Metrology System for Inter-Alignment of Lasers, Telescopes, and Mechanical Datum

By Oren Aharon, Duma Optronics Ltd / Co-author Itai Vishnia, PLX

To avoid over-specifying of mechanical and optical tolerances, it is helpful to use final alignment and assembly processes that can achieve high levels of accuracy and superior overall performance. The system's assembly level should provide the engineer with the most appropriate assembly technique and gear to perform the alignment task that will improve performance without added cost of manufacturing of very accurate parts.

Advances in sensor technology have opened the door to a new measuring instrument, based on autocollimation principles combining laser beam collimation and direction measurement, accurate telescopic measurement, focusing techniques with sophisticated software and computing techniques. Of special interest is the laser analyzing autocollimator since it combines laser-analyzing technology with angular reflection technology.

Principles of the Electronic Autocollimator

An autocollimator projects a reticle pattern as a collimated beam to infinity by a telescopic lens. A mirror positioned in its optical path reflects the beam into the autocollimator’s aperture. The reflected beam generates the autocollimation image that is observed by the user via an eyepiece. In general, the autocollimation effect and name are derived from the fact that the same telescopic lens is used to both project the image and collect its back reflection from a mirror element.

The shift of the autocollimation image from the center of the reticle in both an x and y direction is proportional to the mirror’s tilt angle. An electronic autocollimator presents the angular deviation using CCD cameras with resolutions down to 0.01 arc sec.

For increased capabilities, a new breed of autocollimators was designed with built-in laser beam profiling for analyzing incoming collimated beams for measuring divergence and incoming angle with respect to autocollimators center.

Lateral Offset Device (LOD)

The uniqueness of the Lateral Offset Device is that it can cancel the parallax between several lines of sight over an almost continuous distance. The LOD illustrates two Rotary Mounts orthogonally mounted with respect to each other and a Hollow Periscope fixed to the top Rotary Mount.

The orthogonally mounted Rotary Mounts’ purpose is to steer the periscope mounted on the top Rotary Mount. By doing so, the distance between an incoming light beam into the periscope and its outgoing direction is controlled.

Combining the laser analyzer autocollimator with an LOD opens the door to numerous intricate alignments that would otherwise be quite difficult and time consuming to produce.

Axial Flow CO2 laser

This is the preferred method of achieving an extended active length while minimizing overall dimensions and power supply cost. The optical cavity is folded once to utilize two plasma tubes positioned side by side.

This is a relatively simple configuration, however, the same principles are applicable for more complicated cavities with multiple three dimensional folding's.

Proper alignment of an optical cavity especially if folded is crucial. Alignment to mechanical datum improves production repeatability and downtime costs in case of laser replacement.

The main alignment goals are as follows:

- Alignment of laser tubes to each other and mechanical datum
- Alignment of folding mirrors
- Alignment of pointing visible laser and cavity mirrors

Adjustment of Mechanical Parallel Rollers

Materials such as paper, plastic film, newspaper, wide bed printers, foil and metal sheets are often produced in long machines with multiple parallel rolls. These rolls are usually mounted on accurate bearings and are parallel to each other, having a significant alignment requirement regarding the parallelism between rollers. Parallel rollers prevent skewing of processed material as it passes through the processing path. Measurement of parallelism alignment of rolls is often impossible while the machine is processing the material.

Automatic measurement based on these principles can yield web-guiding systems to be positioned just before a critical stage on a converting machine, for example, just before print station.

Center of traced circle is exactly at the center of rotation of one of the rollers. Perfect alignment of rollers’ parallelism is when all reflected-traced centers have the same center.

3D solid drawing showing layout

We start by aligning the autocollimator to the mechanical datum by directing its line of sight to the reflective datum by using the pan and roll features of LOD. Next, by using the mounted V-blocks on the laser tubes, we align the tubes to be parallel to each other and mechanical datum.

This is further achieved by the LOD device shifting the autocollimator’s line of sight to the reflective elements mounted on top of the CO2 tubes and adjusting the tubes accordingly. An external laser can also be adjusted to the same line of sight and projected through the first tube towards the folding mirrors, enabling adjusting the folding mirrors until perfect parallelism between incoming and returned beam is achieved.

Laser beam delivery system

There are different configurations of industrial laser cutting machines: moving material, hybrid, and flying optics systems. These refer to the way that the laser beam is moved over the material to be cut or processed. For all of these, the axes of motion are typically designated as X and Y-axis. If the cutting head may be controlled, it is designated as the Z-axis.

On flying optics machines, even minute changes in beam direction relative to the working table can cause large positional deviations due to the laser’s long path. In other words, the deviation (D) is directly proportional to the angular deviation (A) multiplied by total path travel (T).

\[ D = A \times T \]

Where D is the deviation, A is the angular deviation, T is the total path traveled.

Thus, examining beam angle variations across the working table is a very important feature, crucial for total accuracies in material processing by flying optics methods.