Phaser

Software Requirements Specification

Version 3.1

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# Revision History

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| --- | --- | --- | --- |
| **Date** | **Version** | **Description** | **Author** |
| 2012-06-05 | 1.0 | Initial draft pulled together from 1995 SRS, Krest Wiki, reverse engineering existing code, and discussions with stakeholders | Ryan Slominski |
| 2012-06-07 | 1.1 | Incorporated feedback from Chris Slominski | Ryan Slominski |
| 2012-06-08 | 1.2 | Incorporated feedback from Jay Benesch, Chris Slominski | Ryan Slominski |
| 2012-06-11 | 2.0 | Incorporated feedback from stakeholder meeting | Ryan Slominski |
| 2012-07-25 | 2.1 | Cleaned up for entry in Jira | Ryan Slominski |
| 2014-07-22 | 3.0 | Project split into two pieces; renamed to Phaser. | Ryan Slominski |
| 2016-03-18 | 3.1 | Continuous running and incremental correction now experimental only; added support for applying corrections after all measurements are taken | Ryan Slominski |

# Introduction

## Overview

The goal of RF cavity phase angle optimization is to contribute the most amount of energy to the accelerator beam, while maintaining the least amount of energy spread. A long-standing tool for optimizing RF cavity phase named AutoKrest or Krest for short is no longer meeting the needs of Jefferson Lab and will be rewritten as Phaser. The new project will be developed in two parts: A graphical user interface (GUI) client, and a server. The communication protocol between the two parts is defined in the Phaser Client-Server Protocol specification document.

## Method of Operation

The off-crest phase error of a RF cavity can be estimated by analyzing imbalances in relative momentum for symmetric phase changes +/- about the starting phase. The process can be generalized to work on gang phase settings of zones and linacs as well, although this method will be unsupported in Phaser because unless the cavities in a zone or linac drift off phase with the same magnitude and direction gang phase correction may actually do more harm then good. The process can be broken into two main components: The data collection component, referred to as the diagnostic, and the analysis component, referred to as the algorithm. The energy changes are measured by the diagnostic using the beam energy monitor (BEM).

The phase angle change magnitude (kick) must be chosen carefully on a per cavity basis. A fixed kick would generally result in vastly different energy changes among C25, C50, and C100 cavities due to energy differences. Generally, larger kicks will improve phase angle estimate accuracy, but can have a negative impact as follows:

1. May be invasive to the quality of beam delivered to end stations. This level of kicking should only be used when the Phaser procedure is being run in an accepted invasive situation such as beam studies.
2. May cause beam transport problems, causing beam loss due to aperture diameter. This happens when either the change is introduced too quickly for energy lock facilities to appropriately compensate in time, or for the final magnitude of the kick to be beyond the capabilities of the locks.

## Historical Perspective

Krest was originally created in late 1994 by Michael Tiefenback and Kurt Brown. The program was most recently updated by Yves Roblin. The characteristics of Krest which have prompted a rewrite include:

1. Consists of a collection of TCL scripts, AWK scripts and C++ code which can be consolidated
2. Coded for HPUX, which is end-of-life at JLab
3. Code could be more flexible and more easily support future algorithm and diagnostic changes
4. Documentation is sparse
5. There are many enhancements desired:
   1. Visualize what program is doing (phase change, cavity sequence, start time)
   2. Track phasing history (corrected phase)
   3. Run continuously or n times; pause
   4. Report cavities frequently off-crest
   5. Enforce single instance of phasing process that is uninterrupted by operator shift changes

## Customers

Phaser is a tool for accelerator operators.

## Impact

Phaser modifies the phase settings of cavities. This affects many aspects of beam operations and may prompt the need for executing FudgeIt and LEM. Depending on phase kick and hall tolerance, Phaser may be considered invasive.

## Dependencies

Phaser has a dependency on the EPICS control system and one or more diagnostics, such as the energy lock system or the fast feedback system.

## Scope

Phaser operates only on individual cavities. Injector cavities and zones will be supported, though it is understood Operations may choose to phase the Injector manually and may even purposely run off-crest.

Changes in individual cavity energies as a result of Phaser may lead to a scenario where energy locks are no longer able to maintain the desired machine energy (i.e. they become railed). In this case it is up to operators to correct the machine state (generally they’ll run FudgeIt and LEM at a time when beam delivery can be interrupted). However, Phaser must detect this scenario and cannot phase during this machine state as described below in the requirements.

## Bibliography

1. Software Requirements for AutoKrest – M. G. Tiefenback and K. Brown (1995)
2. [Automated RF Cresting at CEBAF - M. G. Tiefenback and K. Brown (1996)](https://jlabdoc.jlab.org/docushare/dsweb/Get/Document-31578/96-020.pdf)
3. Runtime Accelerator Configuration Tools at Jefferson Laboratory – M. G. Tiefenback, L. Doolittle, and J. F. Benesch (1997)
4. [Beam-Based Phase Monitoring and Gradient Calibration of Jefferson Laboratory RF Systems - M. G. Tiefenback and K. Brown (1997)](http://www.jlab.org/div_dept/admin/publications/papers/97/ACT97-07.pdf)
5. [Krest on TWiki - M. Joyce, others (accessed 2012)](https://devweb.acc.jlab.org/twiki/bin/view/AHLA/Krest)
6. Krest data directory at /cs/opshome/hlaps/krest
7. Krest source in CSUE project krestv2

# Specific Requirements

## Functional

### Core

1. The system shall operate on jobs
2. The system shall process only one job at a time
3. A job is specified with the following attributes:
   1. An ordered set of cavities
   2. Initial maximum phase angle error (degrees)
   3. Initial maximum momentum error (dp/p)
   4. Number of samples per kick
   5. Continuous or run-once option [Experimental Only]
   6. Incrementally Correct or measure-only option [Experimental Only]
4. The system shall Phase sequentially one cavity at a time from an ordered set of cavities recording the measured phase angle error into the database
5. The system shall skip control system bypassed cavities and cavities at GSET=0
6. The system shall operate in one of two user selectable loop modes:
   1. Continuous - Phase the specified cavities in a loop until a user interrupts [Experimental Only]
   2. Run Once – Phase the specified cavities once
7. The system shall operate in one of two user selectable correction modes:
   1. Incrementally Correct – corrections are calculated and applied as each cavity is encountered [Experimental Only]
   2. Measure - corrections are measured / calculated but not applied (corrections can be applied all-at-once later or measurements can be used purely for diagnostics)
8. The system shall allow phasing to be stopped: phasing of the current cavity is terminated, the starting phase is restored, and the working set of cavities is cleared
9. The system shall allow phasing to be paused: phasing of the current cavity is terminated, the starting phase is restored, and the set index position is saved for future use
10. The system shall allow resuming phasing after being paused; the cavity being phased during abrupt pause is restarted from scratch on resume
11. The system shall maintain a history of phasing activity on each cavity, which should include:
    1. Cavity name
    2. Cavity phasing start time
    3. Cavity phasing end time (or duration)
    4. Phase angle error (degrees)
    5. Phase angle (degrees)
    6. Outcome (CORRECTED, MEASURED, BYPASSED, SKIPPED, ERROR)
    7. Correction date
    8. Correction Error Message (in case of error applying correction – but not measuring error as those retry indefinitely)
12. The system shall allow Operators to apply the measured phase angle error corrections stored in the database to the control system in batch at a point in time after all measurements have been taken (allowing Operators to be good and ready to perform LEM, FudgeIt, etc).
13. The system shall execute as a background procedure, not tied to a particular operator or login
14. The system shall assist operators in assuring that a single instance is executing in the control system at one time
15. The system shall expect error conditions; phase measurements should retry indefinately until an operator intervenes, but status messages should be displayed on the interface

### Server - Algorithm and Diagnostic

1. The algorithm shall compute the cavity phase kick based on maximum phase angle error in such a way as to maximize phase angle estimate accuracy, while maintaining integrity of the control system and physics delivery
2. The diagnostic shall take an average of several energy samples to estimate the energy change instigated by each phase kick; the number of samples will be chosen such that the energy estimate meets an algorithmic error tolerance
3. The diagnostic shall report whether it is functioning properly (raise error condition)
4. The diagnostic shall monitor the energy lock (north linac) or fast feedback system (south linac) and report whether it is functioning properly (note: regardless of whether the energy lock / fast feedback system is being used to gather data it must be functioning properly else perturbations will be uncompensated)
5. The diagnostic shall take reasonable steps to detect if measurements are compromised by control system sources outside of Phaser and raise an exception if detected

### Client - User Interface

1. The user interface shall inform the user of the progress by indicating:
   1. Server Status (IDLE, WORKING, PAUSED, ERROR RETRY WAIT)
   2. Start time of machine phasing
   3. Machine phasing loop number
   4. Name of current cavity being phased
   5. Start time of phasing of current cavity
2. The user interface shall allow specification of the following configuration when a phasing operation is requested:
   1. Correction mode (Correct vs Measure only)
   2. Loop mode (Continuous vs run-once)
   3. Maximum phase angle error – Determines invasiveness and accuracy
   4. Maximum momentum error
   5. Number of kicks per sample
   6. Set of cavities to phase
3. The user interface shall report the configuration that the user specified upon requesting the Phase operation
4. The user interface shall allow inspection of the phasing history database
5. The user interface shall allow users to start, stop, resume, and pause the Phaser process; the action a user is allowed depends on the state of the program; start only when IDLE, stop and pause only when WORKING, and resume only when PAUSED

## Non-Functional

### Usability

The monitoring and control program will be used by MCC control room operators, and must be designed consistent with tools with which they are familiar. Any given operator will infrequently use this application, therefore a large learning curve and need to maintain privy knowledge between uses is undesirable. The graphical user interface design will be included in any design review activities for the project. The operator needs to understand that Phaser may be invasive to beam delivery depending on hall tolerance and phase kick. The set of users allowed to operate Phaser will be limited to operators. There will be no practical limit to the number of user interface instances running at one time.

### Reliability

The accuracy of the phase correction must be within two degrees.

### Performance

With a fixed accuracy goal, the time it takes to phase a cavity is proportional to the magnitude of beam energy perturbation allowed by the diagnostic. There are two use cases:

1. Invasive - Maximum perturbation allowed without breaking beam transport, such as during beam studies
2. Non-invasive - Maximum perturbation allowed without disturbing physics delivery

However, the only performance constraint in place is that non-invasive phasing of all cavities in the north and south linac can be completed within 24-hours.

### Supportability

The project must be well documented: The source code must have comments describing each class and each method. In addition a user guide and a design document must be delivered and made easily accessible. In lieu of specific best practices, style guide, and coding conventions the supportability of the project will be strengthened by utilizing the accelerator division certification process.

## Design Constraints

### Environment

The software must run in the accelerator control system environment which is comprised of 32 and 64 bit Intel x86 Red Hat Enterprise Linux (RHEL) 6 machines. The software should be written generally independent of platform to ease transition to future systems such as RHEL 7.

### Algorithm and Diagnostic

The system must be coded such that the choice of diagnostic and algorithm can be easily changed.