WDM SOLUTIONS

Factors to consider when choosing an alignment system

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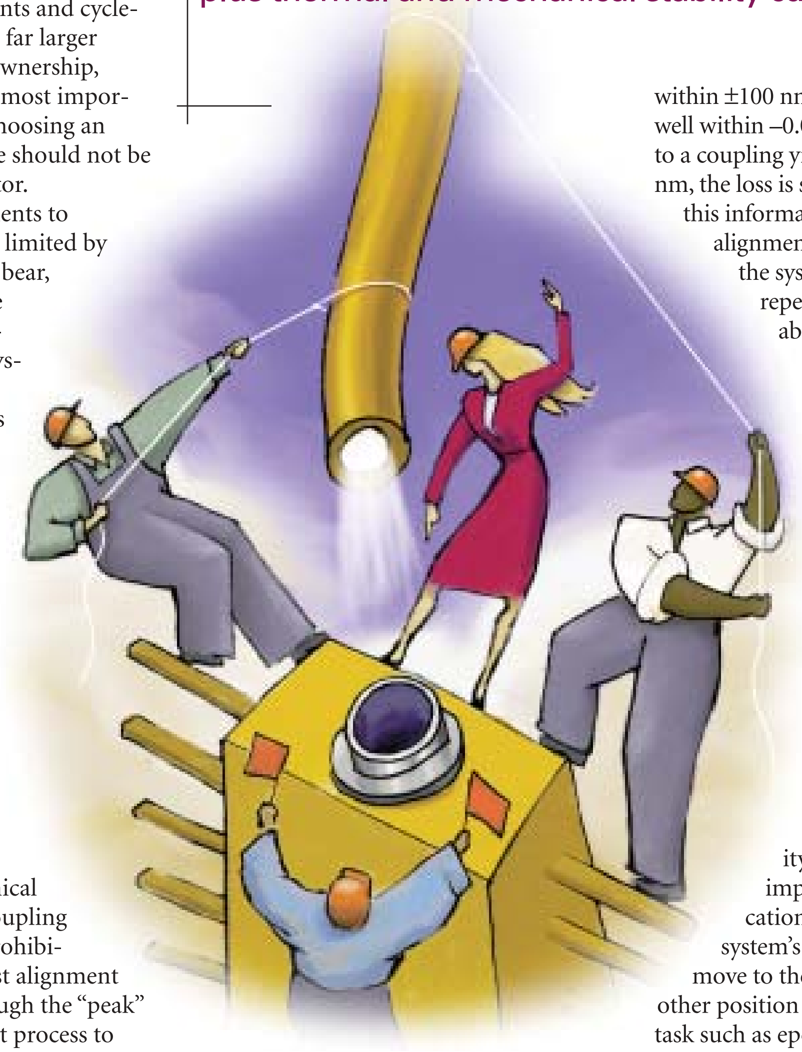
Savvy engineers know that the most economical system balances price with performance. Motion control plus thermal and mechanical stability can't be cut.



Although an economic analysis will usually show that process-yield improvements and cycle-time considerations have a far larger effect on the total cost of ownership, price is usually seen as the most important consideration when choosing an alignment system. Yet price should not be the single determining factor.

True, system improvements to increase coupling yield are limited by prices that the market will bear, which creates an inevitable tradeoff of cost versus performance. An alignment system manufacturer could make the translation stages out of very-low-thermal-coefficient-of-expansion materials like Invar and the thermal effects would be drastically improved, but the system would cost too much. On the other hand, inexpensive stepper motors could be used, but the poor inherent repeatability and high thermal outputs would have a negative effect on coupling yield.

Thus, the most economical system would have high coupling yield without becoming prohibitively expensive. Since most alignment algorithms must pass through the "peak" point during the alignment process to determine that component positioning is indeed at optimum, the coupling yield depends on the ability of the alignment system to repeatedly return to that point (a function of the motion system) and the ability to maintain thermal and mechanical stability during and after the alignment process (a function of the thermal loads and mechanical design of the system).

MOTION CONTROL

A typical power distribution curve for a singlemode 1310-nm transmitter is shown in Figure 1. The graph shows that within ±100 nm of peak, coupling loss is well within –0.01 dB, which corresponds to a coupling yield of 99.8%. But at 300 nm, the loss is significantly higher. Given this information and assuming a target alignment repeatability of 0.01 dB, the system must be capable of repeatedly moving to within about 100 nm of the peak.

The resolution of the motion system is the smallest increment that a motion system can be commanded to move or that can be read on a display, but the system may not consistently make moves equal to the resolution. Minimum incremental motion is the smallest move a system can make but does not describe the consistency of the moves.

Bidirectional repeatability (BDR) is ultimately important in alignment applications, because it measures the system's capability to consistently move to the peak position from some other position after a scan or some other task such as epoxy delivery. In the Figure 1 example, the BDR has to be better than 100 nm.

Most motion specifications are defined in terms of a single translation axis. But for an alignment system, the required performance is based on the entire system consisting of up to six axes of motion per cluster, alignment software, tooling, and environmental considerations such as temperature and vibration.

Since most customers have unique requirements, it is desirable to develop a device-agnostic measurement that anyone can repeat. For example, Newport Corp. uses a 1550-nm singlemode fiber-to-fiber alignment with a 10-µm gap (no index matching gel) and measures the variation (sigma) in decibel loss resulting from repeated approaches to the peak. This results in a very reproducible and objective measurement that accounts for all environmental and systemic factors. For example, a 1-sigma repeatability of 0.01 dB means that the system will repeat the alignment result to within 0.03 dB 99.87% of the time.

Typical power distribution profile

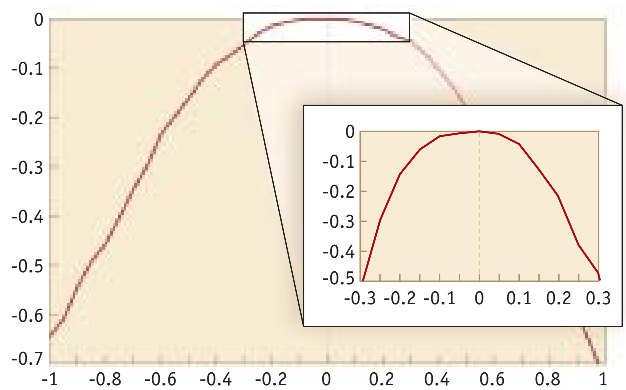


Figure 1. In this profile, the X-axis is the position in microns of the optical fiber as it scans through the light field; the Y-axis is the optical power in decibels; the peak of the curve corresponds to the optimum.

Mechanical design

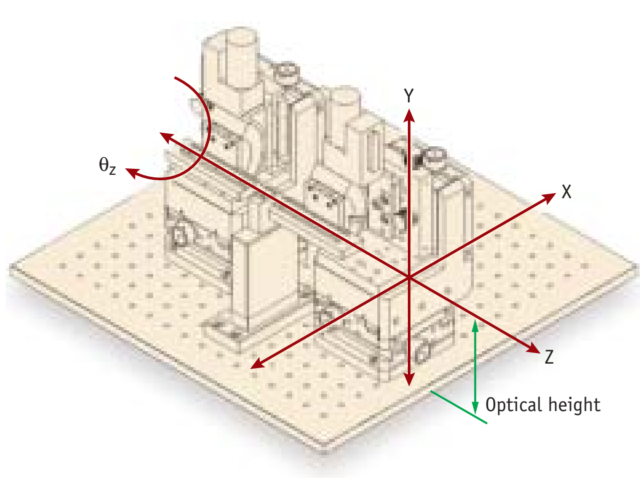


Figure 2. While each axis is important, the optical height of the system is the most reliable measure of system stability.

MECHANICAL DESIGN, THERMAL LOADS

When evaluating an alignment system, the optical height of the stages and fixtures should be used as an indicator of stability that the system may have if the manufacturer does not specify the value (see Figure 2). The optical height is the distance from the center of the optical axis to the base of the system (e.g., the optical table). Increased optical height results in a higher magnitude of Y-axis shift to changes in temperature. The length of the fixtures and stages in the Z direction is important too, but most optical devices are less sensitive in the Z-axis.

Sources of heat must be isolated from the motion system to inhibit the detrimental effects of thermal expansion. A chamber can be used to control the air temperature, but that adds a lot of cost to the system and impairs the system's usability. The best approach to control temperature effects is to reduce the optical height and use cool running stages. The following stages are commonly used in alignment systems; it is important to understand the pros and cons of each type when purchasing the system:

- *Stepper motors.* A low-cost solution, alignment systems using steppers may be limited in application due to poor repeatability. Steppers tend to get very hot, which severely affects stability and repeatability.
- *Piezo actuators.* Piezos offer very high resolution (10 nm) and high strength. However, they introduce measurable hysteresis effects and are difficult to control in closed-loop fashion. Most piezo stages also have very limited travel range. Piezos also have short life spans and tend to require frequent replacement. The unnecessarily high resolution and low cost do not justify the sacrifice in repeatability and system uptime.
- *DC servos.* A cool-running DC servo motor with a good glass scale encoder is the best choice for singlemode applications that require high coupling yield. Additionally, the resolution, accuracy, and repeatability required for the application are readily available (between 50 and 100 nm).

FINAL ALIGNMENT

The critical attributes of an ideal alignment system are high coupling yields and reasonable costs. These may be mutually opposing, but a good compromise can be established to offer a cost-competitive system that has the most important elements designed-in to meet the requirements of the application.

Before purchasing an alignment system, a good understanding of the specifications and how they truly affect the application is necessary. That will enable the buyer to evaluate the system and demand the appropriate specifications from their suppliers. LW

ALIGNMENT-SYSTEM STAGES

	Cost	Heat	MTBF	BDR
DC servos	Moderate	Cool	Good	50-100 nm
Piezo actuators	Low	Cool	Poor	10 nm and less
Stepper motors	Low	Hot	Good	300 nm

BDR – Bidirectional repeatability; MTBF – Meantime between failure

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