ICTP PWF Bangladesh: Summer Internship Program

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Internship Report

On

Analysis of Superconducting Quantum Devices Using Keysight ADS: A Workflow and Feasibility Study

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I. Basic Information

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II. Abstract

This report summarizes work completed during a three-month online internship with the ICTP PWF: Physics for Bangladesh program. The primary objective was a comprehensive theoretical and practical investigation of superconducting quantum devices, focusing on Fluxonium qubits and quantum-limited parametric amplifiers (JPAs and JTWPAs). The methodology combined an intensive theoretical review of device physics—including Fluxonium energy spectra, JPA mixing processes (3WM/4WM), and JTWPA phase matching—with hands-on simulation using the Keysight Advanced Design System (ADS) QuantumPro suite and the KLayout layout editor, following the Keysight Superconducting Quantum Design Challenges Bootcamp. Key practical accomplishments include the full EM simulation and S-parameter analysis of a 4-qubit chip, the extraction of resonant frequencies from a basic JPA circuit, and a feasibility study of GDSII layout interoperability. The principal outcome of this research is the development of two novel, simulation-ready project proposals aimed at addressing critical performance bottlenecks in modern cryogenic amplifiers: (1) a method for enhancing the bandwidth of high-frequency WJPAs and (2) a proposal to investigate gain compression mechanisms in a lumped-element IMPA. This internship provided a robust foundation in quantum device physics and the end-to-end simulation workflow for future research.

III. Acknowledgements

I would like to express my sincere gratitude to my supervisor, Tanvir Ahmed Masum, for his invaluable guidance, support, and mentorship throughout this internship. I also wish to thank the organizers of the ICTP PWF: Physics for Bangladesh Online Summer Internship program for providing this unique and valuable opportunity to engage with advanced research topics.

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List of Abbreviations

- **ADS:** Advanced Design System
- **GDSII:** Graphic Data System II (A file format for IC layout)
- **HB:** Harmonic Balance (A simulation method)
- **IMPA:** Impedance Parametric Amplifier
- **JJ:** Josephson Junction
- **JPA:** Josephson Parametric Amplifier
- **JTWPA:** Josephson Traveling Wave Parametric Amplifier
- **SNAIL:** Superconducting Nonlinear Asymmetric Inductive element
- **WJPA:** Wireless Josephson Parametric Amplifier

1. Introduction

1.1. Internship Context

The ICTP PWF: Physics for Bangladesh Online Summer Internship is a program designed to acquaint students across Bangladesh with advanced research topics in physics and mathematics. This three-month, online internship provided a framework for supervised, self-directed research into the rapidly evolving field of superconducting quantum computing. My work focused on the hardware components that form the basis of this technology: superconducting qubits and quantum-limited amplifiers.

1.2. Objectives

The primary goal of this internship was to gain a deep, functional understanding of two key superconducting quantum devices: Fluxonium Qubits and Josephson Parametric Amplifiers (JPAs). This objective was broken down into several sub-goals:

- Develop a strong theoretical foundation in the device physics and operating principles of these components.
- Gain hands-on proficiency in a state-of-the-art industry design and simulation tool, Keysight ADS QuantumPro.
- Analyze the end-to-end workflow for quantum chip design, from schematic to layout (GDSII) and electromagnetic (EM) simulation.
- Conduct a literature review of current research to identify open questions and performance bottlenecks.
- Utilize this acquired knowledge to theorize and formulate novel, actionable research projects.

1.3. Report Structure

This report details the work undertaken to achieve these objectives. Chapter 2 provides the necessary theoretical background on the devices studied. Chapter 3 outlines the methodology, software learned, and tasks accomplished. Chapter 4 presents the main results of the internship, focusing on identified challenges and the detailed research proposals that were developed. Chapter 5 reflects on the specific skills and knowledge gained, and Chapter 6 provides a final conclusion and outlook for future work.

2. Theoretical Background

A foundational understanding of superconducting circuits is essential for designing quantum devices. This internship focused on two classes of devices: qubits for information storage and amplifiers for information readout.

2.1. Superconducting Qubits: The Fluxonium

Fluxonium is a superconducting qubit architecture that combines the advantages of Transmon and Flux qubits, offering high coherence times and tunability. It consists of a Josephson junction shunted by a large inductance and a capacitor, forming a loop sensitive to magnetic flux.

2.1.1. Key Features:

- Large inductance suppresses charge noise.
- Operates at low frequencies → higher T_1 compared to transmons.
- Highly anharmonic spectrum → reduced leakage to higher states.

2.1.2. Circuit Model & Hamiltonian:

Fluxonium circuit includes:

- A Josephson junction (energy E_J).
- A large inductance (energy E_L).
- A capacitor (energy E_C).

The Hamiltonian:

$$H = 4E_C n^2 + \frac{1}{2}E_L(\phi - \phi_{\text{ext}})^2 - E_J \cos(\phi)$$

Where: $E_C = \frac{e^2}{2C}$(charging energy), E_J= Josephson energy, $E_L = \frac{\Phi_0^2}{L}$(inductive energy), and ϕ_{ext}= external magnetic flux.

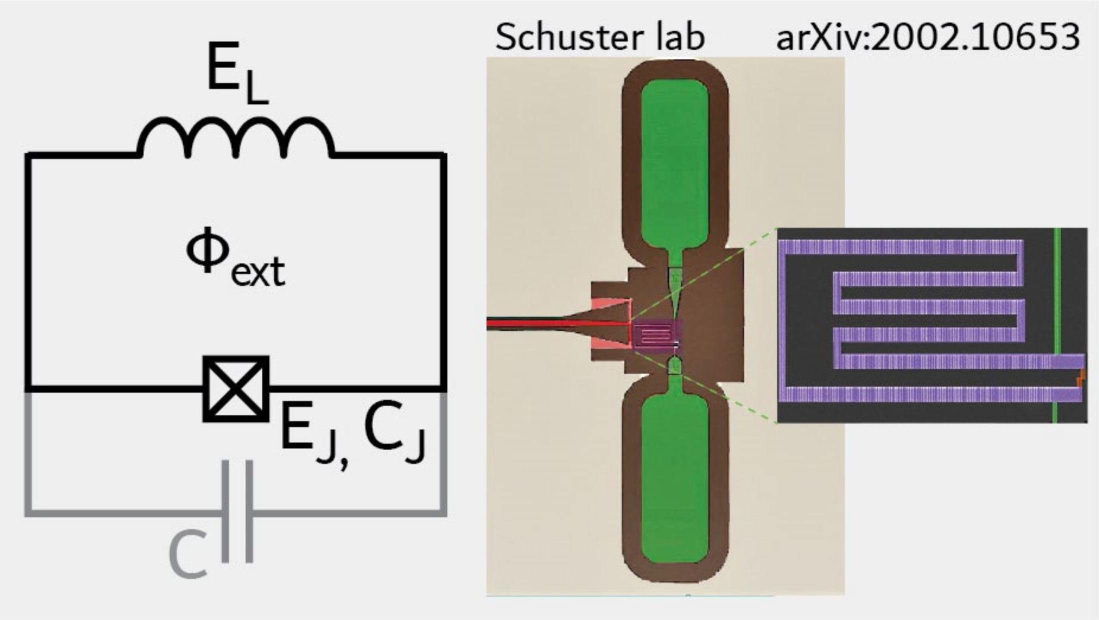


Fig 1: A Fluxonium Qubit Components [1].

2.1.3. Energy Spectrum & Flux Dependence

By tuning external flux ϕ_{ext}, the potential energy landscape changes, modifying the transition frequency f_{01}. Fluxonium typically operates at the **half-flux sweet spot** ($\phi_{\text{ext}} = \Phi_0/2$) to minimize flux noise.

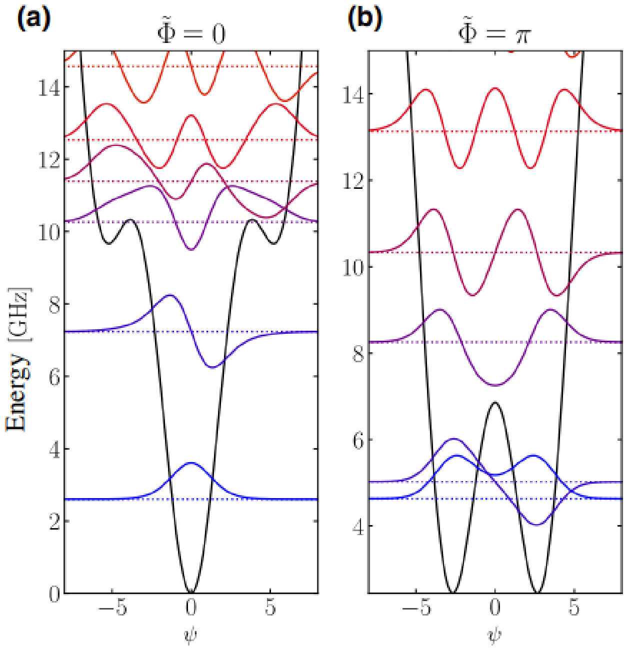


Fig 2: Spectrum of the fluxonium qubit at the two different flux-biasing points [2].

2.1.4. Comparison of Transmon, Fluxonium, and Flux Qubit

Feature	Transmon	Fluxonium	Flux Qubit
Circuit Elements	Josephson junction + capacitor	Josephson junction + capacitor + large inductance (JJ array)	Josephson junction + large inductance
Noise Sensitivity	Charge noise sensitive	Balanced (less sensitive to both charge and flux noise)	Flux noise sensitive
Flux Tunability	Very weak	Moderate (operates at half-flux sweet spot)	Strong
Energy Spectrum	Nearly flat vs flux	Highly anharmonic, tunable	Double-well potential, strongly flux-dependent
Advantages	Simple design, widely used	Best of both worlds: tunability + long coherence	Large inductance, strong flux control
Disadvantages	Limited tunability, dielectric loss	Requires JJ array fabrication	Strong flux noise, complex fabrication

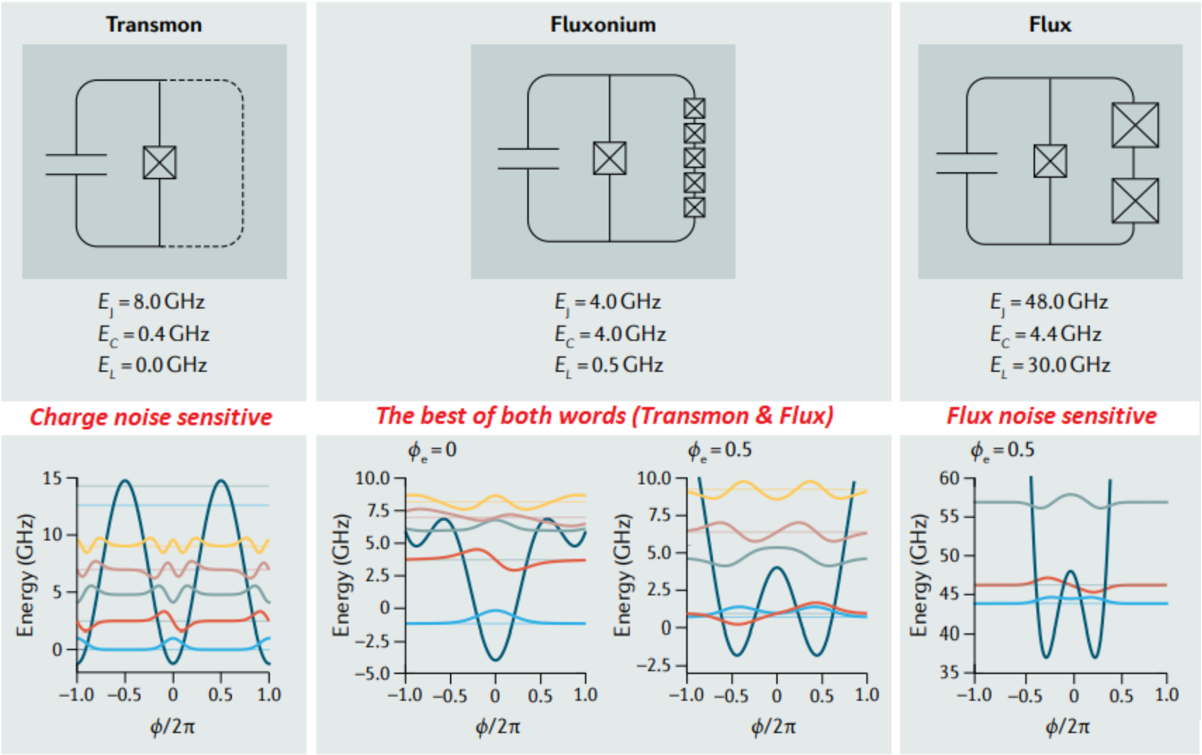


Fig 3: Equivalent circuits and their associated potential energy surfaces (dark blue) with the low-lying wavefunctions (other colours) for a typical transmon, fluxonium and flux qubit.

2.2. Quantum-Limited Amplification

In the fields of quantum computing, precision sensing, and radio astronomy, microwave signals are often incredibly faint, consisting of just a few photons. Standard semiconductor amplifiers (like HEMTs) add a significant amount of noise, typically equivalent to 10-20 photons, which buries these quantum signals.

Josephson Parametric Amplifiers (JPAs) and their broadband counterparts, Josephson Traveling-Wave Parametric Amplifiers (JTWPAs), are superconducting devices designed to solve this problem. They operate at cryogenic temperatures and use the unique nonlinear properties of Josephson junctions to amplify signals while adding the absolute minimum amount of noise allowed by quantum mechanics, known as the Standard Quantum Limit (SQL).

2.3. Josephson Parametric Amplifiers (JPAs)

The JPA is a nonlinear resonant cavity. It is designed to provide very high gain at a specific, tunable frequency, making it ideal for reading out the state of a single superconducting qubit.

2.3.1. Core Components

A JPA is built from two key superconducting elements:

- **Josephson Junction (JJ):**
  A JJ is a weak link—typically a thin insulating barrier—between two superconductors. Unlike a linear inductor, it behaves as a perfect, lossless nonlinear inductance. Its current and inductance depend on the superconducting phase difference ϕacross the junction:

  $$I_s = I_c \sin(\phi), L_J(\phi) = \frac{\Phi_0}{2\pi I_c \cos(\phi)},$$

  where $I_c$is the critical current and $\Phi_0$is the magnetic flux quantum.

- **DC-SQUID:**
  To achieve tunability, JPAs use a dc-SQUID—a superconducting loop containing two JJs. Applying an external magnetic flux Φ_{ext}modifies the effective critical current and thus the inductance, enabling in-situ tuning of the resonator frequency.

  The JPA combines this tunable nonlinear inductor with a capacitor to form an LC resonator, often implemented as a coplanar waveguide (CPW) resonator shorted to ground by the SQUID.

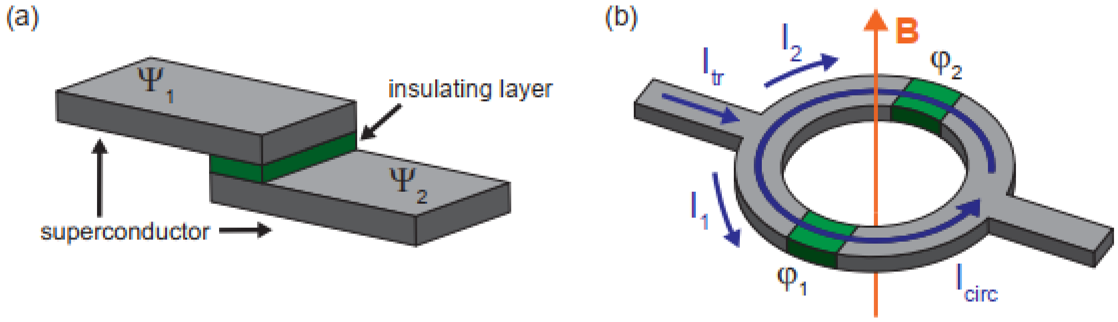


Fig 4: (a) Schematic of a Josephson junction with superconductors in gray and an insulating layer in green. (b) Schematic of dc-SQUID with one Josephson junction in each arm of the superconducting loop [3].

2.3.2. Principle of Parametric Amplification

Parametric amplification transfers energy from a strong pump to a weak signal by modulating a circuit parameter—in this case, the inductance of the SQUID. The nature of the nonlinearity determines the mixing process:

2.3.2.1 Four-Wave Mixing (4WM)

This process arises from the Kerr nonlinearity ($c_4\phi^4$) in the Josephson potential:

$$U(\phi) \approx c_2\phi^2 + c_4\phi^4 + \cdots$$

Two pump photons combine to produce one signal and one idler photon:

$$2\omega_p = \omega_s + \omega_i.$$

4WM is typically used in current-pumped JPAs, where $\omega_p \approx \omega_0$.

2.3.2.2 Three-Wave Mixing (3WM)

This is the most common scheme in modern JPAs. This process requires an engineered second-order nonlinearity ($c_3\phi^3$). One pump photon splits into a signal and an idler:

$$\omega_p = \omega_s + \omega_i.$$

Modern JPAs achieve this by flux-pumping a SQUID at $\omega_p \approx 2\omega_0$, modulating its inductance at twice the resonator frequency.

2.3.3. Operating Modes

- **Nondegenerate (Phase-Preserving):**
  $\omega_s \neq \omega_i$. Amplifies both quadratures equally; noise limited by the Standard Quantum Limit (SQL), adding at least half a photon.

- **Degenerate (Phase-Sensitive):**
  $\omega_s = \omega_i = \omega_p/2$. Amplifies one quadrature while squeezing the other; can achieve zero added noise.

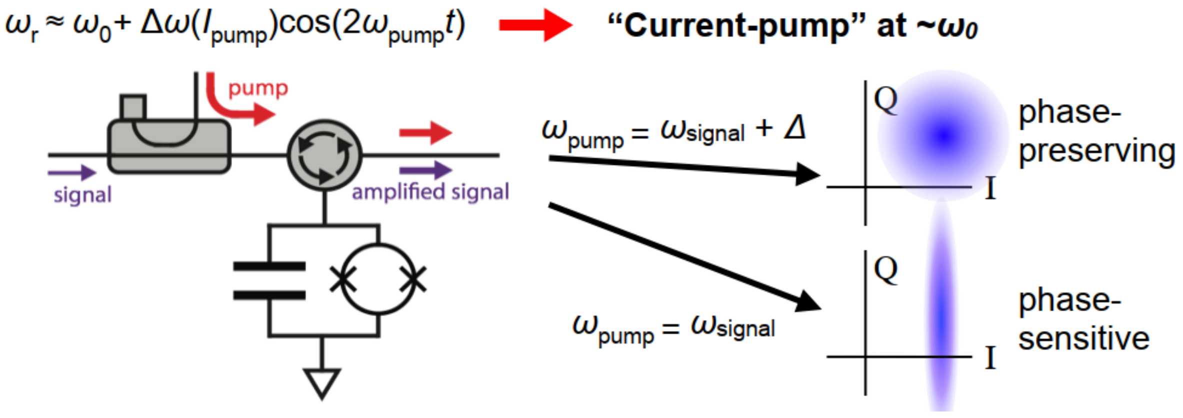


Fig 5: JPA is different operation modes [4].

2.3.4. Performance, Limitations, and Variants

- **Gain & Bandwidth:** As a resonant device, a JPA has a high gain (e.g., 20 dB) but is fundamentally narrowband (typically 10-50 MHz).
- **Dynamic Range:** The JPA saturates at very low input powers (e.g., -130 dBm). This is a major limitation. The solution is to use an array of N SQUIDs instead of one. This increases the total critical current, which scales the dynamic range (saturation power) by N^2.
- **Other Variants:**
  - **Dual-pump JPAs** for bandwidth extension.
  - **Multi-SQUID JPAs** for higher dynamic range.
  - **Squeezing JPAs** for quantum state generation.

2.4. Josephson Traveling Wave Parametric Amplifiers (JTWPAs)

The JTWPA is a nonlinear transmission line. It was invented to solve the primary limitation of the JPA: its narrow bandwidth. A JTWPA can provide quantum-limited gain over a bandwidth of several Gigahertz (GHz).

2.4.1. Fundamental Theory: A Nonlinear Transmission Line

Instead of a single resonant cavity, a JTWPA consists of a long coplanar waveguide (a "transmission line") where the center conductor is periodically loaded with a chain of hundreds or thousands of nonlinear Josephson elements.

The signal and pump are injected at one end of the line. As they co-propagate down this nonlinear medium, the signal is continuously amplified. The gain grows exponentially with the length of the line.

2.4.2. Principle of Operation: The Challenge of Phase Matching

For the small amplification from each of the 1000+ elements to add up constructively, the pump, signal, and idler waves must all travel at the correct speeds to stay in phase along the entire line. This is a "momentum conservation" condition known as phase matching.

$$\text{4WM: } 2k_p = k_s + k_i,$$

$$\text{3WM: } k_p = k_s + k_i,$$

where k is the wavevector.

In a normal waveguide, waves at different frequencies travel at different speeds (a property called dispersion), which quickly breaks this condition. The entire challenge of JTWPA design is Dispersion Engineering: building features into the transmission line (e.g., resonant stubs, periodic structures) to cancel the natural dispersion and force the phase-matching condition to be true over a broad band.

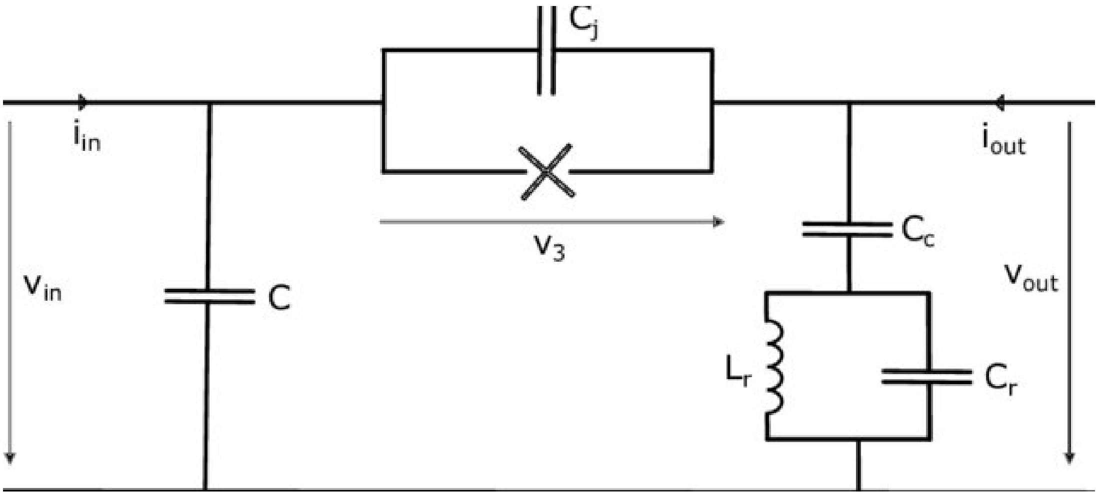


Fig 6: Circuit representation of a JTWPA unit cell element with resonant phase matching (RPM). The Lr - Cr resonant circuit is responsible for a phase shift of the pump frequency [5].

2.4.3. Variants and Advances

- **4WM JTWPAs:** Use Kerr nonlinearity; simpler but harder to phase-match.
- **3WM JTWPAs:** Preferred for broadband operation; implemented using SNAIL elements that provide strong second-order nonlinearity.
- **Kinetic Inductance JTWPAs:** Use the nonlinear kinetic inductance of superconducting wires instead of Josephson junctions.

In summary, the resonant JPA is a high-gain, tunable amplifier for a single frequency, while the JTWPA is a complex but powerful device that provides quantum-limited amplification across a massive bandwidth, enabling the simultaneous readout of thousands of qubits.

3. Methodology and Task Accomplishments

The internship was structured as a simulation-based research project. The methodology was to first learn the necessary tools, then apply them to analyze existing devices, and finally use this knowledge to propose new research.

3.1. Skill Acquisition: Keysight ADS Quantum EDA Workflow

A significant portion of the internship was dedicated to mastering the Keysight Advanced Design System (ADS) software, a leading industry tool for quantum chip design.

- **Keysight Bootcamp:** Successfully completed the Keysight Superconducting Quantum Design Challenges Bootcamp [6]. This provided a holistic, end-to-end overview of the integrated workflow.
- **Workflow:** The learned workflow includes:
    1. **Quantum Circuit Design:** Building schematic-level models of quantum circuits (e.g., qubits, resonators) using the Quantum EDA.
    2. **Quantum Layout Design:** Translating the schematic into a physical layout (GDSII file) for fabrication, managing layers and component footprints.
    3. **EM Simulation:** Using QuantumPro's integration with EM simulators to extract key parameters like qubit frequencies, anharmonicity, and coupling strengths from the physical layout.

3.2. Device Architecture and Layout Analysis

The ADS software suite was used to explore and deconstruct existing device designs.

- **ADS Example Library:** Explored several example projects, including a single qubit chip and a JTWPA architecture, to understand how complex devices are modeled and simulated.
- **GDSII Interoperability:** A key task was to analyze the feasibility of importing GDSII layouts generated by other software (e.g., open-source libraries like Qiskit Metal) into Keysight ADS for simulation. This proved to be a significant challenge, as discussed in Chapter 4.
- **KLayout:** Used the KLayout GDSII viewer/editor to manipulate and analyze the layer stack of quantum chip files. This provided a much clearer understanding of the physical structure and fabrication process, which is often abstracted away in design software.

3.3. Theoretical Review and Open-Source Tool Study

Alongside simulation, a deep theoretical review was conducted.

- **Literature Review:** Studied state-of-the-art papers on JPA and JTWPA architectures to understand current performance metrics, limitations, and research trends.
- **Open-Source Tools:** Investigated the JosephsonCircuits.jl simulator (a Julia-language package) as a potential open-source alternative for analyzing the performance of JPA and JTWPA architectures, offering a way to cross-check results from proprietary software [7].
- **Project Theorizing:** This combined study of simulation tools and device physics led to the "Theorizing new project ideas" task, which culminated in the proposals detailed below.

4. Results and Discussion

The primary results of this internship are not experimental data, but rather a critical analysis of simulation workflows and the formulation of two high-impact research proposals based on the knowledge gained.

4.1. Simulating a 4 Qubit Chip in Keysight ADS

4.1.1. Schematic View of a 4 Qubit Chip

Using the Keysight ADS inbuilt ‘Quantum Devices’ Library, we can now build a superconducting quantum chip incorporating many qubits. There are varieties of superconducting devices including Transmon and Fluxonium Qubits, SNAKE and SNAIL devices, DC and RF Squid element etc.

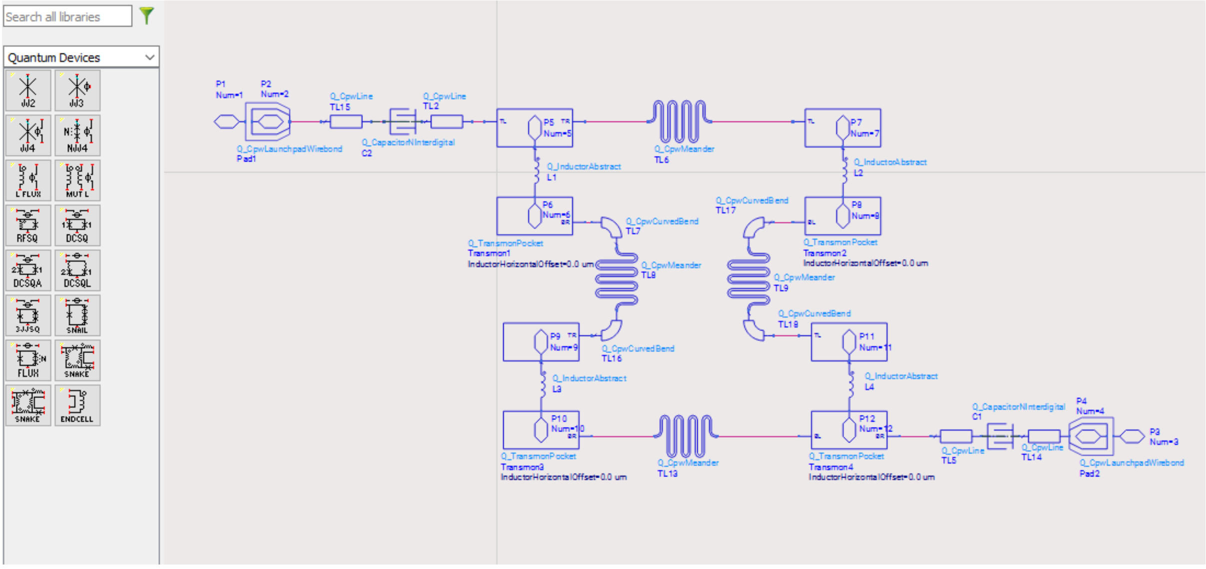
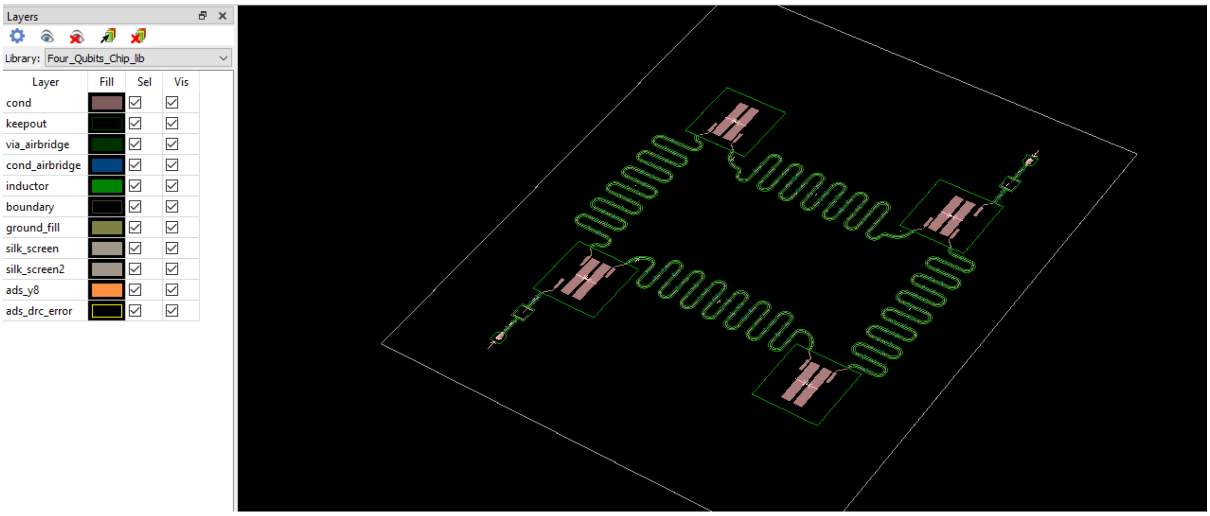


Fig 7: Schematic View of a 4-qubit chip

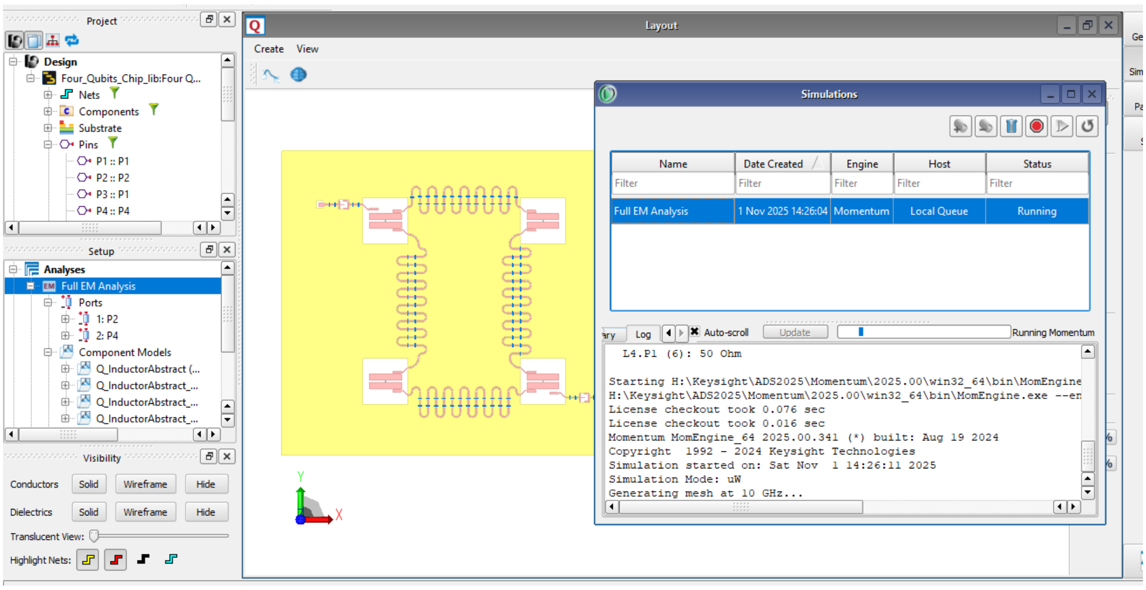
4.1.2. Layout View of a 4 Qubit Chip:



Layer	Fill	Sel	Vis
cond	■	☑	☑
keepout	■	☑	☑
via_airbridge	■	☑	☑
cond_airbridge	■	☑	☑
inductor	■	☑	☑
boundary	■	☑	☑
ground_fill	■	☑	☑
silk_screen	■	☑	☑
silk_screen2	■	☑	☑
ads_y8	■	☑	☑
ads_drc_error	■	☑	☑

Fig 8: Layout View of a 4-qubit chip

4.1.3. EM Analysis

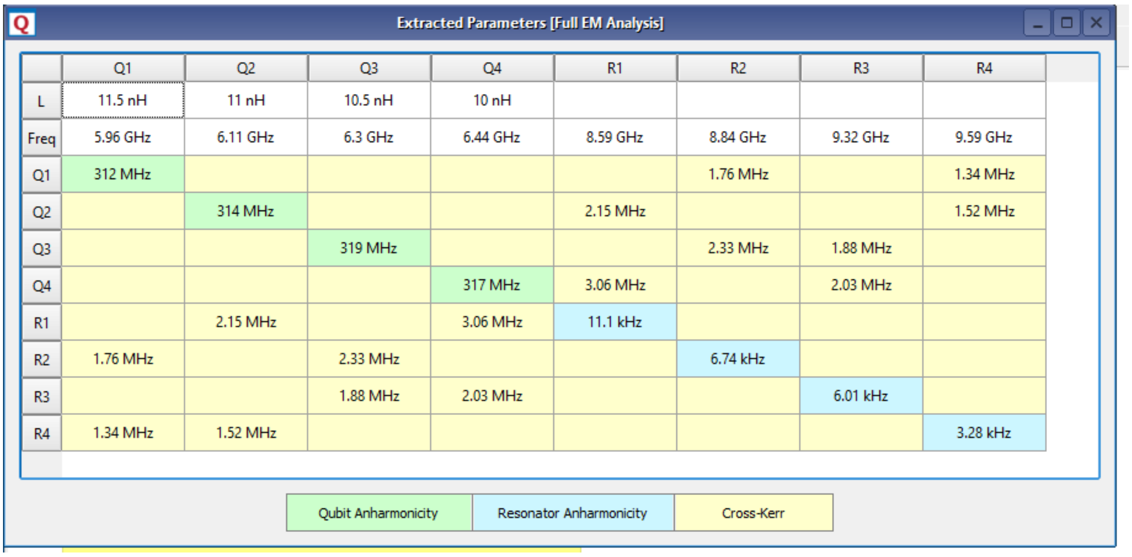


Name	Date Created	Engine	Host	Status
Full EM Analysis	1 Nov 2025 14:26:04	Momentum	Local Queue	Running

```
  L4.P1 (6): 50 Ohm

Starting H:\Keysight\ADS2025\Momentum\2025.00\win32_64\bin\MomEngine
H:\Keysight\ADS2025\Momentum\2025.00\win32_64\bin\MomEngine.exe --en
License checkout took 0.076 sec
License checkout took 0.016 sec
Momentum MomEngine_64 2025.00.341 (*) built: Aug 19 2024
Copyright  1992 - 2024 Keysight Technologies
Simulation started on: Sat Nov  1 14:26:11 2025
Simulation Mode: uW
Generating mesh at 10 GHz...
```

Fig 9: EM Analysis Window



	Q1	Q2	Q3	Q4	R1	R2	R3	R4
L	11.5 nH	11 nH	10.5 nH	10 nH				
Freq	5.96 GHz	6.11 GHz	6.3 GHz	6.44 GHz	8.59 GHz	8.84 GHz	9.32 GHz	9.59 GHz
Q1	312 MHz					1.76 MHz		1.34 MHz
Q2		314 MHz			2.15 MHz			1.52 MHz
Q3			319 MHz			2.33 MHz	1.88 MHz	
Q4				317 MHz	3.06 MHz		2.03 MHz	
R1		2.15 MHz		3.06 MHz	11.1 kHz			
R2	1.76 MHz		2.33 MHz			6.74 kHz		
R3			1.88 MHz	2.03 MHz			6.01 kHz	
R4	1.34 MHz	1.52 MHz						3.28 kHz

Qubit Anharmonicity	Resonator Anharmonicity	Cross-Kerr

Fig 10: Extracted Parameters from full EM Analysis

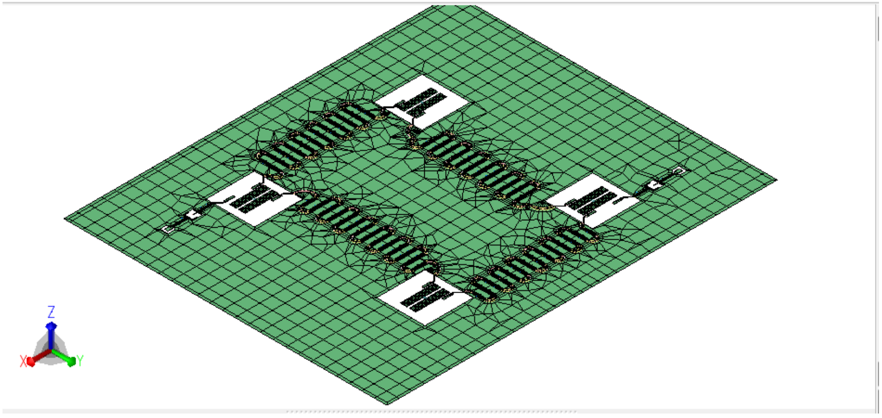


Fig 11: Mesh View of the chip

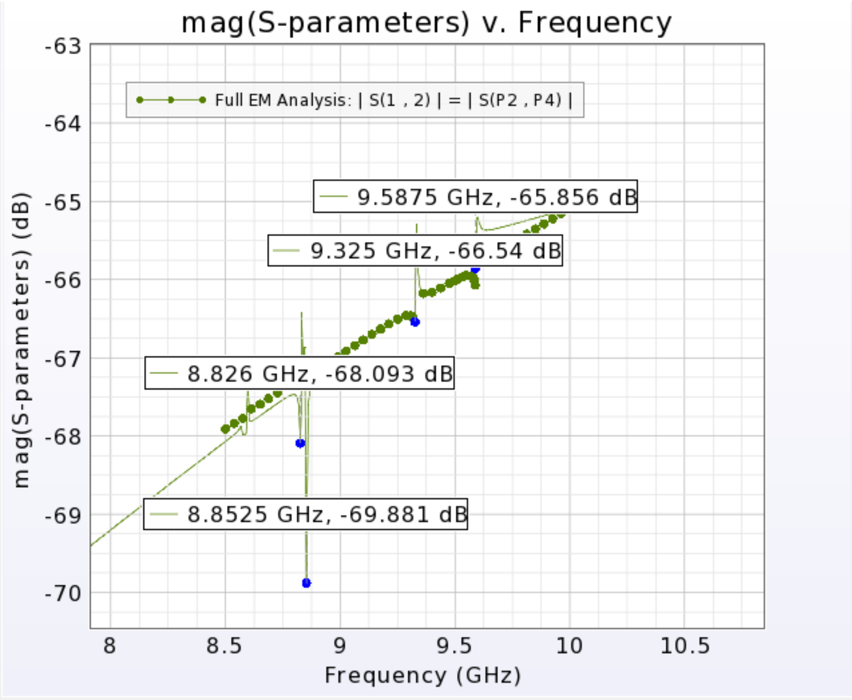


Fig 12: S-Parameter Analysis shows the peaks of the resonators' resonant frequencies

4.2. Simulating a basic Josephson Parametric Amplifier in Keysight ADS

4.2.1. Finding Resonant Frequency

The resonant frequency can be found in frequency sweep when the reflection at the junction becomes maximum in the absence of a pump signal. The scattering parameter (S_{21}) is plotted at different biasing conditions.

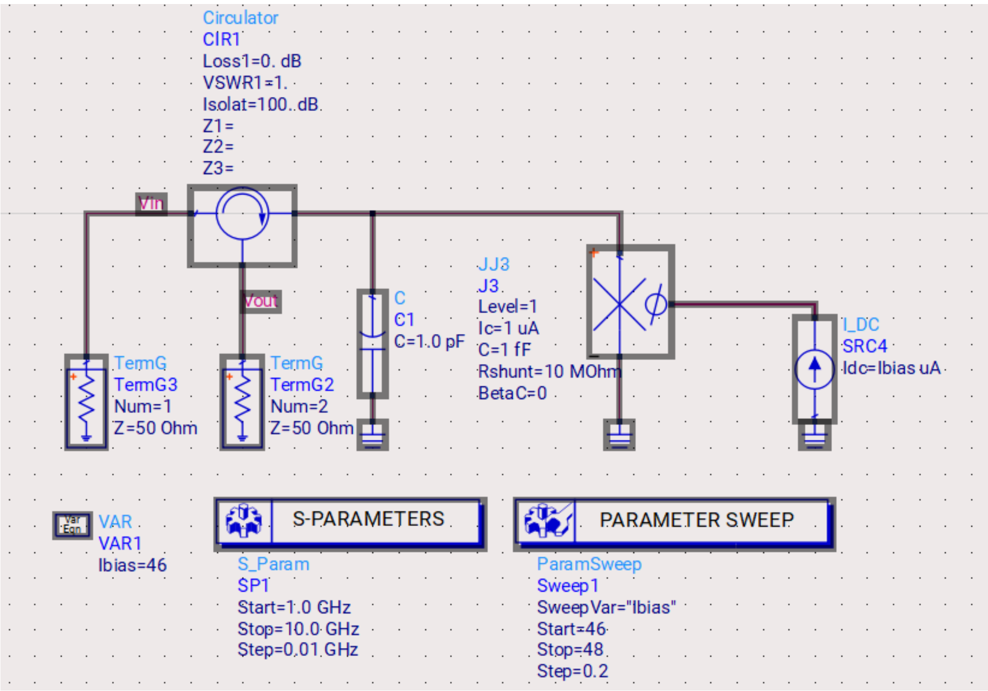


Fig 13: Circuit for Resonant Frequency Analysis of JPA

Here, Josephson Junction Critical Current, I_c = 1 uA, JJ Capacitance, C_J = 1 fF, JJ Shunt Resistance R_{shunt} = 10 MΩ, and damping factor β_c = 0.

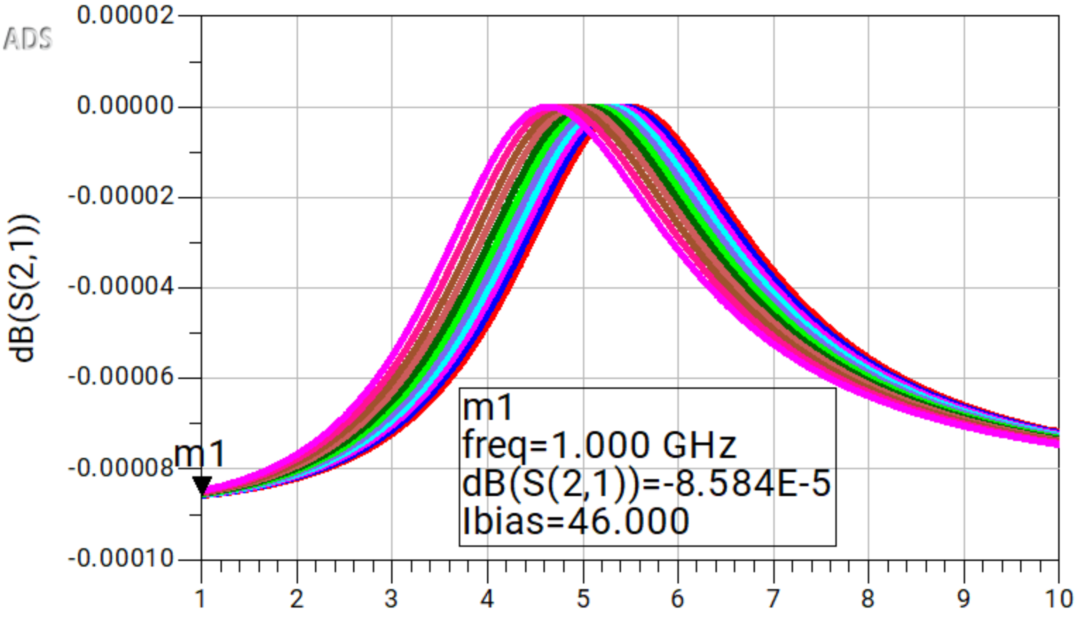


Fig 14: S-Parameter Plot for Resonant Frequency Analysis of JPA

As shown in the plot, when the JJ bias current is set at 47.2 uA, the reflection would peak at around 5 GHz.

We can also do pump power sweep, bias current sweep and gain compression analysis for JPA in Keysight ADS.

4.3. Manipulating GDSII file in KLayout and Importing in Keysight

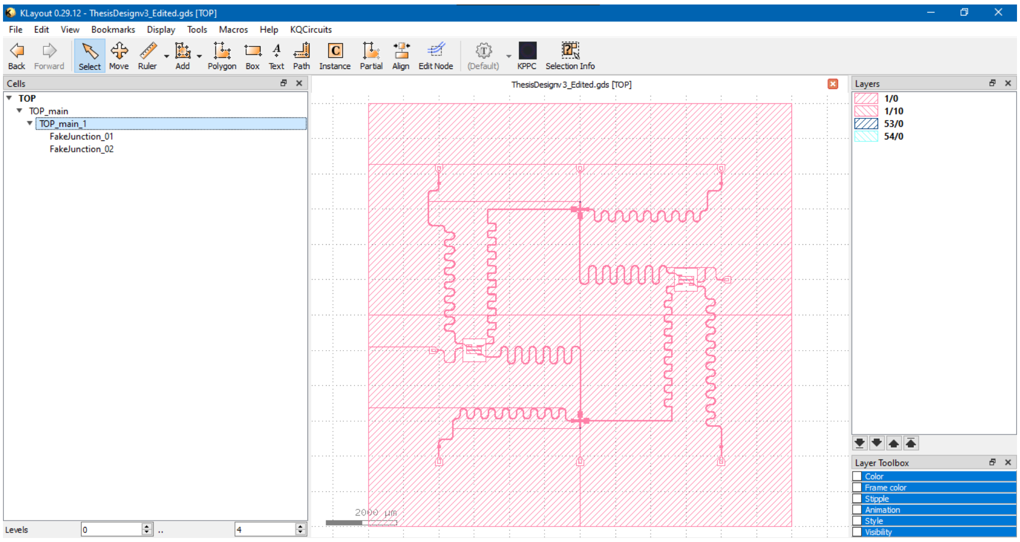


Fig 15: 4-Qubit Chip Layers in KLayout

Here, the basic learning outcome was to identify the layers of the chip from the GDSII file and make it easier for EM simulation and EPR analysis.

Unfortunately, after importing this GDSII file in Keysight ADS, there was a problem in identification of JJ's present in this chip, which needs further investigation.

4.4. Key Challenges Identified

During the workflow analysis, two significant challenges in the current quantum device design landscape were identified:

- **1. GDSII Interoperability:** A major limitation was discovered in the ability of Keysight ADS to seamlessly import and "understand" pre-built GDSII files from other sources. While GDSII files can be imported visually, they are often not "parameterized" in a way that ADS can use for EM simulation without significant manual re-work. This creates a "walled garden" effect and hinders interoperability with the growing ecosystem of open-source design tools like Qiskit Metal.
- **2. Software License Limitations:** The reliance on proprietary, licensed software (like Keysight ADS) presents a barrier to verification. Without access to multiple simulation tools or robust, validated open-source alternatives, it is difficult to cross-check and verify obtained results, which is a critical step in scientific research.

4.5. Primary Outcome: Future Research Proposals

The "Task Accomplishments" of "Theoretical studies" and "Theorizing new project ideas" converged to produce the main deliverable of this internship. The following two project proposals represent a direct application of the skills and knowledge developed. They identify specific, high-impact problems from the literature and propose a clear, simulation-based methodology to solve them using the learned tools.

4.5.1. Project Proposal 1: Bandwidth Enhancement of High-Frequency Wireless JPA using a Lumped Chebyshev Filter

Abstract:
The practical application of high-frequency (>20 GHz) Wireless Josephson Parametric Amplifiers (WJPAs), such as the device demonstrated by Hao et al. [8], is severely constrained by an extremely narrow operational bandwidth, measured at approximately 3 MHz. This project proposes to overcome this critical limitation by designing and simulating a compact, lumped-element Chebyshev impedance matching network. Drawing insight from recent successes in broadbanding Impedance Parametric Amplifiers (IMPAs) using similar filter topologies (Kaufman et al. [9]; Moskaleva et al. [10]), this work will develop a 2- or 3-pole filter within the Advanced Design System (ADS) simulation environment. A key methodological innovation is the exclusive reliance on fast, passive S-parameter simulations for optimization, an approach recently validated by Shin et al. [11] for effective impedance characterization. The methodology will involve modeling the passive WJPA resonator and the filter's lumped L/C components, then utilizing an optimizer to tune component values. The primary optimization goals are to match the resonator's impedance to 50 ohm and maximize the reflectionless ($S_{11} < -15$ dB) bandwidth over the target K-band frequency range. The novelty of this work lies in adapting and scaling state-of-the-art matching techniques to a challenging high-frequency device, offering a high-feasibility pathway to address a key performance bottleneck in next-generation cryogenic amplifiers.
Tools to be used: Keysight ADS, KLayout, Cadence AWR

4.5.2. Project Proposal 2: Investigating Gain Compression Mechanisms in a Lumped-Element IMPA

Abstract:
Understanding the mechanisms that limit gain compression is critical for optimizing the dynamic range of Josephson Parametric Amplifiers (JPAs). Recently, Le Gal et al. [12] introduced a novel analysis method for traveling-wave parametric amplifiers (JTWPAs) that distinguishes between pump depletion and nonlinear phase mismatch as the cause of saturation by monitoring pump reflection. Concurrently, new compact amplifier architectures, such as the lumped-element Impedance Parametric Amplifier (IMPA) by Moskaleva et al. [10], present different operational regimes. This project proposes to apply the saturation analysis technique from Le Gal et al. to the specific resonant IMPA architecture from Moskaleva et al. The methodology will employ Harmonic Balance (HB) simulations within the Advanced Design System (ADS), utilizing a flux-aware model for the SNAIL component. By sweeping the input signal power (P_{sig}) and simultaneously monitoring both the signal gain (S_{11} at f_{sig}) and the reflected pump power (S_{11} at f_{pump}), this work aims to identify the dominant saturation mechanism. The novelty lies in applying a state-of-the-art analysis technique, originally developed for JTWPAs, to a modern, lumped-element resonant amplifier to provide new insights into its high-power physics and P_{1dB} compression point.
Tools to be used: Keysight ADS, KLayout, Cadence AWR

5. Learning and Skill Development

This internship was an intensive learning experience that significantly enhanced both my technical and professional skills.

5.1. Technical Skills

- **Quantum Device Simulation:** Gained proficiency in Keysight ADS QuantumPro for end-to-end design, simulation, and analysis of superconducting quantum circuits.
- **IC Layout:** Acquired hands-on experience with GDSII file manipulation in KLayout, providing a practical understanding of fabrication layers and physical chip design.
- **Simulation Techniques:** Learned to apply specific simulation methods, such as Electromagnetic (EM) simulation for parameter extraction and Harmonic Balance (HB) for analyzing non-linear device physics (as proposed for Project 2).

5.2. Theoretical Knowledge

- **Fluxonium Physics:** Developed a strong conceptual understanding of Fluxonium qubit architecture, flux quantization, and the role of "sweet spots" in qubit tuning.
- **Parametric Amplifiers:** Gained a deep knowledge of the device physics and operating principles of various JPA and JTWPA architectures, including their respective advantages (e.g., gain, bandwidth) and limitations.

5.3. Professional Skills

- **Literature Review:** Honed the ability to conduct a comprehensive literature review of state-of-the-art research, identify knowledge gaps, and synthesize information.
- **Problem Formulation:** Developed the crucial research skill of translating a "bottleneck" or "open question" from the literature into a well-defined, actionable project proposal with a clear methodology.
- **Self-Directed Research:** Successfully managed a three-month online research project, demonstrating strong time management, discipline, and independent problem-solving.

6. Conclusion

6.1. Summary of Achievements

This internship successfully met all its primary objectives. A strong foundational knowledge of Fluxonium qubits and Josephson Parametric Amplifiers was established. Proficiency in the Keysight ADS QuantumPro and KLayout software suites was achieved, and the end-to-end quantum design workflow was analyzed. This analysis led to the identification of key challenges in software interoperability. The research and theorizing tasks culminated in the two detailed research proposals presented in Chapter 4, which stand as the principal accomplishment of this internship.

6.2. Scope for Further Research

The "Scope for Further Research" is explicitly defined by the two proposals generated during this internship. These projects are simulation-ready and represent clear, high-impact next steps:

1. **Executing Project 1** would involve building the Chebyshev filter model in ADS and optimizing it to demonstrate a viable path to broadband, high-frequency quantum amplifiers.
2. **Executing Project 2** would provide new, fundamental insights into the saturation physics of compact resonant amplifiers, helping to inform the design of next-generation JPAs with higher dynamic range.

6.3. Final Remarks

The ICTP PWF: Physics for Bangladesh Online Summer Internship provided an exceptional opportunity to bridge the gap between textbook knowledge and active, high-level research. The skills and experience gained in quantum device simulation and analysis have built a strong foundation for future academic and professional pursuits in the field of quantum computing.

7. References

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Approval

The internship report titled “Analysis of Superconducting Quantum Devices Using Keysight ADS: A Workflow and Feasibility Study” submitted by Fahim Shahriar Anim, a participant of the ICTP PWF: Physics for Bangladesh Online Summer Internship, has been found satisfactory in partial fulfillment of the requirements of the internship program.
The internship was conducted under the supervision of **Tanvir Ahmed Masum** during the period **15 July 2025** to **15 October 2025**.

Supervisor

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