LCLS Physics Requirements Document # 1.4 – 003	Undulator	Revision 0

Beam Based Alignment System Requirements

Paul Emma (Author) Signature Date

Steve Milton (Undulator Manager) Signature Date

Heinz-Dieter Nuhn (Undulator Physicist) Signature Date

John Galayda (Project Director) Signature Date

Brief Summary: This document summarizes the undulator system requirements necessary to support successful beam-based alignment of the undulator trajectory..

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Beam-Based Alignment System Requirements

The electron trajectory through the FEL undulator must be straight to a level of about 2 microns over one FEL gain length (~5 m). This level is difficult to achieve using standard component survey methods, and therefore requires a special electron beam-based alignment algorithm which samples undulator BPM readings at three different beam energies (14, 7, and 4.5 GeV).

Detailed simulations have been made which indicate that adequate beam-based alignment can be achieved if specific undulator systems are constructed, and beam stability is within, tight tolerance specifications. Table 1 summarizes these specifications for the most critical parameters, while Fig. 1 shows the simulated *x* and *y* trajectories after 3 passes of the beam-based alignment (BBA) procedure, under the conditions shown in Table 1.

Table 1: Undulator and beam specifications for the most critical parameters (quadrupole magnet gradient is 60 T/m with mean quadrupole spacing of ~3.9-m).

Parameter Description	**Value**	**Unit**
Maximum BPM rms position resolution (*x* and *y*)	1	μm
Quadrupole magnet-mover *x* and *y* positioning repeatability	±2	μm
Initial rms uncorrelated quad and BPM alignment	100	μm
Initial rms correlated quad and BPM alignment	300	μm
Maximum BPM mean and rms calibration error	10, 3	%
Maximum quadrupole mean and rms gradient error	0.3, 0.3	%
Maximum quadrupole-mover mean and rms calibration error	5, 3	%
Maximum random rms undulator pole field errors	0.05	%
Incoming rms shot-to-shot trajectory jitter (% of rms beam size)	<20	%
Maximum uncertainty in knowledge of beam energy	2	%
BPM absolute read-back rms stability over one hour	2	μm
Minimum quadrupole-mover dynamic range	±500	μm
Earth's magnetic field compensated in undulator shimming	<0.05	G

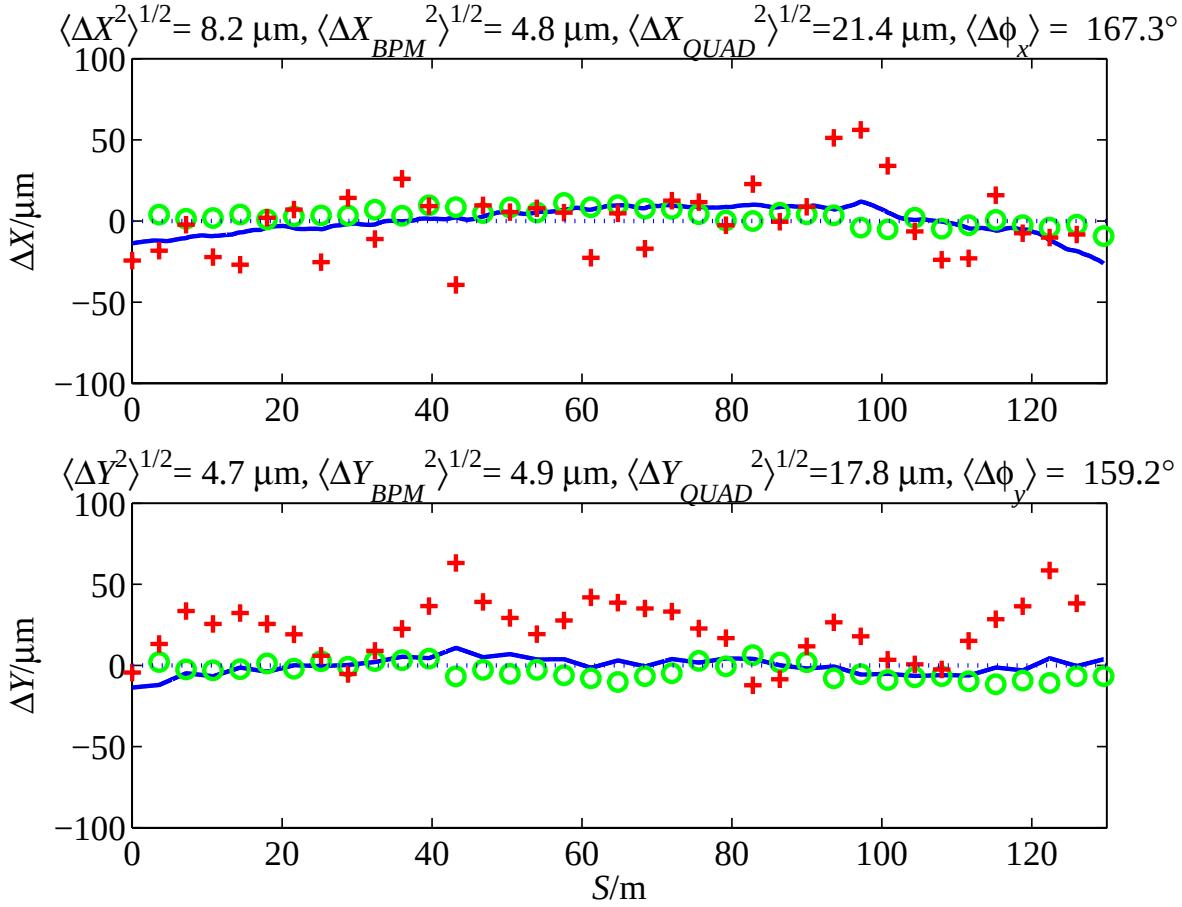

Fig. 1. Electron *x* and *y* trajectories through undulator at 14 GeV after 3 passes of the BBA procedure. The true trajectory is in solid-blue (8.2 μm and 4.7 μm), the BPM read-backs are green-cirlces (4.8 μm and 4.9 μm), and the final quadrupole centers are red-plus-signs (21.4 μm and 17.8 μm). The total phase error at 1.5 Å is <330˚.