Development of a high-speed diagnostics package for the 0.2 J, 20 fs, 1 kHz repetition rate laser at ELI Beamlines

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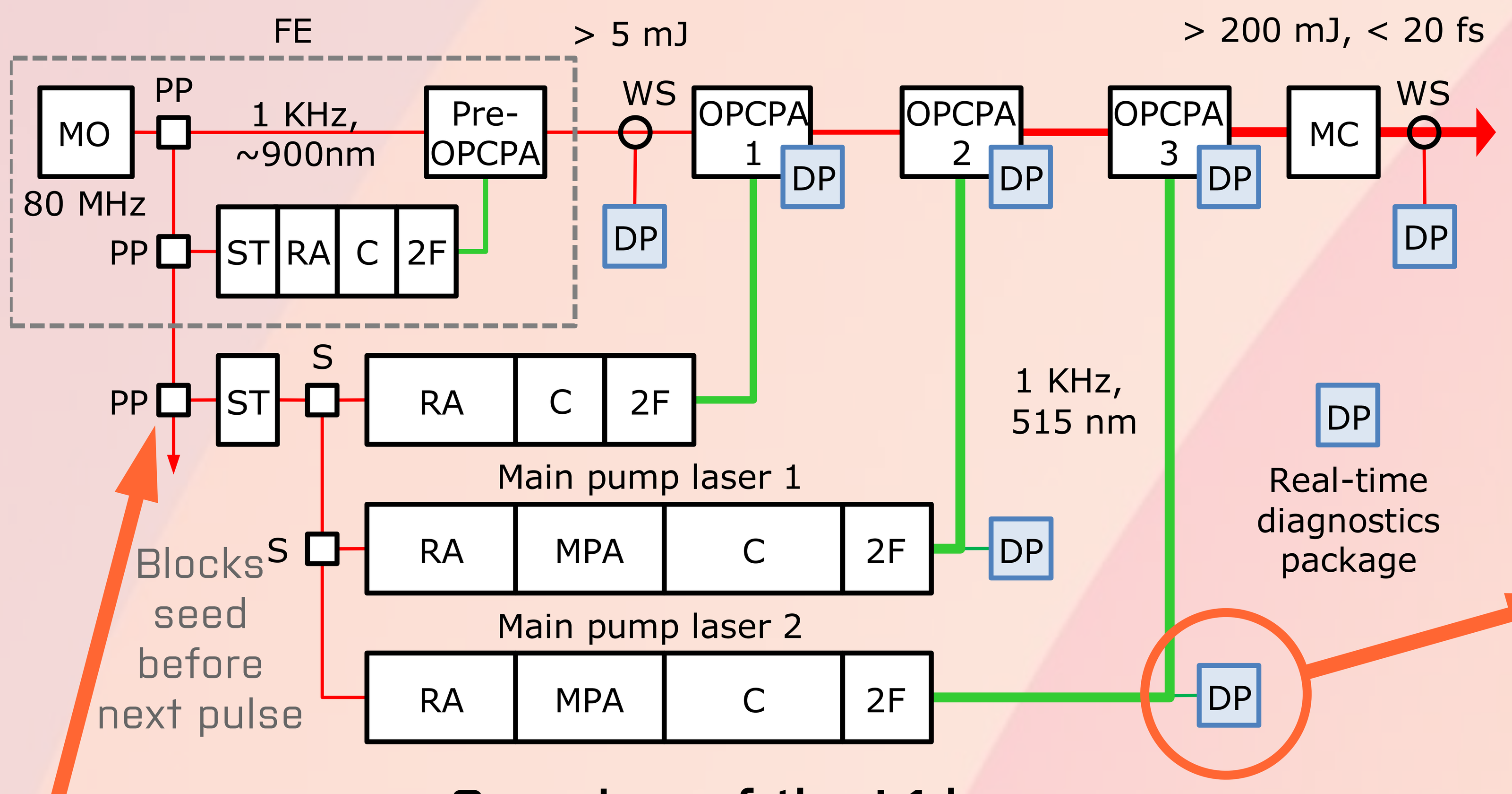
Introduction

ELI Beamlines will provide a **user-dedicated facility** housing four high repetition rate **TW-PW femtosecond lasers**. Experiments based on X-ray generation, plasma research and particle acceleration will target the molecular, biomedical and materials sciences.

L1 is the **highest repetition rate (1 kHz)** and the lowest energy at 0.2 J (~2 TW peak power). It is also the **cheapest laser (7 M€)** so is scalable for universities and smaller facilities.



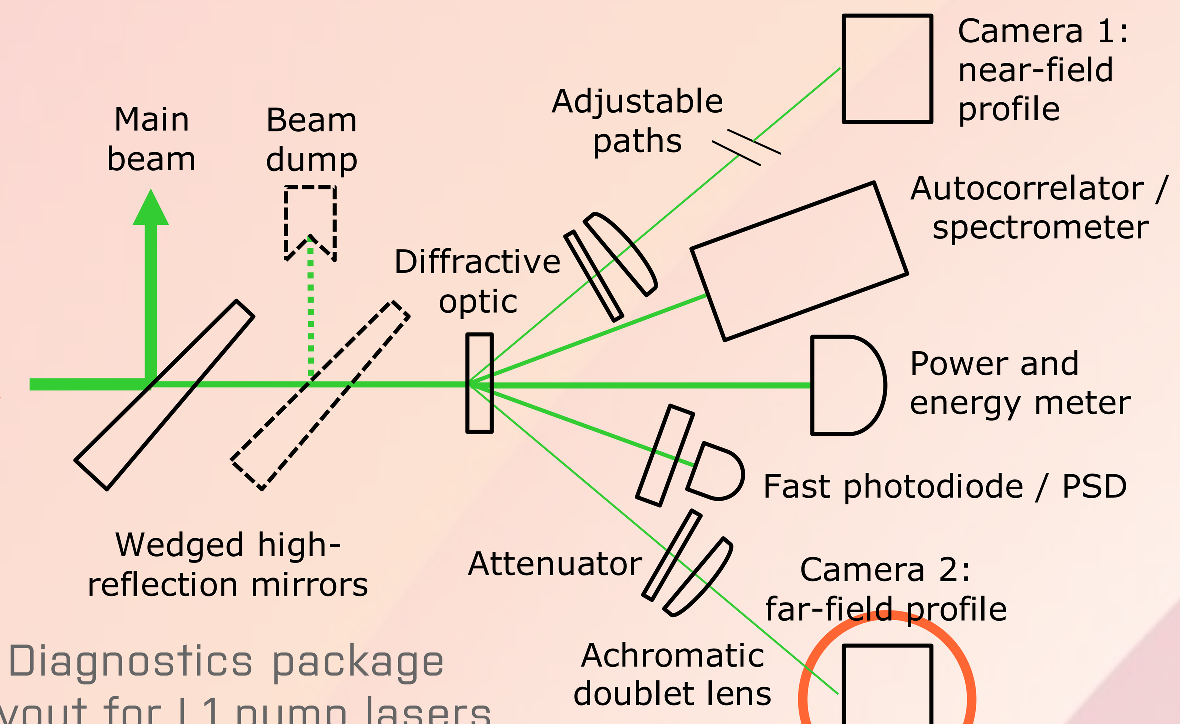
Overview of the L1 laser

PIN diode interlock switch

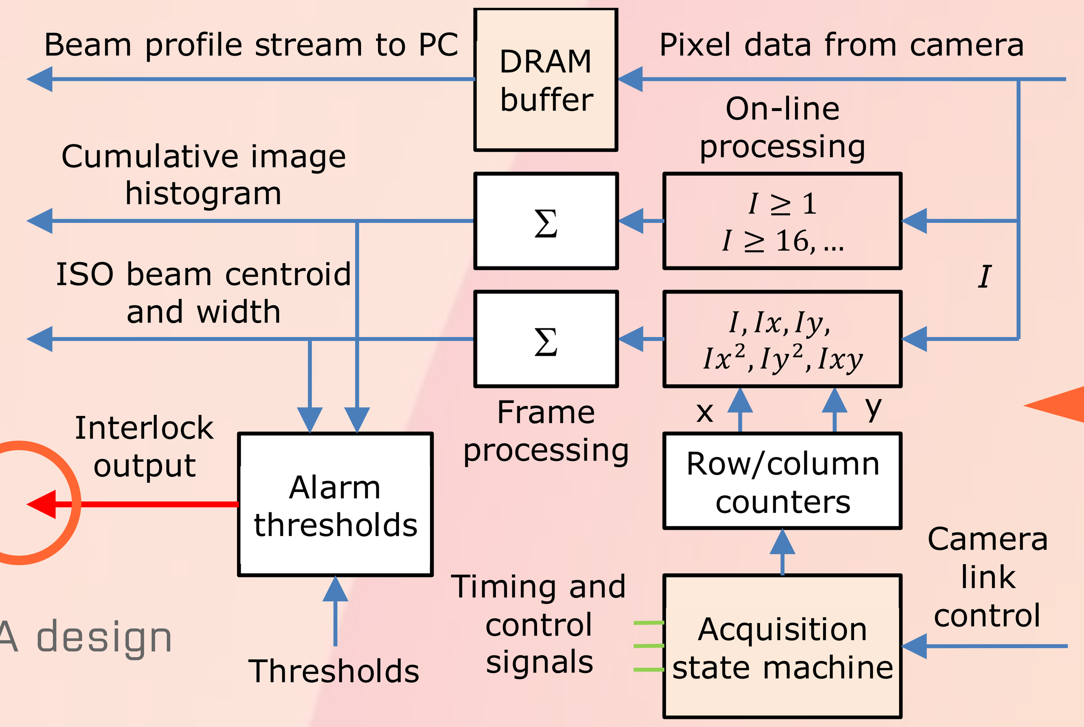
Diagnostics package

A modular package was designed for the **L1 control system** to support the many **diagnostics at 1 kHz**, including: pulse energy and power; pulse contrast (ratio of pulse power to background); beam **centroid**, **width** and **spatial profile** as well as **aberrations** that might cause or signify damage to optical components.

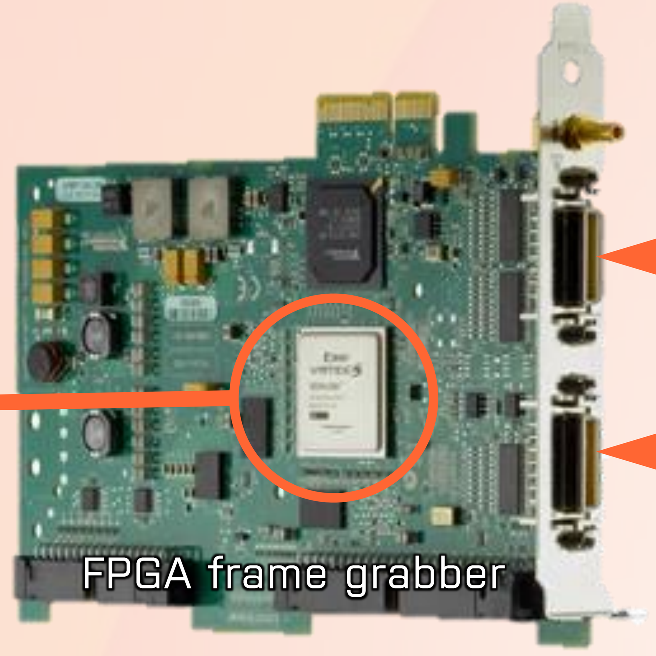
We present here our recent **developments in designing and testing** the components and systems to support these **real-time diagnostics**.

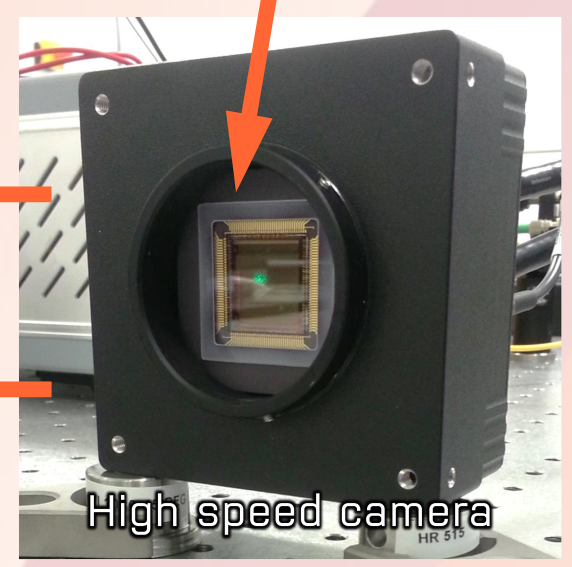


Diagnostics package layout for L1 pump lasers



FPGA design



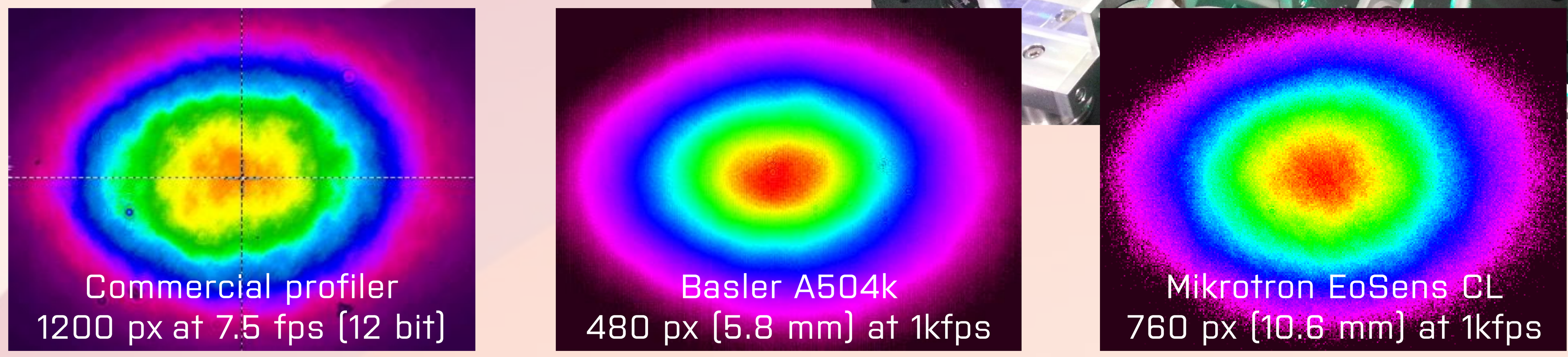


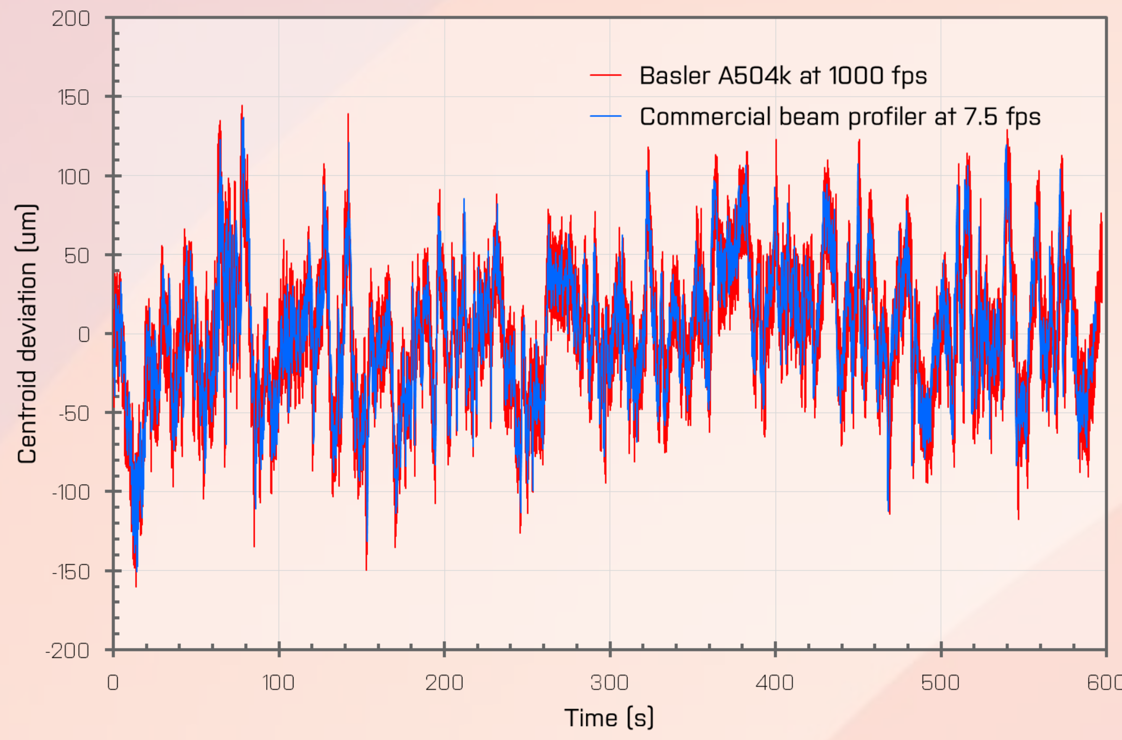
1000 fps camera evaluation

To measure beam spatial properties on an every-shot basis requires a camera capable of taking **1000 frames per second at high resolution.**

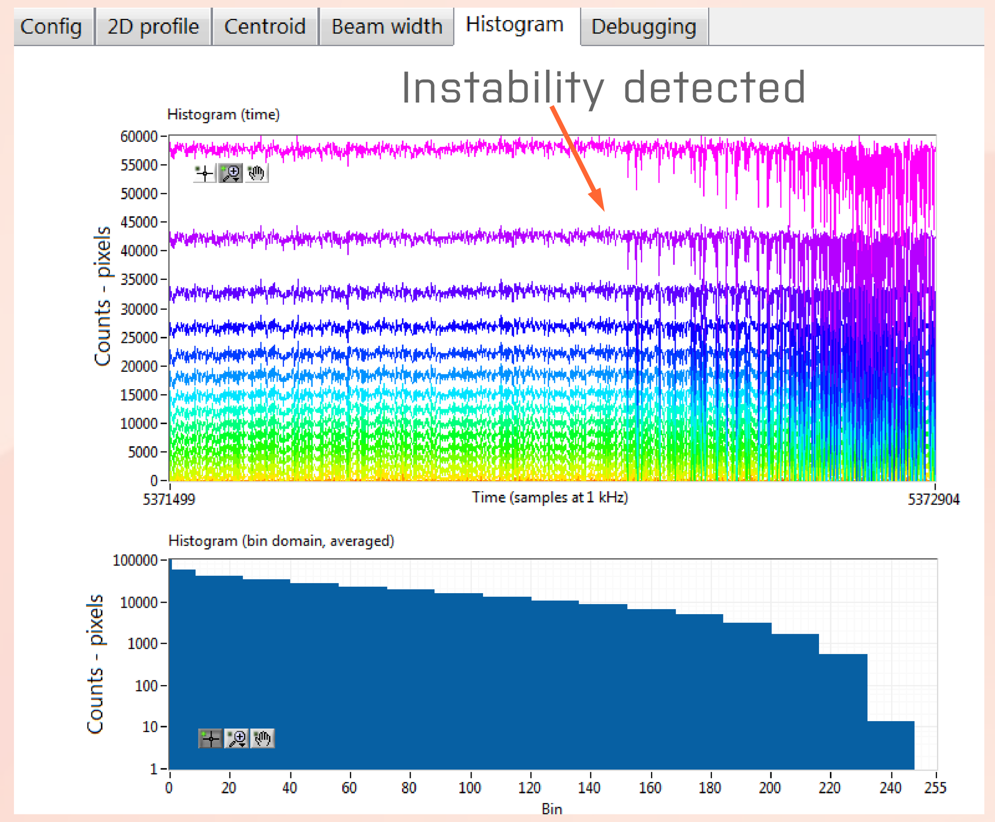
A prototype testing platform was built to evaluated different high-speed cameras. It is based on an NI **FPGA-based frame grabber** in an industrial PC platform with **real-time OS**

The system was tested on the 10 mJ preamplifier pump laser in the far-field. Systematic **differences were seen between cameras**. Further testing and error analysis is therefore required.





Measurements of beam centroid are precise and consistent. At 1 kHz this information can also be used for pointing stabilisation, eliminating the need for additional sensors



System front panel. Real-time histogram analysis gives early warning of amplifier instability that might be masked in measurements of pulse energy alone

Next-pulse interlock

Pulse energy and power are insufficient to diagnose subtle problems. Aberration indicators such as intensity distribution, change detection and spatial transforms, calculated from the beam profile, can be used to identify bright/dark spots, optical coating damage and amplifier instability. If an error is detected, **the next pulse from the L1 front-end is blocked**, giving the best possible chance of damage prevention. A fast switch stops any seed pulses reaching the amplifiers and prevents pulse emission. With the majority of the time taken up by the transfer of pixel data, **on-line and parallel processing** must be used to reach the **µs latencies required**.

FPGA design

For rapid development, **LabVIEW FPGA** was used. As well as real-time image streaming, **beam centroid and diameter** according to ISO 11146 are calculated, together with **a cumulative real-time pixel intensity histogram** that helps identify bright spots caused by optical crystal damage. 425 million multiply-accumulate operations per second are carried out on the pixel data using Xilinx DSP slices.

Conclusions

We have **introduced the diagnostics package for the L1 beamline**. A 1 kfps camera-based **beam profile analysis system has been built**. Beam centroid, width, profile and histogram data can be measured and collected in **real-time at 1 kHz**. The system can detect errors and operate a **next-pulse interlock system** to block seed pulses at the laser front-end within a 1 ms window.

Algorithms for **change detection** and **aberration indicators** will be developed in the near future. We will monitor developments in **high speed cameras** and test all cameras systematically to **address the sources of systematic error** found in profile imaging.

Fyzikální ústav
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