Stratospheric Aerosol Composition and Loading Experiment

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Introduction

This work describes the development of an instrument named the Stratospheric Aerosol Composition and Loading Experiment (SPARClE) that can infer two aerosol properties: particle radius and complex refractive index from a sample. This instrument uses a CCD camera and a photomultiplier tube (PMT) to measure the phase function and scattered light. Based on these data, a numerical retrieval method can be applied to calculate the aerosol properties. The advantages of this method are that there is no physical or chemical alteration of the aerosol sample-which could affect its refractive index - and also that the instrument is designed to be compact, able to fit into unmanned aerial vehicle

Instrument Design

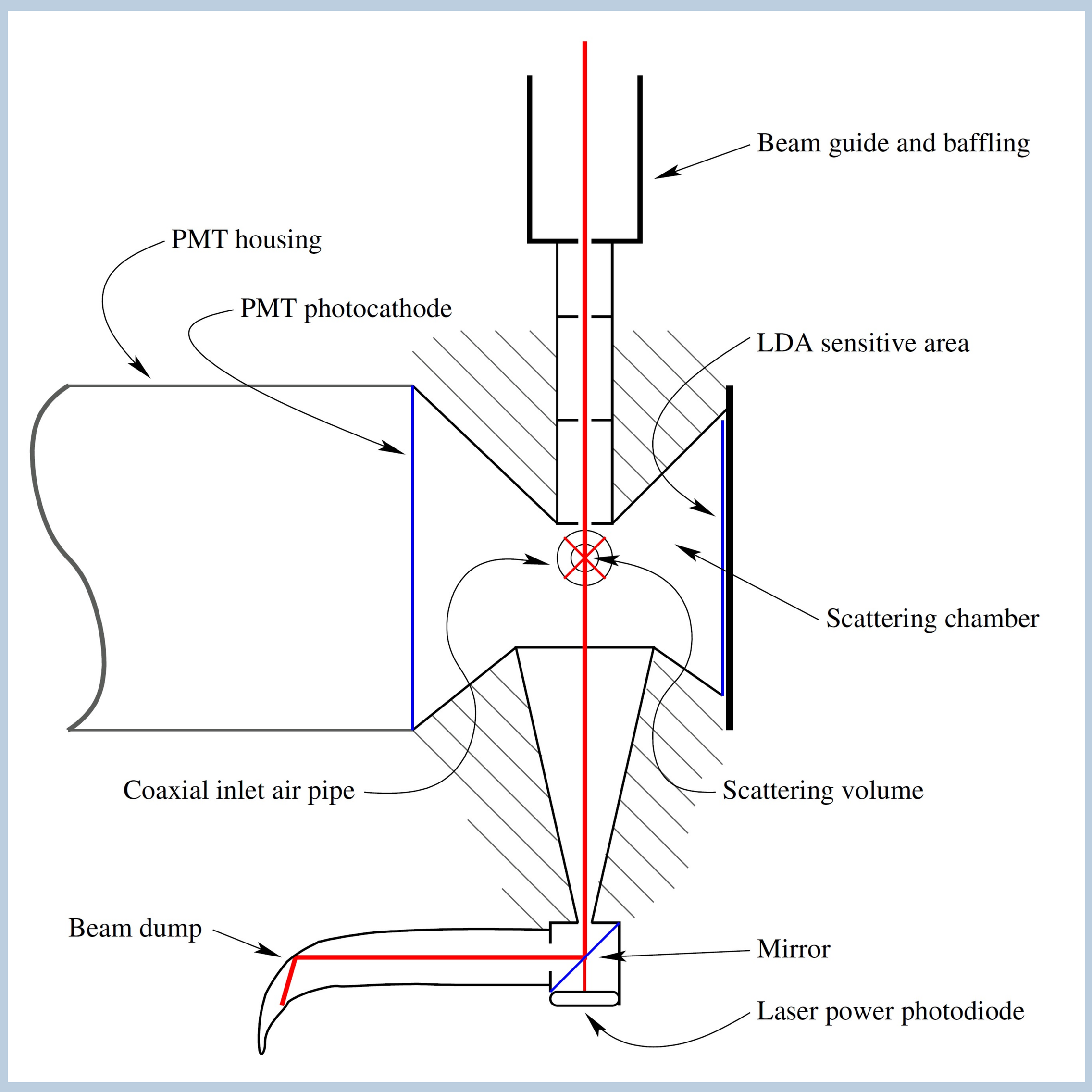

Figure 1: SPARCLE Design

Conclusion

Calculation of PMT and CCD response as a function particle radius and refractive index has been performed. The outcome of those two measurement can be used to develop retrieval algorithm to infer particle radius and refractive index. However, cost function of our design shows many local maxima/minima which make developing retrieval algorithm more challenging.

References

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Rodgers, C.D. 2000. Inverse Methods for atmospheric sounding: Theory and Practice. Singapore: World Scientific.

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Method

The scattered radiation from the interaction between light and spherical particle is described by Mie equation :

$$I(\theta,\phi) = E_\theta \frac{\lambda^2}{4\pi^2}(i_1 sin^2\phi + i_2 cos^2\phi) \quad (1)$$

with

$$i_1(x,m,\theta) = \left| \sum_{n=1}^{\infty} \frac{2n+1}{n(n+1}(a_n\pi_n + b_n\tau) \right|^2 \quad (2)$$

and

$$i_2(x,m,\theta) = \left| \sum_{n=1}^{\infty} \frac{2n+1}{n(n+1}(a_n\tau_n + b_n\pi) \right|^2 \quad (3)$$

Based on these equations, it could be concluded that by measuring scattered light over some certain angles, aerosol radius and refractive index could be retrieved using numerical inversion technique.

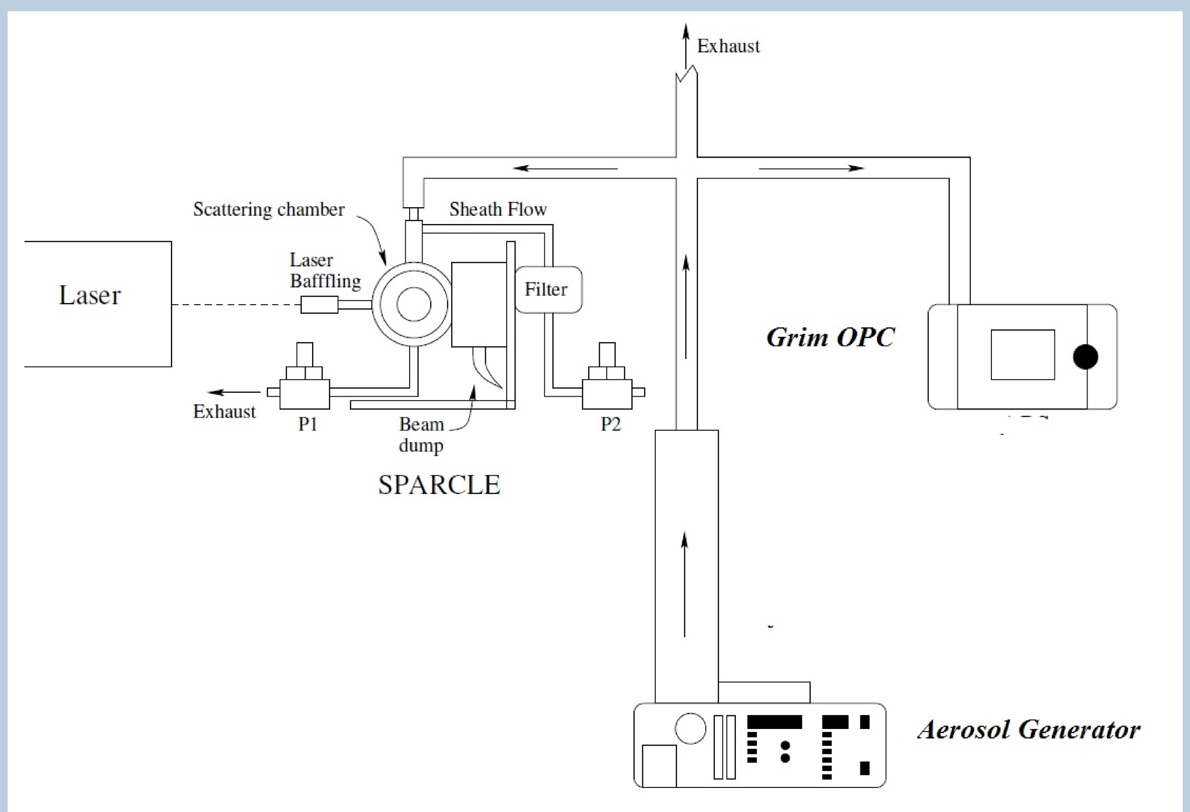

Figure 2: Experiment Scheme

PMT and CCD Camera response and retrieval challenge

Response from PMT and CCD Camera is calculated from SPARCLE design.

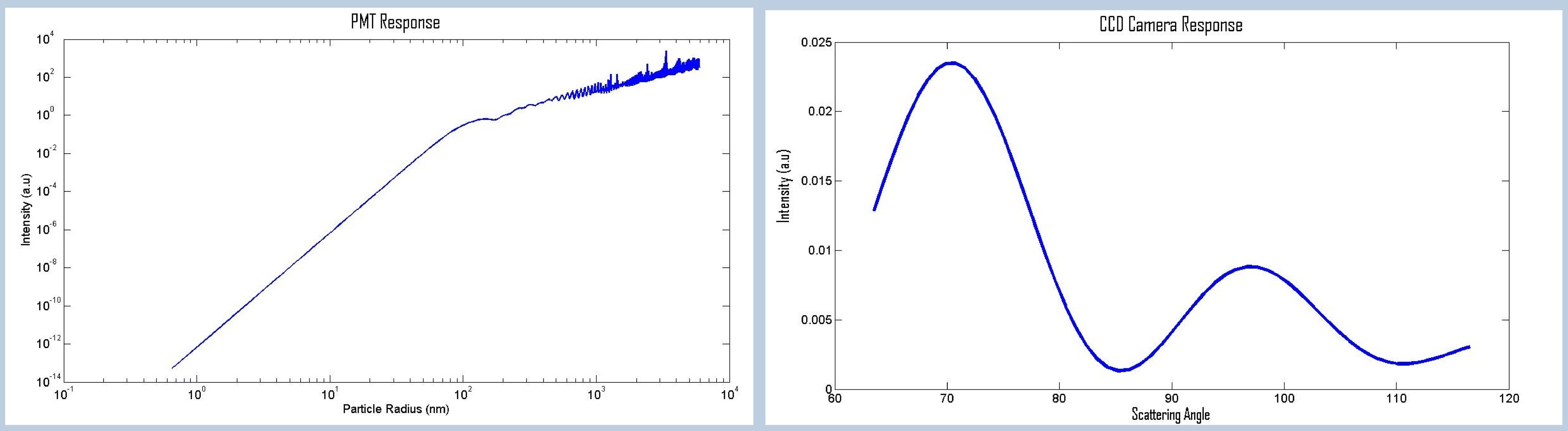

Figure 3: Calculated PMT response (left);Calculated CCD camera response (right)

As can be seen from the figure, roughly linear correlation between particle radius and PMT response is applied up to about 1 μm while higher particle radius shows a highly nonlinear profile.

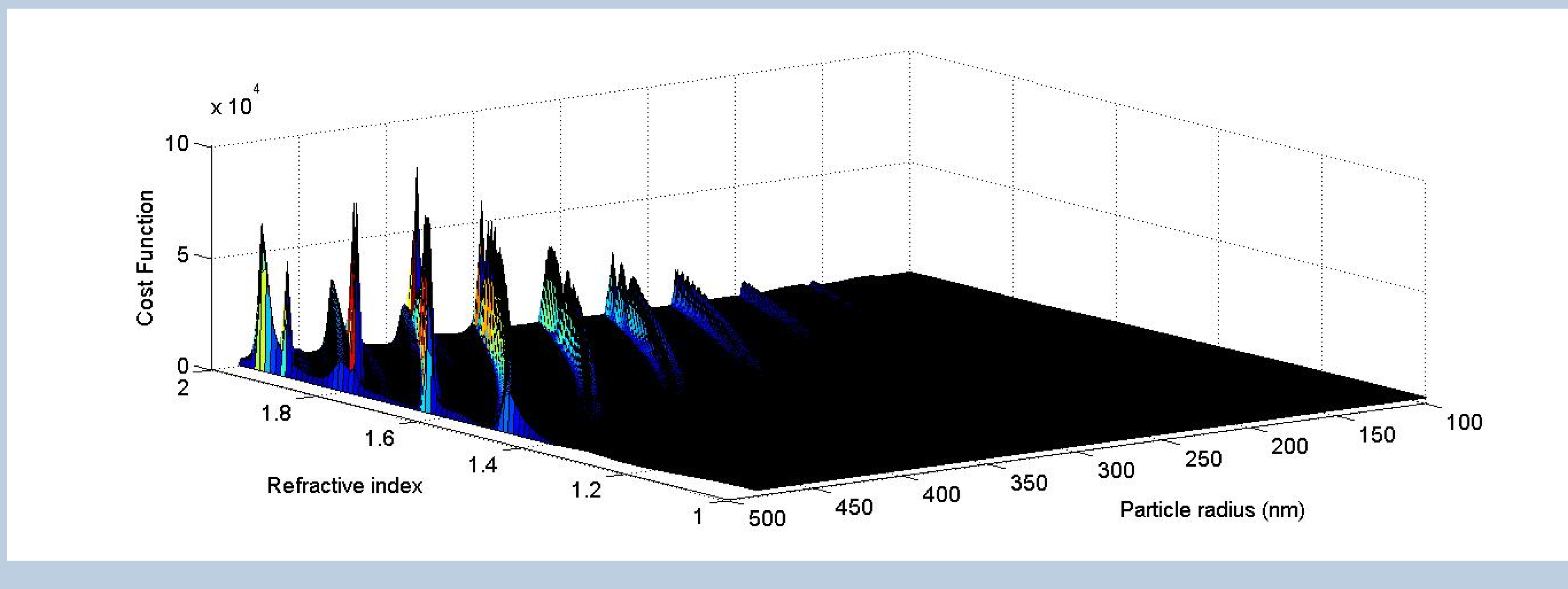

Figure 4: Cost function

The cost function of our design is calculated based on the equation

$$-2LnP(x|y) = [y - F(x)]^T S_\epsilon^{-1}[y - F(x)] + [x - x_a]^T S_a^{-1}[x - xa] \quad (4)$$

Figure 3 is cost function calculated from measurement vector produced by non-absorbing spherical particle with 412 μm radius and 1.4 + 0.0i refractive index. It is clear that we have many local maxima and minima surrounding the true value which make retrieval algorithm prone to misleading estimation.