Manufacturing photonic devices by Nd:YAG welding

Geoff Shannon

Unitek Miyachi Corporation

1820 S. Myrtle Ave PO Box 5033 Monrovia CA 91017-7133 USA

T: +1 626 930 8448 F: +1 626 599 9636 E: geoff@axiasys.com

Photonic devices are the elemental components of the fibre telecommunications network, providing sources, means to combine and split signal wavelengths, signal amplification and restoration, receivers along with devices offering numerous other functions. The signal sources and amplification devices are referred to as' active', since they contain a light-generating component such as a laser diode. By contrast, wavelength splitters and combiners are passive devices, since they optically transform signals with no internal generation of light. Active devices require the light source to be coupled into an optical fibre with a core diameter of around 6 – 9 µm. In order to achieve the required coupling efficiencies the fibre must be located in space relative to the diode, to a tolerance of around 0.2 µm. It is to meet such demanding fixturing requirements that laser welding is implemented as the attachment technology.

The Nd:YAG laser is ideally suited to photonics welding applications, offering multi-beam output, time-share capability, highly controllable pulsed output, power feedback, and spot-size selection. 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 – lap, butt, edge butt, thickness etc. Typical laser-weld pulses in optoelectronic attachment applications provide 1 to 4 J over 2 to 5 ms, producing weld spots around 300 to 600 µm in diameter. There are a number of example components that are routinely welded, here the laser pump module is described.

Manufacturing pump lasers

A pump laser is used to amplify optical signals, and on long haul networks these are typically spaced around 50 miles apart. The basic construction has an outer package, known as a butterfly package, in which the optical sub assembly sits, see figure1. This subassembly generally comprises a thermoelectric cooler, a welding platform and the diode mount. In fixing these components, which is achieved by soldering, a glass fibre has to be precisely located in space relative to the diode.

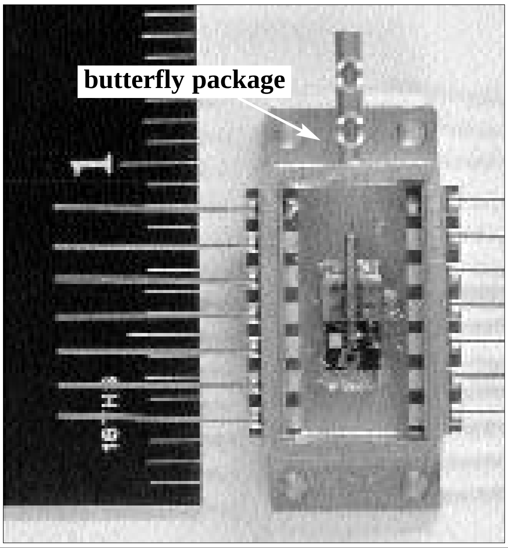
In order to make the fibre weldable it is gold metalized, then soldered into a kovar (iron-nickel-cobalt alloy) jacket known as a ferrule. The ferrule is fixed in space using a welding clip, which is made of kovar in order to match thermal expansion coefficients. The basic manufacturing sequence involves part loading, alignment of the fibre to the diode, welding the fibre in place, then post welding bending of the deformable clip to re-align the fibre and diode. The key aspects of the process are how much the fibre moves during welding, known as post weld shift, and the realigning process.

Part loading and alignment

The physical size of the parts and delicacy of the fibre tip make the initial loading of the parts time consuming. A typical ferrule is 1mm diameter, and 4-6 mm in length, a welding clip has a footprint of around 3 x 2 mm and can be only 150 µm thick. An off line pre-loading station is used where the fibre and clip are manually loaded into place on a mount. The assembled parts can be fed directly into the machine or stacked in palettes.

Once loaded the ferrule is gripped and optically aligned to the active source in 4-6 axes to a resolution of 50nm and 0.1 degrees. To increase optical coupling the optical fibres have faceted ends with a defined focus length . This implies that the fibre must be aligned along the axis parallel to the fibre, as well as in the orthogonal linear and angular axes.

The typical focal length of the faceted optical fibres lies in the range of 5-15 µm, but the fibre tip must not touch the laser, so the alignment is extremely important and is generally automated by means of optimized search algorithms.



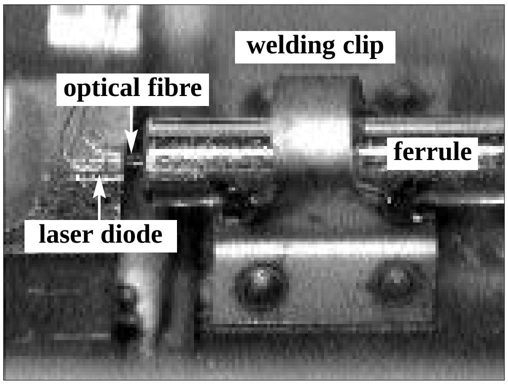


Figure 1 A "butterfly" style pump laser diode package. The magnified picture above clearly shows the ferrule, welding clip and diode, and the location of the spot welds fixing the clip to the base and the ferrule to the clip.

The welding process

The most important consideration of the welding process is the post weld shift.

After aligning the fibre to the diode to within 50nm, welds 300 µm wide and over 300 µm deep are placed on the base. these welds are followed by slightly lower penetration welds in the clip and ferrule. The likelihood of maintaining this alignment through weld solidification and thermally-induced stress is remote.

Although the size of the post weld shift is small, around 2-20 µm, this is relatively large in alignment terms.

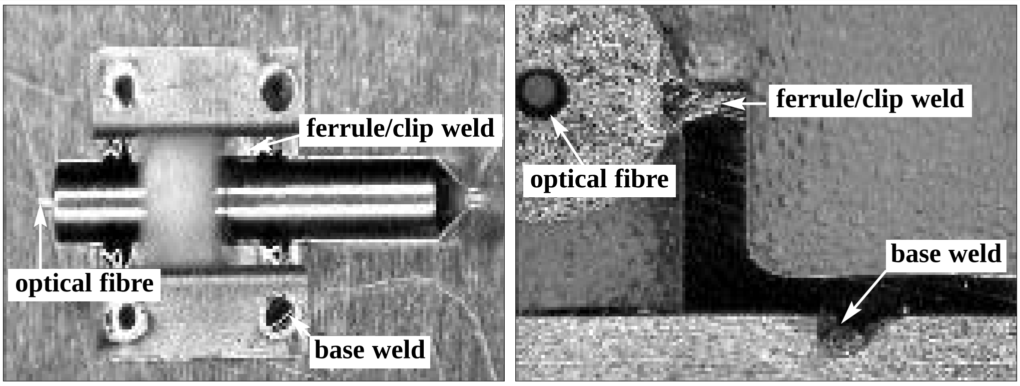


Figure 2 The left picture shows a plan view of the ferrule and clip assembly, with base welds and clips welds. The right picture is a cross section of one side of the ferrule and clip. Notice the fibre centered in the ferrule, this is 125 µm in diameter. The base lap weld and the ferrule to clip fillet weld are shown. To avoid the tooling the beams are angled typically 25 degrees from normal; this angle is apparent in the base weld.

The welding sequence and shift occurs as follows: the first welds are the base welds, as the clip and still gripped ferrule are a slip fit very little or no signal loss occurs. The second set of welds are the clip to ferrule welds, the first set are placed nearest the diode and move the ferrule downward relative to the diode. The rear ferrule clip welds then move the ferrule upward as the downward shift is translated to upward movement, since it pivots around the two front ferrule/clip welds.

Through the design of the clip and ferrule joint, and the force and location of the grippers for alignment prior to welding, the extent and direction of the shift are determined. Nominally, the majority of shift occurs in the vertical axis, which is unfortunate since this is the most optically sensitive axis, a result of the elliptical cross section of the diode laser output. The key for the welding process is to minimise the size and range of the shift.

The first step in minimising shift is to complete welds either side of the clip simultaneously. This requires the laser to provide two balanced energy-shared beams. Through design of the welding clip, the weld geometry, laser parameters and beam delivery, the shift can be characterised and minimised.

Once the shift has been characterised, the use of offsets prior to welding can be introduced. For example, if one knows that over all welds the shift occurs downward by around 7-10 µm, then the ferrule can be offset relative to the diode by, say, 8 µm upward.. This enables a percentage of the signal to still be coupled ready for the clip to be plastically deformed to fully realign the fibre and diode.

Bend Align

After the welding process, if the coupled signal is below the required specification a post-alignment process must be undertaken to locate the fibre to the laser chip. The clip is a deformable mount firmly welded to a base, with sufficient stiffness to be robust but not too stiff that it cannot be bent to re-align the fibre. With some percentage of the coupled signal typically remaining after the attachment process, the gripper tooling, motion system and control software combine to assess where the peak signal lies, and how much bending is necessary to re-align. The bending of the ferrule and clip assembly is achieved by grippers that affect the rear of the ferrule away from the diode. By successive bends of the clip a peak signal is obtained, with typically 90+% of the original signal recovered. In most cases the alignment is to a 0.3 - 0.5 µm plateau, which would appear unobtainable by such gross methods but in practice it works well.

In some of the more sensitive alignments, the package may be temperature cycled and re-bent to produce long term coupling stability. The package is then removed to go through test procedures to be concluded with hermitic sealing of the package by welding the lid to the top of the package, and solder sealing the optical feedthrough.

Summary

This brief synopsis illustrates the many steps required to manufacture a pump laser. As a system provider, Unitek Miyachi work closely with the customer from product concept through design and material selection, prototype packages and finally to production.