Error Budgeting for Multi-Axis Laser Machining Systems to Understand Achievable Performance for Percussive Via Drilling

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Understanding a precision machine's fundamental motion error is essential for meeting required part tolerances. Precision laser processing machines demand additional attention because linear servo and galvanometer-based laser scan head axes have independent error motions. The interaction between these subsystems has a measurable effect on part tolerances [1, 2] produced by the laser processing machine. It could be catastrophic to design and produce a machine without doing some fundamental analysis of the expected output quality. This presentation proposes a method of estimating system performance, analyzing a laser processing system's motion performance, and producing a part to compare to the estimated performance values.

Many high-throughput laser processing systems use a multi-axis servo stage configuration to manipulate the workpiece within the laser scanner's field of view. A standard metrology process may be used to independently calibrate servo and laser scan head error motions in the context of a fixed sensitive measurement. With advanced motion control features that coordinate servo and laser scan head motion, such as Infinite Field of View (IFOV), it is necessary to characterize any additional error motions that arise from a slight deviation of the fixed sensitive calibration conditions. By calculating an RSS value of the laser scan head and servo stages' independent error motions, one can determine a reasonable approximation of combined performance [1]. This approach is validated with a 2D laser scan head and XY servo stage stack, using a contrived calibration pattern and thru-via drilling patterns in a representative substrate.

Successful implementation of this method allows for laser machine designs to be characterized solely by quantifying the constituent stage error motions and calculating their combined RSS value. This enables reasonable performance estimation with minimal impact on the overall system design timeline.

[1] S. Schmidt and W. Land II "Estimating Combined Servo and Galvo Motion Accuracy" *Aerotech*, December 2021, https://www.aerotech.com/estimating-combined-servo-and-galvo-motion-accuracy/
[2] J. Lindell "Multi-Axis Motion System Error Budgeting" *Aerotech*, 3 April 2022, https://www.aerotech.com/multi-axis-motion-system-error-budgeting-2/