Allied Vision

WHITE PAPER

Sensor Alignment for Alvium Cameras

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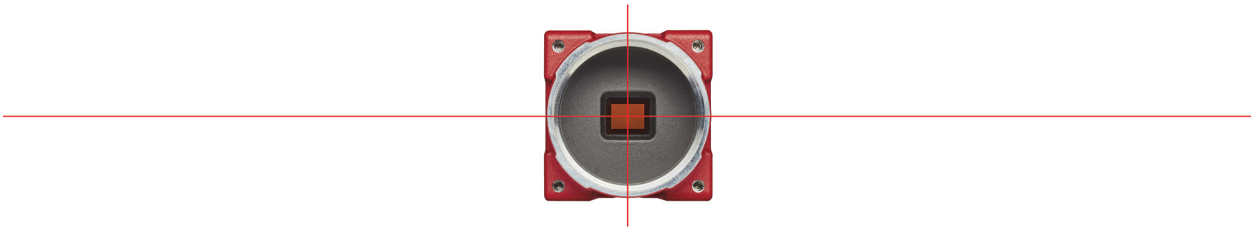


Challenge in manufacturing high-precision cameras

Modern camera solutions for digital image processing consist of numerous different components. Ideally, these components would have constant dimensions and would fit seamlessly to high precision products. In practice, all parts have tolerances, invisible to the naked eye. For example, typical sensors are allowed to have a tilt of 1 degree according to the specification.

The assembly of sensor board and front flange is critical. Even micrometer deviations can reduce the image quality of a high-grade lens on a powerful sensor. This must be considered for the production of high-precision cameras.

Axes for sensor positioning

The following schematics show parameters for sensor positioning.

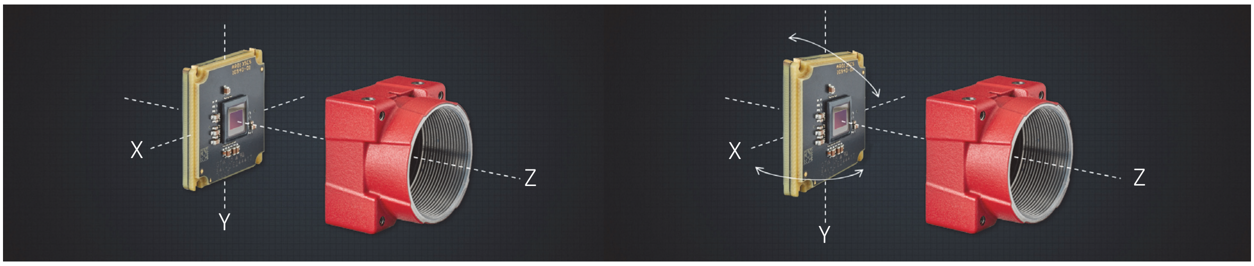


Figure 1: Accurate sensor alignment (left) and sensor tilt on the Z-Axis (right)

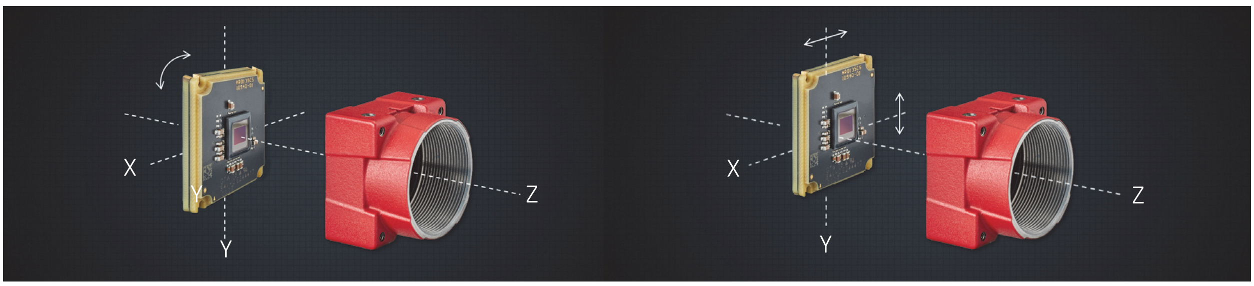


Figure 2: Sensor rotation around the Z-Axis (left) and sensor shift on the X-Axis or Y-Axis (right)

Effects of insufficient sensor alignment

In this document, we show the effects of a misaligned sensor and how it influences the image quality or field of view of an image. The introduced deviations are not exaggerated, but are real world examples from sensor specifications. Additional tolerances from other components and from assembly worsen the sensor position accuracy if cameras are manufactured without sensor alignment.

Specification	**Value**
	Camera-lens assembly
Resolution	3000 (H) × 2000 (V); 6 MP
Sensor size	9 mm × 6 mm; 10.8 mm diagonal
Pixel size	3 µm × 3 µm
Aperture	F1/2.8
	Misalignment
Tilt on Z-Axis[1]	90 µm (0.573 deg)
Rotation around Z-Axis	1 deg
Shift along X-Axis	200 µm (~66 pixels)
[1]Variance between the highest and lowest pixel of a sensor along the optical axis	

Table 1: Specifications of a fictitious sensor and tolerances

Example images

For the examples, we edited an image without artifacts. The red rectangle in the left bottom corner marks the detail view used to simulate typical effects from insufficient sensor alignment.

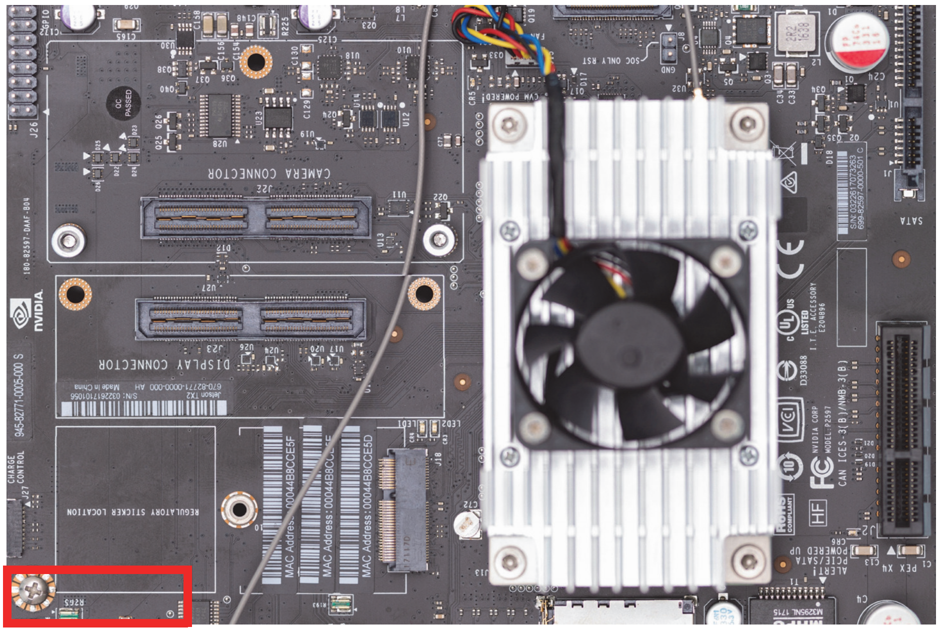


Figure 3: Image without sensor alignment issues

Comparing effects of insufficient sensor alignment

Accurate sensor alignment

The image shows no alignment issues.

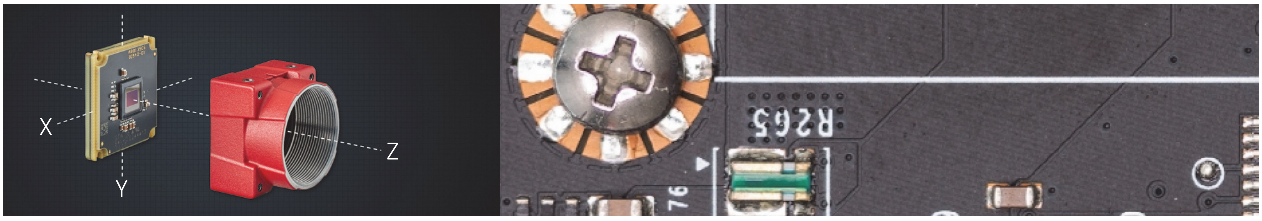


Figure 4: The sensor is accurately aligned to the optical axis of the lens

Tilt on the Z-Axis

The image has a variance of 90 µm between the highest and lowest horizontal pixel of the sensor measured along the optical axis. This equals a rotation of 0.573 degrees around the Y-Axis. The resulting focus drift blurs the vertical edges

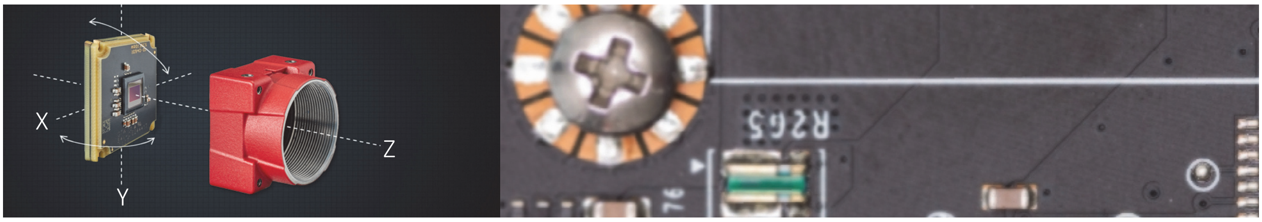


Figure 5: The sensor is tilted to the lens mount

Rotation around the Z-Axis

The image is rotated clockwise by 1 degree. The white horizontal line slightly drops to the right.

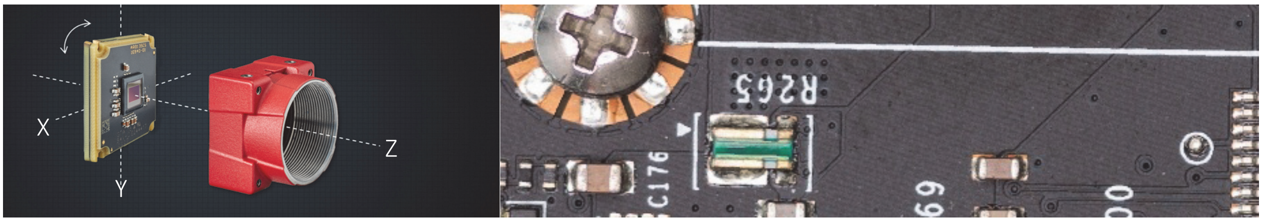


Figure 6: The sensor is twisted to the edge of the PCB (printed circuit board)

Shift along the X-Axis or Y-Axis

The image is shifted to the right by 200 µm (~66 pixels). The screw head is cropped on the left.
Note: Depending on the lens, the sharpness can be different between the image corners. Potential vignetting is shifted out of center as well, which is harder to correct than typical vignetting that is centered.

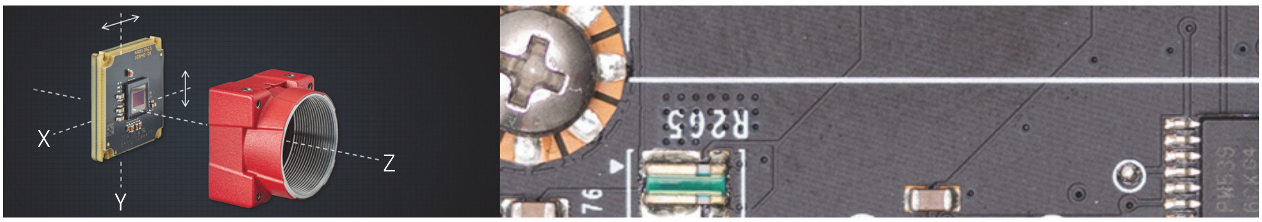


Figure 7: The sensor is shifted along the X-Axis

Evaluation

Each of the shown three effects does not occur alone. The all-over sensor position inaccuracy caused by these effects is significant. We have simulated images for a fictitious 6 MP sensor with 3 µm pixel size. Consider, that effects increase for sensors with higher resolutions and smaller pixel sizes.

Conventional manufacturing: What can be done?

Many manufacturers assume that the given tolerances of the individual components enable an adequate result. Therefore, cameras with insufficient image quality may be shipped to the customer.

In the best case, the manufacturers test the cameras extensively after the assembly. If the test passed, the cameras are shipped to the customers. Otherwise, if the test failed due to insufficient image quality, the cameras are disassembled by hand to localize and fix the error. In the worst case, a camera must be scraped that has just been manufactured.

These comprehensive measures can cause high production costs, especially when components are faulty. The additional costs are passed on to the customer.

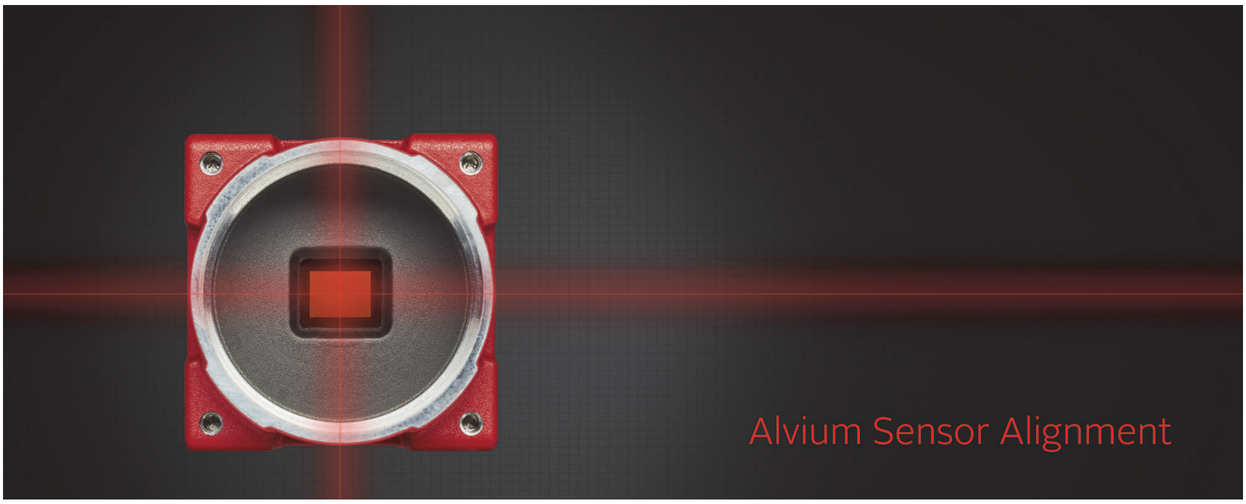
Moreover, reducing the tolerance range for the components manufacturer increases production costs even more. Finally, typical manufacturing works fine in theory; in practice it may fail by adding tolerances of the individual components.

Sensor Alignment: What do we do?

Alvium Sensor Alignment avoids expensive corrections known from conventional production.
A fully automated workflow compensates for tolerances to guarantee high-precision cameras in a reproducible process.

The distance to the lens mount front flange is aligned, and the tilt angle is perfectly adjusted. The center of the sensor array is aligned to the sensor board. Next, sensor and filter glasses are checked for defects and impurities to be cleaned if necessary.

A test image is produced in the final functional test to prove the perfect interaction of the assembled parts. The fully automated process uses pick-by-light systems to eliminate human influence on the production quality. The measurements are logged to be processed in database systems to continuously improve the production quality. Sensor Alignment at Allied Vision enables high-quality technology at affordable prices. Let us take another step towards industry 4.0!



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