DESIGNING OPTICAL 2:1 MULTIPLEXER USING NON LINEAR PHOTONIC CRYSTAL RING RESONATOR

Project Review Presentation Under the Supervision of

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Photonic crystals (PhCs)

- Photonic crystals (PhCs) are periodic structures made of two materials with high and low refractive indices.
- They are categorized as 1D, 2D, or 3D based on their structure.
- **Photonic Band Gap (PBG):** The periodic nature of PhCs creates photonic band gaps, which prohibit the propagation of optical waves in specific frequency ranges.
- **Advantages of 2D PhCs:** Complete PBG and ease of design and fabrication make 2D PhCs more popular than 1D or 3D variants.
- PhCs are essential for designing optical devices like filters, demultiplexers, switches, and logic gates, critical for optical communication networks.
- They provide low loss, high bandwidth, and immunity to electromagnetic interference which is good for optical communication

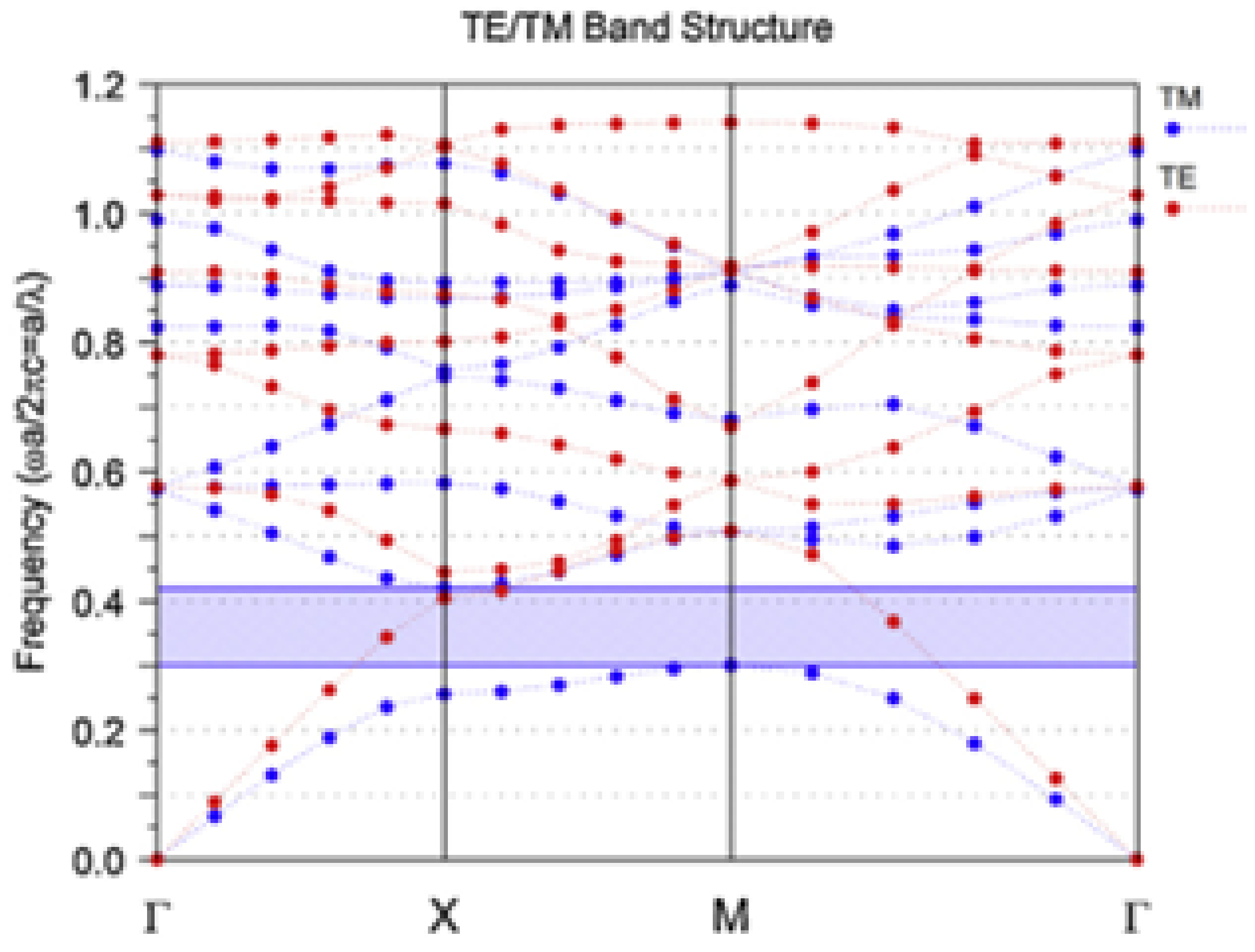
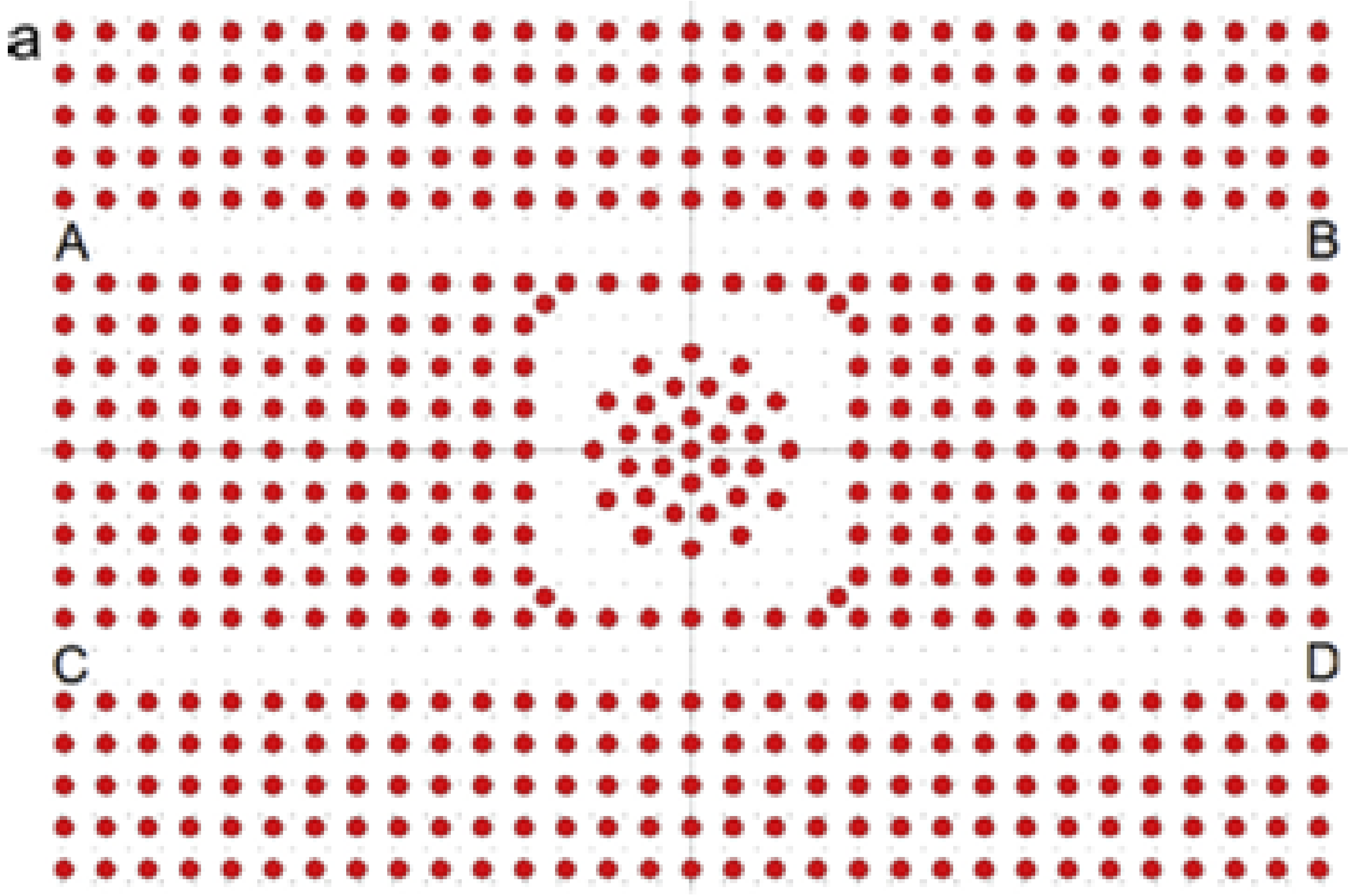


Fig. 1. The band structure of the fundamental structure.

PhC Ring Resonator(PhCRR)

- PhC ring resonators (PhCRRs) emerged as a compact and efficient alternative for optical filters, switches, and demultiplexers.
- PhCRRs consist of a resonant ring between bus and drop waveguides, allowing light at specific wavelengths to drop into the waveguide.
- Nonlinear effects, such as the Kerr effect, enable controllable optical behavior, allowing their use in designing optical devices

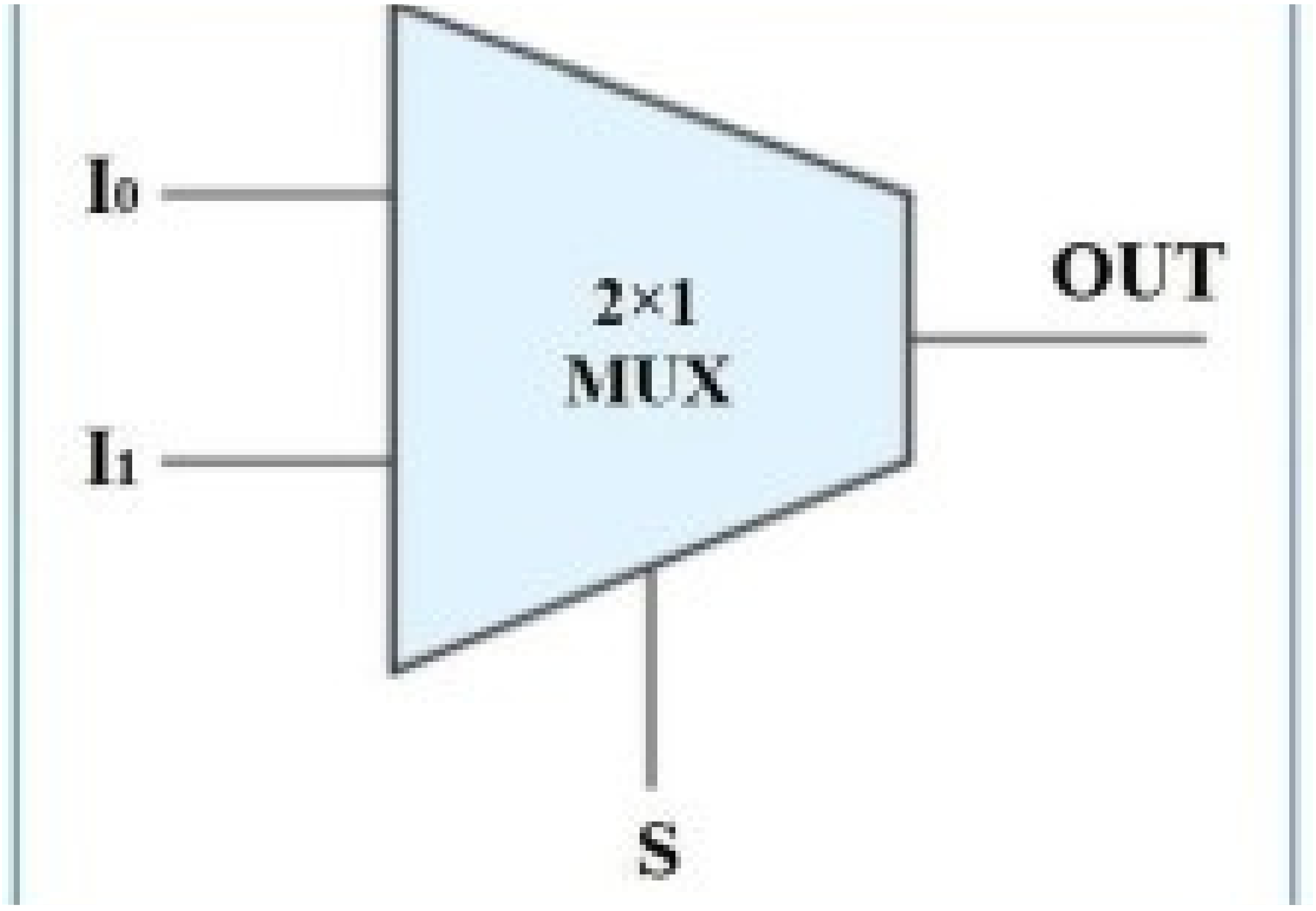


schematic Diagram of PhCRR

2:1 Multiplexer

- **Definition**: A 2:1 multiplexer is a circuit that selects one of two input signals (A or B) and forwards it to a single output (Y) based on the control signal (S).
- **Logic Function:** The output is determined by Y = A·S' + B·S, where S' is the complement of the selection signal.
- **Truth Table:**

  1) S = 0: Output Y = A, 2) S = 1: Output Y = B
- **Optical Implementation:**
- Uses photonic components like waveguides and ring resonators for signal routing.
- **Applications**: Optical 2:1 multiplexers are critical for high-speed communication systems, integrated optical circuits, and optical computing.



schematic Diagram of PhCRR

RELEVANCE

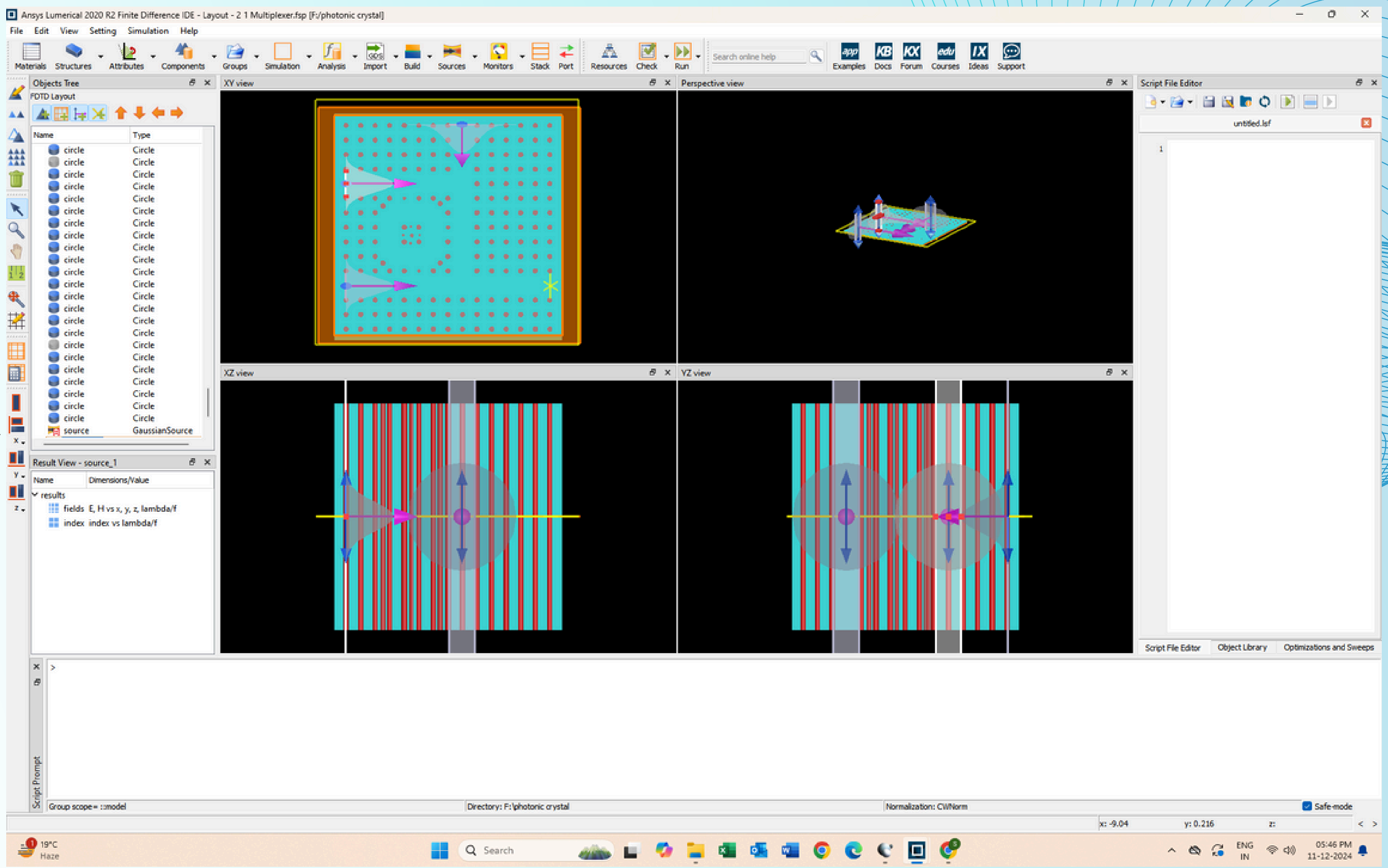
- **Need for High-Speed Communication**: High-capacity and high-bandwidth channels are critical for modern telecommunications, driving the demand for efficient and compact optical devices.
- **Advantages of Optical Structures:** Optical circuits using photonic crystals overcome issues like minor bends, enabling smaller dimensions and easier integration compared to traditional structures based on total reflection.
- **Multiplexing in Telecommunications**: Optical multiplexers allow efficient use of communication channels by enabling wavelength division multiplexing (WDM), which combines multiple wavelengths for transmission and separates them at the destination.
- **Challenges with Existing Structures**: Traditional photonic crystal-based multiplexers have limitations like large dimensions and long delay times, making them less suitable for integrated optical circuits.
- **Proposed Solution and Validation:** The design of a fast, compact, and high-precision multiplexer addresses these challenges, with rigorous validation using RSOFT software and advanced simulation techniques like Plane Wave Expansion (PWE) and Finite Difference Time Domain (FDTD).

FEASIBILITY OF THE PROJECT

- **Technological Readiness**: Advanced simulation tools like ANSYS Lumerical and accessible fabrication techniques for photonic crystals and nonlinear materials make the project technically feasible.
- **Material Accessibility:** Availability of silicon rods and nonlinear materials (e.g., those with Kerr effect) ensures cost-effective sourcing and compatibility with the design requirements.
- **Compact and Scalable Design:** The project leverages adjustable photonic crystal parameters for precise tuning, enabling a small, efficient design suitable for optical integrated circuits.
- **Cost and Time Efficiency:** Simulation-based validation reduces development time and cost, while scalable fabrication methods enable economical mass production.
- **Practical Applications and Challenges Addressed:** The design's compatibility with telecommunication wavelengths (e.g., 1.55 μm) and its ability to overcome limitations like large dimensions and long delay times highlight its practicality and relevance.

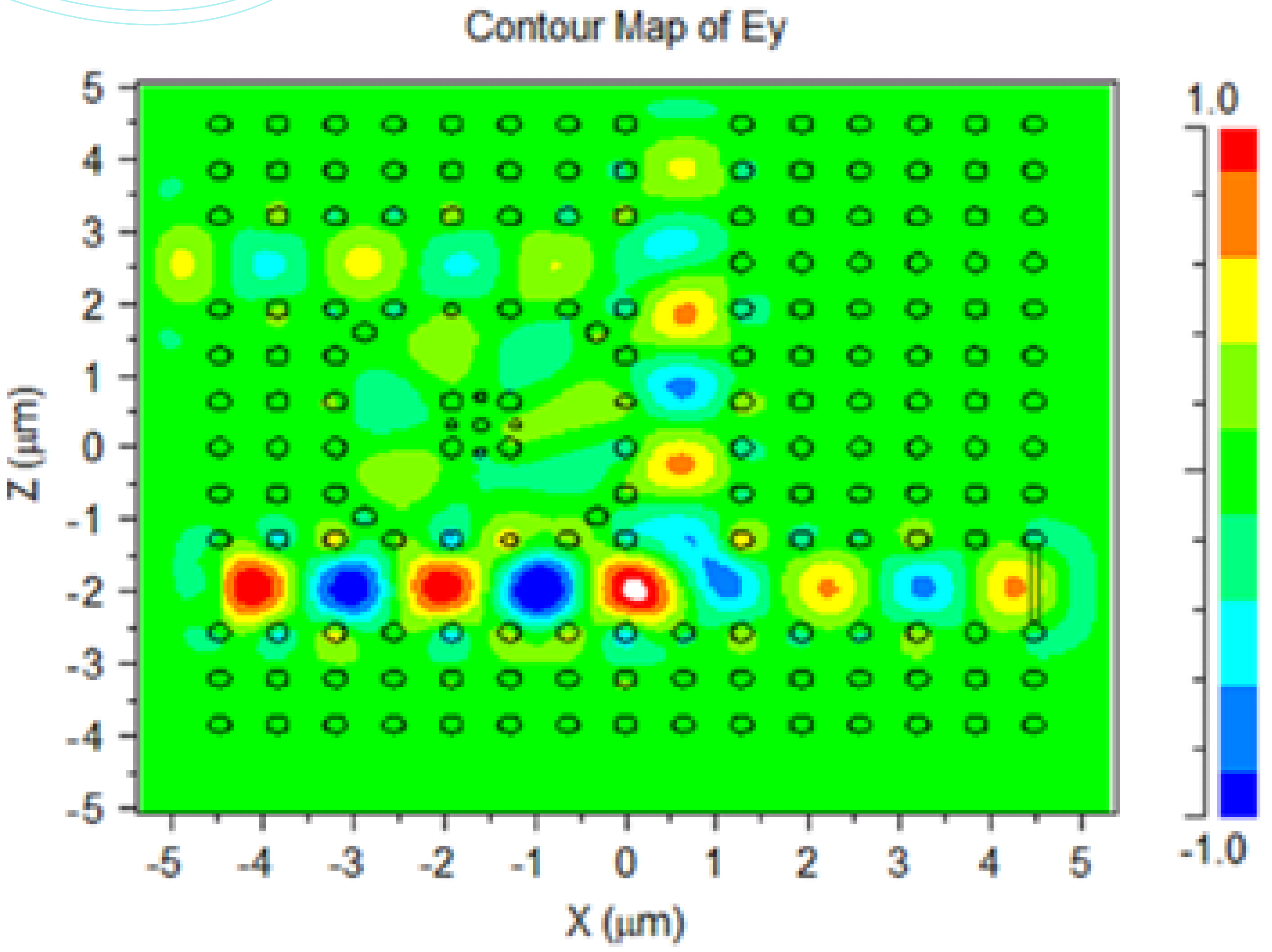
SYSTEM MODEL

1. **Optical 2×1 Multiplexer Design:**
   - The system is a 2×1 optical multiplexer utilizing 2D photonic crystals and a ring resonator to perform logic operations, designed for a refractive index of 3.4 for the silicon rods and 1 for the air background.
2. **Structure and Configuration:**
   - The system consists of three waveguides arranged in a 14×15 square lattice of silicon rods with a radius of 115 nm and a lattice constant of 0.64 µm, set within an air background (refractive index of 1).
3. **Ring Resonator Functionality:**
   - The ring resonator couples light power between waveguides, directing optical power to represent logic 1 (high power) or logic 0 (low power) based on input conditions, using the material's refractive index to control light propagation.
4. **Optimization and Phase Adjustment**:
   - Simulations optimize rod sizes to improve power distribution, with phase adjustments (e.g., -70˚ for input source A and 10˚ for output source B) to enhance output performance.



HARDWARE / SOFTWARE REQUIREMENTS

- **Software:**
  - ANSYS Lumerical FDTD for simulating optical interaction and analyzing resonance pattern

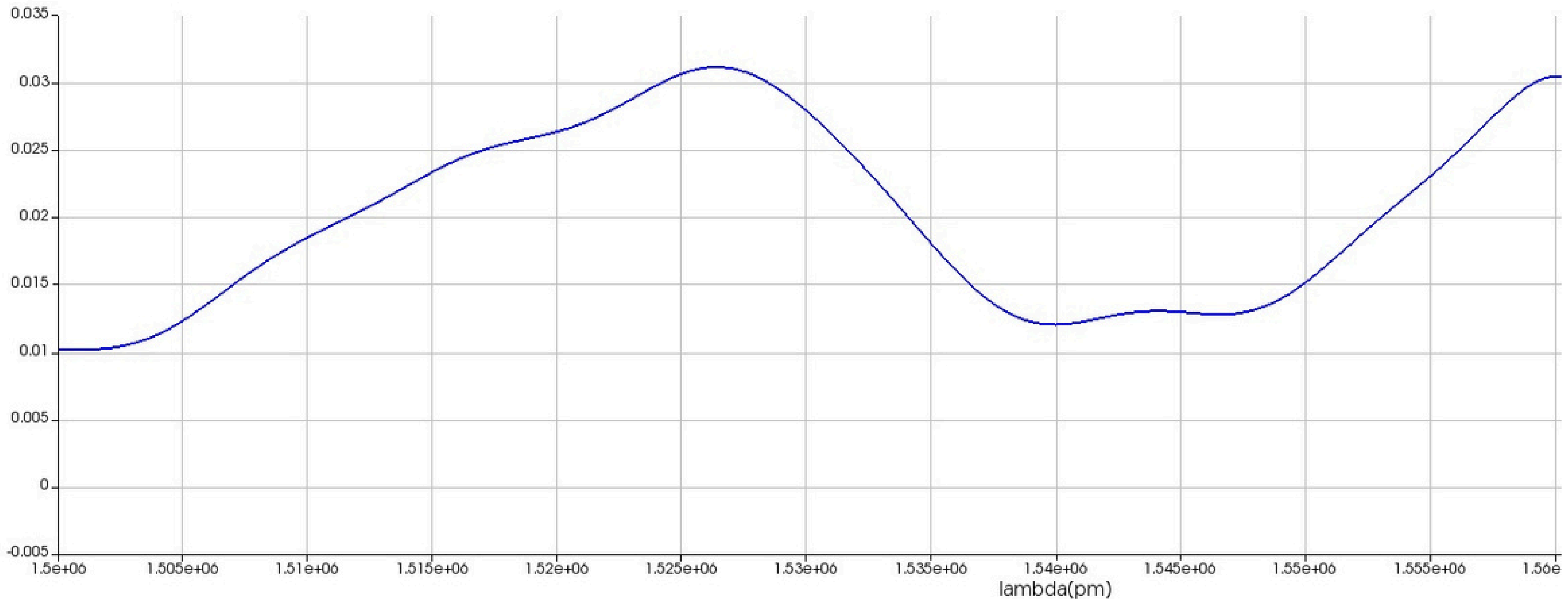


METHODOLOGY

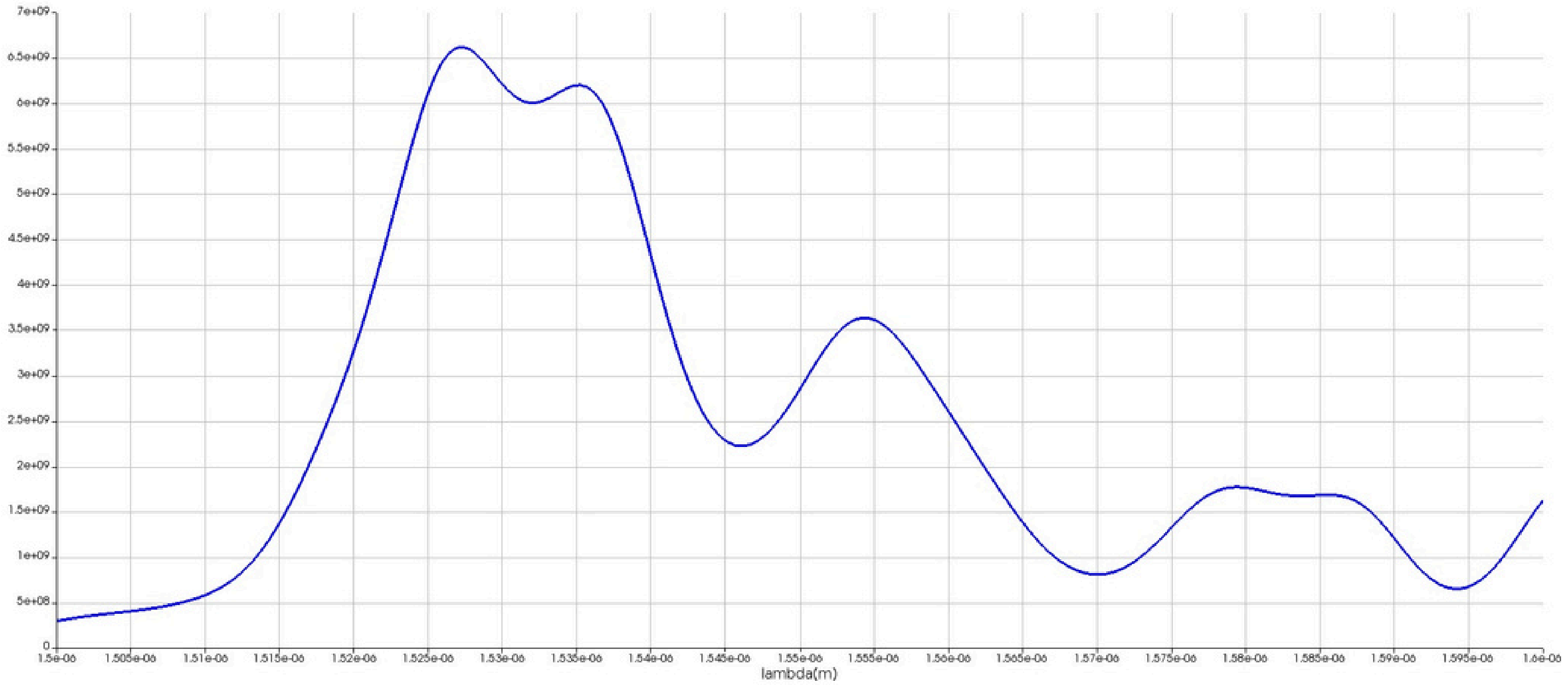
- **Simulation Setup:**
- Define photonic crystal lattice with specified rod arrangement.
- Implement a nonlinear ring resonator coupled between waveguides.
- **Design Optimization:**
- Adjust rod radius and nonlinear coefficients to enhance coupling and logical differentiation.
- **Simulation:**
- Use the Finite Difference Time Domain (FDTD) method for optical signal propagation.
- Validate logic states by evaluating power at outputs.

RESULTS

- Observed the wavelength vs power plot using Ansys Lumerical FDTD.
- Verified changes in light propagation with varying power intensities, demonstrating nonlinear Kerr effect behavior.
- Observed efficient coupling of light from the input (bus) waveguide to the drop waveguide at specific conditions.

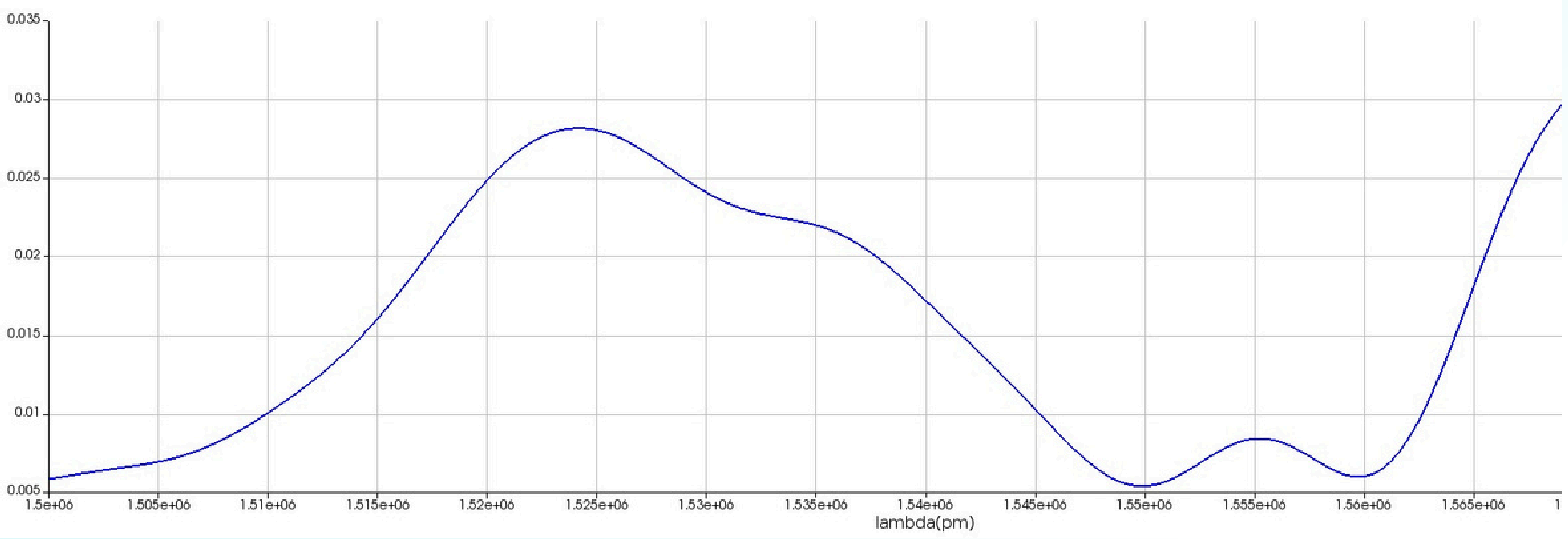


OUTPUT POWER DIAGRAM FOR S = 1, A = B = 0

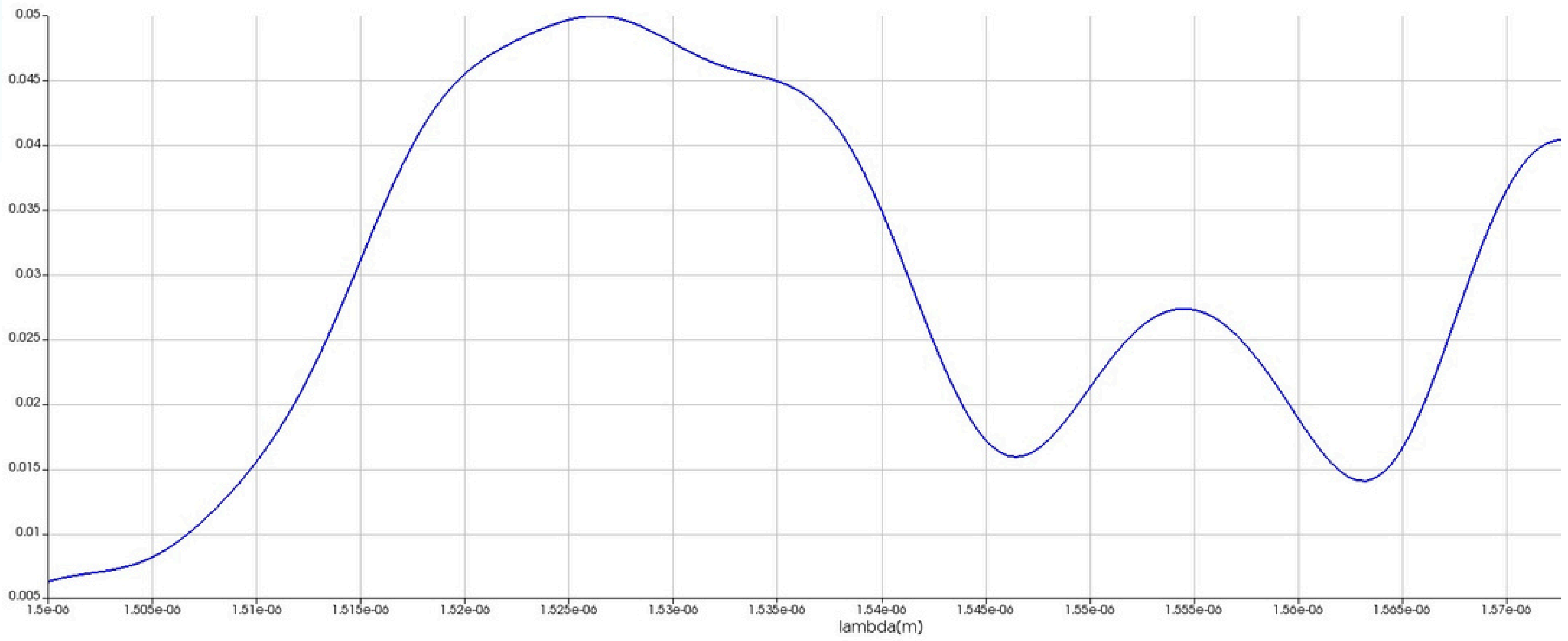


OUTPUT POWER DIAGRAM FOR S = A = 0, B = 1

RESULTS

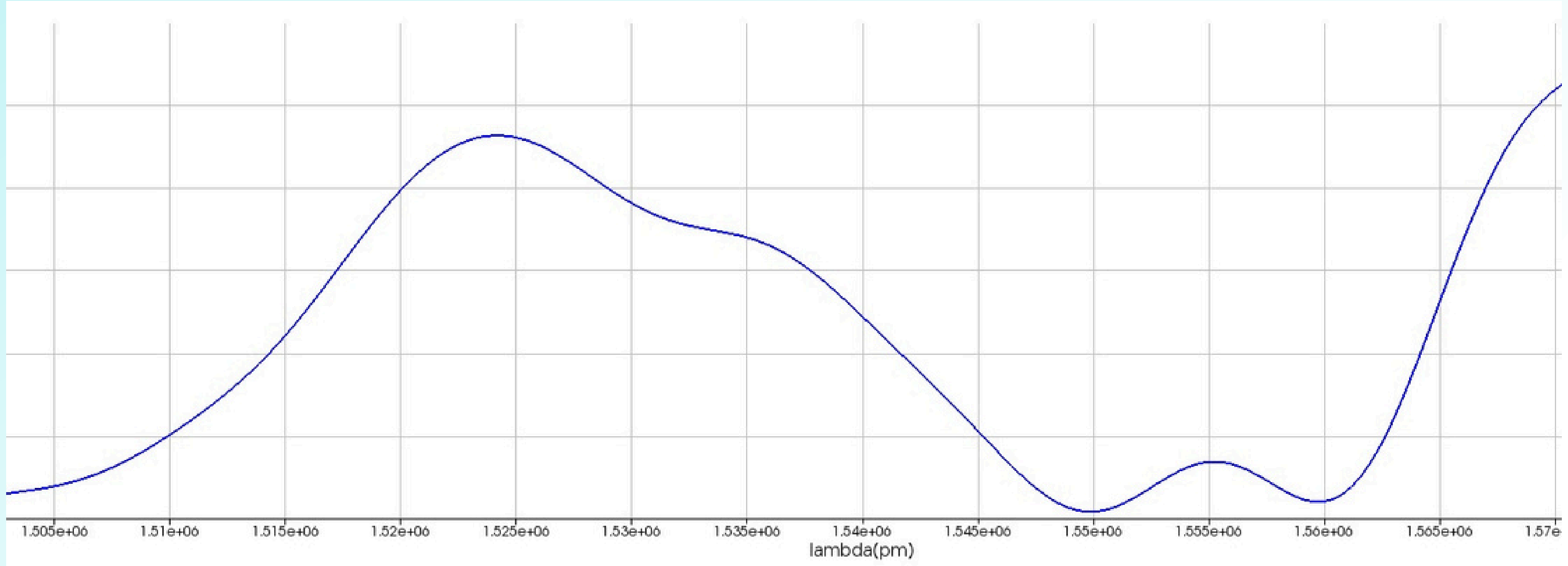


OUTPUT POWER DIAGRAM FOR S = 0, A = B = 1

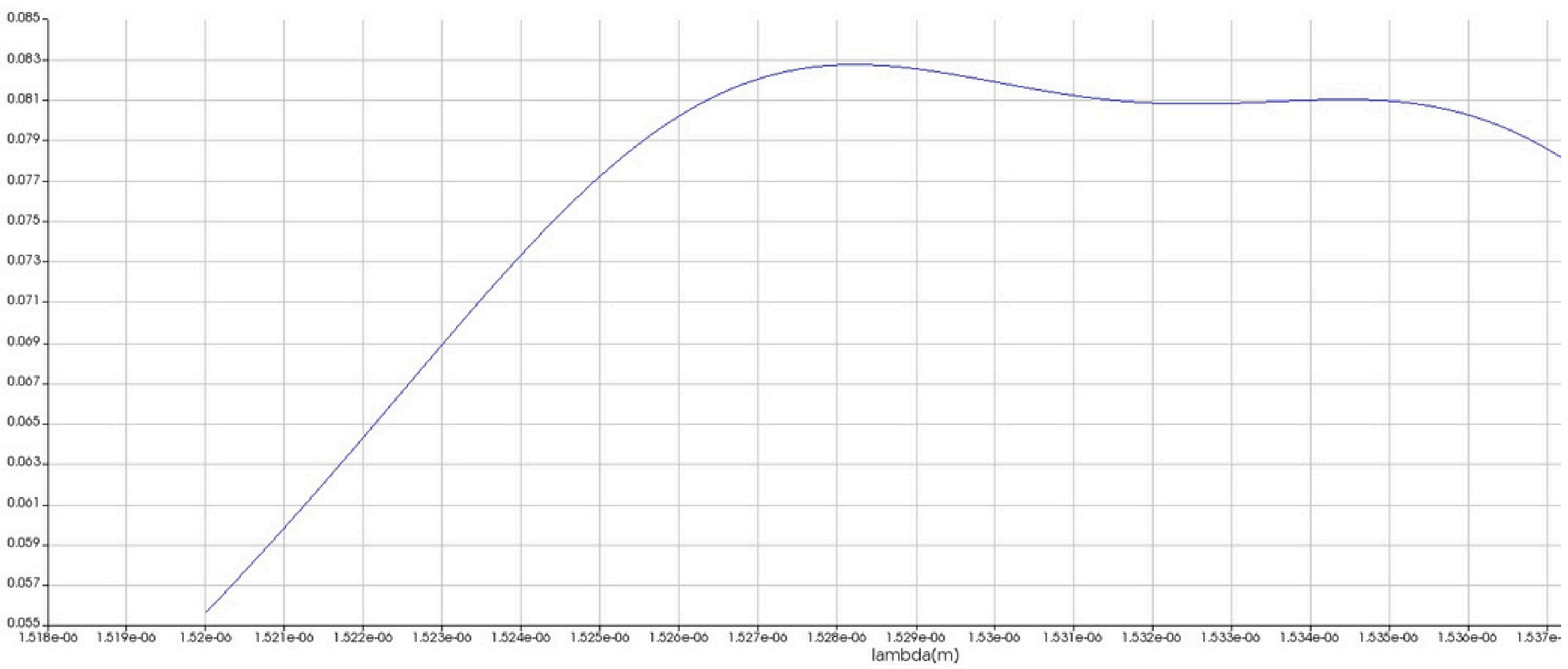


OUTPUT POWER DIAGRAM FOR S = A = B = 1

RESULTS

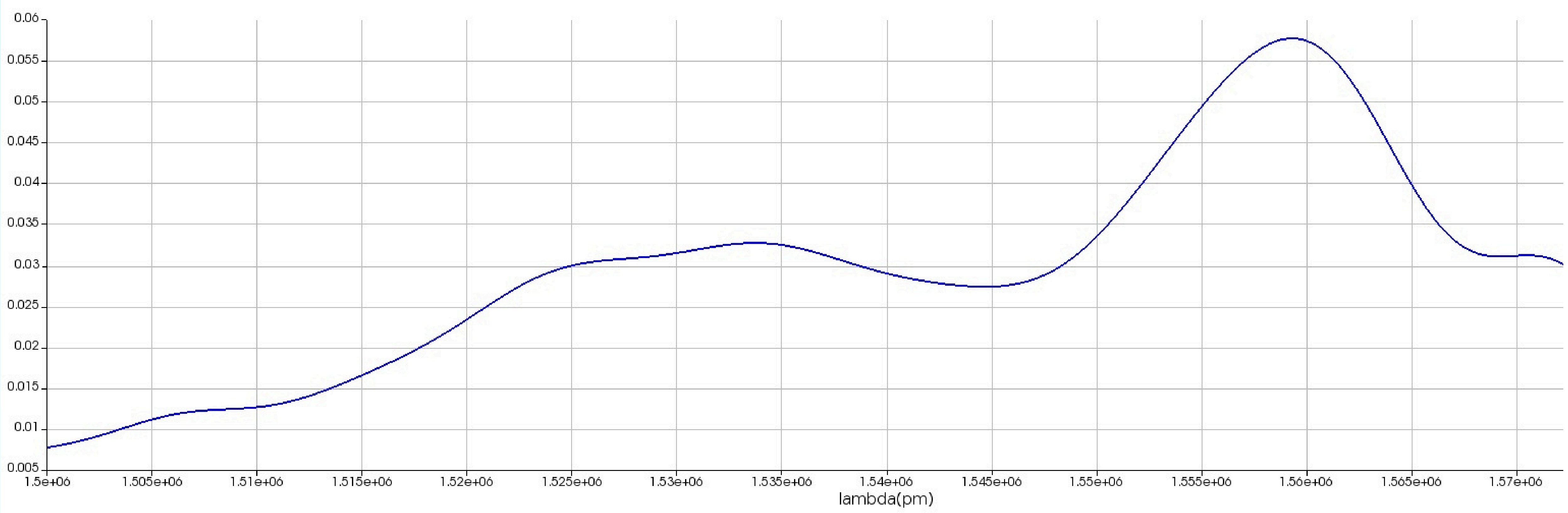


OUTPUT POWER DIAGRAM FOR S = 0, A = B = 1



OUTPUT POWER DIAGRAM FOR S = B = 0, A = 1

RESULTS



OUTPUT POWER DIAGRAM FOR S = A = 1, B = 0

PROSPECTUS OF EXTENDING AS A MAJOR PROJECT

- Explore integration into larger photonic circuits for all-optical computing systems.
- Potential for extending designs to Half adder.
- Applications in high-speed data processing, secure communications, and quantum computing.
- investigate further miniaturization for compatibility with existing chip technology.

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THANK YOU