Speckle reduction in clinical widefield fundus imaging, using a pulse-tuned laser diode

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PURPOSE

Many commercial fundus cameras provide infrared video preview of the retina to facilitate patient alignment. For systems that illuminate a wide field-of-view, relatively high-power infrared sources are required, particularly if indocyanine-green angiography must be supported as a secondary function. Laser diodes can provide high radiant power with very low cost and a small form-factor, but their tendency to generate speckle [1] can be problematic for image quality.

Speckle is an interference pattern inherent to coherent imaging systems, due to mutual interference of coherent wavefronts produced by diffuse reflections (see Figure 1). The result is a granular texture in the image, which is usually unwanted because it degrades the contrast of image features.

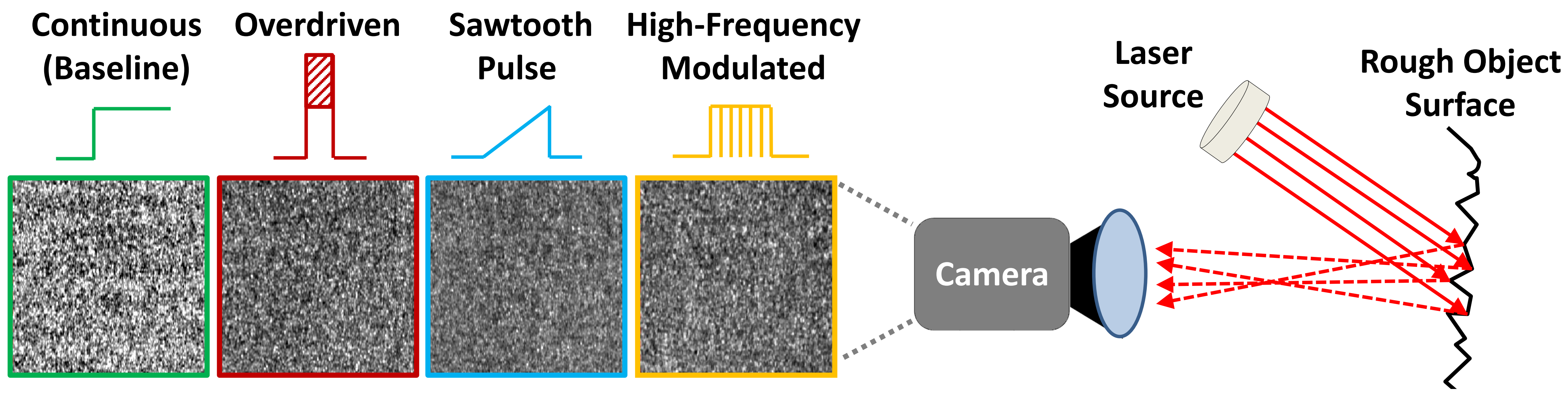

Figure 1: Speckle formation in a coherent imaging system, using various drive-current schemes.

Pulse-shaping of injection current can suppress laser speckle, thus improving imaging contrast (Figure 2A). We compared the effectiveness of three electronic methods for reducing speckle in clinical images acquired with a widefield fundus camera.

METHODS

- A prototype 90° widefield slit-scanning fundus camera with a 790 nm single-mode infrared laser diode was used for video preview imaging at 10 frames/second. In order to suppress speckle, the laser diode was driven with modulated current pulses.
- Three different pulse types were tested: i) overdriven, ii) sawtooth, iii) high-frequency modulated. The pulse-shaping induces thermal tuning of the laser wavelength [2], with the resulting superposition of speckle leading to reduced speckle contrast in the final image (Figure 2B-C).
- We imaged N=9 human subjects, without pupil dilation. Speckle contrast was calculated as the ratio of the standard deviation of intensity fluctuations to the mean intensity.

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RESULTS

The mean speckle contrast across subjects was 0.12±0.024 for overdriven pulses, 0.11±0.018 for sawtooth pulses, and 0.12±0.017 for high-frequency modulated pulses. Overall, the speckle contrast achieved was not significantly different among any of the three tested methods ($p<0.05$).

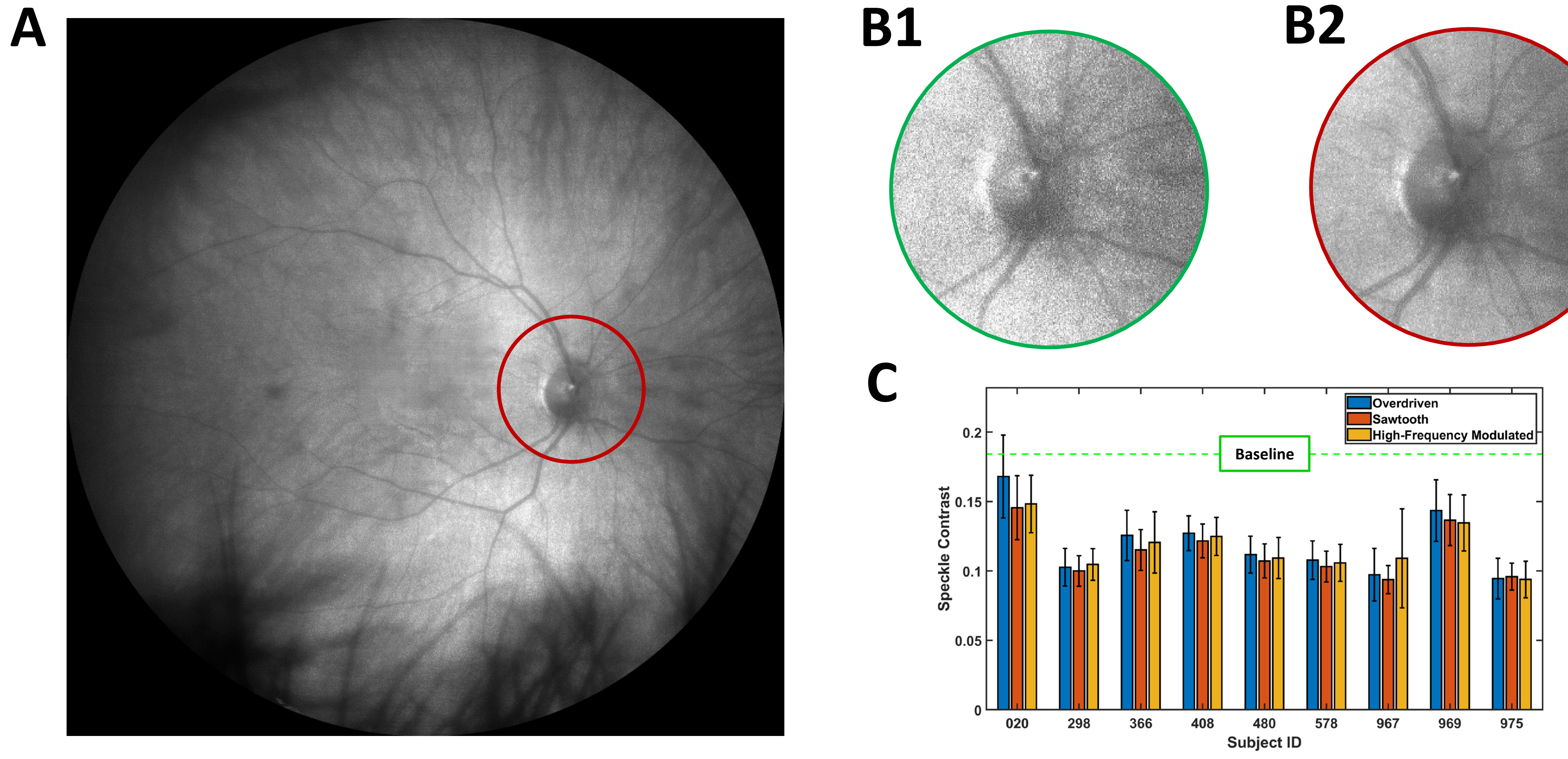

Figure 2: (A) 90° infrared fundus image; (B1) Speckle significantly degrades contrast; (B2) Suppression of speckle via pulse-shaping; (C) Speckle contrast computed from fundus images acquired with each pulsing scheme. Continuous current (baseline) speckle contrast is marked by a dashed green line.

CONCLUSIONS

Pulse-modulation of laser diode current can provide a simple and low-cost means of reducing the impact of speckle in coherent widefield fundus imaging. Though we found that three different pulsing schemes achieved similar levels of speckle contrast reduction in fundus images, there may be other important metrics (such as impact on laser lifetime) to consider when choosing the most suitable drive-current scheme for a laser-diode based imaging system.

REFERENCES

[1] Trisnadi, J.I., "Speckle contrast reduction in laser projection displays." Projection displays VIII. Vol. 4657. *International Society for Optics and Photonics* (2002).

[2] Bartl, J., et al., "Tuning of the laser diode." *Measurement Science Review*, 2(3), 9-15 (2002).