Laser Speckle Contrast Imaging

Explanation and Theory

The moorFLPI-2 is a Laser Speckle Contrast Imaging device (LSCI) for assessing tissue blood flow. The principle of operation for LSCI is based on the fact that when coherent laser light is incident on tissues the scattered* light forms a speckle pattern on the detector surface of a video camera.

When the tissue contains moving blood, the speckle pattern moves; the faster the blood moves, the faster the speckles move.

The video camera has a finite exposure time and when blood is moving very slowly, the speckles are imaged quite sharply, there is good contrast between the light areas (constructive interference of light waves) and the dark areas (destructive interference). However, when blood moves quickly, the image is blurred such that contrast between light and dark areas is reduced (because some of the light areas move into previously dark areas during the exposure time).

Compare this with a simple still camera taking photos of a runner – the faster the runner moves, the more blurred is their photographic image; by measuring the blur, we could measure the running speed.

In practice, when used in 'spatial mode', the speckles are mapped over a small grid of detector pixels (typically 5x5) and the contrast is assessed as the standard deviation (SD) of pixel intensities (average pixel intensity = I); SD is low for fast moving speckles (high blood flow) where the image is blurred, and SD is high for slow moving speckles (low blood flow) where the image is not so blurred.

The basic formula for LSCI assessment of tissue blood flow (Flux) is:

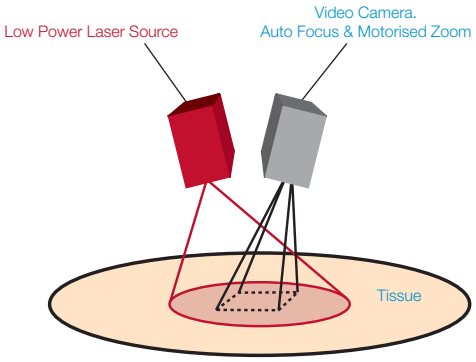
$$\text{Flux} \propto \left(\frac{\langle I \rangle}{SD}\right)^2$$

In 'Temporal mode', the intensities of individual pixels during at least 25 successive images are used to calculate average intensities and SDs. This mode is at-least 25 times slower than spatial mode but its resolution is 5 times higher.

For an in-depth description and theory of LSCI, please refer to Briers et al, 2013 and the references it contains:

David Briers, Donald D. Duncan, Evan R. Hirst, Sean J. Kirkpatrick, Marcus Larsson, Wiendelt Steenbergen, Tomas Stromberg, Oliver B. Thompson (2013).
Laser speckle contrast imaging: theoretical and practical limitations.
J. of Biomedical Optics, 18(6), 066018 (2013). https://doi.org/10.1117/1.JBO.18.6.066018

(*Scattering by small particles, e.g. blood cells, is the absorption and re-emission of light, with potential for Doppler shift. This is different from 'reflection', where there is no Doppler shift.)



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