Application Note

Fiber Alignment Using The HXP50 Hexapod

PROBLEM

The production of low-loss interconnections between two or more optical components in a fiber optic assembly can be tedious and time consuming. Interfacing optical fibers to other fibers or to other photonic components in TOSA/ROSA or other devices requires precise alignment that maintains the linearity of the optical axis through these components. The effective automation of this process using electromechanical servo-mechanisms requires a great deal of geometric flexibility and sub-micron-level precision in the positioning of fibers and components relative to one another.

BACKGROUND

Traditional motion solutions for fiber alignment have been limited to a stack of stages with linear and rotational adjustments (Figure 1).

Such stages allow for linear motion in three directions, with a limited rotational motion around the three axes of linear motion. These solutions are typically bulky and extremely awkward to use in the tight spaces common in many optical set-ups. To address this issue, MKS has developed the Newport® family of VP stacked, integrated six-axis stage solutions. The VP family address the problems typical of six-axis stacked stages through the use of a highly compact XYZ system specifically designed for fiber alignment. The VP, together with the XM linear motor family of stages, are now commonly used in the production of telecom devices due to their minimal incremental motion (MIM), repeatability and speed.

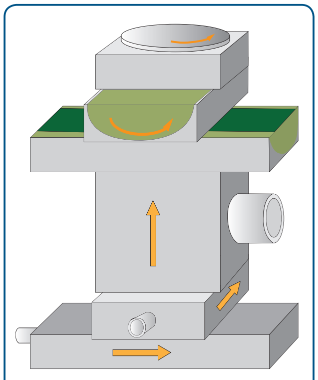

Figure 1 - A typical stacked stage structure used for fiber alignment

Recently, the addition of parallel-kinematic hexapods, (Figure 2), to fiber alignment configurations has proven advantageous. Hexapods consist of two platforms; one fixed and the other movable. The movable platform is supported by six actuator legs (struts) that are attached to the base (Figure 3). These actuators expand and contract in a parallel, coordinated manner that allows the movable platform and any attached devices to move in any direction. The movable platform has six degrees of freedom (DOF) relative to the base, allowing movement in the three linear (lateral, longitudinal and vertical) and three angular (pitch, yaw and rotation) directions. The presence of six degrees of freedom in the movable platform of the hexapod allows it to move and position attachments in ways that conventional, stacked stage motion systems cannot.

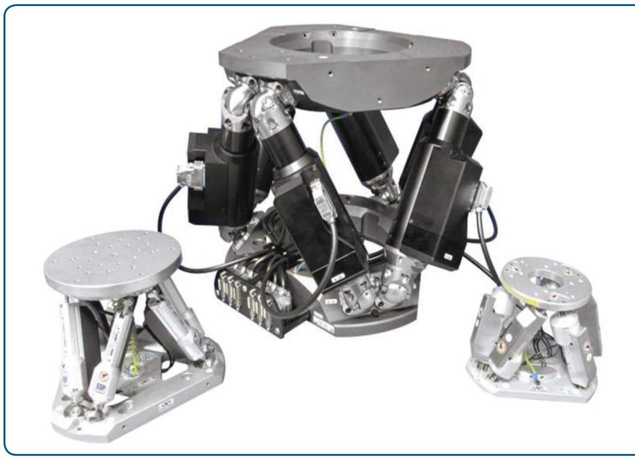

Figure 2 - Parallel-kinematic hexapods

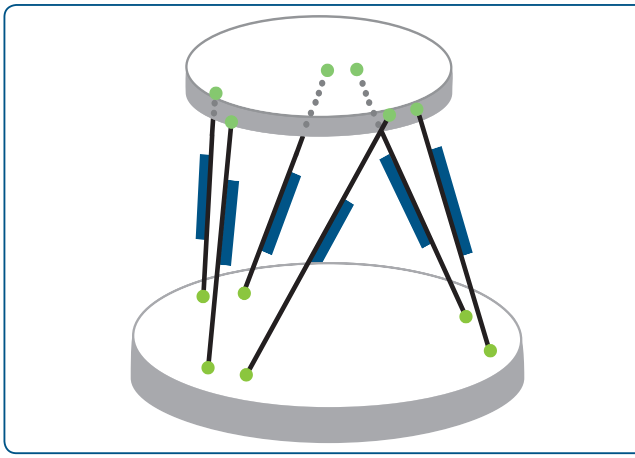

Figure 3 - Schematic of a hexapod showing the six actuator legs supporting a movable platform

Hexapods offer a number of advantages over conventional six-axis stacked stage systems. The mobile platform has low mass and therefore low inertia relative to that which exists in stacked stage systems (in which the bottom stage must support its own weight plus that of the other 5 stages stacked upon it). Low inertia in the mobile platform reduces settling times and results in improved precision in positioning devices attached to the moving platform. Whereas a stacked stage system suffers from the accumulation of runout and tilt errors, the different operating principle of the hexapod avoids these sources of errors. A unique advantage in hexapods is the ability to freely define the pivot points of motion for the movable platform and attachments. Newport hexapods have two virtual centers of rotation (Work and Tool) that can be set using software. Stacked stage systems are inflexible in this respect. Finally, hexapods have a higher overall system stiffness, another characteristic that contributes to the precision of motion using these devices.

With recent advances in actuators, joints and three dimensional transformation algorithms, the precision of positioning using a parallel-kinematic hexapod has been dramatically improved. Parallel-kinematic hexapods can now deliver precise motion, positioning down to 0.05 microns (50 nm). The above attributes, coupled with the compact size of hexapods (which make them easier to use in cramped optical systems) has led to their becoming a preferred tool for micro-positioning tasks such as fiber optic alignment.

SOLUTION

The HXP50 Hexapod

Recently, MKS introduced the Newport HXP50 parallel-kinematic hexapod, Figure 4, as an affordable alternative to stacked-stage tools in fiber alignment applications [1]. The HXP50 can hold attachments with mass up to 5 kg. It has six DC servo-motor driven actuators with encoder feedback at the leadscrew nut, providing precise MIM, low backlash and fast speeds. It has a stiffness of 2 N/µm in the X and Y directions and 25 N/µm in the Z direction. The HXP50 hexapod has linear motion ranges of ±17 mm (X), ±15 mm (Y), and ±7 mm (Z) and angular ranges of ±9° (Θx), ±8.5° (Θy), and ±18° (Θz). MIM values are 0.1 µm, 0.1 µm, and 0.05 µm (X, Y, Z) and 0.1 mdeg, 0.1 mdeg, and 0.05 mdeg (Θx, Θy, Θz). Maximum linear speeds range from 5 mm/s (Z) to 14 mm/s (X, Y); rotational speeds go from 0.6°/s (U,V) to 15°/s (W).

The HXP50 hexapod uses a Cartesian coordinate system for translation and Bryant angles for rotation to uniquely define the position of the movable platform (Figure 5). This mixed coordinate system, frequently used in robotics and aviation, is discussed in detail in an available Technical Note [2].

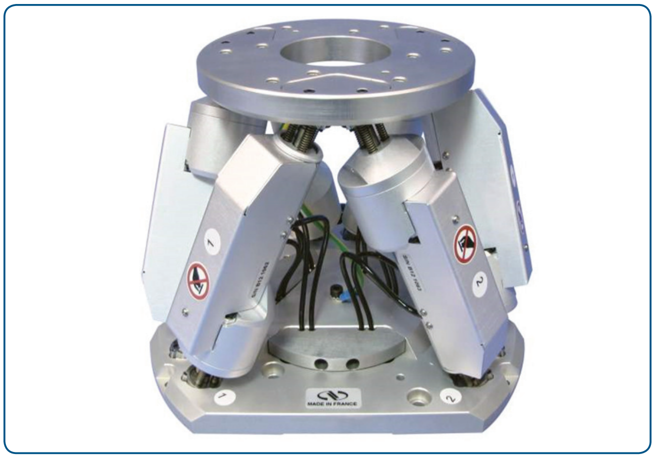

Figure 4 - The Newport HXP50 6-axis parallel-kinematic hexapod

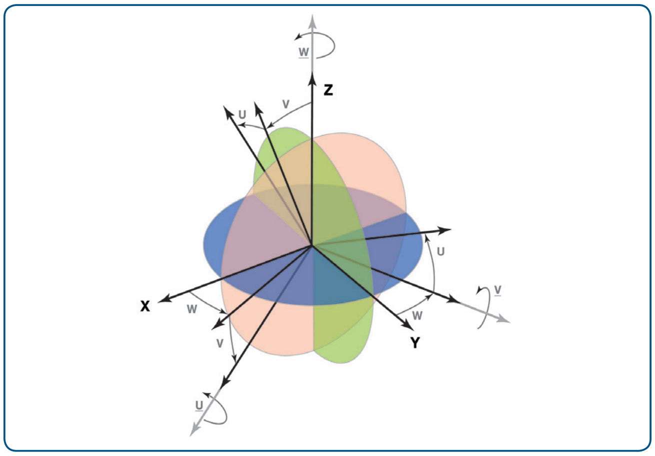

Figure 5 - Motion co-ordinate system used in the HXP50 hexapod

Briefly, within the coordinate system, a position (X Y Z U V W) represents the X, Y, Z location of the center point of the movable platform using a right-handed Cartesian coordinate system combined with angular coordinates, U, V, W, for roll, pitch and yaw. The HXP50 software transforms the XYZUVW coordinates of the desired position of the center point of the movable stage to specific settings for each of the six hexapod actuators.

In operation, the HXP50 is unique in that it defines three coordinate systems (in terms of XYZUVW). These coordinate systems relate the positions of the optical axis in the fixed and movable components and are referred to as the "Tool", "Work", and "Base", shown in Figure 6. Reference [2] provides a discussion of the relationship between these coordinate systems and how they are used in the hexapod.

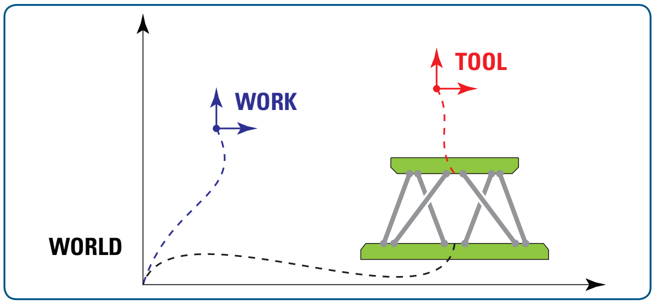

Figure 6 - Definition of the "Tool", "Work", and "Base" coordinate systems

The use of Tool and Work coordinate systems allows the HXP50 to define two programmable pivot points for motion control. In fiber alignment applications, this permits the user to adjust the orientation of both the optical beam and the sample during component manipulations.

The HXP50 is relatively small, fitting conveniently into crowded optical set-ups. Its operations are fast with high precision and high repeatability, all critical requirements for automated optical alignment systems. It is well suited to aligning single channel devices; as well, the programmable Work and Tool pivot points greatly facilitate multi-channel device alignment (Figure 7).

The possible optical fiber and photonic device alignment applications for the HXP50 include:

- multi-mode fibers
- single-mode fibers
- waveguides
- multi-channel
- silicon photonics

Since the release of the HXP hexapod series, a number of fiber alignment applications have been developed with the HXP in mind. We will describe two such applications in this note.

Fiber Alignment Process with Real Time Data Gathering GUI

In the fiber alignment example shown in Figure 8, an HXP50 holds a laser diode on the left hand side of the image while on the right hand side, a VP-25XL XYZ stack holds a lens and sensor. The Graphical User Interface (GUI), (Figure 9) developed for this application provides real time data about the process, including loss within the fiber, the efficiency of the search algorithm in use and the status of the process.

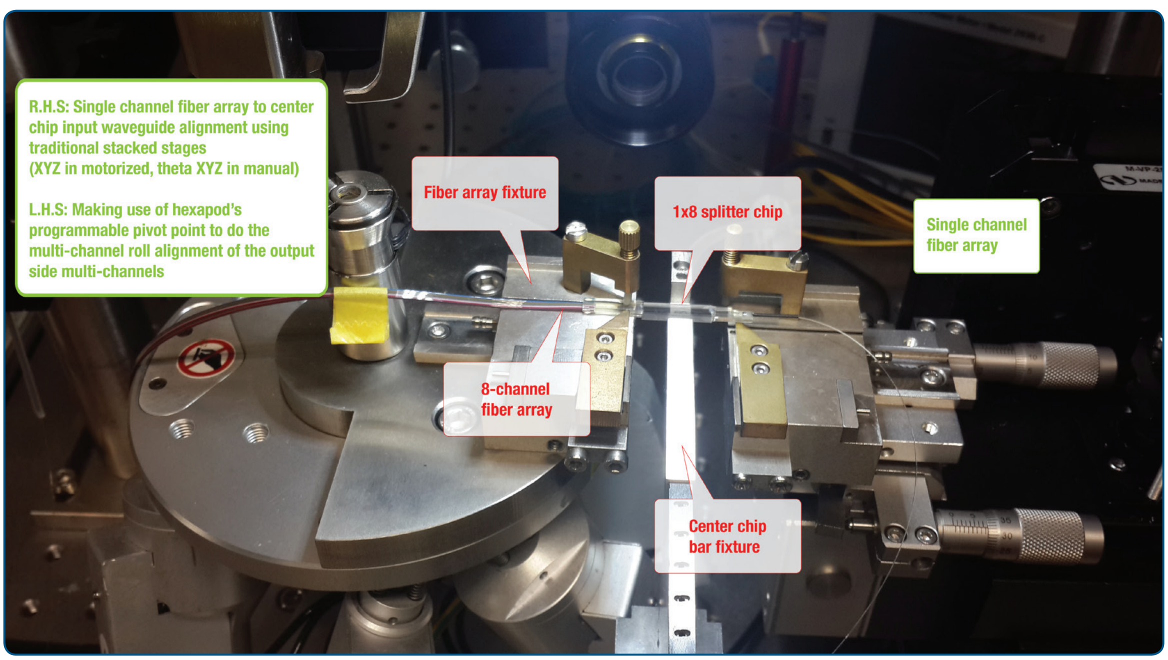

Figure 7 - Application of HXP50 hexapod in multi-channel alignment application

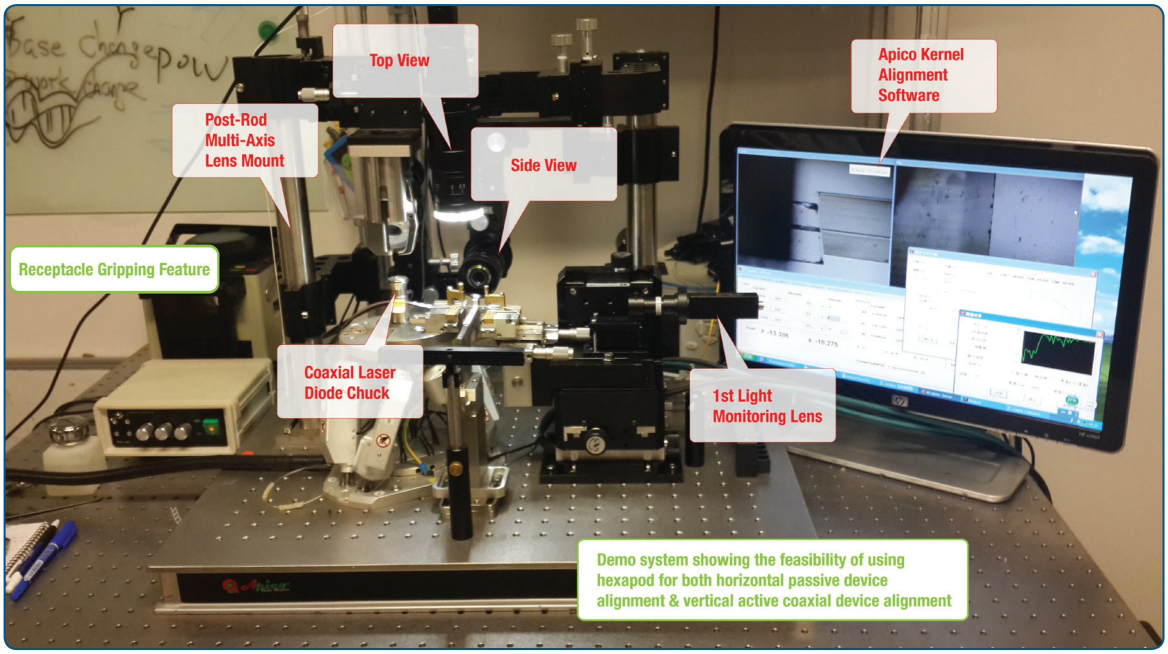

Figure 8 - HXP50 hexapod in a fiber alignment process

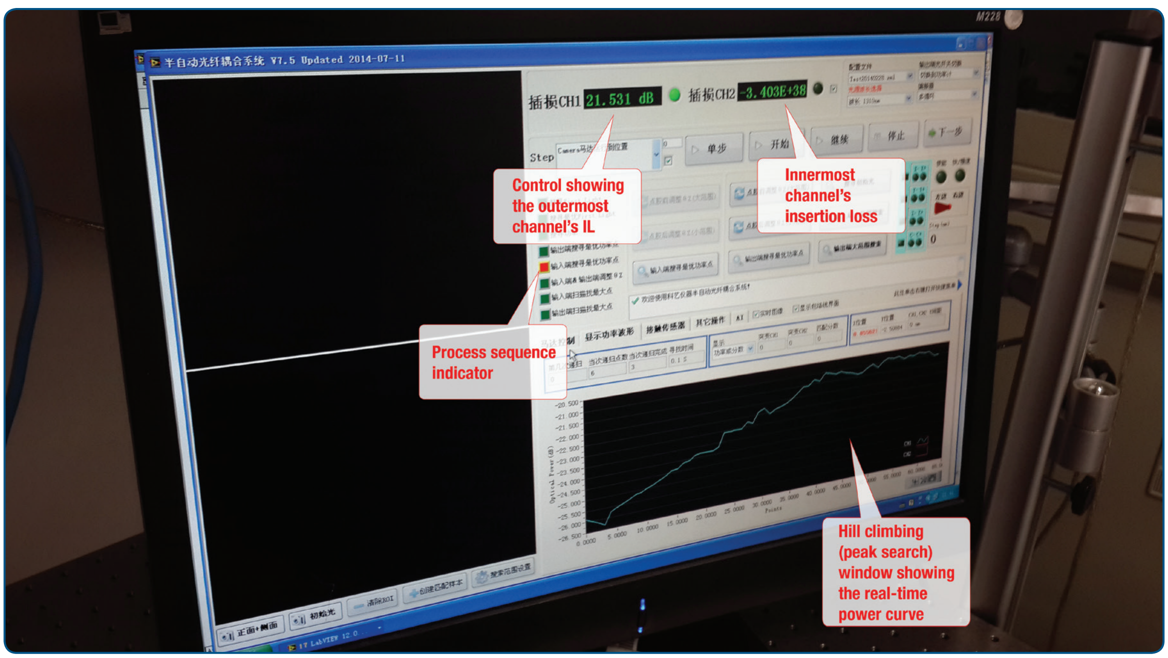

Figure 9 - The Graphical User Interface (GUI)

Other panels in the GUI can display the images from a vision system which can be used to reference or predict collisions. The GUI can also be tailored to a customer's specific process and process data requirements.

Bonding Assembly

With its programmable Work or Tool Coordinate system (pivot points, Figure 10), the center of each fiber can be programmed into the HXP50 in multi-array bonding applications. The 3D illustration in Figure 11 shows the HXP50 hexapod in such a bonding assembly application. The HXP50 holds a multi-channel COB (chip on board) device while a high precision stack of manual stages holds a fiber array. Once the fiber array is set, the multi-array COB is aligned using the HXP50 hexapod. The system can either align to each channel one by one, or average the power across the channels, using the extreme channels as the baseline (Figure 10).

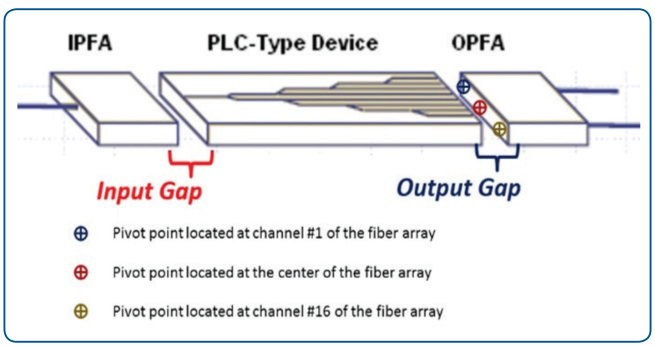

Figure 10 - Pivot point definition in multi-fiber alignment

Vision devices can be integrated into the assembly to assist users in monitoring the status of the process and for confirming the location of the components. Two perpendicular cameras that enable viewing of the components are shown in Figure 11. In addition, a UV LED is shown, for use in curing of the adhesive. The HXP controller can also handle the bonding process, activating the adhesive nozzle, applying the adhesive at a point or as a bead and activating the UV source for curing.

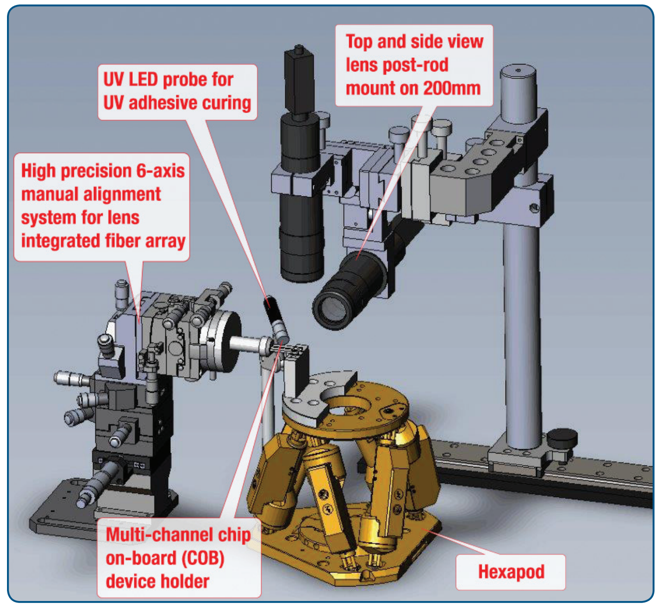

Figure 11 - Application of the HXP50 hexapod in bonding assembly

CONCLUSION

The Newport HXP50 hexapod is a multi-axis motion and positioning system that is uniquely suited to fiber optic and photonic device alignment applications. With six independent axes of motion, the HXP50 can define two software-programmable centers of rotation (pivot points) that greatly facilitate single- and multiple-fiber device alignment procedures. The six DC servo-motor driven actuators of the HXP50 combine precise MIM, low backlash and high speed to deliver fast, precise and repeatable positioning for fiber optic and other photonic component alignment applications.

REFERENCES

[1] Newport, "6-Axis-Parallel Kinematic Positioning Systems HXP50 Hexapods," Newport Corporation, [Online]. Available: https://www.newport.com/medias/sys_master/images/images/h83/h5b/9006281949214/HXP50-Data-Sheet.pdf.

[2] Newport, "Technical Note - Motion in D-D: Newport Hexapod Coordinate Systems," Newport Corporation, [Online]. Available: https://www.newport.com/medias/sys_master/images/images/ha8/h3a/8797213032478/Motion-Tech-Note-Hexapod-Coordinate-Systems.pdf.

For more information on Hexapod Technology, link to: https://www.newport.com/f/hxp-series-hexapods

For a general catalog of Newport products from MKS, go to https://www.newport.com

For further information, call your local MKS Sales Engineer or contact the MKS Applications Engineering Group at 877.835.9620

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