USER'S GUIDE

Quadcell Photoreceivers

Model 290X

CAUTION! *These photoreceivers are sensitive to electrostatic discharges and could be permanently damaged if subjected even to small discharges. Ground yourself adequately prior to handling these detectors or making connections. A ground strap provides the most effective grounding and minimizes the likelihood of electrostatic damage*

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Document Number 90099915 Rev. A

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Introduction

Overview

The Model 290X family of photoreceivers use a combination of a quadrant cell photodiode and signal-processing amplifiers to generate position-sensitive signals from an incident light source.

Versions of the photoreceiver are available for visible (Model 2901) or infrared (Model 2903) beams. The photoreceiver can be operated from battery or a ±15 V DC power supply (we recommend the low-noise Newport Model 0901 power supply for best performance).

Each model has a photodiode with a 3-mm diameter active region.

Tips for Best Operation

Avoid Room Lights

The 290X quadrant cell photoreceiver has a large active area. For a typically illuminated room of 1–10 µW/mm^2, the SUM output can reach 1 V on the 30-µW saturation gain setting. The 120-Hz component of fluorescent room lights is extreme, and will almost certainly cause measurement difficulties.

The best solution is to shield the receiver as much as possible from room lights. A Newport Model 1280 can be installed into the threads on the detector housing to hold filters or a light shield.

Limiting Measurement Bandwidth

As seen in the discussion “Impact of Noise on Position Measurement” on page 19, the measurement bandwidth plays an important role in the noise of your system. Select a measurement bandwidth consistent with your measurement goals. For instance, observation of thermal drifts in the sub-Hz range will benefit greatly from signal averaging or other bandwidth-limiting actions.

Using Optical Filters

Narrow-band optical filters, which transmit your laser’s wavelength while blocking other light sources, can be installed in a Newport Model 1280 1" filter holder. Many filters are commercially available.

When using optical filters during position measurement, please consider the effects of multiple surface reflections. The ideal filter has a wedge shape, and good anti-reflection coating on one surface to ensure that the optical beam incident on the receiver does not contain interference fringes.

Operation

Setting up the Receiver

1. Supply power. The Model 290X is powered either by a single 9-V alkaline battery, or by a +/-15 V DC power supply. If both battery and external power are present, an internal relay connects the external power to the amplifier circuitry. To check the battery condition, push the red power switch to the BATT CHK position. If the green LED lights up, the battery is in good condition; if the LED does not light, the battery needs to be replaced (see page 8). Adjust the power switch to ON.

   Note: *Remember to switch the power OFF when not in use to maximize battery life.*

2. Mount the photoreceiver. Use the 8-32 thread (M4 for metric versions) on the bottom of the casing to mount the photoreceiver to a post or pedestal.

   Be careful not to over-tighten when attaching to a post or pedestal, or the threaded insert can strip out of the plastic pad.

3. Connect the receiver output. Connect your voltmeter, oscilloscope, or other instrument to the X, Y and SUM connectors on the back of the receiver.

   Note: *The threading is seated in a non-conductive plastic pad to reduce the electrical noise associated with ground loops.*

Electrical ground is only introduced to the housing through the BNC outer shells, and the power-supply ground pin. If you use a floating measurement instrument or a floating power supply, the photoreceiver may not be electrically grounded.

4. Align an optical beam onto the detector. Be careful to keep the optical power below the stated limits to avoid damage to the photoreceiver and amplifier circuitry.
5. Adjust the gain. Use the rotary switch on top of the receiver to set the gain. The table on page 13 gives a detailed description of the different channel gains and bandwidths associated with each switch setting.

Checking and Replacing the Battery

The Model 290X is powered by a single, standard 9-volt alkaline battery. Under normal operating conditions with low light levels and a high impedance load attached to the BNC connectors, the photoreceiver draws about 25 mA from the battery, and the battery lifetime will be approximately 40 hours.

To check the battery condition, push the power switch to the **BATT CHK** position. If the green LED lights up, the battery is in good condition.

When the battery voltage falls below about 6.5 volts, the green LED will not light, and the battery should be replaced.

1. Switch off the power and disconnect any external power supply.
2. Remove the screw in the back of the photoreceiver casing and remove the back cover.
3. Unplug the old battery by rotating it away from the circuit board about the snap-on terminal contacts.

4. Install a new 9-volt alkaline battery.
5. Reinstall the back cover and screw. Take care not to pinch the power wires from the external power connector.
6. Test the new battery by pushing the power switch to the **BATT CHK** position.

Using an External Power Supply

The Model 290X can be operated from any power supply which can supply 50 mA of ± 15V DC power. Newport recommends use of the Model 0901 Power Supply, which features three pairs of low-noise linear ±15 V DC outputs.

If using the Model 0901 Power Supply, connect the Model 0923 M8B-to-M8B cable from the power supply to the jack on the back of the Model 290X.

If using a third-party power supply, connect the Model 9024 banana-plug-to-M8B cable from the power supply to the jack on the back of the Model 290X. The red jack should be connected to +15 V DC, the black to -15 V DC, both with respect to the green jack, which should be connected to the power supply COMMON terminal. It is recommended, but not required to use the green wire as an earth ground.

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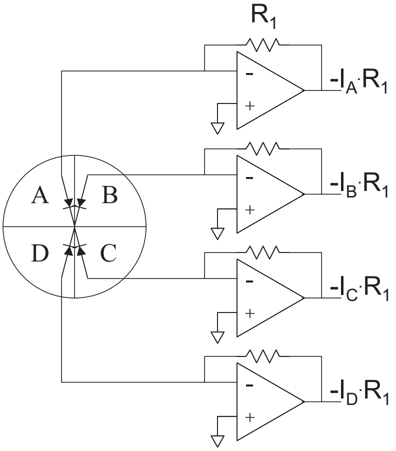
General Features and Principles

Amplifier Circuitry

The circuitry inside of the Model 290X consists of a two-stage amplifier, with parallel gain paths for X, Y, and SUM outputs. Each stage has an adjustable gain and bandwidth. Figures 1 through 3 illustrate the basic circuit design, and the table on page 13 shows the gain and bandwidth of each amplifier stage for each possible setting of the rotary switch.

Each photocurrent from the quadrant photodiode is amplified at a first-stage amplifier. The value of R_1 depends on the gain setting, and can vary from 200 Ω to 200 kΩ.

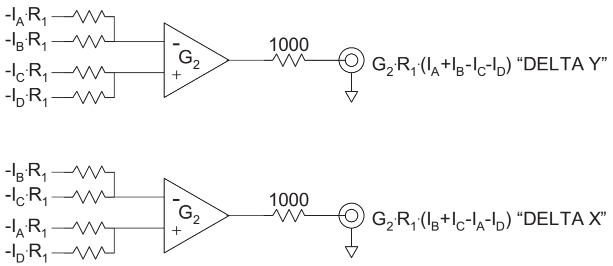
Figure 1: Each photocurrent is amplified at a first-stage amplifier



The signals from each quadrant are differenced and amplified at a second-stage amplifier. The value of G_2

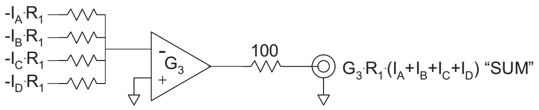
depends on the setting of the gain switch, and can vary from 1 to 10. The bandwidth of this gain stage also varies, as indicated in the table on page 13.

Figure 2: Signals from each quadrant are differenced and amplified at a second stage amplifier



The signals from each quadrant are summed at a second-stage amplifier. The value of G_3 is fixed at unity. The bandwidth of this gain stage is fixed at 30 Hz.

Figure 3: Signals from each quadrant are summed at a second-stage amplifier



Gain and Bandwidth

The following table shows the gain and bandwidth of each amplifier stage as a function of switch setting.

Switch Position	R_1 Gain (V/A)	1st-Stage BW (kHz)	G_2 Gain (V/V)	Δ-Stage BW (kHz) approx.	G_3 Gain (V/V)	Sum-Stage BW (kHz)
30 mW (1)	200	100	1	100	1	0.03
30 mW (3)	200	100	3	100	1	0.03
30 mW (10)	200	100	10	100	1	0.03
30 mW (10)	200	100	10	0.03	1	0.03
3 mW (1)	2000	100	1	100	1	0.03
3 mW (3)	2000	100	3	100	1	0.03
3 mW (10)	2000	100	10	100	1	0.03
3 mW (10)	2000	100	10	0.03	1	0.03
0.3 mW (1)	20,000	100	1	100	1	0.03
0.3 mW (3)	20,000	100	3	100	1	0.03
0.3 mW (10)	20,000	100	10	100	1	0.03
0.3 mW (10)	20,000	100	10	0.03	1	0.03
30 µW (1)	200,000	100	1	100	1	0.03
30 µW (3)	200,000	100	3	100	1	0.03
30 µW (10)	200,000	100	10	100	1	0.03
30 µW (10)	200,000	100	10	0.03	1	0.03

Normalization of Outputs

The signals X and Y vary in response to changes of the light position relative to the center of the quadrant photodiode. Because X and Y also vary in response to changes of the total light power, the SUM signal is provided as a means of normalization.

Note: *The bandwidth of the SUM signal is limited to 30 Hz. Therefore, the normalization cannot be performed for rapid power fluctuations characteristic of some laser beams.*

Position Transfer Function

When normalized, the signals X/SUM and Y/SUM can be used to measure position. For clarity, we will use the dimensionless units V/V for the normalized signals when describing the measured position transfer function. Because the signals are normalized, position output does not depend on R_1 gain setting, only on G_2.

Figures 4 and 5 illustrate the output response as a function of input position for an ideal Gaussian laser beam input. The nearly linear portion of the output response has a slope of 0.65 radii/V/V. For example, a normalized output of 0.5 V/V would occur for a Gaussian beam displaced 0.5 V/V * 0.65 radii/V/V = 0.32 radii from the center of the quadrant photodiode. If the beam radius in the above example were 1 mm, the normalized output of 0.5 V/V would occur at a displacement of 0.32 mm from the photodiode's center.

If the optical beam under measurement is not Gaussian, the above relationship will not hold. For example, if the beam is elliptical, the transfer function will be different along the major and minor axes. You can calibrate the position transfer function effectively by placing the photoreceiver on a two-axis translation stage and measuring output as a function of position.

Figure 4: Normalized position output transfer function for $G_2=1$ settings assuming Gaussian beam input

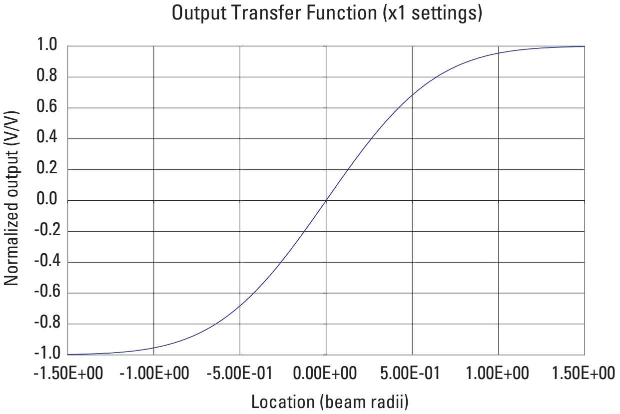
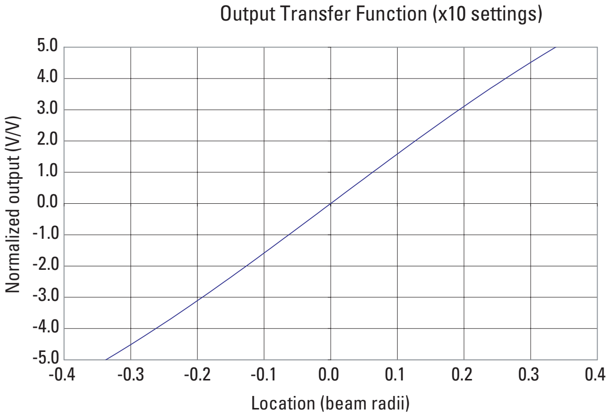


Figure 5: Normalized position output transfer function for $G_2=10$ settings assuming Gaussian beam input



Selecting the Optimal Gain Setting

In order to maximize signal fidelity, you should select the maximum gain setting possible, but not saturate the amplifier. The first and second stage gains can saturate independently, so you must take care to select an optimal value for each.

It is easy to identify if the first stage is saturated. The SUM output will reach its “rail” voltage of 2.5 V. Any time the SUM output exceeds 2 V, it is a good idea to reduce the gain setting by reducing R_1 by one decade.

Saturation of the second stage depends on the position of your optical beam relative to the photodiode center. X and Y can reach a maximum of ±2.5 V or G_2 * SUM, whichever is smaller. Test for saturation at your desired gain setting by creating the maximum expected beam displacement and observing the X and Y outputs. If the signal saturates, reduce the value of G_2 by selecting a different gain switch setting.

Frequency Response and Noise

Measuring Bandwidth

The frequency response and noise characteristics of the quadrant cell photoreceiver depend on the selected gain. Figures 6–10 on the following pages give the typical frequency response and noise behavior for the photoreceivers at each of the 16 possible gain settings. The frequency response of the receiver in Figure 6 is plotted using the expression

$$20*\log[V_{out}(f)/V_{out}(DC)]$$

where $V_{out}(f)$ is the output from the X, Y, or SUM output of the receiver. Newport uses the -3 dB electrical definition for bandwidth.

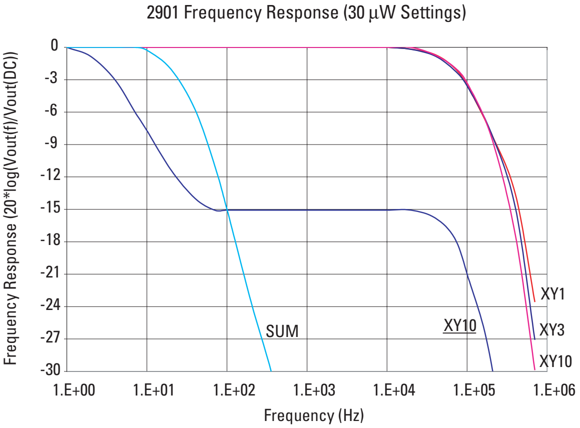


Figure 6: Frequency response for X, Y and SUM outputs with 30-µW saturation setting (R_1 = 200 ohm)

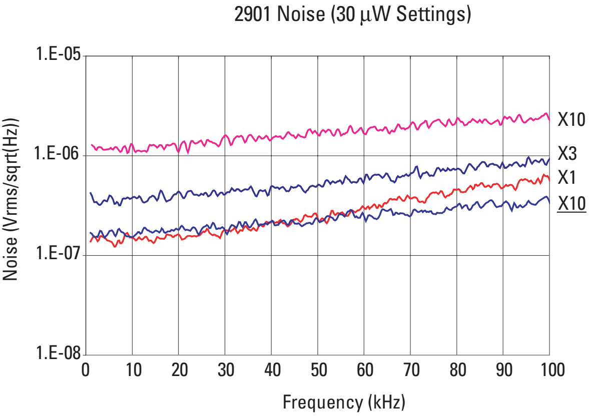


Figure 7: Output voltage noise spectral density for X, Y outputs with 30-µW saturation setting (R_1 = 200 kΩ)

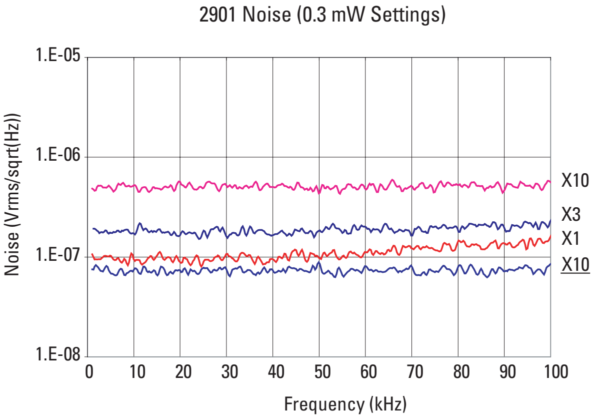


Figure 8: Output voltage noise spectral density for X, Y outputs with 0.3-mW saturation setting (R_1 = 20 kΩ)

Figure 9: Output voltage noise spectral density for X, Y outputs with 3-mW saturation setting (R_1 = 2 kΩ)

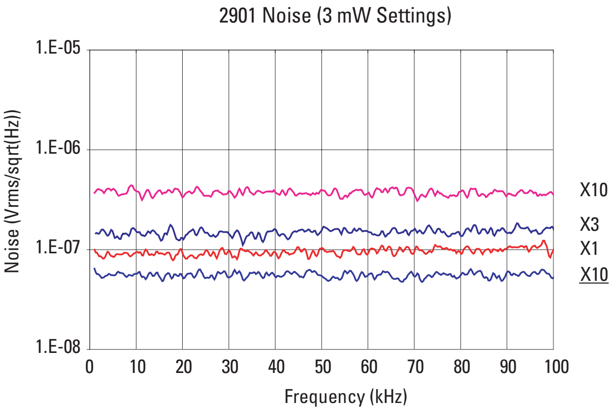
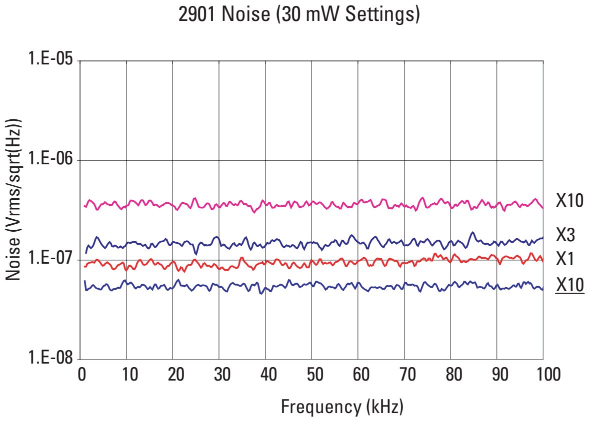


Figure 10: Output voltage noise spectral density for X, Y outputs with 30-mW saturation setting (R_1 = 200 ohm)



Measuring Noise

The photoreceiver noise (V_n) is measured as a noise spectral density [$V_{rms}/\sqrt{Hz}$]. The noise spectral density at each of the gain settings is provided in Figures 7–10 on the previous pages. Depending on your measurement system, you may utilize only a fraction of the receiver's available bandwidth. The noise in your measurement will be the integral of the receiver's noise spectral density over the frequency range (f_{min} to f_{max}) observed by your measurement system:

$$\sqrt{\int_{f_{min}}^{f_{max}} V_n^2 df}$$

For a flat noise spectrum in a DC-coupled measurement system with a 3-dB bandwidth of f_{3dB}, the measured rms noise will be .

$$V_n \cdot \sqrt{f_{3dB}} \cdot \frac{2\pi}{4}$$

Impact of Noise on Position Measurement

Unlike photoreceivers which are often used to measure optical power, the quadrant cell photoreceiver is a position transducer. Therefore, the receiver's output noise is observed as position measurement noise. Although a real measurement system may also have noise due to laser power instability, or undesired mechanical vibrations, the receiver's output noise sets a lower limit on position sensitivity.

Recall that the position transfer function for a Gaussian beam is 0.65 radii/V/V of normalized output. For other beam shapes, the position transfer function will differ. Considering that the electrical noise of the receiver effects both numerator and denominator of the normalized output, you can approximate the expected noise in the normalized output signal as

$$\mathrm{SIGNAL}_{\mathrm{actual}} + \Delta\mathrm{SIGNAL} = \frac{X_{\mathrm{actual}} + V_{n_x}}{\mathrm{SUM}_{\mathrm{actual}} + V_{n_{\mathrm{SUM}}}}$$

$$\approx \frac{X_{\mathrm{actual}}}{\mathrm{SUM}_{\mathrm{actual}}} + \frac{V_{n_x}}{\mathrm{SUM}_{\mathrm{actual}}}$$

The bandwidth of the SUM output is intentionally limited to 30 Hz, which reduces the contribution of V_{n_SUM} to negligible in most cases. Therefore, the position uncertainty is simply equal to the output voltage noise divided by the normalized SUM output, multiplied by the position transfer function.

If you take the worst case, which shows up for the 30-µW settings (200 kΩ R_1) and 10 voltage gain second stage, the Y output noise level peaks at about 2 $\mu V(rms)/\sqrt{Hz}$. All other gain settings have lower noise.

Over the 100 kHz bandwidth of the receiver, this noise integrates to about 0.5 mV(rms). If your voltage converter, such as an oscilloscope has wider bandwidth, you may observe somewhat more voltage noise. If you reduce the second stage gain to 1, the integrated noise in 100 kHz drops to about 0.1 mV(rms).

As an example we can approximate the position measurement noise you might observe in a typical application. If you have about 1 mW of HeNe power, you will use the 3 mW setting (2 kΩ R_1). If you are trying to observe small, high frequency position changes, the 10 setting for G_2 will give you a voltage swing in the X/SUM or Y/SUM calculated output from -1.56 to +1.56 when the beam travels over the range of 0.1*radius to +0.1*radius. The position transfer function is therefore given by X/SUM/1.56 = x/0.1*radius, or x = 0.064*radius*X/SUM. The SUM output will be 1 mW * 0.5 A/W (responsivity at 633 nm) * 2 kΩ = 1 V. The integrated voltage noise in 100 kHz bandwidth on this setting (Figure 9) is 0.1 mV rms. Putting it all together, the observed position noise due to electronics will be 6.4×10^{-6} *radius (rms). If the beam radius is 300 microns, the position noise due to electronics is 0.002 microns (rms).

In practice, laser power fluctuation, air turbulence, table vibrations, and other factors may give you larger noise. You should also take care to acquire the data and normalize X/SUM and Y/SUM or else power fluctuations will map into perceived position changes.

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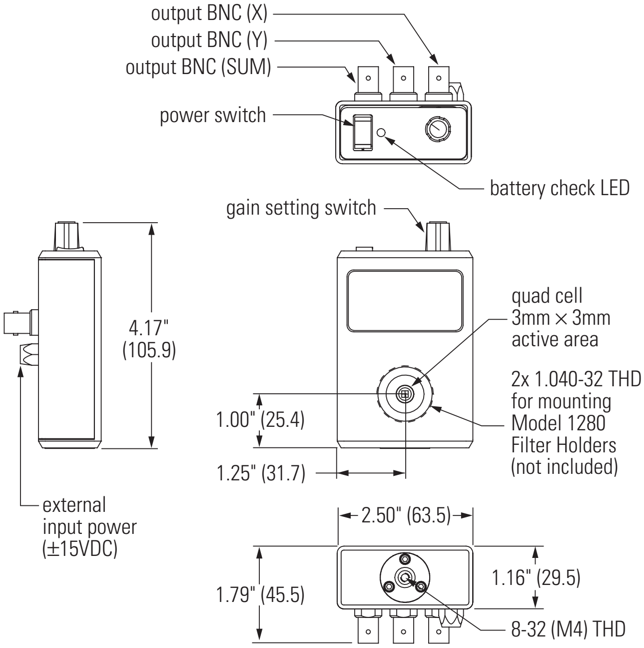
Characteristics

Physical Specifications



Operating Specifications

	Model 2901	**Model 2903**
3-dB Bandwidth (typical)	100 kHz	100 kHz
Conversion Gain	10^2 to 10^6 V/W	$2x10^2$ to $2x10^6$ V/W
Maximum Responsivity	0.5 A/W	1 A/W
Transimpedance Gain	$2x10^2$ to $2x10^6$ V/A	$2x10^2$ to $2x10^6$ V/A
Outputs	X, Y, SUM	X, Y, SUM
Output Impedance	1 kΩ	1 kΩ
cw Saturation Power (per channel)	30 mW	15 mW
Output Voltage Range	-2.5 to +2.5 V	-2.5 to +2.5 V
Photodetector Material	Si	InGaAs
Photodetector Size	3 mm x 3 mm	3 mm dia.
Electrical Output	BNC	BNC
Power Requirements	±15 V or 9-V Battery	±15 V or 9-V Battery

Customer Service

Technical Support

Information and advice about the operation of any Newport product is available from our technical support engineers. For quickest response, ask for "Technical Support" and know the model number and serial number for your product.

Hours: 8:00-5:00 PST, Monday through Friday (excluding holidays)

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Support is also available by email and chat

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In the event that your device malfunctions or becomes damaged, please contact Newport for a return merchant authorization (RMA) number and instructions on shipping the unit back for evaluation and repair.