Photonic Sensor Based Real-Time and Low-Noise IoT-Enabled 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), electrical 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.

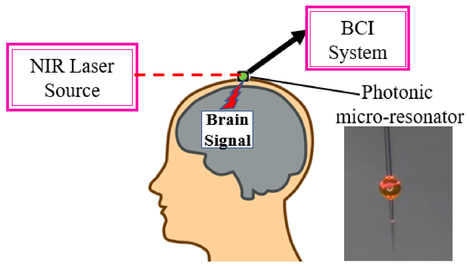


Fig. 1: A BCI system using a photonic micro-resonator.

Problem Overview

- It is well established that the brain produces electric pulses in its 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.

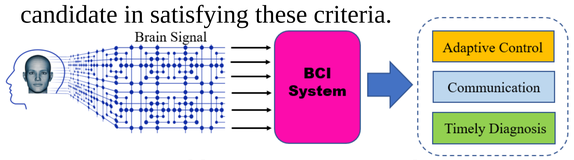


Fig. 2: A typical brain computer interface system.

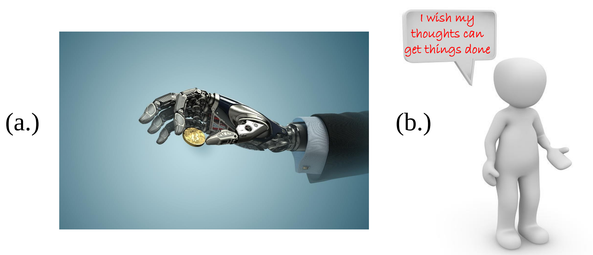


Fig. 3: Possibility from disability: amazing future of BCI.

Research Method and Materials

- 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 Morphology Dependent Resonance (MDR), in an uninterrupted way that directly mimics the continuous production of electric pulses from different parts of the brain. The micro-resonator responds to electric field strain with some deformation which is interpreted as MDR shift. That is, the wavelength at resonance is shifted based on the morphology of the micro-resonator.

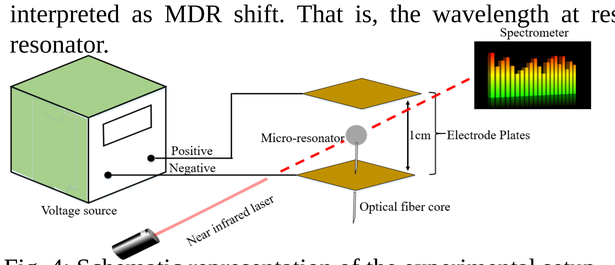


Fig. 4: Schematic representation of the experimental setup.

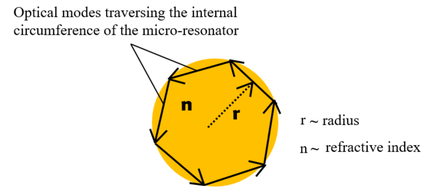


Fig. 5: Ray optical approximation for traveling optical modes around the internal circular surface of the dielectric resonator.

Design Model

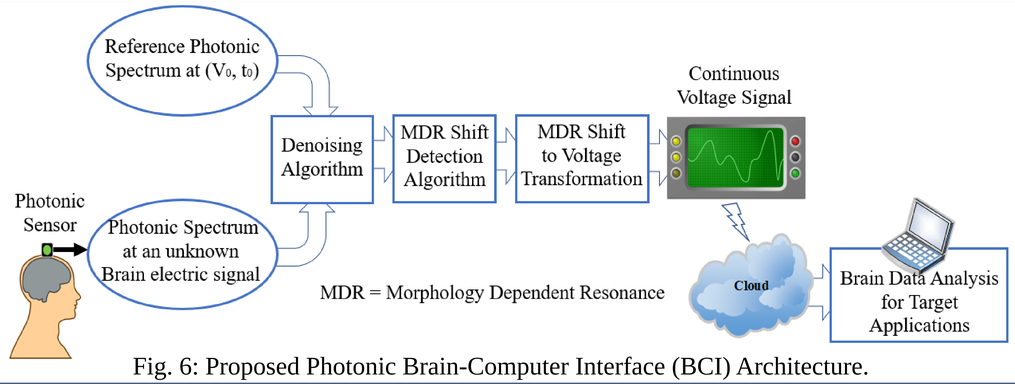


Fig. 6: Proposed Photonic Brain-Computer Interface (BCI) Architecture.

Experimental Results

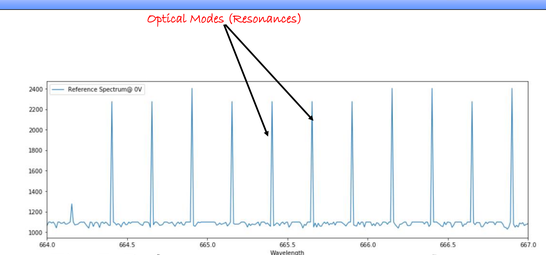


Fig. 7: Reference spectrum at zero voltage

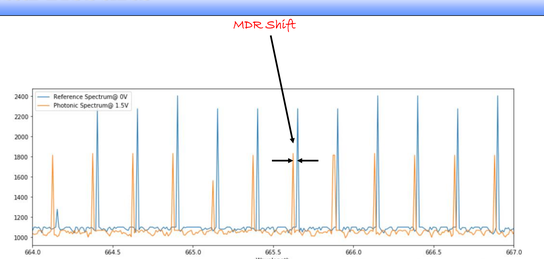
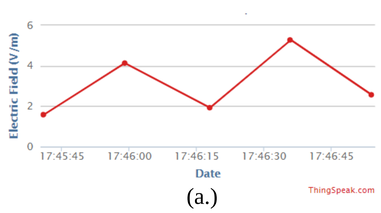
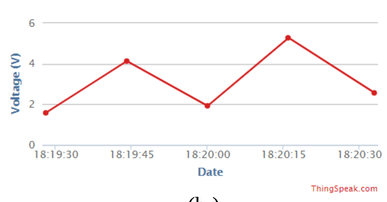


Fig. 8: Spectra at the reference and another voltage



(a.)



(b.)

Fig. 9: Real time cloud update of electric field.

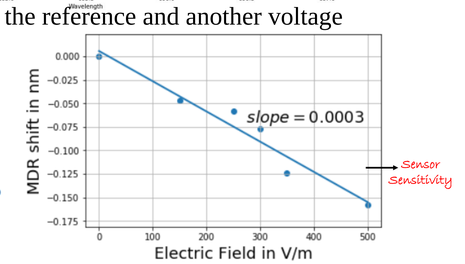


Fig. 10: A plot of MDR shift vs Electric field.

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 (Fig. 4).
- 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.

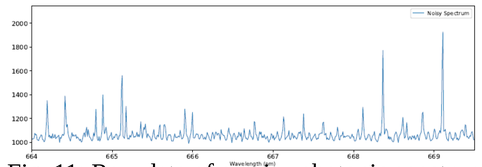


Fig. 11: Raw data of a noisy photonic spectrum.

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 11% and a Mean Square Error (MSE) of 0.19.
- Future work is to further reduce the error and design real human applications for diagnosis, communication and control.

References

[1] I. L. Olokodana, S. P. Mohanty, E. Kougianos, and M. Manzo, "Towards Photonic Sensor based Brain-Computer Interface (BCI)", in *Proceedings of the 4th IEEE International Smart Cities Conference (ISC2)*, 2018.

[2] Maurizio Manzo, Microlasers Based Dye Doped Polymeric Resonators for Brain Activity Stimulation and Monitoring, US patent pending, 2018.

[3] Maurizio Manzo, "Microlasers-Based Brain Activity monitoring ", journal under peer review, 2018.

[4] M. Manzo and T. Ioppolo, "Untethered photonic sensor for wall pressure measurement", *Optics letters*, 40.10, 2015, pp. 2257-2260.