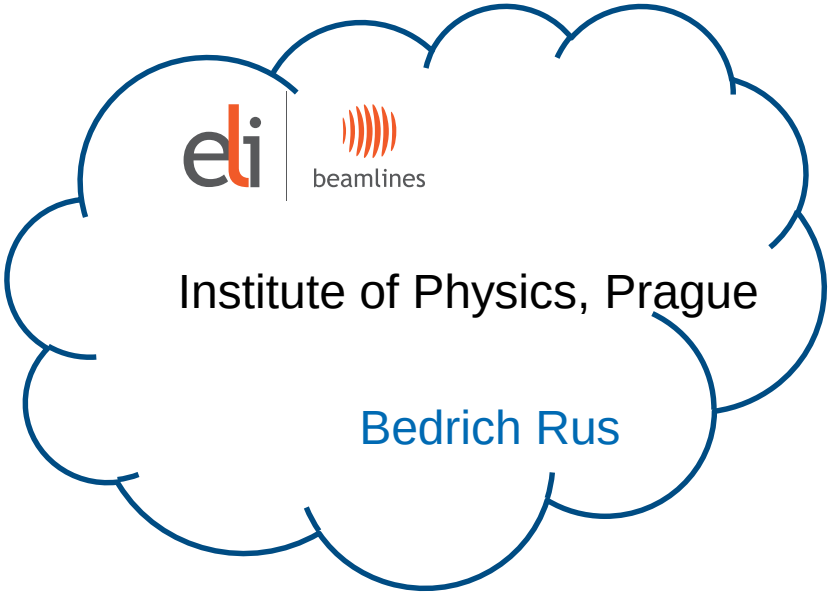
Development of Diagnostics for PW and multi-PW lasers

Jaroslav Moravec

FOTON, s.r.o.

Why ? What ? Who ?



- FOTON, s.r.o.
- ELI Beamlines
- PW diagnostics + Challenges

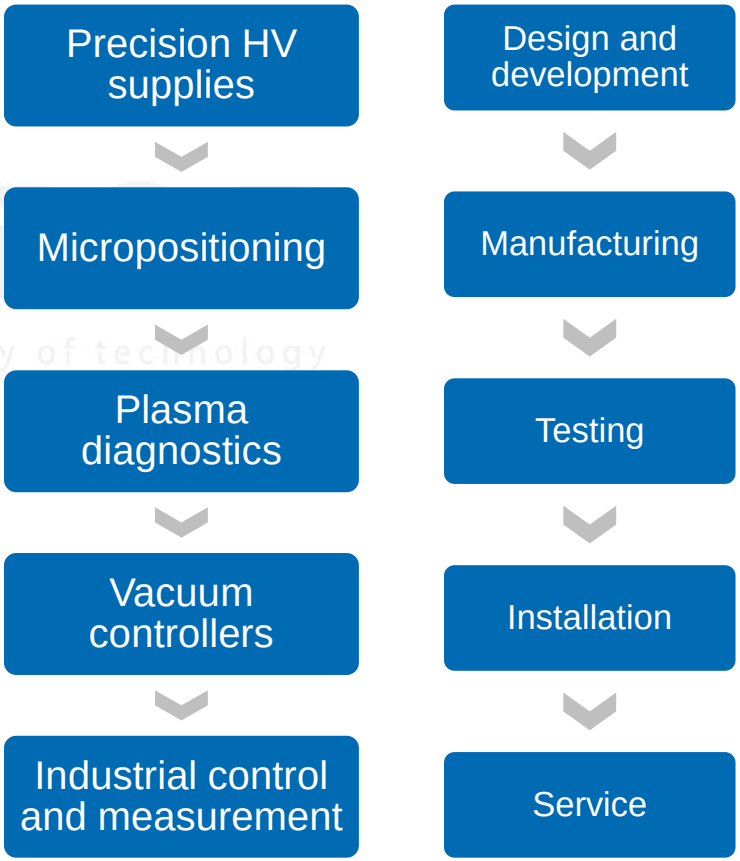
FOTON, s.r.o.

- ***founded 2000***
- ***Czech private company (LTD)***
- ***Development and manufacturing of special electronic devices***

- Studénka 1
  509 01 Nová Paka
  Czech Republic **www.fotons.cz**

„From system design to k delivery of final product …”

- ***Founded 2000***
- ***SME***
- ***PIC (FP7) : 968991880***
- ***Special innovative firm***
- ***R&D + manufacturing***



Complex services for R&D

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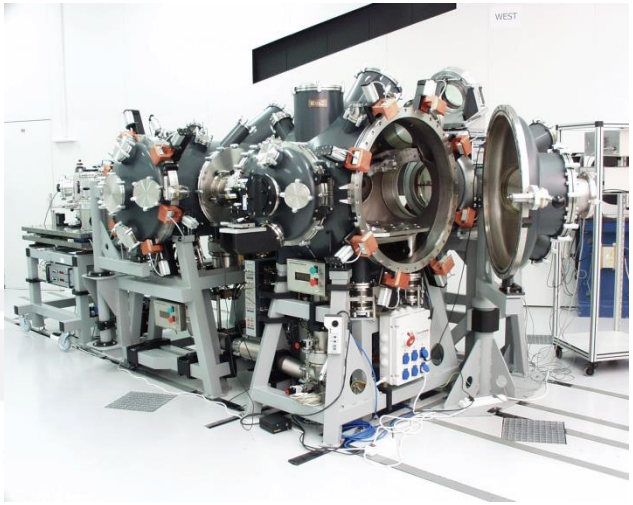
Company history

- ***2000*** *FOTON founded, instrumentation for PALS*
- ***2001*** *X-ray laser instrumentation*
- ***2002*** *diagnostics for tokamaks*
- *first high voltage supplies*
- *Multidrive16*
- *first exports*



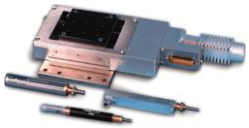
- ***2007*** *Škoda Auto a.s.*
- ***2008*** *Joint Institute of Nuclear Research, Dubna, RF*
- ***2010*** *ELI – vacuum system*
- ***2011*** *LA3NET (Liverpool)*

Products overview

More than 140 prototypes during 15 years

nA-100s A *uV-10s kV*
uW-kW *UV-IR*

High voltage supplies



Micropositioning

Optoelectronics

High temperature plasma diagnostics

Special systems

Vacuum controllers

Current and voltage power supplies

Industrial control systems

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High voltage power supplies

Low – middle – high power, voltage up to 20kV (60kV)

HVS 04

HV 8002

HVG 2000

HV 5000+

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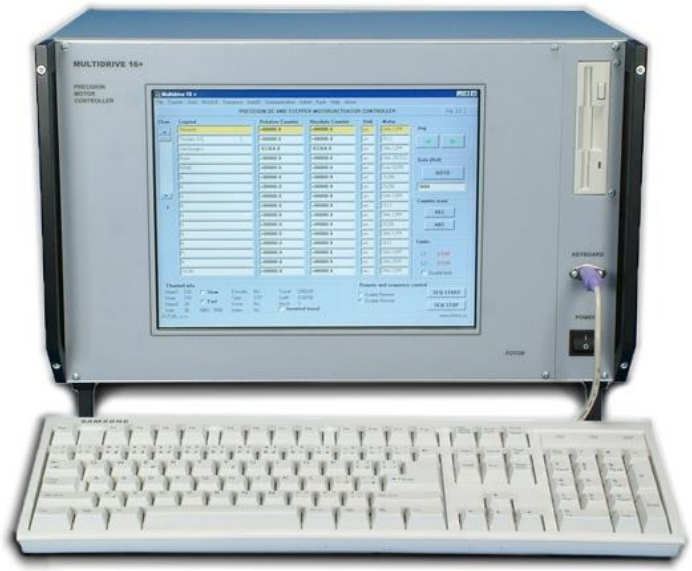
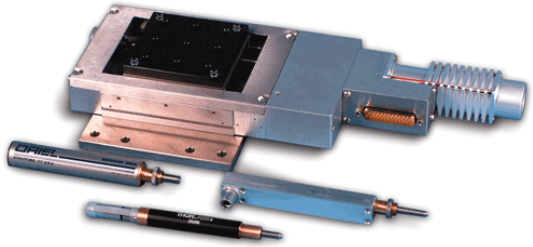
Micropositioning

System Multidrive 16+



Multidrive 16+



High temperature plasma diagnostics

Signal processing, generators and controllers for experiments

DLS 08

HPD 4.1

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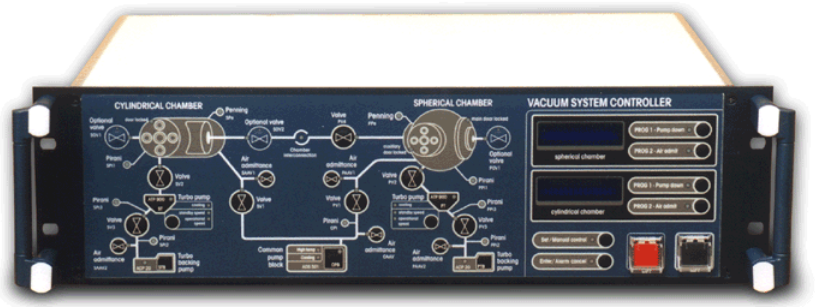
Vacuum control systems

High reliability control systems (HW, SW) for vacuum pumping



VCU 2000

ASU 2009

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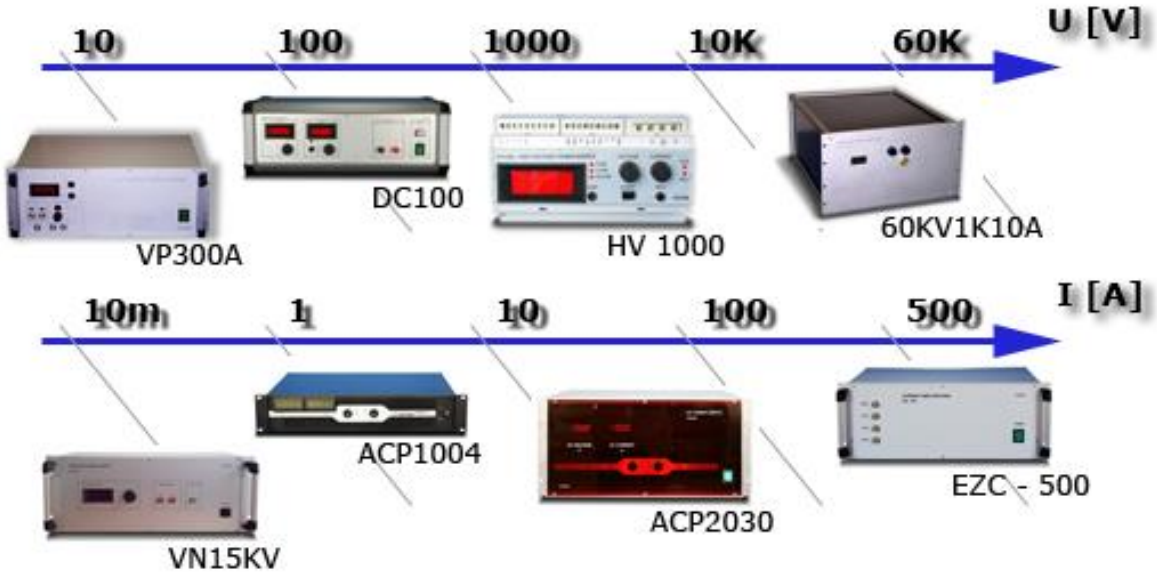
Voltage and current power supplies

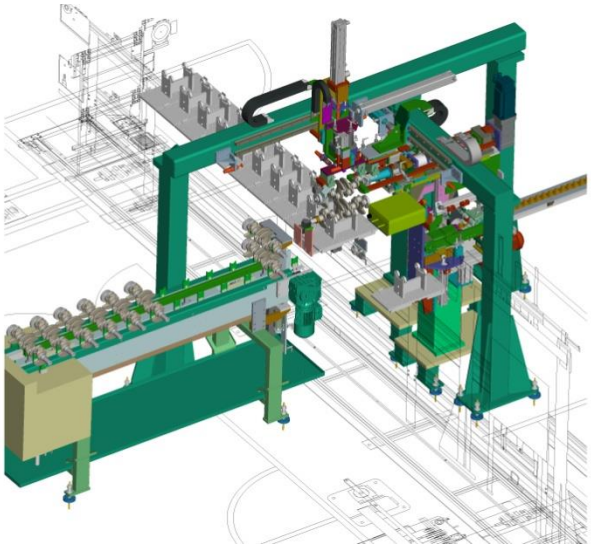
DC – AC – waveform – programmable, up to 500 A, peak power 40 kW



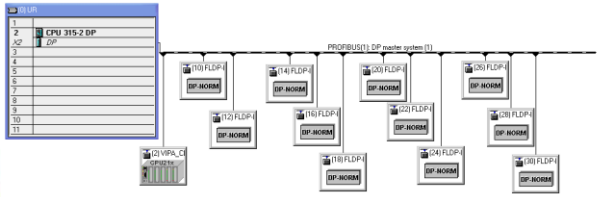
Galva 2001

Automation and industrial process control

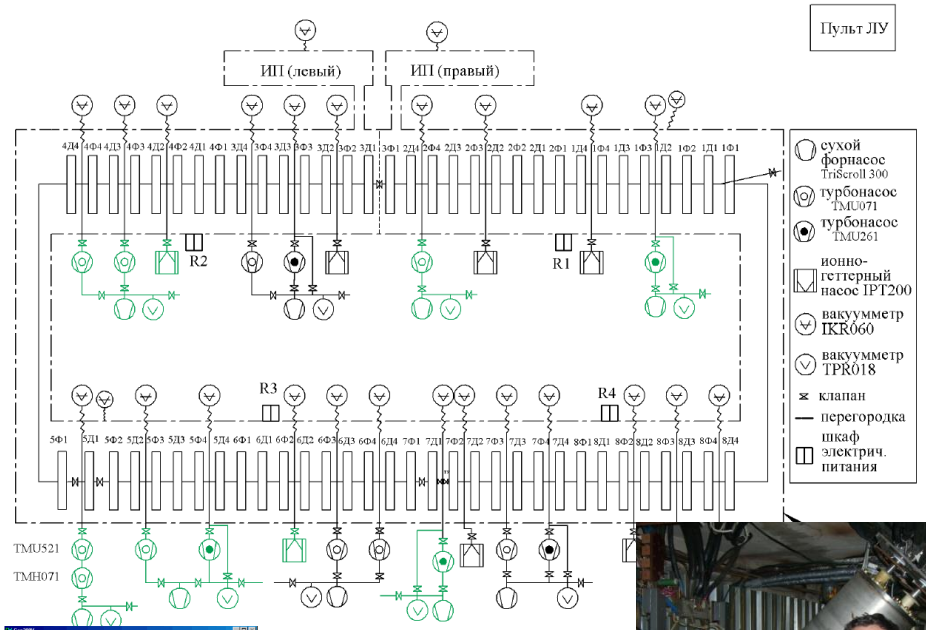
Industrial projects:

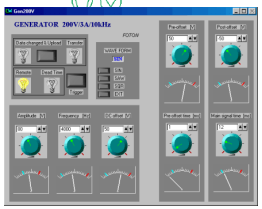


Automatic pressure station



Large experiments:





Particle accelerator

Do you need a solution ?

You know, WHAT, but you don't know HOW?

Have you not power / capacity?

…contact FOTON

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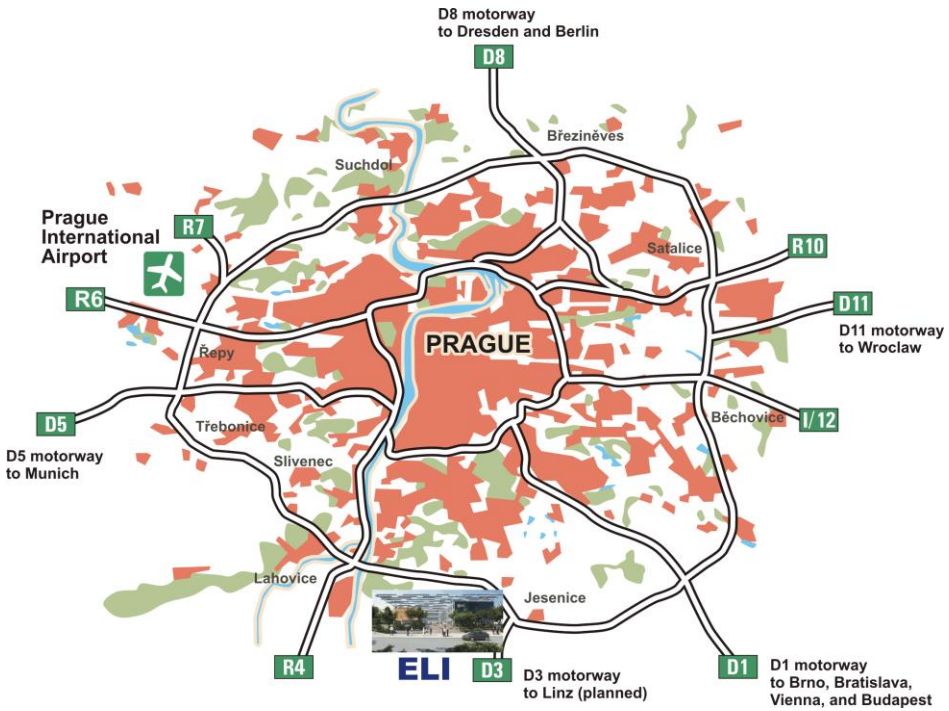
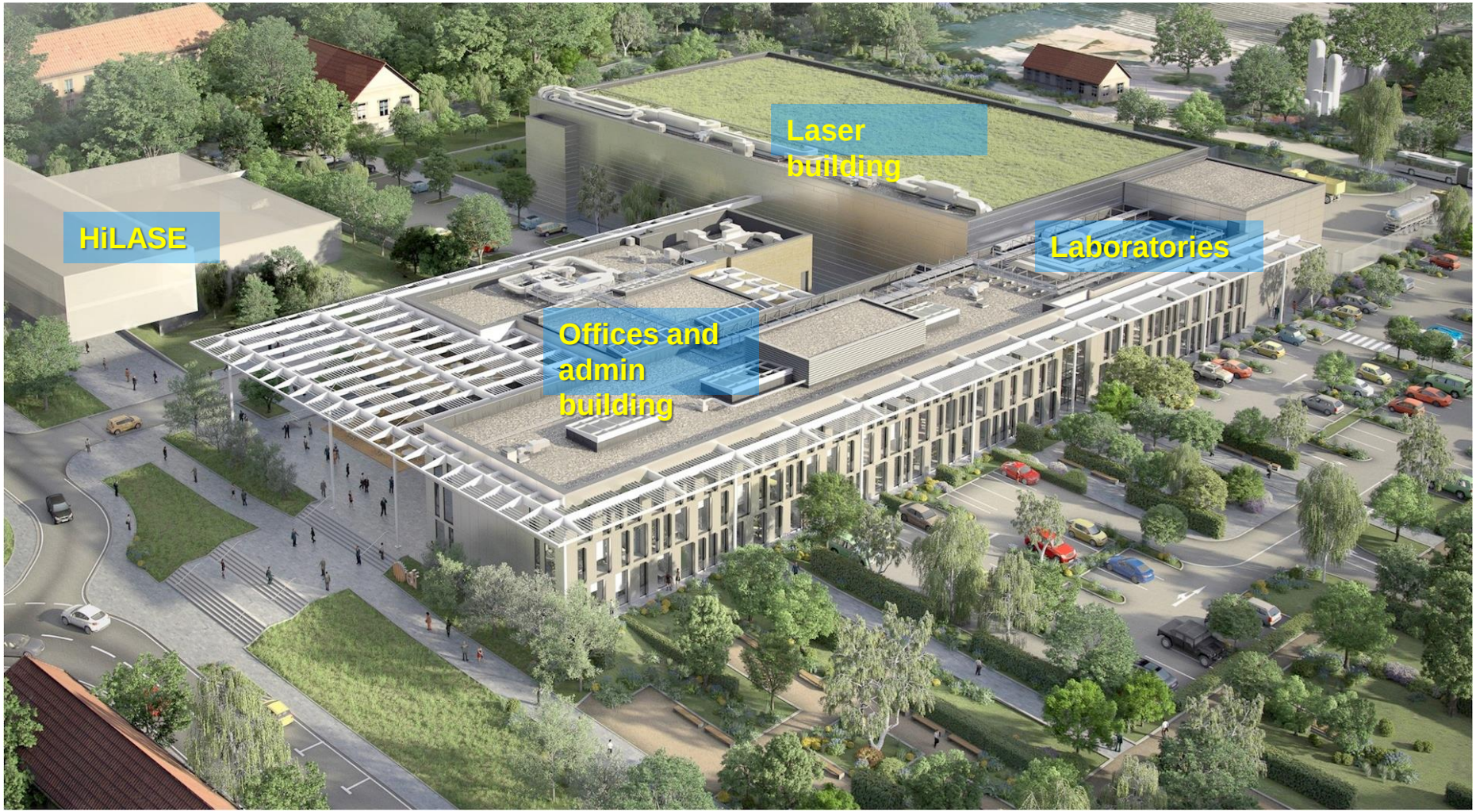
ELI-Beamlines: European laser research facility

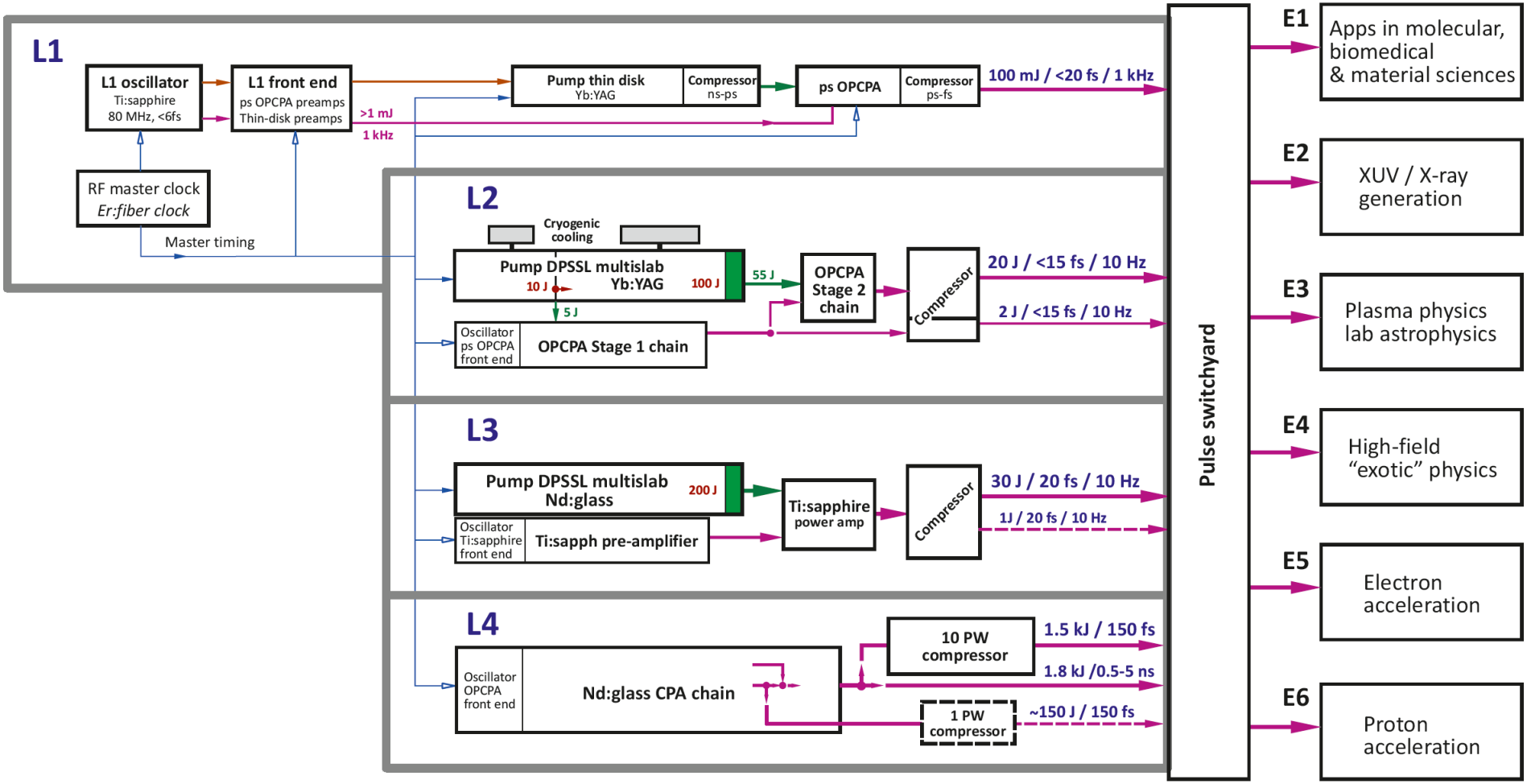


ELI-Beamlines aerial view – 2011 artist's impression



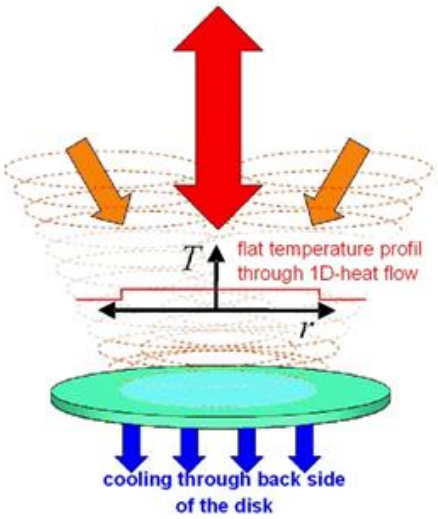
July 2015: building opened for technology installation

ELI-Beamlines master scheme: 4 laser systems



ELI-Beamlines will use new concepts of heat extraction from the laser gain medium to achieve high repetition rates

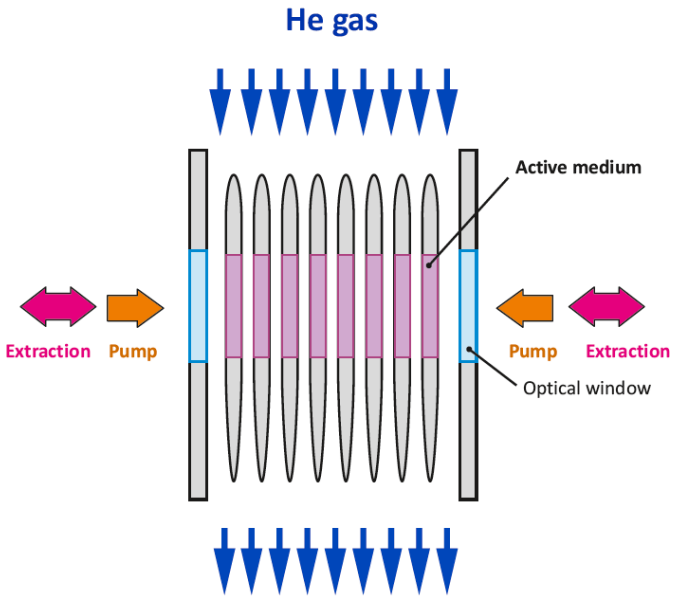
THIN DISK:
active mirror
≥kHz rep. rates
~kW average power



Courtesy T. Metzger (MPQ Garching)

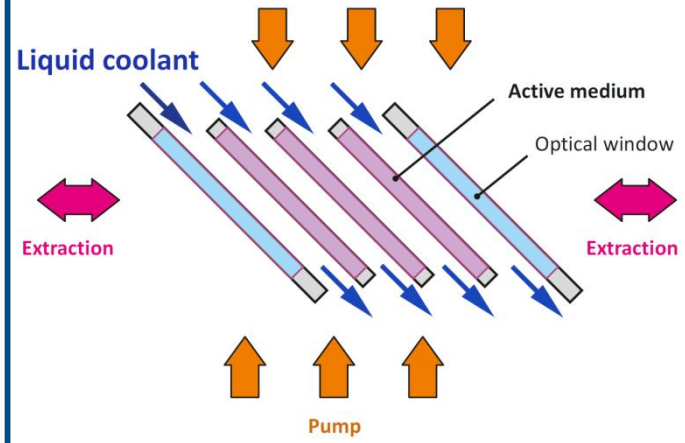
Used in L1

MULTISLAB:
face cooling by He gas
≥10 Hz rep. rates
> kW average power



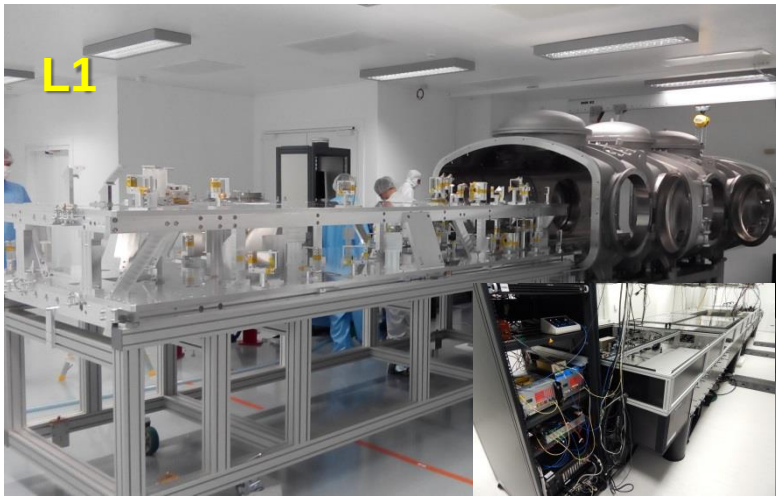
Used in L2 and L3

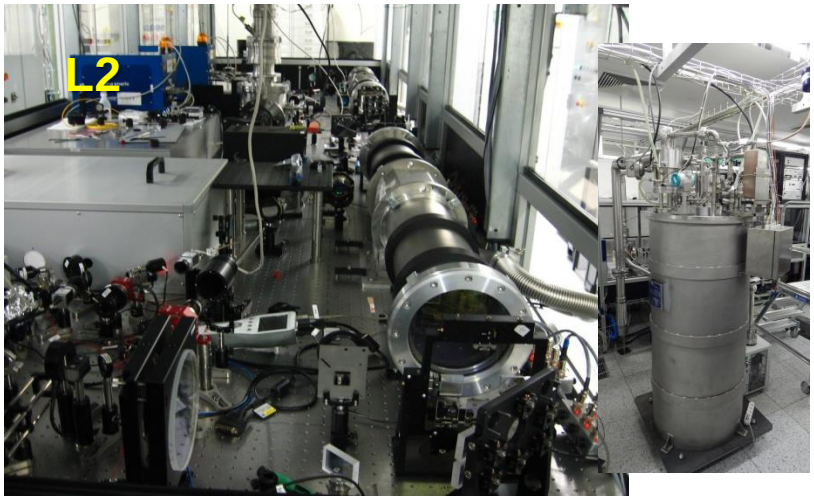
MULTISLAB:
face cooling by liquid
up to 10 Hz rep. rates
High energy (>kJ) lasers

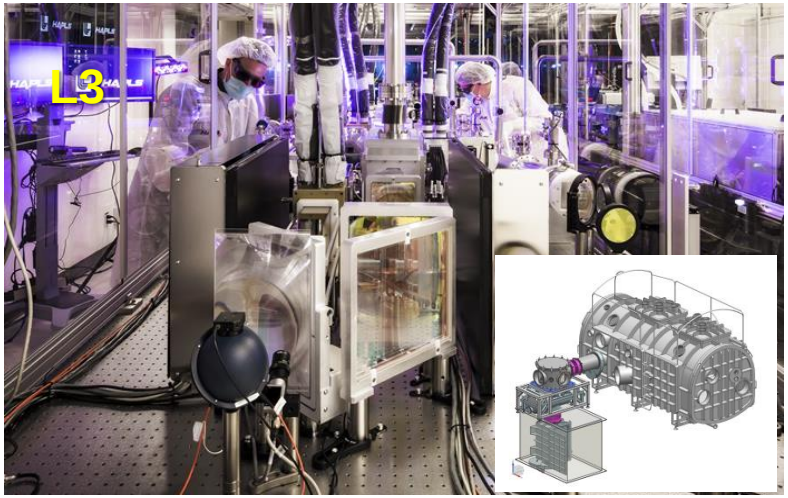


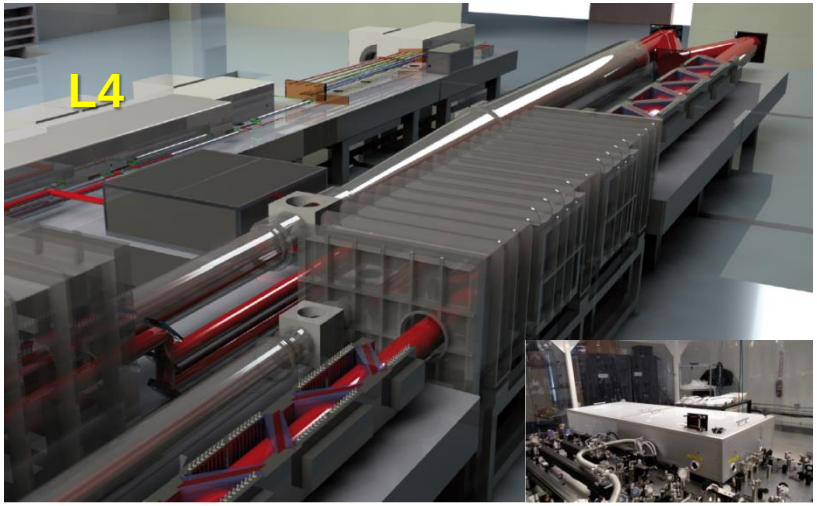
Used in L4

ELI-Beamlines laser systems: L1 / L2 / L3 / L4









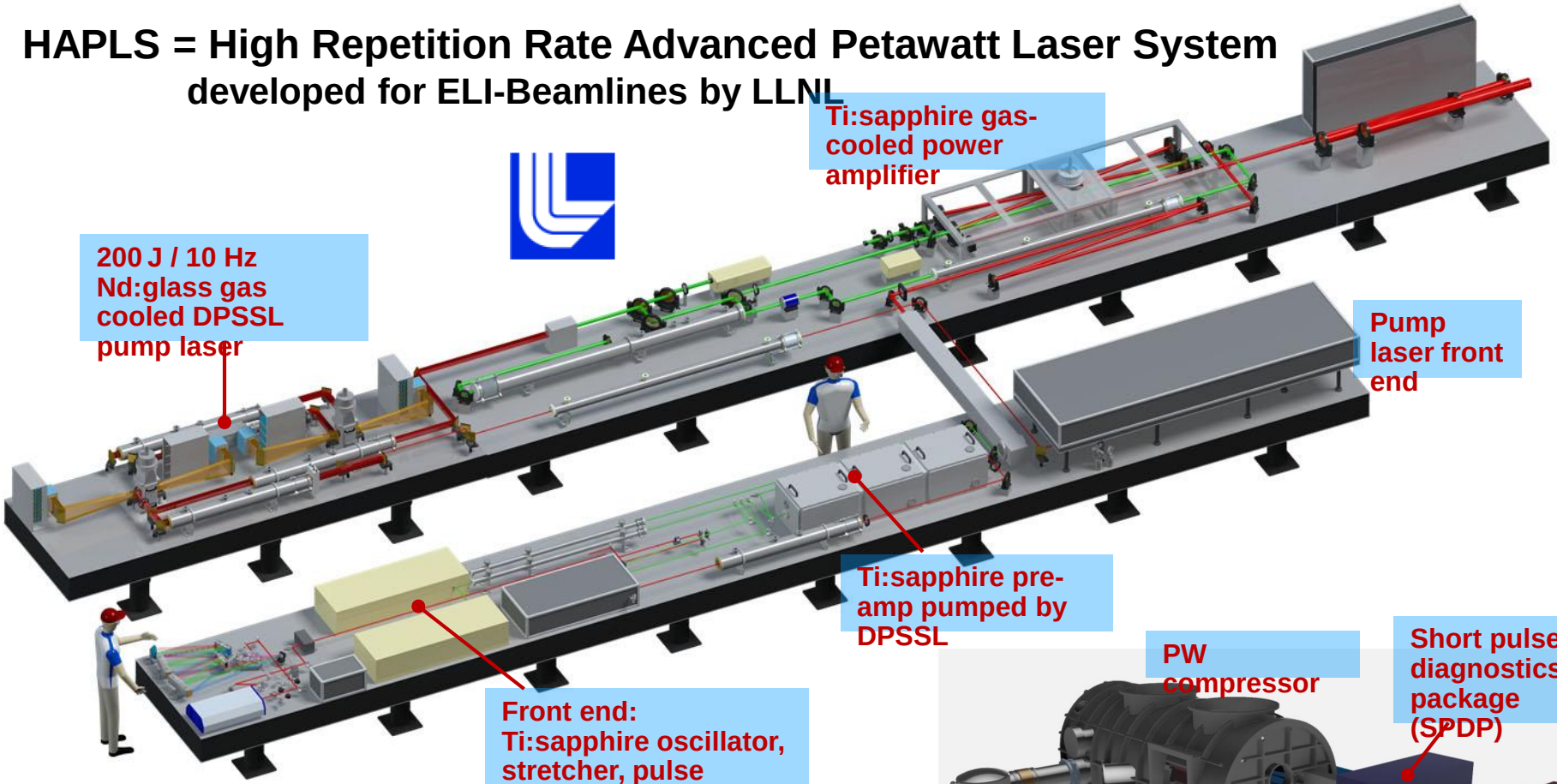
ELI-Beamlines lasers: in-house development + suppliers

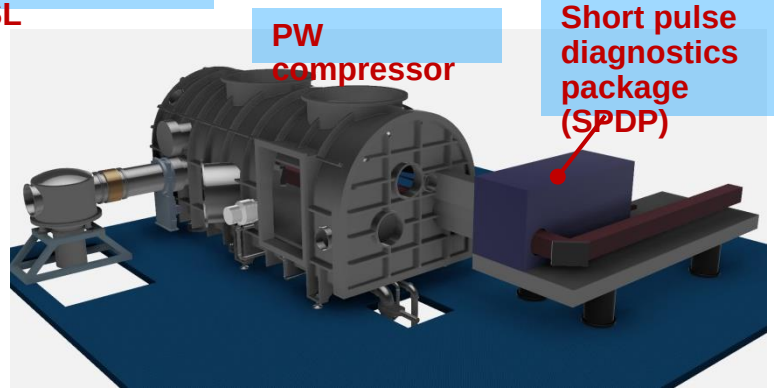
Beamline	L1	L2	L3	L4
Peak power	>5 TW	PW	≥PW	10 PW
Energy in pulse	100 mJ	≥15 J	≥30 J	≥1.5 kJ
Pulse duration	<20 fs	≤15 fs	≤30 fs	≤150 fs
Rep rate	kHz	10 Hz	10 Hz	1 per min
Supplier	Pump lasers from commercial suppliers	External supplier / developer	Major contractor	Major contractor
ELI-Beamlines development	Short pulse chain developed in house	Specific technology development	Cooperative development of subsystems	Cooperative development of subsystems
	Development of diagnostics of short pulse (15 fs to ps) laser pulses			

Example of ELI-Beamlines laser technology: L1 picosecond compressor

L3-HAPLS laser: cooperation with Lawrence Livermore National Laboratory (USA)

HAPLS = High Repetition Rate Advanced Petawatt Laser System
developed for ELI-Beamlines by LLNL





PW compressor & diagnostics
developed by Inst. of Physics

Main challenges for development of PW laser diagnostics

1) **High repetition rate**
   - The diagnostics must operate at high repetition rates (1 kHz for the L1 laser, and 10 Hz for the L2 and L3 lasers) and data has to be retrieved & stored

2) **On-line measurement capability**
   - Laser pulse parameters have to be provided “on the shot”, i.e. without deviating entire laser output to the diagnostics (deviating of attenuated laser output to diagnostics is a widely used approach in current diagnostics)
   - Diagnostics of the output laser pulses has to provide machine safety functions, e.g. stopping the laser if any early signs of damage of optics are detected

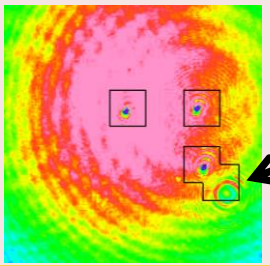
3) **Automation**
   - The diagnostics package must be a “turnkey” system and must be integrated into control system of the laser

4) **Reproducibility and reliability**
   - The diagnostics must provide same data over extended period of time, without need for readjustments and/or for realignment

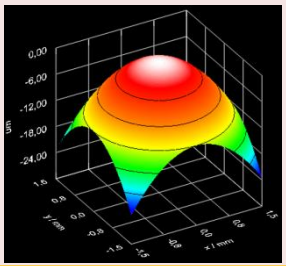
Example: automated spatial diagnostics developed

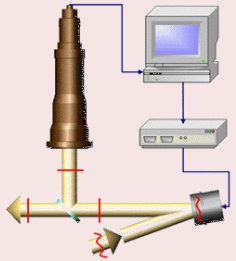
1) Near & Far field + Wavefront

Intensity profile
pointing, wavefront



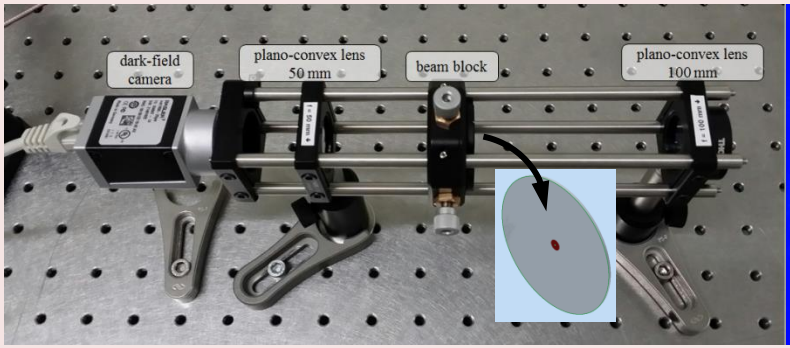
Real-time changes detection

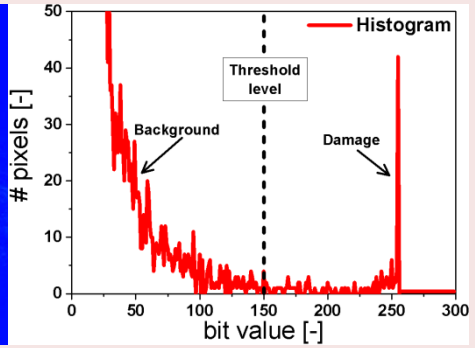




2) Dark field

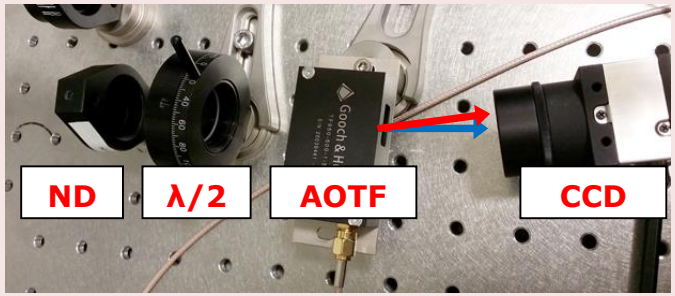
Real-time damage detection

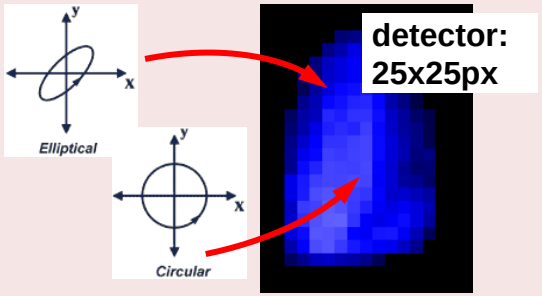




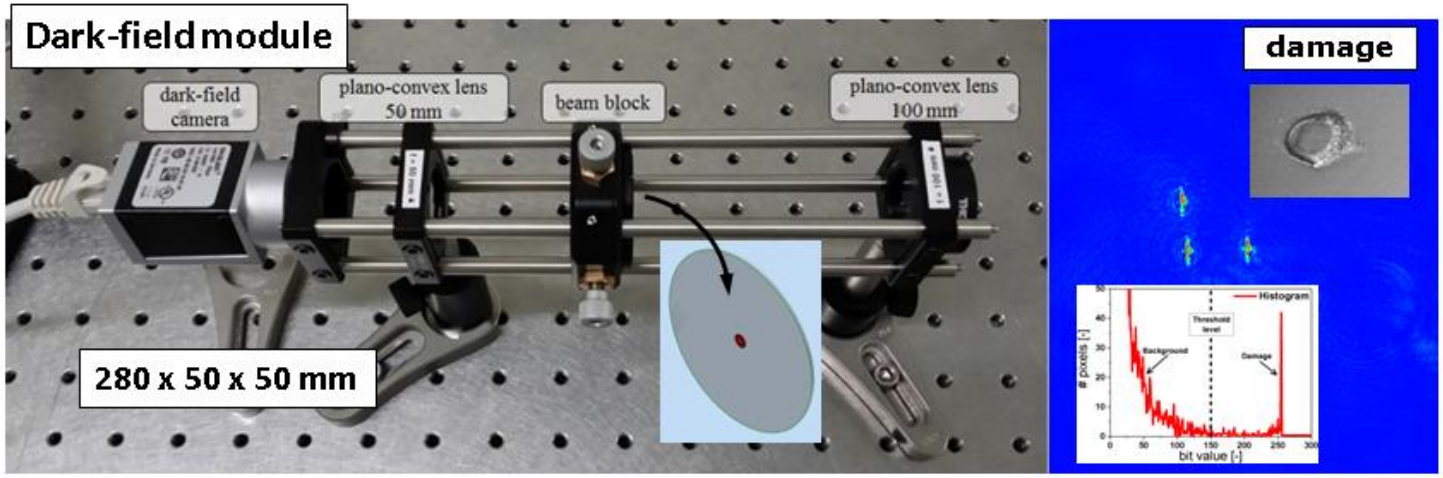
3) Polarization measurement

Spatially / spectrally resolved polarization

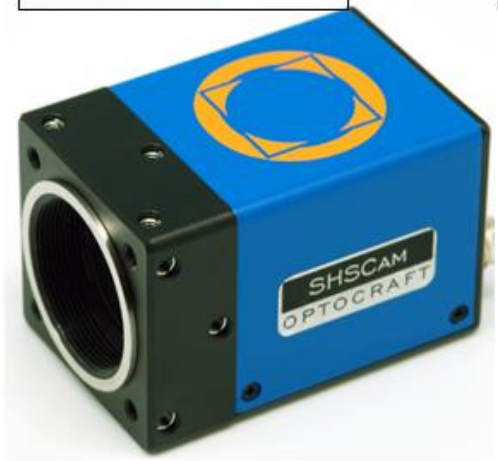




Dark field image: automated beam spatial diagnostics

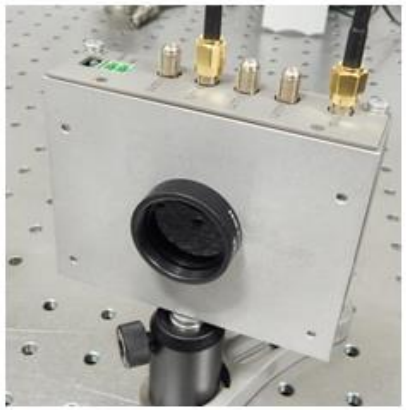


Wavefront sensor



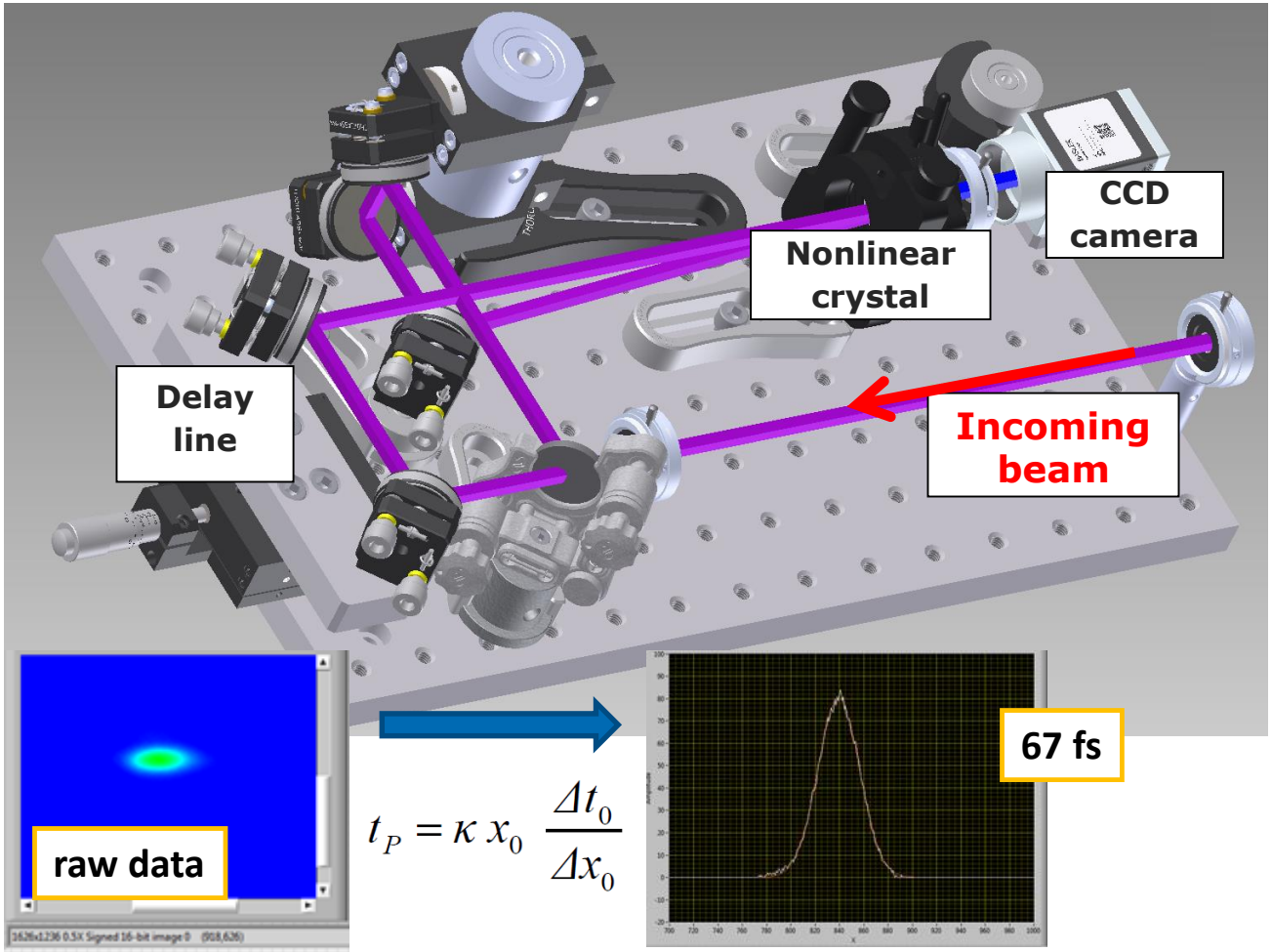
Near-field & Far-field modules

PSD



Temporal diagnostic: single-shot autocorrelator pulse length

Development of system with LabView real-time (LVRT) drivers and SW



Specifications

Pulse duration:
12-70 fs

Required energy:
>10 µJ

Resolution:
up to 1.7 fs (4.4 µm px)

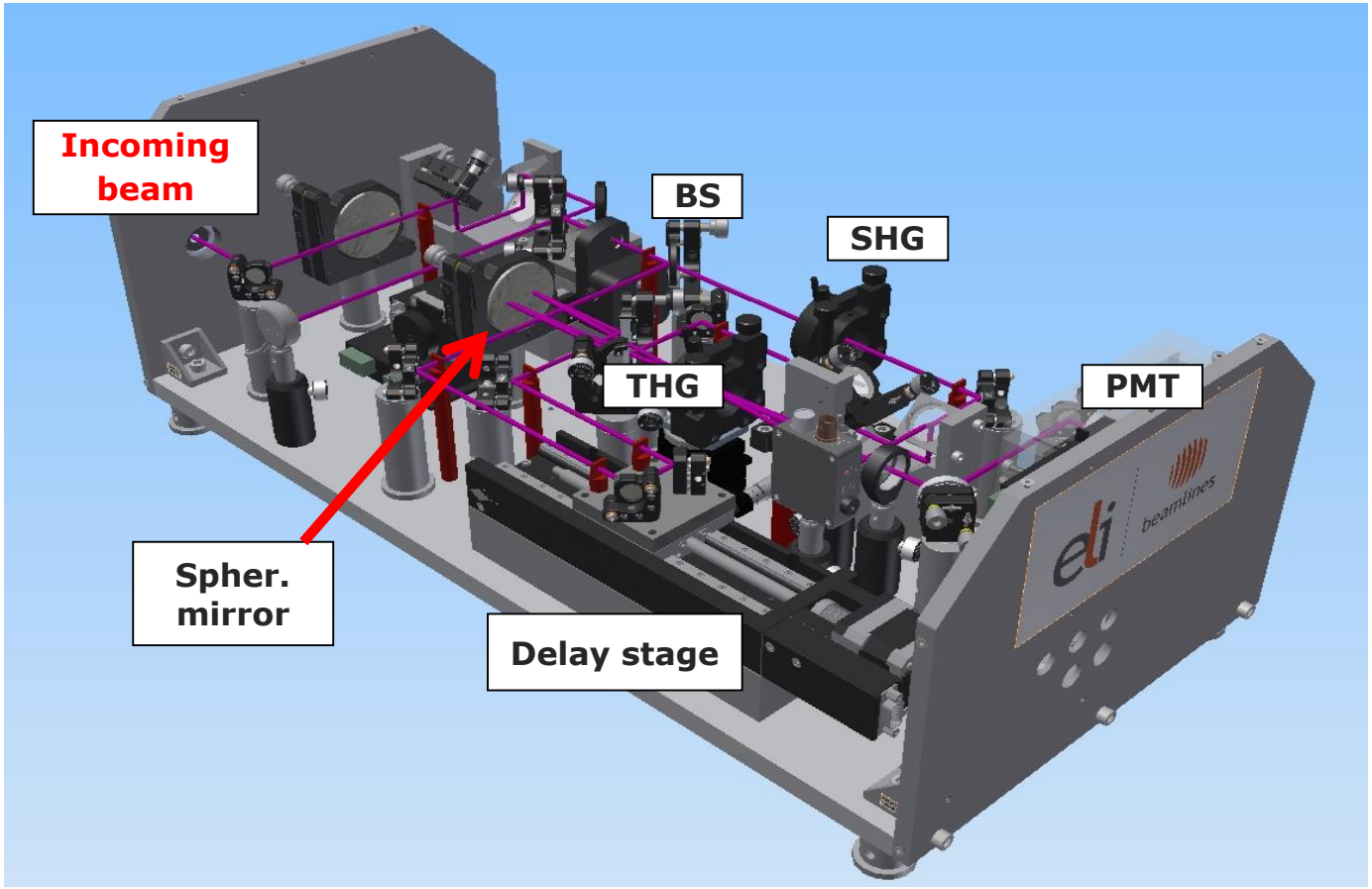
Repetition rate:
up to 20 Hz

Attenuation:
fully variable (0-max)

Polarization:
linear

Third-order autocorrelator (contrast measurement)

Development of core functions on LabView real-time drivers & SW & library for processing



Specifications

Dynamic range:
>10^{10} (100 dB)
goal 10^{11} (110 dB)

Scanning range:
up to 200ps

Required energy:
>100μJ

Repetition rate:
Slow - scanning
(depends on resolution)

Polarization:
linear

Example: Integrated short pulse diagnostic package

Temporal diagnostics

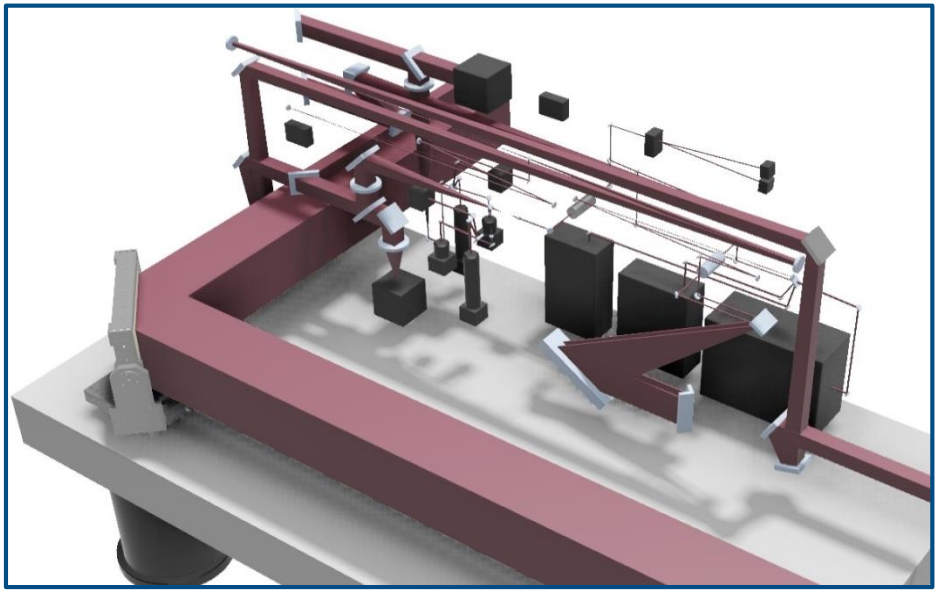
SHG autocorrelator (pulse duration)
SPIDER / Wizzler (pulse duration, spectral phase)
3rd order correlator (contrast measurement)

Spatial diagnostics

Near-field camera (beam profile, alignment)
Far-field (wavefront, alignment)
Wavefront sensor (wavefront)
Polarization module (spatially & spectrally resolved)
Dark-field (damage recognition)

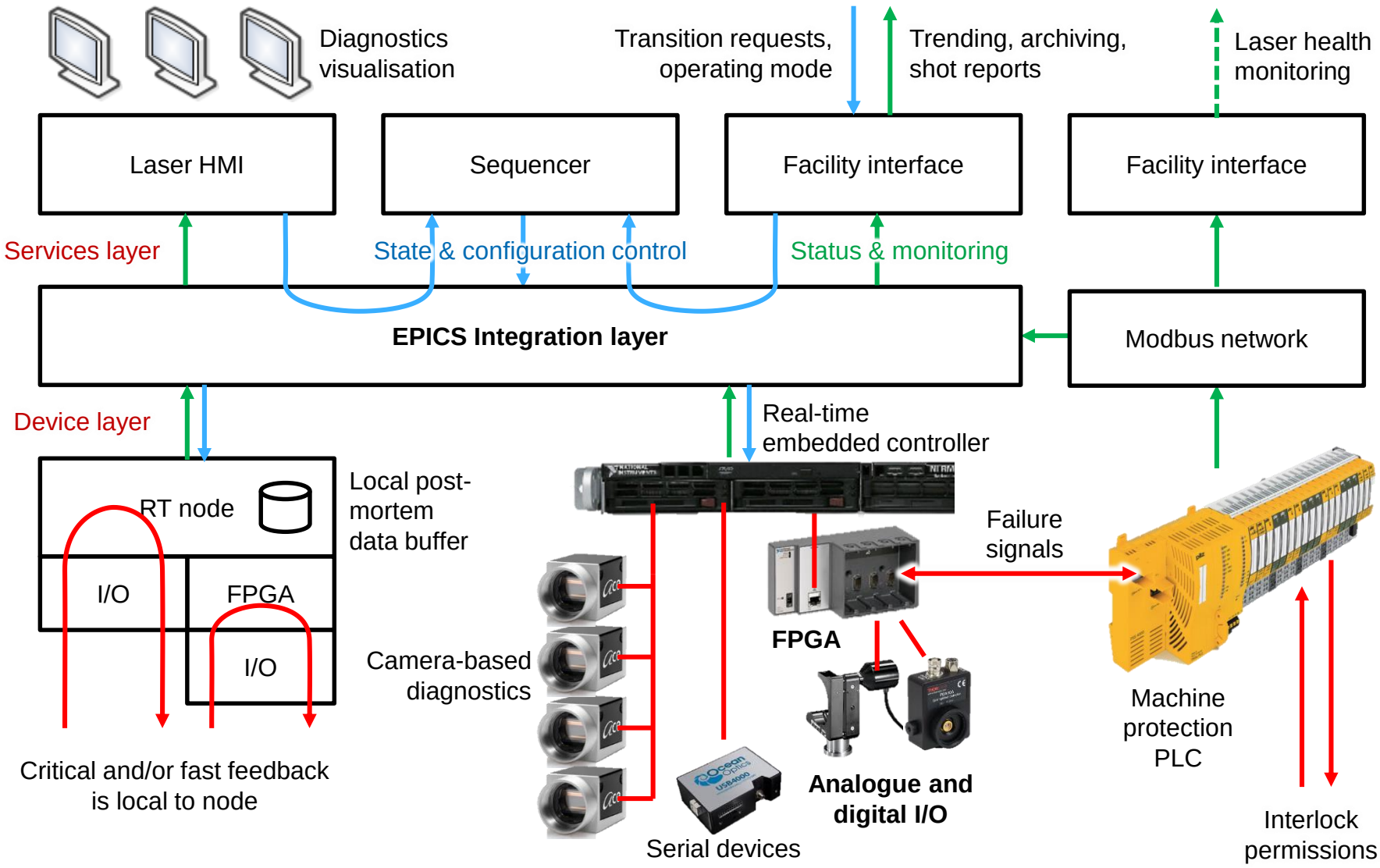
Power/energy, spectrum

Full aperture power meter (absolute meas. & calibration)
Pulse shot-to-shot energy (diode + integrating sphere)
Pulse optical spectrum



- **Fully automated, 10 Hz real time operation**
- **Signals for feedback and alignment**
- **Pulse / beam diagnostics at the output of the final amplifier (before compression) and diagnostics of the compressed pulse**

Diagnostics integration with laser control system



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Studénka 1, 509 01 Nová Paka, Česká republika | +420 491 618 020 | info@fotons.cz | www.fotons.cz