

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 >10K (avg. incoming optical power 1 kW/cm²)

Method:

- Generate training data (~15K) for Perf NN using simplified COMSOL model (EM freq. domain + thermal time domain)
- Divide 2x2 μm repeating unit cell into 100 nm sub-pixels (20x20)
- 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

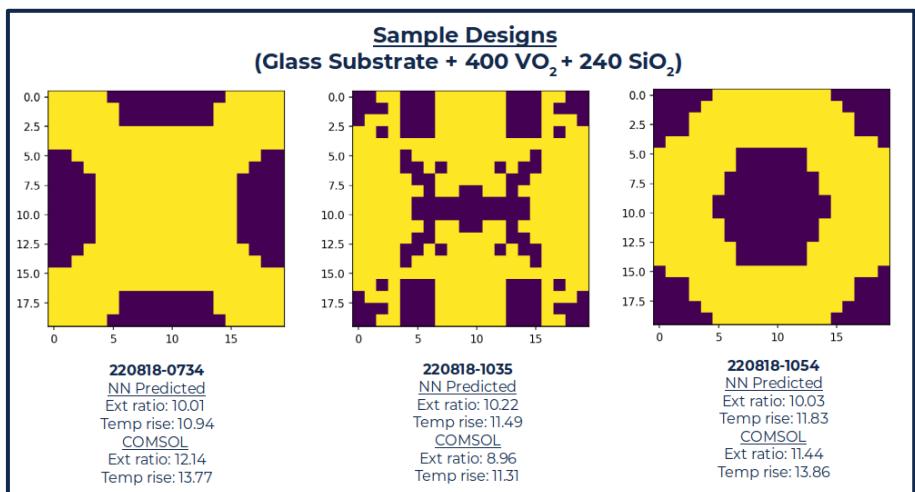
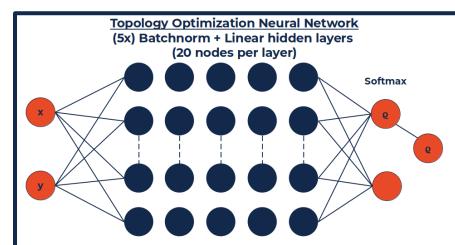
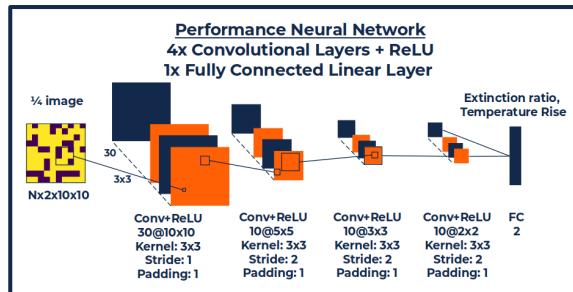
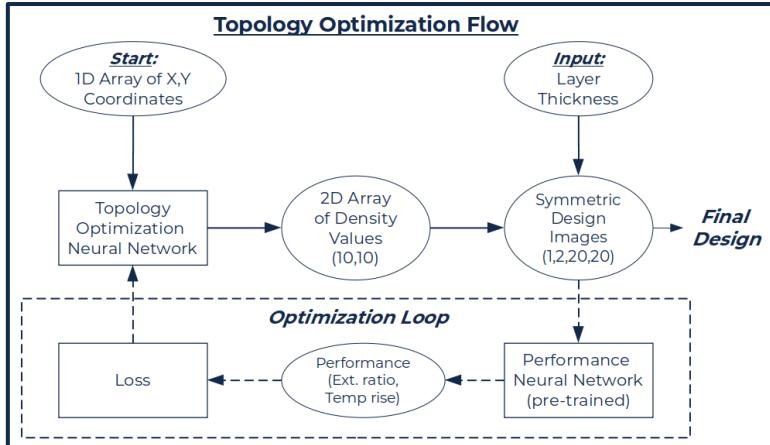
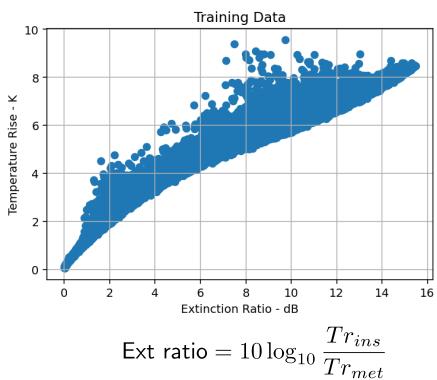
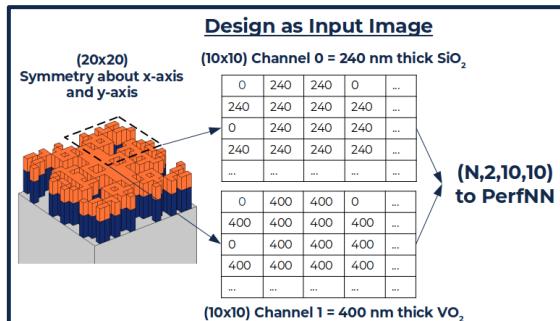
[2] Chen et al, <https://doi.org/10.48550/arXiv.2111.05949>

Results:

- Perf NN training performance
 - Avg abs error: ~13% ext, ~0.4% 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



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