Sustainable Photonic Biosensor System for Psychiatric Evaluation

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Introduction

Approximately 280 million people worldwide are dealing with depression. Currently, the standard of care is to meet with a psychiatrist who prescribes antidepressants and then meet with a therapist weekly to resolve the issue. A more scientific depression diagnosis method would lead to more accurate treatment methods and the ability to monitor treatment effectiveness over time. A lack of brain-derived neurotrophic factor (BDNF) serum is a leading hypothesis for the indication of depression in the neurobiological world. If our project could create a portable system that could relate BDNF levels in the human body to depression, we could enable cost-effective depression diagnosis for individuals and organizations of all socio-economic backgrounds.

Research Goal

Our team plans on detecting BDNF levels in the human body using a reusable optical biosensor chip. The system has shown accurate detection of SARS-CoV-2 SP and influenza NP. We hope to show a relationship between BDNF levels and mood so psychiatrists may better treat their patients

Methods

The waveguide and micro-ring function on the fundamental properties of total internal reflection, constructive interference, and optical coupling. Total internal reflection is when a ray of light striking a body is unable to pass through due to a combination of the angle of approach and refractive index of the material. This is possible when the angle of incidence is less than the critical angle and the refractive index within the medium is higher than outside, causing the light to be reflected back inside the medium itself. By definition, the waveguide and micro-ring must abide by the properties of total internal reflection to ensure the optical signal passed to the input is not corrupted at the output. Constructive interference is when two waves, once added together, increase the overall amplitude as opposed to decreasing it. Micro-rings are designed in a way such that as light cycles through, the overlapping waves do not cancel each other out. Optical coupling is to ensure light can be transferred between the micro-ring and waveguide. This is done by physically placing the micro-ring and waveguide extremely close together, usually a width less than a wavelength, so light can jump between the two. Because of this phenomenon, light can be passed into one end of the waveguide and the resulting shift in wavelength can be measured on the other side after it has passed through the micro-ring

Figures and Results

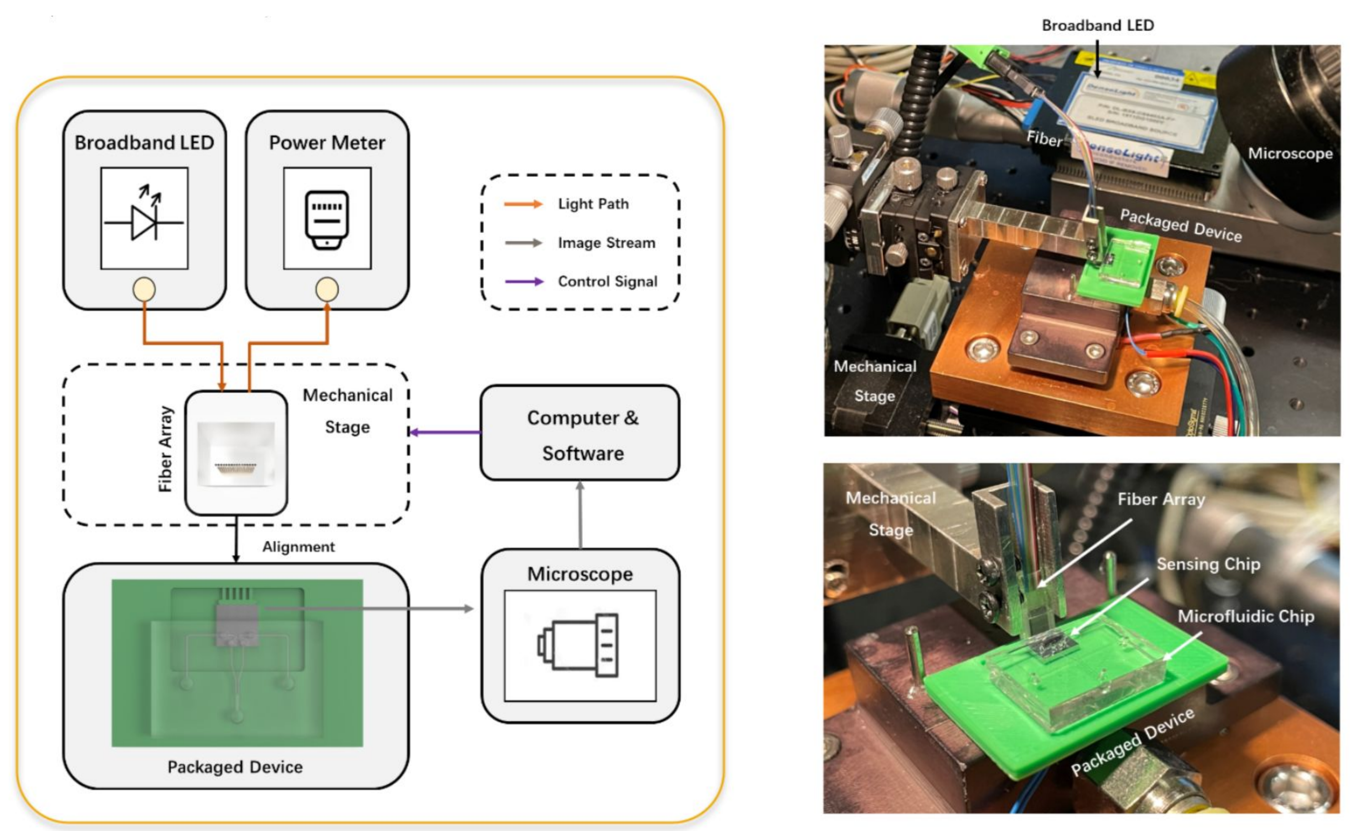

Figure 1. Overview of lab test-bench setup

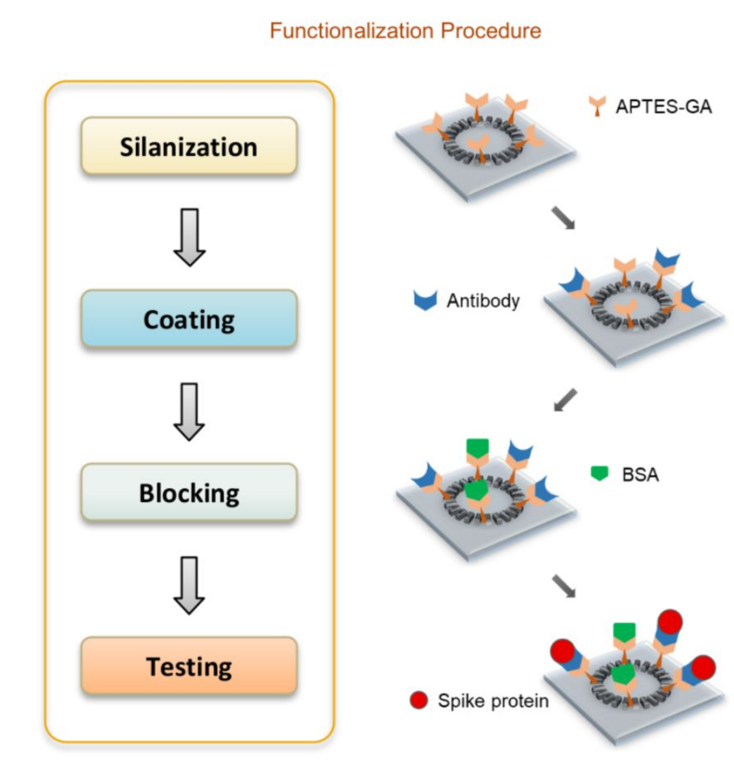

Figure 3. Visualization of biomarker detection process

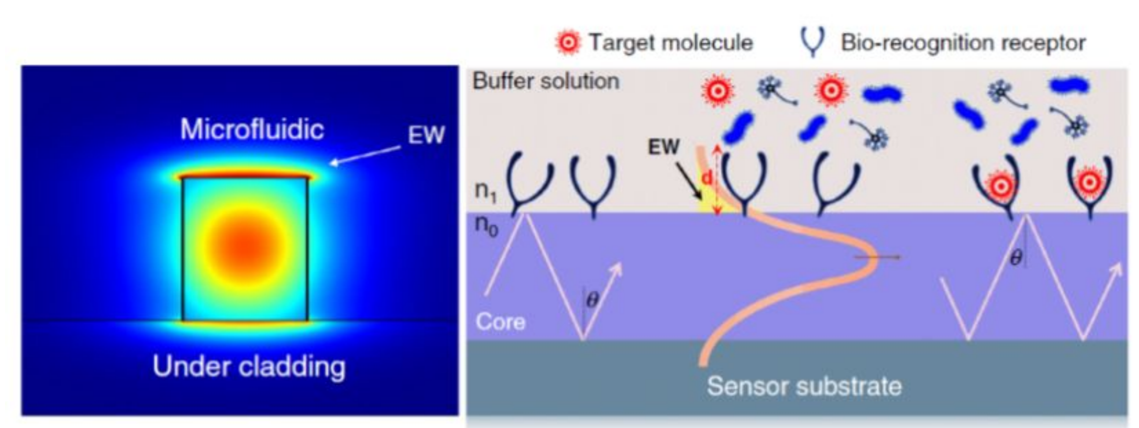

Figure 2. Integration of biomarkers using microfluidic channel

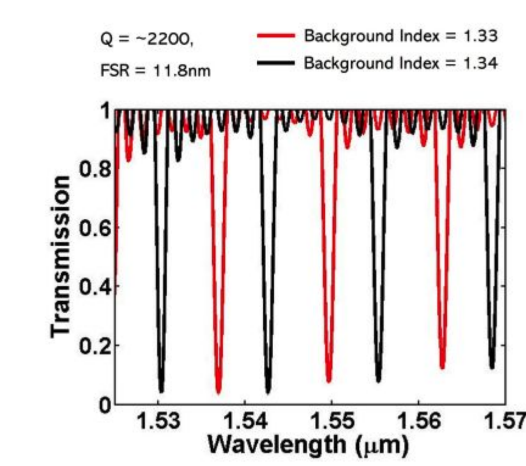

Figure 4. Peak-shift indicating existence of biomarker

Reusability
To ensure our system is usable across all socioeconomic backgrounds we need to minimize operating costs. Right now, the biggest recurring cost is the silicon chip as it is expensive, and needs to be replaced after every test, so we set out to make it reusable. To do this, our team incorporated magnetic beads into the system design, so that antibodies would no longer be attached directly to the silicon, but rather to magnetic beads which would in turn be magnetized to the chip. This process will make it so our chips can be used in successive tests, lowering the cost of operating our system, and making it more accessible.

Performance
Creating a system that is accessible to all is a noble gesture, but if that system is unable to perform well, then it'll just be useless to more people. Thankfully, our system has shown great specificity and a very low limit of detection in the past as noted in "Silicon photonic chip-based biosensor for COVID-19 and flu detection with high sensitivity and specificity", where concentrations as small as 100 fg/mL were detectable and distinctions were able to be made between Covid and the flu (diseases with very similar symptoms).

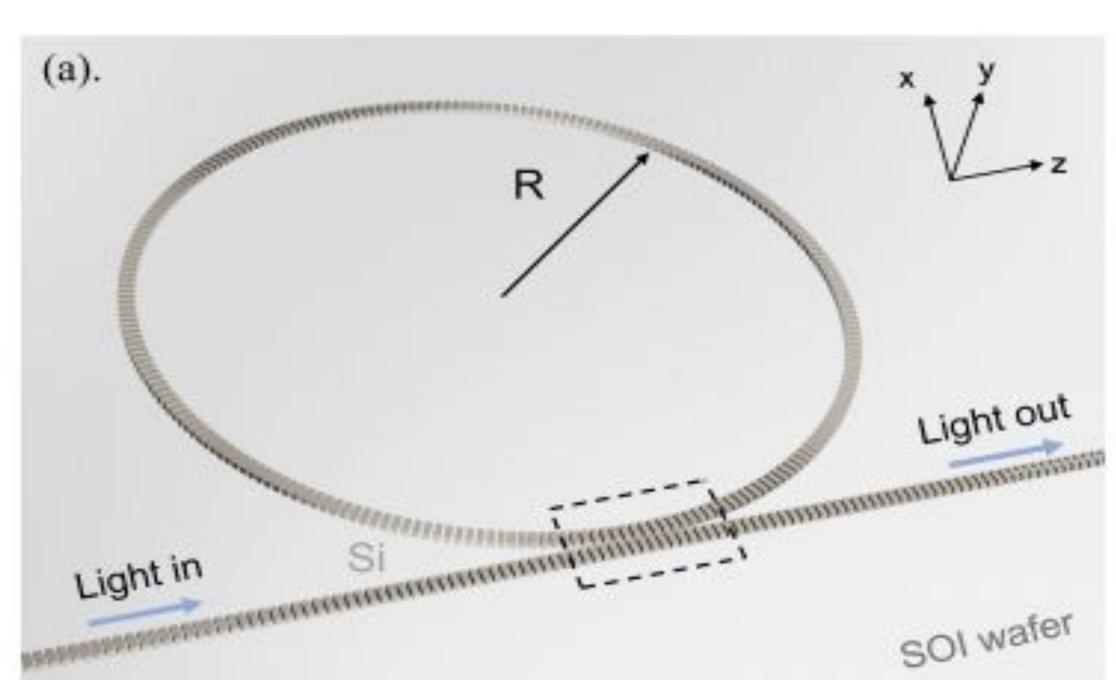

Figure 5. Schematic of the micro-ring structure

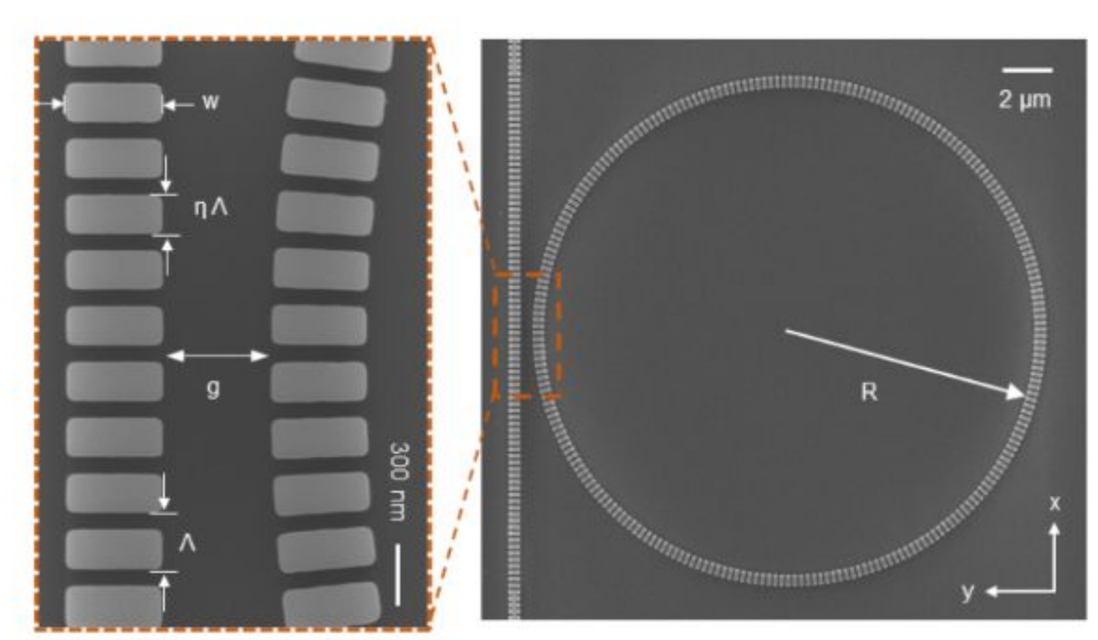

Figure 6. SEM images of SWG micro-ring resonator

Conclusion

Figure 7. Fully packaged portable system

Our system is able to accurately and precisely determine if a tested individual has Covid-19. For our system to help a broader set of people we set out to create a reusable device (lowering operating costs) and extend its functionality into depression detection (greater functionality).

Acknowledgments

The support provided to us throughout this project by Dr. Chen and his research team (James Fan, Shupeng Ning, & Vivian Chang) has been invaluable to our technical understanding and every day progress.

The structure provided to us by the Electrical and Computer Engineering Senior Design team (Leonard Register & Bharath Kumar Rayachoty) has pushed us to constantly think ahead and approach each aspect of this project in a methodical/structured manner.

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[3] S. Ning, C. Wang, H. Chang, K. M. Yoo, J. Fan, D. Shoemaker, M. Nakos, M. H. Hlaing, Y. Lu, H. Tian, and R. T. Chen, "A Point-of-care Biosensor with Subwavelength Grating Waveguide-based Micro-ring Resonator for Detection of COVID-19," in Conference on Lasers and Electro-Optics.