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LCLS Undulator Coordinate System

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Abstract

This note defines the LCLS undulator coordinate system and relates that coordinate system to the linear accelerator coordinate system. The slight downward pitch of the SLAC linac and the finite radius of the Earth necessitate some choices and definitions for the undulator layout which is described here. The layout described is consistent with the LCLS optics MAD file "LCLS13APR04".

Introduction

In the SLAC linac, locations on drawings and in CAD parts are conveniently identified relative to a system of about 100 datums called station numbers with 100-ft separations. These are nothing more than a set of regularly spaced points in space on a straight line representing the theoretical Linac beam axis. The beam axis of the linac is not level with respect to gravity and has approximately a 0.5 % slope as explained below. The LCLS electron and photon beamlines will extend almost a kilometer beyond the present day linac, and on the contrary, will be level with respect to gravity at the center of the undulator. Consequently it would not be convenient to describe locations relative to the existing linac based station number system. For this reason we defined a new coordinate system, *rotated* and translated with respect to the origin of the Linac-based coordinate system, for which LCLS components will generally have a constant height coordinate.

1 SLAC Linear Accelerator Coordinate System

The SLAC linear accelerator coordinate system will be used for the LCLS injector and accelerator structures and systems installed in the accelerator enclosure. The origin is at the beginning of the linac and the z axis follows the (straight) beamline. The station number datums are located on this z axis. The current revision of the LCLS component locations in the Linac coordinate system is in a file titled "Symbols EXCEL file", and can be found at URL:

http://www-ssrl.slac.stanford.edu/lcls/linac/optics/LCLS.xls

2 LCLS Undulator Coordinate System

The SLAC accelerator is designed with a downward slope heading eastward, with respect to the local gravity vector, of ϕ_{50} = 5.000000 mrad at station-50 (in the middle of the linac). This downward slope, due to the Earth's curvature, becomes ϕ_{100} = 4.760000 mrad at station-100 [1] in the beam switch yard. Reference 1 gives a table of the slopes along the accelerator every 50 feet; it is derived from a set of three deflections of the vertical using a local sphere of best radius along azimuth $\alpha = 261.45°$. Starting in the 1980's, all alignment computations were based on the Gaussian sphere associated to the Clarke's ellipsoid of 1866 for a latitude of 37º 25' which set R = 6372508.025 m. Note that the station-100 accelerator level is located at a height h = 77.643680 m [2] above mean sea level, and 1.857543 m [3] downbeam of the center of the 50Q1 quadrupole magnet, and 14.325082 m [3] upbeam of the center of the 50Q2 quadrupole magnet.

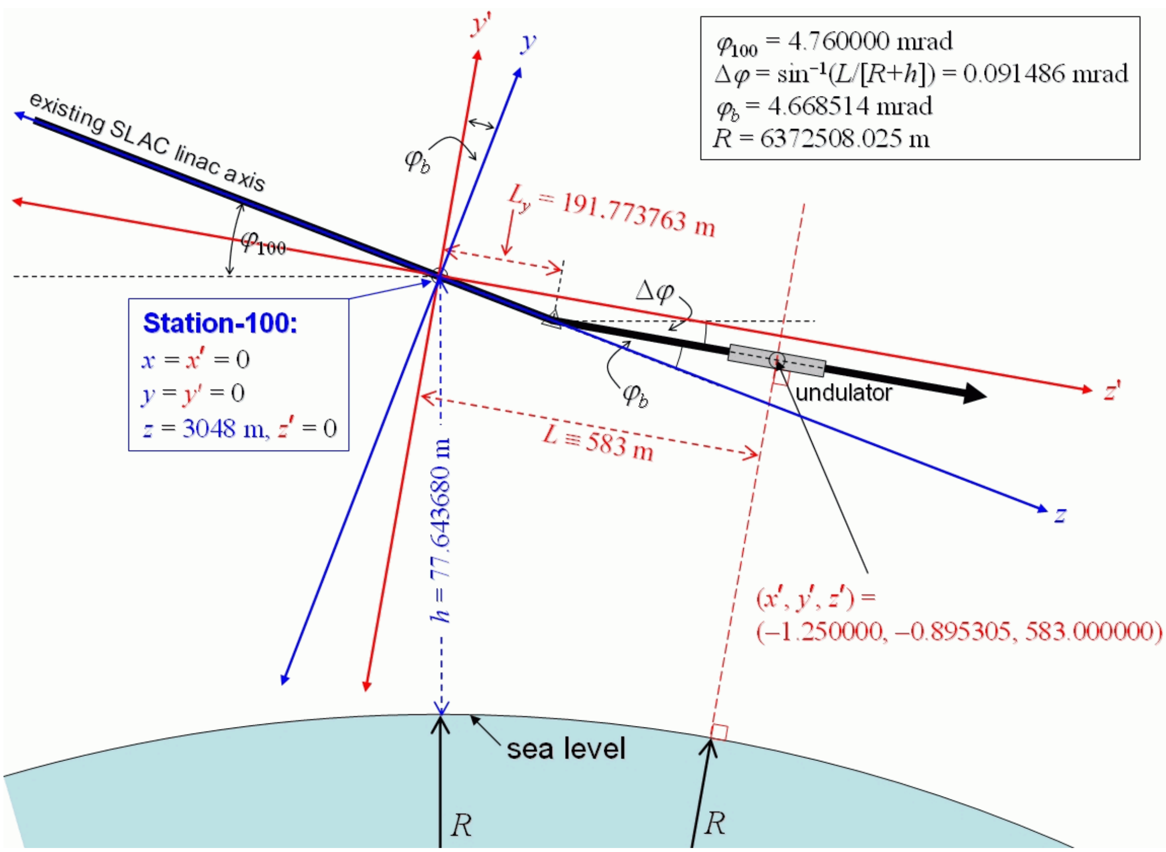

Figure 1: SLAC linac coordinate system (x, y, z), and LCLS undulator system (x', y', z').

In order that the center of the LCLS FEL undulator be level with respect to its local gravity vector, a pair of vertical bending magnets will be located downstream of station-100 in what is the present FFTB enclosure. The center point between these two bends (their effective bend center) is located L_y = 191.773763 m downstream of station-100 [4, 5]. Defining the distance from station-100 to the center of the undulator as exactly $L \equiv 583$ m [4], which is the undulator center [6] rounded to an integer number of meters, this bend pair must then deflect the beamline upward a total angle of $\phi_b = \phi_{100} - \sin^{-1}(L/[R + h])$ = 4.668514 mrad. The layout is depicted in Fig. 1, where the (x, y, z) coordinates (in blue) are established along the existing linac axis (with $z = 3048$ m at station-100 [7]), while the (x', y', z') coordinates (in red) are vertically normal to the Earth's surface under the undulator's (integer) center.

These primed coordinates are rotated with respect to the un-primed coordinates by $\phi_b = 4.668514$ mrad (see Fig. 1), and are the chosen LCLS coordinate system for the beamline downstream of the muon-plug wall (LTU, Undulator, Beam Dump, X-ray optics, Near Hall, and Far Hall). This choice provides non-sloping beamline coordinates for all points downstream of the final vertical bend (BY2), and also generates negative values for the y' coordinates here. For example, the center of the undulator displays a y' coordinate equal to $L_y \tan(-\phi_b) = -0.895305$ m. Note that the x-axis and also the x'-axis (not shown here) are both perpendicular to the respective vertical plane to create a right handed coordinate system with north in the positive x direction. Four horizontal bends in the LTU displace the undulator to the south by $x' = -1.250000$ m, but still parallel to the linac axis. The current revision (LCLS13APR04) of this *undulator* coordinates file, which includes beamline from just upbeam of station-100 to the LCLS dump, is labeled as "LTU EXCEL file" and can be found at URL:

http://www-ssrl.slac.stanford.edu/lcls/linac/optics/LTU-LCLS.xls

3 References and Notes

1. Unpublished note from Geodesy Division, Coast and Geodetic Survey, *Appendix J*, February 26, 1963.
2. Value adopted during SLC installation and used ever since for projects originated in the BSY.
3. This distance is measured along the local beamline.
4. This distance is measured along a line which is parallel to the LCLS FEL undulator (*i.e.*, parallel to the z' axis of Fig. 1).
5. The location of the effective bend center, L_y, determines the height of the undulator with respect to station-100.
6. The definition of the undulator center is the point between the start of the first, and end of the last 3.4-m long undulator segments, a full length which covers 130.342000 m in the present layout (LCLS13APR04).
7. The value of 3048 m is exact and is based on 100 feet of linac length per station number.