Deliverable 11.4

# ML² – Multi Layer Micro Lab

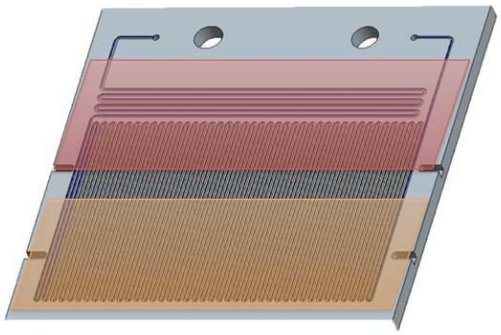
## Demonstration of interoperation capabilities

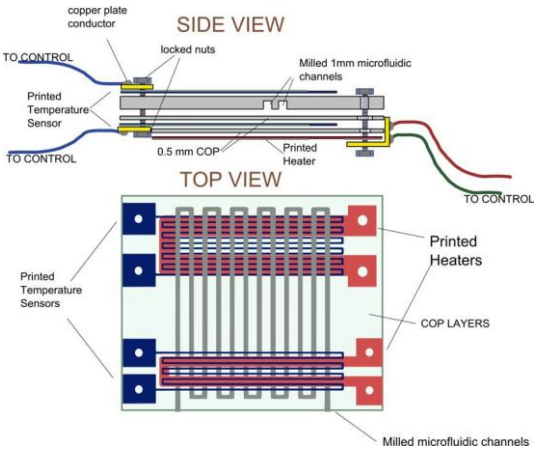
## 1. Introduction

The three demonstrators developed in ML² project are designed in multilayer architecture. The electrical, optical and microfluidic functions are located on different layers. This deliverable demonstrates interoperation capabilities between different functional layers. For each demonstrator the essential interoperation is shown and the current state of development is described

## 2. Demonstrator 1: electronic - microfluidic

Demonstrator 1 is the continuous flow polymerase-chain reaction (PCR) chip. The crucial function of the chip is the two zone heating of the fluid to ensure the multiplication of the DNA information contained. The fluid is heated up to 60°C ±0,5°C in the annealing zone and up to 95°C ± 3°C in the denaturing zone (see Figure 1, left). Therefore the microfluidic channels are covered by printed heaters with printed temperature sensors to allow a closed loop temperature control (compare Figure 1, right)



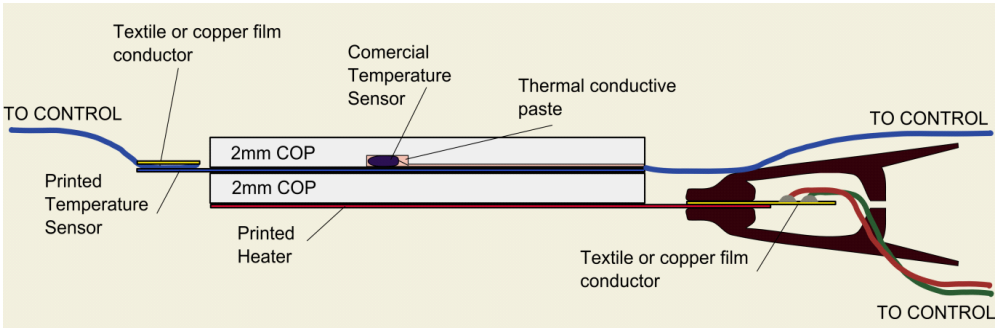


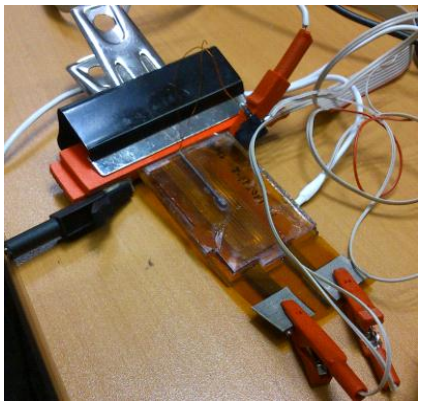

**Heating zones: Denaturing zone (red), Annealing zone (orange)**

**Development setup in multilayer architecture**

**Figure 1: General layout of microfluidic channels and heating zones (left) and design of printed heaters with temperature control sensors (right)**

To proof the performance of the printed heating structures and to evaluate the quality and accuracy of the printed sensor a measurement and test setup as illustrated in Figure 2 has been assembled. Between printed heater and printed temperature control sensor a sheet of 2 mm COC polymer represents the microfluidic layer according to the current chip design. To compare the temperatures measured by the printed sensor a commercial temperature sensor is embedded into the setup. A thermal imaging camera is used to illustrate the temperature distribution. The test bench is designed to optimize the interoperation capabilities of the microfluidic channels and the heater for the annealing zone.



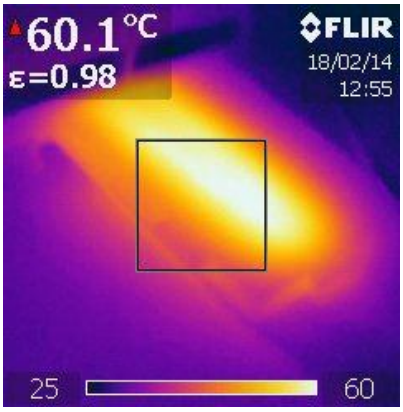



**Figure 2: Heating tests (setup, realisation and results)**

Figure 3 illustrates the results for the PID controlled annealing zone heating mentioned above. The targeted reference temperature of 60°C can almost be reached within the required tolerances of ±0,5°C. The heating rate at the beginning can be changed by variation of the closed loop parameters. Both temperature sensors permit the conclusion the temperature can be kept at a stable level after a ramp up of ca. 500 seconds. The deviation of the printed and the commercial temperature sensor could be a matter of sensor calibration or manufacturing.

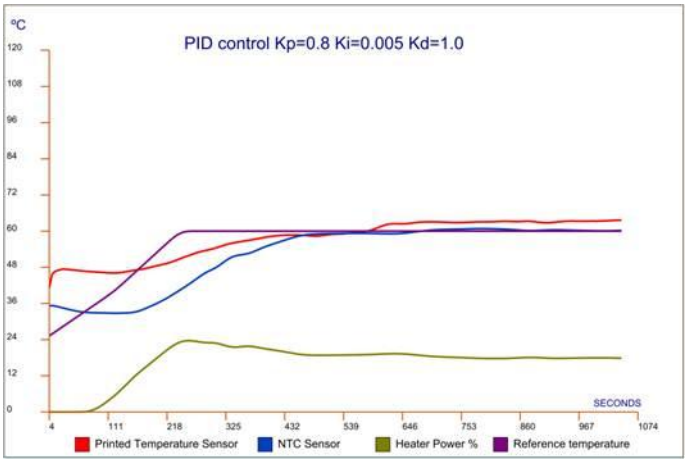



**Figure 3: Closed loop temperature control**

Similar test are performed to proof the quality of the heater in the denaturing zone. As the acceptable temperature deviation tolerances are of a wider range it is expected to achieve even better results.

## 3. Demonstrator 2: optical – microfluidic

Demonstrator 2 is an on-site water detection chip to evaluate the pollution of water with toxins lethal in extremely low concentrations. The detection principle is based on autofluorescence measurements which require a certain excitation wavelength at precisely located spots within a microfluidic chamber. Figure 4 shows the lightguide layer with specially structured spots to provide an outcoupling of the guided spectrum perpendicular to the surface. Those structures can be manufactured into the bottom layer of the required microfluidic channels. Surface functionalization treatments and the application of reagents for the immobilization of the molecules to detect are additional process steps to generate the detection system.

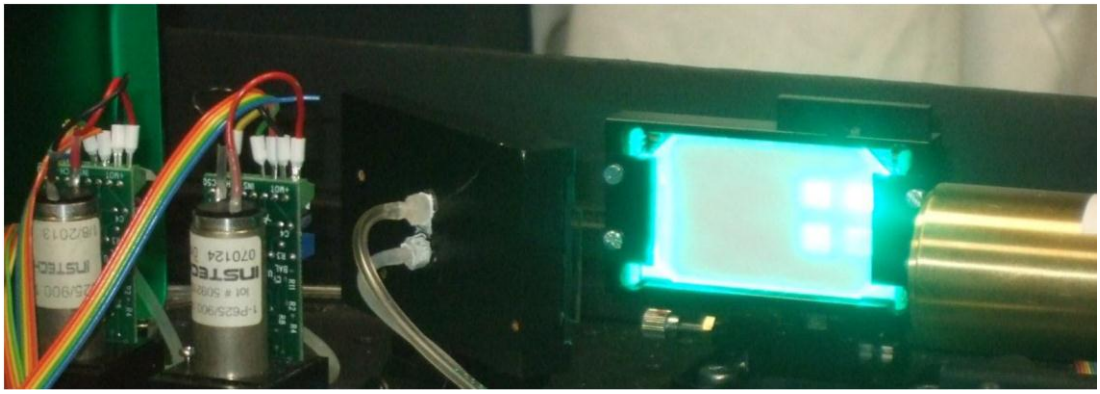


**Figure 4: Lightguide layer for autofluorescence excitation**

In Figure 5 different autofluorescence measurement are shown. The picture present the excitation spot within the microfluidic channel with various combinations of surface treatment and light wavelength. It's obvious that the interoperation capabilities of optical and fluidic layer will provide a sufficient performance for the targeted test method.

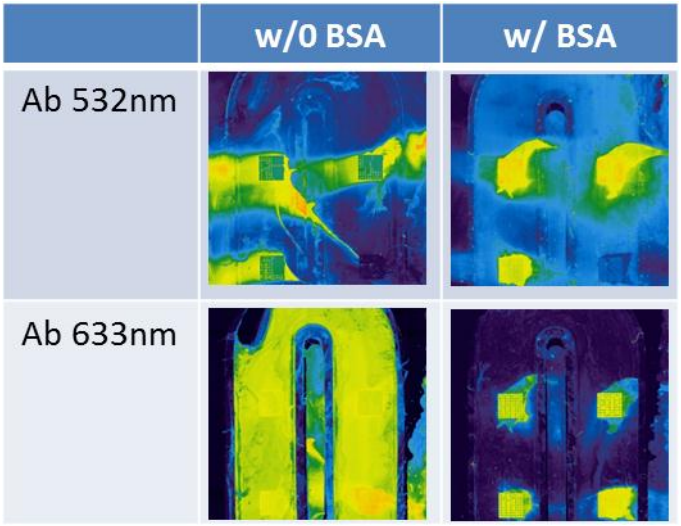



**Figure 5: Autofluorescence visualisation**

## 4. Demonstrator 3: electronic – microfluidic

The pregnancy test targeted with demonstrator 3 detects hCG (human chorionic gonadotropin) linked to paramagnetic particles by printed inductive coils. The urine probe is collected by a sample pad, blended with paramagnetic particles and guided over printed detection coils. Figure 6 depicts the test setup to analyse the interoperation capability of microfluidic and electric layer and the sensitivity of the sensor approach.

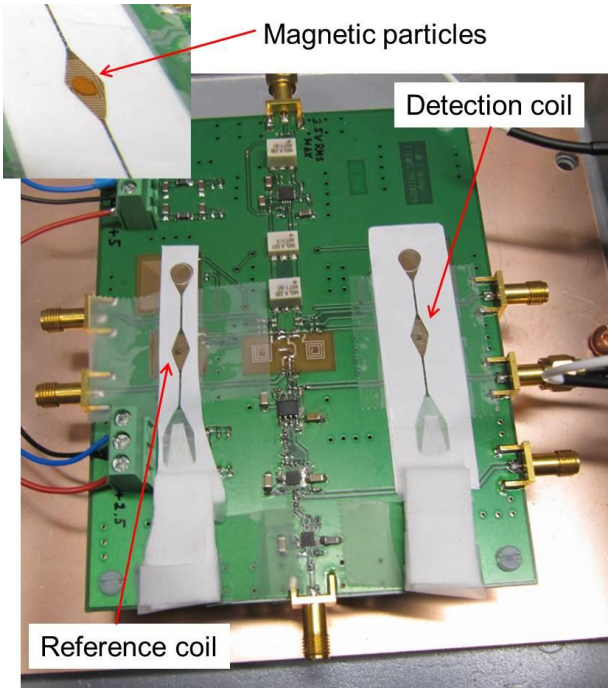



**Figure 6: Test setup**

At the beginning of the test series both channels are dry. Different amounts (10, 50, 100 M) of dried magnetic particles on 20 µm thick PET are placed on top of the coil and response is measured. Both channels are filled with 1 w% NaCl-DIW solution (resembles human urine). Due to capacitive effects of the conductive liquid layer, the sensor output shifts. The sensor "zero-level" is recalibrated. Different amounts of particles are placed again on top of the coil and response is measured. Very similar response was obtained with both dry and salt water filled channels. This requires that the sensor is calibrated when the channels are wet but no particles are present on coils. Response values have been in the range of:

| Amount of dried particles | Change in signal $\Delta V$ |
|---|---|
| 10 M | 200 µV |
| 50 M | 450 µV |
| 100 M | 800 µV |