Water-cooled System for RF Amplifiers

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Abstract

Heat management and stability of the gain of RF amplifiers can be greatly improved by introducing a water-cooled system. It is therefore beneficial to switch from air cooling to water-cooled breadboards. The goal of this semester project is to construct a water-cooled system which optimizes space utilization and shields the surroundings from the RF signals produced by the RF amplifiers. The shielding was assured by constructing a aluminium box around the water-cooled breadboard.

Contents

1 Introduction

In experiments, where fast switching and frequency modulation of laser beams are required, it is of great benefit to use acusto-optic modulators (AOM's). In order to operate an AOM, the radio frequency (RF) signal from the source has to be amplified by a RF power amplifier.
Up until now, the amplifiers in our lab have been air cooled with heat sinks. This is an easy and affordable way to keep the temperature at a reasonable value. However, there are two main problems with amplifiers cooled with heat sinks: Although the absolute temperature is not a big concern for the amplifier itself, it may affect other temperature sensitive devices in their neighbourhood. Furthermore, fluctuations in the temperature of the amplifier will cause an unstable AOM output, leading to an unstable laser beam power.
The goal of this semester project is to switch from air cooled amplifiers to water cooled ones. This project is based on concepts from [1], where they fixed some amplifiers on top of a water cooled plate. This concept will be improved in terms of space utilization and shielding of the surroundings.

2 Motivation

2.1 Heat management

Heat management becomes a very important factor for laboratories with many temperature sensitive devices. Figure 1 shows the temperature of a RF amplifier during two working days. We can see that the temperature varies from $\sim$20 °C, corresponding to night time, where the amplifier is unused, to $\sim$30 °C, corresponding to daytime, where the amplifier is used. Since the TIQI lab uses a considerable amount of amplifiers which heat up to $\sim$30 °C, other devices may be affected by the rise of temperature of the room. This can mostly be prevented by a water-cooled system for the amplifiers.

2.2 Stability of light intensity

It is favourable to have a stable light intensity of the laser beam coming out of the AOM. In order to achieve stable light intensity, we need a stable AOM output which again needs a stable RF signal as an input. Stable RF signal input means that the RF amplifier needs a stable gain which ultimately requires a stable temperature of the amplifier. In Figure 1 we can see that

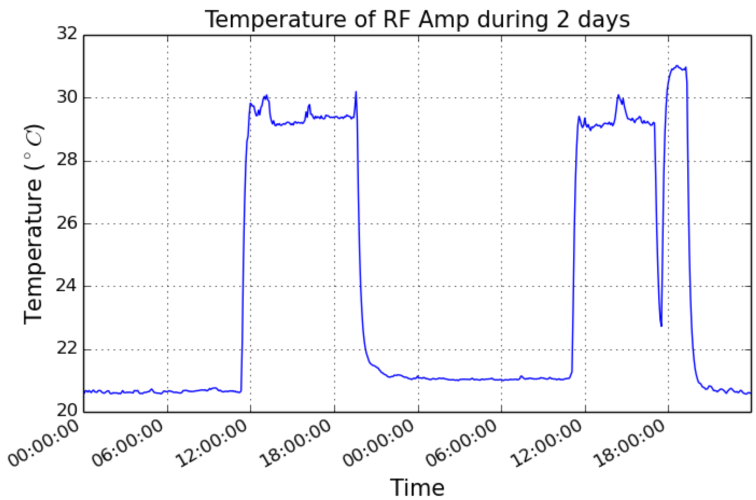


Figure 1: Temperature of *ZHL-1-2W-S(+)* RF amplifier during two working days. The temperature peaks correspond to daytime, where the amplifiers are being used.

the fluctuations of the temperature of the RF amplifier while being used is in the order of 2 °C. These fluctuations in temperature corresponds to ∼ 0.07 dB fluctuations in gain, as we can see from Figure 2. Again, this can be greatly improved by introducing a water-cooled system for amplifiers.

2.3 Characterization of the AOM from Brimrose

To further motivate the project, we measured the properties of an AOM from Brimrose by using an amplifier cooled with a heat sink.

2.3.1 Set-up

The AOM we have tested is the *TEF-200-20-397-2FP* fibre-coupled AOM from Brimrose Corp. The set-up is shown in Figure 3. Note that the amplifier is cooled with a heat sinks.

2.3.2 Measurements

Before the fibre, the power of the laser beam was measured to be ∼ 28.5 mW. A power of ∼ 9 mW coupled into a similar fibre (P3-405PM-FC-2)

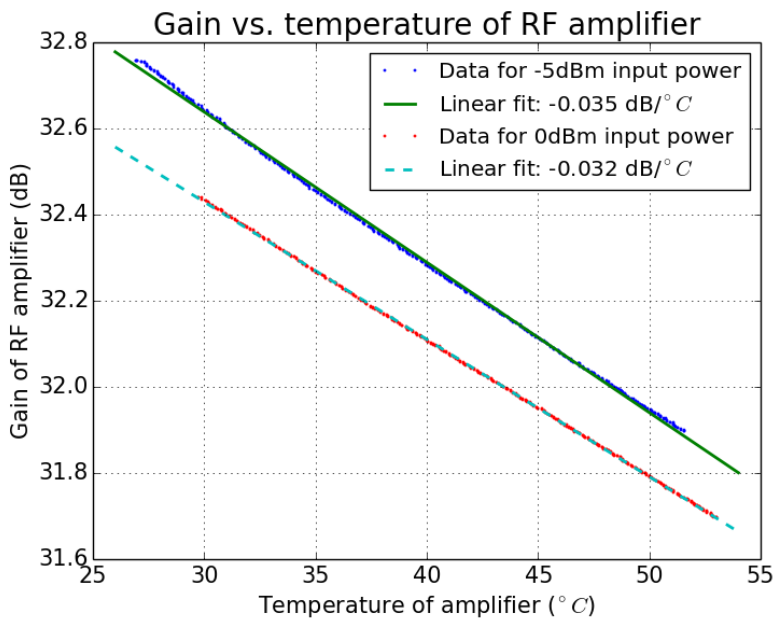


Figure 2: Gain of the *ZHL-1-2W-S(+)* amplifier measured as a function of the temperature for two different power inputs (coming from the TPI RF source): once with -5 dBm (top curve) and once with 0 dBm (bottom curve).

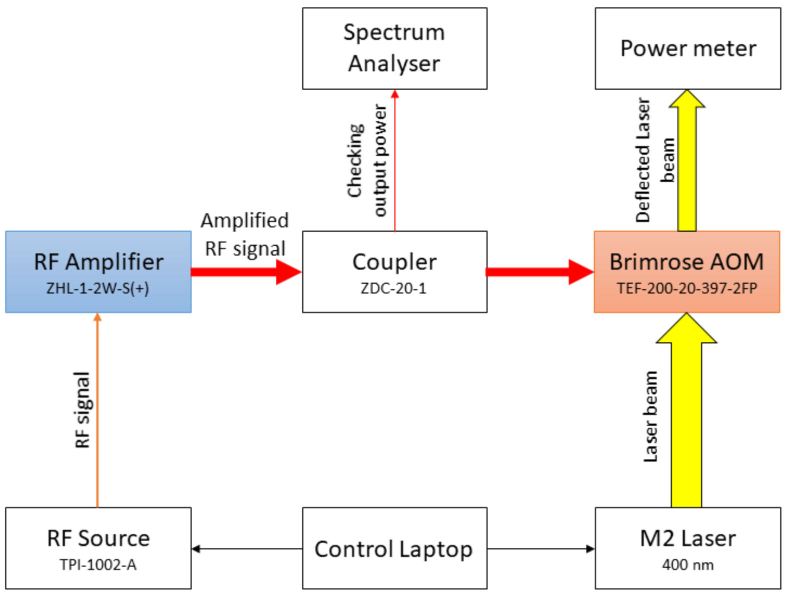


Figure 3: Set-up for testing an AOM: First, the RF source generates a RF signal which is then amplified by the amplifier. The signal then gets to the coupler, where a small amount of the signal gets transferred to the spectrum analyser to check the output power. The majority of the signal gets to the tested AOM, where the RF signal is used to deflect the incoming laser beam. The laser beam power after the AOM is smaller than the input beam, since there are losses due to imperfect fibre coupling and imperfect deflection.

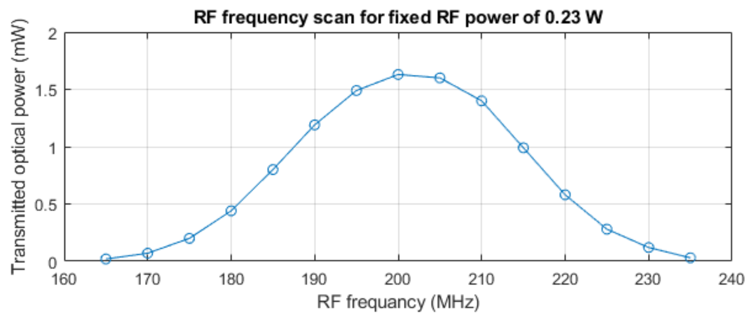


Figure 4: Transmitted optical power from the AOM as a function of the frequency of the RF source. The RF power was set to 230 mW which produces the maximal transmitted power, as shown in Figure 5. The power of the beam before the AOM was $P_{\text{beam}} = 28.5$ mW.

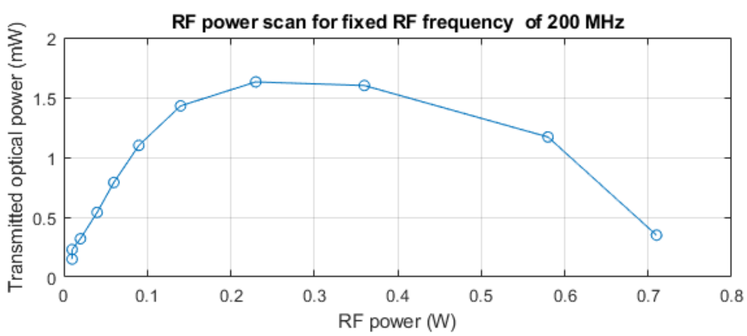


Figure 5: Transmitted optical power from the AOM as a function of the RF power coming from the RF source and amplified by the amplifier. The frequency was set to 200 MHz which leads to a maximum transmitted optical power as shown in Figure 4. The power of the beam before the AOM was also $P_{\text{beam}} = 28.5$ mW.

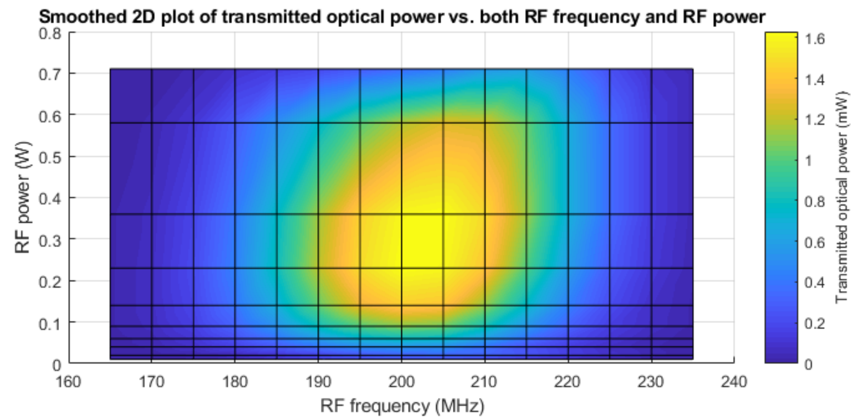


Figure 6: Smoothed plot of transmitted optical power from the AOM as a function of RF frequency and RF power.

to the fibre of the AOM, resulting an efficiency of ~ 30 %. In our further calculations, we will assume that a power of ~ 9 mW also couples into the fibre of the AOM.

The actual experiment consisted of two parts: First, we measured the transmitted optical power coming out of the AOM as a function of the RF frequency. The result is shown in Figure 4. We can see that the transmitted power peaks at a RF frequency of 200 MHz which agrees with the specifications [2].

In the second part, we measured the transmitted optical power from the AOM as a function of the RF power which is shown in Figure 5. We can see that the transmitted optical power peaks at $P_{sat} = 0.23$ W, where P_{sat} is the RF power at which the AOM saturates. Lastly, we measured the transmitted power as a function of both RF frequency and RF power, as shown in the Figure 6, to ensure that the maximum transmitted power is indeed at around 200 MHz and $P_{sat} = 0.23$ W.

2.3.3 Discussion

Note that P_{sat} might seem surprisingly low. This could have several reasons, as $P_{sat} \propto \frac{k\lambda^2 H}{2LM_2}$, where λ is the wavelength of the laser beam, k is the transducer conversion loss, H and L being the height and length of the crystal and M_2 is the figure of merit. This is further discussed in [3]. It is

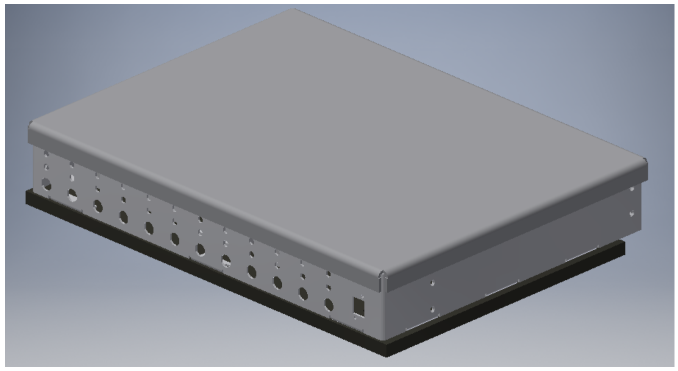


Figure 7: Aluminium box with removable roof on top of the water cooling plate. The water input and output channel of the cooling plate is at the back. The front panel is designed for maximal 12 amplifiers (12x2 holes for SMA, 12 holes for BNC and one hole for ethernet adapter).

possible that the low saturation power is due to an uncommon size of the crystal. Furthermore, it is an uncommon behaviour of the AOM that the transmitted optical power declines after reaching the saturation power, as shown in Figure 5.
The main concern, however, is the value of the maximal transmitted optical power using the optimal settings. For 9 mW input power we only get maximally 1.8 mW out of the AOM, which corresponds to a total insertion loss of ~ 7 dB. After contacting Brimrose, they suggested to optimize the fibre coupling, since they have measured a total insertion loss of only ~ 5.4 dB. However, we could not resolve this issue.

3 Construction

The main goals of the construction of the water-cooled system for the amplifiers are optimization of space utilization, as well as shielding the amplifiers from the surroundings and vice versa.
The result is shown in Figures 7 and 8. The precise components for the construction of one water-cooled system are shown in appendix A. The following points have been considered in the construction process:

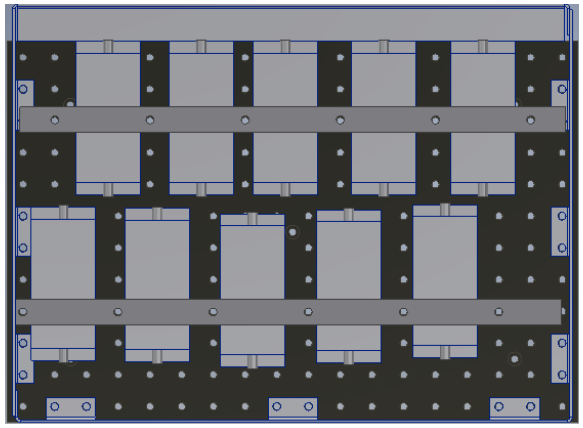


Figure 8: Top view of cooling plate with aluminium box but without roof. This is a possible arrangement for 10 amplifiers.

Sliding shelf It is beneficial to have easy access to the amplifiers at all times. Since the water-cooled system has to be places inside a 19" x 700 mm rack, it is favourable to build everything on a sliding shelf.

Water-cooled breadboard In order to optimize space utilization, i.e. placing many amplifiers into a small area, it is of great importance that the breadboard has enough cooling power to ensure a reasonable cooling effect. Since our breadboard from Thorlabs has a well constructed water channel system, this should cause no problem. Furthermore, an optical breadboard allows a flexible arrangement of the amplifiers. Note that the width of the breadboard is slightly bigger than the width of the rack. However, by filing about 1 mm away from the rack, this problem can be solved.
The water channel input and output are at the back of the construction, such that the water hoses are at the back of the rack, preventing accidental removal of the hoses.

Box To shield the surroundings from the RF signal produced by the amplifiers and vice versa, an aluminium box was built around it. The side wall is divided into two parts, because it simplifies the manufacturing. To ensure access to the amplifiers, the lid was designed to be easily removable.

Front panel The front panel is designed in such a way that a maximum of 12 amplifiers can be placed inside the box:

- 24 small holes for RF signal input and output with SMA connection. See Figure 9b in the appendix for the panel cut out.
- 12 big holes for the power with BNC connection. See Figure 9a in the appendix for the panel cut out.
- One square hole for an ethernet adapter which can be used to measure the temperature inside the box.

4 Summary & Outlook

We have seen that the main reasons to introduce a water-cooled system for the RF amplifiers are on the one hand better heat management in laboratories and on the other hand better stability of the temperature of the amplifiers which ultimately leads to a more stable laser beam power. We have then characterized one specific AOM from Brimrose. The design of this system was aimed to optimize space utilization and to shield the surroundings from the RF signal. This was realized by using a well constructed water-cooled breadboard and building an aluminium box around it.
It still has to be determined, how well the water-cooled system improved the issues regarding heat management and temperature stability of the amplifiers.
By introducing an interlock, which cuts off the power to the amplifiers in case of problems with the water supply or too high temperature, the water-cooled system can be greatly improved in terms of safety and durability of the amplifiers.

References

[1] AG Schmidt-Kaler. Privat communication with Thomas Ruster. Johannes Gutenberg Univerity Mainz.

[2] Brimrose. Fiber-coupled acousto-optic modulators, specifications. https://www.brimrose.com/fiber-coupled-acousto-optic-modulators.

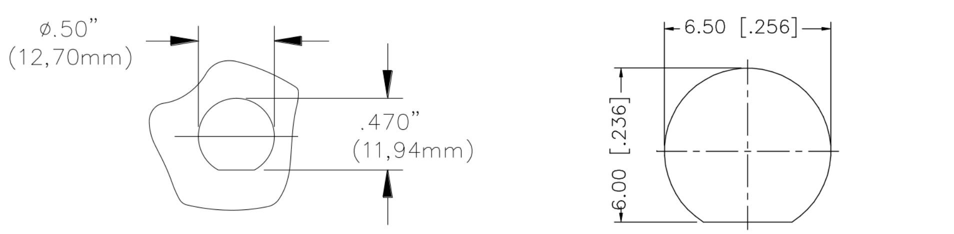
[3] ISOMET. Acusto-Optic Modulators. http://www.isomet.com/App-Manual_pdf/AO%20Modulation.pdf.

Appendices

A Construction

Component	Reference number	Order from	Amount required
Water-cooled breadboard	MBC3045/M	thorlabs.com	1
Front and right side of box	'Box_1' in J-drive[2]	Workshop[3]	1
Back and left side of box	'Box_2' in J-drive[2]	Workshop[3]	1
Lid	'Box_3' in J-drive[2]	Workshop[3]	1
Sliding Shelve	226757550	it-budget.de	1
Stabilizer stick 1	'Befestiger_1' in J-drive[2]	Workshop	1
Stabilizer stick 2	'Befestiger_2' in J-drive[2]	Workshop	1
Amplifier	ZHL-1-2W-S(+)	minicircuits.com	≤ 12
BNC adapter (female to female)	See Figure 9a	e.g. Distrelec	12
SMA adapter (female to female)	See Figure 9b	e.g. Distrelec	24
Ethernet adapter	'Ethernet' in J-drive[2]		1
SMA cable (male to male)			24
BNC cable (male to male)			12

Table 1: Components for one water-cooled system.



(a) Dimensions of the panel cut out for the BNC adapter

(b) Dimensions of the panel cut out for the SMA adapter

Figure 9: Details for the panel cut out for ordering BNC and SMA adapters.

[2] J-Drive of TIQI group: J:\Projects\aom_amp_watercooling_box\Inventor

[3] We sent the step files to the workshop, where they outsourced the flattened version of the file.