As seen at OFC 2002

Polytec PI

Microrobotic Packaging Automation of Collimated Photonic Devices

Alignment of collimated photonic elements remains a costly manual process for many device manufacturers. Automation here is as attractive as it is in other photonic packaging operations—the improved yield, productivity, labor utilization and return-on-investment of automation are well-established[i]. But the angular alignment tolerances required—coupled with the parasitic transverse motions inherent in tip-tilt operations—have made these alignments even more difficult to automate than the exacting transverse alignments of waveguide and laser diode pigtailing. Until recently, flexible production-automation equipment was simply not available for the collimated elements in devices ranging from MEMS cross-connects to simple DWDM add/drops.

PI's popular F-206 microrobot is the first automation subsystem capable of flexibly addressing the industry's need for fast, production-worthy angular as well as transverse alignment automation. Based on a groundbreaking six-axis hexapod configuration, its digital robotic controls allow the user to instantly place the tip-tilt pivot point anywhere in space. Alignment automation can then proceed in a smooth, fully-vectorized manner which optimizes both throughput and device safety. This breakthrough capability means the rotation center can be placed on any optical sweet spot: on a fiber tip, an optical axis, a beam waist, or wherever is optimal for a given application.

Figure 1. The OFC 2002 Collimator Alignment demonstration performed thousands of exacting collimator-collimator transverse/angular alignments right on the exhibition floor during the week of the conference.

Setup

For a stringent demonstration of the ability of the F-206 to align collimated couplings of all sorts, we constructed a test jig (see Figure 2) using commercial GRIN-rod lens collimators with 8º cleaves. We fixtured the collimators with an air gap of several millimeters.

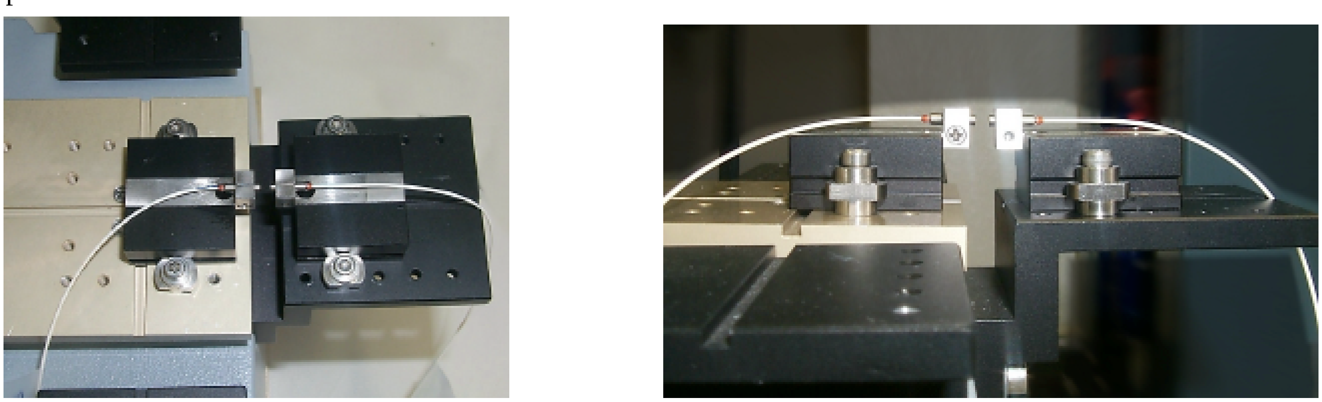

Figure 2. The Collimator-Collimator alignment setup simulates many DWDM packaging applications. For this demonstration, the rotational pivot point for the mechanics is set (via the F-206's SPI command) to lie on the optical axis of the source collimator. The collimating lenses are angled 8º with respect to their ferrules; an index mark was used to orient them visually.

Mounted on the F-206 were two PI cylindrical-optic mounts so that the two ferrule-mounted angled collimators could be brought into eyeball alignment. To illuminate the setup, we used an Oz Optics Model 2836 hand-held source operating at 1550nm without an optical isolator.

Since one of the benefits of the hexapod approach is the ability to set the rotational pivot point anywhere in space with a single software command, a pivot point coinciding with the optical axis and approximately on the face of the input collimator (in this case, the fixed collimator) was selected.

Software

A LabVIEW graphical workstation was constructed to perform a full X, Y, ?x, ?y alignment repetitively, with each sequence commencing with an offset of almost 2º and ~150µm transversely. At the conclusion of each alignment sequence, the F-206's internal power meter voltage is read. These readings are plotted several ways in our software (see Figure 3): (1) the raw data is plotted; (2) the data is plotted with any monotonic trendline (generally due to drift of our unisolated Oz Optics source) removed; (3) the de-trended coupling reproducibility data is then plotted as a histogram, which most clearly visualizes the variation of coupling repeatability versus average. The average execution time per trial (in msec) is also displayed, as is a scattergram of the terminal XY positions from the transverse alignment.

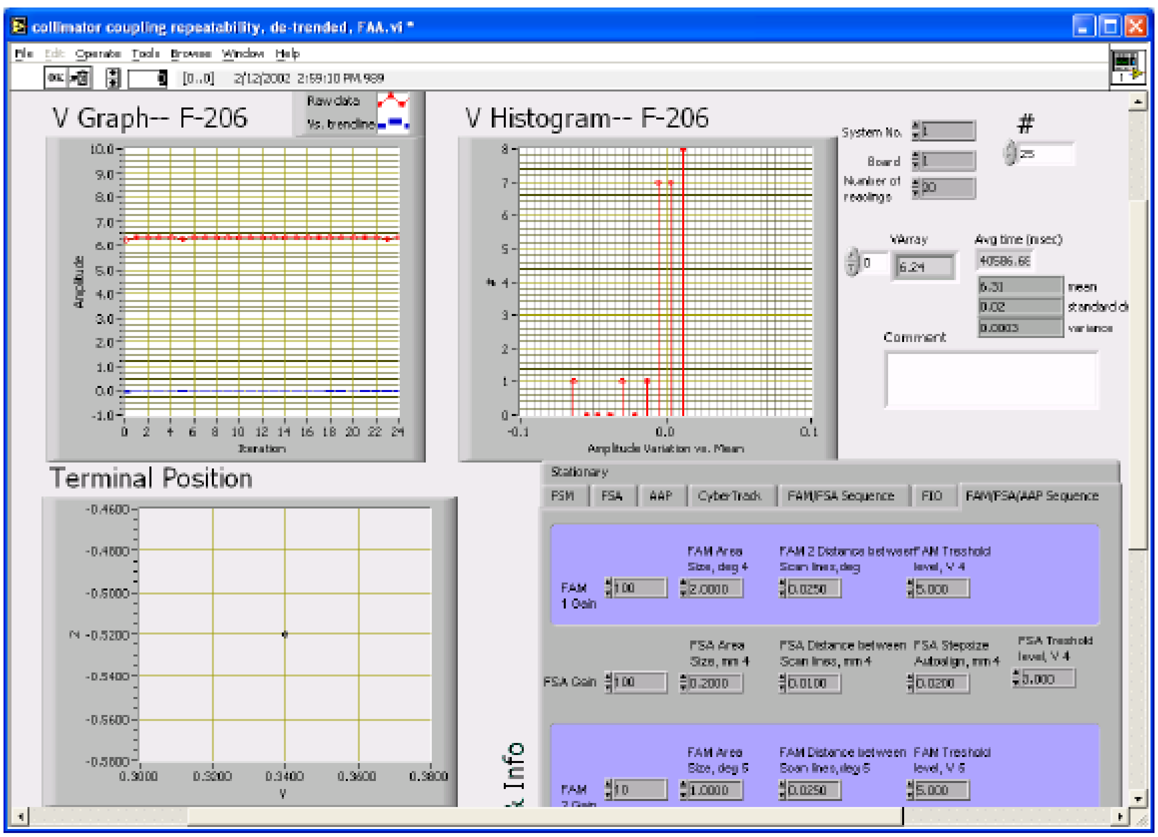

Figure 3. The software test panel. (Note: the screen extends vertically below the bottom edge of this clip; only operational parameters are truncated, however.)

The test was then run for N=25 alignments. Initially, the environment was a standard laboratory environment, with the F-206 mounted on an unfloated optical table. The test was then repeated continuously as a self-running demonstration at OFC 2002, with the F-206 simply resting on a booth bench on an aisle at the conference's teeming exhibit floor. The following summaries feature both sets of data.

Alignment Methodology

The F-206's extensive "toolkit" includes COM-compliant DLLs and an extensive LabVIEW library which fully supports the controller's suite of built-in, high-level alignment algorithms, plus a graphical user interface called HexControl which allows easy exploration of the system's full capabilities. Since the first task in any alignment application is choosing the sequence of operations and the parameters appropriate to the devices being aligned, we started with HexControl. This allowed us to determine that a good alignment sequence for these collimators was:

- Coarse 2º gimbaling scan alignment to achieve first-light. This is a single F-206 command (FAM, for "fast angle scan to maximum").
- High-speed transverse raster to achieve a higher threshold of light, followed by a hill-climb gradient search to optimize the transverse alignment (FSA, "fast scan/align")
- Fine gimbaling alignment to achieve a higher throughput (FAM)
- A "criss-cross" sequence of individual single-axis gimbal scans, first in ?x and then in ?y, then repeating.

For fastest execution, this sequence leverages the fact that the tip/tilt pivot-point is commanded to reside on the optical axis. Thus, only one transverse alignment is necessary. If it were not possible to flexibly place the pivot point this way, a transverse alignment could be necessary after every angular motion!

The specific optical characteristics of a user's devices (and the fixturing) might recommend a different sequence and yield different coupling and time results, but our experience in five years of F-206 sales suggests that this is a good starting point for most collimator-collimator applications.

Laboratory Results

For the laboratory tests, see Figure 4.

- 23 of 25 runs were clustered within 0.5% variation, or better than approximately 0.1dB. The full envelope of the histogram is better than 5%, or better than approximately 0.3dB.
- The aligned angle was ?x = -1.5º, ?y = -0.46º versus initial positions of 0º, 0º --quite a significant alignment. The scattergram seen in Figure 2 shows only one point, indicating that the X,Y position of +0.34, -0.52 is consistently recovered each time. With each iteration, transverse alignment had commenced ~150µm offset from this optimum.
- Average execution time is seen in Figure 3: approximately 40 seconds for the full X, Y, ?x, ?y alignment, with each trial commencing almost 2º and ~150µm off of aligned.

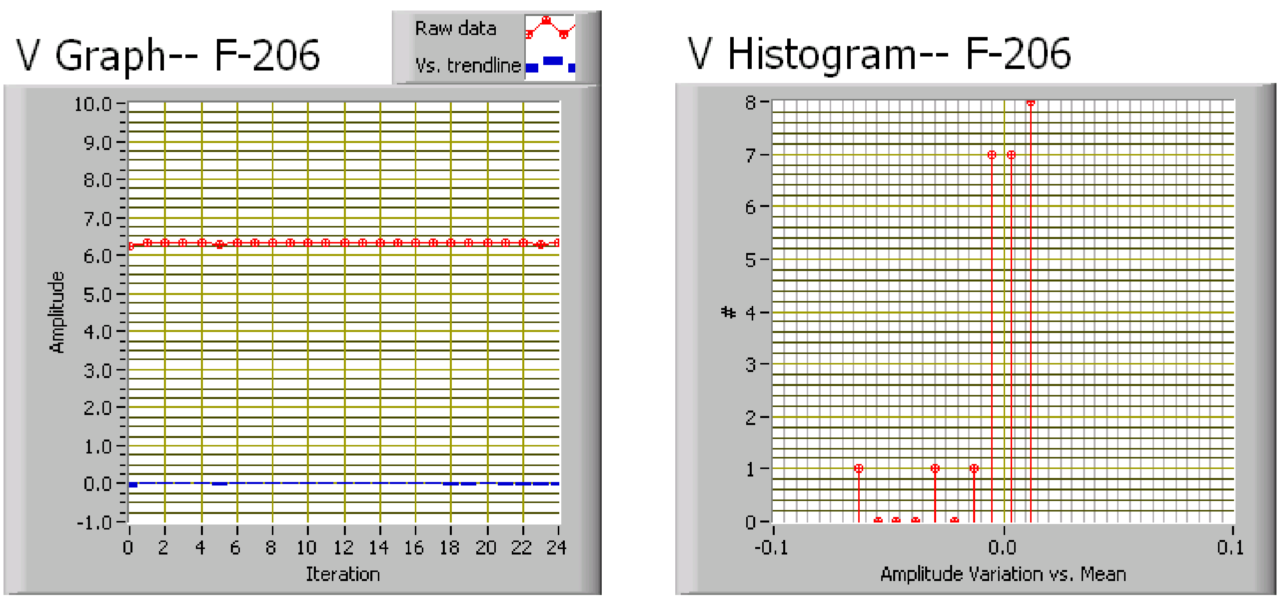

Figure 4. Results from N=25 collimator-collimator dealignment/realignment sequences.
The initial dealignment for each data-point is almost 2º and ~150mm.
Note that the histogram shows an overall envelope of less than 5% variation, or better than ~0.3dB, with 23 of 25 runs clustered within ~0.5% variation, or better than ~0.1dB.

Demonstration Results from the floor of OFC 2002

As a severe (and risky!) test, we carried the F-206 setup to the floor of OFC 2002 in Anaheim, California (see Figure 1.)

As more than 30,000 attendees milled throughout the exhibit hall, the alignment test repeated continuously throughout the week, performing thousands of angular/transverse alignments. Figure 5 shows screen-shots of the optical coupling repeatability histogram taken during the week.

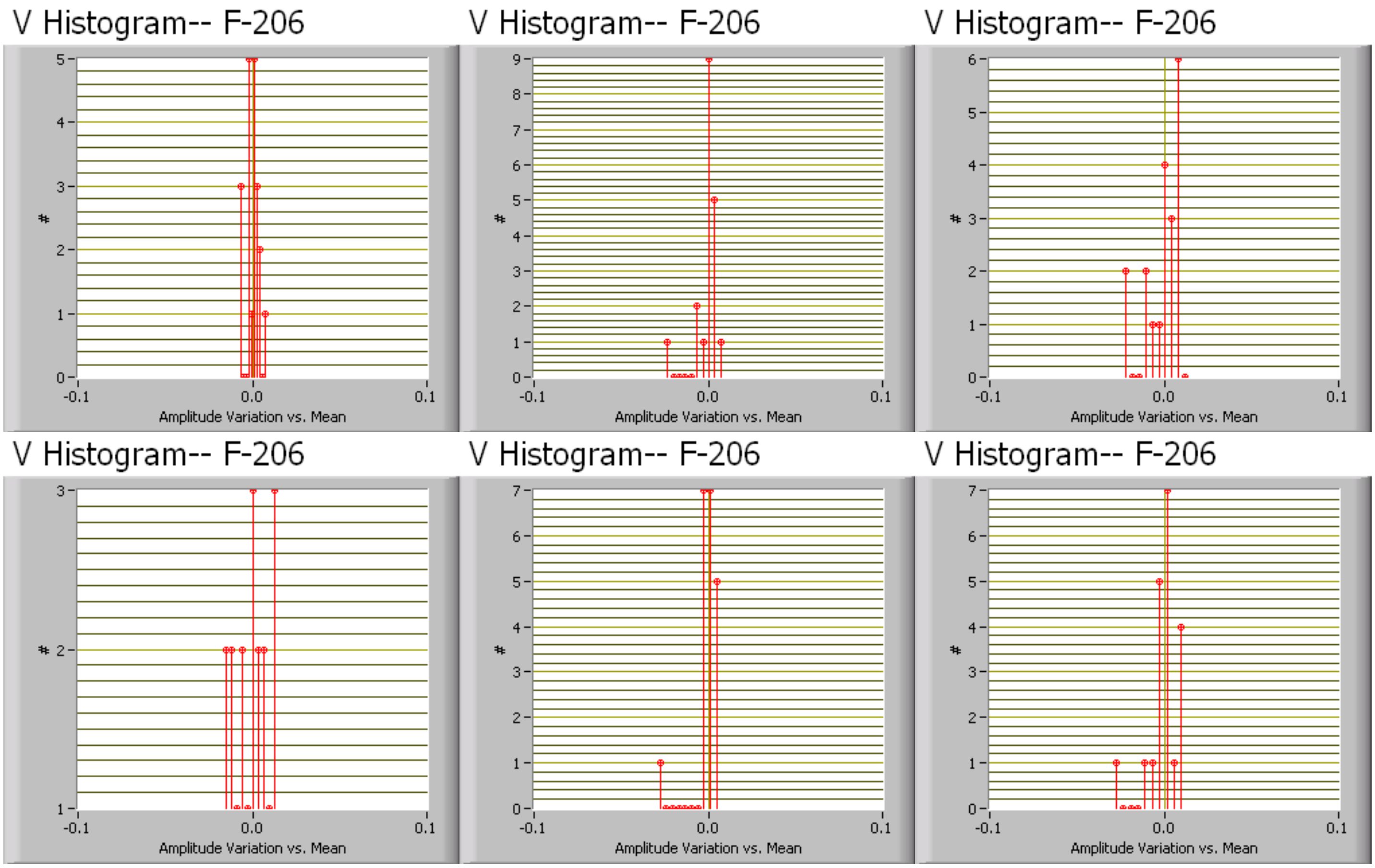

Figure 5. On the floor of OFC 2002, the alignment test ran continuously, performing thousands of transverse/angular alignments of the collimators. Shown above are screen-snaps of the optical coupling repeatability histogram taken during the exhibition.

Conclusion

Certainly it is no surprise that the F-206 succeeded at aligning collimators, as a collimator-based demonstration has been a staple of our articles, demonstrations and exhibitions for years. Here we demonstrate the reproducibility of this alignment in a statistically-intensive manner. The results show that collimator-collimator alignment reproducibility on the order of 0.1-0.3dB is achievable with the built-in firmware commands, in well under the one-minute cycle-time. While may vary with specific devices, these results validate the F-206's functionality for high-yield, low-insertion-loss alignment of collimated devices.

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[i] For a discussion of the economics of photonics process automation, see "Packaging automation drives WDM component assembly", *WDM Solutions*, http://wdm.pennnet.com/Articles/Article_Display.cfm?Section=Archives&Subsection=Display&ARTICLE_ID=93791