Flash Capture Application Note

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1. Introduction

Many of the International Light Technologies (ILT) radiometers feature the ability to measure flashed light sources. These flashed light sources can be pulsed Xenon sources, flashed LED's including smart phone camera flashes, rotating reflector beacons and more. In many cases, one is only interested in measuring the total energy in a sequence of flashes. This total energy is referred to as the integral, or the *dose*, or sometimes the *fluence*. Many of the ILT products offer simple Start Measurement, Stop Measurement functionality to measure this energy. In other scenarios, experimenters might be interested in the frequency of the flashes, the count of the flashes, or the consistency of the flashes in time, relative amplitude, and energy. This application note will explain the many measurement techniques and outcomes available across the ILT product offering, including any limitations involved in such measurements.

2. The Analog Front End (AFE)

Because the flash of light only lasts a brief amount of time, the radiometer circuitry uses a special analog front-end (AFE) to, effectively, slow down the flash pulse such that its total energy can be measured. This analog manipulation sometimes creates a disparity between the real, physical flash profile (height and shape) and that of the measured pulse profile within the meter. This is especially true for high speed "discharge" flashes with extremely fast rise and fall times.

Figure 1 depicts a representative comparison of the physical irradiance, over time, compared to the curve presented by the analog front end. It is important to note that the curves are both normalized to their 100% value. The physical curve, in this example and particularly for discharge sources, has a faster rise time than the AFE curve. The rise time is defined as the time it takes for the level to increase from 10% to 90% of its maximum. The AFE curve rise time is limited by its time-constant, with the AFE rise time being slower than the irradiance spike produced by a discharge source, but usually as fast or faster than that produced by a typical LED "flash". It is also interesting that the AFE curve has an asymmetrical rise (faster) and fall (slower) time. This is due to the changes in the circuit when a flash is present (high current flowing through the circuit), and when the flash has fully discharged (little or no current flowing in the AFE).

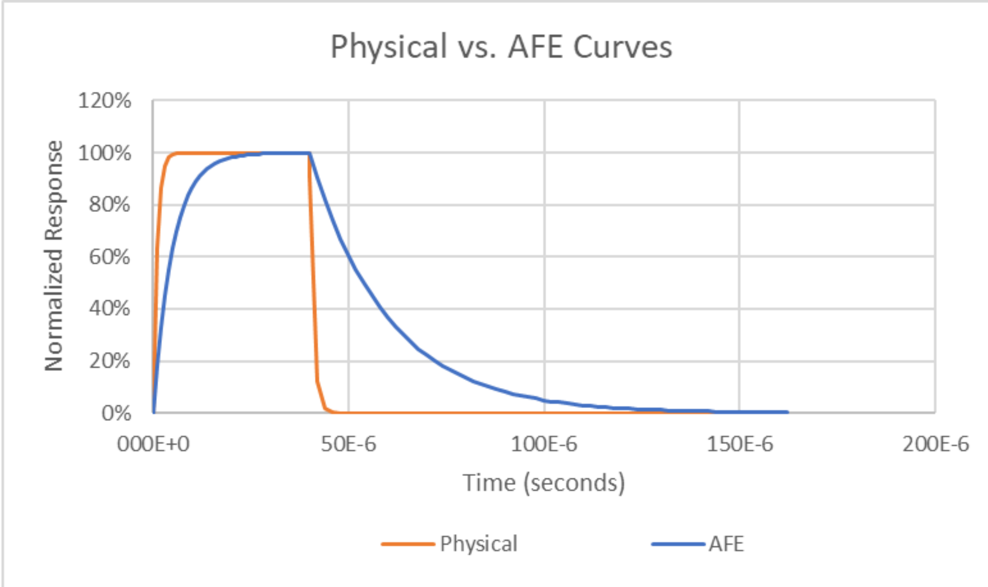

Figure 1. Physical vs. Analog Front End (AFE) Response. NOTE: Both curves are normalized to their 100% value.

Figure 2 depicts "reference" amplitude, demonstrating the disparity between what the meter is measuring at the AFE, and what is happening in the physical world. In this example, an ideal 100µS square flash is graphed along with the AFE's response to the flash. The AFE is charged while the flash is present, and then begins to discharge, at a much slower rate as discussed above, until the AFE signal returns to zero. In this case, because the physical flash energy rises much faster than the AFE, the AFE will report a lesser peak value, what we refer to as the *relative* peak. This peak will then continue to discharge for a considerable time after the physical flash is gone. It is also important to note that, in the end, the area under the AFE *absolute* curve (sometimes referred to as the integral, dose, or fluence) is approximately equivalent to the area under the physical curve. If the shape of the physical curve is known or can be approximated, the actual peak value can be derived. If the physical curve is rectangular, for example, the physical peak can be approximated as follows:

$$Physical\ Peak = \frac{Integral\ of\ AFE}{Time\ of\ Physical\ Pulse}$$

In the case of the example below, the integral of the [normalized to 1.0] AFE curve is 1.11e-3. If the physical curve is known to be a 100µS square wave, its physical peak can be derived as:

$$Physical\ Peak = \frac{1.11e-3}{100e-6} = 11.1\ [Irradiance\ Units]$$

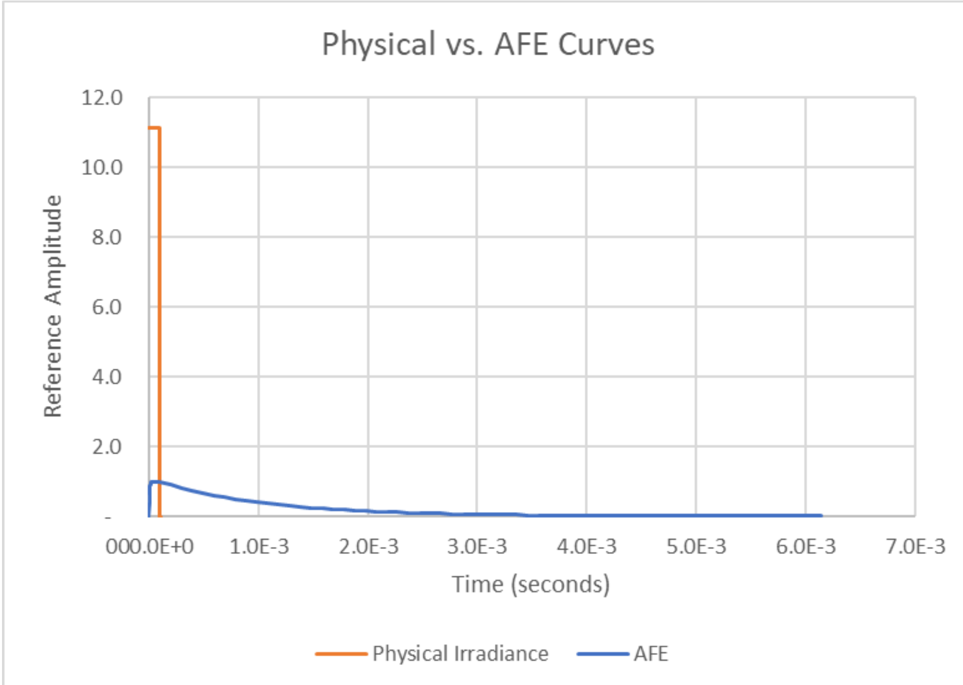

Figure 2. Physical vs AFE response.

Figure 3 shows a close-up of the first 1mS of the AFE curve, depicting the start of decay after the physical curve has returned to zero. Figure 4 expands the Y-axis to better illustrate the AFE curve. This curve is representative of the results when capturing flash discharge profiles with the ILT meters when measuring with their lowest electrical gain, typically referred to as the "1mA" (one milliamp) or "RF1" stage. This "RF1" stage allows capture of the highest light levels and is used to capture higher energy flashes. For lower power pulses, additional gain will be necessary ("RF2" or "3uA" gain stage).

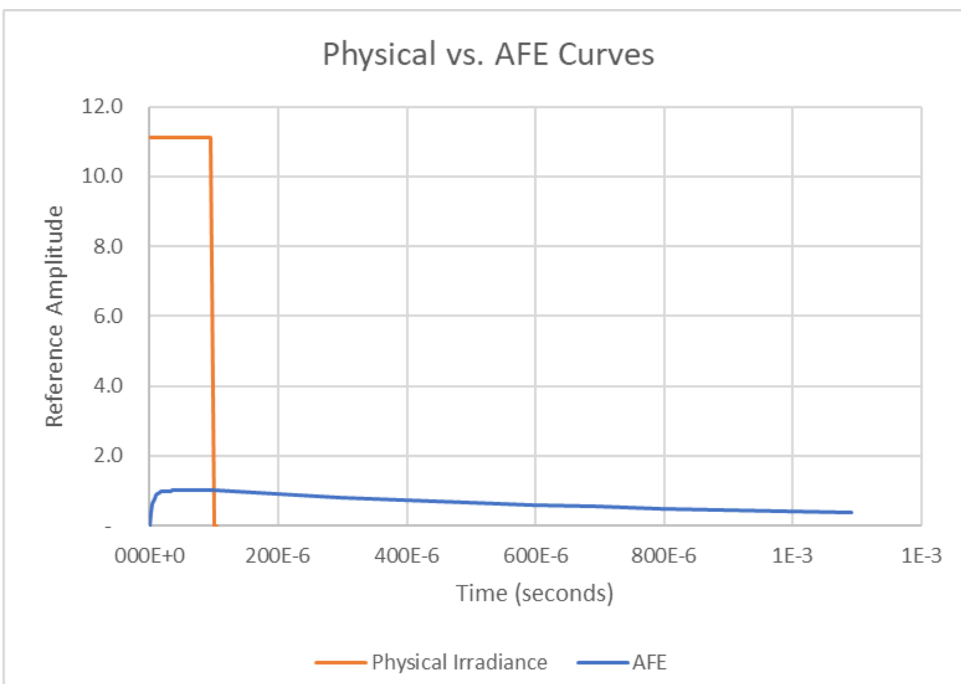

Figure 3. Zoomed time axis of physical and AFE curves.

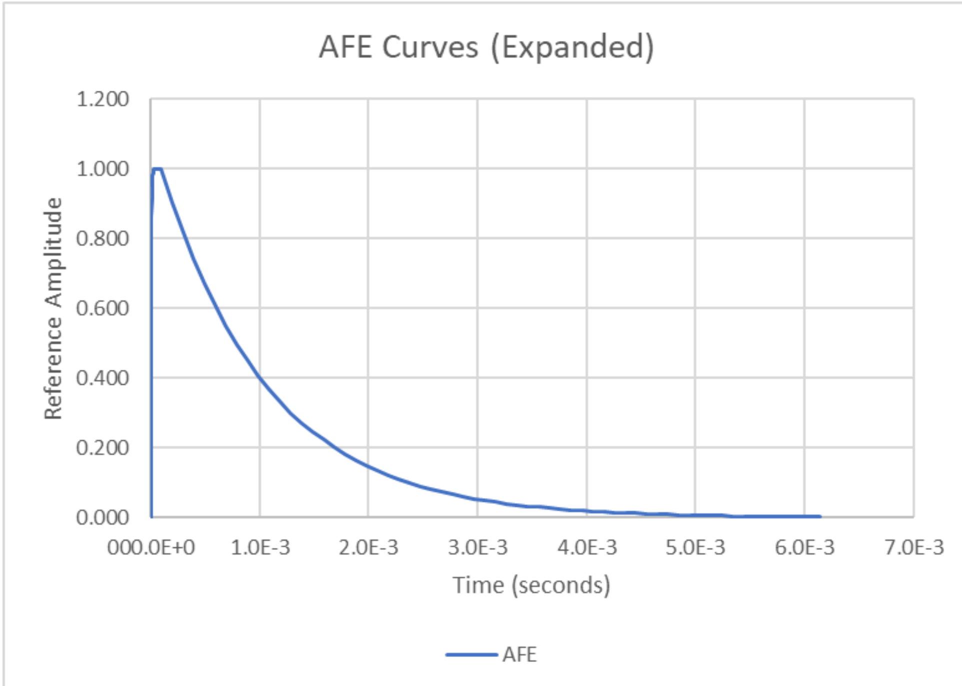

Figure 4. Zoomed Y-Axis of AFE curve

2.1. The Time Constant, T and Flash Measurement Frequency *f*

Figure 4 depicts a discharge time for the AFE of approximately 4ms. This is driven by the *time-constant, T,* of the circuit and defines how high a frequency of pulses can be accurately measured by the device. Based on its exponential decay, the AFE will be reduced by approximately 98% after a time of *4T*, or about 4ms in Figure 4. Because the circuit needs to be nearly fully decayed before the next pulse can be accurately measured, the next pulse cannot start within the *4T* time period. If the pulses are arriving at a regular rate, the maximum pulse frequency is calculated as:

$$f = \frac{1}{4T}$$

When *4T* is equal to 4ms as depicted in Figure 4, the frequency is calculated as follows:

$$f = \frac{1}{4ms} = 250Hz$$

When measuring flashed sources, particularly with trends toward higher flash frequencies that achieve higher dosage in less time, it is important to understand the light meter's frequency capabilities.

2.2. Frequency Capability Across ILT Meters and Modes

Table 1 below shows the frequency capability for the ILT radiometers that are commonly used for flash measurement applications. Note that other ILT models accommodate flash measurements, and some OEM-specific models support custom circuitry and frequency capabilities. When in doubt contact ILT technical support to understand the frequency capabilities of your meter.

Fixed Gain Range Setting	ILT2500	ILT5000
1mA Gain Range • Includes Flash App's "HIGH Light" mode.	250 Hz	250 Hz
3uA Gain Range • Include Flash App's "LOW Light" mode.	25 Hz	17 Hz
300nA Gain Range	3 Hz	2 Hz

Table 1. Flash Frequency Capabilities of the ILT2500 and ILT5000

3. Meter Modes

The ILT line-up of radiometers include a variety of settings to accommodate a wide range of light measurement applications. When measuring flashing sources, it is important to configure the meter settings appropriately. Figure 5 shows the most common settings for measuring flashed light sources. These settings are typically available within the Settings screen but can sometimes be found in other meter or desktop application screens. The settings are also all available via the CLI application and text-based API.

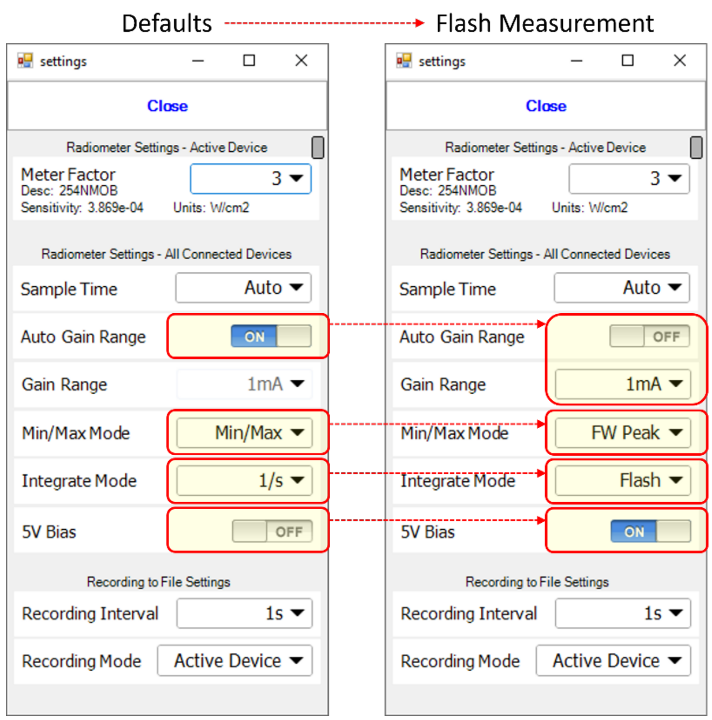

Figure 5. Meter Settings for Flash Measurements.

The changes to these settings are described below.

3.1. Auto Gain Range = OFF

Description	This prevents the meter from automatically switching internal gain stages and, as a result, requires the user to manually select the appropriate gain range.
Advantages	This setting allows for the fast and continuous sampling required to catch a fast-rising flash edge.
Drawbacks	As opposed to the meter automatically scaling over [up to] 10 decades of dynamic range, the user must narrow in one range, typically covering 3 to 4 decades of dynamic range. As a result, some experimenting may be necessary to select the best gain range.

3.2. Min/Max Mode = FW Peak

Description	"Firmware Peak". Changes the search for a maximum (Peak) light level from the sample time, which includes averaging, to a singular sampled value that is acquired at the speed of firmware.
Advantages	When monitoring a flashed source, the peak is only present for a short period of time. Tracking the peak at the firmware level improves the ability to better capture the *relative* peak as seen by the AFE described above.
Drawbacks	This setting does not allow detection of both the minimum and maximum signal. There are no drawbacks when measuring the peak signal.

3.3. Integration Mode = Flash

Description	Like the “FW Peak” mode above, this increases the rate of light level sampling to better ensure that the brief peaks of flashing light are captured and included in the integration of the signal.
Advantages	When monitoring a flashed source, the integration is heavily influenced by how well the peak is detected in real time. The “Flash” integration mode improves the ability to capture the *relative* peak as seen by the AFE described above.
Drawbacks	Depending on the meter model and software version, this mode either provides slower display of intermediate integral values (on the order of every 5 seconds) or only display of the final integral value.

3.4. 5V Bias = ON

Description	This setting applies to solid state photodiodes and creates an anode that is at a lower potential than the cathode. This reduces the diode junction capacitance and allows the light detection circuit (AFE) to respond faster to increases in light.
Advantages	When monitoring a flashed source, the integration is heavily influenced by how well the peak is detected in real time. The lower junction capacitance allows the AFE to rise faster, capturing more of the immediate front edge of the pulse.
Drawbacks	Theoretically biasing the photodiode in this manner can increase dark current, but this is rarely a concern when measuring flashed sources.

4. Flash Integration and Capture Examples

The examples provided below are selected based on some of the more common use-cases. They use various applications, applets and meter modes. Please refer to the respective user guides for more detailed information on the tools themselves.

4.1. Simple Flash Integration with the ILT2500 Meter Tall Applet

Perhaps the most basic form of flashed light measurement is to capture the integral (sometimes referred to as the dose or fluence) of a flashed light source. In this example the ILT2500 is capturing and integrating 26 pulses from a Xenon light source that is pulsing at 1 Hz. The embedded Meter Tall applet is being used and the settings are configured as illustrated in Figure 6, which include the settings described in Section 3 above, along with disabling the Use Scientific Notation setting. This last setting will allow integral units to auto-scale among nano-units (10^{-9}), micro-units (10^{-6}), milli-units (10^{-3}), etc. If the meter will be used predominately for flash measurement, these settings can be saved by scrolling down and selecting "Save Settings". This will persist these settings across power cycles.

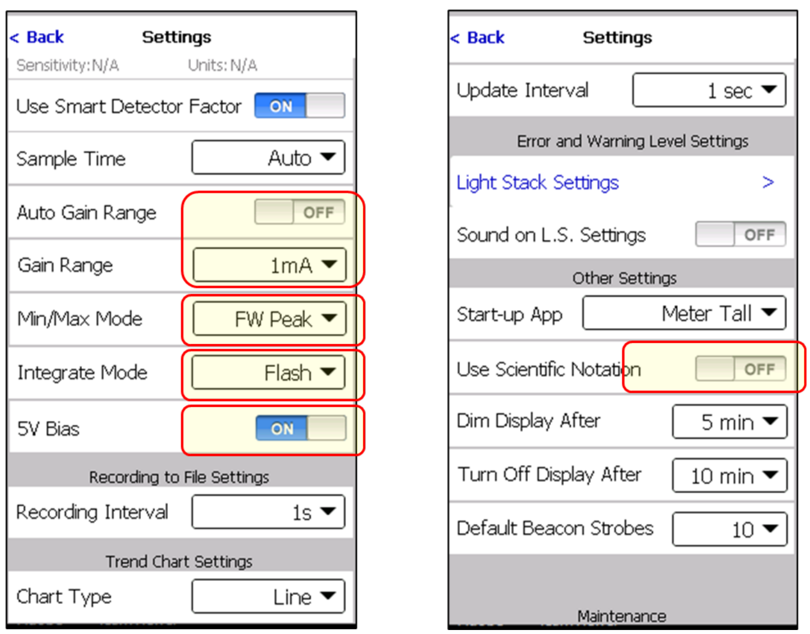

Figure 6. ILT2500 settings for flash measurement.

Figure 7 illustrates using the Meter Tall integrate function. Once the *Integrate* button is pressed the meter displays “Integrate” while it measures and integrates the flashes in the background. Pressing the Integrate button again displays the integral and places the meter in the hold mode, as indicated by the highlighted *Hold* button in the figure.

Figure 7. Simple flash integration with the ILT2500 Meter Tall applet.

4.2. Simple Flash Integration with the ILT2500 Flash Applet

In this example the ILT2500 Flash Applet is being used with the same light source and detection settings used in the example immediately above. It is important to note that the Flash Applet automatically applies these settings when entering the applet and resets them, when leaving the applet, to the settings in place prior to running the applet. Along with capturing the integral of the flashes, the Flash Applet also has an algorithm to count the number of flashes. In the rightmost screen capture in Figure 8 this is shown as "26", in the upper left of the box displaying the "2.602" integral value. The figure also depicts the two Flash Applet gain settings of HIGH Light (for measuring brighter pulses up to frequencies of 250Hz) and LOW Light (for measuring lower light levels, but only to frequencies of 25Hz).

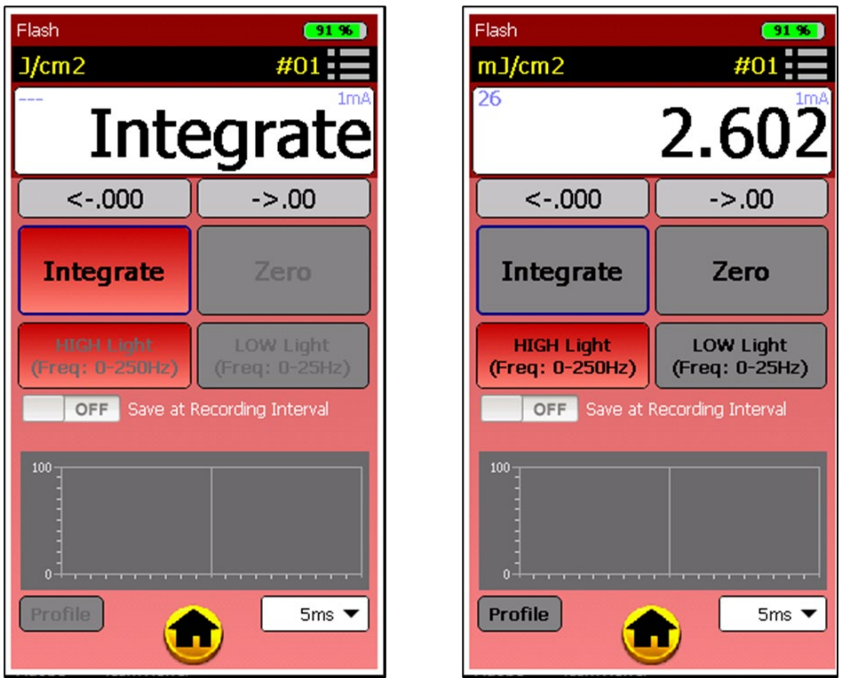

Figure 8. Flash integration with the ILT2500 Flash Applet.

4.3. Simple Flash Profile with the ILT2500 Flash Applet

The ILT2500 Flash Applet can capture and display a profile of a single flash within these parameters:

Maximum pulse width: 2 ms
Maximum profile time: pulse rate / 4

This profile is attained within the ILT2500 Flash Applet by selecting the *Profile* button while the light source is flashing one or more times. A typical result is shown in Figure 9. The profile function uses an algorithm to detect the rising edge of a flash, followed by capturing irradiance data based on the time set in the lower right of the window. This data is saved to the meter's internal flash memory for transfer to a computer for further analysis. See the ILT2500 manual for more information. Note that in this example, the "Settings" -> "Use Scientific Notation" setting is enabled.

IMPORTANT: As stated above in the description of the AFE, the shape of this profile is not representative of the physical flash. While the integral is representative, the height is a relative measure and the shape will always represent an exponential decay for high speed, brief flashes. Further, the shape and integral are impacted by the gain range selected (HIGH Light or LOW Light). The HIGH Light setting will result in an exponential decay that lasts on the order of 4 to 5ms. The LOW Light setting will (a) show a lower relative peak for the same flash, and (b) require 40 to 50ms for a full decay and integral capture.

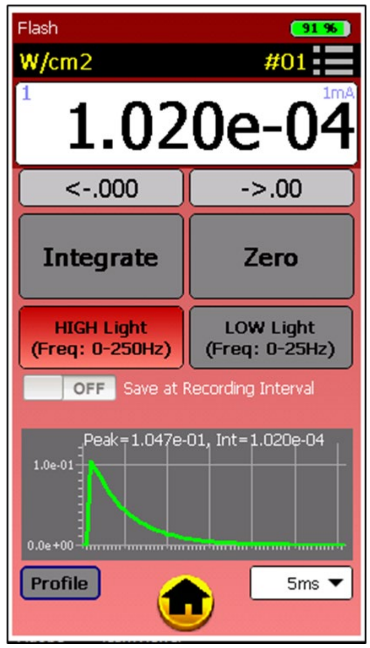

Figure 9. ILT2500 Flash Applet profile.

4.4. Capturing a Flash with the Windows Flash Application

Both the ILT2500 and the ILT5000 can use the Windows Flash Application to capture flashes. Below is a sequence of tests to determine the correct Windows Flash Application settings to capture one flash or a series of flashes. If using the ILT2500, it is important to quiesce the embedded meter application by positioning the meter on the home screen (see Figure 10).

Figure 10. ILT2500 Home Screen.

The steps to correctly capture a flash are performed as follows:

1. Configure the Windows Flash Application: 1mA, Low Sensitivity range; Manual Flash Capture Trigger, and an Integration Time of 40 milliseconds (see highlighted items in Figure 11).

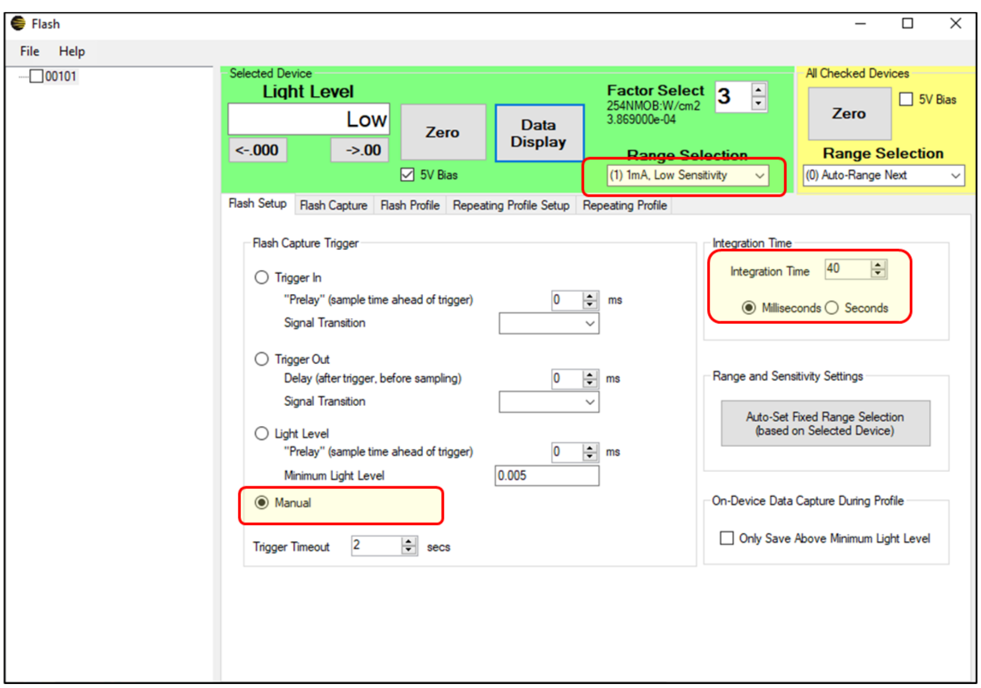

Figure 11. Windows Flash application manual flash capture.

2. Activate the flashing source to flash at a repetition rate faster than 25 Hz. This will ensure that a flash is captured within the 40ms integration period. Note that a 100 Hz flashing source is used in the subsequent steps.
3. Move to the "Flash Profile" tab and select *Capture + Profile*. See Figure 12 for an example capture.

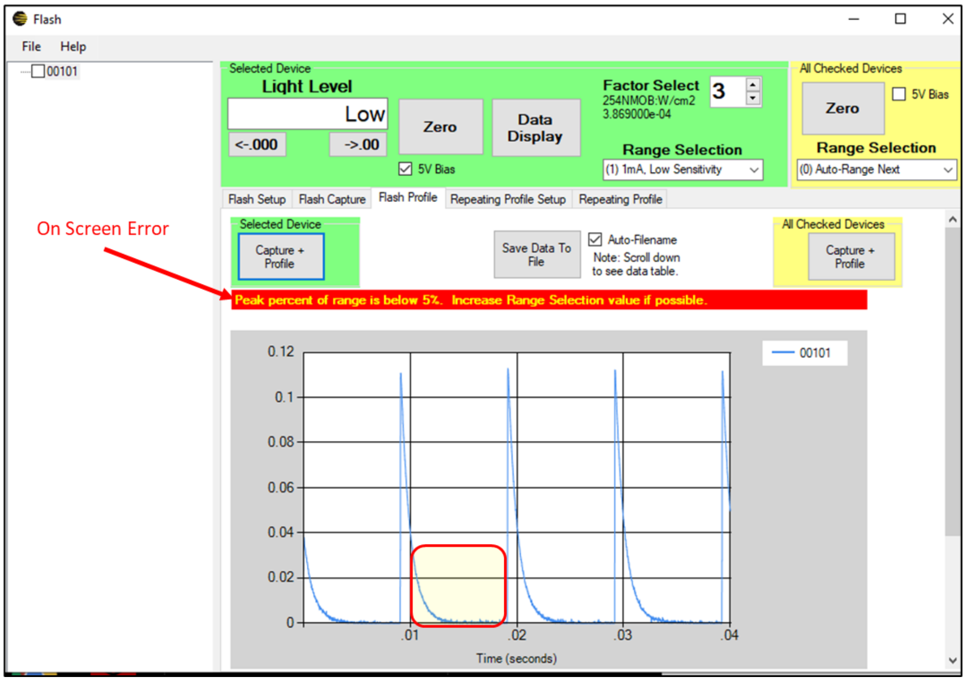

Figure 12. Manual trigger capture with error.

4. If there is a saturation error message, the light source is too close to the detector, or a neutral density filter is required to lower the light level incident on the detector. If the signal is too low, an error message will be displayed and there may be noise seen within the exponential decay of the signal. Figure 12 has examples of both situations. When this is the case, as it is in this example, increase the Range Selection to the next higher range and retry the capture. In this example moving to Range Selection "(2) 1mA, Med Sensitivity" resolved the error. See Figure 13. Note that, below the graph, is the actual data contained in a table (see Figure 14).

5. Once a repeated flash profile is capture as shown in Figure 13, it is possible to capture a single flash using the Light Level trigger. To apply the proper minimum light level, a point about 20% up the flash profile is used as a trigger level. Based on the flash profiles in Figure 13, a value of 0.02 is used in the "Minimum Light Level" field within the "Flash Setup" tab (see Figure 15). When using the light level trigger, a "Prelay" can also be used. The "Prelay" is a time period captured before the start of the flash. This is set to 2ms and reflected in the graph in Figure 16.

The “Flash Capture” tab always captures data associated with the profile captured within the “Flash Profile” tab. Figure 17 shows the data associated with the flash profile in Figure 16.

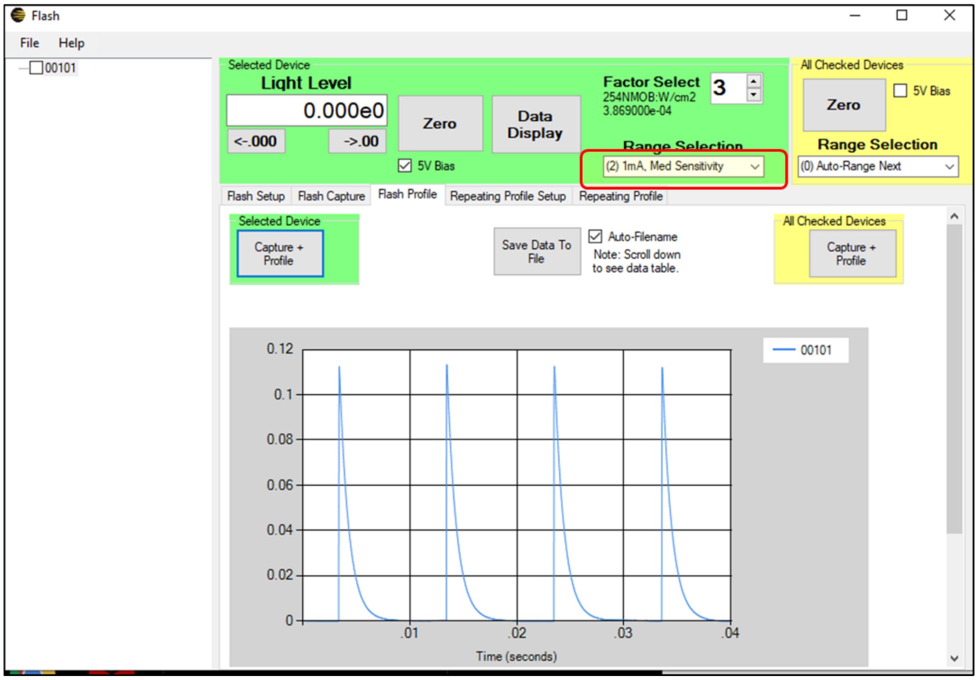

Figure 13. Manual trigger capture without error.

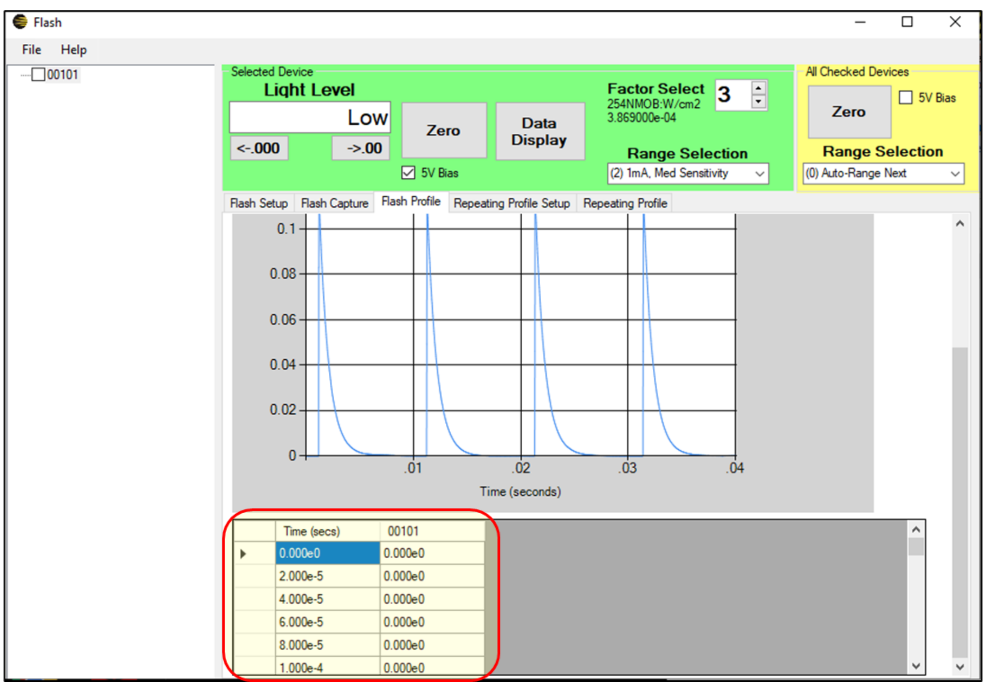

Figure 14. Data table below profile chart.

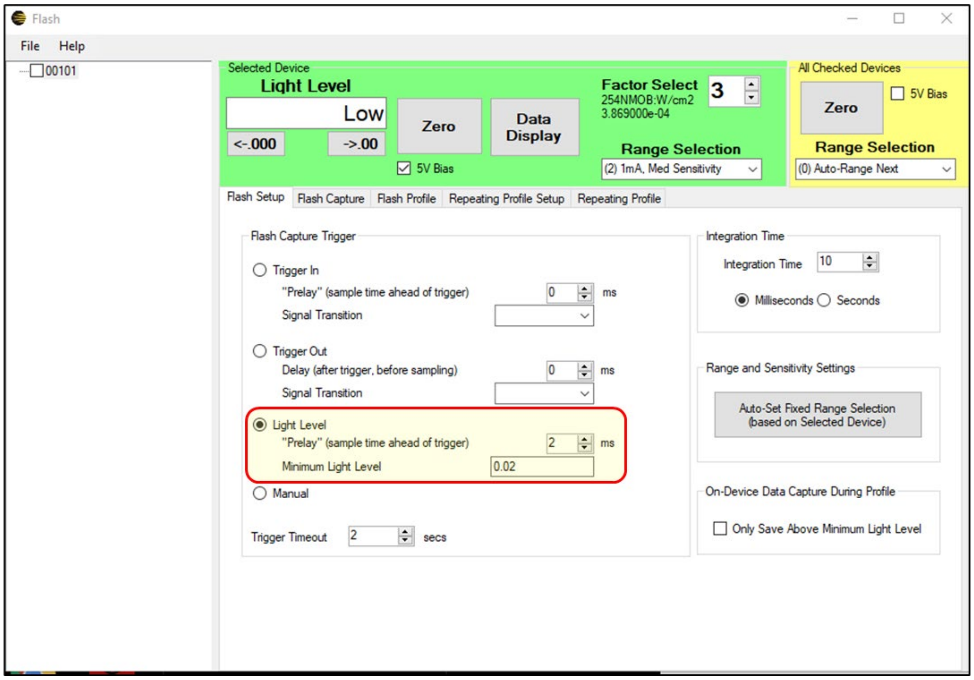

Figure 15. Light Level flash capture trigger.

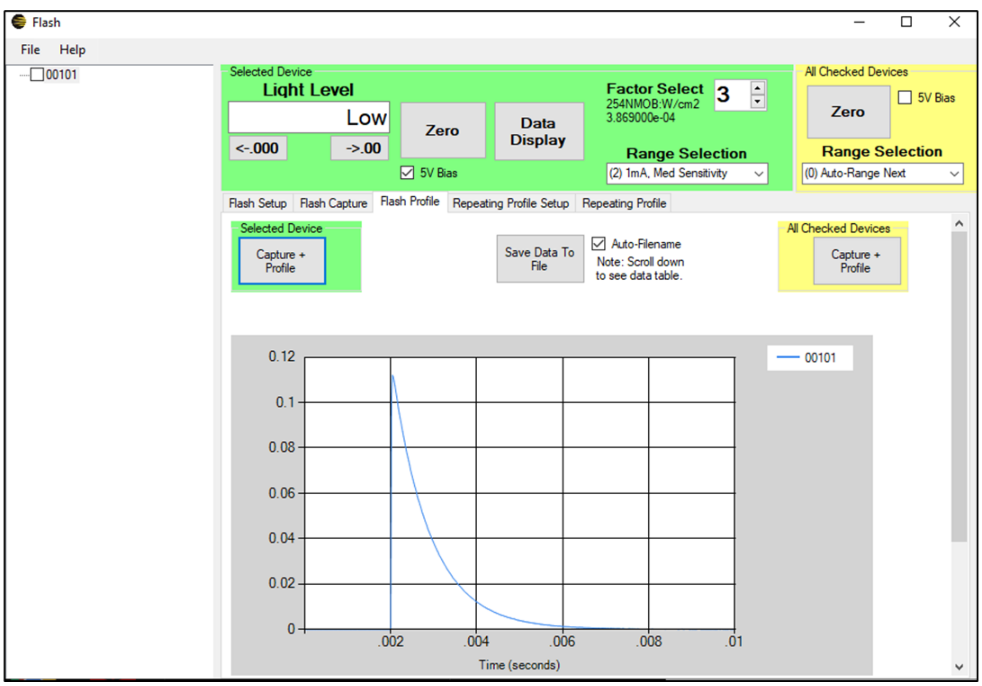

Figure 16. Single flash capture with light level trigger.

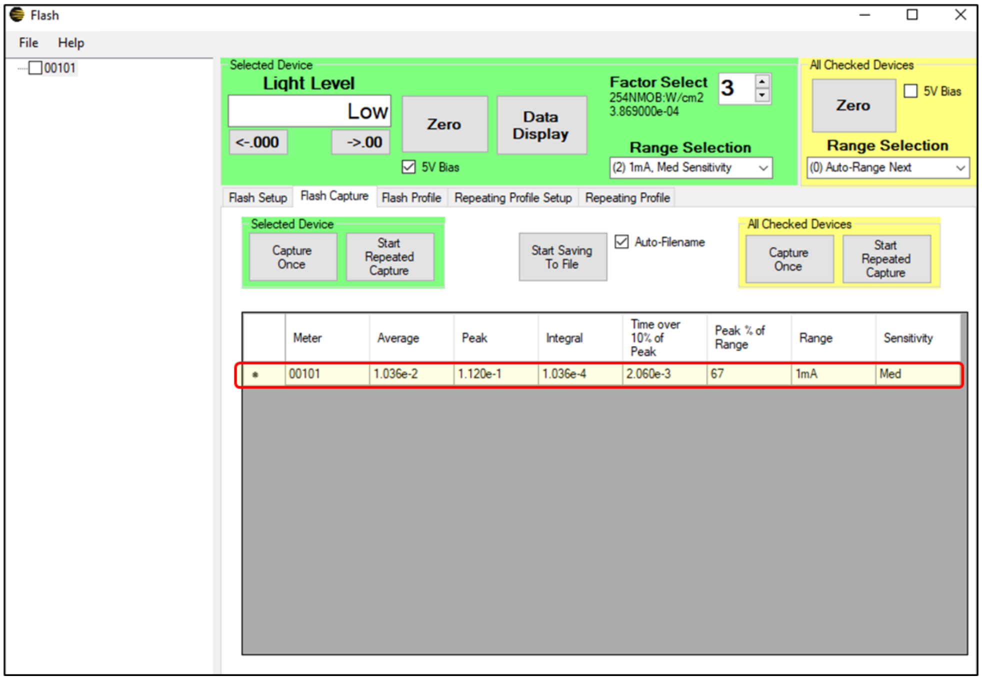

Figure 17. Flash Capture tab with flash results.

4.5. Frequency Capability Visualization with the Windows Flash Application

Sections 2.1 and 2.2 above explained the frequency capabilities of the meters based on their time constants. The Windows Flash Application is used in the images below to depict how the flash frequency affects the flash readings.

In Figure 18, a 200Hz flashing source is measured with the Windows Flash application. Because the 200Hz frequency is within the measuring capability of the meter for the range used (1mA), each pulse has enough time to rise and [exponentially] fall before the next flash begins. As a result, the meter will record an accurate measure of the integral of the flashes. Figure 19, on the other hand, attempts to capture a 500Hz flashing source. Because 500Hz is beyond the capability of the device for flash measurement, each flash does not have enough time to fully decay before the subsequent flash begins. As a result, the integral will be understated.

Figure 20 depicts a 20Hz flashing source using the 3uA gain range. Because this frequency is within the limits of the measurement circuit, each pulse has enough time to rise and fall. Figure 21 increases the flashing frequency to 100Hz, beyond the capability of this gain range. As in Figure 19, each flash does not have enough time to fully decay before the subsequent flash begins and the integral is understated.

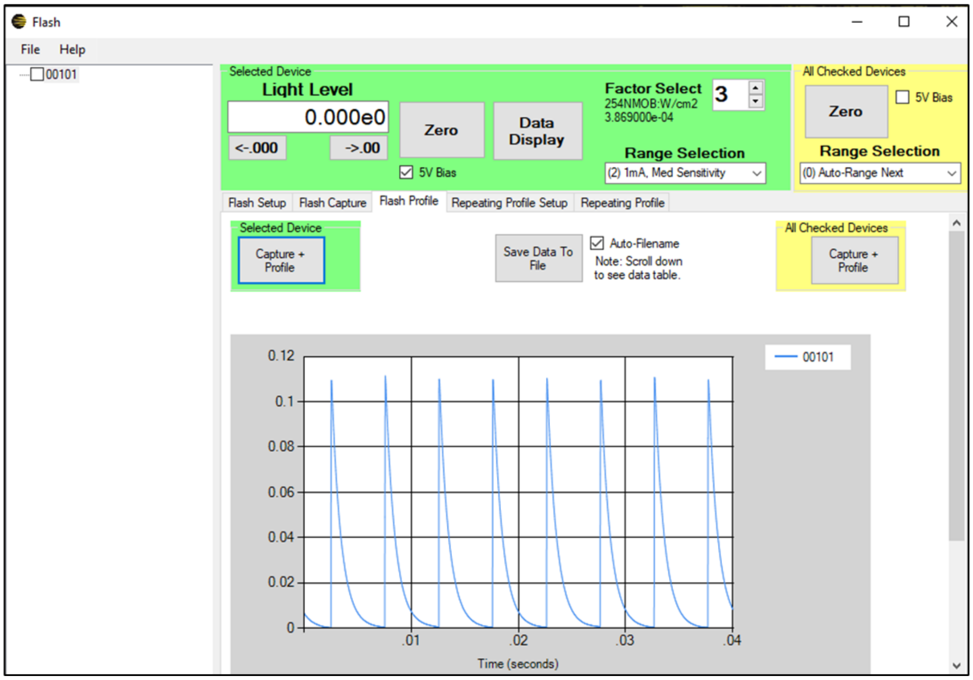

Figure 18. 200Hz flash capture, 1mA range.

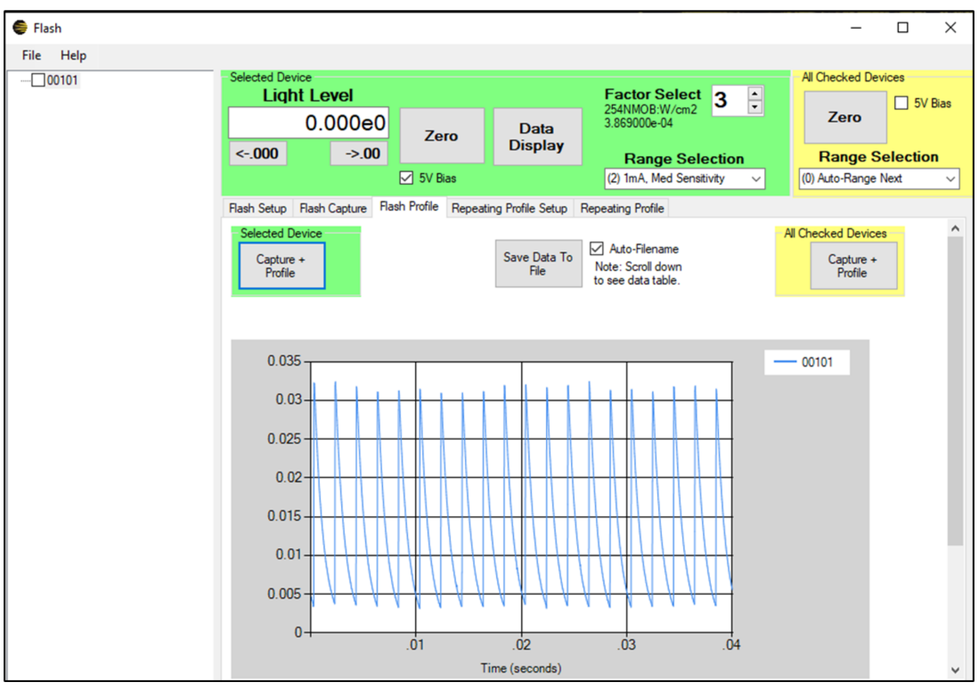

Figure 19. 500Hz flash capture, 1mA range.

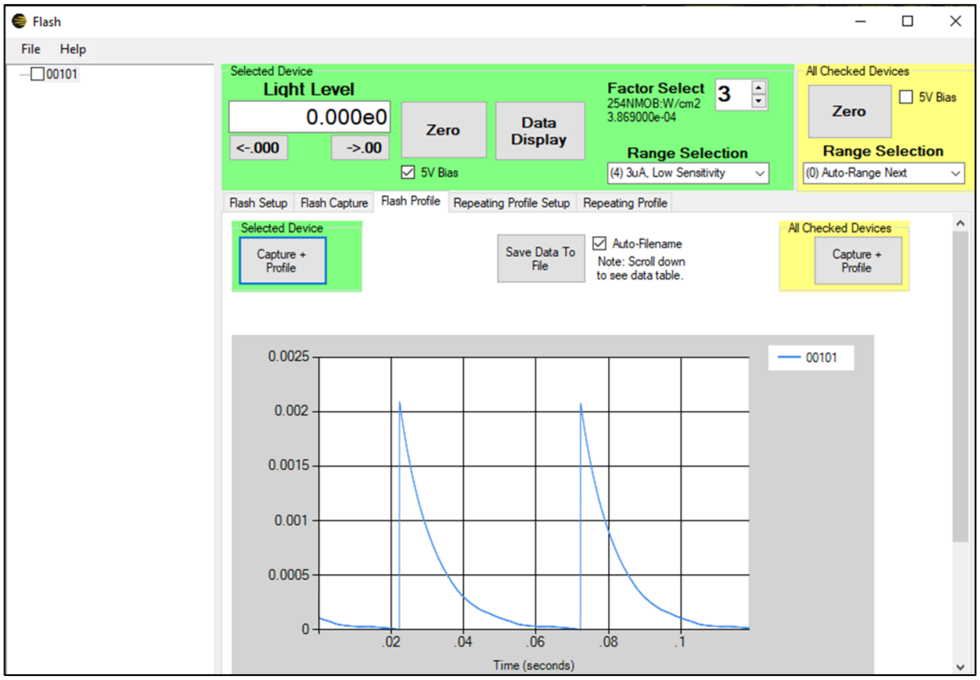

Figure 20. 20Hz flash capture, 3uA range.

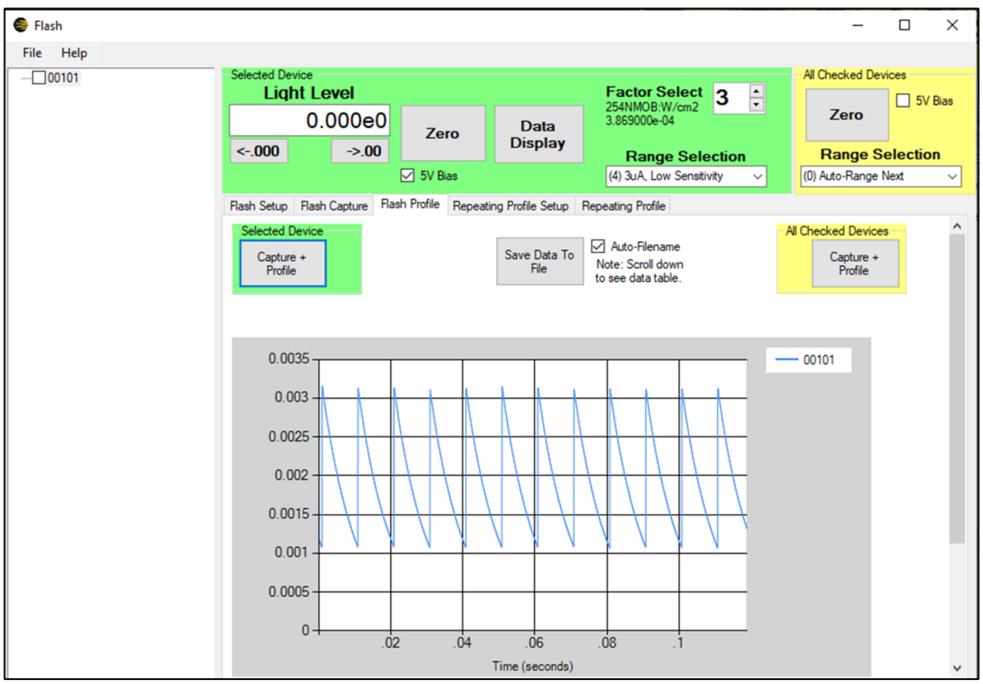

Figure 21. 100Hz flash capture, 3uA range.

4.6. Monitoring Flashes with the Beacon Applet

The Beacon applet is available on the ILT2500 meter as well as within the DataLight III Windows Meter application. The applet is designed for use in measuring periodic beacon lights including those required under the National Fire Alarm and Signaling NFPA72 standard. The applet captures a pre-determined number of strobes, capturing per-strobe statistical data. The Beacon applet can also be used to capture repeating flashes, albeit only at low flash frequencies (< 4Hz). In Figure 22 the applet was used to capture 26 pulses at a frequency of approximately 1Hz.

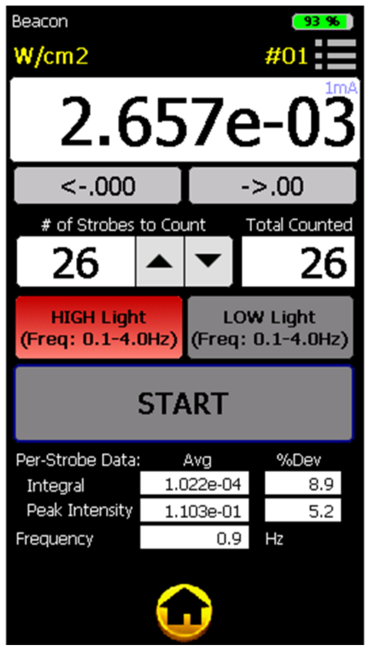

Figure 22. Flash capture with ILT2500 Beacon Applet.

5. Conclusion

The ILT meters and software offer several solutions for flash measurement. Understanding the underlying circuits and specifications, along with the common usage of the several applications and applets, allow for the most informed flash measurements and studies.