Fact Sheet No: 21/9

FAST*tracka*

Fast Repetition Rate Fluorimeter

The award winning Fast Repetition Rate Fluorimeter, FAST*tracka* II is a new generation of oceanographic instrument, which has the capability to measure the photosynthetic reaction of chlorophyll in the ocean.

FAST*tracka* II is typically used in a towed oceanographic vehicle undulating astern of the ship, however, it can be used on vertically profiling systems and on moorings. A titanium pressure housing provides water integrity and durability in the hostile marine environment.

INTRODUCTION

The FAST*tracka* Fluorimeter offers rapid, real-time, *in situ* measurements of photosynthetic characteristics of marine and freshwater phytoplankton. By exposing phytoplankton to a series of microsecond flashes of blue light at 200 kHz repetition rate, a saturation profile of PSII variable fluorescence is observed and recorded. Analysis of the observed fluorescence signal and knowledge of the excitation protocol allows calculations of the absorption cross section of PSII, the efficiency of photochemical conversion, and the rates of electron transport from PSII to PSI. The FRR Fluorimeter is designed to measure these parameters on dark adapted and ambient irradiated samples *in situ*.

Analysing the saturation profile of variable fluorescence induced by a sequence of fast repetition flashes allows evaluation of the following parameters:

Fo:	background fluorescence yield when all reaction centres open
F:	background fluorescence yield under ambient light
Fm:	maximum fluorescence yield when all reaction centres closed
τ:	time constants of electron transport from PSII to PSI (s)

Additionally, PAR is measured using an external irradiance sensor attached to the instrument. Including the measured photosynthetic parameters in appropriate models relating fluorescence and photosynthesis allows calculation of photochemical/nonphotochemical quenching, photochemical conversion efficiency, and primary production. Other incidental parameters are recorded by the instrument for monitoring performance and calibration, and include internal temperature, battery status, and error codes.

The FAST*tracka* may be deployed for profiling or for moored operations. In constant-duty profiling operations, the FAST*tracka* will continuously log up to 24 h of data at a 1 Hz acquisition rate when powered from the standard 15 Ah battery pack. In a moored operation, the acquisition lifetime may be extended to the timescale of months by reducing the flash repetition rate and properly managing the instrument sleep cycles. The FAST*tracka* may be powered externally through either the Interface or the Battery external bulkhead connectors, thus removing the limitation of the standard battery pack.

The FAST*tracka* is designed for maximum user flexibility. A comprehensive software package operates on an internal microcontroller and handles data collection, primary data reduction, and basic instrument functions. Data may be stored internally on a PCMCIA flashdisk, exported to a CTD or similar device over two 0-5 volt scaleable analogue channels, or transmitted serially over a host cable to a computer or terminal device. For most operations, flashdisk storage is recommended for simplicity and speed. Analogue interfacing is more complicated due to the differences between each manufacturer's CTD/logger specifications, and CI does not claim that the FAST*tracka* is compatible with all CTDs or loggers, especially older or custom models. However, our technical support team is ready to assist and advise users to interface the FAST*tracka* to any CTD or analogue logger. Since there is much variability in CTD performance, older models might require reconfiguration of the instrument analogue output channel or reconfiguration of the CTD itself. Please contact CI technical services for help with interfacing the FAST*tracka* with any other intelligent instrument.

The FAST*tracka* is shipped standard with a 15 Ah rechargeable battery pack, with an integral intelligent battery charging circuit which monitors battery temperature and charge characteristics. The internal charging circuit greatly simplifies the user's task of battery maintenance. Battery charge algorithms are computed internally with respect to charge state and temperature; the user is required only to provide adequate voltage and current at the charge plug. Proper charging capability is provided through the FAST*tracka* Deck Unit, but the customer is expected to ensure that the charging current and voltage to the battery pack does not exceed the specified limits for effective charging when using sources other than the Deck Unit to charge the battery pack. The battery lifetime and power consumption rates are heavily dependent on the flash rate and the excitation protocol intensities.

The FAST*tracka* is shipped with a Deck Unit, a deck unit interface cable, and a serial cable to allow RS232 communication between the FAST*tracka* and the user's computer or terminal emulator. The user is required to provide an adequate terminal emulation package (e.g. PCPlus) in order to communicate with the FAST*tracka*. In addition to allowing communication, the Deck Unit supplies power to the FAST*tracka* via an internal switch mode PSU. Consequently the instrument may be operated through the Deck Unit alone, without a battery pack. Finally, the Deck Unit contains a second internal switch mode PSU to properly charge the battery pack. Since this PSU is separate from the Host supply PSU, battery pack charging can occur simultaneously and independently of host operation.

The electronic systems of the FAST*tracka* include a Motorola MC68332 microcontroller operating at variable clock speeds up to 16MHz, a flexible FPGA digital logic system, and a nonvolatile PCMCIA flashdisk. The FAST*tracka* optical system utilises a proprietary high-speed/ fast repetition rate blue LED light source and a sensitive photomultiplier emission detector, both specially engineered for the excitation and observation of chlorophyll fluorescence.

Since the FAST*tracka* has been designed for maximal flexibility, each user's application may be as customised as is desired. Technical information is provided to help the user operate the FAST*tracka* with most standard deployment scenarios, but we realise that many items have been either customised or require additional information. Our technical services are ready to help you effectively use our instrument in any situation you require, in house or in the field.

INSTRUMENT RATINGS

Physical Specifications

Length	635 mm	Instrument can + guard
	355 mm	Battery pack
	990 mm	Total mounted length
Diameter	160 mm	
Weight		
Without Battery pack	in Air: ~23kg	in Water: ~15kg
With Battery pack	in Air: ~39kg	in Water: ~24kg
Exterior Materials	Titanium, grade 2, or epoxy powder coated anodised aluminium Annealed black Delrin 316 stainless steel	
Pressure rating	500m	

Electrical Specifications

Power Consumption	650 mA @1Hz FSRR @ 14V
	300 µA @ sleep mode @ 14V
External Power voltage range	Interface Connector: 18 - 72 VDC
	Battery Connector: 13.5 - 18 VDC
	CTD Operation: 10.5 - 18 VDC

Performance

[Chl *a*] sensitivity	0.1-30 $\mu g l^{-1}$

Data Communication

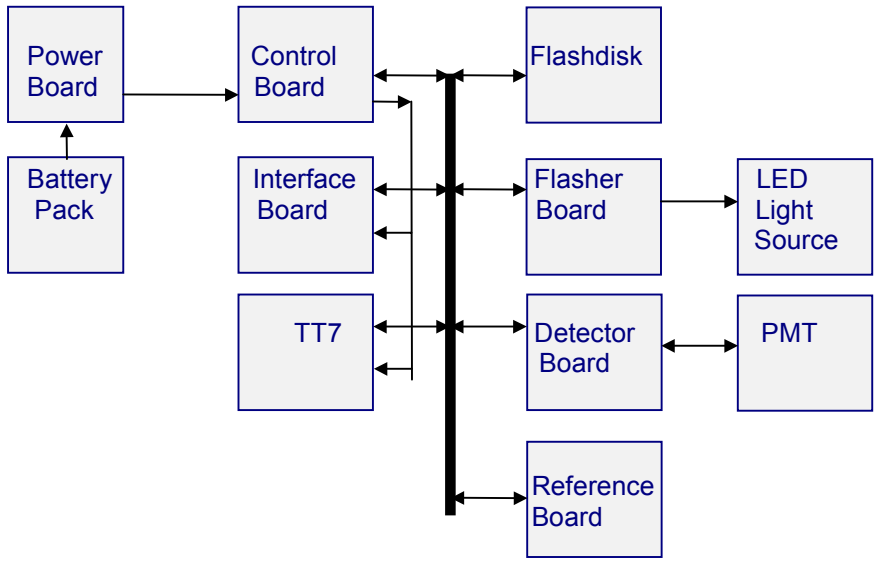
Standard	RS422
Standard Serial Parameters	9600 N 8 1
Flashcard Download	9600 N 8 1 or 57600 N 8 1

TECHNICAL REFERENCE

Due to the complexity of the instrument circuitry and optics, service of the FAST*tracka*, involving removal or inspection of the internal components, should be attempted only by CI trained technical support staff. There are no user serviceable components inside the instrument. Any attempt to open the instrument or battery assembly and service any of the componentry will void the warranty.

This notwithstanding, a short technical description of the FAST*tracka* and its subsystems has been provided to inform the user of the internal operation of the instrument. This description is designed to be functional in nature, and many details will be omitted in order to provide only the information which is pertinent to the instrument operation.

A block diagram of the FAST*tracka* is pictured below:



The operation of the FAST*tracka* is supervised by a controller system built around a MC68332 based datalogger, a TattleTale Model 7 (Onset Computer Corporation, Pocasset MA USA). The datalogger resides on a controller board, which services the datalogger and provides a supervisory control circuit. Nonvolatile mass storage is provided by a PCMCIA flashdisk, and nonvolatile system parameters are stored in a Dallas NVRAM. The Dallas NVRAM also provides clock functions for system wakeup and long term deployment programming.

An interface board controls FRRF protocols while simultaneously monitoring a PMT detection and amplification system. The interface board is also responsible for monitoring auxiliary sensors such as the add-on temperature and pressure probes, as well as the standard CI external PAR sensor. A power management board provides automatic power switching between battery operation and externally supplied power, preferentially protecting the battery pack while external power is available.

Control Board

The control board is designed around a Tattletale Model 7 datalogger from Onset Corporation (Pocasset MA, USA) and a PCMCIA Flashdisk (M-Systems, Santa Ana CA, USA). The automatic data protection, absence of moving parts and the low power consumption of a flashdisk makes this solution applicable for mooring applications, where vibration and power saving concerns are critical.

The main datalogger is controlled by a supervisory circuit to achieve maximum power management. Toggling the magnet switch or pre-programmed operations will place the instrument into wake-up state. Further communication from the Interface connector through a RS-422 transceiver on the power board allows protocols stored in NVRAM to be modified or deleted. The instrument operating program is burned into the datalogger flash ROM during FRRF assembly at CI and is set to auto-launch whenever the power supervisor circuit dictates.

The datalogger has a variable speed digital clock, which is set according to the tasks executed by the instrument. During periods of numerical computation, the clock speed is increased to 16 MHz to efficiently process and reduce the raw fluorescence data. At other times the microcontroller clock is automatically reduced to 32 kHz to minimise power consumption. The controller board has shutdown control over the remaining subsystems, maintaining the proper duty cycle for further minimisation of power consumption.

Interface Board

The interface board executes the FRRF protocols, provides interface to the auxiliary sensors and handles A/D and D/A conversions. It is based around an Atmel 6005 field programmable gate array (FPGA) which emulates the logic circuitry for generating FRRF flash protocols, and twin 10 bit flash AD converters. The FPGA implements all the glue logic, generates timing for FRR protocols, data acquisition and conversion, and interfaces between the controller board and the external PAR sensor.

Flaster Board

The flasher board is responsible for triggering the LED light sources at 200kHz repetition rates. For each optical channel there are six chains of LEDs connected in parallel, with each chain of 14 LEDs connected in series. The entire flash board assembly is mounted in a shielded enclosure to minimise electronic noise.

An optical rod position in the centre of each lamp assembly provides a reference signal proportional to the flash intensity. This signal is measured on the Reference board simultaneously to the fluorescence emission. This excitation light data is presented to the user as REFERENCE data.

***WARNING**: Never look directly into the LED light source of the FASTtracka. Although the LED sources, unlike flashlamp sources, do not emit appreciable amounts of UV, the LEDs are focussed into a small sample volume and the intensity is correspondingly high. Damage to the eyes may occur if the beam is viewed directly.*

Detector Board

A Hamamatsu R928 side-on photomultiplier tube (PMT) is used to detect the fluorescence from phytoplankton exposed to excitation light. The emission light, after passing the entrance of the optical windows and aperture, is directed by a series of prisms to a passive collimator. After collimation, the emission light is filtered by a CI custom specified fluorescence band pass interference filters (Corion Coporation, Holliston MA, USA), and then passes through 12mm of Schott RG-665. After filtering, the emission light is focused onto the PMT photocathode.

The PMT gain is controlled by a programmable PMT high voltage supply. Varying the HV on a PMT will consequently vary the overall PMT gain characteristics, and the FAST*tracka* controls its gain in a series of steps, each step being a factor of four greater than the previous. After amplification, the PMT signal and the reference excitation signal described above are sent to the interface board for digitisation, manipulation and storage.

An onboard PMT calibration system provides a history of PMT performance over time. Periodically, a small and known amount of red light is leaked to the PMT from an onboard stable LED. The observed PMT signal is compared to a factory determined pre-set level, and differences between the present and the pre-set level indicate the amount of PMT wear.

Power Board

The instrument takes power from its own battery pack or from the Interface connector, or from power on the Battery connector. The Battery input is 13.5 -18 VDC, unless the CTD detect line is enabled, which allows voltages down to 10.5 VDC. Host power is 18 - 72 VDC.

Battery Pack

The battery can contains three tiers of 7 Gates X cells, each at 2V nominal and 5Ah. A vented charging connector is accessed through a charging plug in the bottom of the can. Power output is provided through a bulkhead connector and waterproof pigtail in the top of the can. An intelligent battery charging circuit is designed into the battery can to automate the charging cycle.

PAR Sensor

The FAST*tracka* is fitted with a bulkhead connector and external connecting cable which mate directly to a Chelsea Technologies Group PAR Irradiance Sensor, which is shipped standard with the instrument. The PAR sensor is powered by the FAST*tracka* , and the PAR signal is returned to the FAST*tracka* for measurement. The FAST*tracka* outputs PAR readings in the range 0 to 4095. This corresponds to an analogue input range of 0 to 4095 mV. The light intensity can then be calculated from this value using the formula supplied on the PAR sensor calibration sheet.

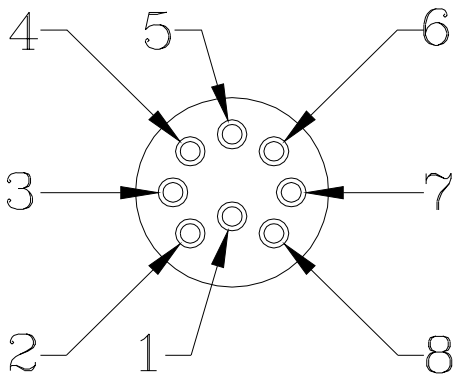
Pressure Sensor Option

The FAST*tracka* is fitted with a bulkhead Auxilliary connector for connection of the Chelsea Technologies Group Pressure Sensor option. The Pressure sensor is powered by the FAST*tracka* , and the pressure signal is returned to the FAST*tracka* for measurement. The FAST*tracka* outputs pressure readings in the range 0 to 4095. This corresponds to an analogue input range of 0 to 4095 mV. The pressure can then be calculated from this value using the formula supplied on the Pressure Sensor calibration sheet.

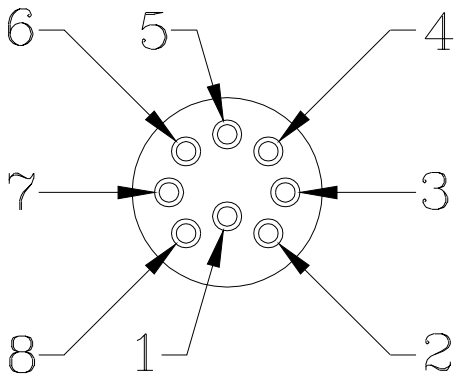
External Connectors

The FAST*tracka* instrument has waterproof bulkhead connectors on both the instrument can and the battery can. Additionally, the battery can has a sealing plug which needs to be removed in order to access the battery charging receptacle.

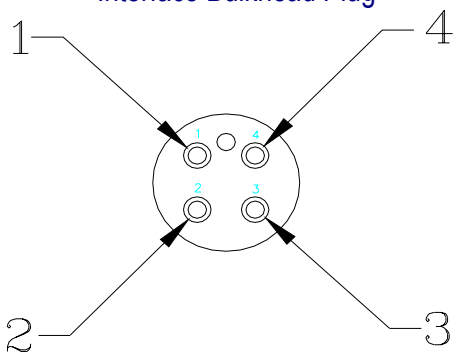
FAST*tracka* FRRF Housing Interconnections



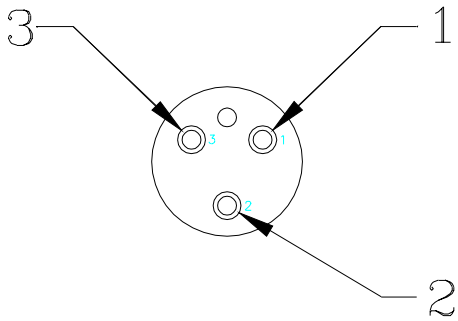
Interface Bulkhead Plug



Auxiliary Bulkhead Socket



Par Sensor Bulkhead Socket



Battery Bulkhead Plug

Interface Connector – Impulse BH-8-MP

Pin	*Description*	
1.	HOSTPWR+	18-72VDC 600mA @18V input
2.	HOSTPWR(ret)	Host Power return
3.	RXA	RS422 receive A input
4.	RXB	RS422 receive B input
5.	TXA	RS422 Transmit A output
6.	TXB	RS422 Transmit B output
7.	NC	No connection
8.	CENTRAL GND	Central ground

Auxiliary Connector - Impulse BH-8-FS

Pin	*Description*	
1.	0V	Pressure sensor 0V
2.	HISIG	Pressure sensor high signal input
3.	LOSIG	ressure sensor low signal input
4.	12VOUT	Pressure sensor 12V supply output
5.	F0	F0 signal output 0 - 5V
6.	Fm	Fm signal output 0 - 5V
7.	SIG RET	Signal return for F0
8.	SIG RET	Signal return for Fm

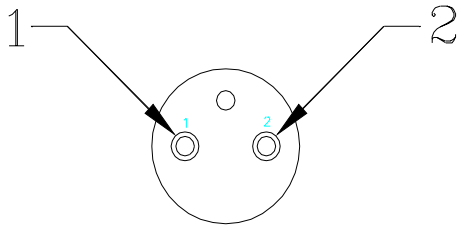
Battery Connector - Impulse BH-3-MP

Pin	*Description*	
1.	BATT IN+	10.5 - 18VDC, 650mA @ 14V input
2.	BATT RET	Battery power return
3.	CTD detect	Connect to pin 2 for CTD operation

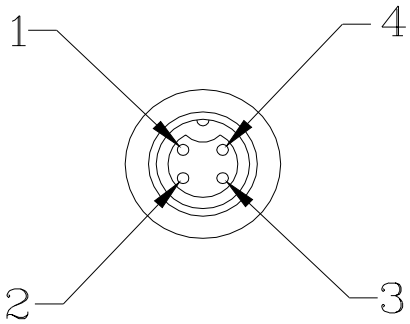
PAR Sensor Connector - Impulse BH-4-FS

Pin	*Description*	
1.	0V	Par sensor 0V
2.	HISIG	Par sensor high signal input
3.	LOSIG	Par sensor low signal input
4.	12VOUT	Par sensor 12V supply output

FAST*tracka* Battery Housing Interconnection



Battery Interconnection
Bulkhead Socket



Battery Charging
Bulkhead Socket

Battery connector - Impulse BH-2-FS

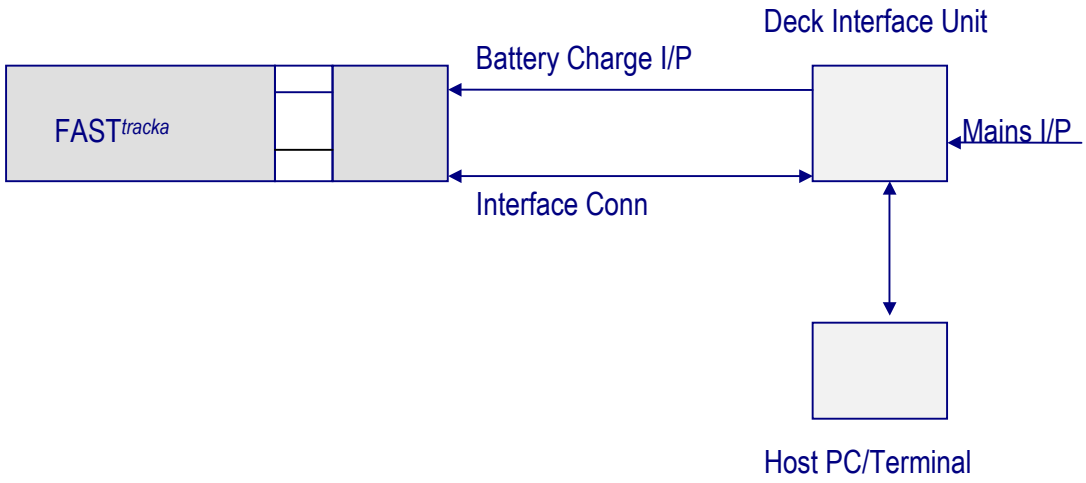
Pin	*Description*	
1.	BATT OUT +	Battery positive output nominally 14V
2.	BATT RET	Battery negative output

Battery charging SOCKET - Switchcraft EN3P4F

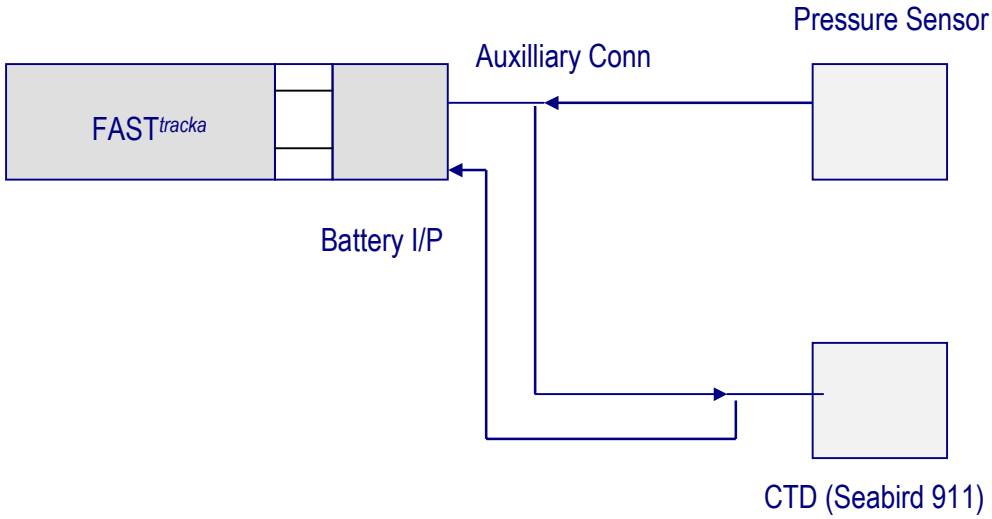
Pin	*Description*	
1.	CHARGE RET	Battery charger input return
2.	CHARGE IN	Battery charger input +28V
3.	CHARGE RET	Battery charger input return
4.	CHARGE IN	Battery charger input +28V

Interconnection Diagrams

FAST*tracka* Interconnection Diagram for battery charging and host communication.



FAST*tracka* Interconnection Diagram for CTD operation and Pressure Sensor Option.



GLOSSARY

Flash Repetition Rate	The rate at which flashes occur in a flash sequence. (~200kHz)
Flash Sequence	A series of saturation and relaxation flashes (usually SFC = 100, DFC =20).
Flash	A single burst of light from LED flashlamps, on the order of microseconds.
Flash Sequence Rate	The rate at which flash sequences are repeated (up to 8 Hz).
Acquisition	Any combination of flash sequences which lead to one final set of FRRF data values. Several flash sequences may be averaged to produce one final acquisition.
Excitation Signal	The blue light from the LED flashlamp used to stimulate PSII. Also referred to as the Reference Signal.
Excitation Channel	One of two optical windows on the optical head from which the FRRF excitation light is delivered. These are labelled channel A and B.
Emission Signal	Any red light (fluorescence) observed from the phytoplankton, including both biological signal and contamination.
Emission Channel	The single optical path leading to the PMT from the optical head, having two optical windows, one for each excitation channel.
PMT	Photomultiplier tube, used in the emission optical channel to detect fluorescence.
Light Channel	The Excitation Channel open to solar illumination. Channel A is configured at the factory to be the Light Channel, and shows the indicator LEDs.
Dark Channel	The Excitation Channel shielded from ambient illumination by means of the dark chamber assembly. Channel B is configured at the factory as the Dark Channel, and does not have indicator LEDs.
Signal Contamination	Any fraction of the emission signal which does not result from chlorophyll fluorescence.
Saturation Flashes	Closely spaced, brief pulses of light generated by the FRRF to gradually saturate the phytoplankton photosystems. The factory default for these is 1 us in duration, 1us spacing (i.e. 50% duty cycle).
Relaxation Flashes	Widely spaced, brief pulses of light generated by the FRRF to gradually probe the phytoplankton photosystems after saturation in order to observe relaxation kinetics. The factory default for these is 1 us in duration, 50 us apart. Also referred to as Decay Flashes.

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