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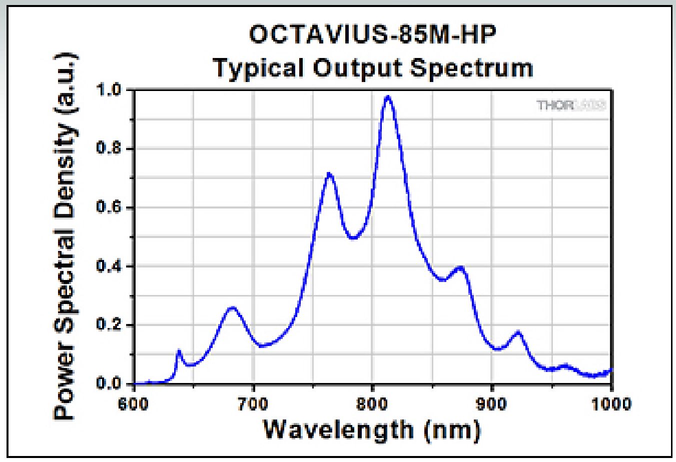
OCTAVIUS-85M-HP- August 22, 2024

Item OCTAVIUS-85M-HP was discontinued on August 22, 2024. For informational purposes, this is a copy of the website content at that time and is valid only for the stated product.

TI:SAPPHIRE FEMTOSECOND LASER (<8 FS)

- Ti:Sapphire Laser with <8 fs Pulse Width
- >600 mW Average Output and >200 nm Bandwidth
- 85 MHz Repetition Rate
- Robust Design and Turnkey Operation

OCTAVIUS-85M-HP
Ti:Sapphire Oscillator, <8 fs, >200 nm Bandwidth



OVERVIEW

Features

- Long Term Output Power Stability (±1% Over 900 Hours)
- >600 mW Output Power and <8 fs Pulse Width
- Turnkey, Maintenance-Free Operation

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OCTAVIUS-85M-HP Ti:Sapphire Oscillator Output Spectrum

Thorlabs' Octavius® Femtosecond Laser is a maintenance-free, Ti:sapphire oscillator that emits one of the broadest spectra commercially available. It has a high average output power of >600 mW, while maintaining a <8 fs transform-limited pulse width. The broadband spectrum of this ultrafast laser system is well suited for amplifier seeding, particularly for Optical Parametric Chirped Pulse Amplifiers (OPCPA), or use in pump/probe experiments. For detailed specifications, please see the *Specs* tab.

Applications

- Attosecond Science and High Harmonic Generation (HHG)
  - Optional CE-Phase Stabilization for Ti:Sapphire Chirped Pulse Amplifier (CPA) Seeding
  - Optical Parametric Chirped Pulse Amplifier (OPCPA) Seeding
- Two-Photon Fluorescent Imaging
- Surface Plasmon Resonance
- Terahertz Generation
- Nonlinear Optics
- Ultrafast Spectroscopy

The Octavius Ti:sapphire fs laser is ideal for life science applications such as multiphoton or coherent anti-Stokes Raman scattering (CARS) imaging. With a pulse duration of less than 8 fs, this laser provides an exceptionally high peak power of more than 700 kW and a large spectral bandwidth spanning more than 200 nm at -10 dB. This wide bandwidth, covering more than half the typical tuning range of most Ti:sapphire oscillators, allows for the simultaneous excitation of several spectrally separated fluorophores at their optimal absorption wavelengths without tuning.

Technology

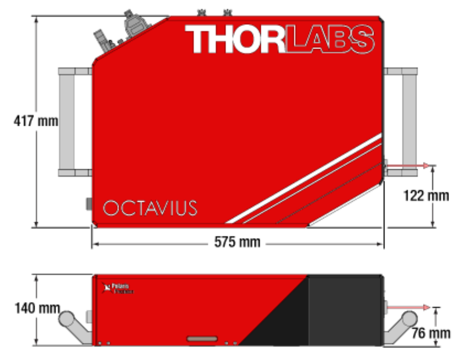
The Octavius fs laser is a soft-aperture Kerr-lens mode-locked (KLM) Ti:sapphire laser. The laser cavity incorporates dispersion-compensating mirror (DCM) pairs, which are required for smooth, high-precision group delay control over the octave-wide bandwidth. The fabrication of these unique mirror pairs requires the optimization of a 150-coating-layer design.

Mechanical Design
Ease of use and mechanical robustness were at the forefront of the design for the Octavius fs laser. Unlike typical laser designs, which use traditional translation stages for tuning and alignment, the alignment of the Octavius is controlled via a unique flexure stage design that eliminates the various materials generally used for springs, bearings, and frames while still maintaining unprecedented accuracy and repeatability. Custom tooling and fixtures guarantee stress-free machining during production and therefore minimize drifts and misalignment of the laser cavity caused by stress relaxation.

Pump Laser
The Octavius Ti:Sapphire Oscillator includes an integrated pump laser. The pump laser is based on state-of-the-art Optically Pumped Semiconductor Laser (OPSL) technology, which allows for high compactness.

Please contact techsupport@thorlabs.com for more information about this system, customization options, or to request a quote.

SPECS



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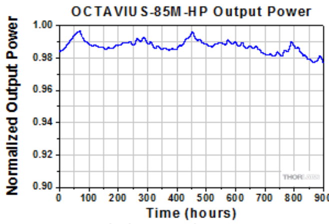
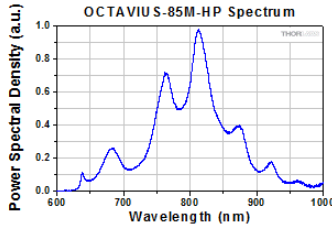
Item #	OCTAVIUS-85M-HP
Pulse Specifications	
Transform-Limited Pulse Width[a]	<8 fs
Bandwidth (at -10 dB)	>200 nm
Average Output Power	>600 mW
Repetition Rate	85 MHz
M^2 (at 800 nm)	<1.3
Beam Diameter	750 µm (Nominal)
Beam Ellipticity	1.15 (Nominal)
Divergence	<2 mrad
Polarization Ratio	>90:1
Power Stability Over 8 Hours	±0.3%
RMS Noise (10 Hz to 625 kHz)	<0.2%
Physical Specifications	
Laser Housing Dimensions	575 mm x 417 mm x 140 mm (22.6" x 16.4" x 5.5")
Controller Dimensions	432 mm x 267 mm x 381 mm (17" x 10.5" x 15")
Controller Power Consumption	750 W
Chiller Dimensions	203 mm x 386 mm x 277 mm (8" x 15.2" x 10.9")
Chiller Power Consumption	625 W (Max)
Air Circulator Dimensions	483 mm x 178 mm x 330 mm (19" x 7" x 13")

Air Circulator Power Consumption	25 W

a. The output pulse is chirped to account for dispersive materials outside the laser. To obtain the transform-limited pulse width, dispersion compensation is needed to counter-chirp and compress the pulse.



Click to Enlarge
Output Power of the OCTAVIUS-85M-HP Measured Over 900 Hours



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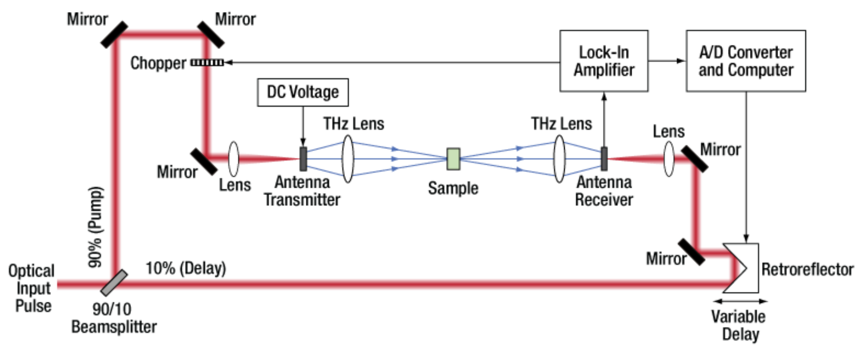
Measured Spectrum of the OCTAVIUS-85M-HP

THZ APPLICATION

THz Time-Domain Spectroscopy System Overview



The diagram above shows an example time-domain spectroscopy system that could be built using a pair of PCA800 antennas.

Time-domain spectroscopy (TDS) using THz radiation allows for measurements of both the amplitude and the phase of the interrogating radiation, unlike spectroscopy with optical fields, where only the intensity of the field can be directly measured. A wide range of materials, including metals and gases, can be measured using this technique. The THz radiation used in these systems can be both generated and detected by a pair of PCA800 Photoconductive Antennas, allowing for spectroscopic measurements in the range of 0.1 - 3 THz. The system above gives an example of the types of components used and the basic optical layout of a THz TDS system that could be built using a pair of PCA800 THz antennas. For a detailed tutorial on THz TDS, please see Neu and Schmuttenmaer's "Tutorial: An introduction to terahertz time domain spectroscopy (THz-TDS)."[1]


Click to Enlarge
The frequency-doubled output of the FSL1550 Femtosecond Fiber Laser can be used as the pulse source for the PCA800 antenna.

THz Radiation Generation

The main input to the THz TDS system, shown at the bottom left of the diagram above, is a femtosecond laser pulse centered around 800 nm. This pulse could come directly from a source, or by frequency-doubling the output of the FSL1550 Femtosecond Fiber Laser using an NLC07 β-BBO crystal. Both lasers have been used in a system like this to provide performance data for a pair of PCA800 antennas.

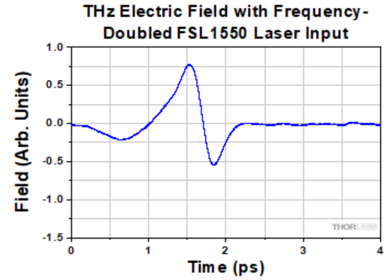
In the system shown above, the optical input pulse is split into two beams, with the majority (90%) of the light going into generating the THz radiation (labeled the Pump beam in the image above). Because the signal at the receiver antenna will be small, and a lock-in amplifier is recommended, the THz emission signal should be modulated. This can be done either through the use of an optical chopper in the Pump beam, or through modulation of the of the bias voltage on the antenna. The system above uses an optical chopper to modulate the input optical pulse, which will in turn result in a modulated THz emission from the antenna.

The Pump beam is then directed normal to the optical input surface of the antenna and focused down to the active area of the antenna for efficient THz generation. Note that the laser polarization needs to be aligned parallel to the Pol. Axis marking on the input side of the PCA800 antenna. Be careful not to exceed recommended fluence levels (J/cm^2) on the antenna.

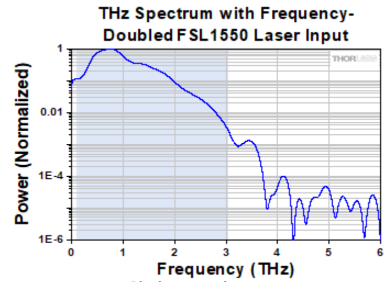
Up to the saturation level of the antenna, more optical power into the antenna will result in more THz power out. The THz output spectrum also depends on the optical input characteristics. For example, the dispersion compensation of the input pulse has been shown to affect both the efficiency of THz generation and the spectral profile of the THz output.[2] A shorter, transform-limited input pulse will result in THz output radiation with broader spectral content than that resulting from a longer, chirped input pulse, because the temporally delayed frequency components of the chirped pulse lead to destructive interference of the THz radiation and affect its spectral profile.

In addition to the input optical pulse, a voltage is applied across the PCA800 antenna through the integrated coaxial cable. For the system above, a DC voltage is applied to the antenna. A larger applied voltage, within the recommended limits, will result in more THz power emitted from the antenna. Alternatively, if an optical chopper is not used, a modulated voltage can be applied to the antenna to modulate the THz output.

The THz output from the emitter antenna has a divergence angle of 15° relative to the optical axis, which can be collected and collimated or focused using either THz lenses or off-axis parabolic mirrors. Once the radiation has traversed the sample under test, the same types of lenses or mirrors can be used to send the light into the THz receiver antenna. 1:1 imaging from the emitter antenna output to the receiver antenna input is recommended. The THz input beam will be collected by the hyper-hemispherical Si lens on the THz input side of the receiver antenna.



Click to Enlarge
Click Here for Data
This graph shows the THz electric field measured using a frequency-doubled FSL1550 Femtosecond Fiber Laser input and two PCA800 antennas.



Click to Enlarge
Click Here for Data
This graph shows the Fourier Transform of the THz electric field. The blue shaded region of the THz Spectrum graph indicates the range of frequencies over which the PCA800 antenna is recommended for use.

Optical Delay Line and Detection of THz Signal

Both the THz input and the femtosecond laser input pulse are required for detection at the receiver antenna. As shown in the figure above, 10% of the pulse used to generate the THz radiation at the emitter antenna is split off for use with the receiver antenna. This is labeled the Delay beam in the figure above.

For a given optical pulse, the paths are set so the Delay portion of that pulse arrives at the receiver antenna simultaneously with the THz pulse generated by the Pump portion of the optical pulse. In setting this Delay path, be sure to consider the full optical path from the 90/10 beamsplitter to the PCA800 receiver antenna. This includes the HRFZ-Si lenses integrated into the PCA800 antennas, which are 7.1 mm thick with an index of refraction of ~3.41, as well as any additional optical components in the THz portion of the optical train. At the receiver antenna, align the input laser beam onto the active area of the detector antenna using the same conditions as the emitter arm, except the intensity can be much lower, ~10% of that used at the emitter antenna.

The femtosecond optical pulse is significantly shorter in duration than the THz pulse. Therefore, they only overlap in time at the antenna for a short time, given by the optical pulse width. In order to sample the entire THz pulse, the optical pulse delay is scanned, for example through the use of retroreflector mirror mounted on a motorized stage (such as one driven by a stepper, DC servo, or voice coil). Thorlabs also offers integrated solutions for a variable delay of up to 4000 ps through the optical delay line systems.

The signal level on the receiver antenna output BNC cable will be low, so a lock-in amplifier and averaging are recommended. The signal to the optical chopper, or the modulation signal to the emitter antenna, is used for triggering the lock-in amplifier.

An example of THz field data is presented in the graph on the top right. For this experiment, the input to the PCA800 Antenna was the second harmonic generation of an FSL1550 Femtosecond Fiber Laser. The optical input spectrum was centered at 775 nm and dispersion compensated, resulting in a 24 fs pulse duration. The antenna had a 15 V DC bias applied through the BNC connector, and the signal modulation frequency was 4 kHz, driving an optical chopper in the input laser beam. A pair of MPD229-M03 off-axis parabolic mirrors were used to collimate the THz radiation from the PCA800 antenna remitter and refocus it onto the PCA800 antenna receiver. By taking the Fourier Transform of the electric field, the spectrum of the THz radiation can be calculated, as shown in the graph to the right.

This system can be used for time-domain spectroscopy experiments. The optical path length of a sample can be measured by measuring its effect on the electric field signal. Any additional path length inserted into the THz radiation beam path would result in a shift of the electric field signal in time. The spectral properties in the THz regime may also be measured by comparing the THz spectrum with and without a sample inserted into the beam path.

References

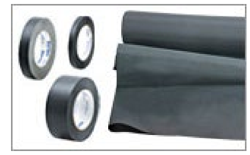
1. J. Neu and C. A. Schmuttenmaer, "Tutorial: An introduction to terahertz time domain spectroscopy (THz-TDS)," *Journal of Applied Physics* 124.23 (2018) p. 231101.
2. J. Hamazaki, K. Furusawa, N. Sekine, A. Kasamatsu, and I. Hosako, "Effects of chirp of pump pulses on broadband terahertz pulse spectra generated by optical rectification," Japanese Journal of Applied Physics 55.11 (2016) p. 110305.

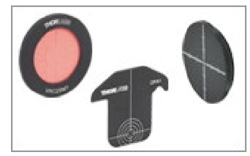
Laser Safety and Classification

Safe practices and proper usage of safety equipment should be taken into consideration when operating lasers. The eye is susceptible to injury, even from very low levels of laser light. Thorlabs offers a range of laser safety accessories that can be used to reduce the risk of accidents or injuries. Laser emission in the visible and near infrared spectral ranges has the greatest potential for retinal injury, as the cornea and lens are transparent to those wavelengths, and the lens can focus the laser energy onto the retina.

Safe Practices and Light Safety Accessories







- Laser safety eyewear must be worn whenever working with Class 3 or 4 lasers.
- Regardless of laser class, Thorlabs recommends the use of laser safety eyewear whenever working with laser beams with non-negligible powers, since metallic tools such as screwdrivers can accidentally redirect a beam.
- Laser goggles designed for specific wavelengths should be clearly available near laser setups to protect the wearer from unintentional laser reflections.
- Goggles are marked with the wavelength range over which protection is afforded and the minimum optical density within that range.
- Laser Safety Curtains and Laser Safety Fabric shield other parts of the lab from high energy lasers.
- Blackout Materials can prevent direct or reflected light from leaving the experimental setup area.
- Thorlabs' Enclosure Systems can be used to contain optical setups to isolate or minimize laser hazards.
- A fiber-pigtailed laser should always be turned off before connecting it to or disconnecting it from another fiber, especially when the laser is at power levels above 10 mW.
- All beams should be terminated at the edge of the table, and laboratory doors should be closed whenever a laser is in use.
- Do not place laser beams at eye level.
- Carry out experiments on an optical table such that all laser beams travel horizontally.
- Remove unnecessary reflective items such as reflective jewelry (e.g., rings, watches, etc.) while working near the beam path.
- Be aware that lenses and other optical devices may reflect a portion of the incident beam from the front or rear surface.
- Operate a laser at the minimum power necessary for any operation.
- If possible, reduce the output power of a laser during alignment procedures.
- Use beam shutters and filters to reduce the beam power.
- Post appropriate warning signs or labels near laser setups or rooms.
- Use a laser sign with a lightbox if operating Class 3R or 4 lasers (i.e., lasers requiring the use of a safety interlock).
- Do not use Laser Viewing Cards in place of a proper Beam Trap.

Laser Classification

Lasers are categorized into different classes according to their ability to cause eye and other damage. The International Electrotechnical Commission (IEC) is a global organization that prepares and publishes international standards for all electrical, electronic, and related technologies. The IEC document 60825-1 outlines the safety of laser products. A description of each class of laser is given below:

Class	Description	Warning Label
1	This class of laser is safe under all conditions of normal use, including use with optical instruments for intrabeam viewing. Lasers in this class do not emit radiation at levels that may cause injury during normal operation, and therefore the maximum permissible exposure (MPE) cannot be exceeded. Class 1 lasers can also include enclosed, high-power lasers where exposure to the radiation is not possible without opening or shutting down the laser.	
1M	Class 1M lasers are safe except when used in conjunction with optical components such as telescopes and microscopes. Lasers belonging to this class emit large-diameter or divergent beams, and the MPE cannot normally be exceeded unless focusing or imaging optics are used to narrow the beam. However, if the beam is refocused, the hazard may be increased and the class may be changed	

	accordingly.	
2	Class 2 lasers, which are limited to 1 mW of visible continuous-wave radiation, are safe because the blink reflex will limit the exposure in the eye to 0.25 seconds. This category only applies to visible radiation (400 - 700 nm).	
2M	Because of the blink reflex, this class of laser is classified as safe as long as the beam is not viewed through optical instruments. This laser class also applies to larger-diameter or diverging laser beams.	
3R	Class 3R lasers produce visible and invisible light that is hazardous under direct and specular-reflection viewing conditions. Eye injuries may occur if you directly view the beam, especially when using optical instruments. Lasers in this class are considered safe as long as they are handled with restricted beam viewing. The MPE can be exceeded with this class of laser; however, this presents a low risk level to injury. Visible, continuous-wave lasers in this class are limited to 5 mW of output power.	
3B	Class 3B lasers are hazardous to the eye if exposed directly. Diffuse reflections are usually not harmful, but may be when using higher-power Class 3B lasers. Safe handling of devices in this class includes wearing protective eyewear where direct viewing of the laser beam may occur. Lasers of this class must be equipped with a key switch and a safety interlock; moreover, laser safety signs should be used, such that the laser cannot be used without the safety light turning on. Laser products with power output near the upper range of Class 3B may also cause skin burns.	
4	This class of laser may cause damage to the skin, and also to the eye, even from the viewing of diffuse reflections. These hazards may also apply to indirect or non-specular reflections of the beam, even from apparently matte surfaces. Great care must be taken when handling these lasers. They also represent a fire risk, because they may ignite combustible material. Class 4 lasers must be equipped with a key switch and a safety interlock.	
All class 2 lasers (and higher) must display, in addition to the corresponding sign above, this triangular warning sign.		

PULSE CALCULATIONS

Pulsed Laser Emission: Power and Energy Calculations

Determining whether emission from a pulsed laser is compatible with a device or application can require referencing parameters that are not supplied by the laser's manufacturer. When this is the case, the necessary parameters can typically be calculated from the available information. Calculating peak pulse power, average power, pulse energy, and related parameters can be necessary to achieve desired outcomes including:

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- Protecting biological samples from harm.
- Measuring the pulsed laser emission without damaging photodetectors and other sensors.
- Exciting fluorescence and non-linear effects in materials.

Pulsed laser radiation parameters are illustrated in Figure 1 and described in the table. For quick reference, a list of equations is provided below. The document available for download provides this information, as well as an introduction to pulsed laser emission, an overview of relationships among the different parameters, and guidance for applying the calculations.

Equations:

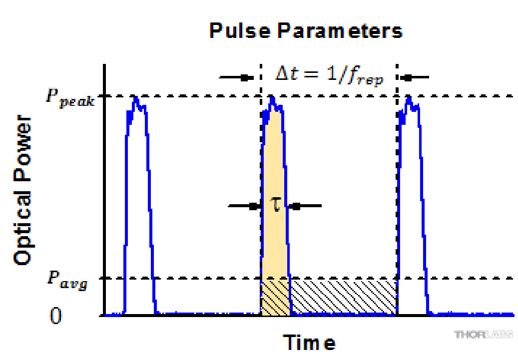
***Period* and *repetition rate* are reciprocal:** $\Delta t = \frac{1}{f_{rep}}$ and $f_{rep} = \frac{1}{\Delta t}$

***Pulse energy* calculated from *average power*:** $E = \frac{P_{avg}}{f_{rep}} = P_{avg} \cdot \Delta t$

***Average power* calculated from *pulse energy*:** $P_{avg} = \frac{E}{\Delta t} = E \cdot f_{rep}$

***Peak pulse power* estimated from *pulse energy*:** $P_{peak} \approx \frac{E}{\tau}$

***Peak power* and *average power* calculated from each other:**



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$$P_{peak} = \frac{P_{avg}}{f_{rep} \cdot \tau} = \frac{P_{avg} \cdot \Delta t}{\tau}$$ and $$P_{avg} = P_{peak} \cdot f_{rep} \cdot \tau = \frac{P_{peak} \cdot \tau}{\Delta t}$$

***Peak power* calculated from *average power* and *duty cycle**:**

$$P_{peak} = \frac{P_{avg}}{\tau/\Delta t} = \frac{P_{avg}}{duty\ cycle}$$

*Duty cycle ($\tau/\ \Delta t$) is the fraction of time during which there is laser pulse emission.

Figure 1: Parameters used to describe pulsed laser emission are indicated in the plot (above) and described in the table (below). **Pulse energy** (**E**) is the shaded area under the pulse curve. Pulse energy is, equivalently, the area of the diagonally hashed region.

Parameter	Symbol	Units	Description
Pulse Energy	**E**	Joules [J]	A measure of one pulse's total emission, which is the only light emitted by the laser over the entire period. The pulse energy equals the shaded area, which is equivalent to the area covered by diagonal hash marks.
Period	**Δt**	Seconds [s]	The amount of time between the start of one pulse and the start of the next.
Average Power	$\mathbf{P_{avg}}$	Watts [W]	The height on the optical power axis, if the energy emitted by the pulse were uniformly spread over the entire period.
Instantaneous Power	**P**	Watts [W]	The optical power at a single, specific point in time.
Peak Power	$\mathbf{P_{peak}}$	Watts [W]	The maximum instantaneous optical power output by the laser.
Pulse Width	τ	Seconds [s]	A measure of the time between the beginning and end of the pulse, typically based on the full width half maximum (FWHM) of the pulse shape. Also called **pulse duration**.
Repetition Rate	$\mathbf{f_{rep}}$	Hertz [Hz]	The frequency with which pulses are emitted. Equal to the reciprocal of the period.

Example Calculation:

Is it safe to use a detector with a specified maximum peak optical input power of **75 mW** to measure the following pulsed laser emission?

- Average Power: 1 mW
- Repetition Rate: 85 MHz
- Pulse Width: 10 fs

The energy per pulse:

$$E = \frac{P_{avg}}{f_{rep}} = \frac{1\ mW}{85\ MHz} = \frac{1\ x\ 10^{-3} W}{85\ x\ 10^{6} Hz} = 1.18\ x\ 10^{-11} J = 11.8\ pJ$$

seems low, but the peak pulse power is:

$$P_{peak} = \frac{P_{avg}}{f_{rep} \cdot \tau} = \frac{1\ mW}{85\ MHz\ \cdot 10\ fs} = 1.18\ x\ 10^{3}\ W = \mathbf{1.18\ kW}$$

It is ***not safe*** to use the detector to measure this pulsed laser emission, since the peak power of the pulses is >5 orders of magnitude higher than the detector's maximum peak optical input power.

Part Number	Description	Price	Availability
OCTAVIUS-85M-HP	Ti:Sapphire Laser, <8 fs Pulses, >200 nm Bandwidth, >600 mW Average Output	$0.00	Lead Time