White Paper

Trimble SX12 Tracking And Target Separation

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Revision A

TECHNOLOGY THAT
transforms

Trimble.

All Trimble total station use Autolock® technology to find, track, and lock onto prisms. The Trimble SX12 scanning total station uses a digital camera-based system for its Autolock implementation. One major advantage of the SX12's camera-based system is that it can better differentiate between multiple reflections within the tracker field of view.

This means when aiming to permanent target installations, the SX12 requires a smaller prism separation than what's possible with analogue trackers. Similarly, when tracking, the SX12 is able to keep following the currently locked target, even when one or more undesired reflective objects come into view of the tracker.

Some key takeaways from this paper include:

- The tracker, EDM and telecamera are all coaxial
- Minimum prism separation depends on prism size and range. The images of two targets need to be separate on the detector for the tracker to interpret them as two targets.
- The SX12 has good target separation capabilities: about 40 mm center-to-center at close distances, and 85 mm at 100 m.

Trimble SX12 Tracker Implementation

The SX12 illuminates the target laser light from its tracker transmitter and aims the instrument toward the reflected light from the target.

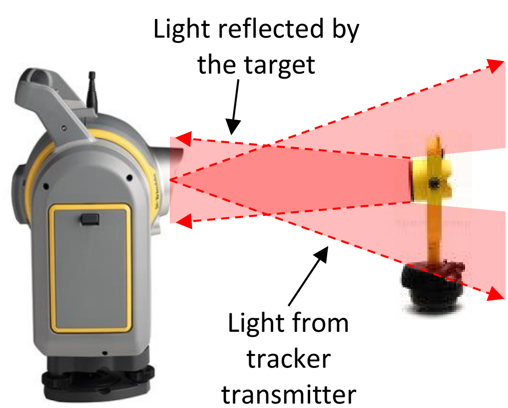

Figure 1. *Shows the SX12 illuminating the target from the tracker transmitter and the target reflecting light back to the instrument.*

The light reflected from the target is focused by the SX12 front lens to a dedicated tracker camera sensor (called the tracker detector). The light from the target will create an image on the tracker detector.

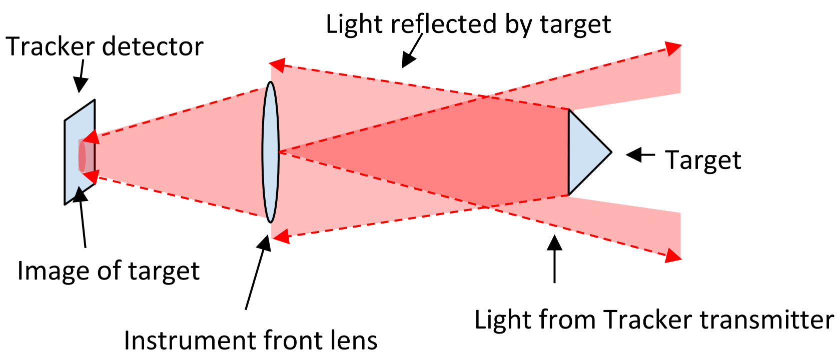

Figure 2. *A schematic view of the SX12 tracker locking onto a target.*

The tracker, EDM and telecamera are all coaxial, as shown in the telescope cross-section image below. An advantage of there being no eyepiece on the SX12 instrument is the ability to have the tracker detector at the back center of the telescope; this gives the most stable optical path for the tracker, and therefore the best performance.

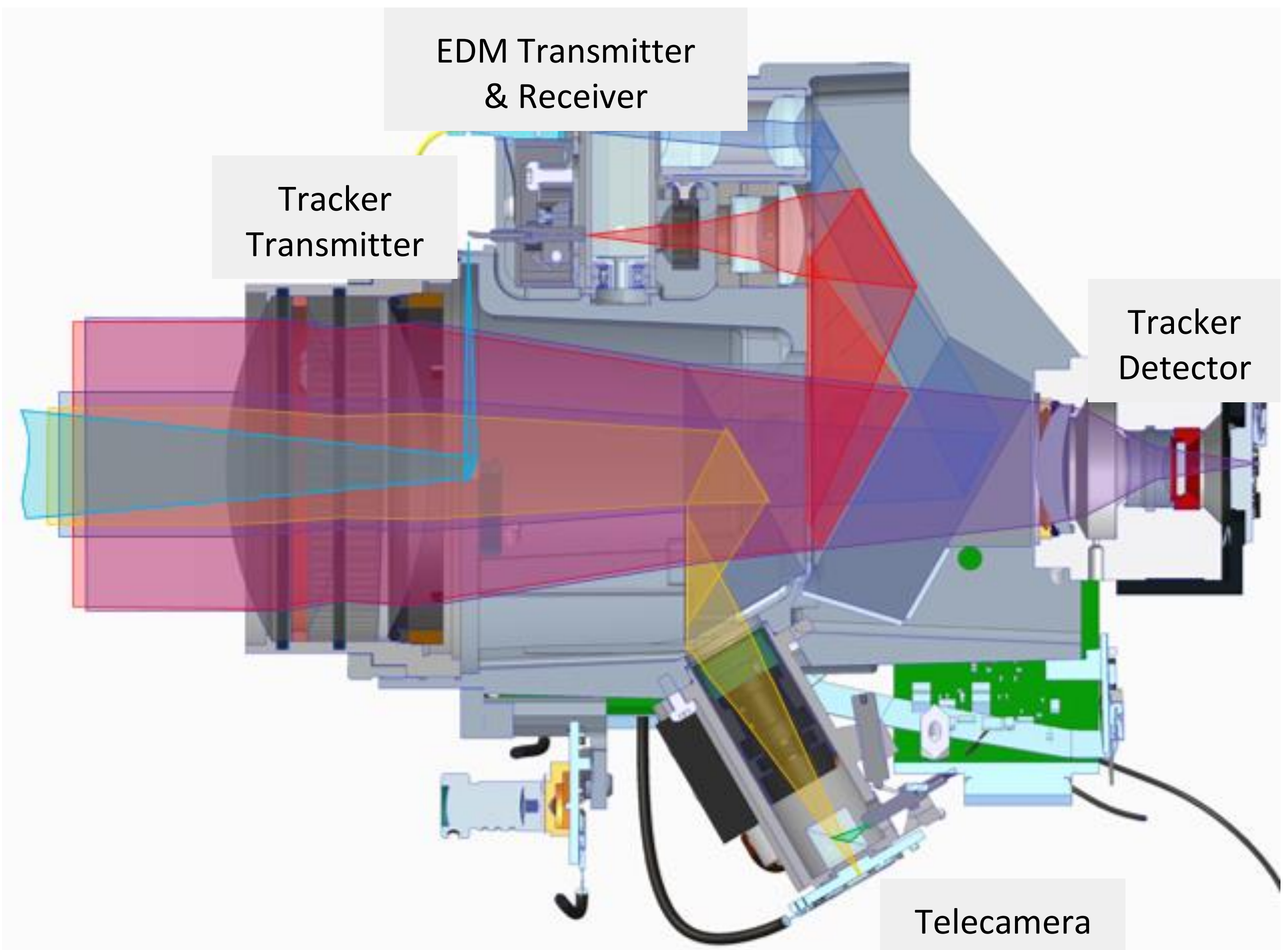

Figure 3. *A cross section of the telescope optics of the SX12.*

The tracker uses a three step process to detect the target. This process is repeated over 100 times per second to provide smooth autolock tracking functionality:

1. The transmitter emits an infrared light and an image is captured using the tracker detector.
2. The transmitter is turned off and a second image is captured using the tracker detector.
3. The prism(s) can be identified by taking the differential of the two images, as shown in the image below:

Figure 4. Shows how the target is detected using the difference between two images, one with the transmitter on and one with the transmitter off.

SX12 Field of View

The SX12 tracker field of view roughly equals the telecamera field of view. If you can't see your target in the telecamera then the tracker will not be able to see it either.

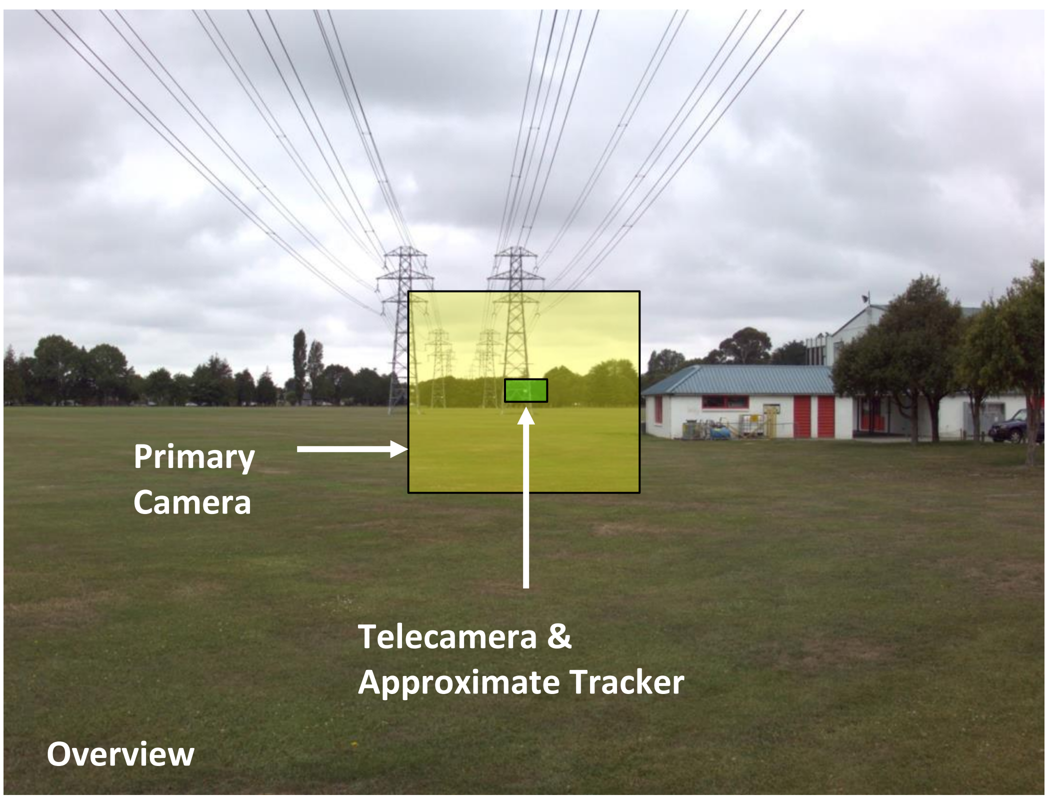

Figure 5. *Shows the field of view of the SX12 cameras and the tracker system.*

Minimum Prism Separation - Theory

The minimum prism separation required to detect two prisms as separate signals depends on the size of the prisms and the distance from the total station.

The prism size and the distance from the total station define how big the image of the target appears on the tracker detector, and how far apart the images of two targets will appear on the detector. The tracker can only distinguish the two separate target images if they do not overlap.

It's worth noting there is one situation where it is desirable for multiple prisms to be seen as a single target: when using a 360 prism. The reflected signals from multiple small prisms inside of a 360 prism are seen as one target in order for the total station to aim to the center of the cluster.

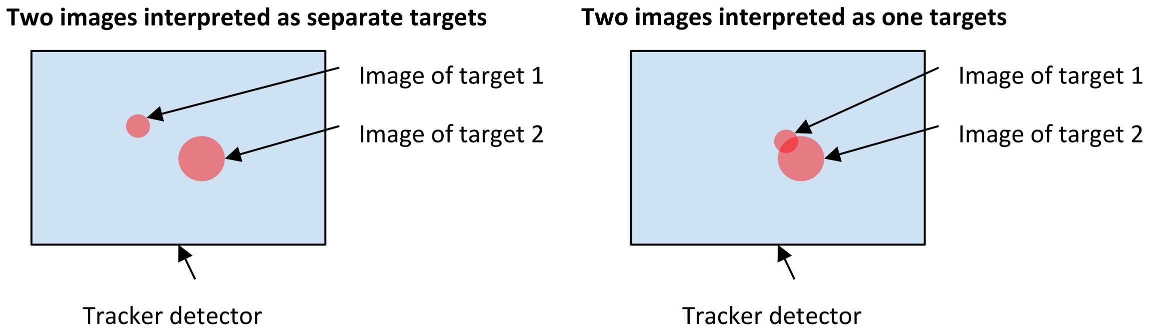

Figure 6. *Shows how two prisms will be interpreted as separate targets as long as the image of them on the tracker detector does not overlap.*

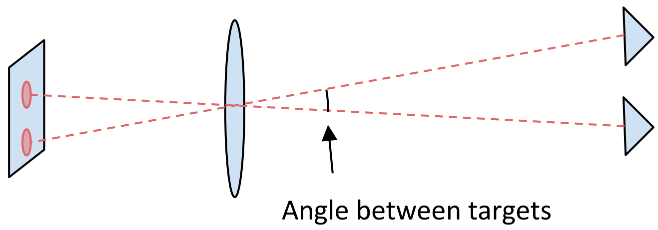

Figure 7a. *Shows how the angle between the two targets creates a distance between the two images on the tracker detector.*

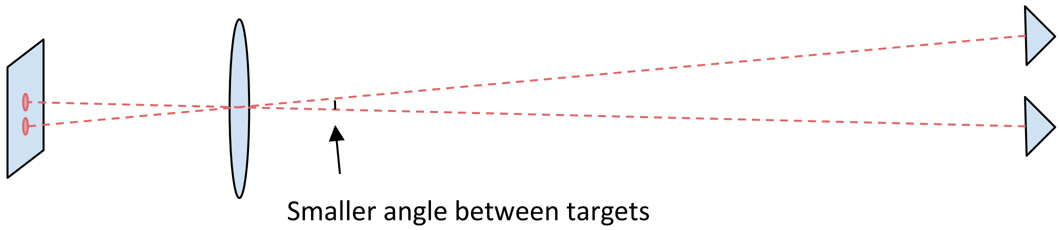

Figure 7b. *Shows the same two targets as in figure 7a but now at a longer distance. The separation between the two targets are still the same in mm but the longer distance gives a smaller separation angle, and therefore the two images appear closer together on the tracker detector.*

The tracker camera is focused to infinity while the target is at a closer range, affecting the size of the target's image. This is the same effect as background blur in a camera image, where small light sources that are not in focus get expanded into bright discs in the image. The bright defocused discs will become bigger the further out of focus the light sources are, and the bright discs will also become bigger if the camera has a larger lens.

Figure 8a. *The picture shows some bright light sources. The camera is focused at the light sources.*

Figure 8b. *The picture shows the same bright light sources as figure 8a but now the camera is focused at a much longer distance. Note how the images of the light sources get expanded into bright discs in the image due to the defocus.*

For an SX12, the small light source is the tracker transmitter laser that illuminates the target and gets reflected back by the prism to the instrument. The tracker detector sees the reflection of the tracker transmitter through the prism and will perceive it as being two times further away than the prism itself. This is similar to when you look into a mirror and the distance between you and your reflection is twice the distance between you and the mirror.

The prism target is a mirror that allows the SX12 to see and aim to its own tracker transmitter. The tracker transmitter laser is essentially a point source but since the tracker system is focused to infinity, the image of the target will become bigger when the target moves closer to the instrument, due to defocus, as seen in figure 8b.

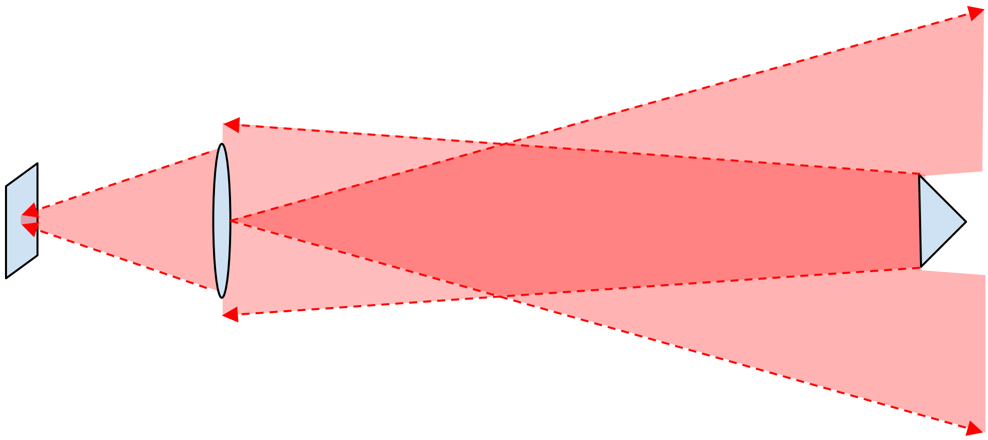

Figure 9a. *A target at a longer distance will create a smaller image on the tracker detector.*

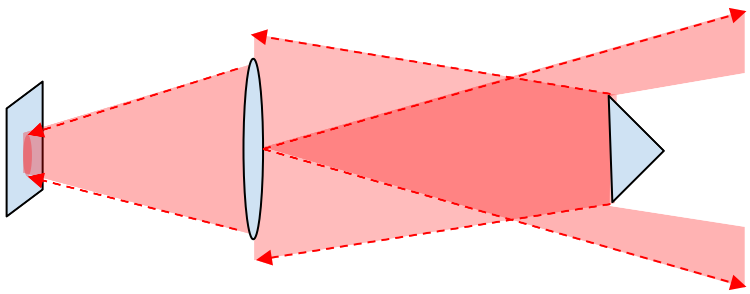

Figure 9b. *The same target at a closer distance gives a larger image on the tracker detector.*

The image size of the targets will decrease as the distance to the targets increases. This means that at longer distances the angle between two prisms can decrease and the SX12 can still separate them. This is true until the resolution of the optics and the tracker detector itself sets a lower limit for the angle separation between two prisms.

The SX12 tracker lens is 50 mm in diameter but the entire lens surface will only receive light if the prism is big enough. Prisms that are 25 mm or bigger will fill the entire lens and will therefore get defocus discs of the same size, which means that the smallest prism separation (center-to-center) is the same for all prisms 25 mm or larger. Prisms smaller than 25 mm, on the other hand, will render smaller defocus discs and can therefore be placed closer together and still be distinguished by the tracker.

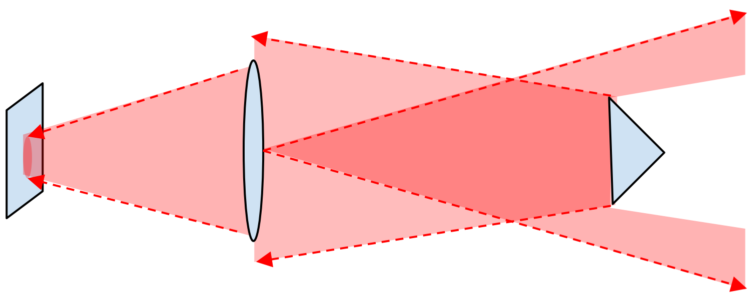

Figure 10a. *When a large prism is used (above 25 mm) the light returning from the target fills the entire instrument lens and the lens limits the amount of light that is focused towards the detector. When the prism is 25 mm or larger the image size is limited by the lens size and a larger prism would not increase the size of the image.*

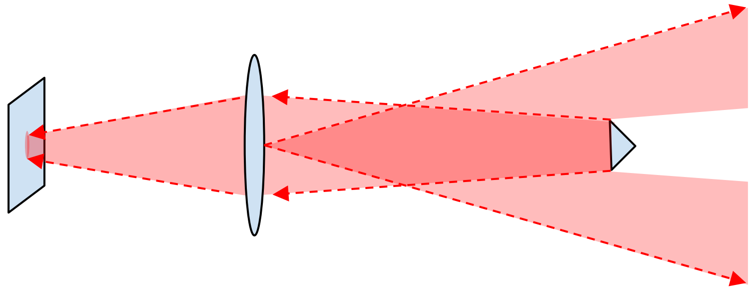

Figure 10b. *The light returning from a small prism does not fill the entire front lens of the instrument and gives a smaller image on the detector.*

To summarize, we can conclude that:

- The tracker, EDM and telecamera are all coaxial.
- Minimum prism separation depends on prism size and range. The images of two targets need to be separate on the detector for the tracker to interpret them as two targets.
- The SX12 has good target separation capabilities: about 40 mm center-to-center at close distances, and 85 mm at 100 m.
- At short range, the minimum separation will mainly be limited by the defocus, though a smaller prism will allow for a smaller minimum prism separation.
- At long range, the minimum prism separation will be limited by the resolution of the tracker system and will approach a constant angle.
- Prisms that are 25 mm in diameter or larger have the same center-to-center minimum prism separation.

Minimum Prism Separation - Practical Measurements

	Prism size 25 mm diameter or larger		Prism size 12.5 mm diameter	
Distance to Target [m]	Minimum Separation [mm]	Minimum Separation [deg]	Minimum Separation [mm]	Minimum Separation [deg]
5	39	0.447	22	0.244
10	43	0.244	26	0.146
15	47	0.179	30	0.114
20	50	0.142	33	0.095
30	55	0.105	39	0.074
50	64	0.073	49	0.056
100	85	0.049	72	0.041
250	124	0.028	118	0.027

Figure 10. *The table above shows the minimum separation where the instrument can still distinguish two prisms as separate targets. Both distance and angle refers to the center-to-center distance or angle between the prisms.*

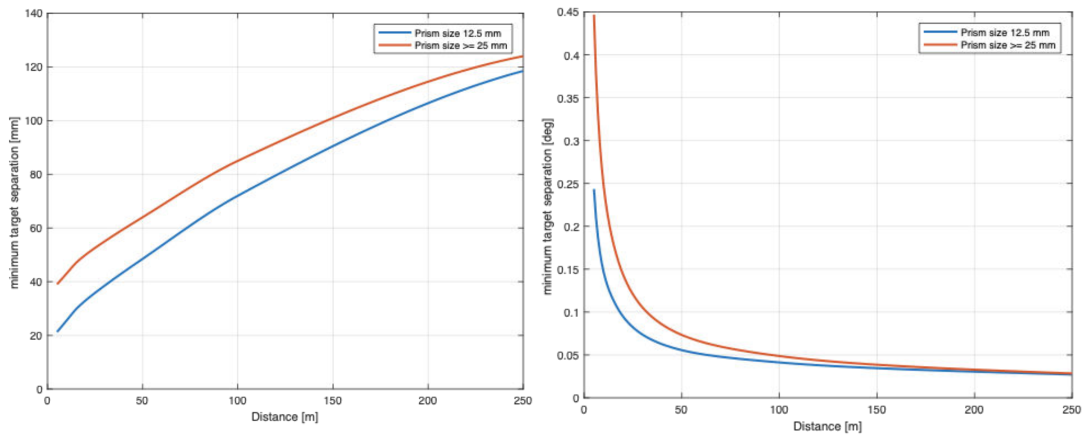

Figure 11. *The same data as in figure 10 but in plots instead.*

To calculate the minimum distance between two prisms of different size, simply use the average of the minimum separation of the two prism sizes.

For example, calculate the minimum separation for two prisms at 30 m range: one with 25 mm diameter and one with 12.5 mm diameter:

First, look up the minimum separation in Figure 10:

At 30 m range, the 25 mm prism requires 55 mm separation from a prism the same size

At 30 m range, the 12.5 mm prism requires 39 mm separation from a prism the same size

Next, average the two to calculate the required separation:

(55 mm + 39 mm) ÷2 = 47 mm

Answer:

At 30m range, the 25 mm prism and 12.5 mm prism need a minimum separation of 47 mm from center to center

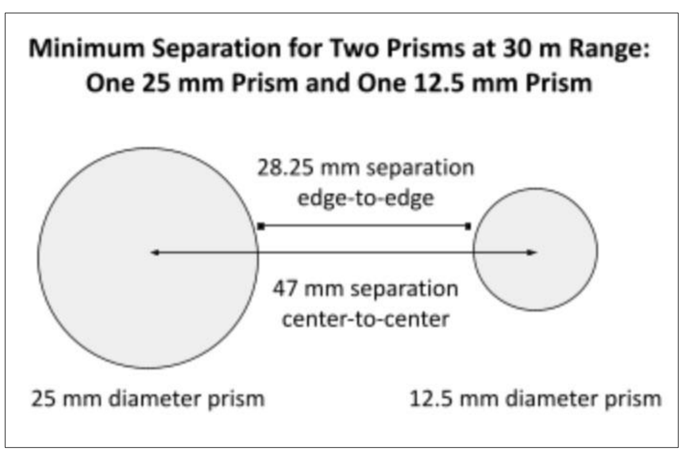

Figure 12. *Minimum separation example calculation*

To calculate the minimum separation angle for two targets at different distances, use the average of the minimum separation angle for the two sizes.

For example, calculate the minimum separation for two 25 mm diameter prisms: one at 10 m range, and one at 100 m range:

First, look up the minimum separation in Figure 10:

At 10 m range, a 25 mm prism requires 0.244° separation from a prism the same size

At 100 m range, a 25 mm prism requires 0.049° separation from a prism the same size

Next, average the two to calculate the required separation:

(0.244°+0.049°) ÷2 = 0.147°

Answer:

One 25 mm diameter prism at 10 m range, and one 25 mm prism at 100 m range require 0.147 degrees of separation from center-to-center

Relation to Trimble S Series

All Trimble S series total stations include the ability to find, track, and lock onto prisms using Trimble Autolock technology.

Trimble FineLock® is available on Trimble S7, S9 and S9HP instruments, which allows for a smaller prism separation than the other S series instruments. FineLock uses only the inner fine detector of the tracker receiver which has a very narrow field of view, removing the interfering reflections from other prisms and allowing the instrument to center on a single prism.

The SX12 tracking abilities are also attributed to Autolock technology, though the implementation is slightly different since the SX12 uses a camera based tracking system. For the SX12, narrowing the field of view would not affect minimum separation needed, and so something like FineLock is not needed for the SX12.

Comparing the S series and SX12, at distances farther than 40 m, the SX12 requires smaller target separation than the S Series.

	Minimum Target Separation between Two Prisms of 25 mm Diameter		
Distance to Target [m]	SX Series [mm]	S Series FineLock Monitoring Installations [mm]	S Series FineLock General Survey Workflows [mm]
10	43	16	40
25	52	40	100
50	64	80	200
100	85	150	400
200	114	300	800

Figure 13. *The table above shows the minimum separation where the instrument can still distinguish two prisms as separate targets. The separation values refer to center-to-center distance between prisms.*

In other words, at long distances the SX12 requires 10x smaller prism separation than the S series using FineLock.

Common Prisms

For monitoring applications, these are Trimble's most commonly used prisms:

Description	Part Number	Prism Diameter	Image
Small Monitoring Prism	58008030	25 mm	
Large Monitoring Prism	58008042	62 mm	
Asphalt Mount for Prisms	4520802-MON	12.5 mm	

For More Information

To learn more about available Trimble accessories, please visit:

Geospatial.Trimble.com/Optical-Accessories

Monitoring.Trimble.com/Accessories

To learn more about S Series FineLock or to compare total stations, please visit:

Optical Tip of the Month – FineLock for Trimble S Series Instruments

Total Station Portfolio – Comparison

For all other questions, please contact your local Trimble representative.
To find a local representative, please visit https://geospatial.trimble.com/where-to-buy

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