Deep Tissue Penetration of Radiation: Modelling and Experiments

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Four different wavelengths (532 nm, 800nm, 1064nm and 1278nm) were used for the investigation of the transmission through chicken breast tissue. The transmission at each wavelength was assessed for both Bessel-beam and Gaussian-beam geometries. The laser beam was directed through different sets of lenses for telescopes to tailor the incoming beam to the experimental requirements.

The beam waist was measured with a beam profiler. Each of the incoming Gaussian beams was set to have a beam diameter of 1.0-1.4mm (FWHM), except for one case that involved a beam diameter of 3mm. Bessel-beams were produced using an Axicon with an apex angle of 178° and each Bessel beam was filmed with a camera sensitive to 1278nm radiation for the alignment, measurement of the radius of the central spot and for the measured transmission pattern as shown in figure 2a. The calibration was done with a microscope reticle placed in the beam. To investigate the effect of the rings surrounding the central spot of the Bessel beam, different Bessel beams were set up having 11 rings and 4 rings, respectively. Beams having different numbers of rings but having the same total power or the same power in the central spot were assessed. Furthermore, Bessel beams were compared with Gaussian beams having either the same diameter as the smaller Bessel beam, or a diameter comparable to central spot of the Bessel beams. For all the beams, the light transmitted through the tissue is collected by a lens and directed to a power meter.

It was demonstrated that the beam geometry did not influence the transmission behaviour through strongly scattering tissue, but as expected, the wavelength plays a major role. As expected, the transmission from the Cr:Forsterite-laser at 1278nm (which lies in the transparency window of most biological tissues [1,2]) is six times higher than at 532nm and more than three times higher in the NIR, at 800 and 1064 nm. These results are displayed in figure 1.

Figure 1: Transmission through chicken breast at different wavelengths with different beam geometries

![Figure 1](image1)

![Figure 2](image2)

Figure 2: Transmitted radiation patterns after 7mm of chicken a) measured b) smooth model c) clumpy model

We have modelled the propagation of laser light through the chicken breast using a three-dimensional Monte Carlo radiation transfer code that treats accurately the multiple, anisotropic scattering. Figure 2 shows measured (a) and modelled (b, c) light patterns. The models show the scattered light pattern emerging through the tissue for an input Gaussian beam. The two models assume uniform density and a fractal structure for the chicken breast. By modelling the total intensity received and its scattered light pattern, the scattering properties of the chicken breast can be determined at all wavelengths. The model calculations reproduce the measured transmission patterns very well.