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Proposal for the Alignment of the "Loose End"*

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Abstract

The "loose end" of the girder presents an alignment problem because there is no beam based alignment procedure available to position it. The positioning always depends on the fiducialization of the undulator. A direct way to position the "loose end" to the next quadrupole is to measure their fiducials in relation to each other. By spanning a wire over a distance of several girders, each undulator and quadrupole can be measured by reading its distance to the wire with a portable wire sensor. The pitch of a girder can be determined by measuring height differences at different points on the girder. To measure the height differences a portable HLS is used. During the measurements of the portable system the permanent Wire Position Monitor and the permanent HLS are used to monitor the interim movements of the girder. After the initial alignment the position of the "loose end" can be monitored with the permanent systems in relation to the quadrupoles.

Portable wire measurements

A wire is spanned over 6 girders using the space at the long breaks to setup stands for the wire. To measure the position of the wire, capacitive wire sensors (Fogale WPS-2D) are used. Two are setup at the end of the wire to monitor its stability and one "portable" sensor is used for the actual measurements. The portable wire sensor has to be mounted on an extension arm to bridge the distance from the wire to the undulator fiducials. The details of the extension arm interfaces have to be determined. By using the same sensor for all measurements an absolute calibration of the sensor is not necessary. We can measure all fiducials in relation to an unknown line determined by the and parallel to the wire. From the measurements to the quadrupoles we can derive the nominal position of the "loose end". Advancing the wire setup by 3 girders at a time over the entire length of the undulator all loose ends can be determined at least twice.

After all measurements are done the permanent wire position monitoring system can be initialized and used to position the "loose ends" in relation to the neighboring quadrupoles.

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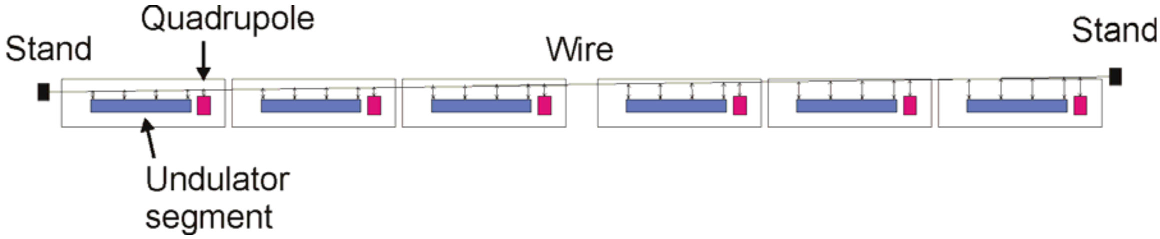

Figure 1 Portable wire measurement setup

Estimation of the uncertainty

The sag of the wire (CuBa wire, diameter 0.14 mm, tension weight 4.5 kg) over a 25 m distance is less than 2 mm allowing measurements in the high precision range of the sensors.

Testing the sensors with the magnetic measurement bench (Kugler) which has a straight trajectory of its carriage horizontally better than 2 μm has shown the potential of the sensor. The readings gave a straight line at the same accuracy level. The main uncertainties in this setup are therefore not the sensor readings but the placement of the sensor with respect to the fiducials and a possible vibration of the wire due to airflow. Single readings result in an uncertainty of 52 μm for the undulator readings, see Table 1. The uncertainty for a quadrupole measurement is 18 μm. By fitting a line to the quadrupole data points the uncertainty of the line is reduced to less than 4 μm at the extremes. The line is fitted to 6 quadrupole data points at the same time with a degree of freedom of 4 therefore the increase in accuracy of the line. The combined uncertainty with which an undulator loose end can be set in respect to the beam line is 52 μm.

Table 1 RMS horizontal positioning

Undulator measurements	
Undulator Fiducials (see PRD 1.4-004-r1)	50 μm
Wire stability	10 μm
Sensor fixture repeatability	10 μm
Sensor readings	2 μm
Single reading uncertainty	52 μm
Quadrupole measurements	
Quadrupole Fiducials (see LCLS-TN-05-11)	10 μm
Wire stability	10 μm
Sensor fixture repeatability	10 μm
Sensor readings	2 μm
Single reading uncertainty	18 μm
Line fitting uncertainty to quadrupoles	<4 μm
Undulator to beam line uncertainty	**52 μm**

The uncertainty of the undulator position is mainly caused by the uncertainty of the undulator fiducials determined in the MMF, the measurement uncertainties are negligible.

Portable HLS measurements

HLS measurements are gravity based. The loose end has to be linked to a neighboring quadrupole only. Measurements have to be taken at two points left and right of the quadrupole and left and right of the undulator "loose end". The portable HLS has a measurement range of 10 mm, all measurement points should therefore be on the girder surface. The horizontal distance is, with limitations, not a factor for the accuracy. The results of the measurements are the roll and pitch of a girder. The heights of the "loose end" is determined to 49 µm, see Table 2.

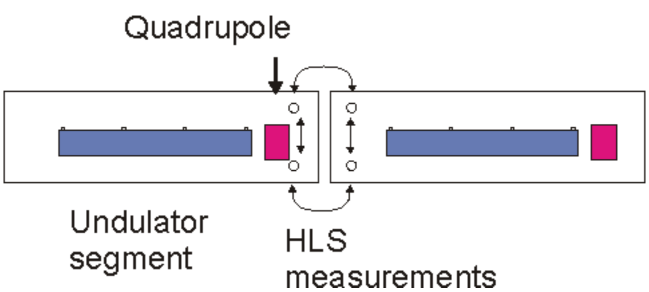

Figure 2 Portable HLS measurement setup

Table 2 RMS vertical positioning

Girder fiducial at the loose end	
Undulator Fiducials (see PRD 1.4-004-r1)	40 µm
Undulator segment roll-away repeatability	10 µm
Girder fiducials	10 µm
Sensor fixture repeatability	10 µm
Sensor readings	10 µm
Single reading uncertainty (undulator)	45 µm
Girder fiducial at the quadrupole side	
Quadrupole Fiducials (see LCLS-TN-05-11)	10 µm
Girder fiducials	10 µm
Sensor fixture repeatability	10 µm
Sensor readings	10 µm
Single reading uncertainty (quad)	20 µm
Height difference uncertainty quadrupole to undulator	**49 µm**

Conclusion

The two portable systems allow an accurate way to solve the problem of the loose end without taking up beam time. Once the initial alignment is complete the permanent systems will monitor the loose end and provide information on its position. The achievable accuracies are 52 μm horizontally and 49 μm vertically assuming a random behavior of all uncertainty sources.

Besides the determination of the loose end, other advantages exist which are reasons by themselves to perform these measurements:

- Double check of the position of the quadrupoles before the beam is turned on
- Double check of the position of the undulator segments on the slides after its installation in the tunnel in horizontal direction.
- Combining the measurements of the conventional alignment with the additional portable system readings the accuracy of the positions of the quadrupoles and undulator segments can be improved before the beam is turned on.

References

Z. Wolf, *A Vibrating Wire System For Quadrupole Fiducialization*, LCLS-TN-05-11

H-D. Nuhn, *Undulator Beam Finder Wire*, PRD 1.4-004-r1