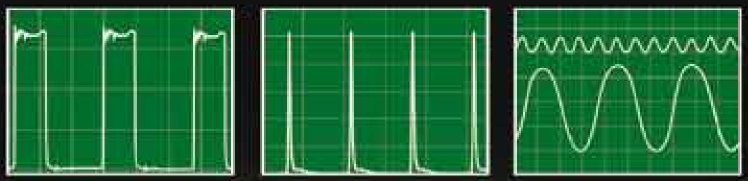
PicoQuant

Diode Lasers

Flexible turn-key solutions for pulsed, switched and modulated output



A Family of Diode Lasers

Compact turn-key diode laser solutions

All PicoQuant laser products are based on small, compact and reliable laser diodes. Sophisticated driving electronics provide various output patterns of the laser emission that can be used for numerous applications ranging from fundamental research to daily routine applications.

Lasers have become a fundamental tool in today's research. They are available in many different types, sizes and operational modes. However, many laser types are bulky or expensive or require frequent maintenance, which make them unattractive for daily operation. In order to put the focus on the application rather than on the experimental set-up, PicoQuant's philosophy is to provide a wide range of affordable compact turn-key laser solutions that can be operated without special knowledge and without the need for cumbersome alignment procedures.

LDH-FA Series

- picosecond pulsed operation with optical amplification and frequency conversion
- 266 nm to 1530 nm

LDH Series

- picosecond pulsed and cw operation
- nanosecond pulsed
- modulated output
- 375 nm to 1990 nm

PLS Series

- picosecond pulsed LEDs
- 245 nm to 600 nm

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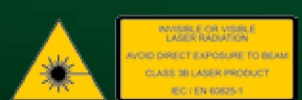
Detailed specifications can be found on our website www.picoquant.com/_lightsources.htm



MDL 300

- driver for modulated output
- up to 1.8 GHz modulation frequency

FSL 500

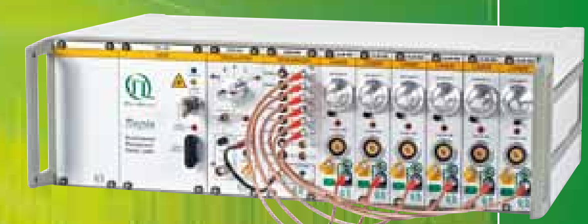
- driver for nanosecond pulses
- variable pulse width

PDL 800-B/D

- driver for picosecond pulses
- up to 80 MHz repetition rate

PDL 808 "Sepia I"

- driver for picosecond pulses
- manual control for up to 6 laser/LED heads



PDL 828 "Sepia II"

- driver for picosecond pulses
- computer control for up to 8 laser/ LED heads

Diode Lasers

Diode Lasers

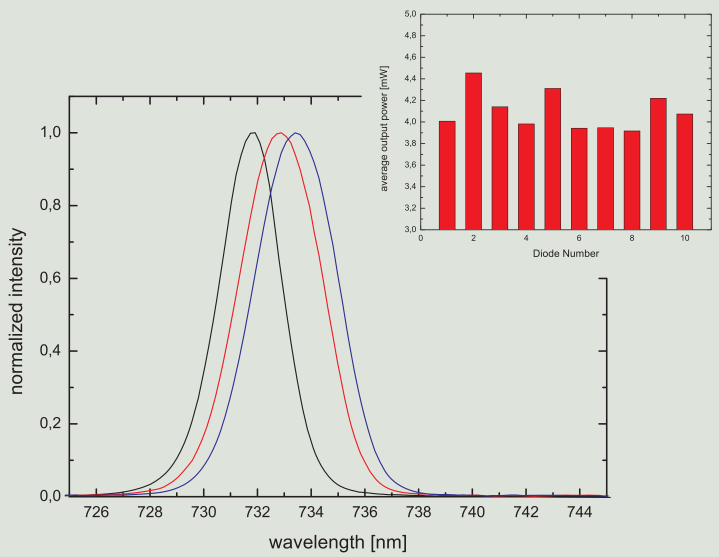
Common features

All PicoQuant lasers are based on laser diodes, which are small and compact semiconductor units. They are packaged in different housing types, depending on the target system. The emission of laser light from these diodes is initiated by applying electric current. By varying the current using sophisticated, proprietary driving electronics, various emission patterns can be created that are used for diverse applications ranging from the excitation of a fluorophore to detector testing and quantum optics.

Unique laser diodes

A general characteristic of laser diodes is their uniqueness. Although laser diodes are usually manufactured in great numbers in one process, every laser diode is slightly different in comparison to another unit of the same batch. As a consequence, the emission properties such as central wavelength, shortest pulse width or achievable output power does slightly vary from diode to diode. This variation enables a very high flexibility for selecting the best suited diode for a specific application. On the other hand, it also means that it is extremely difficult to manufacture two lasers with exactly the same specifications. Nonetheless, these small variations are not critical for most of the applications where diode lasers are used.

Example of an often used laser diode type in a TO package.



Laser diodes are unique in their emission properties, which for example can be seen in the variation of the laser diodes' central emission wavelength of the same type. Another indicator is the maximum achievable output power in pulsed mode as shown in the inset for 10 randomly picked diodes of the same type.

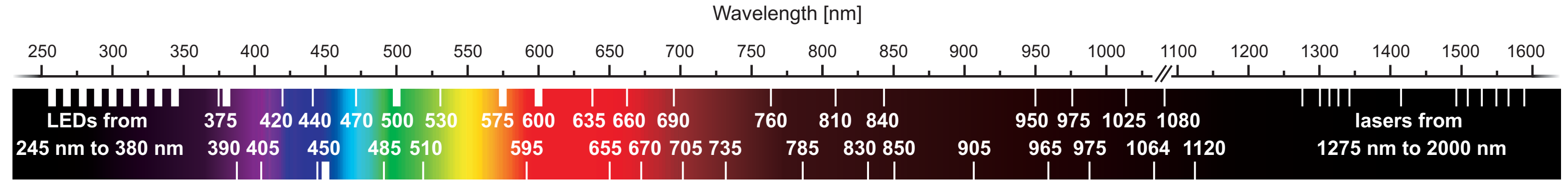
All PicoQuant laser systems are designed as a combination of two basic components: the driver and the laser head.

Turn-key systems

All PicoQuant laser systems are designed as turn-key systems, which are reliable and very easy to use. The systems always consist of two basic components: the driver and the laser head.

Each laser head includes specialized and individually balanced control electronics in order to ensure maximum performance and protection for the laser diode used. They are designed as compact units with little or no user adjustable parts. There is also no need for cumbersome beam alignment.

The drivers are designed as a universal unit that can control all laser heads of the same series. There are specialized drivers for picosecond pulses, modulated output and fast switched rectangular pulses (nanoseconds). Wavelength changes are simple and only require to change the corresponding laser head.



Wavelengths from UV to NIR

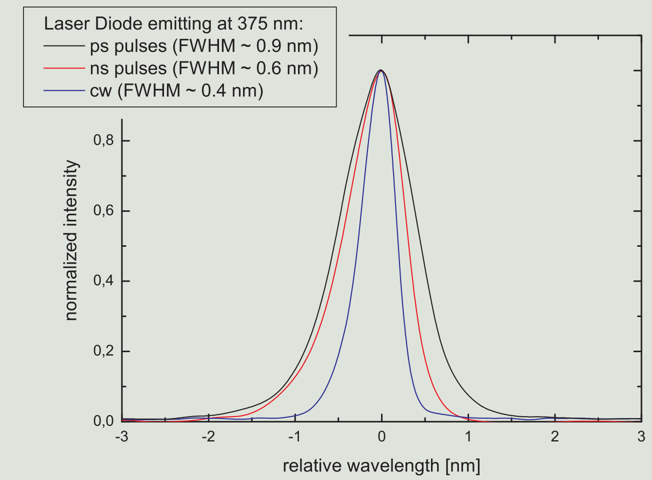
Diode lasers are available at many different wavelengths ranging from the ultraviolet (UV) to the near-infrared (NIR). In the UV, blue and green, laser heads can be provided at several different wavelengths between 375 nm and 510 nm. In the red and near-infrared spectral range even more individual wavelengths are available, which sum up to currently more than 40 different laser heads. However, one notable gap in the spectrum that is not yet covered by laser diodes is the green/yellow range between 510 nm and 635 nm. One possibility to fill this gap is to use frequency conversion techniques of amplified diode lasers, which gives access to wavelengths like 532 nm and 596 nm. The other alternative is to use LEDs instead of lasers. Although their output power is lower and they do not have the superior beam characteristics of lasers, they are suited for many different applications. Furthermore, LEDs are the only available light sources today that emit directly in the deep UV at wavelengths down to 245 nm.

Fixed emission wavelength

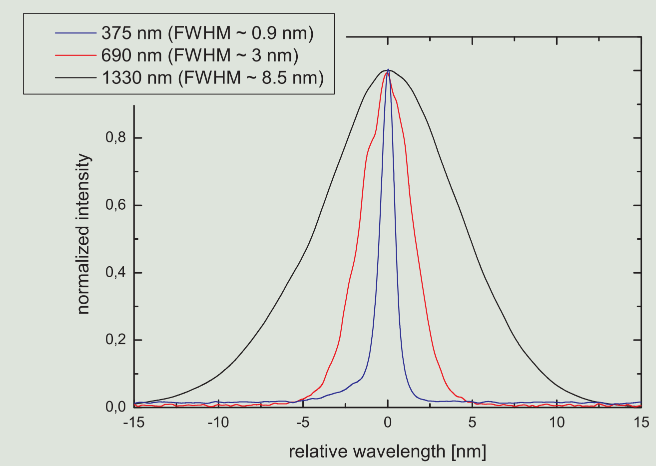
All diode lasers as well as LEDs have a fixed emission wavelength, which can vary by a maximum of ± 10 nm between two diodes of the same type as a result of their uniqueness. The emission wavelength can be tuned to a small degree by changing the operation temperature of the diode. However, typical values are only in the order of 0.2 nm per Kelvin. In some cases the emission wavelength also shifts slightly with increasing laser power.

Spectral width down to 1 nm

The spectral width of the emission depends on the emission wavelength of the diode as well as on the operation mode. In general, the spectral width increases with increasing emission wavelength and decreases with increasing pulse width. In picosecond pulsed mode, typical values are around 1 nm (FWHM) in the UV and up to 20 nm in the NIR. For nanosecond pulses and continuous wave operation, the spectral width is slightly smaller.
There are also special laser diodes available (DFB, DBR) that have a very small spectral width of typically less than 0.3 nm. This small spectral width is achieved by a grating included in the diode structure. As a side effect, this grating also leads to only small variations in the central wavelength for diodes of the same type.



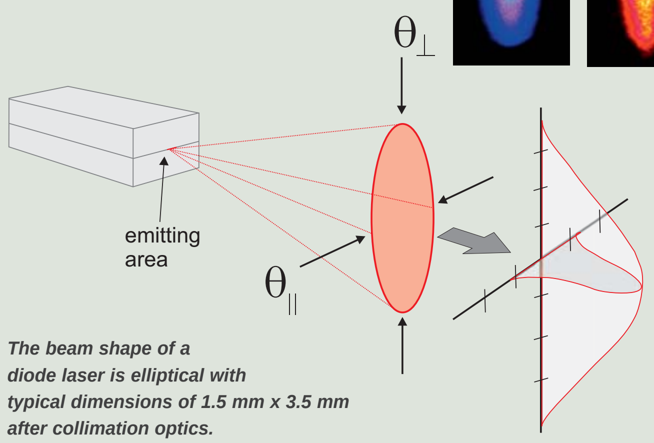
The spectral width of the emission depends on the operation mode. A decreasing pulse width generally leads to a broader spectral profile. The different pulse profiles in the plot are generated using the same type of laser diode, but different driving electronics (PDL 800-B for picosecond pulses, FSL 500 for nanosecond pulses and PDL 800-D for cw operation) along with the corresponding laser heads.



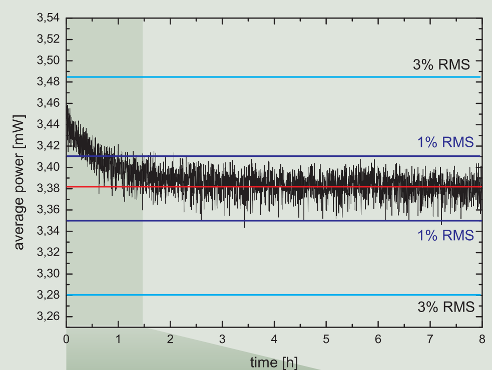
The spectral width of the emission depends on the emission wavelength. In general, an increasing wavelength leads to a broader spectral profile. The different pulse profiles in the plot correspond to the emission of the picosecond pulsed laser heads of the LDH-P/D Series.

Diode Lasers

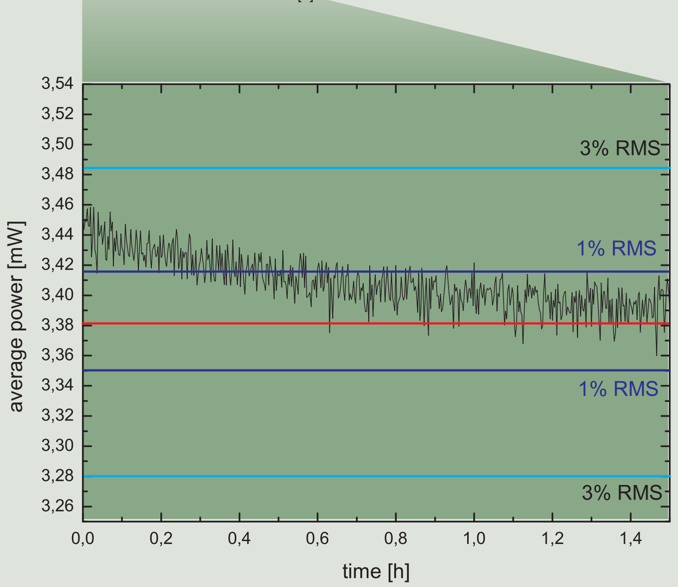
Common features




The beam shape of a diode laser is elliptical with typical dimensions of 1.5 mm x 3.5 mm after collimation optics.



The output power stability of the laser emission is very high with only 1 % rms for cooled laser heads. Nonetheless, all laser heads need a few minutes to reach their stable working conditions.



Elliptical beam shape

All laser heads emit a collimated beam with an elliptical beam shape of typical dimensions of 1.5 mm x 3.5 mm. This elliptical beam is due to several factors. One reason is the shape of the emitting aperture of the edge emitting laser diode end facet which is highly elongated rather than circular. A second cause for the elliptical beam shape is the divergence of the laser beam, which is different for the two axis: the horizontal (slow) axis of the emitting aperture ($\theta_{||}$) has a rather small divergence of typically 0.11 mrad with collimation optics, whereas the vertical (fast) axis ($\theta_{\perp}$) has a larger divergence of typical 0.32 mrad. A third reason is astigmatism of the beam with some µm length that can hardly be corrected by compact optics.

Polarization extinction ratio greater 90 %

The output beam is linear polarized with a polarization extinction ratio greater than 90 % - the polarization direction is in most cases in the slow axis. The polarization extinction ratio is lower close to the laser threshold and generally increases with increasing laser output power.

High power stability

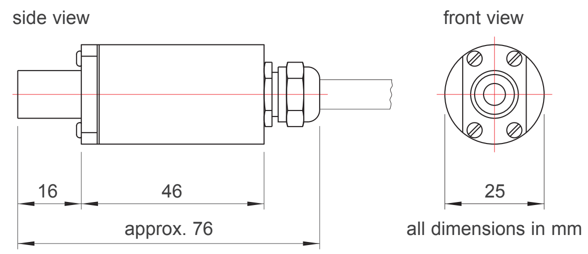
The power stability of the laser emission does mainly depend on the diode temperature. If the temperature is constant, which can e.g. be achieved by using a laser head with integrated temperature control, the output power fluctuations within 12 hours are less than 1 % rms or 3 % peak to peak. For uncooled laser heads the output power fluctuations are slightly higher, but still low at around 3 % rms. After switching on the lasers, all laser heads need several minutes to reach their stable operating conditions. However, these slight changes in output power are usually no problem at all for the majority of applications.

Compact laser heads

The laser heads are designed as compact and robust units. They are typically equipped with a thermoelectric cooler to stabilize the output. Picosecond pulsed diode lasers without amplification and with wave-lengths greater than 635 nm can also be supplied without the cooler in an even more compact housing. All cooled laser heads have several threaded holes to mount the laser heads in the experimental set-up.

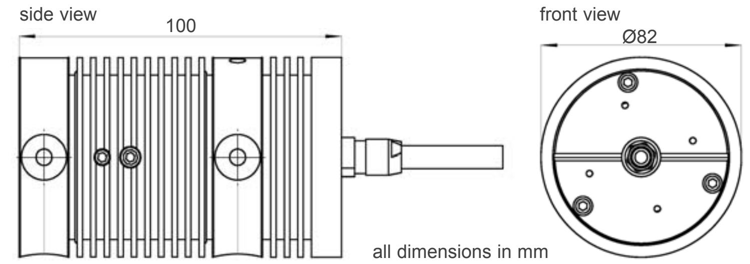
Design of the uncooled laser heads

The uncooled laser heads are very compact units with only 25 mm outer diameter. They are only available for picosecond pulsed laser heads with wavelengths greater than 630 nm.



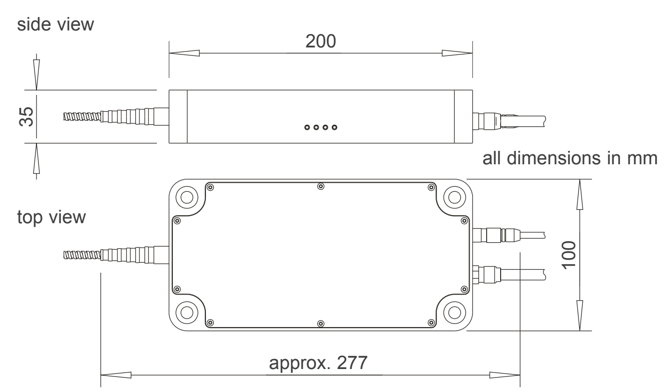
Design of the cooled laser heads

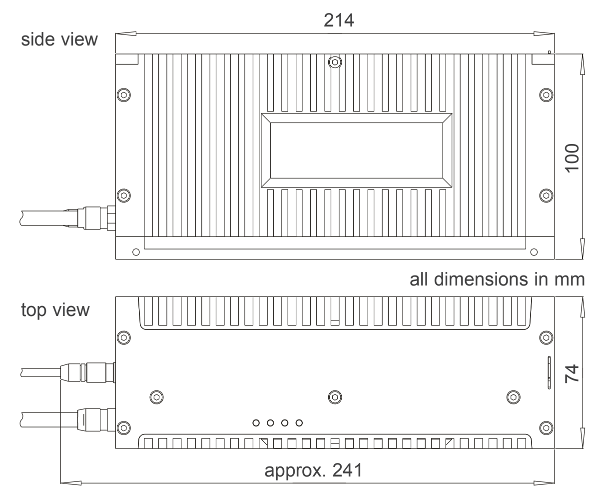
The thermoelectric cooled laser heads are the standard laser heads for all picosecond pulsed, modulated or fast switched laser systems. They are slightly larger than the uncooled laser heads but still very compact.



Design of the LDH-FA laser heads

The LDH-FA Series laser heads have two designs: one version that always emits from a polarization maintaining single mode fiber and a second, slightly larger version that emits a collimated beam.






Diode Lasers

Fiber coupling

All laser heads of the LDH Series emit a collimated beam that can be used for many different applications. As an alternative to the collimated output, all lasers can also be coupled to optical fibers, which enhances their flexibility but also has an influence on the beam characteristics. Just as the standard laser heads, fiber coupled laser heads are easy to use and do usually not need any realignment.

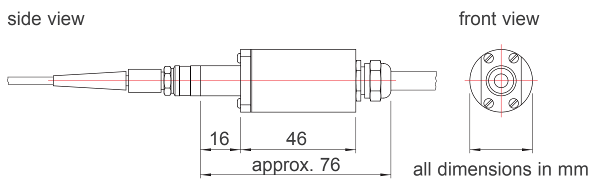
Fiber coupler directly mounted

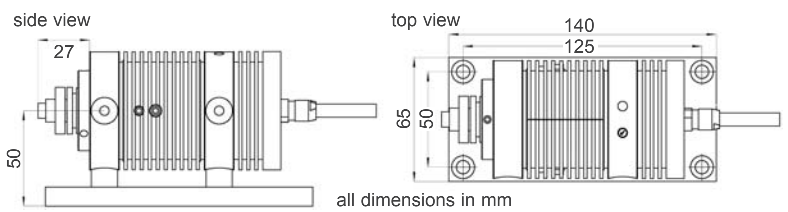
Fiber coupling of the laser heads is achieved by adding suited coupling optics as well as a corresponding fiber. The fiber coupler is always directly mounted to the laser head and is available in different versions, optimized for the emission wavelength range of the corresponding laser head as well as adapted to the individual mechanical design. The output connector of these fiber couplers is usually angled by 8 degrees in order to avoid backreflections of laser emission into the laser head, which can influence the laser stability and lead to distortions in the output.
Depending on the desired output qualities of the laser beam, different fiber types can be attached to the fiber coupler. Available fiber types are multi mode fibers, single mode fibers as well as polarization maintaining single mode fibers. They can be supplied with different lengths as well as optimized for different wavelength ranges.

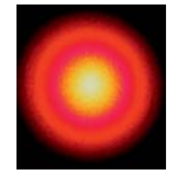
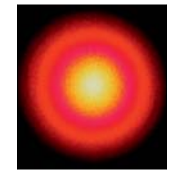
Altered emission properties

Coupling the beam into an optical fiber always alters the emission properties of the laser beam. Typically single mode fibers are used, because they transform the elliptical beam shape into a diffraction limited gaussian beam shape. However, there are also other beam characteristics that are influenced by an optical fiber such as

- polarization – depending on the type of fiber, the linear polarization of the laser emission is either preserved or scrambled
- interference – in case of multi mode fibers, interference between the different modes in the fiber lead to a speckle pattern, which is sensitive to movements of the fiber
- output power – coupling the laser emission into an optical fiber always leads to a reduced output at the end of the fiber. The coupling efficiency is typically higher than 40 % and may reach more than 80 % for a multi mode fiber.





Fiber type	Multi mode	Single mode	Polarisation maintaining
Beam shape	"Top hat profile" with speckles	Gaussian	Gaussian
			
Polarisation	scrambled	partly scrambled	linear
Typical coupling efficiency	> 80 %	> 40 %	> 40 %

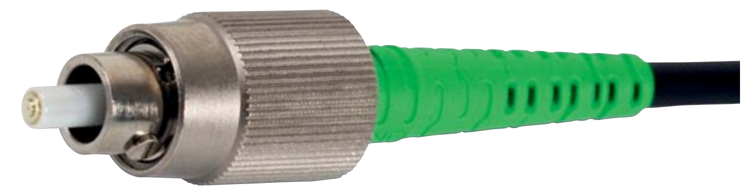
Summary of the most prominent influences of fiber coupling using different fiber types.

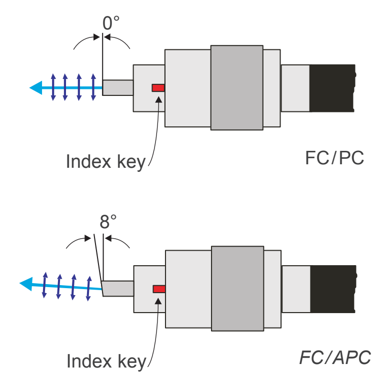
The output at the end of a fiber is also no longer collimated, but divergent. It can be recollimated with a suited fiber collimator. Depending on the type of lens used in these special collimators, different beam diameters can be achieved.

Different connector types

For most applications, a Ferrule Connector (FC) is used. These connectors have a floating ferrule with index key that provides good mechanical isolation. They are available in two versions: either with a flat output end as FC/PC (Physical Contact) connectors or with an 8° angled output as FC/APC (Angled Physical Contact) connectors. For the majority of applications an angled FC/APC connector is recommended to prevent backreflections into the fiber that could interfere with the laser stability. FC connectors have a fiber index key that locks the fiber into a defined position and prevents a possible rotation of the fiber inside the connector. Especially for polarization maintaining single mode fibers, this is of crucial importance.

For multi mode fibers also SMA connectors are available. Compared to FC connectors they have a lower mechanical stability as no fiber index key holds the fiber into a fixed position. As a consequence they have a lower positioning accuracy and are thus not recommended for the majority of applications.

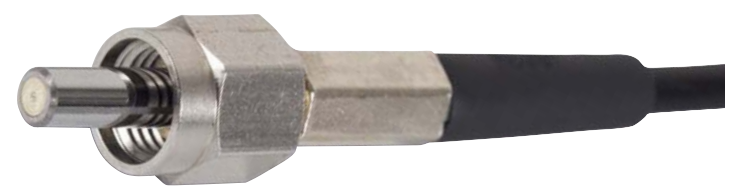


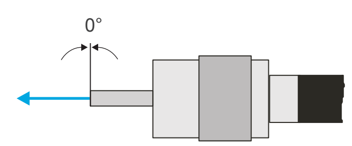


FC/PC or FC/APC connectors have an index key that locks the fiber into position, which leads to a high mechanical stability. In contrast to FC/PC connectors, FC/APC connectors have an angled output to prevent backreflections.

Pre-aligned and optimized

All fiber coupled laser heads are pre-aligned to maximum performance before delivery. Although fiber as well as fiber coupler can be unmounted from the laser head, this is not recommended at all, as a remounting of the fiber always requires a realignment of the coupling. Especially for single mode fibers, which have a core diameter of only a few micrometer, this is a demanding task that requires great experience.





Compared to FC/PC connectors, SMA connectors do not have an index key that locks the fiber into position. As a consequence, their mechanical stability is lower compared to FC/PC connectors.

LDH-P/D Series

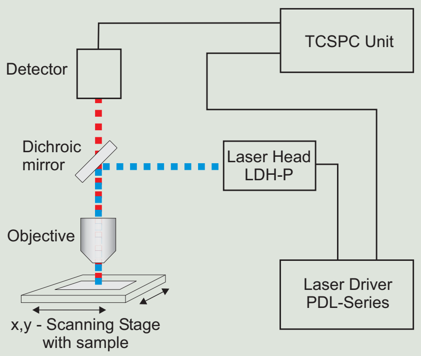
Picosecond pulsed diode laser heads

The picosecond pulsed diode lasers of the LDH-P Series are compact, easy to use and need no alignment of the beam at all. They can be pulsed at repetition rates up to 80 MHz and deliver pulse widths below 100 ps at average pulse powers in the lower milliwatt range. A special version, the LDH-D Series works in continuous-wave (cw) as well as in picosecond pulsed mode.

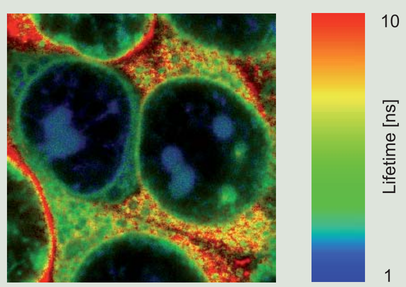
The laser heads of the LDH-P/D Series are the ideal product for all applications that require picosecond pulses at a variable repetition rate. They are build around a variety of different diode types, which allows to offer these heads at many wavelengths with different power values and spectral widths. Typical diode types like Fabry-Perot (FP), Distributed Feedback (DFB) or Distributed Bragg Reflector (DBR) are used. Each laser head contains additional special driving electronics that are matched to the individual diode.

Application Examples

Fluorescence Lifetime Imaging (FLIM)



Sketch of a basic set-up for Fluorescence Lifetime Imaging (FLIM). In FLIM the sample is scanned and the fluorescence lifetime is measured at each image point (pixel) and displayed in a false color scheme. The ideal technique to measure the fluorescence lifetime is Time-Correlated Single Photon Counting (TCSPC). For this technique it is essential to have a short pulsed laser with variable repetition rate – conditions that are ideally matched by the diode lasers of the LDH-P Series.



FLIM image of macrophage cells incubated with CdSe/ZnS quantum dots ot two size. The sample was excited by a laser of the LDH-P Series at 70 nm and the fluorescence lifetime image was acquired using the time-resolved confocal microscope MicroTime 200 from PicoQuant. Image courtesy of Yury Rakovich, CSIC Material Physics Centre, Spain.

Gain switching

Gain switching generally means that the laser diode is stimulated by injecting a large number of carriers into its active region. As long as the carrier density is below the laser threshold, only spectrally broad spontaneous emission can be seen. When the carrier density exceeds the laser threshold a relaxation occurs in form of one or more short optical pulses.

All laser heads are gain switched by a well dosed amount of charge injected to the active region within a very short time. This permits to generate picosecond pulses with a minimum of decay, ringing or background after the pulse.

Adjustable output power

By varying the total number of carriers (i.e. the charge injected) in the diode it is possible to change the energy of a single pulse and subsequently the average power. However, a higher pulse power, i.e. a higher injected current leads to additional oscillations inside the laser diode. These oscillations can be seen as additional peaks or shoulders in the temporal pulse profile. As a consequence, an increased output power of the diode always results in an increased pulse width and a non-uniform temporal pulse shape. "Clean" and near symmetrical pulses are therefore best achieved close to the lasing threshold.

All functions of the laser heads such as repetition rate and output power are controlled and adjusted by any driver of the PDL Series. The laser heads are simply connected to the driver and no further adjustment is needed.

Pulse widths below 100 ps

All laser heads emit picosecond pulses with a full width at half maximum (FWHM) around 100 ps or below at the "low power level", which is short above the lasing threshold. For some laser heads even pulse widths down to 50 ps are possible. The pulse width itself cannot be controlled directly, but does depend on the selected power level (i.e. driving current) of the laser head. At maximum driving current ("high power level"), the pulse width is broadened due to shoulders or additional peaks.

KEY FEATURES

- *available at wavelengths between 375 nm to 1990 nm*
- *pulse width down to 50 ps*
- *adjustable (average) power up to 20 mW*
- *repetition rate from single shot to 80 MHz*
- *picosecond pulsed and cw operation*

Average power of several milliwatts

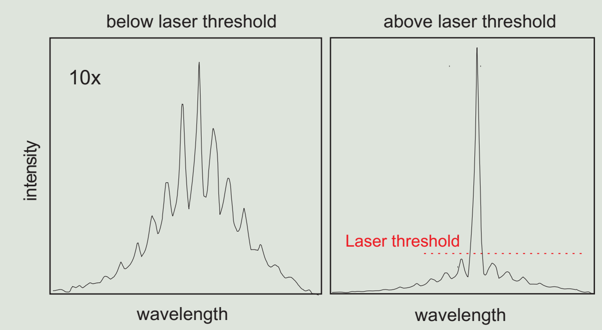
All laser heads are designed to emit an about constant pulse energy at a given intensity setting. Doubling the repetition rate therefore effectively doubles the average output power. This relation strictly holds at low repetition rates, whereas at high repetition rates the effective average output power may be decreased due to saturation effects. The achievable pulse energies are typically in the order of several tens of picojoule, which corresponds to maximum average output powers of several milliwatts at 80 MHz repetition rate.

Repetition rates up to 80 MHz

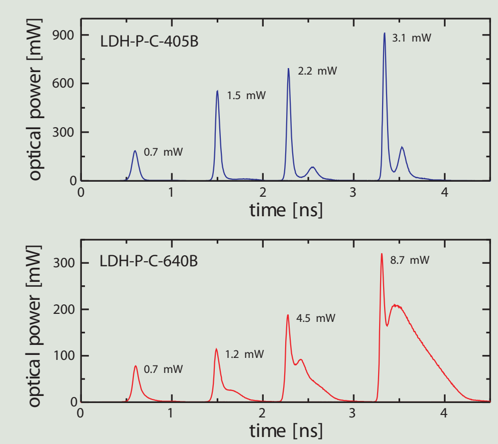
All laser heads are designed to work at repetition rates from single shot up to values in the MHz range. The maximum repetition rate for all laser heads is typically 80 MHz. For some laser heads it is, however, necessary to reduce the repetition rates to ensure their lifetime. Driving signals with repetition rates in the MHz range are readily delivered by the PDL Series drivers.

Pulsed and cw operation

As a special type, the laser heads of the LDH-D Series can be operated in pulsed and cw mode. In cw operation, they can emit up to 400 mW of output power for selected diodes, while in pulsed mode their performance is not different to the corresponding laser heads of the LDH-P Series. This dual mode operation is only supported by the PDL 800-D and the PDL 828 "Sepia II" drivers.



The picosecond pulses are generated by gain switching, which involves sending a short current pulse into the laser diode. Below the lasing threshold only spectrally broad spontaneous emission can be seen. Only above the lasing threshold, a short laser pulse is emitted. However, the spontaneous emission is still present in the output to a small extend and can be removed by suited laser clean-up filter.



Typical pulse profiles of "blue" and "red" laser heads of the LDH-P Series. The upper image shows the emission of a LDH-P-C-405B laser head and the lower image of a LDH-P-C-640B laser head. The different curves are generated by changing the driving current to the laser diode using the corresponding settings of the driver of the PDL Series.

LDH-FA Series

Amplified picosecond diode laser heads

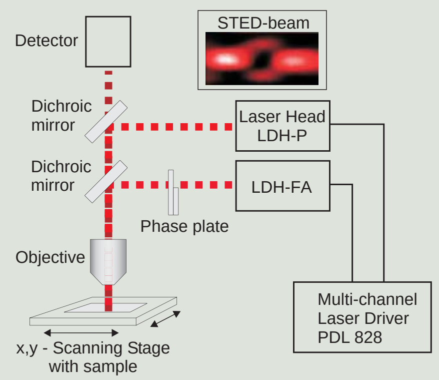
The LDH-FA Series are amplified picosecond diode lasers that work at variable repetition rates up to 80 MHz. The high output power of the amplified lasers allow efficient frequency conversion yielding ultraviolet, green, yellow or red laser emission.

KEY FEATURES

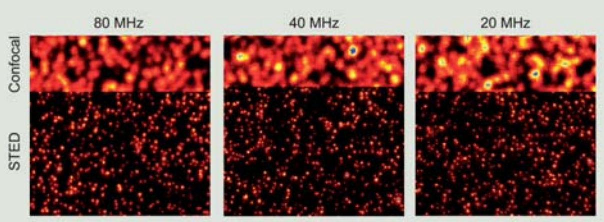
- *available at wavelengths between 266 nm and 1530 nm*
- *pulse width < 100 ps*
- *adjustable (average) power up to 1 W*
- *repetition rate up to 80 MHz*
- *collimated or fiber-coupled output*

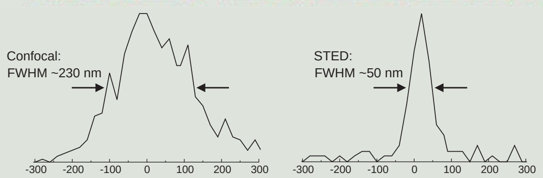
Application Examples

Stimulated Emission Depletion Microscopy (STED)



Sketch of a basic set-up for Stimulated Emission Depletion Microscopy (STED), a technique that allows to break the Abbe limit of diffraction. The fundamental principle behind STED is the saturation of an optical transition, which "inhibits" (quenches) the fluorescence in that area. The high power beam is formed into a "doughnut" shape using special designed phase plates. As a consequence only fluorescence from the center can be detected and high optical resolutions can be achieved.





Comparison between confocal and STED images of Crimson beads (20 nm diameter). The beads were excited using the LDH-P-C-640B, the LDH-P-FA-765 was used as the STED laser at different repetition rates. The upper part of the images shows the beads imaged with a standard confocal set-up, whereas the lower part shows the STED images of the same sample region. The resolution enhancement is clearly visible in the plotted crossections through one bead, with the STED images reaching a spatial resolution of approx. 50 nm. Images courtesy of A. Honigmann, C. Eggeling and S.W. Hell, MPI Göttingen

The LDH-FA Series laser heads are the lasers of choice for applications that require high laser power at variable repetition rates in the infrared. They also allow to use efficient wavelength conversion techniques of infrared emission, making it the only known semiconductor lasers commercially available that deliver picosecond pulses in the ultraviolet, green or yellow spectral range at variable repetition rates in the MHz range.

Based on a MOFA concept

The picosecond pulsed laser diode heads of the LDH-FA Series are based on a Master Oscillator Fiber Amplifier (MOFA) concept with optional frequency conversion. The master oscillator generates infrared picosecond pulses with variable repetition rates up to 80 MHz using the proven gain-switching techniques of the LDH-P Series laser heads. The output of this seed laser is directly connected to a single or double stage fiber amplifier, which boosts the output from the seed laser by several 10 dB while maintaining the other characteristics of the seed laser beam like e.g. the emission wavelength, polarization and the short pulse width.

Conversion to UV, green, yellow or red

The high pulse energies of the amplified infrared lasers permit an efficient wavelength conversion using, for example, single pass second harmonic generation (SHG) or fourth harmonic generation (FHG). In that way it is for the first time possible to generate picosecond pulses at 266 nm, 531 nm or 766 nm with adjustable repetition rates up to 80 MHz. A sum frequency generation technique even permits to generate yellow laser emission at 596 nm, which is currently not available from a direct emitting laser diode.

All functions of the LDH-FA Series laser heads such as repetition rate and output power are controlled and adjusted by any driver of the PDL Series. The laser heads are simply connected to the driver and no further adjustment is needed.

Clean temporal pulse shapes

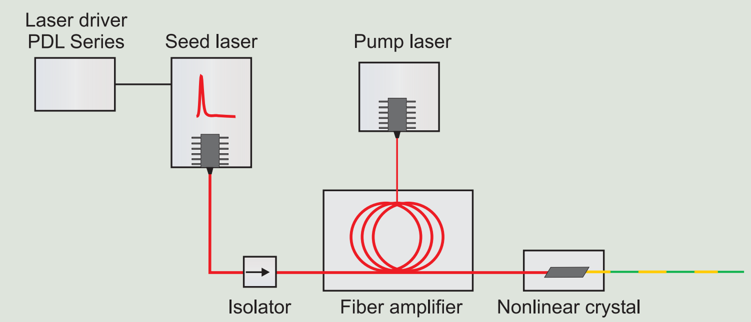
The final pulse widths can be as short as 130 ps (FWHM) for the yellow laser head and even < 100 ps (FWHM) for the infrared, red, green and ultraviolet laser heads. In contrast to the laser heads of the LDH-P Series, the green and ultraviolet laser heads show a clean temporal pulse shape independent from the selected power level.

Average power up to 1 W

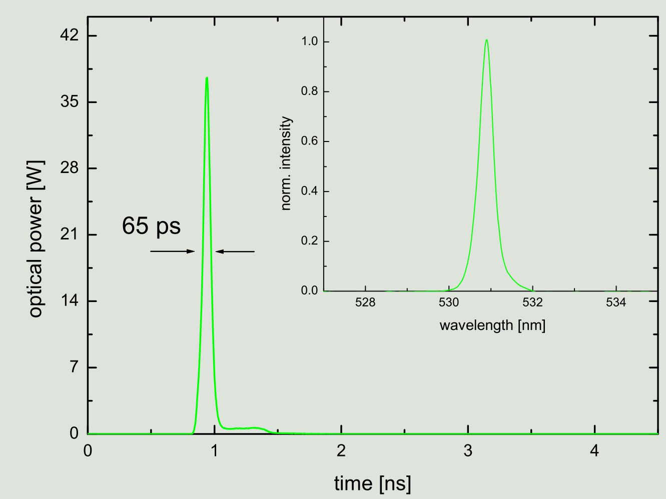
The laser heads are available in two versions that either emit from a polarization maintaining single mode fiber with FC/APC fiber connector or generate a collimated output beam. The fiber coupled versions are available at 596 nm and 531 nm and can generate more than 300 µW (yellow) or up to 6 mW (green) average output power at 80 MHz repetition rate.
The laser heads with collimated output are available at 1532 nm, 1062 nm, 766 nm, 531 nm and 266 nm. The achievable average power levels of these laser heads depend on the number of amplification stages and the efficiency of the optional frequency conversion stage. They reach from 1 mW for the 266 nm laser to 200 mW for the 531 nm laser and more than 1 W for the 1062 nm laser at 80 MHz repetition rate. The output beam of these laser heads typically has a lower ellipticity than the standard diode lasers and the coupling efficiency into single mode fibers is increased to values greater than 50 %.

Repetition rates up to 80 MHz

All laser heads of the LDH-FA Series are designed to work at repetition rates between 1 MHz and 80 MHz. For the low power, all fiber versions, even repetition rates down to 10 kHz are possible, allowing to match repetition rate and thus average output powers to the requirements of the application.



Scheme of the LDH-FA Series laser heads – a picosecond diode laser of the LDH-P Series is used as a seed for a fiber amplifier in a Master Oscillator Fiber Amplifier (MOFA) arrangement. Optionally, a nonlinear crystal is added to alter the emission wavelength.



Typical pulse profile of a high power 531 nm laser (LDH-P-FA-530XL) along with the spectral profile of the emission. The pulse width is considerably shorter than the pulse width of the infrared seed laser. The average output power of this laser reaches 200 mW at 80 MHz repetition rate.

PLS Series

PLS Series

Sub-nanosecond pulsed LEDs

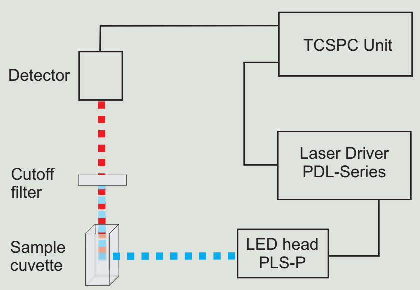
The pulsed LEDs of the PLS Series are the fastest miniature sub-nanosecond pulsed LED sources commercially available. With the LEDs of the PLS Series inefficient flashlamps or bulky frequency-tripled Titanium:Sapphire lasers are no longer necessary for many applications, i.e. for the direct excitation of natural fluorescent amino acids like tyrosine or tryptophan.

KEY FEATURES

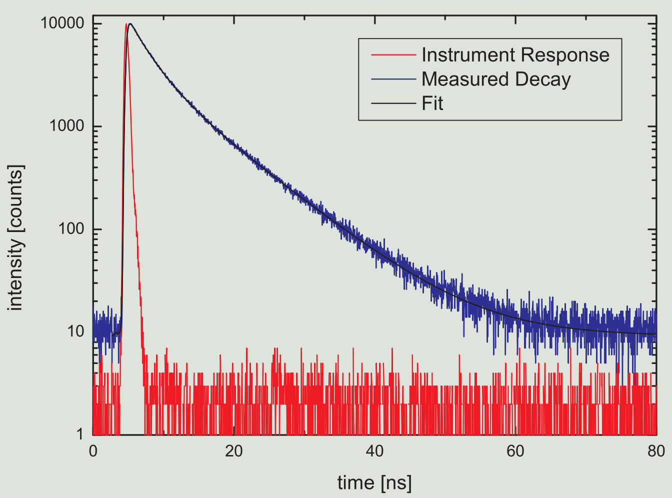
- *available at wavelengths between 245 nm and 600 nm*
- *pulse width down to 500 ps*
- *adjustable (average) power up to 80 μW*
- *repetition rate from single shot to 40 MHz*
- *compact design*

Application Examples

Fluorescence lifetime measurements



Sketch of a basic set-up for fluorescence lifetime measurements. The fluorescence lifetime is ideally measured using Time-Correlated Single Photon Counting (TCSPC). For this technique it is essential to have a short pulsed excitation source with variable repetition rate – conditions that are ideally matched by the pulsed LEDs of the PLS Series or the pulsed lasers of the LDH-P/D Series.



This example shows the fluorescence lifetime measurement of L-Tryptophane in water, excited with the PLS 300 using TCSPC. As can be expected for L-Tryptophane the decay is best described by a triple exponential decay function. The recovered lifetimes are 0.35 ns ± 0.18 ns, 2.65 ns ± 0.1 ns and 7.93 ns ± 0.1 ns.

Current driven LED

As LEDs usually do not have a resonant cavity like laser diodes, the effect of relaxation oscillation cannot be used for the generation of picosecond pulses. The optical output follows almost linearly the carrier density. Thus the minimal achievable pulse width is physically limited to a few hundred picoseconds.
On the other hand no multiple oscillations, as shown by some laser heads, occur at higher power. When changing the pulse energy of a LED, the pulse broadens at most by a factor of two and the pulse shape remains more or less identical.

Non-uniform beam shape

The most important difference between the pulsed LEDs and pulsed diode lasers is the fact that the emission of the LEDs is divergent, not coherent, not polarized and also non-uniform in its intensity distribution. Depending on the LED used, different beam shapes can be seen ranging from near-round to elliptical. Fiber coupling into single mode or multi mode optical fibers has therefore only very low efficiency – a notable exception are large area fibers such as liquid light guides. However, for short range interactions e.g. in a compact time-resolved fluorescence lifetime spectrometer the LEDs of the PLS Series are very useful excitation sources.

All functions of the PLS Series LED heads such as repetition rate and output power are controlled and adjusted by any driver of the PDL Series. The LED heads are simply connected to the driver and no further alignment is needed.

Direct emission in the ultraviolet

The LEDs of the PLS Series are the only available compact pulsed light sources that emit directly in the ultraviolet spectral range at wavelengths as short as 245 nm. Eleven different LEDs with central wavelengths between 245 nm and 340 nm even allow to choose a peak wavelength according to the needs of the application. With repetition rates up to 10 MHz, these UV LEDs are ideal excitation sources for time-resolved spectroscopy.

Pulse widths down to 500 ps

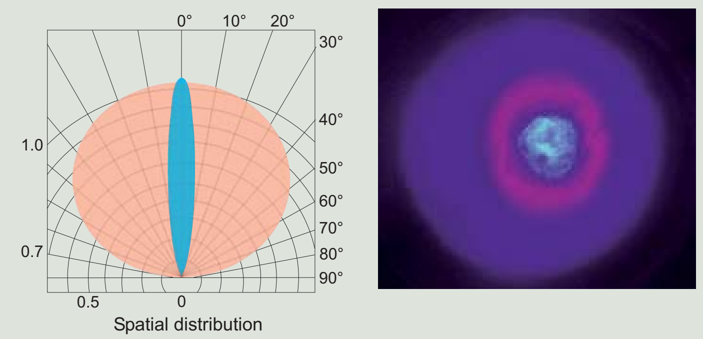
All pulsed LEDs emit picosecond pulses with a full width at half maximum (FWHM) of less than one nanosecond – at some wavelengths even pulse widths down to 500 ps are possible. The pulse width itself cannot be controlled directly, but does depend on the selected power level of the LED. Unlike other pulsed LEDs, the PLS Series features a very high extinction ratio with no pulse tail.

Average power of several microwatts

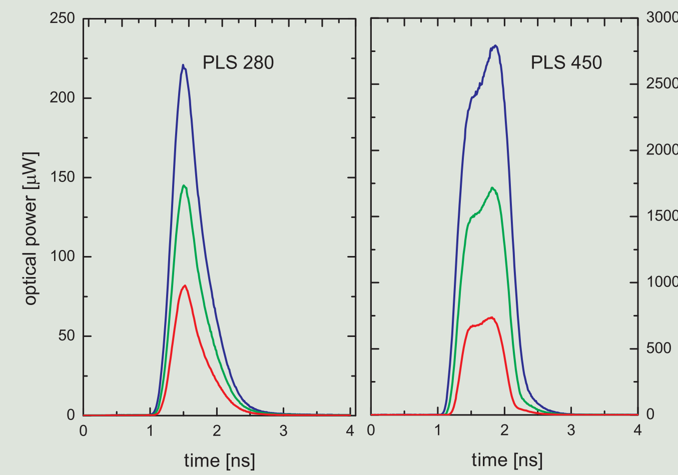
All LED heads are designed to emit an about constant pulse energy at a given intensity setting. Doubling the repetition rate therefore effectively doubles the average output power. The achievable pulse energies of the LEDs in the visible spectrum can reach up to two picojoules, which corresponds to average output powers up to 80 microwatts at 40 MHz repetition rate. For the UV LEDs the achievable pulse energy is lower and typically below 1 picojoule. At their maximum repetition rate of 10 MHz, this corresponds to average output powers around 1 microwatt. Such a relative low power can hardly be visualized, but is still high enough to use these LEDs as efficient fluorescence excitation sources.

Spectral width down to 20 nm

The spectral emission profile of all pulsed LEDs is broader than for pulsed diode lasers. For the UV LEDs the spectral width is smaller than 20 nm, whereas for the LEDs in the visible it may be as large as 50 nm. A further reduction of the spectral width is possible by using suited bandpass filters.



One of the notable differences between pulsed LEDs and pulsed diode lasers is the fact that the emission of the LEDs has a strong divergence. This is illustrated in the left image, which shows a comparison between the typical spatial distribution of the emission of a LED (red) and a diode laser (blue). Clearly, the emission of the LED is far more isotropic than that of the laser diode, which is also shown in the beamprofile of a blue LED on the right.



Typical pulse profiles of "visible" and "UV" LEDs of the PLS Series. The different curves are generated by different intensity settings of the driver of the PDL Series.

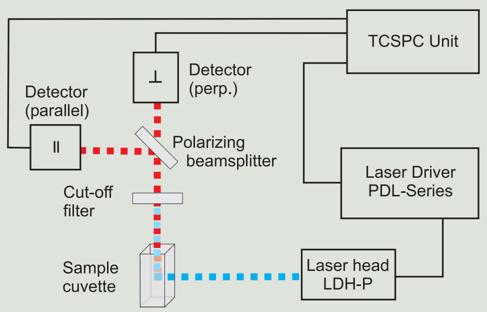
PDL 800-B/D

Single channel picosecond diode laser driver

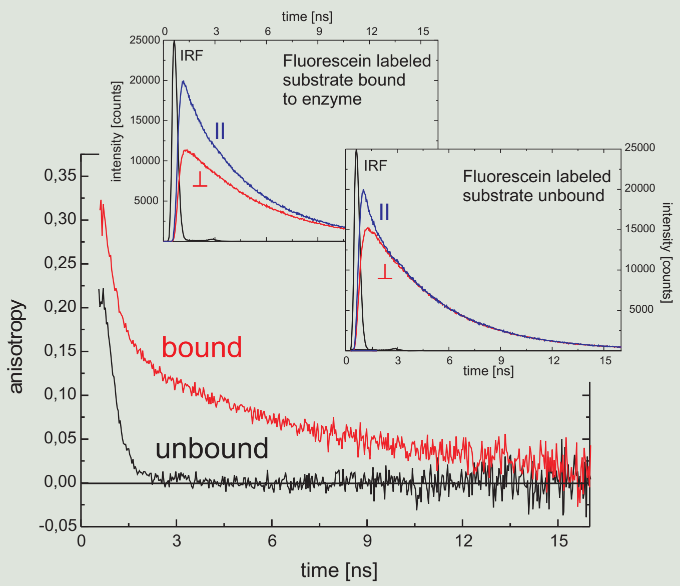
The PDL 800-B/D is the dedicated driver for single wavelength applications. It is designed as a universal driver for all laser heads of the LDH-P/D Series, all pulsed LEDs of the PLS Series as well as for the LDH-FA Series laser heads. The driver can be used without any special training or experience in laser operation. Wavelength changes are simply performed by plugging in a different laser or LED head.

Application Examples

Measurement of fluorescence anisotropy



Sketch of a basic set-up for anisotropy measurements. The anisotropy of a sample describes the spatial distribution of the fluorescence emission and can therefore be used to e.g. gather information about orientation and movement of a sample as well as association/dissociation processes. A typical set-up is based on time-resolved detection of the fluorescence emission in "parallel" and "perpendicular" contribution.



Example of an anisotropy measurement of a fluorescein labeled substrate with and without the presence of a binding enzyme. Upon binding to the enzyme, the mobility of the substrate changes, which can be clearly seen in the anisotropy curves.

Repetition rates up to 80 MHz

The PDL 800-B/D provides driving pulses for the laser/LED heads with repetition rates up to 80 MHz, which are derived from an internal low-jitter crystal oscillator. The PDL 800-B is available in two versions, that differ by the maximum repetition rate provided by the system, which is either 40 MHz or 80 MHz. As an extended feature, the PDL 800-D even has two internal crystal oscillators of 80 MHz and 1 MHz, which can be individually selected by the user. In order to match different application needs, the PDL 800-B/D allows to further reduce the repetition rate by factors of 2, 4, 8 or 16 – the PDL 800-D also features an additional factor of 32. This reduction is easily accomplished by a switch on the front panel and leads to repetition rates between 80 MHz and 2.5 MHz for the PDL 800-B and between 80 MHz and 31.25 kHz in case of the PDL 800-D.

External trigger input/synchronization output

Working at other repetition rates even down to single shot is also possible with the PDL 800-B/D by supplying an external trigger signal. The trigger level can be chosen between -1 V and +1 V and the trigger signals can be as short as 2 ns. The quality of the trigger source is of course essential to maintain the picosecond timing quality of the PDL 800-B/D.

All laser pulses generated by the PDL 800-B/D and the corresponding laser/LED head are accompanied by a synchronization output at the front panel. This signal is always synchronous to the light pulse, independent from the selection of triggering mode. The signal is ideally suited to e.g. synchronize other devices in the set-up such as Time-Correlated Single Photon Counting (TCSPC) electronics.

Manual control for laser power

The PDL 800-B/D also provides the possibility to vary the output power of the connected laser/LED head. This is achieved by means of a potentiometer on the front panel. Due to the non-linear behaviour of laser diodes, the potentiometer setting can not be directly related to the output power. Nonetheless, the capability to vary the output power is extremely useful to match the excitation power to the sample in order to avoid e.g. photobleaching. Due to the correlation between pulse power and pulse width, it can also be used to influence the pulse width to a certain degree depending on the connected laser/LED head.

Besides the variation of the laser power in pulsed mode, the PDL 800-D is additionally capable to operate the laser heads of the LDH-D Series in continuous wave (cw) mode. The change between pulsed and cw operation mode is simply accomplished by a switch on the front panel of the driver. In cw mode it is of course also possible to change the output power using the potentiometer.

KEY FEATURES

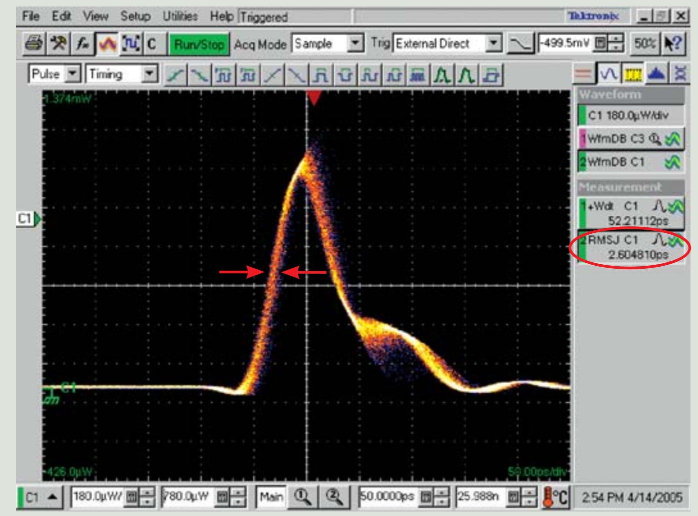
- *lowest possible jitter at internal triggering*
- *internal repetition rate up to 80 MHz*
- *external trigger input*
- *free adjustment of laser power*
- *synchronization output*
- *cw and gating option*

Gating options

For special applications like scanning devices, the PDL 800-B/D provides special gating options that allow to suppress the laser emission by an external signal. For the PDL 800-B, a gate with transition times in the microsecond range is available as an option. The PDL 800-D has two different gating options included: A slow gate and a fast gate. The slow gate reduces settling times of the laser heads to a minimum at slow on/off periods (seconds) and works also in cw mode. The fast gate can perform transitions within nanoseconds, i.e. in between two pulses. The fast gate also provides high pulse stability when the on/off signal is periodic and fast (milliseconds).

Laser safety features

The PDL 800-B/D as well as all other laser drivers from PicoQuant are equipped with standard laser safety features such as a key switch and an interlock. The drivers do also conform to international safety regulations such as CE, UL, CDRH or TÜV.



The PDL 800-B/D features the lowest possible pulse-to-pulse jitter at internal triggering. The image shows results of a corresponding measurement, demonstrating the high stability with a jitter of only 2.6 ps.

As an alternative to the PDL 800-B/D, the PDL 200-B is available. This driver has five fixed internal, user-selectable repetition rates of 8, 4, 2, 1 and 0.5 MHz. It can also drive all laser heads of the LDH-P Series as well as all LEDs of the PLS Series.

PDL 808 “Sepia I”

Multichannel picosecond diode laser driver

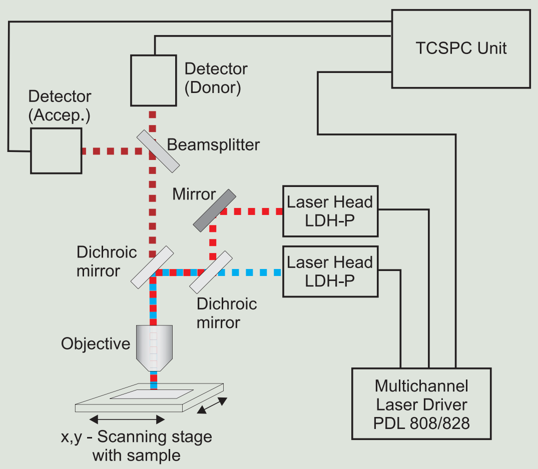
The PDL 808 “Sepia I” is the dedicated driver for multi wavelength applications such as Ranging measurements or Förster Resonance Energy Transfer (FRET) using Pulsed Interleaved Excitation (PIE). It is designed as a modular driver unit for all laser heads of the LDH-P/D Series, all pulsed LEDs of the PLS Series as well as for the LDH-FA Series laser heads.

KEY FEATURES

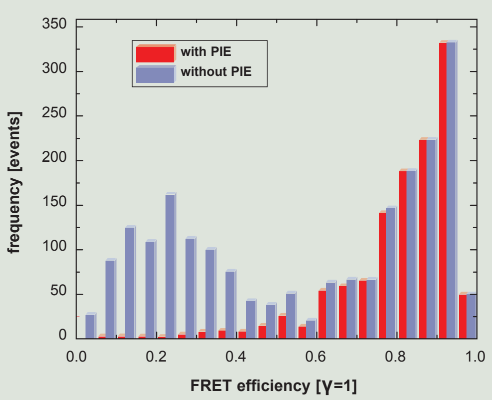
- *up to 6 laser or LED heads*
- *modular design*
- *simultaneous, sequential or burst operation*
- *internal repetition rate up to 80 MHz*
- *external trigger input*

Application Examples

Förster Resonance Energy Transfer (FRET)



Sketch of a basic set-up for Förster Resonance Energy Transfer (FRET). FRET is a nonradiative process in which energy from an donor molecule is transferred to an acceptor molecule. The rate of energy transfer can be used to measure intermolecular distances.



In Pulsed Interleaved Excitation (PIE) two laser pulses are used sequentially to excite the donor and the acceptor molecule independently. The resulting fluorescence emission patterns can be used to discriminate between molecules showing FRET, molecules that do not show FRET and molecules without the acceptor molecule. Data courtesy of PTB, Berlin, Germany

Individual modular assembly

The PDL 808 is available in different sizes to control any number of laser/LED heads between 2 and 6 at the same time. Each PDL 808 is assembled individually from a mainframe with power supply and a selection of four different modules: an oscillator module, a sequencer module, a splitter module and up to six laser driver modules. The jitter-sensitive triggering of the modules is achieved via external cabling. Delays (e.g. for Pulsed Interleaved Excitation) can thus be easily inserted by using different cable lengths. The PDL 808 allows to produce a range of user-definable pulse patters such as sequences. All connected laser/LED heads can also be fired at the same time.

Laser driver module

A laser driver module is needed for each connected laser/LED head that needs to be controlled by the PDL 808. The timing of the emitted pulses is controlled by an external trigger signal, which is typically provided by the oscillator, the sequencer or the splitter module. Each laser driver module additionally allows to control the output power of the connected laser/LED head by means of a potentiometer. It also has two different gating options included: a slow gate, that reduces settling times of the laser heads to a minimum at slow on/off periods (seconds) and a fast gate, that can perform transitions within nanoseconds, i.e. in between two pulses.

Oscillator module

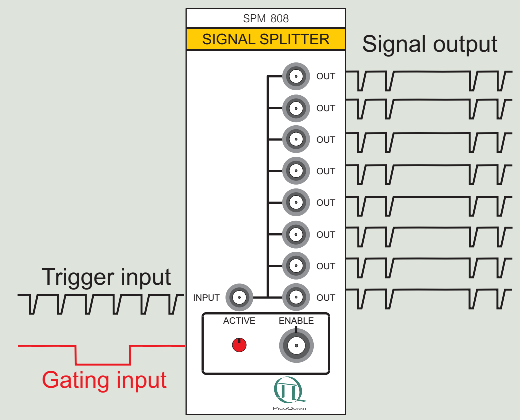
The oscillator module is used to generate the repetition rate for all connected laser heads. It is based on an internal low-jitter crystal oscillator with up to 80 MHz base frequency. Analogous to the single channel driver PDL 800-B, it is also possible to divide the repetition rate by factors of 2, 4, 8 or 16. This is easily accomplished by a switch on the front panel and leads to repetition rates between 80 MHz and 2.5 MHz. Working at other repetition rates even down to single shot is of course also possible by supplying an external trigger signal. All laser pulses generated by the PDL 808 and the corresponding laser/LED heads are accompanied by a synchronization output at the front panel, which can be used to synchronize the laser pulses with other electronics in the set-up such as Time-Correlated Single Photon Counting (TCSPC) electronics. The oscillator module has two trigger outputs, which can be used to supply the necessary trigger signal to two laser driver modules. If more than two laser heads need to be controlled at the same time, either the sequencer or the splitter module can be used.

Splitter module

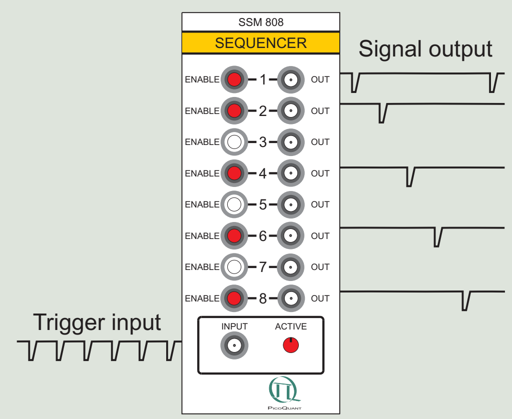
The splitter module splits the trigger signal into eight identical outputs without any additional jitter. It can therefore be used for applications that require multiple laser pulses at the same time. An additional gating input also permits to enable or disable the signal output, which can e.g. be used for burst generation.

Sequencer module

The sequencer module offers another way of signal distribution. Like the splitter module, it has 8 signal outputs. However, each input pulse is sent to only one of the eight outputs at a time. Then the module switches to the next output. The signal is thus routed to the outputs in a rotational sequence. Furthermore, each output can be individually enabled or disabled and only active outputs are involved in the sequencing pattern.



The incoming trigger signal is splitted into eight distinct trigger signals of the same amplitude at exactly the same time. These outputs can then be used to trigger more than two laser heads simultaneously or even to synchronize a more complex set-up. In addition, an external signal can be applied to the module to enable or disable the output signal (gating).



The sequencer module has one input and eight outputs, which can be each enabled or disabled manually. Each triggering signal is sent to only one of the enabled outputs at a time. With the next trigger signal the module switches to the next enabled output. The signal is thus routed to the enabled outputs in a rotational sequence.

PDL 828 “Sepia II”

PDL 828 “Sepia II”

Computer controlled multichannel picosecond diode laser driver

The PDL 828 “Sepia II” is a high-end, ultra flexible diode laser driver for numerous applications that range from time-resolved fluorescence spectroscopy to quantum optics and diffuse optical tomography. It is designed as a modular driver unit for all laser heads of the LDH-P/D Series, all pulsed LEDs of the PLS Series as well as for the LDH-FA Series laser heads.

KEY FEATURES

- *up to 8 laser or LED heads*
- *modular design, complete computer control*
- *bursts, simultaneous and sequential operation*
- *wide range of internal repetition rates*
- *external trigger input*

Ultra flexible driver solution

The PDL 828 “Sepia II” provides maximum flexibility for multiple wavelengths applications such as Diffuse Optical Tomography (DOT). It drives any combination of up to eight laser or LED heads in parallel or in a user defined sequence. The whole system has no manual controls – instead it is easily configured and controlled through a dedicated control software via a USB connection. Last settings are saved inside the PDL 828 to allow stand-alone operation, making it a powerful device for measurement automation. A software library to access the functions of the PDL 828 for custom development is also provided with the system.

Individual modular assembly

The PDL 828 is available in different sizes to control up to eight laser/LED heads at the same time. Each PDL 828 is assembled individually from a mainframe with power supply and computer interface and two types of modules: an oscillator and burst generator module and up to eight laser driver modules. The jitter-sensitive triggering of the modules is achieved via external cabling. Delays can thus be easily inserted by using different cable lengths. The PDL 828 allows to produce a wide range of user-definable pulse patterns such as sequences or bursts. All connected laser/LED heads can also be fired at the same time.

Powerful oscillator module

The oscillator and burst generator module has eight trigger outputs (channels) which can be addressed individually. For example, channels can be combined to be activated at the same time or each channel can be individually activated in a sequence. To enable burst operation, multiple pulses can be output from one channel (or from combined channels) before the next channel becomes active. The oscillator has its own (delayable) synchronization output, an external trigger input as well as an auxiliary input and output connector. The extremely powerful functions of the oscillator module are described in detail on the next double page.

Flexible laser driver module

A laser driver module is necessary for each laser/LED head that needs to be driven simultaneously by the PDL 828. The timing of the emitted pulses is typically defined by an external trigger signal, which is provided by the oscillator module or any other source of a NIM compatible signal. As a special feature, each laser driver module can also operate independently from an external signal driven by its internal low-jitter oscillator at six fixed, user-selectable frequencies (80, 40, 20, 10, 5 or 2.5 MHz). All emitted laser pulses are accompanied by a synchronization output at the front panel of the laser driver module. This signal is always synchronous to the light pulse, independent from the triggering mode (i.e. external or internal triggering).

Complete control of laser power

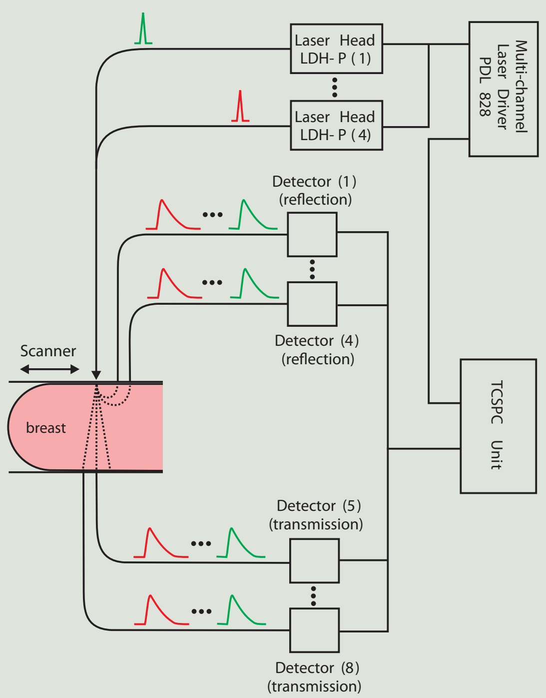
The intensity of the laser emission is controlled via an internal voltage in steps of 1 % of its full scale value. However, due to the non-linear behaviour of laser diodes, the voltage setting does not linearly correspond to the output power, i.e. a voltage of 50 % does not correspond to 50 % of the maximum output power. As the picosecond laser heads are purely current driven and not power regulated a calibrated power scale would not be reliable due to e.g. temperature and degradation effects. The actual power should therefore always be monitored with external power meters.
A special feature of the PDL 828 is to switch between cw and pulsed mode with the LDH-D Series of laser heads.

Two special gating options

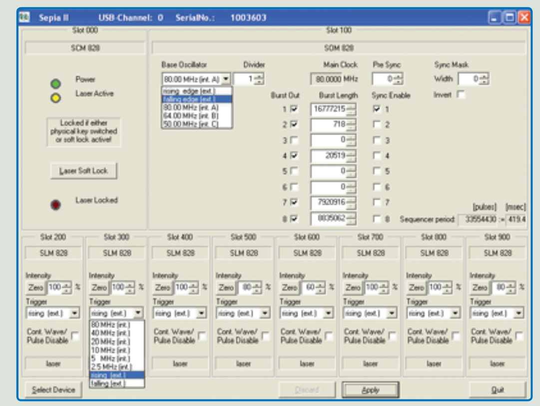
For special applications like scanning devices, the laser driver module has two gating functions which allow to suppress the laser emission by an external signal: a slow gate and a fast gate. The slow gate reduces settling times of the laser heads to a minimum at slow on/off periods (seconds) and works also in cw mode. The fast gate can perform transitions within nanoseconds, i.e. in between two pulses. The fast gate also provides high pulse stability when the on/off signal is periodic.

Application Examples

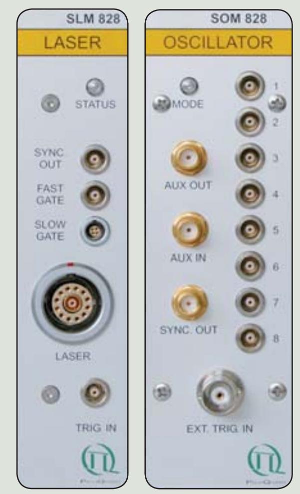
Optical mammography



Sketch of a basic set-up for optical mammography. Optical mammography is a new method of breast cancer diagnostics. Instead of X-rays, this method uses laser light. The breast tissue is imaged in vivo by using pulsed laser radiation of several wavelengths simultaneously in combination with time-resolved transmission and reflection measurements to estimate optical properties of different types of breast tissue and tumors. Especially the possibility to define a variable burst length for each connected laser head make the PDL 828 “Sepia II” an ideal choice for optical mammography as this allows to compensate different pulse energies of the laser or different transmission properties of the tissue.



All functions of the PDL 828 “Sepia II” are easily configured and controlled through a dedicated control software. This includes all functions of the oscillator module such as the repetition rate, the setting of burst length as well as the control of the synchronization signal. All functions of the laser driver module such as laser intensity or trigger mode are also accessible. A “laser soft lock” allows to switch off the laser heads from software.

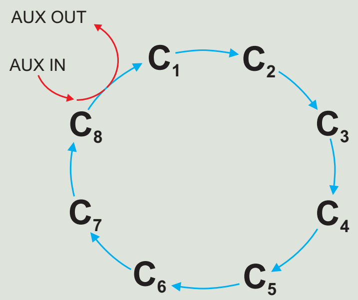


While all functions of the PDL 828 “Sepia II” are controlled by the software, the triggering between the modules is achieved via external cabling. The necessary connectors for this are provided on the frontpanels of the modules. All other signal options of the PDL 828 like the synchronization signal output or the gating connectors are also easy accessible. No special requirements and knowledge is needed to work with this laser system.

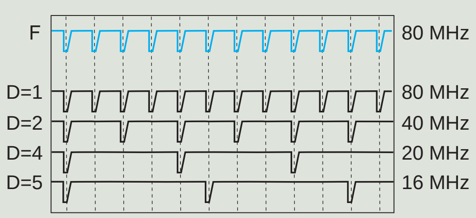
PDL 828 “Sepia II”

Understanding the flexibility of the oscillator module

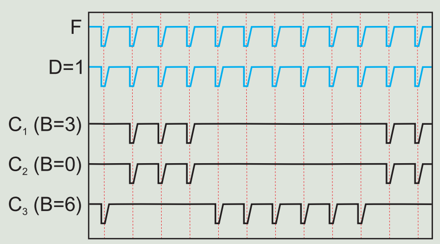
The oscillator module of the PDL 828 “Sepia II” offers numerous possibilities for different pulse patterns or synchronization schemes. It combines not only all features of the oscillator, sequencer and splitter module of the PDL 808 “Sepia I” into one single module, but also widely extends their capabilities.



The oscillator works in a rotary fashion, i.e. the channels (C) are activated in sequence: 1, 2, 3, 4, 5, 6, 7, 8, 1, 2, 3, ... The basic operation therefore generates a sequenced output on all channels. However, adjacent channels can also be combined to be activated at the same time. An additional auxiliary input can be used to inhibit the oscillator to start the output period, i.e. to “start” the output on channel 1 where as the auxiliary output is used to signal the start of a period.



The repetition rate is derived from an internal low-jitter crystal oscillator by division (D) of the base frequency (F) through any integer value between 1 and 255.



The number of actual output pulses for each channel can be set between 1 and 16.7 million. It is therefore possible to generate numerous pulse patterns by using different burst lengths (B). Adjacent channels can also be combined by setting the number of pulses to zero.

The oscillator module has eight individual trigger outputs (channels) that can each be addressed individually in a rotary sequence. This means that the programmed sequence of channel 1 through channel 8 must be completed, before channel 1 becomes active again. Adjacent channels can, however, also be combined to be activated at the same time. To enable burst operation, multiple pulses can be output from one channel or from combined channels before the next channel becomes active. All these features permit to define a large number of different pulse patterns and make the PDL 828 the most flexible diode laser driver available.

Large selection of repetition rates

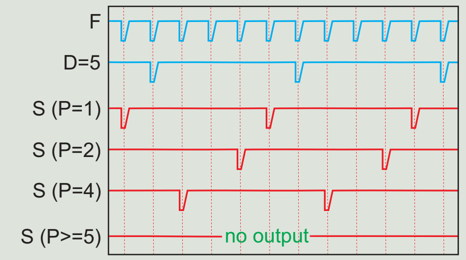
The oscillator module provides more than 700 different internal user-selectable repetition rates to generate pulses at the eight output channels of the module. In general, all repetition rates are derived from an internal crystal oscillator along with a frequency divider. The oscillator module has three internal user-selectable low-jitter crystal oscillators with base frequencies of 80 MHz, 64 MHz and 50 MHz. This base frequency can be further reduced by division through any integer value between 1 and 255. Thus, repetition rates between 196 kHz and 80 MHz can readily be chosen. Instead of using one of the three internal oscillators, it is also possible to provide an external trigger signal. As the frequency divider is also active on external trigger signals, virtually all repetition rates between single shot and 80 MHz can be realized with the PDL 828.

Defining bursts and combining channels

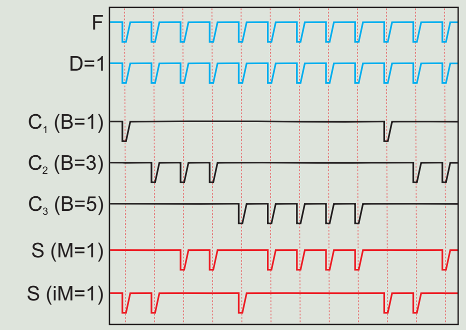
The oscillator module is not only used to generate the trigger signals for the laser head – it also allows to define the number of pulses for each output channel before the next channel becomes active. The number of pulses can be varied between 1 and 16.7 million, which corresponds to maximum burst lengths of more than 200 ms at 80 MHz repetition rate. Adjacent output channels can be combined to emit pulses at the same time. Furthermore, the output of each channel can be individually enabled or disabled. This does, however, not mean that the channel is “eliminated” from the rotary working principle. Instead the programmed number of pulses is still processed, but simply no signal is present at the output. This is e.g. very useful to insert time gaps between two bursts.

Variable synchronization signal

Each pulse that is output at any of the eight channels can be accompanied by a synchronization signal at the sync out connector of the oscillator module. This synchronization signal can be used to control external hardware like e.g. provide the start pulse for a Time-Correlated Single Photon Counting (TCSPC) system. It can be enabled and disabled individually for each channel. One special feature of the PDL 828 is that the synchronization signal can be shifted in time at lower repetition rates. If the divider ratio of the base frequency is > 1, the synchronization pulse can be moved within the time between two trigger signals in steps of the selected crystal oscillator’s period. With this unique feature no external delays are needed anymore for TCSPC at low repetition frequencies.
An additional option to influence the synchronization signal is to mask a defined number of pulses. Masking in this context means that the synchronization signals are not output. The number of omitted pulses can be set to any integer value between 1 and 255. It is also possible to define if the synchronization signal shall be omitted at the start of a burst or at the end of the burst.



The synchronization signal (S) can be output in advance to the output of each channel. The corresponding time difference (pre-sync - P) can be changed in the stepsize of the selected crystal oscillator’s period.



The synchronization signal (S) can be masked (M) or inverted masked (iM), i.e. omitted or allowed for a defined number of pulses. As a result, pulses at the beginning resp. at the end of the burst are not accompanied by a synchronization signal.

MDL 300

Modulated diode laser

The MDL 300 along with the laser heads of the LDH-M Series are a complete system to generate widely adjustable modulated laser emission with modulation frequencies up to 1.8 GHz. It is an ideal ultra fast excitation source for e.g. phase modulation fluorescence lifetime measurements or testing of optical detectors in a compact set-up.

The MDL 300 laser systems consists of a universal driver and different laser heads for different wavelengths. Wavelength changes are thus easily accomplished by changing the connected laser head.

The MDL 300 has a build-in internal sine wave generator but can also work with an external modulation signal.

KEY FEATURES

- *modulation frequency up to 1.8 GHz*
- *wavelengths from 375 nm to 1550 nm*
- *adjustable modulation depth*
- *internal sine-wave oscillator up to 250 MHz*

Internal or external modulation

The MDL 300 permits to generate modulated laser output via internal or external modulation. At internal modulation, sinusoidal output can be generated at six user-selectable modulation frequencies of 250, 100, 25, 5, 1 and 0.25 MHz. All frequencies exhibit a high stability and are derived from a low-jitter crystal generator. For other waveforms or frequencies up to modulation frequencies of 1.8 GHz, the MDL 300 provides two connectors for external modulation signals. A synchronization output at the front panel allows the modulation signal to be monitored externally.

Modulation up to 1.8 GHz with adjustable depth

The modulation depth of the laser output can be controlled by the front-panel settings for any modulation frequency. It can be varied in the range of typically 30 dB and is working as an adjustable multiplier for any waveform. It effects both the internal or external modulation signals. By overdriving the modulation level, even pulsed output of the connected laser head is possible.
The modulation depth depends of course on the modulation frequency and the frequency response of the modulation amplitude is different for every wavelength. Typical frequency responses are fairly flat until about 600 MHz to 900 MHz where the modulation amplitude drops to 50 % (3 dB bandwidth). However, modulation (with lower gain) is still possible up to 1.8 GHz.

Regulated output power

The average output power of the MDL 300 is regulated by a control loop that measures the optical output with a monitor photo diode. This control loop is slow enough to allow high frequency modulation via an external input signal. The corresponding RF input has a high-pass behaviour and allows modulation frequencies between 100 kHz and 2 GHz.

The average output power can additionally be changed through the set-point of that control loop, either manually by turning the bias level potentiometer or electrically through the DC/LF input. As the modulation may never work "against" the control loop, the region around its own time constant (1 kHz to 100 kHz) is blocked.

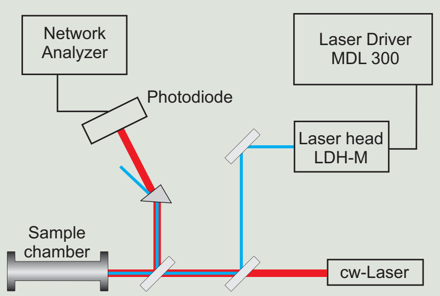
The laser heads of the LDH-M Series, which are designed for the MDL 300 are included in a cooled housing for temperature stabilization. They emit a collimated beam and can optionally be coupled to optical fibers. As the emission of the laser head is always on, it is essential for the laser heads of the LDH-M Series to only use angled fibre connectors (FC/APC). Otherwise, in case of flat fiber connectors (FC/PC or SMA), backreflections from the fiber reduce the laser stability, as they influence the signal from the monitor photo diode.

Average optical output power up to 35 mW

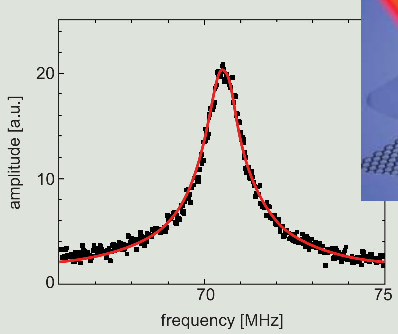
The laser heads of the LDH-M Series are available at various wavelengths between 375 nm and 1550 nm.
The average optical output power emitted by the laser heads depends on the wavelength and is typically between 5 mW and 35 mW. At modulation depths up to 90 % around the average optical output power, this corresponds to peak powers of more than 60 mW. The output stability of the laser emission is very high – typical fluctuations of the peak output power during modulation are only in the order of 3 %. However, for some laser heads, the power fluctuations might reach 10 %, which is nonetheless still acceptable for most applications.

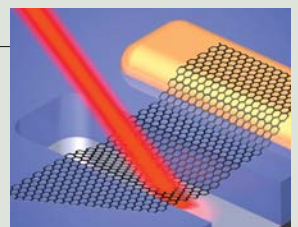
Application Examples

Electromechanical resonance from graphene



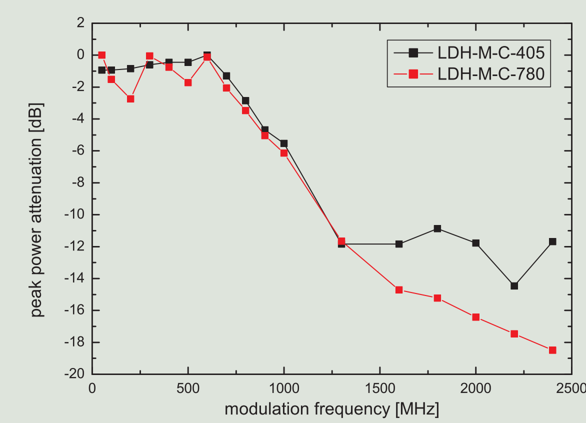
Simplified sketch of the experimental set-up used to analyse electromechanical resonators from suspended graphene sheets at the group of Prof. Jeevak M. Parpia at Cornell University, Ithaka, NY, USA. Vibrations in these nanoresonators were actuated optically by the MDL 300 and detected by interferometry.



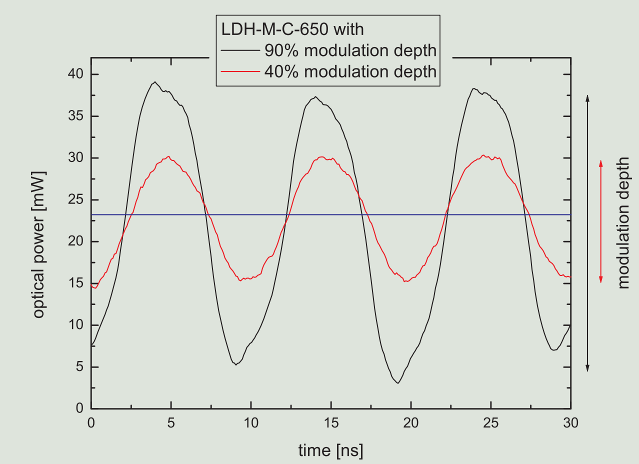


The plot shows measured amplitude versus frequency for the fundamental mode of the single layer graphene resonator. A Lorentzian fit of the data is shown in red and yielded a fundamental resonance mode at f_0 = 70.5 MHz. The plot is adapted from Bunch, J. et al., "Electromechanical Resonators from Graphene Sheets", Science 315, 490–493 (2007).

Frequency response of modulation amplitude



The graph shows typical examples of a modulated laser head at 405 nm and 780 nm.



Example of a laser head at 650 nm, modulated sinusoidally at 100 MHz. The plot shows the laser output at different modulation depths. The blue line corresponds to the average optical output power.

FSL 500

Fast switched diode laser

The FSL 500 along with the laser heads of the LDH-S Series form a complete system to generate rectangular laser pulses with an adjustable pulse width between 3 ns and 100 ns at repetition rates up to 12 MHz. By supplying an external trigger signal even cw operation is possible. The FSL 500 is an ideal device for e.g. time response characterization of optoelectronic devices or as a seed laser for amplification systems.

The FSL 500 laser systems consists of a universal driver and different laser heads for different wavelengths. Wavelength changes are thus easily accomplished by changing the connected laser head.

The FSL 500 can work in three different operation modes: internal, level and slope triggered mode, that differ in the pulse width and repetition rate achievable.

Internal trigger mode

In the internal trigger mode, the pulse width as well as the repetition rate are controlled by the internal electronics using the corresponding settings of the front panel. This trigger mode allows to vary the pulse width from 3 ns to 100 ns in approx. 1 ns steps. It also features three internal user-selectable repetition rates of 3, 6 and 12 MHz.

Slope trigger mode

In the slope trigger mode, the pulse width is controlled by the internal electronics using the corresponding settings of the front panel, whereas the laser pulse is triggered by the rising edge of an external trigger input signal. This allows a variable repetition rate between 10 Hz and 12 MHz as well as adjustable pulse widths between 3 ns and 100 ns.

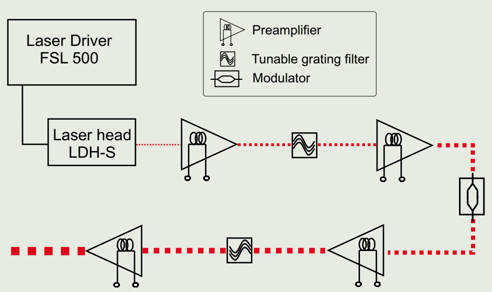
Level trigger mode

In the level trigger mode, the pulse width as well as the repetition rate are controlled by an external signal, which thus allows a wide variation of pulse patterns. In this mode, the output of the FSL 500 follows the signal pattern of a trigger input signal with some limitations. These limitations are due to a switch-on delay for each laser diode that changes with power level and duty cycle. The pulse width is corrected to a possible degree when the pulse width is set internally, where as at level triggered mode the optical pulse width is shortened by that switch-on delay.

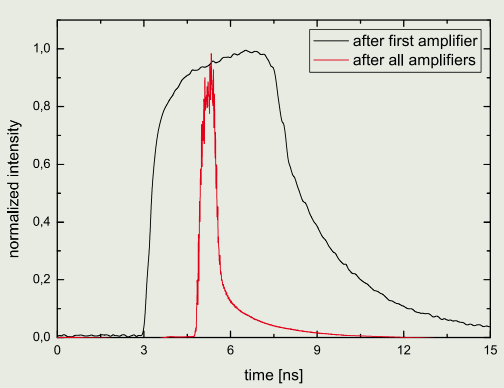
The laser heads of the LDH-S Series, which are designed for the FSL 500, are included in a cooled housing for temperature stabilization. They emit a collimated beam and can optionally be coupled to optical fibers.

Application Examples

Seed laser for amplifier systems



Sketch of a basic set-up used to amplify nanosecond pulses of a FSL 500 build at the group of Prof. Ajoy Kar at Heriot Watt University, Edinburgh, Scotland. The set-up consists of several EDFA fiber amplifiers along with necessary filters and modulators to remove ASE generated by the amplifiers.



The whole system yielded a final peak power of more than 5 kW at 10 kHz repetition rate. These high powers present in the system also lead to a narrowing of the pulse width due to nonlinear effects in the system. The plot shows the pulse shape after the first amplifier and after the final amplifier – the compression of the pulse is obvious.

KEY FEATURES

- *pulse width adjustable between 3 ns and 100 ns*
- *ultra short rise/fall time down to 0.3 ns/0.8 ns*
- *repetition rate from single shot to 12 MHz*
- *completely switched off between pulses*

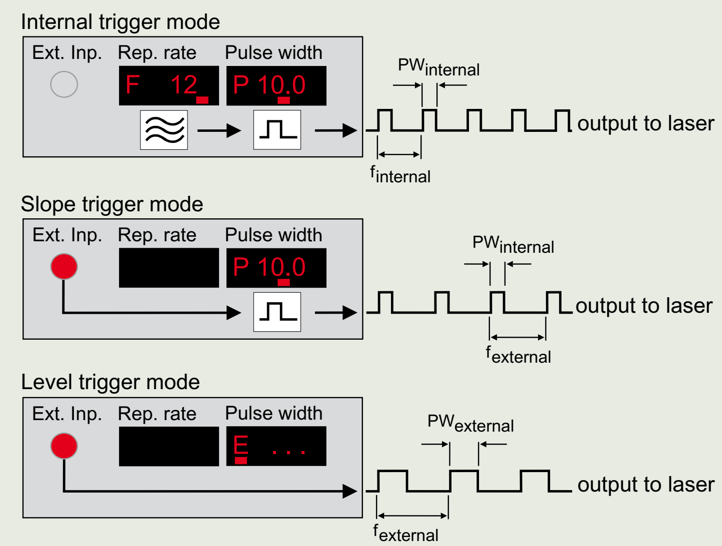
Due to the relatively long laser pulse it is essential for the laser heads of the LDH-S Series to only use angled fiber connectors (FC/APC). Otherwise, in case of flat fiber connectors (FC/PC or SMA), backreflections from the fiber end do interfere with the laser pulse and lead to ringing and other distortions in the temporal laser pulse.

Optical power up to 400 mW

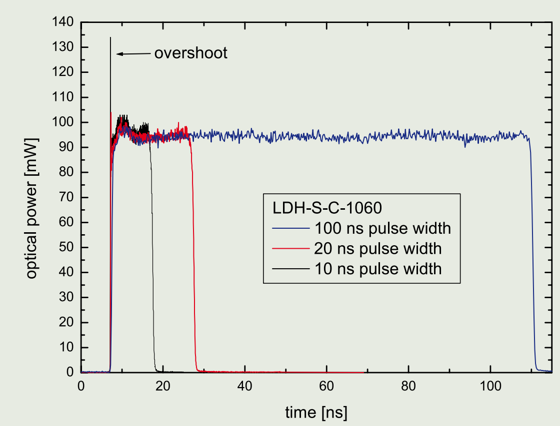
The laser heads of the LDH-S Series are available at various wavelengths between 375 nm and 1550 nm. The optical power emitted by the laser heads during the pulse duration depends on the wavelength and is typically between 10 mW and 30 mW. However, for some selected wavelengths optical powers of more than 400 mW can be achieved. For applications requiring lower power values, it is possible to reduce the optical power of the pulse to 30 % of the maximum power using a dedicated switch on the front panel of the FSL 500.

Highest extinction ratio

A general design feature of the FSL 500 is that the driving current to the diode and hence the laser emission is completely switched off in between two pulses, even at very high repetition rates. The corresponding rise and fall times of the optical emission is in general extremely fast and can reach values of less than 0.5 ns for the rising edge and less than 1 ns for the falling edge. However, a side effect of this special design is that a short and intense optical pulse ("overshoot") at the beginning of the pulse can be emitted. The amount and temporal relaxation of this overshoot depends on each diode and can reach up to 100 % of the specified power value. However, the relaxation of the overshoot is usually very fast and can therefore hardly be seen with most detectors.



The FSL 500 can work in three different operation modes: internal, level and slope triggered mode, that differ in the pulse width and repetition rate achievable.



Example of the pulse profile at different pulse width settings of a laser head at 1060 nm. The fast rise and fall times as well as the overshoot at the beginning of the pulse can clearly be seen. The amount and temporal relaxation of this overshoot depends on each diode.

OEM Laser

OEM Laser

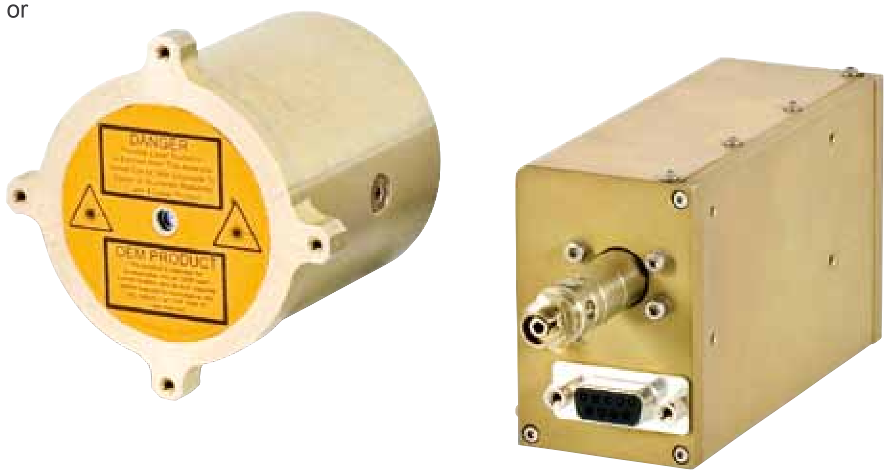
According to your needs

The OEM laser products of PicoQuant are based on the well established picosecond pulsed, fast switched or modulated laser sources such as the PDL Series, FSL 500 or MDL 300. Based on the already developed core technology PicoQuant is able to offer OEM modules for large scale manufacturing or system integration.

Our strength lies in the individual engineering and design solutions we can offer to suit our customers needs with regard to system integration in different industries. The modules can basically be used in each possible application where diode lasers help to e.g increase production efficiency or control the quality of a process. They are designed both for industrial applications and for scientific or laboratory use.

KEY FEATURES

- *compact design*
- *custom housing*
- *pulsed, modulated or fast switched operation*
- *adaptable to customers needs, optics and applications*



Typical applications where our OEM lasers can be used include free space data transmission, fluorescence lifetime related measurements or time-resolved refractometry measurements to name only a few. They can easily be incorporated in larger systems such as readers, wafer tester or other industrial optical devices.

PicoQuant conducts its own development based on customers needs and offers complete integrateable solutions. Manufacturing and testing will be done at PicoQuant and high class products can be delivered on demand. Please ask for special design or a custom tailored solution.

For all applications and designs, the customer decides about

- internal or external power supply
- fixed or variable repetition rate/modulation frequency
- fixed or variable output power
- fixed or variable pulse width/modulation depth
- free space output or fiber coupling
- cooled or uncooled design
- rugged design, special materials
- …

We offer a solution.

Quality Control

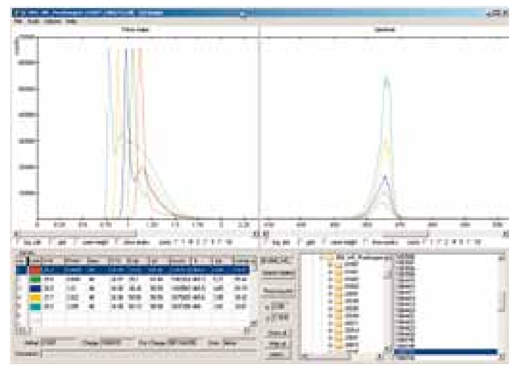
Quality Control

It is more than just a diode...

High quality and high reliability are two fundamental principles of all PicoQuant products. These high demands are achieved by high quality standards in every step from first development to final assembly. For our laser products these arrangements include a thorough testing of each laser diode before it is finally used.

Characterization of each single diode

Each diode is fully characterized with respect to pulse shape, pulse energies and spectral output before it is included into our stock. This allows to sort out diodes with low quality at a very early stage in the production process. Our stock usually holds several hundred individual laser diodes as well as readily assembled and characterized laser heads. This allows for quick deliveries as well as fast reactions to special requirements, like the selection of a special emission wavelength or pulse power.



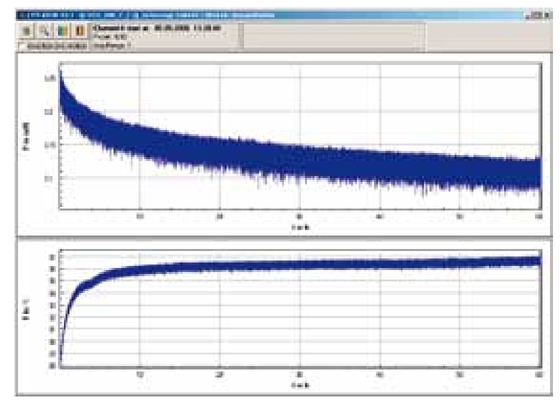
Screenshot of the software from a specially developed laser diode testing machine that is used to characterize each single unit.

Long term stability tests

All laser heads are tested in a burn-in procedure for at least 36 hours before they are finally delivered to the customer. This allows to judge laser stability over long and short times and permits to sort out laser diodes with a short predicted lifetime. Lifetime in this context does of course not mean that the laser stops emitting – instead it is related to the decrease of average output power to 50 % of the initial value.

The exact lifetime of each laser diode can, however, not be predicted, but more than 15 years experience with data from several thousand laser diodes allow us to derive typical values of:

- > 2000 working hours for UV/blue laser heads (and LEDs)
- > 6000 working hours for red laser heads

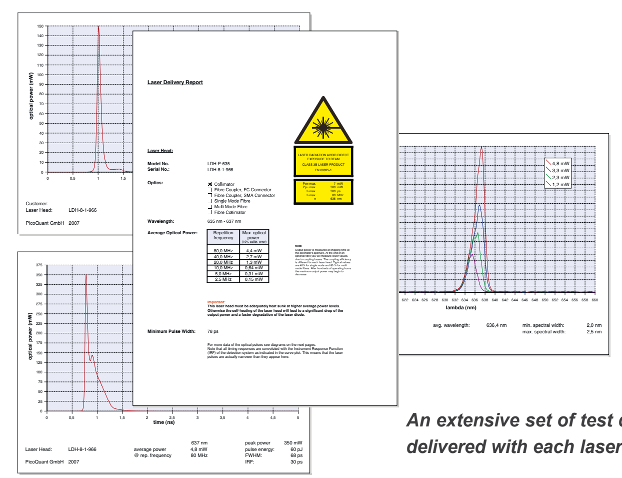


Long term stability tests of laser/LED output power to predict the lifetime of each unit.

Both values are related to conditions where the laser head is driven in an appropriate matter at maximum settings of repetition rate and output power. Working at lower repetition rate and output power increases the lifetime accordingly.

Extensive test data sheet

All laser and LED heads are shipped with an extensive set of test data sheets. These data sheets document pulse profiles and power values as well as the corresponding spectral emission profiles at different intensity settings of the driver unit. All data sheets are also stored into our database for future references, which already holds measurement data from the last 15 years.



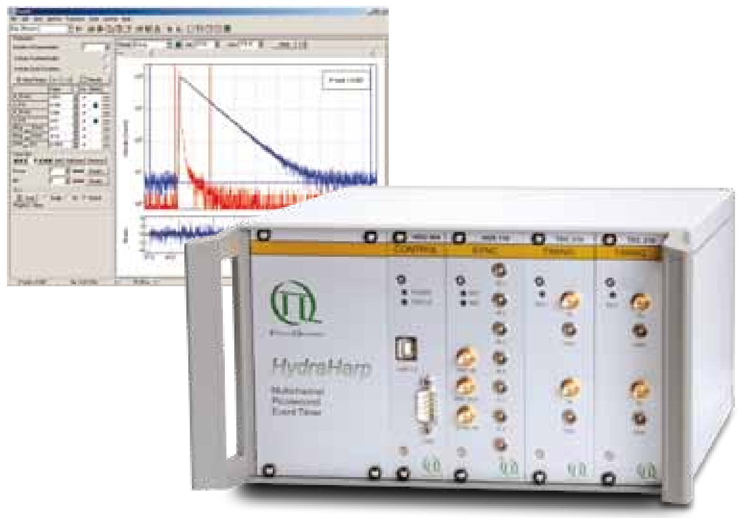
An extensive set of test data sheets is delivered with each laser and LED head.

There Is More Than Diode Lasers…

PicoQuant is not only known for manufacturing state-of-the-art diode lasers, but also to be leading in the field of single photon counting and fluorescence lifetime systems. We do offer a large choice of individual modules or complete systems, individually matched to the requirements of the user.

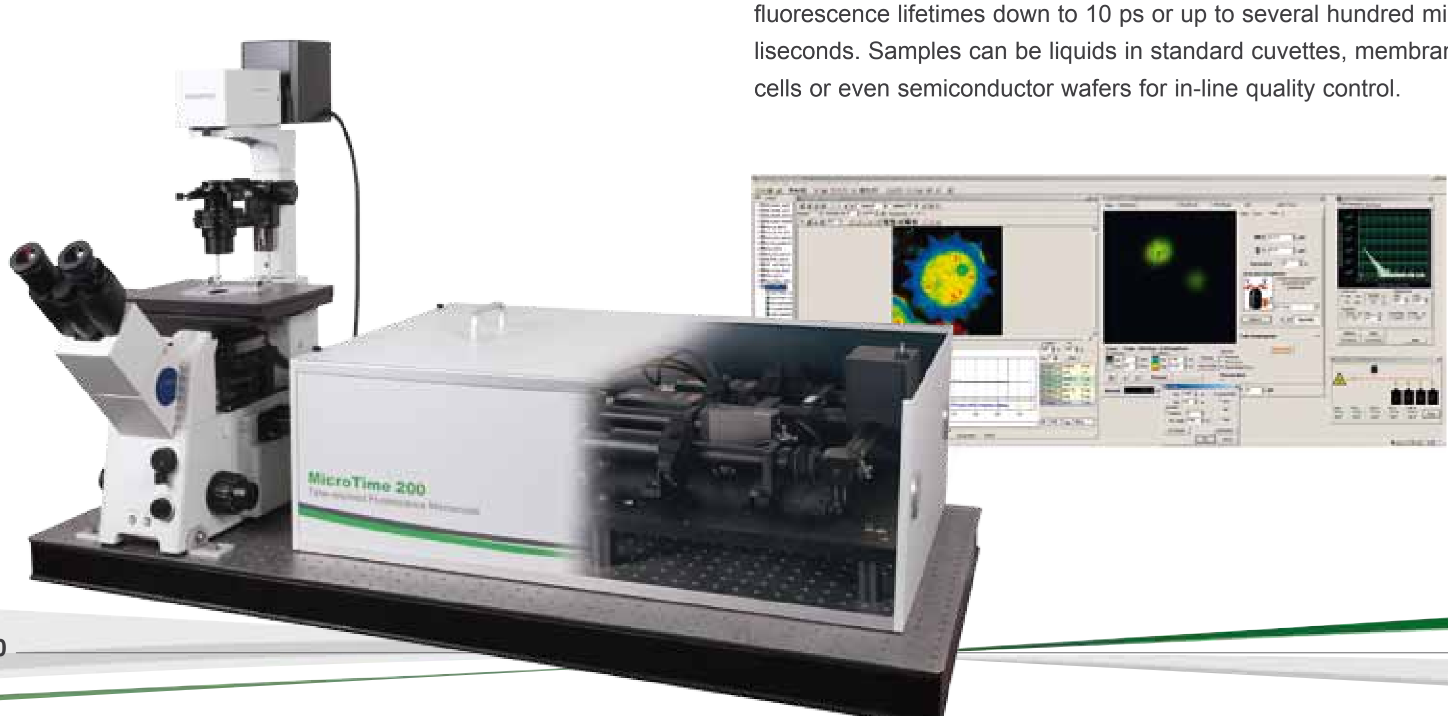
Photon counting instrumentation

High accuracy timing and fast photon counting is one key area of PicoQuant's leading technological competence. Notably, the HydraHarp, PicoHarp and NanoHarp Series of Time-Correlated Single Photon Counting (TCSPC) and Multichannel Scaling (MCS) systems have become an acknowledged brand worldwide. These versatile instruments for event timing and TCSPC readily support sophisticated techniques in single molecule spectroscopy, correlation spectroscopy, quantum optics and scanning applications. The product range is completed by high speed photon counting detectors, specialized analysis software and various other accessories.



Fluorescence lifetime systems

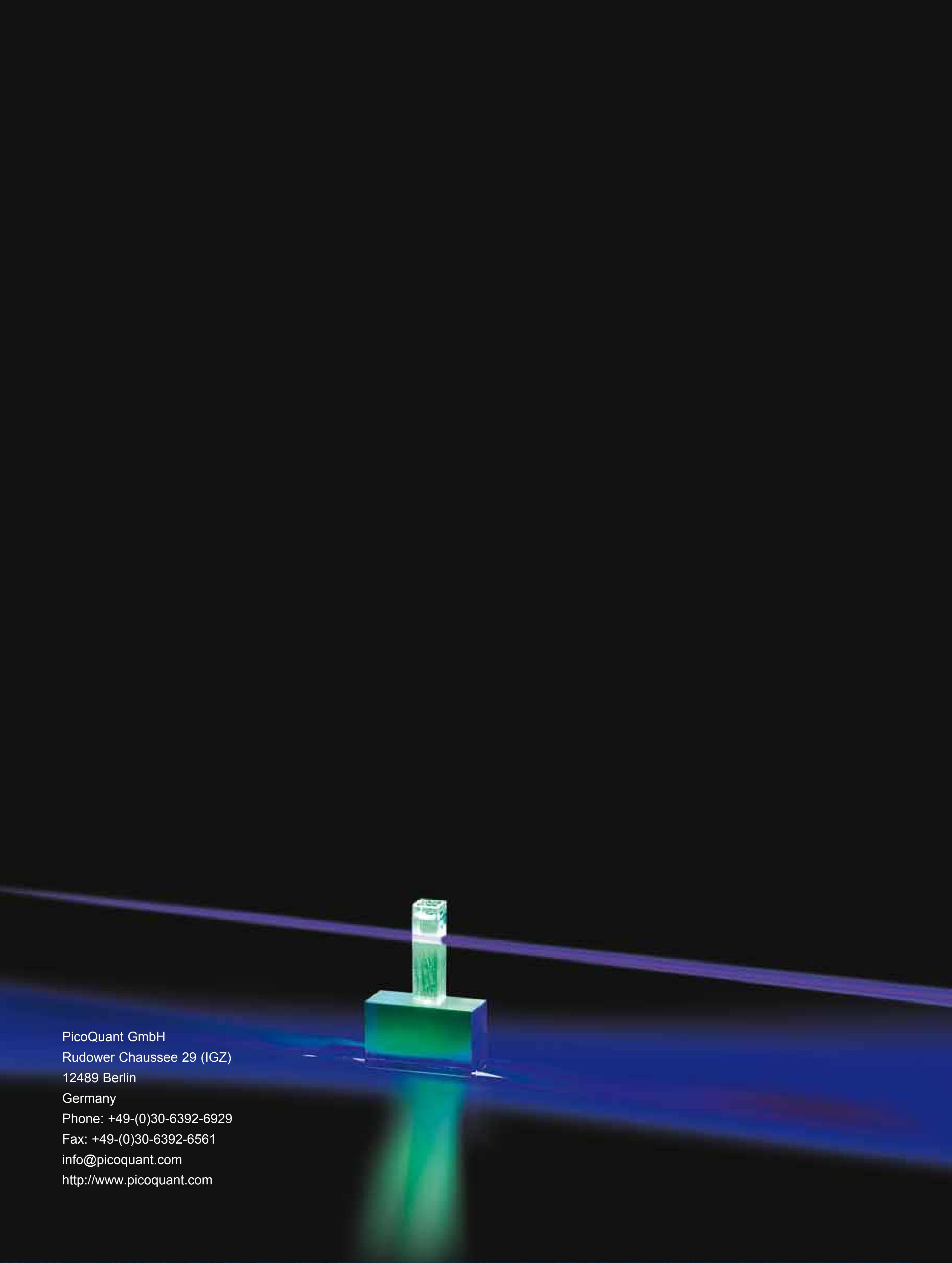
PicoQuant offers compact or automated modular time-resolved spectrometers, lifetime upgrade kits for laser scanning microscopes and complete time-resolved confocal microscopes with 3D scanning at sub-µm resolution for applications like Fluorescence Lifetime Imaging (FLIM), Fluorescence (Lifetime) Correlation Spectroscopy (F(L)CS) or Förster Resonance Energy Transfer (FRET). All systems are available at variable configurations that even meet the requirements of the most demanding sensitive analytical applications such as single molecule spectroscopy. Individual set-ups allow to resolve fluorescence lifetimes down to 10 ps or up to several hundred milliseconds. Samples can be liquids in standard cuvettes, membranes, cells or even semiconductor wafers for in-line quality control.



PicoQuant GmbH

PicoQuant GmbH was founded in 1996 to develop robust, compact and easy to use time-resolved instrumentation and systems. Today, PicoQuant GmbH is known as a company leading in the field of single photon counting and time-resolved fluorescence instrumentation. Our instruments are used all over the world. They help to prepare papers in Nature and Science as well as carrying out routine quality control and production processes of global industrial players. Starting from traditional time-resolved fluorescence detection in bioanalytics, the range of applications is continuously increasing and includes semiconductor quality control, diffuse optical tomography, quantum information processing, optical detector testing and telecommunications. Due to our easy to use products, researchers can now focus on their problems in biology, medicine, environmental science, or chemistry without needing a large background in physics, electronics or optics. Our intention is to offer state-of-the-art technology, which has been co-developed and tested by renowned researchers, at a price affordable to scientific groups and cost sensitive industry. Following this philosophy, we are always looking for new challenges.

PicoQuant especially encourages OEM inquiries for its products, notably for applications where time-resolved techniques were considered too expensive and cumbersome in the past. PicoQuant's innovative and dynamic team of physicists, chemists, biologists, designers, and electronic and mechanical engineers work together to offer you a full range of modules for optical excitation, photon counting, as well as complete and automatic instrumentation for a wide range of electrooptical measurement tasks. The combination of more than 15 years R & D work, several thousand units sold, and cooperation with experts for special applications provides a stable basis for new outstanding developments always driven by our customers' needs and inspirations. We invite you to visit our website or contact our specialists directly to discuss your specific needs. And, of course, you are always welcome to visit our application labs during your travel to Germany. Our annual workshops and courses are another perfect opportunity to learn about new techniques and to discuss your needs.



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