Automated calibration and real-time web-based control interface for fiber lasers

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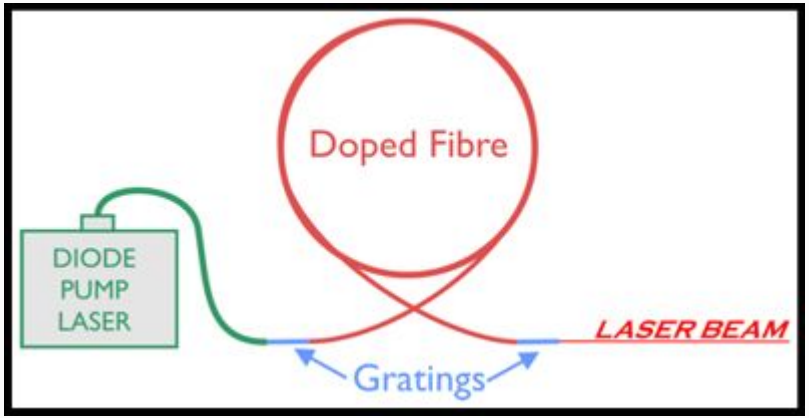
Background: IPG Photonics

- IPG Photonics is the leading developer and manufacturer of high-performance fiber lasers and amplifiers for diverse applications in numerous markets.
- IPG Photonics' diverse lines of low, medium and high-power lasers and amplifiers are used in materials processing, communications, entertainment, medical, biotechnology, scientific and advanced applications. IPG products are displacing traditional technologies in many current applications and enabling new applications for lasers.

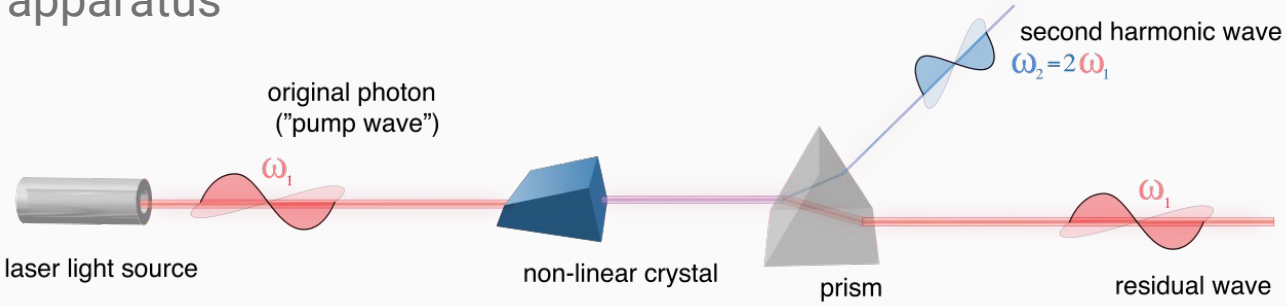
Background: Fiber Lasers

- Diode pumped laser
- Optical fiber gain medium
- IPG: Ytterbium doped fiber



Background: Non-linear optics

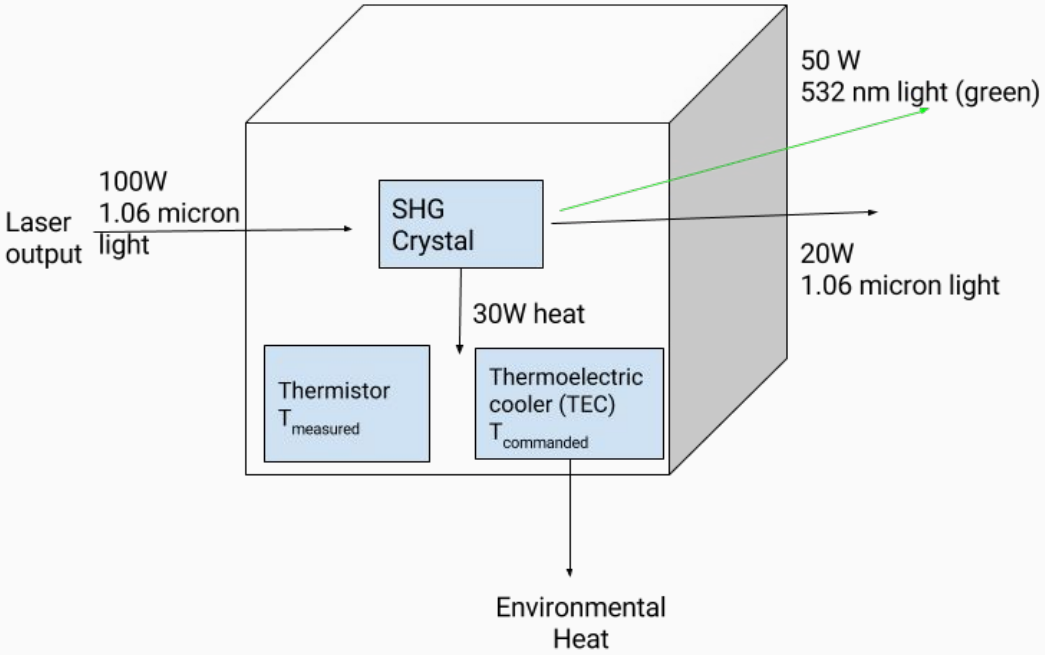
- Second-harmonic generation (SHG) crystals
  - Halves output wavelength, used to generate green colored light (1.06 microns * ½ = 530 nm)
- Optical apparatus



Background: SHG Apparatus

- SHG crystal index of refraction depends on temperature
  - **Temp of SHG crystal is T_{actual}**
- Optical housing for SHG crystal contains thermoelectric cooler (TEC) and thermistor (temperature sensor)
  - **Thermistor temp = $T_{measured}$**
  - **TEC temp = $T_{commanded}$**

Background: SHG Apparatus



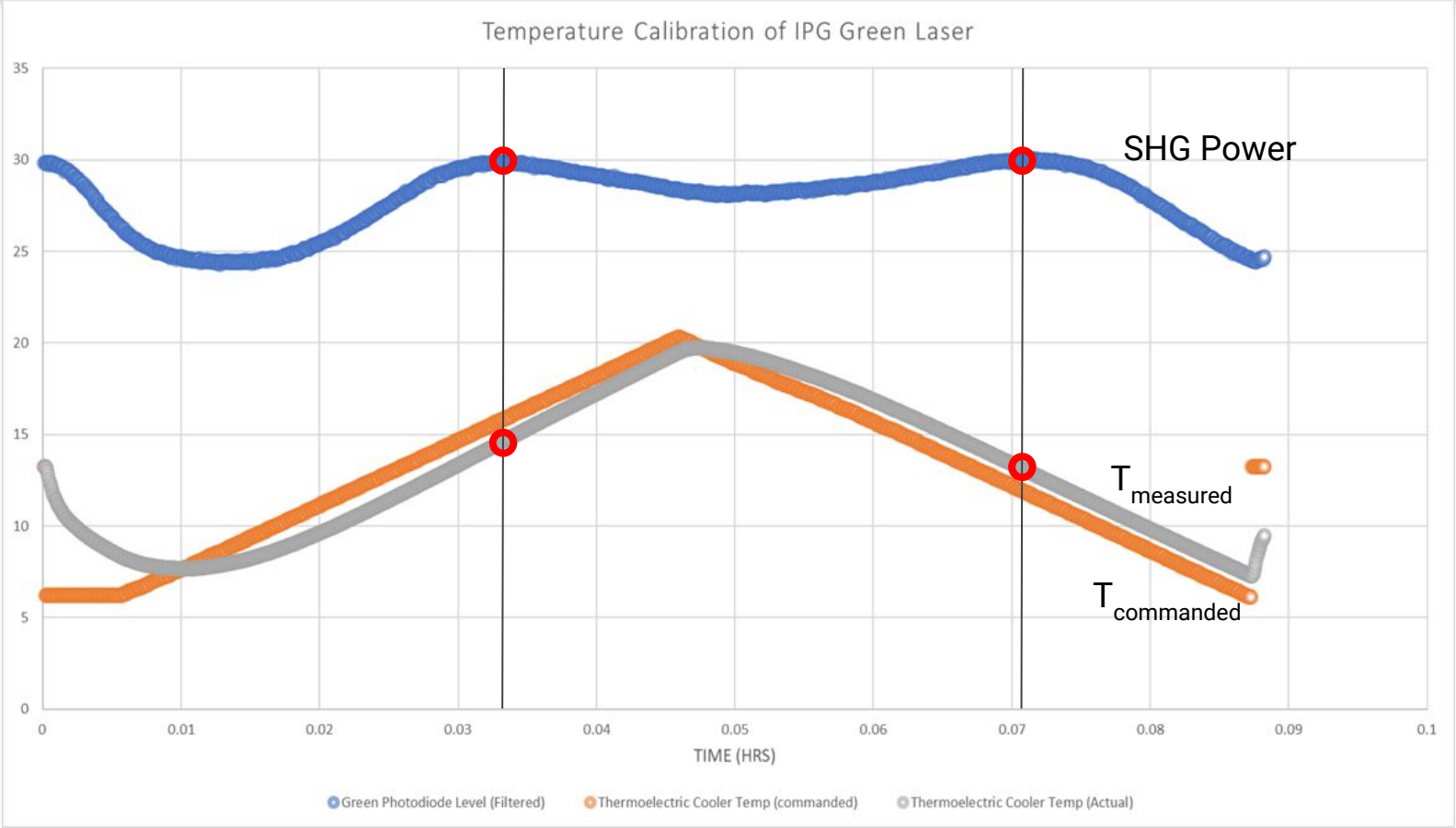
Laser Calibration Process

- **Goal: Find T_{actual} that maximizes second-harmonic output.**
- Assume:
  - $|T_{measured} - T_{actual}| <$ constant
  - Optical input power is fixed

Method:

1. Command TEC to execute heating followed by cooling cycle ($T_{commanded}$)
2. Find maximum SHG power during each cycle
3. Average $T_{measured}$ values corresponding to maxima to find optimal T_{actual}

: $T_{measured}$


Temperature Calibration of IPG Green Laser
35
30
25
20
15
10
5
0
0
0.01
0.02
0.03
0.04
0.05
0.06
0.07
0.08
0.09
0.1
TIME (HRS)
SHG Power
T measured
T commanded
Green Photodiode Level (Filtered)
Thermoelectric Cooler Temp (commanded)
Thermoelectric Cooler Temp (Actual)

Research Question 1

How can we improve current (manual) calibration processes?

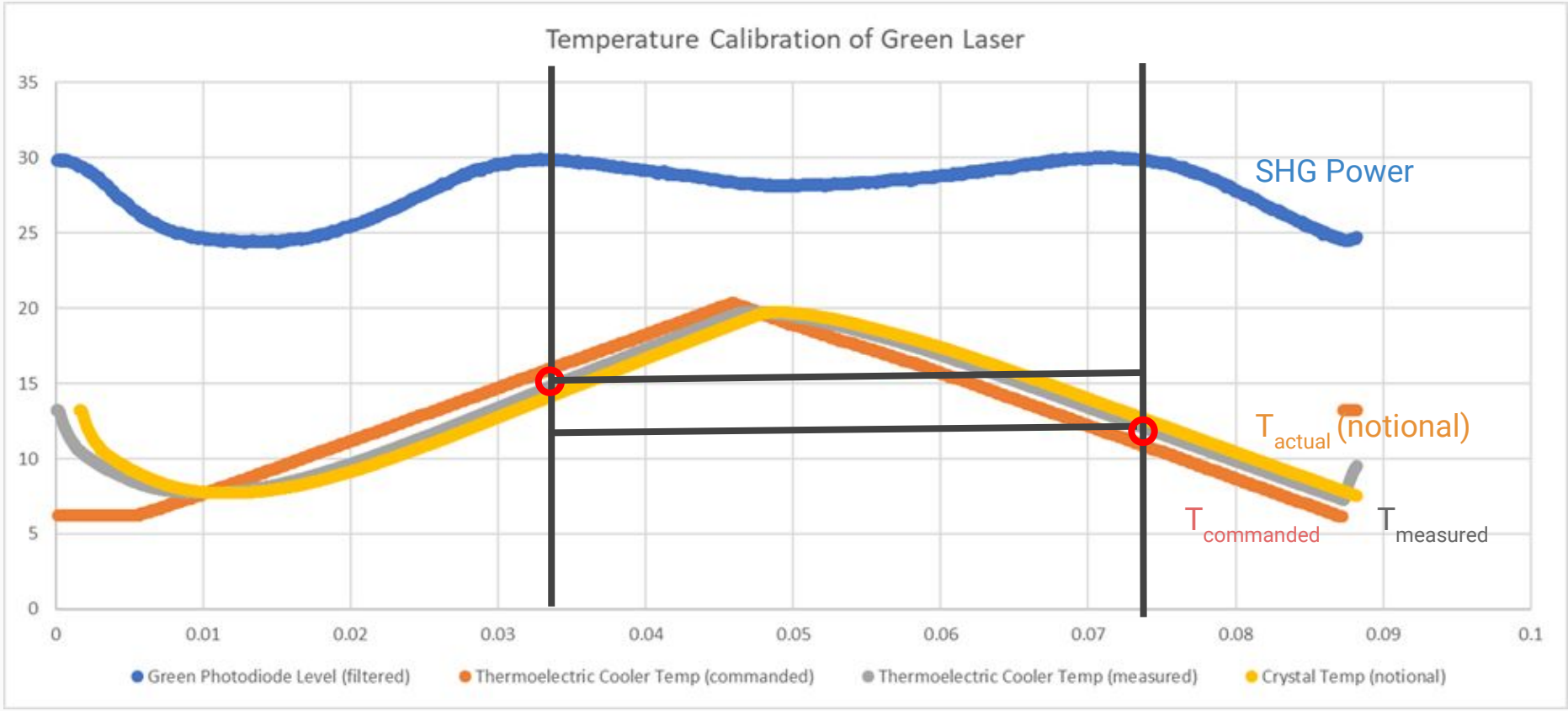
- Labor intensive (~1 hr)
- Poor laser efficiency (optimal T_{actual} poorly identified)

Automated Calibration

Same process, but automated

1. Find the two local maxima of SHG power output
   a. Curve fitting or standard deviation
2. Correlate each maximum to the corresponding $T_{measured}$
3. Average the two $T_{measured}$ where power is maximized to find T_{actual}

: $T_{measured}$


Temperature Calibration of Green Laser
35
30
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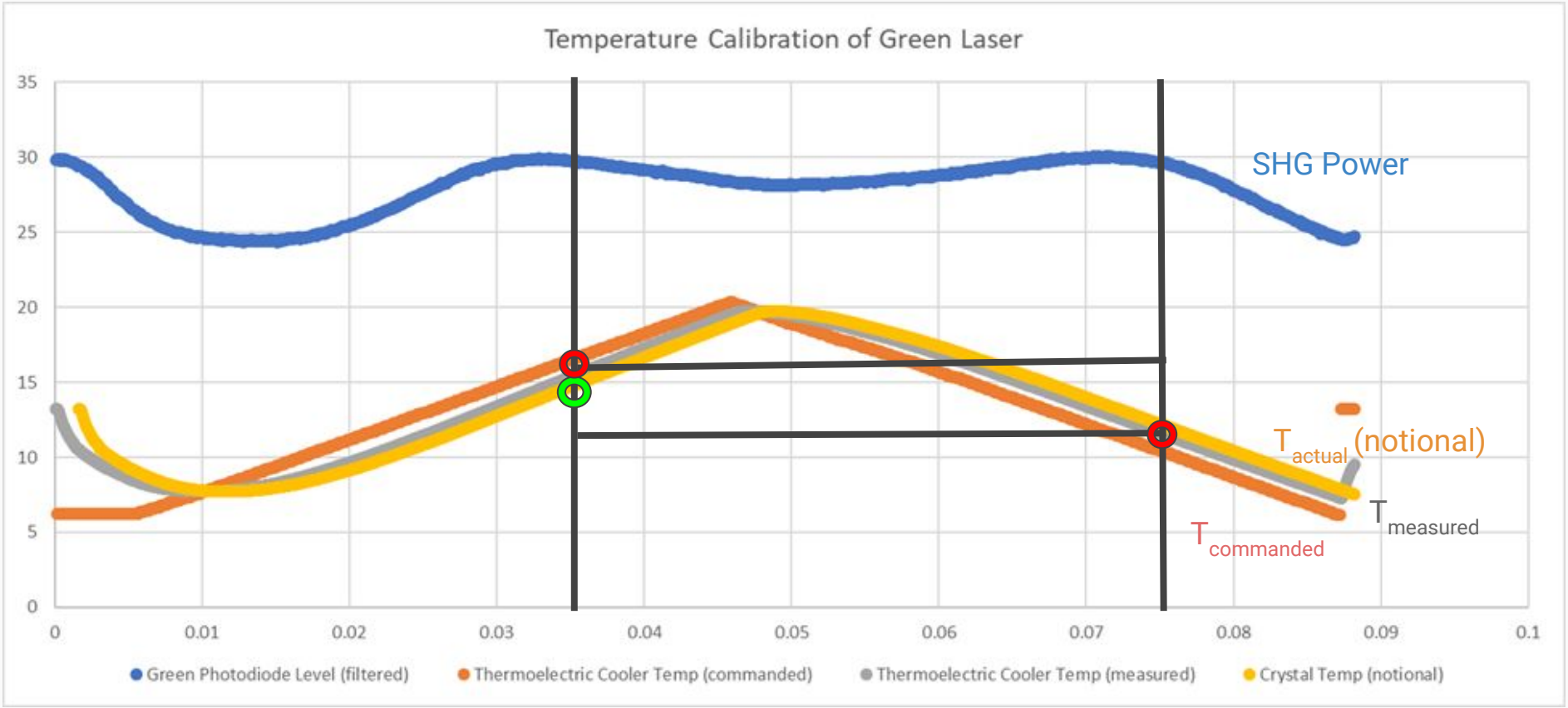
20
15
10
5
0
0
0.01
0.02
0.03
0.04
0.05
0.06
0.07
0.08
0.09
0.1
SHG Power
T actual (notional)
T commanded
T measured
Green Photodiode Level (filtered)
Thermoelectric Cooler Temp (commanded)
Thermoelectric Cooler Temp (measured)
Crystal Temp (notional)

: T_{actual}, the midpoint of the two $T_{measured}$: $T_{measured}$



Data Processing

How do we find the local maxima accurately?

- Curve Fitting
  - Least Square Fit (Regression)
  - Functions as Noise Reduction
  - Choosing domain
- Standard Deviation
  - if (y_{curr} - y_{max} > $k \cdot$ standard deviation) $y_{max} = y_{curr}$
  - k determined experimentally

Applications in Industry

Cinema Projectors

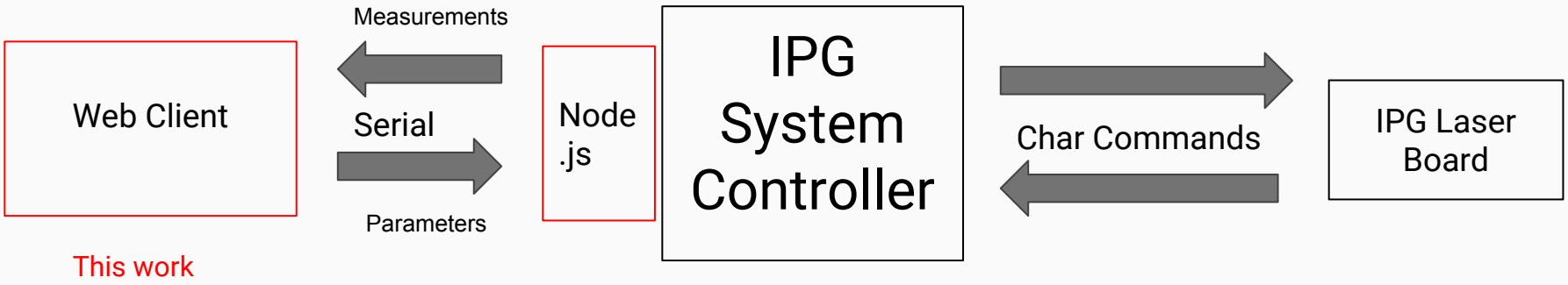
- Currently in use in NEC laser projectors
- Chicago

Research Question 2

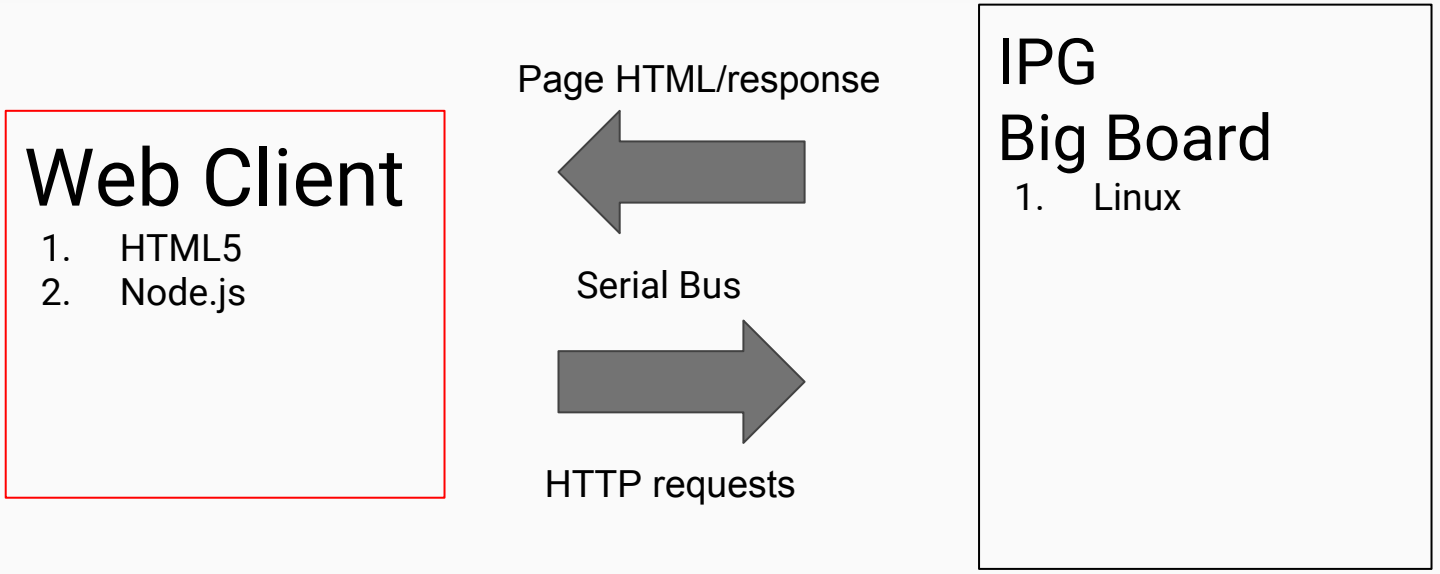
How can we design a web-based real time interface to simplify laser development?

- Restarts required
- No Real-time data collection
- Calibration separated

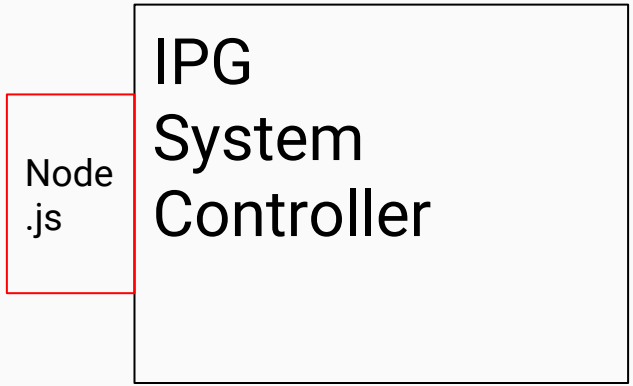
Real-Time Web Interface



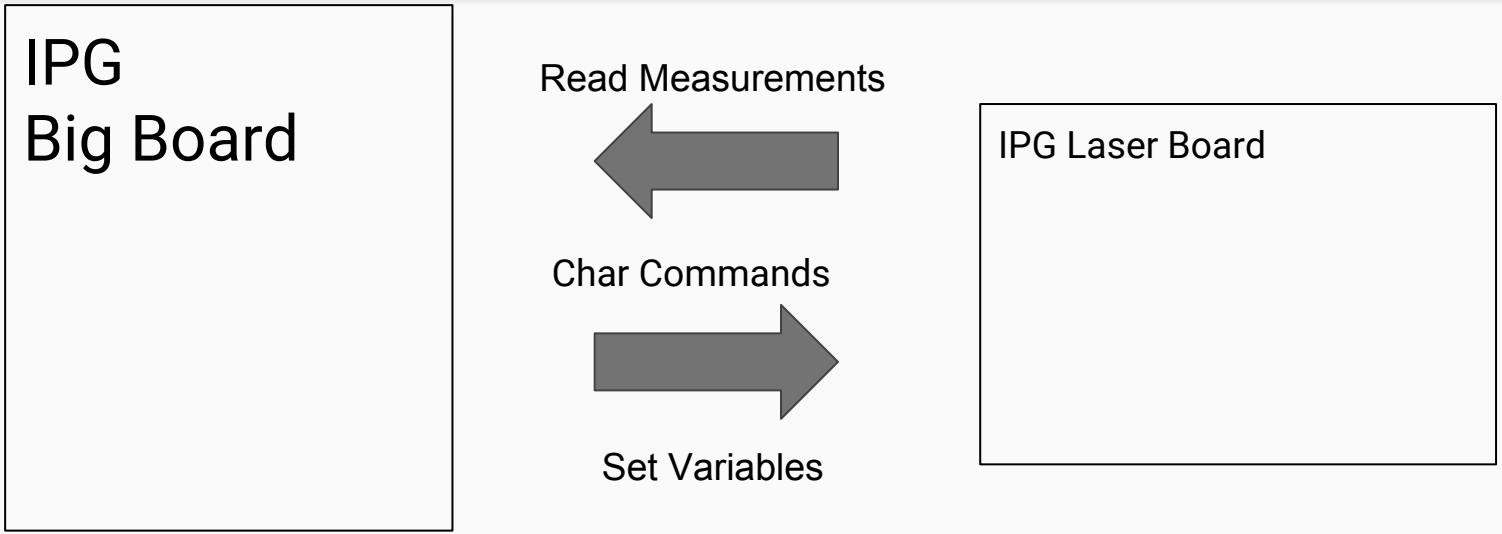
External Client Side



Main Control Loop



Laser Controller Side



Short Term Plans

- Regression Modeler
- Node Addons / C-bindings
- Investigate BeagleBone

Works Cited

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