ENPH 455/555 Mid-Winter Progress Report
Quantum Logic Gates on Time-Bin Encoded Photonic Qubits

By

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Introduction and Problem Definition

Among the various approaches to quantum computing, photonic qubits present themselves as excellent candidates for information processing having been able to show quantum advantage [1]. Many photonic systems capable of performing linear unitary transformations using Mach-Zehnder interferometers exist, with the Clement's configuration being a commonly used approach but becomes challenging when dealing with large mesh sizes [2]. Introducing time-bin encoding allows for the system to be simplified, reducing its experimental complexity. Previous work has shown that implementing time-bin encoding using a loop architecture allows for these meshes to be recreated, reducing the number of components needed [3].

Progress Update

The previously proposed loop architecture will not yield the desired mesh configuration, and a new architecture has been identified. The previously proposed architecture would only allow for a Reck style mesh to be implemented [3]. The hardware could be modified to yield the desired mesh, but this would increase the number of components and add more loss to the system, defeating the purpose of the project. The new architecture can recreate a Clement's mesh while keeping all original goals in place. In Figure 1 the originally proposed architecture can be seen on the right (A), and the new one can be seen on the left (B) [4].

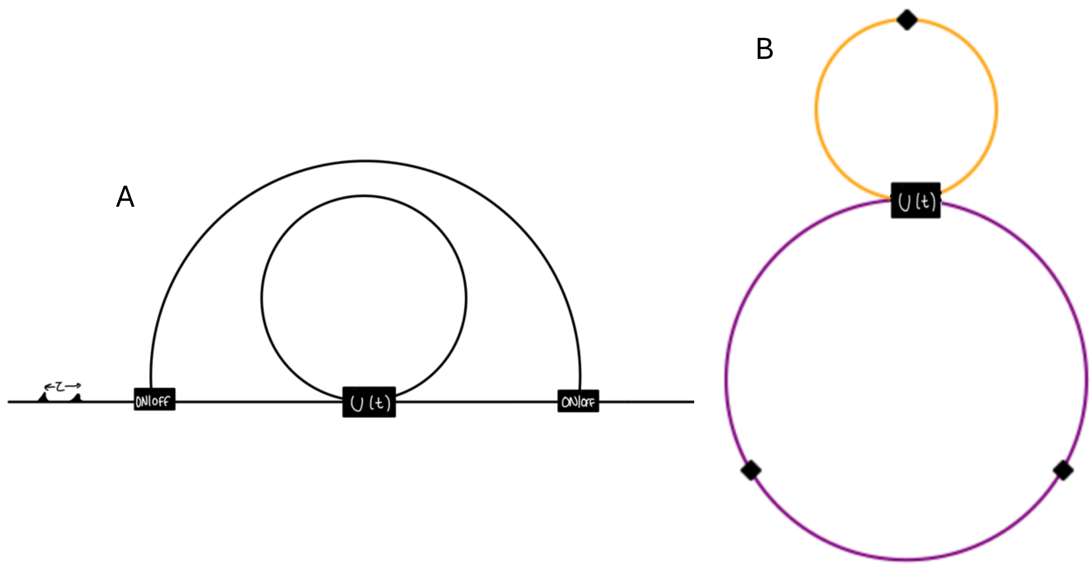

Figure 1: Diagrams of previously proposed architecture (A) and new architecture design (B). The new architecture includes one input switch on the bottom loop, and one interferometer where the bottom and top loop meet (labelled U(t)). Each black diamond in B represents a time-bin.

This new implementation utilizes two loops, one top and one bottom loop with an interferometer where the top and bottom loops meet [4]. This new system works by sending pulses in each time bin, with odd modes entering through the large loop first and then coupling them into the upper loop. Once coupled, the even modes are added into the system; these couple into the bottom loop. An extra void mode is added at the end, which allows for switching between loops. The spatial representation of how this corresponds to a traditional Clement's mesh can be seen in Figure 2, with the two-loop system above it. The coloured lines correspond to what loop each mode is coupled to. The vertical dashed lines depict a ‘switch’ which is mathematically represented by a π phase shift, which causes the mode present in one loop to change spots with the mode present in the other [4]. Each new loop diagram represents a time step, and the modes are represented by the numbers in red.

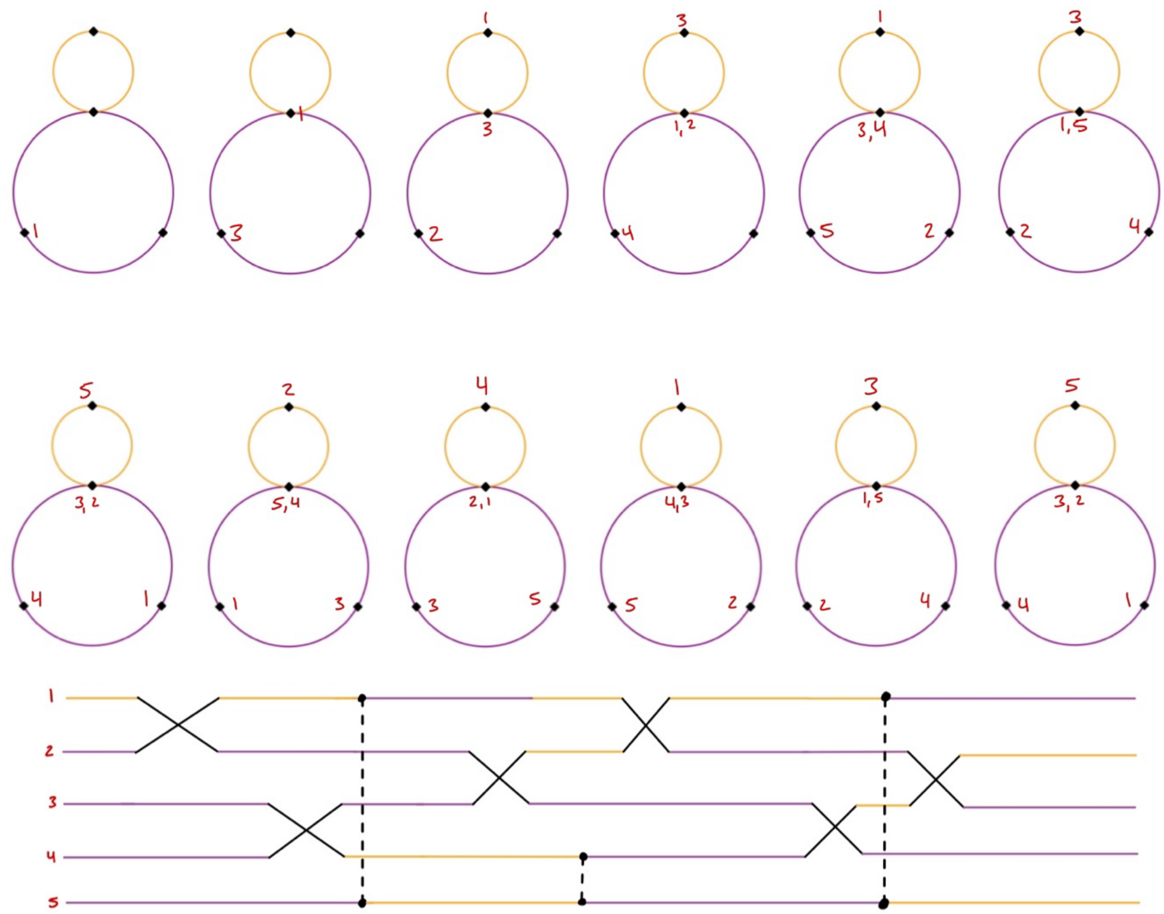

Figure 2: Loop diagram depicting where each mode goes as well as the corresponding Clemet’s mesh at the bottom. The colours of the mesh correspond to what loop the mode is found in.

Currently, work is being done to complete the algorithm and transfer it to code as well as creating a meaningful table that includes the phase shifts happening in each time-bin. Much of the previous research done pertaining to imperfections can be re-used as the architecture follows a similar idea as the one previously proposed [5]. Some changes will be made to this as the project reaches its conclusion.

Plan for Completion

The next steps in the project include finishing the algorithm for the even mesh, adding imperfections. The addition of imperfections is predicted to take a significant amount of time. The major contributors to imperfections should be properly described by the end of the project. A Gantt chart outlining the division of the next few weeks reflecting the design changes can be seen in Figure 3. Code iteration occurs in tandem with testing and iterations. Once the perfect code is finalized, the loss can be implemented into the perfect system. Two weeks are being allocated to design iteration, which will allow for any challenges to be overcome. An extra week has been added for contingency planning, which will allow for any problems that arise to be addressed appropriately, allowing for the successful completion of the project.

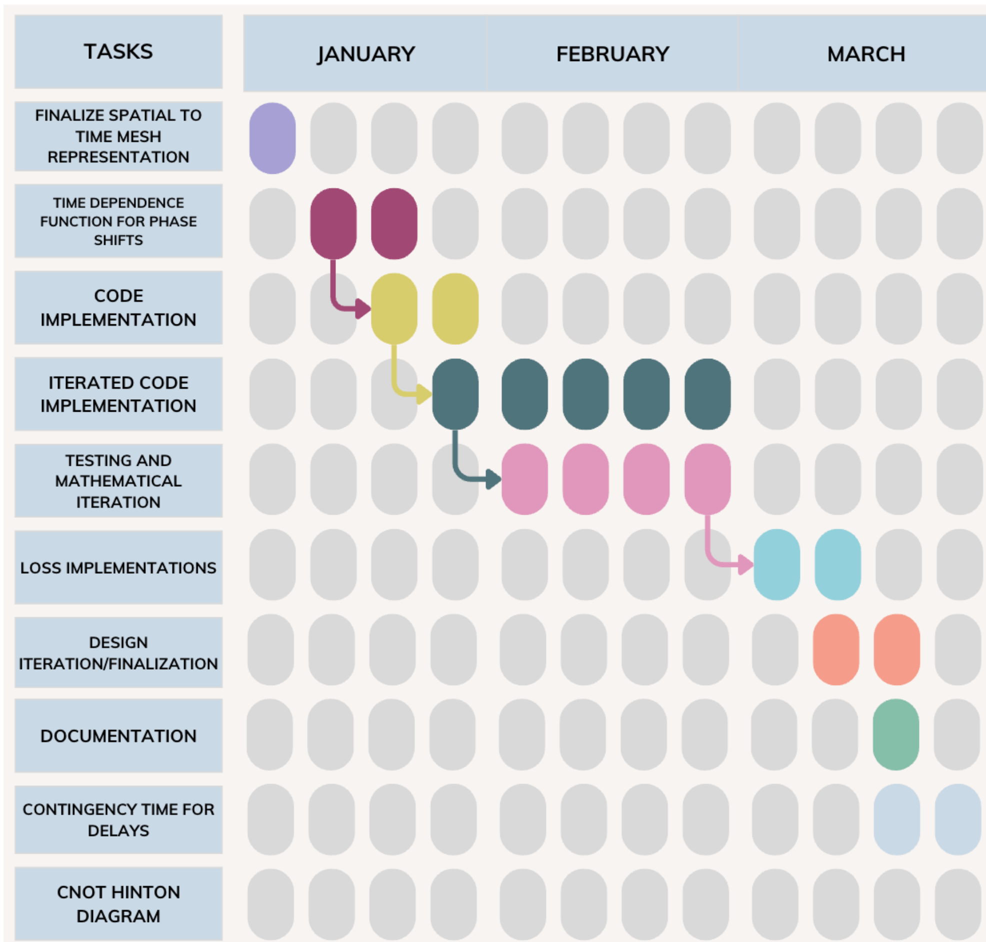

Figure 3: Gantt chart outlining the plan for the remainder of the semester.

Word Count: 579

Works Cited

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