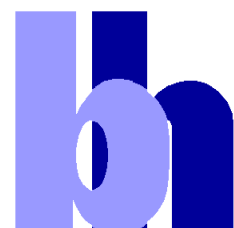


Becker & Hickl GmbH

BDS-SM Series with LSB-C

Picosecond Diode Lasers

2019





BDS-SM Series Picosecond Diode Lasers



- Small-size module, 40 x 40 x 120 mm³ or 40 x 70 x 120 mm³**
- Wavelengths 375, 405, 445, 473, 488, 515, 640, 685, 785, 1064 nm**
- Free-beam or single-mode fibre output**
- Pulse width down to < 40 ps**
- Pulse repetition rate 20, 50, 80 MHz, and CW mode**
- Ext. trigger via sync. input: Single shot to 80 MHz**
- Power in pulsed mode up to 1.3/3/5 mW @ 20/50/80 MHz**
- Power in CW mode up to 50 mW**
- Fast ON/OFF and multiplexing capability**
- High power stability**
- All electronics integrated, no external driver unit required**
- Simple +12 V power supply**
- Compatible with all bh TCSPC devices**



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Overview

The bh BDS-SM picosecond diode lasers deliver picosecond light pulses at high repetition rate. They are thus perfectly compatible with advanced TCSPC techniques [1, 2]. The lasers also have a CW mode to generate a continuous high-power beam of light.

In the picosecond mode, the pulse shape is almost gaussian up to an average power of 1 to 2 mW, with a pulse width on the order of 50 to 80 ps. The pulse width typically remains below 200 ps up to an average power of 4 to 8 mW at 80 MHz repetition rate. Both in the ps mode and in the CW mode, the output power is stabilised by an internal power regulation loop. The lasers thus feature low intensity noise and high power stability.

The BDS-SM lasers are available with and without integrated beam-profile correction optics. Lasers with correction optics deliver beams of about 0.8 mm diameter, approximately circular cross section, and low astigmatism. The beams can be coupled into single-mode fibres at high efficiency.

The output power of the lasers and the ON/OFF state can be controlled by external signals. Therefore, the lasers are well equipped to multiplex several lasers on the microsecond or millisecond time scale, and to turn off the laser emission during the beam flyback in scanning applications. The ON/OFF input is also used for combined fluorescence and phosphorescence decay applications in combinations with the bh TCSPC devices [3].

The BDS-SM lasers have a trigger input to synchronise the laser to an external clock source. With an external source the BDS-SM lasers can deliver pulses from single shot to 80 MHz repetition rate.

The complete driver electronics of the BDS-SM lasers is integrated in the laser head. Operation of the lasers does not require anything but a +12 V power supply, in the simplest case a wall-mounted AC-DC converter. To meet the requirements of laser safety, the lasers come with a connection box that contains the mandatory key switch, a safety interlock and the emission indicator.

The lasers are fully compatible with the bh SPC or Simple-Tau series TCSPC devices [2]. They are also part of the DCS-120 confocal scanning FLIM systems, and of the bh FLIM systems for various other laser scanning microscopes.

General Description

System Components

The BDS-SM lasers come with a small wall-mounted +12V power supply and a ‘laser switch box’ that contains the key switch mandatory for class 3B lasers. The power supply, the laser switch box, and the laser module are shown in Fig. 1, left to right.



Fig. 1: BDS-SM laser. Left: Wall mounted power supply. Middle: Switch box with safety key, frequency switch for CW and pulsed operation, power control and SMA connectors for external control. Right: Laser module containing the complete driving and control electronics.

Laser Switch Box

Starting from May 2018, the 3-Frequency BDS lasers are operated via the new LSB-C switch box. The laser switch box is shown in Fig. 2.



Fig. 2: LSB-C Laser Switch Box

At the front panel, the LSB-C box has the mandatory key switch, a switch for the pulse frequency, a potentiometer for the laser power, and SMA connectors for an external power control signal and the laser ON/OFF signal. At the rear panel the box has a 9-pin connector for a +12V power supply, a 15-pin connector to the laser, and a 15-pin connector for external control signals. The ‘Interlock’ connector of the LSB-C box is used to build up a laser-safety loop when the BDS laser is integrated in larger systems. To enable laser operation the safety cable delivered with the LSB-C box must be connected to the interlock connector, and the blue wire connected to the black wire or to ground either directly or via the laser safety loop.

Laser action is indicated by three LEDs of different colour. The red ‘POWER’ LED indicates 12 V power connection, the green LED key switch and the blue LED laser emission. The laser switch box also contains a switch to select between three pulse frequencies and CW operation, and input connectors for the control signals of the laser.

The connectors for the control signals are shown in Fig. 2. There are two SMA connectors, one for the ON/OFF signal and one for the power control signal. The same signals can be connected to a 15 pin sub-D connector. This connector has also inputs for switching between 20, 50, and 80 MHz, and CW operation. Please note that the frequency switch must be in the 'ext.' position when external frequency control is used. The 15-pin connector at the laser side 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.

From the technical point of view, the laser switch box is not absolutely required to operate the BDS-SM lasers. It is, however, part of the laser safety concept. Thus, if the BDS-SM laser is operated without the box, e.g. in OEM applications, the user is responsible to comply to the usual laser safety regulations by suitable design of the instruments into which the BDS-SM laser is integrated.

The BDS-SM lasers may also be operated without the Laser Switch Box when they are integrated in other bh systems. For example, in the DCS-120 confocal scanning FLIM system the laser switch box is replaced with the DCS connection box shown in Fig. 3. This box contains the key switch, the repetition rate selectors for two lasers, and the signal distribution logics to control the lasers from the GVD-120 scan controller of the DCS system.



Fig. 3: Signal distribution and control box of the DCS-120 confocal scanning FLIM system

Application Information

Frequency Selection

The 3-Frequency-Version BDS laser can be operated at three internal clock frequencies, 20 MHz, 50 MHz and 80 MHz, and in the CW mode. The frequency and the mode are selected by three TTL input lines, F1, F2, F3 and CW. The pin assignment is shown in Table 1.

Signal	Pin at 15-pin laser connector	Frequency	Logic Level
F1	7	50 MHz	active H, internal pull-up resistor
F2	3	20 MHz	active H, internal pull-down resistor
F3	10	80 MHz	active H, internal pull-down resistor
CW	9	CW mode	active H, internal pull-down resistor

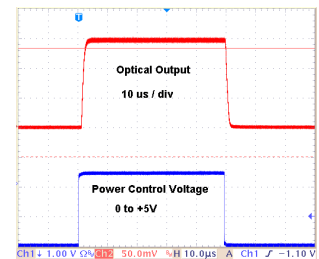
Signal	Pin at 15-pin LSB-C	Frequency	Logic Level
F1	3	50 MHz	active H, internal pull-up resistor
F2	2	20 MHz	active H, internal pull-down resistor
F3	4	80 MHz	active H, internal pull-down resistor
CW	8	CW mode	active H, internal pull-down resistor

F1	F2	F3	CW	Function
H	L	L	L	50 MHz
L	H	L	L	20 MHz
L	L	H	L	80 MHz
L	L	L	H	CW mode
L	L	L	L	No laser operation. Don't use. Use Laser ON/OFF to turn off emission.
H	H	H	L	Several frequencies active simultaneously. Don't use.
open	open	open	open	50 MHz

Table 1: Pin assignment and function of the control signals at the laser head connector

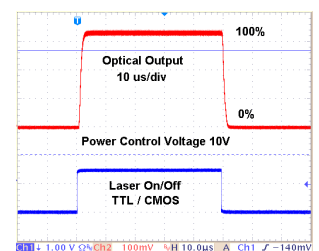
Power Control

The optical power is controlled via a 0 to 10 V analog signal. The signal is connected to pin 8 of the 15-pin connector of the laser or pin 12 at the LSB-C control box. The source of the signal should have less to 100 Ω source impedance. If the input is left open the laser runs at approximately 20 % of its maximum power. The reaction to a change in the power control voltage occurs within a time of about 2 μ s, see diagram on the right.



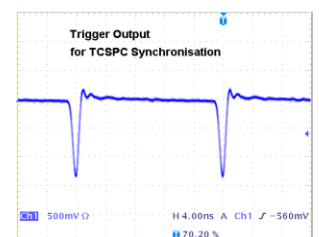
ON / OFF / Multiplexing Control

The optical output of the laser can be switched on and off by a 'Laser ON/OFF' signal at pin 7 of the 15-pin connector of the laser. The logic level is TTL /CMOS, H means 'Laser ON', L means 'Laser OFF'. The laser is 'ON' if the input is left open. The reaction time to the Laser ON/OFF signal is in the range of 1 to 5 μ s, see figure on the right. The SYNC output of the laser becomes inactive when the Laser is in the 'OFF' state. When several lasers are multiplexed their SYNC signals can be combined into a single SYNC line to a TCSPC module by a simple resistive power combiner.



Synchronisation Output

The laser delivers a synchronisation (SYNC) output for TCSPC modules. The pulse polarity is negative, the amplitude is about -1.2 V. The pulse duration is about 1ns. The SYNC output is inactive when the laser is in the 'OFF' state (Laser ON/OFF = L). When lasers are multiplexed their SYNC Out signals can be combined by a simple resistive power combiner.



Synchronisation Input

The synchronisation input is used to synchronise a BDS laser to an external clock source. The input signal must be TTL/CMOS compatible, and DC coupled into the synchronisation input from a 50 Ω source. The pulses must be positive, with a duty cycle of no more than 30 %. With a signal like that, the laser automatically recognises that a synchronisation signal is connected, and switches its clock path from the internal clock generator to the synchronisation input.

The principle of clock source switching is shown in Fig. 4. The average voltage at the Sync input connector is sensed via a low-pass filter. The output voltage from the filter sets a switch. If the average voltage is $> 3 \text{ V}$ the clock comes from the internal clock generator, if the voltage is $< 3 \text{ V}$ it comes from the Sync input connector. The active edge of the input signal is the rising edge.

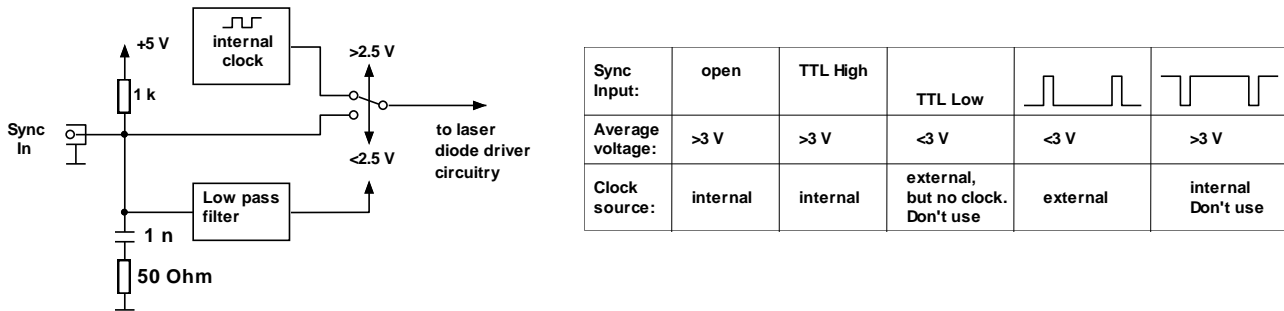


Fig. 4: Principle of switching between the internal clock generator and an external clock source

Power Regulation Loop

Light generation in a laser diode is a highly nonlinear process. The slightest changes in the driving conditions or junction temperature, or mode fluctuations and back-reflection of light into the laser diode can result in large changes in the optical power. Therefore, the BDS-SM lasers have an internal power regulation loop, see Fig. 5. The laser power is monitored by a photodiode, and the photodiode current, I_{pd} , compared with a reference current, I_{ref} . The difference of both is amplified, and used to control the electrical driving power to the laser diode. Thus, the difference between the photodiode current and the power control signal is regulated down to zero. That means the optical power is linearly related to the power control signal. Changes in the optical power due to temperature variation, variation in the supply voltages, or mode fluctuations in the laser diode are largely suppressed.

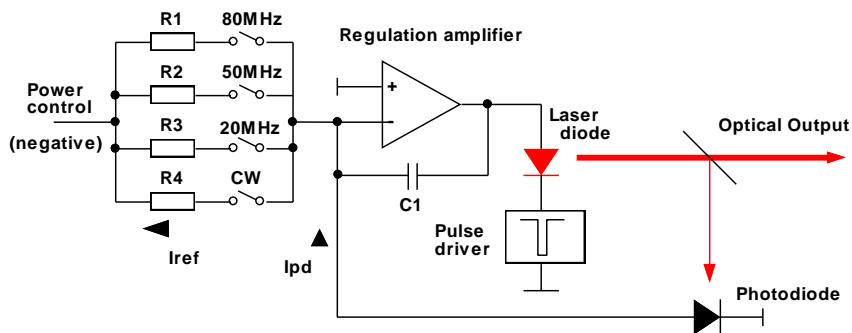


Fig. 5: Principle of power regulation loop

The regulation loop reacts to the average intensity of the optical output, not to the peak intensity of the laser pulses. For constant average power the peak power changes with the pulse repetition rate. When the lasers are running with the internal clock oscillators the variation with the repetition rate is taken into account by switching the resistors, R1, R2 and R3, in proportion to repetition rate selected. For operation with external clock frequencies the peak power changes with the pulse period. To obtain a reasonable power regulation range with an external clock we recommend to choose the F1, F2 and F3 signals for an internal clock frequency closest to the external clock frequency.

Dependence of Pulse Shape on Laser Power

When a laser diode is sharply driven from the off state into the on state it emits a short pulse of light before it settles into its steady-state intensity. In a picosecond diode laser, driving conditions are chosen which result in short duration and high peak intensity of the initial pulse. The pulse shape depends on the amplitude of the current pulse that drives the diode. At low pulse current light pulses of near Gaussian shape are emitted. The pulses get narrower with increasing pulse current. If the pulse current through the diode is increased further emission by the normal light generation mechanism occurs. It more or less follows the current flowing through the diode junction, and forms a bump following the initial peak. At very high power, the amplitude of the bump can reach or exceed the amplitude of the initial peak, and, eventually, become the dominating part of the pulse profile. Please see pulse shapes at page 1 of this data sheet. The change of the pulse profile versus the laser power makes it recommendable to keep the laser power at a constant level within one series of experiments.

External Laser Control with LSB-C Laser Switch Box

At the front panel, the LSB-C box has SMA connectors for an external power control signal and the laser ON/OFF signal. At the rear panel of the box a 15-pin connector for external control signals is located. The pin assignment for the control signals is shown in Table 2.

Pin number	Function of Signal
15 pin control connector of LSB-C	
1	do not connect
2	F2: 20 MHz ^{1,2)}
3	F1: 50 MHz ^{1,2)}
4	F3: 80 MHz ^{1,2)}
5	GND
6	reserved, do not connect
7	Laser ON/OFF, TTL/CMOS, parallel to SMA connector
8	CW Operation ^{1,2)}
9	not connected
10	not connected
11	reserved, do not connect
12	Power control signal, 0 to +10 V, parallel to SMA connector
13	not connected
14	not connected
15	GND

1) Put frequency switch in 'EXT' position

2) Only one of the inputs must be in H state, the other two inputs must be pulled to Low (GND).

Table 2: Control signals at 15-pin external-control connector of LSB-C laser switch box

The lasers are, however, fully operable without the switch box, e.g., for integration into other instruments. These must then have their own laser safety provisions incorporated.

Safety Interlock Connector

The 'Interlock' connector of the LSB-C box is used to build up a laser-safety loop when the BDS laser is integrated in larger systems. To enable laser operation the safety cable delivered with the LSB-C box must be connected to the interlock connector, and the blue wire connected to the black wire or to ground either directly or via the laser safety loop.

Application Examples

Controlling the BDS Lasers from a DCC-100 Card

The BDS series lasers can be controlled via the bh DCC-100 detector / laser controller card (Fig. 6). One of the outputs, Con1, is connected to the control input connector of the laser switch box. The laser power can then be controlled via the ‘Gain’ slider, and the laser output be turned on and off via the +5V button. The other output, Con3, can be used to control a detector or a second laser. Con2 is reserved for controlling shutters and optical attenuators.

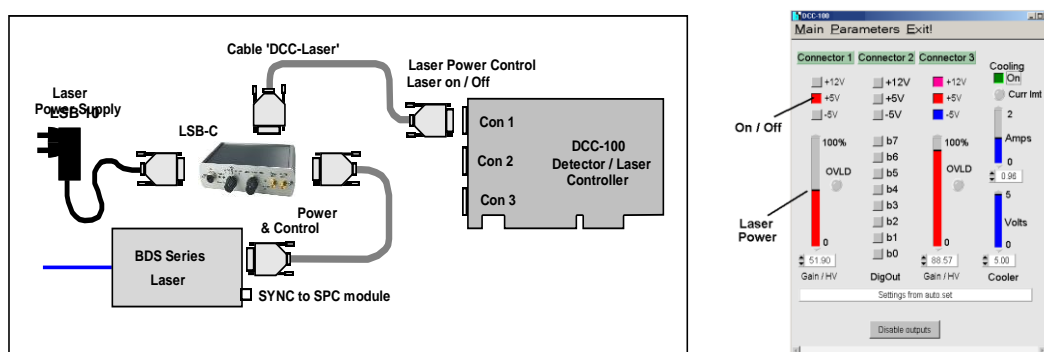


Fig. 6: Controlling the BDS-SM from a DCC Detector / Laser Controller card

Simple Fluorescence-Decay Experiment

The setup shown in Fig. 7 uses a BDS-MM or BDS-SM laser for a simple fluorescence lifetime experiment. The sample is excited by the picosecond pulses from the laser. The fluorescence photons are detected by a bh HPM-100 or PMC-100 detector, and recorded by an SPC-150N, or SPC-130EMN TCSPC module (any bh TCSPC module will work). The timing synchronisation signal for the TCSPC module comes from the Sync output of the laser. Both the laser and the detector are controlled by a DCC-100 detector / laser controller card. The entire setup is operated via the bh SPCM TCSPC operating software, see Fig. 7, right.

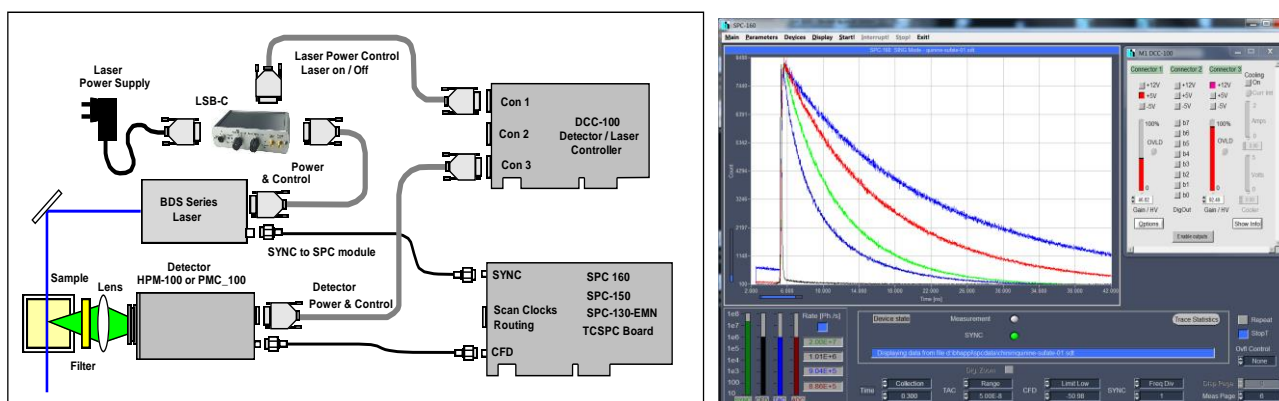


Fig. 7: Simple fluorescence-lifetime experiment. Left: System setup. Right: SPCM panel.

Laser Multiplexing

Two or more lasers are switched ON/OFF alternately at a period in the microsecond or millisecond range. Simultaneously with the switching of the lasers, the memory block address in the SPC module is switched. Thus, photons excited by each laser are stored in separate memory blocks in the SPC module [1, 2].

A connection diagram is shown in Fig. 8. The laser ON/OFF signals are generated in a DDG-210 pulse generator card. Switching of the lasers is achieved via the ‘Laser ON/OFF’ inputs of the lasers.

The DDG-210 card also generates the routing signal for the SPC module. It is applied to the lowest routing bit, R0, via the 15-pin control connector of the SPC module. Please see [2] for details.

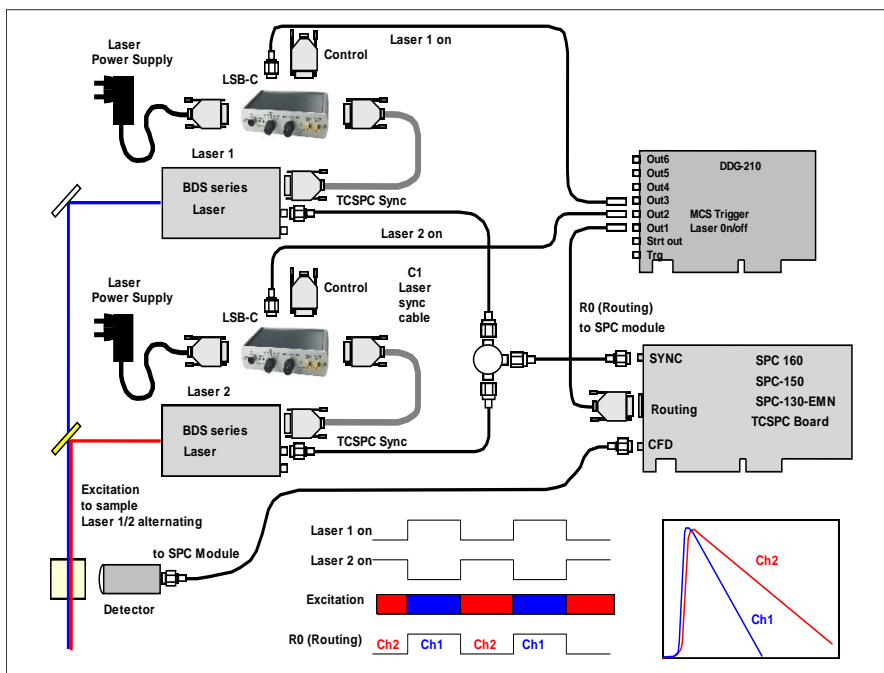


Fig. 8: Laser multiplexing. The lasers are switched ON/OFF alternatingly, the photons excited by different lasers are stored in separate TCSPC memory channels

Combined Fluorescence / Phosphorescence Lifetime Detection System

The system shown in Fig. 9 can be used to simultaneously record fluorescence and phosphorescence decay curves. Only one laser is used, the other one is blocked optically or replaced with a LSG-02i sync generator [2]. The laser is ON/OFF modulated at a period in the microsecond or millisecond range. In the ‘ON’ phase fluorescence is excited and phosphorescence is build up. In the ‘OFF’ phase pure phosphorescence is observed, see Fig. 9, left. Fluorescence decay curves are built up from the photon times in the laser pulse period, t_{micr} , phosphorescence decay curve from the times in the modulation period, $T - T_0$. A result is shown in Fig. 9, right. The method can be combined with confocal or two-photon laser scanning. Details are described in [2, 3, 4].

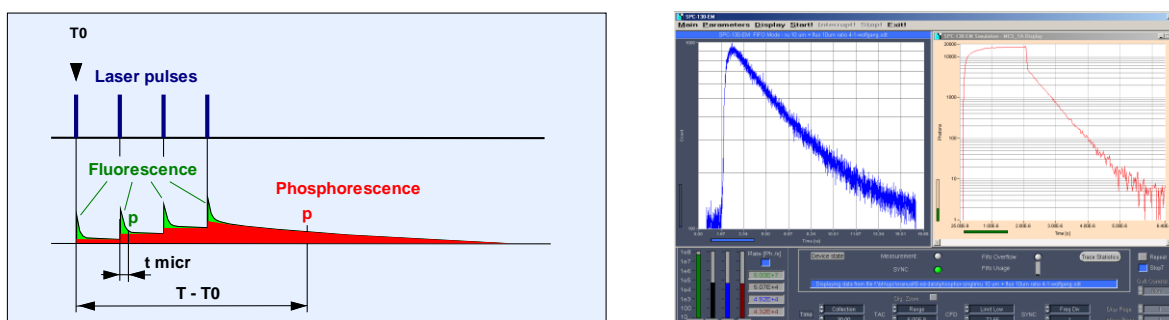


Fig. 9: Simultaneous recording of fluorescence and phosphorescence decay curves. Left: Principle. Right: Display of fluorescence (left) and phosphorescence decay (right) in SPCM software

Stage-Scanning FLIM System with the BDS-SM Laser

The optical principle of a simple FLIM system with a BDS-SM laser and a piezo scan stage is shown in Fig. 10, left. A BDS series ps diode laser is coupled into the system via a single-mode fibre. A Qioptics fibre collimator is used to obtain a collimated beam out of the fibre. The beam is reflected down into the microscope beam path by a dichroic mirror. A lens focuses the laser into the upper image plane of the microscope. The laser thus forms a focused spot in the sample. The fluorescence light from the sample is collected back through the microscope lens, collimated by the lens, and

separated from the laser beam by the dichroic mirror. A bandpass or longpass filter in the collimated beam selects the detection wavelength range. The light passing the filter is focused into a multi-mode fibre by a second lens, and transferred to an id-100-50 SPAD detector. The electrical connections are shown in Fig. 10, right. The scanner is controlled via a bh GVD-120 scanner control card, the FLIM data are recorded by an SPC-150N, SPC-160, or SPC-830 TCSPC / FLIM module. Please see [5, 6] for details.

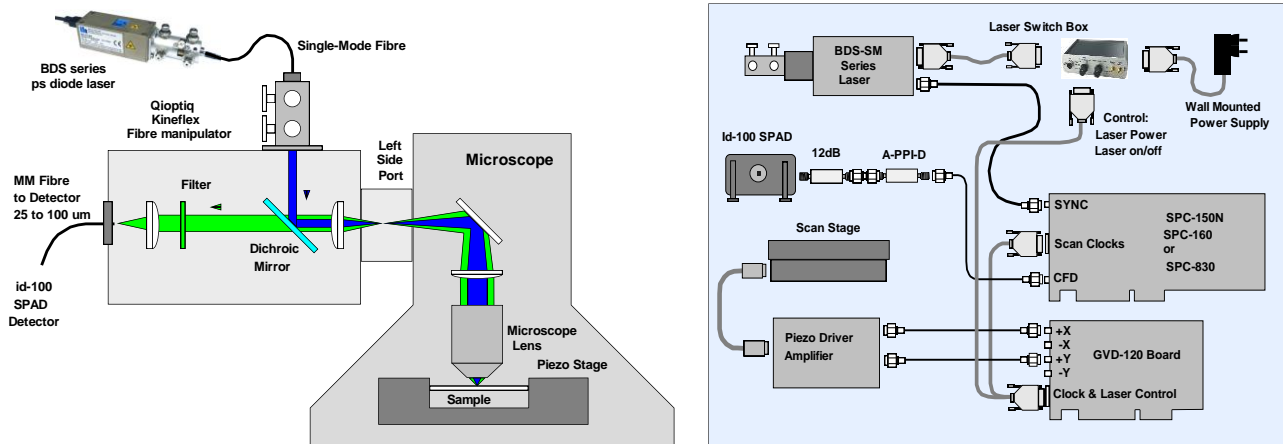


Fig. 10: Stage-scanning FLIM System with BDS-MM laser. Left: Optical principle. Right: System connections

Fig. 11, left, shows a FLIM image recorded by this setup. Decay curves in selected pixels are shown in Fig. 11, right.

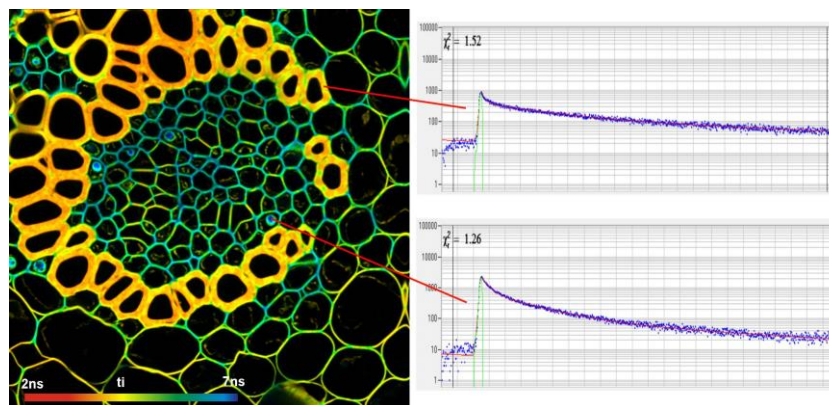


Fig. 11: FLIM of a Convallaria sample. 512x512 pixels, 1024 time channels per pixel. Decay curves in selected pixels shown right.

References

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BDS-SM

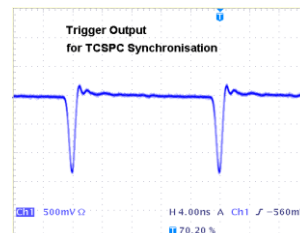
Optical

Repetition Rate, switchable by TTL signal
 Wavelengths
 Pulse width (FWHM, at medium power)
 Pulse width (FWHM, at maximum power)
 Power control range (power in free beam)
 Power control range (CW mode, power in free beam)
 Beam diameter, free beam
 Polarisation
 Coupling efficiency into single-mode fibre, typically

20 MHz, 50 MHz, 80 MHz and CW, other repetition rates on request
 375, 405, 445, 470, 485, 515, 640, 685, 785, 1064 nm, other on request
 30 to 90 ps
 60 to 300 ps
 0 to 1 mW 0 to 5 mW (depends on wavelength version)
 0 to 20 mW 0 to 50 mW (depends on wavelength version)
 0.8 mm (circular) or 1 x 3 mm (elliptical, depends on version)
 horizontal
 up to 60 % (circular version)

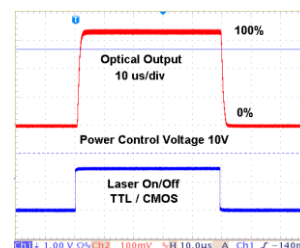
Trigger Output, to TCSPC Modules

Pulse Amplitude -1.2 V (peak) into 50 Ω
 Pulse Width 1 ns, see figure right
 Output Impedance 50 Ω
 Connector SMA
 Jitter between Trigger and Optical Pulse < 10 ps



Synchronisation Input

Input amplitude +3.3 to +5 V into 50 Ω
 Duty cycle 10 to 30 %. DC equivalent must be < 2.5 V
 Input frequency single shot to 80 MHz
 Active power stabilization / power control 10 to 80 MHz
 Connector SMA
 Switch between internal clock and sync input automatic, by average voltage at trigger connector



Control Inputs

Laser ON/OFF
 Response of optical output to ON/OFF signal
 External Power Control
 Response time of optical output to power control
 F1: 50 MHz
 F2: 20 MHz
 F3: 80 MHz
 CW
 TTL / CMOS, 'low' means 'OFF', internal pull-up
 < 4 us for power 10 to 100 %, see figures right
 analog input, 0 to +10 V
 < 4 us for power 10 to 100 %, see figure right
 active H, internal pull-up resistor
 active H, internal pull-down resistor
 active H, internal pull-down resistor
 active H, internal pull-down resistor

Laser runs at 50 MHz when Frequency/CW inputs unconnected

Power Supply

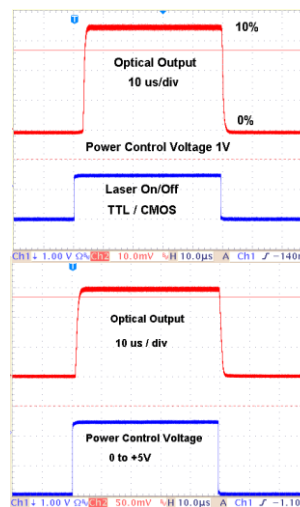
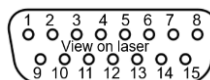
Power Supply Voltage +9 V to +15 V
 Power Supply Current at 12V 200 mA to 500 mA ¹⁾

Mechanical Data

Dimensions (OEM) 40 mm x 40 mm x 120 mm
 Dimensions (w/ cooling) 40 mm x 70 mm x 120 mm
 Mounting holes four holes for M3 screws
 Heat sink requirements < 2 °C / W ²⁾

Connector Pin Assignment

Connector version Mini Sub-D 15 pin
 Power supply +12V 1, 2
 GND 4, 5, and case
 Power control voltage 8
 Laser ON/OFF (TTL/CMOS, active H) 6
 F2: 20 MHz (active H, int. pull-down resistor) 3
 F1: 50 MHz (active H, int. pull-up resistor) 7
 F3: 80 MHz (active H, int. pull-down resistor) 10
 CW (active H, int. pull-down resistor) 9
 Do not connect: 11, 12, 13, 14, 15



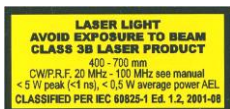
Maximum Values

Power Supply Voltage 0 V to +15 V
 Voltage at 'Laser ON/OFF' and 'Frequency' inputs -2 V to +7 V
 Voltage at 'Laser Power' input -12 V to +12 V
 Ambient Temperature 0 °C to +40 °C ²⁾

1) Depends on case temperature due to laser diode cooling. Cooling current changes with case temperature.
 2) OEM version without active cooling must be mounted on heat sink. Case temperature must remain below 40 °C.

Related Products

BDS-MM picosecond diode lasers, BDL-SMN picosecond and CW diode lasers, 375, 405, 445, 473, 488, 515, 640, 685, 785, 1064 nm



Caution: Class 3B laser product. Avoid direct eye exposure. Light emitted by the device may be harmful to the human eye. Please obey laser safety rules when operating the devices. Complies with US federal laser product performance standards.

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