MLab - STI Unit

Digital Holography Microscope (DHM) for Automatic Disease Identification Using AI

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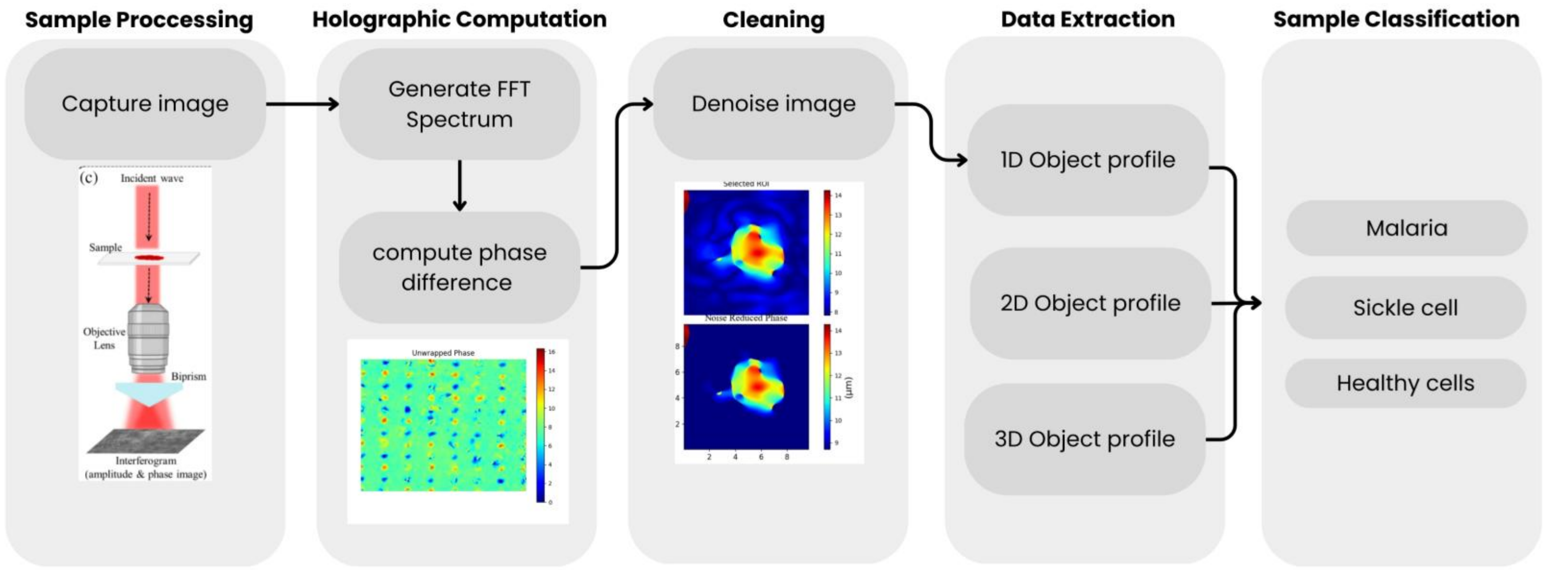
Trieste, August 2025

The Abdus Salam International Centre for Theoretical Physics

Outline

- Introduction and Project Overview
- Methodology
- Experimental Setup and Results
- Future Work
- Conclusions

Project Introduction & Overview: DHM System Pipeline



Methodology

1. Deployment of the Sagnac Setup

1.1 Structural and Physical Architecture

1.2 Testing and Calibration

2. DHM Software Enhancement

2.1 Enhancing current software architecture

Phase 1: Reverse engineering and Code refactoring
Phase 2: Hardware migration

2.2 Transforming architecture

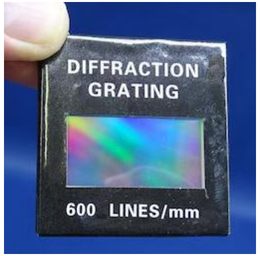
Phase 3: Remote Setup and Server Integration
Phase 4: AI image cleaning
Phase 5: AI classification algorithm

3. DHM Hardware Enhancement

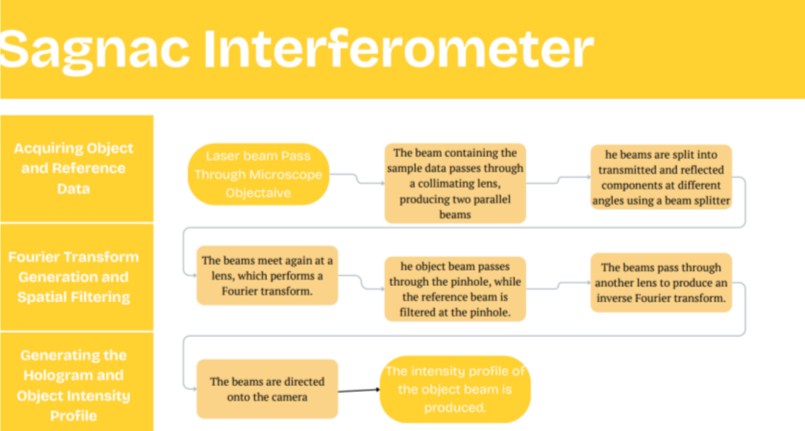
Deployment of the Sagnac Setup: Structure and Physical Architecture

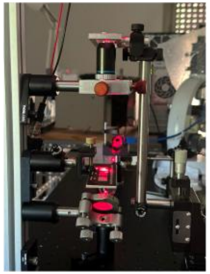
In an effort for making a more affordable digital holographic microscope version, we implemented the **Sagnac setup**

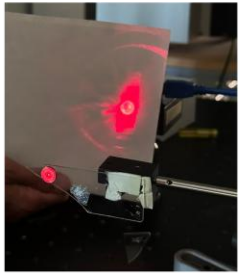
Fresnel Prism
(Old setup)

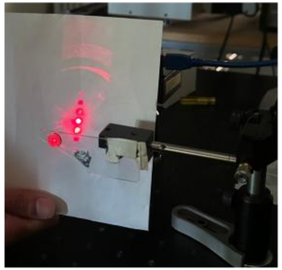


Grating
(New setup)



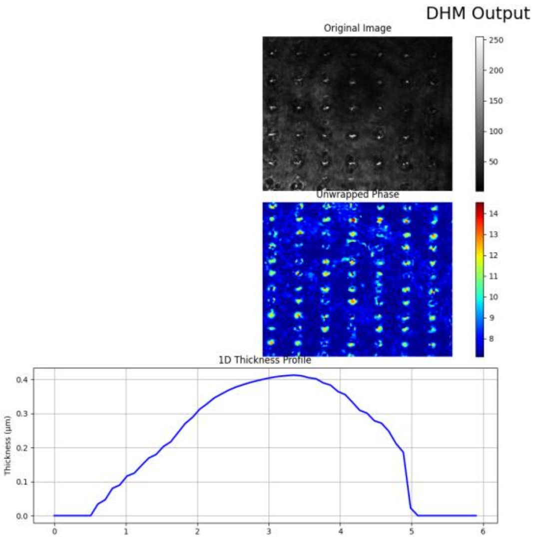




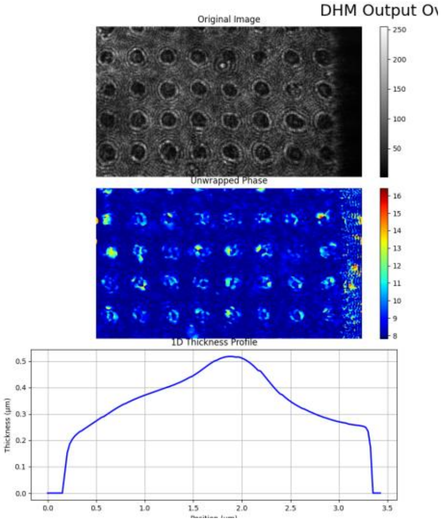


Deployment of the Sagnac Setup: Results

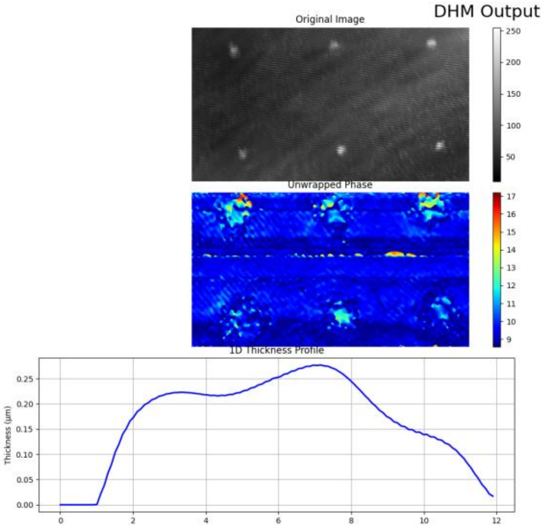
Prism Setup



Grating setup – without pinhole



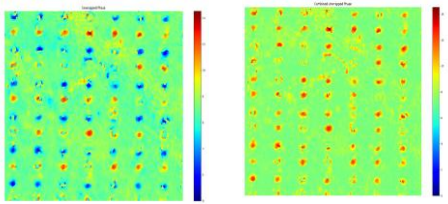
Grating setup – with pinhole



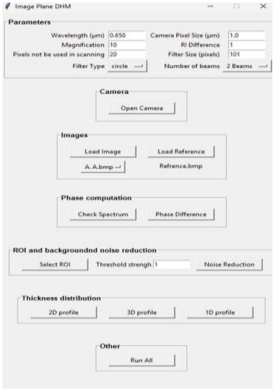
Software Enhancement: Enhancing current software architecture

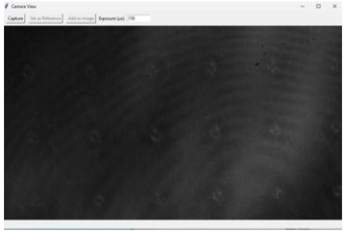
Phase 1: Reverse Engineering and Code Refactoring

- Camera Integration



- Solved Self-referencing Problem





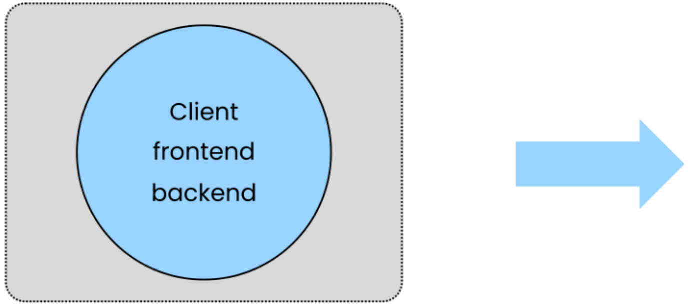
Phase 2: Hardware Migration

FPGA

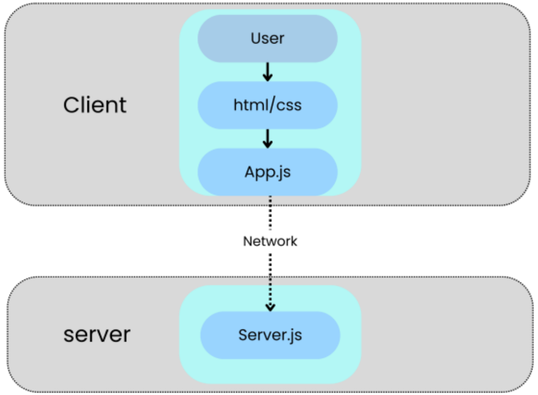
RasberryPi5

Software Enhancement : Architecture Transformation
Phase 3: Remote setup

1-tier local architecture



2-tier remote architecture

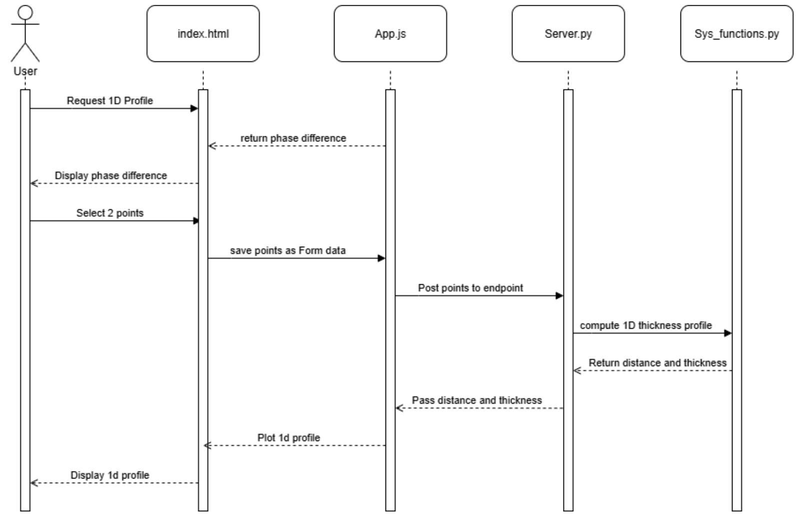


- Simple interface with limited scale
- Complex for development and maintenance

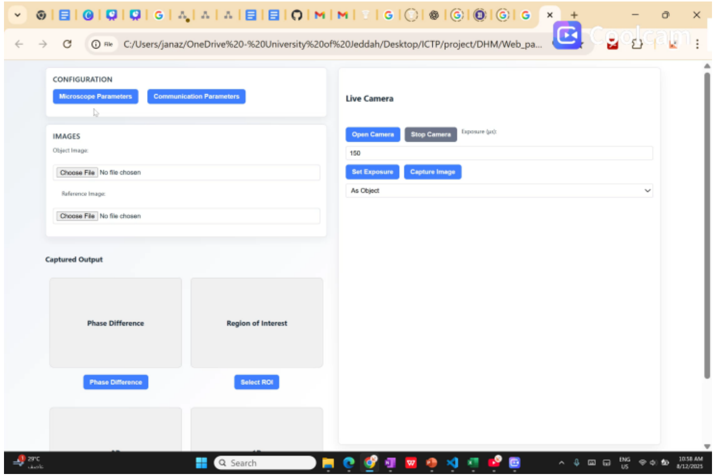
- Light weight on the RP5
- Less Dependencies
- Scalable

Software Enhancement : Architecture Transformation
Phase 3: Remote setup

Sequence Diagram of 1D Profile Plot



UI of Enhanced System Software



Software Enhancement : Architecture Transformation
Phase 4: Noise Reduction

Noise Reduction

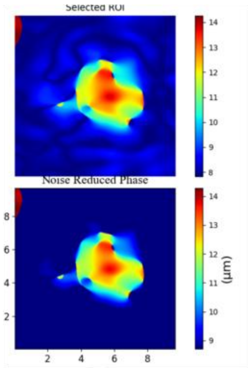
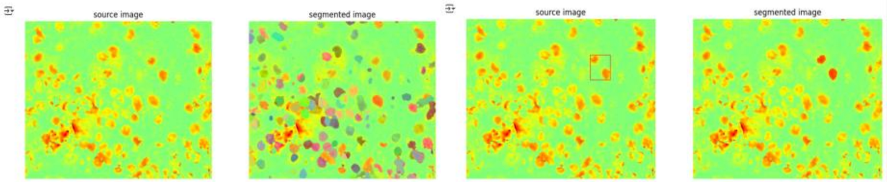
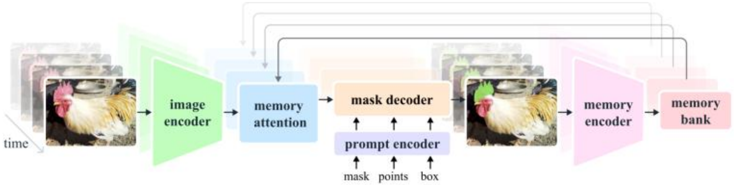


Image Segmentation





Mean-level Thresholding

- Same threshold is applied to the whole image
- Can distort small details
- Not noise-model aware

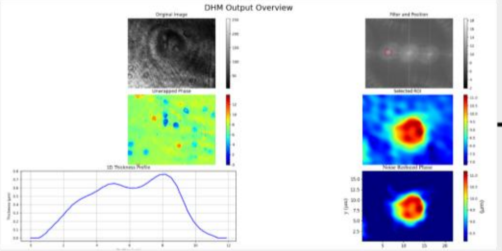
SAM Pretrained Model

- Preserves sample details
- Modular

Software Enhancement : Architecture Transformation
Phase 5: AI Classification Algorithm

- received dataset of features of normal cells
- Consultation with hematology specialist

Dataset Collection



Architecture Selection

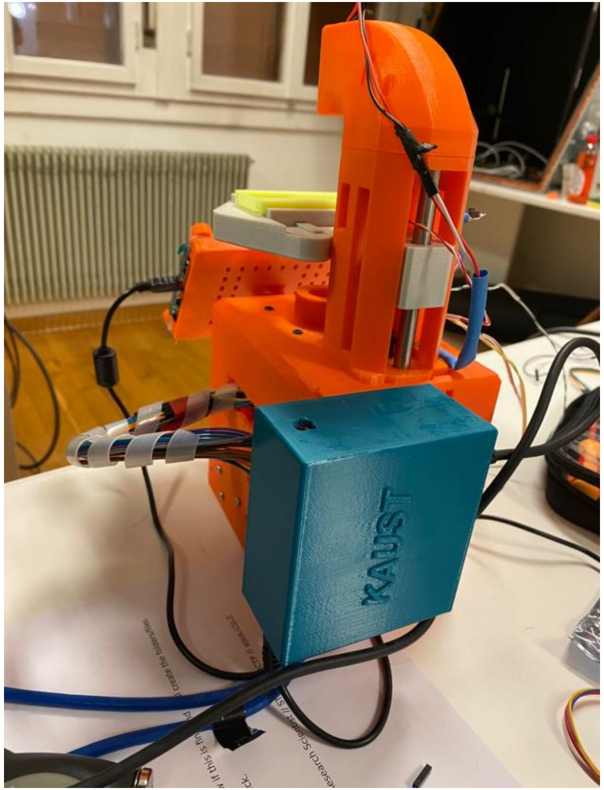
Classification

Architecture	Input Type	Use Case
Random Forest / SVM / XGBoost	Feature vector (morphology, phase thickness)	Fast prototyping, small datasets
ResNet18 / ResNet34	2D grayscale phase/intensity image (128×128, 224×224)	Medium data, transfer learning
MobileNetV2	Grayscale image	Deployment on Raspberry Pi or Jetson Nano
EfficientNet-B0	EfficientNet-B0 Phase/intensity images	Better performance on smaller datasets
2- or 3-layer CNN (manual)	1 or 2 channels (phase + intensity)	Specific to Holograms
ViT / Swin Transformer	Phase/intensity images	Very large dataset, high-performance scenarios

Future Work

- explored application of DHM in classification of Thalassemia and Iron deficiency
- Conduct more testing on sagnac setup to improve results
- Integrate AI segmentation into the same pipeline
- UI enhancements: outputs in higher resolution

Multi-axis Microscope Control and Hardware Setup



Controlling Motors

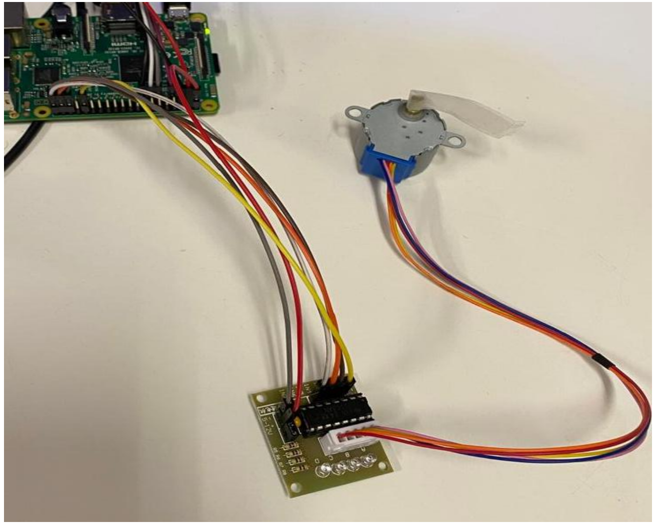
- A motor driver is a circuit that allows low-power devices like microcontrollers boards to control motors.

- It enables directional movement and speed control by acting as an interface between logic-level signals and high-power motor currents.

- In this project, the drivers control stepper motors, which move in precise steps — ideal for accurate positioning.

Motor Setup

- Raspberry Pi 3: control unit for sending logic signals
- Stepper Motors (28BYJ-48)
- ULN2003 Driver Boards: Interface between Pi and motors



Motor Control Software

- Successfully developed a C-based stepper motor driver

- Built a command-line interface to control motors in real-time

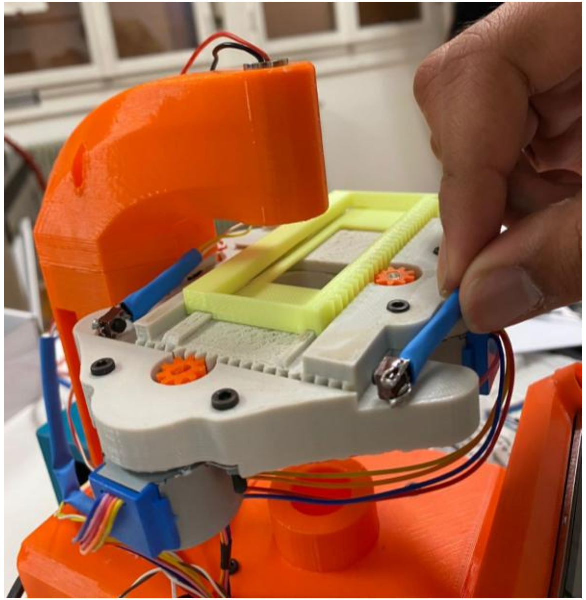
- Implemented directional control, step count, and latency/frequency settings

```
• ./stepper <motor> <steps> <latency> <direction>
```

```
./test 1 512 1 0
```

Touchdown Detection System

- Used Start Contact (SC) and End Contact (EC) switches as position sensors
- Run motor until EC is activated (motor at endpoint)
- Finally, return the number of steps taken for reference or debugging



Digital Encoder and Emegency Abortion Systems

- Developed a system that reads the current position of the sample
- Activated a kill switch or that cuts power to stop motor movement
- Prevents mechanical damage and ensures safety

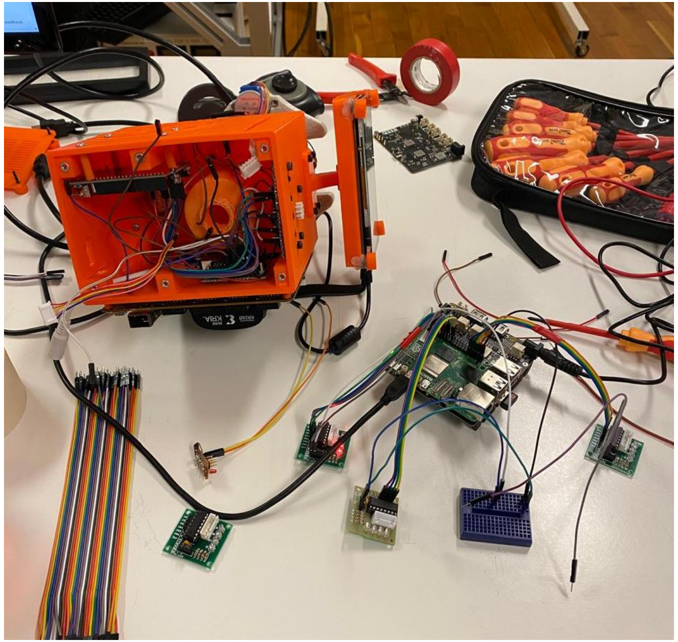
```
void setup_interruption_pins();
void kill_program();

volatile int kill_signal = 0;
```

```
void kill_program()
{
    kill_signal = 1;
    printf("aborting program ... \n");
}
```

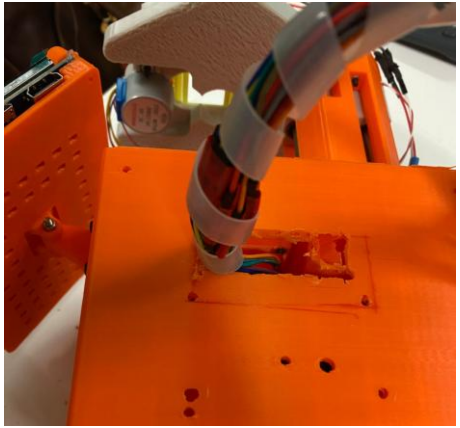
Hardware Challenges Faced

- Turning on/off the Raspberry Pi
- Raspberry Pi overheating
- Limited space inside the microscope
- Risk of wiring damage & short-circuit
- Microscope body design not adequate for our system



Wiring & Cabling Integration

- Used wire strainers and velcro straps for optimal wire protection and robust structure
- Sketched and drilled openings for optimal wiring
- Managed tight spaces in a complex assembly (after I completed my final assembly, thankfully, I never had to debug :)



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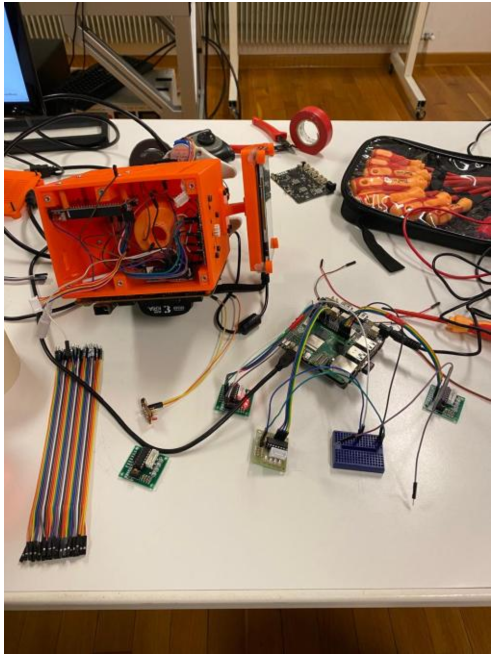
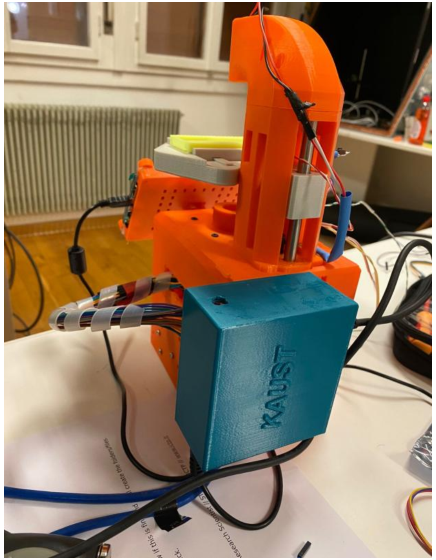
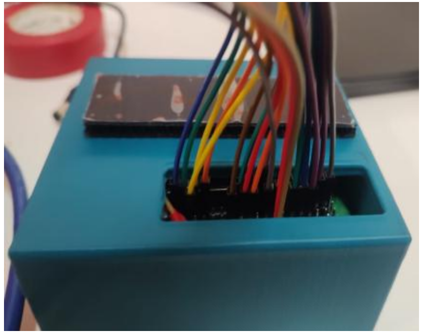
Before



After



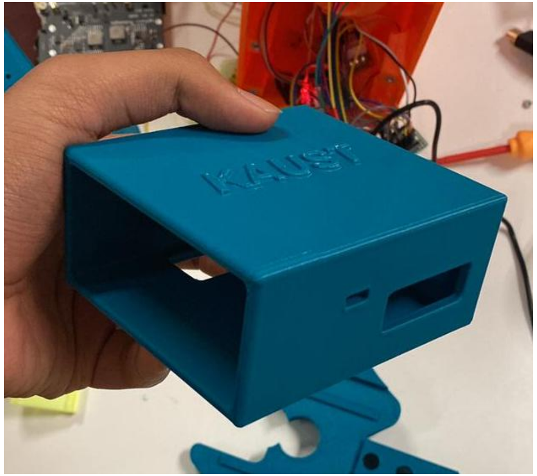


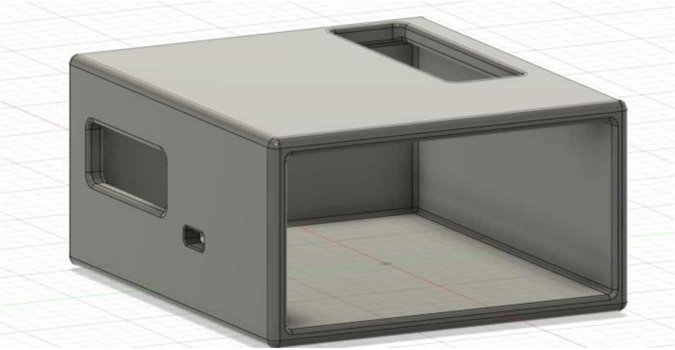
Raspberry Pi Casing

- Improves airflow & cooling to prevent overheating during long operations

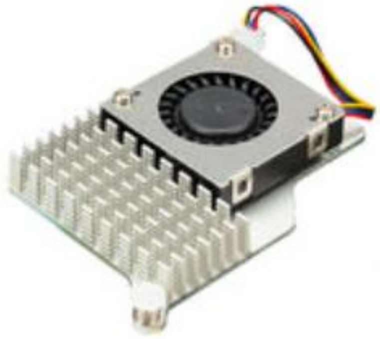
- Eases access to USB, HDMI, and GPIO ports without interfering with microscope workspace

- Organized cable routing for a cleaner, safer setup





Raspberry Pi Cooling System



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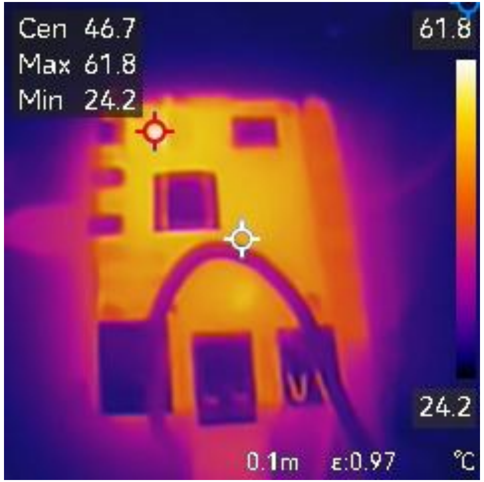

After

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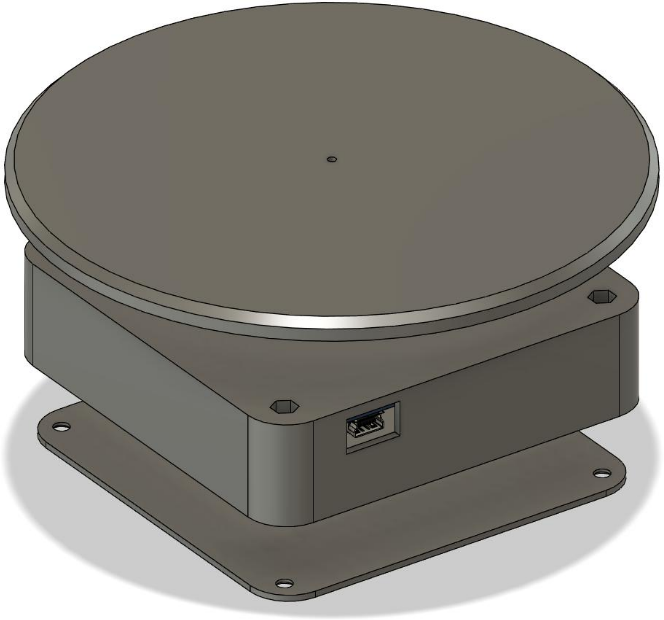
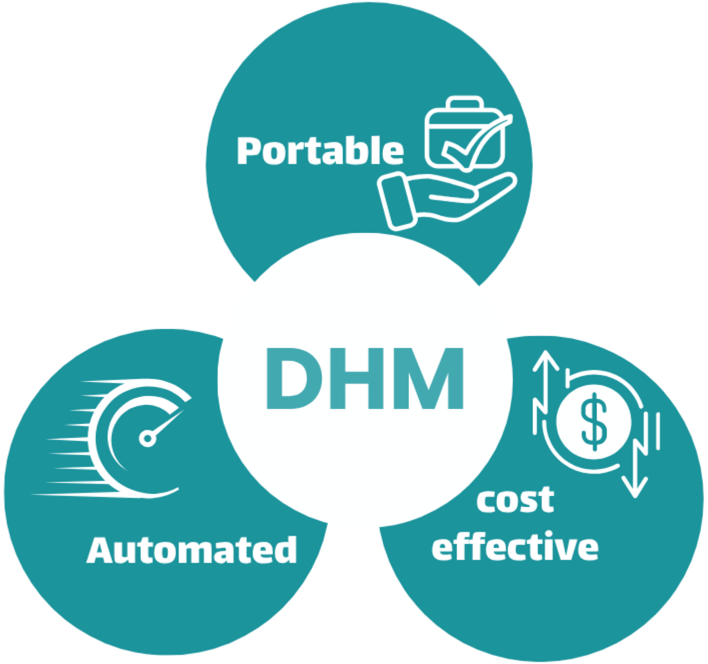
Side Project – Microtomographer Rotating Station



Conclusions



Thank you!

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