Optical Manufacturing

Laser-weld attachment enables repeatable submicron precision

BY GEOFF SHANNON AND EDWARD PALEN

Laser-welding attachment of photonic devices in a production environment is possible, practical, and affordable if the optical-alignment and weld-attachment processes are well understood, the device is designed for laser-weld manufacturability, and the alignment stations are compatible with volume production requirements.

The ability of laser welding to join optoelectronic components with repeatable submicron precision distinguishes it from other forms of attachment technologies, including laser soldering, ultraviolet-cured epoxy, and thermally cured epoxy. The need for submicron precision arises from the requirement to efficiently couple single-mode fibers, waveguides, or modulators.

Process yield and repeatability have often dictated the use of laser welding in the manufacture of laser modules. Typical attachment tolerances can be 250 nm, with alignment requiring optical beam-profiling step sizes of 50 nm. This level of precision generally precludes the use of epoxy and soldering attachment due to difficulty in achieving repeatability at submicron tolerance in a manufacturing environment.

Attaining this level of precision with laser welding demands substantial processing, materials, and welding knowledge. All processes require active alignment, typically using optical power monitoring. More recent transmitter modules that have integrated wavelength tuning and other features may need to track other optical-alignment performance measurements such as wavelength, wavelength stability, or noise.

Nd:YAG laser systems

Neodymium:YAG-laser delivery systems are robust industrial tools that have been used effectively for metal joining and package-lid sealing in hermetic microelectronics packages for decades. The Nd:YAG laser is ideally suited to photonics-welding applications, offering multibeam output, time-share capability, highly controllable pulsed output, power feedback, and spot-size selection.

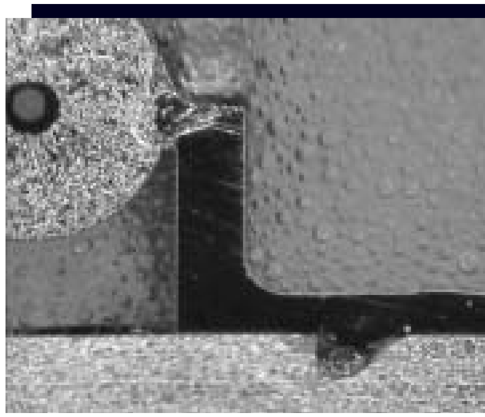

FIGURE 1. The cross section of a deformable weld clip shows the base and ferrule welds. Analysis of the weld by cross-sectioning is essential in weld-schedule process development and quality assurance.

For optoelectronics attachment, the pulsed Nd:YAG is used in single-shot mode. The pulse can be tailored to the need of each attachment configuration. Typical laser-weld pulses in optoelectronic attachment applications are 1 to 4 J over 2 to 5 ms, producing weld spots around 400 to 600 μm in diameter.

Two main approaches are used to apply laser-weld attachments to the precision tolerance requirements of photonic-module fabrication: deformable holders or rigid structures with machined parts.

Deformable holders or clips are used to attach an optoelectronic component to a submount. The holder is fabricated to be mechanically soft, without any mechanical memory or residual spring component. After optical alignment, the holder is mechanically secured to a submount using laser-weld pulses. The optoelectronic component is then attached to the holder using another set of laser-weld pulses. Any shift in the relative position of the components from their optimum position is corrected by mechanically bending the deformable holder while tracking the optical coupling.

Typically, this method uses a laser pulse split into two beams of equal energy delivered to two separate spots. This configuration is often referred to as a "planar weld" configuration. A widely used form of the deformable clip in the optoelectronics industry is the bendable "weld clip," for which there are many proprietary designs (see Fig. 1).

The other approach uses machined parts that hold the optoelectronic components and fit together to form a rigid assembly once attached by laser welds. The most common version of this is in "coaxial" or TO-can style packages and is also applied to fixing components to the outside of butterfly packages.

The laser pulse is split into three beams of equal energy and delivered 120° apart in one plane to control the symmetry of post-weld shift in that plane. In contrast to the planar-welding packages, the weld-joint designs and beam accessibility can be component-specific.

Laser-weld development

Ideally, the development of a laser-welding application begins with part design, joint tolerance, and material selection. Once these criteria are fixed, a robust laser-welding setup and schedule can be developed.

Part design. Coaxial packages require a number of weld sets that are placed along its length. Through similar joint design the repositioning of the focus heads between sets should be minimized, while still allowing alignment freedom of the parts. When welding inside a butterfly package, the prime consideration is the clip design for both laser welding and bend alignment. In addition, all designs are directed toward minimized and predictable post-weld shift.

Joint tolerance. The instantaneous fixing that occurs between welded parts, unlike the epoxy or solder process, means that there is less opportunity for active alignment during the actual welding process. Fixing accuracy is therefore a function of how well the joint interfaces fit together. This is especially applicable to the coaxial packages that consist of machined parts. For a butterfly package that utilizes a weld clip, this relates more to the manufacture method of the clip and subsequent handling prior to welding.

Material selection. The materials used for submounts, metal ferrules, and various attachment holders need to be constructed from laser-weldable materials. Such materials include Kovar, nickel alloys, invar, alloy 52, and 304/304L stainless steel. In most cases, for thermal expansion concerns, like materials are welded, though dissimilar materials can also be welded. Kovar and stainless steel are routinely welded, for example. Material selection also has a significant effect on joint tolerance because of fabrication tolerance; Kovar can only be machined to 10 times the tolerance of stainless steel 304L.

Generally, material composition needs to be selected to minimize carbon, sulfur, and phosphorous content, with avoidance of highly reflective materials such as copper. In addition, the thickness of gold plating needs to be limited to around 50 µin. This coating should be electrolytic, but electro-less plating can be used in some instances.

Laser-welding setup

Laser-welding setup and schedule development can follow dedicated design for laser welding or can be applied to existing designs that are suitable. The first task is to select laser parameters, beam delivery, and focus-head position to achieve sufficient weld nugget-size dimensions and orientation to match joint geometry and strength requirements.

FIGURE 2. Parts handling represents a challenge for both tooling and automation. A gripper tool is used to secure and position the ferrule and clip as a subassembly.

The second, more subtle phase involves tailoring the weld schedule and possibly beam orientation on the part to produce minimal, repeatable shift and to address any thermal heating issues. Throughout this process, cross-section analysis of the weld joint is essential as an initial quality-assurance measure, in addition to optical-power coupling change for production lines.

As with any joining technology, parts handling represents a challenge for both tooling and automation (see Fig. 2). In the case of laser welding, it is necessary to allow clear access of the beam to the welding area. As the exact dimensions of the focusing laser beam are known and consistent, it can be simply modeled like any other part of the tooling setup

The laser-welding process is fully consistent with the move to automation. A dedicated system requires little or no operator presence, the laser pulse for each joining operation is defined and called up as required, and the laser has no short-term consumables and is highly reliable.

Processing solutions

Potential users of laser-weld processing for optoelectronics packaging should consider whether to buy hardware or a process that uses the hardware to deliver the attachment solution desired. Partnering with a source of the processing knowledge offers an optimal solution, qualification, and comprehensive support.

A typical auto-align laser-welding system is useful for prototype fabrication and laser-weld process development. The prototype station can be used to define requirements for alignment, process sequencing, design for automation compatibility, robust tooling design, alignment-software algorithms, and post-weld shift correction. OM

GEOFF SHANNON is a laser-welding scientist at Axia Systems, a division of Unitek Miyachi Corp., 1820 S. Myrtle Ave., Monrovia, CA 91016. He can be reached at geoff@axiasys.com. EDWARD PALEN is a consultant specializing in optoelectronics-packaging design and manufacturing. He can be reached at epalen@earthlink.net.