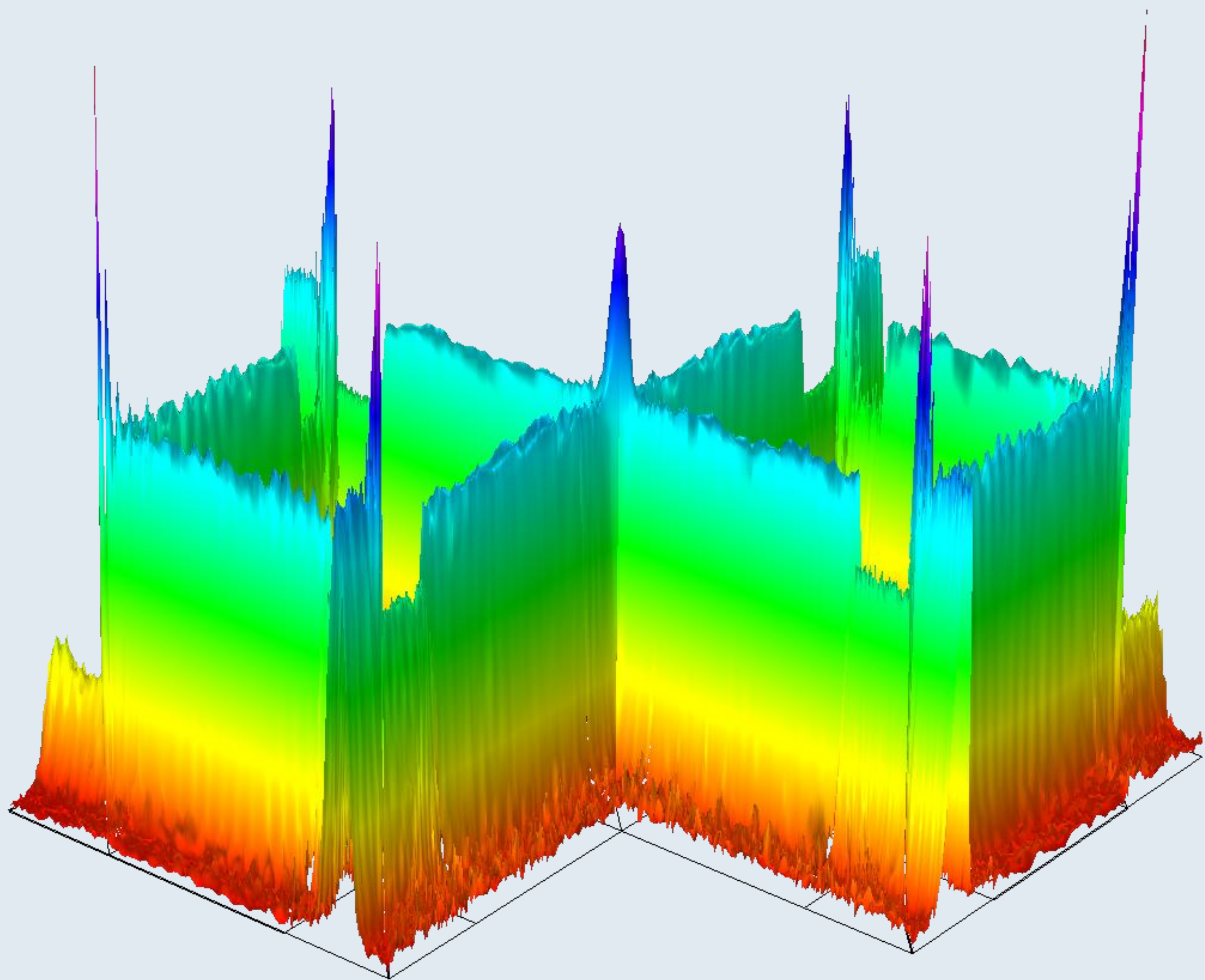




Modeling a Linear Optical Quantum Computer to identify and optimize sources of optical loss

Perform a multivariable sweep changing gaussian beam characteristics, organizational configurations of optical components, and environment temperature to observe impact on loss in a Linear Optical Quantum Computer

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Abstract

Optical systems are a promising platform for quantum computation, but one of the engineering constraints that hinder development in the field is optical loss within linear optical quantum computers (LOQC). LOQC systems use photons to serve as the qubit source and optical components such as beamsplitters and wave plates to apply quantum logic gates. Consequently, optical loss contributes to the decoherence of quantum states in an LOQC, which physicists aim to minimize. Optical loss can arise from several sources,

including but not limited to: mismatch of characteristic photon parameters relative to design specifications, material properties differences dependent on environment temperature, and the physical organization of these components. We are interested in seeing if we can recreate a three qubit LOQC in COMSOL, and perform a multivariable parameter sweep over a loss function that we aim to minimize in order to find the most optimal LOQC design parameters.

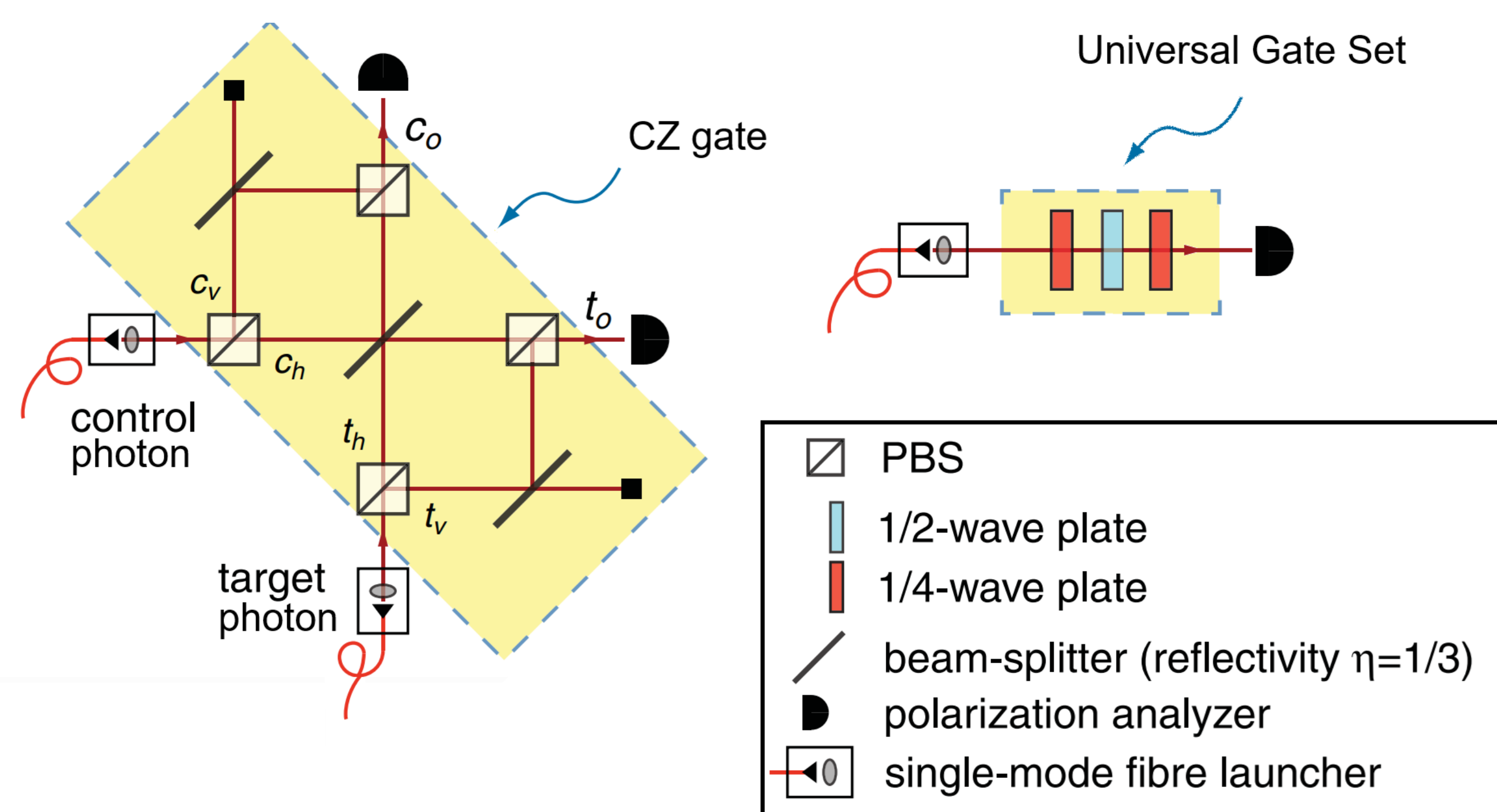


FIGURE 1: Organization of optical components required to implement an entangling CZ gate and Universal Gate set on photonic qubits. Image reproduced and modified from reference 1.

Methodology

Our LOQC will be comprised of a Control-Z gate applied to qubits 1 & 2, and a universal gate set being applied to qubit 3. The Control-Z gate is designed according to the interferometric CZ gate model (ref. 1), comprised of 4 Polarizing Beamsplitters (PBS), 3 non-polarizing beamsplitters that split inputs at a 2:1 ratio, and two input photon sources. We utilize COMSOL's PBS application builder [ref 2] to design a PBS constructed with SF5 glass prisms and 7 alternating thin film layers of alternating Zinc Sulphide and Magnesium Fluoride. The design input wavelength is 900nm and bandwidth of 400nm. Beamsplitters are simply constructed using Silver thin films. The universal qubit gate set is modeled by implementing quarter, half, and quarter waveplates made of Magnesium Fluoride in succession following the third photon source. Perfectly Matched Layers are used to prevent inaccurate standing wave reflections together with scattered light capture from matched boundary conditions.

Results

We run a parameter sweep over wavelength and beam width of the gaussian beam (photon source), the temperature (refractive index parameter, and air domain length (organizational distance). Integration operations of the Poynting power flow vector are used to determine the proportions of light outputted at the photon dumps and qubit output boundaries. In a 100% ideal experiment, Photon Dumps = $\frac{2}{3} * P_{out}$, Qubit Output = $\frac{1}{3} * P_{out}$, and Photon Dumps + Qubit Output = $P_{in} = P_{out}$. In practice, the change in wavelength from design specifications alone can lead to huge variance from the target results.

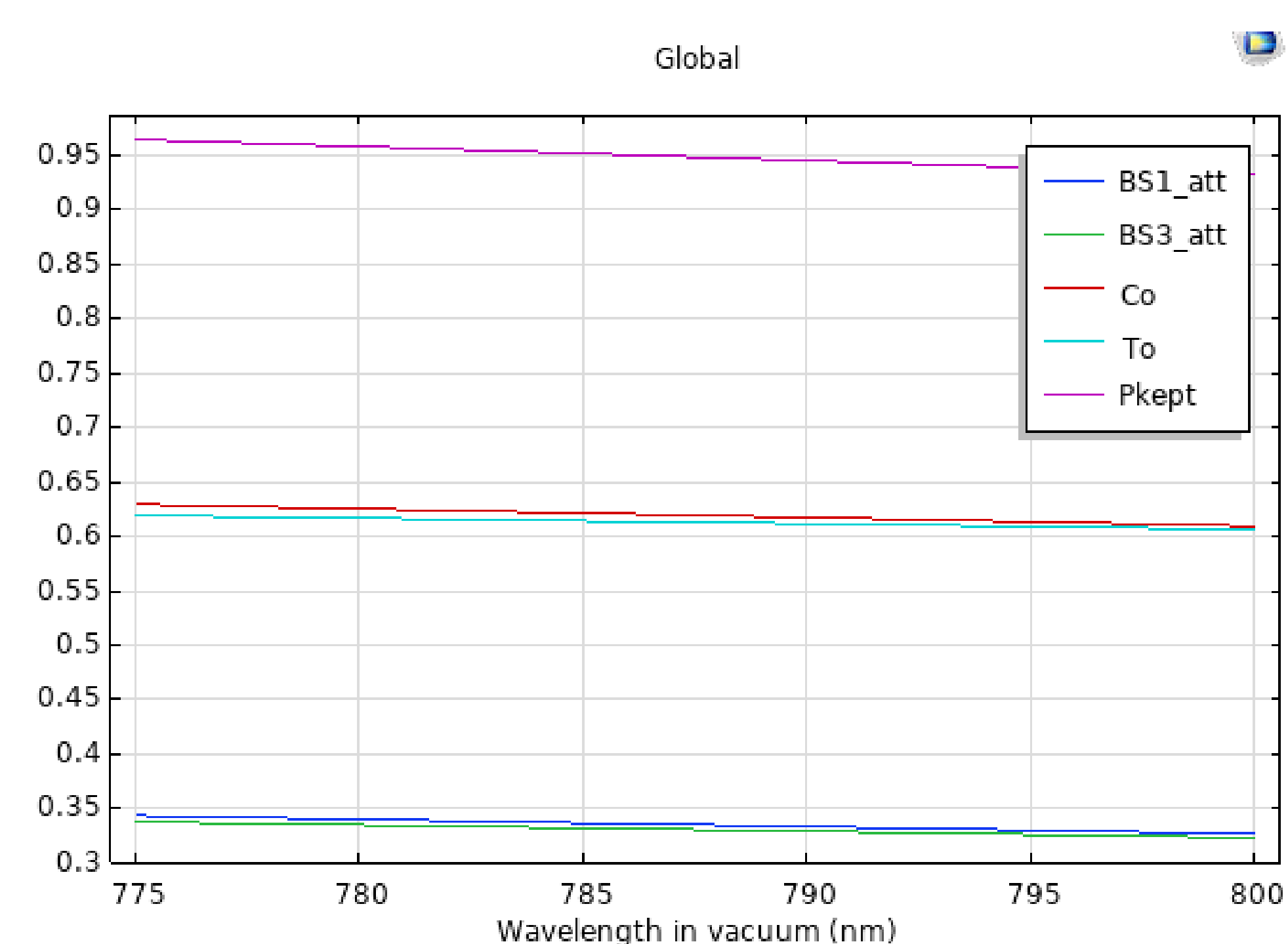


FIGURE 2: Plot of simulated attenuation factors for the photon dumps and the fraction of the qubit outputs for the qubit measurements in the CZ gate.

REFERENCES

1. N. K. Langford et al., "Demonstration of a Simple Entangling Optical Gate and Its Use in Bell-State Analysis", Physical Review Letters, 95 (vol.), 210504 (pp.), 2005.
2. A. Weingartner, "Study the Design of a Polarizing Beam Splitter with an App", COMSOL Blog, 2016.



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