TRANSPORATION POOLED FUND PROGRAM
QUARTERLY PROGRESS REPORT

Lead Agency (University or Contractor):__Kansas DOT_____

INSTRUCTIONS:
Project Managers and/or research project investigators should complete a quarterly progress report for each calendar quarter during which the projects are active. Please provide a project schedule status of the research activities tied to each task that is defined in the proposal; a percentage completion of each task; a concise discussion (2 or 3 sentences) of the current status, including accomplishments and problems encountered, if any. List all tasks, even if no work was done during this period.

Transportation Pooled Fund Project Number **TPF-5(351)**	**Transportation Pooled Fund Program - Report Period:** ☐Quarter 1 (January 1 – March 31) ☐Quarter 2 (April 1 – June 30) ☐Quarter 3 (July 1 – September 30) XQuarter 4 (October 4 – December 31)	
Project Title: Self De-Icing LED Signals		
Project Manager: Carla Anderson	**Phone:** 785-296-0357	**E-mail:** Carla.anderson@ks.gov
Project Investigator: Hongyi Cai	**Phone:** 785-864-2597	**E-mail:** hycai@ku.edu
Lead Agency Project ID: **RE-0721-01**	**Other Project ID (i.e., contract #):**	**Project Start Date:** August 15, 2016
Original Project End Date: **August 2019**	**Current Project End Date:** **August 2019**	**Number of Extensions:** 0

Project schedule status:

X On schedule ☐ On revised schedule ☐ Ahead of schedule ☐ Behind schedule

Overall Project Statistics:

Total Project Budget	Total Cost to Date for Project	Total Percentage of Work Completed
$240,000	$21,329	15%

Quarterly Project Statistics:

Total Project Expenses This Quarter	Total Amount of Funds Expended This Quarter	Percentage of Work Completed This Quarter
$17,171	$17,171	10%

Project Description:

This pooled fund project will develop new self de-icing LED signals for highway signalized intersections and railroad signaling applications to solve a well-known problem of the existing LED signal light whose lens is too cool to melt snow and de-ice in wintery conditions. The self de-icing LED signals will adopt two novel architectures (Figure 1), including (a) "Heated Lens Lighting Arrangement" (non-provisional patent application No. PCT/US14/53503, filed on Aug 29, 2014) that uses a single high-power LED and (b) "Heat Arrangement of LED Arrays in Low Profile" (Provisional patent application filed on April 15, 2016) that deploys multiple LEDs. The heat generated by the LED(s) is harvested by the passive heat exchanger and stored to heat the lens for melting snow and de-icing in wintery conditions.

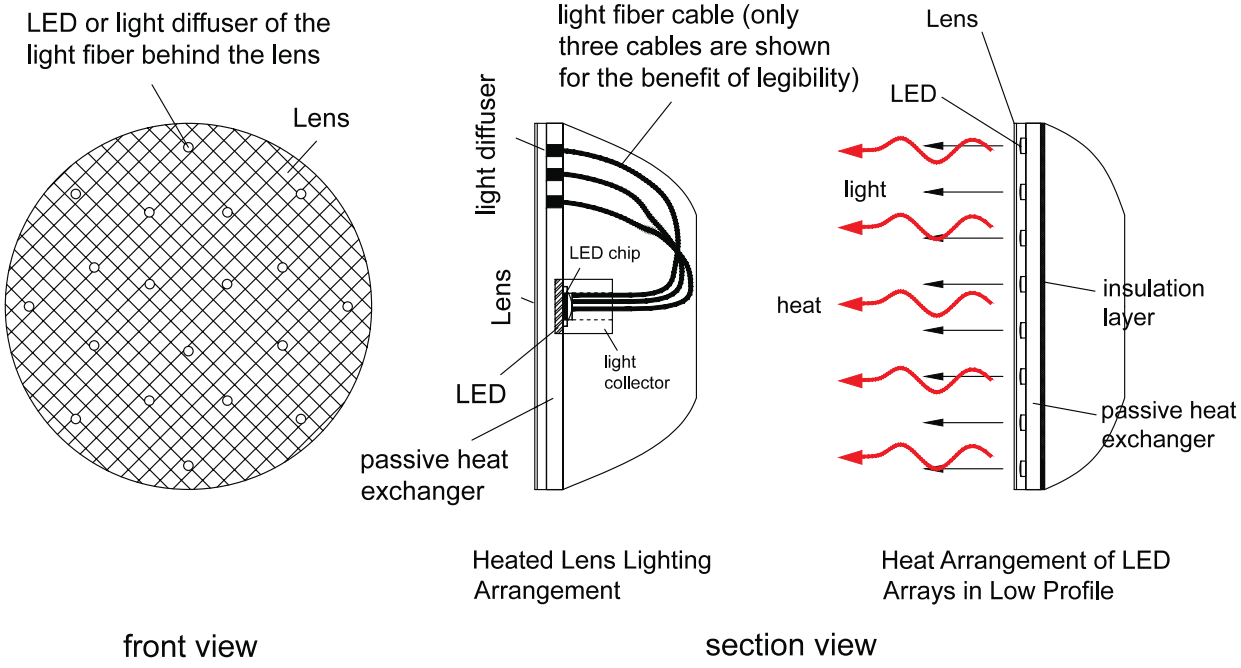


Figure 1 The concept of the self de-icing LED signal light, which adopts new architecture of "Heated Lens Lighting Arrangement" or "Heat Arrangement of LED Arrays in Low Profile"

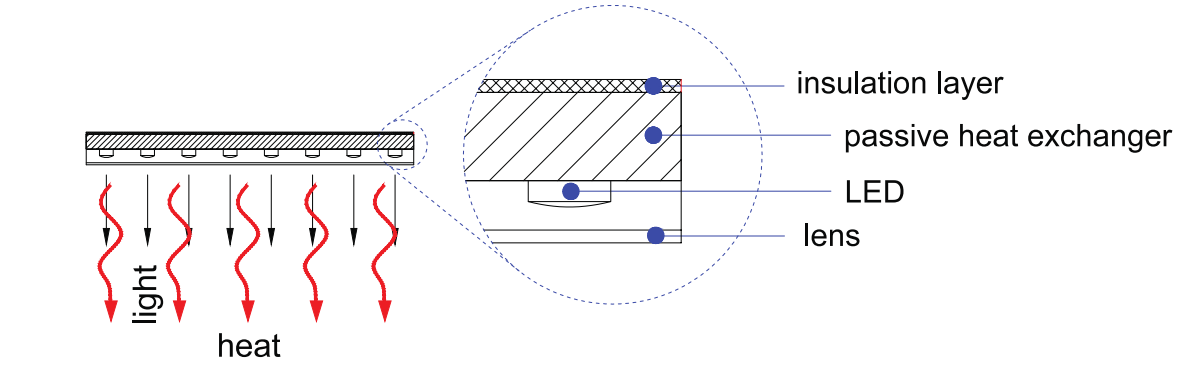
Fully working prototypes of the self-de-icing LED signals are under development and tests in the laboratory. They will be tested in closed-course settings and then in field on highway intersection and railroad wayside or at-grade crossing signal lights. Each participating agency is required to provide support of three years of funding ($20,000/year, totaling $60,000) and will be guaranteed a field test site in each state for testing the custom-made prototypes catering to their specific needs of the new type of signals. The research team will work with each participating agency to identify the desired test site on highway intersections or rail track sections and the desired technical specifications of the prototypes.

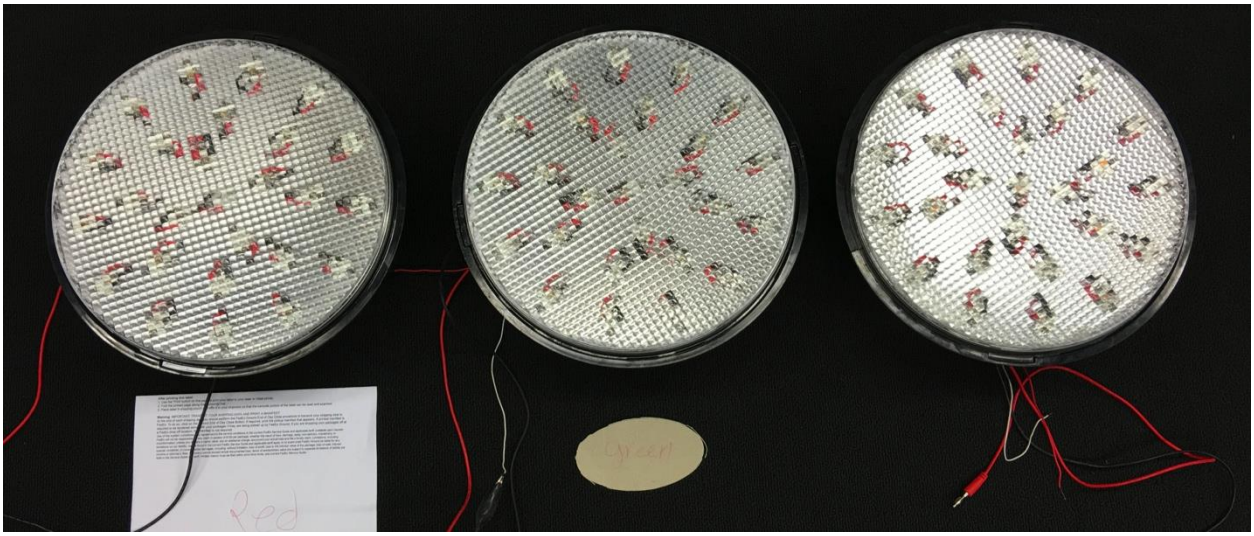
The investigative approach for the proposed project is divided into the three stages. Work in Stage 1 is underway that focuses on laboratory development and tests. Work in Stage 2 will focus on testing the three prototypes in a closed-course setting, for example, mounted on the roof of the University of Kansas engineering complex and powered by the signal controller cabinet. Work in the third and final stage will involve field testing of the developed prototypes on identified highway signalized intersections and rail track sections. On-site demonstration of the prototype signals will also be held for project partners and state DOTs to initiate the implementation process. A final report will provide all relevant data and results along with plans for implementation of the self-de-icing LED signals in affected states.

Progress this Quarter (includes meetings, work plan status, contract status, significant progress, etc.):

During the fourth quarter of project period, we have the following accomplishments.

First, in the past quarter, we tested the three preliminary prototype signals (Red, Yellow, and Green) of Type 1 developed via "Heat Arrangement of LED Arrays in Low Profile" (Figure 1), each deploying 26 custom-made color LEDs mounted in an array on a new shape of aluminum alloy passive heat exchangers. The Type 1 signal was thoroughly tested in laboratory for improvements. Their thermal and lighting performance was evaluated and compared to that of the Type 2 signal using "Heated Lens Lighting Arrangement" (Figure 2, the Type 2 signal deploys a single high-power LED and multiple optical fibers). While both types of signals have almost equivalent thermal performance, the Type 1 signal can have a smaller housing and lower costs than the Type 2 signal that need additional components including fibers, light collectors, and light diffusers. The Type 1 signal also appears to offer better lighting performance than the Type 2 signal. However, these findings are subject to further laboratory tests when the fully working prototypes become available for tests in later stages.





Red Green Yellow

Figure 1 Type 1 signal using the architecture of "*Heat Arrangement of LED Arrays in Low Profile*" (provisional patent filed in April 2016) to harvest both the light and the heat generated by the same LEDs via a mingled path for lighting and heating uses.

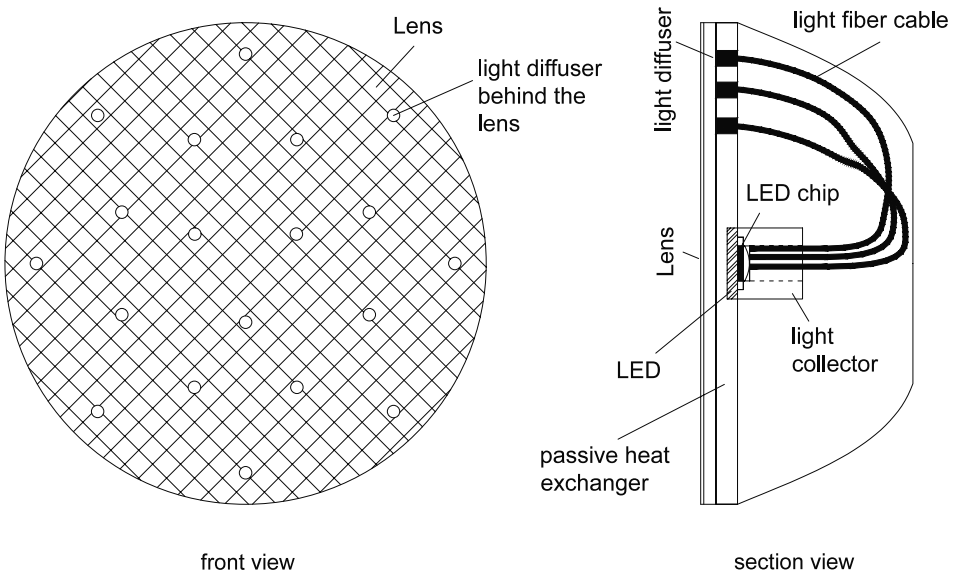
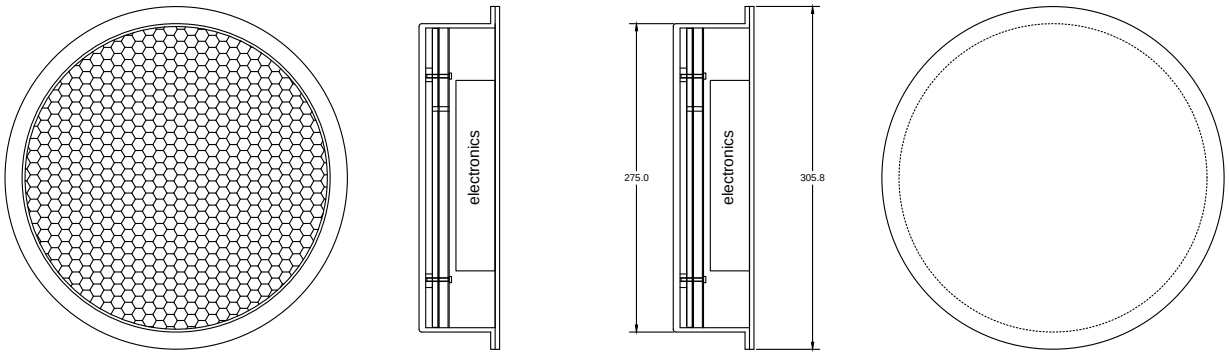


Figure 2 Type 2 signal deploying the architecture of "Heated Lens Lighting Arrangement" (non-provisional patent application No. PCT/US14/53503) using a single high-power color LED module, a light collector and multiple light fibers.

Second, with the aid of the industrial partner – Sunlite Science & Technology, Inc, the research team has finalized the design of the self de-icing LED signal for custom making fully working prototypes of Type 1, which has a new small housing in low profile, a new lens, and a new light engine in low profile with better insulation performance and more uniform light distribution on the lens. The new type of lens has optimized design for enhanced lighting and heating performance of the proposed self de-icing LED signals. The finalized light engine deploys a total of 97 mediate-power LED chips (only 0.25 Watt each) evenly distributed across the passive heat exchanger via the architecture of "*Heat Arrangement of LED Arrays in Low Profile*", and mounted ¼ inch behind the lens for uniform light and heat distribution. In addition, we adopted a new mounting method of the LED chips – mounting those LED chips directly on the metal printed-circuit board (MPCB) which has an aluminum back plate of 3-5 mm serving as the passive heat exchanger. The new mounting method cancels the need of visible wiring of those LEDs using red/black wires (instead, we use printed circuit board) and holes punched on the passive heat exchanger for securely fasten of those LED chips. As a result, the new design will have reduced size of housing, tighter structure, better insulation, more reliable performance and decreased costs due to less components. Currently, the research team is working with the industrial partner and factories to custom make three fully working prototypes for testing and improvements.

Third, the state of Maryland has joined the project in Nov. 2016 with additional contributions. By the end of 2016, a total of seven states, including Kansas, California, Michigan, New Jersey, Wisconsin, Pennsylvania, and Maryland have officially signed on participating in field tests and evaluation of the prototypes.

Figures 3-6 illustrate the finalized design of the Type 1 self de-icing LED signal.



front view section view back view

self de-icing LED signal

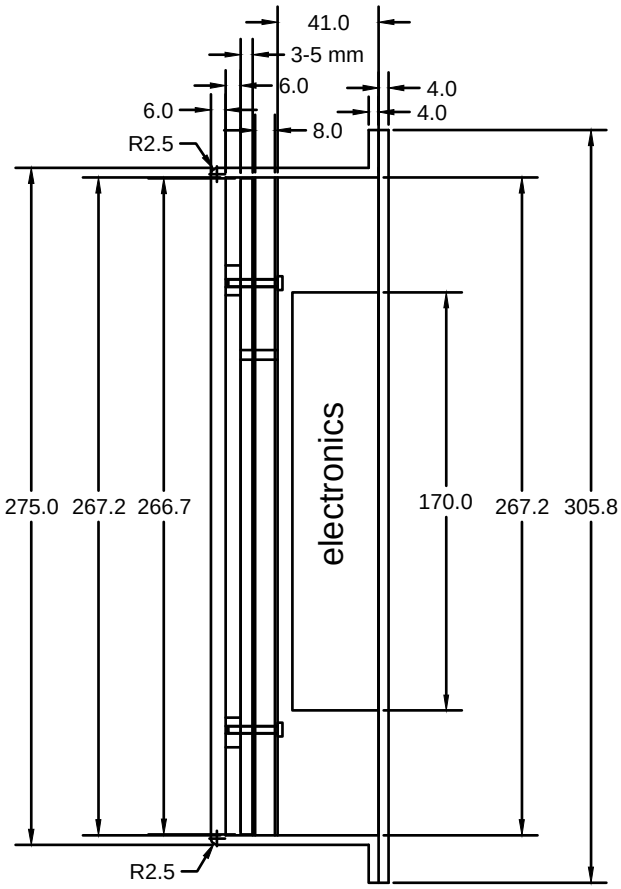
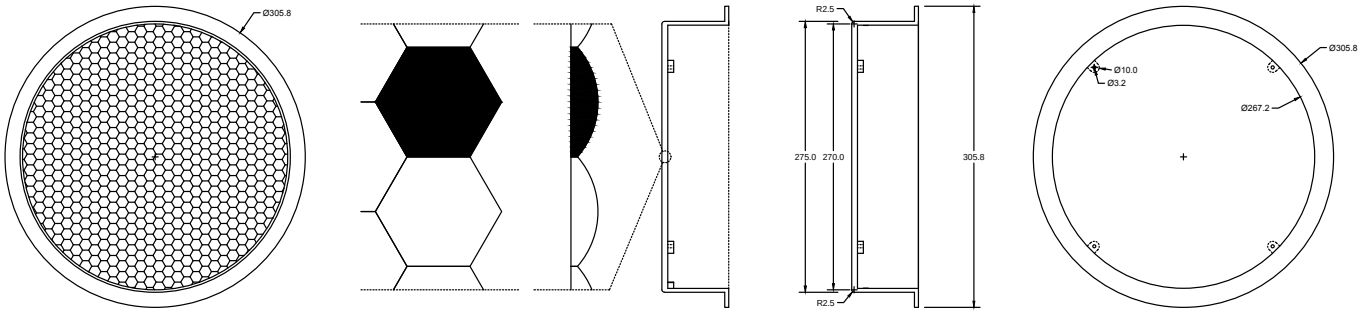


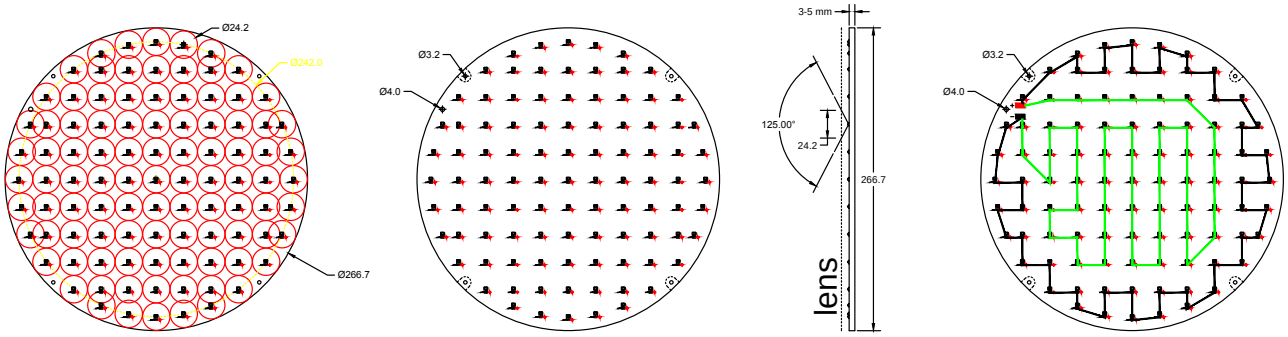
Figure 3 The outlook of the finalized design of the self de-icing LED signal of Type 1, with approximate dimensions shown in the section view, in low profile (approx. only half of the thickness of current LED signals mounted in the field).



front view | section view w/ zoom in | section view size | back view

lens design

Figure 4 The detail of the new lens design of the self de-icing LED signal of Type 1. In this design, the lens adopts a whole piece design with smooth and flat outside surface and hundreds of small plano-convex lenses on the inside surface to focus the light serving as a collimator lens. This design allows a small gap between the LEDs and the lens as small as ¼ inch for enhanced thermal performance.

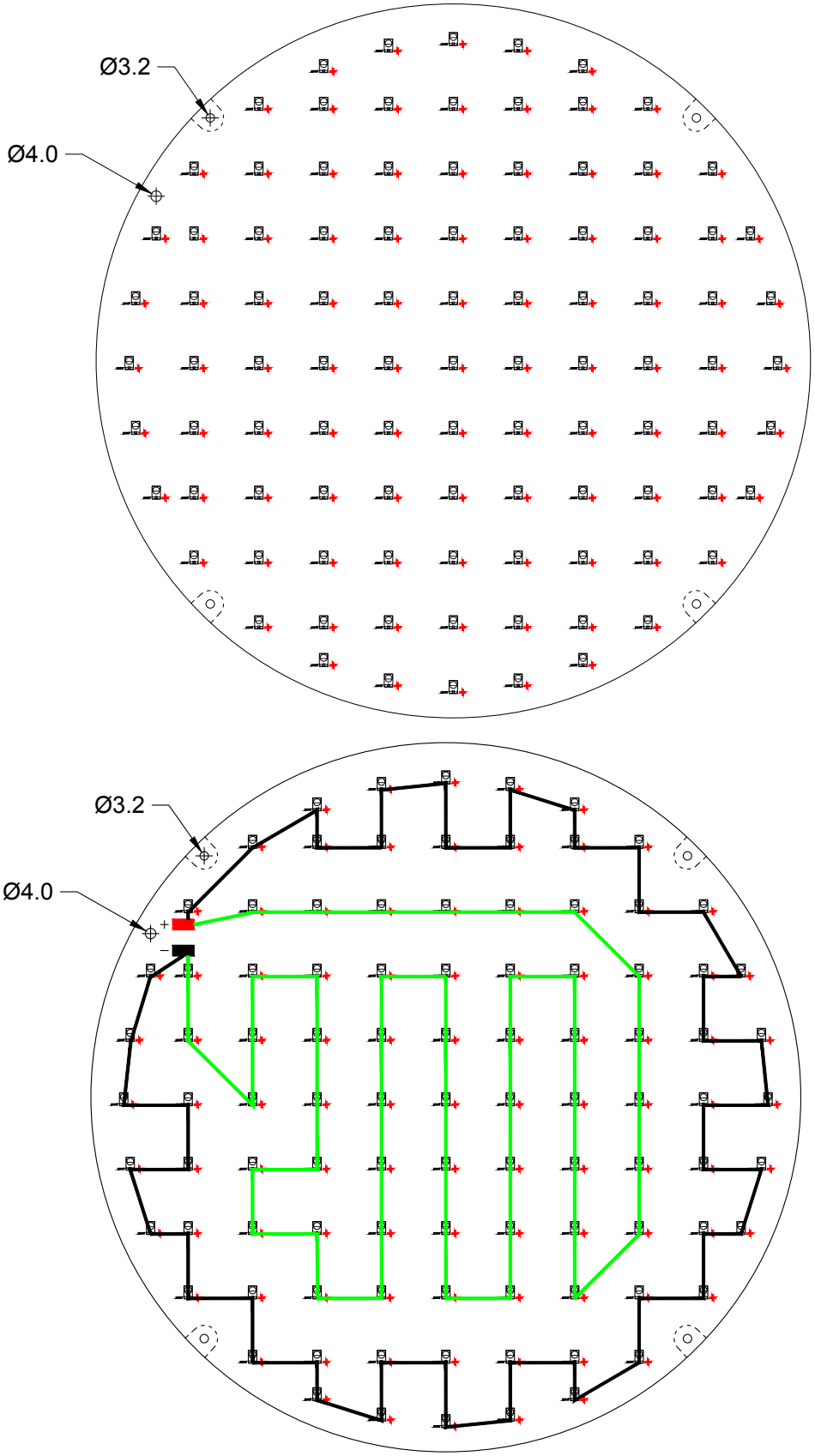


printed circuit board, two groups of wiring (white - 49 LEDs,green - 48 LEDs)

light engine

a total of 97 LEDs directly mounted on a 3-5 mm thick MPCB board serving as the passive heat exchanger. The 97 LEDs in a total of approximately 20-26 W are wired in two groups in parallel, connected to 110 V.

Figure 5 The detail of the light engine design of the self de-icing LED signal of Type 1 (with two zoomed in picture on next page). In this design, a total of 97 mediate-power LED chips are mounted on the MPCB board with an aluminum back plate of 3-5 mm serving as the passive heat exchanger. Since the LEDs are mounted on the circuit directly printed on the aluminum board, no need of additional wiring and holes punched on the passive heat exchanger, which can save components, reduce housing space, increase the reliability and decrease the costs.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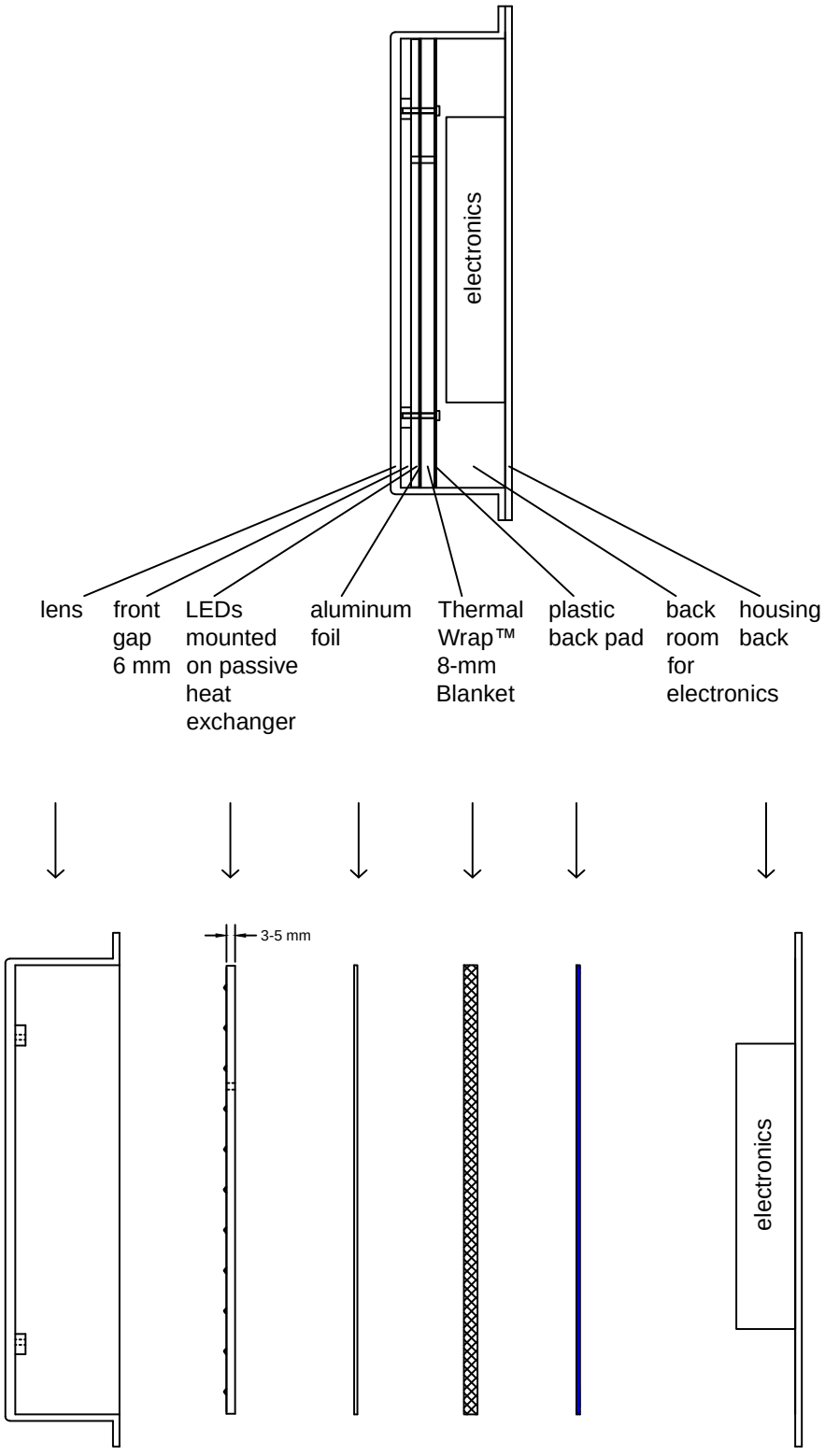
electronics
lens
front gap 6 mm
LEDs mounted on passive heat exchanger
aluminum foil
Thermal Wrap™ 8-mm Blanket
plastic back pad
back room for electronics
housing back
3-5 mm
electronics

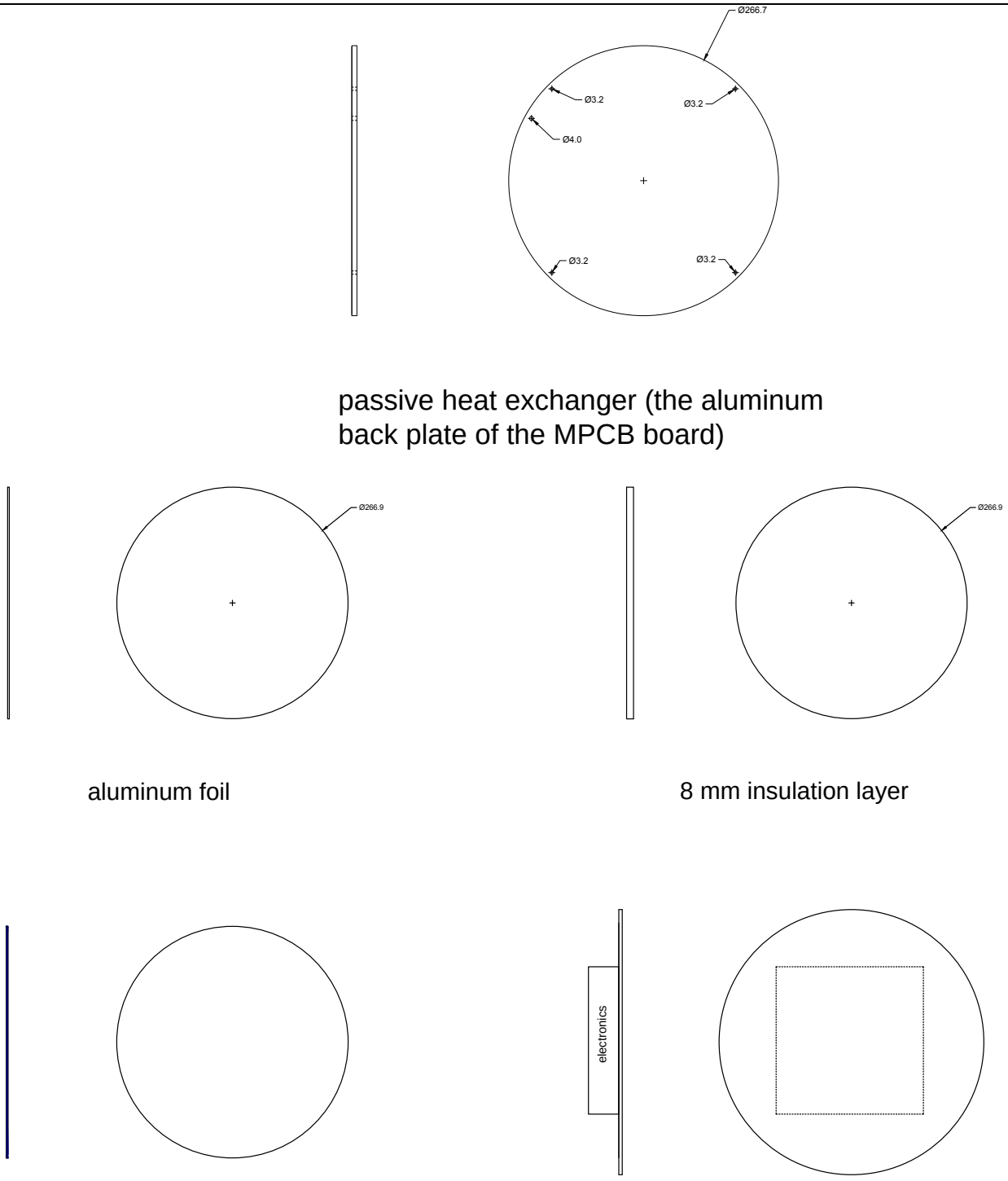

Figure 6 Different layers of the self de-icing LED signal of Type 1 for improved lighting and thermal performance. The electronics (drivers, etc.) are attached to the backpack that could be detached from the back of the signal light for easy maintenance.

Anticipated work next quarter:

Starting from Jan 01, 2017 till March 31, 2017, we are planning to conduct the following tasks.

1. Develop fully working prototypes of Type 1 signals that deploy 96 mediate-power LEDs via the architecture of "Heat Arrangement of LED Arrays in Low Profile", and continue to test them in laboratories in Stage 1.

2. Design and custom make the new lens, housing, and accessories for the Type 1 self de-icing LED signal lights, with the aid of the industrial partner.

3. Test the fully working prototypes in closed-settings in Stage 2.

Significant Results:

As of Dec 31, 2016, we have achieved the following significant results.

- This project was launched in Aug 2016 with six participating states (Kansas, California, Michigan, New Jersey, Wisconsin, and Pennsylvania) and an initial budget of $240,000. Maryland is expected to officially join the study by the end of this year with additional contribution of three years funding.

- An expert panel meeting was held in early March. Discussions were held on desired specifications of the prototype signals and possible field test sites as well as the field evaluation of the prototypes.

- A new provisional patent of "Heat Arrangement of LED Arrays in Low Profile" was filed in April 2016. Non-provisional patent application is under preparation and will be filed before April 15, 2017.

- Necessary equipment, components and insulation materials are being procured to develop and build the fully working prototypes of the finalized design and test for their thermal and lighting performance. We will continue to order LED drivers, electricity monitors, waterproof security video cameras, other mounting accessories and materials, etc., for monitoring the performance of the prototypes in the field tests in the upcoming winter season.

- Appropriate color LED modules, which are not available in the market, were designed in-house and custom-made with the aid of the industrial partner.

- Three preliminary prototype signals (Red, Yellow, and Green) of Type 1 have been developed in house, each deploying 26 custom-made color LEDs mounted in an array via "Heat Arrangement of LED Arrays in Low Profile". They are under laboratory testing for improvements.

- Tested the lighting and thermal performance of the preliminary prototypes of the Type 1 signal lights (Figure 1). Based on the test results, new design with a lot of changes and improvements has been finalized as shown in Figures 3-6 for final products.

- Finalized the design of Type 1 self de-icing LED signals using 96 custom-made mediate-power color LEDs mounted in an array via "Heat Arrangement of LED Arrays in Low Profile". Designed in house and custom-made our own color LED modules (for each color R, G, Y) for making the fully working prototype signals of the first type with the aid of our industrial partner. We are working with the factories to optimize the mounting method of the custom-made LED modules on the 3-5 mm thick aluminum MPCB back plate serving as the passive heat exchangers of aluminum alloy for assembly.

- Seven states have officially participated in this project, including Kansas, California, Michigan, New Jersey, Wisconsin, Pennsylvania and Maryland to provide support. Utah is interested in participation and we are working with Utah DOT to join in the pooled fund project with additional contribution.

Circumstance affecting project or budget. (Please describe any challenges encountered or anticipated that might affect the completion of the project within the time, scope and fiscal constraints set forth in the agreement, along with recommended solutions to those problems).

None.