Research of tin droplet generation, diagnosis and synchronization with laser

Wang Xinbing *, Wang Junwu, Zuo Duluo, Lu Peixiang

Wuhan National Laboratory for Optoelectronics, Huazhong University of Science & Technology, Wuhan 430074, China

Guangdong Intelligent Robotics Institute, Dongguan, GuangDong, China

E-mail: xbwang@hust.edu.cn

Introduction

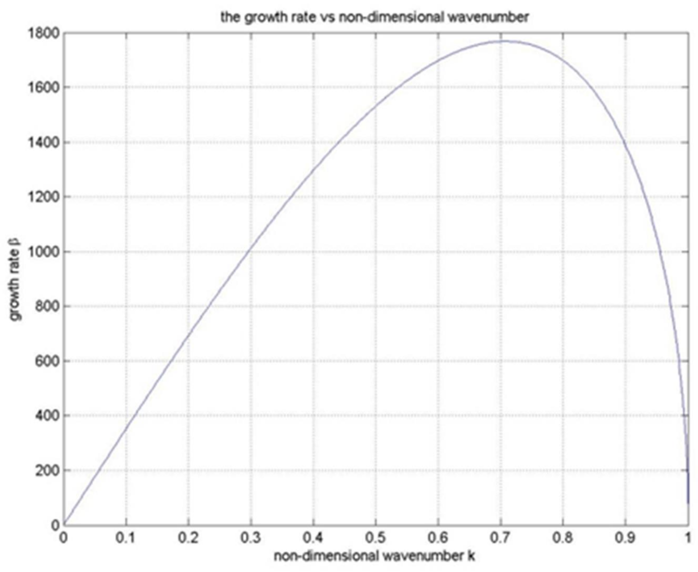
Based on fluid dynamics theory of jet breakup, theoretically the production process of tin droplets was simulated by the use of Ansys Fluent software. Experimentally a tin droplet generator was developed. An online monitoring system was built to evaluate the performance of the tin droplet generator. Stable spray tin droplets with diameter of 180 μm and 20 kHz was obtained. A spatial-temporal synchronization system of pulsed laser and droplet interaction is constructed, which can continuously and accurately focus the laser pulse to a single tin droplet.

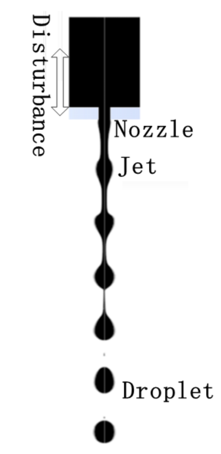
Simulation of tin droplet generator

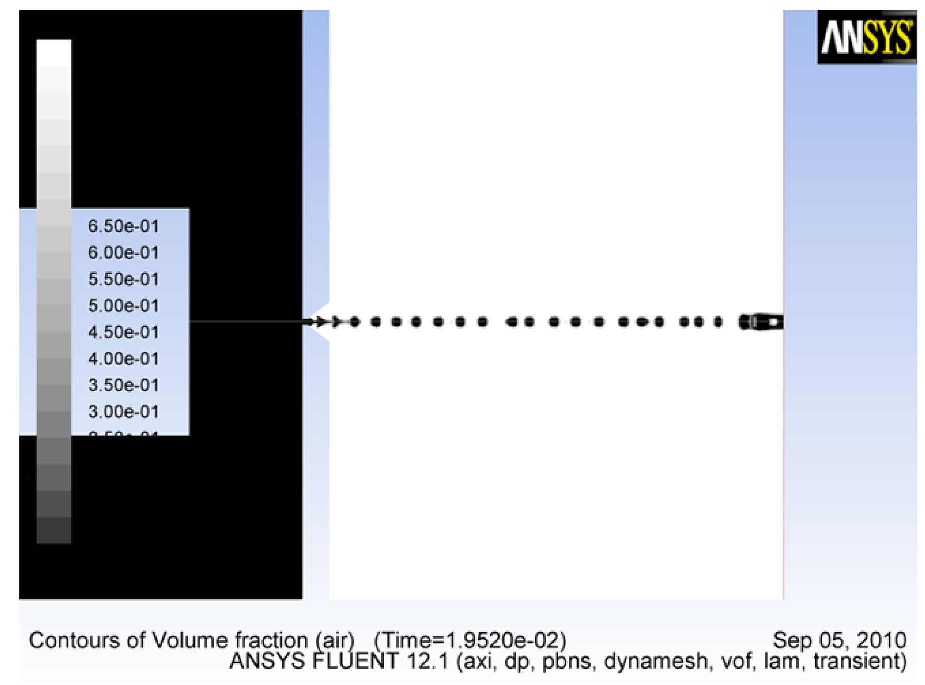
The main principle of the droplet generator based on jet perturbation is to first generate a jet and perturb the jet in the axial direction. At this time, the disturbance will be transmitted along the axial direction. When the growth rate reaches a certain condition, the jet will break.

Weber Equation for jet breakup

$$\beta^2 + \frac{3\mu k_0^2}{\rho r_0^2}\beta = \frac{\sigma}{2\rho r_0^3}\left(1-k_0^2\right)k_0^2 + \frac{v^2\rho_a k_0^3 K_0\left(k_0\right)}{2\rho r_0^2 K_1\left(k_0\right)}$$

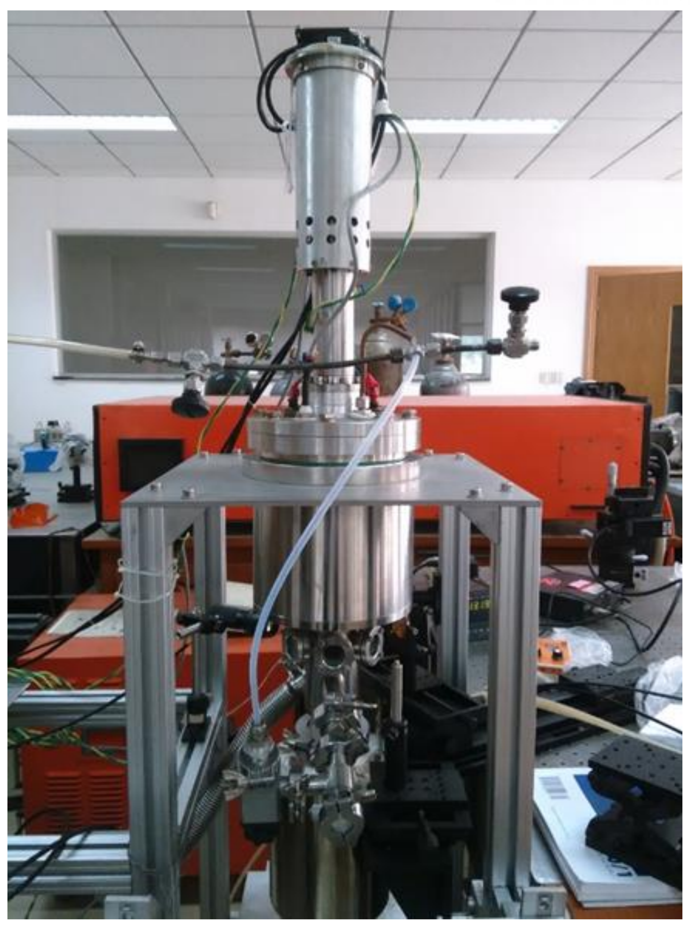




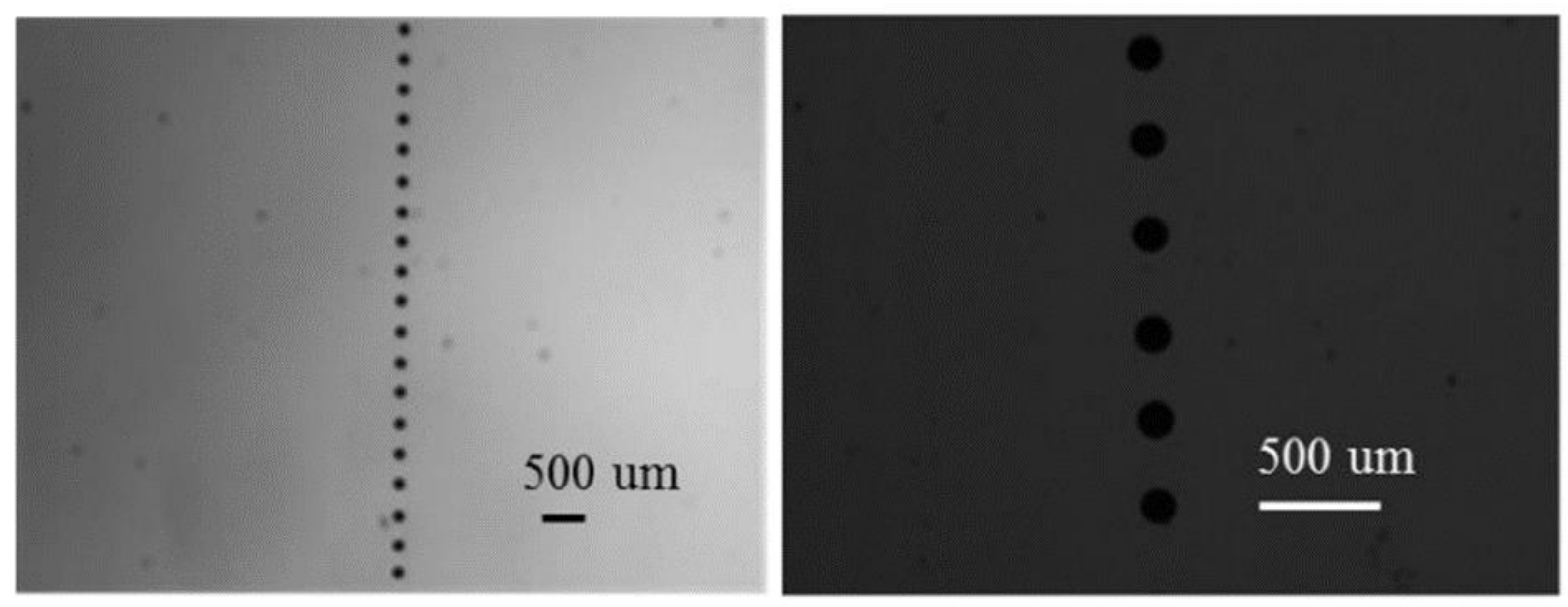


Tin droplet generator development

Based on the simulation, we got the best conditions for jet breakup and built a droplet generator. It can operate at pressure of about 10 MPa temperature of 300℃. By changing nozzles, background pressure and disturbance frequencies, droplets with different sizes, speeds and frequencies can be obtained.

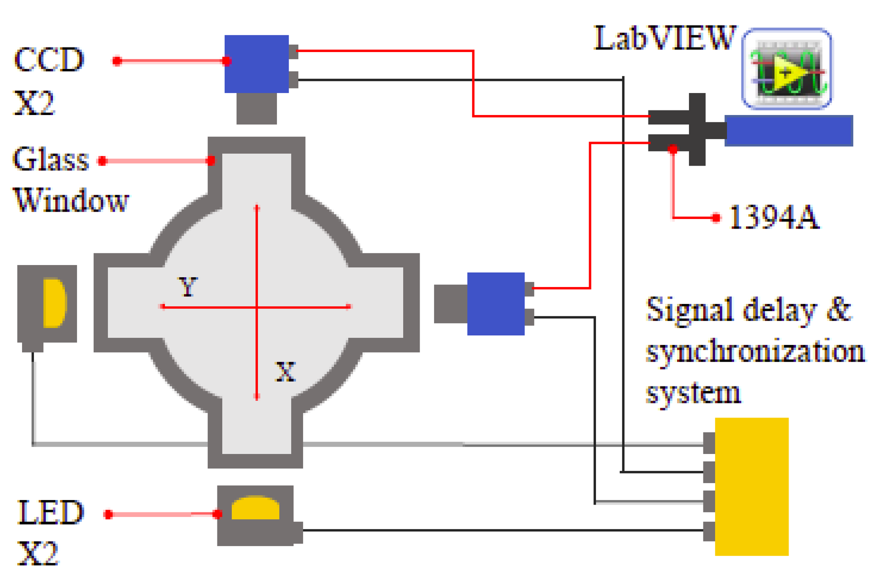


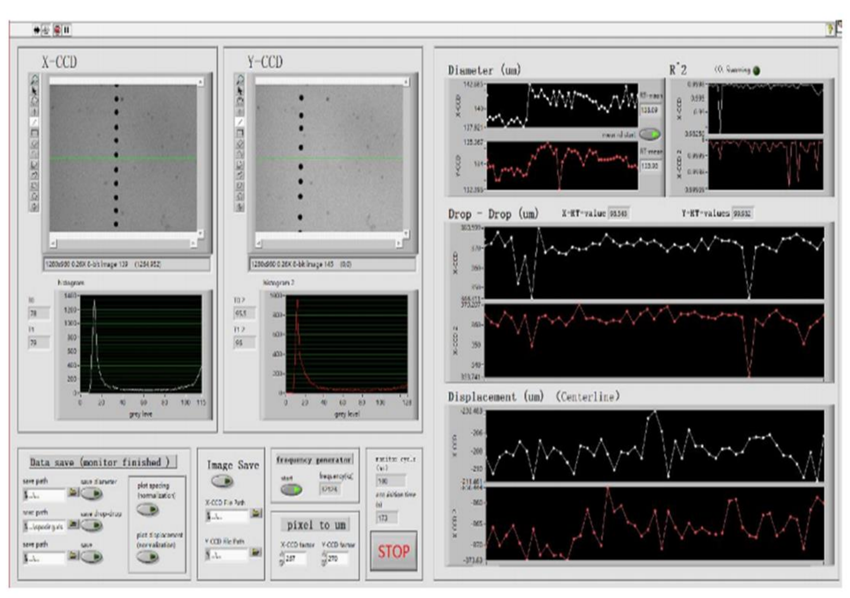
Nozzle diameter 100 μm, frequency 20 kHz, pressure 7 bar

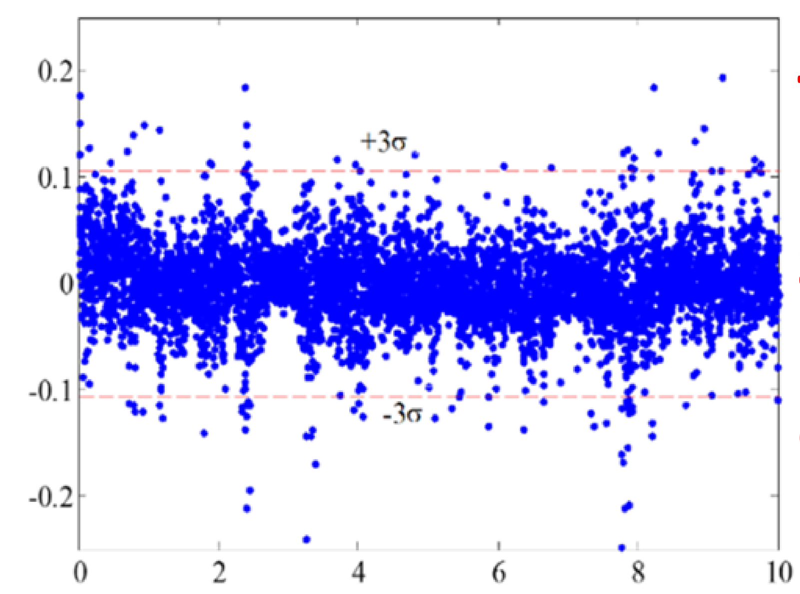


Tin droplets performance

Two Orthogonal CCDs are set up at the orthogonal angle to detect the characteristics and stability of tin droplets. The motion and stability of the tin droplets can be displayed by image capturing and processing in real time.

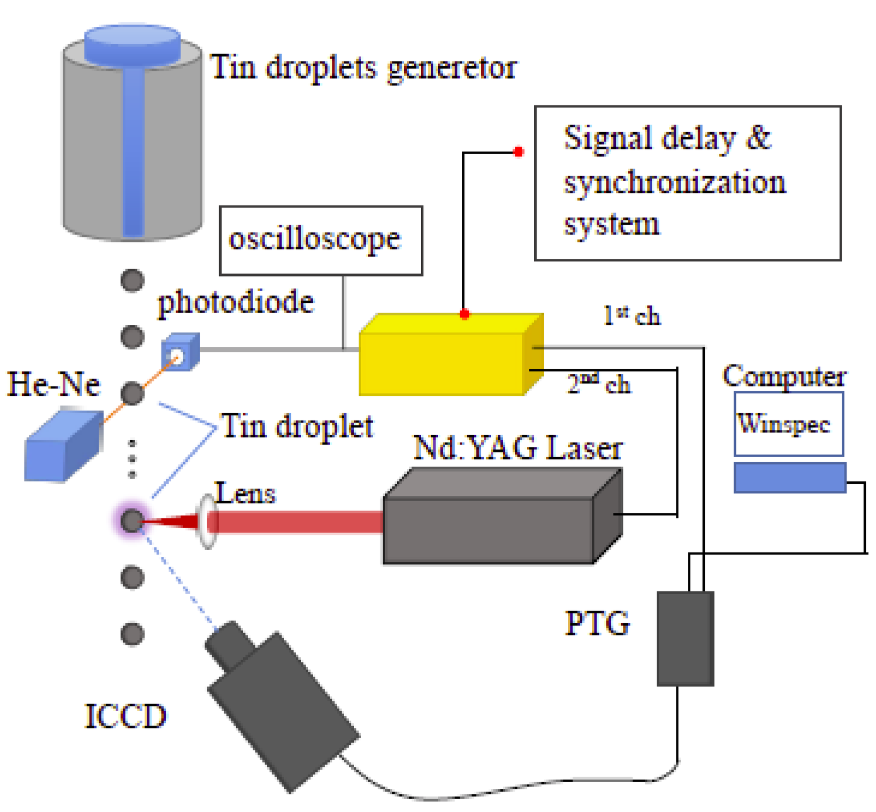


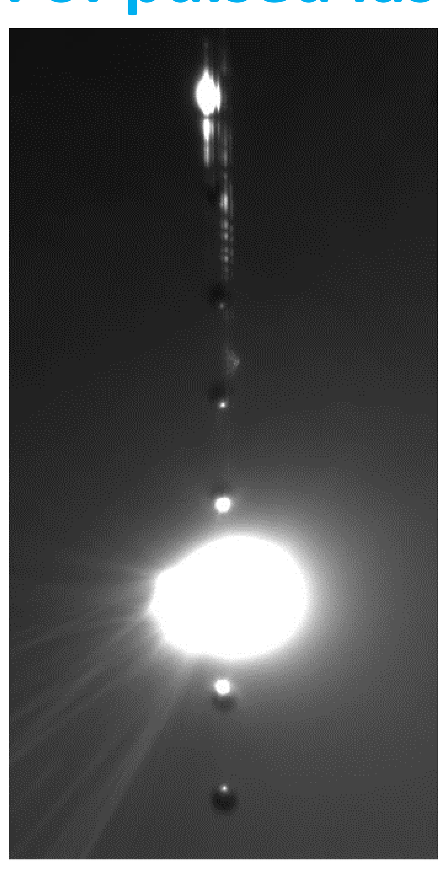


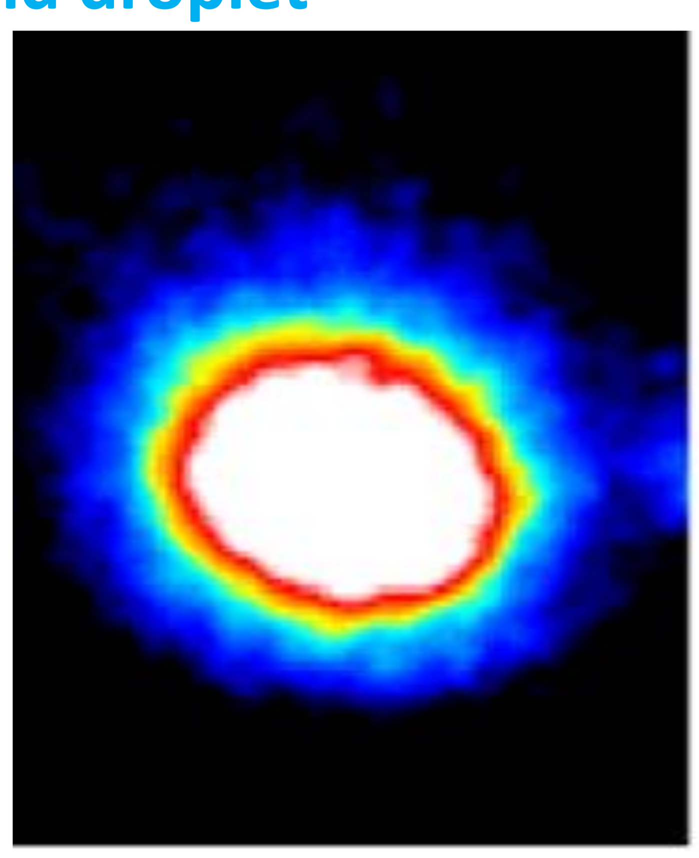


Tin droplets Dia. 180 μm
Droplet spacing 450 μm
Spray speed 9 m/s
Droplet stability 10% of its diameter

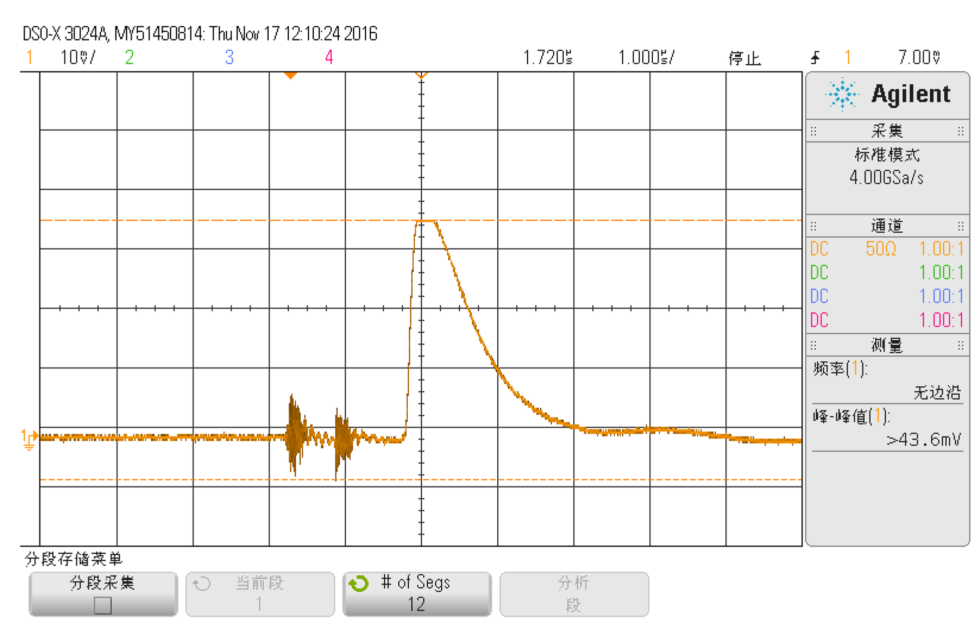
Spatial-temporal synchronization of pulsed laser and droplet







ICCD Plasma plume evolution



EUV signal from E-Mon-A6283

Conclusion

A tin droplet generator with online monitor system was developed. The Spatio-temporal synchronization ensures 20 kHz droplets interact with 1~10 Hz Nd:YAG laser through the signal frequency division. The EUV CE in 2% band at 13.5 nm into 1.6π was about 1%.

Future work

1. Droplet size should be reduced, and stability should be further improved;
2. High repetition laser (>10 kHz) interaction with droplet.