SodiumStar 20/2

High Power cw Tunable Guide Star Laser

Laser Guide Star

Adaptive Optics Facilities

LIDAR

Atmospheric Monitoring

Laser Cooling

TOPTICA PROJECTS GmbH

MPB Communications Inc.

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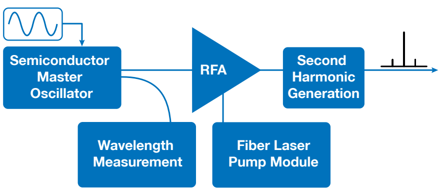
High Power cw Tunable Guide Star Laser

Existing and upcoming next generation optical telescopes require highly reliable 589 nm high-power laser sources with excellent beam quality – so-called Guide Star Lasers – for the implementation of adaptive optics. Under contract from the European Southern Observatory (ESO) and the W.M. Keck Observatory, industrial partners TOPTICA Photonics and MPB Communications have jointly developed, produced and field-tested such a Guide Star Laser for direct integration into the ESO VLT telescope structure and established the new standard for this emerging field.

Operational Principle

A master oscillator signal from a linearly polarized 1178 nm cw diode laser is stabilized to a high resolution (10 MHz) wavelength meter. Its output is efficiently amplified in a polarization-maintaining (PM) Raman fiber amplifier (RFA) based on ESO's patented technology. The spectrally narrow output is mode-matched to an efficient resonant frequency doubling cavity delivering more than 20 W of optical output at 589 nm.



Schematic of Laser Unit architecture comprising a semiconductor master oscillator serving as seed source for a PM Raman fiber amplifier which is pumped by a polarized fiber laser. The emission wavelength is stabilized via a highly accurate wavelength meter. Subsequent to amplification, the high-power laser radiation is converted to the yellow spectral region within the second-harmonic generation module (SHGM). Frequency sidebands for optical repumping are generated via current modulation of the seed laser.

Modular Design and Highest Availability for Astronomical Observation

Utmost care was taken to design and test the laser unit for remote operation in the harsh environments encountered on the top of a mountain, driving thermal, vibrational and even earthquake stability to the limits of current technology. Total weight of 700 kg, warm-up times of less than 30 minutes, power consumption of about 700 W (@ BOL), integrated optical sideband generation (D_{2b} repumping) and a novel remote pumping option along with many other features provide next generation telescope designers with unprecedented degrees of freedom.

The SodiumStar represents a paradigm shift in operational simplicity. This eliminates the need for labor-intensive daily alignment tune-ups and lengthy system warm-up times. The complete laser unit consists of line-replaceable units (LRUs) which can be swapped on-site for service and repair. The maintenance is reduced to minimize downtime and manpower requirements at the observatories. For future needs, the design offers the possibility of scaling the output power to even higher levels while preserving the excellent beam quality.

Direct Integration into the Telescope Structure

In contrast to the currently used dye or solid-state laser systems which rely on a stationary laser clean room at the observatory facility, the SodiumStar can be directly integrated into the telescope structure with its gravity-varying condition. As part of ESO's 4LGSF, four of these lasers are remotely operated via an Ethernet connection.

The distributed feedback based seed laser technology guarantees:

- intrinsic single-mode operation
- precise wavelength stabilization
- fast wavelength toggling for measuring the Rayleigh scattering background.

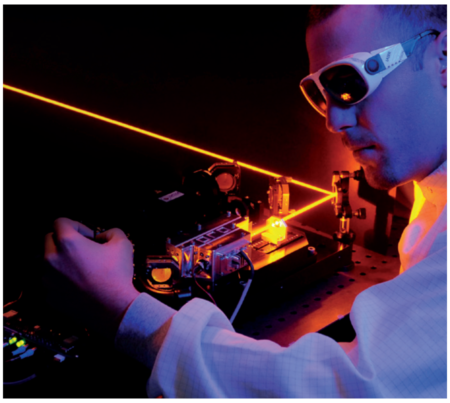
The high-power Raman fiber amplification has its known strong points:

- surface-to-volume ratio of fiber lasers allows favorable power scalability
- no need for optical alignment due to all-fiber approach
- absence of linewidth broadening during amplification.

The frequency doubling technique employs a newly-developed doubly-resonant SHG:

- highly efficient and robust
- fast control electronics
- based on state-of-the-art optomechanics
- active beam control options.

The system architecture avoids wavefront-critical optical modulators such as EOMs or AOMs and guarantees excellent beam quality.

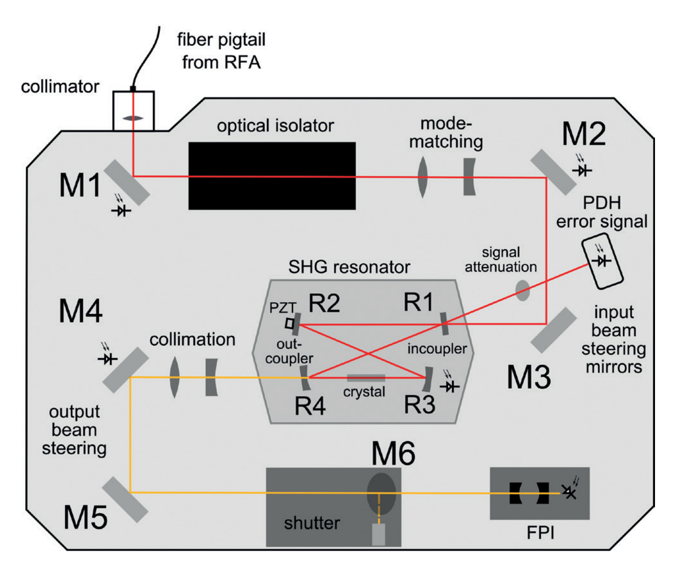


Remote Pumping: The inclusion of the control electronics in the SHG module, in combination with the flexibility of the RFA / fiber pump laser architecture, makes "remote pumping" possible. This novel technique allows spatial separation between the compact Laser Head and the Electronics Cabinet of 32 m and therefore enables highly flexible telescope integration. The compact Laser Head can be located for example in close proximity to the laser launch telescope while the Electronics Cabinet containing the pump diodes, drive electronics and power supplies (heat sources), can be installed in a more convenient location well separated from the launch telescope.

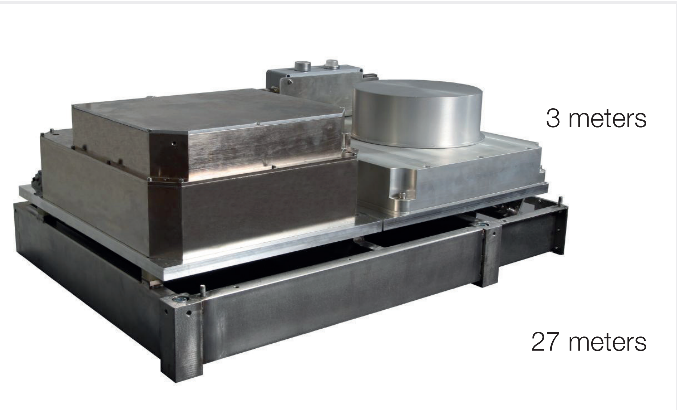
The engineering of a deployable laser system based on ESO's original concept has resulted in a ruggedized, compact and modular solution, with focus on reliability and serviceability. Options of support for integration on-site, periodic inspections for preventive maintenance as well as full service support are offered.

Fully Engineered
Ready for Integration

SodiumStar 20/2 laser head with RFA (left) and SHGM (right) on a water-cooled cold plate.

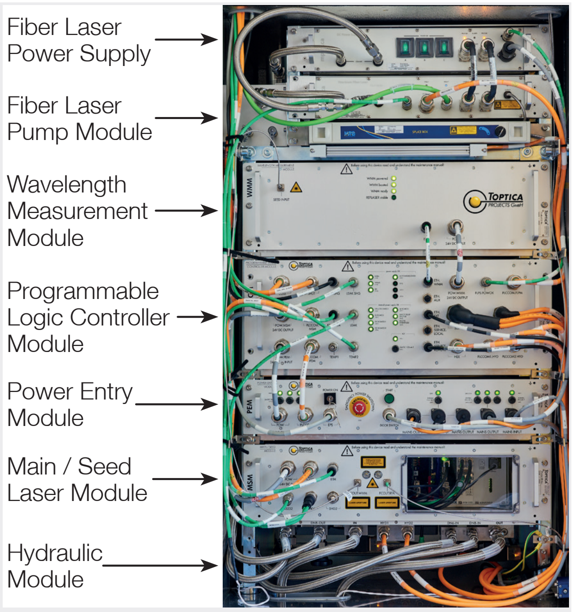


Schematic of the second harmonic generation module (SHGM).

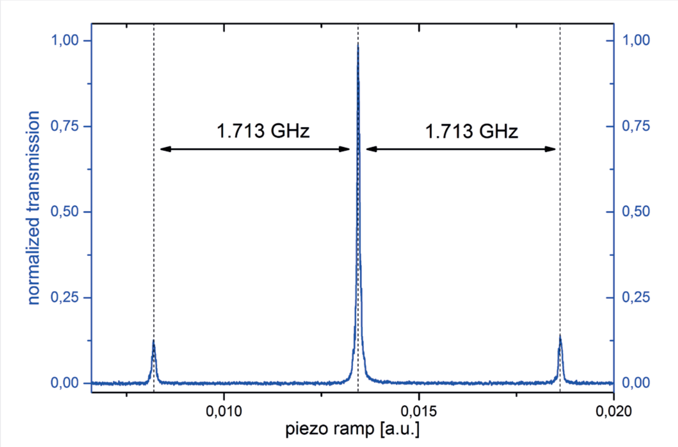


Remote pumping option: The laser head can be separated up to 32 meters from the electronics cabinet.

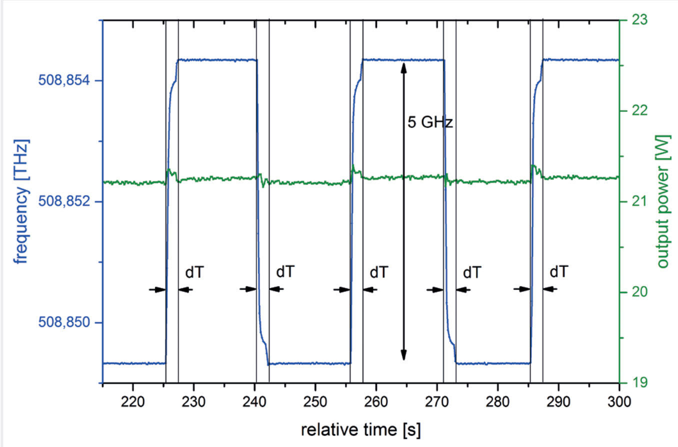
SodiumStar 20/2 electronics cabinet.



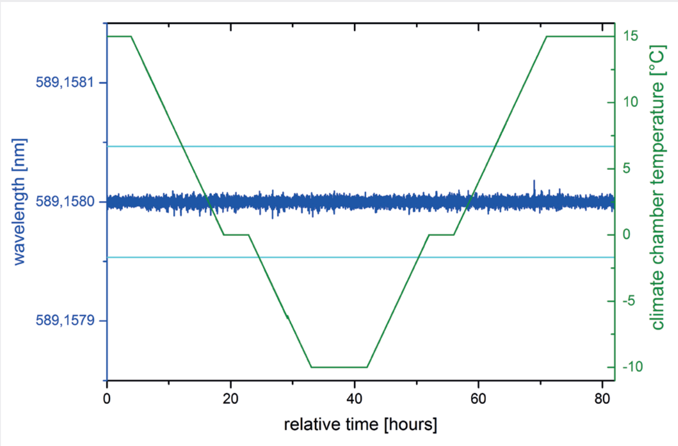
Interior view of SodiumStar 20/2 electronics cabinet.



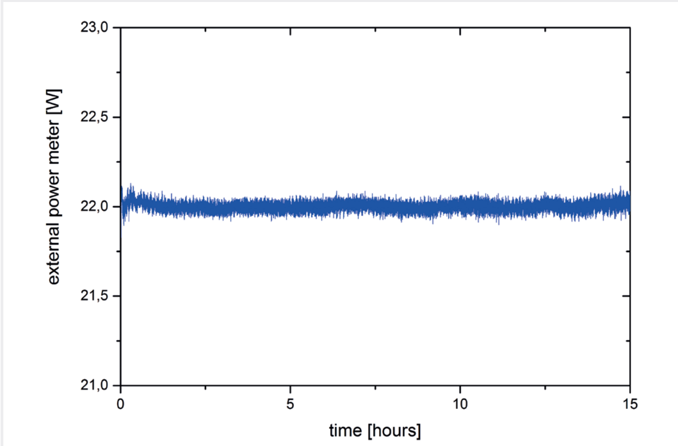
Emitted spectrum of the laser recorded via a scanning FPI with sidebands for repumping (Na D_{2b}).



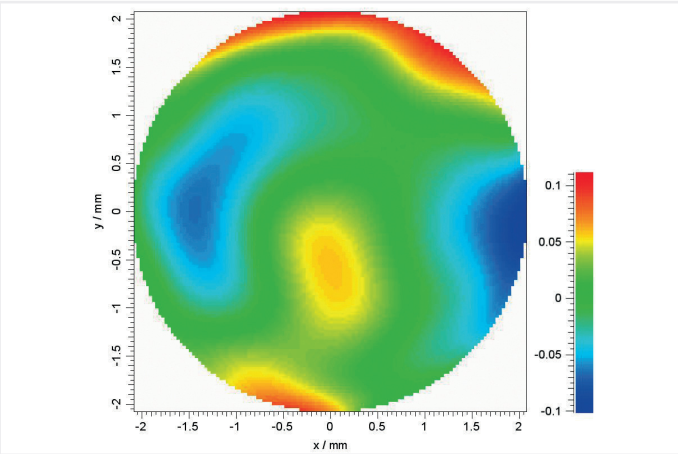
Fast detuning of emission frequency by 5 GHz within 2.5 s for measuring the Rayleigh scattering background.



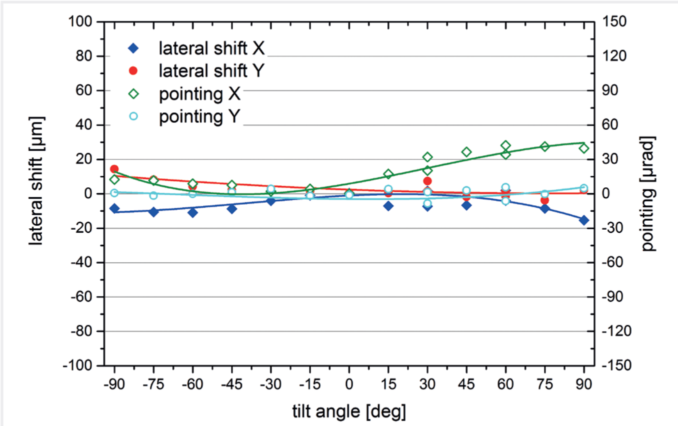
Emission wavelength during climate chamber test ±40 MHz spec, ambient temperature over 80 hours.



Long-term power measurement showing a mean value of 22 W with peak-to-peak variation of 2.1 %.



Shack-Hartmann wavefront measurement of the output beam with rms wavefront error of 23 nm.



Pointing and lateral shift of the laser output beam during a tilting test of the laser head carried out at full operational power level of 22 W of output power at 589 nm.

Specifications and Key Features

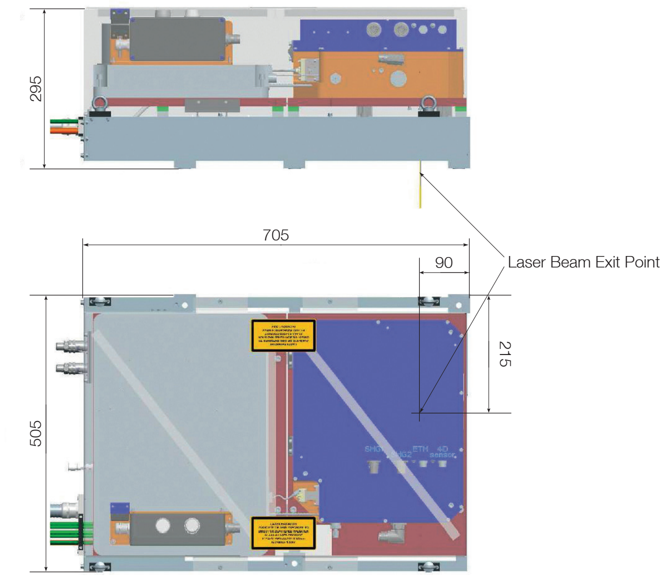
Optical Specifications	
Laser output power	≥ 20 W
Laser wavelength*	589.159 nm
Wavelength tunability	± 6 pm
Frequency stability	± 40 MHz
Laser linewidth	~ 5 MHz
Power stability peak-to-peak	< 10 %
Intensity noise rms	< 3 %
Optical beam diameter 4σ	3 ± 0.1 mm
Beam ellipticity	< 5 %
Beam quality (rms wavefront error)	< 50 nm
Beam pointing rms	< 160 µrad
Beam shift rms	< 100 µm
Polarization extinction ratio	> 100:1
Linear polarization stability	< 2°
Repumper amplitude	0 .. 15 %
Cooling System Specifications	
Coolant temperature	15 °C
Temperature stability	± 0.75 K
Coolant flow rate	~ 5l/min
General Specifications	
Electrical power consumption	< 1 kW
Operating temperature range	-10 .. 25 °C
Operating altitude (above sea level)	< 4300 m
Dimensions laser head (including insulation cover)	44 x 93 x 73 cm³ (HxWxD)
Weigth laser head	80 kg
Dimensions electronics cabinet	173 x 91 x 93 cm³ (HxWxD)
Weigth electronics cabinet	600 kg
*other wavelength / beam diameter on request	

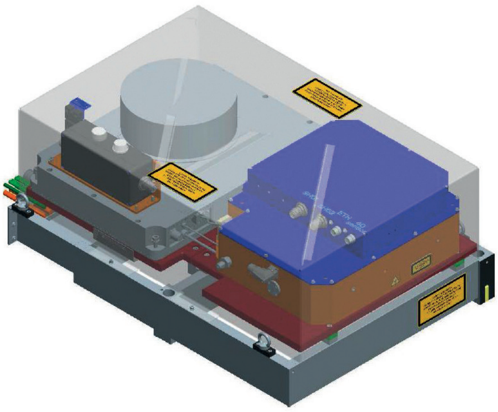
Key Features

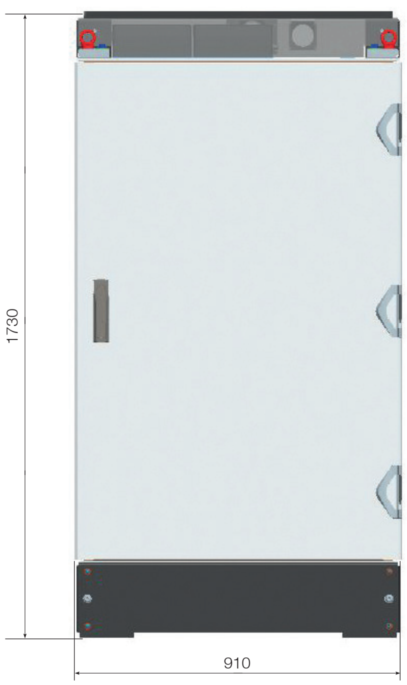
- Robust and fully engineered system
- Direct integration into telescope structure
- Gravity invariant operation
- All polarization-maintaining fiber approach
- Excellent polarization properties
- High wall-plug efficiency
- Minimized cooling requirements
- State-of-the-art optomechanics
- Active beam control implemented
- Remote pumping scheme (optional)

TOPTICA Projects GmbH and MPB Communications, Inc. are licensees of the ESO Fiber Raman Amplifier Technology (EFRA) developed and transferred by ESO (www.eso.org).

Mechanical Drawings







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Max. Power: ______ mW and ______ mW