Linear Encoders for CHESS Compact Undulator Magnet Array Position Measurement

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I. Test Setup

The Compact Undulator is undergoing ongoing testing in the Wilson Lab Annex. All of the testing has taken place on the magnetic testing bench. The bench consists of a Hall probe on an air bearing supported carriage with 3 degrees of freedom- the y and z axes are controlled with stepper motors and the x axis with an electromagnetic linear motor. The x position is controlled using a laser for feedback.

The undulator has an additional degree of freedom that must also be controlled; the phase between the upper and lower arrays adjusts the magnetic field strength and the K factor of the undulator. The purpose of the linear encoder, then, is to measure the position of the driven (upper) array with respect to the fixed (lower) array. Since the array is within the vacuum chamber, the encoder must locate position off of the linear motor which is outside of the vacuum chamber (not yet fabricated).

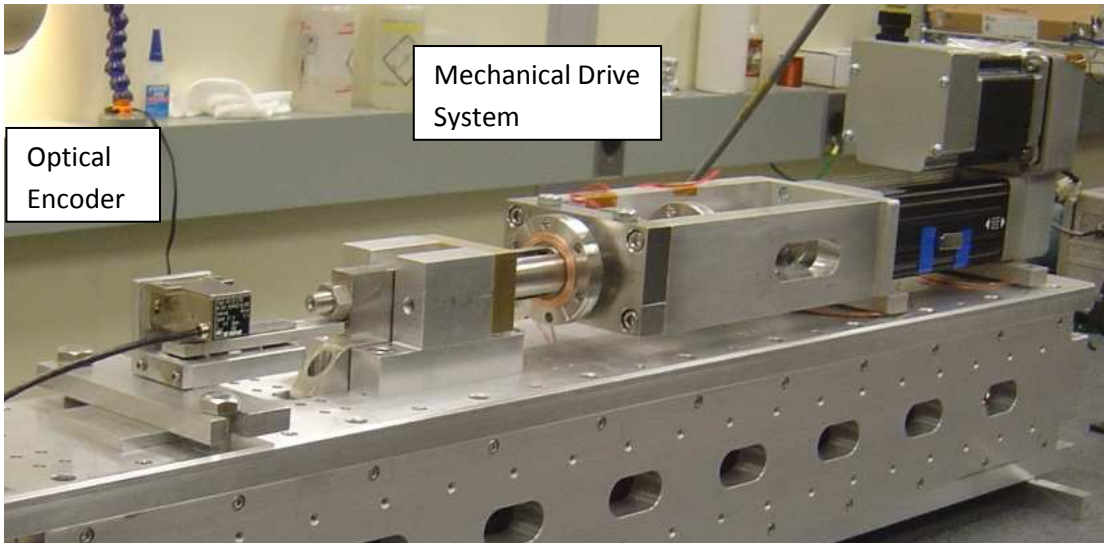

Figure 1: Locating position off of the upper array using an optical encoder. Since we do not have the vacuum chamber, we are able to install the encoder in a few otherwise impossible locations.

II. Test Result

We have access to a few different types of encoders.

a. Optical encoder RSF Elektronik

We first tested the optical encoder RSF Elektronik MS 52-27G, but the signal drifted due to electrical noise from the stepper motor. Even after grounding and shielding the device, the interference was significant.

b. Tresna Instrument caliper

Setup for Tresna Instrument caliper is shown in Fig. 2.

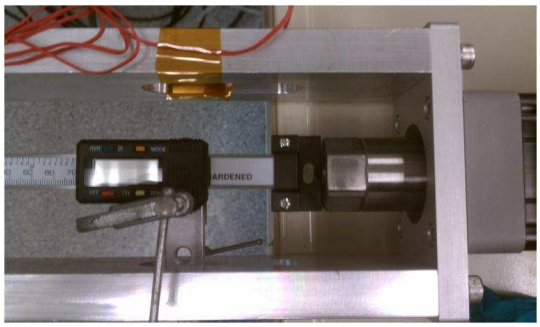

Fig. 2: Tresna Instrument Caliper against the linear actuator.

We calibrated the linear motor using a Tresna Instrument caliper. The caliper data verified the 0.4µm per motor step resolution that the optical encoder originally produced. The caliper response is very linear.

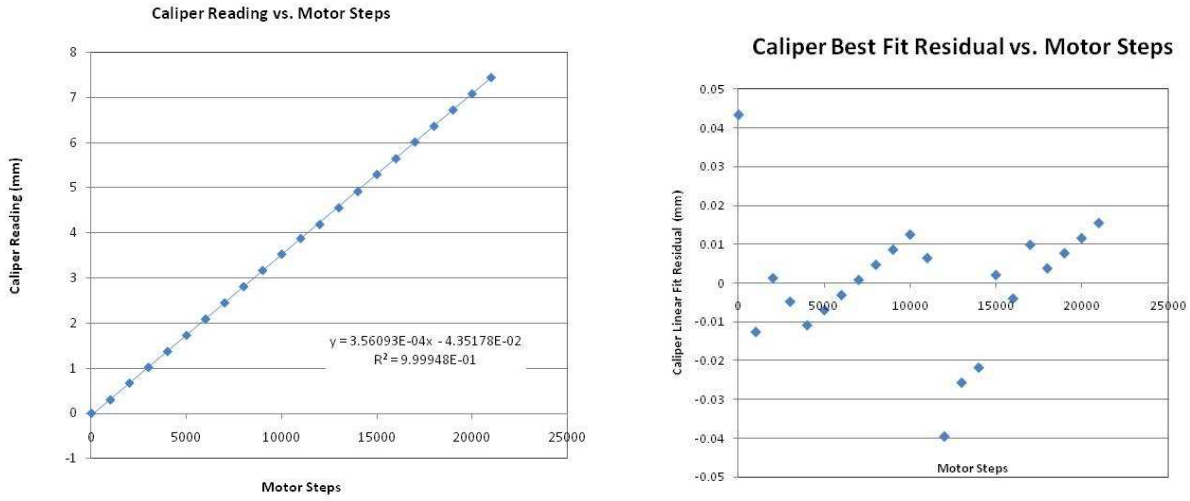

Fig. 2: Tresna Instrument Caliper reading as a function of the linear actuator position. RMS residuals of 0.016 mm.

c. Omega LD300-15 LVDT

We also tested the Omega LD300-15 LVDT. It offers more precision that the Tresna Instrument Caliper, but it also has a noisy signal. Linear variable differential transducers work by measuring differences in magnetic fields that change with position. The problem is the stepper motor creates a magnetic field to hold its position. This is what causes the interference in the system.

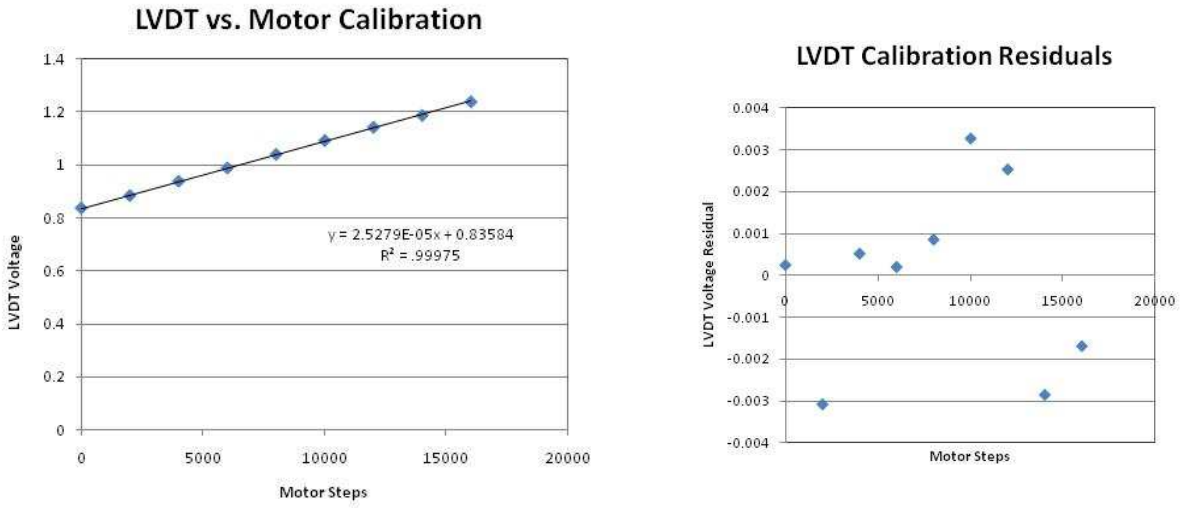

Fig. 3: *Omega LD300-15 LVDT* reading as a function of the linear actuator position. RMS residuals of 0.033 mm.

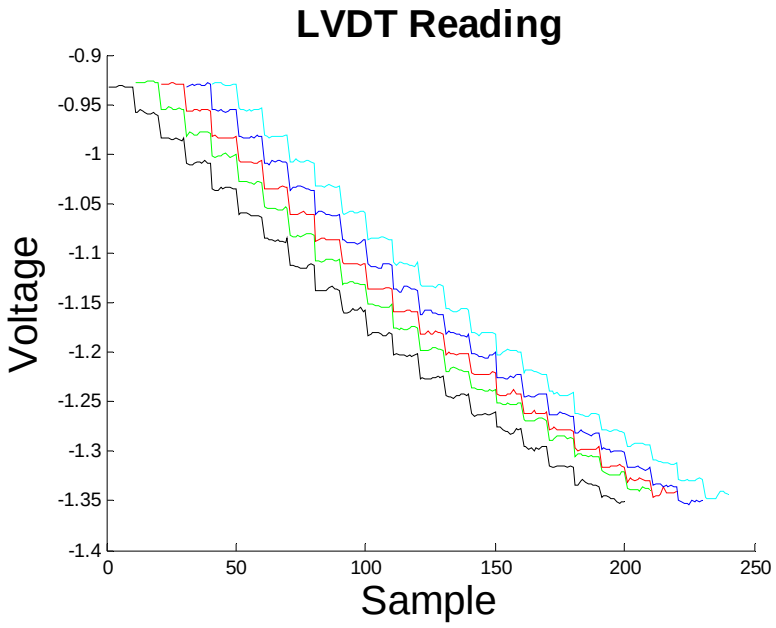

Fig. 4: *Omega LD300-15 LVDT* repeatability test.

For 10 readings at each of 20 positions, separated by 0.4mm, signal has an unacceptable amount of noise. Over 5 tests, the positions are not repeatable.

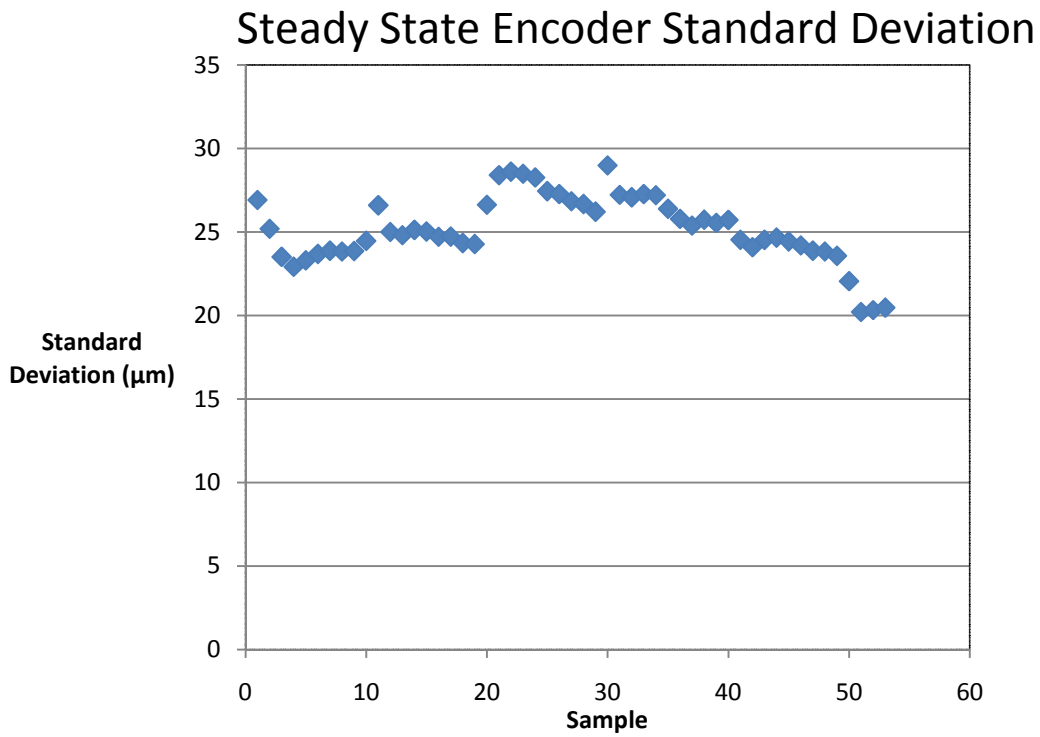

Fig. 5: *Omega LD300-15 LVDT* drift illustration.

The average standard deviation of the LVDT signal is 25.2 µm.

III. Conclusion

We are currently looking for a linear encoder that is accurate, precise, and not sensitive to electrical or magnetic noise. For now, a mechanical dial gauge satisfies these requirements and is being used to locate off of the upper array's copper transition. This, in conjunction with the linear motor position, will provide accurate, repeatable positioning until the vacuum chamber is installed.