D2.1: 461 nm laser systems

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GLOSSARY

VECSEL	Vertical-External-Cavity Surface-Emitting Laser

TABLE OF CONTENTS

Executive summary

A high-power laser at 461 nm ($^1S_0$-$^1P_1$) is the workhorse cooling laser capturing atoms from the oven and cooling them to mK temperatures in a "blue" magneto-optical trap (MOT). For this purpose, VEXLUM has developed a novel industrial VXL™ product. The 461 nm VXL in AQuRA is built upon VEXLUM's highly efficient intra-cavity frequency doubling technology, which produces high power directly from a single frequency oscillator avoiding the need for complex master-slave laser architectures and offers the improved mechanical stability needed for high TRL applications.

1 List of contributors

Name	Org.	Role(s)
Jussi-Pekka Penttinen*	Vexlum	CTO
Emmi Kantola*	Vexlum	COO
Topi Uusitalo*	Vexlum	Laser Control Manager
Sanna Ranta*	Vexlum	Manager of Semiconductor Epitaxy
Roope Vuohenkunnas*	Vexlum	Laser Specialist
Elina Anttola*	Vexlum	Laser Engineer
Iisa Aromäki*	Vexlum	Laser Engineer
Susanna Rouru*	Vexlum	Laser Engineer
Matias Rautanen*	Vexlum	Laser Engineer
Riku Keskinen*	Vexlum	R&D Engineer
Mariia Bister*	Vexlum	Laboratory Technician

* Personnel employed partly or fully under the AQuRA project.

2 Specifications - Cooling laser 461 nm

Parameter	Value	Pass/Fail	Comments
Frequency	650.50382 THz	Pass	See 4.1
Seed wavelength	921.7239 nm	Pass	See 4.1
Optical output power (after fibre)	> 400 mW	Pass	Free space output power >1.5W
Optical locking output port	>1 mW at 922 nm	Pass	See 4.4
Output connectors	PM FC/APC using PM405-XP fibre slow axis aligned	-	Menlo fibre-couples
Fibre length	5 m	-	Menlo fibre-couples
Cable length (driver to head)	3 m	Pass	
Coarse Tunability	Tuning range sufficient to find transition	Pass	See 4.3
Fine (Piezo) tuning	+/- 500 MHz (20 MHz/V)	Pass	See 4.2
Piezo bandwidth	20 kHz	Pass	
Fast actuator range	Not required	-	
Fast actuator bandwidth	Not required	-	
Analog Input signal	Piezo max voltage 200 V	Pass	See 4.2
Digital interface	Ethernet	Pass	See 3.3
Interlock input	Closed contact at driver preferred	Pass	

Power supply requirements	200 W, 100-240 V, 50-60 Hz	Pass	
Height units	3 HU laser head (+ control unit 3 HU in rack)	Pass	

3 Physical deliverable - VXL^{TM} single-frequency laser

3.1 VECSEL head and pump laser

The laser head dimensions are shown in Figure 1. The pump laser module is a separate unit, with the dimensions shown in Figure 2 . The laser head and the pump module are connected by an optical patch cord, see Figure 3 for an application example on an optical table.

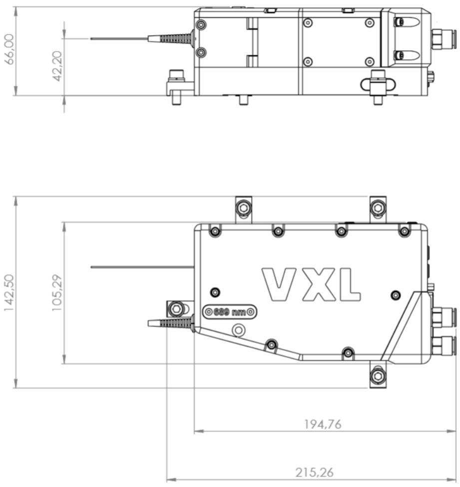

Figure 1 VXL^{TM} Laser cavity dimensions,

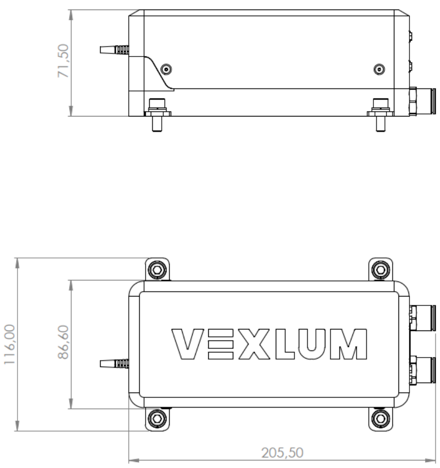

Figure 2 VXL^{TM} Pump dimensions

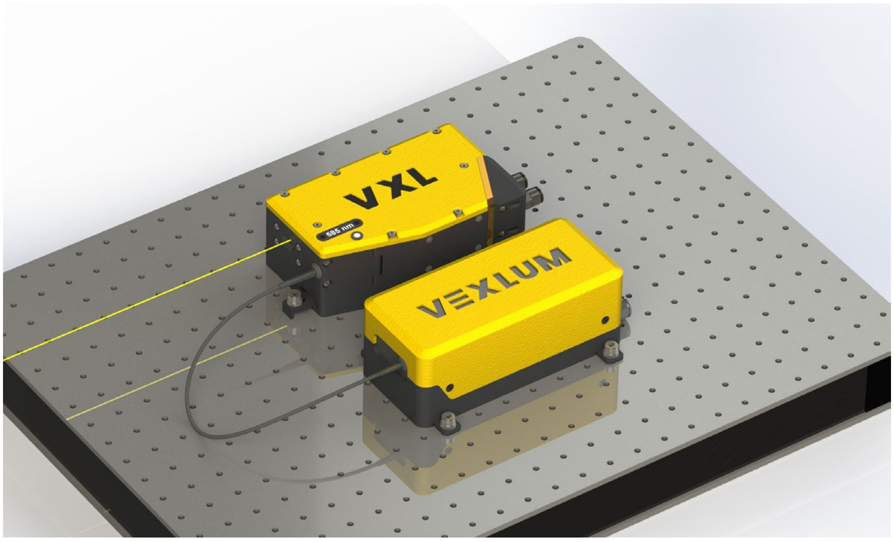

Figure 3 VXL Application example

3.2 Block diagram

The space requirements in 19” rack units (U) and the connections between the different subsystems are summarized in Figure 4.

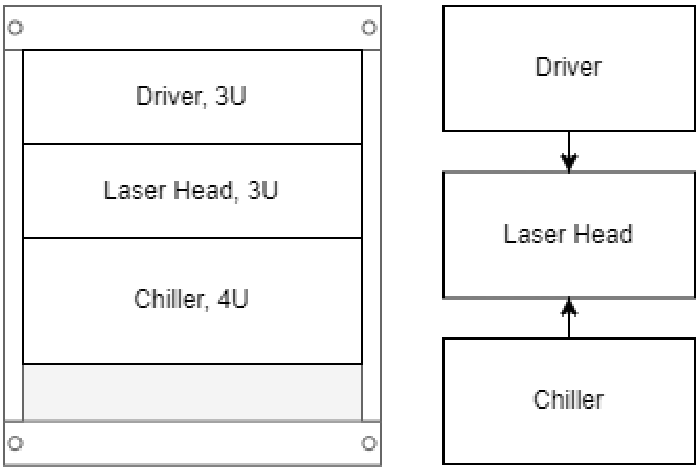

Figure 4 Left: Subsystem space requirements. Right: Dependencies between the subsystems. The driver supplies the laser head with bias and control signals, the chiller removes excess dissipated heat from the laser head.

3.3 Vexlum Control Unit (VCU)

Figure 5. Example front panel of the VCU.

Parameter	Specification
Dimensions (L x W x H)	19” rack mountable, 3HU + 1 HU required for ventilation, 483 x 375 x 133 mm
Mass	11 kg
Cooling Method	Air cooling
Housing Material	Aluminium

Parameter	Specification
AC input range	100 – 240 V, 50/60 Hz
Maximum power usage	500 W (theoretical 1200 W [1])
Interfaces	Ethernet SCPI Remote Interface

[1] The actual power usage during laser operation is much lower and depends on several factors.

4 Characterization data

Model: VXL SHG – single frequency 461 nm	**Serial Number:** 04611057

Measured and accepted by:

Emmi Kantola 2024-09-26

4.1 Output power

The output power characteristics at 460.8624 nm were measured with basic setpoint values. The wavelength shift related to power ramping was compensated by etalon and piezo tuning.

Table 1. Output power vs Laser Diode Driver (LDD) current. Wavelength recorded with a Toptica WS6-200 wavemeter (absolute accuracy ±200 MHz).

LDD current (A)	Output power (W)	Wavelength (nm)	ETALON Temperature (°C)
24	1.60	460.8624	49.37
23	1.39	460.8624	49.37
22	1.21	460.8624	49.47
21	1.03	460.8624	49.57
20	0.86	460.8624	49.57
19	0.66	460.8624	49.77
18	0.53	460.8624	49.87
17	0.38	460.8624	49.97
16	0.24	460.8624	49.97
15	0.137	460.8624	50.17
14	0.055	460.8624	50.37
13	0.006	-	-
12.4	Threshold	-	-

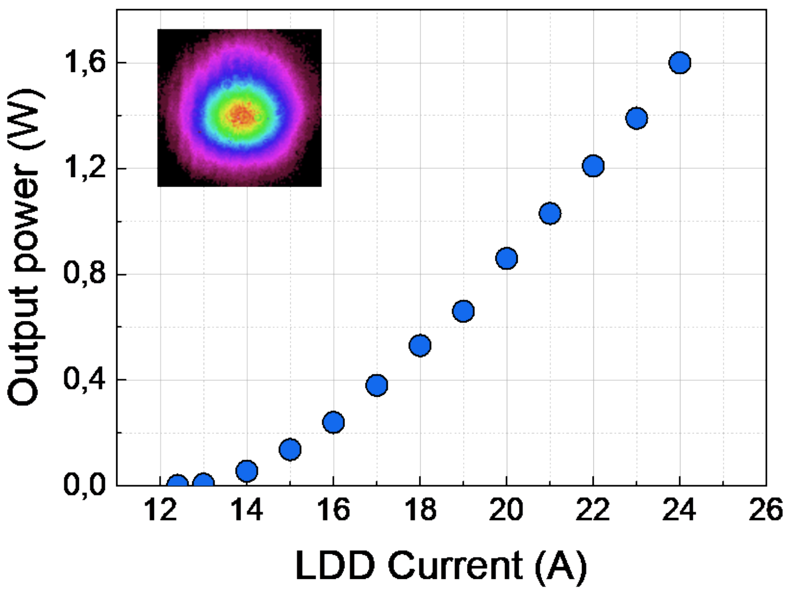

Figure 6. Output power vs Laser Diode Driver (LDD) current.

4.2 Finetuning with piezo voltage

When to use: To fine tune laser exactly to the target wavelength and for frequency stabilization.

Piezo voltage tuning coefficient: ~ -0.057 pm/V continuously near 461 nm, > +/-0.5pm (> +/- 700MHz)

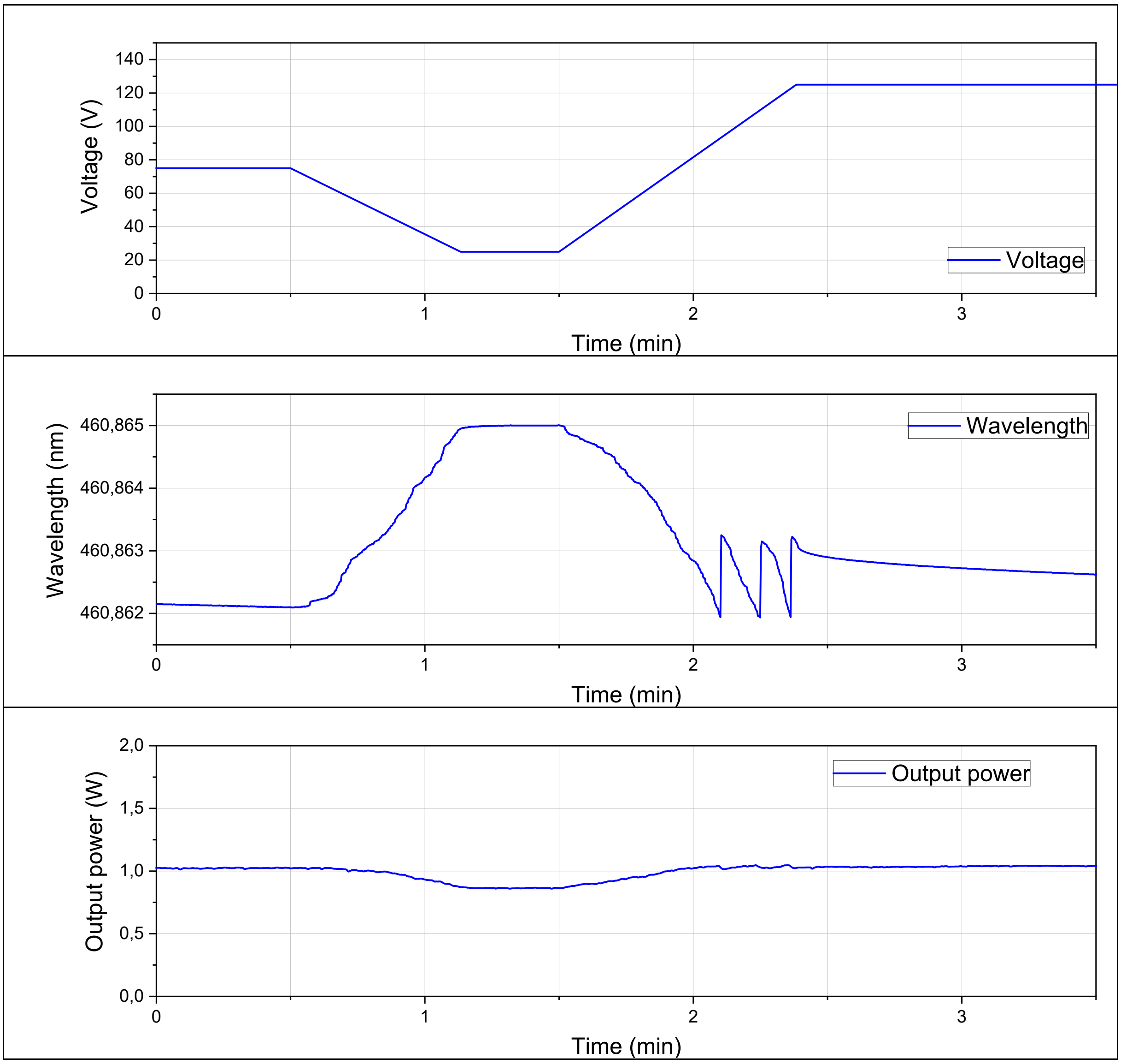

Figure 7. Tuning with piezo voltage.

4.3 "Coarse" tuning with etalon temperature

When to use: tuning the laser within 0.002 – 0.4 nm range and/or to optimize output power (to have better overlap with etalon transmission peak and lasing cavity mode. Only small ± 0.1 ˚C changes are needed for optimization).

Etalon temperature tuning coefficient: ~5.3 pm/°C in steps of 1.4 pm (~2GHz) or multiples of it.

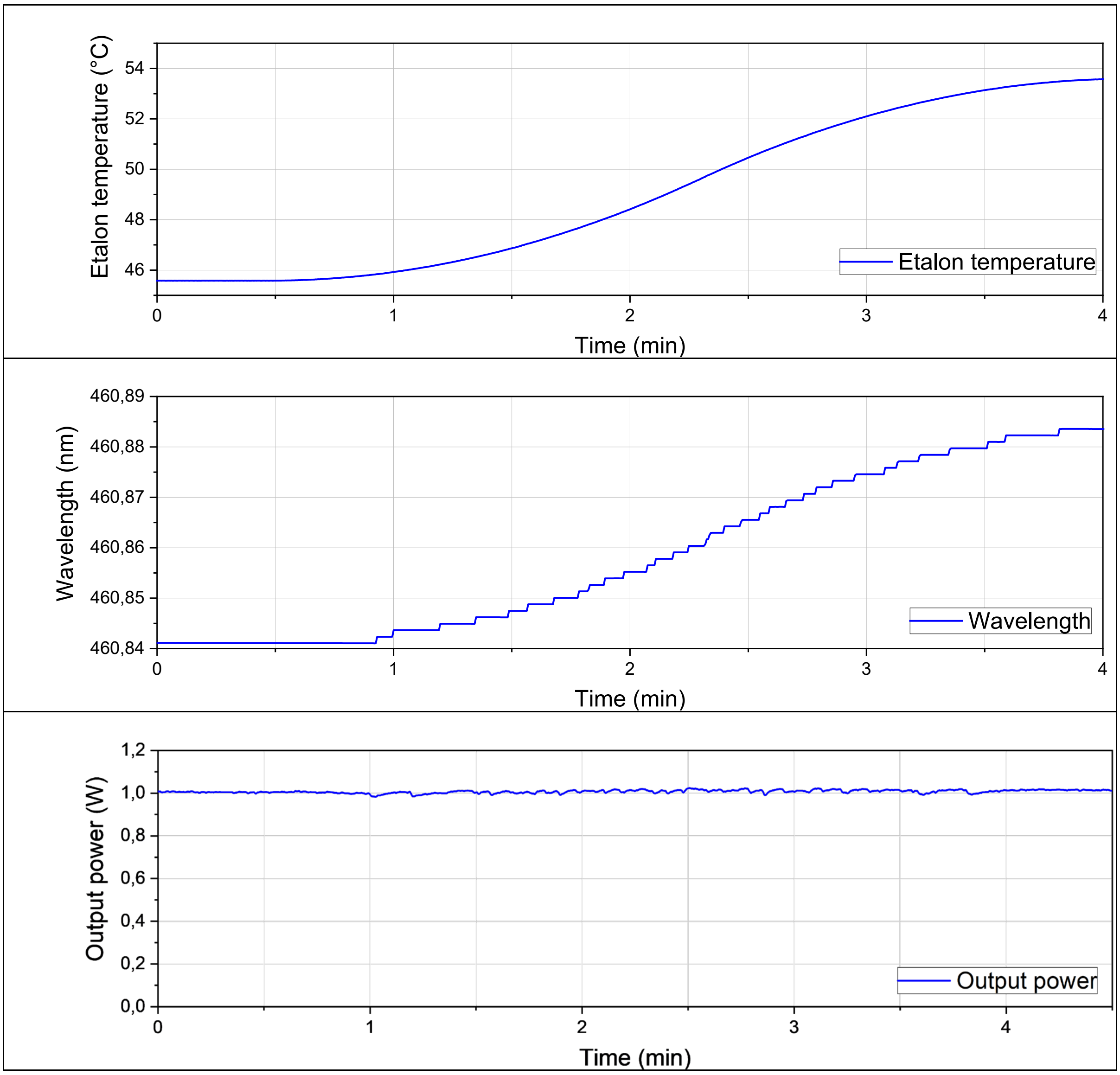

Figure 8. Tuning with etalon temperature.

4.4 Output beam(s)

The laser head has two output beams shown in the Figure 9 below:

1. The main high power blue beam exits to the left
2. Secondary lower power NIR beam exist to the right. This beam includes also some blue SHG radiation. The combined NIR and SHG output power is < 100 mW (at 21 A and 460.862 nm + 921.724 nm).

The laser output beam is circular Gaussian (TEM00) with $M^2 < 1.1$. The output beam exits the laser casing **uncollimated and diverging**, and roughly parallel to the side of the laser casing. The beam waist is ~150 µm in diameter and located ~120 mm from the casing's main output end face.

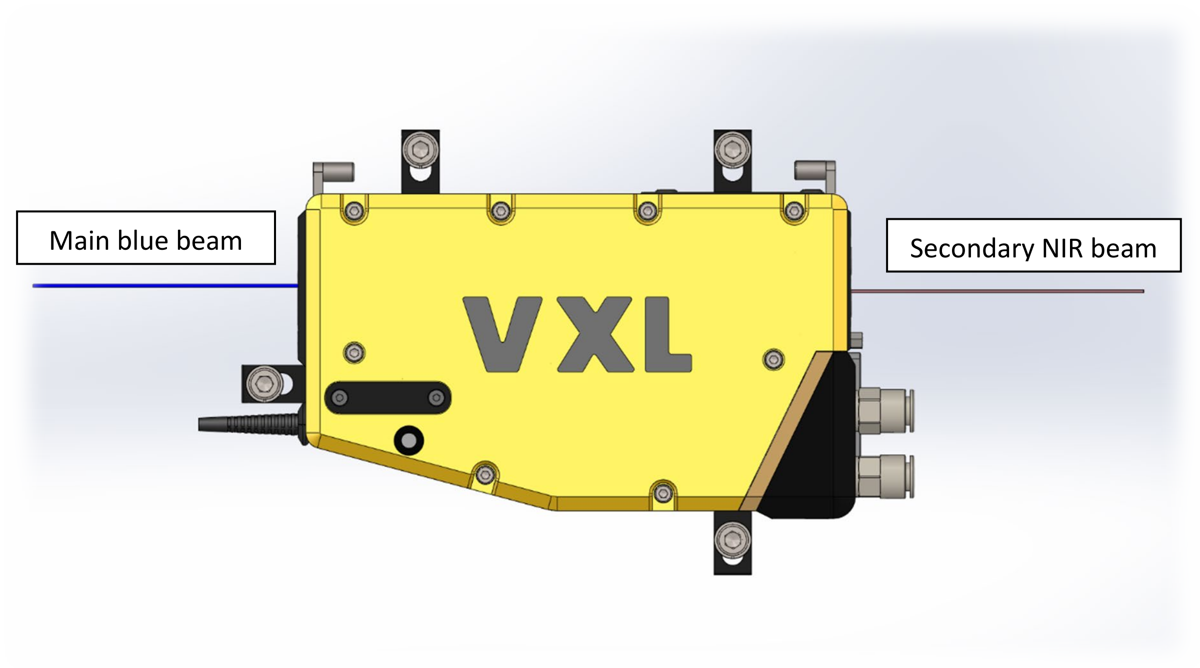

Figure 9. VXL output beams.