# ACTIVE ALIGNMENT WILL BE CRITICAL FOR FUTURE OPTICAL SYSTEMS MANUFACTURING

## EXECUTIVE SUMMARY

New usage models and applications for technology products, such as machine learning and artificial intelligence, created a need for computers to “see” the outside, physical world. We refer to this as “computer vision”. As these usage models and markets evolve, higher quality imaging systems are needed to enable better optical performance. Consumer expectations for thinner devices and better-quality images contribute to the increased demand for high quality imaging and drive up the complexity of manufacturing these optical systems. As complexity increases, so do manufacturing challenges. For example, the use of lower cost materials adds to part-to-part variation, and high failure rates (scrap) make it difficult for manufacturers to deliver these complex optics systems at scale.

There are several manufacturing processes for affixing optics to sensor devices. Each process delivers a different degree of image quality as well as different benefits and challenges for the manufacturer. Mediocre-quality imaging systems can deliver a relatively good image and may be easier and less costly to affix, but they require more computing cycles on the backend to clean up image anomalies caused by the system’s lens or focusing technology. The highest-quality imaging solutions require more costly and complex manufacturing processes, but they require less computer assistance on the backend to deliver accuracy. Product manufacturers must consider these factors in deciding how best to meet market requirements.

**Active alignment** describes the process of affixing imaging technology components, typically a lens and a sensor, while continuously measuring image quality throughout the alignment process to achieve the highest accuracy of images captured. Kasalis is an industry leader in the active alignment manufacturing process and is owned by Jabil Optics. Jabil Optics has a long history of manufacturing optical systems and brings extensive design and manufacturing experience to customers participating in these rapidly evolving markets. Together, Jabil Optics and Kasalis offer compelling capabilities for the manufacture of high quality, complex optical imaging systems.

## INDUSTRY TRENDS DRIVE DEMAND FOR BETTER IMAGING SYSTEMS

Smartphone cameras have established the expectation among consumers that image quality will continuously improve, and optic solution quality is one point of competitive differentiation in the market. The ever-increasing apertures (the physical opening through which the image is captured) in these smartphone cameras require sharper and higher quality optical systems. The introduction of both augmented reality (AR) and virtual reality (VR) and their growth into a new industry also drive demand for improved optical systems. This is especially true in AR, where the systems tend to be untethered, head-worn devices that must be thin and light, like a pair of glasses. As AR and VR headsets get thinner and smaller, the complexity of optical systems, including both camera and projection optics, will increase

Other applications for computer vision, like self-driving cars, are much more safety-based and require mission-critical levels of accuracy. For the massive arrays of cameras to properly inform the on-board computers of a self-driving car, they need to capture and send the most accurate images possible, so that the computer algorithms can quickly identify objects, calculate distances, and dictate the appropriate response. For this market, high quality optical systems are a necessity.

Thanks to the advent of machine learning and neural networks, security cameras are now smarter and require better computer vision. The ability to record a high quality video is no longer good enough; these cameras must also identify who and what they see. This task is far more easily done with higher quality images.

Drones also need improved optics for many reasons. Like smartphones, they are frequently used for taking high quality videos and photos, but they also have multiple cameras and sensors for navigation and object avoidance. Since a drone’s efficiency is linked to its weight, there is more demand for miniaturized and lightweight optical systems. Drones are now regulated aircraft and must operate within a much tighter set of rules, which includes not colliding with people, buildings, or other aircraft. Better quality optics drive the advancement in computer vision algorithms and machine learning algorithms needed for better object avoidance and overall responsiveness.

## ACHIEVING IMAGE ACCURACY THROUGH ALIGNMENT

To deliver the necessary image quality to meet current and future market requirements, solution providers have limited options. They can purchase higher quality lenses to use in their solutions, which increases the overall bill of materials (BOM) cost. They can increase the number of frames captured or the amount of time the aperture is open, but this also increases the amount of time the camera is on and the computational clean-up necessary to render the sharper image. Or they can start with a better image by fine-tuning the alignment of the optical components in their solutions and deliver the best possible images for the components used. Component alignment offers the most effective way to improve image quality while keeping costs down.

The optical industry is moving away from glass as a lens material and towards plastic lenses. There are several reasons for this trend, including cost, breakage, and the physical limits of silicon in lens crafting, sizing, and installation. However, glass lenses introduce fewer anomalies than plastic, and using plastic requires optical systems to have better alignment for the same or better image quality.

The industry is building more complex optical systems to meet the demands of thinner electronic devices. Folded optics are a good example of very complex systems. Folded optics allow a beam of light to reach a specific distance and go through a certain number of lenses without having to travel in a straight line. Using multiple angled lenses that bend the light in different directions shortens the length of the optical system without shortening the distance the light needs to travel, allowing for more lens elements and a clearer picture. If not aligned and affixed properly, these complex optical systems and new materials, in some cases, result in poorer image quality, which in turn require more computational correction to clean up the poor image quality to acceptable levels. By implementing technologies like folded optics, the industry is moving towards imaging systems that are more difficult to manufacture properly.

## WHY ACTIVE ALIGNMENT?

There are multiple methods of manufacturing an optical image assembly. They vary in complexity and cost as well as precision and can result in drastically different image qualities.

One of the simplest methods is placement of system components without any alignment. This method is generally the least labor- and technology-intensive but also the least accurate and usually produces the lowest quality imaging. Simple placement generally has one of the lowest yield rates as well, but if used with extremely inexpensive materials it could make sense in very small production runs.

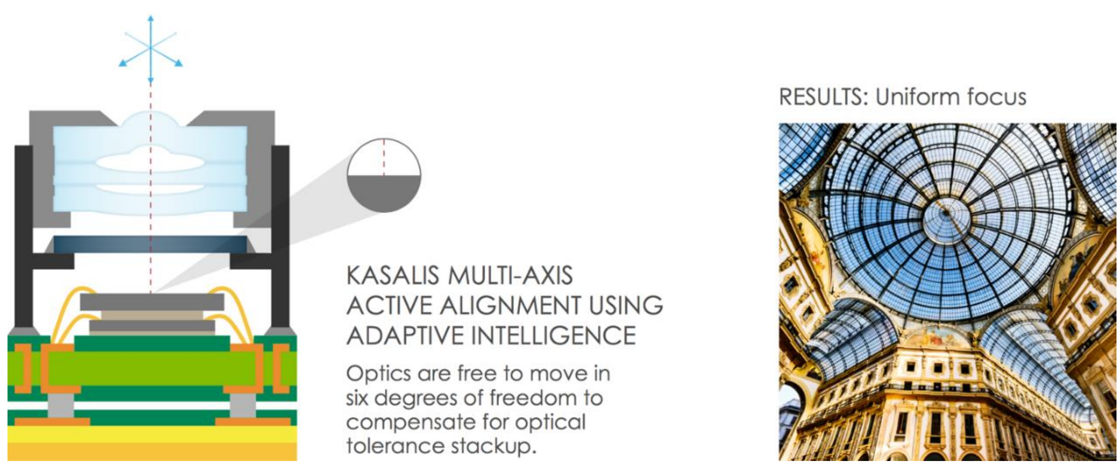
A better method of optical image assembly is one in which optics are screwed onto a fixed mount and can be adjusted on at least one axis. Screw mount manufacturing usually relies on a constant feed of images as the components are threaded on, which helps find the sharpest image based on (only) the Z position of the lens relative to the sensor. This method is more accurate than simple placement of the optics on top of the sensor but does not account for image sharpness on other axes nor manufacturing imperfections including lens variations and sensor or PCB variation. Dust caused by the screw thread can also cause particle contamination on small pixel sensors.

## FIGURE 1: CONVENTIONAL LENS & SENSOR ASSEMBLY


*Source: Jabil Optics*

Active alignment is a dynamic method of affixing an optical array in an optical image assembly. This method usually incorporates image data from the sensor through a feed that allows the machine to adjust for imperfections and optimize the alignment across the entire image plane. Depending on the manufacturing needs of the customer and the capabilities of the equipment and software, active alignment results in higher precision manufacturing and image quality.

## FIGURE 2: KASALIS ACTIVE ALIGNMENT OF LENSES & SENSOR




*Source: Jabil Optics*

## Active Alignment Applications

Optical devices manufactured using active alignment processes have numerous applications in established markets as well as some in their infancy. The obvious areas of application for high quality imaging systems using active alignment are automotive, AR, drones, photography, security, and VR. These applications all benefit from improved image quality, which active alignment is designed to produce. However, other applications may include small image projection systems, gesture recognition, and fiber optics signal transmission. Fiber optics are extremely sensitive to the position of the beam of light, and the more focused the beam, the better the signal. This is the original use case of some active alignment technologies, which eventually transitioned to apply to many other optical systems. These less obvious applications of active alignment have to do with imaging system complexity and miniaturization, which both require high precision results.

## Kasalis Pixid 300

“Active alignment” is a generic description of a dynamic assembly process. Several companies have active alignment capabilities, including AEI, HVS, Kasalis, and TriOptics. The process itself may vary in several ways: how the lens assembly is placed on the sensor, how the assembly is aligned, and how the bonding agent is cured.

Kasalis positions its leadership in active alignment processing with the Pixid 300, a machine it developed to manufacture the optical image assembly in a three-step, 15 seconds per cycle process. All the components necessary to build the optical image assembly are placed in the Pixid, either by hand or with an automated assembly line. Once the components are loaded, the Pixid applies the glue adhesive and tests for sensor functionality and dust particles. After the engineered adhesive is applied, the machine places the lens above the sensor assembly, adjusts it in six degrees of freedom, along three linear axes (x,y,z) and three rotational axes (pitch, yaw, and roll) using an active feedback system to optimize alignment, then cures the adhesive with ultraviolet light. This end-to-end system can deliver active alignment in what is known as six degrees of freedom.

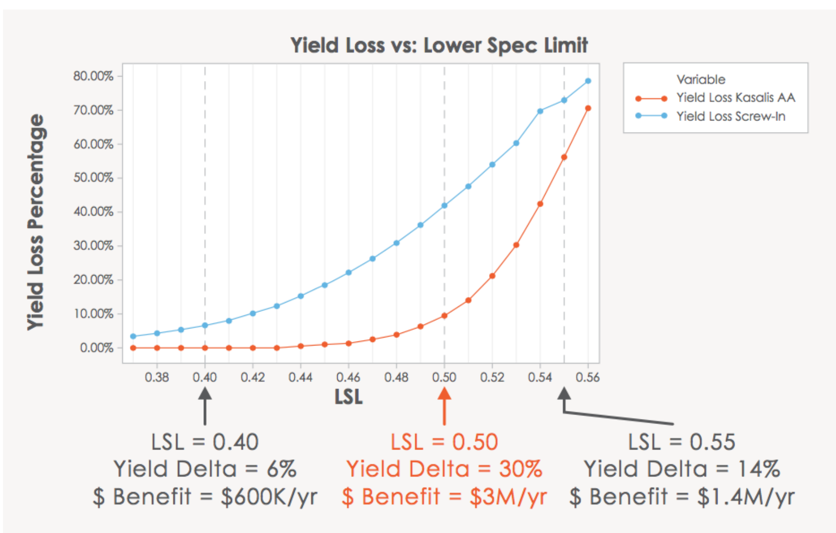
The optical feedback system of the Pixid uses targets to align the lenses with the sensor and allows the manufacturer to use data feedback to improve the product and process, which results in smaller variance and better yields. The rapid testing ability within the process enables quality assurance and machine learning to prevent major manufacturing problems. Having more precise optics delivered by the Pixid means that fewer computational camera features are needed to improve the fidelity of a final image.

Kasalis Pixid equipment does have limitations, however. When assembling cameras, it requires an active feedback chain between the image sensor and the machine itself. Projectors do not have sensors, so the output image needs to be captured by the machine using cameras or beam profilers and analyzed for the process to work. This may not be possible in all manufacturing situations and may not apply to all optical image assemblies. The Pixid also requires handling key components that must be placed into the machine. It can be installed as part of a manufacturing line, but the parts still must be placed. There is also an upper volume / space limit within the machine itself of about 12 cubic inches for the parts to be placed, meaning that very large optical image assemblies with a very large lens and sensor likely will not fit. Further, the maximum load of the equipment and the arms and motors inside is only a few pounds.

## Active Alignment Outcomes

The highly accurate optics delivered with the Pixid enable complex image systems like folded optics, which are becoming more common and difficult to manufacture. In some cases, optics made with active assembly may have better focusing capability and better thermal fluctuation tolerance and compensation for sensor heat.

## Figure 3: Conventional Screw-In vs. Kasalis Active Alignment Yield Loss




*Source: Jabil Optics*

Also compelling are the cost savings due to lower scrap rates compared to screw mounting manufacturing. According to data provided by Jabil Optics and Kasalis, this is frequently in the 20-30% range. This improvement completely depends on the minimum acceptable performance cutoff level defined by the customer. The active alignment process also shortens the time between development and manufacturing by incorporating data feedback into the prototyping and production processes.

## FIGURE 4: YIELD LOSS COMPARISON

| | SCREW-IN ALIGNMENT | KASALIS ACTIVE ALIGNMENT |
|---|---|---|
| YIELD LOSS | 36.2% loss | 6.1% loss |
| PPM DEFECTS | 362,405 ppm | 61,114 ppm |

*Source: Jabil Optics*

## WHY JABIL OPTICS / KASALIS ACTIVE ALIGNMENT?

Jabil Optics' approach to manufacturing is systems- and solution-based, meaning Kasalis' Pixid active alignment equipment and process are a part of the whole Jabil Optics solution for its manufacturing customers. As an industry-leading contract manufacturer (CM), Jabil Optics works with Kasalis as the provider of optical image assembly equipment to help customers improve the performance and manufacturability of their devices' optical designs. This vertical integration of the manufacturing process enables Jabil and Kasalis to cooperate closely and offer top manufacturing capabilities. Jabil also offers a unique CM suite, which helps manufacturing customers manage their supply chains more effectively and anticipate and address problems before they arise.

Jabil Optics has its own in-house optics design capabilities and many years of materials and process expertise to make the overall optical manufacturing more robust and to help solve customer problems. Additionally, Jabil Optics and Kasalis use their custom algorithm development to help improve the final product and the manufacturing process. These algorithms complement and work in tandem with the active alignment Pixid machines, which act as the reliable manufacturing hardware, supported and enabled by the algorithms to reach optics design goals.

Jabil's size can help companies get better pricing from suppliers than they might achieve on their own. Jabil has extensive manufacturing capabilities around the globe, crowned by its Blue Sky facility in San Jose where it performs materials science research that ultimately benefits its customers. This includes evaluating adhesives for processes like active alignment and finding the right adhesive to match the needs of different optical applications.

Jabil's size, expertise, and vertical integration help the company develop new and difficult processes that are less attainable at smaller scale. Jabil helps design products and manufacturing processes to make retooling less expensive. Modular toolsets like the Pixid 300 allow for quick changes and adjustments, and with the Pixid 300's data feedback, Jabil can rapidly adjust and retool a process as needed for a customer. Using its own resources as a global CM, Jabil can help a small to medium sized company ramp quickly to market.

## Conclusion

The new visual world is pushing many different verticals within the technology industry towards imaging systems that require high quality optics. Virtual and augmented reality systems, smartphones with single and dual cameras, 360-degree cameras, action cameras, and autonomous driving solutions are driving demand for higher quality, more complex optics with higher resolution sensors.

Active alignment offers a solution to making these high precision optical image systems manufacturable and feasible in final products. Active alignment helps improve time-to-market, scrap costs, and overall image quality.

Kasalis and Jabil Optics have effective, innovative, and integrated capabilities that go beyond the Kasalis Pixid machine and active alignment. Jabil's approach, scale, material science, and customer services are supplemental to having precise optics.

The integration of Kasalis with Jabil Optics' technological capabilities allows for the manufacturing of products that would not be possible without active alignment. The joint development of products with Jabil Optics enables novel and unique optical solutions for customers to differentiate their own products from the competition. According to Jabil Optics, this tight integration with Kasalis can result in a faster time to market and better image quality.

## Call to Action

Optical device OEMs seeking to improve the image quality and manufacturability of their products should investigate contract manufacturers for active alignment expertise and capabilities. Moor Insights & Strategy recommends considering Jabil Optics and Kasalis when choosing a manufacturing partner for optical products.

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