Optical Readout Photomechanical Imager

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Abstract:
Agiltron is developing optical-readout photomechanical imagers where the modularity of the readout architecture allows for extra design freedom that is not possible in bolometers, overcoming fundamental trade-offs, such as NETD versus thermal time constant. Agiltron has advanced the photomechanical imaging platform over several technology generations, improving both the optical readout system and the photomechanical sensor chip, which has enabled reductions in size, weight and power (SWAP) and NETD over successive generations. The current-generation photomechanical imager has the size equivalent to a digital camera and an \( f/1 \)-equivalent NETD and MDTD of sub-100 mK.

Summary of Research:
Agiltron has been developing a disruptive approach to thermal imager manufacturing for several years. The approach employs our MEMS-based LightLever® photomechanical sensor array with an optical readout system to convert a commercial-off-the-shelf (COTS) CMOS imager into a thermal imager. By exploiting the significant advances made in the fields of CMOS imaging and MEMS fabrication over the last decade, we lower the economic barriers to drive toward the price and performance targets demanded by the thermal imaging market.

A schematic diagram of the photomechanical imager is pictured in Figure 1. One major difference between the photomechanical imager and a bolometer is the optical instead of electrical readout, which is facilitated by the physical separation of the sensor chip from the readout integrated circuitry (ROIC). The heart of the photomechanical imager is the LightLever® sensor chip, which comprises an array of MEMS-based photomechanical pixels. Each pixel acts as a transducer that converts absorbed infrared radiation from the scene into a mechanical deflection. Readout light supplied by an LED illuminates the spatially varying deflected pixels, which are simultaneously projected onto a CMOS imager using a \( 4f \) optical readout system. The resultant image projected on the CMOS imager is thus a faithful reproduction of the infrared scene captured
by the sensor chip. Further details of the operating principle of the photomechanical imager has been reported elsewhere [1,2].

Another major difference between the photomechanical imager and a bolometer is the thermally actuated photomechanical pixel. A photomechanical pixel is depicted in Figure 2. Both the sensor and compensation arms are bilayer cantilevers that deflect upon heating. In the case of heating from ambient thermal drift, both the sensor and compensation arms deflect equally, and there is no net deflection of the pixel. In the case of heating from infrared absorption, the sensor arm is heated more than the compensation arm due to the presence of the thermal isolator, and the pixel deflects. In contrast to a bolometer pixel, whose responsivity is closely pegged to a given temperature-dependent material property (e.g., the temperature coefficient of resistance), the responsivity of a photomechanical pixel varies according to the geometry of the design.

The responsivity can be increased by using thinner sensor and compensation arms or inserting corrugations in the arms to effectively extend their length. Either variation has the effect of increasing the thermal bending sensitivity of the arms without affecting the other parameters of the pixel.

In this manner, additional degrees of freedom are available in the photomechanical pixel design to negate the fundamental trade-off between NETD and thermal time constant inherent in bolometers. The photomechanical imager has undergone rapid evolution in both functionality and performance since Agiltron’s first imager-level demonstration in 2004. The evolution is marked by different generations of development, with each successive generation showing improvement in both the imager SWAP and NETD, as tracked in Figures 3 and 4, respectively. The generational SWAP improvements are as follows (the year of demonstration is in parentheses):

*Generation 0 (2004)* was a benchtop photo-mechanical imager using discrete components for the 4f optical readout system. The path of the optical readout is axial, which necessitated a long path length.

*Generation 1 (2006)* was the first stand-alone photomechanical imager. All components were assembled into a single, unified housing. The path of the optical readout remained axial, hence the reduction in SWAP was only moderate.

*Generation 2 (2007)* was the first photomechanical imager to feature a folded path for the optical readout, and the reduction in size and weight was substantial. However, the layout of the imager did not lend itself to fit neatly into a cuboid-shaped volume.

*Generation 3 (2009)* adjusted the folded path for the optical readout so that the imager could fit neatly into a cuboid, including the full readout electronics. The size of the photomechanical imager is equivalent to a digital camera.

References:
