AVOIDING LASER WELDING IMPLEMENTATION PITFALLS: Achieving Yield, Throughput & Time-to-Market in Today and Tomorrow's Photonics Industry

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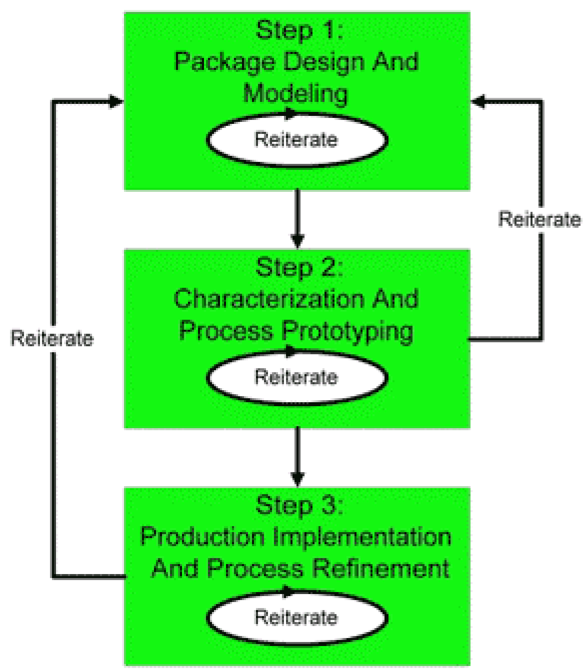
The use of laser welding for assembly of optical and photonic packages has become the bonding method of choice for many applications. This is primarily due to long-term bond integrity, improved reliability, and reduced optical components migration over time, among other reasons. However, as with any sophisticated process technology, introduction of production-grade laser welding systems in the real world for these applications is typically challenging. This article intends to highlight some of the key elements required for successful planning and implementation of an effective laser welding system.

There are a number of basic pitfalls to avoid for successful laser welding implementation. Obstacles to be overcome include:

- There are limited standard products, packaging, and processes in today's market.
- The processes, and even the products, are not well defined up-front.
- Optical modeling versus reality is limited in its accuracy.
- You don't know what you don't know until you need to know it.

It is not as simple as just buying a given laser welding system or a complete automated or semi-automated welding station, at least not if you are to achieve the best possible yield and throughput. Indeed, it may not be possible to make the assemblies at all. The key to addressing these issues is applying the appropriate care and planning in the definition and implementation of your laser welding system.

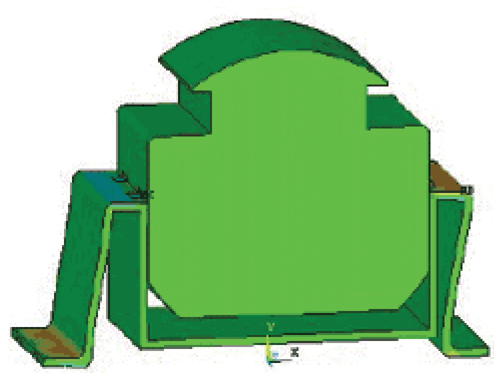


Iterative loop of process/product refinement

The first important step is to develop a reasonably complete model of your full optics or photonics package. At a minimum, this will include an accurate 3D CAD model of your package and the components to be included within it. The optical components inside the package include various types of lenses, modulators, isolators, optical fibers, and other optical elements, as well as the clips/fixtures/holders that keep these optical elements in place. In addition, a finite element analysis (FEA) model of the optical components and holding clips/fixtures may be helpful to determine the susceptibility of the overall design and of the individual components' designs to vibration, shock, temperature cycling and other environmental conditions the product will need to endure in service. FEA is also valuable to evaluate and select the optimal materials for the holding clips/fixtures.

Developing an optical model that considers the optical performance of the full optics train is generally suggested. This modeling, at a minimum, needs to consider issues such as focal lengths and numerical apertures of optical components step-by-step through the optical train. This can help determine the positional tolerance requirements of the optical components in your package necessary to achieve essential overall performance requirements such as power throughput. It can, of course, also determine if your basic design is even viable and help you refine it as needed.

Another important benefit of creating the CAD, FEA, and optical models is that these can be valuable elements when implementing an effective design for manufacturing (DFM). DFM encompasses many elements of product and packaging design, such as selection of materials, simplification of manufacturing processes, and reduction of component count. At this stage, CAD and optical models are typically put to use to adjust the design up-front. This accommodates access into the package so as to place and hold components, as well as to make sure there is enough room to adjust the positions of the various components when addressing variances in optical performance for the individual optical components. For laser welding purposes, make sure that the converging laser beam trajectory can be focused on the required weld locations without clipping the component-holding grippers of the laser welding system and/or the walls of the product package.

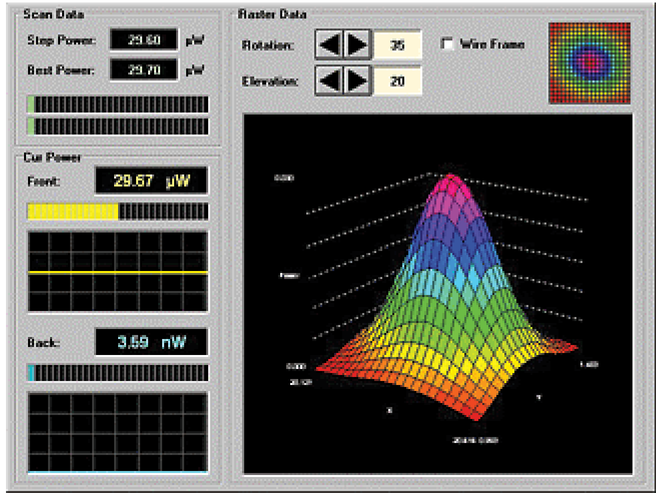


Finite element model of lens in holder and clip

The second important step is to verify the accuracy of the models and to refine the overall package and product design, including the design and processing (alignment and welding) of the individual components. This requires a function referred to as process prototyping. The first element of process prototyping is component and system characterization to determine the detailed performance of the individual components and overall package. This is essential to verify the optical models and to make adjustments as needed to reflect real-world performance versus theoretical.

Ideally, at this stage you should be using a semi-automated means to perform the characterization function. Unlike using manual stages, this allows you to perform repeatable positional experiments to fully characterize the performance of the components versus position and orientation in the optical train.

The development of component alignment and welding processes is another important element of the process prototyping protocol. This includes prototyping of automated or manual material handling processes for the components, often employing flexible machine vision technologies. This development effort is often done parallel to and then subsequent to the component and overall package performance characterization. Understanding the performance characterization of an individual component allows you to select the best alignment algorithm or method to repeatably find the position and orientation of the component in the optical train for optimal performance.

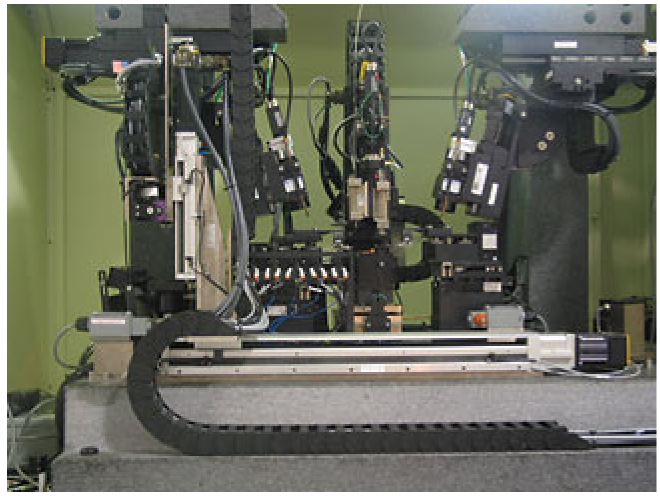


User interface showing process characterization plot

Once the alignment method for a specific optical component has been prototyped, there is the need to define an optimal laser welding profile. This is the definition of the number of welds, the positioning of the welds, and the laser weld schedule to achieve the welding of the component in place. The optimal laser weld profile will be such that the component and its holding fixture/clip will maintain pre-weld alignment performance and optimum weld integrity.

Achieving this is often much more difficult than it seems, for a variety of reasons. The challenge here is that the specific sequence of the individual welds in a given laser welding profile must be such that the optical element and its holder will not shift significantly from peak optical alignment, a phenomenon known as post weld shift (PWS). For example, although weld points are often executed in parallel from opposing angles as part of the weld profile to minimize lateral shift, there is still the issue of imperfect energy balance between the two laser delivery heads. An energy balance of 3% between laser heads is typical. The thermal expansion and contraction during the laser welding process in general also causes shifts due to necessary asymmetries in fixture geometries. These and other issues all make defining the laser weld profiles an iterative process at the experimental level and also often require reiteration of component fixture design and modeling to achieve required optical performance levels.

The third important step, once the process prototyping has been completed, is the implementation of laser welding in production. Here is where a common implementation mistake is made. Although it might be least expensive initially to implement an automated or semi-automated laser welding station with the capability to execute only the laser welding functions defined in the steps above, this is typically not the best long-term solution. Your product and process will need to continue to evolve to support higher yield, higher throughput, and lower component count and cost. This implies an additional iteration loop between the production implementation of the laser welding station and the design and process prototyping/refinement steps.



Automated laser welding machine

The primary obstacle here is that the first and second-generation laser welding stations currently available as either new or second-hand equipment just aren't flexible enough. They don't have the highly flexible and reconfigurable machine vision technologies and other key capabilities to easily and quickly adapt to use different optical components or holding fixtures for these components in the package. They are designed for high volume production of the same component over and over again. Even if you will be making the same package in volume (although that is not likely in today's market) you will still need to continue to quickly modify your process and product to get your manufacturing costs down. Realistically, you will need to either enhance the flexibility of the currently available "standard" laser welding stations or create your own from the ground up with the needed flexibilities.

Successful implementation of laser welding systems for a range of applications in optics and photonics can be achieved if you remember the rules. First, it is important to not think that you can simply buy a new or used laser welding machine and start turning out parts in production. Second, you will not achieve success without first thoroughly developing/optimizing your process and package design.

And lastly, you will need to have the capability in your laser welding station to continue to refine your process for continued increase in yield, increase in throughput, and reduced manufacturing cost. With product lifetimes of less than 18 months and new designs coming to market every 24 months, there will be a point where your competitors could outpace your market position. Think in terms of the need for continuous improvement and the associated requirement for flexibility in the automation you implement to ensure that competitors are always several steps behind your advancements.

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