



# Laser Doppler Theory

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## Laser Doppler Theory

A low intensity beam of monochromatic light, emitted from a laser diode inside an BLF21-Series flowmeter, travels via the probe's fiber optic light guide through the probe head to illuminate the tissue under study.

There, the laser beam is scattered by reflective components within the tissue. A portion of the light is reflected back, via the probe's receiving fiber optic light guide, onto a photo detector inside the flowmeter. Generally, this received light has been reflected many times by stationary structures within the tissue as well as by one or more moving particles (mainly red blood cells) within the tissue. It is the moving Doppler effect.

The received signal spectrum is processed in the BLF21 monitor in accordance with algorithms derived by Dr. R.F. Bonner for this type of reflective environment<sup>1</sup> to calculate volume flow ( $\text{ml} \times \text{min}^{-1} \times 100^{-1} \text{g}$ ) of tissue. While the actual volume of tissue sampled by the BLF21 varies with the optical properties of the tissue, it is approximately  $1\text{mm}^3$ .

## Flow $\text{ml} \times \text{min}^{-1} \times 100^{-1} \text{g tissue}$

While theory puts output from a laser Doppler flowmeter in units of milliliters per minute per hundred grams sampled ( $\text{ml} \times \text{min}^{-1} \times 100^{-1} \text{g}$  of tissue), in practice this is somewhat problematic for several reasons. The most significant reason is that the actual volume of tissue sampled is unknown. This volume is assumed in the calculations to be  $1 \text{mm}^3$ , but it may vary widely with differing optical properties of the tissue. The output of the flow monitor is proportional to absolute flow in the tissue sampled, but since this quantity of tissue sample is different from one spot to another and one patient to another, the "constant" of proportionality differs for each placement of a probe.

Besides being unknown, the volume of tissue sampled is very small; this is both a strength and a weakness. Since the volume sampled is so small, laser Doppler flowmetry can look at very localized perfusion without being influenced by underlying tissues. But it can be misunderstood as, for example, a gauge of a whole organ perfusion rather than very local perfusion. This can be exaggerated by the unit ( $\text{ml} \times \text{min}^{-1} \times 100^{-1} \text{g}$  of tissue). Assuming the nominal  $1 \text{mm}^3$  is sampled, this sample weighs about  $0.001 \text{g}$ ; therefore, the more correct but unprecedented unit to quote would be hundredths of microliters per minute per milligram of tissue ( $0.01 \mu\text{l} \times \text{mg}^{-1}$  of tissue.) Of course, these units have the same ratio of volume to weight but it is important to remember that only about  $1/100,000$  of that one hundred grams of tissue is being sampled.

While typical range for certain tissues (notably free flap donor sites used in microvascular reconstructions) are very desirable and potentially useful, they must be used with upmost care. These ranges are subject to very large tolerances because meter to meter, probe to probe, tissue site to tissue site and patient to patient, variations are all additive.

From this discussion, we can conclude that the best and highest usage for laser Doppler flowmetry is for relative measurements. If the probe can be placed at one location, to continually monitor a given site for the duration of the critical period, the changes noted are directly proportional to absolute volume flow changes in the sampled tissue when proper monitoring technique is maintained.

<sup>1</sup>Bonner, R.F., Clem, T.R., Bowen, P.D., Bowman, R.L., "Laser-Doppler Continuous Real-Time Monitor of Pulsatile and Mean Blood Flow in Tissue Microcirculation", in Scattering Techniques, Applied to Supra-Molecular and Nonequilibrium Systems. Chen, S.H., Chu, B., Nossal, R., eds. New York: Plenum, pp 685-702.

