

Optimization of an Optical Shutter using Machine Learning

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Purpose/Goals:

- Sensor protection using optical shutter with phase change material vanadium dioxide (VO_2)
- Desired optimization of optical shutter design
- Coupled electromagnetic (EM) / thermal inverse design problem
- Use performance neural network (Perf NN) trained to representative data to replace costly solver calls
- Utilize Perf NN along with fully connected NN (TopOpt NN) [1] to perform topology optimization

[1] Chandrasekhar and Suresh,
<https://doi.org/10.1007/s00158-020-02748-4>

Background:

- VO_2 : insulating to metallic phase at 67°C (340 K)
- Metrics include extinction ratio (how effective the filter is) and temperature rise (important for switching performance)
- Focus optimization on extinction ratio of 10 dB and temperature rise of $>10\text{K}$ (avg. incoming optical power 1 kW/cm^2)

Method:

- Generate training data (~15K) for Perf NN using simplified COMSOL model (EM freq. domain + thermal time domain)
- Divide $2\times2\text{ }\mu\text{m}$ repeating unit cell into 100 nm sub-pixels (20×20)
- Utilize symmetric image [2] to minimize DOFs
- Train Perf NN to predict design performance
- Couple TopOpt NN (closely matches [1]) w/ trained Perf NN
- Train TopOpt NN to predict density function

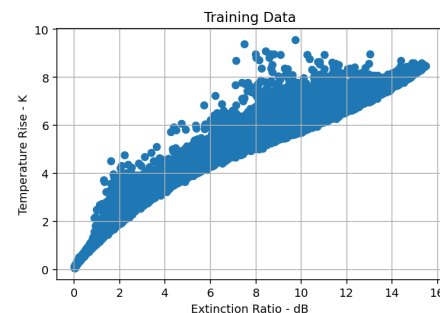
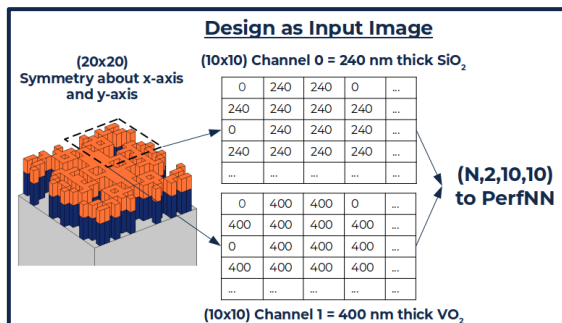
[2] Chen et al,
<https://doi.org/10.48550/arXiv.2111.05949>

Results:

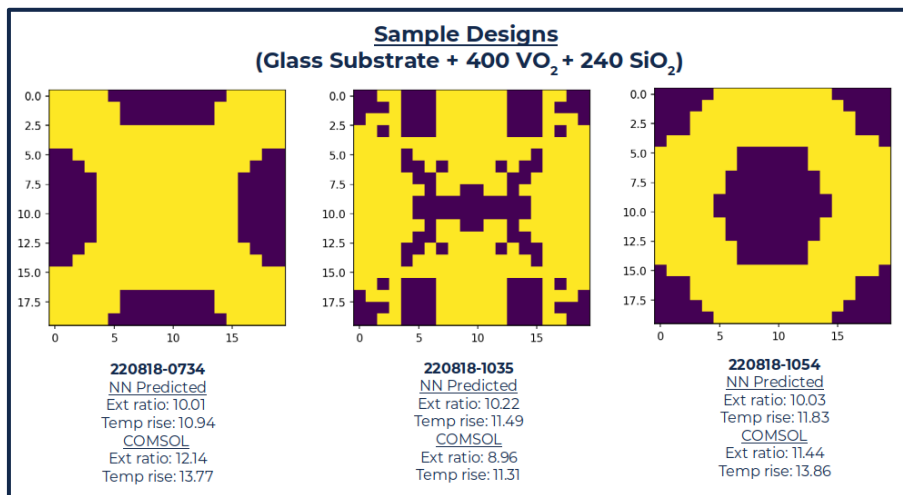
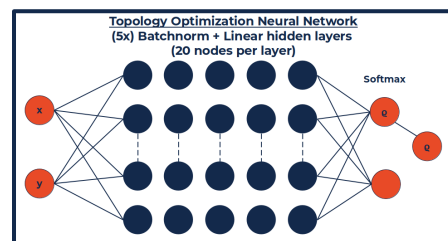
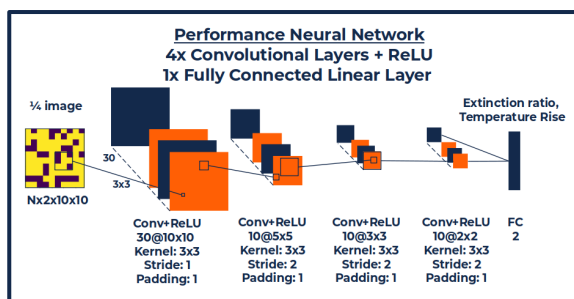
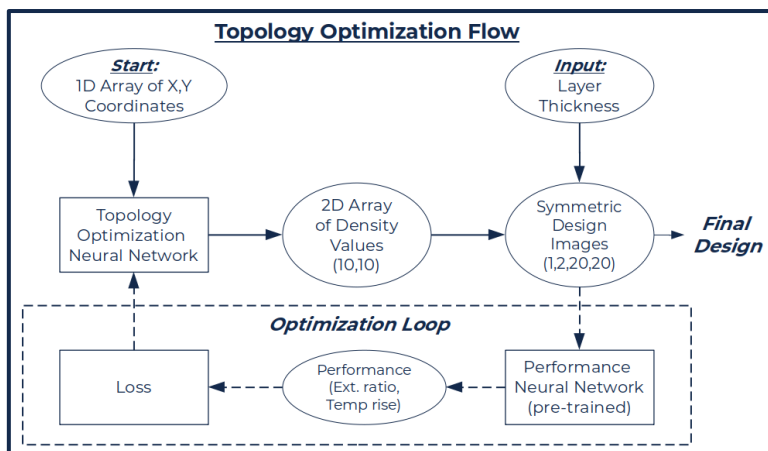
- Perf NN training performance
 - Avg abs error: ~13% ext, ~.04% temp
 - Max diff: ~1.5 dB ext, ~1.6 K temp
- TopOpt NN minimizes loss function and provides a proposed solution (not unique)
- COMSOL confirms that proposed design exceeds performance of training data

Potential future work:

- Fabrication and testing of designs
- Expand on use of NN's to solve the inverse design/optimization problem



$$\text{Ext ratio} = 10 \log_{10} \frac{Tr_{ins}}{Tr_{met}}$$



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