# Reduction of speckles in digital holography

seit 1558

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The reduction of speckles can be realized by the summation of the gray-values of pictures with different speckle-patterns of one object. The speckles are created by coherent illumination. Averaging the statistically patterns will reduce the speckles significantly and will improve the picture quality. We use either a scattering plate, an LCoS (Liquid Crystal on Silicon - Display) or the combination of them to generate different speckle-patterns on the object . This can be realized by changing the position of the scattering plate or by controlling the phase of the wave front by the LCoS.

The best speckle reduction is obtained by changing the position of the scattering plate.
For interferometric use it is necessary to control the phase distribution defined. Therefore, the LCoS has to be used. Adding the scattering plate in a fixed state gives an even higher image quality.

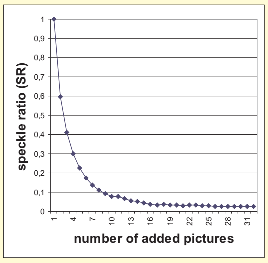



Fig. 2: General trend of speckles in dependence of the number of pictures

## Setup for reducing speckles in digital holography

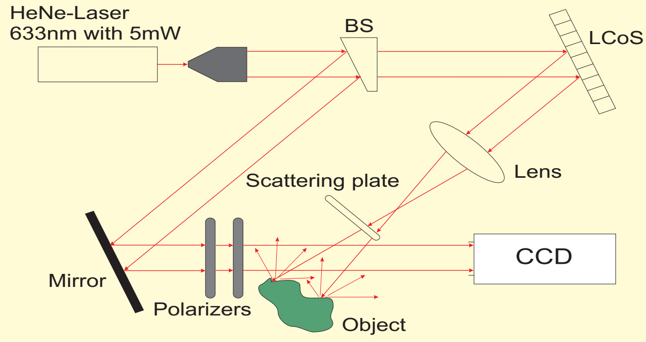



Fig. 1: General setup

To characterize the speckles on an image it was necessary to create a value to describe the quality of pictures. We called it the "speckle rate" (SR). The SR is the ratio of the number of the "pixels identified as speckles" SP and the total number of image-pixels TP. One pixel is "identified as a speckle", if the sum of the absolute value of the difference between the mean value MW of a pixel and ist eight neighbours and those nine grey-scale values GW divided by nine is bigger than a certain intuitive number p.
The SR yields no information about size, quantity or other properties of the speckles! But it has shown, that it is a good size to characterize the degree of speckles in a picture.

$$\frac{1}{9}\sum_{i=1}^{9}\left|GW_i - MW\right| > p$$

$$SR = \frac{SP}{TP}$$

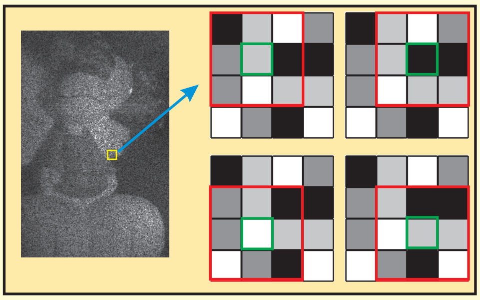


Fig. 4: Principle of SR calculation

Fig. 5: Examples of SR-values left SR = 45.57, right SR = 3.99

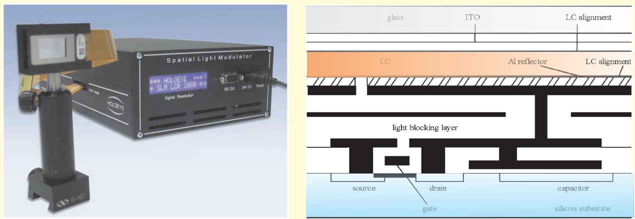



Fig. 3: LCoS and sheme of function [1]

The LCoS consists 1920 times 1200 pixels and can be driven with up to 60 frames per second. It is able to change the phase up to 1.2 PI over a range of 8 bit. Therefore, it is possible to create a great number of different variants of speckle-patterns on the object. This allows us to restore each wave front in an identical shape.

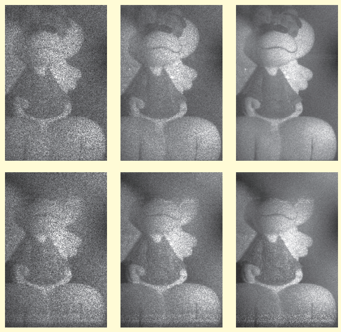


Fig. 6: top: sum of 1, 4 and 16 pictures using a scattering plate
bottom: sum of 1, 4 and 16 pictures using an LCoS

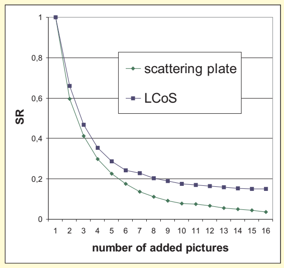



Fig. 7: Comparison of the speckle ratio by using an LCoS or a scattering plate

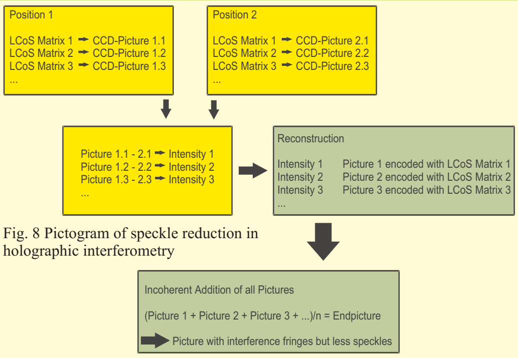



Fig. 8 Pictogram of speckle reduction in holographic interferometry

By using the property of the LCoS to reproduce phase-patterns in the illumination wave we are able to reduce speckles in holographic interferometry, too.
High attention has to be paid to the stability of the system. The interference fringes have to be stable in the range of $\lambda/10$.
Otherwise the interference fringes will be washed-out.

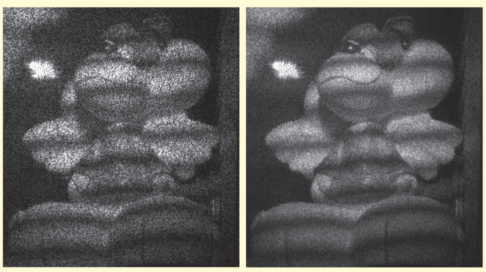
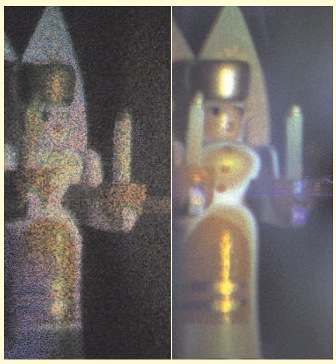


Fig. 9: Holographic interferogram without and with speckle reduction

Fig. 10: Colored holograms
left: consisting of 3 mono-colored pictures
right: speckle reduced by averaging 20 pictures in each color



Finally we tested our approach for digital color holography. Therefore, three holograms of one object were recorded each one with a laser of a different color (red, green, blue). The result is shown in Fig. 10 on the left side.
To improve the quality of the colored image the same procedure as described above was applied for each color separately. The result is demonstrated in Fig. 10 on the right side.

[1] Hai Tao Dai et al.: Characteristics of LCoS Phase-only spatial light modulator and ist applications, Optics Communications 238 (2004) p. 269–276
[2] U.Schnars, W.Jueptner, "Digital Holography", 2005 Springer Verlag

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