

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):

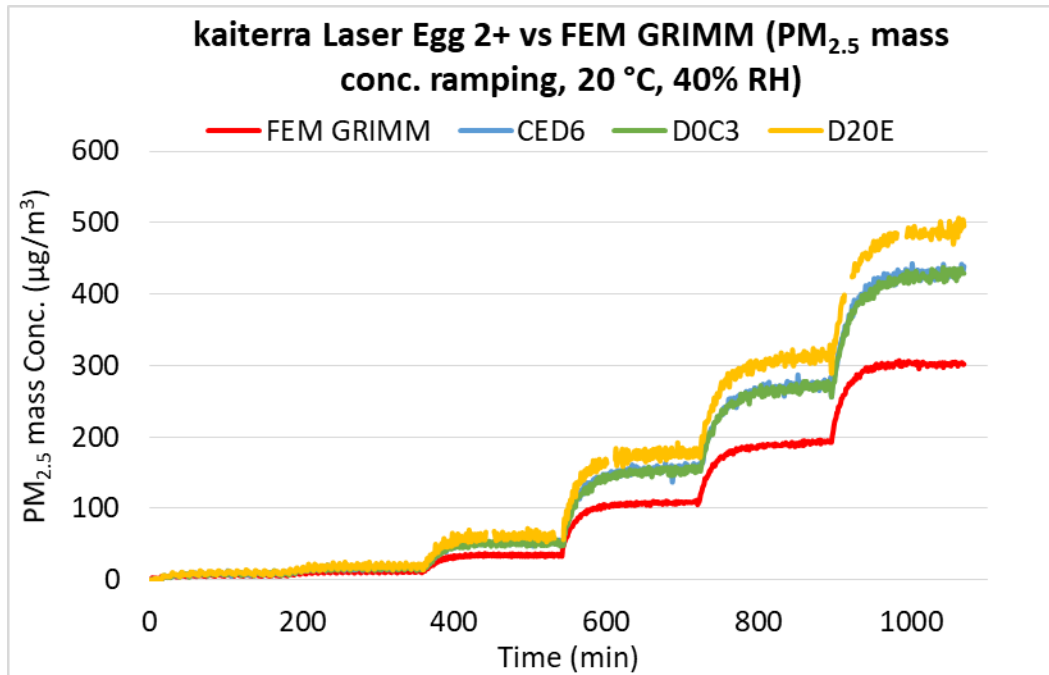
- Particle sensor: Laser Particle Counter (**optical; non-FEM**) (model PMS3003 by Plantower)
- Each unit reports: PM_{2.5} and PM₁₀ (μg/m³), Temperature (°C), Relative Humidity (%)
- Also measures TVOC (ppb)
- **Unit cost: \$199**
- Time resolution: 1 min
- Units IDs: CED6, D0C3, D20E
- Differences from Laser Egg: In addition to PM_{2.5} and PM₁₀, 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 PM₁ mass conc. from particle number measurements
- **Cost: ~\$25,000**
- Time resolution: 1-min

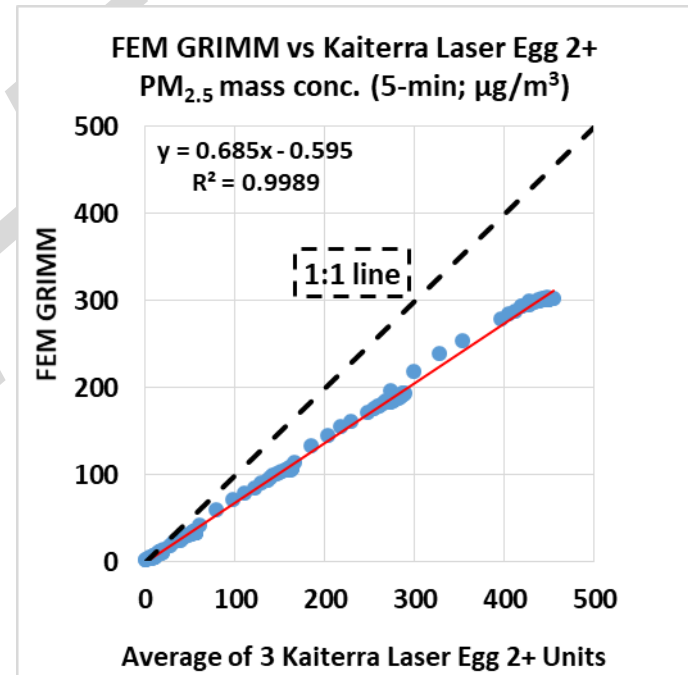


Laser Egg 2+ vs FEM GRIMM (PM_{2.5} mass conc.)



- 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.

Coefficient of Determination



- 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_{2.5} Accuracy

- Accuracy (20°C and 40% RH)

Steady state #	Sensor Mean (µg/m ³)	FEM GRIMM (µg/m ³)	Accuracy (%)
1	9.4	6.5	54.5
2	17.4	11.4	47.2
3	47.0	34.8	64.9
4	163.3	108.8	49.9
5	287.1	193.5	51.6
6	451.0	302.7	51.0

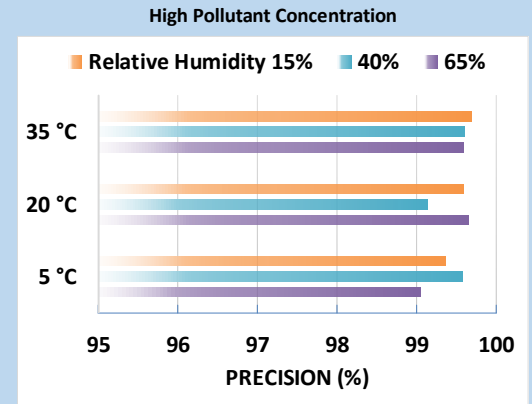
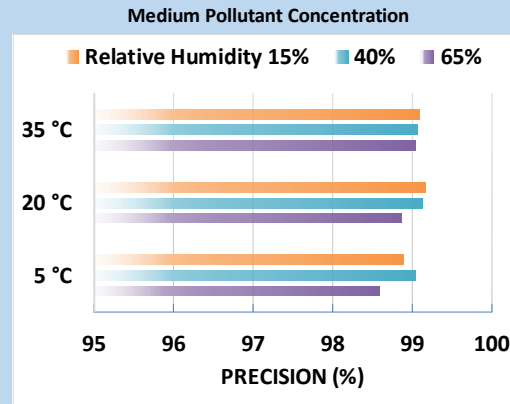
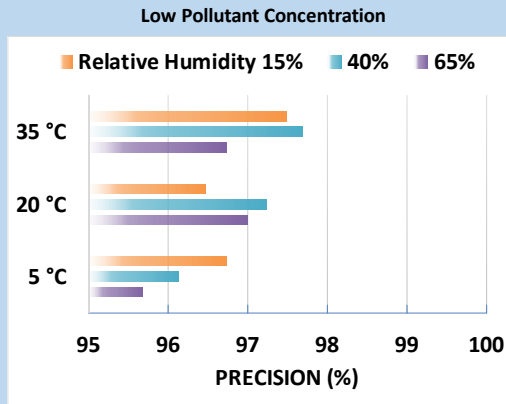
- The Laser Egg 2+ sensors overestimated FEM GRIMM PM_{2.5} mass concentration at 20 °C and 40% RH. The accuracy of the Laser Egg 2+ sensors was fairly constant (47% to 65%) over the PM_{2.5} mass concentration range tested.

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

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

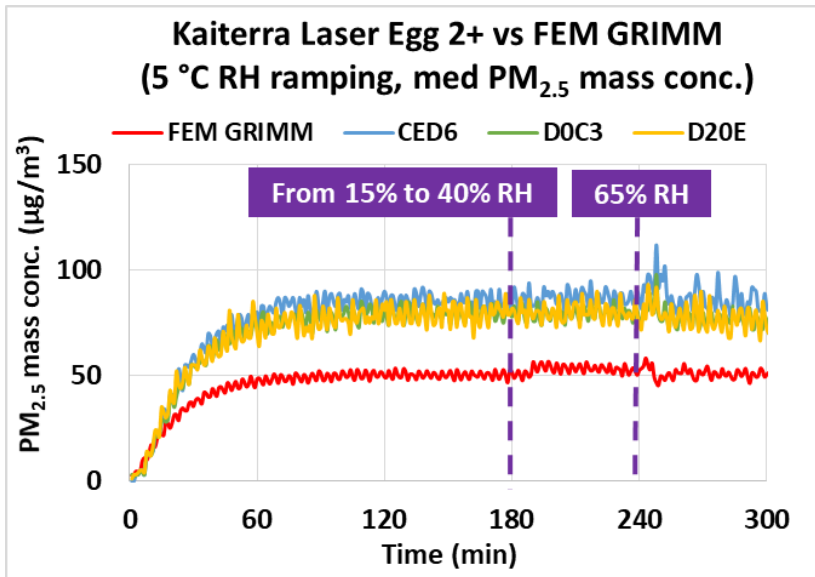
Laser Egg 2+ PM_{2.5}: Precision

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



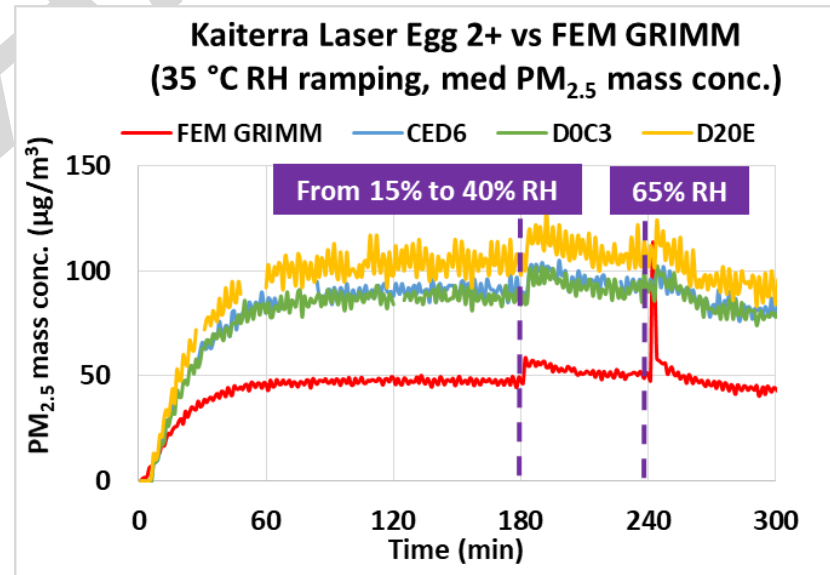
- Overall, the Laser Egg 2+ sensors showed high precision for all of the combinations of low, medium and high PM_{2.5} conc., T, and RH.
- Precision was relatively higher at higher PM_{2.5} concentrations.

Laser Egg 2+ PM_{2.5}: Climate Susceptibility



**Low Temp – RH ramping
(medium conc.)**

**High 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.