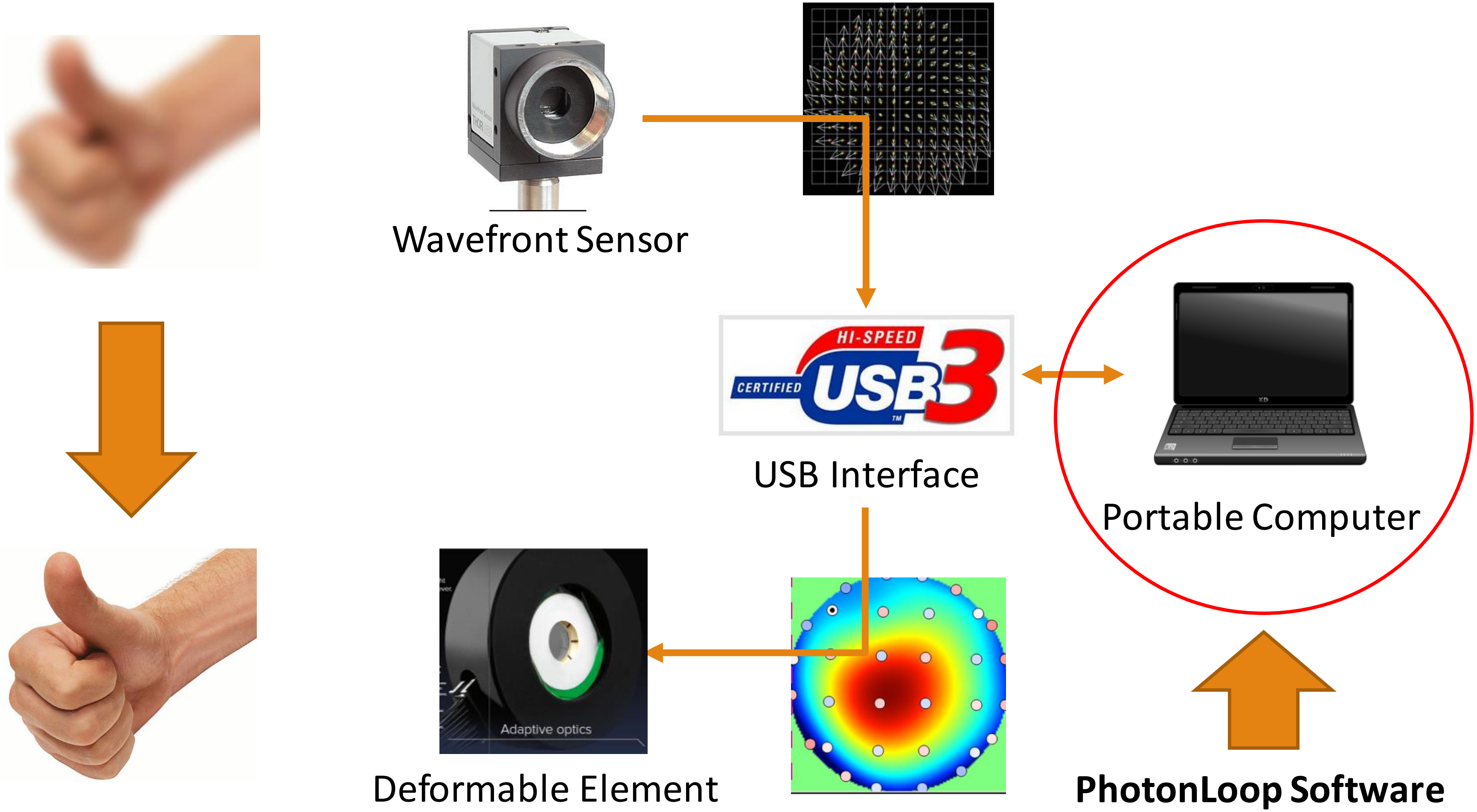
A flexible and user friendly CPU-based AO software

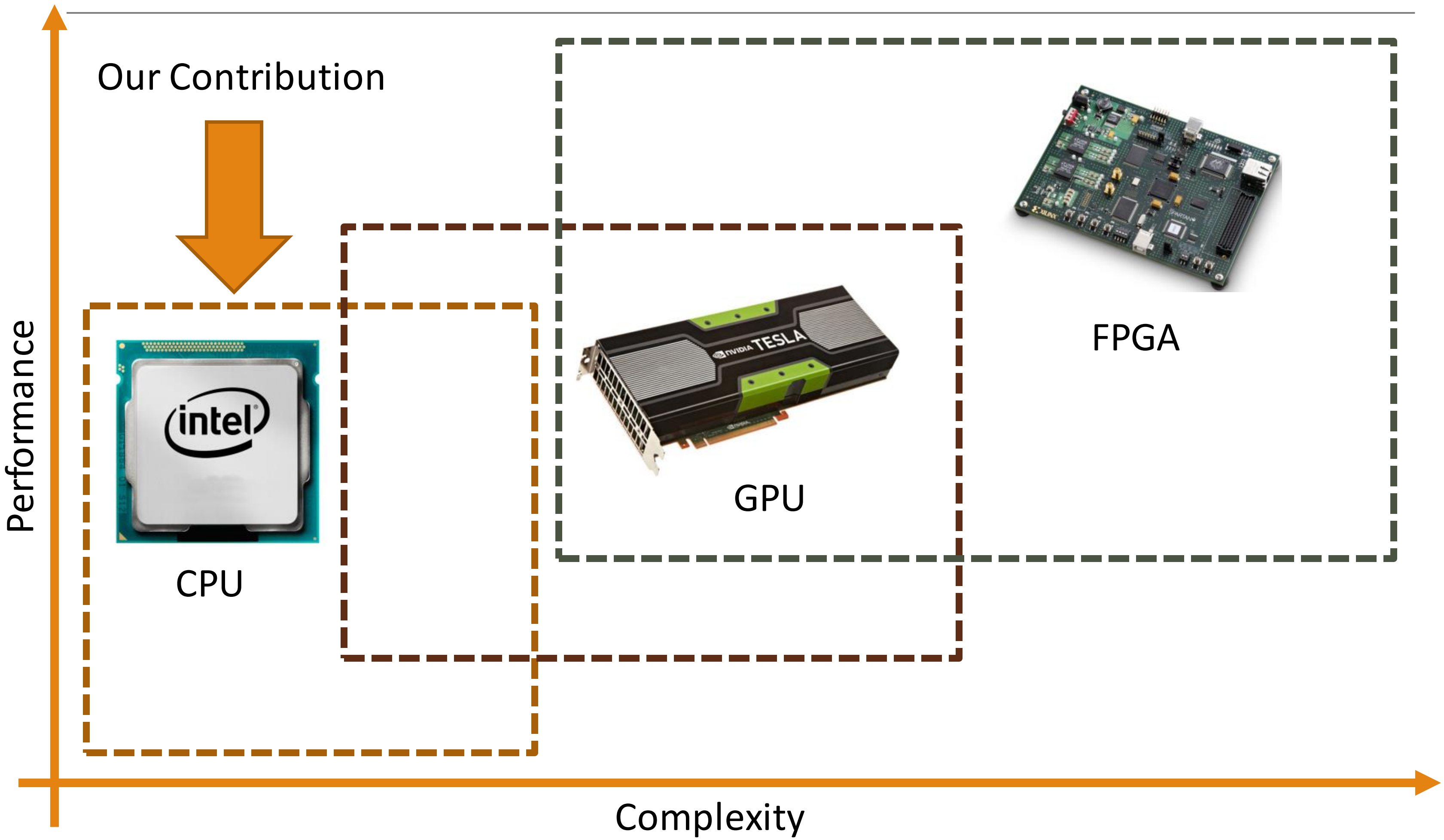
J. MOCCI, M. QUINTAVALLA, C. TRESTINO, S. BONORA AND R.MURADORE

UNIVERSITÀ DEGLI STUDI DI VERONA
CNR-IFN, PADOVA

Adaptive Optics – Basics



Adaptive Optics – Architecture



PhotonLoop – Introduction

PhotonLoop is a **flexible** and **user-friendly CPU-based Adaptive Optics** software.

Measures:

- **Zernike polynomials** and **wavefront shape** from wavefront slopes (using a Shack-Hartmann WFS).

Corrects:

- **closed-loop** and **open-loop** with PI control; **Hadamard** calibration; can apply **Zernike offset** to be generated by the controller.

PhotonLoop – Introduction

Flexible:

- **any size** of WFS aperture (any number of centroids); **any number** of DM actuators; fully scriptable.

User Friendly:

- **graphical representation** of all data structures; advanced tools for WFS and DM calibration; **real-time** performance monitors.

Fast:

- closed-loop frequency **up to 500Hz**; total closed-loop latency of 2-3 ms (**2 frames**).

PhotonLoop – Development

C++:

- guarantees **high performance** and promotes **Object-Oriented Programming (OOP).**

Qt Framework:

- **cross-platform** utility libraries for GUI and OS-dependent operations**.**

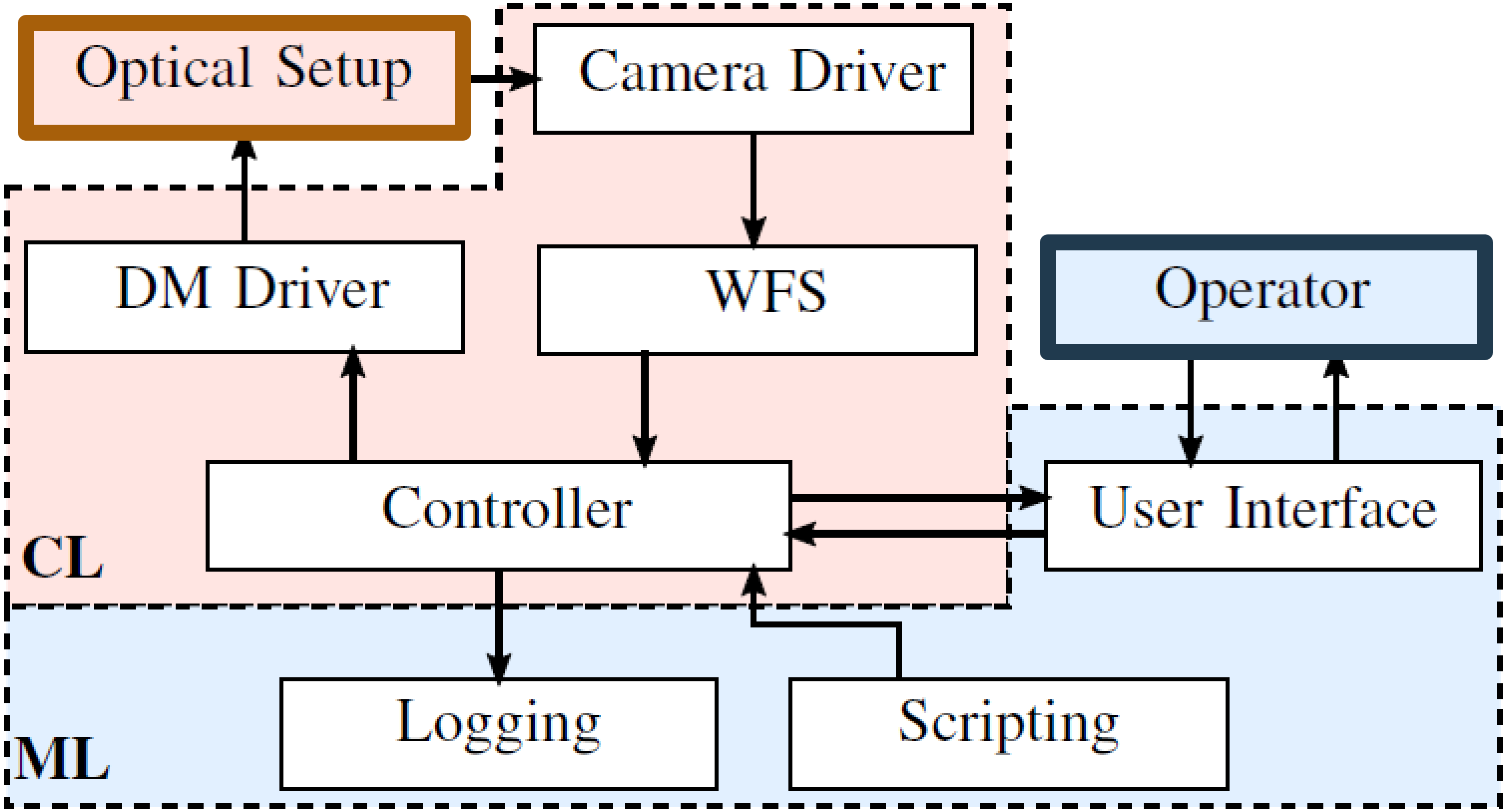
Eigen:

- **efficient** vector and matrix operations.

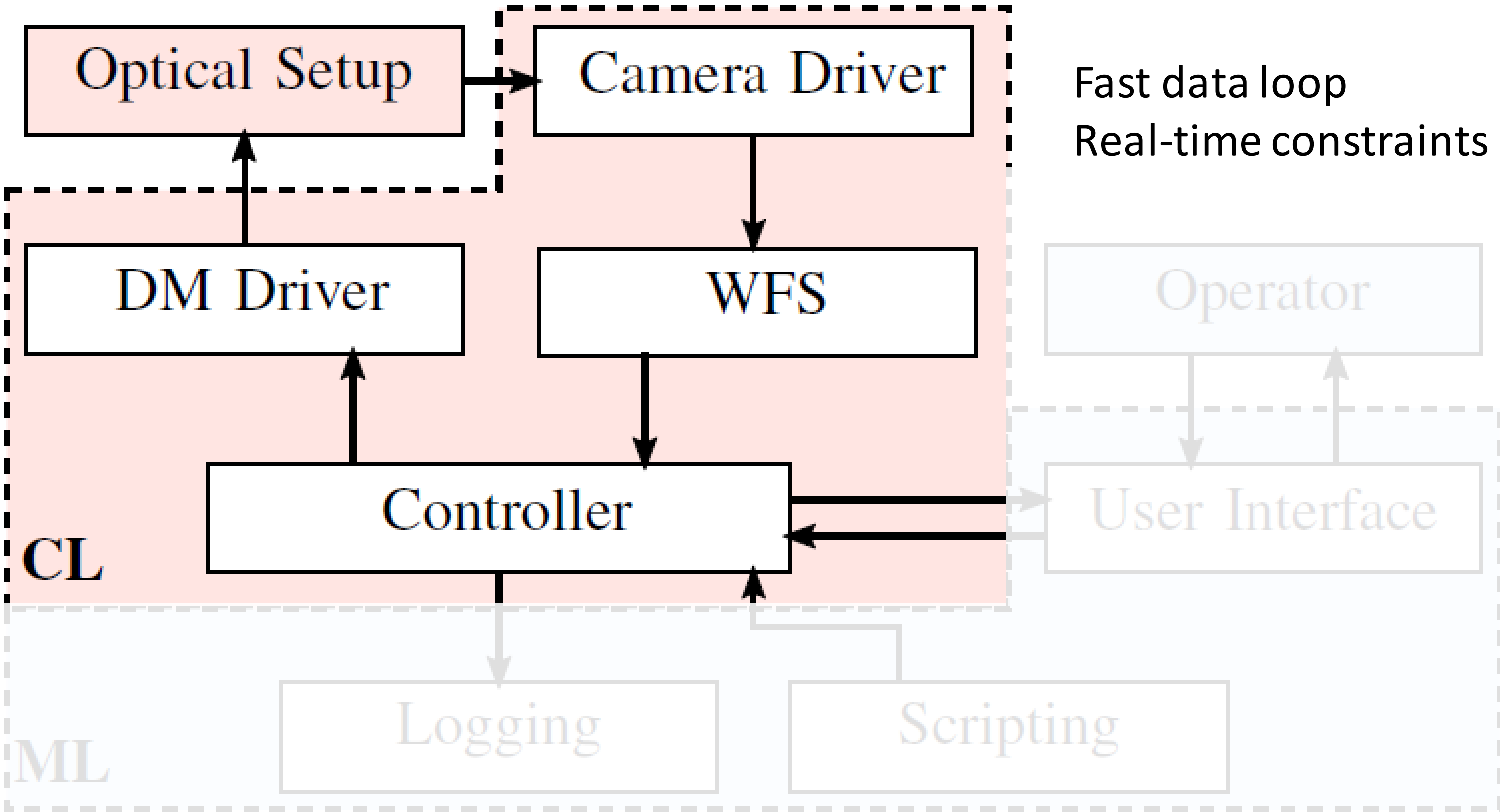
C++

The Qt Company

PhotonLoop – Architecture



PhotonLoop – Control Layer



Fast data loop
Real-time constraints

PhotonLoop – WFS

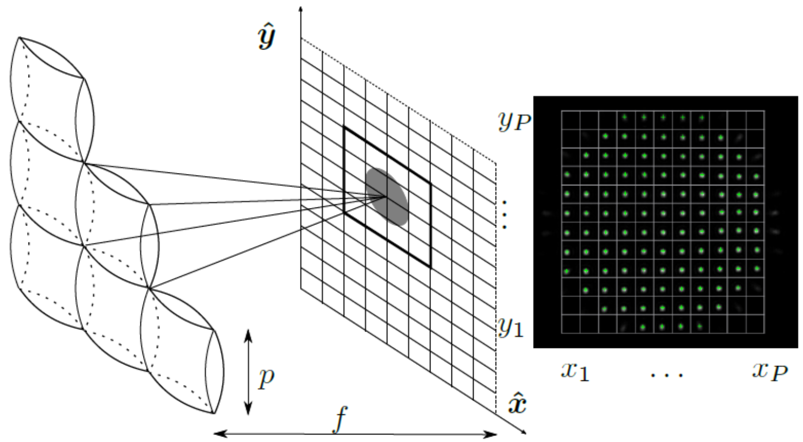
Fast centroiding algorithm:

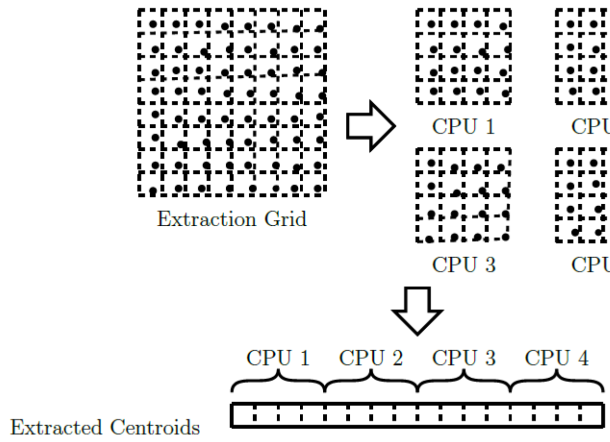
- Uses Thresholded Weighted Center of Gravity.

Operation on **integers** for speed.

Parallellized:

- independent centroids are offloaded to the single CPU cores





PhotonLoop – WFS

Reference

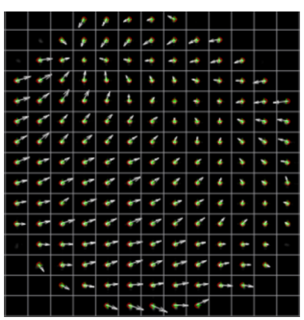
- Can remove **global tilt**; can be set **relative** to centroids.

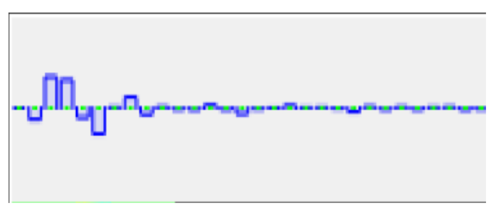
Zernike

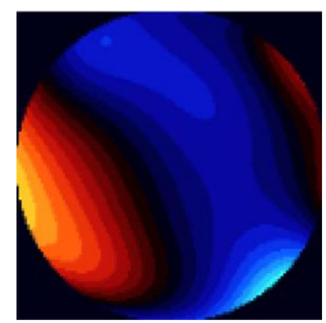
- Decompose the **wavefront slopes** to any number of **Zernike terms** with least-squares methods.

Reconstruction

- Uses **modal reconstructions** from Zernike terms







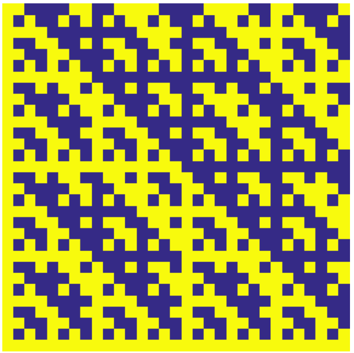
PhotonLoop – Controller

Calibration:

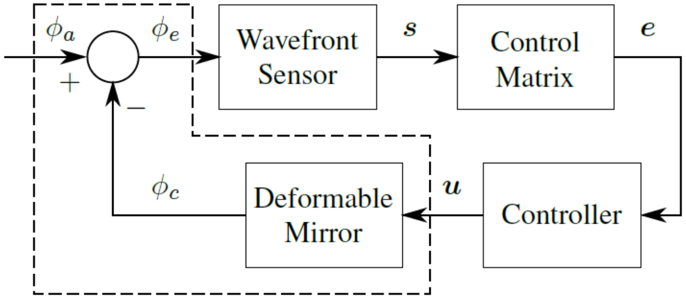
- DM is calibrated with **Influence Functions** or **Hadamard patterns**
- the interaction matrix is processed with **SVD decomposition**

Closed Loop:

- parallel array of **PI compensators** with **anti wind-up** to avoid actuators saturation

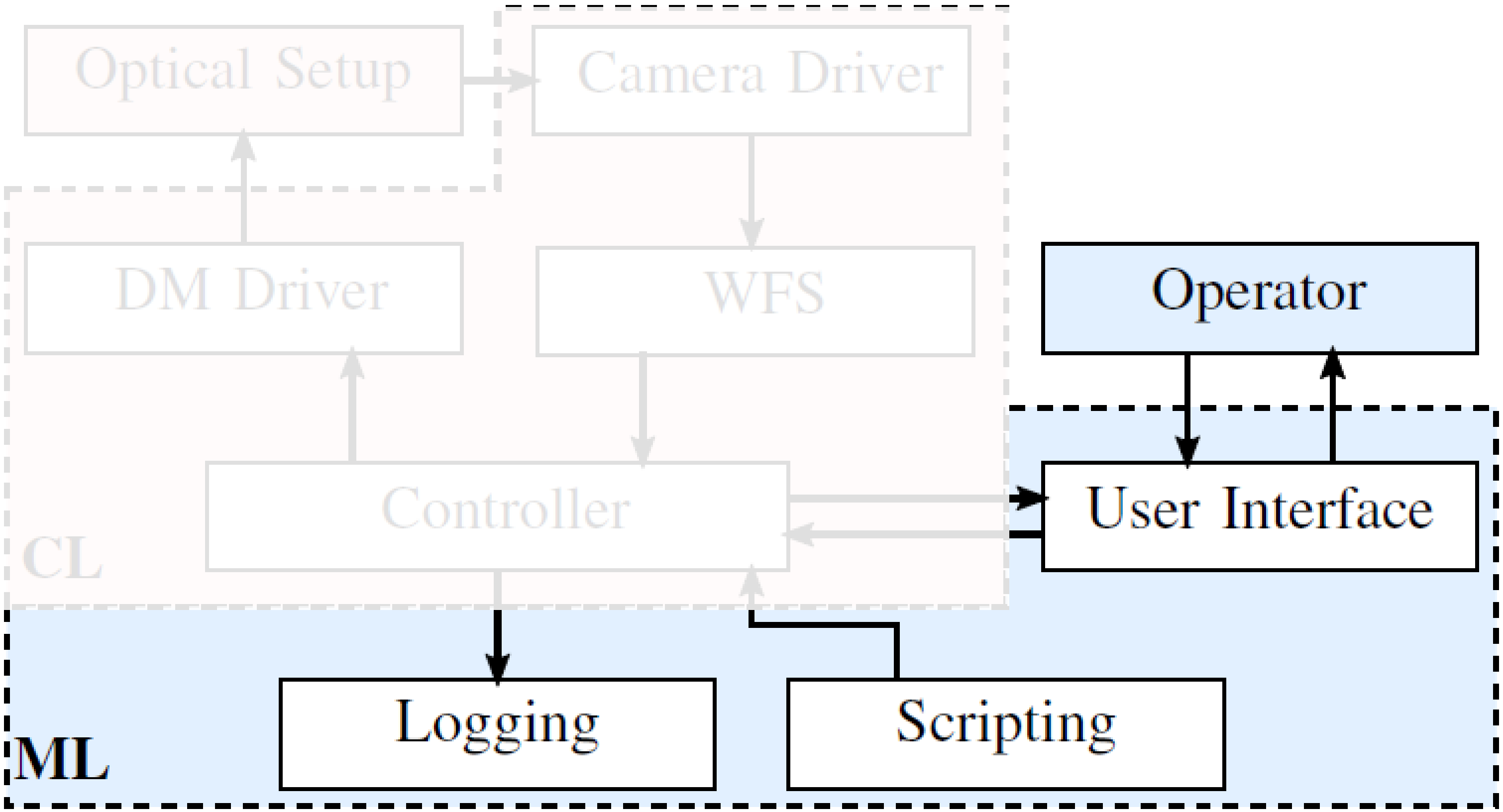


Hadamard Matrix

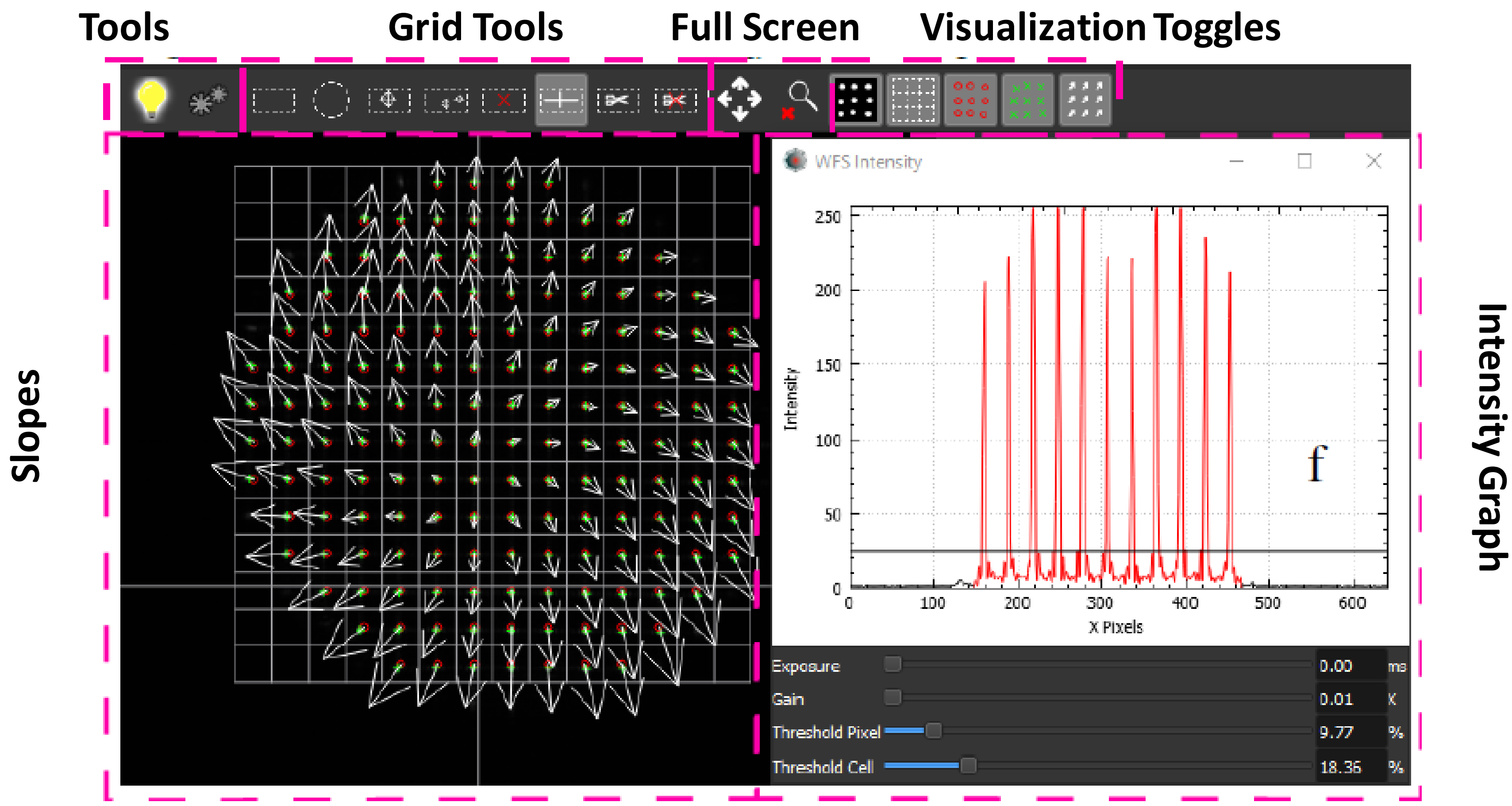


Controlled Plant Scheme

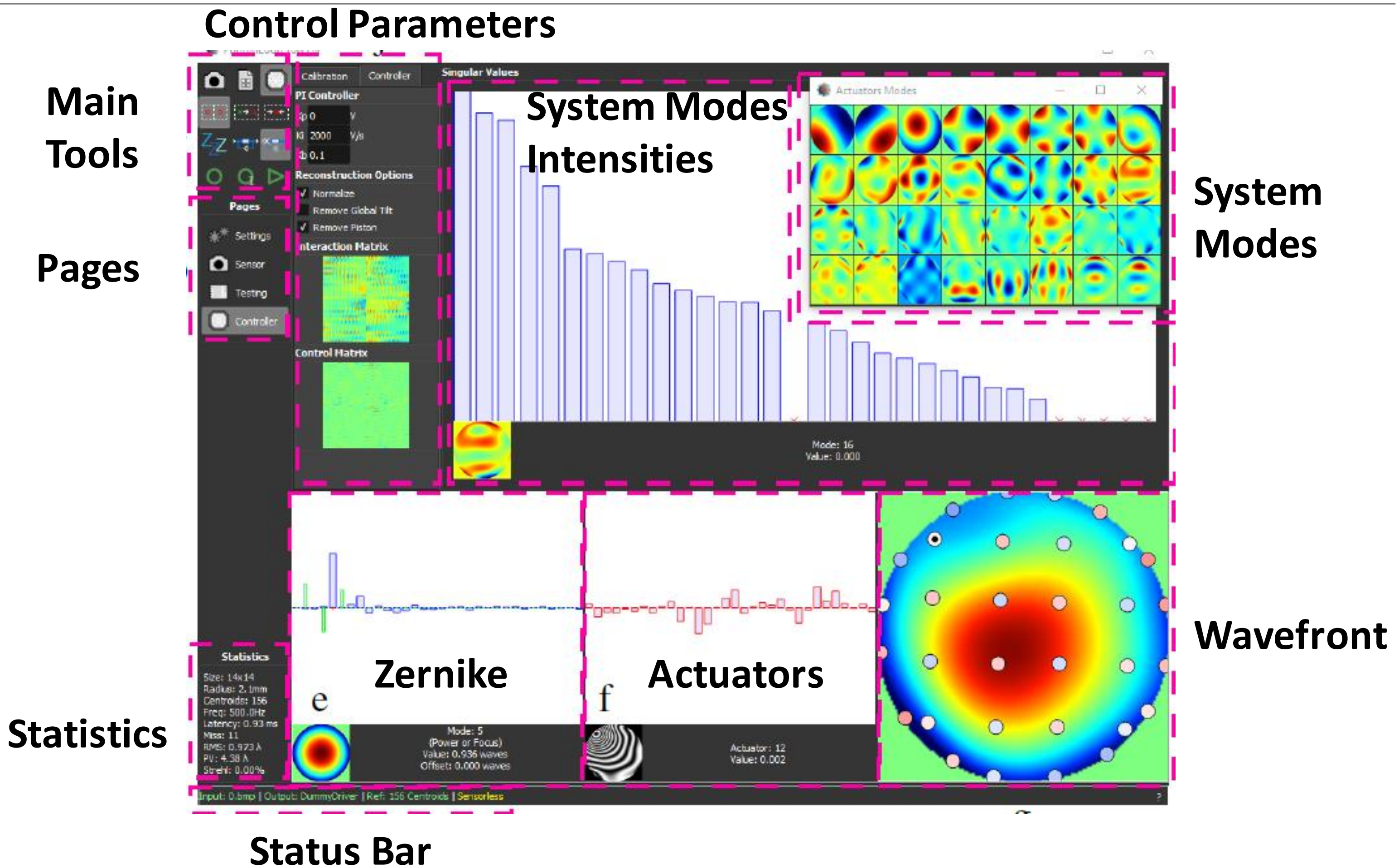
PhotonLoop – Monitor Layer



PhotonLoop – User Interface



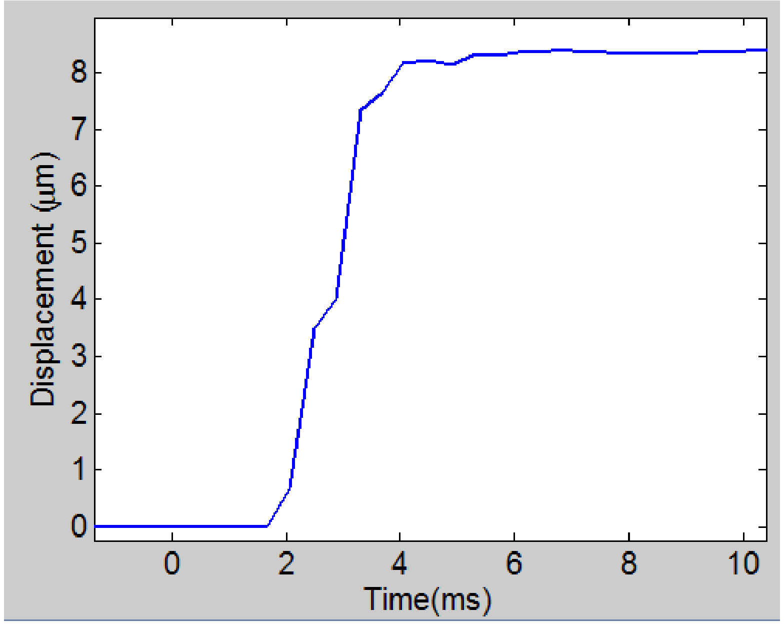
PhotonLoop – User Interface



PhotonLoop – Logging

Logging

- Flexible log engine to record **time series** of the internal **data**
- Can be saved to disk as **contiguous** or **segmented sessions**

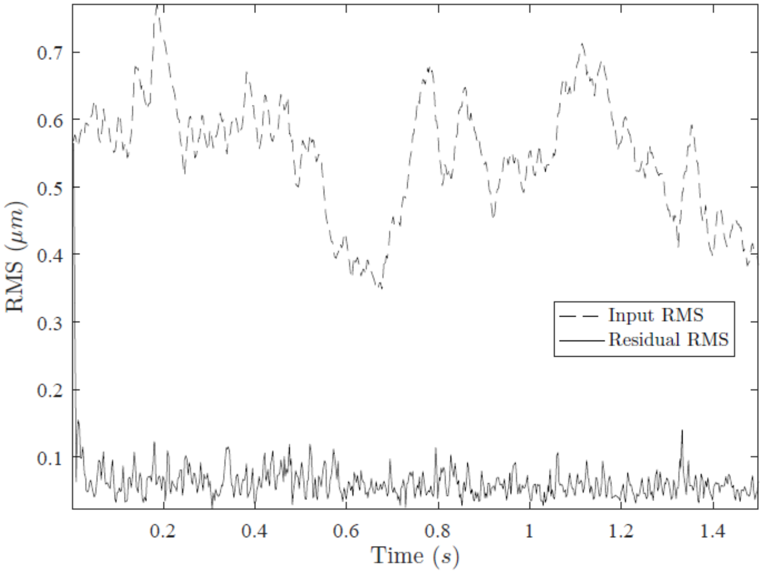


Actuator Rise Time @ 2.5kHz

PhotonLoop – Playback

Playback

- Recorded time series can be **given as input** for testing purposes
- Especially useful when **testing correction performance** amongst devices with **fair comparison**



Correction of a pre-recorded Zernike time series

PhotonLoop – Scripting

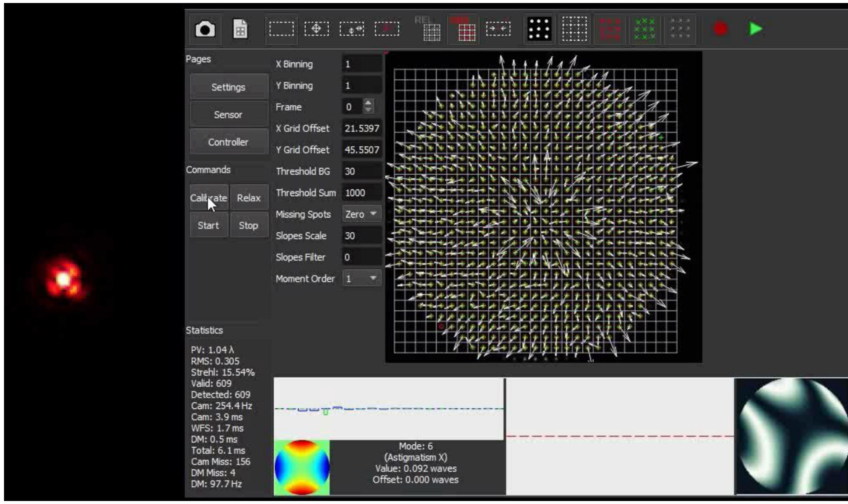
Scripting

- PhotonLoop can be **commanded** by **Javascript files**
- Can connect to **Matlab** or other softwares by **TCP-IP communication**

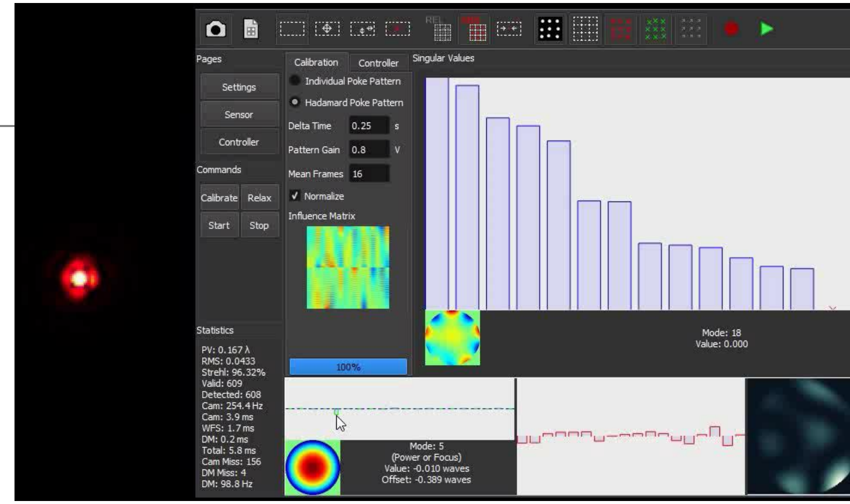
```
title = "Udiny";
description = "1hr long experiment";

logIterations = 3;
logTime = 1;
logPause = 2;

sc.initLogSession();
sc.initLog(title, description);

for (i=0; i<logIterations; i++)
{
	sc.playSound("ping")
	sc.startLog();
	sc.pause(logTime);

	sc.playSound("okay");
	sc.pauseLog();
	sc.pause(logPause);
}

sc.stopLog();
```

Sample Javascript File

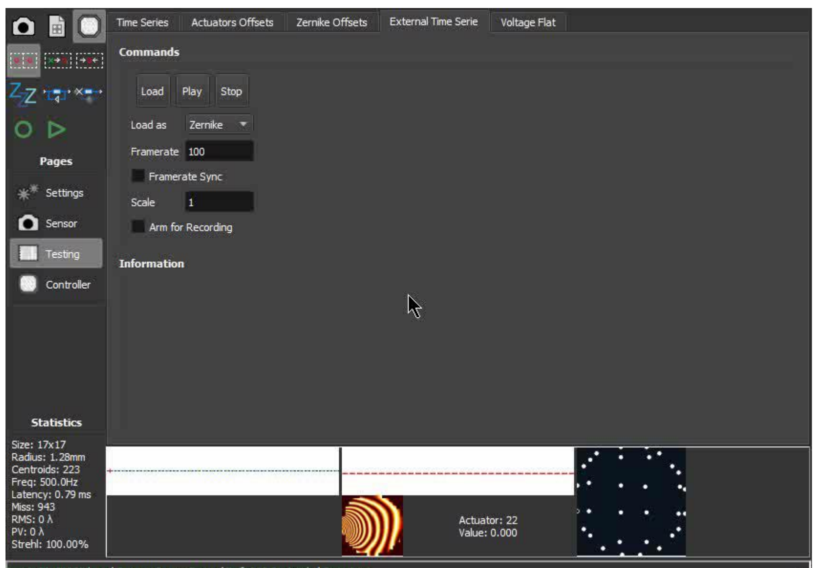
PhotonLoop – Demonstration



Hadamard Calibration



Zernike Generation



Aberration Playback and Correction

Conclusion

We have presented an **AO software controller** which is

- **Fast:** limited by WFS FPS; **500Hz**; **2 frames** closed-loop latency
- **Flexible:** record, playback and script engines
- **Friendly:** responsive GUI with plenty of **calibration tools**

We tested it in **real world optical setups**

- Atmospheric turbulence eval (MBDA, La Spezia)
- High power laser (Udyni, Politecnico di Milano)
- Deformable Mirror/Lens comparison framework (CNR-IFN, Padova)