I. DYNAMICS PARAMETERS

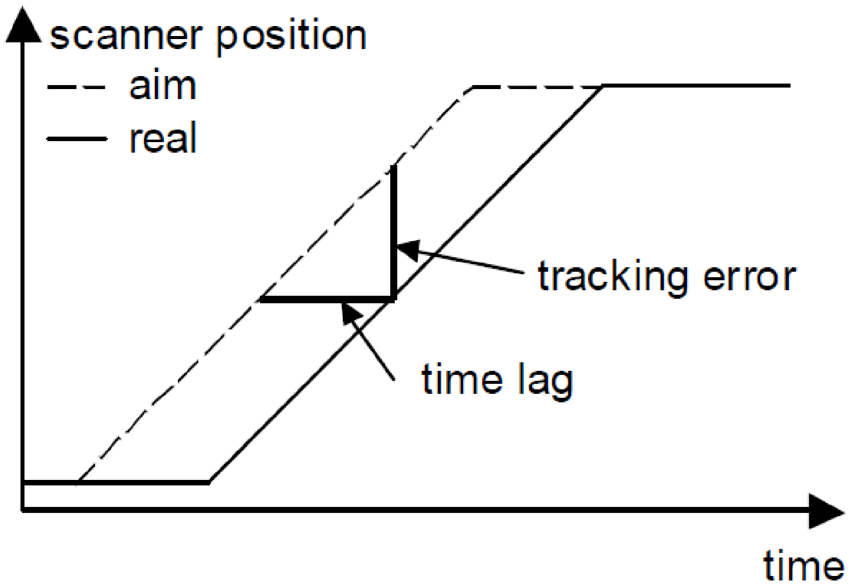
Tracking Error:

Due to the finite inertial of the mirror, it is not possible to move the mirror to the set position instantaneously. The time that the mirror required to reach set position is called time lag [in ms] and the corresponded position mismatch is called the tracking error [in µrad or µm] see figure below.

This time lag is constant over a wide range of scanning speed, thus one can determine the tracking error by simply multiplying time lag with speed. For example,

Intelli*SCAN$_{se}$* 10 has a time lag of 0.11ms (even though in the product brochure it is call tracking error) and a typical marking speed of 3.5m/s (with f=160mm objective). Thus the corresponded tracking error of the scanner at 3.5m/s = 3.5m/s * 0.11ms = 0.385mm.

One more parameter that is influenced by the tracking error is the acceleration time (to desire speed). As a rule of thumb, it can be approx. 1.5 – 2.5X of the time lag.



In practice it is possible compensate this time lag using the delays (laser or marking delays). For example, during a vector marking, the mirrors need to be accelerated to the desired speed and position. To ensure that the laser will not be turned on before it reaches the velocity, the laser can be subjected to turn on after the "laser_on_delay" command.

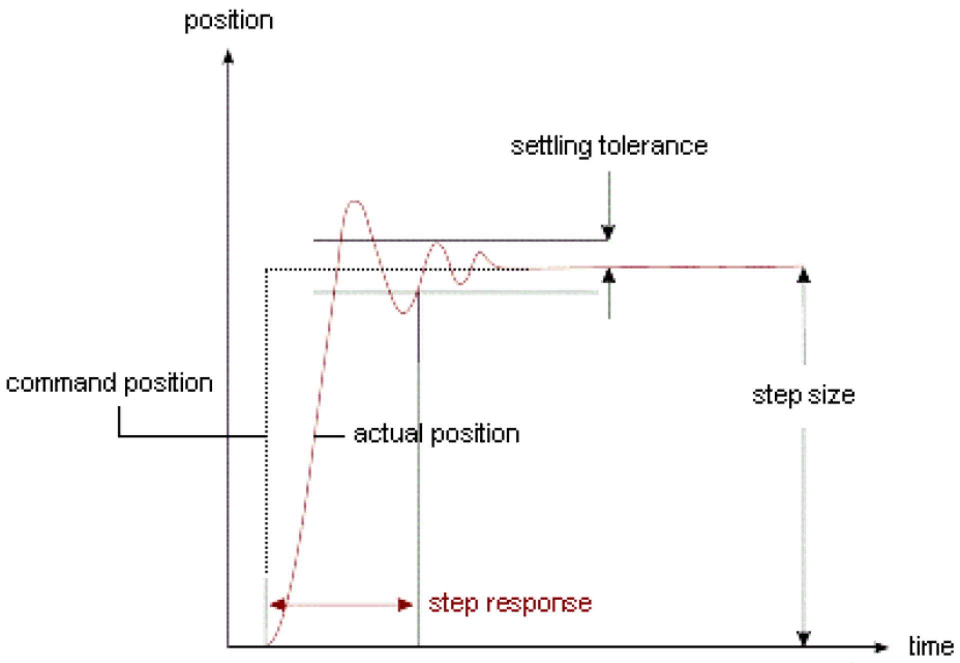
The following delay parameters can be used as starting guideline:

Laser_on_delay	60% of time lag
Laser_off_delay	120% of time lag
Mark_delay	100% of time lag
Polygon_delay	50% of time lag
Jump_delay	200% of time lag

Step response time:

Step response is a specification which define how long will a scanner take to settle within a defined settling tolerance after a hard step. A hard step means that the positioning is without splitting into small micro vector steps (for example using the command “goto_xy”). As for the settling tolerance, it is usually defined as 1/1000 of the full scale.

Again, using intelli*SCAN*$_{se}$ 10 (given 1% step response= 0.4ms) as example, combined with f=160mm objective and delivered as image field size of approx. 100x100mm^2. After a hard jump, it would take the scanner to travel 1 $\pm$ 0.1mm (1% of 100mm, 1/1000 settling)



Marking speed vs positioning speed

Unlike the Marking speed, positioning speed (or jump speed) does not taken the laser parameters, laser-material interaction and marking quality into account. Thus, it is usually has a higher speed as compared to marking speed.

The marking speed stated in the product brochures has a marking quality similar to the high writing quality in cps.

In principle, it is possible to go beyond the positioning speed stated on the product brochure; however, such a high positioning speed will lead to the significant overshooting problem, which usually compensate with large jump delay (typically 200% of the time lag).

II. PRECISION

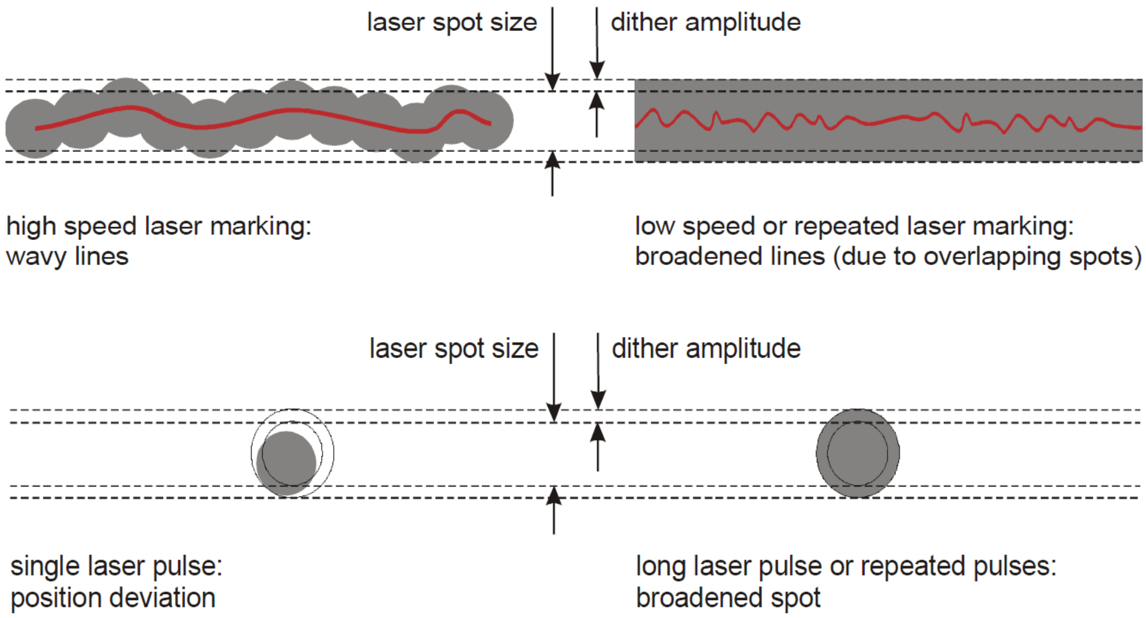
Achievable precision is determined several factors: dynamic/ static stability and the resolution of the controller. Dynamic repeatability describes the scanner ability ot travel to the set position without any oscillation or noise. It is usually described by wobble, jitter and dither values.

Dither

Dither is the randomize position introduced by residual noise of the scanner electronic. Even if the scanner is set to be stationary, the real position of the scanner will oscillate with a broad spectrum between 200Hz – 20 KHz. The magnitude is specified by the standard deviation of the mechanical scan angle. It is the intrinsic properties of the scanner and cannot be corrected.

Luckily, the effect of the dither is not that severe and does not play an important role in the conventional applications (such as marking or engraving. It is usually play an important role in the micromachining application which use laser with short wavelength with good beam quality and where µm accuracy is needed. Thus, this value is normally specified in the high end scanners.

For example in vector line marking application, dither will cause the irregular wavy lines in the high speed marking. As for the jump and shoot application, dither will cause the real position deviate from the set position.



How to calculate the dither in the real life application? Let's take again intelli*SCAN*$_{se}$ 10 as our example. As stated in the product brochures, intelli*SCAN*$_{se}$ 10 has a RMS dither value of <2.0µrad, thus the corresponded peak to peak dither value (full optical angle') = 2*3*2µrad = 12µrad. In combine with a f= 100mm objective, it will result in the 1.2µm of position deviation.

Wobble/ jitter are the mechanical oscillation of mirror during scanning motion. Wobble = oscillation in the perpendicular to the scan direction; jitter= oscillation perpendicular to the scan direction.

Resolution

The resolution of a scan head depends on the 2 things: resolution of the position detector of the galvo and the resolution capability of the control board.

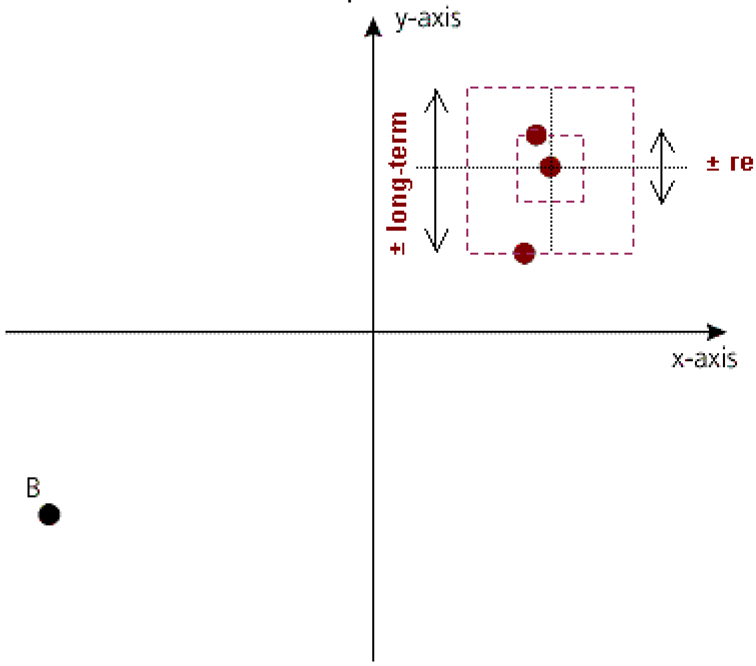
The typical control boards (XY2-100 interface) available on the market are mostly with 16 bit of resolution (1/65,536 resolution), that include RTC3 and RTC4 control board from SCANLAB. As for the RTC5 (or RTC6 in future), it has a resolution up to 20 bit (1/1,048,576 resolution) and is 16x higher resolution as compared to the conventional control board.

Depending on the models, the position resolution of the SCANLAB scanners varies from 16 bit up to 20 bit. For example, *SCAN*cube or hurry*SCAN* series has a 16 bit resolution, intelli*SCAN* / intelli*SCAN* III has 18 bit resolution and intelli$SCAN_{se}$ or intelli$SCAN_{de}$ could give 20 bit of resolution.

Take intelli$SCAN_{se}$ 10 as example again, 0.7rad full optical scan angle/ 2^20 ~0.67µrad resolution.

Repeatability

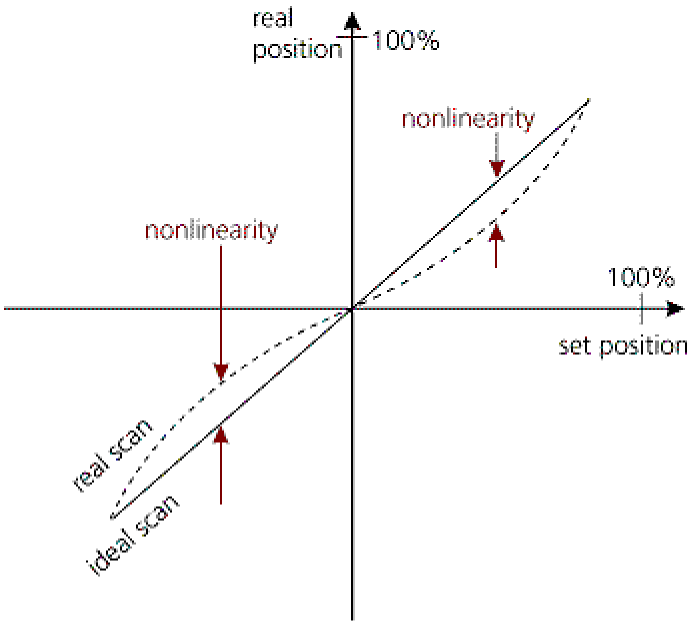
This parameter describes the accuracy and consistency of the scanning system when return to a specific position from any directions.
The values stated in our product brochures are all obtained from the experiments.



III OPTICAL PERFORMANCE

Nonlinearity

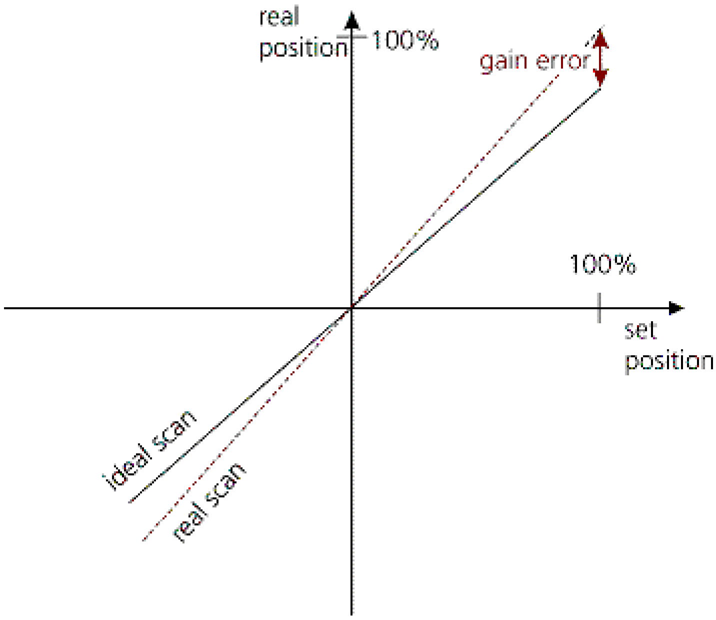
angular position of one axis



In practice, the response of a position detector could deviate from an ideal linear transfer function. This static deviation is referred to as nonlinearity.

Gain error

angular position of one axis

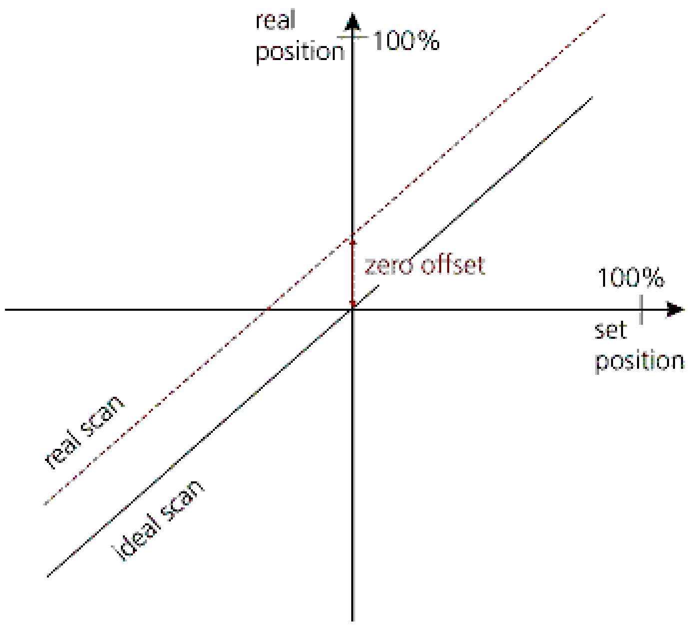


Gain error refers to a static angular deviation of the real position from the set position after subtraction of zero offset (deviation from the calibrated full angle, e. g. at +/-4.8 V input signal the mechanical angle is +/-10.7 deg. with an error of max. +/- 5 mrad optically referring to one axis).

Zero offset

Zero offset refers to a static angular deviation from the nominal zero position at an input signal of 0 V (angular difference between center of image field and real position after e.g. goto_xy (0,0) command).

angular position of a single axis

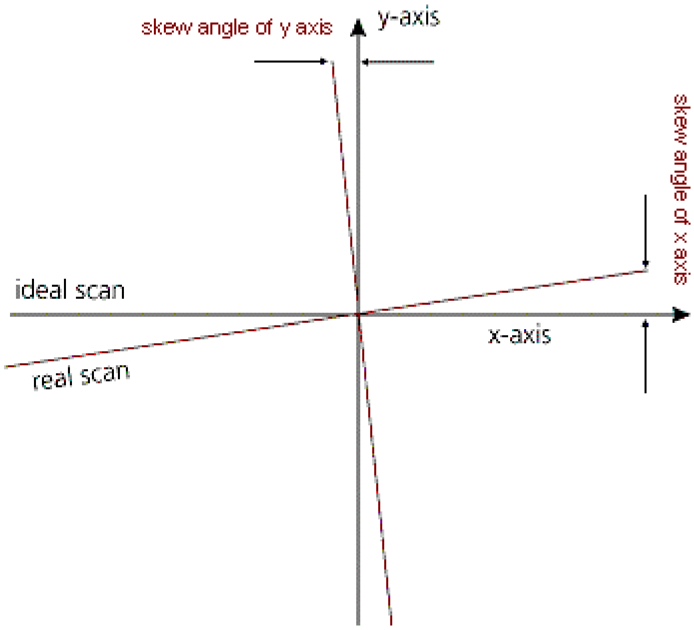


Skew

Skew refers to a static angular deviation between the axes of the coordinate system defined by the orientation of the scan head and laser and the axes defined by scanning either the X-mirror or the Y-mirror (max. angular difference between ideal scan axis and real scan axis).

The two skew angle leads to an overall rotation and slant of the image field.

image field



All the non-linearity, gain-error, zero offset and skew can be compensated using high precision calibration (e.g correXion Pro).

IV. DRIFT VALUES

During the long term operation (for example in production), the accuracy of the system might be influenced by the fluctuation in the environment. Two important drift values that one should take into consideration: first one is the long term drift / 8 hrs, the other one is the temperature drift.

Two things will happen:

1. Shift of the image field size. This alteration is described by the offset drift value.
2. Change of the size of the scan factor. This alteration is described by gain drift.

Long term drift/ 8 hrs drift:

This drift values describe the position deviation during constant temperature operation(temperature drift does not play a role here), with at least 30 min of warm up phase.. For example, intelli*SCAN*$_{se}$ has following 8 hr drift value: Offset <20µrad, Gain < 20ppm. Combining with an f=100mm objective:

Offset drift: = 20µradx 100mm = 2µm
Gain: = 20ppm x 0.35 rad (half scan angle) x 100mm = 0.7 µm

Thermal drift

intelli*SCAN*$_{se}$ has the following thermal drift values : Offset<15µrad/K, Gain<8ppm/K Assuming that the temperature fluctuate approx. 10 K within a certain period of time and f=100mm objective.

The corresponded temperature drift is then:
Offset: 15µrad/K x 10 x 100mm = 15 µm
Gain: 8ppm/K x 10 x 0.35 rad x 100mm = 2.8 µm

So in the worst case scenario, after 8 hrs of operation and a temperature fluctuation of max.10K, one should expect a total drift value of = 2 + 0,7 + 15 + 2.8 = 20.5 µm