NON-INVASIVE OPTICAL MEASUREMENT OF CELLULAR ELECTRICAL ACTIVITY

Karen Regules-Medel, Faculty of Engineering
University of Nottingham, UK.

wes 2026 ANNUAL Conference

A MICROSCOPE-BASED OPTICAL APPROACH FOR MEASURING CELLULAR MEMBRANE ELECTRICAL SIGNALS WITHOUT INVASIVE ELECTRODES

HEALTH & MEDICAL DEVICES

BACKGROUND

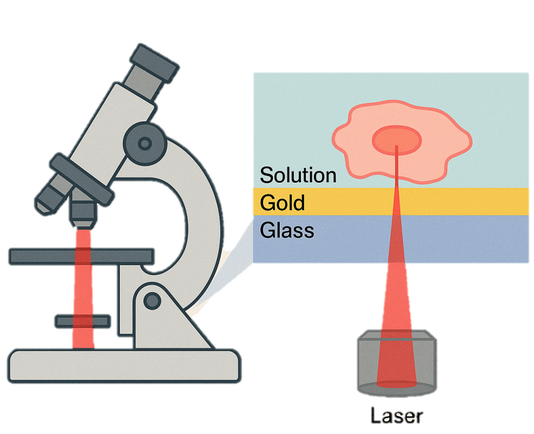
- **Electrical signals in cells regulate essential body functions.**
- **Challenge:** Current microelectrode techniques = accurate signals but limited to single-point membrane measurements; invasive and complex.
- **Need for innovation:** Non-invasive, scalable methods are needed for studying networks of cells and large datasets.

RESEARCH OBJECTIVE

To develop and evaluate an optical approach, based on **a conventional microscope configuration** with **gold thin films**, for non-invasive, high-sensitivity measurement of cellular electrical activity.

METHODS

1) **Optical Setup:** Conventional microscope [**1**] + gold thin films + cells cultured on top.



2) **Modelled optical intensity** variations in response to applied voltages from **±200 mV**. [**1,2**]

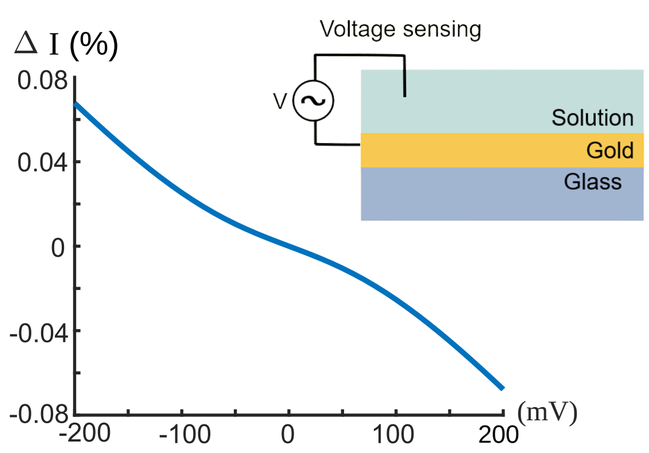
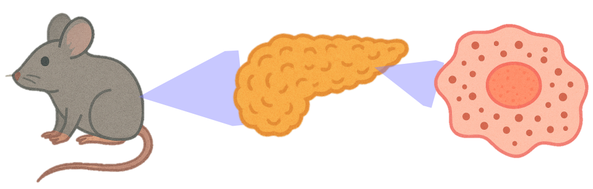


Fig 1. Simulated reflectivity (%) as a function of applied voltage for a glass/10 nm gold/NaCl electrolyte system.

3) **Target cells:** Insulin-secreting pancreatic cells (beta cells) [**3**].



4) **Microelectrode data:** Measured action currents (**-3 to 5 pA**) used to characterise signals [**4**].

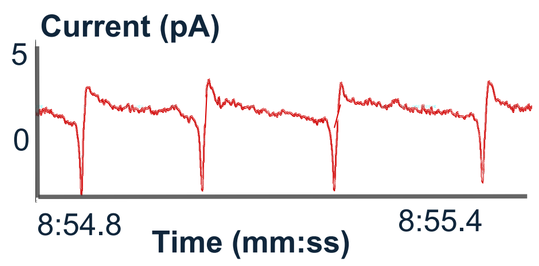
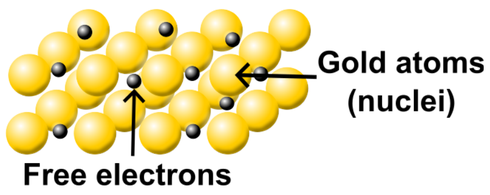


Fig 2. Action currents from a beta cell under glucose stimulation (cell-attached patch-clamp).

5) **Benchmarking the optical approach**:

- **Gold is used as an amplifier** for changes in membrane potential [**5**].
- **Microelectrode data → optical data:** compare measured currents **with** membrane voltages (range 0 to –70 mV) [**6**].



RESULTS

- **Simulation and experimental results** showed light modulation with sensitivity to changes **as small as 10 mV** within the ±200 mV range.
- **Identified** key optical parameters for detecting cellular electrical activity:
  - 10 nm **gold thickness**
  - 660 nm **light wavelength**
- Electrophysiology data **validate measurements** under realistic bioelectric conditions (**0 to -70 mV**).

CONCLUSION

- We proved a **measurable voltage-dependent change** in optical intensity (**0.08% across the ±200 mV range**), demonstrating the **sensitivity of the system** to electrical modulation at the metal–electrolyte interface.
- **Impact on research:** Enables non-invasive, scalable, and high-throughput studies of cellular bioelectricity.
- **Applications:** Diabetes research, neuroscience, cancer research, cardiology, bioelectric medicine.

Funded by:

University of Nottingham UK | CHINA | MALAYSIA

CONAHCYT

karen.regulesmedel@nottingham.ac.uk

REFERENCES

[1] REGULES-MEDEL ET AL., PCCP (2025, IN PRESS).
[2] SOMEKH, REGULES-MEDEL & ABAYZEED, JOSA A, 2024
[3] ELSHEIKH & SHYNG, FRONT. ENDOCRINOL., 2023.
[4] ABAYZEED ET AL., SCIENTIFIC REPORTS (2026).
[5] ABAYZEED ET AL., OPT. EXPRESS, 25(25), 31552–31567, 2017.
[6] GÖPEL ET AL., J. GEN. PHYSIOL., 114(6), 1999.