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Attention Mechanisms for Broadband Feature Prediction for Electromagnetic and Photonic Applications

Ergun Simsek[1], Masoud Soroush[1], Gregory Moille[2,3], Kartik Srinivasan[2], Curtis R. Menyuk[1]
[1]*Dept. of Comput. Sci. & Electrical Eng., University of Maryland Baltimore County, Baltimore, MD 21250, USA*
[2]*Microsys. & Nanotech. Div., National Institute of Standards & Technology (NIST), Gaithersburg, MD 20899, USA*
[3]*Joint Quantum Institute, NIST/University of Maryland, College Park, MD 20742, USA*

Ring resonators are widely used in optics and photonics as critical elements of optical modulators, filters, switches, sensors, and lasers [1]. Light is typically coupled in and out of ring resonators via an adjacent waveguide through evanescent coupling. The coupling quality factor (Q_c) is wavelength-dependent, as both the spatial mode overlap and the phase mismatch vary with wavelength.

With the ability to unravel complex relationships between the inputs and outputs of non-linear systems, ML methods have become a popular research topic in recent years in almost all areas of science and engineering, including photonics. In this work, we first use traditional neural networks, namely fully-connected and recurrent neural networks (FCNNs and RNNs, respectively), to predict the Q_c of microring resonators across broad spectral bandwidths. This study is based on a library of results for Q_c for a given ring resonator, which is generated by determining the electric field profiles inside the waveguide and ring resonator for a chosen frequency, and then calculating Q_c using the coupled mode theory formalism. This procedure is followed for a wide range of frequencies, e.g., over an octave, and for a variety of different waveguide geometries (parameterized by the waveguide width, resonator-waveguide gap, and pulley coupling length). For the second part, we try to achieve the same goal with attention mechanisms [2], which are one of the most prominent but least frequently used deep learning architectures, and have the potential to be employed in both time- and frequency-domain applications.

Our results show that when trained with sufficiently large data sets, our models are able to accurately predict the coupling quality factor of microring resonators across broad spectral bandwidths (e.g., input and output data sets include Qc values from f to $1.5f$ and $2f$ to $2.5f$, respectively). However, the most accurate results and efficient learning are achieved with attention mechanisms, see Figs. 1 (a) and (b) to compare ground truth vs. prediction, respectively. We have achieved a six-times reduction in computing time [3]. This approach is a significant improvement over the traditional approaches, which are laborious and computationally intensive, and has the potential to pave the way for new and innovative applications in the fields of electromagnetics and photonics.

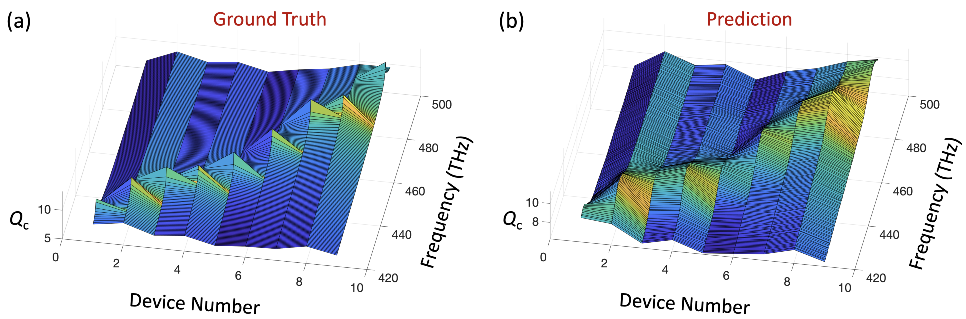

Fig. 1: (a) CMT-determined vs. (b) predicted Q_c values for 9 devices in the frequency range of interest.

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