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Characteristics of mixing enhancement achieved using a pulsed plasma synthetic jet in a supersonic flow

Key words: Supersonic shear layers, Supersonic mixing layers, Plasma synthetic jet, Mixing enhancement

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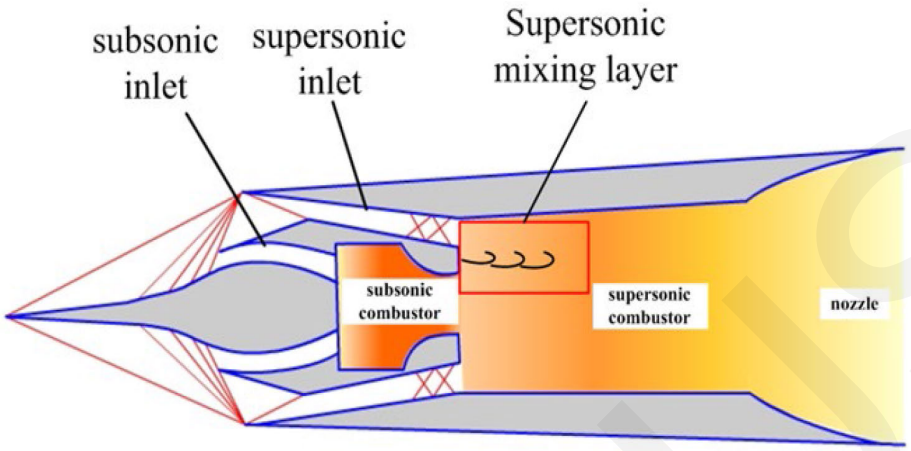
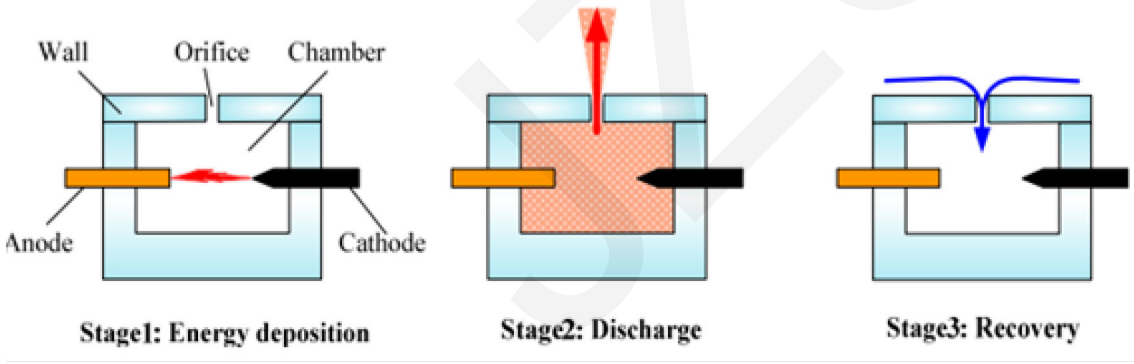
INTRODUCTION



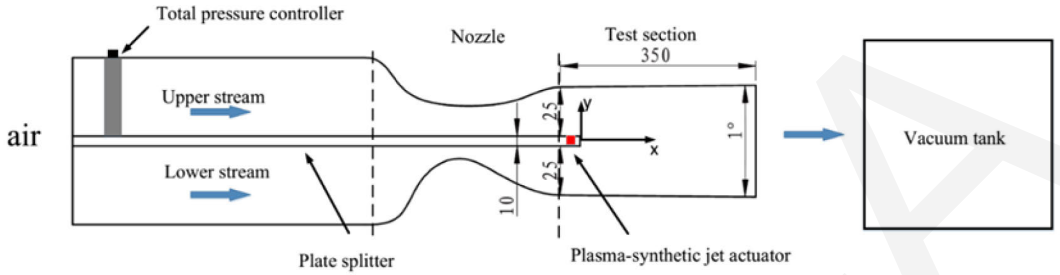
The rapid mixing of fuel and oxidant at short distances is of great importance, but makes it difficult to develop efficient propulsion systems.

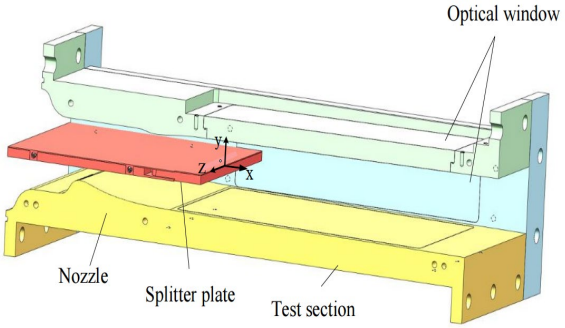


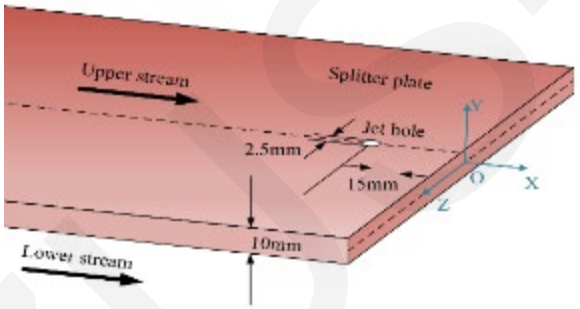
The plasma synthetic jet (PSJ) is regarded as a promising high-speed flow control technique.

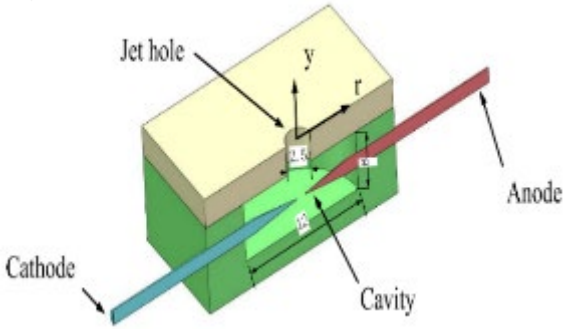
fast response, no moving parts or fluid supply device and wide frequency band

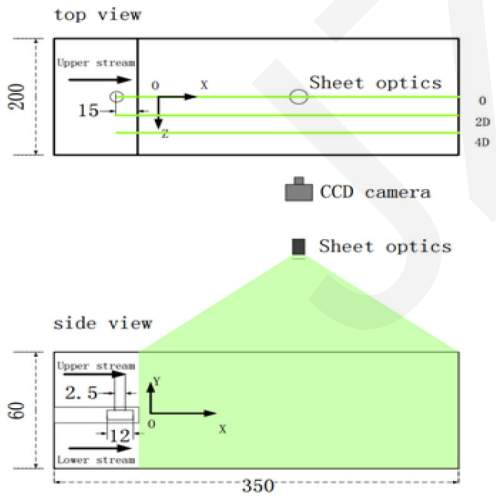
EXPERIMENTAL SETUP

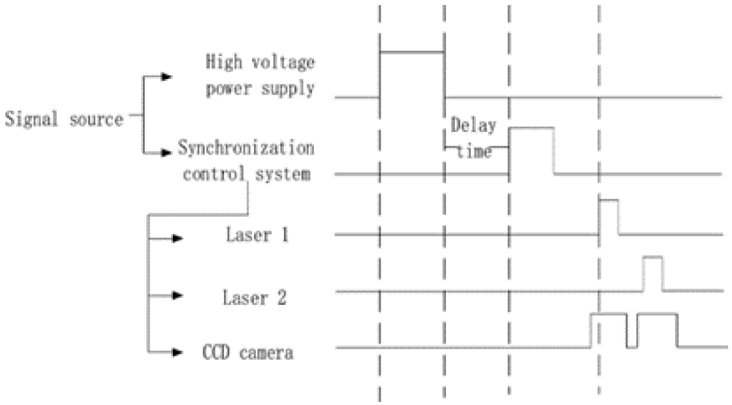




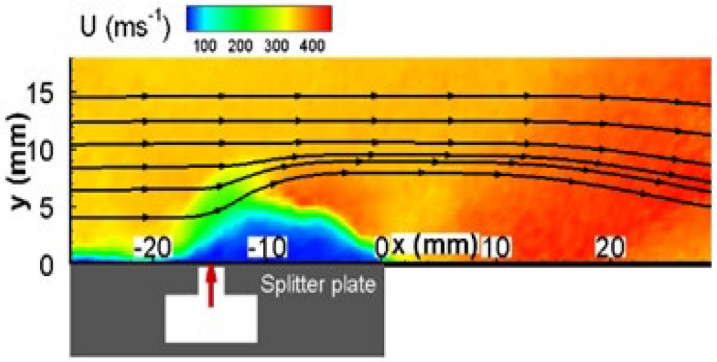




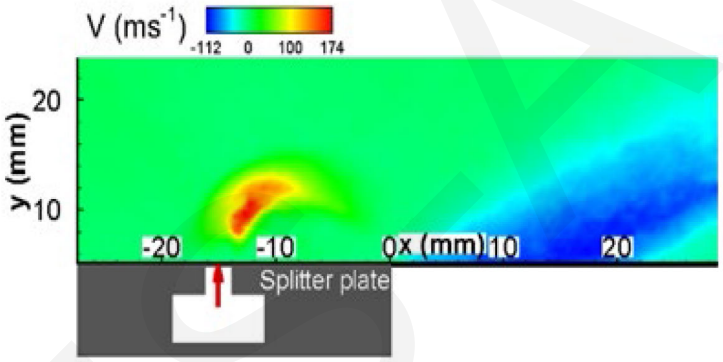




RESULTS



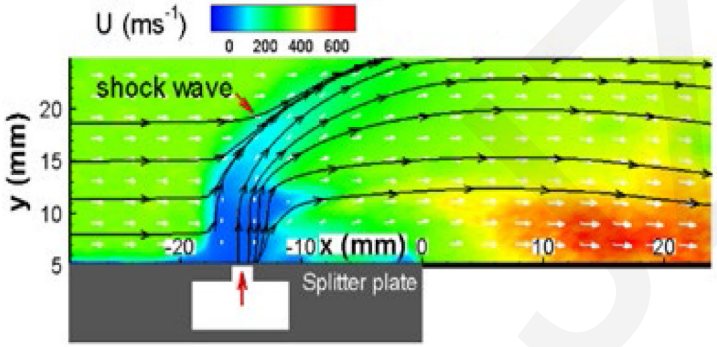
$U\,(\mathrm{ms}^{-1})$



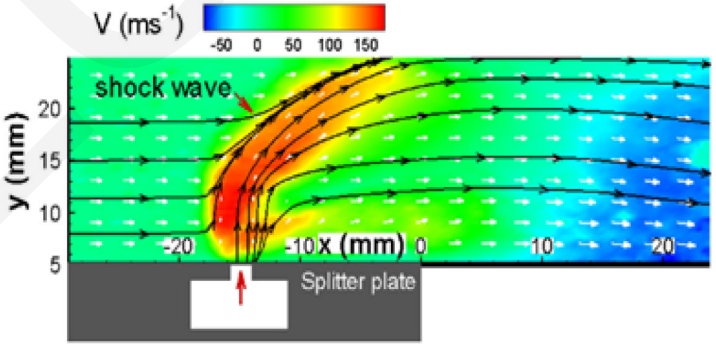
$V\,(\mathrm{ms}^{-1})$

T_0+20 μs PIV results

At T0+20 μs, the upper stream was lifted by the PSJ.



$U\,(\mathrm{ms}^{-1})$



$V\,(\mathrm{ms}^{-1})$

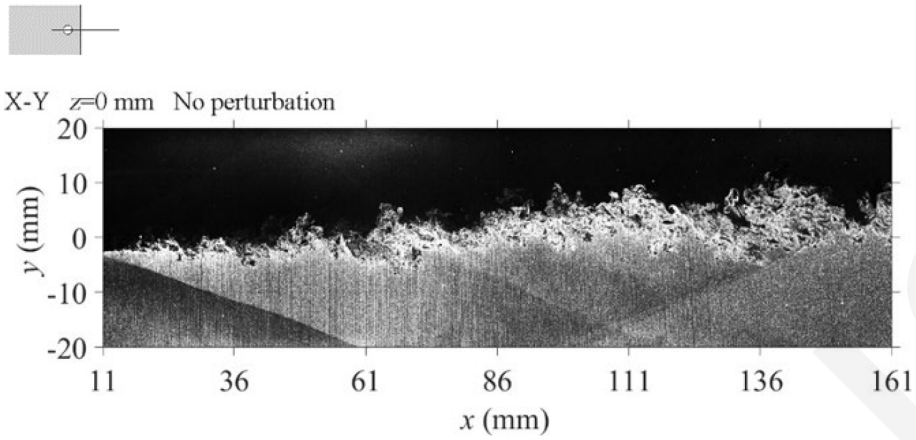
T_0+110 μs PIV results

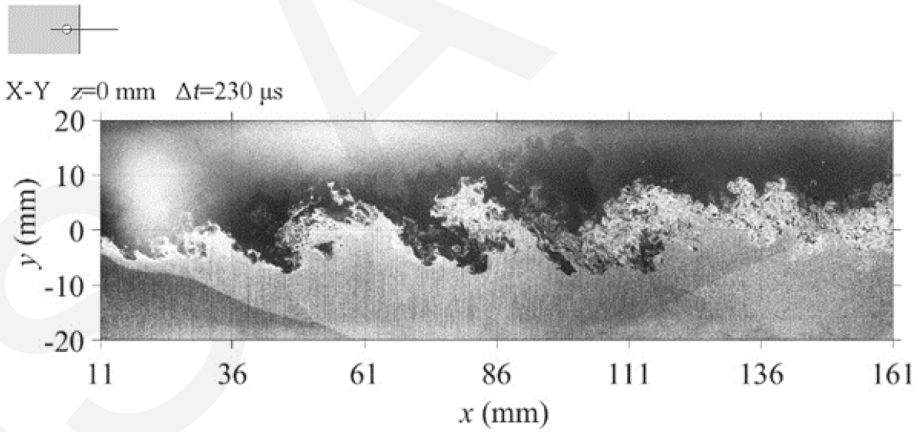
At T0+110 μs, a bow shock wave was produced by the PSJ.

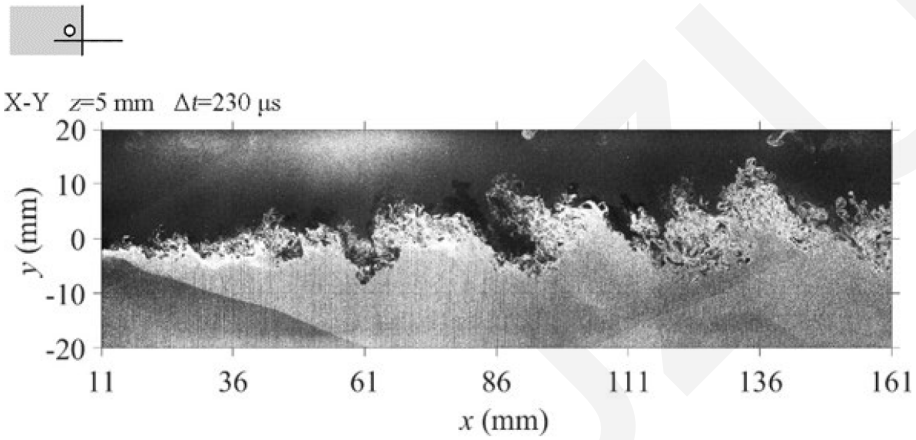
At T_0+20 μs, U_{jet}/U_{∞}=0.497.

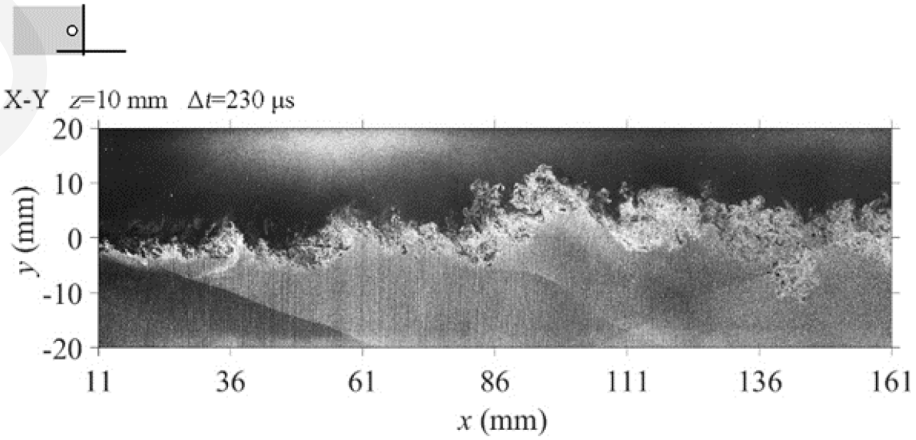
At T_0+110 μs, U_{jet}/U_{∞}=0.514.

RESULTS





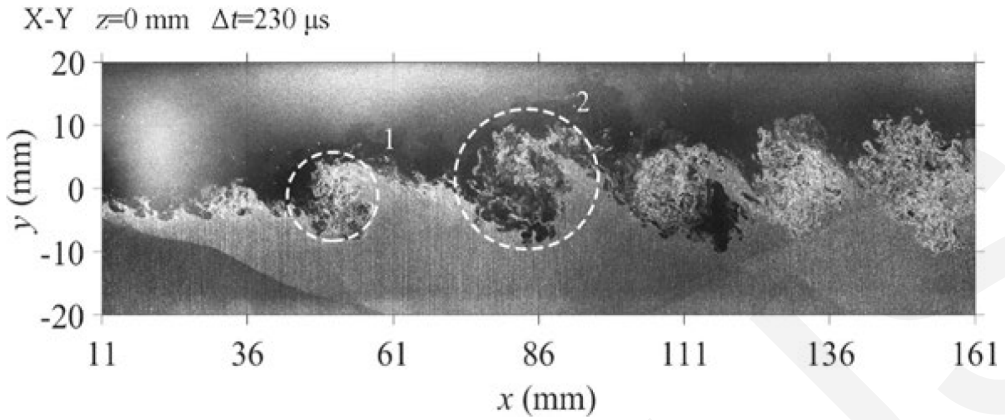


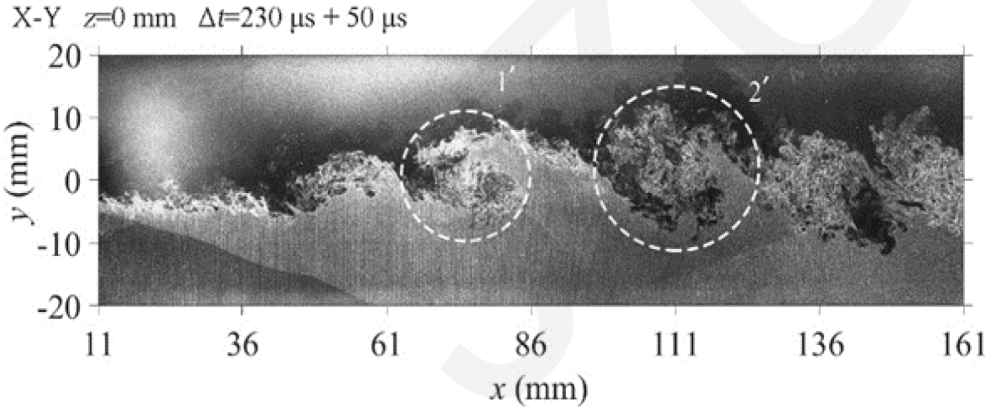


The effect of the PSJ decreased as the distance from the jet hole increased in the spanwise plane.

The effect of the PSJ exceeded 8*D* in the spanwise plane.

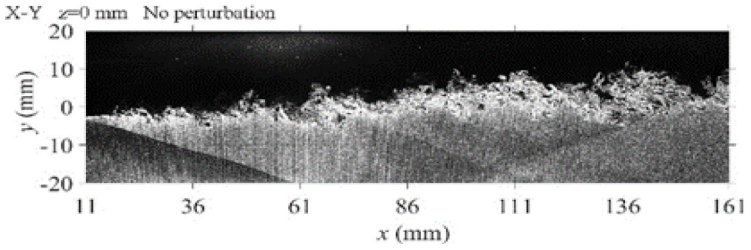
RESULTS

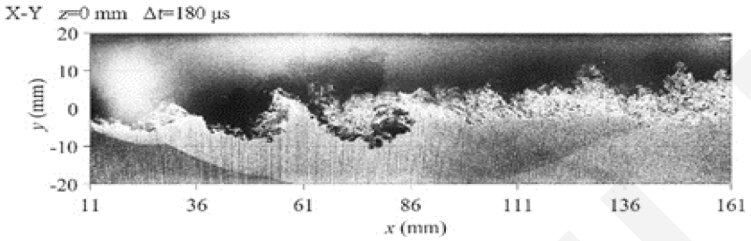


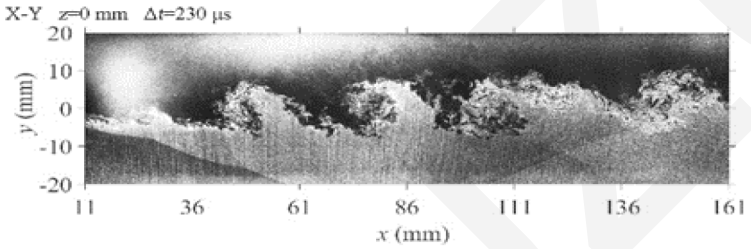


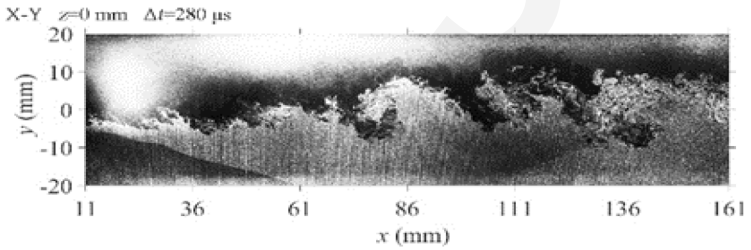
The time interval of the two NPLS visualization results is 50 μs.
The PSJ inside the large-scale vortex structures intensified the turbulent fluctuation, and the PSJ surrounding the large-scale vortex structures enlarged the vortex scale.

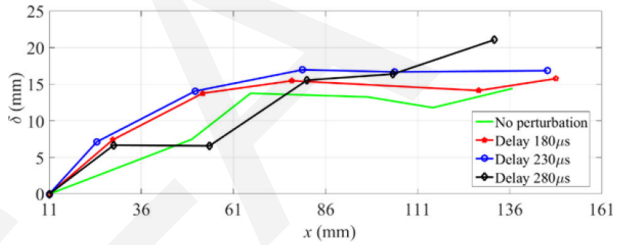
RESULTS

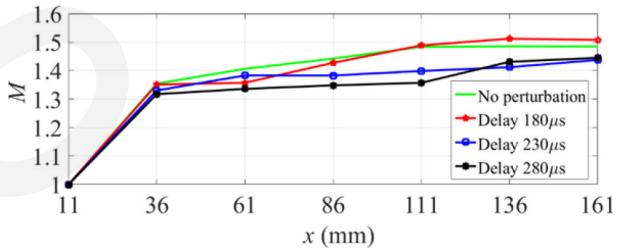












Notably, with the perturbation of the moving downstream, the effect of the perturbation became relatively large. The PSJ can therefore increase the thickness of the supersonic mixing layer.

The high-strength perturbation of the PSJ can improve the number of small-scale vortex structures in the local area, but not over the entire mixing layers.

CONCLUSIONS

- A PSJ can be used as an effective method for mixing enhancement based on the analysis of the NPLS results in three directions. The effects of the PSJ were remarkable in the transverse direction, and more than 8D in the spanwise direction.

- The PSJ inside the large-scale vortex structures intensified the turbulent fluctuations, and the PSJ surrounding the large-scale vortex structures enlarged the scale of the vortices. The PSJ between the two large-scale vortex structures was advantageous for merging the vortices.

- The value of the mixing layer thickness under perturbation was larger than that under unperturbation in the downstream.

- The high-strength perturbation of the PSJ did not improve the fractal dimension values of the fully developed supersonic mixing layers.