

Accuracy Survey of **jetlab**[®] 4 JL4-42

Hans-Jochen Trost
MicroFab Technologies, Inc., Plano, TX, USA

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1 Measurements

The x and y stages for the **jetlab**[®] 4 print station serial number JL4-42 has been surveyed at MicroFab Technologies, on 27-28 April 2010, for the linearity and horizontal straightness errors of its x and y axes as well as the angle between the two axes, using a Heidenhain KGM 181 grid encoder (Dr. Johannes Heidenhain GmbH, Traunreut, Germany). This encoder measures two coordinates simultaneously. The grid has a spacing of 4 μm in both directions, and a resolution of about 0.5 μm can usually be obtained through interpolation techniques built into the control software for the encoder. The data span the x range from -55 mm to $+75\text{ mm}$, and y range from -90 mm to $+40\text{ mm}$.

The linearity and straightness errors and the misalignment angle of the stages have large systematic components that can be reproducibly measured, and on the basis of those measurements compensated for in the control program of the **jetlab**[®] 4 machine. For linearity and straightness, interpolation tables are derived for forward and reverse motion separately, and the angle is obtained as a single datum. The corrections are then applied in the control program such that all coordinates provided by the user are taken to mean coordinates at a temperature of 20°C . With the help of temperature sensors mounted to the housings of the linear encoders of the x and y axes, the motion targets are then corrected for both the temperature and the surveyed errors. The quality of the correction can be judged by repeating the full survey with all of the corrections being applied. On the following pages, the raw measurements (no corrections applied to the machine motion) and check measurements (all corrections applied) are presented.

2 Results

The data were taken at temperatures near 25°C for raw data and 22.5°C for the verification (average of the stage temperatures). The effective linear expansion coefficient is estimated to be 15 $\mu\text{m}/\text{m}/\text{K}$. The forward-reverse differences are within a band of 4 μm everywhere. The following

table summarizes the residual errors after correction, including any forward-reverse differences. The “Range” describes the range spanned by the data points plus their error bars. The “Largest error bar” is the largest individual error bar, which is determined by repeating all measurements 10 times and applying standard averaging procedures.

Error type	Range [μm]	Largest error bar [μm]
X linearity	-9.3 to 13.0	± 1.4
X straightness	-2.8 to 3.5	± 0.9
Y linearity	-3.0 to 4.3	± 0.8
Y straightness	-1.8 to 1.7	± 0.7

The total error band for positioning in x direction is then the sum of the x linearity range, and the y straightness range for a band width of $25.7 \mu\text{m}$. The equivalent number for the y direction is $13.5 \mu\text{m}$. Because all printing will be done with aligning the target substrate on the machine, the lack of symmetry of the ranges about $0.0 \mu\text{m}$ is of no consequence; the substrate alignment will remove all constant offsets.

The deviation of the angle between the positive x axis and the positive y axis (first quadrant) from being a right angle is measured to be $-994.8 \mu\text{rad}$, and the residual angle after correction is measured to be $16.3 \mu\text{rad}$, for a worst-case effect of $2.1 \mu\text{m}$.

Thus, the residual errors are:

Observable	
Positioning in x	$\pm 12.9 \mu\text{m}$
Positioning in y	$\pm 6.8 \mu\text{m}$
Deviation from right angle	$16.3 \mu\text{rad}$

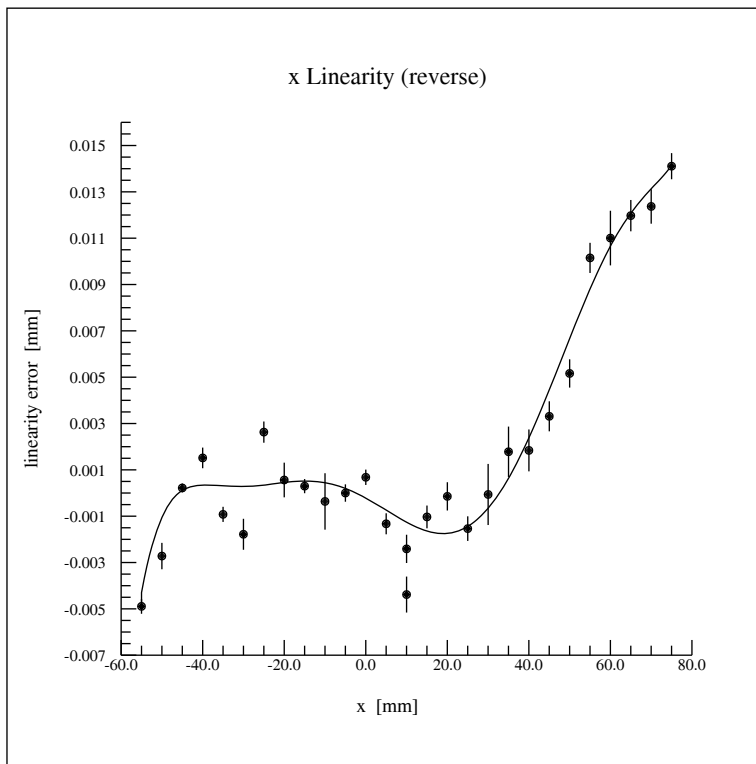
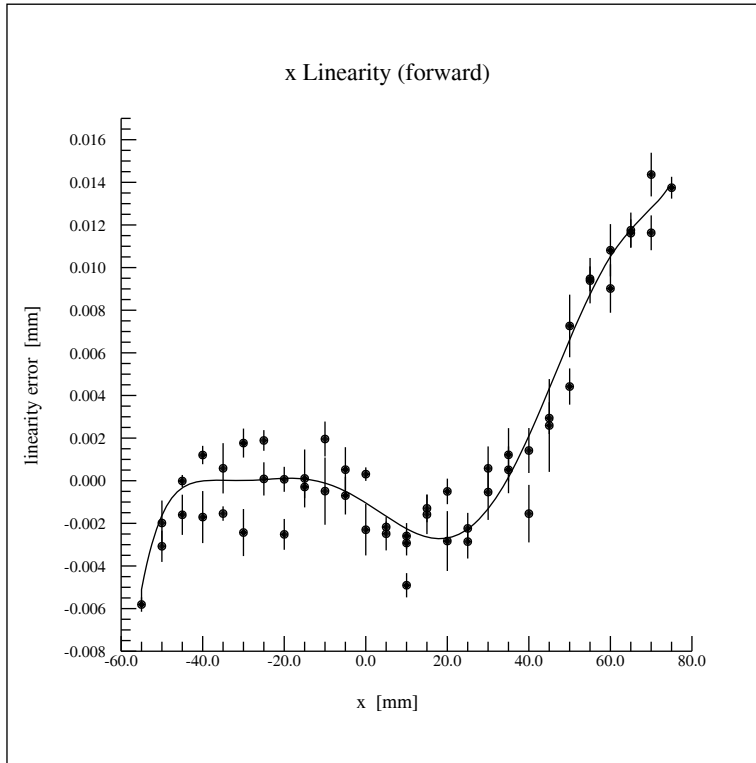
3 Positioning Errors and Printing On-The-Fly

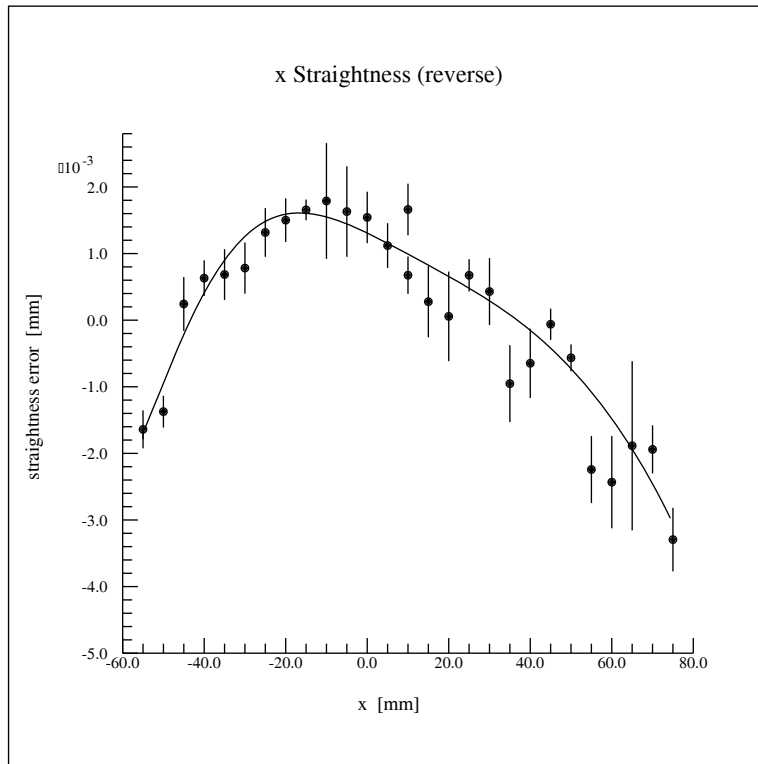
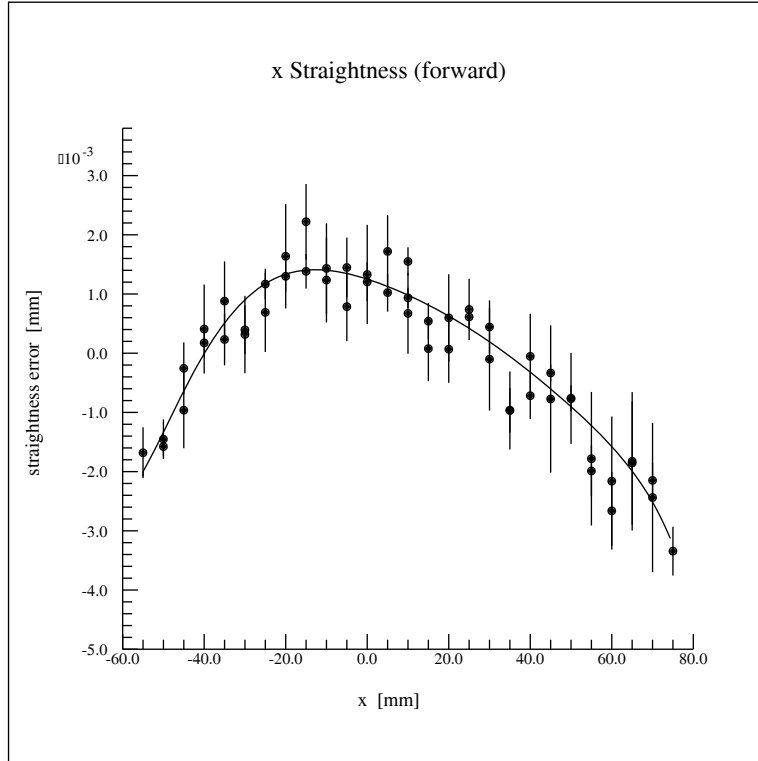
It must be emphasized that the stage survey is a static one, and the full benefit is available only for printing on position.

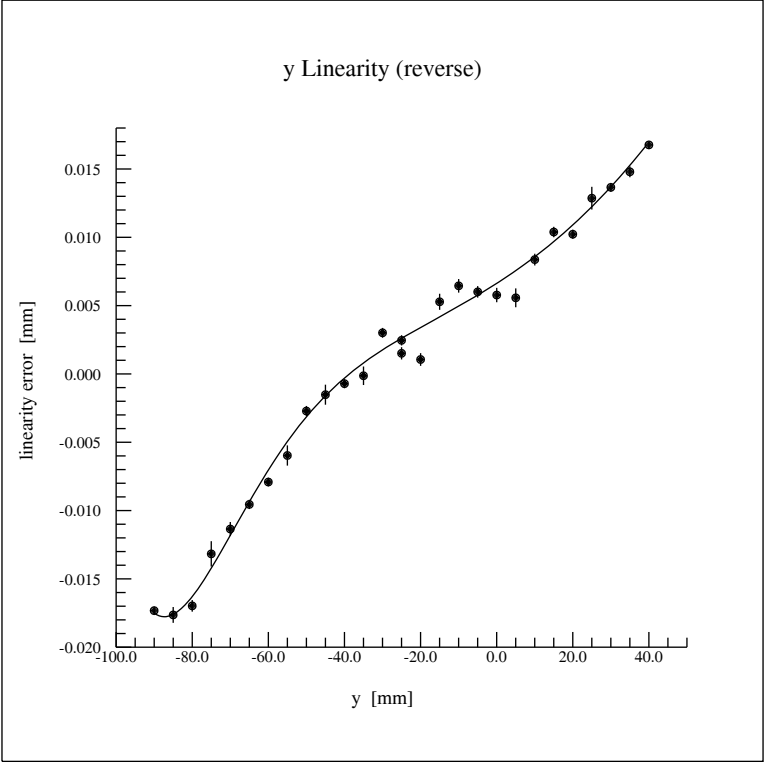
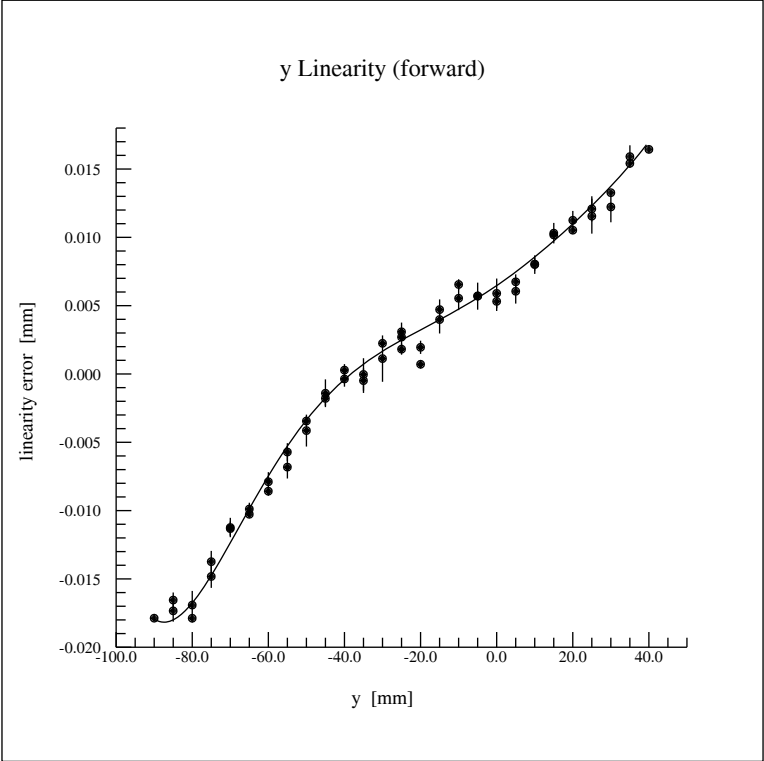
During motion along one axis, the transverse error (straightness) would have to be corrected in real time, which exceeds the capability of the **jetlab**[®] **4** print station and software. In this case, both the linearity and straightness errors of the other axis can be corrected for. Because printing on-the-fly requires space at either end of the printing area for acceleration and deceleration, and the errors being worst near the ends of the motion ranges, the damage incurred is limited.

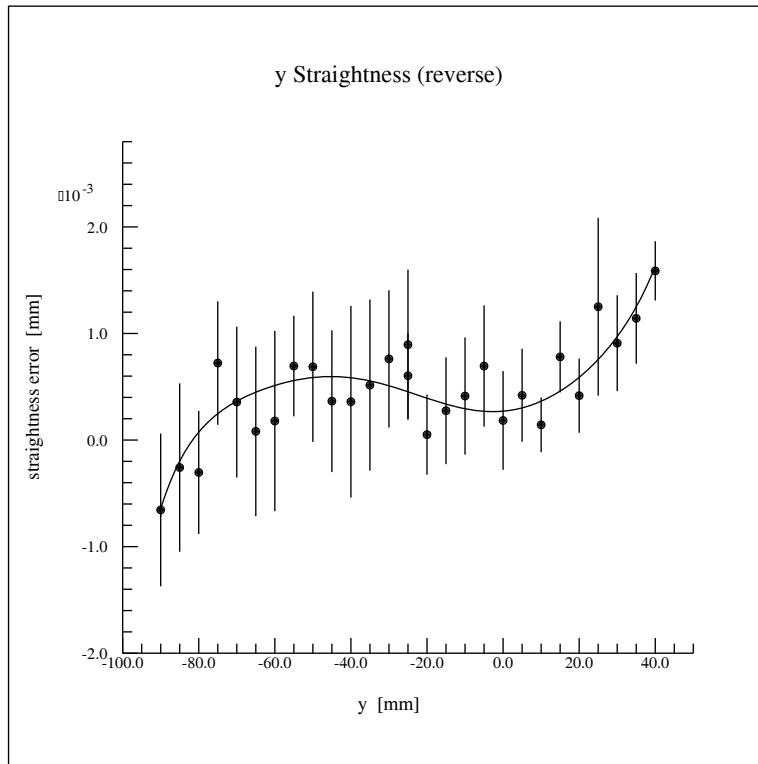
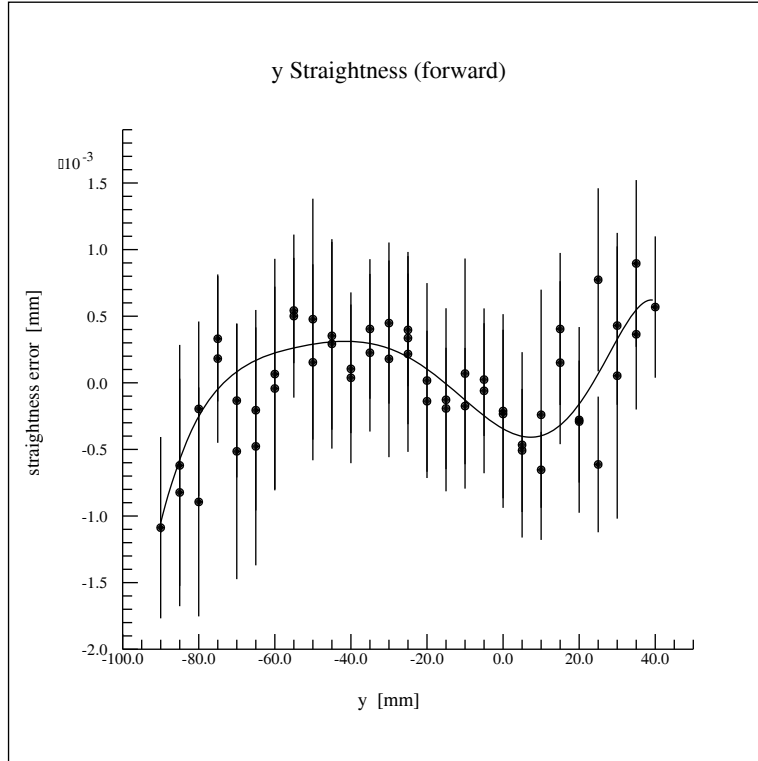
The worst case is printing along a line 45° off of either axis where only the correction of linearity of one axis and straightness of the other are in effect. Drops are located in printing on-the-fly by triggering on the coordinate axis with the larger projection of the flight path. A conservative assumption would be that the larger part of the raw errors will remain uncorrected for.

Raw forward x linearity error for jetlab[®] 4 JL4-42

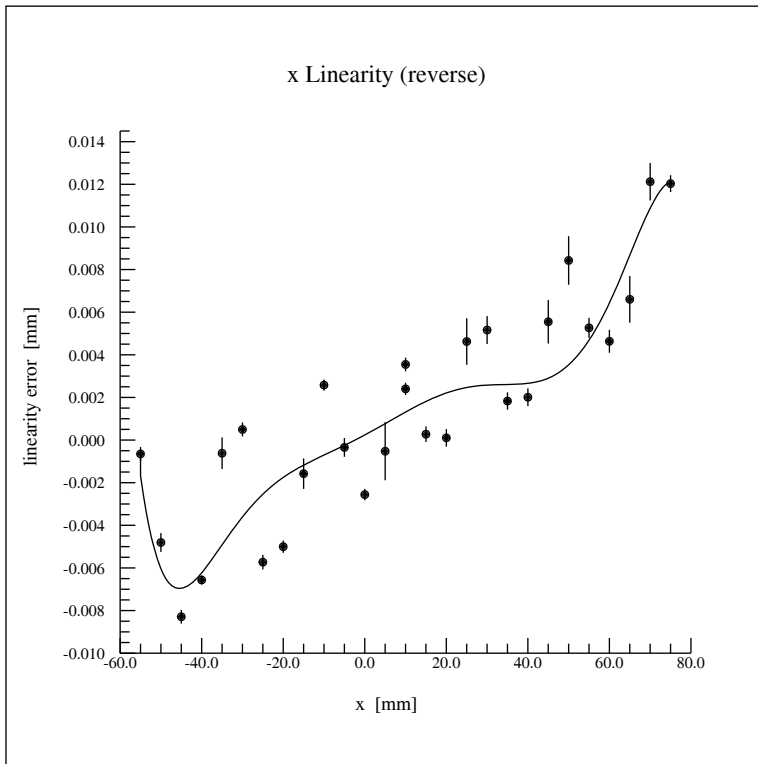
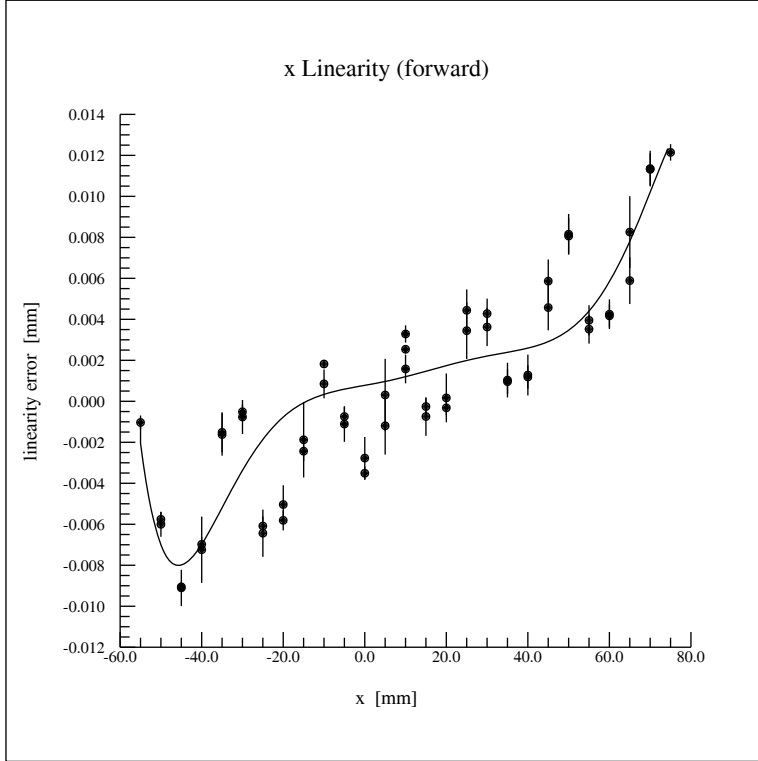


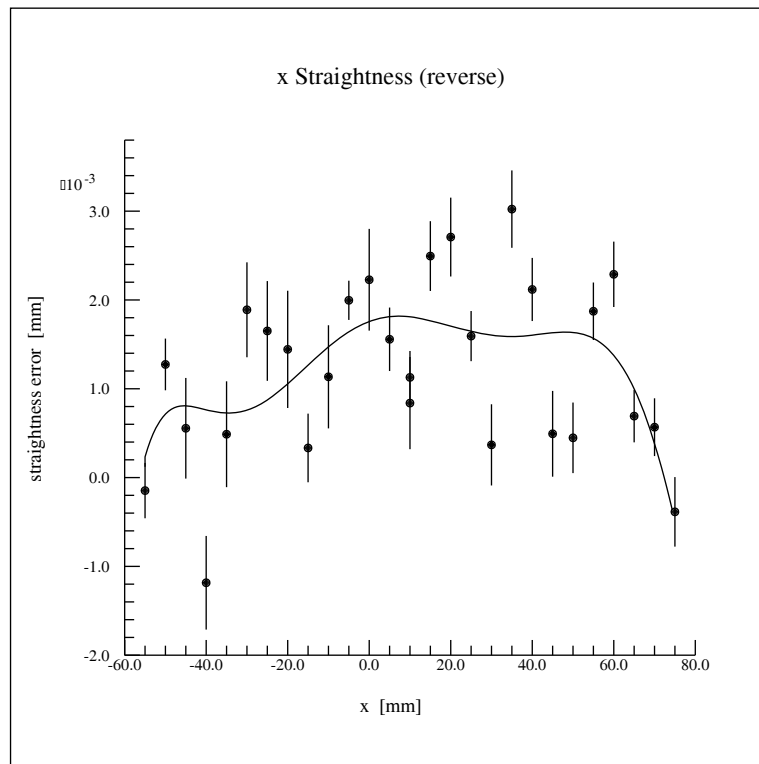
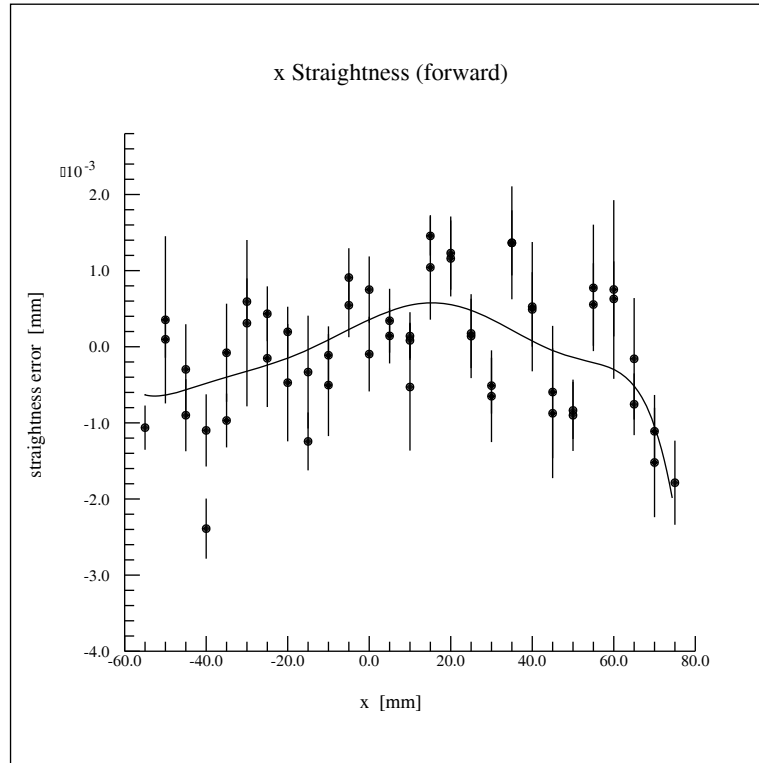






Corrected x linearity measurements for jetlab[®] 4 JL4-42





Corrected y linearity measurements for jetlab[®] 4 JL4-42

