Thin-Film Design Refinement Via Efficient Parallel Combinatorial Search

Jonathan R. Birge

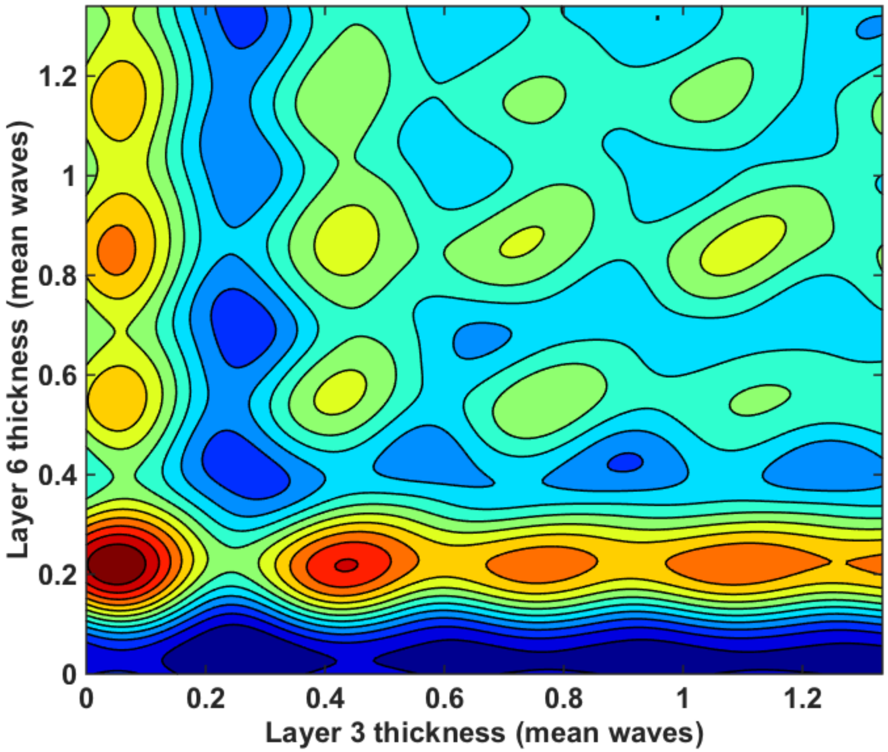
OIC 2016

LINCOLN LABORATORY
MASSACHUSETTS INSTITUTE OF TECHNOLOGY

Thin Film Merit Function Structure

• 14 layer AR coating on 1.52 substrate • Uniform thin layer initial conditions • low index: 1.35, high index: 2.35

Merit function of AR coating versus two layer thicknesses

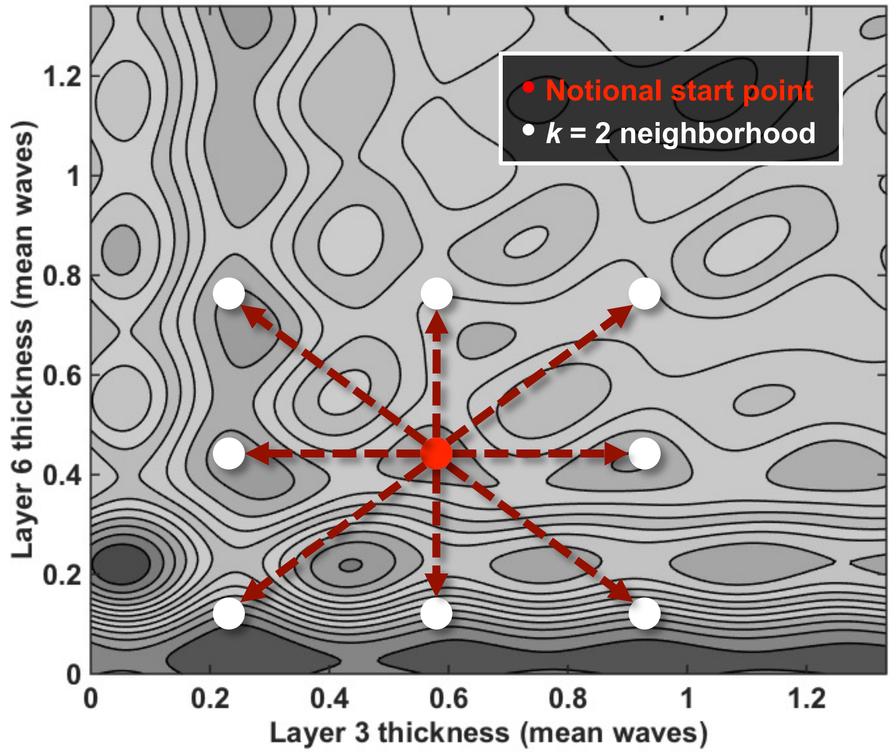


- **Local minima tend to be spaced quasi-uniformly by ¼- to ½-wave of mean optical thickness**

Combinatorial Search Concept

- 14 layer AR coating on 1.52 substrate
- Uniform thin layer initial conditions
- low index: 1.35, high index: 2.35

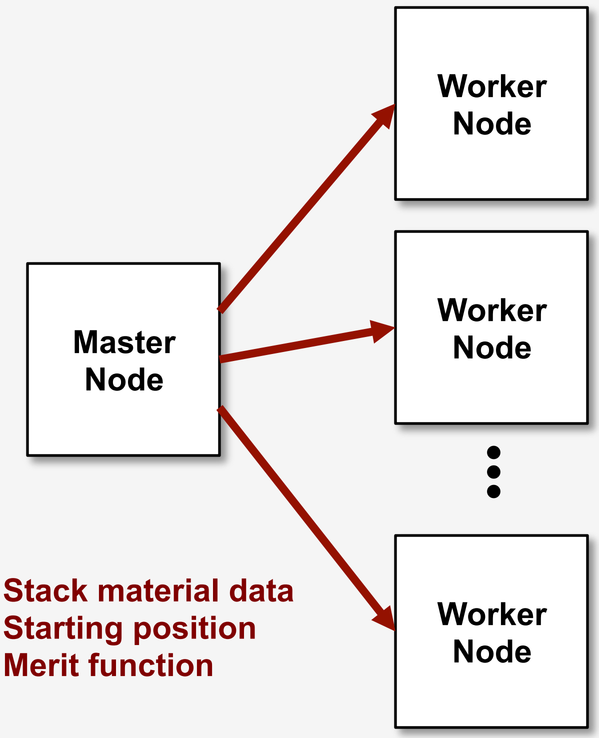
Merit function of AR coating versus two layer thicknesses



- **Searching for better local minima can be done by simultaneously perturbing groups of *k* layers by enough to escape local minima and reoptimizing**

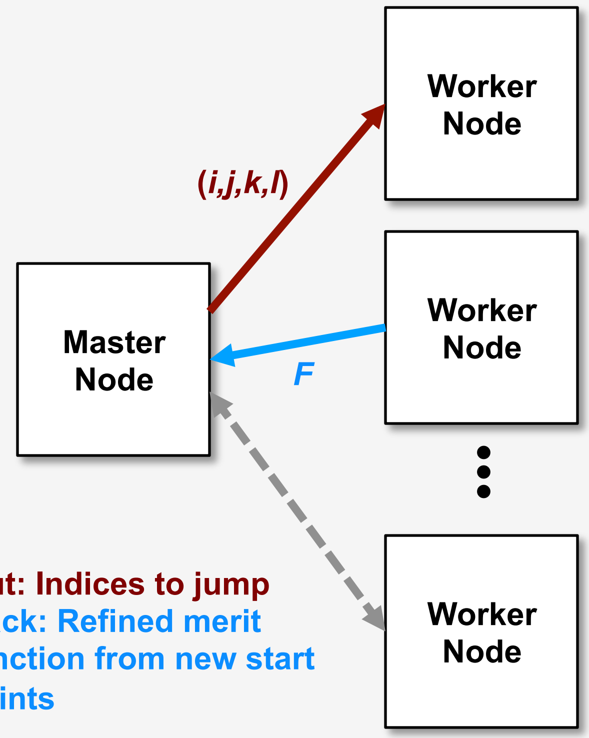
Parallelization Approach

Initialization



- Stack material data
- Starting position
- Merit function

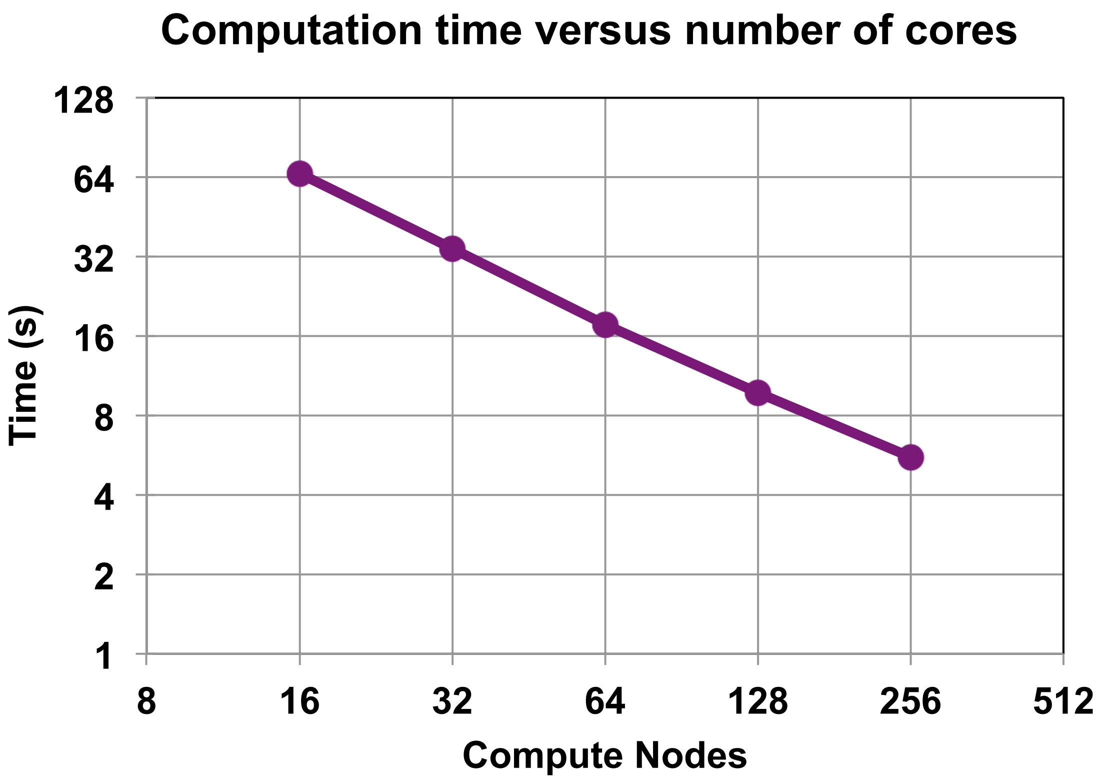
Asynchronous Scheduling



- Out: Indices to jump
- Back: Refined merit function from new start points

- **Dynamic computation assignment prioritizes uniform node utilization over communication efficiency in the face of unpredictable computation times**

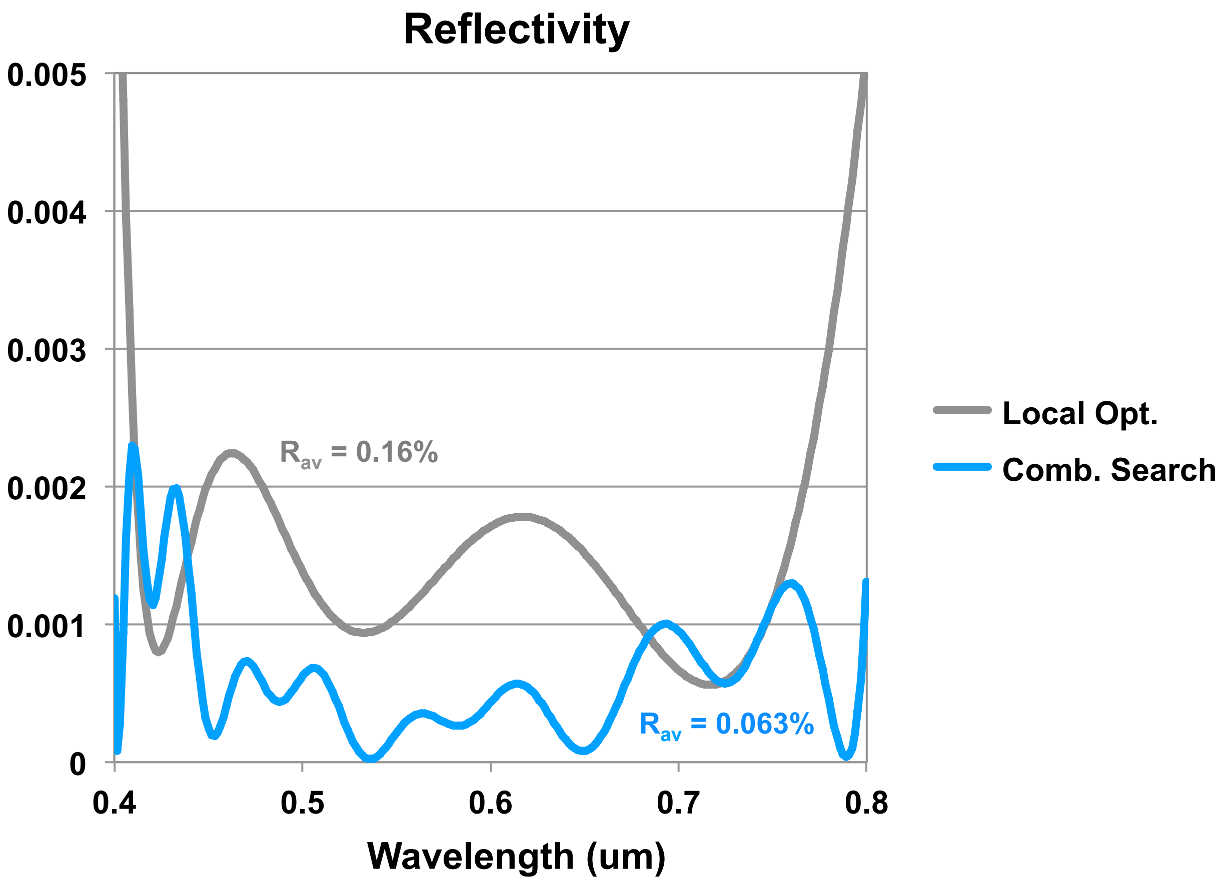
Implementation Efficiency



- **Computation time scales linearly with processor count**
- **Parallel algorithm is not communication-limited**

AR Coating Design Example

- 18 layer AR coating on 1.52 substrate
- Low index: 1.38, high index: 2.35
- Trivial start point: uniform 1/20th mean wave layers
- $k = 2$

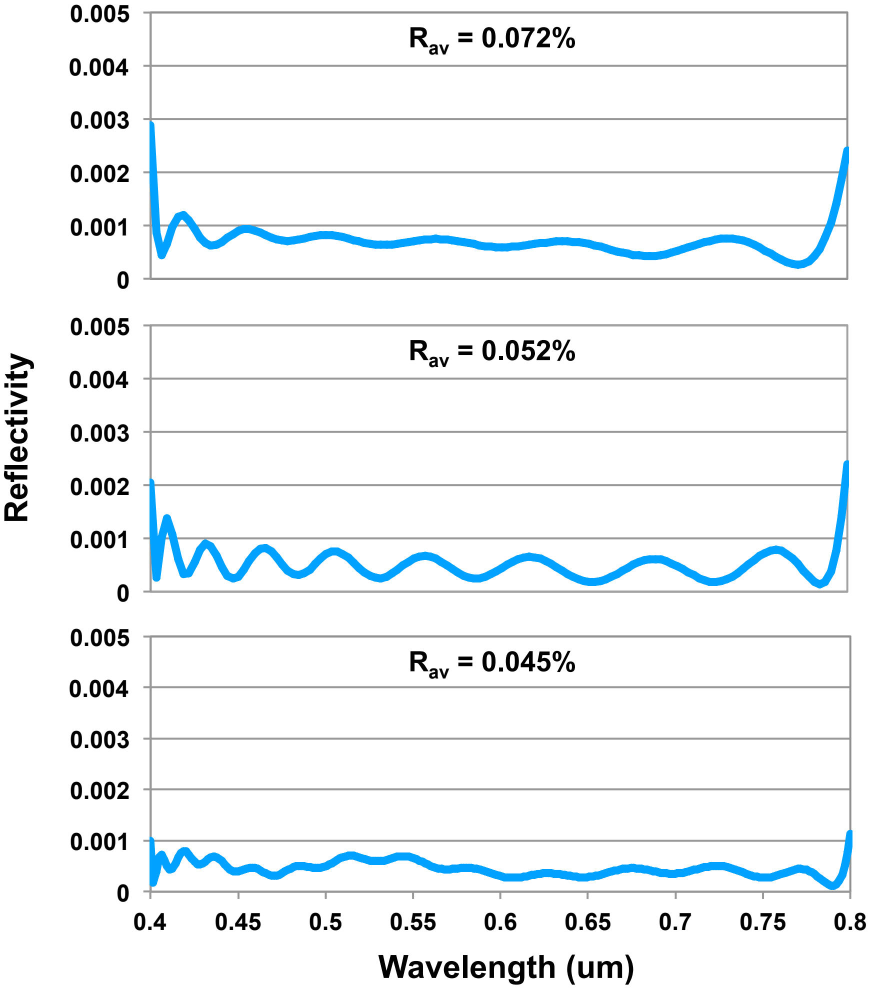


*Following Dobrowolski et al, "Optimal single-band normal-incidence antireflection coatings", Optics Letters **35** (1996)

AR Coating Design Results

• 14 layer AR coating on 1.52 substrate • Low index: 1.38, high index: 2.35 • *k* = 4 search space

Combinatorial opt. from trivial start point

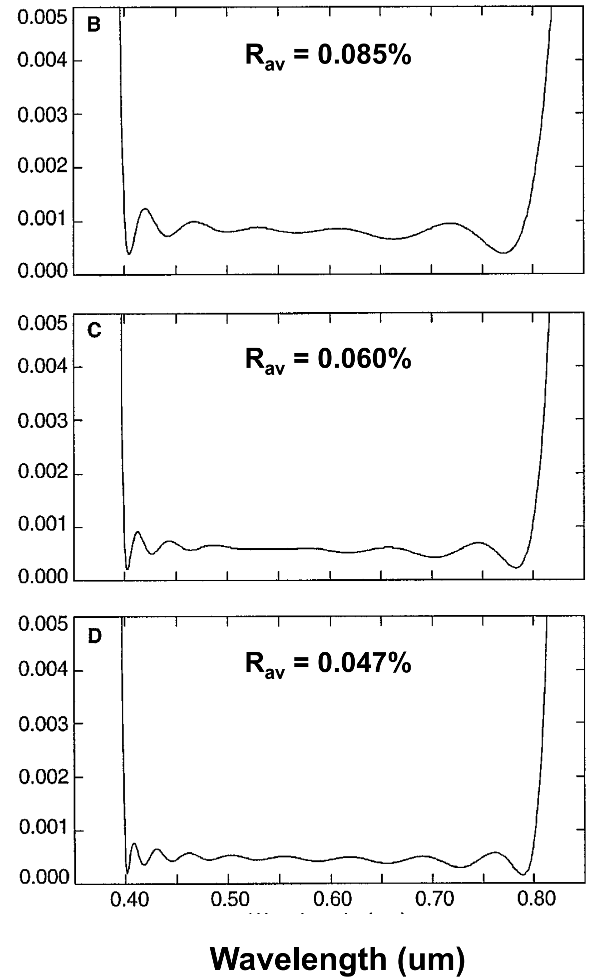


N = 14

N = 20

N = 26

Antireflection coating literature*



*J. A. Dobrowolski et al, "Optimal single-band normal-incidence antireflection coatings", Optics Letters **35** (1996)

Future Work

- Test on other design genres
  - Initial work on stop/pass-band shows promise, albeit not as dramatic as AR coating
- Integrate into larger optimization schemes (e.g. gradual refinement, needle optimization, etc.)
- Adaptive jump size determination
- Implement on commodity cloud hardware (e.g. Amazon EC2)
- Integrate with manufacturing tolerance merit functions