Simulation Tools

Streamline Photonic Component Manufacturing

Virtual pivot-point motion analysis and active-alignment power scanning help end users explore their positioning equipment needs and prove out alignment capabilities before buying a system.

by Thomas T. Markel, Aerotech Inc.

Photonic component manufacturers have to meet the challenges of a commodity-market price structure on products that until recently required a laboratory-type manufacturing environment. As a result, cost-effective mass production of these components has been difficult to realize. However, improvements in the development tools used to design and build automated component manufacturing machines, combined with continuing improvements in automation software, are leading to shorter automation design and build cycles. Toward this end, simulation tools for virtual pivot-point motion analysis and active-alignment power scanning can help end users examine the configuration of automated positioning systems before they make an investment.

With simulation, end users can explore ways to increase overall manufacturing efficiency of devices such as vertical-cavity surface-emitting lasers (VCSELs), butterfly packages, dense wavelength division multiplexers (DWDMs), collimators, optical arrays and microelectromechanical systems (MEMS). These tools help predetermine the effect of various tooling designs on stage stack configurations and travel requirements.

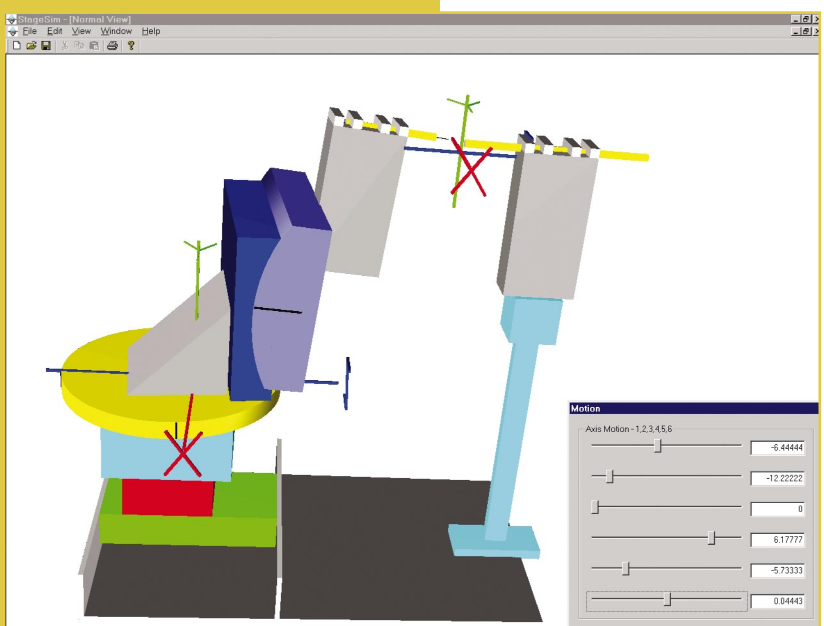

***Figure 1.** Because the fiber pivot point has a large offset from the motion pivot point, virtual pivot-point equations are needed.*

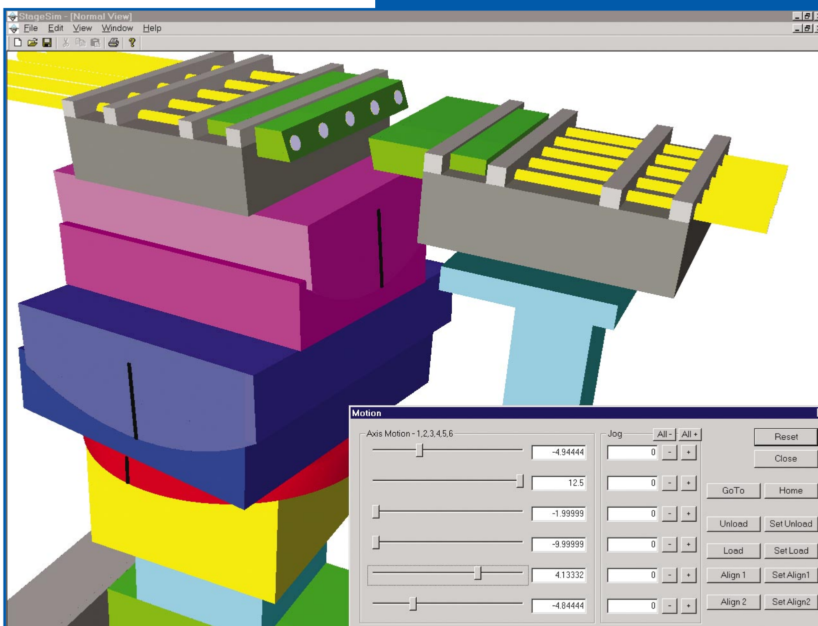

***Figure 2.** Virtual pivot-point simulation allows the user to set the system pivot point on any of the fibers on the left or right device for maximum flexibility.*

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In addition, they allow engineers to prove out alignment process sequences and assess theoretical alignment speed based on different motion parameters.

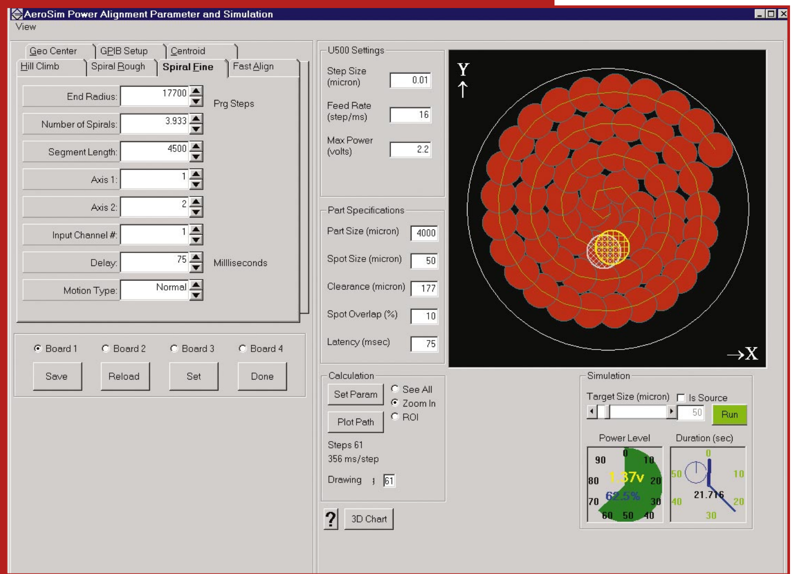
Virtual pivot points

Many photonics customers have unique device requirements that cannot be resolved by a single-configuration alignment system. Components such as collimators, lensed fibers, arrayed waveguides and fiber arrays typically require angular as well as linear alignment for optimal power peaking. X-Y-Z linear motion, combined with pitch, yaw and roll, is used to align these devices.

Component size and optical properties drive the positioning system's linear and angular travel requirements. With modular motion axes, high-precision stages can be stacked in many configurations to meet a customer's changing needs. Simulation of these modular stages allows engineers to analyze the trade-offs among tooling size, mechanical stack size and linear or angular travel at the optical focal point.

Because of the size of photonic devices, a fiber or array being aligned to another device may be located on a tooling arm away from the motion system's point of rotation (Figure 1). The optical device may require angular motion at its face or at a point in space some distance from the face. Because the fiber and motion rotation points are not collocated, rotating the mechanical stage causes a linear translation of the device under test, as well as the rotation. To keep the fiber pivot point in place linearly, the motion system must compensate for this linear translation with a translation in the opposite direction. This is the virtual pivot point of the system. The equations used to perform this motion are called reverse kinematic equations.

Figure 3. In the AeroSim active-alignment simulator, end users can see a spiral search pattern run with the search pattern steps (orange), the target (gray circle) and the resulting source alignment position (yellow).



Putting together test systems, manufacturing test tooling, setting up customer parts and then running extensive experiments of virtual pivot points and active alignments to prove out system functionality can be costly and time-consuming for automation providers and their customers. By implementing graphical simulation of these systems, engineers can quickly identify appropriate motion and tooling features to optimize the design before investing in hardware and test time. The virtual pivot-point

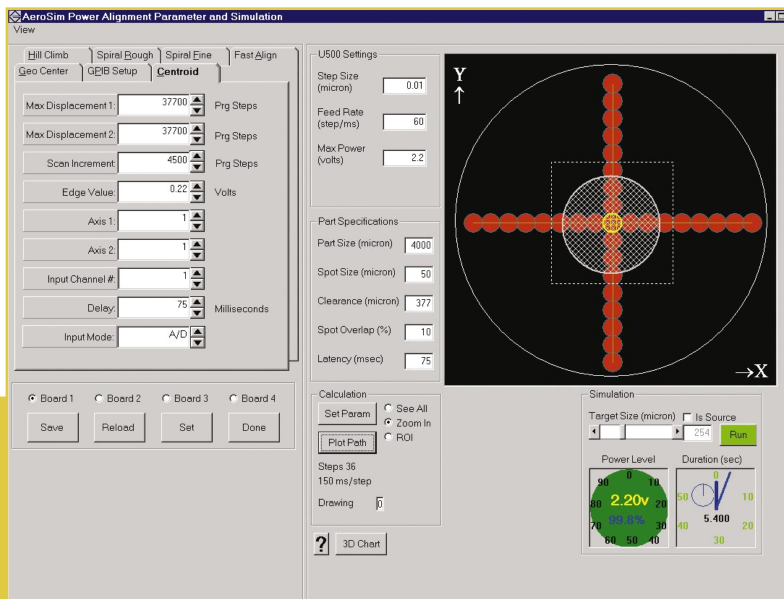


Figure 4. Centroid search simulation will indicate the search pattern, the target (gray) and the resulting source alignment (yellow), including the search power level (green) and estimated duration.

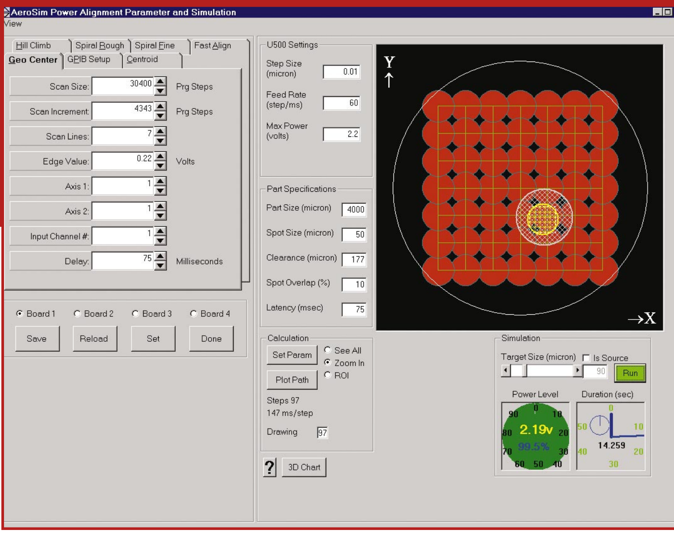


Figure 5. This raster search pattern simulation indicates predicted results for a specific component-manufacturing application.

model can be developed in short order and equations confirmed without a real test system.

A virtual pivot-point simulator models the stage stack with the reverse kinematic equations with variable programmed tool tip offsets from the actual system pivot point, and transforms the motion commands so that rotation occurs at the desired virtual pivot point (Figure 2). The reverse kinematic transforms will simultaneously calculate the translation error and the compensation move during the alignment, sending the proper motion command to all necessary axes. This simulation helps designers and customers visualize system configurations and verify virtual pivot-point functionality with the selected stage stack, tooling and simulated optical device. This proof-of-concept work lets the engineers confirm system feasibility and the motion travel that will be necessary to achieve their optical alignment requirements.

Advances are being made in active alignment simulation as well. Simulating active-alignment power scanning routines and motion relative to customer optical parameters can help realize theoretical alignment speeds before system construction, and it can help customers determine optimized search parameters quickly with the real system.

Photonic component manufacturers are always looking for proof of a motion system's alignment speed. Many times they will ask for consignments and then spend hours setting up and testing vendor equipment to determine what they can expect with various systems. It is time-consuming and costly to evaluate systems and to experiment with search parameters to optimize alignment speed.

Power scan simulation takes the place of much of the initial experimentation and calculation on motion step size during a search relative to the optical device source and target spot sizes (Figure 3). Search routines are generally organized into search patterns used for first light detection, fast alignment routines to get close to maximum energy quickly, centroid search routines that center the alignment location between energy edge thresholds and power maximization search patterns to find the highest possible energy (Figure 4).

Automatic parameter calculation

These search patterns all have associated parameters that determine how far each axis moves, how long the move dwells at the location, what energy thresholds are valid, etc. Needless to say, optical engineers are not too interested in what parameters do — just that they are aligned to the maximum energy as quickly and reliably as possible. With so many parameter combinations possible, it could take days to weeks to optimize routines for speed and repeatability and to connect scan routines just to validate results with their devices.

Simulation software can determine these parameters automatically for the various scan patterns based on the optical source and target size (Figure 5). End users can graphically select or enter these sizes, enter the amount of spot overlap during the search and run the simulation. They can click on the search region to locate the target and watch the pattern run to confirm that the active alignment routine finds the target spot with the source. The simulator takes into account all of the motion time frames to predict the alignment speed of the routine. Because all of the parameters are variables, users can experiment with various changes and quickly determine optimal parameters with just a PC. Parameters for different components can be determined in minutes, instead of days of experiments in the lab.

These virtual pivot-point and power scanning routines are based on modular stage stacks, so that customers involved with imaging system design and optical positioning of large devices such as cameras and lasers can benefit from these simulation tools as well. They can use stage stack models to analyze large, long travel stages as well as the small nanopositioning stages used in fiber optic alignment. These advanced tools are having a beneficial effect on the bottom line because they speed the customer's product time to market, while minimizing risk and development costs. □

Meet the author

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