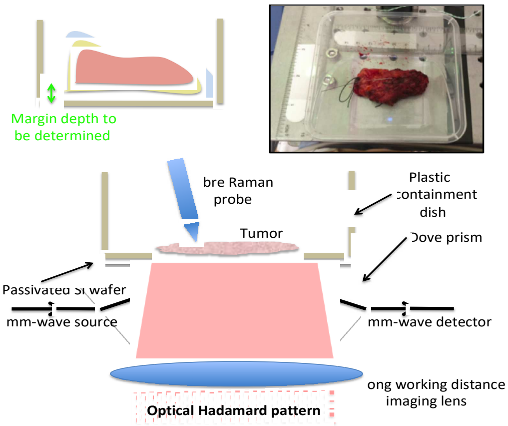
“mm-wave TIR imaging for cancer margins”

Current approaches cannot provide an accurate assessment of breast cancer tumour margins, a key factor for disease recurrence and high rates of required secondary surgery [1]. This project will lay solid foundations for the development of new mm-wave imaging systems designed specifically for cancer margin assessment during surgery. Once fully designed and optimised, we believe that this approach could reduce the occurrence of second surgeries, cancer reoccurrence and metastasis.

Radiation in the mm-wave band is intrinsically safe, and corresponds to a “sweet spot” in the electromagnetic spectrum, where radiation can pass unimpeded through fatty tissues that normally scatter or absorb infrared and visible radiation, while giving rise to useful contrast in protein rich tissues for cancer imaging. This contrast arises primarily from the differing water content in tissues, e.g. water density is typically 10 to 50% higher in breast tumor than similar healthy protein based tissues, depending on type, size and stage [2].

In Exeter, we have developed a total internal reflection (TIR) imaging geometry [3] to determine tissue depths. The design is relatively simple in concept: mm-wave radiation impinges on the sample through a non-absorbing prism onto a spatial light modulator (SLM) – a silicon wafer, passivated to increase photoconductivity. The reflection of mm-wave radiation from the SLM is spatially modulated by a second visible light source. In this geometry, an image of the tumour can be reconstructed by rapidly modulating the mm-wave intensity.

The physical thickness of the probed region can be tuned by the frequency of the mm-wave. Using frequencies in the range 10 to 50 GHz, one can target the probed depth to match UK guidelines for breast cancer (currently 2mm). We have begun testing this principle using tissue phantoms: layered structures formed from gelatine and water designed to mimic the layers of a real tumour. Like real breast tumor tissue, these phantoms are soft and malleable such that it lies flat in container (see inset of figure). We have shown that the margin depth across most of the surface can then be obtained. The aim of the current project is to help design and test the next stage: a miniaturised, portable imaging system suitable to be taken at a later stage to the Royal Devon and Exeter Hospital to carry out tests using real, excised tumours. In the summer project, we will optimise the imaging engineering for this, and test our design using phantoms.



The design of a “stand alone” tool, present to the side in theatre, which surgeons can use to evaluate excised margins during breast cancer surgery, could allow better assessment of surgery endpoint and if and where additional margin is required. By tightening the boundaries for accepted margins, a good margin analysis tool will reduce the need for secondary surgery, while also improving recovery times, cancer reoccurrence and metastasis. While the development of a fully integrated clinical device is beyond the scope of this project, we have plans in place to achieve this on successful project completion.

References

[1] S.S. Tang et al, Eur J Cancer. **84**, 315 (2017)
[2] S.H. Chung et al, Phys. Med. Biol. **53** 6713 (2008)
[3] L.E. Barr et al, Optica **8**, 88 (2021)