Applied Scientific Instrumentation
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Lead Screw Pitch Options for ASI XY Stages: Speed, Resolution, and Repeatability

The following table shows tested (and *expected* in *italics*) specifications for different lead screws pitches, motor gear-head combinations and encoder types. The most popular combinations are use the 6.35 or 1.59 mm pitch lead screw, shown in color below.

Standard Configuration using DC Servomotor with 141:1 Zero-Backlash Gearhead								
			512 Counts/Rev Rotary Encoder			**Linear Encoder**		
Lead Screw Pitch (mm)	**Lead Screw Pitch Name**	**Max Speed** (mm/s)	Encoder Resolution (nm)	Typical RMS Bi-directional Repeatability (with anti-backlash firmware)	Lead Screw Accuracy (µm/mm)	Encoder Resolution (nm)	Typical RMS Bi-directional Repeatability (µm)	Glass Scale Accuracy (per length of scale)
25.40	Ultra-Coarse	28	88	< 3 µm	0.25	10	*< 1.0*	± 3 µm
12.70	Super-Coarse	14	44	< 1.5 µm	0.25	10	< 0.4	± 3 µm
6.35	Standard	7	22	< 0.7 µm	0.25	10	< 0.3	± 3 µm
1.59	Fine	1.75	5.5	< 0.5 µm	0.25	10	< 0.25	± 3 µm
0.635	Extra-Fine	0.7	2.2	*< 0.5 µm*	0.25	10	*< 0.25*	± 3 µm
0.317	Ultra-Fine	0.35	1.1	< 0.5 µm	0. 25	10	*< 0.25*	± 3 µm

Special Configuration using DC Servomotor with 3.71:1 Planetary Gearhead								
			512 Counts/Rev Rotary Encoder			**Linear Encoder**		
Lead Screw Pitch (mm)	**Lead Screw Pitch Name**	**Max Speed** (mm/s)	Encoder Resolution (µm)	Typical RMS Bi-directional Repeatability (with anti-backlash firmware)	Lead Screw Accuracy (µm/mm)	Encoder Resolution (nm)	Typical RMS Bi-directional Repeatability (µm)	Glass Scale Accuracy (per length of scale)
25.40	Ultra-Coarse	480	3.3	*< 4 µm*	0.25	100	*< 2.0*	± 3 µm
12.70	Super-Coarse	240	1.7	< 2 µm	0.25	100	< 1.0	± 3 µm
6.35	Standard	120	0.84	< 1 µm	0.25	50	< 0.5	± 3 µm
1.59	Fine	30	0.21	*< 1 µm*	0.25	50	*< 0.5*	± 3 µm

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The full dynamic average speed range for ASI stages under closed loop velocity control is about a factor of 10,000. However, the slowest speeds are not as smooth, so a good working minimum speed is 200 times less than the maximum speed (for details, see Technical Note 120 – Slow Speed Considerations).

Limits of resolution are imposed by both the minimum encoder resolution (measurement resolution) and by the minimum achievable mechanical motion possible (mechanical resolution). ASI stage controllers can typically move the stage motors to within one encoder count of the desired position. This sets the fundamental resolution limit for our stages. Crossed roller bearing assemblies seem to have a repeatability limit somewhere around 50 to 100 nm. The repeatability is often worse for long moves than for short moves. Repeatability errors can come about because of uncertainty in the measured position from the encoder or because of mechanical uncertainty (backlash) in the mechanical components of the stage.

In the standard configuration, ASI stages use small DC servomotors with zero-backlash gear-heads and an integrated rotary encoder. This motor/gear-head/encoder combination provides excellent closed loop control for high precision microscopy stages where modest speeds are acceptable. The zero-backlash gear-head reduces, but does not completely eliminate mechanical backlash from the stage system.

For applications where speed of movement is an important factor, a different motor /gear-head combination is used. Mechanical backlash can be around 10 µm for these systems if linear encoders or anti-backlash controls are not used.

The MS-2000 stage controller has the ability to automatically correct for most of the backlash present in the mechanical system. On each move, our anti-backlash algorithm causes the stage to move to the target position by moving first to a point a fixed distance away from the target. Hence, the motion to the target is always from the same direction, regardless where the move originated. The anti-backlash routine removes much of the inherent backlash in the mechanical system so that reasonably accurate positioning is possible without using linear encoders.

Overall measurement accuracy depends upon the pitch accuracy of the lead screw if rotary encoders are used, or the accuracy of the optical scale if linear encoders are used. Linear encoders provide significant advantages when high positional accuracy is required. Another source of inaccuracy is turn-to-turn wobble of the lead-screw (frequently of order 10 µm/rev). The linear encoder eliminates this problem, too, but comes with a similar problem of its own. Linear encoders count finely by interpolating the cyclic waveforms derived from the encoder's optical scale. Small interpolation errors can occur with the period of the encoder scale (typically every 4 to 20 µm.) Careful adjustment of the linear encoder is required to minimize such errors.