Development of High-Precision microlenses for enhanced Solar Neutron Tracking

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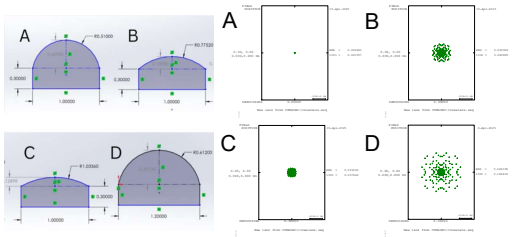
Lens Research & Simulations

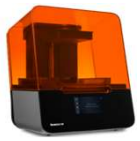
Lens Research
- Refined an Edmund Optics plano-convex model using the lens maker's equation.
- Optimized focal length and spot size to minimize lens-to-SiPM distance and crosstalk.

Simulation
- Used Code V to evaluate multiple lens designs.
- Design D selected for best performance:
  - Back focal length: 0.46 mm
  - Spot size: 0.18 mm

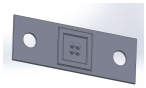


Lens Fabrication and Post-processing

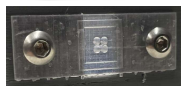
To be ready for testing, the lenses need to be fabricated, post-processed, and then polished. The lens is fabricated using a stereolithography printer and Clear V4 resin. The lens is then polished using a custom mandrel to uniformly smooth the surface.



Formlabs 3 Resin Printer

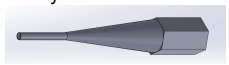


CAD Model of Lens Array

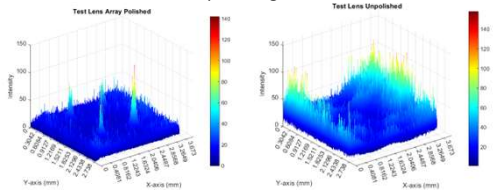


Unpolished Lens Array

Polished Lens Array



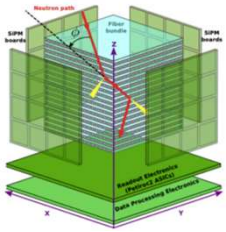
Lens polishing mandrel



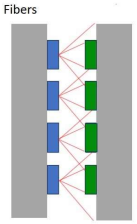
Polished Lens Array spot diagram ISF

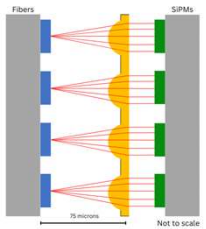
Unpolished Lens Array spot diagram ISF

The Big Picture



NASA SONTRAC internal diagram

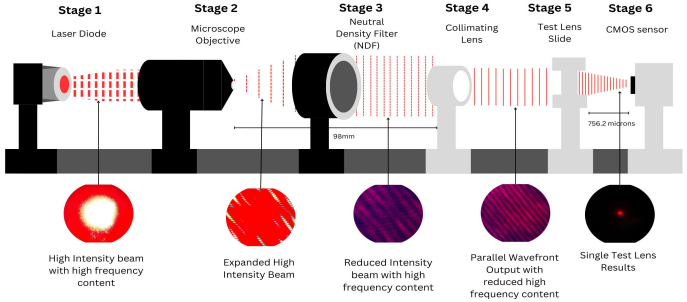




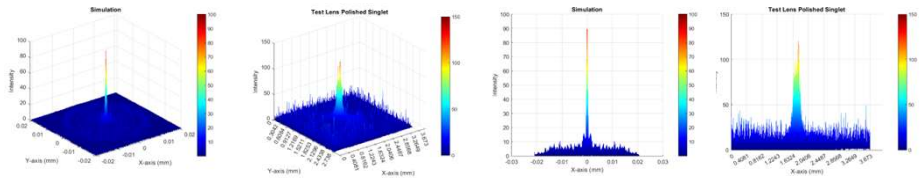
Our lenses have been engineered to focus light emerging from a fiber array directly onto a sensor, countering the natural divergence that can trigger crosstalk in neighboring sensors. These lenses concentrate 435nm photons to maintain signal clarity and performance. These lenses can be a key component of countering NASA's solar neutron tracking module's data errors.

Data Collection

To evaluate spot size, focal length, and back focal length, the lenses are illuminated with parallel wavefronts focused onto the CMOS sensor. This is achieved by expanding, attenuating, and collimating light from a laser diode.



Data Analysis



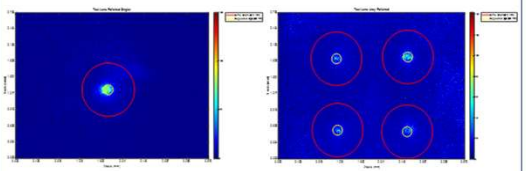
Pre-processing
- Reduce high-frequency noise caused by electrical components and ambient light.
- Image averaging and thresholding are employed instead of low-pass filtering to preserve high-frequency details.

After averaging
- The centroid of the intensity distribution is identified.
- The root mean square (RMS) radius is calculated.

Comparison with simulated spot size
- Visual overlays are applied for better comparison.
- Azimuth view of the distribution is presented for both qualitative and quantitative validation of lens performance.

What did we Find?

Singlet Lens MATLAB Output Data



2x2 Lens Array MATLAB Output Data

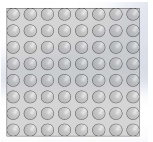
Quantitative Findings (Post 30% Threshold)
- Spot size post 30% noise threshold of 0.14mm.
- Intensity-weighted RMS radius of 0.07mm.
- Discrepancy attributed to thresholding values, noise interference, and rig alignment inaccuracies.

Qualitative findings
- Spot size slightly smaller than the simulated value (0.18mm).
- Light distribution not fully contained within the expected focal area.
- Variations attributed to real-world imperfections in lens fabrication, rig alignment.

What is Next?

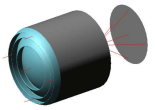
Our findings have opened many paths to explore such as

Full size lens array (8x8)



An 8x8 lens array is needed for a single SiPM cluster

Different Lens Types



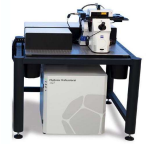
Complex lenses such as fresnel lenses are more efficient with altering light

Different Materials

Clear V5 Optical Resin

BK7 Schott Glass

Different Fabrication Methods



Nanoscribe Photonics Professional GT 2PP printer