Midwave IR LED array for high-temperature target simulation

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Target-simulating infrared scene projections equivalent to a blackbody at 1050K can be provided by IR interband-cascade type-II-superlattice LEDs.

Passive IR imaging and IR detector arrays play vital roles in missile defense operations and systems. Projecting dynamic scenes into these IR sensors has proven very effective for equipment characterization, validation, and functional testing, but improvements are still possible.

Seeker testing, for example, requires large 2D arrays, high frame rates, and wide dynamic-range IR sources. Although a variety of sources are used—including a scanning laser array,1 resistive array,2–4 and digital micromirror devices5—all fall short in scene fidelity.

Midwave IR (MWIR) LED arrays with sufficient dynamic range can provide the needed higher fidelity, and also benefit applications such as IR countermeasures, chemical warfare monitoring, medical diagnostics, and gas sensing.6 In particular, IR interband-cascade (IC) type-II-superlattice LED structures, which operate at liquid nitrogen temperature with emissive power equivalent to a 1050K blackbody, have these desired characteristics.

The IC LED structure discussed here was grown by a Varian Gen-II molecular beam epitaxy machine on a (100) p-type GaSb substrate. After fabricating the LED array using reactive ion etching and a contact metal deposition process, the 2D LED array was diced and flip-chip bonded with an epoxy underfill to a silicon fan-out array. The GaSb substrate was manually thinned using number 4000 (2-4µm grit) SiC paper from the bottom side of the device. Figure 1 shows a schematic cross-sectional view of the LED array flip-chip bonded on the fan-out array. Figure 2 shows a portion of an 8×7 LED array before it was flip-chip bonded. At the center of each LED pixel is the indium bump depicted in Figure 1.

Figure 1. An increase in mesa size yields increases in emission output power and IC LED efficiency in the bottom-emitting LED pixel diagrammed here.

Figure 3 shows the equivalent blackbody temperatures for different LED injection currents. To estimate these temperatures, first the radiance emitted in the detector’s passband was calculated for different blackbody source temperatures, and then the slope was determined for a linear fit of the radiances against the detector signals. Finally, the slope was used to compute the equivalent blackbody temperature for various LED injection currents. The results show that at 15mA injection current, the LED emissions at room temperature operation correspond to a 660K blackbody, and at liquid nitrogen temperature to a 1050K blackbody. For comparison, the maximum emissive temperature from a resistor array is approximately 650K.7 Hence, for IR scene generation, the LED device can simulate a much higher target temperature than can thin-film resistor devices.

Figure 4 shows an image taken with an IR camera of the light emissions from a 2×4 portion of an 8×7 LED array with 100µm mesa structures. Very uniform light emission was observed from the entire 8×7 LED array. An LED single device had a light output of about 2mW power. The emission power and IC LED device efficiency increase with mesa size.

The camera used to image the device operates at 77K, and has InSb detector focal plane arrays with 256×256 pixels. A reflective objective lens with small focal length was used to collect the LED light.

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Figure 2. Pictured here is an $8 \times 6$ section of an $8 \times 7$ LED array before it was flip-chip bonded to a silicon fan-out array. The indium bumps depicted in Figure 1 are at the center of each LED pixel.

Figure 3. At the highest current, the blackbody emissive temperature is about 1050K for the LED operating at liquid nitrogen (LN) temperature and about 660K when operating at room temperature (RT).

The equivalent blackbody emissive temperature can exceed 1050K when the LED operates at liquid nitrogen temperature. We believe this is the highest temperature reported for an LED array, and one that has not been simulated by thin-film resistor arrays.

Figure 4. This image captures the bright emissions from a $2 \times 4$ portion of an $8 \times 7$ LED array. At bottom is the brightness scale in arbitrary units.

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References