

## APP NOTE # 1.0

JANUARY 12

# USING POWER LOCK AND EXTERNAL MODULATION WITH THE SUPERK EXTREME

## Introduction

With the External Modulation and Power Lock Options, the output power of the SuperK EXTREME supercontinuum white light lasers can be controlled by an external signal hereby providing amplitude modulation or power stabilization/locking.

The amplitude modulation can be used in applications where the power must be changed rapidly and/or with high amplitude resolution. It may also be used in connection with lock-in detection needing a modulated source signal.

The Power Lock external feedback control is primarily used for stabilization of the output power using an externally signal from e.g. a photo detector or power meter. This function can be used to keep the power through an optical system constant by compensating for drift in external components. It may also be used to maintain a specific narrow part of the spectrum at a stable power level.

## Enabling the feature

To enable feedback or modulation, press Enter on the SuperK EXTREME to enter the system menu. Turn the dial until the display shows *System menu* → *Operating mode* and press Enter.



**Figure 1: Changing operating mode from the front controls**

Turn the dial to shift between Constant Current and Constant Power. With the External Modulation and External Feedback Options, three additional modes are available

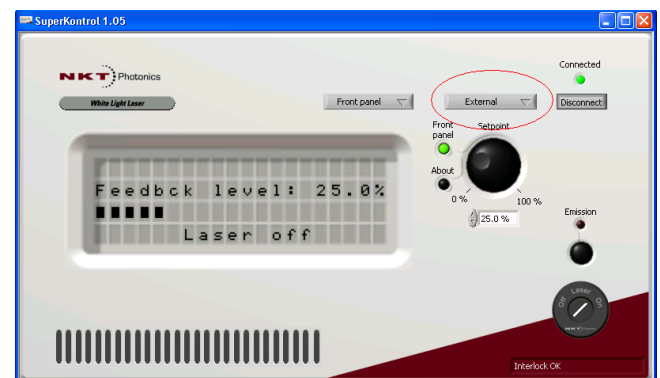
- **Modulated current**
- **Modulated power**
- **External feedback**

Press Enter to choose the desired mode and the Return button to leave the system menu.

In external modulation mode, the maximum current and power level are set by changing "Ext mod curr" and "Ext mod power".

In External Feedback mode, the default Feedback Level is 0%. By turning the dial, the Feedback Level can be set to any value between 0 and 90%. 1.5 seconds after the new level has been set, the system locks to the external feedback signal.

It is also possible to select external modes by using the SuperKontrol software. In this case the required mode is selected by pressing the mode button shown in Figure 2. The software also allows changes to the feedback level, by rotating the dial, or by using the increment/decrement function below the dial.



**Figure 2: Changing operating mode in the SuperKontrol software**

## Input voltage readout

The Input voltage levels can be read out by accessing the *Input Readouts menu*. Select *System menu* → *Input readouts*. Choose *Input readout – Modulation* or *Input readout – Feedback* by turning the dial. The corresponding input voltage is shown in mV.

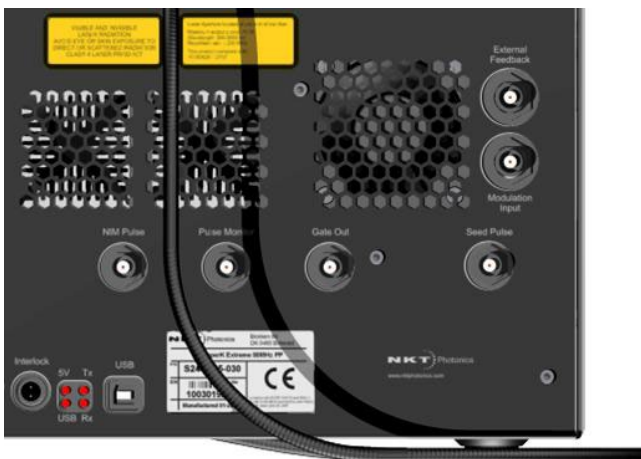
**Note:** In External Feedback Mode it is important that the system gets a valid electrical feedback signal. Otherwise the system may default to maximum output power. Therefore, it is recommended to monitor the Feedback signal via the Input Readouts menu before locking to external feedback.

## Electrical interfaces and specifications

The feedback and modulation interfaces are located on the back panel of the SuperK EXTREME. The electrical interface specification is shown below in Table 1, the interface BNC connectors are shown in Figure 3.

Parameter	Value
Modulation input voltage	0 – 10V
Current mode	
Modulation bandwidth, 3dB	100Hz (typ)
Rise- and fall-time	<5ms (typ)
Power mode	
Modulation bandwidth, 3dB	50Hz (typ)
Rise- and fall-time	<10ms (typ)
Feedback input voltage	0 – 4V
Feedback bandwidth	<200Hz
Feedback sample rate	200Hz

**Table 1: Modulation and Feedback Interface Specifications**



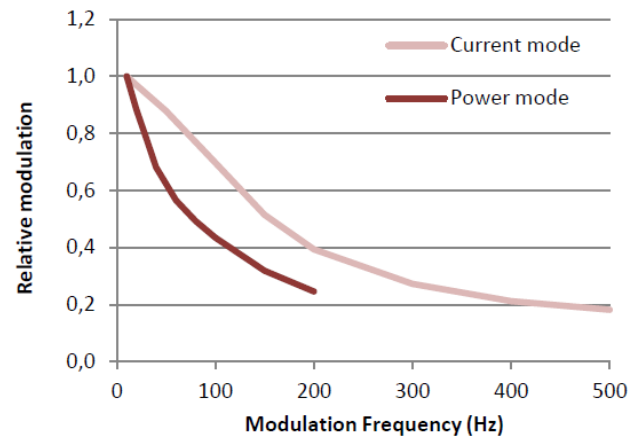
**Figure 3: Back panel of the SuperK EXTREME showing the input for external feedback and modulation**

## External Modulation

In Modulated Current mode, the pump current in the booster is modulated as function of the electrical signal applied to the Modulation Input.

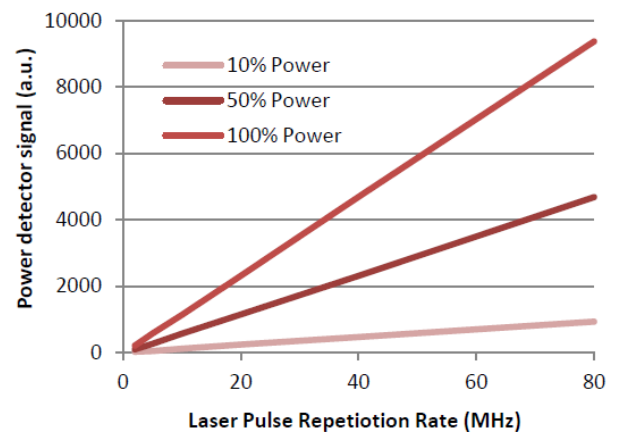
The bandwidth of the Modulation Input is 100 Hz, i.e. with a sinusoidal input, the applied signal should not exceed 100 Hz.

In Modulated Power mode, the output power is modulated as function of the input. The bandwidth is reduced to 50 Hz and for signals other than a sine wave (e.g. square, saw tooth, etc.), the frequency must be limited accordingly.



**Figure 4: Frequency response using external modulation.**

On systems with pulse-picker, the output power is scaled automatically with the laser pulse repetition rate as shown on Figure 5.



**Figure 5: Power scaling with pulse picker in External Modulated Power mode.**

**Note:** The output power is not linearly dependent on the drive current. In current mode, this may cause distortion of the output modulation. Also, the output spectrum depends on the drive current and this may cause distortion of the output modulation in both current and power mode.

## External modulation input

The Modulation Input is a 0 to 10 Volt input. 0 Volt will turn down the output amplitude to minimum level and 10 Volt will turn it up to the level defined by the *Ext mod curr* set point level. If the set point is set to e.g. 50% in Modulated Power mode and the voltage on the Modulation Input is 5 Volt, the output power from the SuperK EXTREME will be 25%. The input impedance is on the order of 10 k $\Omega$ . If no feedback signal is present in the modulated modes, the system defaults to minimum power. If the feedback signal exceeds 10 Volt, the optical output is limited to the set point value.

## Power Lock External Feedback

Systems featuring the Power Lock option can operate in External Feedback mode where it is possible to lock the output power to an external signal, such as the Power Lock Monitor on e.g. SuperK SELECT or SuperK VARIA, or an external signal in the customer's detection system.

## External Feedback Input

The External Feedback input accepts signals up to 4.1 Volt. However, best performance is obtained using a feedback signal between 1V and 3.5V. The input is equipped with an internal 470 k $\Omega$  pull-up resistor, which will turn the output down to minimum level if no signal is applied. The input voltage is regarded as relative to the output power. This means that no calibration of the feedback signal is needed and the feedback will simply lock to the actual voltage on the input when the locking mechanism is activated.

## Feedback Level

The Feedback Level corresponds to the Current Level when operating in Current mode. Before entering the External Feedback mode it is recommended to operate the system in Current mode to determine the Feedback Level to use.

The Feedback level can be set to any value between 0 and 90%.

## External Feedback Function

The output power level of the SuperK EXTREME is adjusted by setting the Feedback Level. **1.5 seconds after the level has been set, the system locks to the external feedback signal.**

The External Feedback stabilization is digital with a sample rate of approximately 200 Hz, which means that the circuit can suppress variations up to approximately 100 Hz.

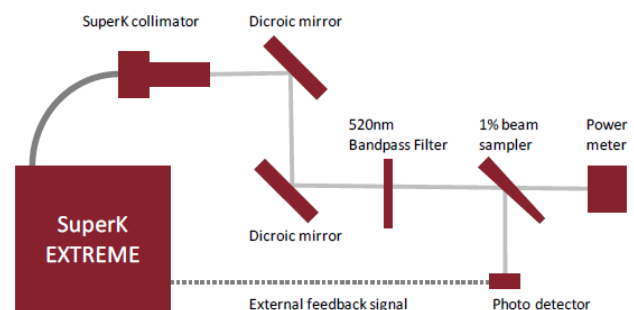
When Emission ON/OFF is turned OFF and then turned ON again, the system will start up at the current level specified by the Feedback Level. External Feedback is disabled by selecting a different Operating Mode.

### Please note

- **The feedback loop will only allow slow changes on the order of a few percent per second (at 100% power)**
- **The sample rate of the feedback loop is approximately 200Hz and the signal applied to the feedback input will be low pass filtered before sampling to reduce aliasing.**
- **The output may become unstable if the time constant of the external power monitor is slower than 200Hz**
- **The feedback signal slope must be positive – i.e. increasing output power yields increasing feedback signal**
- **The signal locking procedure must be repeated if a different power level is required, or if the pulse repetition rate is changed**
- **Stabilizing the output power in one part of the spectrum may result in reduced stability in other parts of the spectrum**

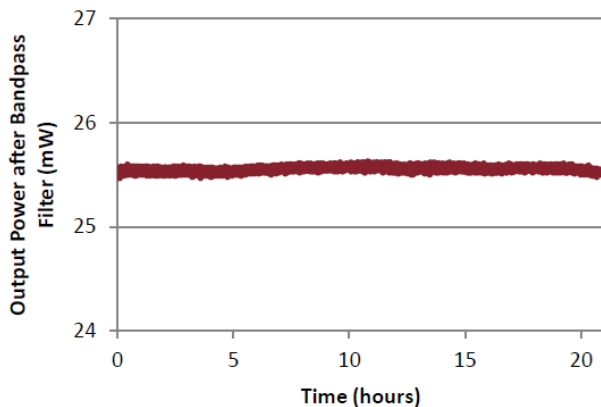
## Performance example

In this example, the output from the SuperK was filtered with a bandpass filter at 520nm.



**Figure 6: Experimental setup for External Feedback operation.**

The external feedback signal was generated by sampling 1% of the filtered and directing this to a large area photo detector. The power after the beam sampler was measured with an Ophir PD300 power meter over a period of 21 hours.



**Figure 7: Performance example using External Feedback mode over 21 hours test time.**

The filtered power is maintained over the entire period with a peak-to-peak variation of  $\sim 0.1\text{mW}$ , corresponding to a relative Variation of 0.4%. The relative standard deviation is 0.15%. These variations include the measurement uncertainty of the power meter.

**Note:** If the feedback signal ratio changes, e.g. due to thermal, polarization or wavelength dependence, this can influence the stability.

## Using Power Lock with the SuperK Accessory range

The external power feedback functionality is also designed to be using in combination with Accessory Modules SuperK SELECT and SuperK VARIA in order to enable single-channel power stabilization. The installation of the power monitors is optional and not mandatory for operation of the SuperK VARIA or the SuperK SELECT.

The power monitors is provided in two different configurations:

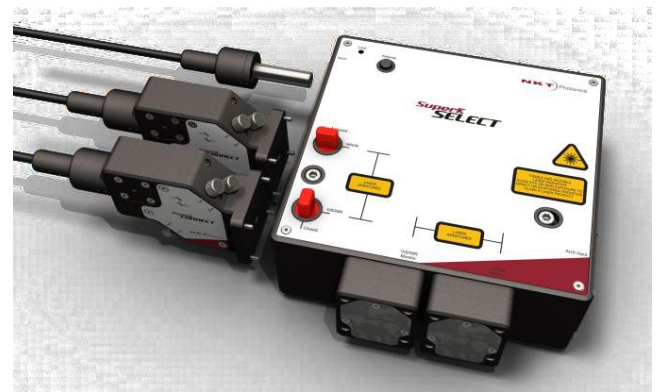
- 1) Visible and near-IR covering 400 to 900 nm.
- 2) IR range covering 1100 to 2000 nm.

The visible power monitor is best suitable for the SuperK VARIA, whereas the Visible/NIR and the IR monitors can be used to cover the Visible/NIR and IR output of the SuperK SELECT, respectively. The power monitor is usually pre-installed and calibrated from factory and does not require any further re-adjustment once installed.

For a general description and how to enable external feedback, please refer to the previous section.

## SuperK SELECT with Power Lock Monitors

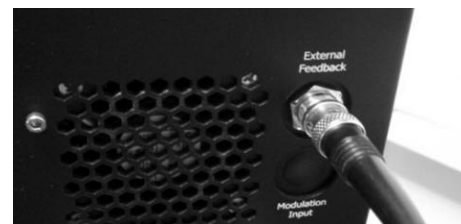
The SuperK SELECT equipped with a Power Lock Monitors can provide a feedback signal to the SuperK EXTREME light source for stabilization of the output power. Below is shown a picture of the SuperK SELECT with a Visible/NIR and an IR monitor installed.



**Figure 8: SuperK SELECT with Power Lock monitors installed**

## External Feedback electrical interfaces

To use the Power Lock external feedback, connect the "External Feedback" BNC port on the back panel of the SuperK EXTREME to the connector labeled "Monitor output" on the SuperK SELECT, see Figure 9 and 10. Please note that the external feedback loop can only lock on to one output channel from the SELECT.



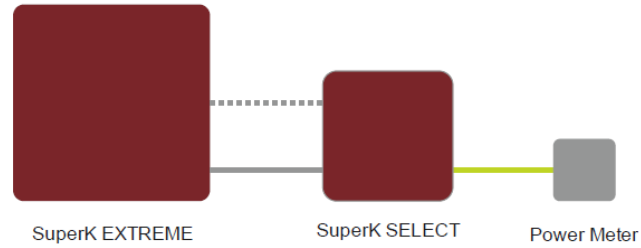
**Figure 9: Electrical interface at the back of the SuperK EXTREME**



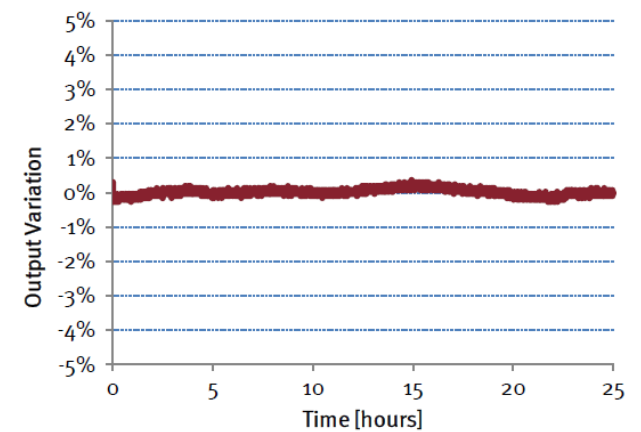
**Figure 10: Electrical interface at the back of the SuperK SELECT**

### Performance example

In this example the output from the SuperK EXTREME was filtered using the SuperK SELECT. In the SuperK SELECT, the external feedback signal is generated by sampling 1% of the filtered signal and directing this to a photo detector. The output of the SELECT was measured with an Ophir PD300 power meter over a period of 25 hours. In this test the SELECT is set to filter 550 nm for output.



**Figure 11: Experimental setup for External Feedback operation.**



**Figure 12: Performance example using External Feedback mode over 25 hours test time.**

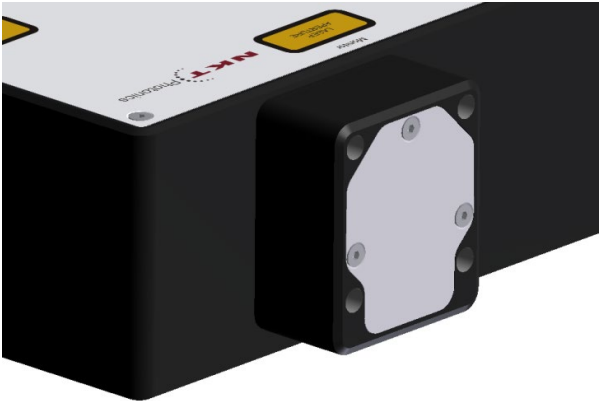
The filtered power is maintained with a relative variation of 0.4%. The corresponding relative standard deviation is 0.1%. These variations include

the measurement uncertainty of the power meter. Results for four different filtering wavelengths are summarized in the table below.

Filter wavelength [nm]	Relative Variation [%]	Standard deviation [%]
460	+/-1	0.38
490	+1/-0.7	0.33
550	+/-0.4	0.1
595	+0.45/-0.25	0.11

### SuperK VARIA with Power Lock module

The SuperK VARIA equipped with a Power Monitor can also provide a feedback signal to the SuperK EXTREME for power stabilization. Below is shown a picture of the VARIA with a Visible/NIR monitor installed. The electrical signal from the monitor is available on the BNC connector on the SuperK VARIA as shown below in Figure 14.



**Figure 13: Power Lock monitor installed on the SuperK VARIA**



**Figure 14: Power monitor electrical signal is available on the BNC connector**

The Monitor output from the VARIA is connected to the External Feedback input on the backside of the SuperK EXTREME. Power Locking to the monitor signal is activated as described in the previous sections.