Extreme Light Infrastructure Beamlines (ELI-Beamlines) High Repetition Rate Advanced Petawatt Laser Control System (L3-HAPLS)

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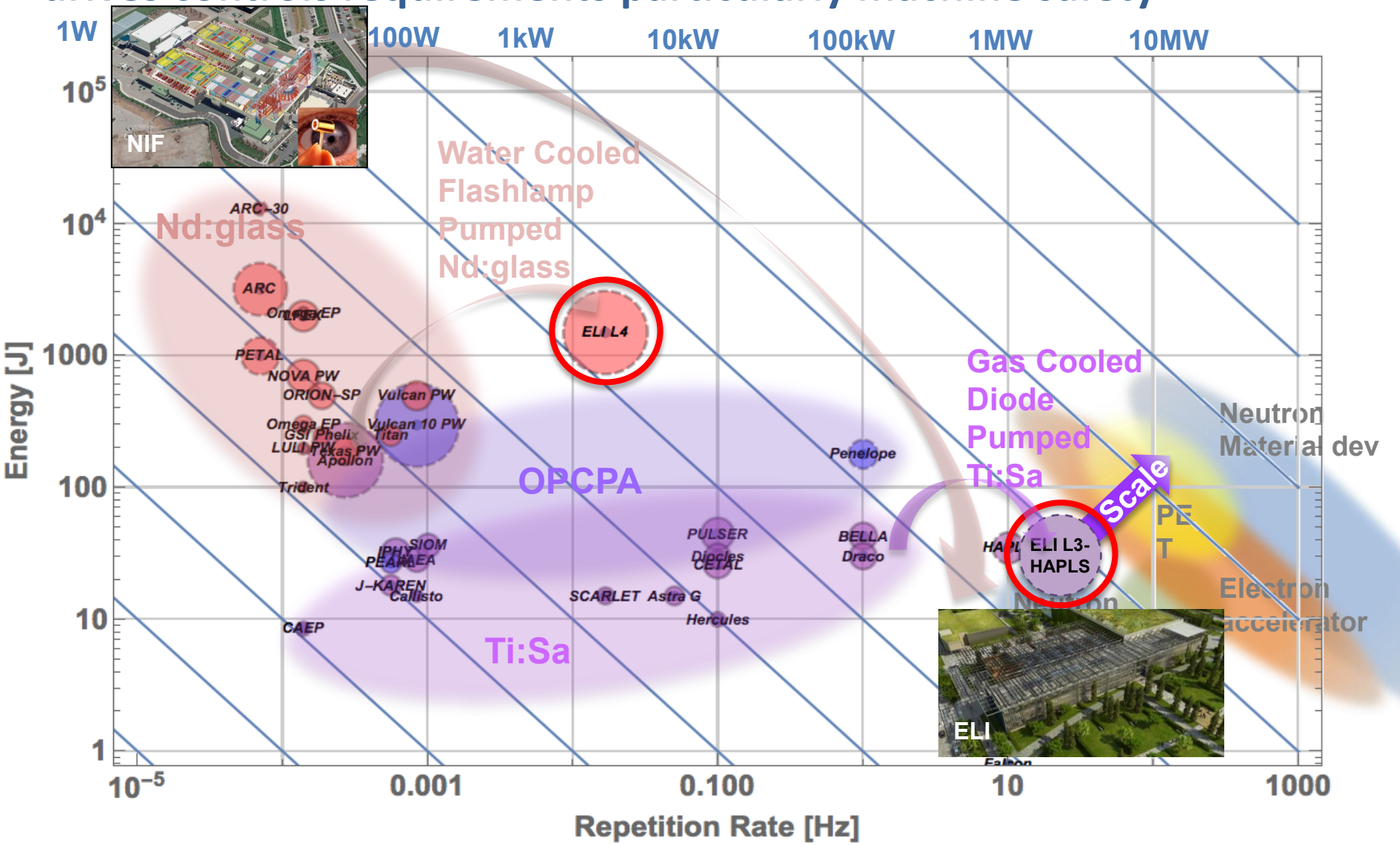
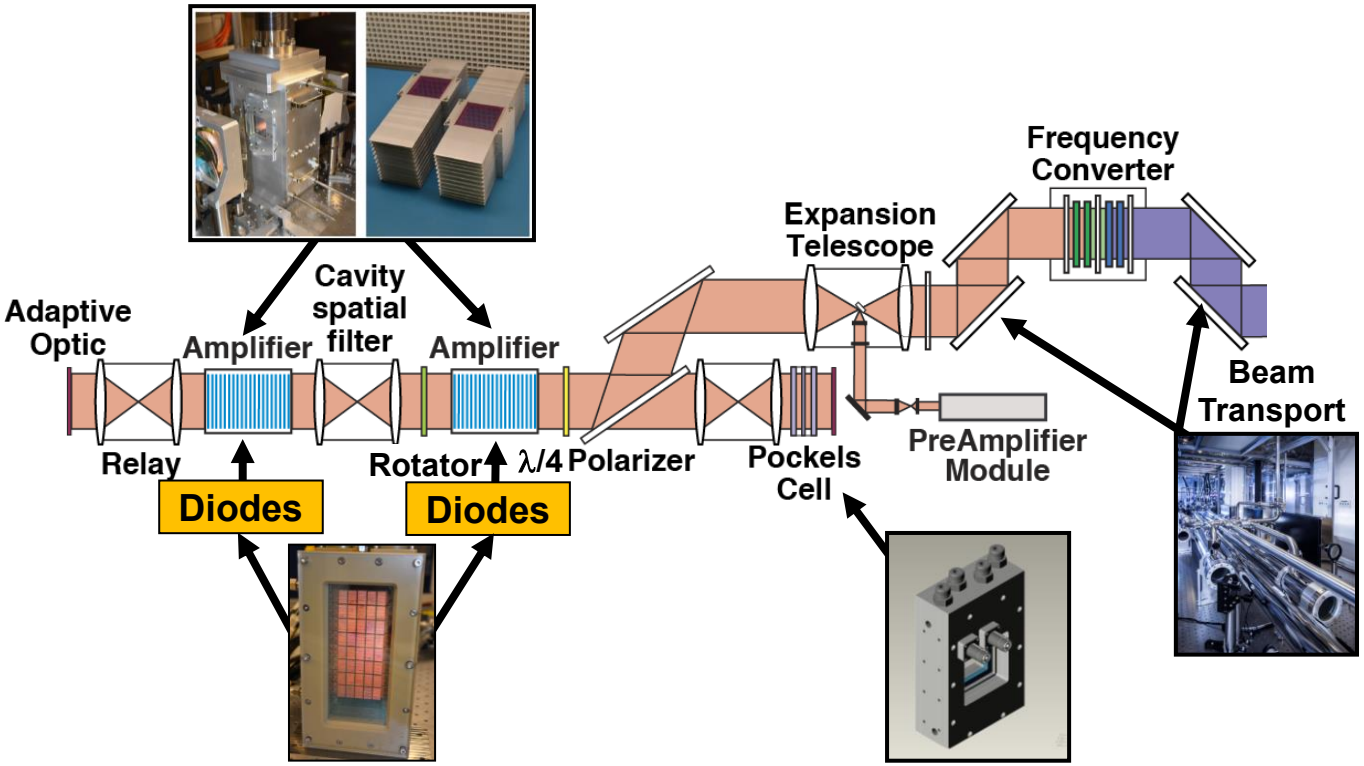
L3-HAPLS will be integrated into the "ELI-Beamlines" facility in Czech Republic

- 4 year project (2013-2017)
- Designed, built and commissioned at LLNL
- Shipped and installed at ELI Beamlines
- Re-commissioned and integrated into user facility

Laser technology is moving toward high repetition rate which drives controls requirements particularly machine safety



Laser design combines high efficiency, high average power technology with multipass energy storage amplifier architecture

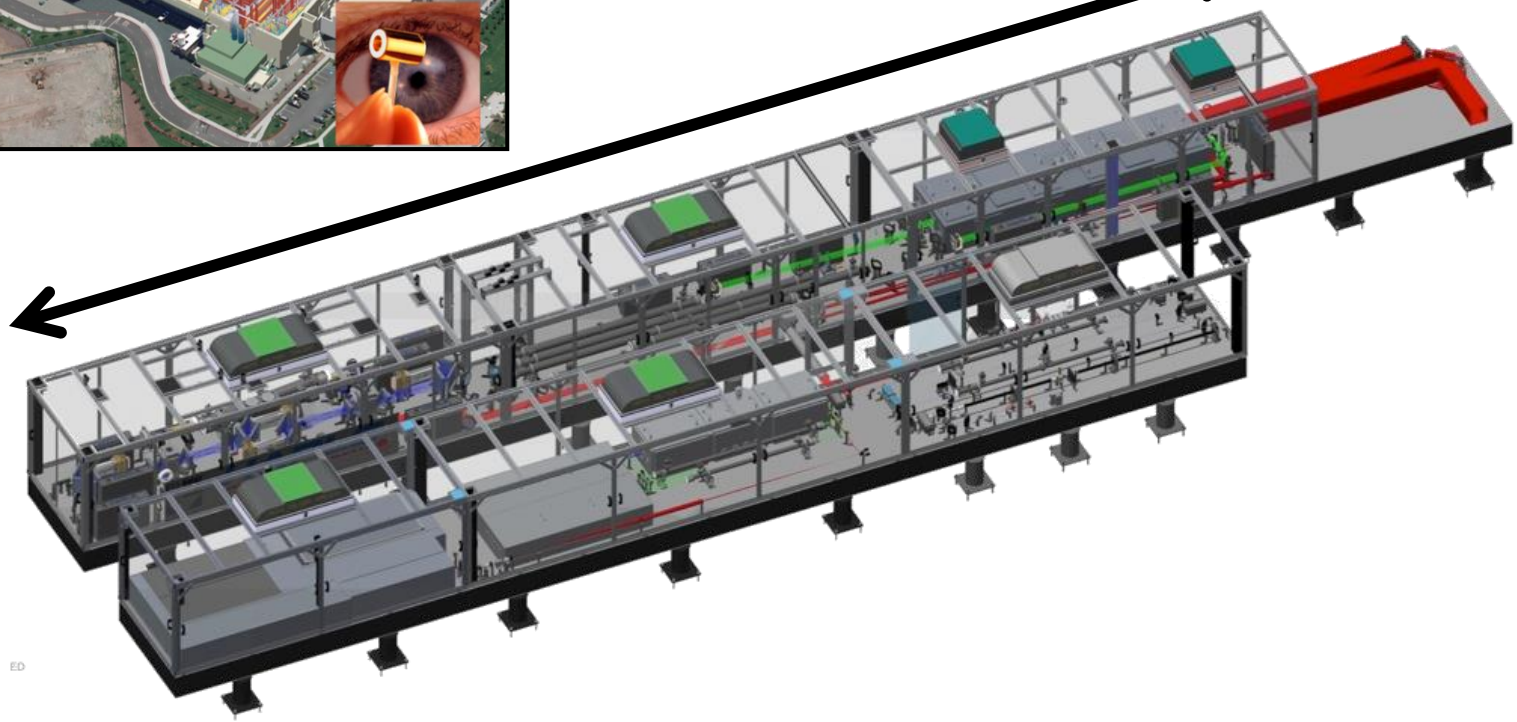


Diode pumps	→	high efficiency
Helium cooled amps	→	high repetition rate (10 Hz) with low stress
Normal amp slabs	→	compensated thermal birefringence, compact amp
Passive switching	→	performs at repetition rate
Lower output fluence	→	less susceptible to optical damage

The ELI L3-HAPLS Petawatt System is very compact and fits into a 17m x 5m footprint

NIF (0.5 PW in 5ns)
200m length

L3-HAPLS (1 PW in 30fs)
15m length

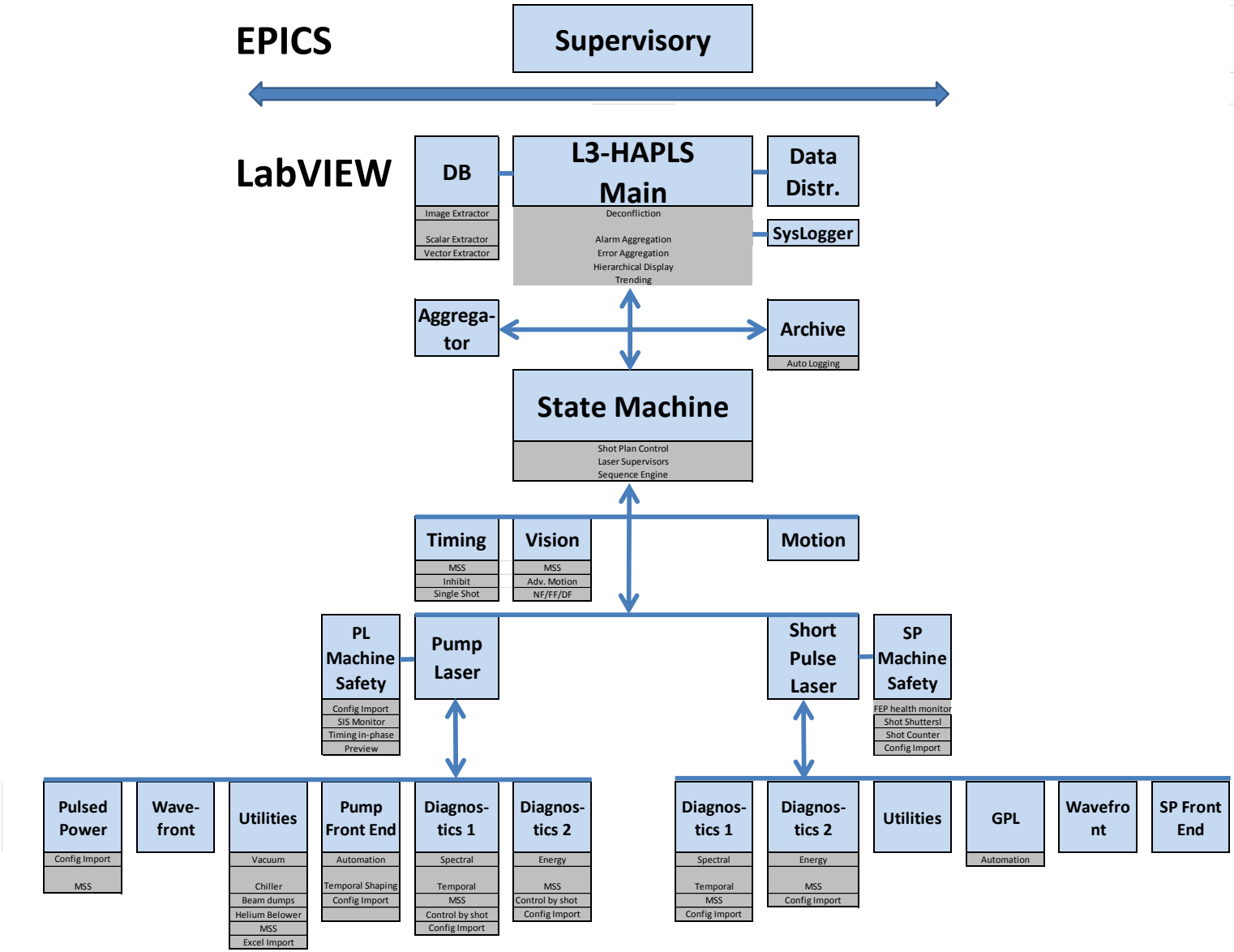



Summer 2014

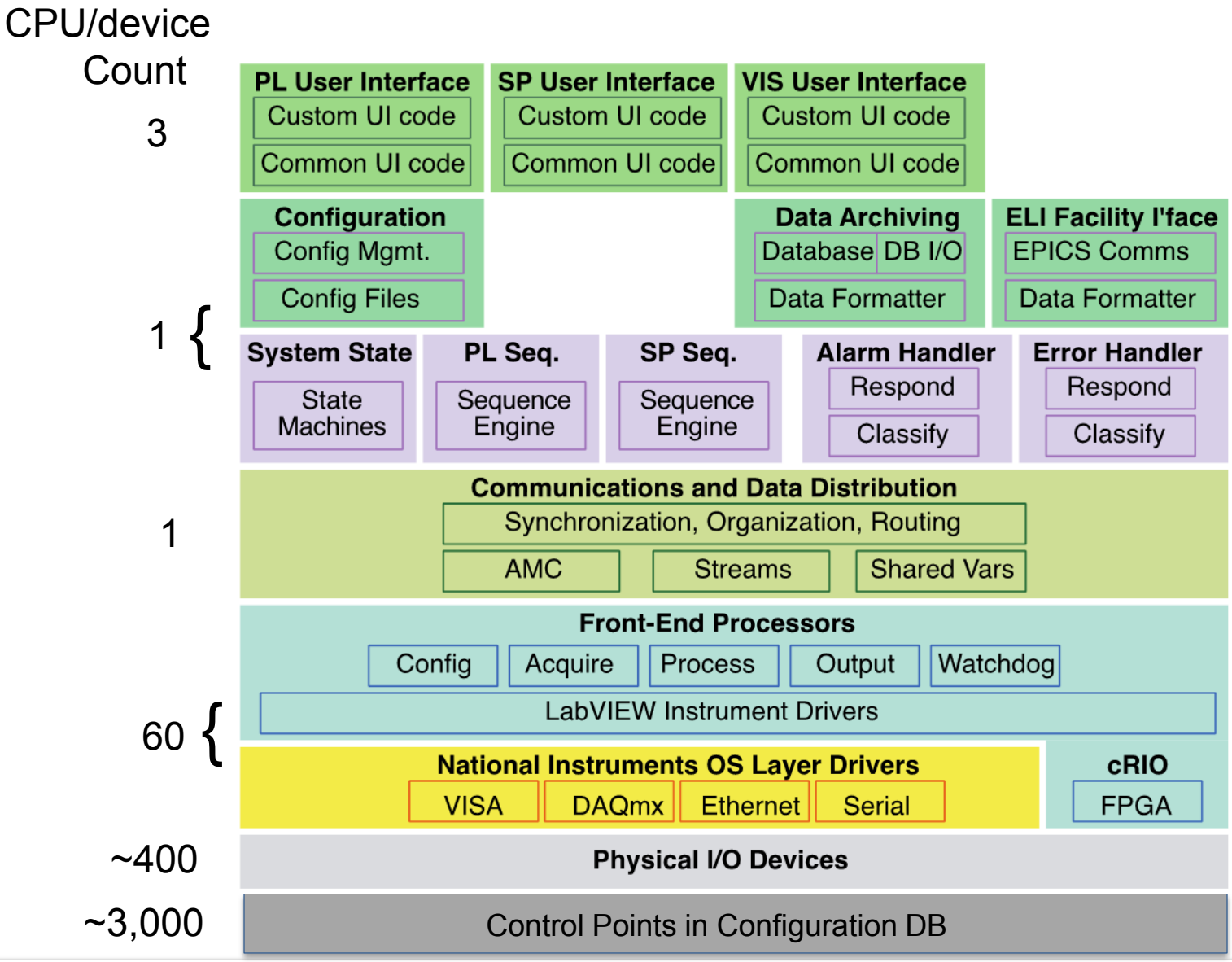

Summer 2015

L3-HAPLS Control System is being commissioned as the laser is ramped to full performance

Control System Architecture

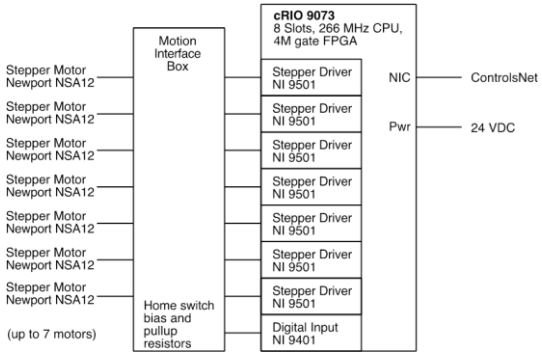


Functional hierarchy of the L3-HAPLS Control System



Common FEP architectures are utilized for replicated systems

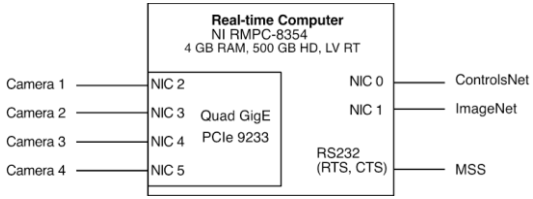
Motion Control
20 FEPs
120 Motors



Each FEP consists of

- 7 Open loop motors
- cRIO FPGA Chassis
- NI 9501 Configurable Driver

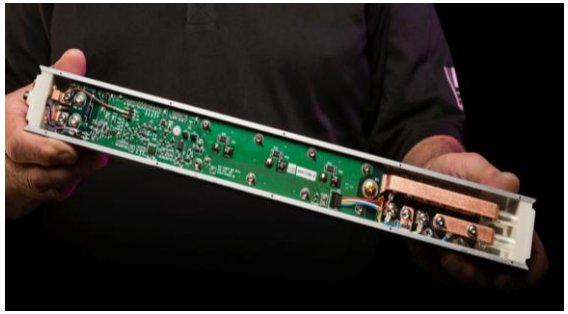
Image Processing
20 FEPs
80 Cameras

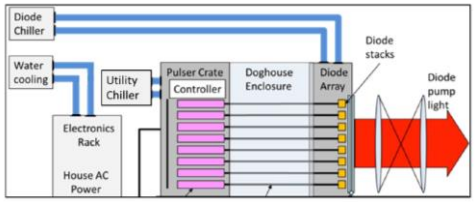


Each FEP consists of

- 4 GigE Cameras
- LabVIEW RT pre-processing
- 10Hz 1.0 Mpixel (Qty2)
- 10 Hz 0.25 Mpixel (Qty 2)

Power Conditioning
4 FEPs
160 Pulsers



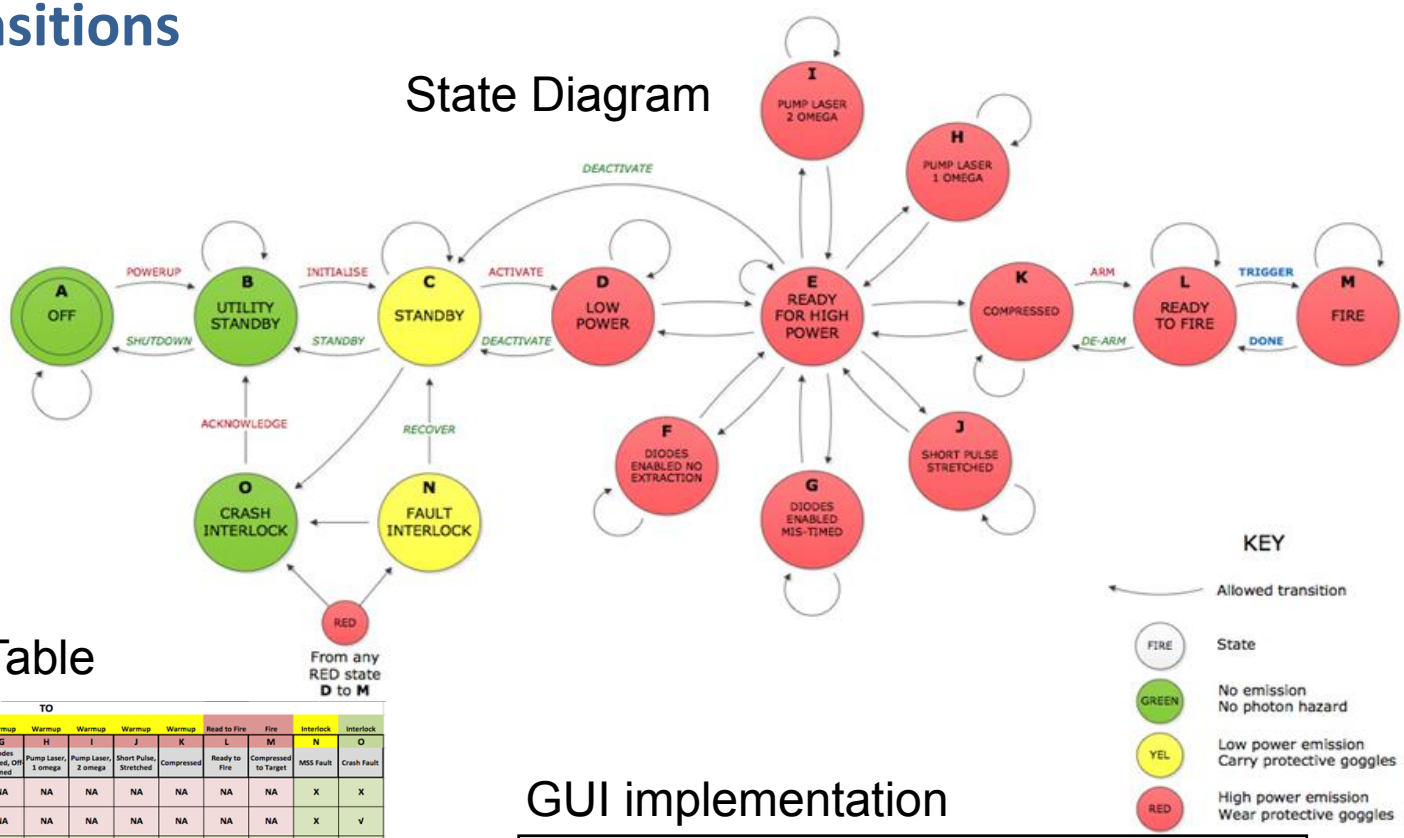


Each FEP consists of

- 40 Diode Array Pulsers
  12.5 kW, 1000A, 90% eff.
- IR communication for electrical isolation
- cRIO FPGA Chassis

L3 Laser automation is controlled by a State Machine with well defined transitions

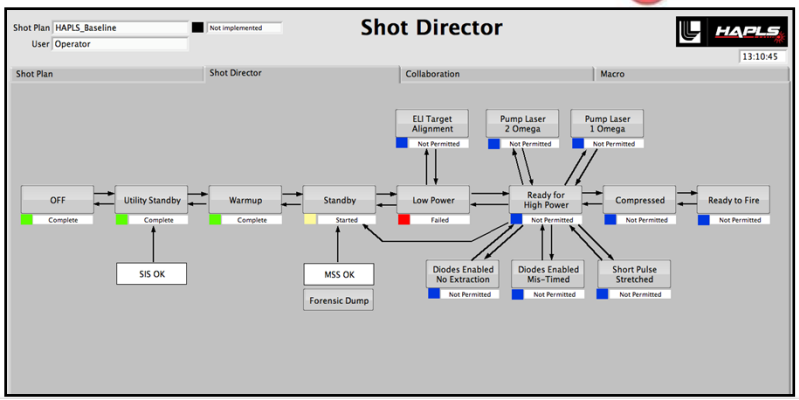
State Diagram



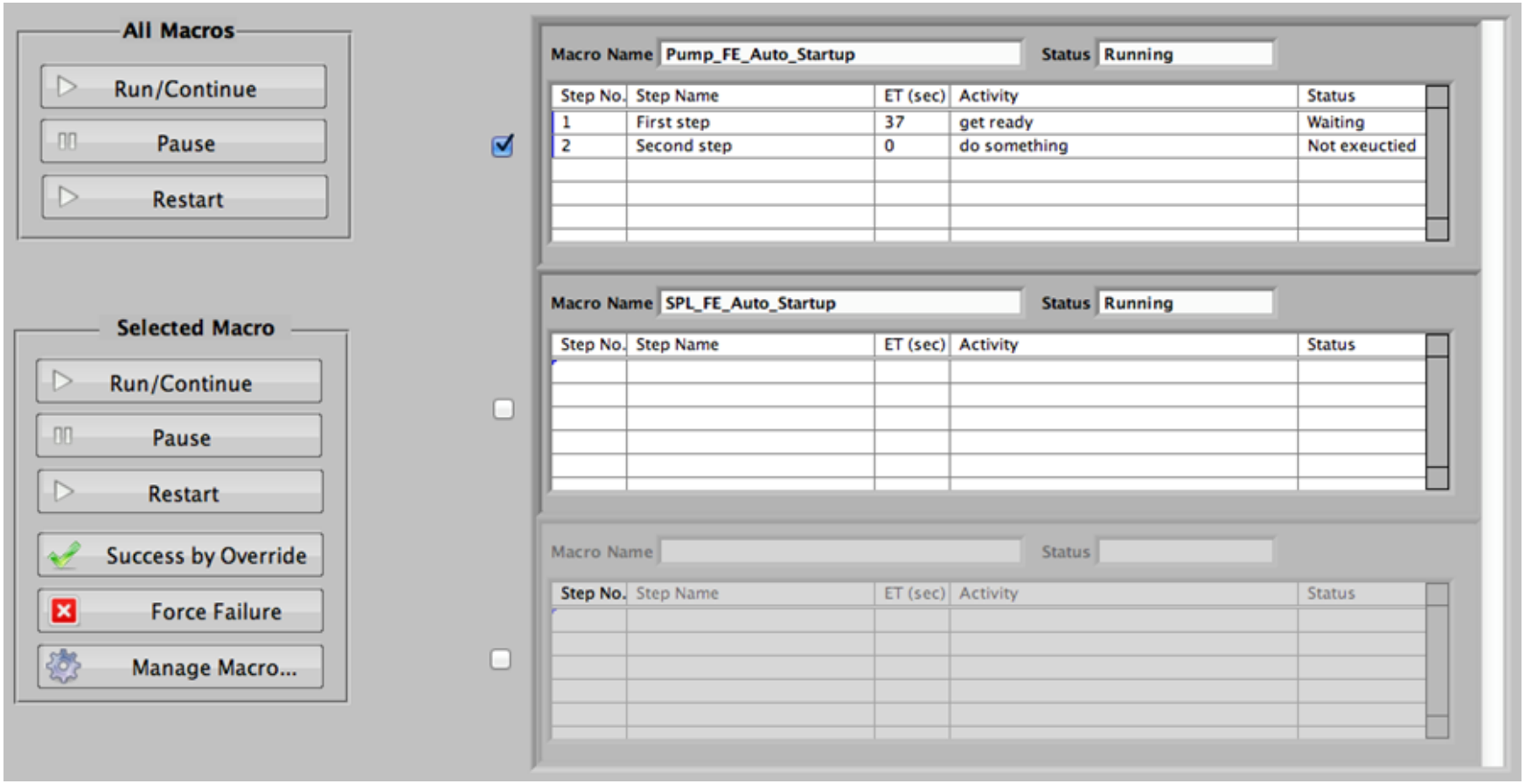
State Transition Table

FROM \ TO	ELI Hall State:	Off	Utility Standby	Standby	Warmup	Warmup	Warmup	Warmup	Warmup	Warmup	Warmup	Warmup	Read to Fire	Fire	Interlock	Interlock
	L3 Hall State:	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
		Off	Utility Standby	Standby	Low Power	Ready for High Power	Diodes Enabled, No Extraction	Diodes Enabled, Off-Timed	Pump Laser, 1 omega	Pump Laser, 2 omega	Short Pulse, Stretched	Compressed	Ready to Fire	Compressed to Target	MSS Fault	Crash Fault
A	Off	-	√	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	X	X
B	Utility Standby	√	-	√	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	X	√
C	Laser Standby		√	-	√										√	√
D	Low Power			√	-	√									√	√
E	Ready for High Power			√	√	-	√	√	√	√	√	√			√	√
F	Diodes Enabled, No Extraction			-		√	-								√	√
G	Diodes Enabled, Off-Timed					√		-							√	√
H	Pump Laser, 1 omega					√			-						√	√
I	Pump Laser, 2 omega					√				-					√	√
J	Short Pulse, Stretched					√					-				√	√
K	Compressed					√						-	√		√	√
L	Ready to Fire					√						√	-	√	√	√
M	Compressed to Target												√	-	√	√
N	MSS Fault	X	X	√	X	X	NA	NA	NA	NA	NA	NA	NA	NA	-	X
O	Crash Fault	X	√	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	-

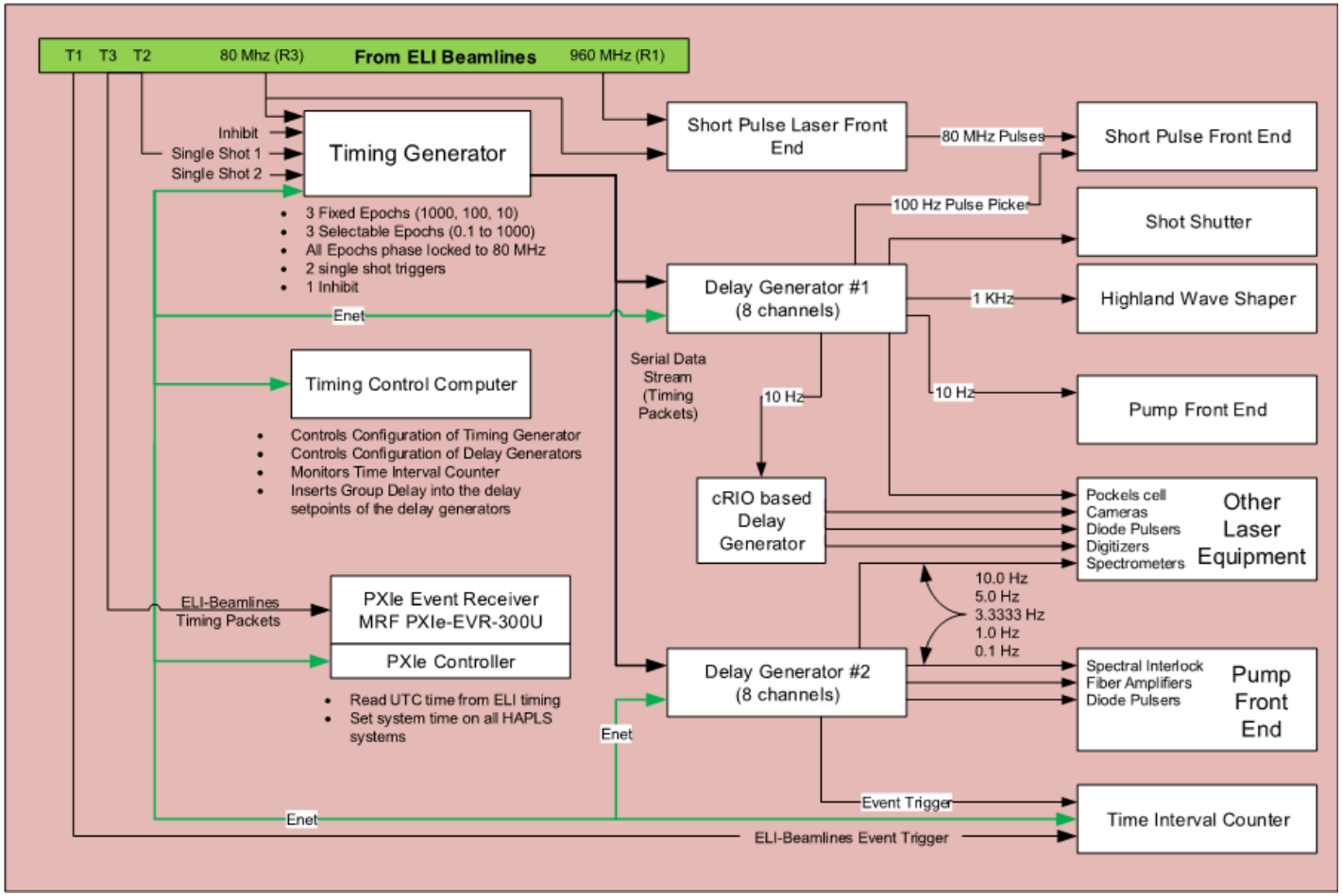
GUI implementation



State machine automation content and transitions are managed by data driven macros or enumerated sequence engines

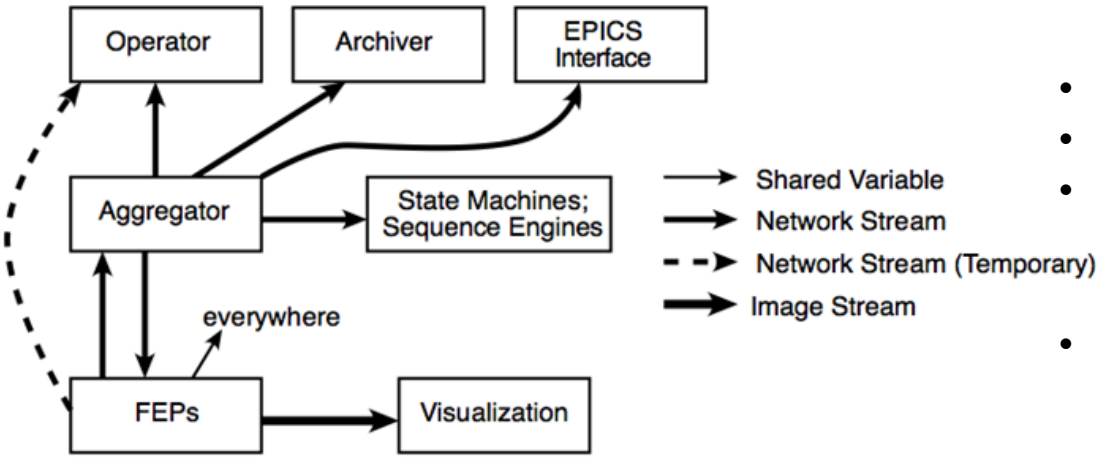


L3 HAPLS Timing System architecture supports three tiers of required accuracy spanning fs to μs

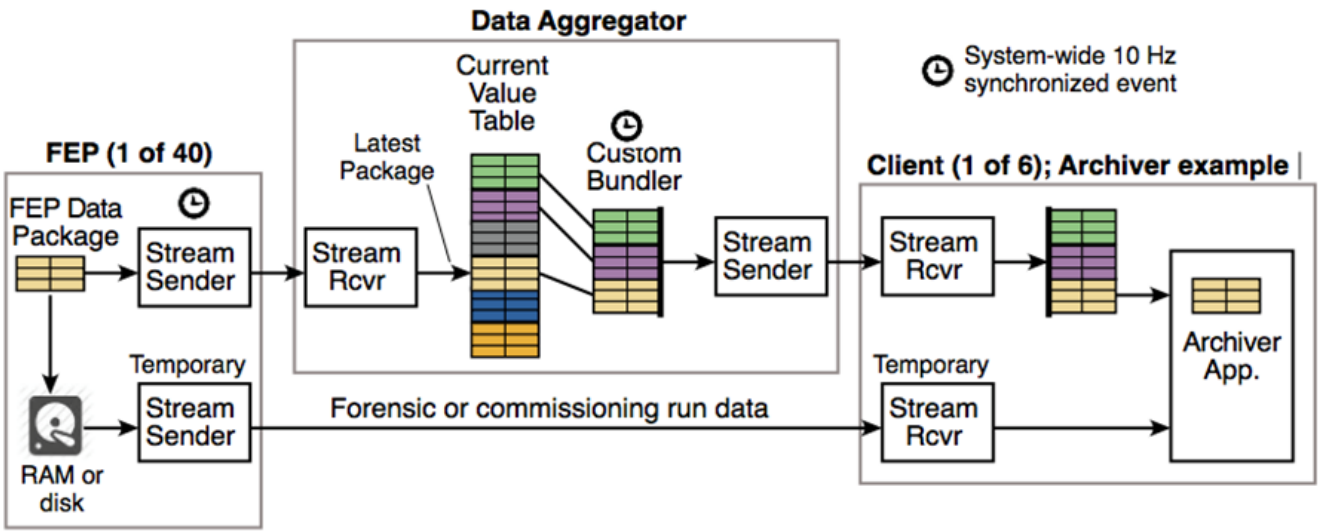


Femtolasers Phase locked master oscillators for ~100fs laser pulse synchronization
Greenfield Technologies Master Transmitter/Delay generators 15ps for fast diagnostics/switches
FPGA 10 μs for pulsed power and slow diagnostics

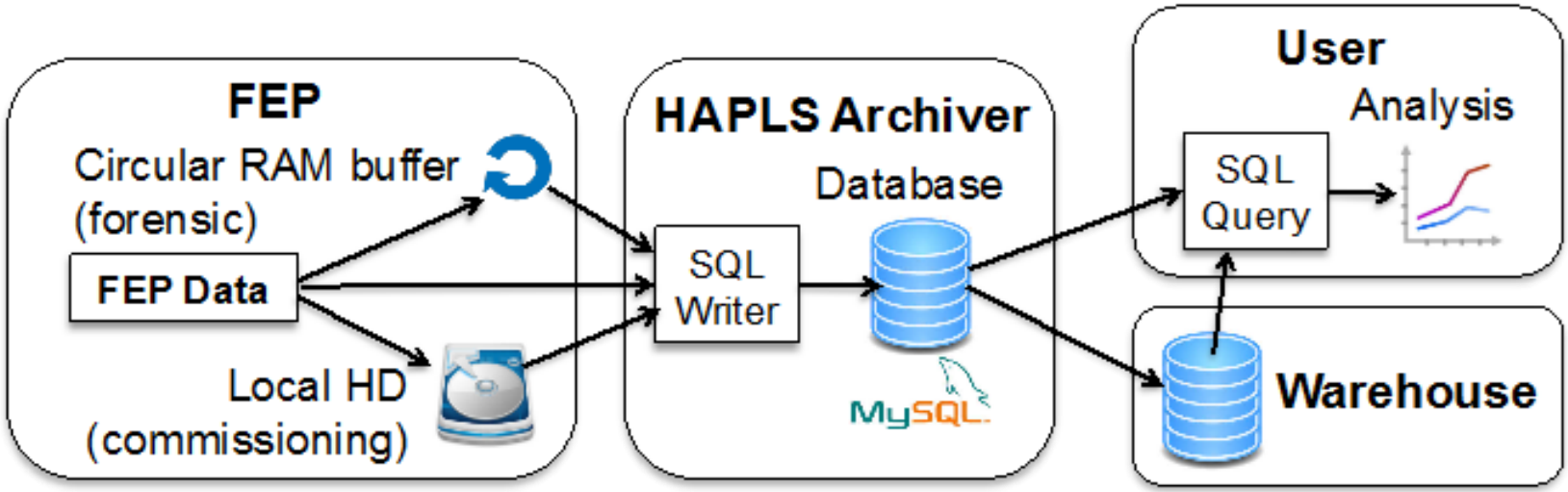
Real Time data aggregation and distribution for streamed data archive implemented as middleware in data distribution layer



- Data Aggregator 10Hz Sync
- 60 FEPs input
- Segmented Network HW
  - ControlsNet 10 GigE
  - ImageNet 10 GigE
- IEEE-1588 Precision Time Protocol time stamp

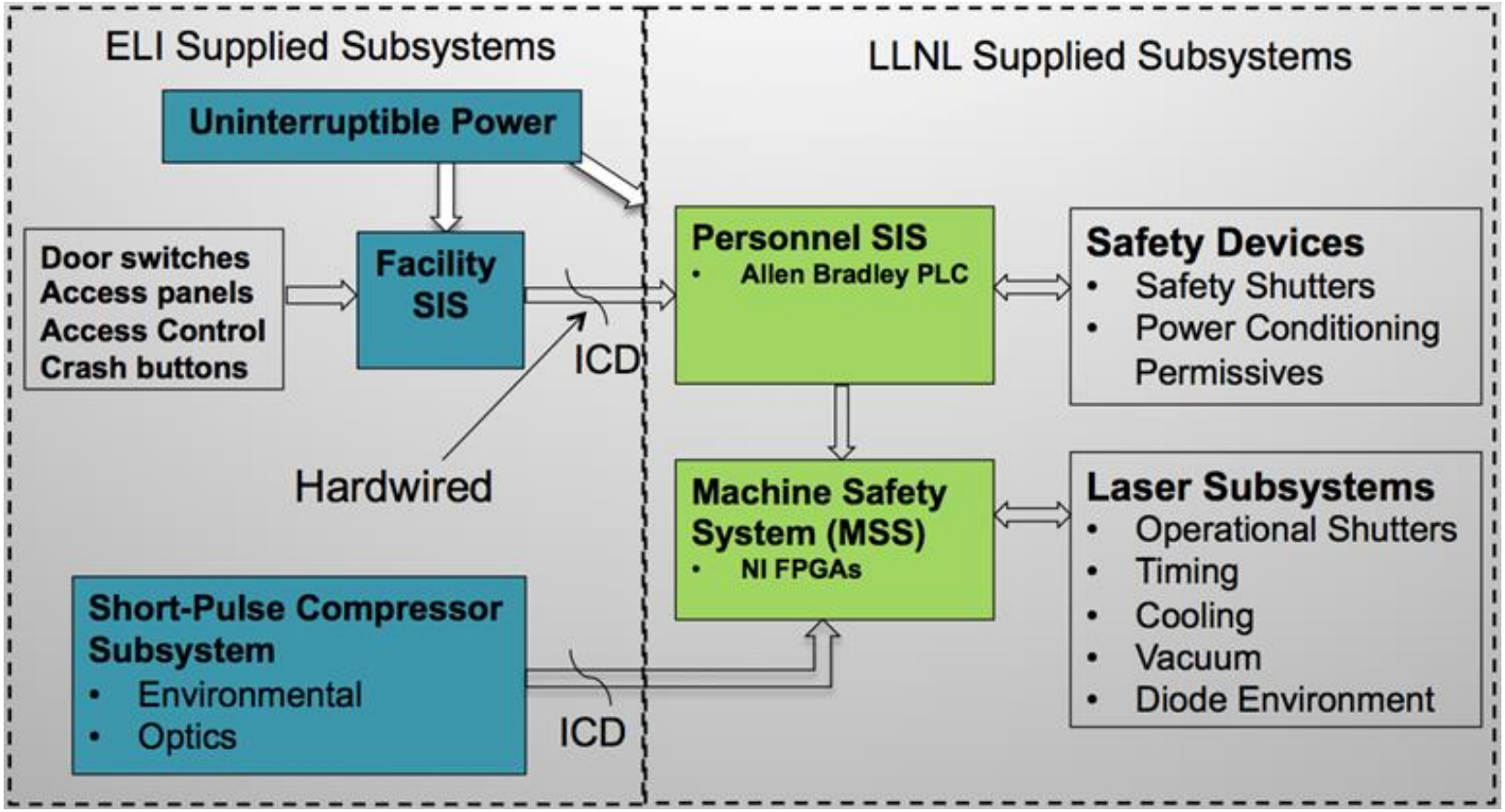


Data archive has 3 layer system of data logging with periodic summary data and full fidelity when appropriate



- Data Logger
  Periodic summary data in long term DB archive/warehouse
- Forensic Logger
  Full fidelity data for 30s in rolling buffer
- Commissioning Logger
  Full fidelity data for >60min on local hard disk

Safety Interlock Systems interface from the L3 laser to the ELI Beamlines Facility Systems



Summary

ELI-Beamlines L3-HAPLS laser is scheduled to be fully commissioned at LLNL in late 2016 and shipped to Prague and then re-commissioned in 2017

- 1 PW 10 Hz short-pulse laser

Control System Status

- Currently operational
  - Pump laser system
- In development
  - Short pulse laser system
  - Automation layer

Many thanks to the controls and laser systems team in both the USA and Czech Republic that made this work possible

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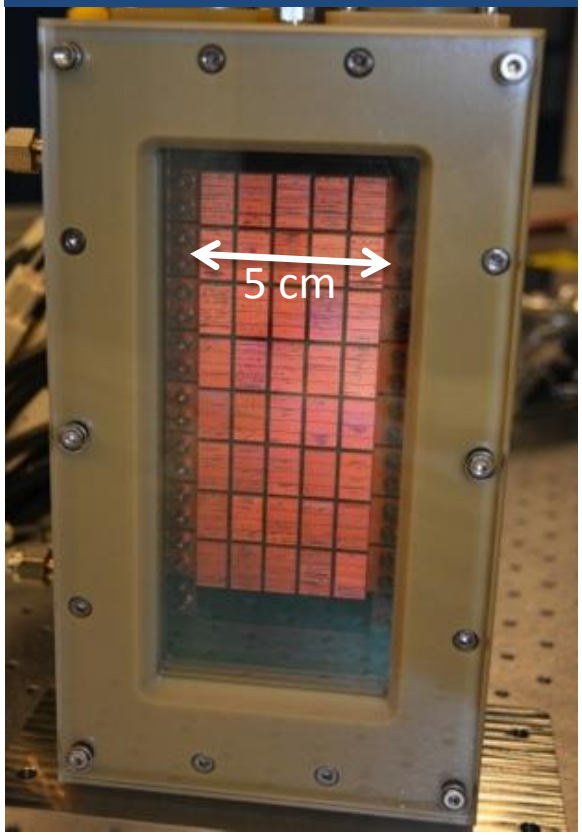
Diode laser array technology enhances repetition rate and laser energy efficiency in a compact package

Flashlamps

1,000 MW white light

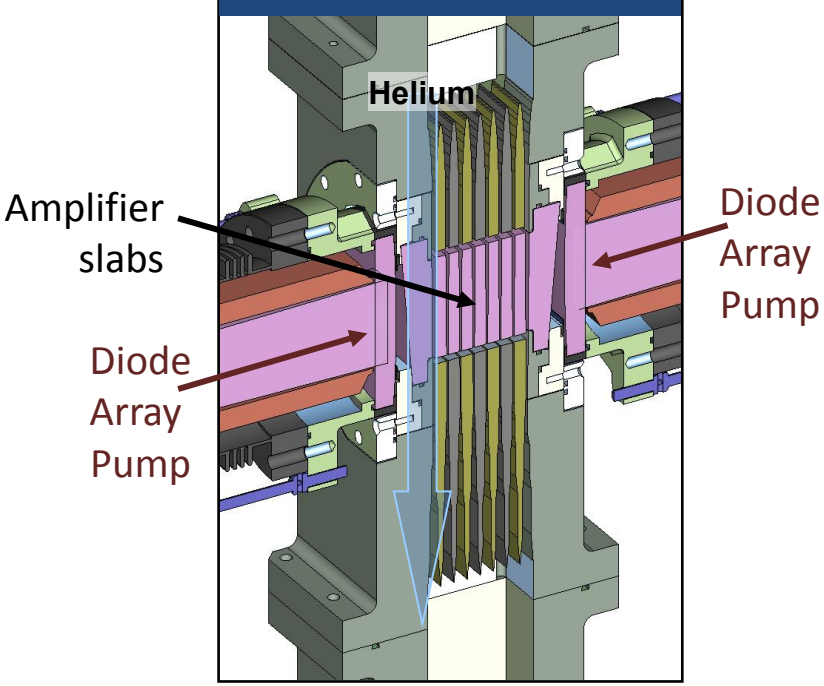
Diodes



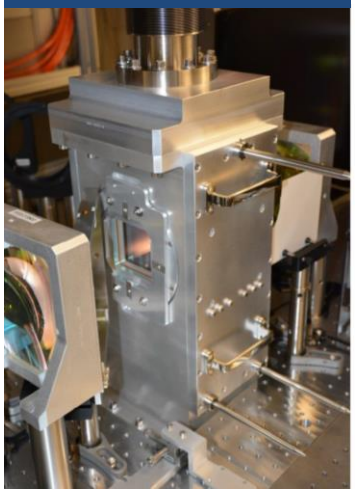
800kW monochromatic light

Laser slabs are cooled by rapidly flowing He gas

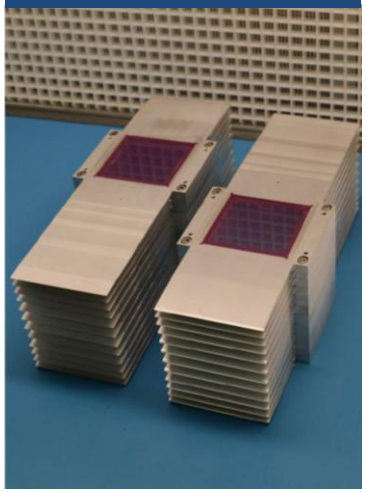
Gas Cooled Amplifier Prototype



HAPLS Amplifier head assembly



HAPLS slabs and vanes



Details:

- Face cooled Nd:Glass slabs
- Helium gas coolant (low dn/dT)
- Gas acceleration vanes Mach 0.1
- Gas Reynolds number 7,000
- ASE Edge claddings

This amplifier design was prototyped and is now operational on HAPLS production laser system