Opto-Acoustical Imaging with an Isotropic Pulsed NIR Source

The Near Infra Red (NIR) light spectrum extends between wavelengths of 750 nm and 950 nm. It is an initial part of the overall infra-red (IR) spectra which stretches between a dark red light and micro-waves.

NIR light possesses an interesting and useful property as it can be only partially absorbed by tissue. The level of absorption depends on tissue structure and in principle can be measured. To achieve this, the NIR light has to be delivered into the target tissue in the form of very short pulses from a laser. NIR light is adsorbed to a greater extent by a denser tissue than by a lighter tissue and by blood itself. Such absorption causes these regions of a denser tissue to release weak ultra-sonic waves, which could be detected by special arrays, see Fig. 1. Computer analysis of the resultant data can be used to generate a three-dimensional image of the inner structure of the target tissue. This, in principle, would allow to locate any abnormal dense formations such as breast tumours or under-skin cancer knots.

Since this method is based on a conversion of a light energy into ultra-sonic signals, it is often called the opto-acoustical imaging.

Over the past 10 years much research has been done using NIR lasers to develop and to perfect this method. Respective publications can be found through search engines under "opto-acoustical imaging" The work has been mainly carried out with narrow beams of NIR lasers to image small objects in tissue such as veins or small tumours. It has attracted significant attention because it is truly a non-invasive and safe method. Indeed, the only requirement is to deliver approximately 0.1–0.2 J/cm^2 of NIR light to a targeted area with a pulse duration not exceeding 1 micro-second. These NIR fluxes cannot increase the tissue temperature by a fraction of a degree centigrade, neither can they cause any biological changes. These advantages position the NIR imaging method way ahead of any other imaging techniques such as an imaging with X-rays or with ultrasonic generators.

However, at present the NIR imaging method has a built-in technical disadvantage simply because of the nature of the NIR laser itself:

- Laser beams are usually just a few mm in diameter and need to cover a larger area such as a woman's breast. The diffusion of the beam leads to a reduction in the intensity of NIR light which in turn cannot generate ultrasonic pulses of a sufficient intensity to be reliably interpreted.
- The level of ultrasonic signals generated can be kept high by scanning the breast with an un-diffused laser beam. This presents a health problem since a monochromatic light of a laser is known to be unsafe – even the light from a simple laser pointer is sufficiently strong to make direct contact with skin, or especially eyes, inadvisable.
- When the cost of either a diffuser or a scanning device along is added to the laser the complete system becomes costly in comparison with full ultrasonic or X-ray imaging systems.

It is possible to avoid the technical and price problems of using a NIR laser by using an isotropic filtered plasma light source. The required spectral output of such a light source is outside the range of conventional flash lamps and is closer to the working range of sub-microsecond plasma sources used for various tasks in plasma physics. The required light source should have sufficient NIR energy output to deliver up to 30 Joules in order to fully cover the largest likely target, e. g. a breast. Since an isotropic source emits equally in all directions, the collection of light and re-direction towards the target is very important since this reduction in wastage/losses significantly reduces the full output requirement of the light source. Calculations show that such a source should generate a total of approximately 300 Joules, should have a pulse duration between 1.0–0.5 microsecond and should have a small size (a few cm) to allow effective light collection. As it turned out, this specification requires to construct a unique device, which would include a special Pulse Forming Network (PFN), a special flash lamp and a NIR filter with sharp spectral borders.

Such a NIR system is shown in Fig. 2. It consists of a desk-top power-control unit connected by a cable with a hand-held lamp. The lamp module can be

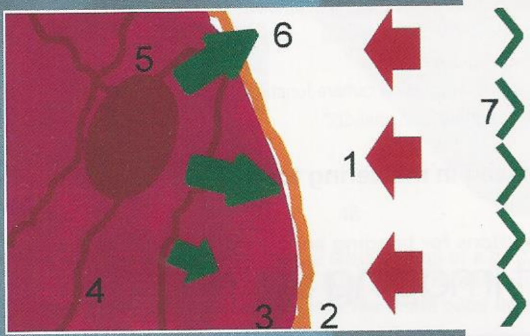

Fig. 1: How the opto-acoustical method works – 1. beam of NIR, 2. skin, 3. light tissue and blood, 4. veins, 5. tumour, 6. ultra-sonic waves, 7. arrays of ultra-sonic detectors

mounted on a tripod if it is desired to have more steady direction of the NIR light at the target tissue. The system has a standard LCD display and soft-keys for programming pulse rate (1 to 10 Hz), pulse energy, and a count-down clock. Full data sheets for this system can be viewed at www.wektec.com.

There is also potential for further improvement – it is likely that a smaller pulse duration at the same energy output would allow still quicker absorption and consequently stronger ultrasonic signals. This improvement of pulse parameters has been done and made it possible to deliver NIR fluxes at sub-microsecond pulse durations (250–350 nano-sec) with NIR energy of 0.1–0.2 J/cm^2 for a largest likely target, e. g. breast. It makes it even more attractive both technically and price-wise to NIR laser systems with associated expanding or scanning devices.

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