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Photon Counting

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BHL-600
BHLP-700
Red and Near-Infrared Picosecond Diode Laser Modules

General

The BHL-600 and BHLP-700 are picosecond laser diode modules with an emission wavelength in the red and near infrared region. The BHL-600 is optimised for shortest pulse width, the BHLP-700 is optimised for maximum power. Both laser modules have a fixed repetition rate of 50 MHz. Customised versions with different repetition rates and special wavelengths are available on request.

For the BHL-600 the average output power for shortest pulse width is typically 200 to 500 µW at 50 MHz repetition rate. Maximum average output power at 50 MHz is typically 0.8 to 1.0 mW. Pulses as short as 50 to 60 ps can be obtained. The BHLP-700 delivers an average power of 5 mW to 15 mW at 50 MHz and pulses of a few 100 ps duration.

The BHLP-700 laser module has a TTL controlled shutdown input that can be used to switch the laser off and on within a time of 1 us. The shutdown feature can be used to multiplex several lasers of different wavelength or to minimise sample exposure by activating the laser only during the measurement time interval [2,3].

The BHL-600 and BHLP-700 lasers are operated from a simple +12 V power supply. Emission indicator LEDs and a key switch are in a box inserted in the power supply cable. The driving generator is incorporated in the laser module.

The BHL and BHLP laser modules are targeted at spectroscopy applications in combination with time-correlated single photon counting (TCSPC) [1-5]. Their high repetition rate and exceptionally low RF radiation make the BHL and BHLP laser modules an ideal choice for a wide variety of fluorescence lifetime, single molecule detection, lifetime microscopy, fluorescence correlation and photon migration applications.

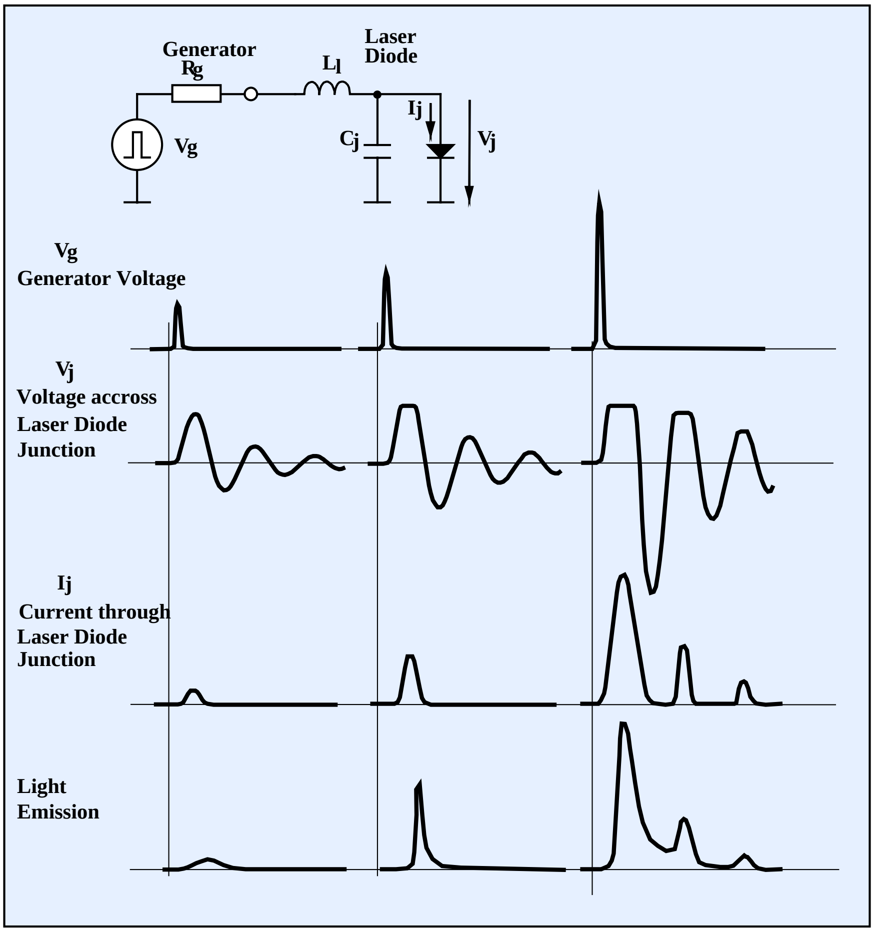
Picosecond Operation of Laser Diodes

Picosecond pulsing of laser diodes requires to drive extremely short current pulses trough the pn junction of the diode. Unfortunately commercial laser diodes are not designed for this kind of operation. In particular, the junction capacitance C_j and the lead inductance L_l form an LC low pass filter that impedes a fast voltage rise across the diode junction. The situation is shown in the figure below.

For low driving power the generator pulse initiates a damped sine-wave voltage across the diode junction. When the first positive peak reaches the forward conducting voltage of the diode, current starts to flow through the junction. As long as the laser threshold is not reached the light pulse is weak and broader than the current pulse.

If the driving power is increased the first positive peak drives a substantial forward current through the diode junction. The dynamic impedance of the junction drops dramatically, preventing the voltage at the junction to increase much above the forward voltage. The current through the junction exceeds the laser threshold for a short fraction of the sine wave period, and a short light pulse is emitted.

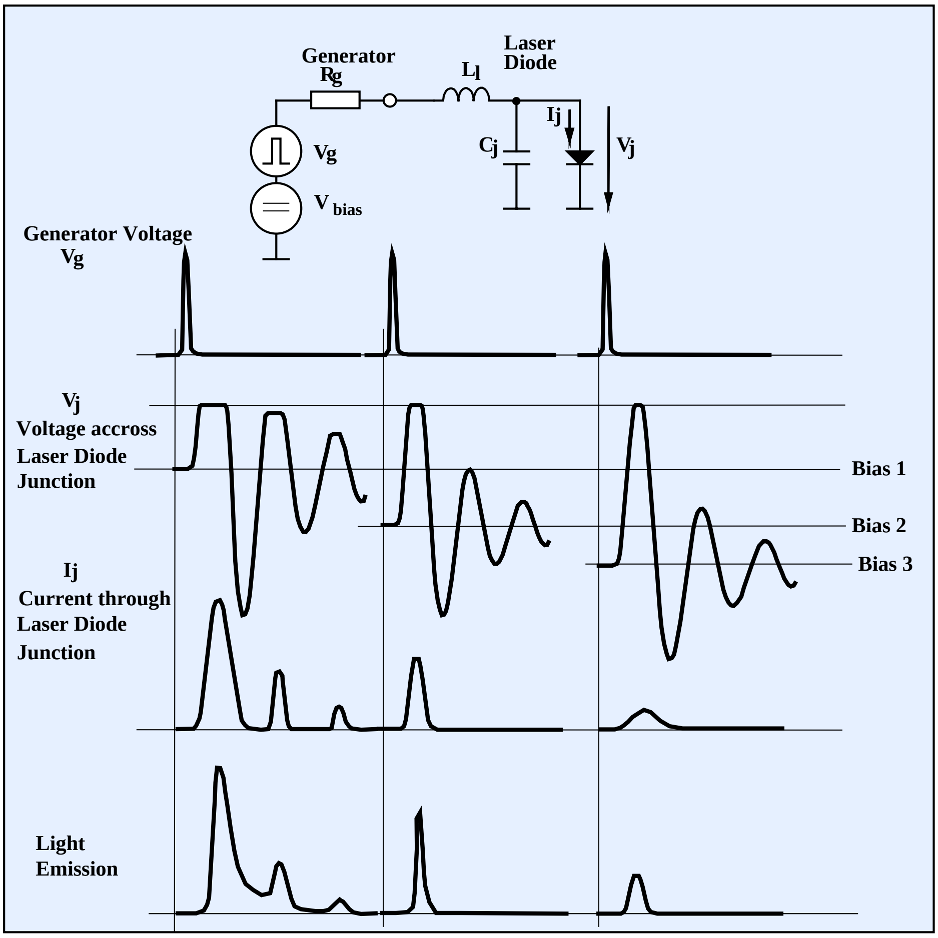
If the driving power is increased further the forward current pulse and consequently the light pulse becomes stronger. Because the dynamic resistance of the pn junction decreases the pulse width decreases. Eventually, the subsequent peaks of the sine wave start to drive a forward current through the diode junction resulting in a tail in the light pulse or afterpulses.



Junction voltage Vj and junction current Ij in a picosecond laser diode for different driving pulse amplitude Vg

The behaviour of the junction current explains why there is a relation between the pulse quality and the pulse power. Good pulse shapes can be obtained only at relatively low power. Taking a stronger diode does not help. It actually makes the situation worse because the junction capacitance is higher.

Basically some improvement can be achieved by DC-biasing the laser diode in reverse direction and using a correspondingly higher driving pulse amplitude. However, laser diodes have a very low permissible reverse voltage so that the safe bias level is limited to -1 to -2 V. The influence of the diode bias is shown in the figure below.

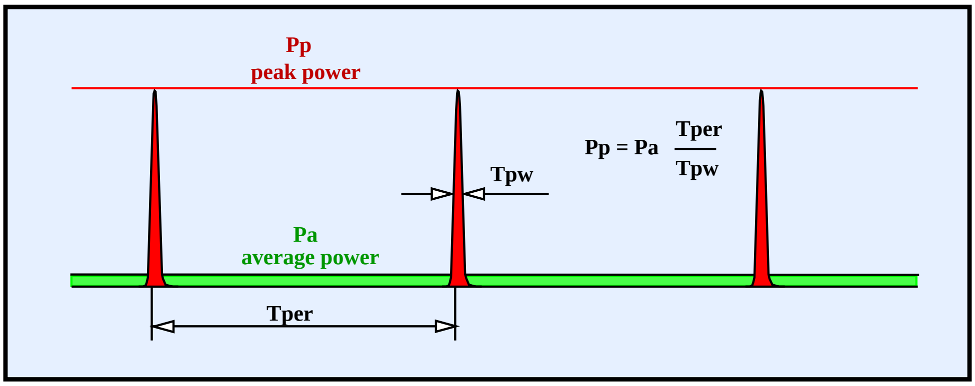


Junction voltage Vj and junction current Ij in a picosecond laser diode for different diode bias voltage

It should be noted that the operating conditions of picosecond pulsed laser diodes are different from those of modulated laser diodes used in communication equipment. A modulated laser diode is always forward biased, and there is a continuous forward current through the laser diode. Consequently, the diode junction has a low dynamic impedance that shorts the junction capacitance. The speed of the diode is then determined mainly by the lead inductance and the generator impedance.

Average Power and Peak Power

The typical pulse width for a picosecond laser diode is of the order of 50 ps to a few 100 ps. For a repetition rate in the 50 MHz range the duty factor can be as high as 400. As shown in the figure below, the result is an relatively high peak power even for low average (cw equivalent) power.

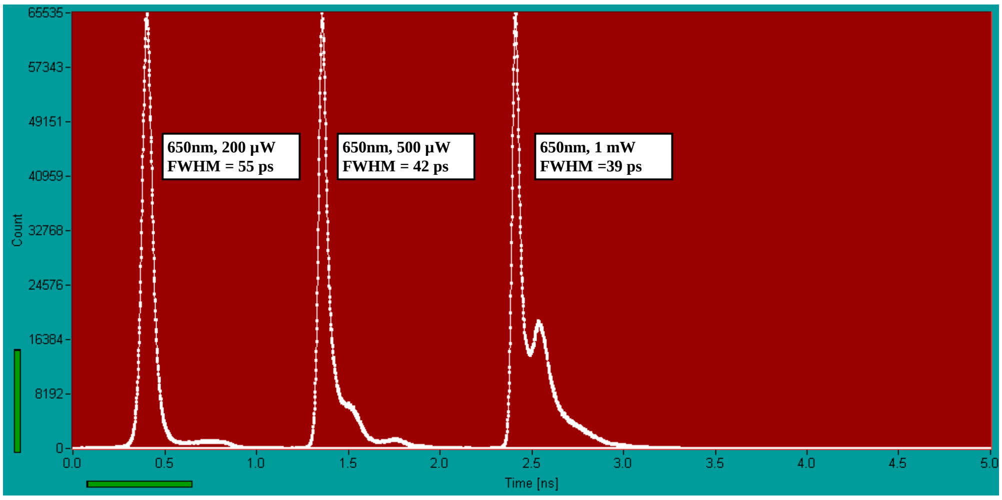


Relation between peak power, average power, pulse width and pulse period

The peak power for all ps diode lasers is far beyond the safe steady state power for the used laser diodes. Due to the short pulse width this is tolerable to a certain extend. However, damage effects in laser diodes are extremely fast and highly nonlinear. For the BHL-600 and BHLP-700 and 50 MHz repetition rate we recommend not to exceed an average power of 1 mW and 15 mW, respectively, for a longer period of operation.

Pulse Shape

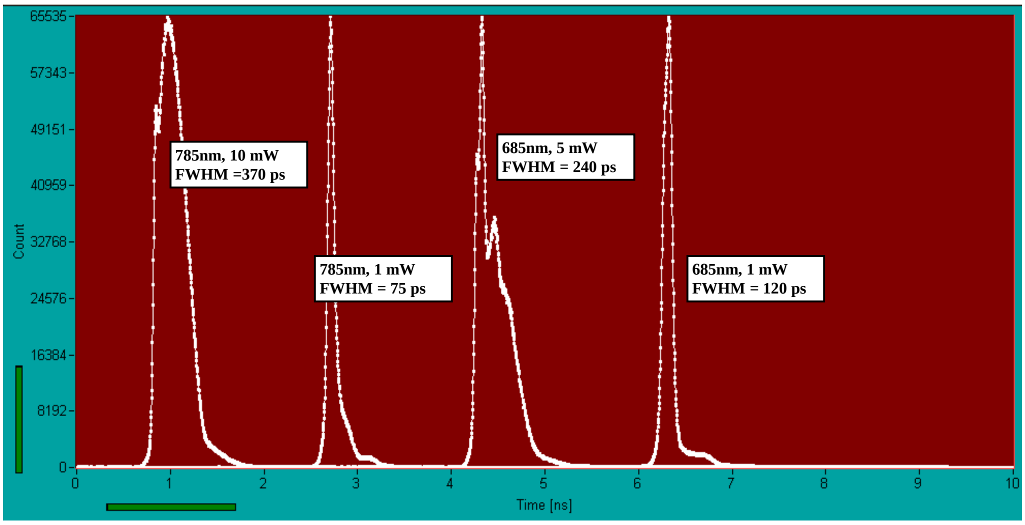
The pulse shape of a diode laser varies with the output pulse power, and, to some extend, with the wavelength version of the diode. Typical pulse shapes for a 650 nm BHL-600 are shown below.



Pulse shapes for a BHL-600 laser module. Wavelength 650 nm, repetition rate 50 MHz, average output power from 200 µW to 1 mW. Recorded with Hamamatsu R3809U-50 MCP [6,7] and BH SPC-630 TCSPC module [2].

In general, the optical pulse becomes sharper with increasing power. However, with increasing power the pulse develops a shoulder and ringing or afterpulsing.

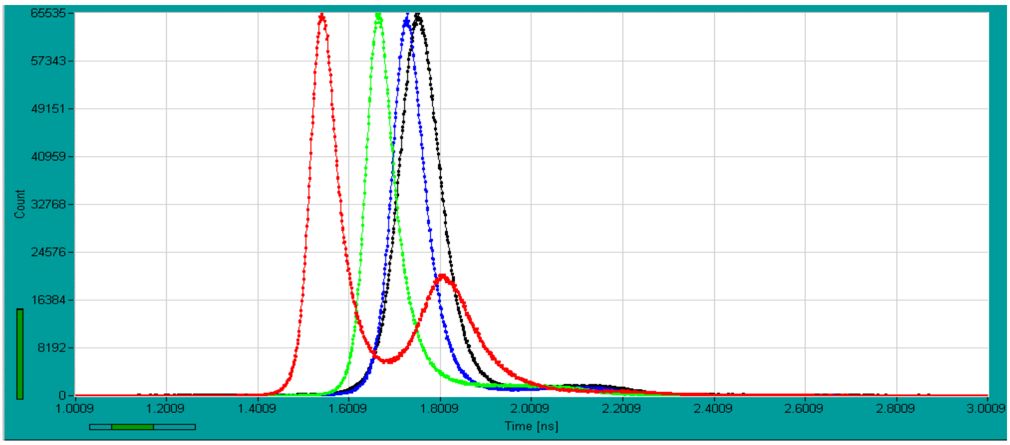
Pulse shapes for the BHLP-700 laser module are shown in the figure below. For medium power the pulse are relatively clean, with a pulse width less than 150 ps. For higher power the pulses become broader and develop a substructure. The shape can be slightly different for different wavelength versions.



Pulse shapes for a BHLP-700 laser module. Wavelength 785 nm and 685 nm, repetition rate 50 MHz, average output power from 1 mW to 10 mW. Recorded with Hamamatsu R3809U-50 MCP [6,7] and BH SPC-630 TCSPC module [2].

Trigger Skew

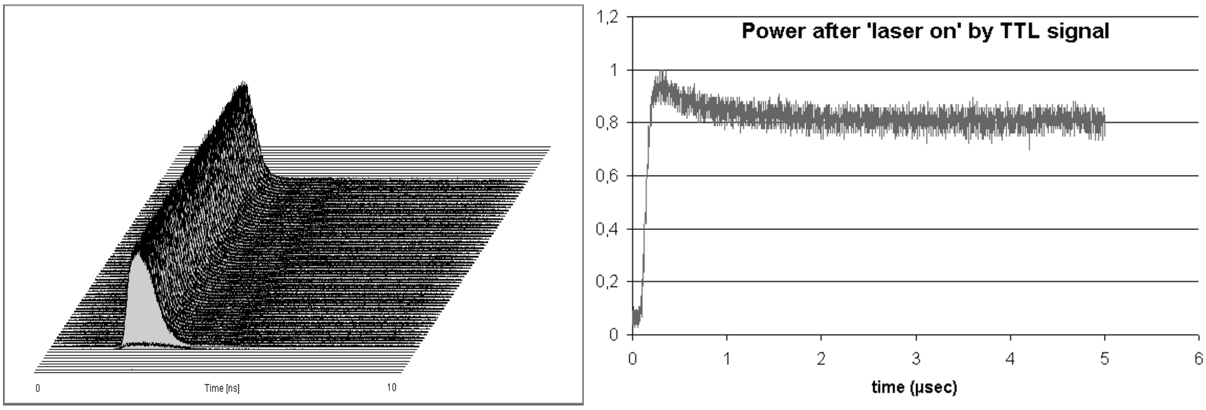
The trigger pulse is derived directly from the output of the laser diode driver. It therefore appears almost simultaneously with the light pulse. For measurements with the bh SPC modules, please use a cable to the SPC SYNC input that is 1 m to 3 m longer that the detector cable. This compensates for the delay in the detector and places the stop pulse behind the end of the recorded time interval [2]. The trigger delay does not change appreciably for different output power and for different repetition rate. The typical shift of the light pulse with the power referred to the trigger pulse is shown in the figure below.



Shift of the light pulse with the output power referred to the trigger pulse. BHLP-700, left to right: Power 0.3 mW, 0.5 mW, 1 mW and 4.0 mW

On-Off Behaviour

The BHLP-700 lasers can be switched on and off by applying TTL/CMOS signal to pin 7 of the sub-D connector. TTL Low or connecting the pin to GND switches the laser off. When TTL Low is applied the optical output and the trigger output shut down almost instantaneously. With TTL High the laser resumes normal operation within 1 us. The switching behaviour for a BHLP-700, 780 nm laser at full power is shown in the figure below. 55 µs TTL high pulses were applied to the /shutdown input, and the sequence was accumulated for 10^6 /shutdown pulses in the Scan Sync Out mode of an SPC-730 TCSPC module. The photons were detected by an R7400 PMT. Each curve of the sequence represents an interval of 1 µs.



On-off behaviour of the BHLP-700 lasers. Left: 55 µs TTL high pulses were applied to the /laser on input. Sequence of the pulse shape in intervals of 1 µs. Recorded by R7400 PMT and SPC-730 TCSPC module.
Right: Output power after switch-on by a TTL-high pulse measured by a photodiode. Power in arbitrary units.

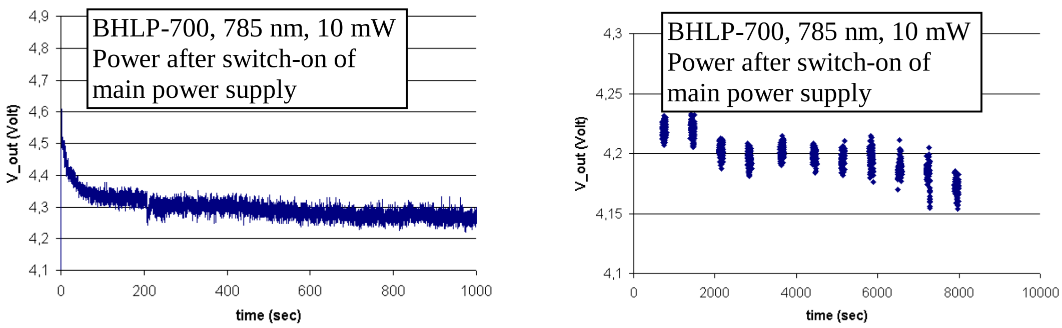
Power Stability

The power of a diode laser can change due to ageing of the laser diode, and temperature changes in the diode and the driving circuits. The effects are different in the BHL and the BHLP.

The BHL-600 uses a stabilisation loop via the internal monitor photodiode in the laser diode. Therefore long term changes of the laser power are efficiently regulated out. However, the power regulation loop works at a limited speed. It takes some milliseconds until the regulation loop settles so that BHL-600 lasers cannot be multiplexed.

The BHLP-700 uses a temperature stabilised laser diode. The constant temperature of the laser diode results in constant efficiency for a constant electrical driving power. The benefit is that the laser can be switched on and off with a response time of a microsecond. Therefore BHLP-700 lasers can be multiplexed at a rate of 10 to 100 kHz. However, it takes some minutes after switching on the main supply until the diode temperature has stabilised.

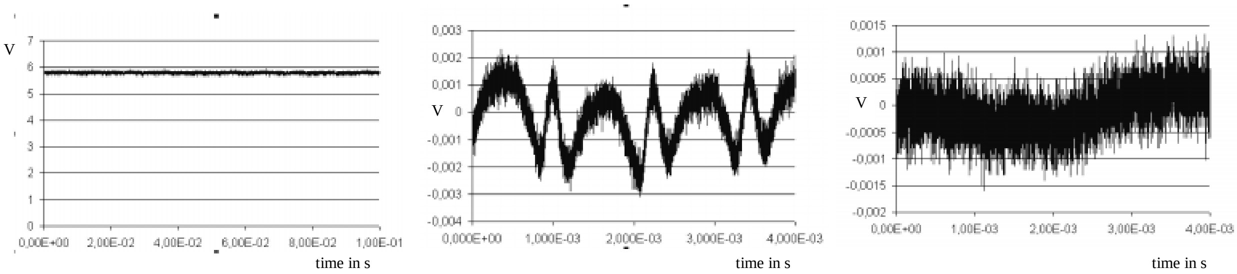
Typical curves of the power after switch-on of the main supply are shown below.



Left: BHLP-700 short term drift of output power after switching on the main power, measured by a photodiode connected to a high-gain amplifier. The decrease in the first 100 s is due to the regulation of the diode temperature. After the diode temperature has stabilised the drift is 1.4% in 1000 seconds. Right: BHLP-700 long term drift of output power. The drift is 1.2 % over 8,000 seconds.

The drift of the power of the BHLP-700 is of the order of 1.4 % in the first 15 minutes after the main supply has been switched on. The drift in the next two hours is 1.2 %, possibly due to slow temperature changes in the driving electronics.

The ripple on the optical power in the millisecond and microsecond range is shown in the diagrams below.



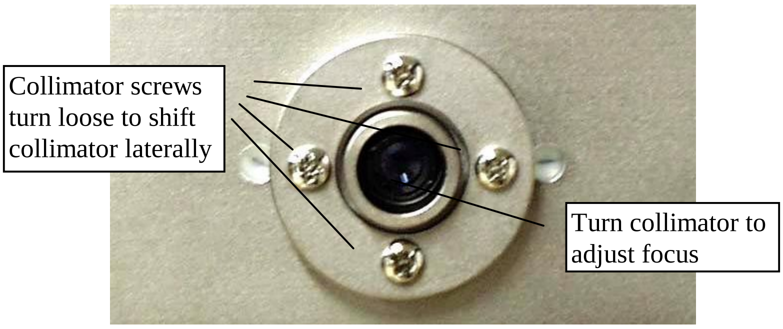
Ripple on the output power of the BHLP-700. Left: Total power-proportional signal delivered by a reversed-biased photodiode. Middle: Ripple on the output power induced by the current spikes of the cooling fan. Right: Ripple on the output power with the fan connected to a separate power supply. (Please note the different voltage scales)

The optical power was recorded by a reversed-biased photodiode and a digital oscilloscope. The left diagram shows the photodiode signal at full scale. The diagrams in the centre and right show the ripple on the photodiode signal. A large part of the ripple in the power is caused by current spikes induced on the supply line by the cooling fan (centre). The ripple is about 4 mV peak-to-peak, or $7 \cdot 10^{-4}$ of the power. The right diagram was recorded with the fan connected to a separate power supply. The remaining ripple is less than $2 \cdot 10^{-4}$.

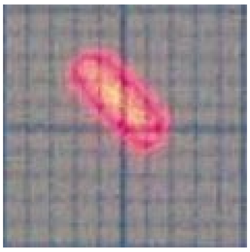
Operating the BHL-600 and BHLP-700 laser modules

Adjusting the Collimator

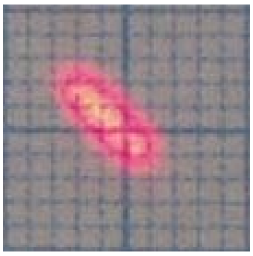
The collimator can be adjusted laterally by loosening the four screws shown in the figure below.



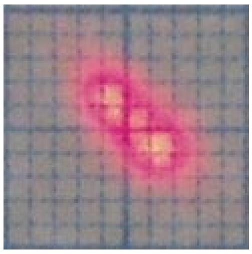
Focus adjustment is done by turning the collimator lens barrel in its mounting thread. The beam divergence can be changed in a wide range. Some beam patterns are shown in the figures below.



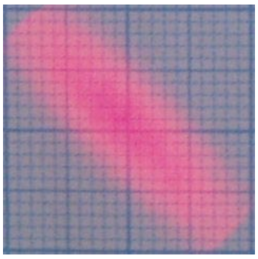
Parallel beam, 10cm from laser



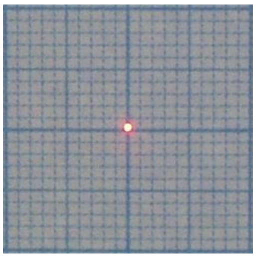
Parallel beam, 1 m from laser



Parallel beam, 4m from laser



Divergent beam, 10cm from laser

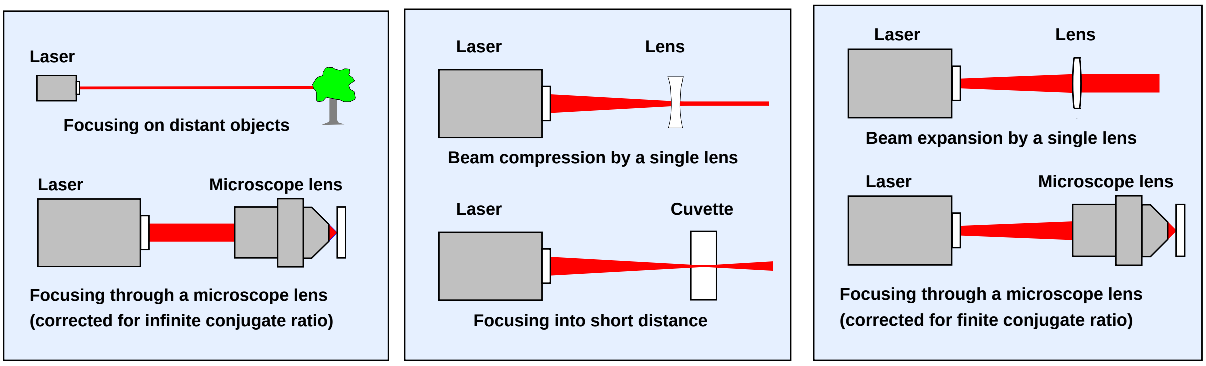


Convergent beam, 10cm from laser

Beam patterns for different collimator adjustment and different distance from laser. Scale is 0.1mm per division. The central parts of the patterns may be overexposed. Therefore the images do not represent the true intensity distribution.

The standard focal length of the collimator lens is 8 mm. This gives a relatively large beam diameter, as can be seen from the figure above (parallel beam 1 m from laser). The long focal length results in a low divergence of the parallel beam. By changing the adjustment of the collimator lens of the laser, the beam can be directly focused into a spot as close as 10 cm from the laser, or a divergent beam can be obtained. The elliptical beam profile of the laser diode itself results in non-circular cross section of the beam. Nevertheless, the beam can be focused into a near-diffraction limited spot. If a more circular beam cross section is needed, e.g. for efficient illumination of a microscope lens, a anamorphotic prism pair or cylinder lens pair should be used to correct the shape.

Typical applications of different beam configurations are shown below. A parallel beam is used for focusing on distant objects, and for focusing by a microscope objective lens designed for infinite conjugate foci, i.e. for microscopes with a tube lens. A convergent beam can be used to focus directly into a small spot or to compress the beam diameter by a single concave lens. A divergent beam can be useful for beam expansion, and for focusing by a microscope objective lens designed for use at conjugate foci, i.e. for microscopes without a tube lens.



Beam patterns for different collimator adjustment and typical applications

The range of beam parameters that can typically be obtained is shown in the table below.

Collimator Adjustment	**Focus distance**	**Divergence mradian**	**Beam cross-section at collimator output**	**Increase of beam diameter over 1m**
Convergent beam	min. 10 cm	max. 45 x 18	4.5 x 1.8 mm	
Parallel beam	-	< 0.1	4.5 x 1.8 mm	< 0.1 mm
Divergent beam	min. -10 cm	max. -45 x -18	4.5 x 1.8 mm	

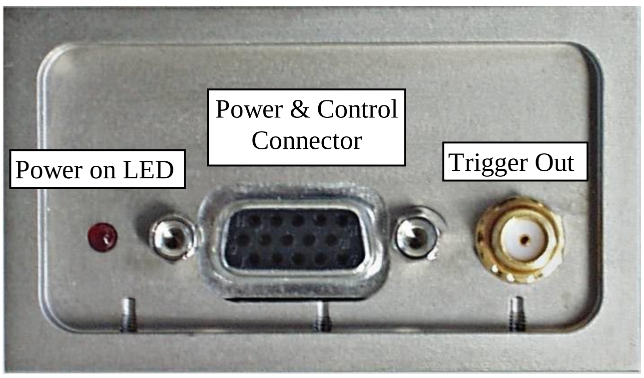
Laser safety regulations demand for a special adjustment tool and a beam stop for class 3B lasers. Please do not make any collimator adjustments on operating class 3B lasers with tools other than specified.

Note: Please do not loosen the plastic screws left and right of the collimator. The screws hold the heat sink of the peltier cooling assembly inside the laser. Loosening them can cause thermal damage to the laser diode and the peltier cooler.

Caution: Light emitted by the device may be harmful to the human eye. Please pay attention to safety rules when operating the devices. Avoid exposure to the laser beam, and do not look into the collimated beam. For wavelengths exceeding 650 nm the light intensity may be much higher than it appears to the eye. In particular, laser safety forbids adjusting the collimator of class 3R and 3B lasers when the lasers are switched on unless a special protecting tool is used. Please see section 'Laser Safety'. Use of controls or adjustments or performance of procedures other than specified herein may result in hazardous radiation exposure or damage to the laser module.

Input and Output Signals

The rear side of the BHL and BHLP lasers is shown in the figure below.



Power and Control Inputs

1	do not connect	9	do not connect
2	do not connect	10	+12V power supply input
3	do not connect	11	not connected
4	do not connect	12	External power control input, 0 to +6 V (BHLP-700 only)
5	GND	13	do not connect
6	not connected	14	not connected
7	/shutdown (BHLP-700 only)	15	GND
8	do not connect		

Pins 5 and 15, Ground

Reference pin for all signals and power supply '-' pin.

Pin 7, /Laser Off (BHLP-700 only)

Connecting this pin to TTL/CMOS Low or GND switches the laser off. The laser beam is shut down and the trigger output becomes inactive. After disconnecting the pin from GND or switching to TTL/CMOS 'high' the laser resumes normal operation within 1 us. Leave the pin open if you want the laser to run continuously. The /Laser Off signal is used to switch off the laser during the beam flyback in laser scanning microscopes or to multiplex several lasers of different wavelength. Please notice that the laser does not deliver trigger pulses when it is switched off by /Laser Off = 'low'. For a connected bh TCSPC modules this is no problem. However, if the /Laser Off signal is pulsed at a high rate the SPC module will display a SYNC rate lower than the actual value.

Pin 10, Power supply input

Pin 10 is the power supply input. The nominal power supply voltage is +12 V. The laser works in a range of +9V to +15 V. However, the BHL-700 may not reach its maximum output power if the supply voltage is below +12V. The power supply current may vary between 100 to 200 mA for the BHL-600 and 200 mA and 1 A for the BHLP-700. In the BHLP-700 most of the input power is used for temperature stabilisation of the laser diode. Therefore the power supply current varies with temperature and with the time after switch-on.

Important note: For reasons of laser safety the BHLP-700 and the BHL-600 laser modules must be operated with the power supply cable delivered with the modules and the box containing the switch box and the emission indicators.

Pin 12, External power control input (BHLP-700 only)

Pin 12 is an external power control input. An input voltage in the range of 0 V to +6 V changes the amplitude of the driving pulse of the laser diode. Positive inputs increase the diode bias and increase the output power. The input resistance of the power control input is 1 kOhm.

Trigger Output

The trigger pulse is derived directly from the output of the laser diode driver. It therefore appears almost simultaneously with the light pulse. For measurements with the bh SPC modules, please use a trigger cable that is 1 m to 3 m longer that the detector cable. This compensates for the delay in the detector and places the stop pulse behind the end of the recorded time interval.

The trigger pulse is negative and has a leading edge of about 500 ps. The amplitude depends on the power and is 100 to 500 mV.

Power Adjust

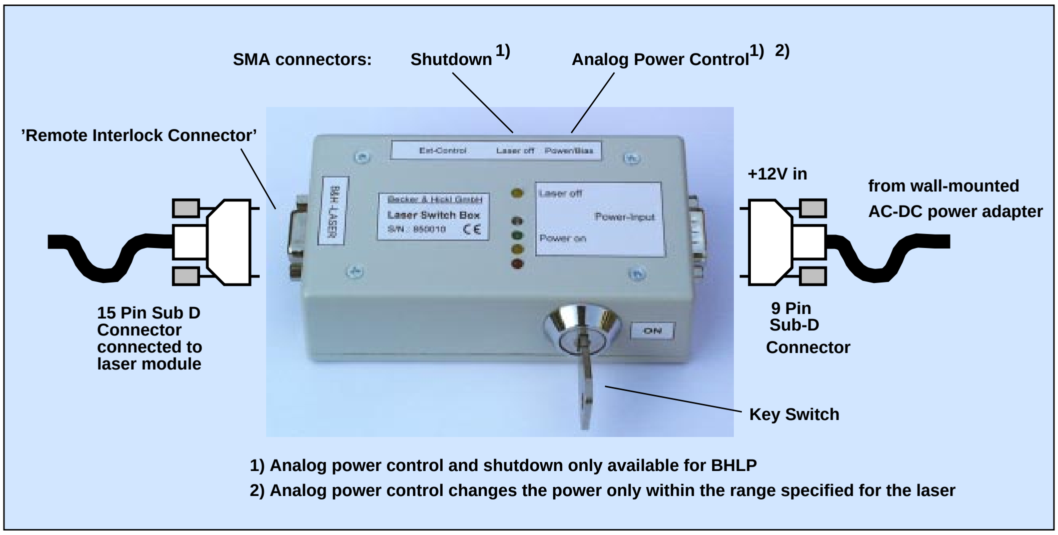
The potentiometers for adjusting the output power is located at one side of the laser module. The ‘Power’ adjust changes the operating voltage of the driving generator.

‘Power On’ LED

The LED turns on when the power of the laser is turned on.

Power Supply Cable for the Class 3R and Class 3B Lasers

The BHLP-700 and BHL-600 laser modules are operated from a simple +12V wall-mounted AC-DC-adapter power supply. The ‘Laser Switch Box’ shown below is inserted in the power supply cable from the AC-DC adapter to the laser. The switch box contains several LEDs of different colour serving as a ‘power on’ indicator. Moreover, for the BHL-700 the box contains the key switch required for class 3B lasers, and connectors for the ‘/laser off’ and analog ‘power control’ inputs. The connectors are at the back of the switch box. The 15 pin connector at the laser side of the box can be used as a ‘remote interlock connector’. The connector can be pulled off or plugged in at any time without causing damage to the laser.



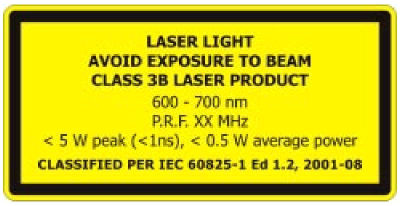
Laser switch box for BHLP-700 with key switch, emission indicator LEDs and control inputs

Laser Safety

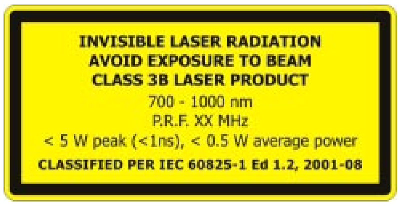
The BHL-600 and BHLP-700 diode laser modules are class 3R and class 3B laser products, respectively. The laser class is indicated on the laser by an ‘explanatory label’, see figure below.

BHL-600, wavelength visible wavelengths

BHL-600, wavelength 700 nm or longer



BHLP-700, wavelength 635 nm to 685 nm

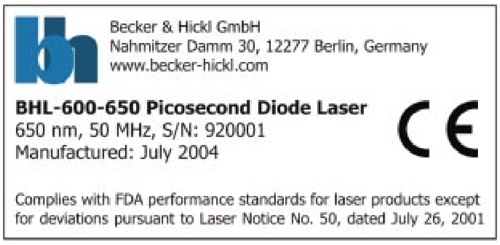


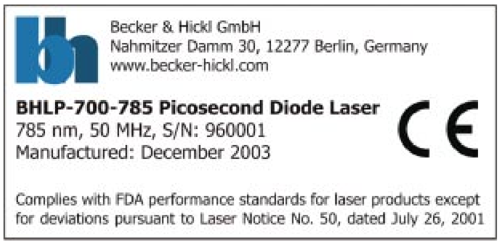
BHL-700, wavelength > 685 nm

Please note that the power and the wavelength on the explanatory label are the permitted range for class 3 R and 3 B lasers. The actual wavelength and power emitted by the laser is specified on the manufacturer label, see below. Also the repetition rate may vary for individual lasers.

The laser aperture is marked with the aperture label and the hazard warning label shown below.

Moreover, each laser has a manufacturer label. The label specifies the type, the wavelength and repetition rate, and the certification of the laser. Examples for the BHL-600 and the BHLP-700 are shown below.





The position of the labels on the laser modules are shown in the figures below.

Explanatory label (yellow label on the left of the front side)

Manufacturer label (white label on the front side)

Aperture label (on top of the laser) and laser hazard labels (left and right of the aperture)

Caution: Laser safety regulations forbid the user to open the housing of the laser, or to do any maintenance or service operations at or inside the laser. Use of controls or adjustments or performance of procedures other than specified herein may result in hazardous radiation exposure or damage to the laser module.

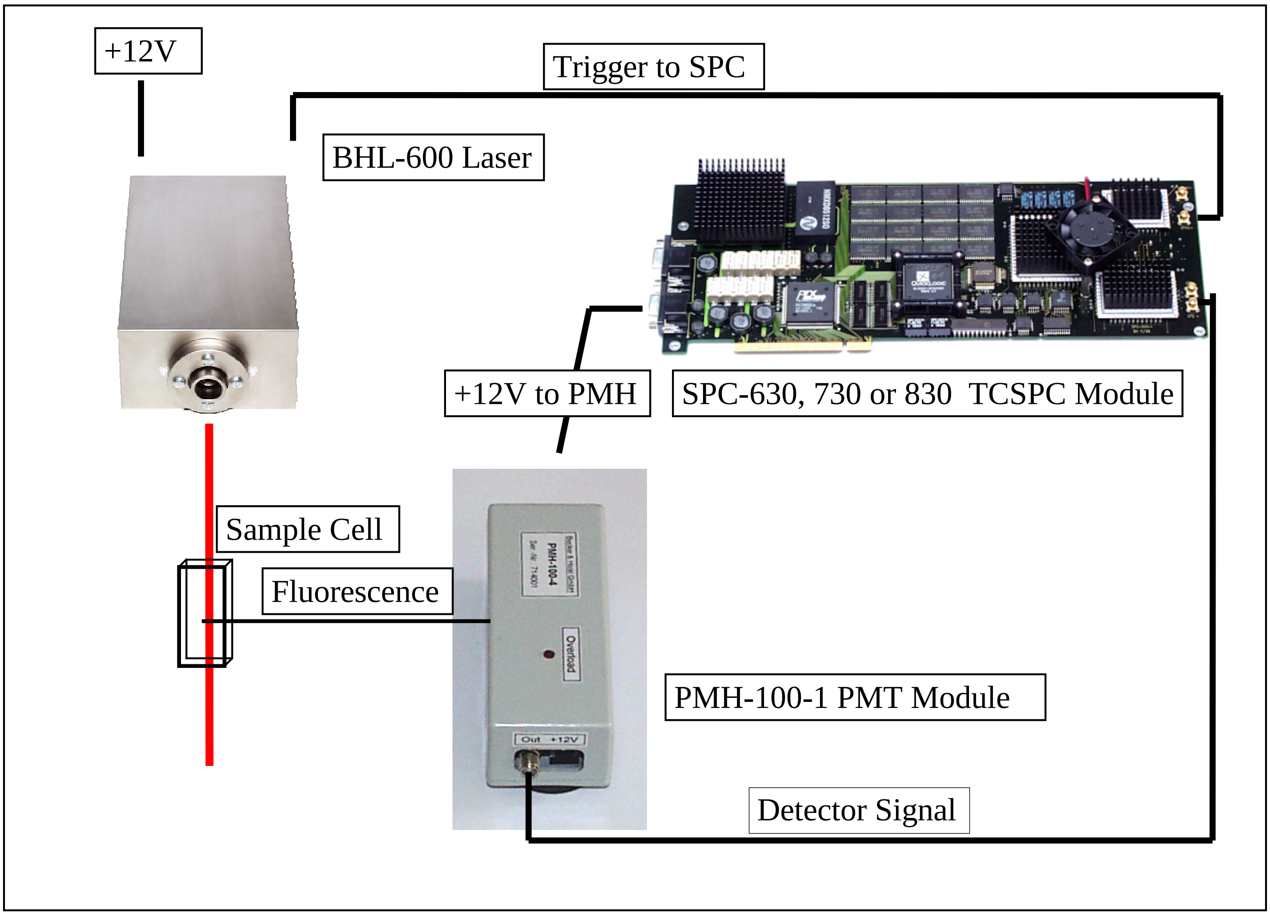
If the collimator of a class 3B laser has to be adjusted, the laser has to be turned off during adjustment, or a special adjustment tool has to be used. Please contact bh.

Moreover, do not look into the laser beam through lenses, binoculars, magnifiers, camera finders, telescopes, or other optical elements that may focus the light into your eye. When using the lasers in combination with a microscope make sure that the beam path to the eyepieces is blocked when the laser is on.

Application to Fluorescence Lifetime Spectroscopy

Fluorescence Lifetime Experiments

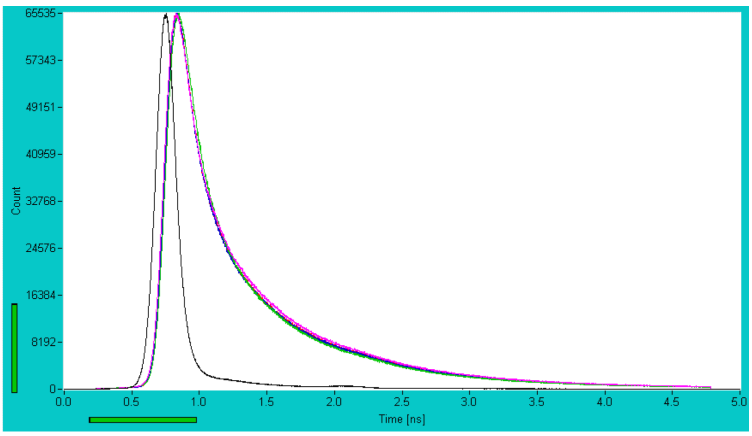
A simple setup for general fluorescence lifetime experiments is shown below.



Electronic components and system connections for NIR fluorescence lifetime experiments

The electronic setup consists of a BHL-600 laser module, an SPC-630, -730 or -830 TCSPC module [2] and a PMH-100-1 detector module. The PMH-100 gets its power supply from the SPC module. The BHL-600 is powered from an external power supply unit.

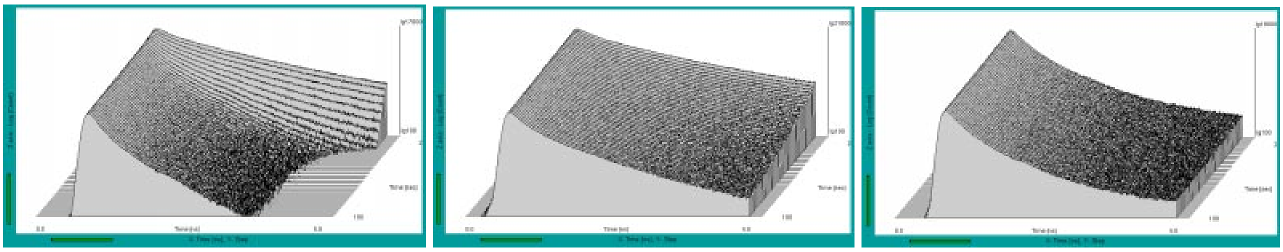
With an optical setup consisting of a few lenses and filters the system can be used for fluorescence lifetime measurements in the NIR range. The decay curves shown below were obtained for chlorophyll in vivo.



Fluorescence decay of chlorophyll in vivo. Excitation with BHL-600, 650nm, detection with PMH-100-1

A BHL-600, 650nm was used for excitation and a PMH-100-1 for detection. The emission wavelength was selected by a bandpass interference filter of 700 ± 15 nm. The left curve is the system response function, the other curves are fluorescence decay curves of different leaves.

Interesting results can be obtained from living plants if a sequence of fluorescence decay curves after the start of the illumination by the laser is recorded. Some examples are shown below.



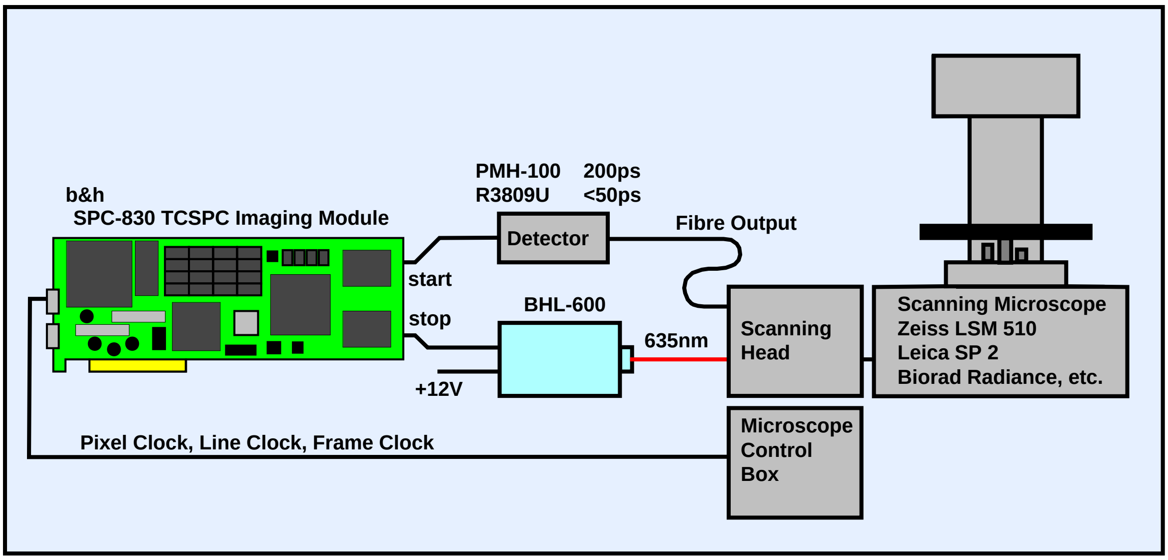
Sequences of fluorescence decay curves of leaves after start of illumination. Left to right: Fresh leaf, faded leaf, dried leaf. Time per curve 2 seconds, logarithmic intensity scale.

For a fresh leaf the fluorescence lifetime decreases considerably after a few seconds of illumination. In a faded leaf the effect is slower and less pronounced. The dried leaf does not show any noticeable lifetime change.

Fluorometers using filters for wavelength selection work with very high efficiency. Therefore PMTs and MCPs with conventional multialkali cathodes, such as the PMH-100 or the R3809U-50, can be used for up to 800 nm detection wavelength. If higher efficiency or detection further in the infrared is required the Hamamatsu H7422-50 or -60 modules, the H8632, or the recently introduced NIR versions of the R3809U can be used.

Fluorescence Lifetime Microscopy and Related Applications

In combination with a confocal microscope and a suitable BH TCSPC module single molecule experiments [8-11], fluorescence correlation measurements and fluorescence lifetime imaging [12-15] are possible. With a wavelength of 635 nm or 650 nm chlorophyll can be excited, making the 635nm and 650 nm versions of the BHL-600 an excellent choice for plant biology. For excitation in the blue and NUV region 405 nm laser diodes have been proved to be applicable [15-17]. For these wavelengths please see the manual of theBDL-375, BDL-405, and BDL-475 blue and NUV laser modules [18]. A typical setup for TCSPC fluorescence lifetime imaging with a confocal laser scanning microscope is shown below.

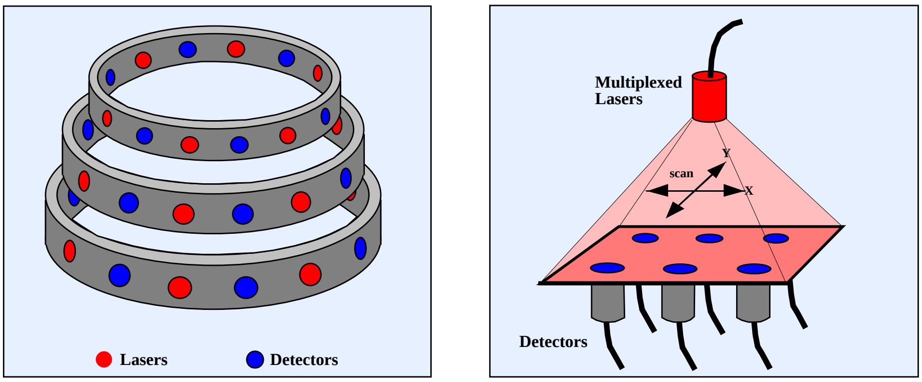


Fluorescence lifetime imaging with confocal laser scanning microscope

The required power in the focus of the microscope objective is less than 50 µW. However, in scanning microscopes the back aperture of the objective is over-illuminated to obtain a uniform intensity distribution over the whole aperture. This gives maximum spatial resolution for a given numerical aperture of the objective, but wastes most of the laser power. When the BHL-600 or the BHLP-700 are used at a scanning microscope the beam geometry should be checked and, if necessary, a telescope be used to obtain the optimum beam diameter. With an available power of the order of 1 mW for the BHL-600 and 5 to 15 mW for the BHLP-700 a reasonable compromise between the power in the focal plane and the spatial resolution can be achieved.

Optical Tomography

Typical applications of optical tomography techniques are optical brain imaging and optical mammography [19-24]. The tissue is transilluminated by NIR light, and the diffusely transmitted or reflected light is detected. If pulsed light is used to transilluminate the tissue, the diffusion of the light through the tissue can be directly observed. This does not only allow to distinguish between scattering and absorption but also helps to improve the depth resolution in structured tissue. Two typical arrangements are shown in the figure below.



Source-detector setups for optical tomography.
Left: Circular arrangement of sources on detectors. Only one source but all detectors are used per measurement step.
Right: Scanning setup with one source and several detectors. Source and detectors are scanned across the sample

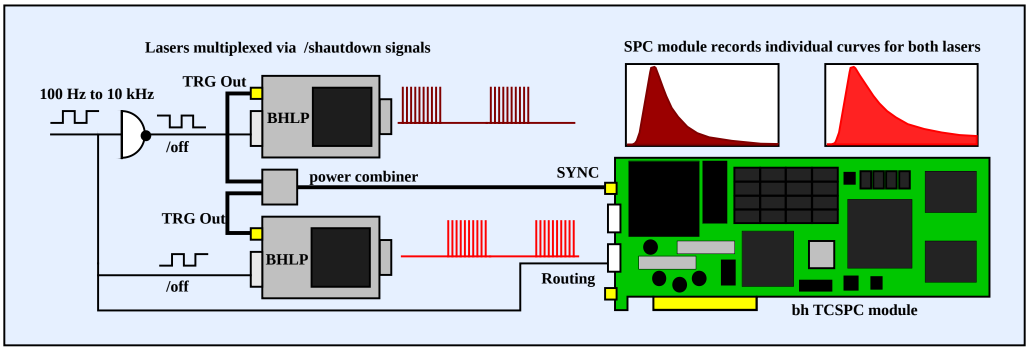
The traditional tomography setup is shown left. A large number of diode laser sources and detectors are arranged around the sample. The sources are switched on one after another and, for each source, the time-of-flight distributions of the photons is recorded by all detectors of a multi-detector TCSPC system [19].

The right setup is used for scanning. Several detectors and multiplexed lasers are scanned across the sample and the time-of-flight distributions are recorded by a multichannel TCSPC system [20-25].

In both setups different wavelengths are multiplexed into the optical source channels. The wavelengths can be multiplexed on a pulse-by pulse basis and recorded in the same TAC interval of one TCSPC module [21-24]. However, higher count rates can be obtained if the lasers are multiplexed in microsecond intervals by using the 'shutdown' feature. The photons of the different lasers are recorded in different memory blocks by using the multi-detector capability of the BH TCSPC modules [2,3].

Multiplexing BHLP-700 Laser Modules

Multiplexing of several laser modules can be required to obtain optical properties of the sample in photon migration experiments or to distinguish between different fluorophores in one sample. Several BHLP-700 laser modules can be multiplexed via the /shutdown inputs, see figure below.



Multiplexing BHLP-700 lasers

Two or more lasers are switched on sequentially by controlling the /shutdown inputs in a way that only one laser is active at a time. On the detection side the routing capability of the BH TCSPC modules is used. Simultaneously with the switching of the lasers the control logic sends a routing signal to the TCSPC module that directs the recorded photons into different memory blocks. Laser multiplexing can be used in conjunction with multi-detector operation [3-5, 25]. The synchronisation signal for the TCSPC module is generated via a passive power combiner (a reversed power splitter). The TCSPC module delivers separate waveforms (fluorescence decay curves, time-of-flight distributions, etc.) for the different lasers. Due to the short switch-on time of the laser multiplexing rates in the 10 to 100 kHz range can be obtained.

Compared to a pulse-by-pulse multiplexing the pulse group multiplexing technique shown above has the benefit that the effective stop rate of the TCSPC module is not reduced. Because the maximum count rate of the TCSPC technique is proportional to the effective TAC stop rate pulse group multiplexing allows to run the experiment at higher count rate. Please see [2, 3] for details.

Specification for BHL-600

Optical	
Repetition Rate	50 MHz, other rates on request
Wavelength	635, 650, 660, 670, 785, 808, 830, 980, 1300 nm [1)]
Average power (adjustable)	0.1 mW to 0.5 mW [2,6)]
Maximum CW power	1 mW [3)]
Average power for best pulse shape (typical value)	0.2 mW
Minimum pulse width (FWHM)	40 ps to 100 ps [4)]
Pulse Width (FWHM, Power 0.5 mW)	<150 ps [4)]
Peak Power	100 mW [4,5)]
Stability of Repetition Rate	± 100 ppm
Pulse-to Pulse Jitter	< 10 ps
Power regulation	within 2% [5)]
Collimator focal length	8 mm
Laser Diode Operation	
Power stabilisation	optical feedback from laser diode
Cooling of laser diode	thermal coupling to module case
Trigger Output	
Pulse Amplitude	typically -100 mV (peak) into 50 Ω. Depends on output power.
Pulse Width	1 ns
Output Impedance	50 Ω
Connector	SMA
Delay from Trigger to Optical Pulse	< 500 ps
Jitter between Trigger and Optical Pulse	< 10 ps
Power Supply	
Power Supply Voltage	+9 V to 12 V
Power Supply Current	100 mA to 200 mA
Mechanical Data	
Dimensions	110 mm x 66 mm x 38 mm
Mounting Thread	two M6 holes
Maximum Values	
Power Supply Voltage	0 V to +15 V
Ambient Temperature	0 °C to 30 °C
Maximum CW power	1 mW [3)]

1) Other wavelengths are available, but pulse width may differ from values given. Please contact bh.
2) Recommended power adjust range. Please note that the pulse width changes with the power. Permanent operation above the given range may impair the lifetime of the laser diode.
3) Absolute maximum of CW power. It is not guaranteed that all versions actually reach this power.
4) Pulse width varies with wavelength version and power. Please contact bh for detailed information.
5) Typical value, sample tested only.
6) Power is regulated via internal monitor photodiode. Reflecting the beam back or shining other light into the laser diode may impair power stability or even shutdown the laser.

Caution: Radiation emitted by the device may be harmful to the human eye. Please pay attention to safety rules when operating the devices. Do not look into the collimated laser beam. For wavelengths exceeding 650 nm the light intensity may be much higher than it appears to the eye.

Specification for BHLP-700

Optical

Repetition Rate	50 MHz, other rates on request
Wavelength	685 nm, 785 nm [1)]
Pulse Width (FWHM, Power 1 mW, typical value)	120 ps
Pulse Width (FWHM, Power 5 mW, typical value)	300 ps
Peak Power	300 mW [2)]
Average CW power (at 50 MHz, adjustable)	0.2 mW to 10 mW [3)]
Stability of Repetition Rate	± 100 ppm
Pulse-to Pulse Jitter	< 10 ps
Power and pulse shape stabilisation after 'Laser on' signal	2 µs
Power and pulse shape stabilisation after switch-on	2 min
Collimator focal length	8 mm

Laser Diode Operation

Power stabilisation	temperature stabilised laser diode
Cooling of laser diode	active cooling by regulated peltier cooler

Trigger Output

Pulse Amplitude	-100 mV (peak) into 50 Ω
Pulse Width	1 ns
Output Impedance	50 Ω
Connector	SMA
Delay from Trigger to Optical Pulse	< 500 ps
Jitter between Trigger and Optical Pulse	< 10 ps

Control Inputs

/Laser Off (Shutdown)	TTL / CMOS low [4)]
Shutdown delay	<100 ns
Power and pulse shape stabilisation after end of '/Laser Off'	2 us
External Power Control	analog input, 0 to +6 V

Power Supply

Power Supply Voltage	+12 V
Power Supply Current	200 mA to 1 A [5)]

Mechanical Data

Dimensions	110 mm x 66 mm x 78 mm
Mounting Thread	two M6 holes

Maximum Values

Power Supply Voltage	0 V to +15 V
Voltage at /Laser Off input	-2 V to +7 V
Voltage at Ext. Bias Input	-2V to +7V
Ambient Temperature	0 °C to 30 °C [6)]

1) Other wavelengths from 635nm to 1300nm are available. Power and pulse width parameters may differ for wavelengths other than specified above. Please contact bh.
2) Typical value, sample tested only.
3) Recommended power adjust range. Please note that the pulse width changes with the power. Power levels above the given range can be selected, but may impair the lifetime of the laser diode.
4) All inputs have 10 kΩ pull-up resistors. Open input is equivalent to logic 'high'.
5) Dependent on ambient temperature. Cooling current changes due to temperature regulation of laser diode
6) Operation below 13 °C may result in unstable power or extended warm-up time.

Caution: Radiation emitted by the device may be harmful to the human eye. Please pay attention to safety rules when operating the devices. Avoid exposure to the beam. Do not look into the laser beam. For wavelengths exceeding 650 nm the light intensity may be much higher than it appears to the eye.

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