D2.3: 679 and 707 nm laser systems

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GLOSSARY

APC	Angled Physical Contact
FC	Field Assembly Connector
FSR	Free-spectral Range
HR	High-reflective
LD	Laser Diode
MRR	Micro-ring Resonators
NTC	Negative Temperature Coefficient Thermistor
SI3N4	Silicon Nitride
SOA	Semiconductor Optical Amplifier
TEC	Thermoelectric Cooler

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Executive summary

Deliverable 2.3 considers the development of two laser systems for the AQuRA atomic clock. In detail, the laser system comprises 2 laser modules at wavelengths 679 nm and 707 nm respectively, 2 optical isolator modules and a software package to control and tune the lasers.

This document provides an overview of the developed modules and interface to control the laser system.

1 List of contributors

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2 Introduction

The goal of AQuRA is to make the best clocks in the world robust and compact enough for real world applications. These "optical atomic clocks" are amazingly accurate. If such a clock had been turned on during the Big Bang, almost fourteen billion years ago, the clock would still be ahead or behind by around a second today!

AQuRA aims to make existing optical clocks smaller and more robust. Currently, these clocks do not look like the clocks in your home; they are complicated machines that fill entire laboratories. AQuRA wants to make these clocks transportable, so that they can be used for measurements in the field and eventually even sent to space using satellites. This could, for example, make GPS systems much more accurate.

2.1 Overview of the laser systems

WP2 activities include the development of laser systems for the AQuRA clock prototype, which are divided among several industry partners, each with expertise in developing lasers with different underlying technologies that are suitable and required for the specific wavelengths used for optical trapping of ultra-cold strontium atoms. The relevant academic partners will execute this validation work using existing resources, such as testbed systems created during earlier projects.

The activities in work package task 2.3 comprise developing and supplying a repump laser module based on silicon nitride integrated photonic circuits by QQU. The module will feature two lasers at wavelengths of 679 nm and 707 nm, and will be combined into a single package with polarisation maintaining fibre output.

The laser cavity comprises a semiconductor optical amplifier (SOA) as gain medium and a silicon nitride (Si3N4) waveguide tunable feedback circuit. The SOA is butt-coupled to the Si3N4 waveguide circuit. The laser is housed in a compact, 14-pin butterfly package, enabling compatibility with standard 14-pin laser diode mounts. The laser package contains an integrated thermoelectric cooler (TEC), thermistor, and a polarisation-maintaining output fiber with an FC/APC connector.

Please note that there is no optical isolator added to the package. To avoid affecting the laser performance due to undesired feedback, it is advisable to connect a fiber-optic isolator directly to the output fiber. The isolator should be suitable for the laser’s operating wavelength range and should have matching FC/APC connectors. Two optical isolators are included with the package.

3 Device assembly and Measurements

3.1 Layout and Operating principle

The main concept of the laser is shown in Figure 1. The gain chip, which contains the SOA, has a high-reflective (HR) coating on the left-hand side and an anti-reflective interface on the right-hand side where it is connected to a TriPleXTM silicon nitride waveguide chip. The waveguide circuit contains two micro-ring resonators (MRRs), indicated as R1 and R2 with slightly different free-spectral ranges (FSRs) to ensure stable single frequency operation by using the Vernier effect. There are four heaters positioned, one to control the phase of the light in the cavity, two to control the resonant wavelengths of the ring resonators R1 and R2, and one controls the fraction of the optical power coupled out of the cavity. The laser’s frequency can be tuned over a large range by tuning the MRRs.

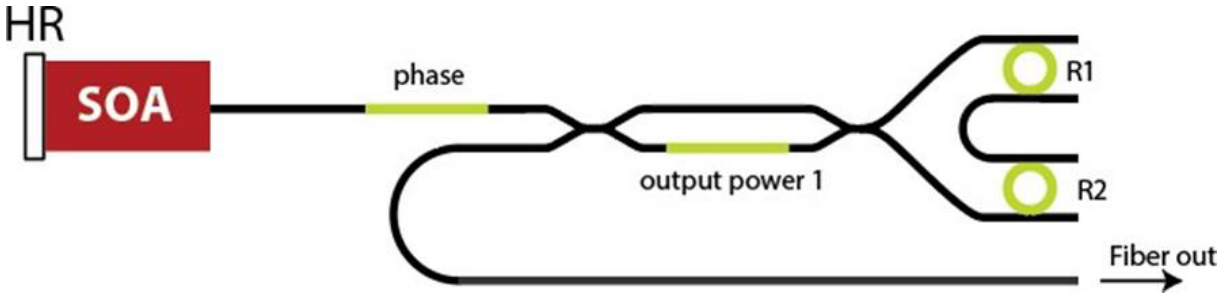
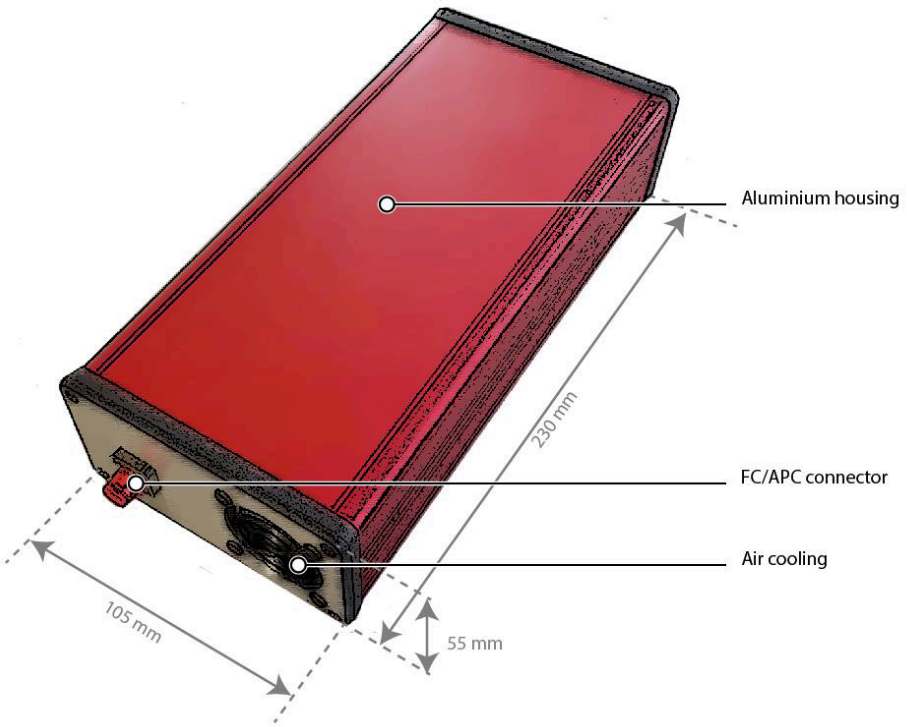


Figure 1 : Schematic layout of the laser

3.2 Mechanical Assembly

The laser driver of both the systems are mounted inside the housing, as shown in Figure 2. In Figure 3 we see that an FC/APC connector is mounted on the front side of the housing, and the back-side holds a USB-B connection for communication with a computer and a 2.0 mm barrel plug connection to supply a DC voltage (12 V, 3 A).



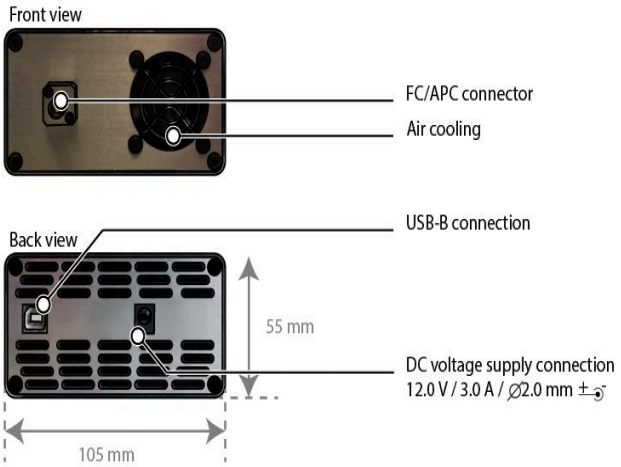


Figure 2 : Electronic housing's dimensions *Figure 3 : Front and back view of housing*

3.3 Product Specifications and Measurement

This section gives an overview of the mechanical assembly of the laser systems and initial measurement values. The recommended pump and maximum pump current for the 679 nm laser are 60 mA and 65 mA respectively. Similarly, the recommended pump and maximum pump current for

the 707 nm laser are 80 mA and 90 mA respectively. Exhaustive list of optical, electrical and mechanical specifications are provided with the user package.

The lasers are assembled in a 14-pin goldbox butterfly enclosure along with a Peltier element. Figure 4 depicts the Pins-out and interior structure of the laser systems.

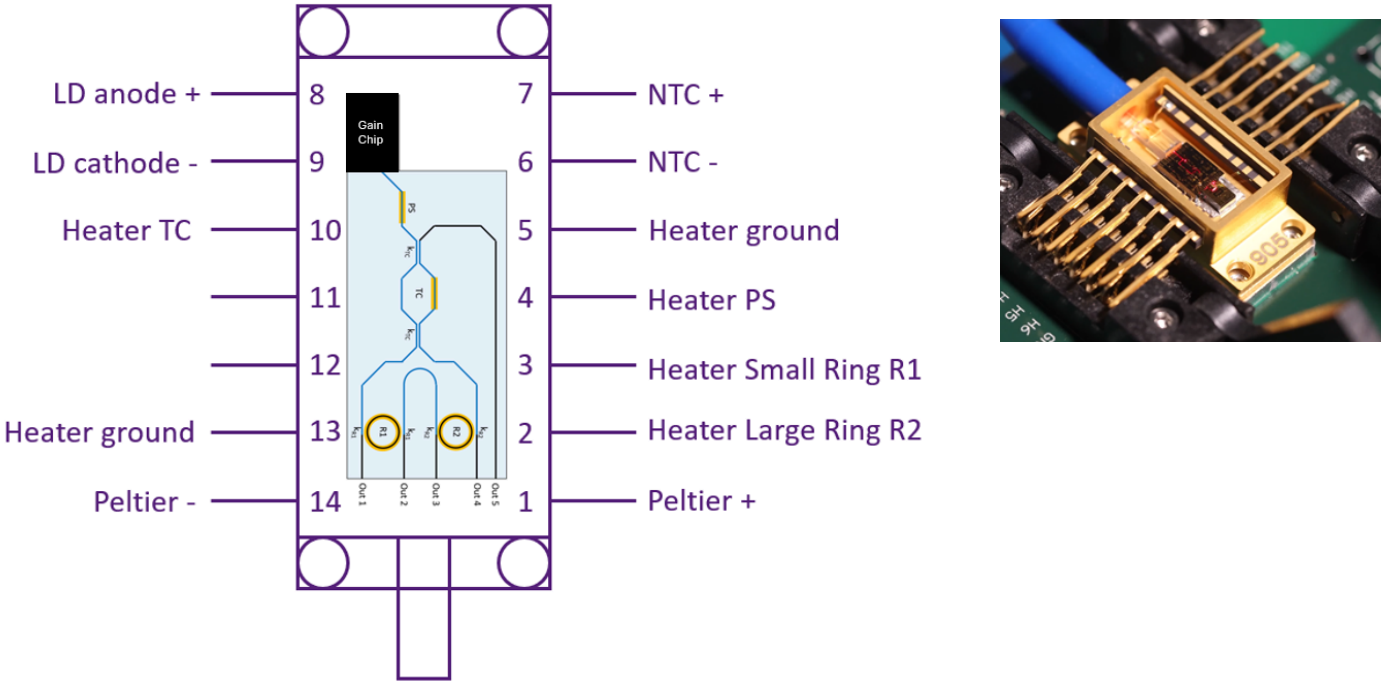


Figure 4 Pins-out and interior structure

Target wavelengths and power are 679.260 nm, 5 mW and 707.202 nm, 2 mW. Initial measurement values are mentioned in the below table. The set values are provided with the package and are to be loaded in the control panel of the laser tuning interface.

Parameters	Set values for 679 nm laser	Set values for 707 nm laser	Parameters	679 nm laser Measurement	707 nm laser Measurement
Heater phase (H5)	3.899 V	2.22 V	Wavelength	679.202 nm	707.640 nm
Heater Ring 1 (H3)	2.299 V	2.70 V	Output power	0.173mW	1.23mW
Heater Ring 2 (H4)	4.777 V	2.05 V			
Heater Tunable coupler (H0)	2.190 V	2.20 V			
Pump current	60 mA	80 mA			

3.4 Control Software

The lasers can be operated and tuned using a control software which is available in the USB Stick (CT3-2022-V1.12-INT.exe). After running this file in the desktop, the laser-specific COM port has to be selected in the software. Figure 5 depicts the user-interface of the software.

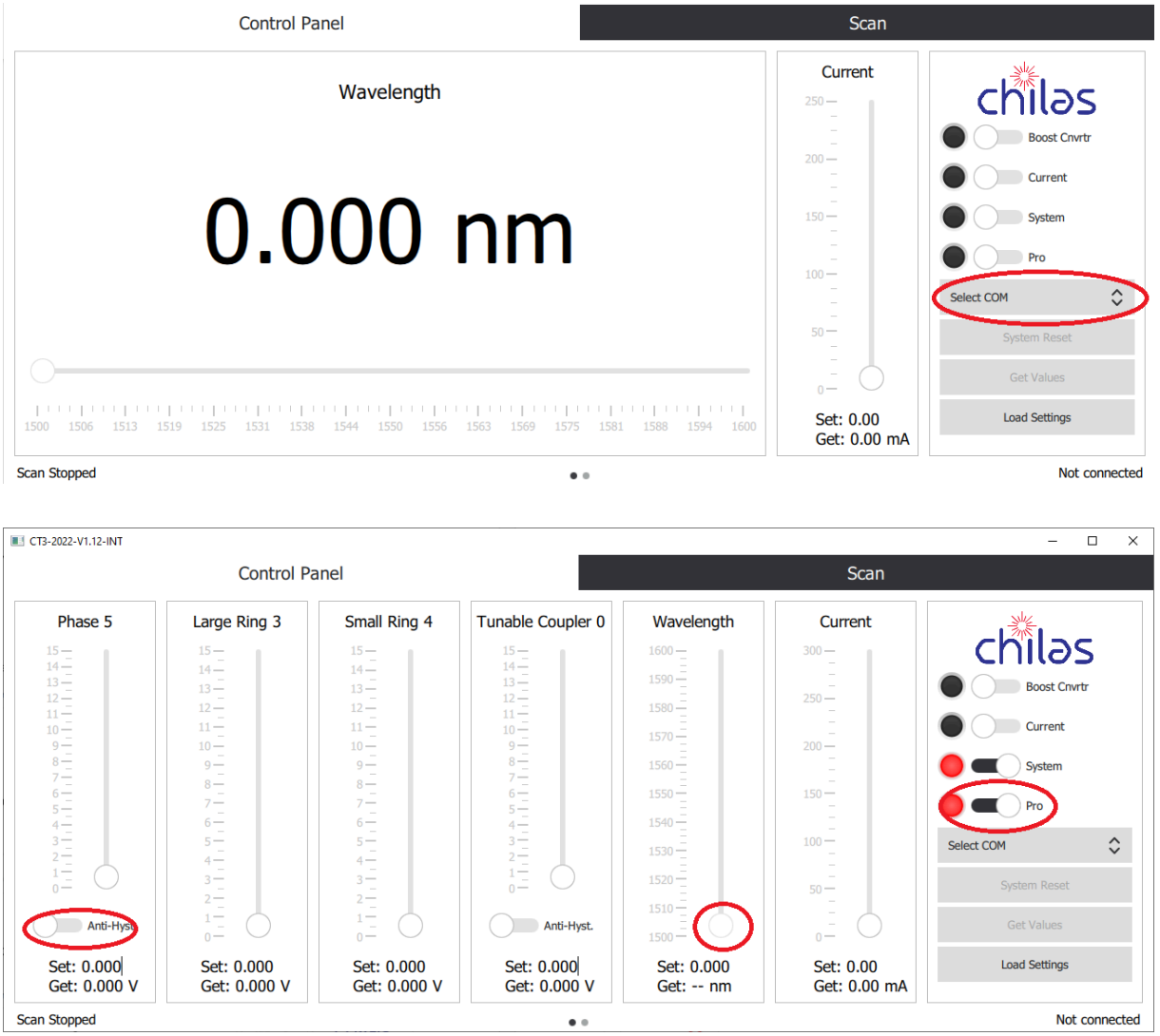


Figure 5 UI of control software

The laser will start to emit light when “Pro” and “System” toggle is turned on. The software enables the operation of the laser using a pre-defined wavelength calibration file which can be uploaded (.csv file). We can also manually tune the sliders for the heaters to enable the laser to operate on a desired wavelength. Note that properly setting these sliders requires understanding of the laser. The laser’s output and performance strongly depend on how these sliders are set. To turn the laser off, set all the sliders to the minimum value, and switch off the “Current” and “System toggle”.

4 Deviations from the description of action

Both the laser systems are delivered to the University of Amsterdam to monitor their precision. Currently, we have precision of up to a GHz value. After the official confirmation from UvA, we will deliver both the lasers to Menlo Systems.
Currently, we see a deviation from the target power for both the lasers. The next step is to manually change the temperature by changing the Peltier controller and measuring if this increases the power. This will be tested (at the UvA) and the effect on wavelength, power and stability will be assessed. If the lasers perform as required on all these 3 parameters, it will be delivered to Menlo systems to be integrated as a part of the AQuRA system.

5 Conclusions

In this document, we have briefly described the modules and components of the 679 nm and 707 nm AQURA red lasers. The 707 nm laser was delivered at UvA on September 5th 2024 for testing a week's stability of the laser. Similarly, the 679 nm laser was delivered on September 20th for further testing and analysis. Post hardware correcting, testing and observations, we will deliver the lasers to Menlo Systems. The lasers have been developed in partnership with Chilas BV.

6 References

Data sheets, installation guide, settings file and the electronics manual for both the lasers are provided with the package (USB Stick).