Optical Bistability As Neural Network Nonlinear Activation Function

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Introduction

All-optical Artificial Neural Networks

Applying integrated photonics to artificial neural networks architecture design

Develop simulations on standard software libraries that help performance comparisons

Outline

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Introduction

Artificial Neural Networks

Microring Resonator

ANN Simulations

Conclusion

Outline

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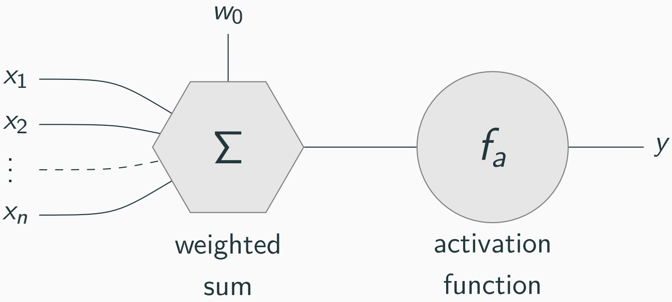
Artificial Neural Networks

ANNs

Artificial Neural Networks are computation systems, composed by a collection of nodes that work seemingly biological neurons.

ANNs blocks

ANNs are composed by single units, *nodes*, which elaborate the information in a way loosely similar to biological neurons.



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- clustering
- pattern recognition
- time series prediction

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figures/foo.png

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figures/foo.png

How do they work?

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ANNs can obtain arbitrary decision regions[1]

The amount of free parameters in an ANN, allow ... ?

[1] R. O. Duda et al., *Pattern classification*, (John Wiley & Sons, 2012)

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  - evaluate loss
  - adjust parameters
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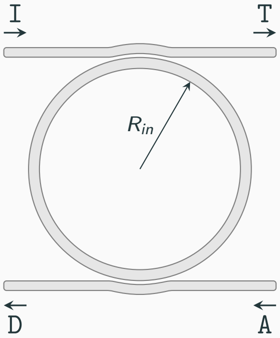
Microring Resonator

MRR

Consider a MRR in the
Add-Drop Filter configuration

$$\mathtt{T}(\omega) = f\,[\ \mathtt{I}(\omega)\ ]$$

$$\mathtt{D}(\omega) = f\,[\ \mathtt{I}(\omega)\ ]$$



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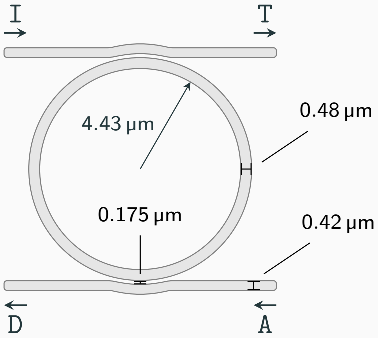

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$$\mathtt{T}(\omega) = f\,[\;\mathtt{I}(\omega)\;]$$
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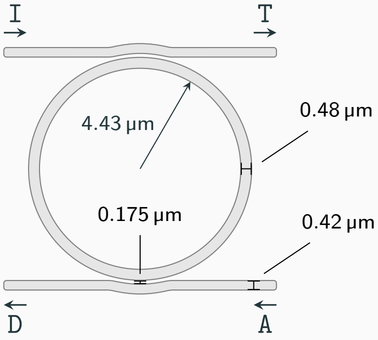
Coupling is governed by

$$\tau \quad \text{and} \quad \kappa.$$



Theory

Linear

Theory

Nonlinear

Experiments

Setup

ANN Simulations

Simulation Framework

What means simulating? PyTorch library

Fundamental blocks

model ($FF[f_a]$)

loss criteria (CEL)

weight update criteria (SGD)

model $(FF[f_a])$

Cross-Entropy Loss (also known as negative log likelihood),

$$L(y,\hat{y}) = f_{CEL}(y,\hat{y}) = -\frac{1}{N}\sum_{n=1}^{N}\sum_{i=1}^{C} y_{n,i}\log\left(\hat{y}_{n,i}\right)$$

Stochastic Gradient Descent

with *momentum*

and *learning rate scheduler*.

Operation Tests

ReLU vs Sigmoid vs f_{fit}

Conclusion

Overview

I assembled an experimental setup from scratch

I characterized the response of the MRR in several aspects

I implemented the bistable response in standard software libraries

Future Perspectives

Continue the current work with a quantitative analysis of specific features

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Enhance the physical theory to describe time dependent phenomena

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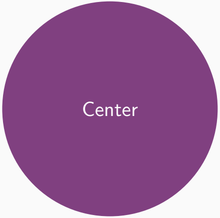
Enhance the physical theory to describe time dependent phenomena

Proceed with the development of the simulations to include all the characteristics of the physical system

Mindmap



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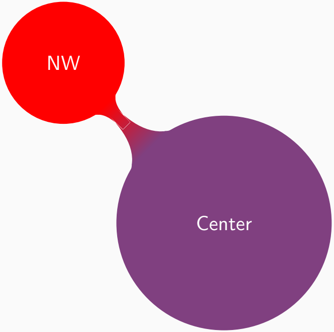

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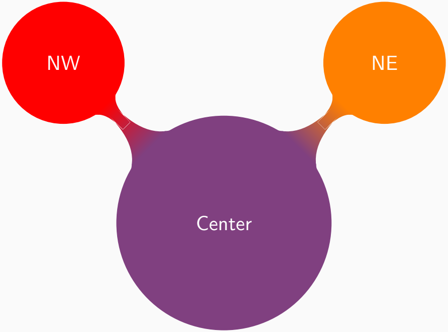

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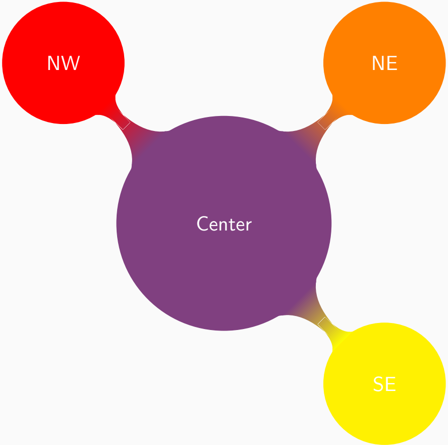

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