Real Time Monitoring of Electric Field via Photonic Sensing for Effective Brain-Computer Interface (BCI)

Ibrahim L. Olokodana[1], *Saraju P. Mohanty*[2], *Elias Kougianos*[3], *Manzo Maurizio*[4]

Smart Electronic Systems Laboratory, Computer Science and Engineering, University of North Texas, Denton, TX 76207, USA.

Email:[1]ilo0008@unt.edu, [2]saraju.mohanty@unt.edu, [3]elias.kougianos@unt.edu, [4]manzo.maurizio@unt.edu

Abstract

- In a Brain-Computer Interface (BCI), electric signals from the brain are used to control artificial body parts or relay the intentions of the human brain.
- This work demonstrates real-time monitoring of the electric field in a self-organizing manner using a photonic micro-resonator as a sensing element.

Figure 1: Possibility from disability: the power of BCI

Background and Motivation

- It is well-established in the literature that the brain produces electric pulses in different parts as a direct consequence of every human action controlled by the central nervous system.
- It is important in BCI applications that the method of retrieving signals from the brain should not cause scalp irritation, have excessive weight, latency or any property that further reduces the comfort level of the subject rather than improving it.
- Photonic sensing has the potential to be an ideal candidate in satisfying these criteria.

Figure 2: The amazing future of BCI

Method and Material

- The micro-resonator used for this work is a chemical combination of Norland Blocking Adhesive (NBA-107) and Di-4-ANEPPS ($C_{28}H_{36}N_2O_3S$) at a predetermined ratio.
- The applied principle is based on the Whispering Gallery Mode (WGM) or Morphology Dependent Resonance (MDR) but in a continuous, uninterrupted way that directly mimics the continuous production of electric pulses from different parts of the brain.
- When the photonic polymeric structure is subjected to certain strains such as pressure or electric fields, it responds with some deformation which is interpreted as an MDR shift. That is, the wavelength at resonance is shifted based on the morphology of the micro-resonator.

Figure 3: A photonic micro-resonator.

Research Model

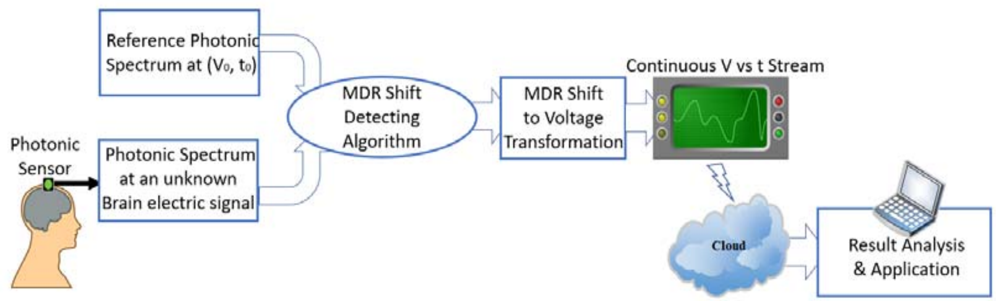

Figure 4: Proposed Photonic Brain-Computer Interface (BCI) Architecture

Data Collection

- The data used for this work were collected locally from the Photonics Micro-Devices Fabrication Laboratory in the Engineering Technology department at the University of North Texas.
- The micro-resonator was suspended between two electrodes which were directly connected to the terminals of a voltage source.
- The reference spectrum was obtained at zero voltage by passing an infrared LASER through it and into a spectrometer. The voltage was then gradually varied to obtain different spectra for different voltages. Each voltage spectrum was compared to the reference to detect the MDR shift, which is directly proportional to the applied voltage or electric field.

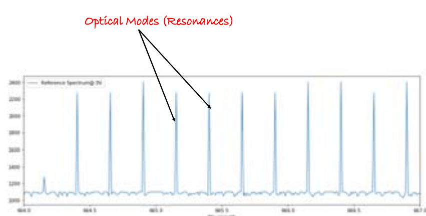

Figure 5: Reference spectrum at zero voltage

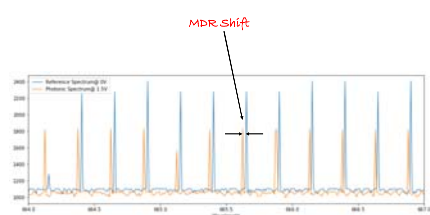

Figure 6: Spectra at the reference and another voltage

Results

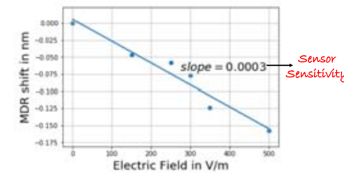

Figure 7: A plot of MDR shift vs Electric field.

(a)

(b)

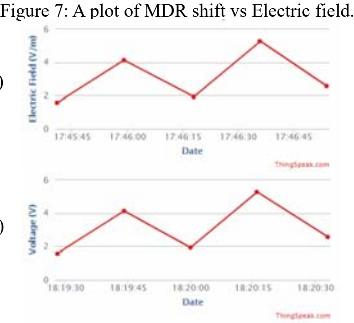

Figure 8: Real time cloud update of electric field.

Conclusion

- Having a pre-existing, tested and reliable system of tracking and interpreting a continuous flow of electric field with marginal error and seamless integration to the cloud can lead to the development of an effective Brain-Computer Interface (BCI) system.
- The proposed method produces a Mean Absolute Percentage Error (MAPE) of 13% and a Mean Square Error (MSE) of 0.19.

References

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