# 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**<br>**TPF-5(351)** | | **Transportation Pooled Fund Program - Report Period:**<br>X Quarter 1 (January 1 – March 31)<br>☐Quarter 2 (April 1 – June 30)<br>☐Quarter 3 (July 1 – September 30)<br>☐Quarter 4 (October 4 – December 31) |
| **Project Title: Self De-Icing LED Signals** | | |
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| **Project Investigator:**<br>Hongyi Cai | **Phone:**<br>785-864-2597 | **E-mail:**<br>hycai@ku.edu |
| **Lead Agency Project ID:**<br>**RE-0721-01** | **Other Project ID (i.e., contract #):** | **Project Start Date:**<br>August 15, 2016 |
| **Original Project End Date:**<br>**August 2019** | **Current Project End Date:**<br>**August 2019** | **Number of Extensions:**<br>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 | $26,832 | 25% |

***Quarterly*** Project Statistics:

| Total Project Expenses This Quarter | Total Amount of Funds Expended This Quarter | Percentage of Work Completed This Quarter |
|---|---|---|
| $5,503 | $5,503 | 10% |

**Project Description**:

This pooled fund project will develop and demonstrate 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" 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.

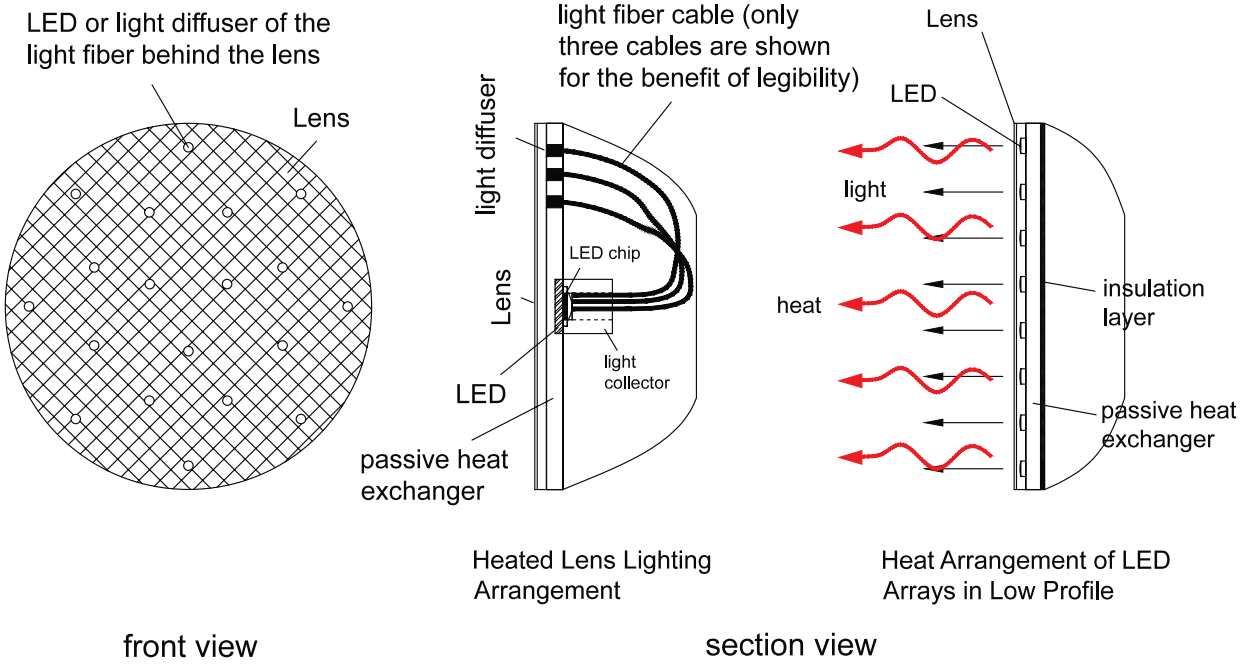



**Figure 1** The concept of the self de-icing LED signal light, which adopts new architecture of "Heated Lens Lighting Arrangement" or "Heat Arrangement of LED Arrays in Low Profile"

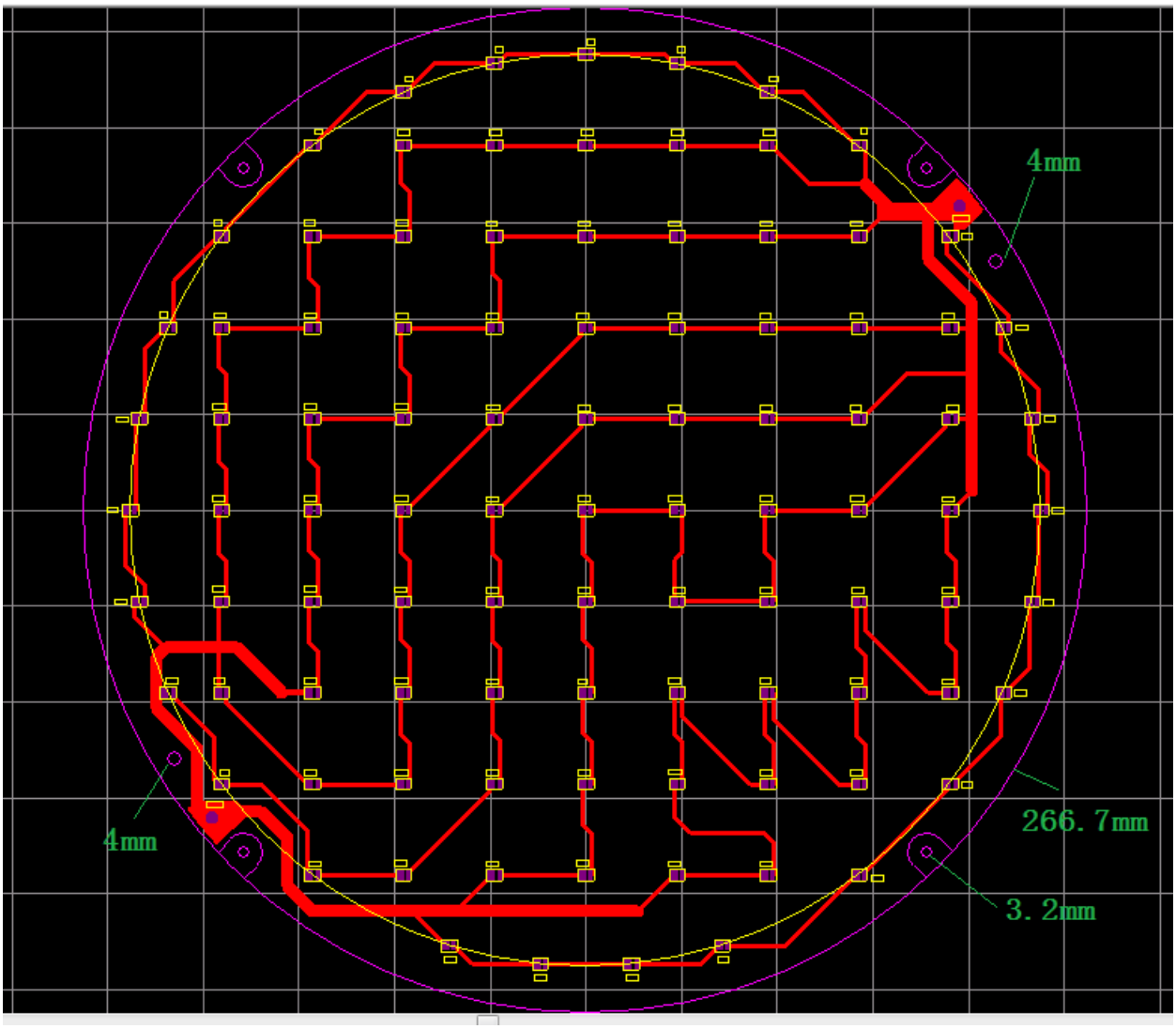
Fully working prototypes of the self-de-icing LED signals are under development and tests in the laboratory. They will be tested in closed-course settings and then in field on highway intersection and railroad wayside or at-grade crossing signal lights. Each participating agency is required to provide 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 first quarter (January 1, 2017 – March 31, 2017) in 2017 of the project period, we have the following accomplishments.

In the past quarter (January 1, 2017 – March 31, 2017), the research team has been working closely with the industrial partner (Sunlite Science & Technology, Inc.) to custom make three fully working prototype signals of Type 1 (which deploys the innovation of "Heat Arrangement of LED Arrays in Low Profile") in the factory. The research team has updated the design and the construction drawings for the fully working Type 1 prototype signals including new light engine (Figure 2) using 96 medium-power LEDs, new housing, and new lens (Figure 3).



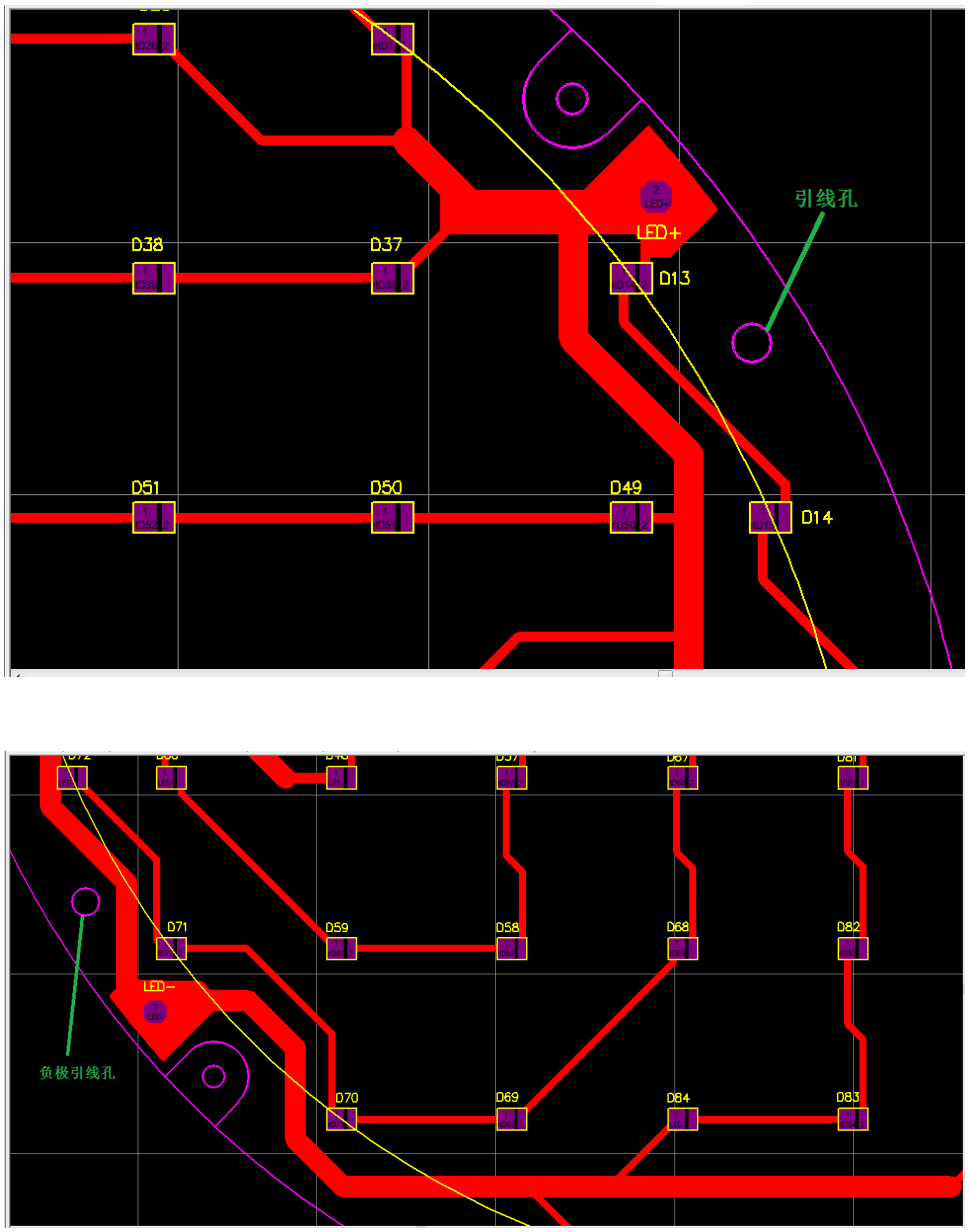
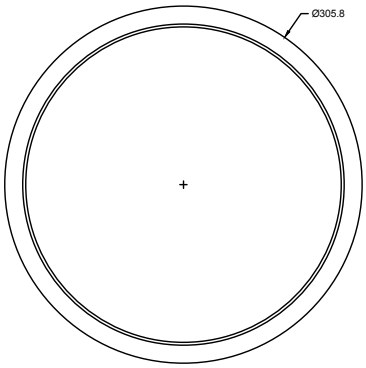
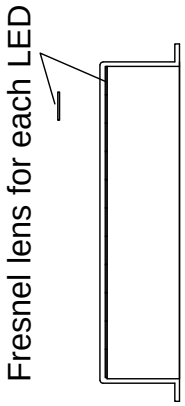


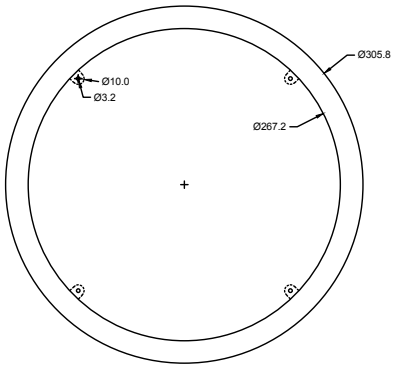

**Figure 2** The finalized MCPCB board design of the self de-icing LED signal of Type 1. In this design, 96 mediate-power LED chips (0.25 Watt each) are mounted on the MCPCB board with an aluminum back plate of 3 mm serving as the passive heat exchanger. There is no need of additional wiring and holes punched on the passive heat exchanger, which can save components, reduce housing space, increase the reliability and decrease the costs.



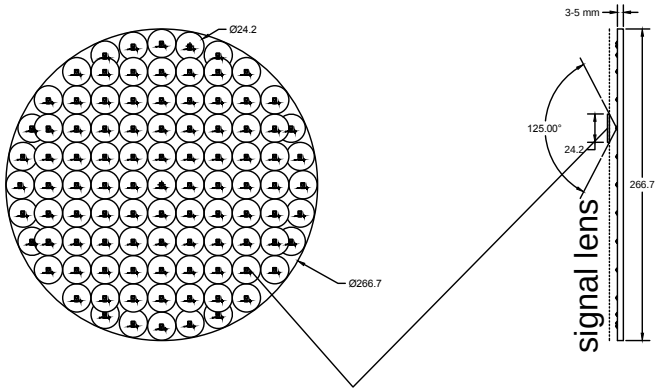

front view of the signal lens




section view of the signal lens with additional Fresnel lens over each LED

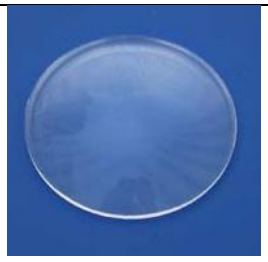



back view of the signal lens




Fresnel lens over each LED

lens design



(example Fresnel lens)

**Being custom made:**

**LED Lighting Fresnel Lens**
Diameter: 24 mm
Thickness: 1.5 mm
**Focal length: 5-6 mm**

**Figure 3** The detail of the updated lens design of the self de-icing LED signal of Type 1. In this design, the signal lens adopts a whole piece design with smooth and flat outside surface and integrated with 96 additional custom-made Fresnel lenses sitting inside the signal lens over each LED 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.

With the aid the industrial partner, the new light engines, the new signal lens (one whole piece) and the integrated new Fresnel lens for each LED are being custom made in the factory to make three fully working prototype signals, which takes time to complete. The research team has been waiting to receive and test the fully working prototypes in the laboratory for further improvements and product optimization.

**Anticipated work next quarter**:

Starting from April 01, 2017 till June 30, 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", continue to test them, and complete the laboratory tests in Stage 1.

2. Develop 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. Start to test the fully working prototypes in closed-settings in Stage 2.

**Significant Results:**

As of March 31, 2017, 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.

- 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.

- Worked 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.

- Custom-made three prototypes of the LED signals of Type 1 using 96 custom-made mediate-power color LEDs mounted in an array via "Heat Arrangement of LED Arrays in Low Profile" and started the laboratory testing for improvements and optimizations to finalize the design.

- Finalized the design of the signal lens that adopts a whole piece design with smooth and flat outside surface and integrated with 96 additional custom-made Fresnel lenses sitting inside the signal lens over each LED on the inside surface to focus the light serving as a collimator lens.

- Seven states have officially participated in this project, including Kansas, California, Michigan, New Jersey, Wisconsin, Pennsylvania and Maryland to provide support.

**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.