Construction Manual of Merlin spectrometer

The first generation of our Merlin Spectrometer is based on the ramanPi Spectrometer. The Project was developed open source with a detailed construction documentation. In the link below you will find some details.

https://hackaday.io/project/1279-ramanpi-raman-spectrometer/log/9583-how-to-build-a-spectrometer

In the working progress we optimized Merlin for our challenges, added some features for calibration, sample handling and other adjustments. In the following part list you will find everything you need for your very own Merlin spectrometer. Furthermore you need access to a 3D-printer to print your spectrometer casing and other components.

Quantity	Component	Cost [€]	Cost [$]
Optics			
1	razors	4	4.60
1	ringt magnet 30mm diameter, 5mm depth, 5 mm hole	2	2.30
1	VIS holographic grating, 1200 grooves/mm, 25mm square	124.24	135.00
1	spherical mirror, 20mm diameter, 80mm focal length		37.50
1	concave mirror, 50 mm diameter, 100 mm focal length		42.50
Control Unit			
1	microcontroller NUCLEO-F401RE	11.49	13.21
1	capacitor 10µF, 25V SMD 1206	0.1	0.12
2	capacitor 0.1µF SMD 1206	0.2	0.23
2	resistor 150 Ω SMD 1206	0.2	0.23
1	resistor 2200 Ω SMD 1206	0.1	0.12
1	74HC04 SMD 1206	0.2	0.23
1	Toshiba Transistor 2SA1015-Y	0.1	0.12
1	USB A cable	2	2.3
1	PCB board	5	5.75
1	Toshiba TCD1304 Linear CCD		4.00
Wiring and Screws			
4	black M2.5 x 30	0.40	0.46
6	black M3 x 12	0.4	0.46
3	black M2.5 x 12	0.3	0.35
2	black M3 screws	0.2	0.23
6	jumper cables	0.6	0.69
Optional Graphic Interface			
1	Rasberry Pi	35	40.25
1	6inch LCD Screen	35	40.25
1	MicroSD card 8 gb	5	5.75
	Total Cost		**250.38**
	Cost with Graphic Interface		**336.63**

Step by step preparations and assembly

Attention!

The diffraction grating and the mirrors should be handled carfully. We recommend disposable gloves and hexagon socket screws to prevent scratches and fingerprints. Be careful when preparing the gap. When working with the shaving blades and the magnet you can easily cut yourself.

First step - download and get started with the 3D-prints

Download every print-file on our website for your own spectrometer and print Merlins spectrometer casing. After printing remove all unnecessary support structures and free every srcew hole. Before all components are installed, it is recommended to put all screws into the housing. Furthermore you need to print the two mirror holders, the diffraction grating mount, and the frame for the CCD modul.

Second Step - fixing optical components to the corresponding holders

Fix the optical components to the corresponding sockets with double-sided adhesive tape. The fixation is secured with a little glue. The diffraction grating frame is secured in the lower area between the frame and the case with a round thin latex strip. The rubber ring is removed from a disposable glove and ensures the security and rotation for later calibration.

Third Step - Prepare slit or small hole

For a narrow gap, two razor blades (7mm * 15mm) are cut out of a razor blade with scissors covering the hole of the magnet to create a fine gap with the desired gap width. The gap is fixed with scotch film without sticking over the gap. For a small square hole, work is done equivalently with four cut razor blades. Optimize the gap width for your requirements and note that as the gap size decreases, the spectral resolution increases and the intensity decreases.

Fourth step - CCD modul

Complete the TCD1304 Linear CCD module following the instructions of Esben Rossel. His detailed instructions can be found in the following link: https://hackaday.io/tvaettbjoern

We used a Otter T1304 PCB board, which has the same port constellation as Esben Rossel´s second SMD-Version. For the PCB board you will need resistors, capacitors, ports; IC, Transistors with following specifications (table 1).To make the depths of the CCD sensor adjustable, we inserted two layers of the socket strips. We recommend to provide the six jumper cables with markings for the connections.

Table1 specifications fort he CCD modul

R1; R2	150Ω SMD 1206
R3	2,2 kΩ SMD 1206
C1; C3	0,1 µF SMD 1206
C2	10 µF SMD 1206
T1	2SA1015-Y
IC1	TC74HC04 SMD 1206
CCD	TCD1304
Socket strips1 (ST1)	4x 11 Female headers BLY 1
Socket strips2 (ST2)	2x 5 Female headers BLY 1
PCB board	The Otter TCD1304 board
6 jumper cables	

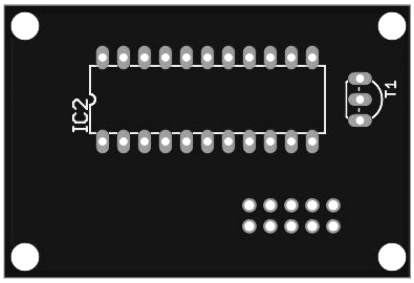

Figure1: Interior view of the PCB board within Merlin on which the ccd sensor is placed on a two-layer socket strips1 (ST1).

In the link below you can find more details about the PCB board:

http://dirtypcbs.com/store/details/863/the-otter-tcd1304-board

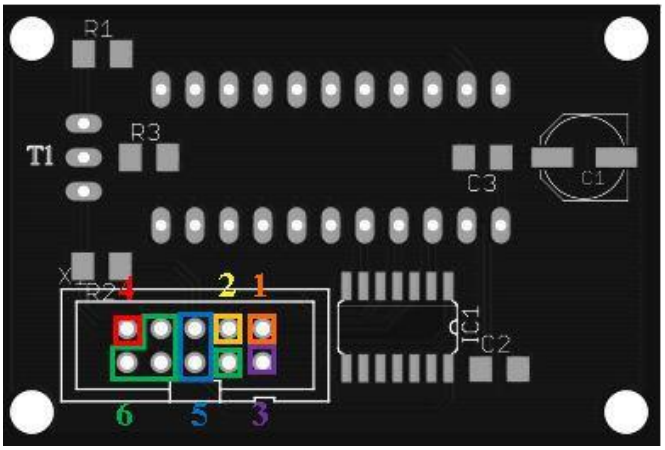

Table2 How to connect the CCD modul with the nucleo

1 fM	connects to	PB0 (A3)
2 SH	connects to	PA1 (A1)
3 ICG	connects to	PA0 (A0)
4 OUTPUT (OS)	connects to	PC0 (A5)
5 +5V	connects to	+5V
6 GND	connects to	GND

Figure 2: The corresponding external view of the PCB board within Merlin to which the IC1, C1, C2, C3, R1, R2, R3, T1 and the socket strips2 (ST2) are soldered.

Fifth step - final assembly

Upon completion of all preparations, all items can now be located at their intended location in the lower part of the spectrometer housing, as shown in figure 3.

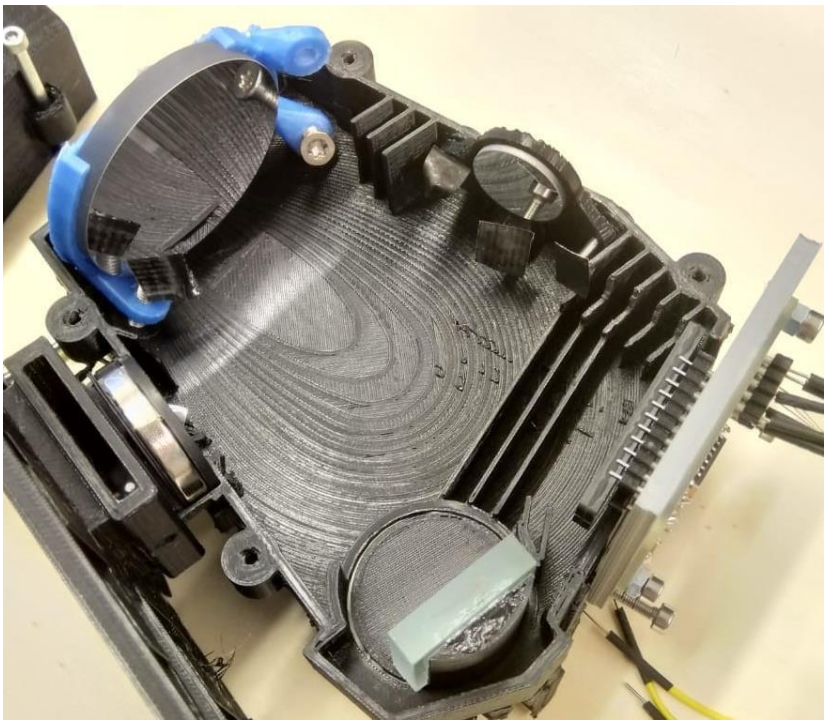

Figure 3: lower half of the Merlin spectrometer with built-in components.

Sixth step - calibration

For coarse calibration, a laser with a defined wavelength is recommended. We used a laser with a wavelength of 650 nm and a power of 0.4 mW, which represents only a low risk for the eyesight. When calibrating with the slit and the above-mentioned laser, it is urgent for a good spectral resolution that the distance from the slit opening to the first small spherical mirror correspond exactly to the focal length of 8 cm so that the reflected light beam is collimated to the diffraction gratingThe distance between the large concave mirror and CCD sensor must also be adjusted with great care to the focal length of 10 cm. After appropriate adjustment of the distances and angles, a vertical narrow red stripe is imaged on the CCD sensor, which is located relatively far to the right of the sensor. A mercury lamp is excellently suited for calibration with its wide discrete light spectrum and provides information on which wavelength range is imaged on the CCD sensor. Each light source with known and constant light spectrum in the visible range is suitable for calibration of the Merlin spectrometer. When evaluating the measured values, it should be noted that the spectral response of the CCD sensor is not constant and drops significantly as of a wavelength of 700 nm. You can find more details in the link below:

https://www.coptonix.com/html/laith_i_ccd.html

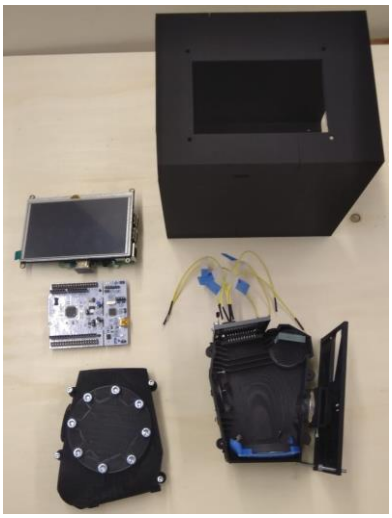

Figure 4: Completed Merlin spectrometer with outer case, nucleo, Raspberry Pi and LCD display.

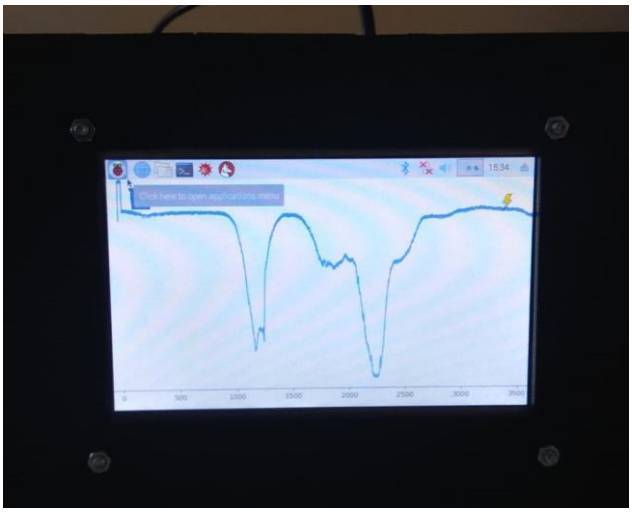

Figure 5: Ready-to-use Merlin spectrometer after fine calibration.

After careful alignment and verification of the spectral resolution. Can the measurement signals be evaluated via a laptop or the Raspberry PI. Note, intensity peaks are inverted by the CCD sensor as valleys.

Have fun and success with your Merlin spectrometer!