

Laser Rack Systems

For Quantum Technology 2.0 Applications



Quantum Computing
Quantum Simulation
Quantum Sensing & Metrology
Optical Clocks
Quantum Communication
Quantum Technology Research
... many other exciting applications



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QUANTUM TECHNOLOGY MEETS INDUSTRY STANDARDS

Today's applications of high-end laser systems are increasingly complex, demand short time to market and require full application focus. Moreover, lab space often is constrained and flexible laser system availability is needed. TOPTICA addresses all of these demands with highly modular 19" T-RACK Laser Rack Systems.

This product family integrates high-end laser systems into an industrial form factor and is based on TOPTICA's unique experience from thousands of TOPTICA lasers installed in scientific laboratories around the world.

All Wavelengths. More Power. Maximum Modularity.

Multiple product groups of tunable diode lasers and frequency combs are all offered in the new form factor. Laser wavelengths are available in the range from 330 nm to 1770 nm, some with output powers of several Watts. Whatever the application requires, TOPTICA is committed to find the optimum combination of modular systems. The T-RACK is future proof

given that it is straightforward to eventually add new modular units and systems.

No Compromise in Performance

TOPTICA's Laser Rack Systems have been designed from the very start for high stability, ease of use and maximum versatility. As a consequence, T-RACK-integrated modular laser systems achieve the same ultimate optical performance as TOPTICA's established table-top systems. All laser light is available from single-mode polarization-maintaining fibers and allows for flexible laser light delivery wherever needed.

Convenient Remote Control

All modular tunable diode laser systems are powered by TOPTICA's proven, versatile and convenient digital laser controller DLC pro. It provides local access via touch screen and complete remote control via Ethernet. The frequency comb is also remotely controlled from a single window.

Just works

The high level of integration not only saves lab space and ensures laser system mobility. With perfectly matching building blocks, TOPTICA guarantees that the complete system reliably works from day one of installation.

Applications

- Quantum Computing
- Quantum Simulation
- Quantum Sensing & Metrology
- Optical Clocks
- Quantum Communication
- Quantum Technology Research
- Many other exciting applications



T-RACK FEATURE HIGHLIGHTS

Broad Application Coverage



Maximum Modularity

Support of any combination of Modular Laser Systems and Modular Units



All Wavelengths.

Modular Laser Systems flexibly address a broad wavelength range from 330 to 1770 nm

Outstanding Laser Specifications - Same as for TOPTICA Table-Top Systems



Thermal Management

- Fanless design, minimizing electronic and mechanical noise
- MTA pro and MSHG pro water cooled



Passive Vibration Isolation

- Double vibration isolation decoupling laser head from rack
- Additional vibration isolation from castors

Industry-Proof Operation



Central Power Supply & Control

- Modular Power Entry Unit (MPE)
- Includes electrical power supply
- Includes central laser interlock for all integrated modular systems



Optimized Footprint

- 2 m height: maximizing vertical space, fits through standard doors
- 600 mm width, 800 mm depth
- 38 RU (Rack Units) total



Convenient Remote Control

- Full remote control of laser systems
- Integrated high-speed Ethernet switch



Safe Transport & Fixation

- Enabled by 4 eye bolts at the top of the T-RACK

Versatile Usage



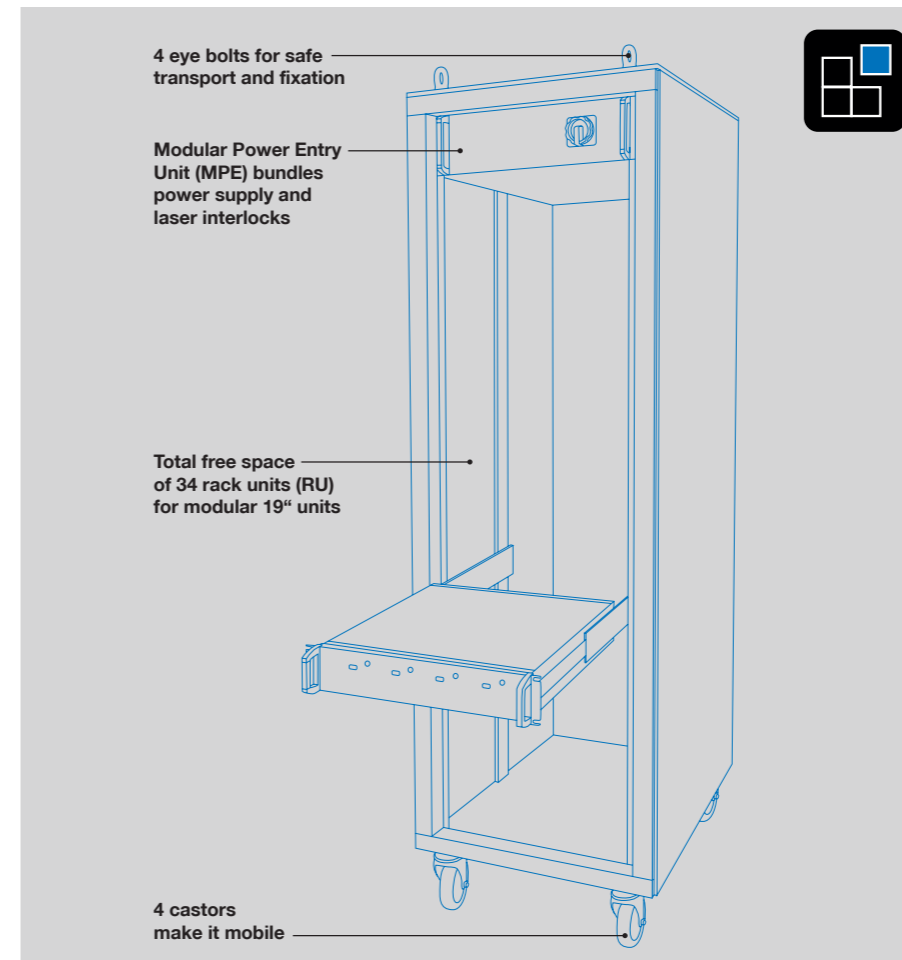
Full Access to Laser Modules

- Easy access to modular units via full-extension pull-out mechanism
- Dynamic cable management with energy chains



Laser System Mobility

- Laser rack system mobility via 4 castors
- All laser systems fiber coupled



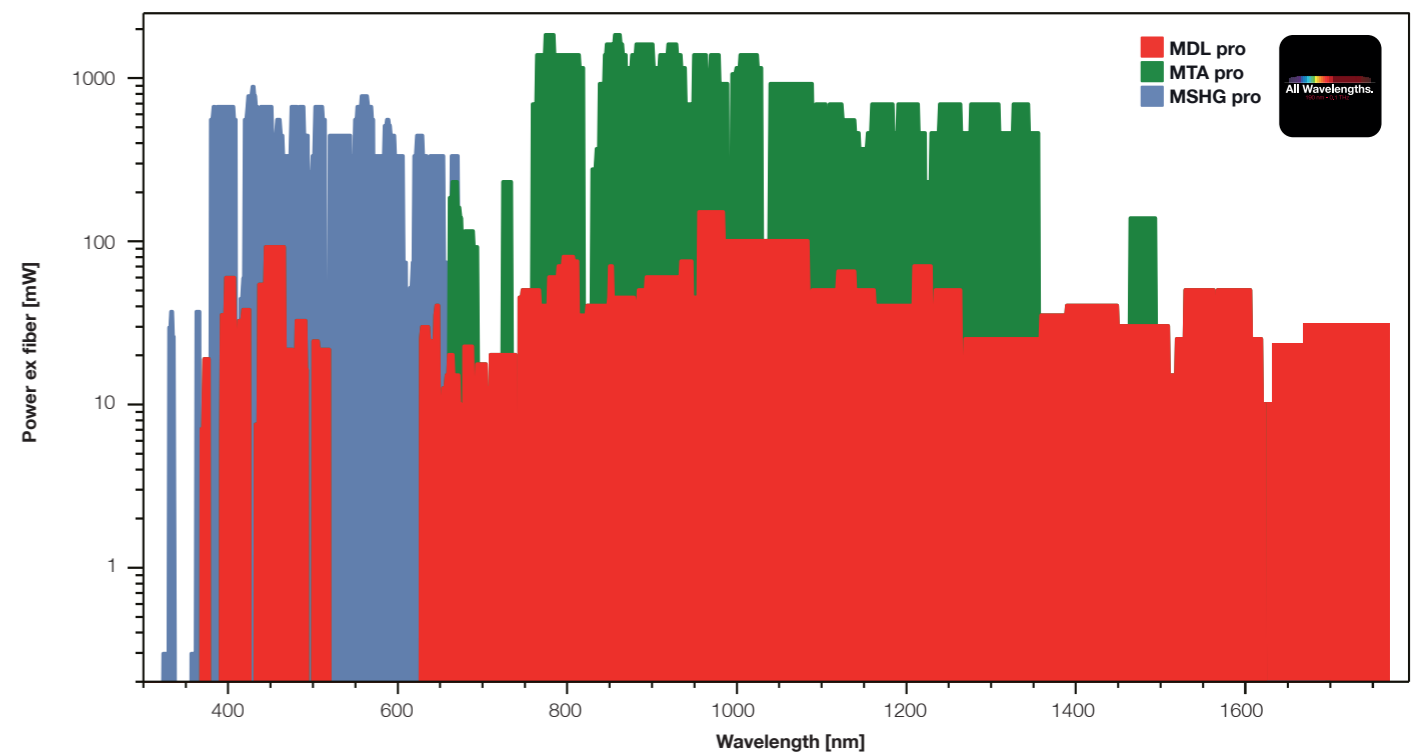
Maximum Modularity

TOPTICA's Laser Rack Systems have been designed as a highly modular platform, which targets to address any quantum technology application, no matter the underlying atomic or ionic species.

In particular, the T-RACK supports any combination of Modular Laser Systems and Modular Units being available within the TOPTICA Laser Rack Systems product family. Only, the number of DLC pro controllers should be limited to five per rack.

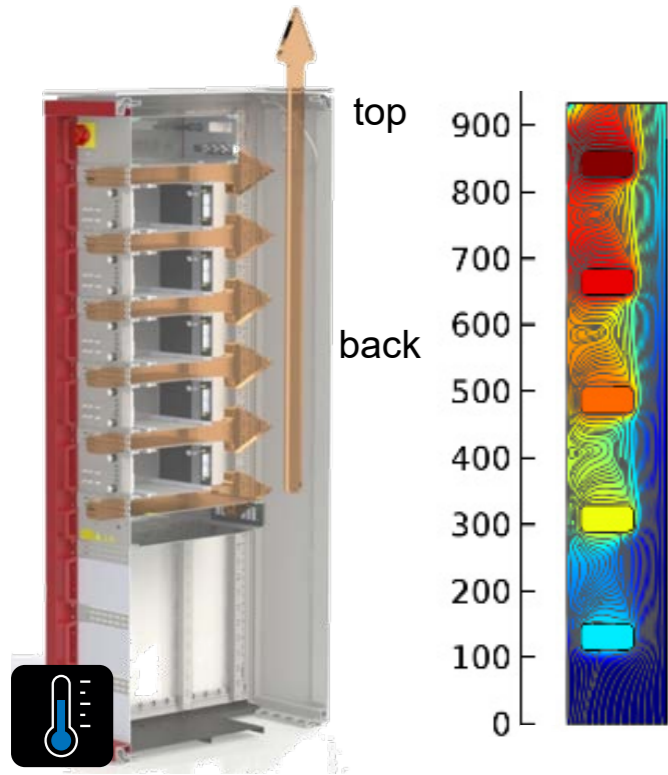
The T-RACK is future proof as it can be retrofitted with any of TOPTICA's Modular Units later, as long as rack space is available.

Just go ahead and configure your own rack! For details and help, please check with TOPTICA.



All Wavelengths.

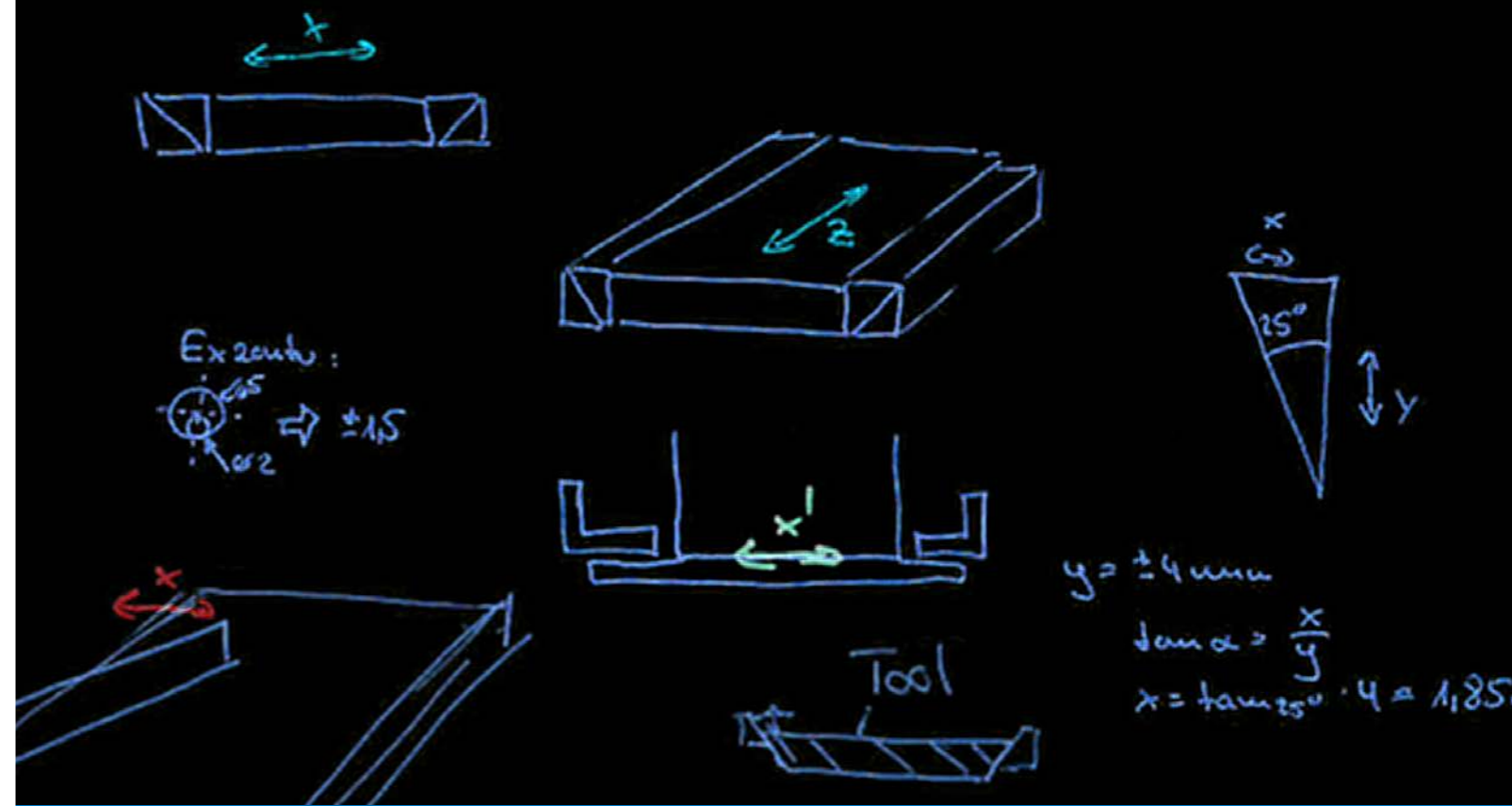
Similar to their table-top variants, rack-mountable Modular Laser Systems MDL pro, MTA pro and MSHG pro cover a broad wavelength range from 330 to 1770 nm. Optical output power values are guaranteed and extend up to 2W ex fiber.



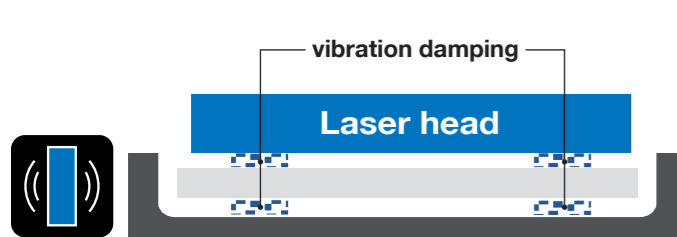
The T-RACK's fan-less thermal management is enabled by a carefully engineered front-to-back-to-top airflow concept which is the result of extensive thermal modeling.



The Modular Power Entry Unit (MPE) centrally distributes and converts power and bundles laser interlocks.



T-RACK SPECIFICATION



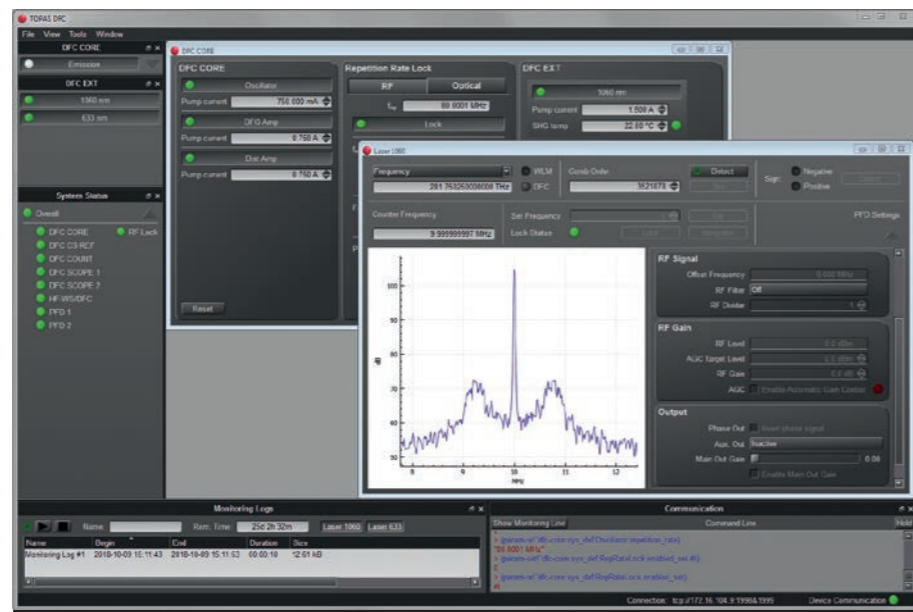
Double passive vibration isolation efficiently decouples the laser head from the rack.



Modular units are equipped with energy chains which dynamically adjust during pull-out, thus enabling dynamic cable management.

Convenient Remote Control

All modular laser and frequency comb systems are remotely controlled via Ethernet and graphical user interfaces. Within the T-RACK, control information is distributed and collected via an integrated high-speed 8-port Ethernet switch.

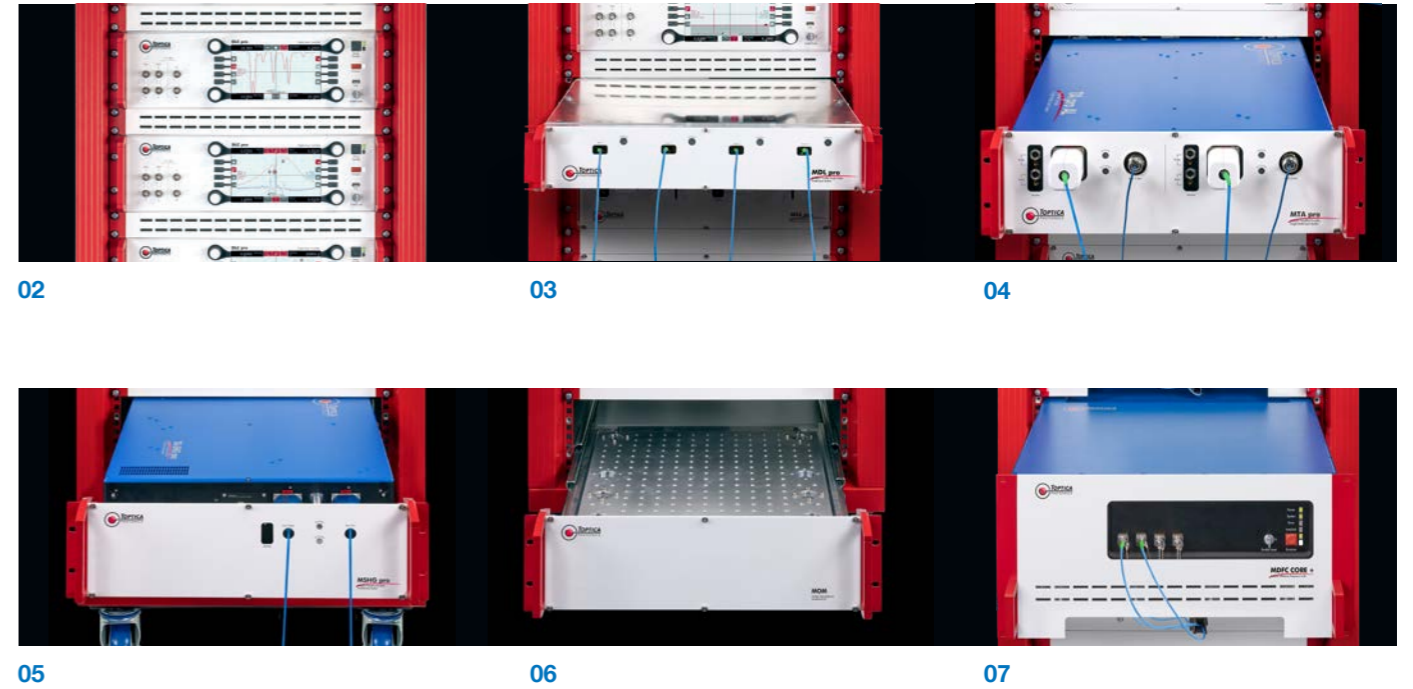
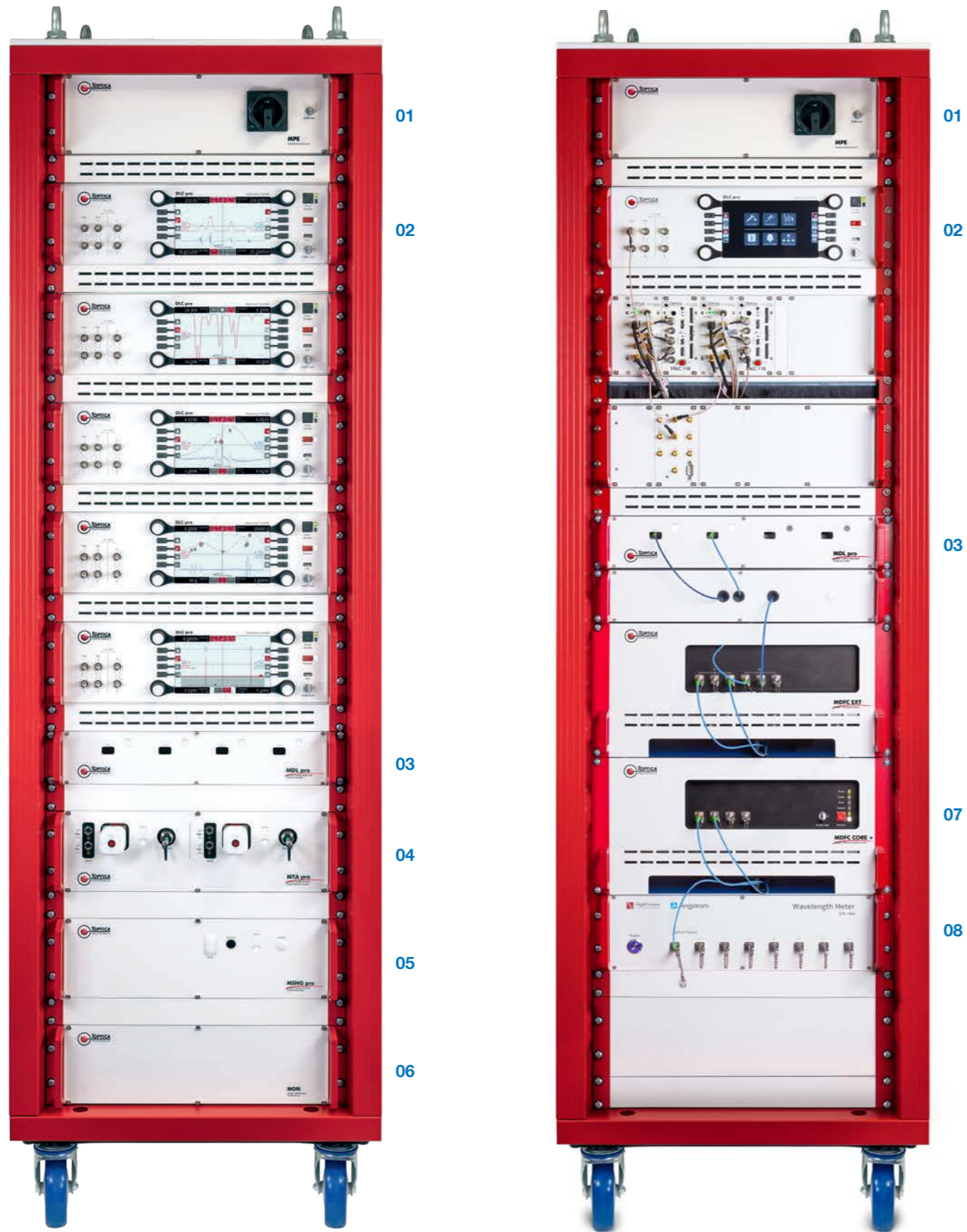


TOPTICA's Laser Rack Systems are composed by the laser rack, the Modular Power Entry Unit (MPE) and any combination of Modular Laser Systems, Modular Frequency Comb Systems and Modular Units. They also include air intake ducts for DLC pro controllers and blanking and ventilation front panels for shielding empty slots and for ensuring efficient air flow between DLC pros. Finally, they are equipped with four castors for system mobility, four eye bolts for safe laser rack transport and fixation as well as an industrial high-speed Ethernet switch for remote control of laser and frequency comb systems.

Specification T-RACK	
Height with / without eye bolts at the top	≤ 2025 / 1970 mm
Height (total number of rack units)	38 RU
Vertical space for additional modular units	34 RU
Capacity	≤ 5x DLC pro, ≤ 3x MDL pro with max 10x laser modules, ≤ 4x MTA pro, ≤ 4x MSHG pro or 8x MOM (total of max 34 RU)
Lateral dimensions (W x D)	600 x 800 mm ²
Weight	≤ 140 kg
Maximum fully loaded weight	400 kg
Environmental temperature	15 - 28 °C (operation), 0 - 40 °C (storage and transport)
Environmental humidity	Non condensing
Specification MPE	
Dimensions	Height: 4 RU (including 1-RU ventilation front panel), Width: 19", Depth: 463 mm
Electrical power input	220 .. 240 VAC, 50 Hz, 1 kW or 100 .. 127 VAC, 60 Hz, 1 kW
Electrical power output	600 W total, optionally 1000 W, 8x input voltage into MPE AC (IEC C13 Female, total 10 A max current), 3x 24 VDC (Neutrik XLR Female), optionally 5x 24 VDC
Environmental temperature	15 - 28 °C (operation), 0 - 40 °C (storage and transport)
Environmental humidity	Non condensing

Laser Rack Systems

Overview of Building Blocks



Available Building Blocks

01 T-RACK

- 19" Laser Rack
- Includes Modular Power Entry Unit (MPE)
- Fan-free thermal management

03 MDL pro

- Modular Tunable Single-Mode Diode Laser Unit
- Supporting up to 4 ECDL or DFB laser modules
- Wavelength coverage: 369 .. 1770 nm

05 MSHG pro

- Modular Frequency-Doubled Tunable Laser Unit
- Efficient frequency-doubling resonator design
- Wavelength coverage: 330 .. 780 nm

07 MDFC

- Modular Difference Frequency Comb System
- Compact, robust, high-end and convenient
- Wavelength coverage: 420 - 2000 nm

02 DLC pro

- All-Digital Controller for Tunable Diode Lasers
- Extremely low noise & precise control
- Convenient local and remote operation

04 MTA pro

- Modular Amplified Tunable Single-Mode Laser Unit
- Supporting up to 2 amplified laser modules
- Wavelength coverage: 660 .. 1495 nm

06 MOM

- Modular Opto-Mechanics Breadboard Unit
- Optical breadboard for custom solutions
- Vibration isolation and pull-out mechanism

08 Wavelength Meter

- Rack-Mountable HighFinesse Wavelength Meter
- Best absolute accuracy down to 2 MHz
- Wavelength coverage: 192 nm .. 11 μ m

TOPTICA's Laser Rack Systems integrate additional building blocks like spectroscopy cells and a variety of locking electronics.

MDL pro

Modular Tunable Single-Mode Diode Laser System



WARNING – VISIBLE AND INVISIBLE LASER RADIATION AVOID EXPOSURE TO BEAM CLASS 3B LASER PRODUCT, EN60825-1:2014



Key Features

- Up to 4 lasers in DL/DFB pro configuration
- Spectral coverage 369 .. 1770 nm
- Low noise and drift, narrow linewidth
- Light provided by single-mode PM optical fibers
- Digital control via DLC pro for best performance and convenience

MDL pro

The MDL pro combines up to four narrow-linewidth tunable diode laser modules into a compact 19" sub-rack and seamlessly integrates into the T-RACK or other suitable 19" racks. Laser modules are based on TOPTICA's DL pro or DFB pro lasers and can be any mix of pre-configured TopSellers or freely configurable MDL DL/DFB pros.

The MDL pro laser modules achieve the same ultimate performance as TOPTICA's established DL pro or DFB pro series: Unprecedented passive stability, unique locking solutions and narrow linewidth.

The MDL pro modular laser unit features a full-extension pull-out mechanism ensuring easy access to the laser modules. Moreover, it offers passive vibration isolation decoupling the lasers from the environment. The unit is highly compact consuming only 2 RU in height. An additional 1-RU space is recommended for thermal isolation between different laser units. Optical output is fiber-coupled allowing for flexible laser light delivery wherever required.

The MDL pro laser modules are controlled with TOPTICA's DLC pro. Its digital architecture enables low-noise laser operation, intelligent locking functions and remote control via Ethernet.

TopSeller: Pre-configured Systems

	DLC MDL pro Ca*				DLC MDL pro Yb*			
	Ion cooling	1 st ionization step	Repump A	Repump B	Ion cooling	1 st ionization step	Repump A	Repump B
Application								
Wavelength (nm)	396.959	422.792	854.444	866.452	369.524	398.912	935.186	760.073
Power ex fiber (mW)	35	38	60	8	7	11	8	17
Linewidth (kHz, typ., 5 μs)	150	150	3000	3000	150	150	3000	3000

Each TopSeller includes 2 DL pro HP lasers, 2 DFB pro lasers (repumps) and 2 DLC pro digital laser controllers.

Configurable Systems

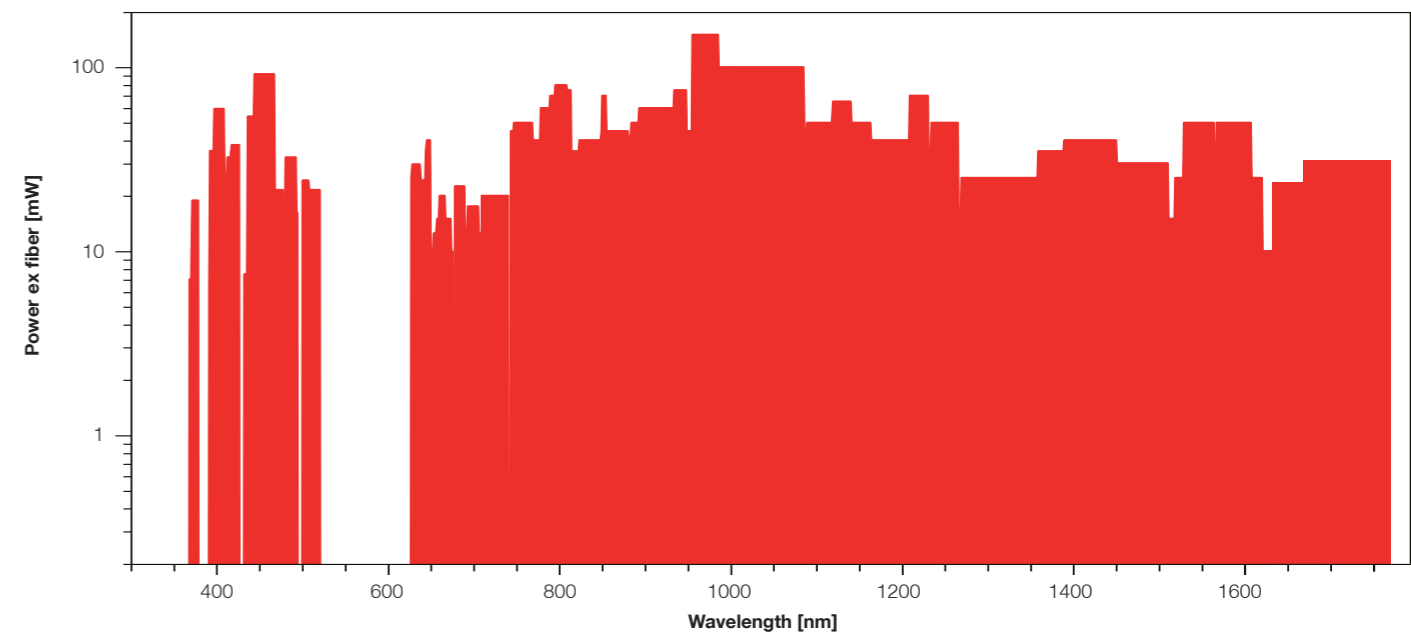
Pre-configured TopSeller Laser Modules*

	HP 369	HP 397	HP 399	HP 420	HP 461	633	HP 637	670	780	850
Typical applications	Yb ion cooling	Ca ion cooling	Yb cooling	Ca cooling, Sr ion cooling, Rb Rydberg	Sr cooling, Cs Rydberg	HeNe laser wavelength	NV center, Yb ion clear out laser	Li cooling	Rb cooling, K cooling	Cs cooling, Ca ion repump
Wavelength interval (nm)	369.2 - 370.2	396.5 - 398.5	398.5 - 401	420 - 423	457 - 461	631 - 635	635 - 639	660 - 673	765 - 805	840 - 875
Power ex fiber (mW)	7	35	11	38	90	17	24	13	55	38
Linewidth (kHz, typ., 5 μs)	150	150	150	150	150	200	500	200	50	100

Configurable Laser Modules*

	Based on DL pro	Based on DL pro HP	Based on DFB pro
Wavelength interval (nm)	369 .. 1770	369 .. 641	633 .. 1770
Power ex fiber (mW)	6 .. 160	7 .. 60	1 .. 80
Linewidth (kHz, typ., 5 μs)	10 .. 300	100 .. 500	200 .. 4000

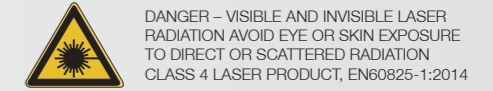
*Free combination of up to 4 laser modules. Includes a DLC pro; if 3 or 4 laser modules are configured a second DLC pro is included. Pre-configured laser modules include DL pro or DL pro HP. For available laser diode visit www.laser-diodes.com.



Available wavelengths and corresponding output power levels (ex-fiber).

MTA pro

Modular Amplified Tunable Single-Mode Laser System



Key Features

- Up to two lasers in TA pro, BoostTA pro or DL/DFB pro configuration
- Spectral coverage 369 .. 1770 nm with power up to 2 W from PM fiber
- Includes AutoAlign for coupling into tapered amplifier and output fibers
- Low noise and drift, narrow linewidth
- Digital control via DLC pro for best performance and convenience

MTA pro

The MTA pro combines up to two MTA TA pro amplified laser systems into a 19" sub-rack and seamlessly integrates into the T-RACK or other suitable 19" racks. The modular design also enables integration of MTA BoostTA pro amplifier only modules or DL/DFB pro laser modules. MTA pro integration of the latter may help to avoid an extra MDL pro and comes with additional features and options.

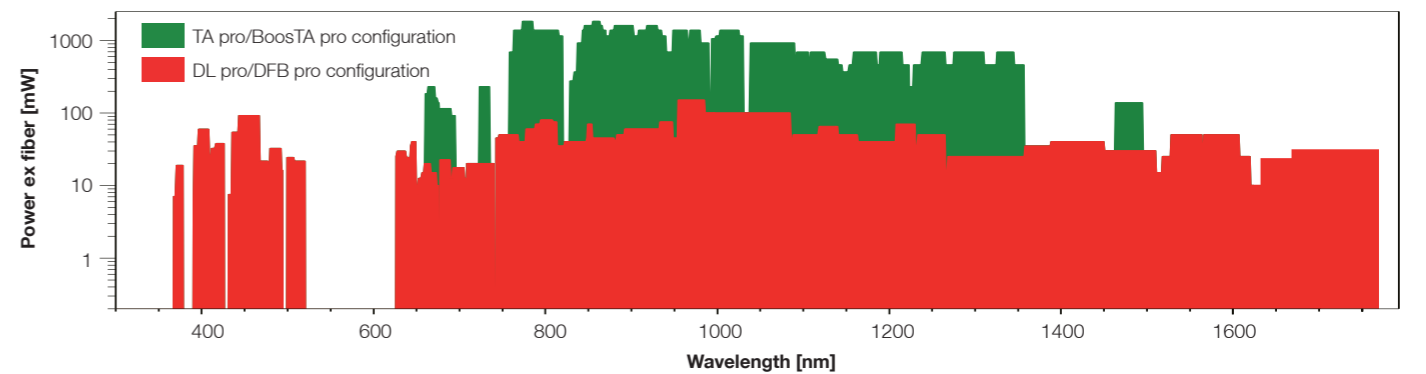
When operated in TOPTICA's T-RACK, the MTA pro has the same optical specifications as a fiber-coupled TA pro system. In addition, it always includes AutoAlign, a fully automated push-button coupling optimization into the tapered amplifier and the optical output fibers. Moreover, MTA pro supports output power stabilization.

The MTA pro modular laser unit features a full-extension pull-out mechanism and dynamic cable management, both ensuring easy access to the laser modules. The unit consumes a total of 4 Rack Units (RU) in height, including an extra 1-RU blanking front plate recommended for thermal isolation between laser units. Optical output is fiber-coupled allowing for flexible laser light delivery wherever required.

The MTA pro laser modules are controlled with TOPTICA's DLC pro. Its digital architecture enables low-noise laser operation, intelligent locking functions and remote control via Ethernet.

Specification				
DLC MTA pro	Includes TA pro AL laser head which is passively vibration isolated against the modular laser base			
Modular Laser Unit	Up to 2 modules of configuration MTA TA pro (HP/DFB/DFB HP), MTA BoostTA pro (HP), MTA DL pro (HP) or MTA DFB pro			
Integrated modules	Up to 2 modules of configuration MTA TA pro (HP/DFB/DFB HP), MTA BoostTA pro (HP), MTA DL pro (HP) or MTA DFB pro			
Dimensions laser unit	Height: 4 RU (including 1-RU blanking front panel), Width: 19", Depth: 722 mm			
Weight	< 30 kg (MTA pro laser unit), < 8.5 kg (DLC pro control unit)			
Power consumption	< 200 W			
Environment temperature	15 - 30° C (operation), 0 - 40° C (storage and transport)			
Environment humidity	Non condensing			
MTA module	MTA TA pro	MTA BoostTA pro	MTA DL pro (HP)	MTA DFB pro
Wavelength range [nm]	660 - 1495*		369 .. 1770*	633 .. 1770*
Power ex fiber [mW]	Up to 2000		6 .. 160	1 .. 80
Typical tuning range [nm]	10 .. 50			2 .. 6
Mode-hop-free tuning [GHz]	20 - 50	depends on seed laser	typ. ≥ 20	Up to 1400
Linewidth (typ. 5 μs)	10 .. 300 kHz (DL pro master), 0.2 .. 4 MHz (DFB/DBR master)	depends on seed laser	10 .. 300 kHz (DL pro master)	200 .. 4000 kHz
Polarization	Linear > 100 : 1			
ASE background (0.05 nm)	typ. < -40 dB	depends on seed laser	typ. < -40 dB	
Optical isolators	Internal and output isolators included where required			
Fiber coupling	Fiber coupling included for all input and output beams			
Output fiber coupling efficiency	min. 50 %, typ. 60 %		min. 55 %, typ. 65 %**	
Monitor photo diodes	Included for monitoring of AutoAlign into amplifier chip and for power stabilization where applicable			
AutoAlign	Included for coupling into amplifier chip and output fibers			
Frequency modulation	Mod AC and Mod DC	N/A	Mod AC and Mod DC	
Intensity modulation	TA-Mod for amplifier included		N/A	
Cooling	Water cooling required (e.g. DLC Chiller)		Active cooling not required	
Control unit	DLC pro (digital)			
Maximum TA current	5 A (with DLC pro TA), 10 A (with DLC pro TA HP)		N/A	
User Interface	Multi-Touch, knob and total remote control			
Locking options	DLC pro Lock, FALC pro, PDH/DLC pro, FALC 110 and PFD			
Dimensions control unit	Height: 4 RU (including 1-RU ventilation front panel), Width: 19", Depth: 308 mm			
Operating voltage	100 .. 120 V / 220 .. 240 V AC, 50 .. 60 Hz (auto detect)			

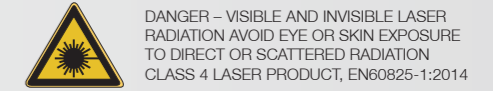
Specifications are subject to change without further notice *Spectral coverage with gaps **Efficiencies are possibly lower with strong ellipticity or short wavelengths



Available wavelengths and corresponding output power levels (ex-fiber).

MSHG pro

Modular Frequency-Doubled Tunable Laser System



Key Features

- Highly-stable resonant frequency-doubling stage
- Spectral coverage 330 .. 780 nm with power up to 2 W from PM fiber
- Includes AutoAlign for coupling into amplifier, doubling stage and fiber
- Low noise and drift, narrow linewidth < 500 kHz
- Digital control via DLC pro for best performance and convenience

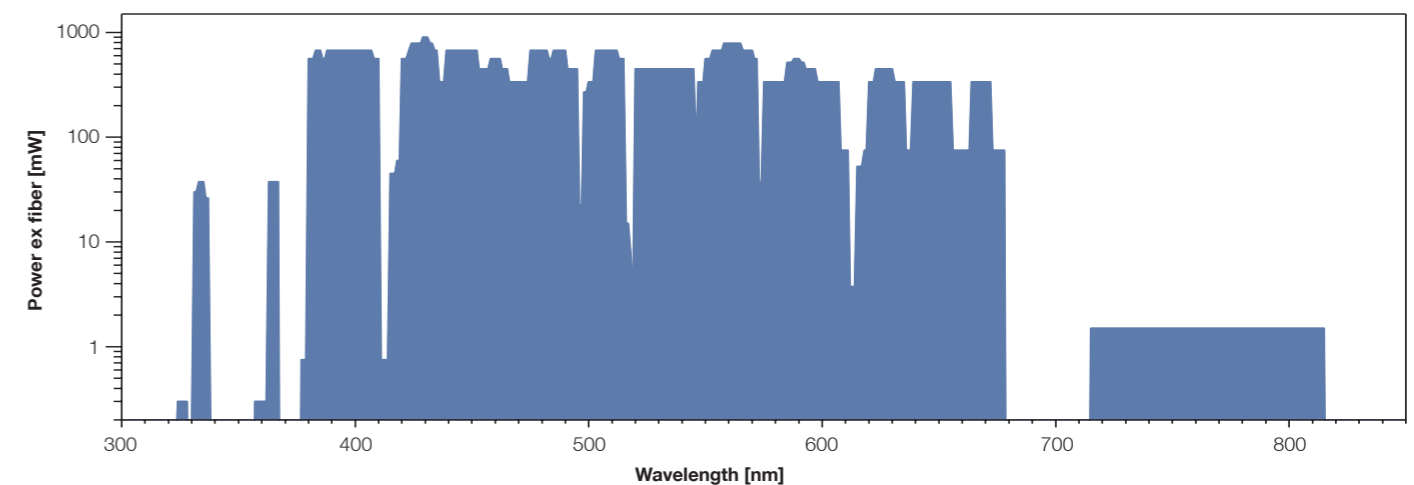
MSHG pro

The MSHG pro is the 19" rack-mountable version of the SHG pro and seamlessly integrates into TOPTICA's T-RACK or other suitable 19" racks. The MSHG pro laser head includes a tunable diode laser, a high-power semiconductor amplifier and an integrated frequency-doubling (SHG) stage. The SHG stage is a folded ring cavity in bow-tie configuration with excellent thermal and mechanical stability.

When operated in TOPTICA's T-RACK, the MSHG pro has the same specifications as a fiber-coupled SHG pro system. It includes AutoAlign, a fully-automated push-button coupling optimization into amplifier, SHG cavity and optical output fiber. Moreover, MSHG pro supports output power stabilization.

The MSHG pro modular laser unit features a full-extension pull-out mechanism and dynamic cable management, both ensuring easy access to the laser modules. The unit consumes a total of 4 Rack Units (RU) in height, including an extra 1-RU blanking front plate recommended for thermal isolation between laser units. Optical output is fiber-coupled allowing for flexible laser light delivery wherever required. The MSHG pro is controlled with TOPTICA's DLC pro. Its digital architecture enables low-noise laser operation, intelligent locking functions and remote control via Ethernet.

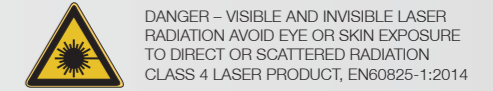
Specification	
Wavelength range	330 .. 680 nm (with semiconductor amplifier), 510 .. 780 nm (on request with fiber amplifier)
Linewidth (typ., 5 μs)	10 .. 300 kHz (DL pro master), 200 .. 4000 kHz (DFB/DBR master)
Seed laser	DL pro, DL DFB
Amplifier	semiconductor amplifier (TA), on request: Fiber amplifier (FA) or Raman fiber amplifier (RFA)
Doubling stage	Folded ring cavity in bow-tie configuration
Coarse tuning	2 .. 20 nm
Continuous scan range	> 20 GHz
Operation	Single frequency
Linewidth (typ., 5 μs)	< 500 kHz
Power ex fiber	Up to 2000 mW, depending on wavelength and amplifier
Spatial mode	Nearly diffraction limited
Optical isolation	Two isolators (DL stage, TA stage) included
Beam shaping	Included
Water cooling	Required, supported
SHG cavity leak rate	< 1E ⁻⁹ mbar l/s
Control unit	DLC pro
Warm-up time	< 5 min typ.
Dimensions laser unit	Height: 4 RU (including 1-RU blanking front panel), Width: 19", Depth: 766 mm
Dimensions control unit	Height: 4 RU (including 1-RU ventilation front panel), Width: 19", Depth: 352 mm
Weight	< 20 kg (MSHG pro laser unit), < 8.5 kg (DLC pro control unit)
Operating voltage	100 .. 120 V / 220 .. 240 V AC, 50 .. 60 Hz (auto detect)
Power consumption	< 120 W
PC Interface	Ethernet, USB, analog control
Environment temperature	15 - 30 °C (operation), 0 - 40 °C (storage and transport)
Environment humidity	Non-condensing



Available wavelengths and corresponding standard output power levels (ex-fiber), higher output power available on request.

MDFC

Modular Difference Frequency Comb



Key Features

- Compact design
- Highly robust operation
- High-end stability transfer down to the 10^{-21} level
- Convenient remote control from a single GUI
- Spectral coverage 420 - 2000 nm

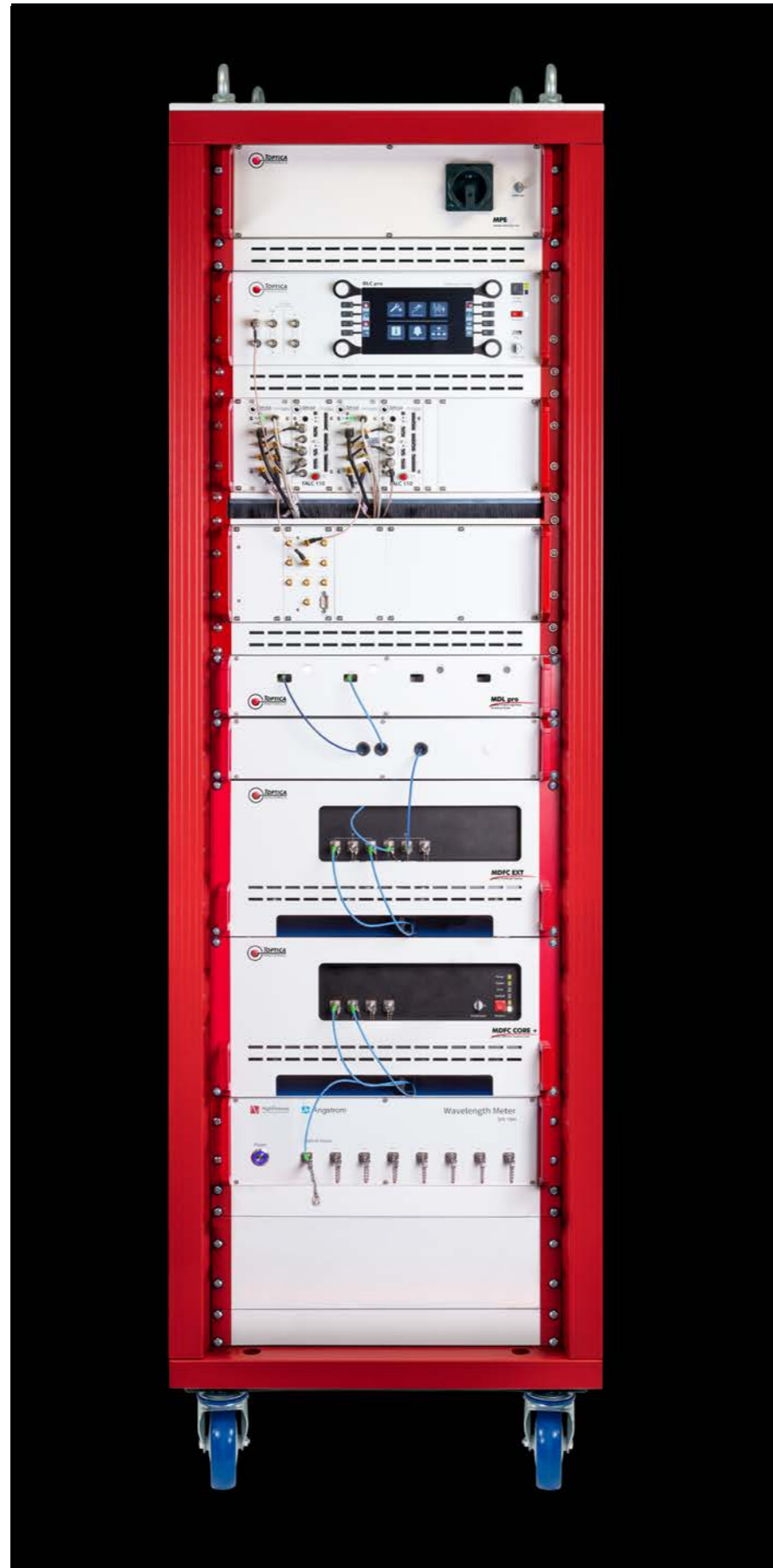
MDFC

The operating principle of the offset-free Modular Difference Frequency Comb (MDFC) relies on generating a broadband supercontinuum from the output of a low noise Er-fiber mode-locked oscillator and subsequent optical difference frequency generation (DFG) between the low- and high-frequency parts of the octave spanning spectrum in a nonlinear crystal. The most important features are an improved stability and an all passive, hence simple and reliable frequency offset stabilization.

The difference frequency comb is compact by design and is conveniently controlled from a single user interface. Any of TOPTICA's tunable diode lasers with a wavelength between 420 nm and 2000 nm can be locked to the MDFC. Frequency-doubled lasers with shorter wavelengths can be stabilized using their fundamental.

The MDFC product line is comprehensive: It includes the MDFC CORE +, any desired wavelength extension, beat units, stabilization electronics, different frequency reference options, digital oscilloscopes and frequency counters.

Finally, the MDFC perfectly integrates with TOPTICA's modular laser systems and wavelength meters, enabling users to source a complete stabilized and rack-mounted laser system solution from a single supplier.

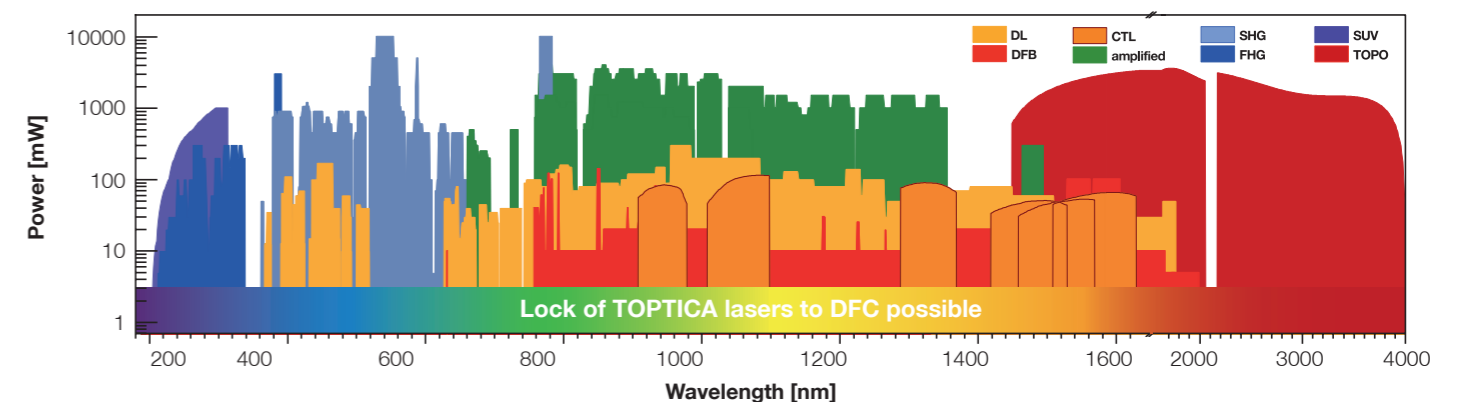


01

02

	Module	Description
01 Frequency Comb	MDFC CORE +	Difference Frequency Comb, 4 (optionally 8) offset-free outputs @ 1560 nm, > 10 mW, > 20 nm
	MDFC EXT	19" sub-rack for wavelength extensions
	DFC IR	Centered @ 1560 nm, bandwidth > 80 nm, typ. 100 nm
02 Wavelength extensions*	DFC NIR	Centered @ 780 nm, bandwidth > 35 nm, typ. 40 nm
	DFC DVIS**	Wavelength range 420 ($f_{rep} = 80$ MHz), 450 ($f_{rep} = 200$ MHz) - 860 nm, bandwidth typ. > 2 nm @ 698 nm, typ. 1 nm @ 420 nm
	DFC SCNIR**	Wavelength range 840 nm ($f_{rep} = 80$ MHz), 860 nm ($f_{rep} = 200$ MHz) - 980 nm, bandwidth > 50 nm, typ. 100 nm @ 935 nm
	DFC SCIR**	Wavelength range 980 - 2000, bandwidth > 150 nm
	Reference	DFC RF
	DFC GPS	GPS frequency reference, output: 10 MHz, stability: $1.3 \cdot 10^{-12}$ @ 1s, $1 \cdot 10^{-13}$ @ 40000 s
Beat units	DFC BC	Beam combiner for DFC and cw-laser, fiber coupled
	DFC BCF	Fiber beam combiner for DFC and cw-laser, 980 nm, 1030 nm, 1300 nm, 1550 nm
	DFC MD	Monochromatic detector unit, fiber coupled, use with DFC BC / DFC BCF
Locking electronics	MDFC LOCK	19" sub-rack for FALC and PFD
	FALC	Fast analog 2-channel PID
	PFD	Phase frequency detector, enables remote locking with FALC
Accessories	DFC SCOPE	Digital oscilloscope with spectrum analyzer (FFT), for convenient beat monitoring from software
	DFC COUNT	4 channel counter
	WS8-30	High Finesse wavelength meter, for convenient determination of comb line number

* other extensions on request, ** tunable (patent protected, US 8284808B2), please inquire for more details



Key Features

- Designed for integration of custom optics, mechanics and electronics
- Highly stable breadboard built by low-strain, flat-surface and 19.5-mm thick aluminum
- Passive vibration isolation decoupling opto-mechanical breadboard and rack
- Full-extension pull-out mechanism and dynamic cable management for easy access and service



MOM

TOPTICA's Laser Rack Systems have been designed for clearing optical tables and for more economical use of valuable lab space. For many applications, dedicated optics, mechanics or electronics are an integral part of the complete system solution. The MOM offers space to researchers and system integrators according to their specific needs.

The passively vibration-isolated breadboard provides the advantages known from optical tables, but in a 19" form factor optimized for rack integration. Therefore, it represents the ideal supplement with TOPTICA's Modular Laser Systems like MDL pro, MTA pro, MSHG pro and MDFC. T-RACK integration of these laser systems together with one or a few MOMs typically allows researchers and system integrators to save a fully equipped optical table.

The MOM is equipped with a full-extension pull-out mechanism and dynamic cable management both ensuring easy access to the custom optics. Its standard variant consumes 4 Rack Units (RU) in height. On request, it is available in other vertical dimensions, too.

Specification	
Dimensions (height)	4 RU front panel, open at top, 90 mm space between breadboard and top of front panel*
Breadboard dimensions	389 mm x 590 mm
Hole size and spacing (metrical variant)	M6 tapped holes on 25-mm centers, 10 mm depth
Hole size and spacing (imperial variant)	1/4"-20 UNC tapped holes on 1" centers, 11.5 mm depth
Required rack	T-RACK or comparable rack (19", 800 mm depth, suitable mounting holes)
Maximum load	25 kg

* Other height variants available on request, smallest available height: 2 RU (45 mm space between breadboard and top of front panel, no energy chains for dynamic cable management)

Key Features

- Support of any combination of modular systems and units from TOPTICA
- Carefully engineered fan-free thermal management
- Highly robust mechanical design
- Includes Modular Power Entry Unit (MPE)
- Laser rack mobility enabled by 4 castors



T-RACK

The T-RACK is a laser rack specifically designed for integration of TOPTICA's Modular Laser Systems and Units, including MDL pro, MTA pro, MSHG pro, MDFC and MOM. Moreover, it integrates additional building blocks like wavelength meters, spectroscopy cells and various locking electronics. The T-RACK excels with a highly robust mechanical design. Fan-less thermal management, passive vibration isolation and dynamic cable management have been carefully engineered to make it a rack for high-tech precision instruments.

By default, the T-RACK is supplied with the Modular Power Entry Unit (MPE) which bundles power supply and laser interlock. Remote control of laser and frequency comb systems is simplified by an integrated industrial fast Ethernet switch with a total of 8 ports.

In addition to the MPE, the T-RACK offers space for modular units with a total height of 34 Rack Units (RU). 4 castors make it mobile and 4 eye bolts allow for safe transport and fixation. The T-RACK is future proof as it can be retrofitted with any of TOPTICA's Modular Units later, as long as rack space is available.

Specification T-RACK	
Height with / without eye bolts	≤ 2025 / 1970 mm
Height (total number of rack units)	38 RU
Vertical space for additional modular units	34 RU
Capacity	≤ 5x DLC pro, ≤ 3x MDL pro, ≤ 4x MTA, ≤ 4x MSHG, ≤ 8x 4 RU-MOM (total of max 34 RU)
Lateral dimensions (W x D)	600 x 800 mm ²
Weight	≤ 140 kg
Maximum fully loaded weight	400 kg
Environmental temperature	15 - 28°C
Environmental humidity	Non condensing

Specification MPE	
Dimensions	Height: 4 RU (including 1-RU ventilation front panel), Width: 19", Depth: 463 mm
Electrical power input	220 .. 240 VAC, 50 Hz, 1 kW or 100 .. 127 VAC, 60 Hz, 1 kW
Electrical power output	600 W total, optionally 1000 W, 8 x input voltage into MPE AC (IEC C13 Female, total 10 A max current), 3 x 24 VDC (Neutrik XLR Female), optionally 5x 24 VDC
Environmental temperature	15 - 28 °C (operation), 0 - 40 °C (storage and transport)
Environmental humidity	Non condensing



Courtesy Institute d'Optique

Complete Laser Solution for a RYDBERG QUANTUM SIMULATOR

The modularity of the Laser Rack Systems offers the chance to integrate all the lasers needed for your experiment into one T-RACK without any compromises in performance. As an example a complete laser solution for quantum simulation experiments with rubidium Rydberg atoms is presented.

Lasers at 780 nm are used to cool and trap the atoms. Two-photon excitation using lasers at 420 nm and 1020 nm drive the atoms to a Rydberg state. An optical lattice is created with an amplified laser system at 850 nm.

The table below shows a list of all lasers and related hardware needed for the realization of the Rydberg quantum simulator. An example of how these components can be integrated into a single T-RACK is shown on the next page. The blue numbers in the table and next to the picture of the T-RACK indicate where individual components are integrated. The last two columns of the table describe how individual lasers can be locked using TOPTICA laser locking electronics.

	Wavelength	Product	Power (ex fiber)	Linewidth (5 μ s)	TOPTICA Electronics and Accessories	Locking scheme/description
MOT cooling	780 nm	01 MDL pro	55 mW	50 kHz	CoSy, DLC pro Lock	Spectroscopy lock with CoSy and DLC pro Lock
	780 nm	02 MTA pro	1600 mW	50 kHz	CoSy, DLC pro Lock	Spectroscopy lock with CoSy and DLC pro Lock
Rydberg 1st step	420 nm	03 MDL pro	38 mW	150 kHz	PDH/DLC pro, FALC pro	PDH lock to external reference cavity using PDH/DLC pro and FALC pro
Rydberg 2nd step	1020 nm	04 MTA pro	1200 mW	50 kHz	PDH/DLC pro, FALC pro	PDH lock to external reference cavity using PDH/DLC pro and FALC pro
Optical lattice	850 nm	05 MTA pro	1200 mW	100 kHz		Lock to HighFinesse WS8
Additional hardware		06 Wavelength Meter HighFinesse WS8 with PCS				For monitoring and locking laser frequencies
		07 T-RACK				For mounting modular systems and units, includes MPE
		08 MOM				For mounting two CoSys



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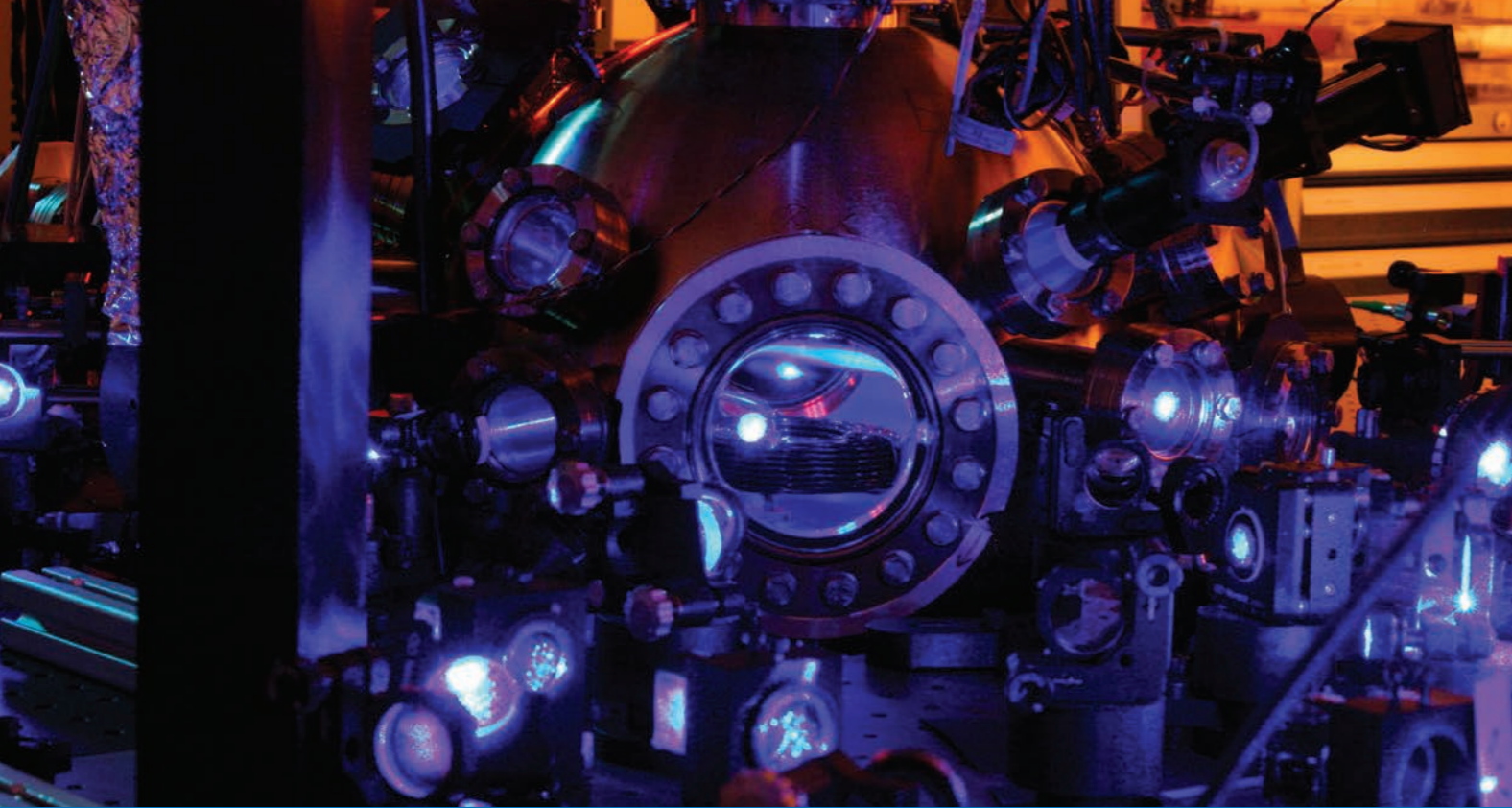
Background: Rydberg Quantum Simulator

Systems composed of neutral atoms excited to Rydberg states are a promising approach for the realization of future large-scale quantum simulators. Because neutral atoms can be held in optical lattices in large numbers without disturbing each other, systems can be scaled up easily. Exciting individual atoms to Rydberg states using lasers gives rise to long-range and controllable dipole interactions between atoms allowing to implement quantum logic operations. This promising approach has been chosen e.g. by the research groups of Mikhail Lukin at Harvard University, Vladan Vuletić at MIT and Antoine Browaeys at Institut d'Optique with spectacular results^{1,2}.

In these experiments, lasers are used to cool and trap atoms but also to control their internal quantum states. Stringent requirements on power, linewidth and the possibility to frequency lock the lasers with high bandwidth have qualified TOPTICA lasers and TOPTICA locking solutions as perfect tools for this kind of experiments. It is now possible to integrate all lasers needed for a typical quantum simulation experiment with rubidium Rydberg atoms into a single T-RACK without compromising optical performance. Fully integrated with TOPTICA's unique locking solutions, the Laser Rack System, working from day one, is the perfect choice for a Rydberg quantum simulator based on rubidium atoms.

Further reading:

¹A. Keesling et al. *Quantum Kibble-Zurek mechanism and critical dynamics on a programmable Rydberg simulator*. Nature **568**, 207 (2019).
²S. de Léséleuc et al. *Observation of symmetry-protected topological phase of interacting bosons with Rydberg atoms*. Science **365**, 775 (2019).

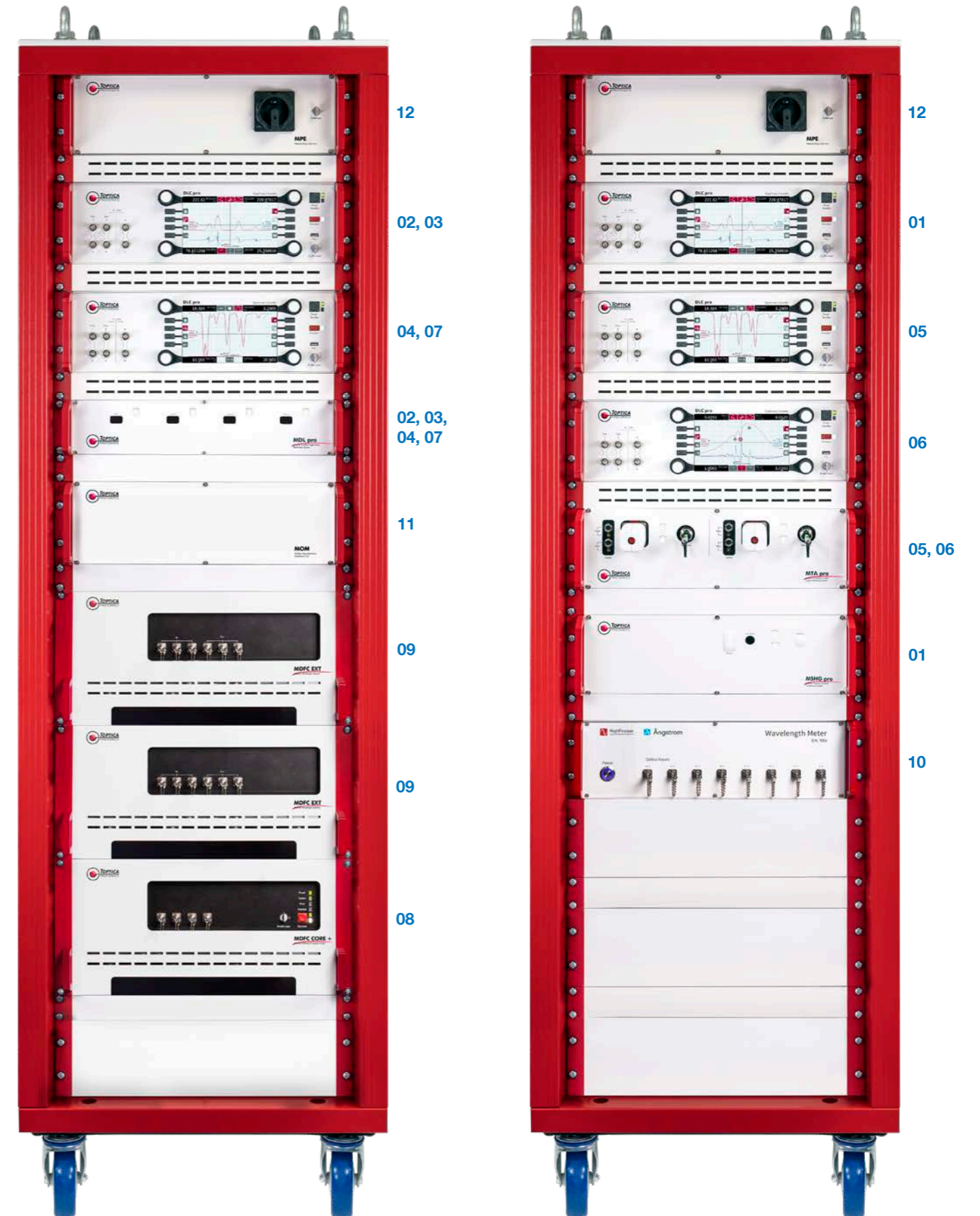


Complete Laser Solution for a **STRONTIUM LATTICE CLOCK**

Strontium lattice clocks are considered a promising candidate for a new frequency standard. Time intervals can be measured with extremely high accuracy.

Here we present a complete laser system solution for the realization of a strontium lattice clock integrated into two T-RACKS. The difference frequency comb MDFC CORE + in combination with the wavelength extensions MDFC EXT offer the ideal reference for the required long-term stability of the lasers. These lasers and additional equipment which is integrated into two T-RACKS are listed in the table below. Furthermore, all necessary frequency comb extensions and TOPTICA laser locking electronics are listed. The last column describes the locking scheme for each laser.

	Wavelength	Product	Power (ex fiber)	Linewidth (5 μ s)	TOPTICA Electronics and Accessories	Locking scheme/description
Strong cooling	461 nm	01 MSHG pro	1000 mW	100 kHz	DFC-SCIR, DFC BC/MD/PFD, FALC	Locked to frequency comb
Repumping	679 nm	02 MDL pro	20 mW	80 kHz		Locked to Wavelength Meter
	707 nm	03 MDL pro	15 mW	100 kHz		Locked to Wavelength Meter
Narrow cooling	689 nm	04 MDL pro narrow linewidth option	11 mW	50 kHz	DFC-DVIS, DFC BC/MD/PFD, FALC	Locked to frequency comb
	689 nm	05 MTA BoostTA pro	100 mW	50 kHz		Seeded by MDL pro at 689 nm
Optical lattice	813 nm	06 MTA pro	1000 mW	100 kHz	DFC-DVIS, DFC BC/MD/PFD, FALC	Locked to frequency comb
Clock	698 nm	07 MDL pro narrow linewidth option	15 mW	50 kHz	DFC BC/MD/PFD, 2 x FALC, PDH/DLC pro	PDH lock to external reference cavity using PDH/DLC pro and FALC; comb locked to clock laser
Frequency comb		08 MDFC CORE +				Core unit of the frequency comb
		09 2 x MDFC EXT				Contains wavelengths extensions of the frequency comb
Wavelength meter		10 HighFinesse WS8 with PCS				For monitoring and locking of laser frequencies
Optical setup		11 MOM				Space for optical setup
Integration		12 2 x T-RACK				For mounting modular systems and units, includes MPE



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Lastek Pty. Ltd.
www.lastek.com.au

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www.optonlaser.com

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