Rapid Software Prototyping into Large Scale Control Systems

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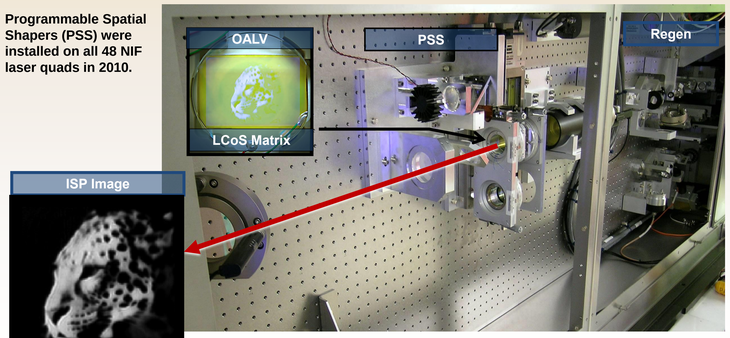
Abstract

The programmable spatial shaper (PSS) within the National Ignition Facility (NIF) reduces energy on isolated optic flaws in order to lower the optics maintenance costs. This is accomplished by using a closed-loop system for determining the optimal liquid-crystal-based spatial light pattern for beamshaping and placement of variable transmission blockers. A stand-alone prototype was developed and successfully run in a lab environment as well as on a single quad of NIF lasers following a temporary hardware reconfiguration required to support the test. Several challenges existed in directly integrating the C-based PSS engine written by an independent team into the Integrated Computer Control System (ICCS) for proof on concept on all 48 NIF laser quads. ICCS is a large-scale data-driven distributed control system written primarily in Java using CORBA to interact with +60K control points. The project plan and software design needed to specifically address the engine interface specification, configuration management, reversion plan for the existing 0% transmission blocker capability, and a multi-phase integration and demonstration schedule.

The Technology

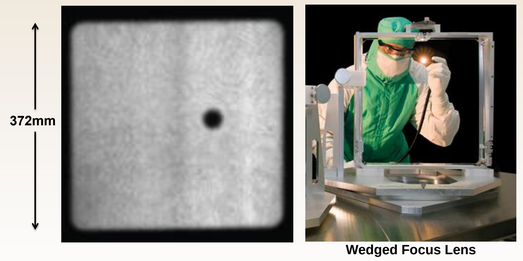
Programmable Spatial Shapers (PSS) were installed on all 48 NIF laser quads in 2010.



Projecting the Liquid Crystal on Silicon (LCoS) display with 470nm light onto the photoconductive layer of the Optically Addressable Light Valve (OALV) spatially modifies the polarization of the beam which, after a downstream polarizer is manifested as an amplitude pattern.

Current Use

Blockers shadow isolated flaws on NIF's final optics from high fluence.



Wedged Focus Lens

Opaque blockers allow NIF to continue operating even with optic flaws present. This allows optics to replaced and/or refinished at opportune times during NIF's operational schedule.

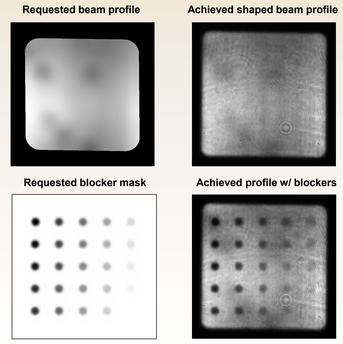
Goals

Arbitrary Beamshaping

- Corrects "hot spots" in beam profiles limiting performance due to final optic intensity/fluence restrictions
- Potential increase of 5-15% peak power

Grey Blockers

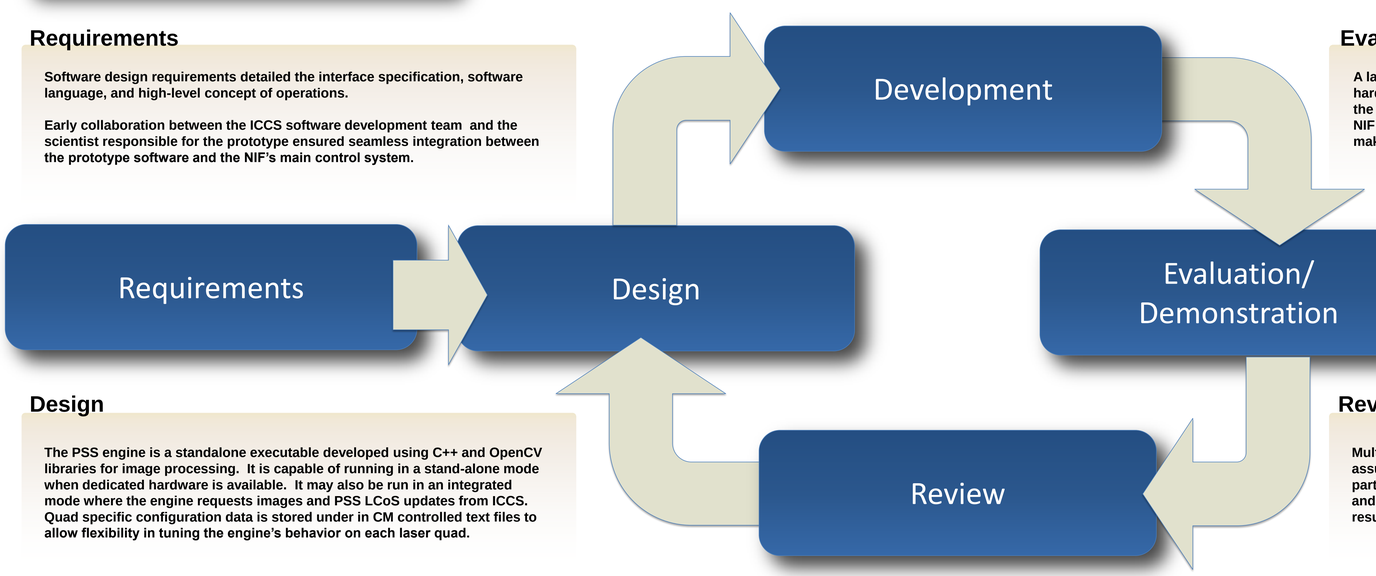
- Adjustable transmission levels for conditioning out blocker 'shadows'
- Recovers some energy lost to unnecessarily opaque blockers



Requirements

Software design requirements detailed the interface specification, software language, and high-level concept of operations.

Early collaboration between the ICCS software development team and the scientist responsible for the prototype ensured seamless integration between the prototype software and the NIF's main control system.



Evaluation/Demonstration

A lab environment provided the necessary NIF camera, PSS, and regen laser hardware to perform an initial proof of concept of the PSS engine. Afterwards the prototype was successfully installed and tested on a single production NIF laser quad. This was a necessary proof-of-concept step required before making investment in integrating the final system with ICCS.

ICCS Integration

ICCS was responsible for starting a new instance of the PSS engine for each shaping and/or blocker placement session. Communication between ICCS and the engine is accomplished via standard in, out, and error streams. Images are transferred over a shared file system as TIFF or PNG files, both lossless image formats. Integration testing was conducted on emulated and real hardware in offline lab environments.

Design

The PSS engine is a standalone executable developed using C++ and OpenCV libraries for image processing. It is capable of running in a stand-alone mode when dedicated hardware is available. It may also be run in an integrated mode where the engine requests images and PSS LCoS updates from ICCS. Quad specific configuration data is stored under in CM controlled text files to allow flexibility in tuning the engine's behavior on each laser quad.

Reviews

Multiple reviews in different phases of the project played a major role in assuring quality. Various stakeholders and subject matter experts participated in reviews for requirements, interface specification, failure modes and effects (FMEA), system design, code design, code, test procedures, results, etc.

Commissioning

The initial commissioning plan specifies the gradual increase of spatial shaping and grey blocker functionality with increasing energy levels. Initial experiments will be limited to rod shots and low energy system shots terminating prior to reaching NIF's final optics. Laser light on the high valued final optic assembly will be avoided until there is 100% confidence in the software's operation.

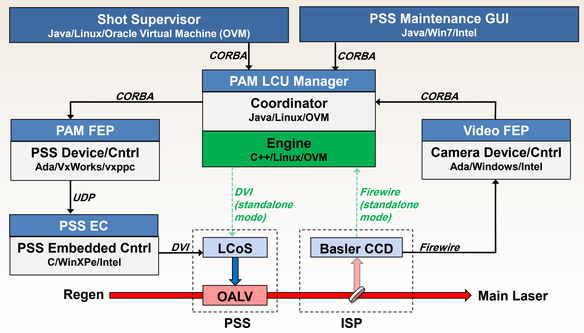
Challenges

There were several challenges identified during the requirements phase and prototype development cycle. These challenges emphasized the need for rapid turnaround of software changes, including a means to perform verification.

CHALLENGE	OALV Manufacturing Variations	LCoS Flicker Instability	Silicon CCD is a poor absorber at 1053nm. Unabsorbed light is results in a background glow (~5% level)	Precision registration between LCoS and ISP	Independent filtering of shaping (strong filter) and blockers (nearly unfiltered)	Drift (LED, LCoS)	ICCS Integration
SOLUTION	Mitigated with closed loop feedback design in engine	Mitigated with half-toned patterns for grey blockers	Measure blur function and use it to deconvolve recorded images prior to processing	Achieved with affine transform matrix	Decoupled strategy in software design. Shaping performed in initial loop with strong filter. Blockers with sharper features then superimposed in subsequent loop	OALV optimized prior to shot cycle. Time between shaping and system shot countdown is minimized	File system I/O for transferring LCoS and ISP images. Standard system I/O streams used for communication

System Design

Loose coupling of the PSS engine from ICCS allowed for autonomous software updates and testing.



Conclusions

- ✓ Grey blockers and spatial shaping commencing the commissioning phase within NIF
- ✓ Early agreement on the interface specification and high-level software design requirements in ensuring a smooth integration process
- ✓ Loose coupling between the prototype and control system allowed for rapid independent software changes in the PSS engine
- ✓ To ensure adequate long-term support by the control system development team, a migration plan is necessary to convert the engine to ICCS coding and design standards.
- ✓ Rigorous high and low level reviews involving stakeholders and subject matter experts ensured high quality in the delivered product
- ✓ This prototyping development model is being considered for new diagnostics enhancements planned for NIF

Acknowledgements

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