultra-high-speed wavelength switching multi-LED-based beam combined illumination or light source device. The purpose of the system is to be an illuminator for microscopes. No other use is recommended.

This instrument is designed for use in a laboratory environment. It is not intended, nor should it be used in human experimentation or applied to humans in any way. This is not a medical device.

Unless otherwise indicated in this manual or by Sutter Instrument Technical Support for reconfiguration, do not open or attempt to repair the instrument.

Do not allow unauthorized and/or untrained operative to use this device.

Any misuse will be the sole responsibility of the user/owner and Sutter Instrument Company assumes no implied or inferred liability for direct or consequential damages from this instrument if it is operated or used in any way other than for which it is designed.

SAFETY WARNINGS AND PRECAUTIONS

Electrical

- **Operate the Lambda 421 using 110 – 240 VAC., 50-60 Hz line voltage. This instrument is designed for use in a laboratory environment that has low electrical noise and mechanical vibration. Surge suppression is recommended at all times.**

- **Fuse Replacement: Replace only with the same type and rating:**

  4 Amp, 125V, 5 x 20mm, Time Delay fuse (EIC 60127-2)
  (Example: Bussmann GMC-4A)

  A spare fuse is located in the power input module.

Avoiding Electrical Shock and Fire-related Injury

- **Always use the grounded power supply cord set provided to connect the system's power adapter to a grounded/earthed outlet (3-prong). This is required to protect you from injury in the event that an electrical hazard occurs.**
- **Do not disassemble the system. Refer servicing to qualified personnel.**
- **To prevent fire or shock hazard do not expose the unit to rain or moisture.**

Electromagnetic Interference

To comply with FDA and CE/EU electromagnetic immunity and interference standards; and to reduce the electromagnetic coupling between this and other equipment in your lab always use the type and length of interconnect cables provided with the unit for the interconnection of its components (see the Technical Specifications appendix for more details).

Operational

Failure to comply with any of the following precautions may damage this device.

- Operate only in a location where there is a free flow of fresh air on all sides. NEVER ALLOW THE FREE FLOW OF AIR TO BE RESTRICTED.
- This instrument is designed for operation in a laboratory environment (Pollution Degree I) that is free from mechanical vibrations, and electrical noise and transients.
- DO NOT CONNECT OR DISCONNECT THE LQUID LIGHT GUIDE BETWEEN THE LAMBDA 421 AND MICROSCOPE ADAPTER (OR THE ADAPTER FROM THE MICROSCOPE) WHILE POWER IS ON.
- Operate this instrument only according to the instructions included in this manual.
- Do not operate if there is any obvious damage to any part of the instrument.
- Do not operate this instrument near flammable materials. The use of any hazardous materials with this instrument is not recommended and, if undertaken, is done so at the users' own risk.
- Do not operate if there is any obvious damage to any part of the instrument.

Avoiding Physical Injury while Powered up and Emitting Light

WARNING

DO NOT LOOK DIRECTLY INTO THE OUTPUT OF THE LIGHT APERTURE OF THE OPTICAL BEAM COMBINER MOUNTED ON THE CONTROLLER, THE CONNECTED LIQUID LIGHT GUIDE, OR THE ATTACHED MICROSCOPE ADAPTER! Always direct the output of the light aperture into the microscope using the appropriate adapters, directed away from anyone's eyes, and not directed toward any reflective surface.

- INFRARED AND ULTRAVIOLET RADIATION: Possible infrared and ultraviolet radiation generated by this lamp can cause significant skin burns and eye damage.

Other

- Retain the original packaging for future transport of the instrument.
- Sutter Instrument reserves the right to change specifications without prior notice.
- This device is intended only for research purposes.

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1. INTRODUCTION

1.1 Introduction

The Lambda 421 is an illumination system designed for the rapid change of wavelength derived from up to four light sources of different wavelengths combined into a single beam. The system comprises of three subsystems: controller, Optical Beam Combiner (ODC), up to four LED light sources, and power supply. All four subsystems are conveniently housed in and on one cabinet. For the most part, this manual is organized around those subsystems to provide you with ready access to information, as you need it.

1.1.1 How to Use this Manual

This manual is organized in a manner that is best suited for the typical manner in which the reader would learn about the system, and then install, operate, and maintain it. Prior to the table of contents of this manual is a disclaimer and a series of cautionary and warning notes – it is important that these be read first. This first chapter provides an overall description of the system, leaving more in-depth technical information towards the end of the chapter. The next chapter describes how to install the system, followed by one or more chapters that provide operation instructions, and ending with a chapter on maintenance. Following the final chapter are several appendices that provide supplemental information. The installation chapter covers everything related to installation, from unpacking the equipment as received, through to ensuring correct installation and operation. The operation chapters cover the two basic types of user interaction with the system: Manual (local) control and external computer control. Please take the time to read these instructions to assure the safe and proper use of this instrument.

1.1.2 Technical Support

Sutter Instrument Company at no charge provides unlimited technical support to our customers. Our technical support staff is available between the hours of 8:00 AM and 5:00 PM (Pacific Time) at **(415) 883-0128**. You may also e-mail your queries to **info@sutter.com**. Furthermore, as this manual is currently under construction, if there are any areas that you feel should be covered in detail we would like to hear from you.

1.2 General Description

CAPABLE OF COMBINING ANY LIGHT SOURCE

ANY SUITABLE WAVELENGTH (LED OR EXTERNAL FILTERED LIGHT SOURCE) CAN BE PLACED IN ANY OF 4 POSITIONS WITHOUT CONCERN FOR THE ORDER

SELECTION AND BEAM REFLECTION USING SEMROCK-STR FILTERS

Figure 1-1. Lambda 421 indicators, controls, and connectors.

The Lambda 421 beam combiner is a new, patented, concept for combining separate light sources with different spectra into a single common output beam. Each separate light source is collimated before entering the optical path through a bandpass filter. The filters for each light source also function as mirrors that reflect the collimated beams from the previous light sources. In the diagram below the optical paths are outlined for each position including the reflections that occur:

Traditionally, combining more than two light sources required the use of a dichroic ladder. Dichroic mirrors, which switch from transmission to reflection at one point in the spectrum, allow the combining of separate light sources, provided that those sources do not have overlapping wavelengths. The downside of this approach is that light sources cannot be easily changed.

Dichroic ladders also demand careful attention to the order in which the light sources are introduced into the optical path, to avoid having the light blocked by the next dichroic in line. Typically, additional bandpass filters must be added in front of each light source before the dichroic, to select the desired range of wavelengths for each source. Each filter and dichroic used in the ladder decreases the total light output of the system.

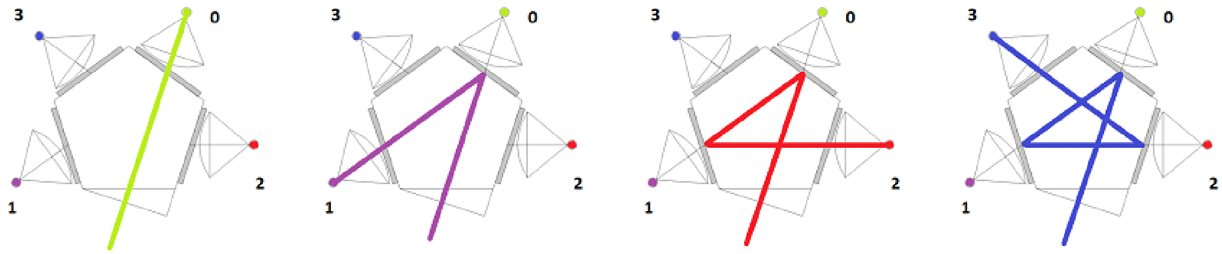

Figure 1-2. Stages of pass-through and reflection from each input light source.

The Lambda 421 was designed to keep the size of the beam combiner small, and the optical path short and efficient. Thin-film bandpass filters, such as Semrock's STR, reflect greater than 90% of out-of-band light. If the band pass of each light source does not overlap, it is possible to use the filters for both attenuation and reflection the light from the other sources. By arranging the filters and sources into a pentagon, we were able to combine four light sources, in a compact design, with lower losses than previously achievable. As an added benefit, the last position in the optical train does not require any filter, since no other input reflects from that position. This input can be used with any sort of light source as long as you are aware of the possible losses if there are filters in use that overlap this light source. The fifth side of the pentagon becomes the output for the combined sources.

The filters are easily exchangeable and are installed on small sliders inside the core of the pentagon. Filters and associated light sources can be arranged in any order around the pentagon.

In the diagram below the position number of each light source is labeled based on the number of total reflections.

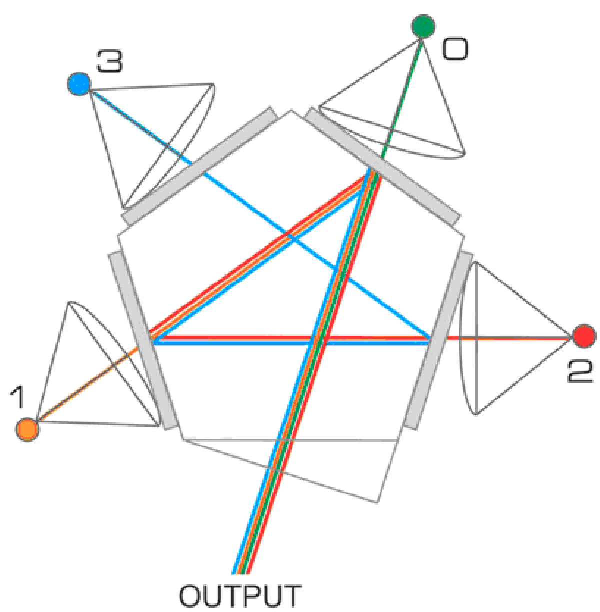

Figure 1-3. Lambda 421 combined output based on the pass-through and reflection of each input light source.

Notes:

- The light from position #0 goes directly to the device output without being reflected. This position might be preferred for the source with the greatest desired output.
- The filter for the fourth light source is not used as a reflective surface and could be omitted if a broadband source were desired.
- In configurations with fewer than four light sources, sources should be filled from lowest to highest number of reflections to ensure the greatest light output.
- The optical path for each input is tilted by 18 degrees relative to the filter for that port. This will cause a small shift in the band pass toward shorter wavelengths. While it would be ideal to have a coating optimized for this application, we have found that stock -STR filters can be used if you correct for the shift in the band pass when selecting the filters. This lends itself to combining narrow-band sources such as LEDs and lasers with broadband sources such as an arc lamps or white light LEDs. In the case of LEDs, wavelengths can be shuttered at the speed of the individual source. Sutter Instrument Lambda 421, HPX, and TLED products can switch in 10-25 microseconds respectively, making the Lambda 421 one the fastest wavelength switcher on the market.

The Lambda Optical Beam Combiner is designed for flexibility and expandability. Should your illumination need change over time a simple configuration change, and possibly additional filters can produce an entirely different output.

2. INSTALLATION

2.1 Unpacking

The Lambda 421 and associated hardware comes packed in a single carton. The following is a list of the components found there. If you believe that any of these components are missing or show obvious signs of damage from shipping, please contact the factory.

- **Lambda 421 cabinet containing factory-installed power supply, control electronics, four light source drivers, Optical Beam Combiner (OBC) mounted with up to four different wavelength LED light sources, front-panel controls, and rear-panel external-control connectors**
- **The OBC's four light source inputs each has installed an LED module for the following wavelength (nanometers): 340, 365, 380, 385, 410, 440, 460, 480, 506, 530, 561, 590, 630, 660, 740, 850, 940, or white light. Each channel's optics (mirror & filter) are especially installed and aligned according to the LED's wavelength chosen.**
- **Power Cord**
- **Liquid Light Guide**
- **Liquid Light Guide dovetail with C-mount extension**
- **Small Zeiss female dovetail**
- **USB Interface Cable**
- **9-pin Serial Interface Cable**
- **25-pin Parallel Interface Cable**
- **Manual**
- **One or more additional LED Assemblies containing different wavelength LEDs (if ordered)**
- **Microscope adapters (if ordered)**

2.2 Getting Started

1. Turn the power switch to the OFF ("0") position.
2. Plug power cable into the mains outlet.
3. Connect the optical output directly to the microscope via the appropriate adapter or to a liquid light guide, as appropriate.
4. Make sure that all of up to four light sources (LEDs or external) are connected to the Optical Beam Combiner (OBC) inputs.
5. Ensure that that the right side switch for each channel (Channel 0 through 3) is in the OFF position.
6. Power up the Lambda 421 rocking the power switch (far right side of the front panel) upwards in "1" position. A red LED immediately to the left of the power switch will illuminate when power is on.
7. Refer to the Operations chapter for instructions on turning on the Lambda 421 and operating the controls on the front panel and making connections to the rear panel.

WARNING: DO NOT LOOK DIRECTLY INTO THE LIGHT GUIDE! The output of the light or the light guide should be directed into the microscope using the appropriate adapters, directed away from anyone's eyes, and not directed toward any reflective surface.

3. OPERATIONS

This chapter describes the operation of the Lambda 421. The locations of the individual indicators, controls, and connectors are indicated in the following figure.

Figure 3-1. Locations of individual indicators, controls, and connectors on the Lambda 421 controller.

3.1 Controls

3.1.1 Power Switch

Main power switch turns unit off/on.

3.1.2 Light Source Channel Control Switch (ON/OFF/TTL)

This is a three-position toggle switch that is used to manually turn the LED on, off, or activate TTL switching through the STROBE BNC connector.

ON: Manually turns on the channel for manual control.

OFF: Turns off internally generated light source and control for the channel. Does not affect externally supplied light source.

TTL: Internally supplied LED light source on/off state is controlled by TTL triggering (via STROBE).

3.1.3 Internal/External Control Switch (INT. / EXT.)

This two-position toggle switch is used to determine whether the internal light source for the channel is controlled manually (front panel) or externally (via an interface to a computer) turn the LED on, off, or activate TTL switching through the STROBE BNC connector.

3.1.4 Dimness/Intensity Control Knob (0-11)

This rotary knob dims or intensifies the light source for a given channel by adjusting the current delivered to the internally powered LED. Current control may cause color shift in the LED's spectral output. However, current-controlled dimming may be preferable in situations involving the use of ultra high-speed cameras. For the CURRENT knob to be effective, the LED Control Switch must be set to ON or TTL.

3.2 Indicators

3.2.1 Power Light

A power light is located to the left of the power switch on the front panel, and is illuminated when the power is on.

3.3 Connectors

3.3.1 Light Beam Combiner Output

Provides the interface between the combined light source output to a microscope or liquid light guide.

3.3.2 STROBE BNC Connector

3.3.3 DAC BNC Connector

3.3.4 SHUTTER BNC Connector

Inputs a triggering signal for opening and closing a SmartShutter (if installed), installed for interference of the Lambda 421's combined light output.

3.3.5 USB Device Interface Connector

Provides the interface for controlling the Lambda 421 by computer via USB connection.

3.3.6 SERIAL Interface Connector

Provides the interface for controlling the Lambda 421 by computer via 9-pin serial connection.

Note that the USB interface is mutually exclusive with the SERIAL interface. The USB interface is enabled at the factory when the Lambda 421 is shipped, unless the SERIAL interface is specifically requested. When the USB interface is enabled, the SERIAL interface cannot be used, and vice versa.

3.3.7 PARALLEL Interface Connector

Provides the interface for controlling the Lambda 421 by external means via 25-pin parallel connection. External control via the parallel interface can be accomplished by TTL (8 lines) or by connecting to the PARALLEL port of a computer using specialized software.

3.4 Operation

The Sutter Optical Beam Combiner (OBC) installed on the Lambda 421 allows for up to four light sources with differing spectral output to be combined and delivered on a common output light path. While OBC has many possible uses, the Lambda 421 provides a means by which one can rapidly select any one of up to four different LEDs as the output. This sort of rapid selection of wavelength is what another Sutter Instrument product, the Lambda DG-4, was designed to do. The DG-4, a popular light source for imaging for many years, is widely supported by imaging software. The DG-4 circuit board was adapted to control the selection of the active LED and the operating current for that LED.

The new Lambda 421 system combines four of our high power LEDs and their drivers, a control circuit board from the new USB version of the DG-4 and the OBC to form a compact, complete light source that functions like a DG-4 without any moving parts.

3.5 Understanding the Basic Operation of the Lambda 421

3.6 Manual control

The 421 has four LED controllers based on the Sutter Instrument Lambda TLED+ controllers. All of the basic controls of the TLED+ are maintained in the 421. First, there is a system power switch located on the right of the cabinet face. Next to the switch is an indicator lamp that shows red when the power supply is in operation. The controls for the four LED drivers are arranged in four groups, each labeled CHANNEL 0 through CHANNEL 3. The channel number ties into the optical configuration in that it represents: The number of reflects required to reach the common output port. The apparent incongruity of the 421's scheme vs. the DG-4's Filter 0 is considered a shutter function and the 4 selectable optical paths are numbered 1-4, is resolved by the arrangement of the 421's front panel's controls and a somewhat altered set of external control commands.

Each channel has a two selector switches and a knob on the front panel. The right-most switch in each group is labeled ON/OFF/TTL from top to bottom. Selecting the middle position (OFF) turns the LED off. Setting the switch to the top position (ON), turns the on. When selecting the lowest position (TTL), the channel is controlled by the DG-4 interface circuit board. The switch to the left is labeled INT./EXT. In the upper position (INT.), the internal current reference is selected. In the lower position (EXT.), the current level is under the control of the DAC setting for whatever filter value is currently selected.

Selecting ON or OFF, and INT., the output is completely under manual control. Select TTL and EXT., the unit is under control of the DG-4 interface. One can also use a combination of manual and automatic switch setting if desired. For instance:

- If selecting TTL and INT. for a particular channel, the LED turns on and off under control of the DG-4 interface, but the DAC output setting for selected filters has no effect on this channel.
- If selecting EXT and either ON or OFF for a particular channel, the DG-4 interface will not control the channel if the channel is gated on or off, but the current for the channel will be controlled by the DAC setting for the currently selected filter.

The knob for each channel offers the ability to manually attenuate the current. The attenuation is active no matter what mode or combination of modes is used so long as the logic or the manual switch turns on the channel. If the EXT. mode is used and the DAC values have reduced the current, the knob will further reduce the current proportionally, as it would in any other mode.

The 421 was designed for LEDs that required 5 amps for maximum output. In some cases, it is desirable to use LEDs with a lower maximum current. Often certain desirable wavelengths are not available in the more potent packages. The driver circuits can be turned down to whatever reduced value of maximum current is required. The DAC input and the knob will still further reduce the current proportionally so their operation will be appear to be the same as the other channels even though the range of currents available has been reduced.

3.7 Control via the DG-4 Interface

In order to understand the Lambda 421 it is important to know the way the DG-4 functions. The DG-4 selects one of four filter paths for the light source. The filter values, in the DG-4 context, are actually just memory locations for the settings assigned to a filter value for positioning the two galvanometers in the optical system. These settings could be any value in the range of 0 to 4095. There are 16 available filter values in the DG-4 command set. Filter values can be any number from 0 to 15. Filter 0 is normally reserved as a shutter function and may have 0 stored for both galvanometers. Filters 1, 2, 3, and 4 typically have settings that deliver the light through one of the four physical optical filters to the output port at full power. Filters 5-12 are typically programmed to select one of the four filter paths at reduced power. The standard setup uses filters 5-8 to select the filters used in 1-4 at 50% output power and 9-12 are 1-4 at 33% output power. Filters 13-15 are available but normally defined at the factory.

We have produced the same sort of control for four LEDs using the new USB DG-4 board. This approach produces an LED version of the DG-4 that will run with existing software that supports the DG-4. Since the DG-4 only works with one filter active at a time this command set does not allow computer selection of more than one LED at a time. We have added some basic logic circuits that convert the value of the filter selected to a signal that activates a specific LED driver. Each LED is gated by a logic level signal and all LEDs will have the analog input connected to the common DAC output on the DG-4 circuit board.

Since only one LED is activated by the DG-4 control at a time, we can use a single DAC to supply the current-controlling analog voltage for all four LEDs. In the DG-4, this DAC is normally used for setting a galvanometer command signal. The DAC value is automatically set to a value associated with a given filter when that filter is selected. We simply connected that DAC output to the analog current control inputs of all 4 LED drivers and we now have a system that automatically sets the desired current for each LED as it is selected. The value for the DAC can be stored and read back using simple software commands.

The logic level signals that active the correct LED for each filter value are derived from the 4 bit binary output normally logic level output used by the DG-4 to indicate the selected filter. We have added logic that converts the binary filter value into four separate TTL level outputs, one for each LED. The original binary output is also available as before. The logic was designed so that filter values 1-4 select the corresponding LEDs, 1-4. Filter values 5 through 8 and 9 through 12 also select LEDs 1 through 4, respectively. Filter values 13-15 select LEDs 1-3. Filter value 0 turns off all LEDs. Looking at this in another way:

LED 1 is activated by filter values 1, 5, 9, and 13.

LED 2 is activated by filter values 2, 6, 10 and 14.

LED 3 is activated by filter values 3, 7, 11 and 15.

LED 4 is activated by filter values 4, 8, 12

Filter 0 does not active any LED.

The DG-4 controller stores two DAC values for each of the 16 possible filter values. We have connected the analog output of one of these two DACs to the analog current control input for all of the LEDs. When you select a particular filter value, you will therefore activate the LED that corresponds to that filter value but you will also set the voltage for the current control to the value that corresponds to the DAC setting set for that filter value. We will likely store DAC values for each filter value according to a scheme similar to the DG-4, but this can easily be changed. Thus, LEDs 1, 2, and 3 have four different programmable current levels selected by calling the correct filter value. LED 4 only has three separate values and there is only one value for OFF: Filter 0.

When operating the Lambda under full control of the DG-4 interface you would set each channel to TTL control and EXT. current control using the front panel switches. The current control knobs can be used to attenuate the output of any channel, if desired. The control of the LEDs then is entirely from the DG-4 interface. The connections for the DG-4 interface are all available on the back panel.

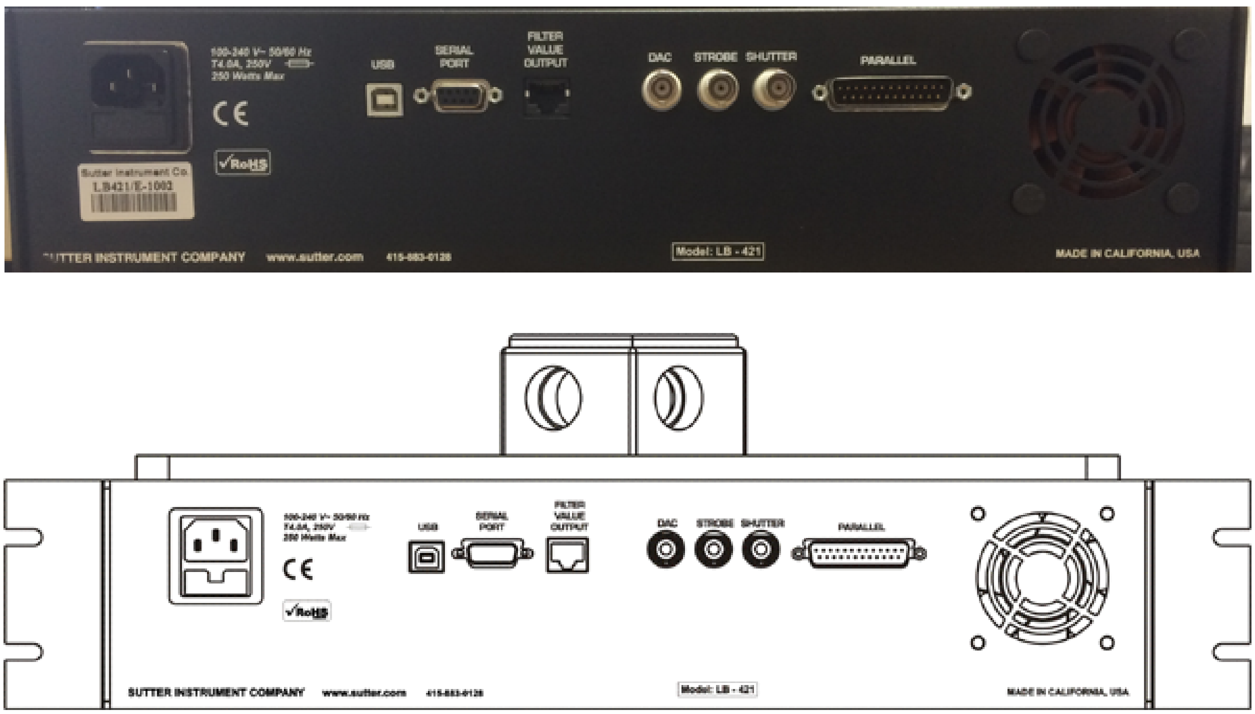

Figure 3-2. Rear panel of the Lambda 421.

The USB interface to a control computer is the default method of control. In most cases, the USB port will be used in the virtual com port mode, which enables this port to support software that was developed for use with serial port control. There is also a true RS232 serial port, but this cannot be used at the same time as the USB port. Selecting which of the two ports is active will be discussed elsewhere. The other option for full control is the parallel port. While this input provides very short latency, few systems offer the full 8 bits needed to input all types of commands. This port is not fully bi-directional, so it does not allow reading settings back to the computer. The most common use of the parallel port is for rapid selection of the active channels via individual TTL signals, as will be discussed elsewhere.

FILTER VALUE OUTPUT RJ-45 Receptacle

In addition to the computer interfaces, there is the Strobe input, which is used as a trigger in the ring buffer mode. There is an analog output and a digital output that are both used to indicate the currently selected filter. The analog output (DAC) produces a voltage of 0 to 6 volts in 16 steps. Each increment in the filter value adds 0.4 volts to the output voltage. The digital output is a binary representation of the currently selected filter number.

Table 3-1. Selecting channel light source intensity via external-control filter value commands.

FILTER VALUE	LED SELECTED	SUGGESTED CURRENT
0	NONE	0%
1	1	100%
2	2	100%
3	3	100%
4	4	100%
5	1	50%
6	2	50%
7	3	50%
8	4	50%
9	1	33%
10	2	33%
11	3	33%
12	4	33%
13	1	15%
14	2	15%
15	3	15%

The actual attenuation is determined by the DAC value associated with each filter value. These are programmed as indicated in the previous table. However, each value can easily be changed from external software.

The new Lambda 421 has a new series of trigger options for the ring buffer. Triggering on the rising edge or the falling edge of the trigger signal can be selected. A special mode that allows the level of the trigger signal to also control the shutter function is also available. This allows a typical shutter control signal to advance the filter selection in the ring buffer while also controlling the on/off state of the light.

4. MAINTENANCE

4.1 Routine Maintenance

Routine cleaning of the Lambda 421 system is required to prevent excessive dust accumulations. Wipe all exterior surfaces with a dry, soft, cotton cloth.

Periodically inspect all cables ensuring that all connections are made well and connectors are evenly seated.

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5. CHANGING LED MODULES

5.1 Making Maximum Current Adjustments Based on LED Module Power Specification

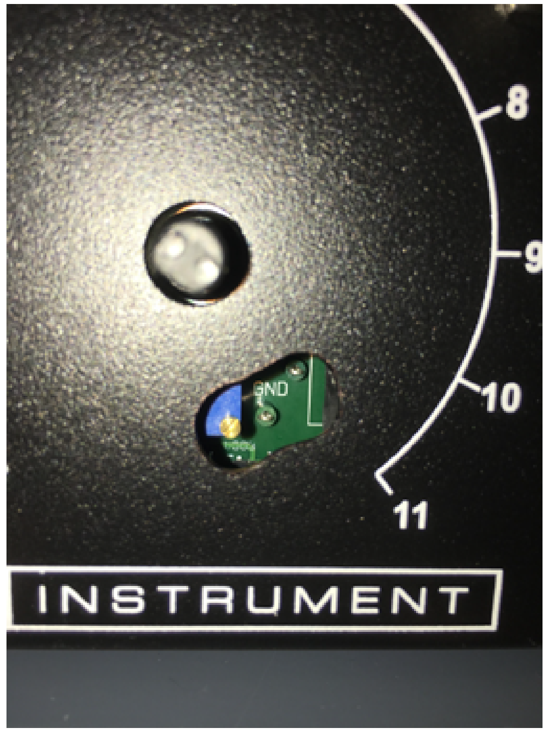
To accommodate a wide array of LED wavelengths with different power requirements, the maximum Current supplied to each of the four LED channels is adjustable. The LED's vary in maximum current from 1A to 5A, and adjustment process is straightforward. You will the following tools:

- Multimeter
- 1.5mm Allen wrench
- Small flat blade screw driver

1. Remove the knob of the channel you would like to adjust with a 1.5mm Allen wrench. It advisable to turn the knob output down to 0.

2. With the knob(s) removed, it should look like the image below. Please note the opening in the sheet metal:

3. Inside the opening you will see 2 test points and blue trim pot with brass head



4. Connect the clip leads from your multimeter to the test points on the board. These test points allow us to measure the voltage across the 0.1-Ohm resistor. Measuring the voltage across a known resistor is a practical use of Ohm's law to determine the Current (V = I*R, therefore, I = V/R). Since we know the Resistance is 0.1 Ohms, and we are measuring the voltage with the multimeter, we can set the Current (A) using a small flat blade screwdriver on the trim pot.

CAUTION: If you are removing an LED rated for 5A, and switching to an LED rated for 1A or 2A, there is a real risk that you can damage the LED accidentally. Please follow these instructions carefully.

5.2 Adjustment Procedure for Switching between a 5A LED to 1A or 2A:

1. Leave the 5A LED connected to channel where the lower Current LED will be installed
2. Make sure all the knobs are turned down, and the main power to the instrument is OFF
3. Turn your Multimeter ON and set to Volts (DC) and Turn on the Main power switch
4. With the 5A LED still connected to channel that you're adjusting flip both switches to "INT" and "ON" (the up positions)
5. Slowly turn up the knob until you start to see a voltage appear on the Multimeter and the LED producing light output
6. Turn the intensity knob all the way up and you will see a Voltage of .5V for a 5A setting.

7. You can now adjust the trim pot with your flat blade screwdriver until you attain a reading of .1V for 1A or .2V for 2A. If you're unsure of the Maximum Current of the LED, please see the list at the end of this document
8. Turn off the main power
9. Remove and Replace the LED in question (1.5mm allen wrench on lens tube)
10. Remove and replace the Filter assembly for that LED position
11. Turn on the main power and confirm the Current setting is still valid for the LED

5.3 Adjustment Procedure for Switching between a 1A or 2A to a 5A LED:

1. Make sure all the knobs are turned down, and the main power to the instrument is OFF
2. Remove and Replace the LED in question with the new 5A LED (1.5mm allen wrench on lens tube)
3. Remove and replace the Filter assembly
4. Turn your Multimeter ON and set to Volts (DC)
5. Turn on the Main power of the Lambda 421
6. With the LED connected to channel that you're adjusting flip both switches in the up position "INT" and "ON"
7. Slowly turn up the knob until you start to see a voltage appear on the Multimeter and the LED producing light output
8. Turn the intensity knob all the way up and you will see a Voltage of .1V for a 1A setting or .2V for a 2A setting. This is the Maximum current setting of the previous LED
9. You can now adjust the trim pot with your flat blade screwdriver until you attain a reading of .5V, which is 5A.

LED power ratings based on wavelength are shown in the following table.

Table 5-1. LED rating based on wavelength.

OBC-Wavelength	Maximum Current (A)
FG-OBC-340	1
FG-OBC-365	1
FG-OBC-385	1
FG-OBC-410	1
FG-OBC-440	5
FG-OBC-460	5
FG-OBC-480	2
FG-OBC-506	2
FG-OBC-530	5

FG-OBC-561	2
FG-OBC-590	2
FG-OBC-630	5
FG-OBC-660	2
FG-OBC-740	1
FG-OBC-850	1
FG-OBC-940	1

APPENDIX A. LIMITED WARRANTY

- Sutter Instrument Company limits the warranty on this instrument to repair and replacement of defective components for two years from date of shipment, provided the instrument has been operated in accordance with the instructions outlined in this manual.
- Abuse, misuse, or unauthorized repairs will void this warranty.
- Warranty work will be performed only at the factory.
- The cost of shipment both ways is paid for by Sutter Instrument during the first three months this warranty is in effect, after which the cost is the responsibility of the customer.
- The limited warranty is as stated above and no implied or inferred liability for direct or consequential damages is intended.
- An extended warranty for up to three additional years can be purchased at the time of ordering, or until the original warranty expires. For pricing and other information, please contact Sutter Instrument.

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APPENDIX B. FUSE REPLACEMENT

In the event that the controller fails to power up when the power switch is turned on, check the line power fuses to see if either or both have blown. The fuses are located in the fuse holder on the power entry module on the back of the controller. To remove the fuse holder first unplug the power cord from the power entry module. Press down on the lever that is located just above the fuse holder and below the power receptacle, and pry the holder straight out of the power entry module.

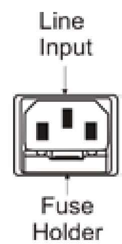

Figure 5-1. Power entry module and fuse location on the rear panel of the Lambda 421 controller.

The fuse holder holds two fuses. Both fuses are of the same type and rating. If either fuse is blown, it is recommended that both fuses be replaced.

The type and rating of both fuses are as follows:

5 x 20 mm glass tube, Time Delay (IEC 60127-2, Sheet III)
4A, 250V
(Examples: Bussmann GMC-4A)

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APPENDIX C. TECHNICAL SPECIFICATIONS

Lamp:	
Output Range	330 to 960 nm, depending LED configuration)
Shuttering	Turn ON/OFF time: <25μs
Noise/Short Term Stability:	0.01%
LED Life	>50,000 hours
Dimensions (W x D x H):	15.75 x 11 x 7.5 in (40 x 27.9 x 19.05 cm)
Weight:	17.8 lbs (8.07 kg)
Light Guide:	
Core Type	Liquid
Length	2 m (6.5 ft)
Diameter	3 mm (0.11 in)
Electrical:	
Mains voltage	110 – 240 V, 50 – 60 Hz
Power cord	10A, 250V, 60°C, PVC, with IEC-320 C13 connector
Mains fuse (rear of cabinet)	Time delay (or time lag) 5 x 20 mm glass tube. For specific fuse ratings, refer to APPENDIX B)
Cables	

Table 5-2. Cable specifications.

	Type	Max. Length	Ferrite at Controller End	Cabling
Parallel	DB-25	6 ft (1.829 m)	Fair-Rite #0443164-251 (See Note 1)	Dielectric separation of circuits. Foil shielding
Serial (RS-232)	DB-9	10 ft (3.048 m)	Fair-Rite #0443167-251 (See Note 1)	Connected to metal faceplates of connectors on both ends. (See Note 2.)
USB	USB-A & USB-B	10 ft (3.048 m)		

Note 1: Fair-Rite Products Corp., P.O. Box J, One Commercial Row, Wallkill, NY, 12589 USA

Note 2: The supplied 9-pin serial RS-232 cable is a “straight-through” cable (Pin 1 of one end wired to Pin 1 of the other, Pin 2 to Pin 2, etc.). Do not substitute the provided cable with a “null-modem” cable, or any cable that has Pins 2 and 3 crossed and/or connected to other non-corresponding pins.

APPENDIX D. EXTERNAL-CONTROL COMMAND REFERENCE

Table 5-3. Filter Position Movement Commands (no return data).

Nominal Filter Pos.			Alt-key-pad entry	Ctrl char	ASCII/-ANSI def./-char.	Phys. Filter Pos.	Move On …	Atte-nua-tion	Details
Dec.	Hex	Binary							
0	00	00000000	-0000	^@		0	Command	0%	Move on command to non-filter pos. where light is blocked (shutter closed)
1	01	00000001	-0001	^A		1	Command	100%	Move on command to LED 1 at full
2	02	00000010	-0002	^B		2	Command	100%	Move on command to LED 2 at full
3	03	00000011	-0003	^C		3	Command	100%	Move on command to LED 3 at full
4	04	00000100	-0004	^D		4	Command	100%	Move on command to LED 4 at full
5	05	00000101	-0005	^E		1	Command	50%	Move on command to LED 1 at half
6	06	00000110	-0006	^F		2	Command	50%	Move on command to LED 2 at half
7	07	00000111	-0007	^G		3	Command	50%	Move on command to LED 3 at half
8	08	00001000	-0008	^H		4	Command	50%	Move on command to LED 4 at half
9	09	00001001	-0009	^I		1	Command	33%	Move on command to LED 1 at 1/3
10	0A	00001010	-0010	^J		2	Command	33%	Move on command to LED 2 at 1/3
11	0B	00001011	-0011	^K		3	Command	33%	Move on command to LED 3 at 1/3
12	0C	00001100	-0012	^L		4	Command	33%	Move on command to LED 4 at 1/3
13	0D	00001101	-0013	^M		1	Command		Move on command to LED 1 at factory-defined level.
14	0E	00001110	-0014	^N		2	Command		Move on command to LED 2 at factory-defined level.
15	0F	00001111	-0015	^O		3	Command		Move on command to LED 3 at factory-defined level.
16	10	00010000	-0016	^P		0	Trigger	0%	Move on command to non-filter pos. where light is blocked (shutter closed)
17	11	00010001	-0017	^Q		1	Trigger	100%	Move on trigger to LED 1 at full
18	12	00010010	-0018	^R		2	Trigger	100%	Move on trigger to LED 2 at full
19	13	00010011	-0019	^S		3	Trigger	100%	Move on trigger to LED 3 at full
20	14	00010100	-0020	^T		4	Trigger	100%	Move on trigger to LED 4 at full
21	15	00010101	-0021	^U		1	Trigger	50%	Move on trigger to LED 1 at half
22	16	00010110	-0022	^V		2	Trigger	50%	Move on trigger to LED 2 at half
23	17	00010111	-0023	^W		3	Trigger	50%	Move on trigger to LED 3 at half
24	18	00011000	-0024	^X		4	Trigger	50%	Move on trigger to LED 4 at half
25	19	00011001	-0025	^Y		1	Trigger	33%	Move on trigger to LED 1 at 1/3
26	1A	00011010	-0026	^Z		2	Trigger	33%	Move on trigger to LED 2 at 1/3
27	1B	00011011	-0027	^[		3	Trigger	33%	Move on trigger to LED 3 at 1/3
28	1C	00011100	-0028	^\		4	Trigger	33%	Move on trigger to LED 4 at 1/3
29	1D	00011101	-0029	^]			Trigger		Move on trigger to LED 1 at factory-defined level.
30	1E	00011110	-0030	^^			Trigger		Move on trigger to LED 2 at factory-defined level.
31	1F	00011111	-0031	^_			Trigger		Move on trigger to LED 3 at factory-defined level.

Table 5-4. Special commands.

Command	Tx/-Rx	Ver.	Byte Count	Byte Offset	Value			Alt-key-pad entry	Ctrl-char	ASCII def./-char.	Description
					Dec.	Hex.	Binary				
Open Shutter	**Tx**	All	1	0	170	AA	1010 1010	Alt-0170			Turns on the same LED(s) that were lit, and restores the state that each was in, prior to the “Close Shutter” command.
	Rx	All	2	0							Echoed command sequence
				1	13	0D	0000 1101			<CR>	Completion indicator
Close Shutter	**Tx**	All	1	0	172	AC	1010 1100	0172			Turns off all LEDs that are currently on (output light beam is extinguished).
	Rx	All	2	0							Echoed command sequence
				1	13	0D	0000 1101			<CR>	Completion indicator
Execute Next Instance of Previous Command	**Tx**	All	1	0	171	AB	1010 1011	0171			Dummy command sent in between any two instances of a different command, allowing both the “before” and “after” commands (which have the same value) to be accepted as valid commands.
	Rx	All	2	0							Echoed command sequence
				1	13	0D	0000 1101			<CR>	Completion indicator
Activate Turbo-Blanking	**Tx**	All	1	0	186	BA	1011 1010	0186			Turns Turbo-Blanking ON
	Rx	All	2	0							Echoed command sequence
				1	13	0D	0000 1101			<CR>	Completion indicator
Deactivate Turbo-Blanking	**Tx**	All	1	0	188	BC	1011 1100	0188			Turns Turbo-Blanking OFF
	Rx	All	2	0							Echoed command sequence
				1	13	0D	0000 1101			<CR>	Completion indicator
Set Specified LED’s DAC Voltage Value	**Tx**	All	4	0	243	F3	1111 0011	0243			Command byte
				1	0-15	00-0F	0000 0000 – 0000 1111	0000 – 0015			Specified filter position
				2	0 – 4095	0000 – FF0F	0000 0000 0000 0000 – 1111 1111 0000 1111	0000+0000 – 0255+0015			Galvo A DAC value encoded into a 16-bit “unsigned short” (2 bytes), Little Endian
	Rx	All	5	0							Echoed command sequence
				4	13	0D	0000 1101			<CR>	Completion indicator

Command	Tx/-Rx	Ver.	Byte Count	Byte Offset	Value			Alt-key-pad entry	Ctrl-char	ASCII def./-char.	Description
					Dec.	Hex.	Binary				
Set Specified Filter's Galvo B DAC Value	**Tx**	All	4	0	243	F3	1111 0011	0243			Command byte
				1	128 – 143	80-8F	1000 0000 – 1000 1111	0128 – 0143			Specified filter position
				2	0 – 4095	0000 – FF0F	0000 0000 0000 0000 – 1111 1111 0000 1111	0000+ 0000 – 0255+ 0015			Galvo B DAC value encoded into a 16-bit "unsigned short" (2 bytes), Little Endian
	Rx	All	5	0							Echoed command sequence
				4	13	0D	0000 1101			<CR>	Completion indicator
Set Galvo A or Galvo B DAC Values for All Nominal Filter Positions	**Tx**	All	33	0	243	F3	1111 0011	0243			Command byte
				1	63 191	3F BF	0011 1111 1011 1111	0063 0191			Galvo A or Galvo B
					0 – 4095	0000 – FF0F	0000 0000 0000 0000 – 1111 1111 0000 1111	0000+ 0000 – 0255+ 0015			Filter galvo DAC value encoded into a 16-bit "unsigned short" (2 bytes), Little Endian
				2	DAC value						Nominal filter 0
				4	DAC value						Nominal filter 1
				6	DAC value						Nominal filter 2
				8	DAC value						Nominal filter 3
				10	DAC value						Nominal filter 4
				12	DAC value						Nominal filter 5
				14	DAC value						Nominal filter 6
				16	DAC value						Nominal filter 7
				18	DAC value						Nominal filter 8
				20	DAC value						Nominal filter 9
				22	DAC value						Nominal filter 10
				24	DAC value						Nominal filter 11
				26	DAC value						Nominal filter 12
				28	DAC value						Nominal filter 13
				30	DAC value						Nominal filter 14
				32	DAC value						Nominal filter 15
	Rx	All	34	0							Echoed command sequence
				33	13	0D	0000 1101			<CR>	Completion indicator
Start	**Tx**	All	1	0	223	DF	1101 1111	0223			Places the controller in a mode that allows a series of filter values to be

Command	Tx/-Rx	Ver.	Byte Count	Byte Offset	Value Dec.	Value Hex.	Value Binary	Alt-key-pad entry	Ctrl-char	ASCII def./-char.	Description
Loading Ring Buffer											loaded in the ring buffer. A maximum of 100 filter values are allowed (all entries in excess of 100 are ignored).
	Rx	All	2	0							Echoed command sequence
				1	13	0D	0000 1101			<CR>	Completion indicator
End Loading Ring Buffer	Tx	All	1	0	240	F0	1111 0000	0240			Sent after the final filter value is loaded in the ring buffer. This saves the new ring buffer values and returns to normal on-line mode.
	Rx	All	2	0							Echoed command sequence
				1	13	0D	0000 1101			<CR>	Completion indicator
Run from Ring Buffer	Tx	All	1	0	241	F1	1111 0001	0241			Begins filter position movement based on what is defined in the ring buffer. A trigger pulse steps from one definition to the next, executing the movement command.
	Rx	All	2	0							Echoed command sequence
				1	13	0D	0000 1101			<CR>	Completion indicator
End Run from Ring Buffer	Tx	All	1	0	242	F2	1111 0010	0242			Returns to normal on-line mode
	Rx	All	2	0							Echoed command sequence
				1	13	0D	0000 1101			<CR>	Completion indicator
Enable Ring Buffer Triggering by Strobe	Tx	All	1	0	202	CA	1100 1010	0202			Selects triggered by strobe line as the ring buffer mode
	Rx	All	2	0							Echoed command sequence
				1	13	0D	0000 1101			<CR>	Completion indicator
Disable Ring Buffer Triggering by Strobe	Tx	All	1	0	203	CB	1100 1011	0203			Deselects triggered by strobe line
	Rx	All	2	0							Echoed command sequence
				1	13	0D	0000 1101			<CR>	Completion indicator
Set Trigger Pulse Mode for Ring Buffer	Tx	All	2	0	246	F6	1111 0110	0246			Sets the immediate ring buffer trigger by strobe mode (immediate (lost at power down) & default (restored at power up))
				1	1	01	0000 0001	0001	^A		Move on rising edge
					2	02	0000 0010	0002	^B		Move on rising edge, then to Filter 0 on signal falling
					3	03	0000 0011	0003	^C		Move on falling edge
					4	04	0000 0100	0004	^D		Move on falling edge, then to Filter 0 on signal rising

Command	Tx/-Rx	Ver.	Byte Count	Byte Offset	Value			Alt-key-pad entry	Ctrl-char	ASCII def./-char.	Description
					Dec.	Hex.	Binary				
					161	A1	1010 0001	0161			Move on rising edge as **default**
					162	A2	1010 0010	0162			Move on rising edge, then to Filter 0 on signal falling as **default**
					163	A3	1010 0011	0163			Move on falling edge as **default**
					164	A4	1010 0100	0164			Move on falling edge, then to Filter 0 on signal rising as **default**
	Rx	All	3	0							Echoed command sequence
				2	13	0D	0000 1101			<CR>	Completion indicator
Get Trigger Pulse Mode for Ring Buffer Status	**Tx**	All	2	0	246	F6	1111 0110	0246			Ring buffer trigger by strobe mode
				1	15	0F	0000 1111	0015	^O		Get mode state
	Rx	All	3	0	246	F6	1111 0110				Echoed command byte
				1	1-4	01-04	0000 0001 – 0000 0100				Mode state
				2	13	0D	0000 1101			<CR>	Completion indicator
Get Ring Buffer Contents	**Tx**	All	2	0	245	F5	1111 0101	0245			Get the contents of the ring buffer
	Rx	All	3-19	0	245	F5	1111 0101				Echoed command byte
				1-16	0-15	00-0F	0000 0000 – 0000 1111				Filter 0-15 * # of filters
				2-17	240	F0	1111 0000				End of filters list marker
				2-18	13	0D	0000 1101			<CR>	Completion indicator
Get Specified Filter's Galvo A DAC Value	**Tx**	All	2	0	244	F4	1111 0100	0244			Command byte
				1	0-15	00-0F	0000 0000 – 0000 1111	0000 – 0015			Specified filter position
	Rx	All	5	0							Echoed command sequence
				2	0 – 4095	0000 – FF0F	0000 0000 0000 0000 – 1111 1111 0000 1111				Galvo A DAC value encoded into a 16-bit "unsigned short" (2 bytes), Little Endian
				4	13	0D	0000 1101			<CR>	Completion indicator
Get Specified Filter's Galvo B	**Tx**	All	4	0	244	F4	1111 0100	0244			Command byte
				1	128 – 143	80-8F	1000 0000 – 1000 1111	0128 – 0143			Specified filter position

Command	Tx/-Rx	Ver.	Byte Count	Byte Offset	Value			Alt-key-pad entry	Ctrl-char	ASCII def./-char.	Description
					Dec.	Hex.	Binary				
	Rx	All	5	0							Echoed command sequence
				2	0 – 4095	0000 – FF0F	0000 0000 0000 0000 – 1111 1111 0000 1111				Galvo A DAC value encoded into a 16-bit “unsigned short” (2 bytes), Little Endian
				4	13	0D	0000 1101			<CR>	Completion indicator
Get Galvo A or Galvo B DAC Values for All Nominal Filter Positions	Tx	All	2	0	244	F4	1111 0100	0244			Command byte
				1	63 191	3F BF	0011 1111 1011 1111	0063 0191			Galvo A or Galvo B
	Rx	All	35	0							Echoed command sequence
					0 – 4095	0000 – FF0F	0000 0000 0000 0000 – 1111 1111 0000 1111	0000+ 0000 – 0255+ 0015			Filter galvo DAC value encoded into a 16-bit “unsigned short” (2 bytes), Little Endian
				2	DAC value						Nominal filter 0
				4	DAC value						Nominal filter 1
				6	DAC value						Nominal filter 2
				8	DAC value						Nominal filter 3
				10	DAC value						Nominal filter 4
				12	DAC value						Nominal filter 5
				14	DAC value						Nominal filter 6
				16	DAC value						Nominal filter 7
				18	DAC value						Nominal filter 8
				20	DAC value						Nominal filter 9
				22	DAC value						Nominal filter 10
				24	DAC value						Nominal filter 11
				26	DAC value						Nominal filter 12
				28	DAC value						Nominal filter 13
				30	DAC value						Nominal filter 14
				32	DAC value						Nominal filter 15
				34	13	0D	0000 1101			<CR>	Completion indicator

Command	Tx/-Rx	Ver.	Byte Count	Byte Offset	Value			Alt-key-pad entry	Ctrl-char	ASCII def./-char.	Description
					Dec.	Hex.	Binary				
Get System Status & Configur-ation	**Tx**	All	1	0	253	FD	1111 1011	0253			Command byte
	Rx	All	17	0							Echoed command sequence
				1							Controller description as an ASCII sequence. E.g., “**LB421**”
				6							Firmware version as an ASCII sequence. E.g., “**V1.11**”.
				11							SmartShutter installation status: Normally “**SS-NC**” (not installed)
				16	13	0D	0000 1101			<CR>	Completion indicator

NOTES:

1. A short delay (usually around 1 ms) is recommended between commands (after the reception of one command and the sending of the next command).
2. All values greater than one byte (8 bits) transmitted to, and received from, the LAMBDA 421 consist of two bytes ordered in “Little Endian” (least significant byte last) format (see NOTE 3). The value stored in these two bytes is always unsigned, meaning that the value will always be positive (negative values are not allowed). These two bytes are converted to and from 16-bit “unsigned short” (C/C++) or “U16” (LabVIEW) value storage entities.
3. “Little Endian” means that the least significant byte is last (last to send and last to receive). Byte-order reversal may be required on some platforms (e.g., LabVIEW always handles “byte strings” in “Big Endian” byte order, requiring that the two bytes containing a DAC value be reverse-ordered before conversion into a 16-bit “unsigned short” (or “word”) value). Whereas Microsoft Windows, Intel-based Apple Macintosh systems running Mac OS X, and some Intel/AMD processor based Linux distributions handle byte storage in Little-Endian byte order so byte reordering is not necessary before converting to/from 16-bit “short” or “word” values.

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NOTES