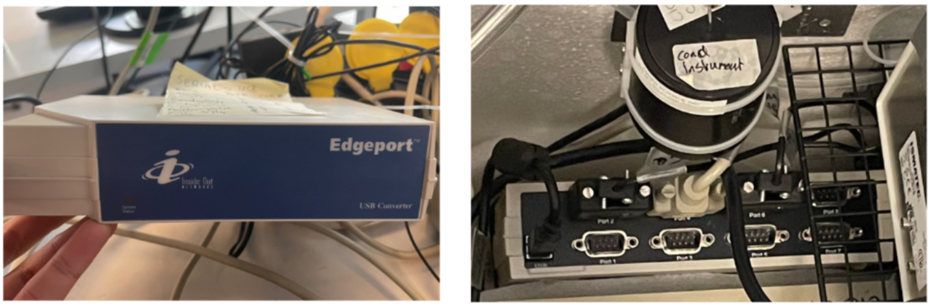

Figure 5.10: Depth plot generated from the new electronic depth registration, recorded during a LISA box freezer test.

5.1.6 Serial to USB connection

The LISA box instruments were originally connected to the computer via an Edgeport USB hub, which converts serial communication to USB (Fig. 5.10). This component was removed and replaced by serial to USB cables.

All LISA box instruments use RS-232 serial communication, with the exception of the melthead temperature control, which uses RS-485. The correct serial to USB cables were found and the corresponding cable drivers were identified and installed.

5.1.7 Other additions

Diatom Filter

A diatom filter was added to facilitate the efficient collection of diatom species from sample wastewater on site. For this, two types of filter were explored. The first option was an inline filter, placed at a tubing junction. The second was a loose mesh filter, placed at the end of the waste line. Waste water was drained from the melthead with the different filters in place, and the drainage time was recorded. Without any filter, 100 ml of water took 30 s to drain. With the inline filter, the time taken to drain 100 ml of water was between 2 minutes 30 seconds and 5 minutes 5 seconds, depending on which part of the tubing it was connected to. When placed closer to the pump, the drainage time was faster. With the mesh filter, the drainage time for 100 ml of water was 40 seconds.

Deciding to use the mesh filter style, a holder was designed by **Nanna Andreasen** (Fig. 5.11).

One of the heaviest components of the LISA box is the high precision main pump, which pulls water from the melthead centre line to the instruments. While high flow rate peristaltic pumps are relatively inexpensive and simple in design, low flow rate peristaltic pumps require multiple rollers to maintain a steady and precise flow rate, necessary for CFA. This makes them larger by nature.

Within the physics of ice and climate department, the gas lab group had ordered six miniaturised double diaphragm pumps [47], which were available for testing in the LISA box. The small size (approximate size shown in Fig. 5.12) and range of possible flow rates made them an attractive option. The flowrates required for the LISA box CFA are 0.14 ml/min, 0.1 ml/min and 1 ml/min [27]. The micropump flow rates could be adjusted from 8 μl/min to 10 ml/min, depending linearly on the back pressure. At 0 mbar backpressure, the pumps provide the maximum flow rate, and at maximum backpressure, the flow rate reduces to 0 ml/min [47]. To achieve the

Figure 5.11: Diatom filter designed by Nanna Andreasen. The black piece with large holes is placed in the opening in the lid of the waste bucket. The two transparent pieces are put together with the mesh fabric filter in between. The small black lid is put on top of the large transparent piece with the tube inside the pink connector in the middle. Two rubber bands can be used to secure the black lid more tightly if necessary. When the filter is changed, the small transparent piece is carefully removed, and the filter is folded so that the top side where the particles are, is inside the fold and stored in a labelled sample bag. .

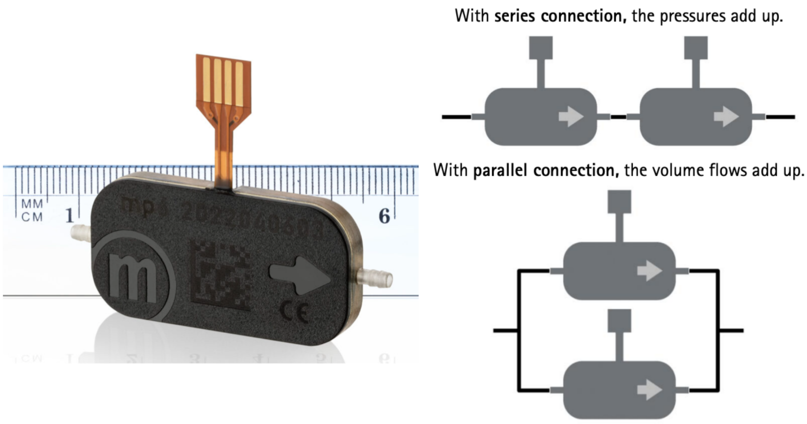

Figure 5.12: Depth plot generated from the new electronic depth registration, recorded during a LISA box freezer test.

highest flow rates, the micropumps were could in series and in parallel, according to Fig. 5.12.

The double diaphragm mechanism is driven by two piezo actuators [47], working as pistons to transfer fluids. Driven by a sine signal, they are placed at a phase shift of 180°, so that the liquid pulled inside the first chamber is then passed on to the second, before being ejected at the other side. The frequency and amplitude of the sine signal can be adjusted to create the desired flow rates. This was controlled via a digital interface, communicating with the pumps through a driver and Arduino.

An Arduino code was available to operate the pumps. The Arduino IDE desktop app was downloaded and installed on the LISA box computer. This Arduino code was uploaded onto the IDE, and the micropump QuadKEY software was installed to test the pumps with different parameter options, to investigate which settings gave the most stable flow rate. The CFA lab flow meter was attached in line after the pump and data was recorded through labview on the CFA lab computer.

Tests exploring different tubing diameters and lengths, arrangements of pumps, and different diaphragm frequency and voltage were performed. The results of some of the frequency and voltage adjustments are presented in Fig. 5.13. In the top two graphs, the effect of increasing the flow rate or increasing the amplitude are investigated. In the bottom two, the flow stability is assessed.

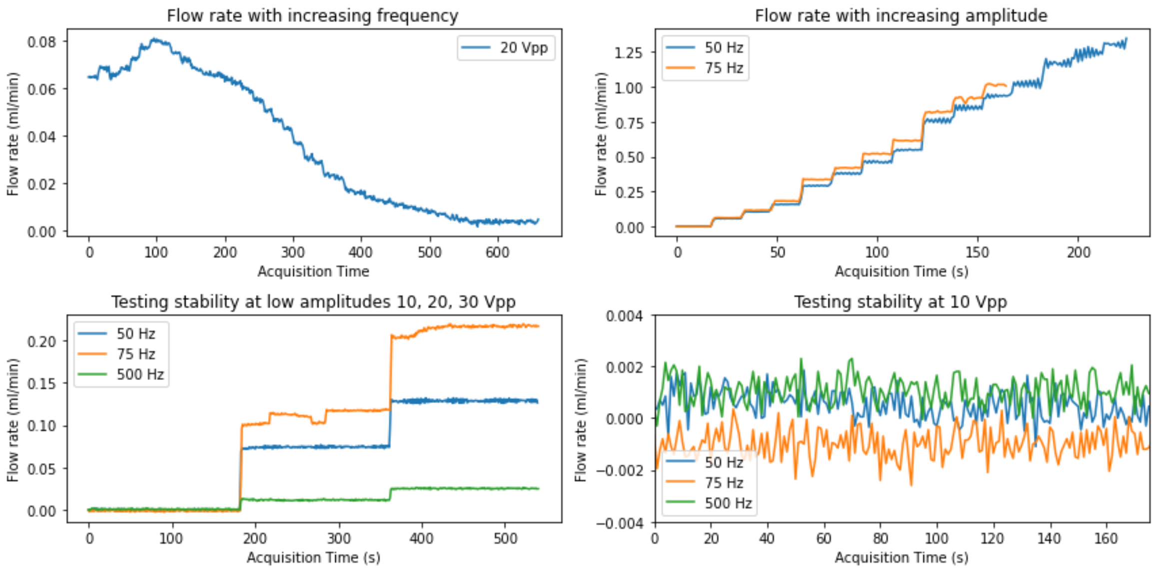

Figure 5.13: Micropump tests exploring how flow rate and flow stability varies with amplitude and frequency for flow under 1 ml/min. Top left: using the lowest stable voltage (20 Vpp), frequency was increased in increments of 10 Hz every 15 seconds, starting from 50 Hz up to 500 Hz. Top right: for two frequencies of 50 and 75 Hz, the amplitude was increased in increments of 10 Vpp every 15 seconds, starting from 10 Vpp. Bottom left: the stability of different frequencies while increasing amplitudes from 10 to 20 and then 30 Vpp (3 minutes each). Bottom right: stability of different frequencies at the lowest amplitude of 10 Vpp.

The highest stability low flow rates were found to be achieved with higher frequencies. The improved stability with higher frequency is intuitive, because more pump cycles are completed within one second, averaging out the variations in the liquid motion. However, one would expect that higher frequencies would yield higher flow rates, but this is not the case. For a set amplitude, the frequency decreases after a certain point. In other tests, this turning point was found to decrease with higher voltages, and increase with larger tubing diameters due to backpressure. The reason for the decreasing flow rate above a certain frequency is the mass inertia and shear forces due to the viscosity of the liquid. The force of the piezo actuators is constant, while the acceleration increases with increasing frequency. Below 20 Vpp, the flow rate measurement became unstable and negative values were sometimes registered (bottom right).

During testing, an issue arose with starting the pumps when there was air in the system, in particular, when using longer tubing (over 10cm), using tubing that was larger or smaller than the tubing provided with the pumps (1.3 mm), and when the reservoir lay beneath the pump. Squeezing the lines sometimes helped to start the flow, and adding a second pump to create backpressure and increasing the frequency to over 300 Hz helped. Changing the reservoir pump tubing to shorter lengths of 10 cm and moving the resevoir up. The smaller tubing diameters were the most problematic to get started, followed by the larger tubing diameters. Therefore, unless

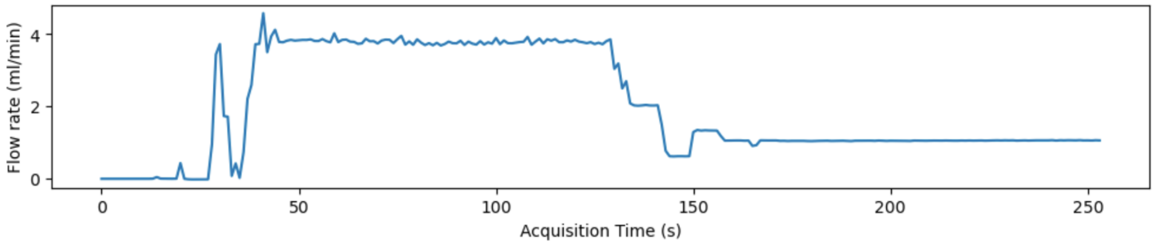

Figure 5.14: Testing one pump with provided tubing at a voltage of 250 Vpp 250 and frequency of 95 Hz. The pump does not start with a consistent flow until 45 seconds, after the tubing is squeezed.

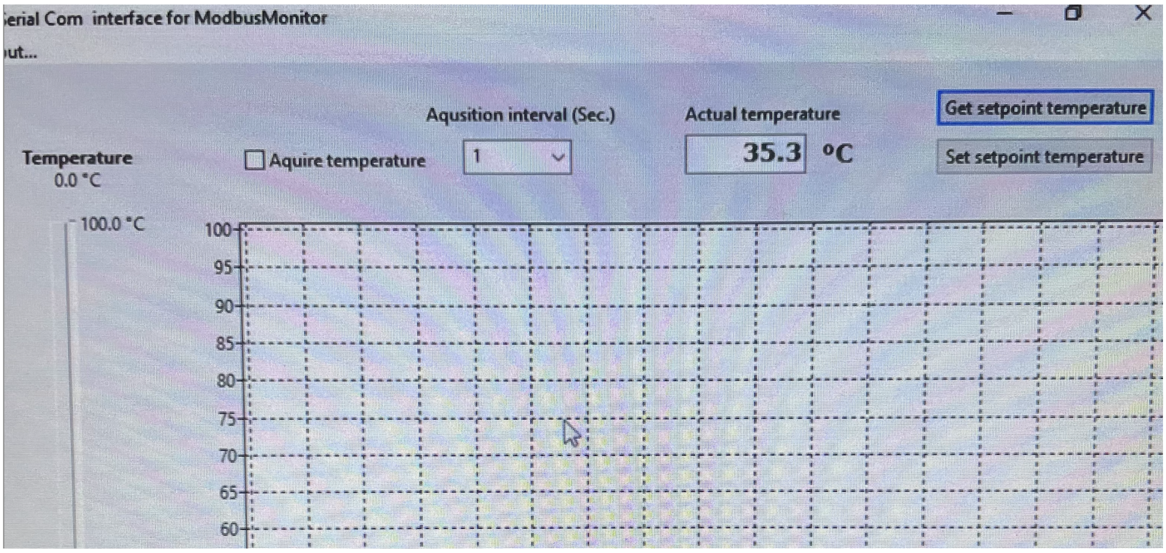

Figure 5.15: Melthead temperature control programme designed by Palle Koch at the NBI workshop.

Despite the promising results found for the high stability at flow rates under 1 ml/min for higher frequencies, the issues with starting the pumps rendered them unsuitable for the LISA box.

Other high precision peristaltic pumps were explored, but the no models with the required precision (~1-2 %), which were lighter-weight than the existing pump were found at this stage.

Melthead temperature control software

The melthead temperature is adjusted through the melthead temperature control. A small display on the temperature control unit shows the current temperature, which can be changed with buttons on the device. An attempt was made to create a python code to communicate with the melthead temperature control, enabling electronic logging of melthead temperature. However, the RS-485 communication was not correctly configured. Instead, the NBI workshop created a Modbus monitor programme, setup to run with the Omega CN 7500 control unit in the Melthead temperature control. An image of the programme is shown in Fig. 5.15, which needs to be optimised for the smaller screen in order to see the full range of plotted data. The software is installed on the LISA box computer but remains to be fully tested.