PATS (SCU)

The SCU project will build a <u>short</u> section of a segmented x-ray FEL with superconducting undulators housed in a cryomodule arrangement. It will use the same type of beamline components as the existing warm x-ray FELs. The SCUs can achieve higher field strengths than Permanent Magnetic Undulators (PMU) which in turn deliver higher power x-rays with shorter wavelengths. Tuning of the SCU is simply a matter of adjusting the coil currents, rather than adjusting the gap. The stronger SCU has a shorter gain length so the overall tunnel length is less, and the smaller dimensions allow undulators to be placed closely side by side to allow multiple undulators to be installed in the tunnel and deliver beams simultaneously to more users.

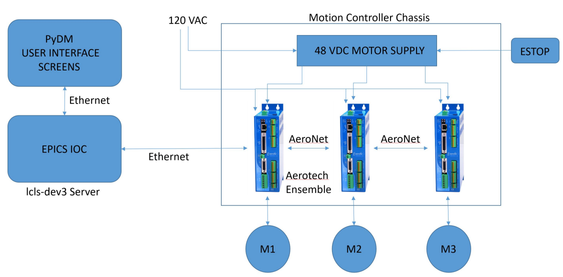
Objective:

Demonstrate that component alignment can be done to the same precision and show the feasibility of a full-length segmented x-ray FEL based on SCU technology.

Challenge:

One of the most challenging aspects of the SCU project is the position control and stability of magnetic components to the micron level, which will be developed and tested with the PATS.

- Frameless COTS Kollmorgen 48V rotor and stator units with built-in Hall Effect Sensors
- BiSS-C absolute encoder with 5nm resolution for position feedback
- Dual end-of-travel motion inhibit and safety stop limit switches
- Three motors to achieve X and Y control of one end of the SCU assembly
- Aerotech Ensemble CP-10 series motion controller



There are two absolute encoders and here is the explanation from Gary: The original design was an actuator with 1 micron repeatability. Harmon specified a linear encoder. An encoder with 50nm resolution was selected. Heinz-Dieter in his PRD stated we needed 250nm resolution. With the linear encoder that resulted in ±5 pulses. Harman said that may be OK, but more pulses would be easier to tune. He suggested the AksIM-2 rotary encoder. I selected 17 bit resolution. That results in 131,072 counts per 500 microns, or .0038147 microns/pulse, approximately 66 pulses/250nm. This may be easier to tune. I put both encoders in this version of the actuator to experiment with both, to determine if one or the other could do the job, or if both are required.

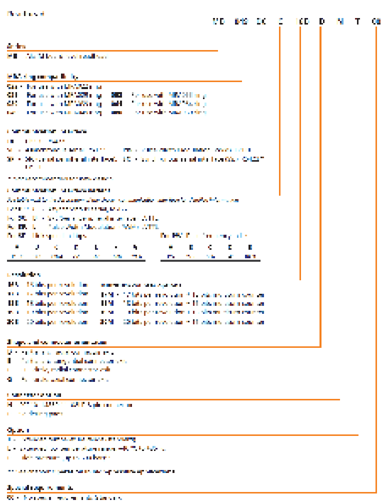
Travel range of each actuator
5 mm (+/- 2.5 mm)
Lead screw pitch
0.5 mm/rev
Required positioning accuracy
0.25 um
Gear reducer

Phase 1 CMM Test:

- There are two vertical actuators and one horizontal actuator with an opposing tensioning spring
- A control system for the three linear actuators and linear encoders plus the optical measurement system will be needed for the phase 1 tests
    - These controls will later be integrated into the LCLS accelerator control system
- The entire assembly shown in Figure 3 will be placed on a coordinate measuring machine (CMM)
    - This will allow the linear encoder positions in the actuators, and the optical position readback to be verified with the CMM data.
- The linear encoders and optical displacement measurement system is designed for submicron resolution, an order of magnitude better than the CMM system measurements
    - by plotting the data over a ±3 mm range of motion and calculating a line of best fit we expect to be able to conclude that the device resolution has been achieved.

Parameter	Values	Unit
Horizontal motion range	**±1.0**	**mm**
Horizontal motion accuracy (rms)	**0.25**	**µm**
Vertical motion range	**±1.0**	**mm**
Vertical motion accuracy (rms)	**0.25**	**µm**
Horiz./Vert. vibration amplitude >1 Hz	**<0.25**	**µm**
Yaw motion range	**±1270**	**µrad**
Yaw motion range accuracy (rms)	**<0.5**	**µrad**
Pitch motion range	**±1270**	**µrad**
Pitch motion range accuracy (rms)	**<0.5**	**µrad**
Roll stability over full motion range (rms)	**<1**	**mrad**

- RENISHAW ABSOLUTE ROTARY ENCODER MRA064BC040DSE00
    - Readhead: MB064DCC17MDNT00



Kollmorgon TBMS-7615-A:

TBM(S) 76 Series Performance Data and Motor Parameters

Motor Parameter	Symbol	Units	TOL	TBM(S)-7615-X A	TBM(S)-7615-X B
Continuous Stall Torque*	Tc	N-m	NOM	0.996	0.996
		oz-in		141	141
Continuous Current	Ic	Adc	NOM	10.8	15.1
		Arms		8.82	12.3
Peak Stall Torque* (25°C winding temp)	Tp	N-m	NOM	2.86	2.15
		oz-in		405	305
Peak Current	Ip	Adc	NOM	36.0	36.0
		Arms		29.4	29.4
Rated Cont Power*	P Rated	Watts	NOM	280	230
Speed at Rated Power	N Rated	RPM	NOM	4025	2600
Design Voltage	Vbus	Vdc	NOM	48.0	24.0
	Vac	Vrms	NOM	33.9	17.0
Torque Sensitivity at Temp*	Kt (hot)	N-m / Adc	+/-10%	0.095	0.068
		oz-in / Adc		13.5	9.68
		N-m / Arms	+/-10%	0.117	0.084
		oz-in / Arms		16.5	11.9
Back EMF at Temp*	Kb (hot)	Vpk / kRPM	+/-10%	9.98	7.15
		Vrms / kRPM		7.05	5.06
Torque Sensitivity at 25°C	Kt (cold)	N-m / Adc	+/-10%	0.105	0.075
		oz-in / Adc		14.9	10.6
		N-m / Arms	+/-10%	0.129	0.092
		oz-in / Arms		18.2	13.0
Back EMF	Kb (cold)	Vpk / kRPM	+/-10%	11.0	7.87
		Vrms/kRPM		7.76	5.56
Motor Constant	Km	N-m/√watt	+/-10%	0.175	0.176
		oz-in/√watt		24.9	25.1
Resistance at 25°C	Rm	Ohms	+/- 10%	0.356	0.180
Inductance	Lm	mH	+/- 30%	0.37	0.19
Inertia*	Jm	$Kg\text{-}m^2$		3.04E-05	
		$oz\text{-}in\text{-}s^2$		4.31E-03	
Weight*	Wt	grams		400	
		oz		14.1	
Max Static Friction	Tf	N-m		0.032	
		oz-in		4.49	
Cogging Friction (Peak-to-Peak)	Tcog	N-m		0.013	
		oz-in		1.79	
Viscous Damping	Fi	N-m/ kRPM		6.65E-03	
		oz-in / kRPM		9.46E-01	
Thermal Resistance*	TPR	°C / watt		2.11	
Number of Poles	P	-		12	

*Notes
1) Continuous Stall Torque and Rated Power assume ambient temperature of 25°C
2) Winding temp = 155°C for Kt and Kb hot
3) Inertia and weight assume max thru-bore
4) TPR assumes motor is housed and mounted to a 7.0" x 7.5" x 0.375" heat sink or equivalent
5) Peak Torques limited by lead wire gauge

RENISHAW ABSOLUTE LINEAR ENCODER: EL26BRB050F30A

- EL: Evolute Linear
- 26B: BISS 26 bit
- R: Side cable outlet IP64
- B: Standard IP64
- 050: Resolution 50 nm
- F: RTLA50/RTLA50-S
- 30: cable length 3.0m
- A: 9 way D