Advanced Methods of Klystron Phasing

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Method 1: Extremum-Seeking

This process is noninvasive and modifies the phases of multiple klystrons at once using extremum seeking methods.

- Created EPICS simulations of each individual klystron and its beam energy contribution and of the total beam energy gain calculated by summing all klystrons’ contributions.
- Created a MATLAB program implements the Update Law, as shown below, in order to iteratively modify the phases of each klystron simultaneously until the total beam energy is maximized.

The Update Law:
\[ p_i(t+1) = p_i(t) - \Delta \hat{a}_i \sqrt{\hat{a}_i^2 + \cos(\pi) \hat{d}_i^2 + kC(t)} \]

\( p_i \) correspond to the phase of each klystron and \( C(t) \) is the value which is maximized (total beam energy), while the other parameters determine the quality (speed, noise, etc.) of convergence.

Further discussion of can be found in Alexander Scheinberg’s Nuclear Instruments and Methods in Physics Research A

Results:

- Program assumes random initial phases with each run; the two plots correspond to two different program runs.
- Data converges consistently with each run in an average of ten minutes.

Method 2: Fast-Phase Scans

This process uses a MATLAB program to collect numerous and robust data points instantaneously as the phase shifter moves.

- Modified and analyzed fast phase scan MATLAB program.
- Ran program to scan phases for multiple klystrons.
- Compared phase data to original scans to determine accuracy.

Results:

- Above is one of the comparison plots of one klystron’s fast and slow phase data
- New data includes numerous data points, is more robust, and is consistent and accurate.
- New data does not include the same inconsistencies as original scan.
- New data does include data bunches which indicate a pause in hardware. Such phenomena requires further exploration into the marriage of hardware and software. Eliminating the hardware pauses will allow scans to run in 23 seconds.

Conclusion

Both methods 1 and 2 offer significant improvements in klystron phasing. Overall, method 1, extremum seeking, is the most successful of the methods as it supplies a solution for each problem involving the original phase method. This method is especially applicable for LCLS II because increasing the number of parameters (phase data information per klystron) does not affect phasing speed. Future work for this project includes further research and documentation of the hardware behind the phase shifters of both LCLS I and LCLS II and creating MATLAB GUI(s) in order to make these methods more applicable and user-friendly.

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