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Compact Optics

Designing effective IR optics for unmanned aerial vehicle sensors requires tradeoffs.

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Miniature unmanned aerial vehicles (UAVs) are a category of aircraft small enough to be transported, launched, operated, and retrieved by a two- to three-person crew. Military and paramilitary organizations use UAVs for remote reconnaissance, with one or more onboard sensors transmitting data back to the operator(s) in real time. Thermal imaging extends the utility of miniature UAVs to operations in complete darkness and limited visibility, but historically thermal imagers have been too large and heavy for this application.

IR imaging payloads for miniature UAVs must be lightweight—well under one pound—so as not to detract from UAV maneuverability, maximum airspeed, and flight duration. They must also be small, because the same parameters affected by weight are generally affected even more so by drag.

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Small and Slow

Optical assemblies often represent a substantial percentage of the overall weight of a thermal imager, so we considered the optical design when building our UAV imager. IR optics are typically made from germanium or other heavy materials. Reducing lens volume is thus an excellent means of reducing system weight. Decreasing the aperture size—choosing a slower lens (higher *f*/#)—is a straightforward approach to smaller lens elements. The signal-gathering capability of the optics is directly proportional to aperture area, however.

A detector array with poor inherent sensitivity demands large, heavy optics to compensate for inadequate performance. Conversely, an array with excellent sensitivity supports a compact optical design with a slower lens. We started with an uncooled detector design and developed a focal plane array for optimum signal-to-noise ratio, resulting in better than 85 mK noise-equivalent delta temperature at *f*/1.6. By choosing an *f*/1.6 design, we obtained a lens-assembly cross section approximately 60% smaller than that of comparable *f*/1.0 optics commonly used with uncooled detectors.

Simplifying the mechanical design provided another method for reducing the size of the lens assembly. Thermal imagers use an internal shutter or other uniform surface to periodically update non-uniformity correction terms. During the update process, the shutter rotates into the image field to normalize the pixel offset. Rather than nesting the shutter assembly in the optical housing, which would have increased diameter, we located the shutter directly in front of the sensor assembly.

Looking Forward

Small isn't small enough, though. Future micro-UAVs will require thermal imagers that are even more compact to allow man-portable systems. Even the compact *f*/1.6 lens assembly described above weighs approximately 30 g, which is several times heavier than the weight budget for the entire payload on a micro-UAV. A slower optical design is unlikely to produce the dramatic weight reduction required for this application. Other potential avenues for lightweight optical assemblies involve diffractive elements and/or alternative materials. Diffractive optical elements essentially eliminate much of the bulk material from a lens element while retaining its light-bending properties. The technology is currently transitioning into the mainstream within the IR industry and offers real potential for lightweight optics. The use of alternative materials such as molded plastics is a less mature technology path but still offers the potential for a breakthrough.

Thermal reconnaissance with man-portable UAV systems provides tremendous opportunity to military and paramilitary agencies. UAVs can be deployed rapidly with minimal preparation or training and without exposing the crew to hostile situations. They are also stealthy, rugged, and low-cost. Thermal imaging cameras' IR imaging capability in absolute darkness and low-visibility conditions further extends the utility of miniature UAVs. With careful optical design and understanding of the tradeoffs involved, it is possible to develop thermal imagers for even ultralight UAVs. **oe**

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