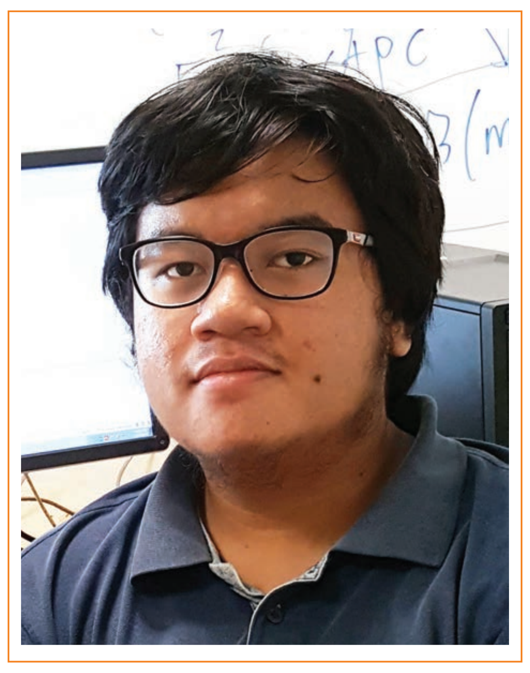

Raditya Weda Bomantara

Awards

- ✓ Materials Research Society (Singapore) Medal for AY 2017/2018
- ✓ Valedictorian at the AY 2017/2018 commencement ceremony
- ✓ Full-time Teaching Assistant award in AY 2015/2016
- ✓ Full-time Teaching Assistant award in AY 2016/2017

Research Summary

My current research interests lie in the area of Floquet topological phases and their potential application in quantum computation. Common themes of my research include exploring how periodic driving alters the topological structure of certain systems, how such a topological structure exhibits features unique only to periodically driven systems, e.g. the existence of π edge modes, and how these unique features can be utilized for quantum computation application. In the following, I outline my motivation to develop the aforementioned research interests and some of my future research plans.

Introduction and Past Research

Topological phases of matter are a novel form of phases of matter which have attracted tremendous attention throughout the years. Indeed, due to their topological features, these exotic phases possess some physical properties which are highly robust against local perturbations. Consequently, implementing topological phases in real life materials may lead to potential applications, such as in the development of a new device which is insensitive against any imperfection, as well as a means to perform fault-tolerant quantum computation at the hardware level.

One current obstacle for the real life implementation of topological phases is their scarcity to exist naturally. As a result, many studies have been devoted towards their efficient construction. One promising theme to achieve the latter is through the use of period driving, which has the ability to turn normal materials into topological materials. Such periodically driven topological phases, commonly referred to as Floquet topological phases, are also known to possess intriguing novel properties which cannot be found in any static topological phases, such as the existence of edge modes at quasienergy π in addition to those at quasienergy 0. As such, Floquet topological phases have developed into an active research direction on their own, which has resulted in many proposals of Floquet topological insulators, Floquet topological semimetals, and Floquet topological superconductors, to name a few.

During my PhD years, I worked mainly along the above exciting topics with focus on the simulation of Floquet topological phases in lower dimensional systems. The common theme of my PhD work is to start with a one dimensional time periodic system which possesses additional one or two system parameters to be regarded as quasimomenta along directions perpendicular to the system's dimension, then study its topological properties from the perspective of two or three dimensional systems. This approach has resulted in three publications [1-3] in *Physical Review E* and *Physical Review B*, one of which is highlighted as *Editors' Suggestion* [1]. The main results of these three papers are summarized in the following paragraph.

In my first paper [1], I discovered how a generalized kicked Harper model can be used to simulate Floquet Weyl semimetal which possesses many Weyl points, whose number can be controlled by simply tuning the kicking strength. This is especially useful to generate a system with large number of zero and π edge modes, appearing as a Fermi arc connecting a pair of Weyl points. In my second paper [2], I studied the quantum nature of the periodic driving and discovered how it can further leads to more exotic phases, such as the recently discovered tilted (type-II) Weyl semimetal. In my third paper [3], in collaboration with scientists from Nanjing University, we considered a generalization of my first paper in the presence of *p*-wave superconductivity. In this case, the many zero and π edge modes observed in my first paper may transform into Majorana zero and π modes, a finding which may be useful for potential application in topological quantum computation (TQC).

Publications

[1] R. W. Bomantara and J. B. Gong, Quantum computation via Floquet topological edge modes, Phys. Rev. B **98**, 165421 (2018).

[2] R. W. Bomantara and J. B. Gong, Simulation of Non-Abelian Braiding in Majorana Time Crystals, Phys. Rev. Lett. **120**, 230405 (2018).

[3] R. W. Bomantara, W. Zhao, L. Zhou, and J. B. Gong, Nonlinear Dirac cones, Phys. Rev. B **96**, 121406(R) (2017).

[4] H.-Q. Wang, M. N.Chen, R. W. Bomantara (co-first author), J. B. Gong, and D. Y. Xing, Line nodes and surface Majorana flat bands in static and kicked p-wave superconducting Harper model, Phys. Rev. B **95**, 075136 (2017).

[5] R. W. Bomantara and J. B. Gong, Generating controllable type-II Weyl points via periodic driving, Phys. Rev. B **94**, 235447 (2016).

[6] R. W. Bomantara, G. N. Raghava, L. Zhou, and J. B. Gong, Floquet topological semimetal phases of an extended kicked Harper model, Phys. Rev. E **93**, 022209 (2016). [Editor's suggestion]

Current and Future Research Plan

Equipped with knowledge and expertise on Floquet topological phases, my research interest has since shifted towards their application in the development of fault-tolerant quantum computers. In particular, TQC is known to be a promising route to achieve the latter due to its ability to protect qubits at the hardware level. Common theme in TQC includes the use of non-Abelian quasiparticles, such as Majorana modes, to encode qubits and manipulate them through braiding.

While TQC has been extensively studied in recent years, as evidenced by the numerous articles published in top-tier journals such as *Nature Physics* and *Physical Review X*, some challenges that hinder its experimental realization have yet to be solved. These include the necessity to find a material which hosts a number of Majorana modes, the construction of complicated geometries to facilitate braiding, and a means to design a scalable architecture to develop a large scale quantum computer, to name a few.

Similar to how Floquet approach emerges as a solution to engineer novel topological phases, it is expected that Floquet topological phases may also have the capability to resolve the aforementioned issues. This possibility is further evidenced by the following features of Floquet topological phases. First, the coexistence of Majorana zero and π modes in Floquet topological superconductors demonstrates their capability to naturally host at least four Majorana modes, the minimum number required to encode a single qubit. Second, the difference in quasienergy between Majorana zero and π modes provides an extra degree of freedom to facilitate braiding without the necessity to implement complicated geometry. Third, the discrete time-translational symmetry of Floquet systems naturally protects these Majorana zero and π modes, preventing them from hybridizing with each other. Indeed, my recent papers [4, 5] utilize the aforementioned advantages offered by Floquet topological phases to perform basic quantum computation using only a single topological superconducting wire. Due to the simplicity of the platform used, scaling it up to carry out more complex quantum computational tasks is also quite straightforward.

References:

[1] R. W. Bomantara, G. N. Raghava, L. Zhou, and J. B. Gong, Phys. Rev. E **93**, 022209 (2016).

[2] R. W. Bomantara and J. B. Gong, Phys. Rev. B **94**, 235447 (2016).

[3] H. Q. Wang, M. N. Chen, R. W. Bomantara, J. B. Gong, and D. Y. Xing, Phys. Rev. B **95**, 075136 (2017).

[4] R. W. Bomantara and J. B. Gong, Phys. Rev. Lett. **120**, 230405 (2018).

[5] R. W. Bomantara and J. B. Gong, Phys. Rev. B **98**, 165421 (2018).