ABSTRACT CONTRIBUTION

Statistical properties of speckle patterns produced by a laser diode in dependence of the pump current

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Speckles are an optical artifact that appears if coherent waves interfering with each other and that is often undesired in imaging. On the other hand, the spatial correlations present in the speckle pattern contain relevant information, which can be used, e.g., to reconstruct the object that generates the speckle [3] or to study flow dynamics of blood [1]. If the light scattering properties of the scattering object are known, speckle patterns can also be exploited for realizing an spectrometer [4].

Using the speckle contrast measure,

$$C = \frac{\sigma_I}{\langle I \rangle}, \tag{1}$$

with $\langle I \rangle$ being the mean intensity of the pattern and σ_I its standard deviation, we determine optimal conditions for recording speckle images and explain the increase/decrease of speckle contrast obtained with other acquisition parameters. Furthermore, we study the effect of intensity of the illumination, and the exposure time of the camera on C.

We are interested in a cost-effective way of speckle reduction for double-pass retinal imaging [2]. Thus in this contribution, we study experimentally how the statistical properties of the speckle pattern formed by a 685 nm depend on the pump current especially when crossing the lasing threshold, $I_{th} \approx 25.4$ mA. In our experiment, we generate speckle within a multimode fiber and record the output of this optical fiber with a camera. In Fig. 1, we show images of the speckle produced by the multimode fiber at different pump currents and their corresponding intensity histograms. The mean intensity of the region containing the speckle pattern is approximately the same for all images (digital level of 30, while the 8-bit camera offers 256 brightness values). The speckle contrast values, C, represent the graininess, which increases from $C = 0.13$ under the threshold to a stable value of $C = 0.70$ above the threshold, corresponding to two independent lasing modes, $M = 2$, $C \propto 1/\sqrt{M} = 1/\sqrt{2} \approx 0.71$ because the polarization is lost in the fiber.

While changing the pump current has an effect on the physical speckle pattern, changing camera settings like the exposure time or adding neutral density filters can change the measured speckle contrast because the digitization of lowly exposed images can lead to large standard deviations at low mean intensities, leading to an increase of C as $\langle I \rangle$ approaches zero.

We conclude that the reduction of speckle contrast close to the lasing threshold can be interesting in imaging applications, although the low laser output intensity has to be taken into consideration. Secondly, the full dynamic range of the camera has to be used to avoid measuring high speckle contrast values even if only a small amount of speckle is produced.

References

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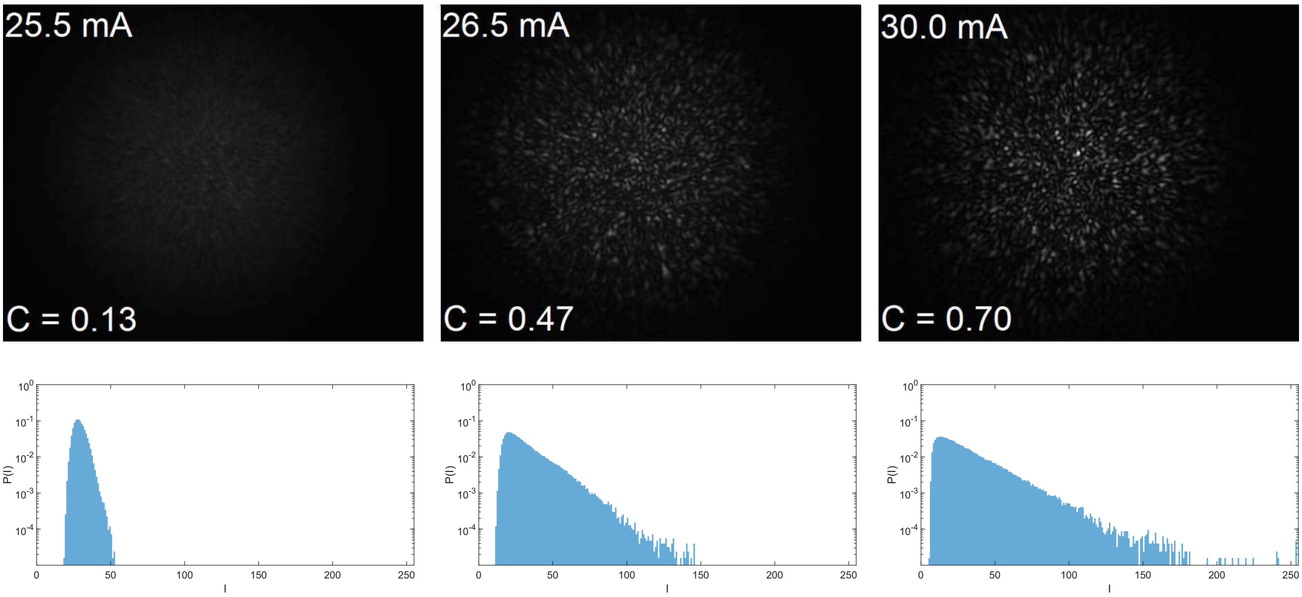

Figure 1. Examples of speckle patterns from a 685 nm laser diode taken at the end of a multimode fiber and their corresponding intensity histograms (logarithmic probability scale). As the pump current is increased from 25.5 mA to 30.0 mA, and the exposure time being adjusted to obtain approximately the same mean intensity values in three images, the speckle contrast increases from $C = 0.13$ to $C = 0.47$ to $C = 0.70$.

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