Experimental Study of In-body Devices Misalignment Impact on Light-based In-body Communications

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Introduction

- Optical communication has gained interest in in-body communication technology.
- The optical system's receiving end typically relies on a photodetector with a limited FOV, necessitating direct LOS connections for effective transmission.
- Any misalignment that occurs in the in-body device can impact the power level and further degrade the received signal quality.
- The position of in-body devices might change, and it creates two events of misalignments: **lateral** or **angular**.
- This work was conducted on the impact of in-body device misalignment on the optical-based in-body communication system (Figure 1).

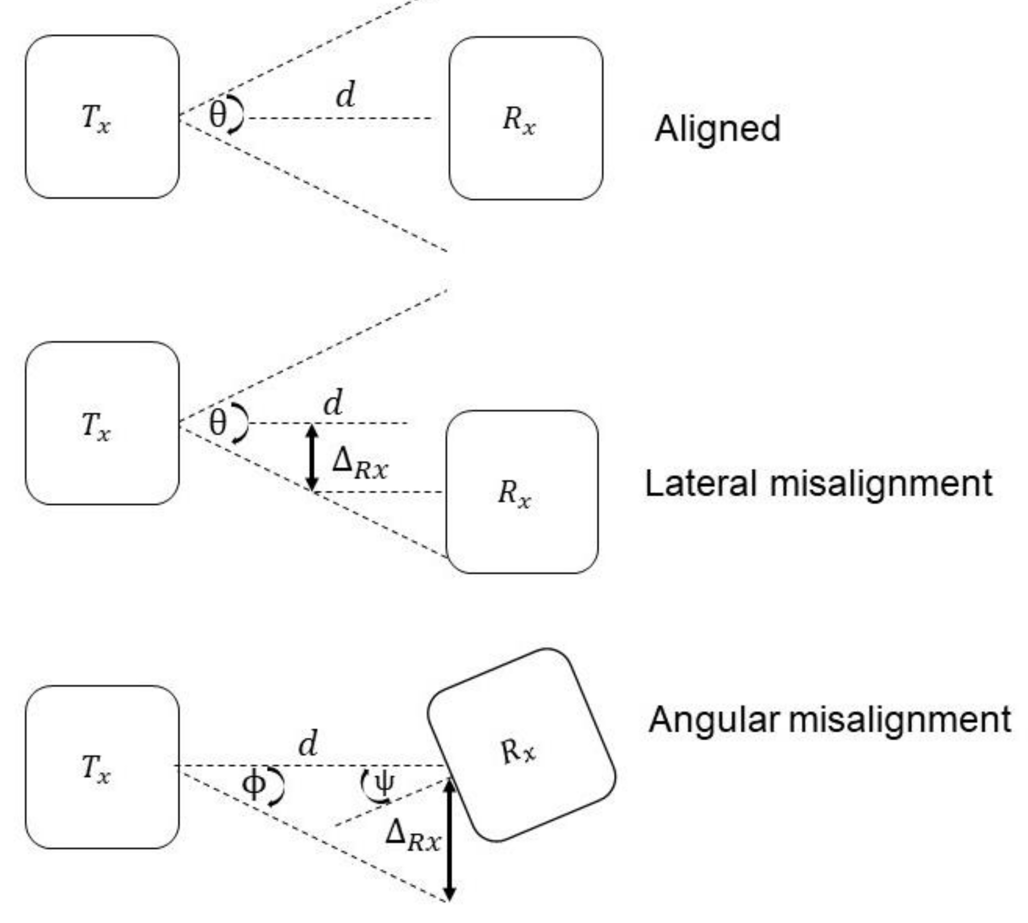

Figure 1. In-body device misalignment.

1) This study explores the potential risk factors associated with postoperative misalignments.
2) It showed the importance of temperature matching to the human body (around 37 ° C) for *ex vivo* experiments on optical-based in-body communications.
3) Our study considered using thicker meat samples.
4) Fat has been found to be a good propagation channel compared to muscle for optical-based in-body communications.

Materials and Methods

- **Transmitter**: Single beam Near-infrared (NIR) LED.
- **Wavelength**: an 810 nm.
- **Variation of LED driver**: 500, 400, 300, 200, and 10 mA.
- **Samples**: pure fat tissue (sample #1) and muscle tissues (#sample 2) with 15 mm thickness at different temperatures (23° C and 37° C), as depicted in Figure 2(a-b). Thicker meat samples, i.e., 30 mm (#sample 3), 38 mm (#sample 4), and 40 mm (#sample 5), consisting of muscle + fat layers) at 37° C.
- **Test bed**: Commercially available components (Figure 3b).

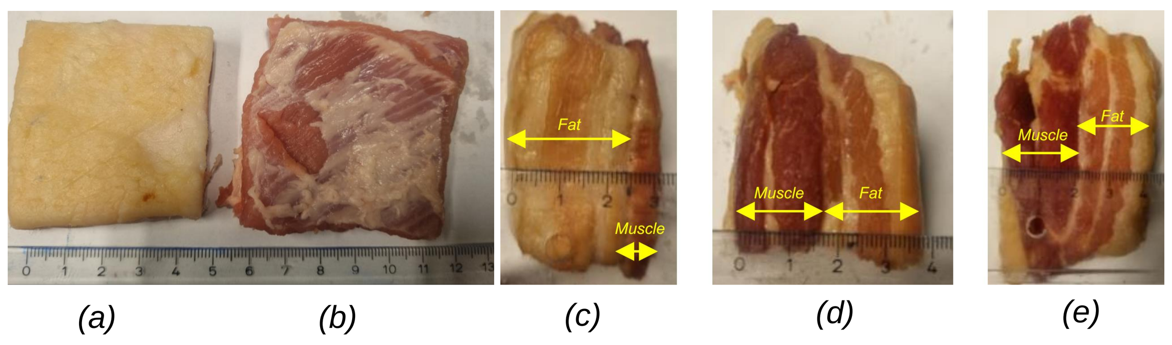

Figure 2. Photographs of the used pork meat samples: (a) fat tissue 15 mm; (b) muscle tissue 15 mm; (c) tissue 30 mm, (d) tissue 38 mm, and (e) tissue 40 mm.

- **Align setting**: The transmitter was directed or exposed toward the surface of the meat sample, while the receiver was positioned precisely on the opposite side (Figure 3a).
- **Lateral**: The receiver was shifted 2 cm.
- **Angular**: receiver was shifted 30 ° .

(All can be seen in Figure 3a).

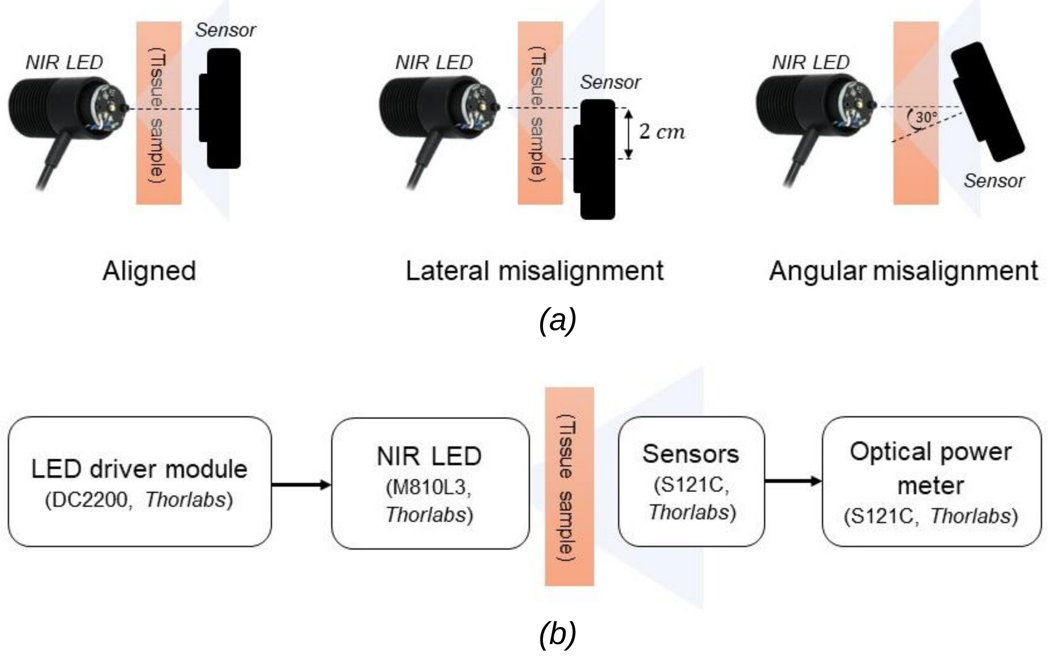

Figure 3. Experimental setup: (a) three different cases; (b) Test-bed.

Results and Analysis

Figures 4(a) and (b) show the results of optical power comparison measurements of samples #1 and #2, respectively. The power density was measured after the NIR light passed these samples. The graph encompasses samples under cold (23° C) and warm (37° C) conditions. Fat tissue is more vulnerable to temperature changes than muscle tissue.

Meat samples were heated to ~37° C resulting in an increased transparency of the biological tissue, allowing for better light propagation through the tissue. **We found the important finding** where most of the papers in the literature did not consider tissue temperature heating to the typical human body temperature.

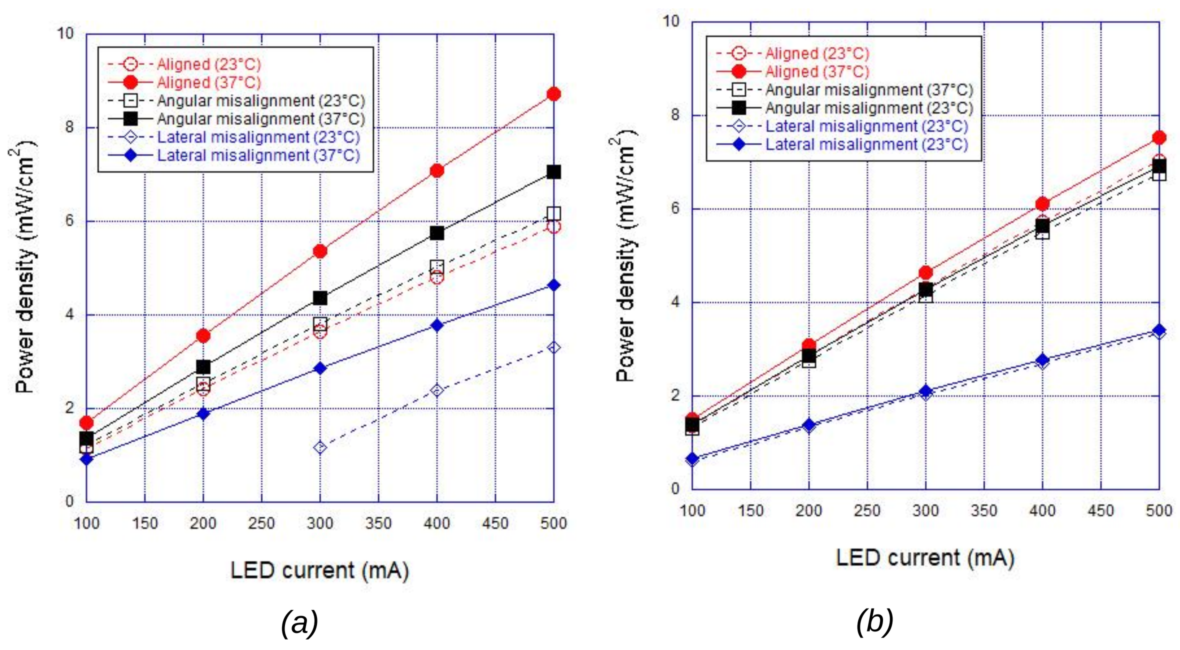

Figure 4. Results of measurement on samples: (a) #1, (b) #2.

- Figs 5(a), (b), and (c) show the results of the measurements for the aligned, angular, and lateral cases, respectively.
- Fig 5(d) depicts the results for different thicknesses, which is fatty and musculus tissues. On average, the received power in lateral and angular misalignments amounted to **93%** and **11%** of the aligned situation, respectively.

- Meat sample with a fatty layer has the potential to achieve a desirable level of reception power density.
- A misalignment situation from the in-body device point of view can negatively impact the performance of optical communication, as the light that propagates through biological tissue may not reach the photodetector's sensitive area due to limited FOV.
- The signal quality received in the lateral misalignment case was poorer than in the angular misalignment case.
- Figure 6 depicts a photograph of the experimental setup in this study.

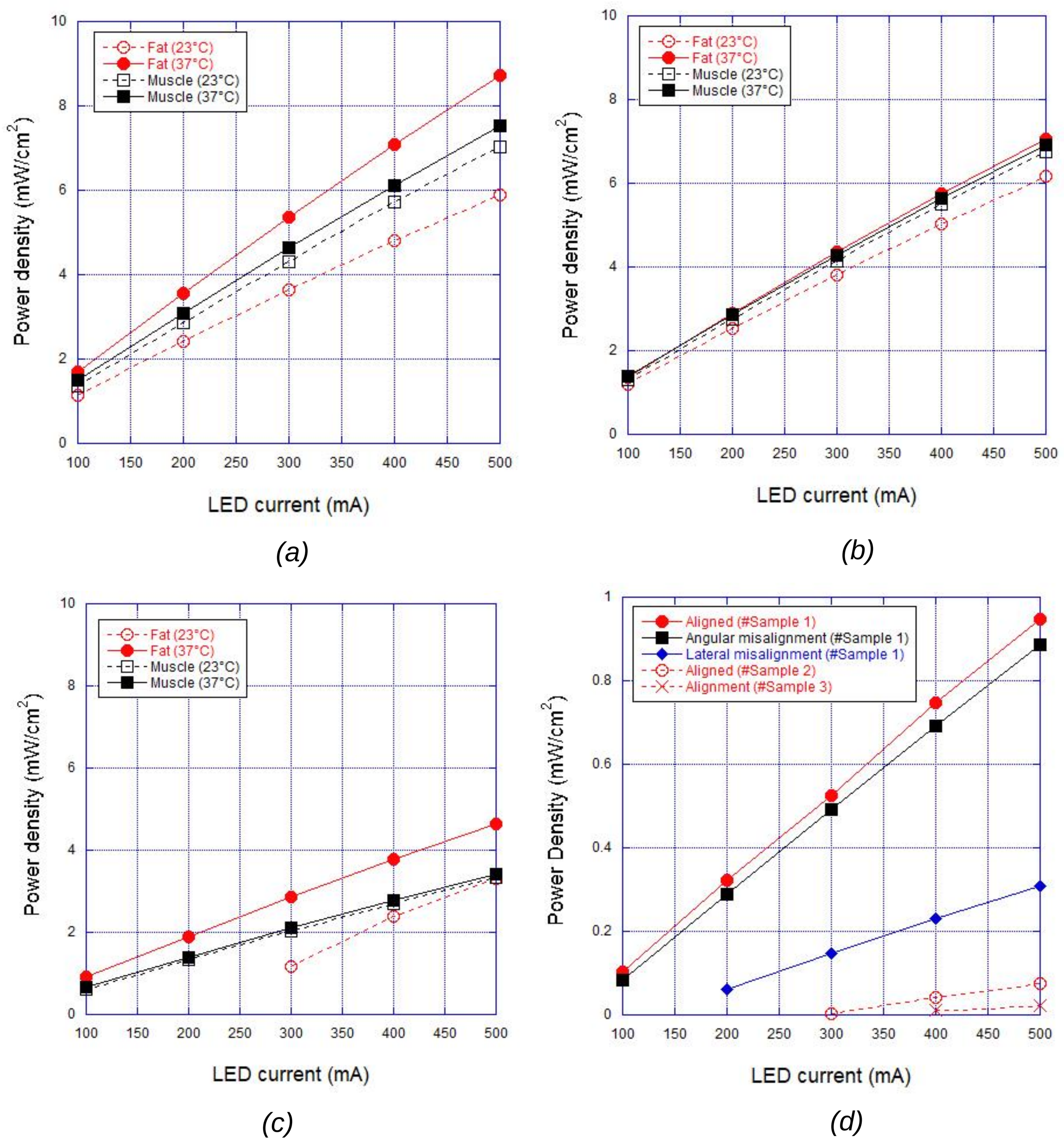

Figure 5. Measurement results in: (a) aligned, (b) angular, and (c) lateral scenarios on samples #1 and #2; (d) samples #3, #4, #5.

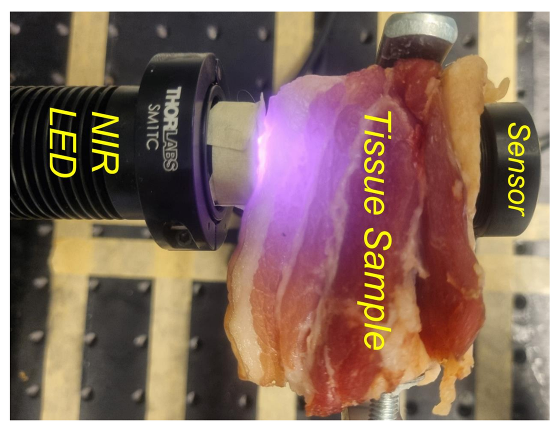

Figure 6. A photograph of experimental setup (aligned reference case).

Limitations

1) The study only focus on postoperative misalignments, temperature matching, and tissue thickness.
2) The study may oversimplify the complexity of in-body tissue environments.
3) More thickness of meat sample to capture the full spectrum of conditions encountered in actual clinical scenarios, and using meat temperatures ranging 36 – 40° C to match the average of human body, should be considered further.
4) The experiment relies on static conditions. Future works should consider to involve dynamics situation.
5) Future investigation should consider the impact of misalignment on the optical link by analyzing parameters such as throughput, SNR, BER, and QoS indicators.

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