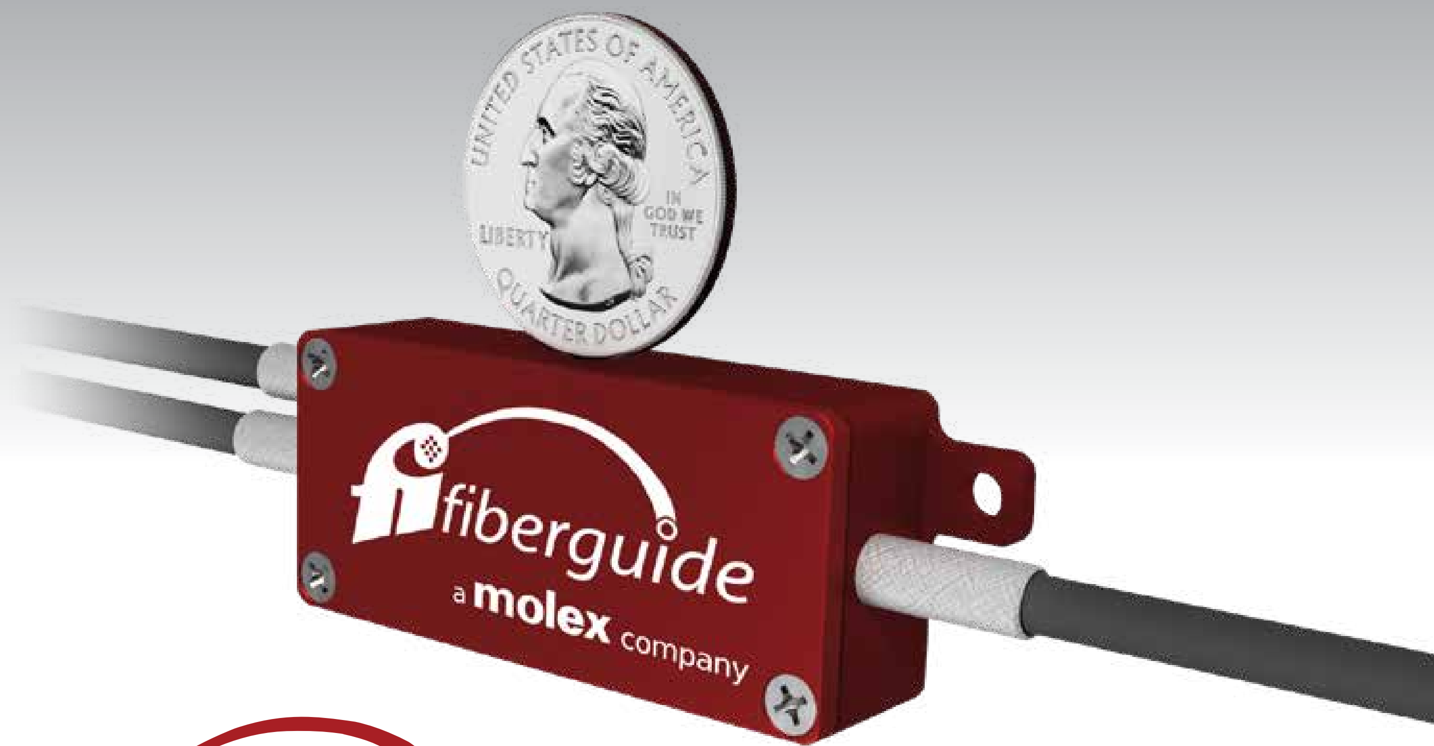

fiberguide
a molex company

A Comparison Study on Laser Speckle Reduction

Luke Westbrook, Research & Development Engineer

January 6, 2021

3409 E Linden Street, Caldwell, ID 83605 USA
Ph: +1 (208) 454-1988
Toll Free: +1 (877) 565-0888

www.Fiberguide.com

Introduction

When inspecting a spot illuminated by laser light, you may notice a granular-like pattern. The pattern, also known as speckle, is due to fluctuations in the intensity of the light hitting the spot. The intensity fluctuations are the result of random differences in the phase of the light being reflected from a surface. Since most surfaces can be considered rough on the scale of optical wavelength, when light is scattered from a surface the phases will constructively and destructively interfere leading to contrasts in the intensity that we see. The changes in contrast have no visible pattern and appear completely random, leading to the static-like appearance of speckle. Speckle also appears when light is transmitted through materials since the surface structures of the materials will randomly change the phase and polarization of the light, leading again to changes in the intensity seen within the illuminated area (Goodman 2020).

While speckle is easy to see with the naked eye, it is important to be able to make quantitative measurements of how much speckle a laser spot has. Speckle contrast is a standard way that laser speckle is measured. It is a measurement of how much the signal varies around the average output of the laser. In other words, it gives a measurement of how rough the output is across the laser-beam cross section. The mathematical expression is:

$$C = \frac{\sigma}{\langle I \rangle}$$

C: Speckle Contrast, reported as a ratio

σ: The standard deviation of the intensity over the radial distance

I: Average intensity of the radial distance

where C is the speckle contrast, σ is the standard deviation of the intensity over the radial distance, and $\langle I \rangle$ is the average intensity over that radial distance. This is reported as a percentage. If there is a lot of variation in the signal, i.e. the signal looks very rough with a lot of speckle, the speckle contrast will approach 1 or 100%. If there is very little variation in the signal, i.e. the signal looks very smooth or has very little speckle, the speckle contrast will approach 0 or 0%. Speckle contrast can be measured in the near field (top-hat profile) or far field (Gaussian profile). Measuring speckle contrast is usually done by either imaging a laser spot on a screen or imaging the beam with a laser-beam profiler. To be able to measure the speckle contrasts of either the near or far field, images can be broken up into small groups of pixels that contain the intensity data of the light stored by the pixels. If a square of pixels contains the beam, speckle contrast can be measured for that local area of the beam. This can be done over the entire beam area and averaged to get an overall speckle contrast for the entire beam profile.

The goal of this study was to compare two different commercial laser de-speckling products for fiber optic systems. The products that were compared were Molex's Fiberguide De-Speckler and the Optotune LSR-3005. Molex's Fiberguide De-Speckler is an inline active unit that averages modal noise in a fiber that homogenizes the signal. The Optotune LSR-3005 is a free space speckle reducer that works by using a moving diffuser which reduces the speckle contrast. While the LSR is most commonly used for free space applications, it is also offered as an option to de-speckle laser light in fiber optic systems.

Methods

Since the study was a comparison of reducing laser speckle in fiber optic systems, both Molex's Fiberguide De-Speckler and the Optotune LSR were setup for testing using their respective optimal setup for a fiber laser system. The laser source used was a single mode 635 nm wavelength laser with the power set at 0.5 mW. Molex's Fiberguide De-Speckler was connected to the source fiber with a fiber to fiber connector. The De-Speckler fiber was then connected directly to the imaging system. The Optotune LSR was setup according to Optotune application notes on how to use the unit in a fiber laser system. A 1:1 relay lens was used to take light out of the source fiber and focus it onto the LSR diffuser film. Another 1:1 relay lens was then used to collect light on the other side of the LSR and focus it into a fiber that was connected to the imaging system. A Beamage 3.0 camera was used to image the light out of the end of the fiber system in both cases. A lens system was used to image the near-field, or top-hat, profile along with ND filters to limit the amount of light reaching the detector. Both systems were tested at imaging frequencies of 2, 3, 4, and 5 kHz. Ten images were taken at each frequency with the unit on and then off in their respective system. A program was then used to analyze all the images and calculate the average speckle contrast at each frequency with a 99.9% confidence interval. Because of the unique application requirements, qualification testing for assessing leak rates under stable conditions as well as under seismic disturbances combined with destructive fire propagation testing on prototype bundles was a requirement.

Results

When the comparison was done with Molex's Fiberguide De-Speckler in its optimal set up, we see that it out preformed the Optotune LSR-3005 in its respective fiber optic setup. The results for the speckle contrast found in each system at the different image frequencies with the speckle reducing unit turned on can be seen in Figure 1. Full results are shown in Table 1. Molex's Fiberguide De-Speckler reduced the speckle contrast in its system between 66 and 72% at the different frequencies while the Optotune LSR-3005 reduced speckle contrast in its system between 23 and 46%. This could be due to an increase in the power transmitted to the receiver. Since the Optotune LSR-3005 uses a diffuser there is significant optical loss along with reflections at each lens face. Molex's Fiberguide De-Speckler has very little loss since it utilizes fiber optic cables and the speckle reduction method it utilizes does not introduce any loss into the system. Our data also showed that at higher imaging frequencies, the Optotune LSR-3005's ability to reduce speckle decreased significantly, while Molex's Fiberguide De-Speckler was still reducing speckle very well. Data collected separately from this experiment has shown that Molex's Fiberguide De-Speckler offers high speckle reduction performance up to 10 kHz.

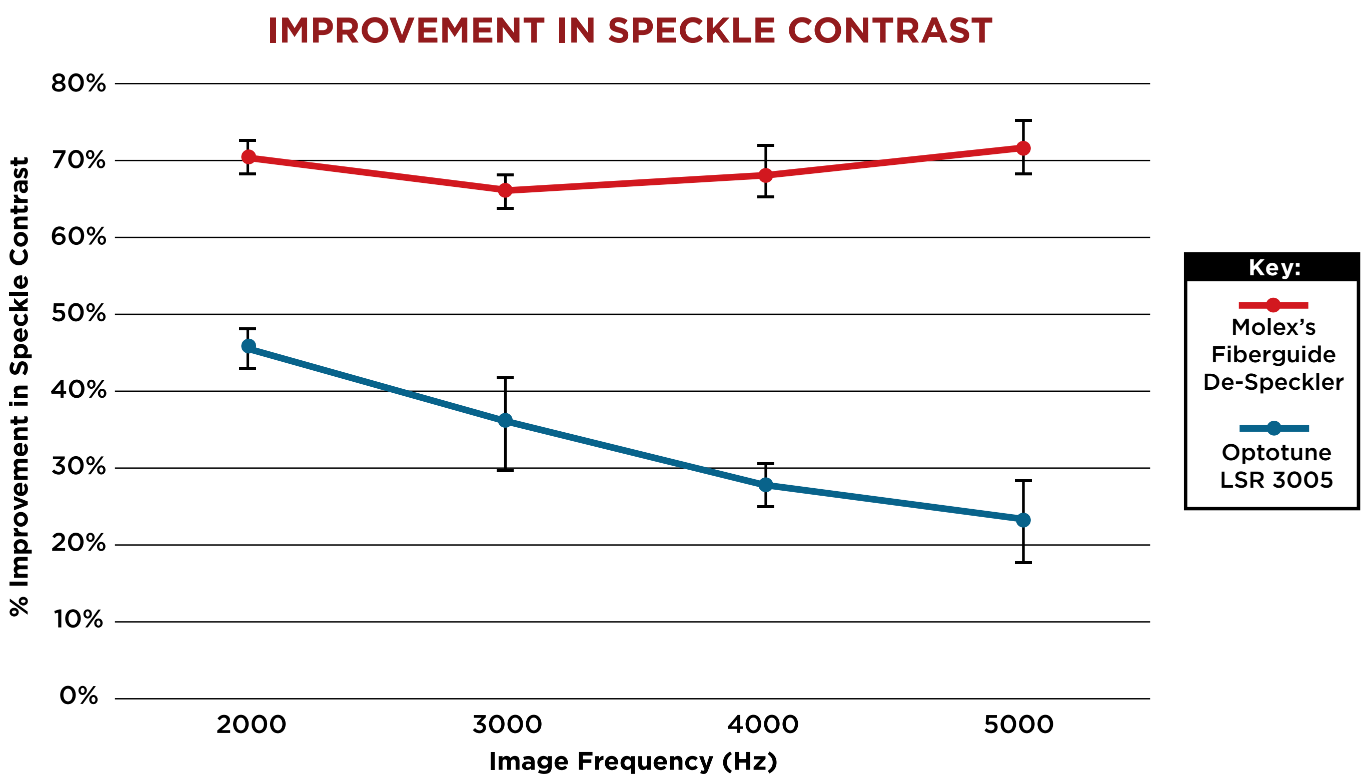

Figure 1: Speckle Contrast vs Imaging Frequency for the Optotune LSR 3005 and Molex's Fiberguide De-Speckler

SPARKLE CONTRAST

Compare:	LSR-3005		De-Speckler	
Image Freq (Hz)	Off	On	Off	On
2000	14.7%	8.0%	14.2%	4.2%
3000	16.2%	10.4%	24.0%	8.1%
4000	16.6%	12.8%	29.8%	8.4%
5000	16.6%	12.8%	29.8%	8.4%

Table 1: Speckle Contrast results for both systems with speckle reduction units both on and off

Molex's Fiberguide De-Speckler has other advantages over the Optotune LSR-3005 as well. If an optical laser system is utilizing fiber optic cables in their setup, it would be much easier to integrate the De-Speckler into the system rather than the LSR-3005. Launching laser light out of a fiber through free space and then coupling it back into a fiber requires high quality optical components and precision alignment. This usually means hundreds of dollars of optics equipment and a lot of time to set up and optimize. Molex's Fiberguide De-Speckler can be integrated very easily into a system, as it is essentially a plug and play unit.

Conclusions

Overall, our tests show that in systems where fiber optics are used, it would be advantageous to use the Molex's Fiberguide De-Speckler over the Optotune LSR-3005.

When comparing Molex's Fiberguide De-Speckler and the Optotune LSR-3005 in a fiber optic system, the De-Speckler is advantageous because of:

- an increase in speckle reduction performance
- a significantly simpler setup (plug and play)
- less optical power loss
- better performance at higher imaging frequencies.

References

Goodman, J. W. (2020). Speckle Phenomena In Optics: theory and applications. S.l.: SPIE PRESS.

To find out more about how Molex's Fiberguide's De-Speckler can improve performance within your application, visit our product page or connect directly with the team.

De-Speckler Product Page:

https://www.Fiberguide.com/product/despeckler/

Contact Us:

https://www.Fiberguide.com/contact/

About Molex's Fiberguide:

Molex's Fiberguide Industries holds more than 40 years of fiber optic design and manufacturing experience in the assembly of complex and standard fiber optic bundles, assemblies, and arrays. We understand what is required to meet your custom design and production needs. Molex's Fiberguide has a fully integrated and rapid prototyping capabilities to accelerate your R&D and new product development needs. Our vertically integrated capabilities enable the best custom fiber optic bundle or assembly solution for your application. As a leading innovator for custom fiber optic bundle solutions, our knowledgeable and experienced engineering team is focused on making your complex design requirements a reality.