An Optoelectronic Muscle Contraction Sensor

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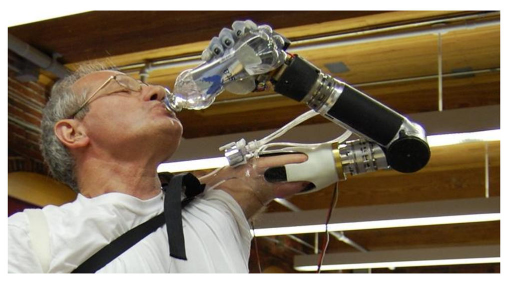
1. Introduction

A key issue in the design of prosthetic limbs is the ability to detect signals from the brain to move the limb. Muscle contractions are a good way of indirectly measuring these signals.



http://www.designnews.com/document.asp?doc_id=245129

http://gizmodo.com/iLIMB-Prosthetic-Hand/]

This work aimed to design, make and test a sensor to detect muscle contraction by measuring a change in the differential parallel-to-perpendicular scattering of light in muscle, Such sensors could ultimately be compact, convenient and flexible.

2.Why?

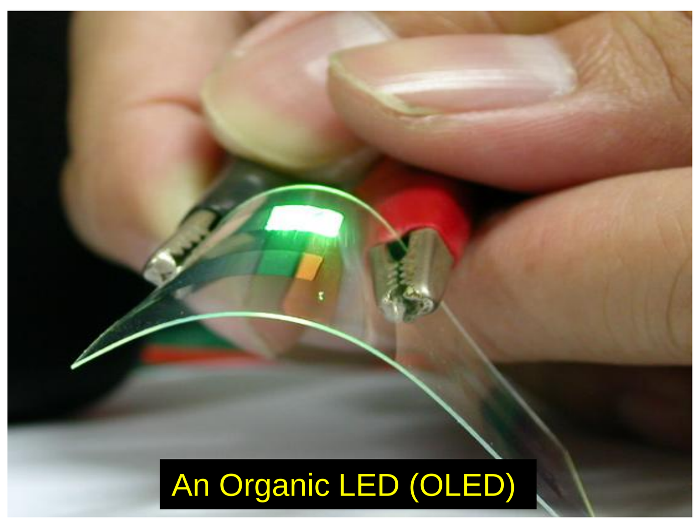
Why Optical Sensing?

•Current sensors use surface electromyography (EMG) which measures electrical nerve impulses.

•EMG is not very sensitive, prone to interference, and requires significant pressure to be applied to the muscle.

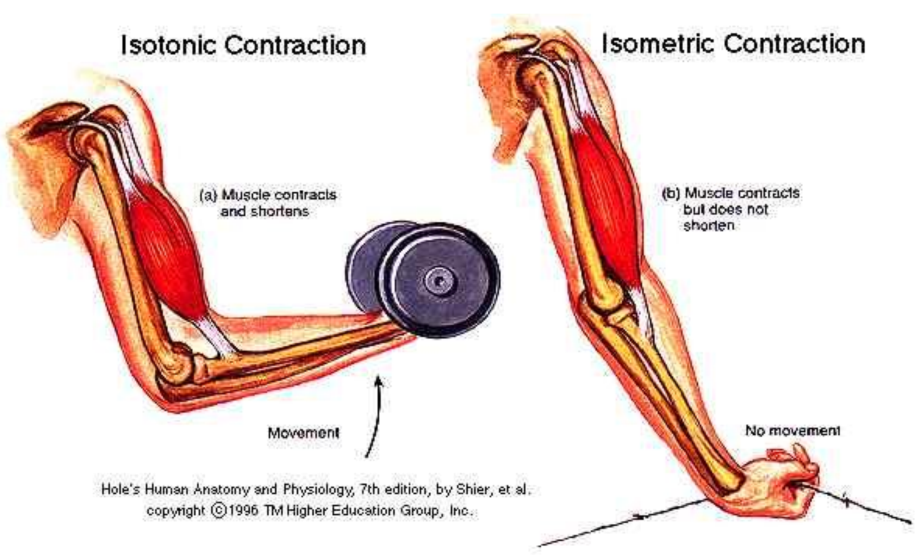
•An optical probe can overcome these issues as it does not depend on electrical contacts.

•Can distinguish between isotonic (constant force) and isometric (constant distance) contractions.



An Organic LED (OLED)

http://www.attendconference.com



Why Organic Components?

Advantages

•Can be made thin and flexible sustrates
•Can be prepared on large areas by solution process techniques
•Tunable emission
•Can emit and detect light

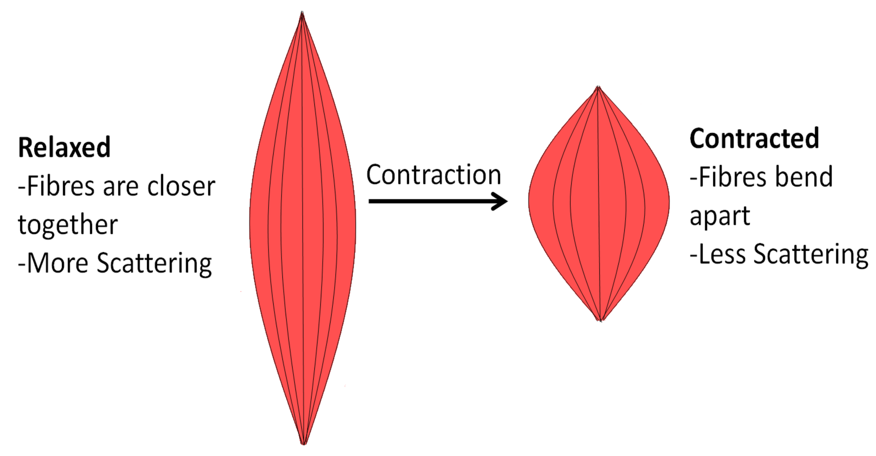
Disadvantages

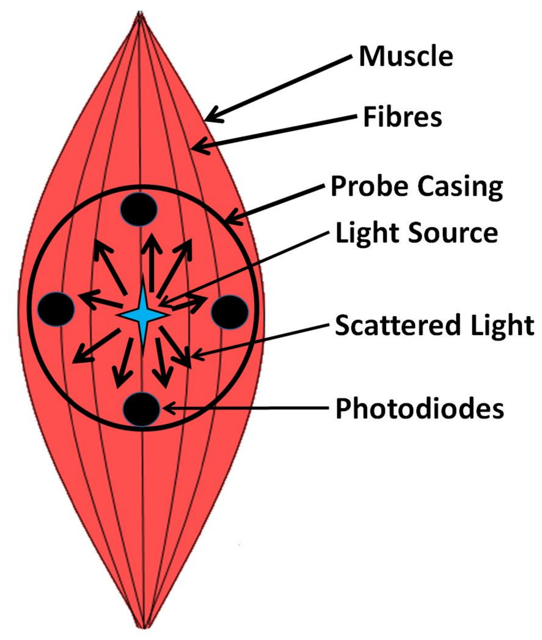
•Currently expensive
•Sensitive to water and air, so need encapsulation.

3. The Concept

Working Principle

- Muscles are intrinsically fibrous
- Light travelling perpendicular to the fibres will be scattered more than light moving parallel to the fibres
- **Fibre aspect ratio changes when muscle is contracted**
- **A change in the differential parallel-to-perpendicular scattering**





Making a Sensor

•Shine Infrared light (850nm) into muscle – light is scattered in all directions through the muscle

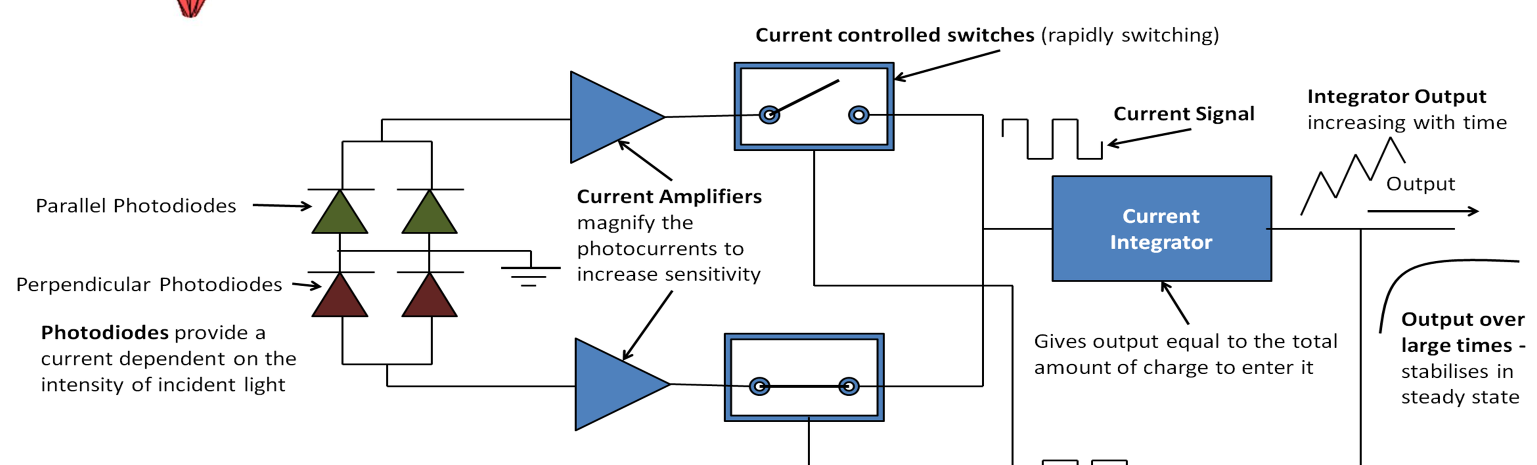
•Place four photodiodes on vertices of a square round source

•Parallel light is scattered less so the parallel photodiodes get more light than the perpendicular photodiodes

•Subtract the parallel and perpendicular photocurrents

•When muscle is contracted more light reaches the perpendicular photodiodes – causes a change in output

•Change in output voltage indicates muscle contraction

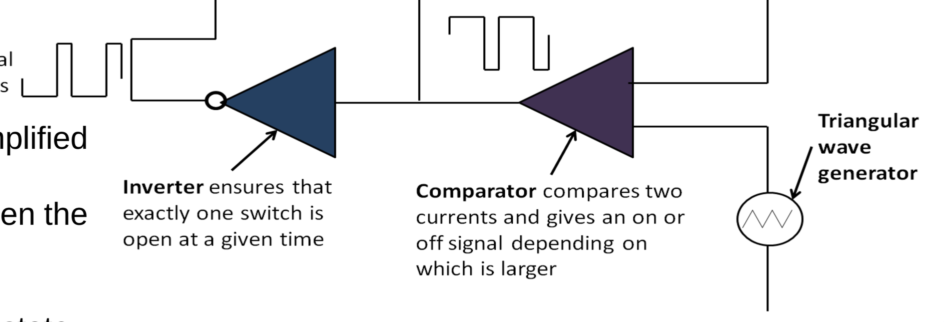


The Circuit

•Signal from photodiodes needs to be amplified

•Needs to remove any imbalances between the photodiodes

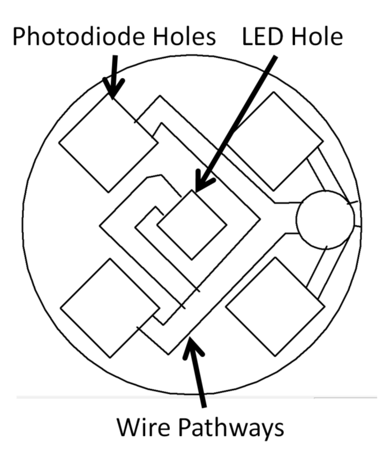
•Needs to have a stable output in steady state

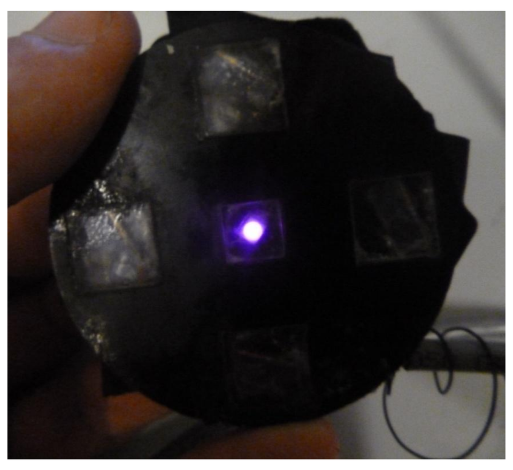


4. Implementation & Results

The Casing

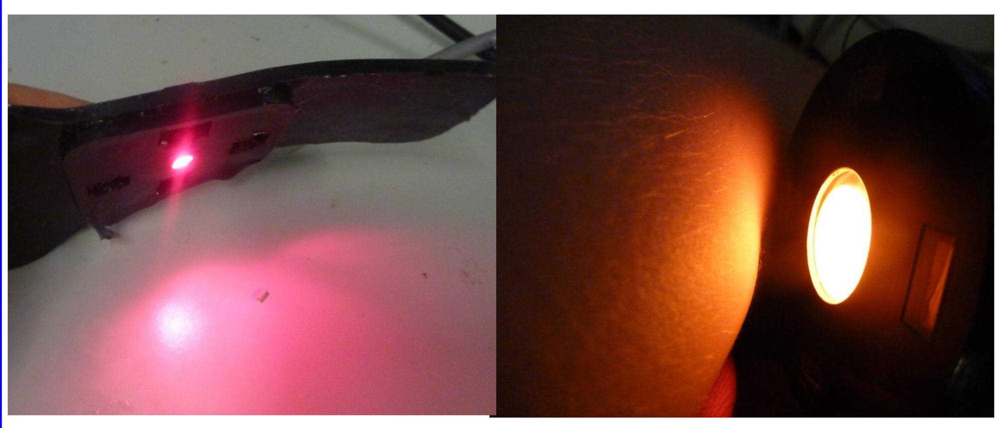
- LED must be Isolated from the Photodiodes to minimize crosstalk
- Casing made of solid black Perspex with individual channels for wiring





A CAD Drawing of the inside of a probe, and a probe with an I.R LED

- The LED in the probe appears purple because cameras can see infra red light!
- Probes were also made using flexible silicone material and with different wavelength LEDs, including an OLED

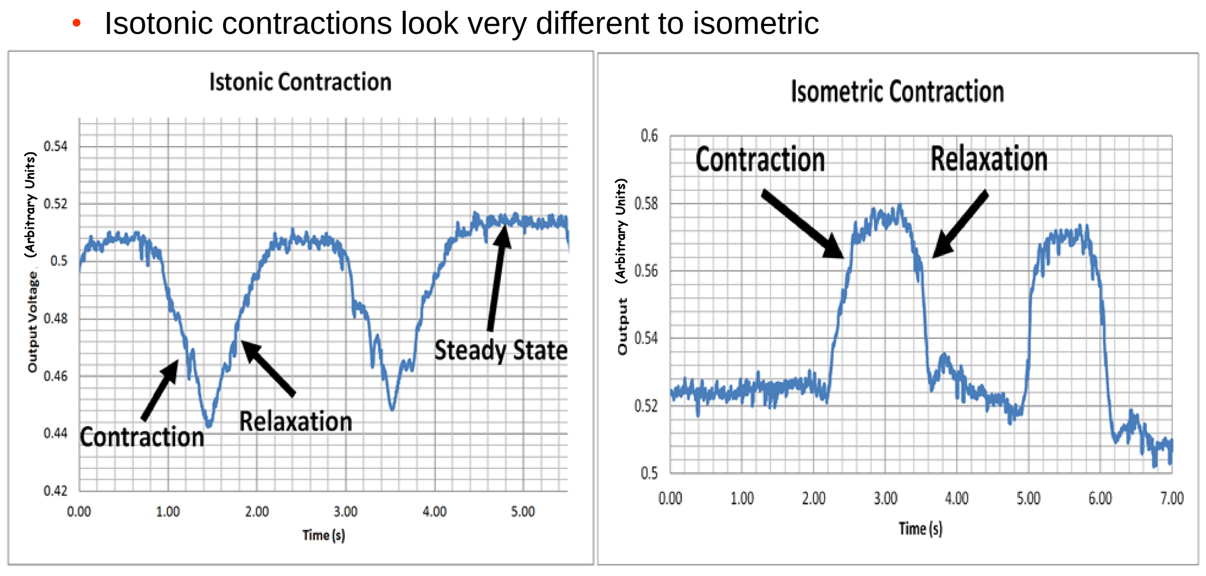


A flexible probe with a red LED and a rigid probe with an OLED

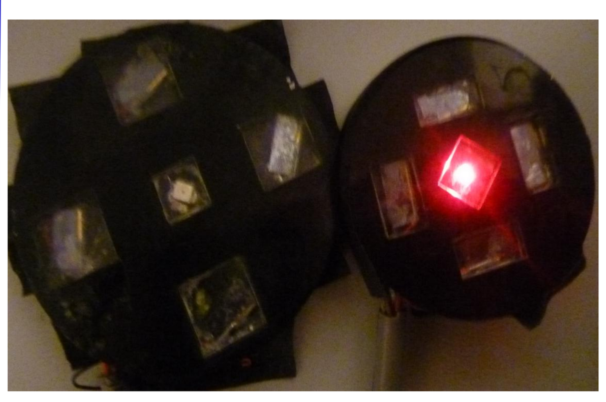
- The flexible silicone probes were made by injection molding
- The majority were made from Perspex which could be quickly made with a laser cutter

Results

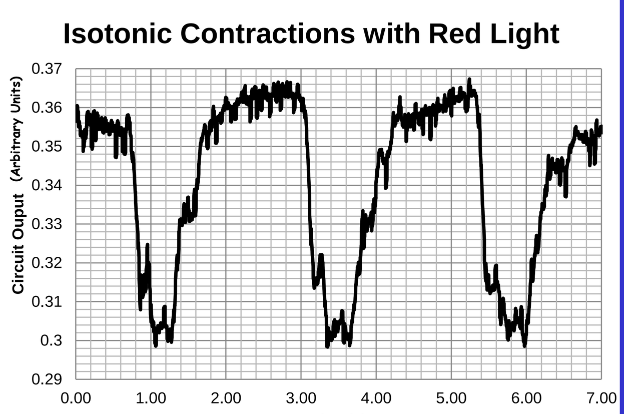
- Infrared light gave best results as expected
- Probe was tested on a healthy subject arm
- Typical output trace of infrared probe shown below
- Isotonic contractions look very different to isometric



- Red light did not penetrate skin as well as infrared light does
- To get a good signal, the photodiodes had to be much closer to the LED
- Requires high intensity of light from LEDs and large photodiodes to get sufficient signal having good signal to noise



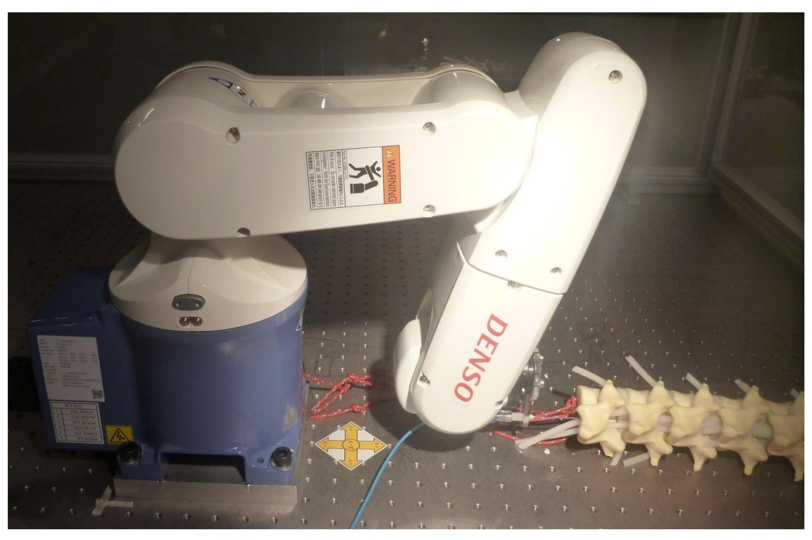
An infrared LED probe alongside a red LED probe, note the photodiodes are closer to the LED



Isotonic contractions with the red probe yielded similar results to the infrared probe

Future Work

- Experiment with fabricating the infrared emitting OLEDs by either down conversion or using different artitecture.
- Complete a probe with organic photodiodes as well as LEDs
- Complete a fully flexible, working probe using organic components printed on flexible substrates
- Program a robotic arm to use signal from the probe as an input.



The Robotic arm we aim to interface with the probe

Summary & Conclusions

- **Optoelectronic probes to sense muscle contraction were designed and built.**
- **The probes were able to detect muscle contraction.**
- **Probes using red light and using Infrared light (650 nm and 850 nm), and using both rigid and flexible casings were demonstrated.**
- **An entirely organic, flexible and wearable probe is feasible using this system.**