CLAIMS

[Claim 1] A sensing device comprising:

a single printed circuit board;

one or more laser diodes configured to emit light at an object;

one or more laser drivers configured to supply power to the one or more laser diodes;

an image sensor configured to receive and capture the light reflected and/or scattered from the object as a plurality of images at a sampling rate of at least 100 Hz, preferably from 100 Hz to 500 Hz; and

a controller configured to process a signal from the image sensor, the signal being related to the received light, wherein the one or more laser diodes, the one or more laser drivers, the image sensor, and the controller are integrally disposed on the single printed circuit board,

wherein each of the plurality of images comprises a plurality of pixels at each timepoint, the controller being configured to determine a Dynamics index at each timepoint, wherein the Dynamics index is calculated as $\left(\frac{I}{S.D.}\right)^{x}$, wherein I is the mean intensity of the pixels, *S.D.* is the standard deviation of the plurality of pixels, and x is from 1.8 to 2.6, preferably x is 2.2.

[Claim 2] The sensing device according to claim 1, wherein at least one of the following is fulfilled:

(i) the image sensor comprises a complementary metal-oxide-semiconductor (CMOS) sensor or a charge-couple device (CCD) sensor;

(ii) the image sensor is configured to operate without an optical conduit to receive the light reflected and/or scattered from the object;

(iii) the signal comprises a plurality of laser speckle patterns;

(iv) the controller is configured to process the signal to measure changes in the plurality of laser speckle patterns; and

(v) the controller comprises a micro system on module or a field-programmable gate array.

[Claim 3] The sensing device according to claim 1 or claim 2, wherein the plurality of pixels comprises an imaging field at a center region of the image sensor, the imaging field having a range from 7 x 7 pixels to 300 x 300 pixels.

[Claim 4] The sensing device according to any one of claims 1 to 3, wherein the controller is configured to generate a plurality of the Dynamics indices at different timepoints based on the sampling rate; to generate a waveform based on the plurality of Dynamics indices; and to convert the waveform into a frequency domain, and/or wherein the controller is configured to determine the Dynamics index without removal of background noise in the signal.

[Claim 5] The sensing device according to claim 4, wherein the controller is configured to determine a ratio of a sum of amplitude values at a heartbeat frequency range in the frequency domain to a sum of amplitude values at a baseline frequency range in the frequency domain, optionally the heartbeat frequency range comprises from a heartbeat frequency minus 0.1 Hz to the heartbeat frequency plus 0.1 Hz and the baseline frequency range is from 0 Hz to 0.5 Hz.

[Claim 6] The sensing device according to claim 4, wherein the controller is configured to determine a ratio of an amplitude of a pulse rate frequency to an amplitude of frequency zero, or a square root of the ratio of the amplitude of the pulse rate frequency to the amplitude of frequency zero.

[Claim 7] The sensing device according to any one of claims 1 to 6, wherein a distance between the one or more laser diodes and the image sensor is at least twice a penetration depth of the light into the object.

[Claim 8] The sensing device according to any one of claims 1 to 7, further comprising at least one of the following:

(i) a display unit configured to display the ratio, or an indication based on the ratio;

(ii) a transmitter;

(iii) a receiver;

(iv) a transceiver;

(v) a power unit configured to provide electrical power to the sensing device, wherein the transmitter, the receiver, and/or the transceiver is coupled to the controller and is configured to communicate wirelessly with an external device;

(vi) the one or more laser diodes each operates at a low optical power of 1 mW to 10 mW and the one or more laser drivers each is a constant current source;

(vii) an operating wavelength of each of the one or more laser diodes is from 450 nm to 1300 nm, preferably from 700 nm to 950 nm; and

(viii) each of the one or more laser diodes has a narrow linewidth of less than 0.1 mm.

[Claim 9] A wearable device comprising the sensing device according to any one of claims 1 to 8; and a fastening mechanism adapted to couple the sensing device to a user, optionally the wearable device comprises a watch, a wristband, or a skin patch to be pasted on a skin of the user.

[Claim 10] A method of externally measuring blood flow, the method comprising:

emitting light at an object with blood flow beneath a surface of the object;

receiving and capturing the light reflected and/or scattered from the object as a plurality of images at a sampling rate of at least 100 Hz, preferably from 100 Hz to 500 Hz; and

processing a signal relating to the received light,

wherein each of the plurality of images comprises a plurality of pixels at each timepoint, and wherein the method further comprises determining a Dynamics index at each timepoint, wherein the Dynamics index is calculated as $\left(\frac{I}{S.D.}\right)^{x}$, I being the mean intensity of the pixels, *S.D.* being the standard deviation of the plurality of pixels, and x being from 1.8 to 2.6, preferably x being 2.2.

[Claim 11] The method according to claim 10, further comprising generating a plurality of the Dynamic indices at different timepoints based on the sampling rate; generating a waveform based on the plurality of Dynamics indices; and converting the waveform into a frequency domain, and/or determining the Dynamics index is performed without removal of background noise of the signal.

[Claim 12] The method according to claim 11, further comprising determining a ratio of a sum of amplitude values at a heartbeat frequency range in the frequency domain to a sum of amplitude values at a baseline frequency range in the frequency domain, and optionally the heartbeat frequency range comprises from a heartbeat frequency minus 0.1 Hz to the heartbeat frequency plus 0.1 Hz and preferably the baseline frequency range is from 0 to 0.5 Hz.

[Claim 13] The method according to claim 11, further comprising determining a ratio of an amplitude of a pulse rate frequency to an amplitude of frequency zero, or a square root of the ratio of the amplitude of the pulse rate frequency to the amplitude of frequency zero.

[Claim 14] A non-transitory computer readable medium comprising instructions that, when executed on a processor, perform the method according to any one of claims 10 to 13.

[Claim 15] A method of determining usability of a laser module in haemodynamic waveform measurement, the method comprising:
emitting light from the laser module at a rough surface of a metal;
receiving the light reflected from the rough surface to capture a plurality of images over a period of time, wherein each of the plurality of images comprises a plurality of pixels at each timepoint; and
determining a Dynamics index at each timepoint over the period of time, wherein the Dynamics index is calculated as $\left(\frac{I}{S.D.}\right)^{x}$, wherein I is the mean intensity of the pixels, $S.D.$ is the standard deviation of the plurality of pixels, and x is from 1.8 to 2.6, preferably x is 2.2, optionally the method further comprises determining the laser module to be usable when the Dynamic index is determined to be from 0 to 20 with a standard deviation of less than 2.