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# THORLABS

## NEL02/M - SEPTEMBER 30, 2021

Item # NEL02/M was discontinued on SEPTEMBER 30, 2021 For informational purposes, this is a copy of the website content at that time and is valid only for the stated product.

### NOISE EATERS / LASER AMPLITUDE STABILIZERS

- ▶ Laser Amplitude Stabilizer / Variable Attenuator
- ▶ Models with Wavelength Ranges Covering 425 - 1620 nm Available
- ▶ Internal Closed-Loop Feedback

Application Idea



Front



NEL01

Back



NEL02 Noise Eater with Half-Wave Plate in CRM1 Rotation Mount

[Hide Overview](#)

## OVERVIEW

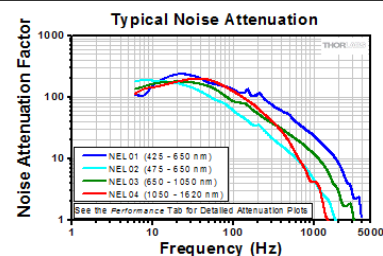
### Features

- Reduces Laser Intensity Noise
- Also Functions as a Variable Attenuator or EO Modulator
- Models for use at 425 - 650 nm, 475 - 650 nm, 650 - 1050 nm, or 1050 - 1620 nm
- Maximum Input Power of up to 1.65 W, Depending on Model, Wavelength, and Beam Size (See the *Operation* Tab for Details)
- Excellent for Sensitive Experiments such as Optical Tweezers
- Ideal for Stabilizing CW Lasers

Thorlabs' Liquid Crystal Noise Eaters / Laser Amplitude Stabilizers are precision instruments for stabilizing, modulating, and attenuating the power of linearly polarized light. These closed-loop systems are designed for use with light in the 425 - 650 nm (NEL01), 475 - 650 nm (NEL02), 650 - 1050 nm (NEL03), or 1050 - 1620 nm (NEL04) wavelength range. We offer noise eater models for low (<60 mW) or high (<1.65 W) power use, all with external modulation inputs. See the *Specs* tab for details.

### Noise Reduction

Utilizing a liquid crystal amplitude modulator, combined with an internal photodiode for power measurement and a feedback control circuit, these noise eaters can eliminate intensity noise in linearly polarized light, achieving amplitude stabilization of within 0.05% of a selected output power. The input power can be set to one of several ranges using the switches on the top of the unit, which permit the noise eater to remove noise without unnecessarily attenuating the signal power. The potentiometer is then adjusted to select the output power (see the *Operation* tab for more information). Long-term performance and frequency characterization for each noise eater model are shown on the *Performance* tab.

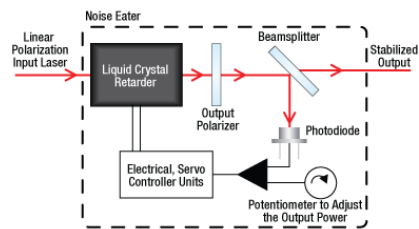


Click to Enlarge

Noise Attenuation Factor is the Ratio of Noise Amplitude Before and After the Noise Eater

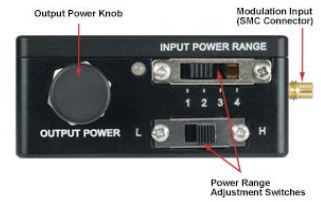
### Power Attenuation and Modulation

These noise eaters are also capable of



Click to Enlarge  
Noise Eater Block Diagram

continuously attenuating and modulating the laser output using the liquid crystal retarder and integrated polarizer. Unlike most attenuators available, Noise Eaters attenuate the laser power rapidly without the use of any mechanical components. The noise eater's attenuation capabilities can be controlled via the onboard potentiometer or electrical modulation input.



Click for Details  
NEL02 Top View Showing Power Range Adjustment Switches and Modulation Input

Thorlabs' Noise Eaters are post mountable in two orientations via 8-32 (M4) tapped holes. They also feature 4-40 tapped holes on the front and back for 30 mm Cage System compatibility and an SM1-threaded (1.035"-40) rear aperture for Ø1" Lens Tube compatibility.

[Hide Specs](#)

**S P E C S**

Item #	NEL01(/M)	NEL02	NEL03(/M)	NEL04(/M)
Wavelength Range	425 - 650 nm	475 - 650 nm	650 - 1050 nm	1050 - 1620 nm
Switchable High Power Mode		✓	✓	✓
<b>Noise Attenuation Performance Specs</b>				
Output Power Stability <sup>a</sup>	±0.05% (Standard Deviation)			
Noise Attenuation Frequency Range <sup>b</sup>	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 <sup>c</sup>	>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
Effective Output Power Attenuation Range <sup>d</sup>	1 - 40		1 - 5	
Internal Polarizer Blocking Damage Threshold (Maximum Power Attenuation)	1 W/cm <sup>2</sup>	10 W/cm <sup>2</sup>		
Attenuation Control	Onboard Potentiometer (10 Turns) or SMC Modulation Input			
<b>Optical Specs</b>				
Transmission (Click for Plot)	>85% at 635 nm	>80% at 635 nm	>85% at 780 nm	>85% at 1550 nm
Power Level Switching	Four Position Power Range Switch	Three Position Power Range Switch	High/Low Power Mode Switch and Four Position Power Range Switch	
Maximum Input Power	See the <i>Max Powers at Various Wavelengths</i> Section on the <i>Operation Tab</i>			
Minimum Input Power	0.5 mW			
Polarization Extinction Ratio at Output	>1000:1 Over Wavelength Range			
Damage Threshold (CW) <sup>e</sup>	0.8 W/cm <sup>2</sup>	8 W/cm <sup>2</sup>		
Input Aperture	Ø5 mm			
Input Beam Diameter <sup>f</sup>	Ø4 mm (Max)			
Output Beam Displacement	1 mm Vertically (in the Direction of Input Polarization)			
Beam Divergence	5 mrad (Max)			
Angle of Incidence	±2° (Max)			
Input Polarization Tolerance	±3°			
Wavefront Distortion	≤λ/4 at 635 nm		≤λ/2 at 635 nm	
AR Coating	R <sub>avg</sub> <0.5% from 400 - 650 nm		R <sub>avg</sub> <0.5% from 650 - 1100 nm	R <sub>avg</sub> <0.5% from 1050 - 1620 nm
<b>Modulation Performance Specs</b>				
Modulation Input	SMC Connector, 0 - 2.5 V, 10 kΩ Input Impedance			

Extinction Ratio <sup>g</sup>	512.6	7.7	6.5
Minimum Rise / Fall Time <sup>h</sup>	0.65 ms / 7.3 ms	0.75 ms / 11.5 ms	2.8 ms / 25 ms
Pulsed Laser Input Repetition Rate	>1 MHz		
<b>General Specs</b>			
Mounting Options	Two 8-32 (M4) Tapped Holes for Post Mounting 30 mm Cage System Compatible via Eight 4-40 Tapped Holes Ø1" Lens Tube Compatible via 4 mm Deep Internal SM1 Threads on Rear Side		
Operating Temperature Range	15 °C to 45 °C		

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. It was tested at 3 mW input power with a noise amplitude of 5% of the input power level. The nominal noise attenuation frequency range can reach up to 2.5 kHz, depending on the model. See detailed noise attenuation plots on the *Performance* tab for more information. The noise eater might not be able to completely eliminate high frequency noise in certain cases, such as a laser source that contains spikes or step-like output power fluctuations.

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 density and laser damage threshold are wavelength-independent. Additionally, the absolute maximum input power varies with wavelength; see the *Operation* tab 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 SMC modulation input.

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

[Hide Performance](#)

## PERFORMANCE

### Noise Eater Performance Graphs

In the graphs below, noise attenuation was measured as one of three parameters was varied: input power level, input signal modulation (noise) amplitude, and output signal attenuation. The graphs show that the noise eaters provide consistent performance regardless of changes in these parameters.

### Graph Definitions

#### Noise Attenuation at Various Input Power Levels

Noise attenuation factor is the ratio of noise amplitude before and after the noise eater. In these graphs, the attenuation factor was measured for several different input power levels, with a fixed signal modulation depth (noise amplitude). The graphs below show that the noise eaters provide consistent performance regardless of input power level.

#### Noise Attenuation at Various Input Signal Modulations

In these graphs, the input signal was modulated with a sine wave to simulate noise. The attenuation factor was measured at a variety of modulation depths (noise amplitudes). The graphs below show that the noise eater provides consistent performance even at large noise levels.

#### Noise Attenuation at Various Output Signal Power Levels

Since the noise eater uses a liquid crystal modulator as the optical control element, the noise attenuation is achieved by attenuating the laser beam when noise appears. Our noise eaters are carefully designed to optimize the noise attenuation performance without needing to severely attenuate the signal. These graphs demonstrate that the specified noise attenuation can be reached with a cost of only 5% - 10% overall attenuation of the output power, and further increases in attenuation does not significantly improve the noise attenuation.

#### Modulation Performance

Noise eaters with a modulation input can also be used as EO modulators. In these graphs, a sine wave with a 2.5 V amplitude and an increasing frequency was used to modulate a noiseless input beam. The graphs show that the maximum modulation depth decreases with increasing modulation frequency. Further testing has demonstrated that the modulation performance is consistent for a given noise eater model, regardless of the laser beam's input power.

### NEL01: Low Power Noise Eater for Visible (425 - 650 nm)

[Click here to download raw data.](#)

Item #	Noise Attenuation			Modulation Performance	Long-Term Noise Attenuation	Transmission
	vs. Input Power	vs. Noise Amplitude	vs. Signal Attenuation			
NEL01(/M)						

### NEL02: High Power Noise Eater for Visible (475 - 650 nm)

[Click here to download raw data.](#)

Item #	Noise Attenuation			Modulation Performance	Long-Term Noise Attenuation	Transmission
	vs. Input Power	vs. Noise Amplitude	vs. Signal Attenuation			
NEL02						

### NEL03: High/Low Power Noise Eater for NIR (650 - 1050 nm)

[Click here to download raw data.](#)

Item #	Noise Attenuation			Modulation Performance	Long-Term Noise Attenuation	Transmission
	vs. Input Power	vs. Noise Amplitude	vs. Signal Attenuation			
NEL03(/M)						

### NEL04: High/Low Power Noise Eater for IR (1050 - 1620 nm)

[Click here to download raw data.](#)

Item #	Noise Attenuation			Modulation Performance	Long-Term Noise Attenuation	Transmission
	vs. Input Power	vs. Noise Amplitude	vs. Signal Attenuation			
NEL04(/M)						

[Hide Operation](#)

## OPERATION

### Noise Eater Operation

Thorlabs' Liquid Crystal Noise Eater is a precision instrument for stabilizing, attenuating, and modulating laser power. The noise eater consists of a variable attenuator (liquid crystal wave plate and polarizer), a calibrated beamsplitter, and a servo controller to control the modulator, as depicted in the block diagram to the right.



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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.

### Mounting and Alignment

The noise eater is designed to work with linearly polarized input light aligned with the direction of the arrow engraved on the noise eater 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 must be placed before the noise eater to polarize the incident light.

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 to the right, the noise eater's cage mount can be used along with a CRM1T cage rotation mount to rotate the half-wave plate, thus aligning the polarization axis with the noise eater.



Click to Enlarge  
The Noise Eater can be post mounted in two different orientations to match the input light's direction of polarization. A CRM1T (/M) Cage Rotation Mount and four 30 mm Cage Rods can mount a half-wave plate for fine tuning the polarization alignment.

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 30 mm Cage System.

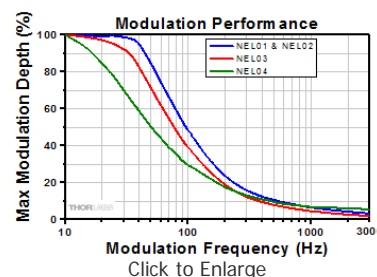
For best performance of the noise eater, it is recommended that the beam be well centered within the input aperture. Due to the optical path inside the noise eater, the output beam will be shifted down by 1.0 mm if the noise eater is mounted vertically, as shown in the left view in the figure to the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

## Modulation

There is an SMC 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 from 0 to full output. Before modulating the output power, first turn the output power level knob clockwise to the end of its travel (minimum output power setting).



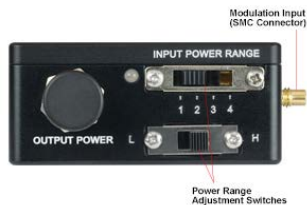
Click to Enlarge  
SMC Modulation Input Jack



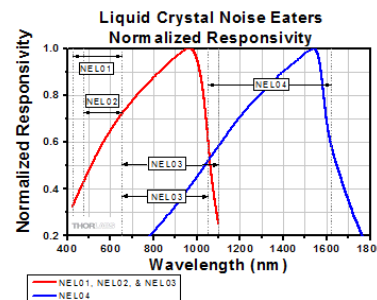
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## Power Range Adjustment

The selection switch(es) at the top of the noise eater are used to select the input power range. 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 NEL01 is being used with a beam power of 8 mW at 635 nm, the selector should be set to position 3, which represents 10 mW. For specifications, refer to the Max Power tables below.



Click to Enlarge  
Top View Showing Power Range Adjustment Switches



Click to Enlarge

The NEL02, NEL03, and NEL04 noise eaters have two selection switches at the top of the case, which are used to select the input power range. When the low/high power switch is set to "LOW", the input power range can be set to one of the lower set of powers; when the status switch set to "HIGH", the input power range can be set to one of the higher set of powers. For specifics, refer to the Max Power tables below. Note that the NEL01 noise eater has only one selection switch.

The NEL01, NEL02, and NEL03 noise eaters use a Silicon detector as part of the feedback loop, while the NEL04 noise eater uses a Germanium detector. The responsivity of the detectors 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 NEL01 and NEL02, 780 nm for NEL03, 1550 nm for the NEL04). The power range at a given wavelength is inversely proportional to the responsivity (a higher responsivity value will result in a lower power range value). The graph to the right 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.

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 attenuating the signal power, the output power level should be set to slightly lower than the minimum power of the noisy signal. See the operating manual for more information.

## 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 (NEL02, NEL03, and NEL04), this damage threshold is 8 W/cm<sup>2</sup>, 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 eater (NEL01), the damage threshold is  $0.8 \text{ W/cm}^2$ , which corresponds to a maximum input power of 100 mW if the input power is again distributed evenly across the Ø4 mm clear aperture.

NEL01 Max Power at Various Wavelengths			
Switch Position	Max Power at 450 nm	Max Power at 550 nm	Max Power at 635 nm
1	2 mW	1.5 mW	1 mW
2	6 mW	4.5 mW	3 mW
3	20 mW	15 mW	10 mW
4	60 mW	45 mW	30 mW

NEL02 Max Power at Various Wavelengths				
Switch Position		Max Power at 450 nm	Max Power at 550 nm	Max Power 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 <sup>a</sup>	450 mW	300 mW
H	3	1000 mW <sup>a</sup>	750 mW <sup>a</sup>	500 mW
H	4	N/A <sup>b</sup>		

~~at~~ 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  $8 \text{ W/cm}^2$ . See the section "Max Powers at Various Wavelengths," above, for details.

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

NEL03 Max Power at Various Wavelengths							
Switch Position		Max Power at 650 nm	Max Power at 700 nm	Max Power at 780 nm	Max Power at 900 nm	Max Power at 1000 nm	Max Power 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 mW
H	1	120 mW	111 mW	100 mW	86.0 mW	89.3 mW	333 mW
H	2	355.5 mW	333 mW	300 mW	258.0 mW	268 mW	999 mW <sup>a</sup>
H	3	600 mW <sup>a</sup>	500 mW	500 mW	430.0 mW	446.6 mW	1650 mW <sup>a</sup>
H	4	N/A <sup>b</sup>					

~~at~~ 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  $8 \text{ W/cm}^2$ . See the section "Max Powers at Various Wavelengths," above, for details.

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

NEL04 Max Power at Various Wavelengths								
Switch Position		Max Power at 1050 nm	Max Power at 1150 nm	Max Power at 1250 nm	Max Power at 1350 nm	Max Power at 1450 nm	Max Power at 1550 nm	Max Power at 1650 nm
L	1	1.9 mW	1.6 mW	1.5 mW	1.2 mW	1 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 mW	13.7 mW	11.7 mW	10.4 mW	10 mW	16 mW
L	4	57.6 mW	48 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 <sup>a</sup>	800 mW <sup>a</sup>	685 mW <sup>a</sup>	585 mW <sup>a</sup>	520 mW <sup>a</sup>	500 mW	800 mW <sup>a</sup>
H	4	N/A <sup>b</sup>						

~~at~~ 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<sup>2</sup>. See the section "Max Powers at Various Wavelengths," above, for details.

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

[Hide Noise Eaters for 425 - 650 nm or 475 - 650 nm](#)

### Noise Eaters for 425 - 650 nm or 475 - 650 nm

- ▶ NEL01(M) is a Low-Power Noise Eater (0.5 mW to 60 mW) with a Modulation Input and 425 - 650 nm Wavelength Range
- ▶ NEL02 is a Switchable Low/High-Power Noise Eater (0.5 mW to 1000 mW) with a Modulation Input and 475 - 650 nm Wavelength Range

Part Number	Description	Price	Availability
NEL01/M	Customer Inspired!&nbsp;Noise Eater / EO Modulator for 425 - 650 nm, M4 Taps	\$1,715.16	Today
NEL01	Customer Inspired!&nbsp;Noise Eater / EO Modulator for 425 - 650 nm, 8-32 Taps	\$1,715.16	Today
NEL02	Customer Inspired!&nbsp;High-Power Noise Eater / EO Modulator for 475 - 650 nm, 8-32 Taps	\$2,224.83	Today

[Hide Noise Eater for 650 - 1050 nm](#)

### Noise Eater for 650 - 1050 nm

- ▶ NEL03(M) is a Switchable Low/High-Power Noise Eater (0.5 mW to 1650 mW) with a Modulation Input

Part Number	Description	Price	Availability
NEL03/M	Customer Inspired!&nbsp;High-Power Noise Eater / EO Modulator for 650 - 1050 nm, M4 Taps	\$2,224.83	Today
NEL03	Customer Inspired!&nbsp;High-Power Noise Eater / EO Modulator for 650 - 1050 nm, 8-32 Taps	\$2,224.83	Today

[Hide Noise Eater for 1050 - 1620 nm](#)

### Noise Eater for 1050 - 1620 nm

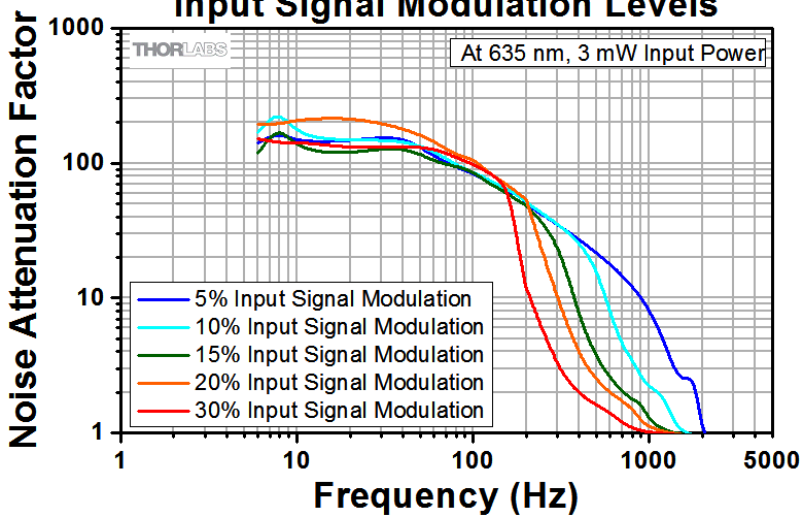
- ▶ NEL04(M) is a Switchable Low/High-Power Noise Eater (0.5 mW to 835 mW) with a Modulation Input

Part Number	Description	Price	Availability
NEL04/M	Customer Inspired!&nbsp;High-Power Noise Eater / EO Modulator for 1050 - 1620 nm, M4 Taps	\$2,456.41	Today
NEL04	Customer Inspired!&nbsp;High-Power Noise Eater / EO Modulator for 1050 - 1620 nm, 8-32 Taps	\$2,456.41	Today

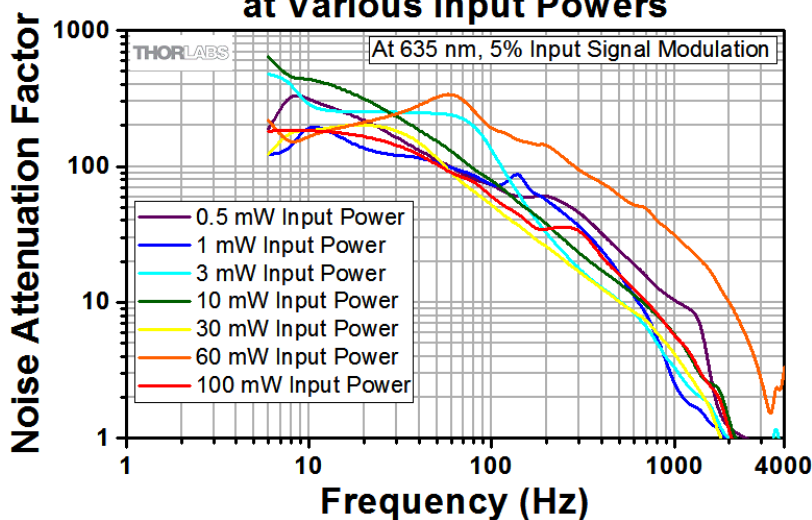
Visit the *Noise Eaters / Laser Amplitude Stabilizers* page for pricing and availability information:  
[https://www.thorlabs.com/newgrouppage9.cfm?objectgroup\\_id=6107](https://www.thorlabs.com/newgrouppage9.cfm?objectgroup_id=6107)



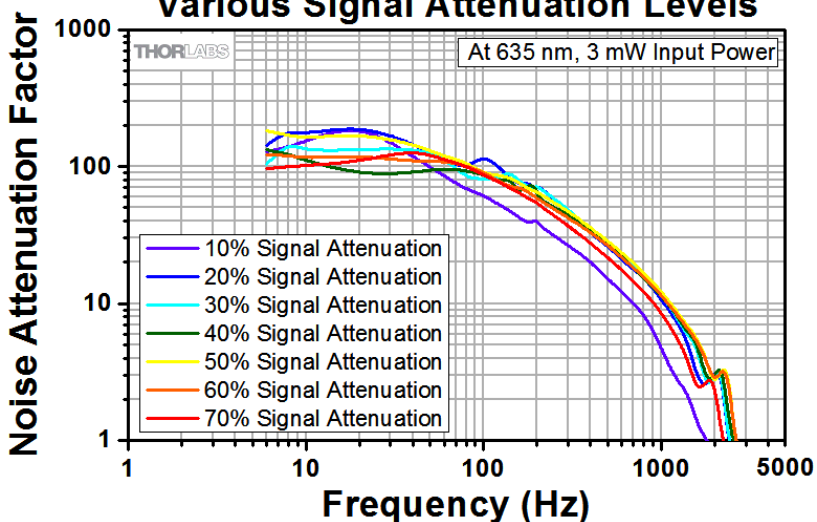
**NEL02 Noise Attenuation at Various Input Signal Modulation Levels**



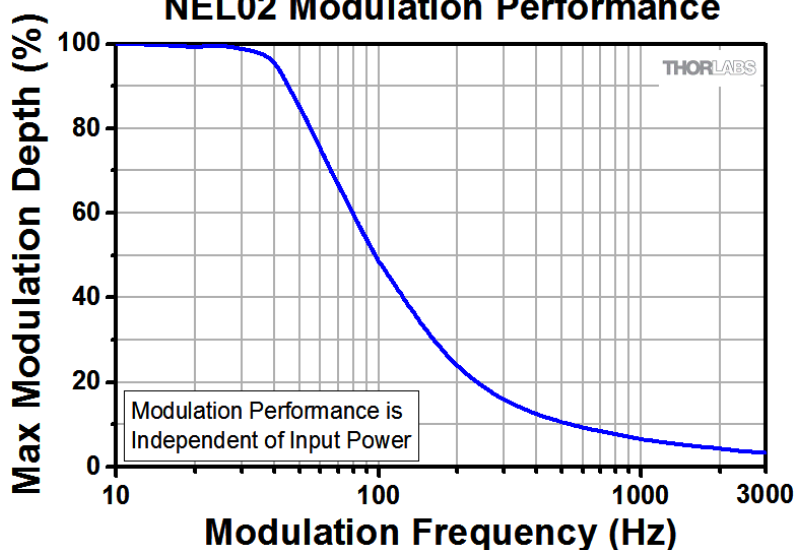
**NEL02 Noise Attenuation at Various Input Powers**



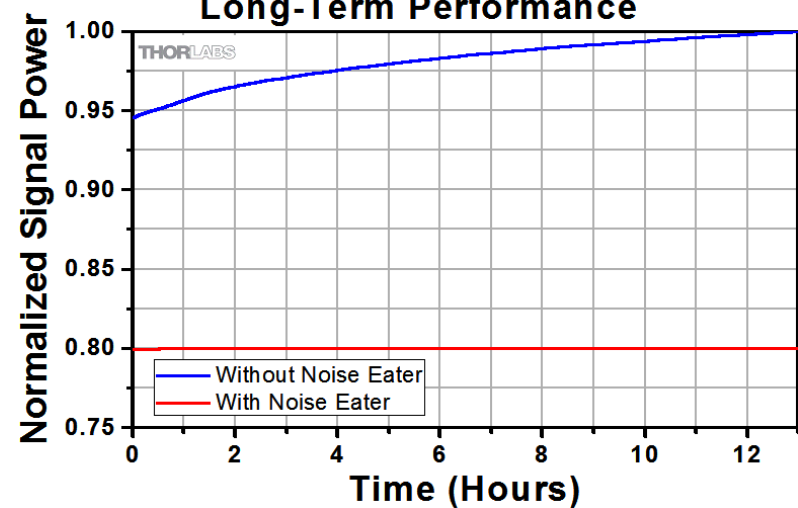
**NEL02 Noise Attenuation at Various Signal Attenuation Levels**



**NEL02 Modulation Performance**



**NEL02 Noise Eater Long-Term Performance**



**NEL02 Noise Eater Transmission**

