Autonomous Monitoring of Control Hardware to Predict Off-normal Conditions using NIF Automatic Alignment System

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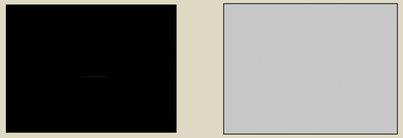
Abstract

The National Ignition Facility (NIF) is a high power laser system capable of supporting high energy density experimentation as a user facility for the next 30 years. In order to maximize the facility availability, we are introducing preventive maintenance enhancements into the system. An example of this is a camera based health monitoring system, integrated into the automated alignment system, which provides an opportunity to monitor trends in measurements such as average beam intensity, size of the beam, and pixel saturation. The monitoring system will generate alerts based on observed trends in measurements to allow scheduled pro-active maintenance before regular off-normal detection stops system operations requiring unscheduled intervention.

2000: Simple Integrity Checks: Gen I

Simple black/white check: The original goal of automated alignment was to align the laser beams, using available alignment images regardless of quality. The challenge was to make the image processing robust enough to deal with any situation.

Measurement for off-normal



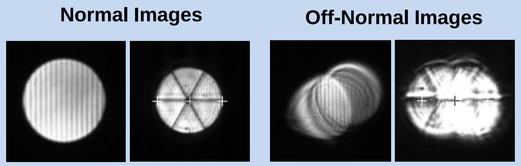
Limitations: Simple binary checks based on absence or presence of light level, neglects conditions in between

2004: More Complex Integrity Checks: Gen II off-normal processing

Complex Integrity Check: Later, it was found that some of the worst alignment images were indicative of opto-mechanical failure. The goal was then to detect these cases, called off-normal images, and stop the alignment until the operator manually resolved the situation.

During commissioning off-normal images were expected. This gave rise to a commissioning mode, for temporarily disabling the off-normal checks.

- Capability of turning ON/OFF (commissioning mode)
- Configurable off-normal criteria
- Uncertainty measurement



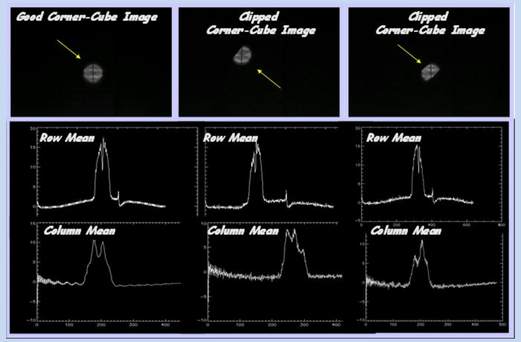
Measurement for off-normal

- Measured Value < Minimum Nominal value

  Example: Light level below a nominal value may indicate the alignment laser source is dying

- Measured Deviation > Tolerance

  Example: Distance or angle deviation more than tolerance may indicate an opto-mechanical or simply mechanical failure

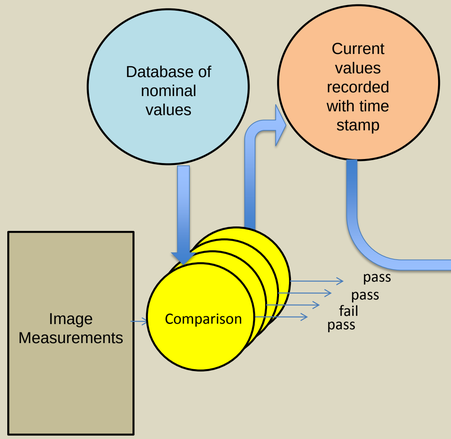


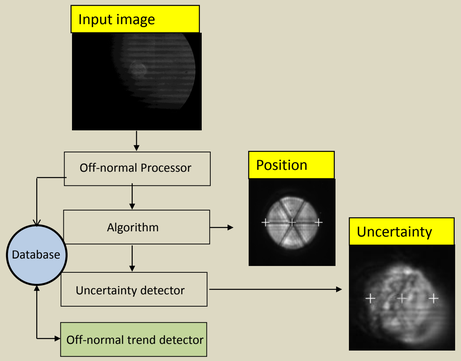
Limitations: Same criterion applied to all beams

2011: Per Beam Off-normal Processing: Gen III

Per beam criteria: The limitations of uniform off-normal criteria is overcome by making off-normal test based on beam dependent nominal value based database.

- Configurable criteria per beam lines.
- Data base of nominal values for all 192 beams.
- Measurements stored in database and compared with the data base of nominal values.

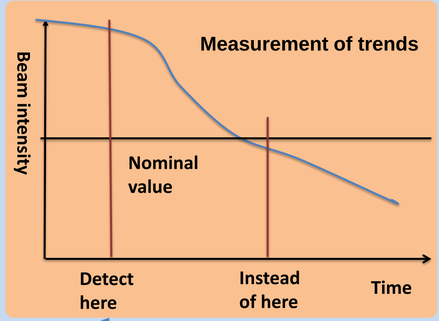




Limitations: Does not provide an early warning

2012: Early Detection of Trends: Gen IV

Enable predictive maintenance: The current work can detect the off-normal early by studying the trend of the image measurements over time.



Benefits of predictive monitoring

- Increase availability
- Avoid failure before it happens
- Better system monitoring
- Planned maintenance/minimize investigation/analysis time

Types of predictive monitoring

- Measure trends in key beam parameter measurements
- Each trend characterized to determine the threshold for generating alert
- Action taken based on the alert
  - changing light sources
  - correcting off-normal situations

Conclusion

- As NIF moves into the mode of a user facility, we need to employ all system measurements data to track the health of the laser system.
- The concept can be extended to new major nuclear power plants, mining and many other similar high risk, high payoff, high consequence situation where camera (or any other sensor) based system can be used to perform predictive monitoring.

Automatic Alignment Process

Automatic alignment uses video images of laser beams to perform alignment. Every alignment images goes through three step process: off-normal processing, position detection algorithm and uncertainty detector.

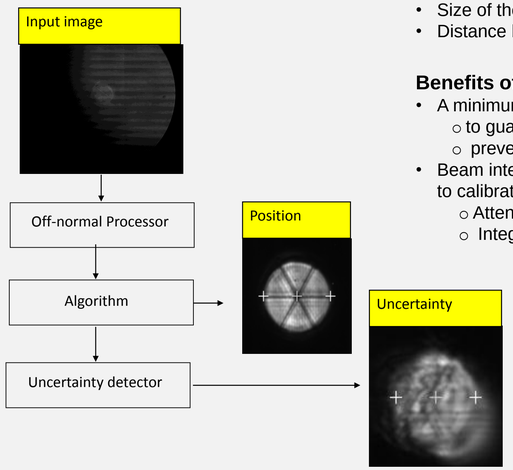


Image measurements used by alignment algorithm

- Average beam intensity
- Distance between spots
- Maximum intensity
- Minimum intensity
- Size of the beam
- Distance between edges

Benefits of image measurements

- A minimum signal level is required
  - to guarantee position accuracy
  - prevent algorithm failure
- Beam intensity parameters needed to calibrate camera parameter
  - Attenuation
  - Integration time

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NIF