New optical size spectrometer for probing atmospheric particulates

March 1 2018

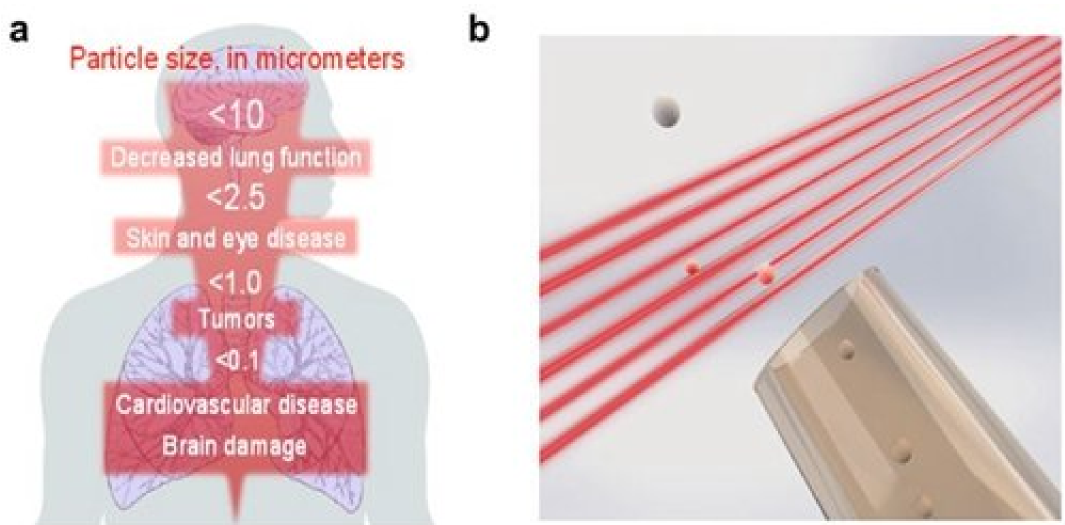

Figure 1. a, Illustration of different diseases induced by different-sized particulate matters. b, A nanowaveguide array structure for probing the size distribution of ultrafine airborne particulates. Credit: Peking University

The global environment is suffering from air pollution due to excess particulate matters, resulting in huge societal and economic costs. Air quality is usually characterized by the mass concentration of fine particulate matters with aerodynamic diameters smaller than 2.5 µm (PM2.5), which is mainly contributed by micron-sized particles, whereas the hazard induced by ultrafine particulates (with diameters smaller than hundreds of nanometers) remains seriously underestimated. In addition to their mass distribution, the size distributions of airborne particulates are becoming increasingly important for the evaluation of air hazards.

A team led by Professor Xiao Yun-Feng at Peking University proposes and demonstrates a low-profile, high-accuracy, cavity-free, and real-time size probing system working in an open environment using a nanowaveguide array structure with a strong evanescent field. This work has been published online in *Light: Science & Applications*.

Ultrafine particulates are believed to have even more aggressive health implications than larger particulates, because they can enter the lungs, causing lung cancer, and can further penetrate the air-blood barrier, invading the circulation system and resulting in respiratory illness and even organ dysfunction. An article featured in *Science* emphasizes that the inhaling of ultrafine airborne pollutants may attack the brain and may even increase risks of Alzheimer's disease and other forms of dementia. Therefore, more attention should be paid to the ultrafine particles, and their size distributions. Compared to the conventional aerosol analysis techniques for measuring the size distributions of particulate matters, the optical methods show great potential for measuring the size distributions of particulate matters due to their non-destructive nature, electromagnetic noise immunity, and real-time in situ detection capability.

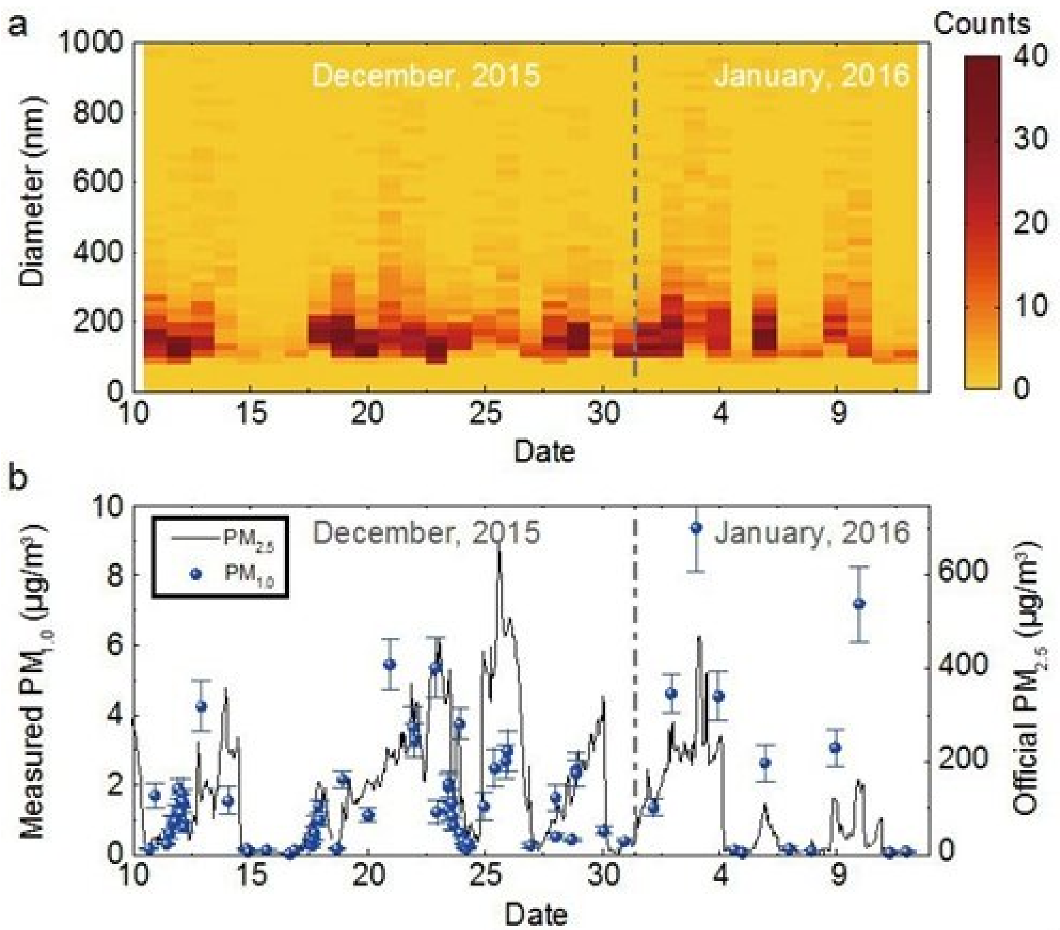

Figure 2. One-month data for PM1.0 measured by the nanofiber-based size spectrometer. The size distribution (a) and the mass concentration (b) of the particulate matter from December 11th, 2015 to January 12th, 2016. The symbols and the solid curve indicate the experimental PM1.0 data and the official PM2.5 data reported by BJMEMC. The error bars indicate the standard deviation. Credit: Peking University

The typical optical methods for measuring the size of nanoparticles mainly utilize absorption or scattering methods. However, the absorption methods are only applicable for lossy targets, while the conventional scattering methods using free space laser light must be operated in a closed cavity to avoid disturbance from environmental light, thus making the system rather complicated. The recently developed optical microcavity sensing systems using scattering methods have removed the requirement for a closed cavity and achieved an unprecedented low detection limit. However, microcavity-based sizing typically requires a tunable laser source and the strict control of near-field coupling.

In the publication, the researchers developed a cavity-free size spectrometer for probing fine and ultrafine particulate matters without the need of a tunable laser and near-field coupling control. "The device utilizes the enhanced particle-perturbed scattering in strong optical evanescent fields, and the probing component is a serpentine patterned nanofiber array. The size information of the analyte is read out by monitoring the power drops of the transmitted light due to the nanoparticle induced scattering. A sizing resolution of 10 nm is achieved for 100-nm-diameter standard polystyrene (PS) nanoparticles by optimizing the polarizations of the probe light." said Dr. Yu Xiao-Chong, a postdoctoral researcher at Peking University, and the first author of this work.

The work highlights the size spectrometer by probing the evolution of atmospheric particulates in the winter of 2015 and 2016. When the airborne particulates flow onto the nanowaveguide, the transmitted light power strongly depends on the particle size, and thus the size distributions can be obtained in real time. The evolution of the particulate diameters in Beijing atmosphere are monitored with a 20-nm step. Using the average refractive index and density of the particulates, the evolution of the size distribution is ready to be converted to that of the mass distribution. The trend in the evolution of the experimental PM1.0 results is consistent with that of the official PM2.5 data, validating the sizing capability of the size spectrometer.

"Except for the mass distributions, the size distributions are more important, because particulates with diameters of hundreds of nanometers may cause irreversible damage to organs, but the conventional PM2.5 data is mainly contributed by larger particulates." said Professor Qiu Cheng-Wei, the collaborator at National University of Singapore. "The developed size spectrometer is superior to monitor smaller particulates and has shown a detection limit of 100 nm. This device can not only be applied in evaluating the air quality, but also can find applications in industries where the size of nanoparticles need to be tracked," said Professor Xiao.

More information: aap.nature-lsa.cn:8080/cms/acc … les/AAP-lsa20183.pdf

Provided by Peking University

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