Technical Note TN25

Measurement performance of customized sensor heads

Working ranges and angular tolerances

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The modular design of the IDS3010 makes cutting-edge measurement performance of interferometry accessible for various applications. Despite the versatility enabled by the combination of different standard components, some complex configurations require products that are tailored individually to a specific setup or machine. attocube´s miniaturized and customizable sensor heads are the key to solve even sophisticated application specific requirements. While collimated sensor heads are most suitable for long-range applications, focused sensor heads are the preferred choice for multiple measurement applications, high angular tolerances, or direct material surface measurements. The focal length is crucial in order to achieve the best performance with the specific setup, as it strongly affects the achievable working distance and travel range of the target. Different sensor head types and individually customized focal lengths open a broad application field, but it can be challenging to understand the correlations and the resulting key performance criteria for the application. This Tech Note therefore gives a detailed overview of the dependency between beam shape, focal length and measurement performance for attocube’s standard and customized sensor heads.

Performance overview

The working distance is the most crucial requirement for many applications. However, the higher the working distance the lower the achievable tolerances regarding angular stability of the setup and surface compatibility. If it is not imperative to measure directly on the target, high reflective surfaces e.g. mirrors or retroreflectors, will always facilitate long distance measurements.

As Figure 1 shows for very long ranges of multiple meter, the best choice is the combination of a collimated sensor head and a retroreflector. This combination offers highest angular tolerances, but it has to be considered that there are significant differences depending on which part of the setup is tilted. For most applications the sensor head is at a fixed position, while the retroreflector, which is mounted to the point of interest, is moved or tilted. In this case, angular tolerances of +-15° are achievable at ranges of more than 5 m.

However, tolerances are reduced with rising working distance if the sensor head itself is tilted during the measurement, as the tilt results in a significant lateral displacement of the measurement point (see Figure 1). The stated angular tolerances are only applicable, if the sensor head or retroreflector is tiltet around its rotational center and there is no additional lateral displacement. Furthermore, collimated sensor heads can also be used with mirrors, but the achievable angular performance is limited and very similar to a focused sensor head with a very long focal length. In very stable setups, e.g. xy-wafer stage positioning, collimated sensor heads allow reliable multidimensional movements of up to 1 m (see Application Note 37).

Focused sensor heads are suitable for low to medium working distances and unlike collimated sensor heads the working range and angular tolerances can be significantly modified by adjusting the focal length. Figure 1 shows the achievable performance areas depending on the measurement surface,

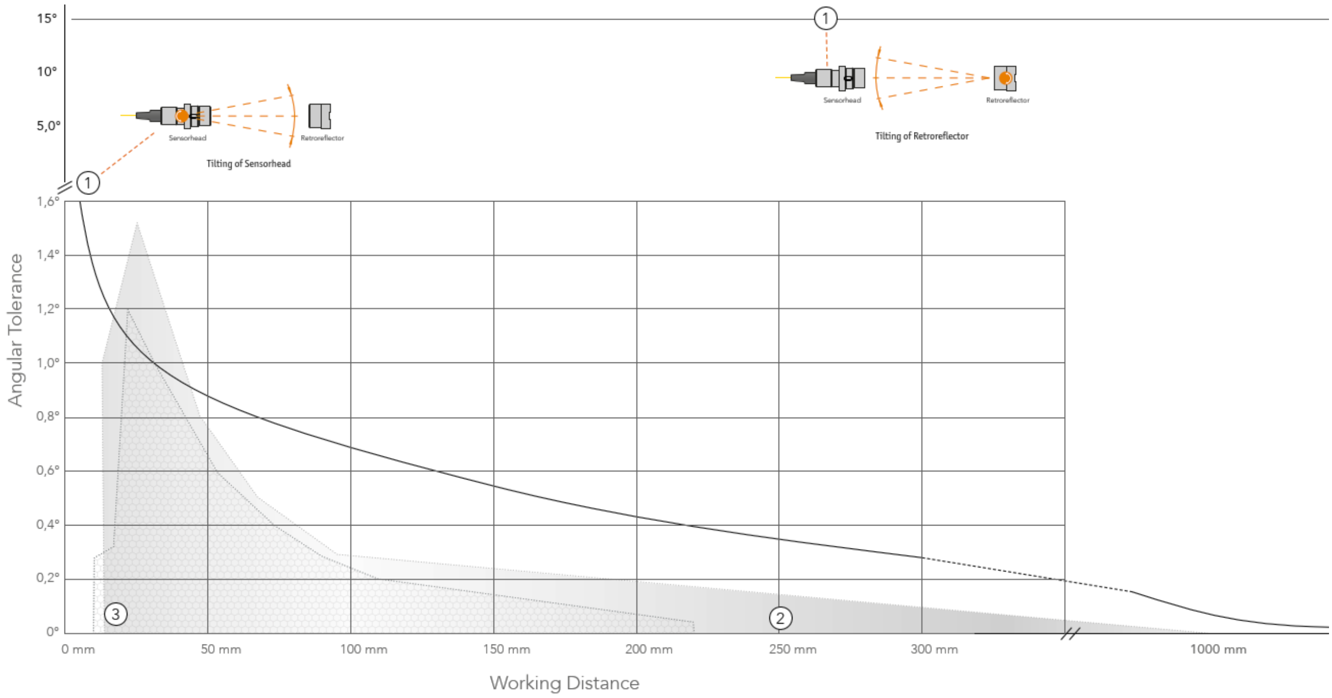

Figure 1: Overview of achievable performance areas covered by adding up all available customized sensor heads.
1 = collimated sensor head on retroreflector, 2 = sensor heads on high reflective targets, 3 = focused sensor heads on low reflective targets (the areas cannot be covered by one individual sensor head)

which can be covered by customizations of the sensor head's focal length.

The focal length is defined as the distance from the sensor head lens to the location where the beam profile has the smallest diameter. In general, the bigger the divergence angle the sharper the beam profile. This leads to higher angle tolerance and in return to a smaller travel range (M12/F40 Figure 2, above). Sensor heads with a flat beam profile cause the opposite effects (D4/F17 Figure 2, below).

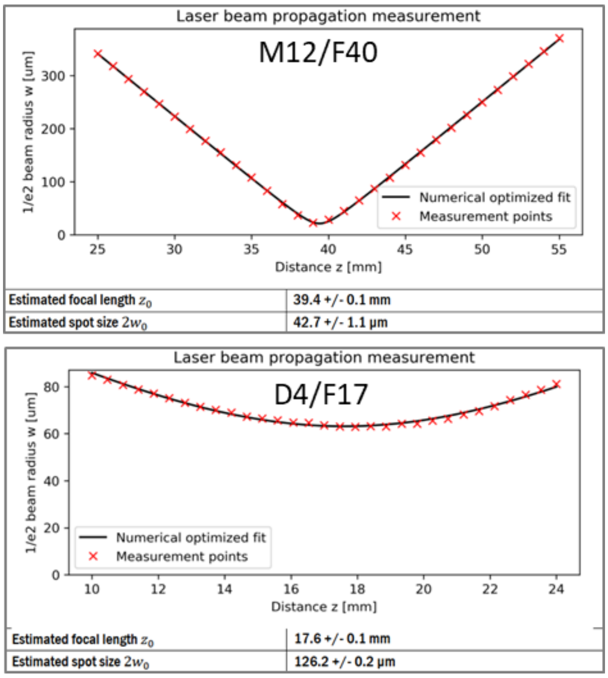

Figure 2: Sensor head beam shapes
(above = M12/F40, below = D4/F17)

The shown performance in Figure 1 cannot be covered by one individual sensor head, but represents the performance data of multiple heads. To collect this data, various sensor heads were characterzied in a precise testing procedure.

Measurement

To characterize the performance of a specific sensor head, in this case a M12/F30 with a focal length of 30 mm, the target is precisely positioned along the x-axis using an attocube ECS piezo based positioner. At each position the target is tilted to defined yaw angles using a ECR rotation stage which offers µ° resolution. The resulting signal quality at each point is detected by the IDS3010 and defines the achievable angular tolerance.

Results

For the M12/F30 in combination with a high reflective mirror target, the effect of different working distances and angular changes on the measurement signal quality are shown in Figure 3. A signal quality of 300 ‰ is sufficient for measurements with the IDS3010. For reliable measurments which avoid the risks of temporary signal losses in dynamic or less stable setups, a signal quality of >500 ‰ is recommended. Measuring close to the focal point significantly increses the signal intensity and is essential for measurements on low relfective targets. However, doing so on high reflective targets will lead to a signal overload (>900 ‰). This effect is represented in the chart by the grey area and can only be avoided by higher angular displacement.

Figure 3 clearly shows the decrease of angular tolerance with rising working distance. The M12/F30 can continously measure from 34.5 – 40 mm and offers maximum angular tolerances staring at 1.2° and decreasing to 0.2°.

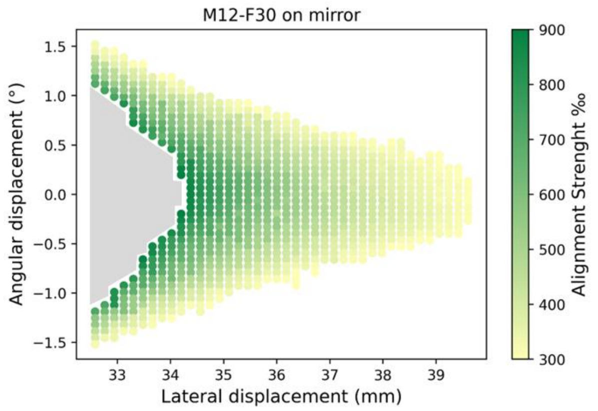

Figure 3: Sensor head characterization

This characterization was done for various focal lengths and sensor head types, and the overview is shown in Figure 4 for high reflective measurement surfaces. Figure 5 shows the performance of the same sensor heads for measurements on low reflective surfaces (e.g. glass). In both cases the displayed sensor heads are only representative examples to give a general orientation. The focal length can be freely chosen by the customer within the stated limitations for each sensor head. Also, the areas in between the shown sensor heads can be covered by individual customizations. Note that the exact values can change depending on the specific measurement setup, e.g. signal damping by optical connectors or feedtroughs can influence the working range and achievable angles.

Overall attocube´s M12 sensor heads offer higher working distances and angular tolerances. However, for applications with relatively short working distance, the D4 and D1.2 heads offer a very good combination of motion range and user friendly angular tolerance. As such sensor heads are designed for the usage in confined spaces the limited working distance is seldomly critical. The comparison of the different surfaces once more shows the benefits of highly reflective targets. Nevertheless, Figure 5 shows that specific sensor heads even allow measurements at up to 220 mm on low reflective surfaces. This once more shows the versatility enabled by the IDS3010 and its modular design.

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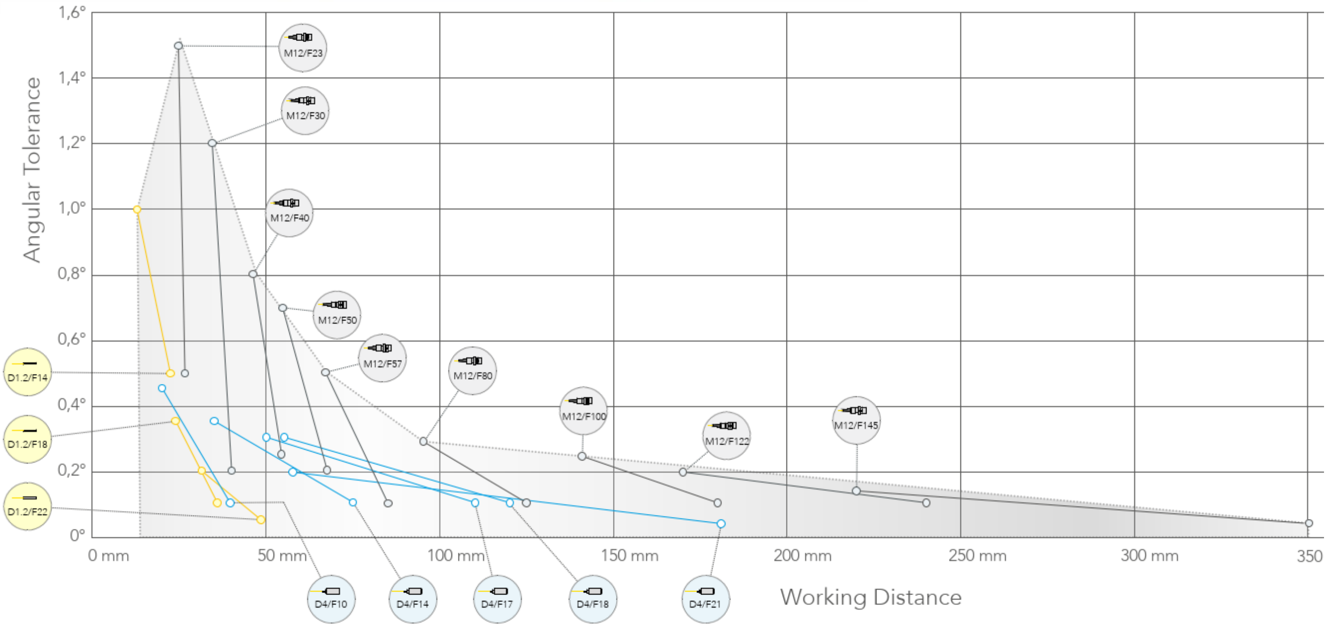

Figure 4: Working distance (=absolute distance sensor head to target), working range (= travel range of the target) and the angular tolerance (= maximum 1 dimensional tilting) of selected customized sensor heads on high reflective targets

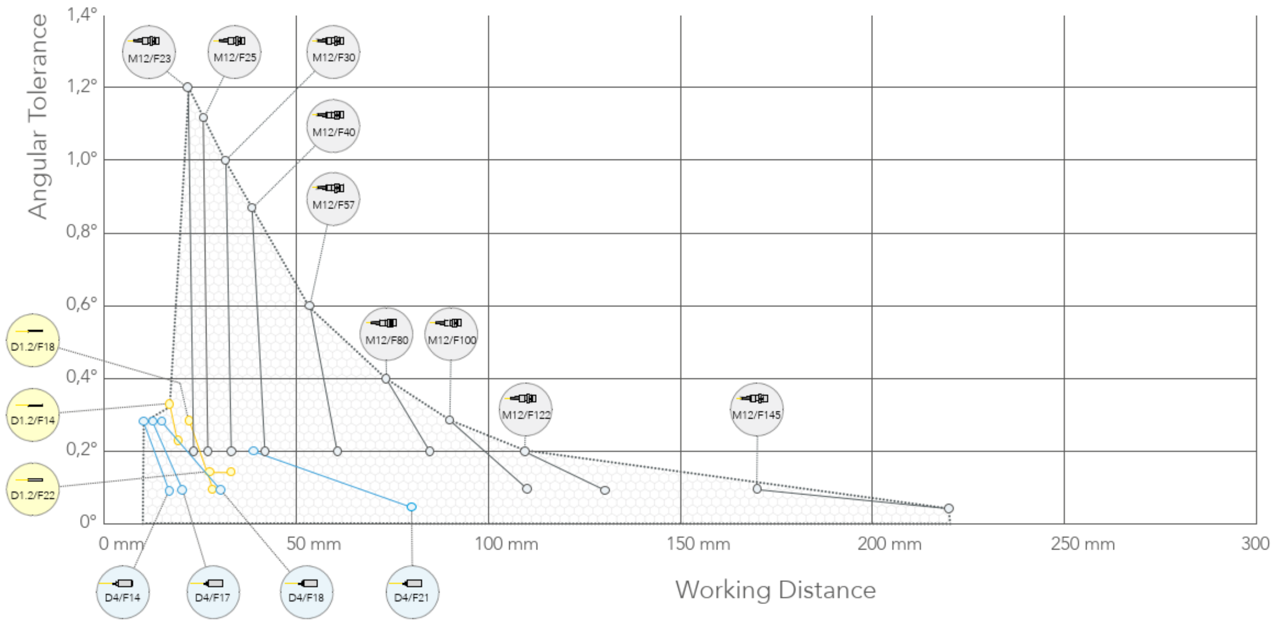

Figure 5: Working distance (=absolute distance sensor head to target), working range (= travel range of the target) and the angular tolerance (= maximum 1 dimensional tilting) of selected customized sensor heads on low reflective targets

Conclusion

The broad selection of customized sensor heads enables an ideal combination of working distance, working range and angular tolerance. These key performance parameters are mainly influenced by the optics sizes and the freely definable focal length. This allows the usage of the IDS for versatile applications and ensures that the performance is perfectly tailored to the customer specific requirements.

To find the best sensor head solution for very challenging or unique applications, attocube also offers test measurements directly on the cutomer’s target. The modular design of the interferometer also allows further customization of fibers, targets and mountings. attocube's application engineers are looking forward to partner up with you and find the best possible solution.