APPLICATION NOTE

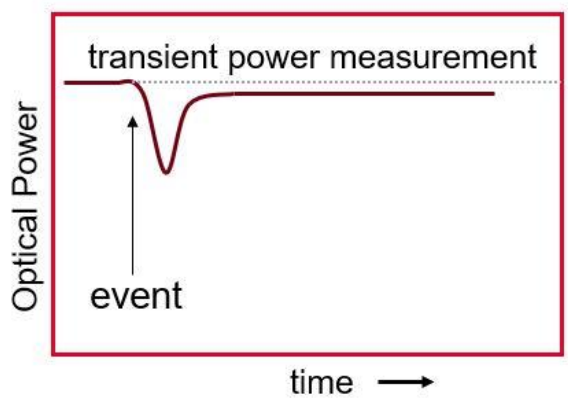
Transient Optical Power Measurements

with the N774-C optical power meters

Introduction

Measuring optical power level changes, to determine fiberoptic switching times or to observe transient fluctuations from fiber movement or network reconfiguration, goes beyond the design of most fiberoptic power meters. These instruments are generally designed for calibrated determination of optical power levels that are constant or change in synchronization with other instruments. The typical sample rates like 10 kHz, data capacity of perhaps 100,000 samples, and the data transfer speed to the controller are often insufficient for general time-dependent measurements. Instead, alternative setups such as a fast optical-to-electrical converter combined with an oscilloscope, have been used and described in standards. These often sacrifice optical power calibration, involve additional integration effort, and are often implemented with an over-dimensioned scope bandwidth.

The N774-C family of optical power meters, successors to the widely used N7744A 4-port and N7745A 8-port optical power meters, offers the performance to make these measurements with a small self-contained programmable instrument that is used together with a controller computer. These power meters accurately log optical power at selectable sample rates and support fast LAN or USB data transfer. Parallel measurement and data transfer provide continuous power monitoring without interruption. Threshold-triggering has also been added to activate the power logging measurement at signal-change events. This application note describes how to make and program these measurements.



Choice of Optical Power Meter

The Keysight N774-C optical power meters have a set of common features that support these time-dependent measurement applications. All have large memory capacity with dual 1-million sample buffers for each power meter port. The buffers can alternate measurement and data uploading to support continuous logging over longer durations than 1M samples. This is also supported by the fast LAN and USB interfaces. The fastest upload rate, about 2M samples (4 bytes each) per second (total for all ports) is achieved with the LAN interface and socket protocol. The instruments also have triggering functionality for starting and synchronizing the data logging, including the new threshold triggering to detect events when the optical signal changes.

Other performance aspects have different emphasis among the instrument models. The fastest sampling can be reached with the 4-port N7744C and 8-port N7745C, as well as the N7742C and for up to +20 dBm the N7743C, which both have 2 and 4-port options and also analog voltage outputs. These all provide averaging times for the samples over the range from 1 µs to 10 s, with corresponding analog bandwidth up to 250 kHz. These models also provide the highest dynamic range for logging power with large changes, important for applications like measuring switching crosstalk.

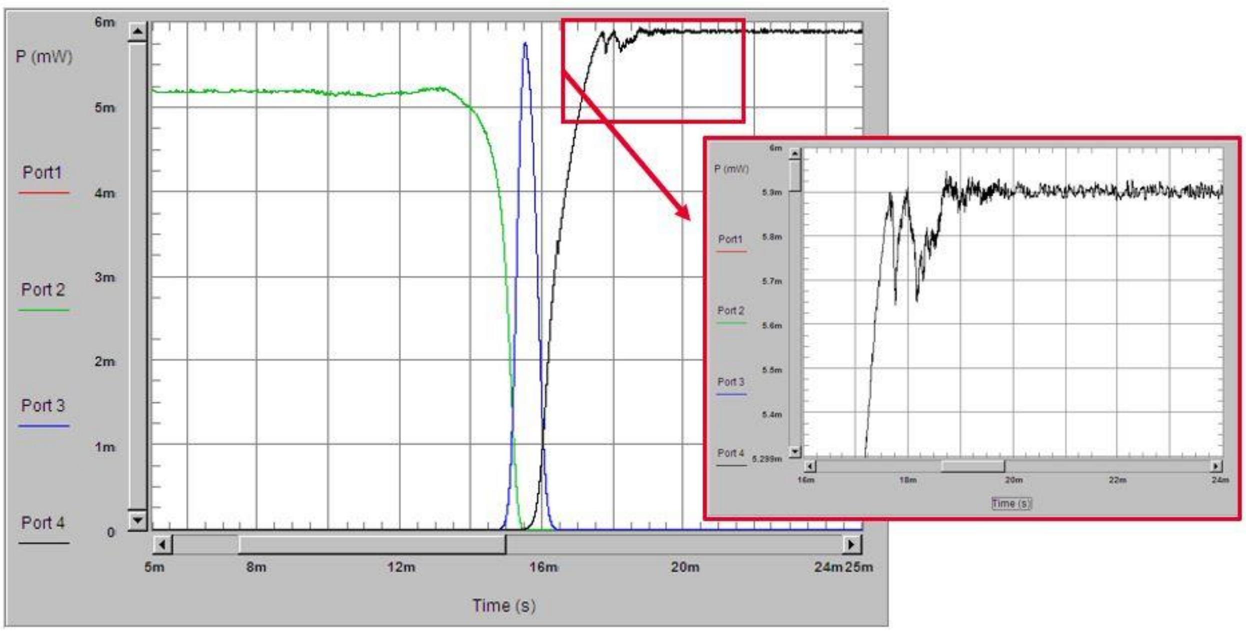


Figure 1. Example of optical power on multiple ports of a 1x4 switch.

Especially valuable for measuring weak signals, the 2-port N7747C and 4-port N7748C provide the highest sensitivity and lowest dark noise level. These have a maximum bandwidth of 5 kHz. The bandwidth is lower for the more sensitive power ranges, as with all other models too. The averaging time can be set as low as 25 µs, but the 100 µs setting is usually the fastest chosen setting, considering the bandwidth. These models also have especially low polarization dependence.

The N7749C is used with remote optical heads. Besides flexible positioning, these heads provide large detector areas, especially useful for measuring open beams, and there are models for high sensitivity, high optical power and different wavelength ranges, depending on the detector semiconductor type. These have minimum averaging times of 100 µs and corresponding bandwidths, depending again on the power range.

Details can be found for the products linked from www.keysight.com/find/oct

Logging Functionality Basics

The measurement of time-dependent signals is realized with the easy-to-use logging function of the optical power meters. The logging function is set up by choosing the number of logging samples, N, and the averaging time of each sample, t. The logging measurement is then started with a programming command or an electrical trigger. The instrument can be configured to make the complete logging measurement of N samples or individual samples when triggered. For logging time-dependence, the measurement will usually be configured for logging all samples without pause over a total time Nt. The multiport power meters, MPPM, can perform this logging simultaneously on optical signals from up to 8 fibers and multiple instruments can also be synchronized with the triggering.

For completeness, note that the instruments also have a stability function that performs similarly, but with a programmable dwell time between samples. This is used for measuring longer term changes in optical power, such as source stability tests. However, this is not discussed here further.

The averaging time for the N7742C, N7743C, N7744C and N7745C can be chosen between 1 µs and 10 s, depending on the model, and up to 1 million samples can be taken. During the logging, a wide dynamic range can be recorded, exceeding 60 dB for averaging times of 100 µs or more, and the power range maximum can be chosen between -30 dBm and +10 dBm (-20 dBm to +20 dBm for the N7743C) in 10 dB steps with frequency response ranging from 10 kHz to 250 kHz as shown in the data sheet.

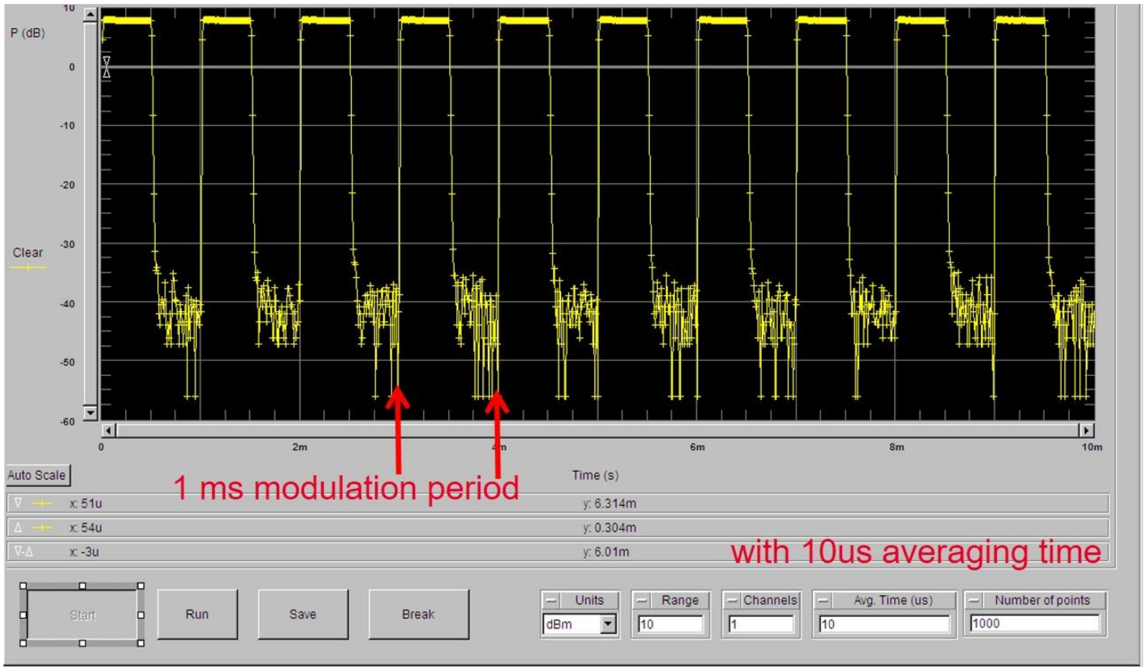


Figure 2. Example measurement of 1 kHz on/off laser modulation, measured with 10 µs resolution.

The N7747C and N7748C have a set of discrete averaging time settings, including: 25, 100, 200 and 500 µs, and 1, 2, 5, 10 ms and so on up to 10 s. The power range can be set between -70 dBm and +10 dBm in 10 dB steps, with frequency response ranging from 300 Hz to 5 kHz.The settings for the N7749C are similar, depending on the details of the attached optical heads.

The MPPM can also be configured to begin a new logging measurement of N samples as soon as the previous measurement finishes. The existing results can be uploaded to the controller computer during the new measurement. This set of functionality provides two methods for making transient measurements, which we label here as triggered logging and continuous logging methods.

Triggered logging is used to measure a fixed number of samples. It starts from a time chosen by software or an electrical signal to synchronize with the event to be measured. This is most useful when the timing of the event to be measured is also controlled, as for setting a switch or shutter, changing an attenuator, or blocking an input signal to an amplifier or ROADM (reconfigurable add/drop multiplexer). The instruments can also be configured to trigger when the input signal changes beyond a chosen threshold for detecting events that occur at unpredictable times. Since 1 million samples can be stored per port, a single logging measurement is usually sufficient. In fact as described later, the data buffers can be used to extend this to 2 million, allowing for example up to 2 s of measurement at 1 Ms/s. Thus all ports can be measured with high temporal resolution over relatively long times without limitation due to the data transfer. The multiple ports of the instrument make it easy to watch, for example, all output ports of a switch during reconfiguration. Measurements like described in the IEC standard 61300-3-21 for switching time and bounce time or transient characterization of optical amplifiers can be, accomplished. Detection of events like disturbed fibers or connections is enabled with the threshold triggering.

Continuous logging is especially useful long-term monitoring and for recording events with unpredictable timing as well as for keeping a very large number of samples. A typical application would be the measurement described in IEC 61300-3-28 for transient loss, where the power from fibers is monitored for change due to mechanical disturbances. This method can be programmed using the same logging function mentioned above, with the extension that the complete logging sequence is repeated multiple times. This is made possible with full-size data buffers that allow logging to continue while the previous data is uploaded. Logging can continue indefinitely as long as the time required to upload the mN samples from m ports does not exceed the time Nt to make the measurement. The current limit is about 2M samples per second. The streaming data to the PC can be monitored for transient events to trigger saving and analyzing data from before and after the event, as well as used for strip-chart style graphics or other post-processing.

Note that the instruments also provide a web-browser GUI that displays power in strip-chart display. But the sampling rate is limited by the 10 Hz rate of reading individual values and the amount of displayed data is also limited. But for simple manual measurements of signal levels, this can be very convenient. Please see the User Guide or GUI itself for details.

Figure 3. Strip-chart recording of optical power with N774-C web browser GUI.

Triggered Logging

Triggered logging applications are easily implemented using the built-in logging functionality of the power meters. The programming descriptions below are based on the SCPI commands for the instruments. Please refer to the programming guide for details of the programming commands. The basic programming structure is described below.

First, it can be a good idea to initialize the instrument like in Step A0.

Label	Command	Example	Comment
A0	:SYSTem:PRESet	SYST:PRES;*OPC?	Preset for known start conditions; use OPC? to wait for completion

Alternately, to avoid clearing all settings, but to be sure the previous logging is stopped, the command A1 should be sent in a loop to **all ports *n***.

Label	Command	Example	Comment
A1	:SENSe[n]:FUNCtion:STATe	SENS1:FUNC:STAT LOGG,STOP	disables any previous logging

The logging function on an instrument should be stopped before new settings are sent to any ports. Only after all ports are configured should the logging again be started on any port. This is due to common timing among the groups of ports and logging with the same parameters and timing is expected for each active port. Thus, the program begins with a loop through each port n, setting the measurement parameters in Steps B before the logging function is started.

Label	Command	Example	Comment
B1	:SENSe[*n*]:POWer:GAIN:AUTO	SENS1:POW:GAIN:AUTO 0	optional, see text below
B2	:SENSe[*n*]:POWer:RANGe:AUTO	SENS1:POW:RANG:AUTO 0	fixed range needed for logging
B3	:SENSe[*n*]:POWer:RANGe	SENS1:POW:RANG -10DBM	
B4	:SENSe[*n*]:POWer:UNIT	SENS1:POW:UNIT 1	for units Watts
B5	:SENSe[*n*]:POWer:WAVelength	:SENS1:POW:WAV 1550nm	for absolute power accuracy, set wavelength
B6	:SENSe[*n*]:FUNCtion:PARameter: LOGGing	SENS1:FUNC:PAR:LOGG 10000,100 µs	sample number, averaging time
B7	:TRIGger[*n*]:INPut	TRIG1:INP CME Or TRIG1:INP THR,1000,-13DBM,-7DBM	see text below

Notes

B1: The Auto Gain functionality of the N7744C, N7745C, N7742C, N7743C and N7744A and N7745A is used to increase the sensitivity within a fixed power range by adjusting the gain in real time. With some modulated signals, especially if the averaging time is longer than the modulation period, this produces irregular results and should be disabled. This setting must precede setting of the averaging time or logging parameters. The instrument itself will disable autogain for averaging time less than 10 µs.

B2: The power range will be constant during the logging and can be set in advance for each port. If autoranging is active before the logging is started, then logging will continue in the current power range. The range should be chosen so that the maximum expected power does not produce an overrange. Overrange usually occurs about 3 dB higher than the nominal range setting.

B4: The ports can be configured to return results in units of Watts, dBm or relative to a reference value in dB. This is an enhancement from the 816x-series power meters, which always return results from logging in W.

B5: By setting the wavelength correctly to that of the signal, the power meter uses the appropriate responsivity calibration. This calibrates the absolute power values but does not impact relative power changes.

B6: Then the logging parameters are set up with the desired number of samples and the averaging time. These should match for all active ports.

B7: The reaction of the instrument to an input trigger can be configured for the application. If configured IGN to ignore, then the logging will begin as soon as the logging start command is given but may be interrupted if logging is then started on other ports.

If configured CME for complete measurement, the logging function can be started for each port and then the instrument waits for a software or electrical trigger before beginning the measurement. This is convenient for coordination with external events.

The instrument can also be configured SME for a single measurement on input trigger, in which case each trigger results in a single sample on each port. In some cases, this could be used to synchronize sampling of the power meter with output triggers from another instrument.

Threshold triggering can be configured THR, followed by 3 parameters that determine:

- the number of samples from before the trigger to keep the sum of this value and the samples after the trigger, configured with B6, must be less than 1M (2^{20}).
- the lower limit of input power below which the logging is triggered or NAN for no lower limit
- the upper limit of input power above which the logging is triggered or NAN for no upper limit

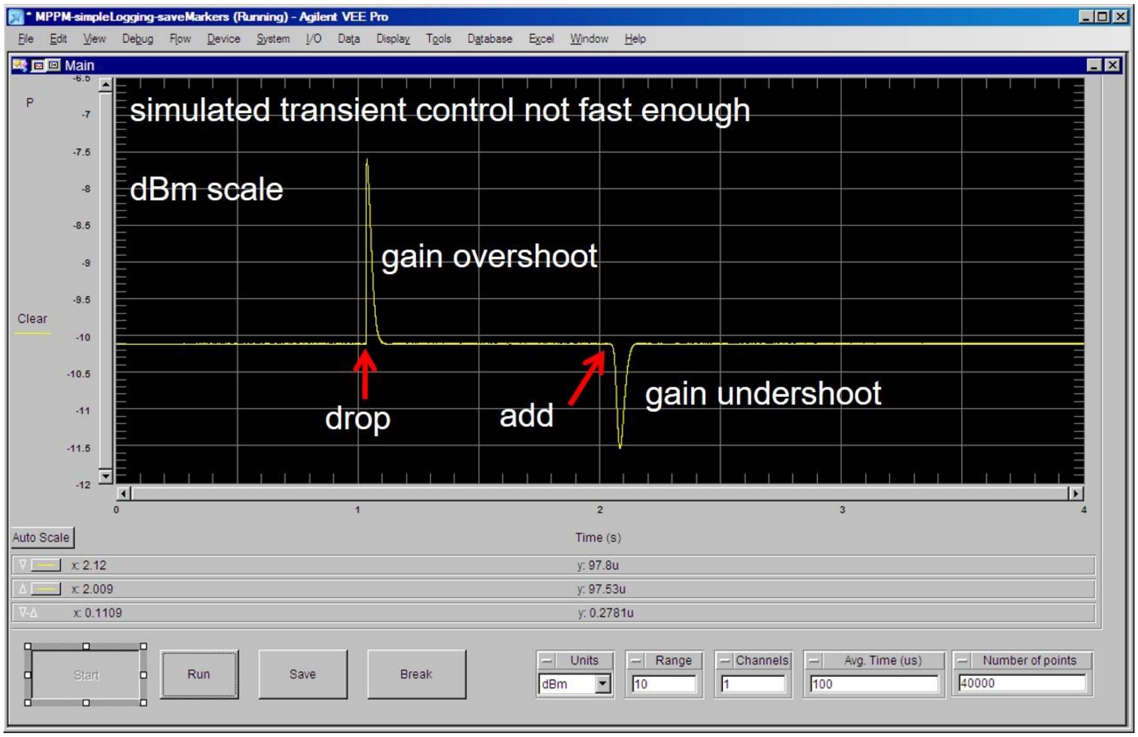


Figure 4. Example of channel add/drop transients from an EDFA.

Then the logging function can be started **at each port**, to wait for the trigger. In the case of multiple ports and IGN triggering, the final port's start command effectively also restarts all previously started ports.

Label	Command	Example	Comment
C1	:SENSe[*n*]:FUNCtion:STATe	SENS1:FUNC:STAT LOGG,STAR	enable logging at all ports

In some cases, a short pause may still be needed before the trigger if the range settings for the ports were changed, especially with the older N7744A and N7745A, which needed 200 ms per port for range setting. If this pause needs to be minimized, the status of the function can be polled until it returns LOGGING_STABILITY, PROGRESS for all ports.

If the triggering has been set to CME, then the logging can be triggered with a software command as in Step D1, or an electrical input trigger. This can be coordinated with the activation of the device or event to be tested.

Label	Command	Example	Comment
D1	TRIGger	TRIG 1	generates an input trigger

This step D1 is not needed if THR triggering is configured. In that case the logging waits for a change in the input signal, once the logging is started.

The logging will be completed after the elapsed time from the trigger Nt, and the status can be queried to confirm that it is complete. It should normally be sufficient to check this for a single port like Step E. After the first comma in the string will be either “PROGRESS” or “COMPLETE”. The index query can also be used, like in the next programming example. A short pause between poll queries, like 50 ms, may be advisable to reduce unnecessary traffic.

Label	Command	Example	Comment
E1	SENSe[*n*]:FUNCtion:STATe?	SENS1:FUNC:STAT?	poll until LOGGING_STABILITY,COMPLETE

When completed, the logging results are read out for each port.

Label	Command	Example	Comment
F1	:SENSe[*n*]:FUNCtion:RESult?	SENS1:FUNC:RES?	data is returned as binary block

The resulting data are an array of 32-bit optical power values from each power meter. The data are transmitted in binary block format, as described in the Programming Guide. Expressing this binary data as real arrays requires attention to the byte ordering. The first few bytes represent ASCII characters. The first is the symbol ‘#’, followed by a digit that gives the remaining number of bytes to interpret as characters. These give a number that tells how many bytes of data follow. For example, ‘#3808’... indicates 808 bytes of data are contained, corresponding to 202 32-bit power values. Each value is transmitted least significant byte first (LSBfirst, little-endian, ‘Intel byte order’).

In some cases, it may be most convenient to handle reading and parsing of binary blocks at the lower VISA level. That is supported by the VISA COM I/O with its IFormattedIO488 interface, setting the property InstrumentBigEndian to ‘false’ and using the READIEEEBlock method. For the power meters, the parameter ‘type’ is set to BinaryType_4.

Continuous Logging

Programming for continuous logging only requires a few changes to the routine described above. An additional Loop parameter is used to enable repetitions of the logging measurement. For each repetition as the logging finishes, the results are kept in the buffer and a new loop is started. Default behavior without repetition, as for the above triggered logging, is set with the Loop value 1. A positive integer value, n, results in n repetitions. For continuously logging over an indefinite period, the value is set to 0. The looping continues until stopped by the program. This is supported by the MME input trigger mode, multi-measurement triggering, where the command to start logging causes the instrument to wait for an input trigger, but then successive loops proceed without additional triggers. The CME mode requires a separate trigger for each loop.

In a special case, the Loop value can be set to make 2 logging measurements for double the number of samples. After the measurements, the results can be read out from the buffers. This means that the sampling rate is not limited to the data transfer rate. This double logging thus provides an extension of the triggered logging method for more points. The double logging therefore provides the SCPI commands for reading the buffered results are described in the programming guide.

:SENSe[n][:CHANnel[m]]:FUNCtion:RESult:BUFA?

:SENSe[n][:CHANnel[m]]:FUNCtion:RESult:BUFB?

The modifications to the program steps for triggered logging to enable continuous logging are described below. Step B for configuring all ports n is modified with the commands B7a and B8a.

Label	Command	Example	Comment
B1	:SENSe[*n*]:POWer:GAIN:AUTO	SENS1:POW:GAIN:AUTO 0	optional, see text below
B2	:SENSe[*n*]:POWer:RANGe:AUTO	SENS1:POW:RANG:AUTO 0	fixed range needed for logging
B3	:SENSe[*n*]:POWer:RANGe	SENS1:POW:RANG -10DBM	
B4	:SENSe[*n*]:POWer:UNIT	SENS1:POW:UNIT 1	fastest upload with units Watts
B5	:SENSe[*n*]:POWer:WAVelength	:SENS1:POW:WAV 1550nm	for absolute power accuracy, set wavelength
B6	:SENSe[n]:FUNCtion:PARameter:LOGGing	SENS1:FUNC:PAR:LOGG 10000,100us	sample number, averaging time
B7a	:TRIGger[*n*]:INPut	TRIG1:INP MME	MME for repeating
B8a	:SENSe[*n*]:FUNCtion:LOOP	SENS1:FUNC:LOOP 0	0 for repeating

Notes

B6: The time for each logging loop is Nt. This determines the update rate for any data graphing or processing on the PC. The values for N, t, and the number of ports should be chosen so that the data can be uploaded before the next loop is completed. For a given averaging time, both the measurement time and actual data upload time increase with the number of samples, but there is additional overhead time for each individual upload. A logging time of 1 s is often a good choice.

B7: The MME input triggering mode is used so that after the first trigger, each loop starts as soon as the previous one finishes.

B8: The Loop setting 0 configures the instrument for an unlimited number of logging repetitions. This should be included in the configuration for each point with the N774-C instruments. (In the N7744A and N7745A, this was a global setting that configured all ports with one command.) As soon as the N samples have been logged, another measurement loop begins, and the data can be uploaded.

Since with Loop value 0 the logging is not complete after a loop, a different query is used to determine when a set of data is ready for upload. This is an index that is incremented after each loop is finished. This index has value 0 until the first results are available, indicated with value 1, and is subsequently again incremented with each additional loop.

Label	Command	Example	Comment
E1a	:SENSe[*n*]:FUNCtion:RESult:INDex?	SENS1:FUNC:RES:IND?	poll until the response increments from previous value

The data are uploaded in the same way as with triggered logging, with the command of Step F, except for the case mentioned above where only two loops are made and the commands to read the two buffers are used when both are finished. The values for N, t, and the number of ports should be chosen so that this can be completed before the next loop is completed.

Steps E and F are repeated for each loop. The program can graph or analyze each segment of data from a loop as it arrives. In a case where the upload time is similar to the measurement time, Nt, the controller PC is almost continuously uploading data. This does not require high CPU usage, so it is valuable to structure the program for multiple threads to allow parallel data processing.

Besides graphing, processing can be used to detect events that cause the power to deviate more than a chosen threshold value. Sufficient data around this event can then be stored and reported. Events can be analyzed for magnitude and duration, overshoot, undershoot and resulting power offset, or rise and fall time, as appropriate. Long series of data without events can be reduced in size by averaging to record long-term stability. Alternately, this monitoring for events is supported by the threshold triggering method described above as well, if the data between events is not needed.

When the Loops value is set to 0 and the repetitions should be stopped, then the logging status should be stopped at each port n.

Label	Command	Example	Comment
G1	:SENSe[*n*]:FUNCtion:STATe	SENS1:FUNC:STAT LOGG,STOP	disables logging function

Figure 5. Transient optical power measurement of a fiber disturbance exhibiting bending loss.

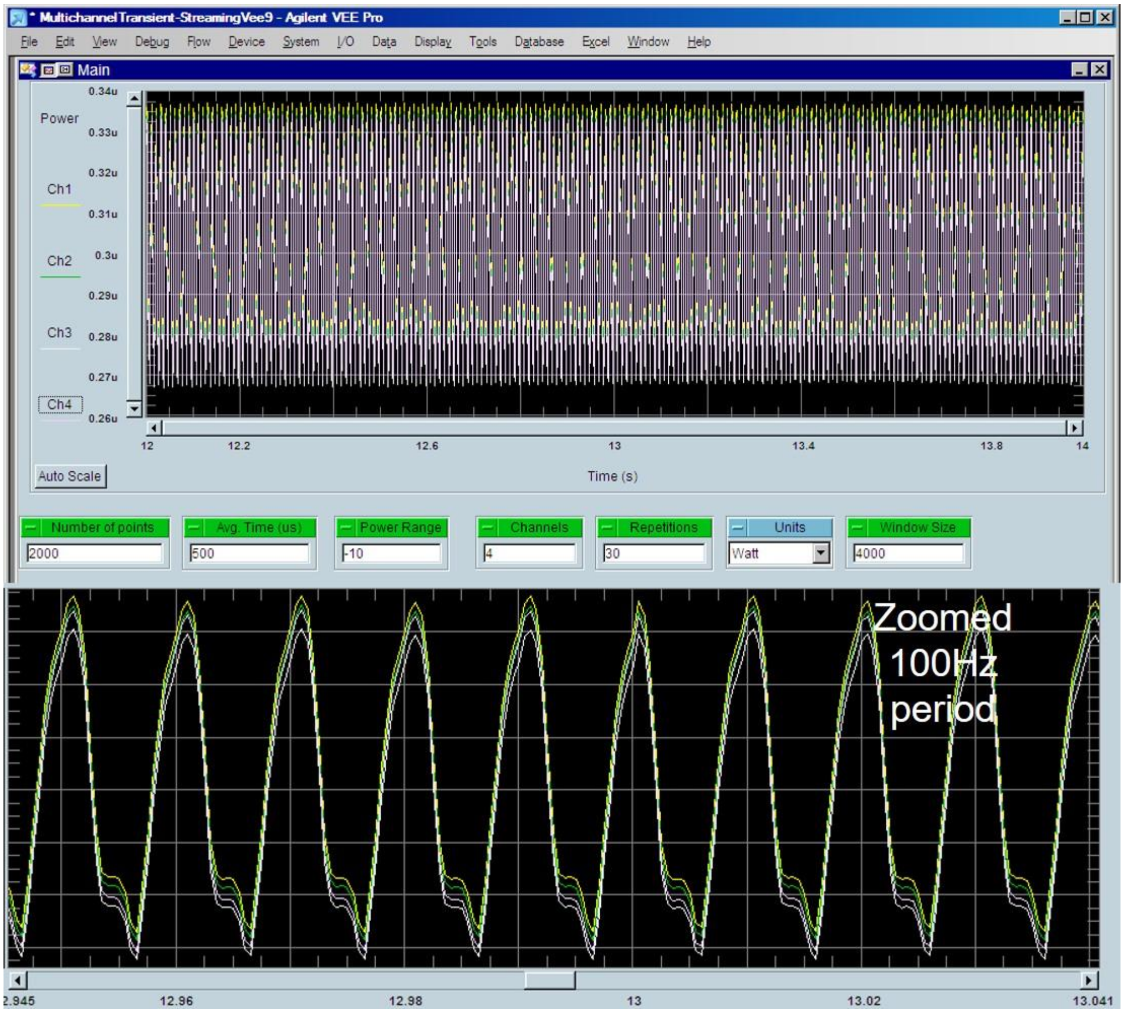


Figure 6. Example for continuous logging of optical power, uploading 2000 samples/second from each of 4 ports. The signal is the ambient fluorescent lighting with 100 Hz flicker.

For further detail to fiberoptic measurement instruments, please refer to www.keysight.com/find/oct

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