Manual: Performance of wafer-fused VECSEL under high power operation

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Abstract

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Contents

1   Measurement Routine

The routine is written in Python [?]. This brings in several advantages: First of all we can actually look through the code and comment on it, where clarification is needed. The Python syntax is simple enough – basically, English with peculiar grammar – so if you can read this documentation, you will understand the program just as well. LabView for example fails at exactly this point; it's very hard to maintain, and the different sections of the script are difficult to interpret (let alone the litteral spaghetti code). And lastly, with Python we don't depend on a third party license. Again, LabView and Matlab fail at this point.

1.1   The routine

You either look at the example given in "exp/eval/routine_measurement.py" and read it through, or you continue to read here. The following long text covers the same.

We choose a set of values corresponding to a) the current of the pump laser, and b) the temperatures of the heat sink. We specify further, a path where to store the results. And lastly, we choose on how often every power current is ought to be measured – repeated measurements in order to obtain the errorbars that inform us on the reliability of the results.

At each temperature, we set the power source to the requested currents, and read out the power meters. The results of each power meter is written in its own file. Each of these files starts with a header line, that contains the state of the relevant settings of the device in question. Consequentially, if we doubt the integrity of the measurements we can look at this header line and at least know what state the device has reported to be in. The information about the power source are also written to its own file, containing the set and actual current. Hence, at each temperature we generate one file for the power source, plus one for each power meter.

At the end of these measurements we write a line in a logfile: The set temperature, the actually reached temperature, the filenames of the files with the results of the different devices, along with a timestamp so we know which measurement took how long. The timestamp also allows us to connect certain effects to the time of the day it was measured. The approach with a logfile and the separate files of each device (whose names are automatically stored in the logfile), facilitates the analysis; all the information a analysis-script needs is specified in the logfile.

At each heat sink temperature we irradiate the sample with different pump powers. Each pump is repeated N times over all. The pump order is selected at random, as illustrated in Fig. 1.1. Thanks to the random sampling the measurement results are detached from the lab environment – most notably time-independent. The heat sink cannot control its temperature with absolute precision. Figure 1.2 illustrates this issue: It shows the actually present heat sink temperature for six set temperatures. In the left column the temperatures are plotted in chronological order. We can identify, the temperature drifts. The right column shows the same temperatures, but corresponding to the set pump. The repeated measurements see a spread of different temperatures but the temporal drifts can not be resolved.

In contrast, Fig. 1.3 shows the heat sink temperature during a measurement without the random pump selection. In this case, clearly, we cannot talk about a single heat sink temperature for all the pump settings for this specific set heat sink temperature. The resulting measurements are highly repeatable, but only given the same pump order. This pseudo-stability we exploit during the calibration process of the different beam samplers and detectors: During the calibration we don't care about reproducibility but solely about the repeatability of two consecutive measurements.
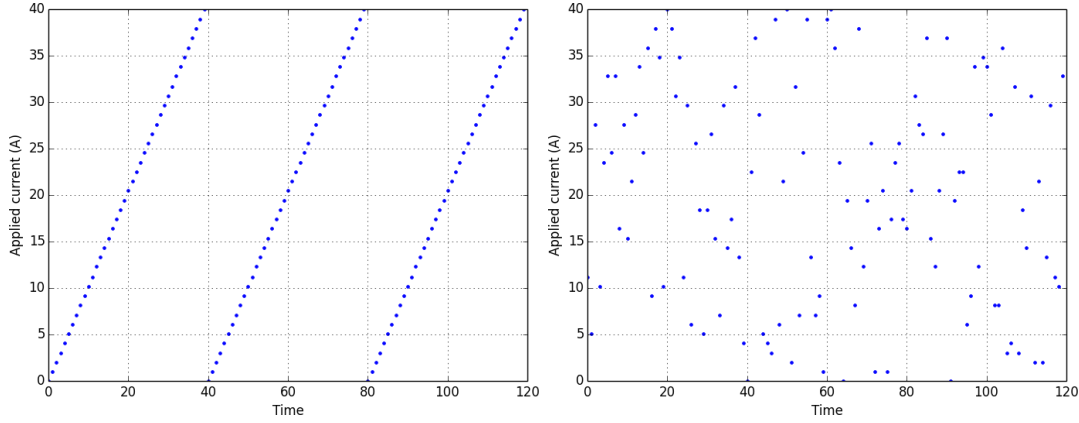
Figure 1.1: Two examples to apply various pump settings, with a repetition rate of 3. Left: A ramp. Right: Random sampling.

The power meter average each measurement point over 200 samples, of which each one sample takes approx. 3 ms [24].

The order of heat sink temperature is still a ramp: I expect the setting of a new temperature to be somewhat time consuming. Therefore, we want to make use of the previously set temperature. The measurement routine looks at the specified temperature range, picks the one closest to room temperature, and increases to every second entry. Once the highest temperature is reached, the residual temperatures are picked, in descending order, until the lowest temperature is reached. From there we heat back up to room temperature. This routine is illustrated in Fig. 1.4.

As mentioned already, we repeated the measurement of each pump setting N times. With this repetition we obtain a measure for how well we know the underlying true value. We are hence interested in the mean of these single measurements and the resulting unbiased standard error [25]

$$\Delta x = \sqrt{\frac{1}{N(N-1)} \sum_{i=1}^{N} (x_i - \frac{1}{N} \sum_{i=1}^{N} x_i)^2}. \tag{1.1}$$

For the uncertainties attached to quantities obtained through fits, I use a so-called Jackknife [26] approach: In a nutshell, this method allows to estimate the influence of the single measurement points on the fit parameters without working through the covariance matrix of the fit. The resulting error value is directly related with the unbiased standard error (1.1), used for the rest of the report.

1.2   Safety precautions

The goal of this script is to automate as much as possible. Ideally, we want to install a new VECSEL, align the output coupler, press start, and return some time later to a complete data set for this specific VECSEL under test. For this we need to be sure our measurement routine handles potential errors appropriately.

For this we must not rely on software. Instead, we have to implement the safety precautions on hardware side. In software we can try to mitigate potential problems through proper error handling. I don't know how this would be done in LabView. In Matlab and Python this is performed through so-called try/catch and try/except handles, respectively. With it I have implemented that if anything goes wrong software side, the power source is shut down (This order itself is so low-level, that it *should* always work.).
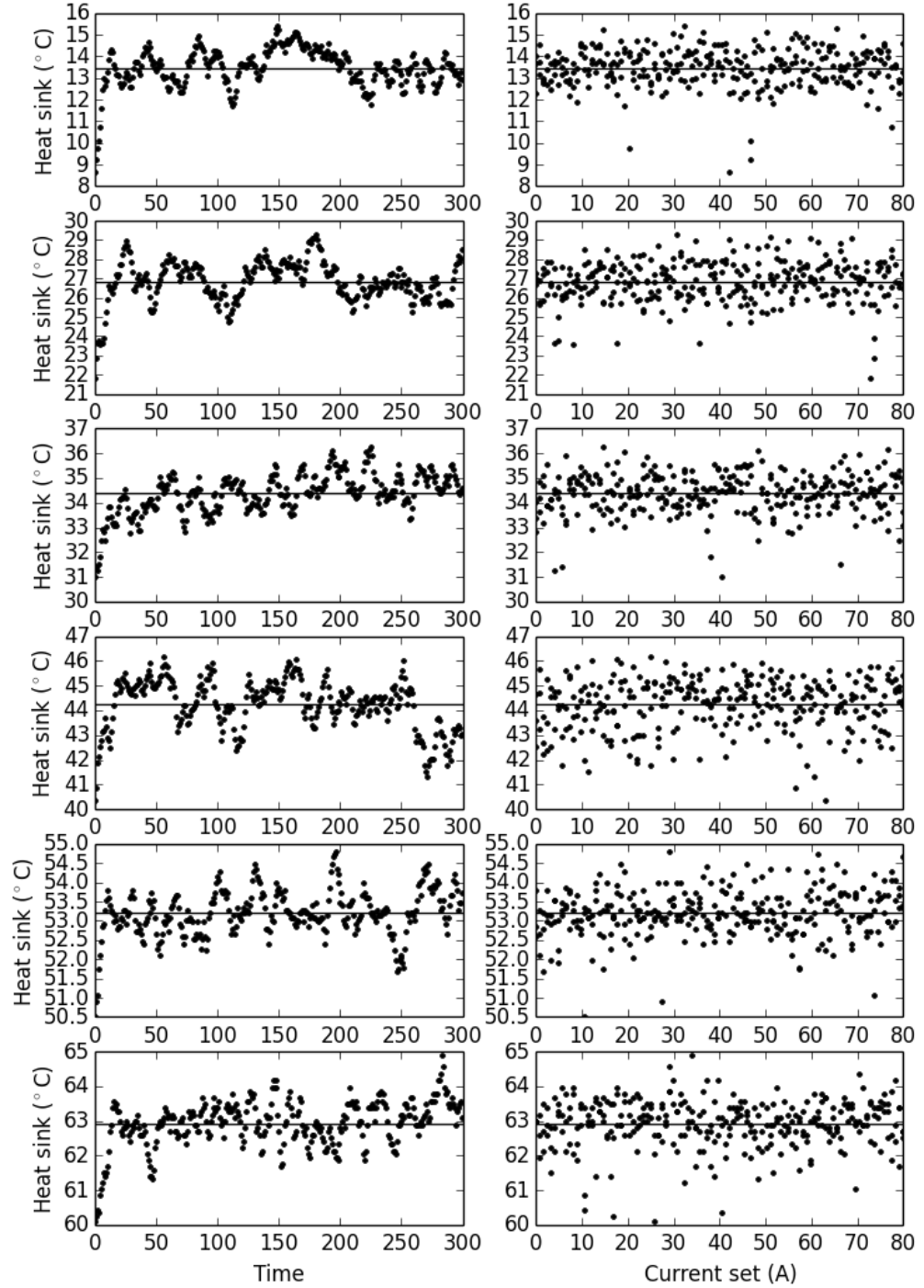
Figure 1.2: The heat sink temperature fluctuates over time (left). Thanks to the random sampling addressed in Fig. 1.1 the measurements don't see these drifts (right).
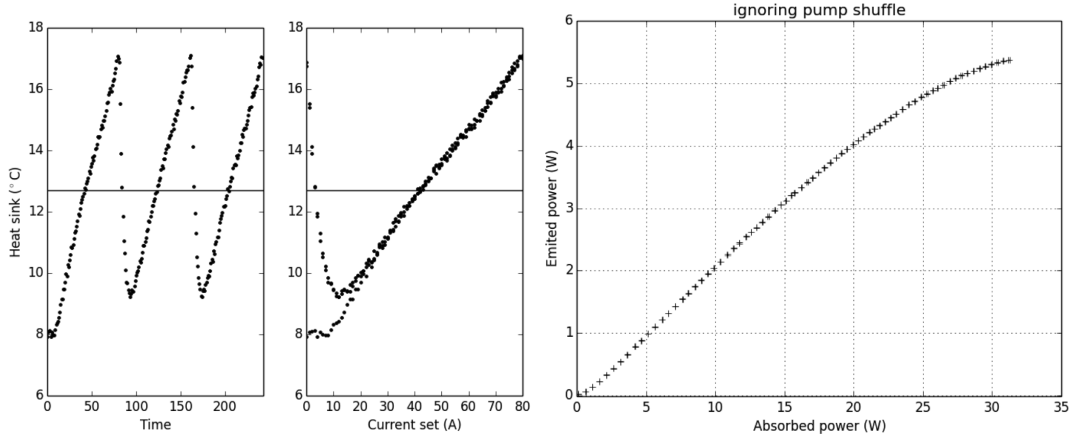
Figure 1.3: In contrast to Fig. 1.2, when we ignore the random pump sampling highlighted in Fig. 1.1, the temperature seen by the single pump settings differ strongly from the average heat sink temperature (left). The resulting LL-characteristic has very little noise on its data points (right). But these small error bars dismiss the fact that the underlying points were measured under very different conditions; eroding the significance of this low noise.
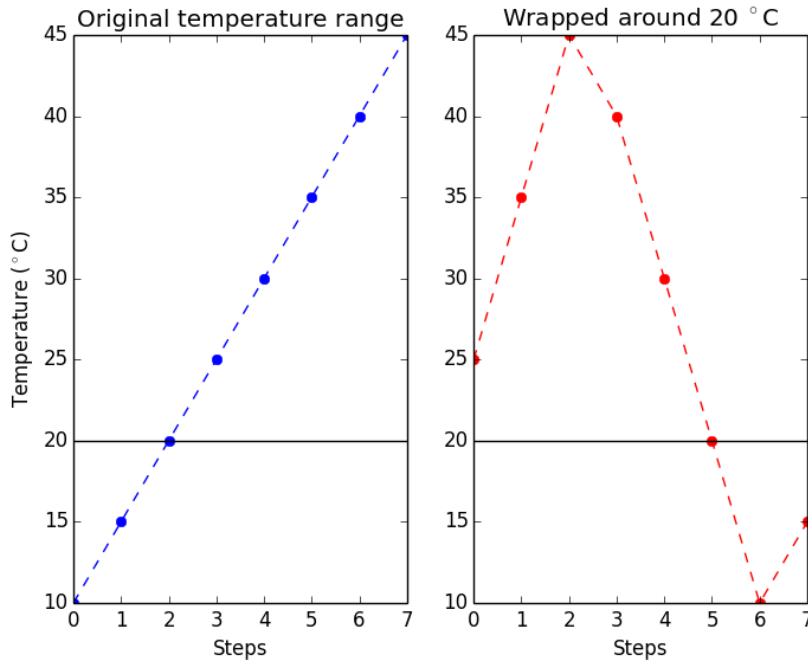

Figure 1.4: An example of how a given temperature range is wrapped around the room temperature (here assumed to be 20 °C).

For example, one of the devices could send an unexpected answer, the heat sink doesn't reach its requested temperature within reasonable time, etc. For the unlikely event that even the power source shut down doesn't work, we have to implement the safety precautions on hardware side.

Our power source has two ways to be shut down: We can disable the current, or we can set the current to zero. In order to disable the current, we first have to ask the power source, whether the current is currently applied. If it is, we toggle it like a light-switch to shut off. However, querying the current state is error-prone. Hence, if an error is caught we leave the shutter to be in what ever state it is and only set the current to zero. Potentially it is still applied. But the light output at $0\,\text{A}$ is barely detectable – but there still *is* a leak flow of photons. Writing to the power source should not cause any new problems, so simply writing $0\,\text{A}$ should go through.

On the hardware side, the "laser on" light in front of the lab is controlled by a logic tied to the power source: As soon as the power source applies a certain specified voltage the laser warning turns on. During the measurements this safety sign therefore is always on.

As a second safety precaution I supply a script that allows us to test modifications on the measurement routine with fake devices. In order to connect the measurement routine with the measurement devices we have to specify a protocol. In the new script we do this by selecting an external file that contains the initiation details. By specifying the fake protocol we can modify the routine without the real devices. This separation in code is, for one, good practice, and secondly convenient if we cannot use one of the devices due to a revision or whatever. To be detached from the physical devices was not possible with the old script – which is one of the reasons why it was possible to toggle the power source shutter while setting the wavelength of the power meter.

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