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Enhanced ablation of silica by the superposition of femtosecond and nanosecond laser pulses

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Abstract :

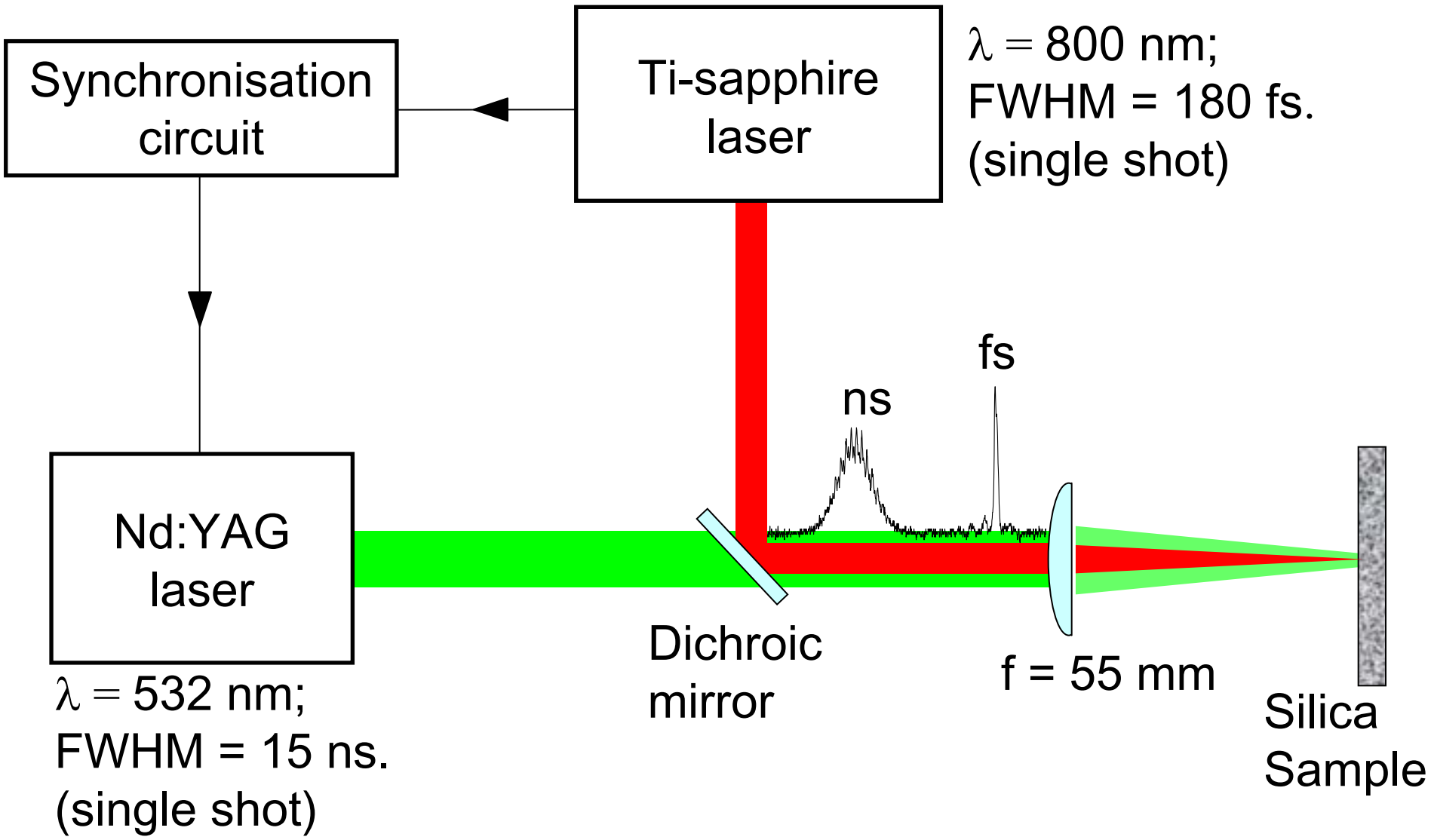
We investigate the ablation process in SiO_2 by the superposition of 180 fs with a 15 ns laser pulse.

Compared to femtosecond laser pulse alone, we observed :

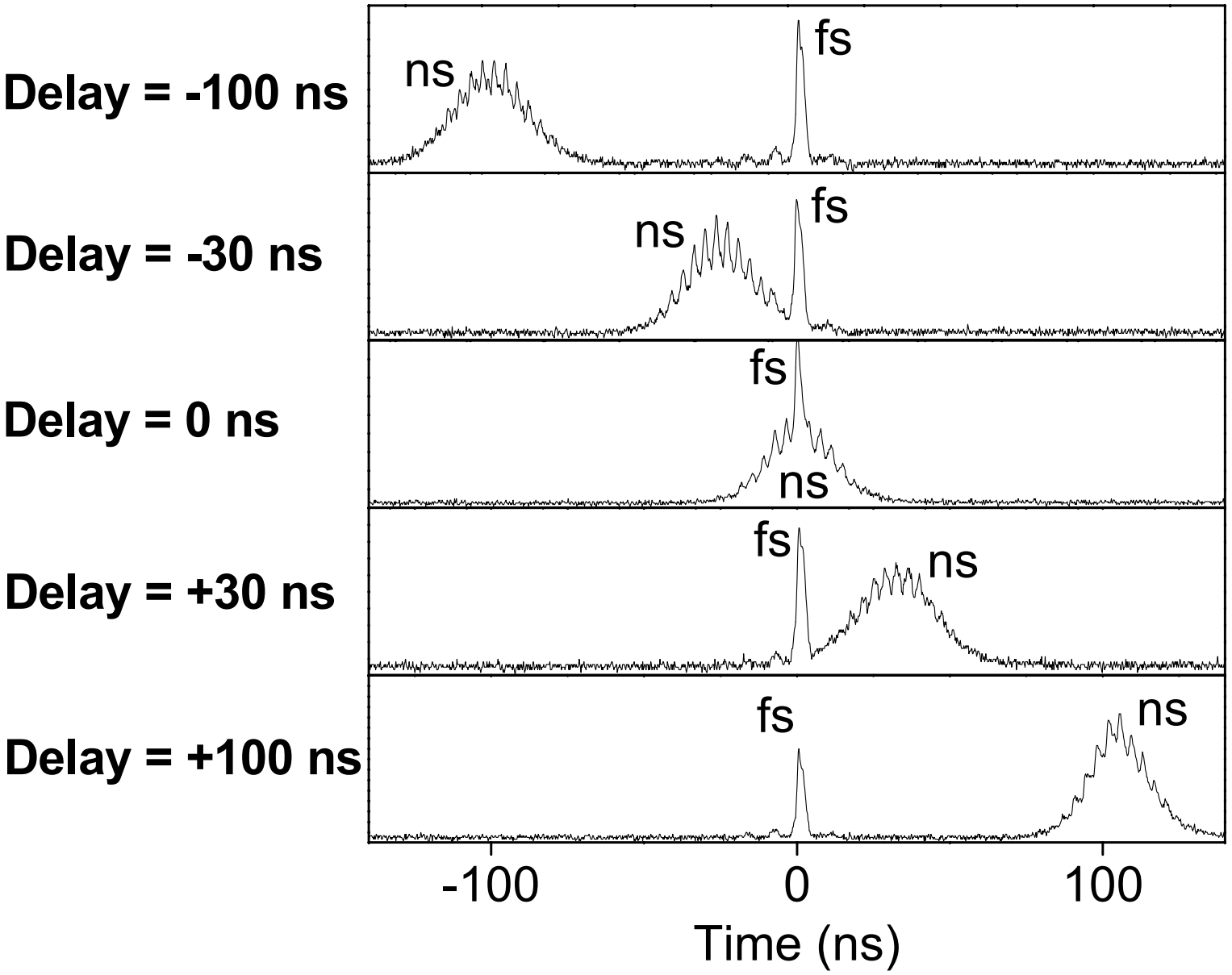
1) An increase of 270±30% of the ejected material;

2) The morphology of crater is similar or even better.

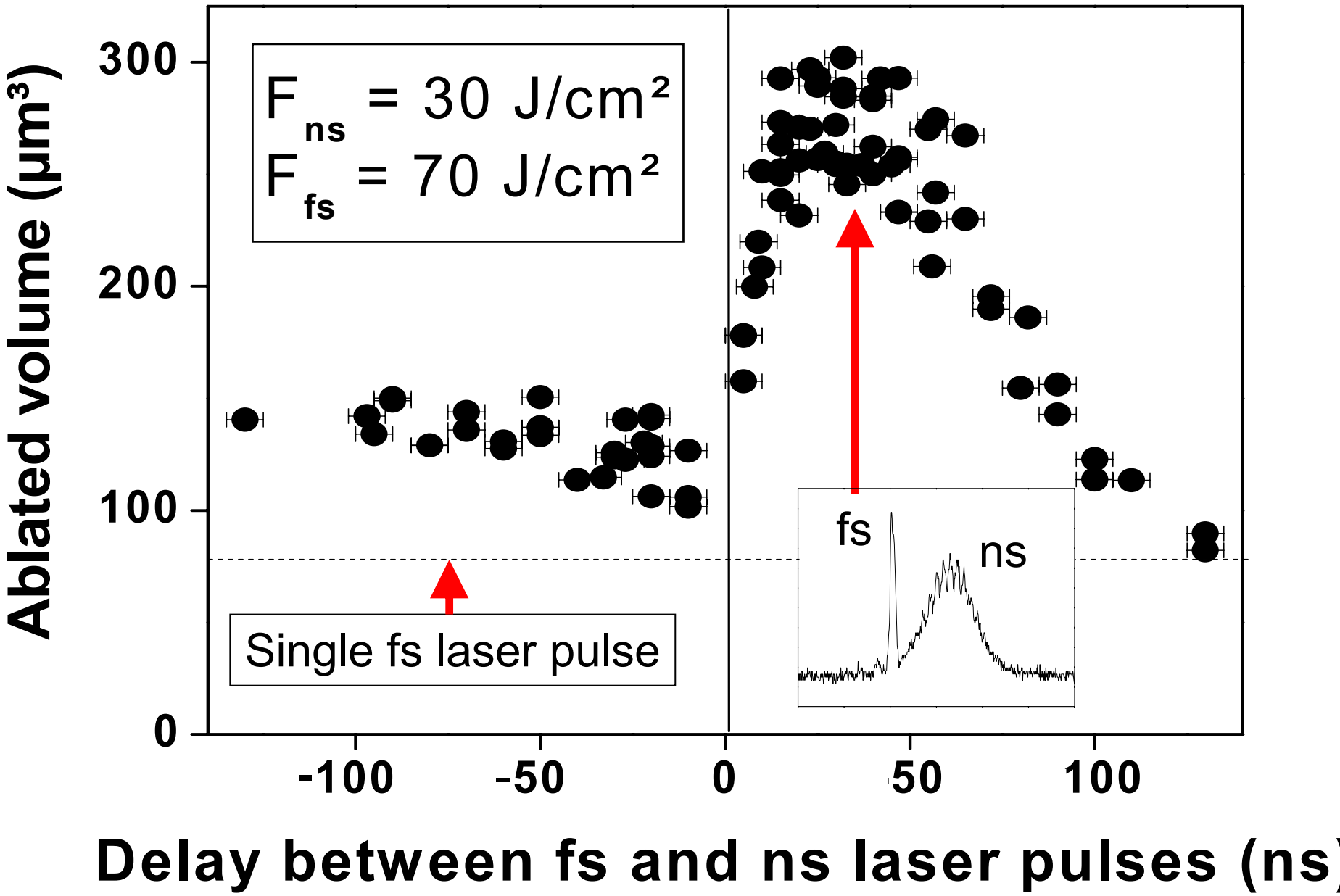
Experimental setup :

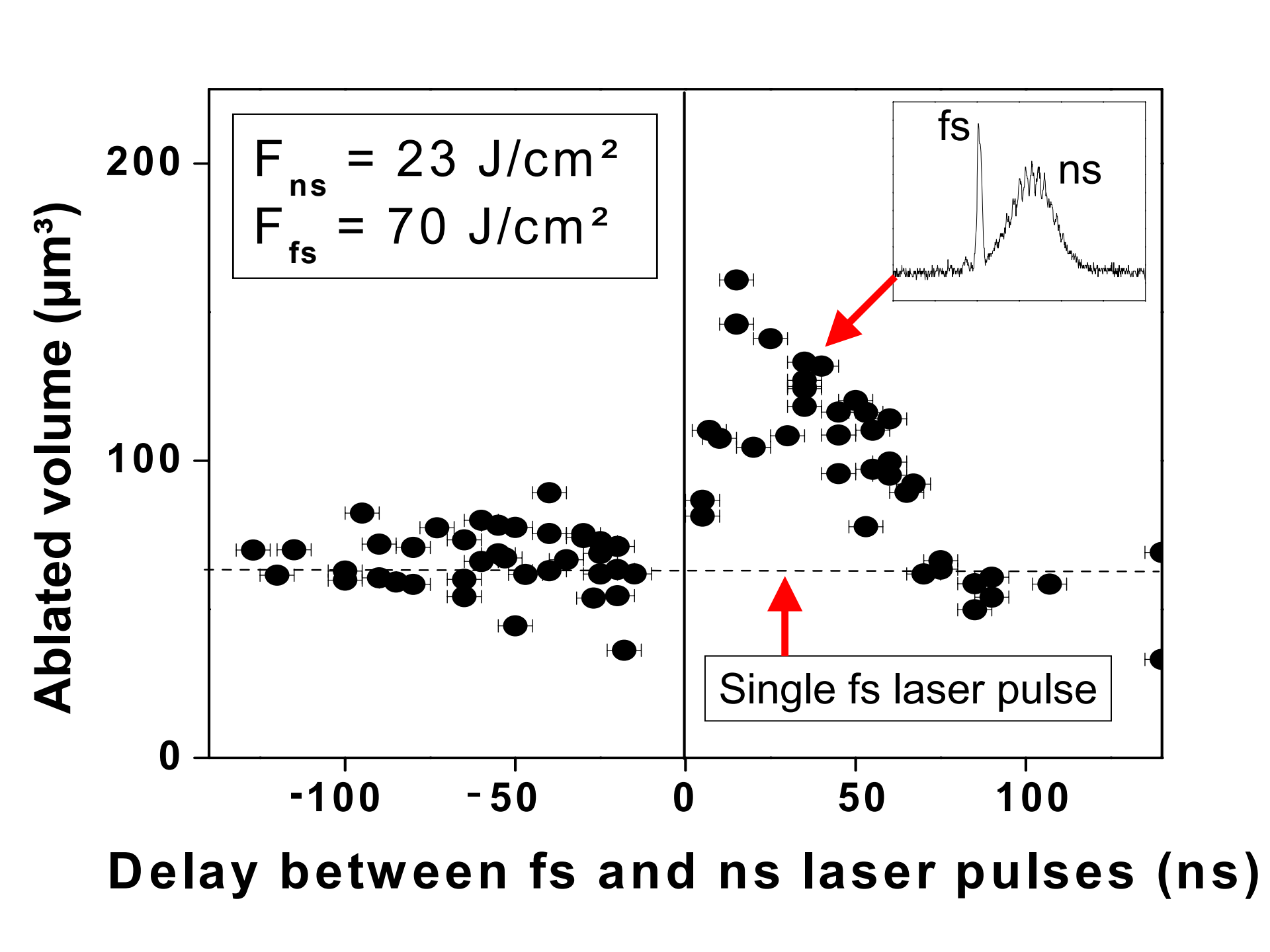


Signal of the fs and ns laser pulses

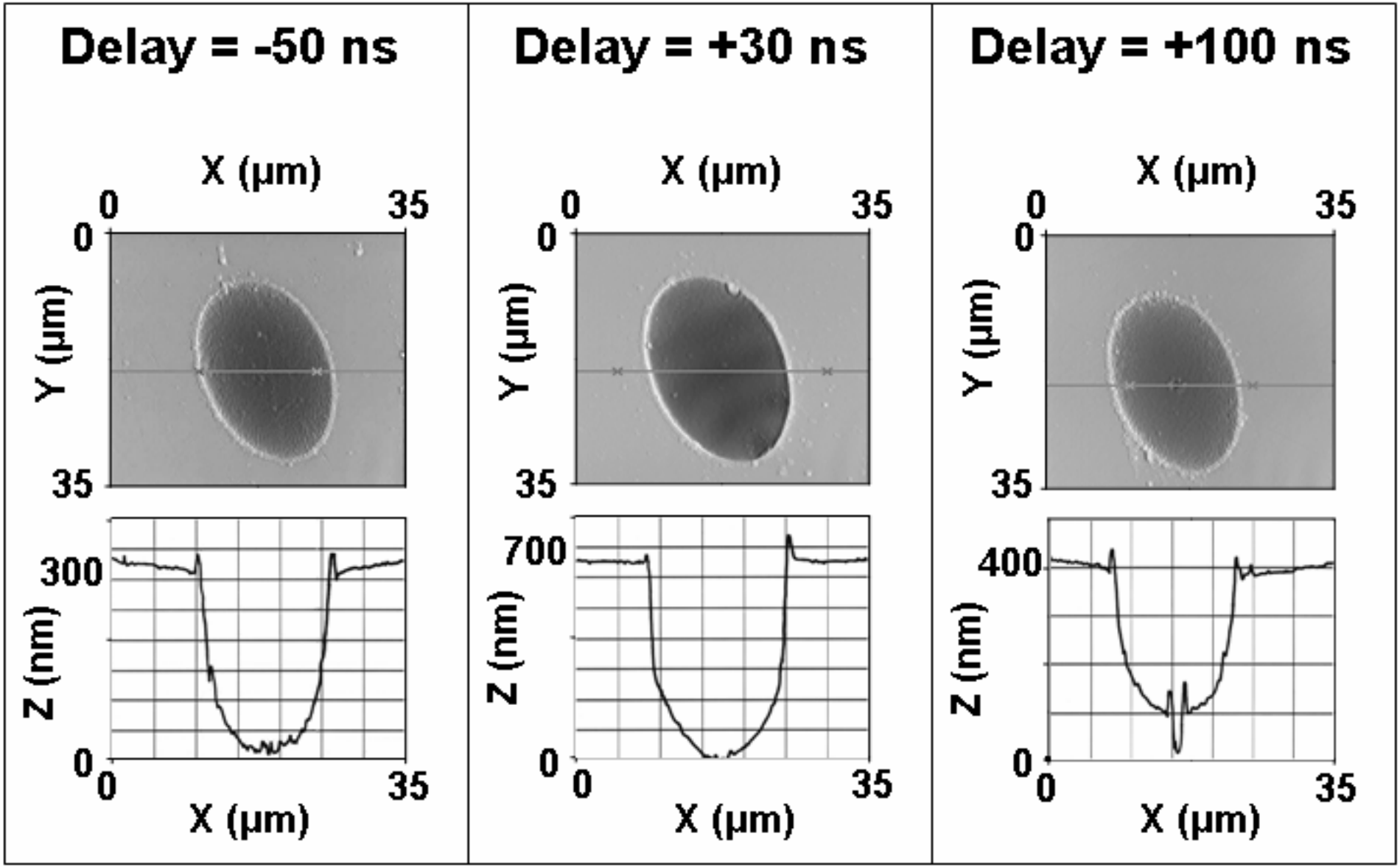


Results :

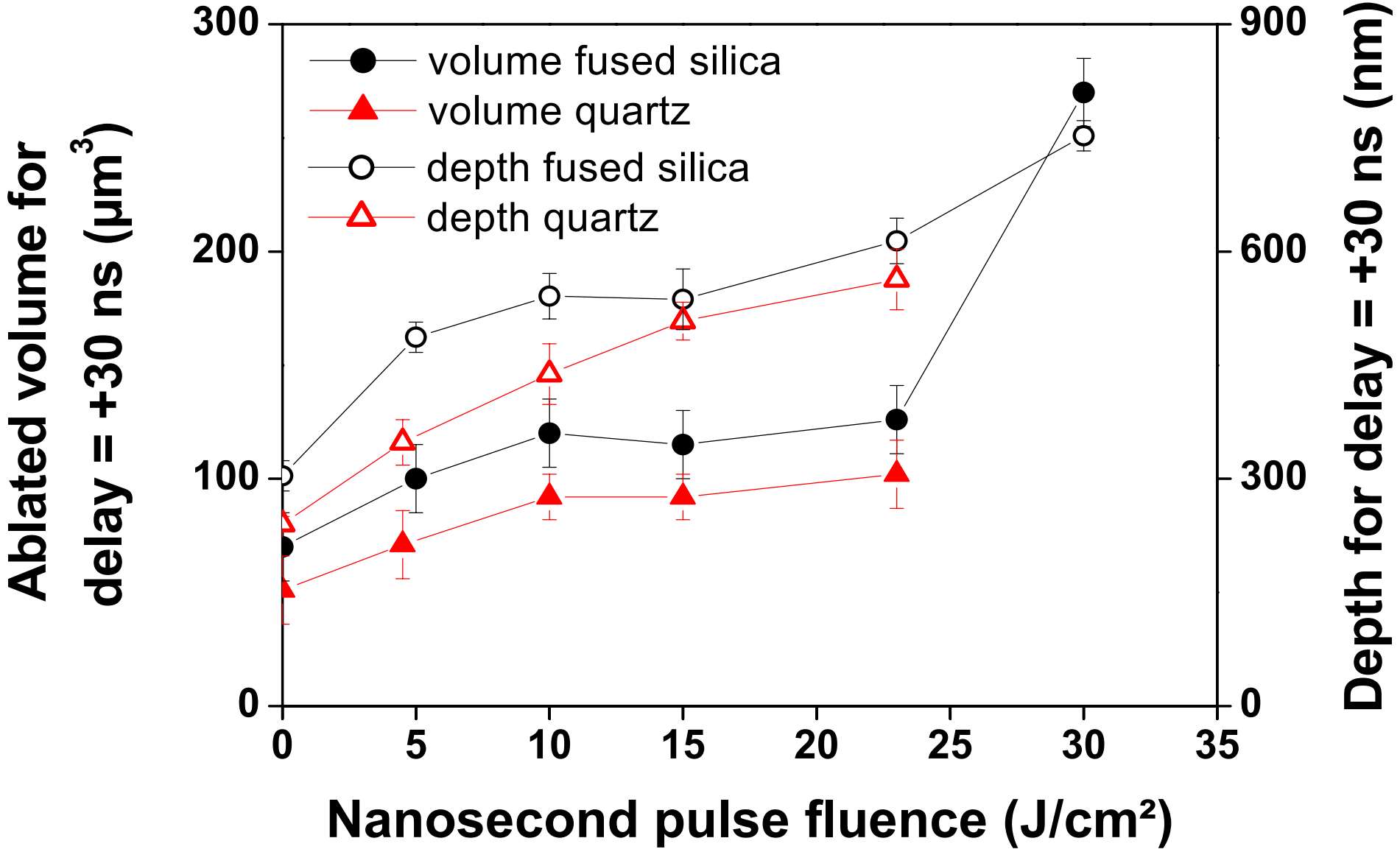

F_{ns} = 30 J/cm²
F_{fs} = 70 J/cm²
Single fs laser pulse
fs
ns
Ablated volume (µm³)
300
200
100
0
-100
-50
0
50
100
Delay between fs and ns laser pulses (ns)


F_{ns} = 23 J/cm²
F_{fs} = 70 J/cm²
fs
ns
Single fs laser pulse
Ablated volume (μm³)
200
100
0
-100
-50
0
50
100
Delay between fs and ns laser pulses (ns)

Morphology of crater from the superposition of fs (F=70 J/cm^2) and ns (F=23 J/cm^2) laser pulses on fused silica



Summary of results :



Discussion :

The increase of ablation is believed to be a consequence of lowering the damage threshold of the nanosecond laser pulse by the irradiation of femtosecond laser pulse on the dielectric surfaces.

1) The nanosecond laser pulse following the femtosecond laser pulse can accelerate the seed electrons in the conduction band produced by the femtosecond laser pulse.

2) The femtosecond laser irradiation can induce defects such as excitons and Frenkel pairs in SiO_2 [1]. These defects would become a source of electrons easily excitable to the conduction band by the following nanosecond laser pulse [2].

3) The high temperature modified lifetime of self-trapped excitons and Frenkel pairs combined with the high temperature of silica [3] could decrease the silica damage threshold of the nanosecond laser pulse on 100 ns time scale.

[1] A. Rosenfeld et al., Appl. Phys. A, **69** (1999) S373-S376.
[2] N. Itoh et al., Opt. Eng., **28** (1989) 1034-1038.
[3] P.R. Herman et al., Proc. SPIE **3616** (1999) 148.

Conclusion :

The superposition of femtosecond laser pulse and nanosecond laser pulse with appropriate delay is more efficient than comparable femtosecond and nanosecond laser system alone.

Acknowledgements :

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