# PERFORMANCE OF THE NEW FAST WIRE SCANNER AT THE LCLS*

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*Abstract*

A new fast wire scanner based on a linear dc servo motor acting through dual bellows has been developed at SLAC. After successful beam testing at LCLS we are now replacing all the old style stepping motor driven scanners with the new type. The fast scanner design allows full emittance scans to be completed in seconds rather than minutes as before, facilitating speedier tuning of the accelerator. The low vibration design allows for wire speeds up to 1 m/s, making it also suitable for use in the new LCLS-II machine where high wire speeds are essential to prevent wire breakage from the high power electron beam with a 1 MHz repetition rate. The wire scanner design is presented along with beam measurements demonstrating its performance.

## INTRODUCTION

The measurement and optimization of transverse emittances in the Linac Coherent Light Source (LCLS) accelerator relies on beam size measurements performed throughout the machine using wire scanners[1]. Beam profile monitors using OTR screens have proved to be unreliable because of the dominance of COTR effects arising from the very short bunches employed at LCLS. The original SLAC wire scanners, originally intended as a backup measurement for the profile monitors, are fairly slow in operation so that a complete emittance measurement may take several minutes of beam time. This early design is based on a stepper motor and ball screw system driving a cantilevered fork at 45° through the beam[2]. The motor speed must be intentionally kept low for measurements of the LCLS beam in order to minimize vibration.

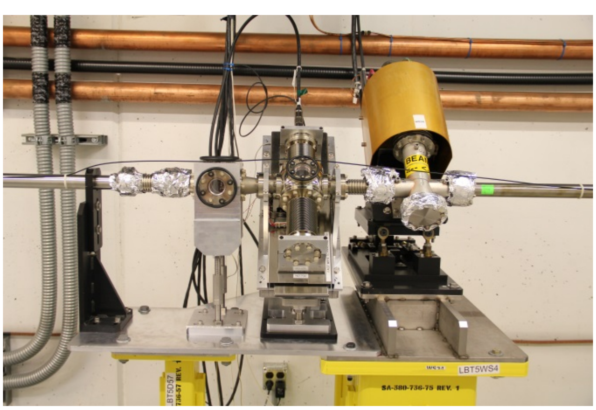

Figure 1: A section of the linac-to-undulator beam line in the LCLS with the new Fast Wire Scanner (middle) installed next to an old style scanner (right).

* This work was supported by Department of Energy Contract No. DE-AC0276SF00515

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The need to reduce the accelerator tuning time has motivated us to develop a new wire scanner with higher speeds and minimum vibration. The first of the new fast wire scanners was installed in the linac-to-undulator beam line of the LCLS, shown in Fig. 1, where it could be tested alongside the old style wire scanner.

The advent of the LCLS-II project at SLAC has also resulted in the need for a wire scanner that can move at speeds sufficient to prevent wire destruction during CW beam operation.

For the nominal LCLS-II beam parameters of 100 pC charge per bunch, a transverse emittance of 0.5 µm, and a bunch repetition rate of 0.6 MHz the minimum wire speed to avoid damage is calculated to be 0.34 $ms^{-1}$.

## DESIGN FEATURES

The wires themselves are mounted on an interchangeable card that typically holds an x, y and u (at 45° to the beam axes) wire. The card is moved by a carriage assembly at 45° to the beam axis so that the horizontal, vertical and skew transverse profiles of the beam are measured sequentially. The carriage acts through dual vacuum bellows so that there is no opposing vacuum force for the motor. The carriage moves smoothly on a linear slide that is integrated into the commercially supplied dc linear servo motor assembly [3].

Vibration is minimized in this design since little force is required to move the carriage and the wire card is held at both ends rather than cantilevered as in the old design.

The motor servo control uses an integrated position encoder that allows the motion to be accelerated smoothly to scanning speed and slowed down again within across the total range of travel of 50 mm.

A second external position encoder reads the exact position of the wire with sub-micron resolution at the time of each beam trigger. With this approach the exact position of the wire does not have to be programmed during the scan since we can correlate the signal with the actual measured wire position. This external position encoder is connected to the Beam Synchronous Acquisition (BSA) system in the LCLS controls to seamlessly integrate the data collection during measurements.

The wire scanner assembly mounted on its 45° motion stage is shown in Fig. 2. The at-rest position is down most, against the stops, where no motor holding current is required. A scan of all 3 wire planes can be done in a single upward motion of the scanner before returning to the downward rest position and takes just a couple of seconds. The peak motor current during acceleration for such a scan is of the order of 10 amperes.

The magnetic field generated by the motor drawing this peak current can perturb the electron beam so we placed mu-metal shielding around the motor stage to virtually

ISBN 978-3-95450-176-2

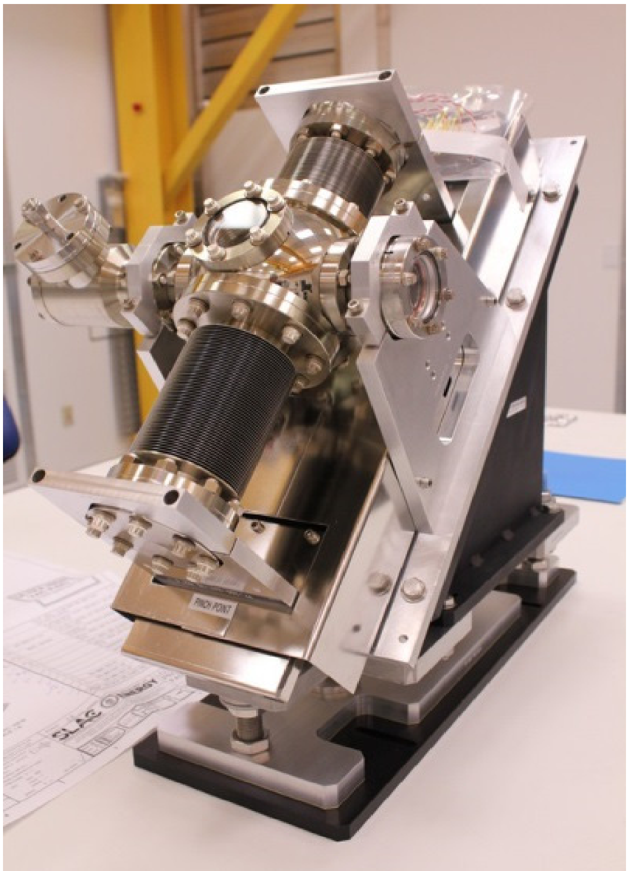

Figure 2: The wire scanner mounted on its 45° motion assembly.

eliminate stray magnetic fields. The linear motor with the shielding removed is shown in Fig. 3.

The mechanical sub-assemblies for the wire scanner are shown in Fig. 4, and the wire card showing details of the arrangement of the x, y and u wires is shown in Fig. 5. Note that in different locations we equip the card with wires of different materials and thicknesses according to how great a beam loss signal we wish to generate. The wires may typically range from 10 µm carbon filaments to 30 µm tungsten wire.

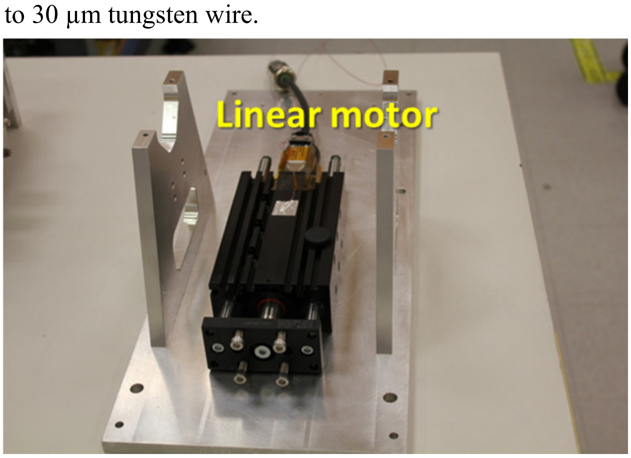


Figure 3: Linear motor slide assembly with magnetic shielding removed.

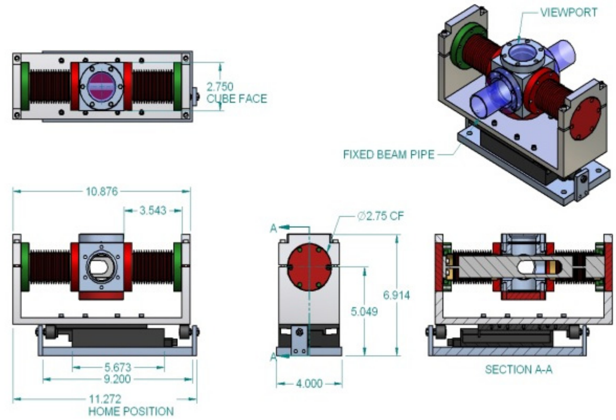


Figure 4: Mechanical sub-assemblies of the wire scanner.

## CONTROL SYSTEM

The wire scanner is integrated into the existing LCLS control system and beam synchronous acquisition data gathering system. The linear motor is powered by a remote power unit located outside of the tunnel. This Linmot power unit also provides the dc servo control of the unit. The motor servo is a PID feedback controller where the PID coefficients can be remotely optimized for a given installation. The PID coefficients typically depend on the mass, spring forces and cable lengths. The Linmot power unit is interfaced to the EPICS control system via a MAXv module as shown in Fig. 6. The MAXv module also interfaces to the external position encoder used to record the wire position during the scans. The MAXv module is installed in a VME crate where it communicates with an EPICS IOC module and the timing module.

A Beckhoff controller interfaces the limit switches to the control system that confirm when the scanner is at the end of its range of travel.

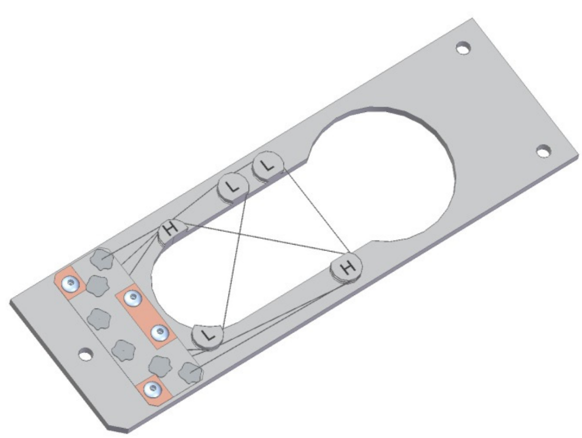


Figure 5: Wire card assembly showing how the x, y and u wires are mounted.



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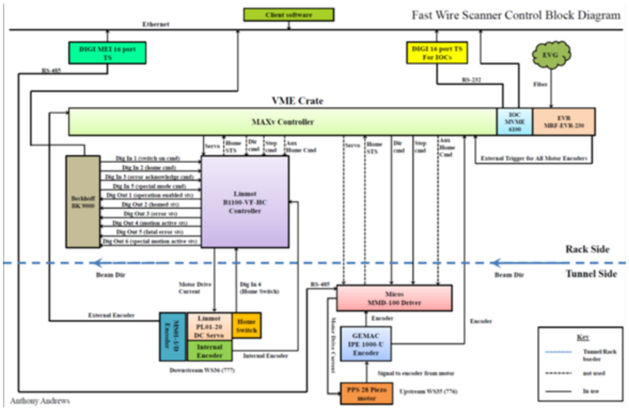


Figure 6: Block diagram of the wire scanner control system.

## BEAM MEASUREMENTS

A wire scan measurement can be initiated from the graphical user interface (GUI), shown in Fig. 7, or from an automated script. The scan ranges are set via EPICS Process Variables (PVs) visible on the GUI and can be set to scan all 3 wires or any single wire.

The top right pane in Fig. 7 shows the result of all 3 wires scanned consecutively, plotted as a function of sample number (or time). The 3 peaks in the beam loss signal indicate the beam intercepting each wire. The position encoder signal is also plotted as a function of time where one can see the wire accelerate and then slow down to scan through the beam core. The optimum wire speed is calculated according to the actual rate of the beam so that one always gets a reasonable number of measurement points across the beam to enable a Gaussian or asymmetric Gaussian curve to be fitted. The fitted beam width is then used in subsequent emittance measurement calculations.

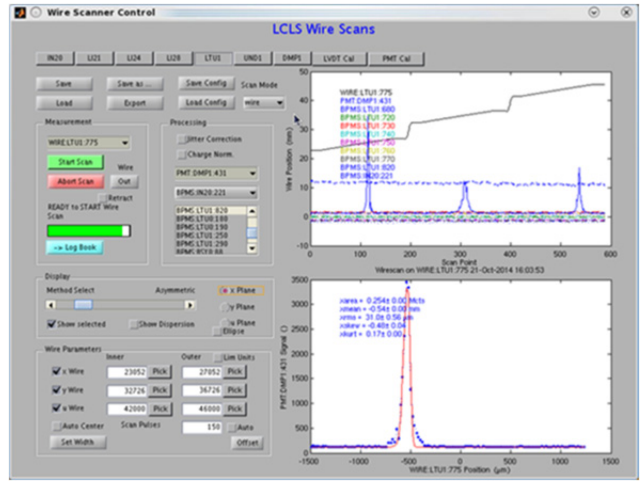


Figure 7: Snapshot of the wire scan graphical user interface showing x, y, and u wire scan signals during a single sweep (top right) and an individual wire scan plotted versus measured wire position (bottom right).

The measured data points in an individual scan show no horizontal deviation from the fitted curve which indicates that there is no measurable vibration of the scanner assembly.

## REFERENCES

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