D2.5: 698 nm laser system

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GLOSSARY

ACOUSTIK	Name of NKT Photonics Koheras rack system
AOMIK	Name of NKT Photonics Koheras acousto-optic modulator module
BASIK	Name of NKT Photonics Koheras DFB fiber laser module
BOOSTIK LC	Name of NKT Photonics Koheras Linecard optical amplifier module
CW	Continuous wave
GUI	Graphical user interface
HARMONIK LC	Name of NKT Photonics Koheras Linecard wavelength conversion module
PPLN	Periodically poled Lithium Niobate
SDK	Software development kit
SFG	Sum-frequency generation
WP	Work package
SDK	Software development kit
SFG	Sum-frequency generation
PPLN	Periodically poled Lithium Niobate

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Executive summary

Deliverable 2.5 considers the 698 nm clock laser system for the AQuRA atomic clock. In detail, the laser system comprises of 2 laser modules at wavelengths 1082.1 nm and 1970 nm respectively, 2 optical amplifier modules, an acousto-optic modulator and a harmonic sum-frequency generation (SFG) module.

A piezo input at both lasers allows for low bandwidth wavelength stabilization while the acousto-optic modulator is used for fast wavelength stabilization. The SFG module mixes the 2 seed laser wavelengths to produce the 698 nm output.

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

1 List of contributors

Name	Organisation	Role(s)
Poul Varming	NKT Photonics A/S	Development and provision of clock laser system, writing deliverable document
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Christian Lisdat	PTB	Internal review of deliverable document

2 Introduction

This document provides an overview of the 698 nm clock laser system for use in the AQuRA atomic Sr clock. This constitutes delivery D2.5 of the Laser Systems work package, WP2.

The laser system is modular build with 6 independent modules integrated in a 19” 3U rack system. All optical input and outputs are available from the front panel of the Koheras ACOUSTIK rack. This is illustrated in Figure 2.1.

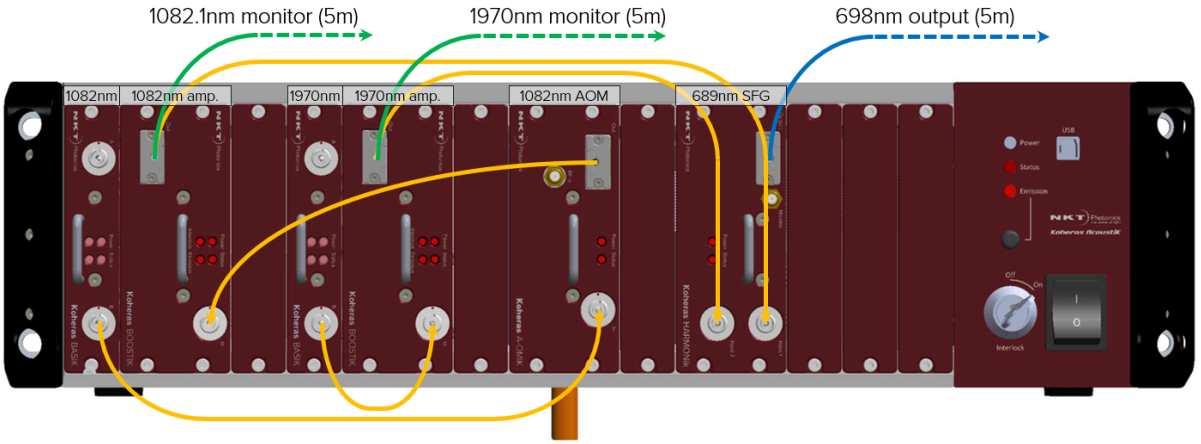

Figure 2.1: 698 nm laser system front *Front panel of Koheras ACOUSTIK rack, including the 6 independent modules, the optical fiber connections, USB interface input, key lock and power switch.*

The AOM is inserted between the 1082 nm seed laser and the 1082 nm optical amplifier. The 1970 nm seed laser is connected directly to the 1970 nm optical amplifier. Both optical amplifiers have an optical monitor output fiber cable that allows for low bandwidth wavelength stabilization using the seed lasers piezo inputs. The AOM has a SMA input for an RF signal that allows for high bandwidth wavelength stabilization.
The back panel of the Koheras ACOUSTIK rack is illustrated in Figure 2.2. This contains the interface for the interlock, piezo input, ethernet cable, power connection and water cooling.

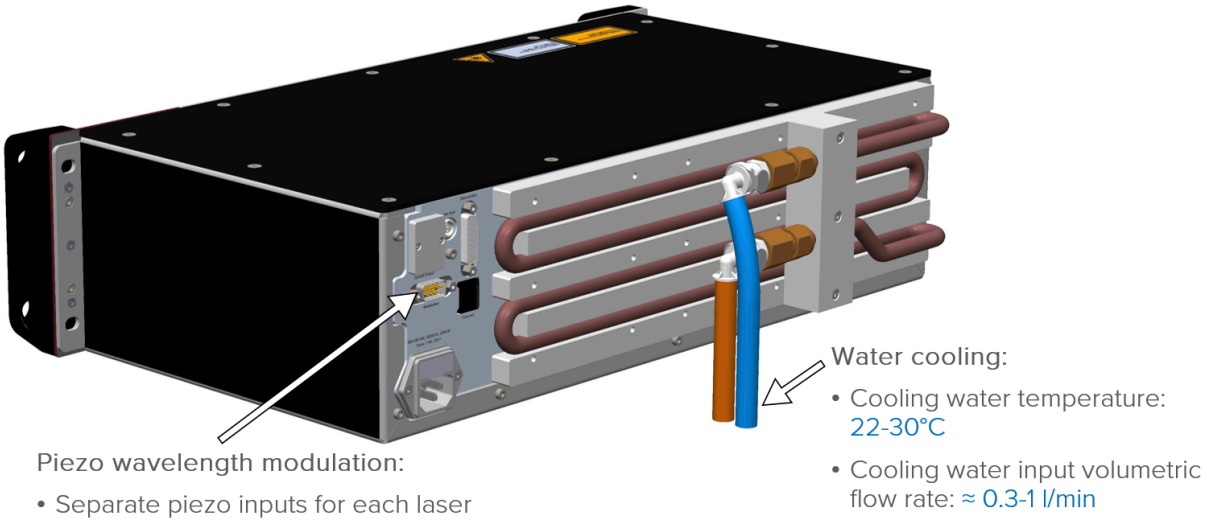

Figure 2.2: 698 nm laser system back *Front panel of Koheras ACOUSTIK rack, including the water cooling interface, ethernet input, piezo control input, interlock input and power inlet.*

3 Main body of report

The laser system consists of 6 independent modules for the ACOUSTIK rack and are shown in Figure 3.1.

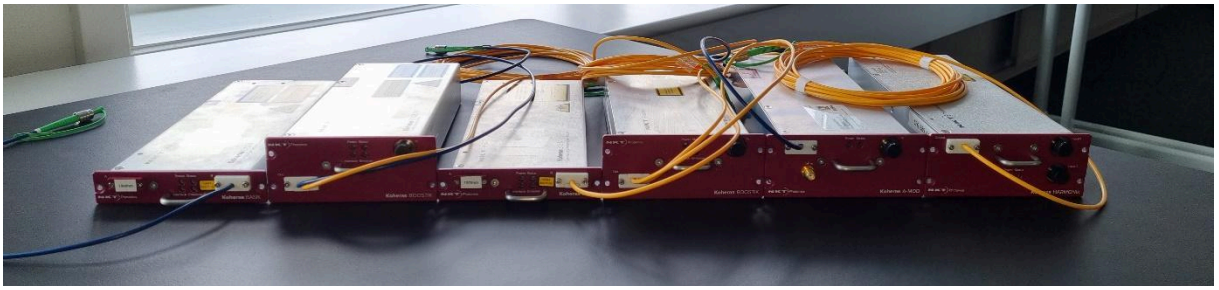

Figure 3.1: 698 nm laser system modules *From the left is the 1082.1 nm seed laser, the 1082.1 nm optical amplifier, the 1970 nm seed laser, the 1970 nm optical amplifier, the 1082.1 nm acousto-optic modulator and the 698 nm sum-frequency wavelength conversion module.*

3.1 Seed laser modules

The 1082.1 nm and 1970 nm seed lasers are both based on the Koheras BASIK DFB fiber laser module platform. They offer low-noise coherent CW output and wavelength tuning using thermal (slow) or piezoelectric (fast) control. Thermal tuning range is ±350 pm for the 1082.1 nm laser and ±600 pm for the 1970 nm laser. Narrow piezo tuning range is 800 MHz for both lasers with a 3dB modulation bandwidth of 2 kHz.

3.2 Optical amplifier modules

The optical amplifiers are based on the Koheras BOOSTIK LC module platform. Both amplifiers have an optical monitor output cable that allows for stabilizing the laser wavelength to an optical reference, such as a frequency comb or stable optical cavity.
The 1082.1 nm optical amplifier provides up to 250 mW output power, while the 1970 nm provides up to 800 mW output power.

3.3 AOM module

The AOM is housed in a prototype AOMIK LC module comprising an RF amplifier and an acousto-optic modulator. A 50 Ω SMA coaxial connector provides electrical in for the RF amplifier. The AOM center driving frequency is 100 MHz and the optimum RF input power is -8 dBm (max. -4 dBm). The driving frequency can be FM modulated at a frequency up to 300 kHz with a phase delay below 45°.

3.4 SFG mixing module

The SFG mixer is housed in a prototype HARMONIK SFG LC module. It comprises a PPLN waveguide SFG module, electronics for controlling and optimizing the SFG module, and optical power monitoring for the 2 input signals and the 698 nm output signal. The electronics allow for scanning the PPLN waveguide temperature to automatically find the setpoint with highest output power.
The optimal setpoint for the 698 nm PPLN waveguide is approximately 49.5°C. The maximum tested output power of the device is 40.3 mW at 698 nm. This was obtained with 250 mW at 1082 nm and 800 mW at 1970 nm.
The SFG module also offers the option of locking the output power to a value below the maximum by controlling the detuning of the PPLN waveguide temperature.
The nominal 20 mW 698 nm output power can be obtained with various combinations of 1082 nm and 1970 nm output powers. An example input setting is 220 mW at 1082 nm and 375 mW at 1970 nm. Figure 3.1 illustrates the 698 nm output power for various combinations of the input power at 1082 nm and 1970 nm.

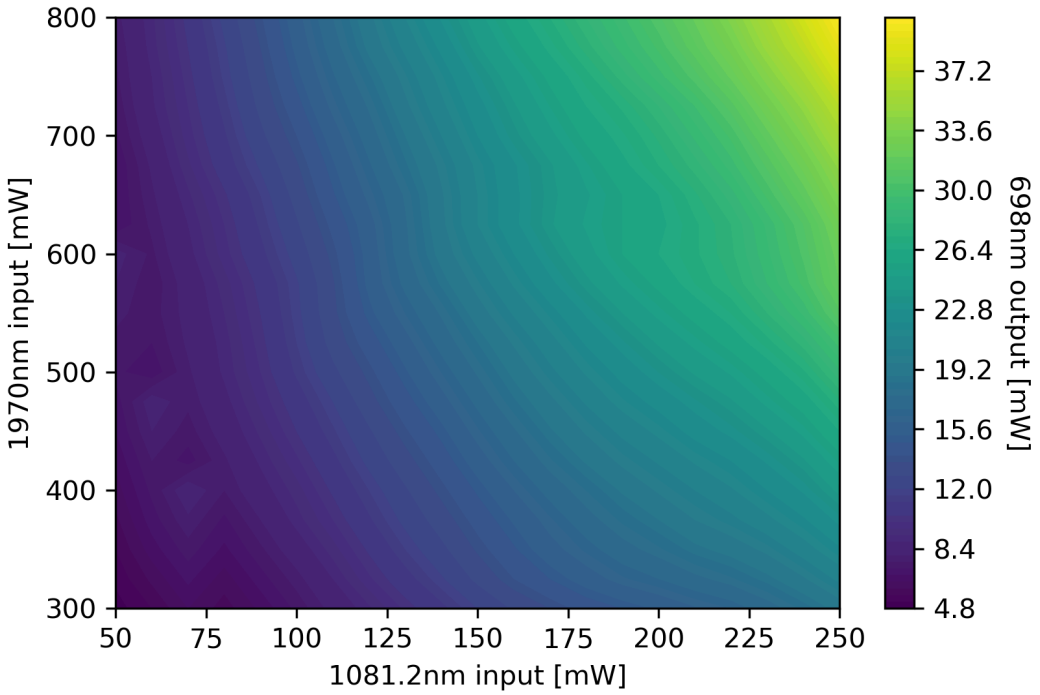

Figure 3.1: 698 nm output power from HARMONIK SFG LC module *The figure shows the 698 nm output power for various combinations of input power at 1082 nm and 1970 nm. The PPLN waveguide temperature is set to 49.5°C.*

Recommended setting for locking of the output power at 20 mW 698 nm is 250 mW at 1082 nm and 400 mW at 1970 nm. Figure 3.2 shows the optical spectrum at the recommended operating settings.

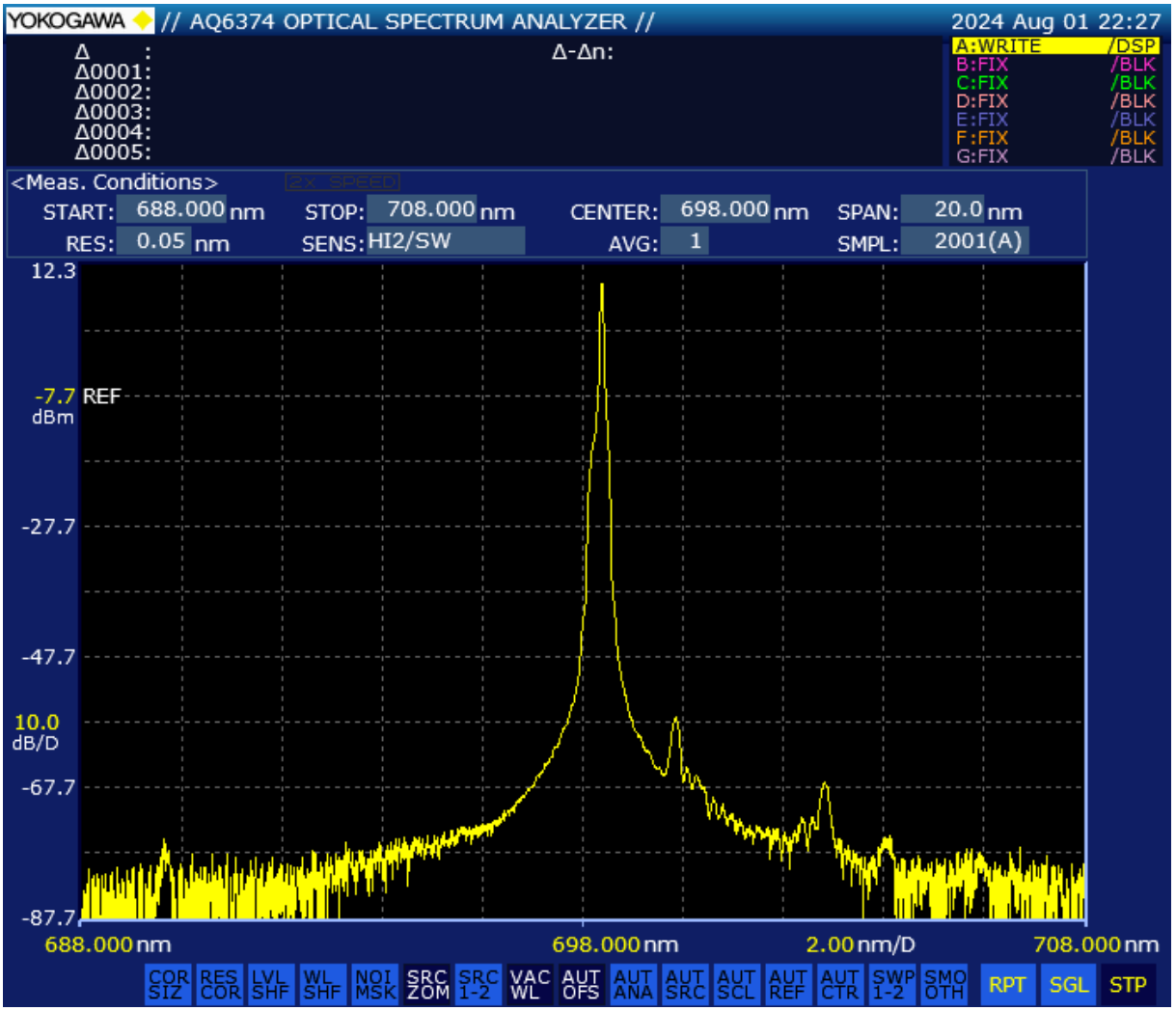

Figure 3.2: 698 nm optical spectrum at recommended settings *The input power* is 250 mW at 1082 nm and 400 mW at 1970 nm. T*he PPLN waveguide temperature is set to power locking at 20 mW output power near 49.5°C.*

3.5 External connections to ACOUSTIK rack

The ACOUSTIK rack system has snap-release connectors for water cooling. It also has several electrical connections:

1. USB interface for control of the laser system
2. Ethernet interface for alternative control of the system
3. 15 pin D-sub connector for piezoelectric control of seed lasers
    a. Converter interface is included that interfaces the Menlo Syncro output to the ACOUSTIK electrical range. The interface includes two LEMO inputs that are compatible with the Menlo Syncro.
4. Interlock interface for external disabling of laser system
5. 110 V/220 V power input

3.6 User interface

The 689 nm and 698 nm laser systems can be monitored and controlled using the NKT Photonics CONTROL graphical user interface (GUI). A special version of CONTROL has been compiled for AQuRA to allow control of the prototype modules (AOMIK and HARMONIK LC). The CONTROL interface is illustrated in Figure 3.2

The laser systems can also be controlled using the NKTP Photonics SDK (software development kit). The SDK and manuals can be downloaded from NKT Photonics webpage. For the prototype modules, separate “Register files” are provided. These files list the controls and monitor registers.

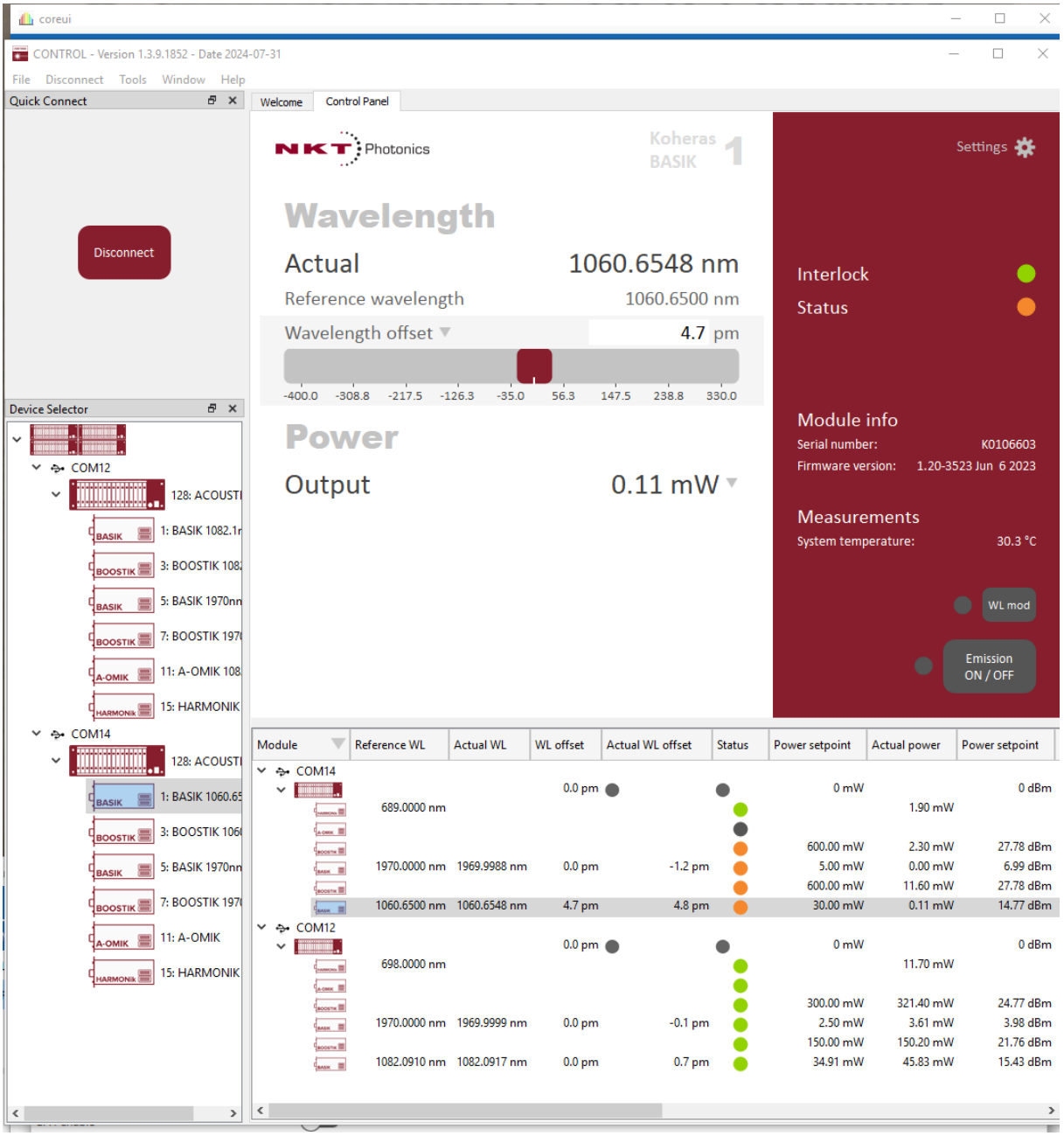

Figure 3.2: CONTROL user interface for the 689 nm and 698 nm laser systems *The CONTROL interface offers convenient control and monitoring of all the NKT Photonics connected to the controlling computer.*

4 Deviations from the description of action

The 689 nm and 698 nm sources from NKT will not be generated using the proposed third harmonic generation (THG), but rather using sum-frequency generation (SFG) in a periodically poled lithium niobate waveguide. The laser systems will mix a 1970 nm source with either a 1060.65 nm or a 1082.1 nm source to generate the required wavelengths. The SFG generation is a much more efficient conversion than the THG and allows for a much more compact all-fibre design that uses less power and has better reliability.

5 Conclusions

In this document, we have briefly described the modules and components of the 698 nm AQuRA clock laser. The laser system has been developed at NKT Photonics and was delivered on August 5 2024 to Menlo Systems for system integration with the laser control system and interface to the physics package.

6 References

The CONTROL GUI and the SDK for controlling the laser system can be downloaded from the NKT Photonics website support page: https://www.nktphotonics.com/support/