Manufacturable Gradient Index Optics (M-GRIN)

SeeMe Proposer's Day

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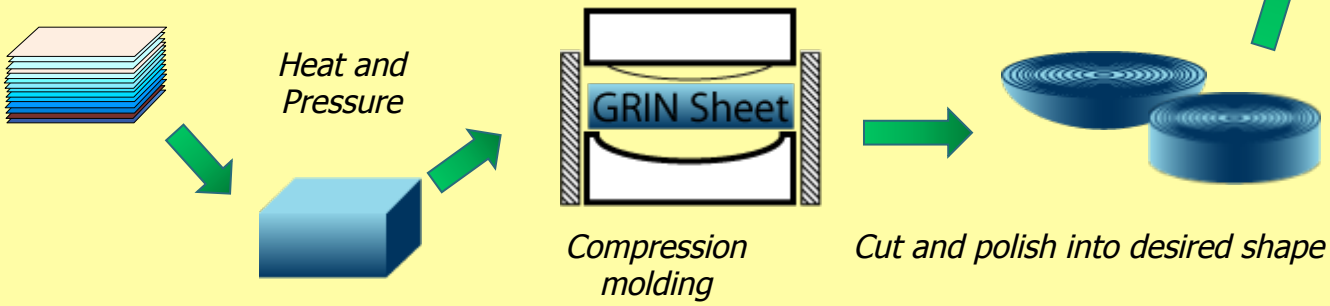
A solution for lenses

By bending light through tailored, graded- index-of-refraction lenses, GRIN optics reduce the complexity of lens assemblies

Conventional SWIR lens

GRIN-based SWIR lens prototype is 7.5x lighter and 3.5x smaller than fielded SWIR lens

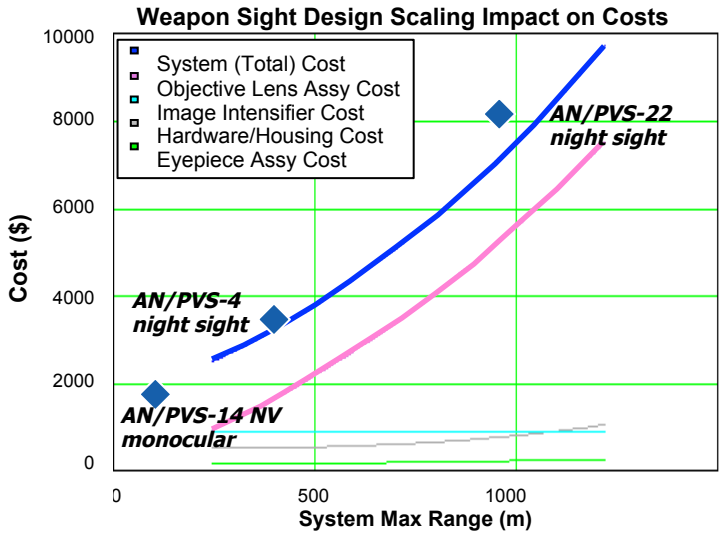
Example enabling technology

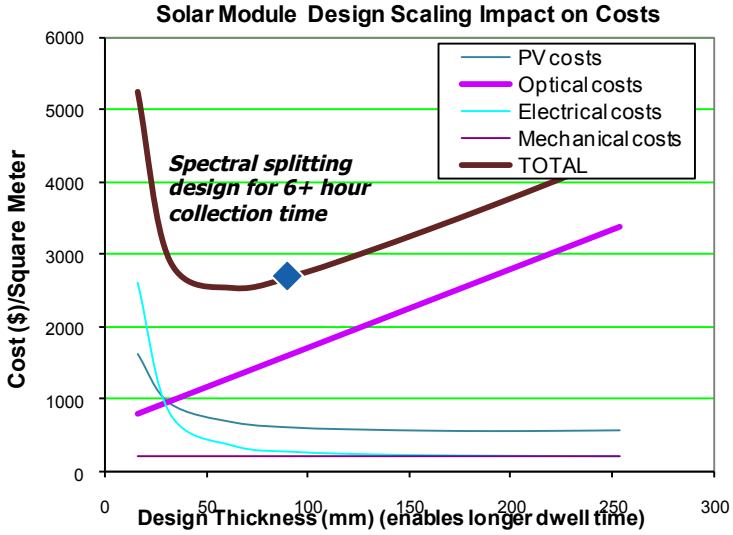


Advances in plastic extrusion enable thin films of different refractive indices to be combined and shaped to direct light arbitrarily through a lens

The problem with lenses

- Every component of an optical system has become lighter and smaller over the last century EXCEPT the optics.
- Conventional lenses have aberrations. Overcoming aberrations leads to complex assemblies of optics/lenses, high costs, and size/weight burdens.





Optics costs are typically dominant as a function of performance

M-GRIN Phase II Program Objectives

- Advance the production of Gradient Index (GRIN) lenses from Manufacturing Readiness Level (MRL) 4/5 to MRL 8 while incorporating cost and new design, fabrication and metrology constraints into the manufacturability model.
  - MRL 8: Critical manufacturing processes demonstrate acceptable yield for pilot line or low rate initial production
- Flexibly produce lenses in units of 1 to thousands for: rapid redevelopment/ prototyping, small volume lots, and large volume lots.
- Develop and demonstrate innovative approaches that enable revolutionary and fundamental advances in the design and fabrication of arbitrarily programmable 3-dimensional GRIN lenses for both imaging and non-imaging systems.
- Establish a design and fabrication infrastructure.

M-GRIN Phase II Program Approach

- Simultaneously develop design, fabrication and manufacturing methods
- Guide development with multiple prototypes; for example:
  - Shrink existing systems: Design and fabricate GRIN-based optic for Night Vision Goggles, rifle scope, laser range finder, etc, seeking 5 – 20x weight reduction with first prototype
  - Enable early adoption of GRIN lenses by designers and system integrators: Design GRIN equivalents of classic lens combinations such achromatic doublets, spectrometer components, etc
  - Enable new capabilities: wide wavelength range with chromatic control for use with wide bandwidth sensors, laser beam shaping, flexible focal length with new materials
- Demonstrate custom GRIN optics manufacturing capability (at MRL 8)
- Develop in-line and end-product metrology compatible with new GRIN optics
- Support distributed manufacturing and rapid prototyping (GRIN Exchange)

GRIN manufacturing requires a different approach to design

Design for Fabrication

Constrain designs for:

- Index of refraction ranges and gradients
- Dispersion control
- Polarization control
- Shaping and polishing methods

Design for Performance and Size/Weight

- 12+ degrees of freedom per lens (vs 1 -2 for conventional lenses)
- Volume-based (vs surface-based) optimization algorithms
- Conformal mapping of optimal lens gradients to constructible gradients or unusual system configurations

Design for Manufacture

- Cost-based tolerancing analysis as part of optimization
- Designs constrained by environmental tolerances (temperature, humidity, vibration, strain)

Manufacturable GRIN

- Goal: Develop and demonstrate all components of a comprehensive manufacturing capability, including optical element design, test and evaluation methods (metrology), materials development, and demonstration prototypes.
- Any materials (e.g., polymer, ceramic, glass…)
- Must achieve MRL 8 and conduct 3 different manufacturing demonstrations:

Capability	Demonstration Goal	Probable Demonstration Volume	Long-term Benefit
Volume lens production	Design and manufacture GRIN lens replacement for common lens modules	3 consecutive units of ≥50 each, scalable to units of 1000	Manufacturing scalability; early adoption by system developers
New concept prototyping and rapid redevelopment	Design and manufacture optical assembly for new DoD applications not possible with conventional lenses	Units of 1	New capabilities; enable previously SWAP-constrained applications
System retrofit	Design and manufacture one GRIN-based optical assembly for existing DoD optical system; ≥5x volume and weight reduction	Units of 10-100	Reduced size and weight for existing systems

Role of the GRIN Exchange

- Establish a geographically distributed GRIN lens manufacturing environment
- Host program-generated design tools and fabrication methods
- Dramatically increase flexible and affordable access to GRIN lens technology
- Allow early GRIN demonstration of custom designs and prototypes
- Promote early technology training and adoption

Program Structure

- Phase 1 (end Jan 2012)
  - Task 1 (Base): Imaging System Design, Fabrication, and Metrology
  - Task 2 (Base): Non-Imaging System Design, Fabrication, and Metrology
  - Task 3 (Option 1): Scale to Manufacturing

- Phase 2 (begin ~ Jan 2012)
  - Technical Area 1: Manufacturable GRIN
  - Technical Area 2 (small studies): Experimental GRIN Materials, Processes, or Metrology Techniques
  - Technical Area 3: GRIN Exchange