

High Power Diode Lasers and Amplifiers

Diode Lasers and Amplifiers

In the past, powerful tunable cw light could only be attained by employing large solid-state lasers or dye ring laser systems with expensive pump sources. In 1998 TOPTICA developed the first tapered amplifier TA 100, a tunable semiconductor laser solution with the lowest operating costs and long lifetime. Since then this Master Oscillator Power Amplifier (MOPA) system has been continuously improved, the TA pro has now superseded the TA 100 and TOPTICA's range of high power systems has grown: today one can choose between laser (TA pro, DLX) and amplifier (BoosTA) systems.

Overcoming power limits of laser diodes

The output power of single-mode laser diodes is limited and not sufficient for a variety of applications. The output facets of these laser diodes (typically $1 \times 3 \mu\text{m}^2$) suffer optical damage at higher power levels, whereas with larger facets the desired spatial mode properties cannot be maintained. With tapered amplifier based laser systems, TOPTICA has managed

to overcome both limitations, offering not only high power and tunability, but also excellent beam quality and extremely narrow linewidth. The master laser beam is coupled into the small single-mode channel at the AR coated rear facet of the tapered amplifier chip. The single-mode channel acts as a spatial mode filter (like a single-mode fiber). The close-fitting tapered angle is adapted to the diffraction angle of a single-mode laser at the specified wavelength. The laser beam is amplified in a single pass through the tapered region, without losing its high spectral and spatial quality, and leaves the chip through the AR coated large output facet.

Versatile solutions

The **TA pro** and **TA DFB** laser systems consist of a grating stabilized diode laser and a spatially separated tapered semiconductor amplifier. This MOPA concept combines the tunability and linewidth of the master oscillator with the high power and excellent beam quality available from tapered amplifiers. The modular and open concept of these

laser systems makes them versatile and flexible. The TA pro is a member of the pro series and consistently follows its concept: maximum stability and ease of use. The TA DFB features a DL DFB as master laser with wide mode-hop free tuning. Together, the TA systems offer the broadest wavelength coverage and highest output powers.

The **DLX 110** laser consists of an external cavity diode laser with a specifically designed high power laser diode. It offers tunable output in a single spatial mode and narrow linewidth. Various options are available, ideally suited for spectroscopy and related applications. Both the TA and DLX laser systems are equipped with TOPTICA's sophisticated driving and control electronics SYS DC 110 including a wide range of user-friendly stabilization and control options (see pages 46–53). The **BoosTA** amplifier system employs the tapered amplifier chips of the TA pro in a low cost and compact amplifier module. For the versed scientist it allows easy integration into an existing setup. The BoosTA features compact electronics that are integrated into the laser head.

TA pro

High Power in pro Design

In MOPA configurations, the stability and linewidth of the system depends crucially on the master oscillator. Therefore the TA pro features a pro master laser (see pages 16–18). The other components have to ensure not only stable beam pointing, but also ideal optical and thermal performance. The TA pro utilizes completely new mirror mounts based on flexure technology that are conveniently adjustable from the top (patent pending). They ensure easy coupling into the tapered amplifier, while offering superior stability to prevent intensity fluctuations that might arise from beam pointing variations. The unit containing the TA chip and optics is optimized to be most stable and to offer best heat conductivity. For beam shaping, TOPTICA uses custom made optical components, achieving excellent beam profile and highest fiber coupling efficiency.

Compact integration with high quality components

A high quality optical isolator placed between the master and the amplifier not only protects the master laser, but also

guarantees spectrally robust operation. Between isolator and tapered amplifier a probe beam is split off and is available for spectral stabilization and monitoring purposes. All mechanical and optical components are integrated in a housing that is machined from a solid block. The complete system has proven its stability in numerous tests and experiments in TOPTICA's and customer's laboratories.

Main advantages

The user benefits from getting a completely integrated MOPA system with its unmatched stability against acoustic noise, vibrations and ambient temperature changes. The TA pro is easy to align, very stable when aligned, and it offers the best possible beam quality available from tapered amplifiers. The TA pro is well-characterized, and available in five standard wavelengths.

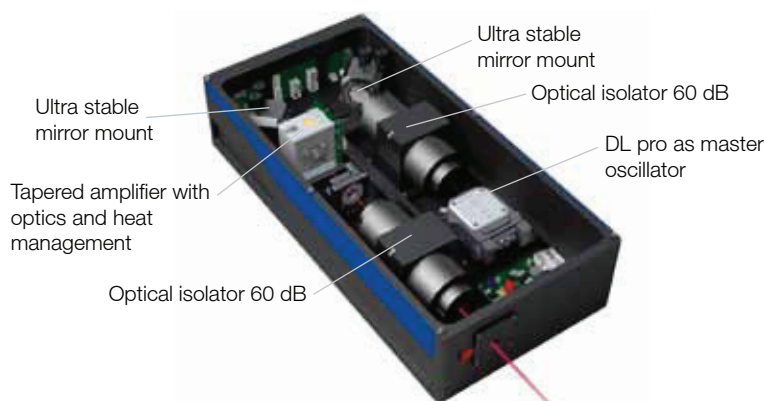
Custom and higher power systems are readily available between 645 nm and 1083 nm. The output power depends on available TA chips and master laser diodes.



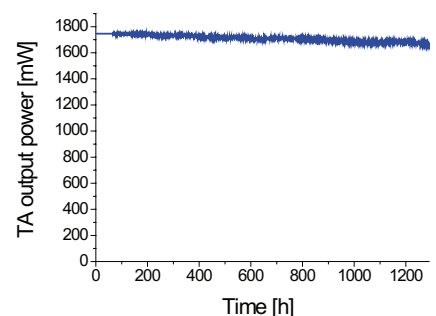
TA pro – next generation of amplified tunable diode lasers.

Key features

- MOPA concept
- DL pro master laser
- Powers up to 2 W
- Excellent beam quality: typ. $M^2 < 1.5$
- Standard wavelengths: 670 nm, 765 nm, 780 nm, 795 nm and 850 nm
- Easy alignment from outside



Setup of the TA pro MOPA system: compact and stable.



Excellent output power stability.

Model SYST TA pro	670	765	780	795	850
Wavelength range [nm]	661 .. 672	758 .. 778	765 .. 790	792 .. 805	835 .. 853
Max. output power [W]	0.50	1.50	1.50	0.50	1.00
Beam quality	< 1.5	< 2	< 1.5	< 1.5	< 1.5
Mode-hop free tuning [GHz]	20 .. 30	30 .. 50	30 .. 50	15 .. 30	30 .. 50

TA pro, TA DFB & Customized Systems

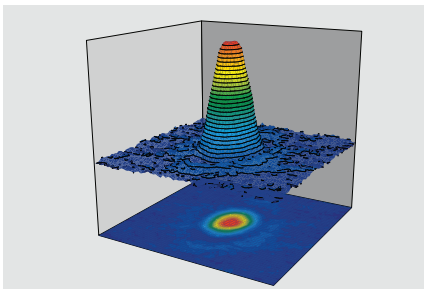
Amplified Tunable Diode Lasers



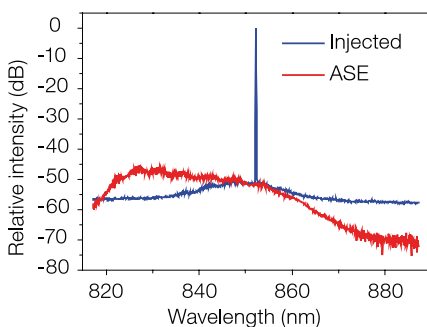
TA pro – High power tunable laser

Key features

- MOPA concept
- Superb single-frequency master lasers
- Highest powers up to 2 W
- Excellent beam quality: typ. $M^2 < 1.5$
- Wide wavelength coverage from 645 nm .. 1083 nm (with few gaps)
- Improved mirror holder for long term stability and convenient alignment



Typ Beam profile of TA pro laser system.



Amplifier output spectrum at 850 nm, with and without injected master laser. With seed the incoherent background is suppressed by approx. -50 dB.

Amplified Tunable Diode Lasers

While our TA pro features a pro design master laser, TA systems are also available with a DFB diode laser as master oscillator. DFB diodes offer wider mode-hop free tuning while ECDLs have wider coarse tuning. DFB laser diodes have their grating integrated into the diode, and are therefore intrinsically extremely stable. They do typically have a larger linewidth. More information about DFB based diode lasers can be found on page 20. The main differences between pro series and DFB master lasers are summarized in the following table.

Laser System	TA pro	TA DFB
Master laser	pro series	DL DFB
Coarse tuning [nm]	5 .. 70	1 .. 6
Mode-hop free tuning [GHz]	20 .. 50	500 .. 1500
Typical linewidth (5 μ s) [MHz]	0.1 .. 1	1 .. 4

Comparison between DFB and pro series master lasers.

Customized versions

With customers, who research at the foremost front in science, TOPTICA has to address ever new demands and requirements. Most of our scientific lasers are open systems and flexible, allowing for adaptations according to customers' needs. For example the following custom versions of the TA pro are available:

- High power versions with up to 2W
- Special master resonator for narrow linewidths
- Motorized wavelength selection
- Optimized versions for certain laser diodes or applications
- Lowest noise amplifier only systems
- Fiber amplified diode lasers for other wavelengths and higher powers

Customized versions might not be available for every wavelength, laser diode and TA chip. Please enquire and let us know about your needs.

Wavelength [nm]	max. Power [W]
765	1.5
780	2*
850	1.5*
915	1.5
970	2*
1010	1.5*
1070	2*

* requires special high power system

Highest output powers available from TOPTICA's tapered amplifiers.

Options TA pro and TA DFB

- Output Isolator (strongly recommended)
- FiberDock for both output (requires isolation) and probe beam
- Noise Eater

DLX

High Power Tunable Diode Laser

Direct power

The DLX 110 is an external cavity diode laser system utilizing a specifically designed high power laser diode. It provides up to 1 W output power in a single spatial mode with very narrow linewidth. Its high wavelength stability makes it ideal for demanding applications such as high-resolution spectroscopy. The operating wavelength can be manually adjusted over more than ± 5 nm around the center wavelength and can be fine-tuned mode-hop free over more than 15 GHz. TOPTICA's proprietary thermal management and robust mechanical design ensures long-term stability and reliable operation.

RockSolid technology

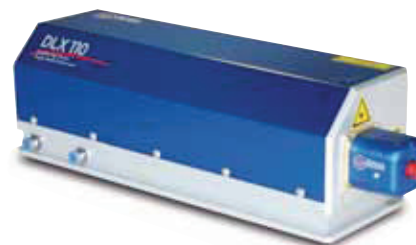
The DLX features a cavity design employing "RockSolid" technology. RockSolid greatly reduces the laser's sensitivity to vibrations and acoustic noise. The laser is therefore easy to stabilize without

compromising the mode-hop free tuning range. The DLX 110 provides the space for integration of a 60 dB isolator into the laser head. It is also available with TOPTICA's robust fiber coupler FiberDock™, offering stable fiber delivery and an extra probe beam for analysis and stabilization.

Modulation and stabilization options

The DLX-Mod option permits fast modulation and control of the laser frequency. Together with the built-in piezo actuator it can be used to tightly lock the laser to atomic transitions or high-finesse cavities to further reduce the laser linewidth. The laser system is complemented by a modular set of control electronics from the established DC 110 series.

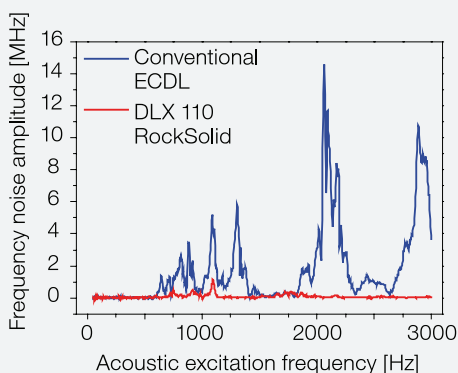
A detailed description of available control modules can be found in the Electronics and Photonics sections (see pages 44–69).



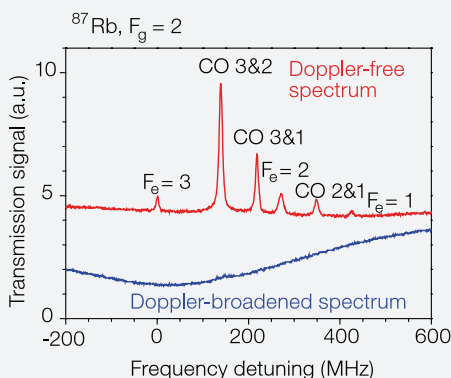
DLX – Single diode high power laser

Key features

- 1 W @ 780 nm, 500 mW @ 767 nm
- RockSolid technology
- Excellent beam quality, M^2 typically ≤ 1.5
- Options: high-frequency modulation, optical isolation, fiber coupling



The RockSolid technology minimizes the susceptibility of the DLX to vibrations and acoustic noise.



Doppler broadened and Doppler free Rb D_2 spectrum (780 nm, CO: "cross over").

BoosTA

High Power Semiconductor Optical Amplifiers

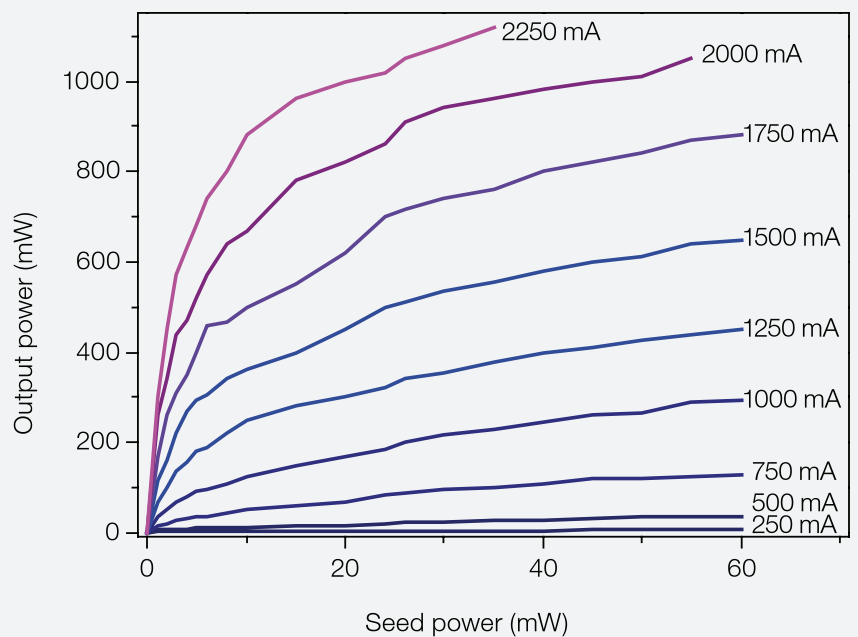


Compact semiconductor optical amplifier for more laser power

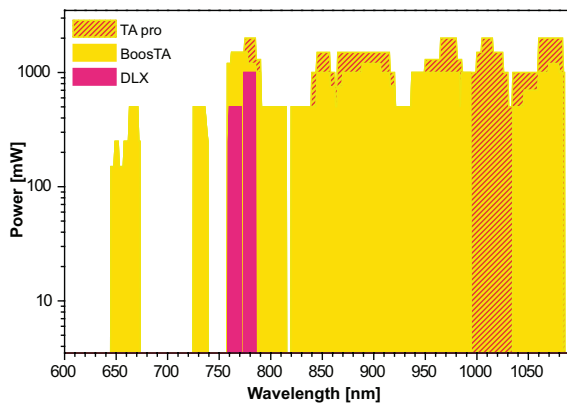
The BoosTA is the economic amplifier alternative for the experienced scientist, who wants to amplify a single mode diode laser or any other linearly polarized master laser. It includes computer controlled stand-alone electronics and all the optics to accept a collimated laser beam as input and to provide a well collimated output beam. The user is responsible for optical isolation of the seed laser, and for appropriate mode matching to the tapered amplifier. The amplifier chips are the same as in the TA pro system, yet the electronics are integrated into the laser head, resulting in a very compact amplifier system. The system features not only a driver current fine adjustment, but also an RS 232 interface to ease maintenance and control of the embedded micro controller via a standard PC. The RS 232 interface can be used to monitor and/or control parameters like temperature, amplifier current and laser power. The separate power supply minimizes the impact of thermal and electronic radiation (EMC) on the laser head. The integration of an optional output isolator into the laser head reduces unwanted back reflections into the amplifier. Optional single-mode fiber coupling is available for fiber input and fiber output. When both are equipped (FiFo option), the amplifier is particularly easy to set up.

Key features

- Compact amplifier module
- Gain up to 20 dB (x 100)
- Output power up to 1.5 W
- Spectral properties of master oscillator are maintained
- Many wavelengths available (645 .. 1083 nm)
- Fiber input and Fiber output optional



Typical saturation behavior of tapered amplifier chips for various amplifier currents (more than 40 mW seed power is not recommended).



Specifications	TA pro	TA DFB	DLX 110	BoosTA
Configuration	MOPA	MOPA	Laser	Amplifier
Master laser	DL pro (integrated)	DL DFB (integrated)		External
Center wavelengths	645 .. 1083 nm*	760 .. 1083 nm*	765, 780 nm	645 .. 1083 nm*
Max. power	2 W	2 W	1 W	1.5 W
Coarse tuning	10 .. 50 nm	1 .. 4 nm	10 nm	10 .. 50 nm
Typical mode-hop free tuning	20 .. 50 GHz	500 .. 1500 GHz	> 15 GHz	Depends on master laser
Typical linewidth (5 μ s)	0.1 .. 1 MHz	1 .. 4 MHz	1 MHz	Depends on master laser
Polarization	Linear > 100 : 1			
ASE background, typ.	< -40 dB	< -40 dB	< -40 dB	Depends on master laser
Beam quality M ²	< 1.5 (< 2.0 for some higher power chips)		Typically 1.5	< 1.5 (< 2.0 for some higher power chips)***
Divergence	< 1 mrad			
Beam height	50 \pm 1 mm		53.9 mm	53.9 mm
Optical isolators	Internal: 60 dB included Output: optional 30 or 60 dB		Output: optional 60 dB	Input: none, Output: optional 30 or 60 dB
Fiber coupling	Optional			Input: optional**** Output: optional
Fiber coupling efficiency**: min. (typ.)	50 % (60 %)			50 % (60 %)***
Control electronics	SYS DC 110			Integrated into laser head + external supply
Frequency mod. option	Included		DLX-Mod	-
Intensity modulation option	TA-Mod included		-	-
Environment temperature: Operating / transport	15 .. 30 °C / 0 .. 40 °C			
Environment humidity	Non condensing			
Operating voltage	100 .. 120 V / 220 .. 240 V AC, 50 .. 60 Hz (auto detect)			
Power consumption	Typ. 120 W Max. 300 W	Typ. 120 W Max. 300 W	Typ. 100 W Max. 300 W	Typ. 35 W Max. 60 W
Size head (L x W x H)	400 x 192 x 90 mm ³	340 x 210 x 114 mm ³	312 x 100 x 85 mm ³	312 x 100 x 85 mm ³
Size electronics (L x W x H)	385 x 465 x 280 mm ³	385 x 465 x 280 mm ³	385 x 465 x 150 mm ³	179 x 175 x 70 mm ³
*Spectral coverage with gaps. **With TOPTICA's FiberDock, isolation required (60 dB for DLX). ***With suitable TOPTICA master laser. ****Requires linearly polarized light from FC/APC PM fiber.				