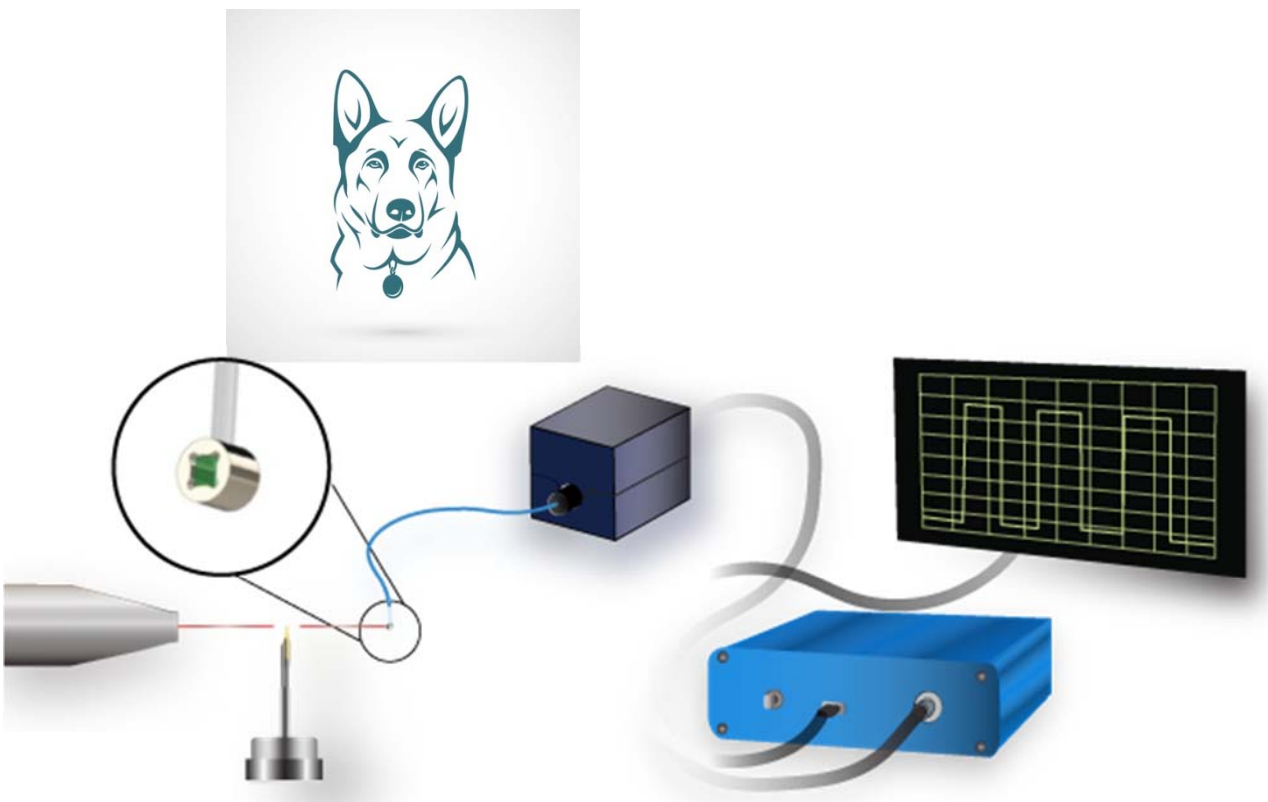
Sentinel X-ray Beamstop and Detector

User's Manual



MiTeGen

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Handling and Operational Precautions

The optical matching gel MSDS is available from Thorlabs (G608N3-MSDS.pdf)

Caution: Attempting to use a standard Sentinel device at energies higher than 16 keV will result in unusable data images.

Caution: The Sentinel device is fragile due to its small size, as it is designed to produce the smallest detector shadow possible. The device's attachment to the fiber can be damaged if the device is bumped or the device is held in position and the fiber is then twisted or stressed. The optical fiber has a short-term bend radius of 20mm and a long-term bend radius of 40mm; installing the device with the fiber bent tighter than the long-term bend radius specified can lead to loss of photons in the fiber, or complete breakage of the fiber if ever bent tighter than the short-term bend radius.

Caution: The Diode-Cable assembly (if biasing is used) must be reverse-biased to less than the diodes 40v reverse-breakdown voltage. The diode must not be subjected to forward-bias.

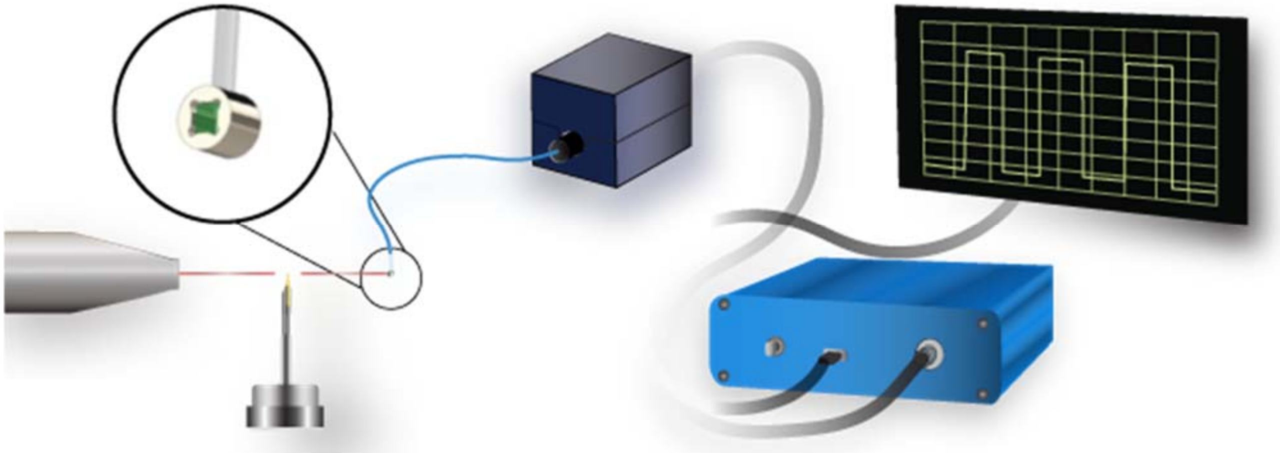
Caution, static sensitive components: The Diode-Cable assembly is static sensitive. Observe precautions for static-sensitive assemblies.

Warning: Bias voltage applied to the rear panel connector will be present at the picoammeter input connector when the external bias is turned on by the software.

Caution: All guidelines for the picoammeter in the picoammeter manual must be followed to avoid damaging the unit.

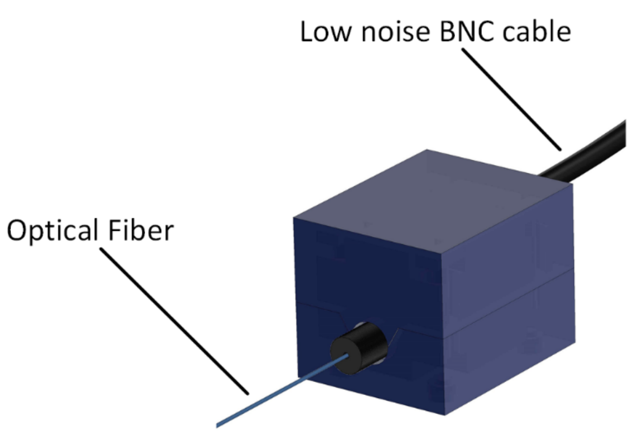
Components

The Sentinel Beamstop System is comprised of the Sentinel beamstop assembly (device and fiber), a Diode-Cable assembly, and a picoammeter.



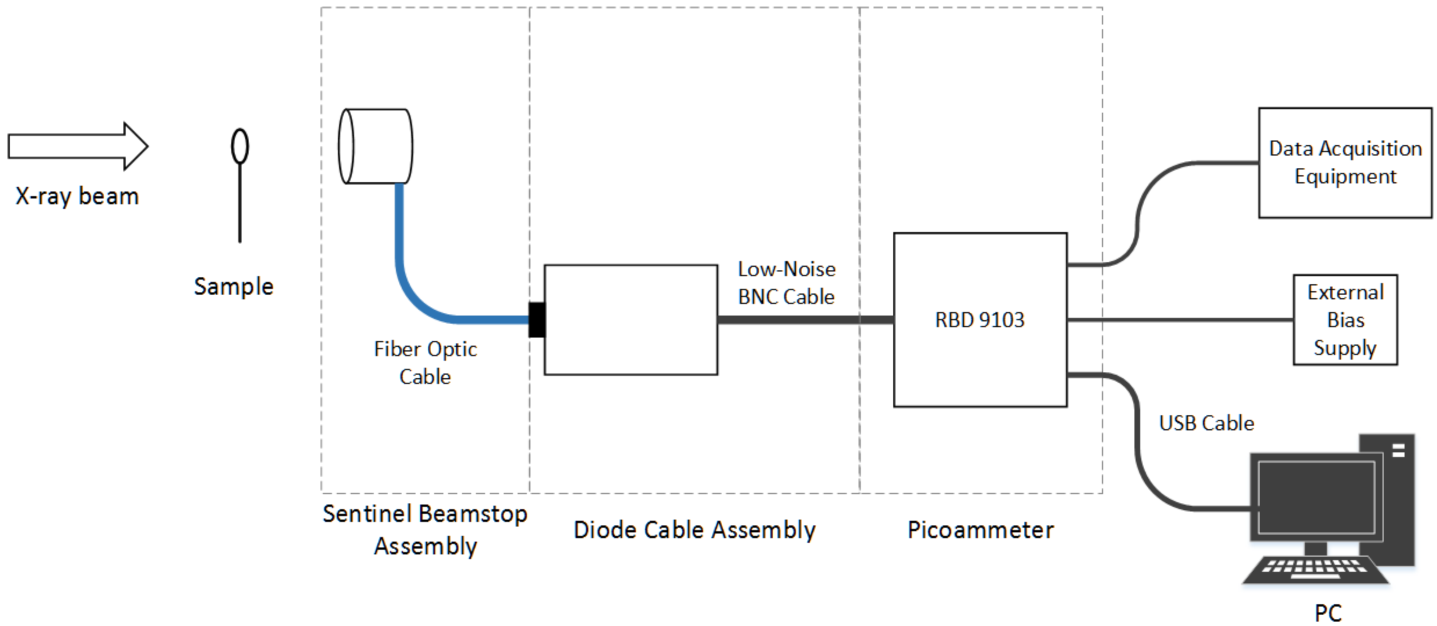
A housing forms the beamstop and the scatter shield around the heart of the Sentinel device. A beam reducer or collimator is not used and is not formed as part of the beamstop. The Sentinel device is attached by the user to a beamstop blade produced by the user. The device signal is coupled into and travels down the fiber optic cable, which connects to the Diode-Cable Assembly.

The Diode Cable Assembly converts the device signal to an electrical current signal, and consists of a mountable housing that contains the photodiode and which connects the photodiode to the low-noise BNC cable.



The autoranging picoammeter amplifies and measures the output of the photodiode and sends the results to a PC running the Actuel (or user custom) software via the USB cable, and it also presents a voltage output at the rear of the picoammeter. The rear-panel output presents the photodiode current input as an output value from -2V to 2V. The output is proportional to the measured current value relative to the full-scale swing for the set or auto-ranged current range.
The Picoammeter has a rear-panel input for applying a reverse-bias to the photodiode. The Actuel (or user custom) control software can turn the reverse-bias on and off, allowing switching between photovoltaic and photoconductive photodiode operation without physical user intervention.

Block Diagram



Theory of Operation

When the device is placed in an X-ray beam, a signal is produced which is coupled into the optical fiber. The base of the Sentinel device stops the incident X-ray beam, and the sides stop any scattered X-ray photons from reaching the imaging detector in use on an experimental station. The usable range of the device is approximately 6 keV to 16 keV.

The device signal travels down the optical fiber to the photodiode. The photodiode may be operated in reverse-bias mode (photoconductive) or unbiased (photovoltaic) mode. Photovoltaic mode is more sensitive and has essentially no dark current and so is usually the preferred mode of operation. When the detector signal reaches the photodiode it creates a current which is carried by the low-noise BNC cable to the picoammeter.

The picoammeter contains an adjustable transimpedance amplifier (current input, voltage output). The amplifier analog output is sent to the internal analog-to-digital and sampling circuitry where the data is sent via the USB cable to the controlling PC (tens of samples per second), and the output is sent to the rear panel connection jacks where external data recording equipment can be connected (samples/second not limited by the picoammeter).

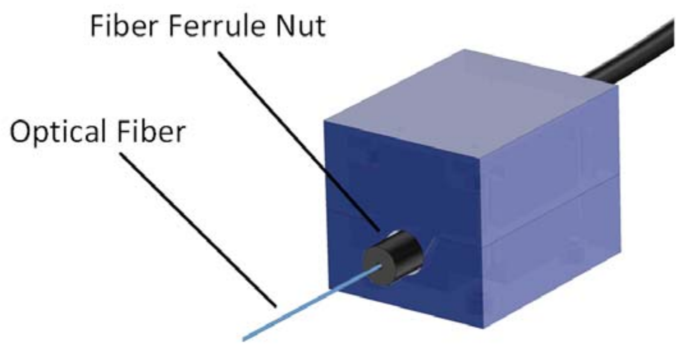
The current in the photodiode depends on the number of X-ray photons per second that strike the active area of the device, the energy of the X-ray photons, and where on the face of the device the X-ray photons are striking.
The active side of the device (faces the X-ray beam) is blackened with adhesive-attached graphite powder to block light from the device.

Pre-Installation Inspection and Testing

The Sentinel system should be inspected for shipping damage or missing parts before installation. The Sentinel system consists of:

- 2 Sentinel beamstop assemblies
- Diode-Cable assembly
- Syringe with optical matching gel
- Picoammeter packaging, containing:
    - Picoammeter
    - USB Cable
    - Torx screwdriver
    - Spare fuses

Verify each Sentinel beamstop assembly has one blackened face with attached optical fiber and that there are no kinks in the attached fiber, and the opposite end of the fiber has a metal ferrule.
Verify the Diode-Cable assembly has the BNC cable attached, has no visible damage to the case, and that the optical fiber connection point has the ferrule nut in place.



MiTeGen recommends some simple functional tests prior to installation.

1) Install the Actuel software and connect the Picoammeter to the PC according to the Picoammeter manual.
2) Confirm the PC is receiving data from the Picoammeter
3) Connect the low-noise BNC cable of the Diode-Cable Assembly to the Picoammeter
4) Alternately cover and shine light into the fiber connector on the Diode-Cable Assembly and verify the Picoammeter displays a higher current when light is admitted, and a lower current when the connector is covered

Installation

Beamstop Assembly Mounting Guidelines and Recommendations

Caution: The small size of the device means it is easy to bend or twist the fiber and apply a relatively sizeable stress on the device attachment (usually adhesive) to the blade, etc, and to the fiber attachment to the device. Securing not just the beamstop itself but the fiber as well helps ensure a durable installation, guarding against damage through accidental contact. If the most useful mounting method has the device mounted and the fiber left free, or if the mounting is done using the fiber alone and the device is unsupported, extra care must be taken to prevent accidental contact.

Note: Make sure to install the active side of the device (the blackened side) pointed toward the incoming X-ray beam; the fiber on the active side has a small paint dot. Installing the device with the active side facing the wrong way will result in no observable signal.
The non-active side is silver and is not blackened to aid adhesive adhesion.

The optical fiber attached to the device has a standard length of 18 inches (+/- 1 inch). This is intended to provide a good compromise between being able to get the Diode-Cable assembly away from parasitic X-ray scatter, and leaving the user with potentially too much fiber which would need to be managed in some way. The fiber has a 40mm minimum bend radius and is fairly 'springy'. Customized assemblies with alternate fiber lengths are available from MiTeGen.

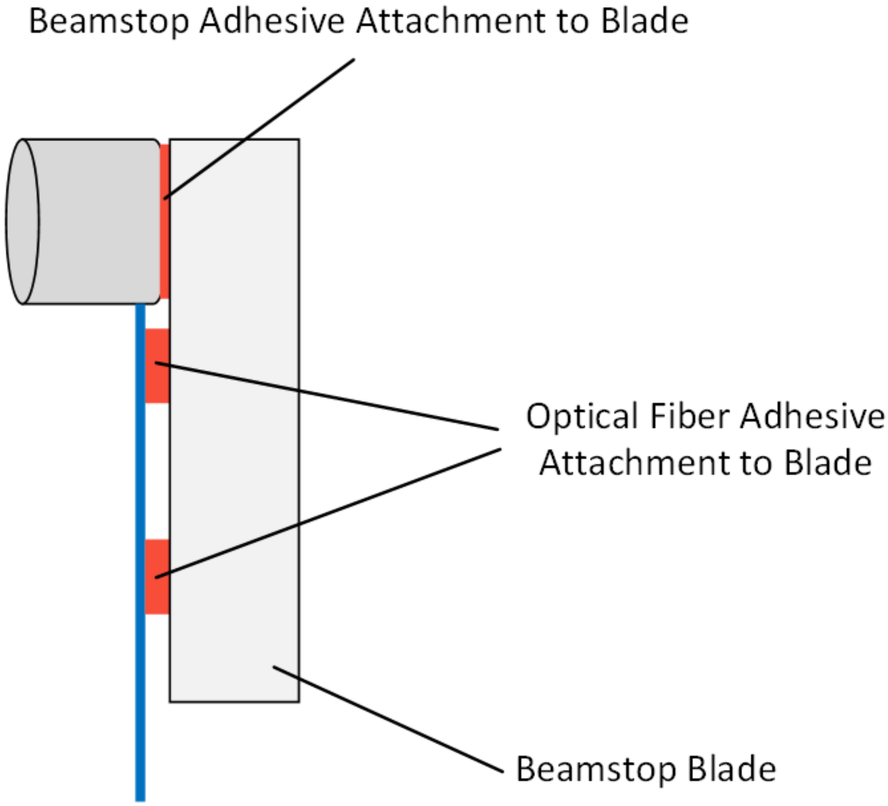
Due to the springiness of the fiber the best order of operations is to secure the fiber somewhat near the device first (being careful to keep the active side of the device facing in the desired direction) in 2 or 3 locations with a small distance between attachments before final mounting of the device. This will ensure that normal stresses on the fiber from attaching it to the Diode-Cable assembly, and from moving or mounting the Diode-Cable assembly will be isolated from the connection to the device.

Ideally the device will be attached to a flat machined on a blade such that the fiber lies directly on the edge of the blade and is glued to it, or the small gap under the fiber where it connects to the device is filled with a glued shim or a glue fillet. Contact MiTeGen regarding the design and manufacture of custom blades and blade adapters.

The blade design and blade mounting should be designed to minimize ‘flutter’- lateral movement of the X-ray beam across the active area of the device can change the size of the signal from the device. Flutter can be caused by air currents or mechanical transients or vibrations. If the device attachment on the blade is such that any flutter will track the beam across the device in a line perpendicular to the optical fiber, this effect should be minimized.

The strongest Sentinel response will be achieved when the X-ray beam impacts the active area of the device as close to the optical fiber attachment point as possible. Generally, aligning the beam to the center of the device generates sufficient response.

Note: Setting the device in a position where you are seeing the largest signal may not be the optimal position. If the position selected is too near the fiber-device joint, a significant amount of unwanted scatter from the device may appear in your images. The optimal placement will balance strong signal with clean images. A few small scattering spots from the device are acceptable, and will not interfere with data results.



Diode-Cable Assembly Mounting

The Diode-Cable Assembly is placed or affixed using the provided through-holes at a convenient location near the beamstop assembly, at a location free of parasitic X-ray scatter (impingement of X-ray photons on the photodiode will generate unwanted diode current). The assembly should also be placed where it will not be directly illuminated, as any light leakage to the diode will generate unwanted diode current.

Fiber Optic Cable Attachment

After the Beamstop and Diode-Cable assemblies are mounted the optical fiber can be attached to the Diode-Cable Assembly. The end of the optical fiber is slightly recessed in the ferrule to protect it against damage in case of accidental contact.

1) Examine the end of the fiber, just inside the stainless-steel ferrule, and ensure it is clean and free of dust and debris. If required, clean with compressed air and/or alcohol and a lint free swab or wipe.
2) Remove the ferrule nut and carefully slide it over the optical fiber, unthreaded-end first.

3) Using the syringe included in the kit, apply a small amount of optical matching gel to the end of the fiber. Ensure there are no air bubbles or gaps in the recessed end of the stainless steel ferrule. Apply enough gel to leave a small amount on the outside of the end of the fiber.
4) Slide the end of the fiber into the diode housing, taking care to not wipe the optical gel off the end of the fiber. Slide the fiber in until the end of the stainless steel ferrule contacts the plastic diode face at the bottom of the hole.
5) Slide the plastic ferrule nut down to the diode housing and tighten it (do not allow the fiber to rotate), securing the fiber into the housing.

Picoammeter location

Locate the picoammeter within reach of the low-noise BNC cable, and where it will be away from any X-ray scatter.

Electrical Connections

1) Connect the low-noise BNC cable to the input jack on the picoammeter.
2) Connect the picoammeter to the controlling PC with either the enclosed or an extended-length USB cable.
3) If an external diode bias is used, connect it to the rear BNC external-bias jack.
4) If the picoammeter rear-panel external voltage output is used, connect it to the recording equipment.

Operation

The standard method of operation for the Sentinel system:

1) Attach the PC used to control the picoammeter to the picoammeter
2) Start the Actuel software, or the user written custom software
3) For photoconductive operation:
    a) Ensure the external bias supply is connected and turned on
    b) Set the picoammeter external bias to ‘ON’
4) For photovoltaic operation:
    a) Set the picoammeter external bias to ‘OFF’
5) Set the picoammeter auto-ranging functionality to ‘OFF’
6) Set the picoammeter range to the range that will cover the planned data collection runs, normally the 2nA to 200nA range.
7) Set the picoammeter graphing and data recording as preferred
8) If external data recording is used, ensure the picoammeter rear-panel analog voltage output is connected to the recording equipment

The picoammeter is powered by the USB connection. If no intensity data is to be collected through the picoammeter and no control during the data collection runs is required, the picoammeter can be connected to the PC using a USB hub, and the PC disconnected after the picoammeter is set up. At the current time if the picoammeter is powered by a USB hub with no PC attached and no setup from a PC, the picoammeter will function according to its default settings, no external bias applied and auto-ranging active. The external analog voltage output will be functional, but the output will indicate the current value for multiple current ranges. For example, the output will be 1V for midscale in the pA range, the nA range, and the µA range.

For photovoltaic operation of the photodiode, the dark current (no X-ray impingement on the device and no light leakage) will effectively be 0nA. For the diode reverse biased at 30V for photoconductive operation, with no X-ray impingement on the crystal the diode will exhibit a dark current of not more than 10nA if there is no light leakage to the photodiode.

Position Adjustment and Calibration

The Sentinel system is supplied as a relative measurement of the X-ray photon flux of the X-ray beam, minus the X-ray photons that are scattered or absorbed by the sample undergoing data collection. For many applications (such as ensuring the beamstop remains in the correct position), no significant calibration is required. For applications where calibration is desired information is provided below on what affects the calibration, and some calibration procedures.

For the Sentinel system calibration comes down to determining the relationship between the device signal reaching the photodiode relative to the rate X-ray photons (of a given energy) enter the device. This varies primarily due to the X-ray photon energy and the where in the device the signal is produced.

The variation with X-ray photon energy is due to characteristics of the device material, such as the X-ray photon absorption efficiency variation with wavelength. For all variables held equal (beam size, beam position, X-ray photon flux), as the X-ray photon energy is varied between 6 keV and 16 keV, the rate of scintillation photon production varies.

The variation due to where in the device material the signal is produced arises from the fact that not all of the signal produced will be coupled into the optical fiber. The amount of signal coupled into the fiber is greater when the X-ray beam strikes the device closer to where the optical fiber is attached (somewhat under control via beam position on the face of the scintillator). The signal strength variation with beam entry point is why it is important to mount the device such that it will not move during data collection.

Care and Cleaning

In normal operation and usage the Sentinel system requires no periodic maintenance or cleaning. If debris collects on the X-ray beam facing side of the Sentinel beamstop assembly it may be gently blown off or removed with a soft dry swab. Most debris should not interfere with the Sentinel's operating performance, as long as it is transparent to X-rays across the energy range used at the experimental station.

If the blackening on the X-ray beam facing side of the Sentinel beamstop assembly becomes damaged through mechanical contact, any opaque non-X-ray-scattering/blocking material (such as graphite aerosol) can be carefully painted over the damaged blackening.

Technical Support

Contact support@mitegen.com or call 1-877-648-3436 for support.