Liquid Crystal Noise Eaters

User Guide

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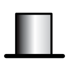
Chapter 1 Warning Symbol Definitions

Below is a list of warning symbols you may encounter in this manual or on your device.

Symbol	Description
	Direct Current
	Alternating Current
	Both Direct and Alternating Current
	Earth Ground Terminal
	Protective Conductor Terminal
	Frame or Chassis Terminal
	Equipotentiality
	On (Supply)
	Off (Supply)
	In Position of a Bi-Stable Push Control
	Out Position of a Bi-Stable Push Control
	Caution: Risk of Electric Shock
	Caution: Hot Surface
	Caution: Risk of Danger
	Warning: Laser Radiation
	Caution: Spinning Blades May Cause Harm

Chapter 2 Safety

Do Not Open Housing!

The Noise Eater has no user-serviceable parts. Service should only be performed by trained service personnel.

All statements regarding safety of operation and technical data in this instruction manual will only apply when the unit is operated correctly.

WARNING

Laser Radiation – Avoid Exposure to Beam

Chapter 3 Product Overview

Thorlabs' Liquid Crystal Noise Eaters are precision instruments for stabilizing and attenuating laser power. The noise eater consists of a variable attenuator (liquid crystal wave plate and polarizer), a calibrated beam splitter, and a servo controller to control the modulator, as depicted in the block diagram below.

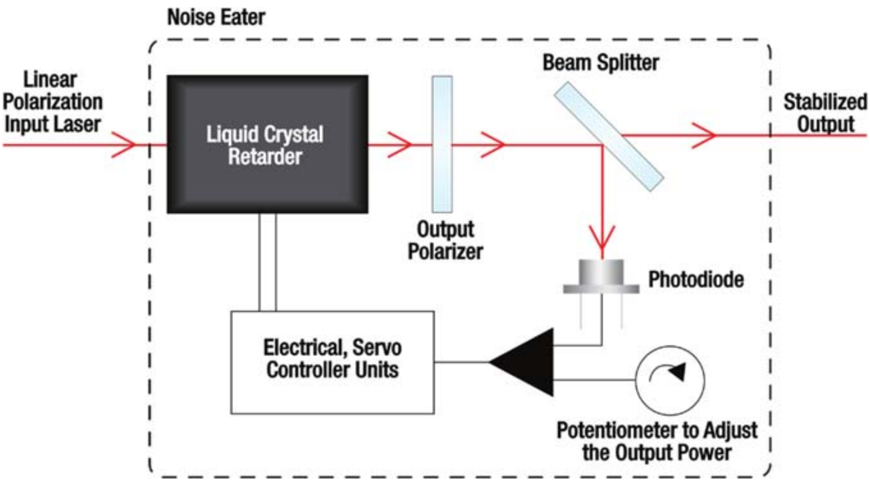


Figure 1 Noise Eater Block Diagram

Linearly polarized light is input into the liquid crystal retarder, which, together with the output polarizer, acts as a variable retarder. A beamsplitter then sends a small part of the beam to a feedback loop consisting of a photodiode and control servo. The servo compares the optical signal to a preset signal level and applies the appropriate adjustment voltage until the optical signal reaches the desired level.

The noise eater can also be used as a variable attenuator even without the presence of noise. By adjusting the resistance of the potentiometer, the user can set the desired output power level.

Chapter 4 Setup

4.1. Mounting and Alignment

The noise eater is designed to work with linearly polarized input light aligned with the direction of the arrow near the input aperture. Linearly polarized light and proper alignment of the direction of polarization are important for achieving the best results from the noise eater.

In order to minimize optical losses, the noise eater does not have an input polarizer. If the incident light is not linearly polarized, a linear polarizer (such as our LPVIS or LPNIR polarizers) should be used before the noise eater.

If the incident light is linearly polarized but is not aligned exactly vertically or horizontally, a half-wave plate can be used before the noise eater to rotate the polarization axis. As shown in the photo below, the noise eater's cage mount can be used along with a CRM1 cage rotation mount to rotate the half-wave plate, thus aligning the polarization axis with the noise eater.

Figure 2 CRM1 Cage Rotation Mount holding a Mounted Half-Wave Plate (such as the WPH10M-633), secured to the NEL02A Noise Eater with ER Cage Rods

For post mounting, the noise eater is equipped with two 8-32 (M4) threaded holes. These holes are offset by 90°, so that light with a vertical or horizontal polarization axis can be aligned with the noise eater. The four 4-40 holes on the front of the noise eater can also be used to mount the noise eater in either a horizontal or vertical orientation using the Thorlabs Cage System

Figure 3 Horizontally and Vertically Mounted NEL02A Noise Eaters. Note the direction of the input polarization indicated by the double arrow.

4.2. Power Supply

The noise eater operates with 12 V DC power. We recommend using the AC/DC power supply that is included with the noise eater for best performance.

4.3. Powering ON the Noise Eater

When the noise eater is connected to the power supply, it automatically powers on. There is no additional power switch.

4.4. Beam Centering

For best performance of the noise eater, it is recommended that the beam is well centered in the input aperture. Due to the optical path inside the noise eater, the output beam will be shifted down by 1.0 mm if the noise eater is mounted vertically as shown in Figure 3 (right). Similarly, the output beam will be shifted sideways by 1.0 mm if the noise eater is mounted horizontally as in Figure 3 (left).

Chapter 5 Operation

5.1. Selecting the Power Range

The NEL02A(/M), NEL03A(/M) and NEL04A(/M) have two selection switches at the top of the case which are used to select the input power range. When the high/low power switch is set to "L", the input power range can be set from 1 mW to 30 mW, and when the status switch set to "H", the input power range can be set from 100 mW to 500 mW.

The NEL01A(/M) has only one selection switch which can set the input power range at 1 mW, 3 mW, 10 mW, or 30 mW. The power selector should be set to the lowest value that is still higher than the actual power of the laser. For example, if the NEL01A(/M) is being used with a beam power of 8 mW at 635 nm, the selector should be set to 10 mW.

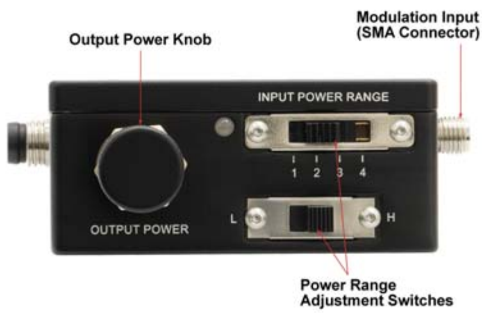


Figure 4 Top View of the NEL02A/NEL03A/NEL04A Noise Eaters. The top of the NEL01A housing appears the same except it does not have the L-H switch for low or high power settings.

The NEL01A(/M), NEL02A(/M) and NEL03A(/M) noise eaters use a Silicon detector, while the NEL04A(/M) uses a Germanium detector, as part of the feedback loop. The responsivity of the detector is different for different wavelengths, and so the power settings on the selector only correspond to the design wavelength of the detector (635 nm for NEL01A(/M) and NEL02(/M), 780 nm for NEL03A(/M), 1550 nm for NEL04A(/M)). The power range at a given wavelength is inversely proportional to the responsivity (higher responsivity value will result lower power range value). The graph below shows the relative responsivity of both detectors at a range of wavelengths. The tables below show a rough estimate of the power settings at various wavelengths for each model.

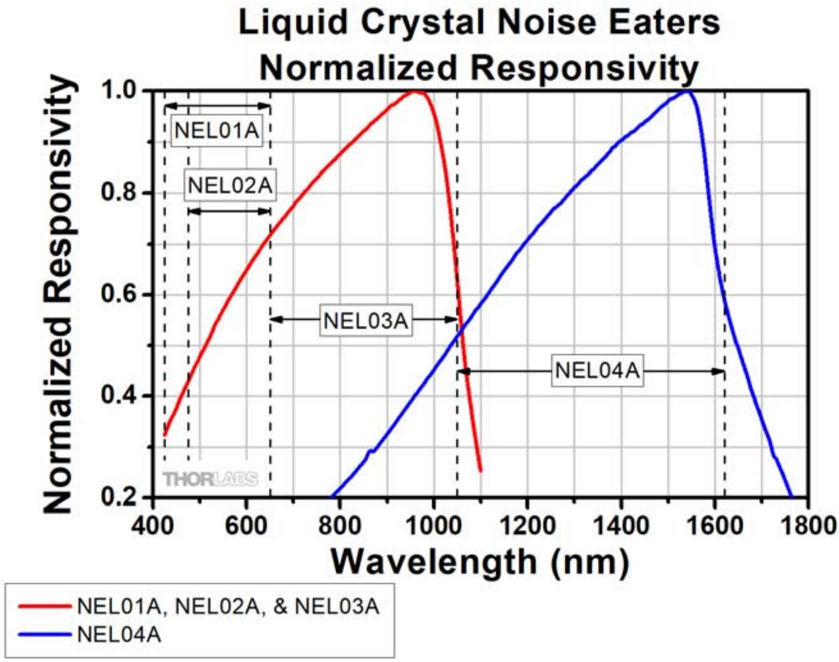


Figure 5 Noise Eaters Normalized Responsivity

5.2. Max Powers at Various Wavelengths

The tables below list the maximum input powers for each noise eater, specified for a variety of input wavelengths and switch settings. Please note that these maximum power levels correspond to the feedback electronics of the noise eater, and in some cases, the actual maximum input power is instead limited by the damage threshold of the noise eater. For the high power noise eaters (NEL02A, NEL03A, and NEL04A), this damage threshold is 8 W/cm^2, which corresponds to a maximum input power of 1 W if the input power is distributed evenly across the Ø4 mm clear aperture. For the low power noise eaters (NEL01A), the damage threshold is 0.8 W/cm^2, which corresponds to a maximum input power of 100 mW if the input power is again distributed evenly across the Ø4 mm clear aperture.

NEL01A(/M) Max Input Power at Various Wavelengths			
Switch Status	**Power Level at 450 nm**	**Power Level at 550 nm**	**Power Level at 635 nm**
1 mW	2 mW	1.5 mW	1 mW
3 mW	6 mW	4.5 mW	3 mW
10 mW	20 mW	15 mW	10 mW
30 mW	60 mW	45 mW	30 mW

NEL02A(/M) Power Ranges at Various Wavelengths				
Switch Status		**Power Level at 450 nm**	**Power Level at 550 nm**	**Power Level at 635 nm**
L	1	2 mW	1.5 mW	1 mW
L	2	6 mW	4.5 mW	3 mW
L	3	20 mW	15 mW	10 mW
L	4	60 mW	45 mW	30 mW
H	1	200 mW	150 mW	100 mW
H	2	600 mW[a]	450 mW	300 mW
H	3	1000 mW[a]	750 mW[a]	500 mW
H	4	See Note [b]		

NEL03A(/M) Power Ranges at Various Wavelengths							
Switch Status		**Power Level at 650 nm**	**Power Level at 700 nm**	**Power Level at 780 nm**	**Power Level at 900 nm**	**Power Level at 1000 nm**	**Power Level at 1100 nm**
L	1	1.2 mw	1.1 mW	1 mW	0.9 mW	0.9 mW	3.3 mW
L	2	3.5 mW	3.3 mW	3 mW	2.6 mW	2.7 mW	10.0 mW
L	3	11.8 mW	11.1 mW	10 mW	8.8 mW	8.9 mW	33.3 mW
L	4	35.5 mW	33.3 mW	30 mW	26.3 mW	26.8 mW	100.0 mW
H	1	120.0 mW	111.0 mW	100 mW	86.0 mW	89.3 mW	333 mW
H	2	355.5 mW	333.0 mW	300 mW	258.0 mW	268 mW	999 mW[a]
H	3	600.0 mW[a]	500 mW	500 mW	430.0 mW	446.6mW	1650 mW[a]
H	4	See Note [b]					

NEL04A(/M) Power Ranges at Various Wavelengths								
Switch Status		**Power Level at 1050 nm**	**Power Level at 1150 nm**	**Power Level at 1250 nm**	**Power Level at 1350 nm**	**Power Level at 1450 nm**	**Power Level at 1550 nm**	**Power Level at 1620 nm**
L	1	1.9 mW	1.6 mW	1.4 mW	1.2 mW	1.0 mW	1 mW	1.6 mW
L	2	5.8 mW	4.8 mW	4.1 mW	3.5 mW	3.1 mW	3 mW	4.8 mW
L	3	19.2 mW	16.0 mW	13.7 mW	11.7 mW	10.4 mW	10 mW	16 mW
L	4	57.6 mW	48.0 mW	41.1 mW	35.1 mW	31.3 mW	30 mW	48 mW
H	1	190 mW	160 mW	137 mW	117 mW	104.7 mW	100 mW	160 mW
H	2	500 mW	480 mW	411 mW	351 mW	313.4 mW	300 mW	480 mW
H	3	835 mW[a]	800 mW[a]	685 mW[a]	585 mW[a]	520 mW[a]	500 mW	800 mW[a]
H	4	See Note [b]						

a. The maximum power levels specified here are for the feedback electronics, but the maximum input power at these settings is limited by the damage threshold of the liquid crystal retarder, which is 8 W/cm^2. See the section 5.2, Max Powers at Various Wavelengths, for details.

b. This setting is not recommended. If used, do not exceed the power level for the H – 3 setting.

5.3. Modulate the Output Power

There is a SMA interface at the right side of the noise eater, which can be used to modulate the attenuation of the noise eater. The modulation input has a 10 kΩ input impedance. A voltage ranging from 0 to 2.5 V can be input to modulate the output power as needed. Before modulating the output power, first turn the output power level knob clockwise to the end of its travel (minimum output power setting).

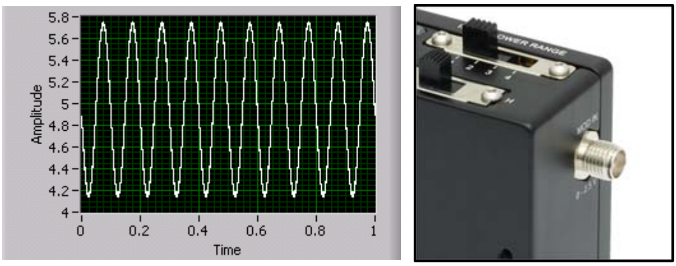


Figure 6 Modulated Output Power with a Sinusoidal Input Signal (Left) and SMA Modulation Input (Right)

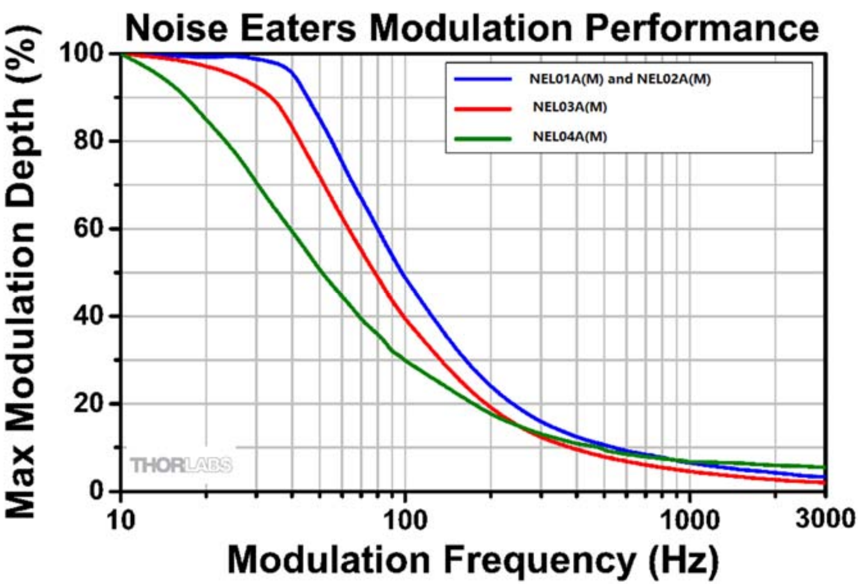


Figure 7 Noise Eaters Modulation Performance

5.4. Setting the Output Power Level

The noise eater operates by varying how much of the signal is attenuated in order to reach the target output power and attenuate the noise. Since the noise eater can attenuate the signal but not amplify it, the clean output beam can only have a power as high as the minimum power level of the noisy signal. In practice, to remove all noise without unnecessarily attenuation the signal power, the output power level should be set to slightly lower than the minimum power of the noisy signal.

There are two methods to maximize the output power while still maintaining a clean output signal. One method uses an external device such as an optical power meter, while the other uses the LED indicator on the noise eater.

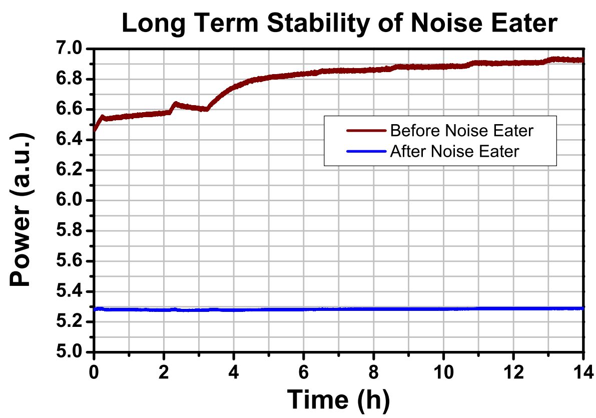


Figure 8 Example of a noisy input beam and set output levels.

5.4.1. Maximizing the Output Power Using an External Measurement Device

To set the target output to a point that attenuates all noise, but does not unnecessarily attenuate the signal's power, first observe the characteristics of the noise of the signal, either by using the statistics screen on the Thorlabs' PM200 optical power meter, or using a detector and an oscilloscope. Once the minimum power level of the noisy signal is established, adjust the output power of the noise eater to an output level slightly below the minimum of the noisy signal.

To set the output power, use the following procedure:

1. After mounting and connecting the noise eater, set the power selector to the highest value, and turn the knob all the way counterclockwise to maximize the output power.
2. Using an optical power meter or a detector and oscilloscope, record the minimum output power of the signal. Note: Depending on the

characteristics of the noise, the signal might need to be recorded over a few minutes to find the minimum.

3. Set the power selector to the suitable value (see Section 5.1).
4. Turn the adjustment knob clockwise until the power reaches 5% below the minimum power you recorded earlier. If you cannot reach the desired power, set the power level to a lower range. Rotate the knob counter clockwise and return to Step 3 to select a different power range.
5. Note: In some cases setting the power level to 10% below the recorded minimum gives better performance. If you cannot reach the desired output power by adjusting the knob, then adjust the power range.
6. Measure the noise level after the noise eater to verify that the noise eater is set up correctly.

Note: When measuring the signal after the noise eater, please remember that the noise eater will attenuate noise up to 2.5 kHz, with the best performance for noise in the DC-100 Hz range. If you are observing the signal in time domain, the time domain signal will include noise in higher frequencies. To best observe the performance of the noise eater, we recommend using a low pass filter, or looking at lower frequencies in the frequency domain.

5.4.2. Maximizing the Output Power Using the Indicator LED

The noise eater is equipped with an indicator LED at the top (near the adjustment knob), which indicates the status using two colors. A red LED indicates that the output is set too high and the feedback loop cannot function well. A green LED indicates that the feedback loop is operating well and the feedback signal is being used to attenuate the noise.

If you do not wish to use an external device, such as a power meter or detector, it is possible to adjust the knob using the LED indicator by following these steps:

1. Set the power selector to the suitable value (see Section 5.1) according to the power of the source.

2. Turn the knob counterclockwise all the way, until the LED turns red.

3. Start turning the knob clockwise slowly until the LED starts blinking, alternating between red and green.

4. Continue turning the knob until the LED turns green and stops blinking.

5. If, after turning the knob all the way clockwise, the LED does not stop blinking and stay green, return to Step 1 and set the power selector to a lower value.

6. To increase the noise attenuation, rotate the knob more in the clockwise direction.

Note: By setting the output level using the LED you are assuring that the noise eater is entering the noise attenuation range. However, the LED alone does not guarantee best noise attenuation and power loss performance. To maximize the noise attenuation while minimizing power loss, we recommend setting the optimal output power using an external measurement device.

Chapter 6 Specifications

Item #	NEL01A(/M)	NEL02A(/M)	NEL03A(/M)	NEL04A(/M)
Operating Wavelength Range	425 – 650 nm	475 – 650 nm	650 – 1050 nm	1050 – 1620 nm
Output Power Stability[a]	0.05% (Standard Deviation)			
Noise Attenuation Frequency Range[b]	DC - 1.8 kHz		DC - 2.5 kHz	DC - 1.4 kHz
Noise Attenuation Amplitude Range	0.1% to 50% of Input Signal			
Noise Attenuation Factor[c]	>150 at 10 Hz, 80 at 60 Hz, 20 at 400 Hz, 4 at 1 kHz			>150 at 10 Hz, 80 at 60 Hz, 10 at 400 Hz, 1.5 at 1 kHz
Transmission	>85% @ 635 nm	>80% @ 635 nm	>85% @ 780 nm	>85% @ 1550 nm
Max Input Power	See Section 5.2, *Max Powers at Various Wavelengths*			
Min Input Power	0.5 mW			
Polarization Extinction Ratio	>1000:1 Over Wavelength Range			
Laser Damage Threshold (CW)[d]	0.8 W/cm^2	8 W/cm^2		
Effective Output Power Attenuation Range[e]	1 - 40		1 - 5	
Internal Polarizer Blocking Damage Threshold	1 W/cm^2	10 W/cm^2		
Attenuation Control	Onboard Potentiometer (10 Turns) or SMA Modulation Input			
Input Aperture	∅5 mm			
Input Beam Diameter[f]	∅4 mm (Max)			
Output Displacement	1 mm Vertically (in the Direction of Input Polarization)			
Max Beam Divergence	5 mrad			
Max Incidence Angle	±2°			
Input Polarization Tolerance	±3°			
Wavefront Distortion	≤λ/4 at 635 nm		≤λ/2 at 635 nm	≤λ/2 at 635 nm
AR Coating	R_{avg} <0.5% from 400 – 650 nm		R_{avg} <0.5% from 650 – 1100 nm	R_{avg} <0.5% from 1050 – 1620 nm
Modulation Input	SMA Connector, 10 kΩ Input Impedance, 0 – 2.5 V			
Extinction Ratio[g]	512.6		7.7	6.5
Min Rise/Fall Time[h]	0.65/7.3 ms		0.75/11.5 ms	2.8/25 ms
Mounting	Two 8-32 (M4) Threaded Holes for Post Mounting 30 mm Cage System Compatible, Ø1" Lens Tube Compatible			
Operating Temperature	15°C to 45°C			
Pulsed Laser Input Repetition Rate	>1 MHz			

a. RMS value over 8 hours.

b. The maximum of the frequency range is defined as the point where 0 dB noise attenuation is obtained. These noise eaters are designed to operate down to DC frequency. However, due to external factors (e.g. ambient temperature, vibration, spatial and/or polarization stability of the light source), the noise attenuation factor below 10 Hz is difficult to measure and quantify. Therefore our specifications are guaranteed at 10 Hz and above.

c. Noise attenuation factor is the ratio of noise amplitude before and after the noise eater. Tested at 3 mW input power with a noise amplitude of 5% of the input signal. See detailed noise attenuation plots at thorlabs.com for more information

d. This is the range of output power adjustment where the noise attenuation factor is guaranteed for a given input power level. If the output power is further reduced, the noise eater might not be able to completely reduce the noise in the signal. This specification does not include losses due to absorption.

e. The maximum input power and laser damage threshold are wavelength-independent. Additionally, the absolute maximum input power varies with wavelength. See Section 5.2 for details.

f. Specified for a $1/e^2$ beam diameter.

g. Extinction ratio is the ratio of the signal power at minimum attenuation to the signal power at full attenuation, regardless of the effective noise attenuation factor, when using the SMA modulation input.

h. Rise time is measured on the rising edge of the output intensity from 10% to 90% of full output power.

Chapter 7 CE/FCC Certification

In accordance with European Council Directive 2014/30/EU, this product has been assessed against and found compliant with the following Applicable Standards:

EN 55011:2009/A1:2010(Class A)	**EN 61326-1:2013**
EN 61326-2-1:2013	**EN 61326-2-2:2013**
EN 61000-3-2: 2014	**EN 61000-4-2:2009**
EN 61000-3-3 : 2013	**EN 61000-4-3:2006+A1:2008+A2:2010**
EN 61000-4-4:2012	
EN 61000-4-5:2006	
EN 61000-4-6:2014	
EN 61000-4-8:2010	
EN 61000-4-11:2004	

This device complies with Part 15 of the FCC Rules. Operation is subject to the following two conditions:

(1) This device may not cause harmful interference, and

(2) This device must accept any interference received, including interference that may cause undesired operation.

Declaration of Conformity

We: Thorlabs Optical Electronic Technology (Shanghai) Co., Ltd
of: Room A101, No.100, Lane 2891, South Qilianshan Rd, Shanghai

In accordance with the following Directive(s):

2014/35/EU	Low Voltage Directive (LVD)
2014/30/EU	Electromagnetic Compatibility (EMC) Directive
2011/65/EU	Restriction of Use of Certain Hazardous Substances (RoHS)

hereby declare that:

Model: ***NEL01A(/M), NEL02A(/M), NEL03A(/M), NEL04A(/M)***

Equipment: ***Liquid Crystal Noise Eater***

Is in conformity with the applicable requirements of the following documents:

EN 61010-1:2010	Safety Requirements for Electrical Equipment for Measurement, Control, and Laboratory Use.
EN 61326-1:2013	Electrical equipment for measurement, control and laboratory use. EMC requirements.

and which, issued under the sole responsibility of Thorlabs, is in conformity with Directive 2011/65/EU of the European Parliament and of the Council of 8th June 2011 on the restriction of the use of certain hazardous substances in electrical and electronic equipment, for the reason stated below:

does not contain substances in excess of the maximum concentration values tolerated by weight in homogenous materials as listed in Annex II of the Directive.

I hereby declare that the equipment named has been designed to comply with the relevant section of the above referenced specifications, and complies with all applicable Essential Requirements of the Directives.

Signed: on: 20. July 2021

Name: Shanshan Song
Position: General Manager

Chapter 8 Maintenance

The noise eater does not require maintenance under normal operating conditions.

There are no serviceable parts in the noise eater and no reason to open the unit. If you suspect a problem with your noise eater, please call Thorlabs and a member of our Technical Support team will be happy to assist you.

8.1. Troubleshooting

Problem	Solutions
No Output Power	Turn the power selector to its maximum value and turn the knob all the way counter clockwise. At this point the noise eater should not attenuate the beam. If you still have no output power then verify that the beam is properly aligned to enter the center of the noise eater's aperture, and that the beam is perpendicular to the noise eater's body. If there is still no optical output power, please verify that your laser's operating wavelength and power are within the specified ranges for the noise eater.
Low Noise Attenuation	Noise attenuation performance depends on many parameters, including target output power setting and alignment of the beam. If, after fine tuning the set-point (see section 4.6), the noise attenuation is still not high enough, we recommend fine tuning the input polarization of the beam using a linear polarizer and verifying that the beam is well centered and that the beam path is perpendicular to the noise eater's body.
Output is Unstable	1) Check the polarization direction of the input light. 2) If the LED is blinking, or if it is red, you need to reduce the output power by rotating the knob counterclockwise, or by selecting a lower power range and readjusting the knob. 3) The angle of incidence of the input light could be too high. Make sure the angle of incidence is lower than 2°.

Chapter 9 Regulatory

As required by the WEEE (Waste Electrical and Electronic Equipment Directive) of the European Community and the corresponding national laws, Thorlabs offers all end users in the EC the possibility to return “end of life” units without incurring disposal charges.

- This offer is valid for Thorlabs electrical and electronic equipment:
- Sold after August 13, 2005
- Marked correspondingly with the crossed out “wheelie bin” logo (see right)
- Sold to a company or institute within the EC
- Currently owned by a company or institute within the EC
- Still complete, not disassembled and not contaminated

Wheelie Bin Logo

As the WEEE directive applies to self contained operational electrical and electronic products, this end of life take back service does not refer to other Thorlabs products, such as:

- Pure OEM products, that means assemblies to be built into a unit by the user (e.g. OEM laser driver cards)
- Components
- Mechanics and optics
- Left over parts of units disassembled by the user (PCB’s, housings etc.).

If you wish to return a Thorlabs unit for waste recovery, please contact Thorlabs or your nearest dealer for further information.

Waste Treatment is Your Own Responsibility

If you do not return an “end of life” unit to Thorlabs, you must hand it to a company specialized in waste recovery. Do not dispose of the unit in a litter bin or at a public waste disposal site.

Ecological Background

It is well known that WEEE pollutes the environment by releasing toxic products during decomposition. The aim of the European RoHS directive is to reduce the content of toxic substances in electronic products in the future.

The intent of the WEEE directive is to enforce the recycling of WEEE. A controlled recycling of end of life products will thereby avoid negative impacts on the environment.

Chapter 10 Thorlabs Worldwide Contacts

For technical support or sales inquiries, please visit us at **www.thorlabs.com/contact** for our most up-to-date contact information.

USA, Canada, and South America
Thorlabs, Inc.
sales@thorlabs.com
techsupport@thorlabs.com

UK and Ireland
Thorlabs Ltd.
sales.uk@thorlabs.com
techsupport.uk@thorlabs.com

Europe
Thorlabs GmbH
europe@thorlabs.com

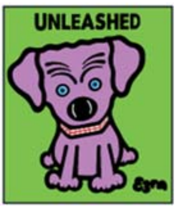
Scandinavia
Thorlabs Sweden AB
scandinavia@thorlabs.com

France
Thorlabs SAS
sales.fr@thorlabs.com

Brazil
Thorlabs Vendas de Fotônicos Ltda.
brasil@thorlabs.com

Japan
Thorlabs Japan, Inc.
sales@thorlabs.jp

China
Thorlabs China
chinasales@thorlabs.com



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