Laboratory Evaluation
Kaiterra Laser Egg 2+ Sensor
Background

Three Kaiterra Laser Egg 2+ Model #LE-201 (hereinafter Laser Egg 2+) sensors (units IDs: CED6, D0C3 and D20E) were field-tested at the South Coast AQMD Rubidoux fixed ambient monitoring station (02/19/2019 to 04/09/2019) under ambient environmental conditions and have been evaluated in the South Coast AQMD Chemistry Laboratory under controlled artificial aerosol concentration/size range, temperature, and relative humidity. The same three Laser Egg 2+ units were tested both in the field (1st stage of testing) and in the laboratory (2nd stage of testing).

Laser Egg 2+ (3 units tested):
- Particle sensor: Laser Particle Counter (optical; non-FEM) (model PMS3003 by Plantower)
- Each unit reports: PM$_{2.5}$ and PM$_{10}$ (µg/m$^3$), Temperature (°C), Relative Humidity (%)
- Also measures TVOC (ppb)
- Unit cost: $199
- Time resolution: 1 min
- Units IDs: CED6, D0C3, D20E
- Differences from Laser Egg: In addition to PM$_{2.5}$ and PM$_{10}$, Laser Egg 2+ also measures T, RH, and Total VOC

GRIMM (reference method):
- Optical particle counter
- FEM PM$_{2.5}$
- Uses proprietary algorithms to calculate total PM, PM$_{2.5}$, and PM$_{1}$ mass conc. from particle number measurements
- Cost: ~$25,000
- Time resolution: 1-min
The Laser Egg 2+ sensors tracked well with the concentration variation as recorded by the FEM GRIMM in the concentration range of 0 - ~300 μg/m³. The Laser Egg 2+ sensors showed very strong correlations with the FEM GRIMM PM$_{2.5}$ mass conc. (R$^2$ > 0.99).
Laser Egg 2+ vs FEM GRIMM PM\textsubscript{2.5} Accuracy

• Accuracy (20°C and 40% RH)

<table>
<thead>
<tr>
<th>Steady state #</th>
<th>Sensor Mean (µg/m\textsuperscript{3})</th>
<th>FEM GRIMM (µg/m\textsuperscript{3})</th>
<th>Accuracy (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>9.4</td>
<td>6.5</td>
<td>54.5</td>
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<tr>
<td>2</td>
<td>17.4</td>
<td>11.4</td>
<td>47.2</td>
</tr>
<tr>
<td>3</td>
<td>47.0</td>
<td>34.8</td>
<td>64.9</td>
</tr>
<tr>
<td>4</td>
<td>163.3</td>
<td>108.8</td>
<td>49.9</td>
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<td>5</td>
<td>287.1</td>
<td>193.5</td>
<td>51.6</td>
</tr>
<tr>
<td>6</td>
<td>451.0</td>
<td>302.7</td>
<td>51.0</td>
</tr>
</tbody>
</table>

• The Laser Egg 2+ sensors overestimated FEM GRIMM PM\textsubscript{2.5} mass concentration at 20 °C and 40% RH. The accuracy of the Laser Egg 2+ sensors was fairly constant (47% to 65%) over the PM\textsubscript{2.5} mass concentration range tested.

Laser Egg 2+: Data Recovery and Intra-model Variability

• Data recovery for PM\textsubscript{2.5} mass concentration from CED6, D0C3 and D20E was 97.5%, 99.8% and 95.0%, respectively.
• Low PM\textsubscript{2.5} measurement variations were observed between the Laser Egg 2+ sensors.
Laser Egg 2+ PM\textsubscript{2.5}: Precision

- Precision (Effect of PM\textsubscript{2.5} conc., Temperature and Relative Humidity)

Overall, the Laser Egg 2+ sensors showed high precision for all of the combinations of low, medium and high PM\textsubscript{2.5} conc., T, and RH.

- Precision was relatively higher at higher PM\textsubscript{2.5} concentrations.
Laser Egg 2+ PM$_{2.5}$: Climate Susceptibility

Kaiterra Laser Egg 2+ vs FEM GRIMM
(5 °C RH ramping, med PM$_{2.5}$ mass conc.)

From 15% to 40% RH
65% RH

High Temp – RH ramping
(medium conc.)

Kaiterra Laser Egg 2+ vs FEM GRIMM
(35 °C RH ramping, med PM$_{2.5}$ mass conc.)

From 15% to 40% RH
65% RH

Low Temp – RH ramping
(medium conc.)
Discussion

- **Accuracy**: Overall, the accuracy of the Laser Egg 2+ sensors was fairly constant (47% to 65%) over the PM$_{2.5}$ mass concentration range tested. The Laser Egg 2+ sensors overestimated PM$_{2.5}$ measurements from FEM GRIMM in the laboratory experiments at 20 °C and 40% RH.

- **Precision**: The Laser Egg 2+ sensors showed high precision for all test combinations (PM concentrations, T and RH) for PM$_{2.5}$ mass concentrations.

- **Intra-model variability**: Low intra-model variability was observed among the Laser Egg 2+ sensors.

- **Data Recovery**: Data recovery for PM$_{2.5}$ mass concentration from Units CED6, D0C3 and D20E was 97.5%, 99.8% and 95.0%, respectively.

- **Coefficient of Determination**: The Laser Egg 2+ sensors showed very strong correlation/linear response with the corresponding FEM GRIMM PM$_{2.5}$ measurement data ($R^2 > 0.99$).

- **Climate susceptibility**: For most of the temperature and relative humidity combination, the climate condition had minimal effect on the Laser Egg 2+ sensor’s precision; at the set-points of RH changes, the sensors showed some small spiked conc. changes.