Playing with the temporal shape of a high-power nanosecond 1064 nm laser pulse to explore EUV generation and different droplet deformation regimes.

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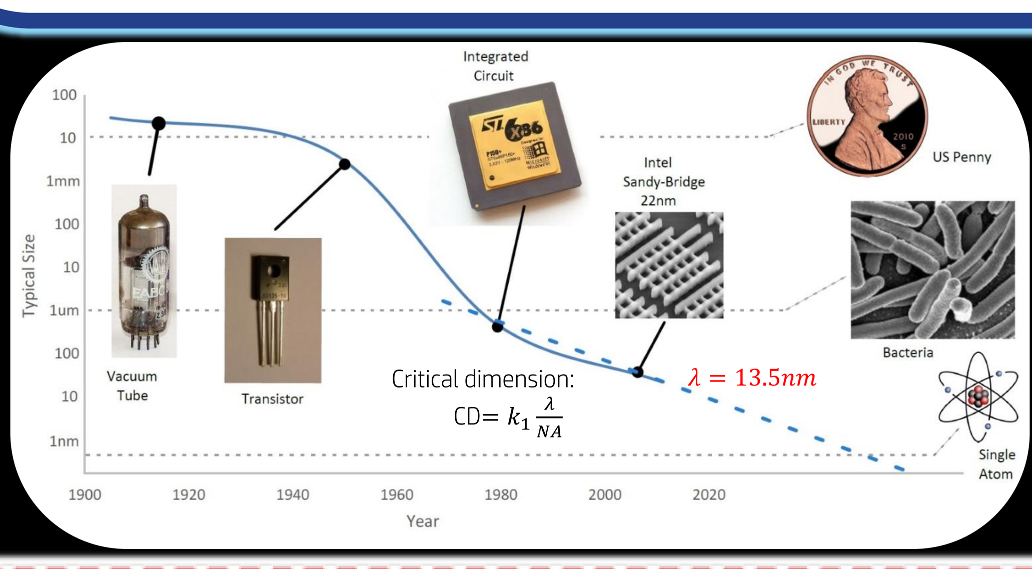
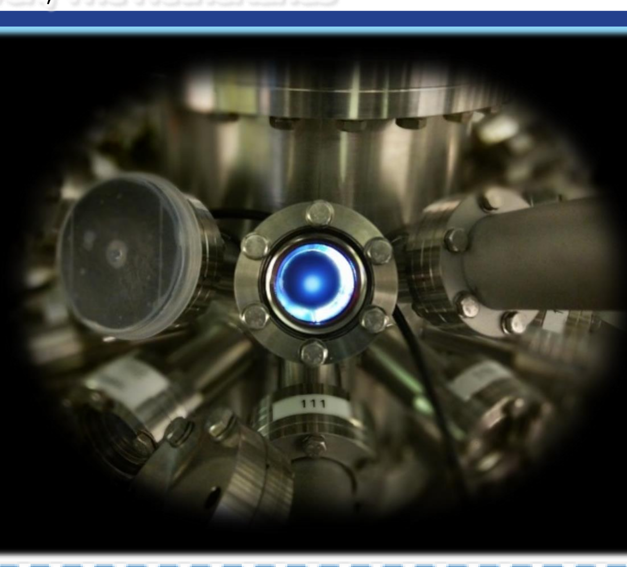


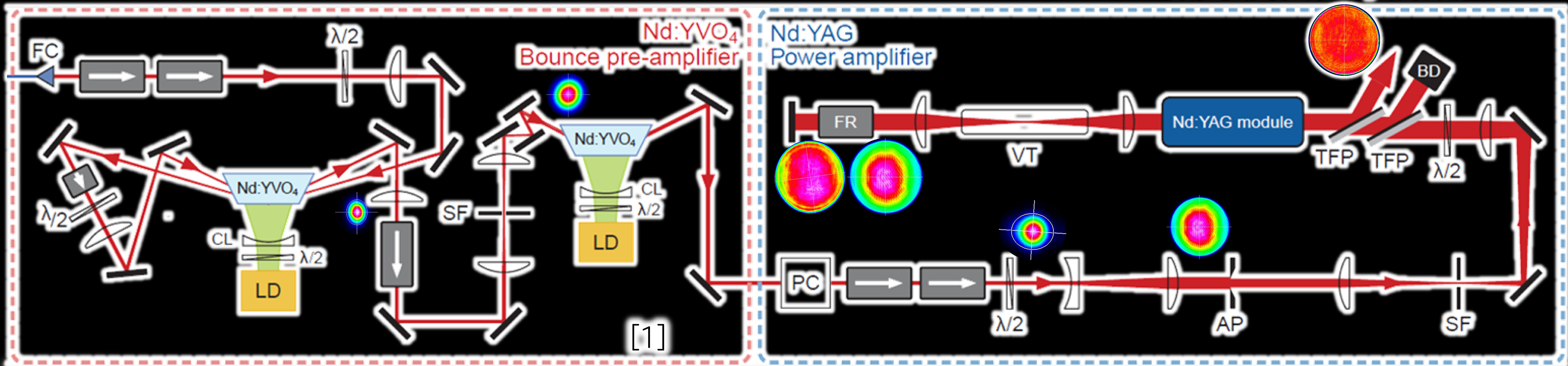
Target: tin droplets

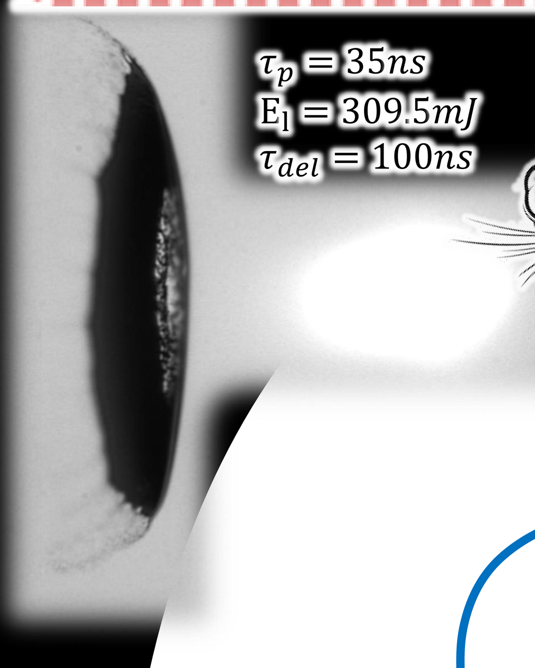
- study plasma formation and EUV generation on pico- and nano-second time scale
- Controlled preparation of tin droplets with temporally shaped pulses

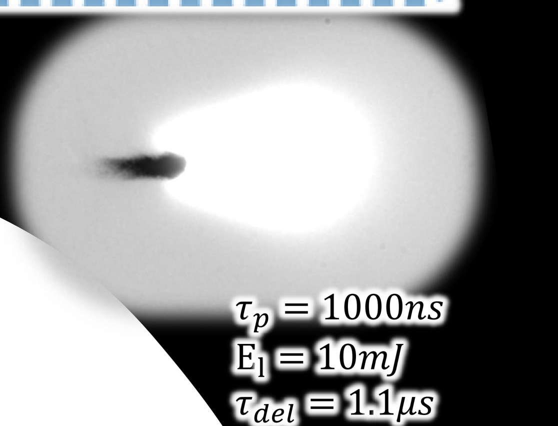


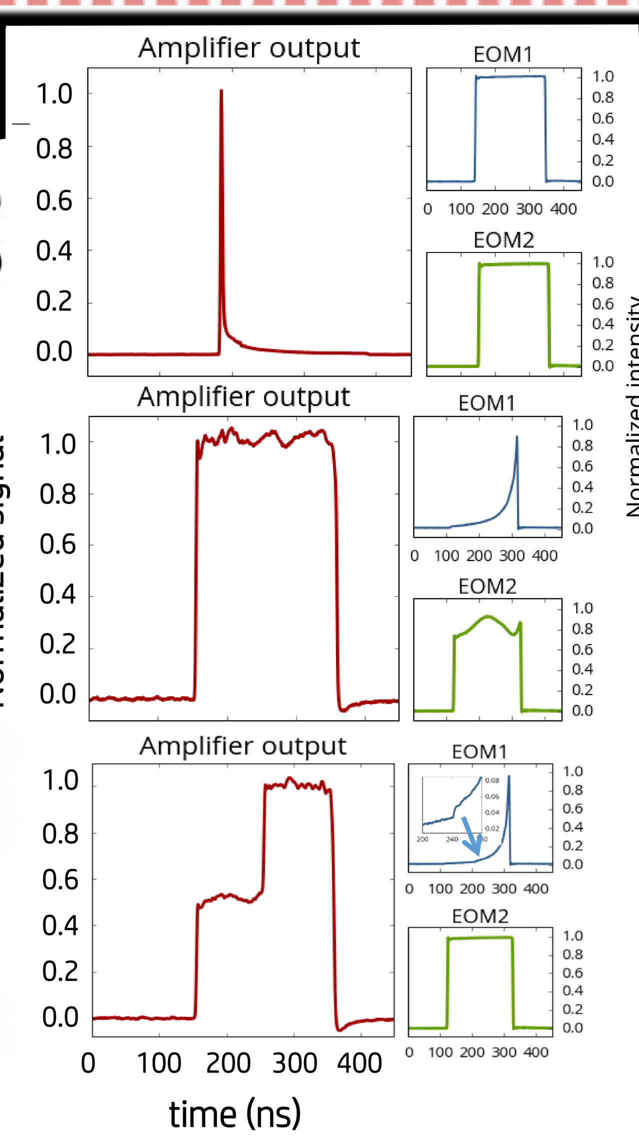
- Current technology uses a CO_2 laser, but:
  - requires a pre-pulse (second laser)
  - back reflections
  - issues with power scalability
- We propose a 1064 nm Nd:YAG
  - Advanced technology
  - Control/Robust
  - Scalability/Availability
  - Temporal pulse shaping

GOAL: controlled EUV generation





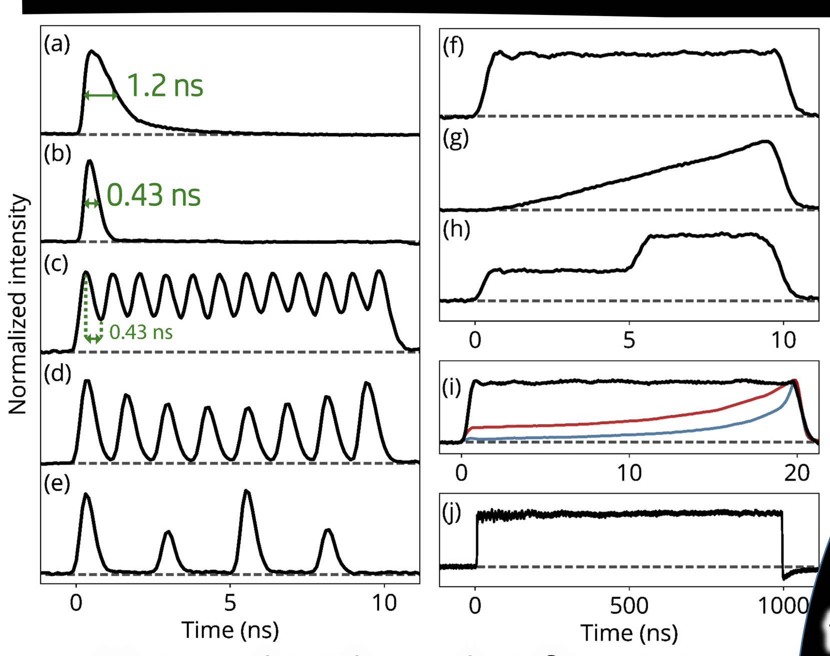




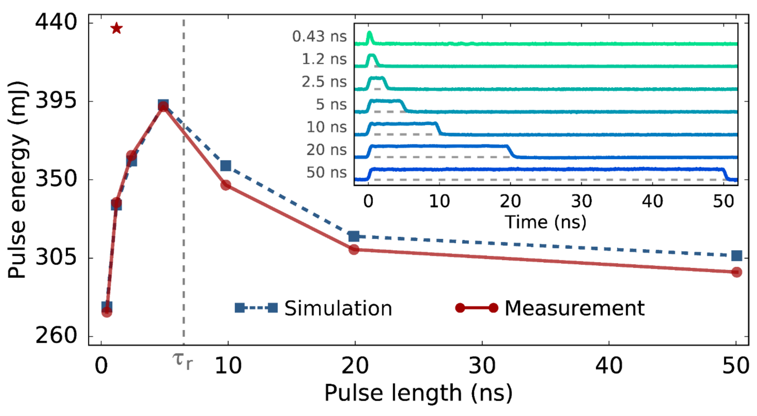
Examples of temporal configurations

- Multiple pulses (each pulse can be separately tuned)
- Square or free form

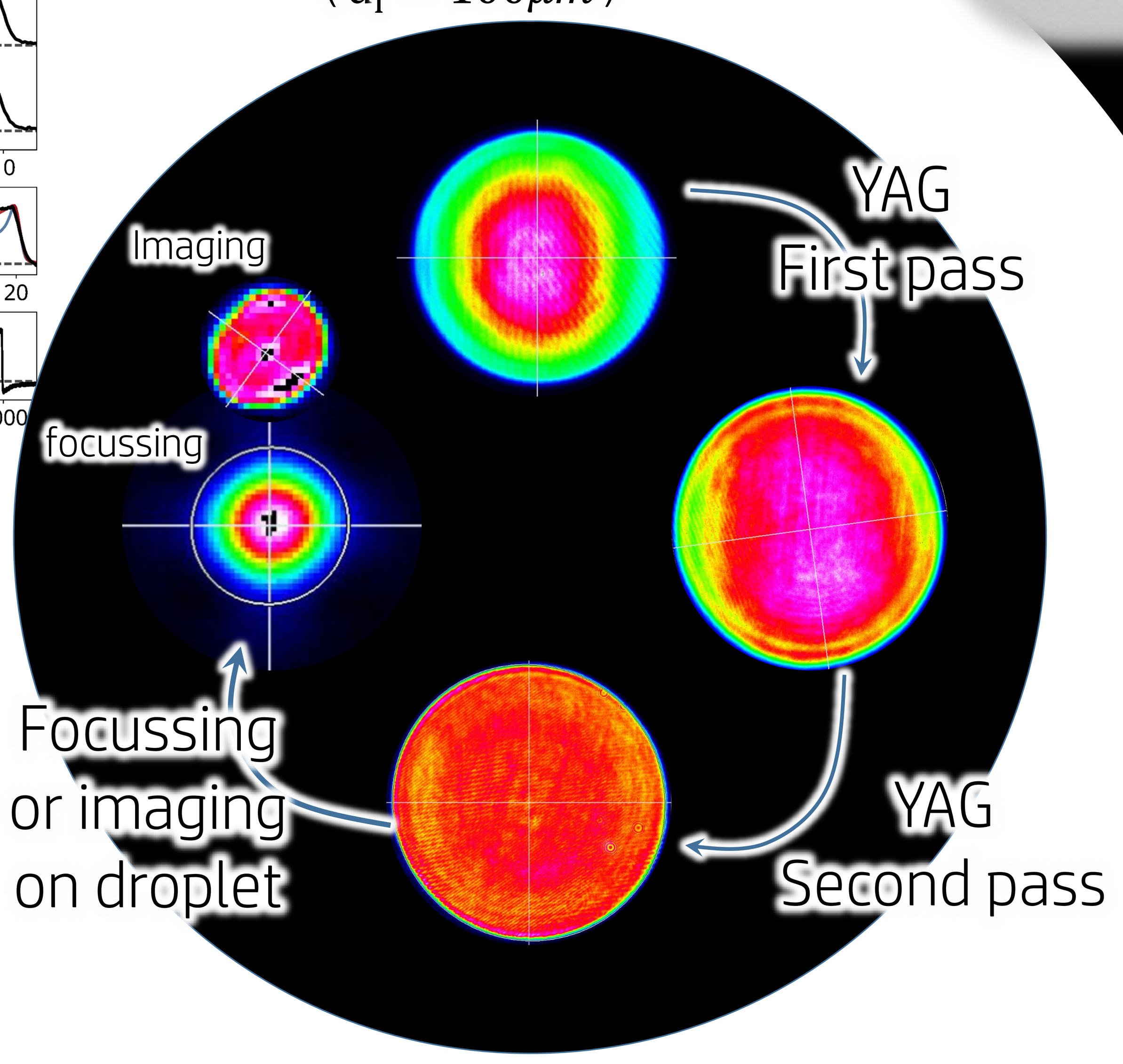
New performances with energies:
0.43 ns pulse → 344mJ
not pre-shaped few ns or more → 490mJ
15 ns square output (as in the graph) → 430mJ



Home developed software: automatic generation of arbitrary shaped pulses.
Future plans: genetic algorithms for optimum EUV generation.

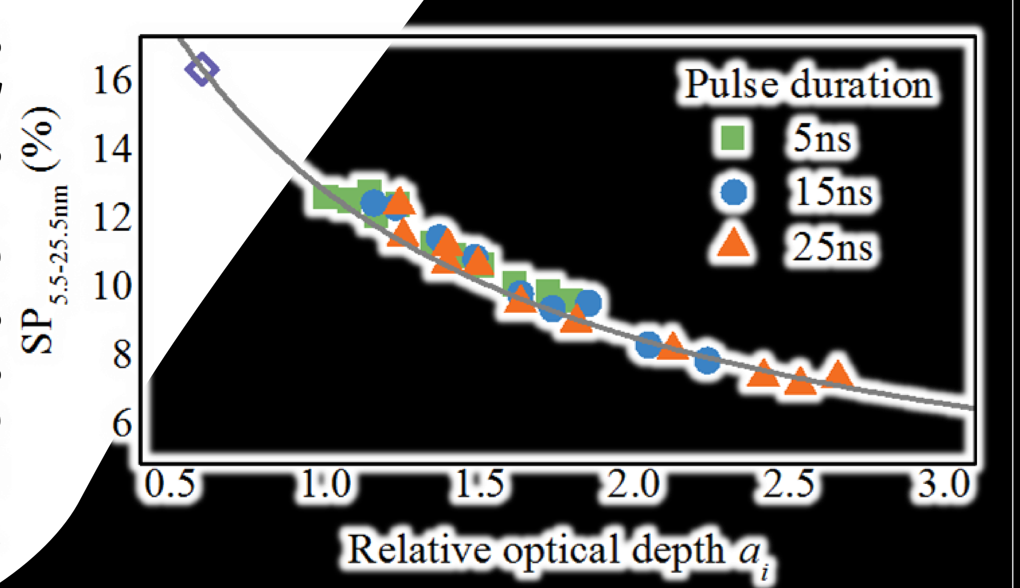


We can focus down to a Gaussian or image the top-hat profile on the droplet ($d_l = 100\mu m$)

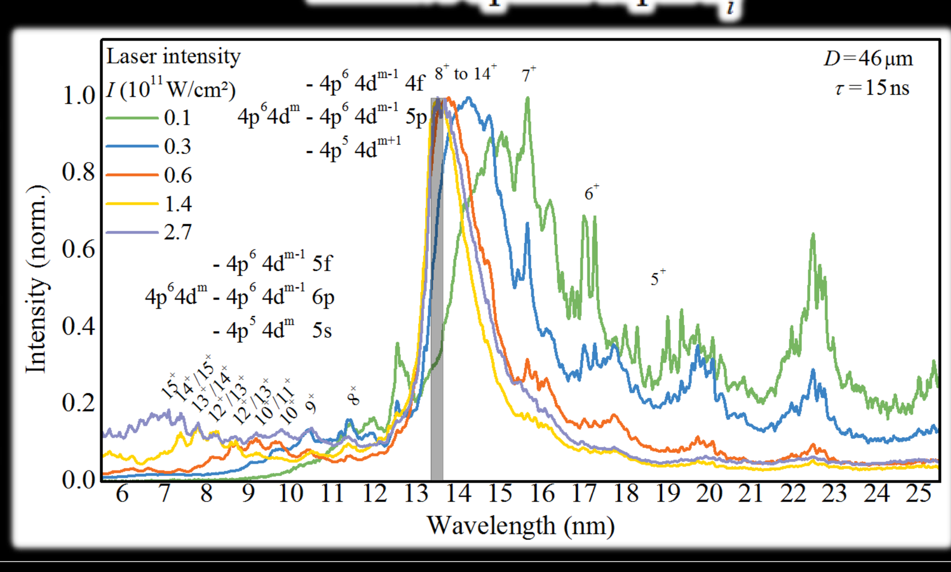


EUV generation [3][4]

Experimental values for spectral purity ($SP_{5.5-25.5nm}$) vs relative optical depth. The dashed line represents $SP_{5.5-25.5nm}$ as calculated from the radiation transported reference spectrum.



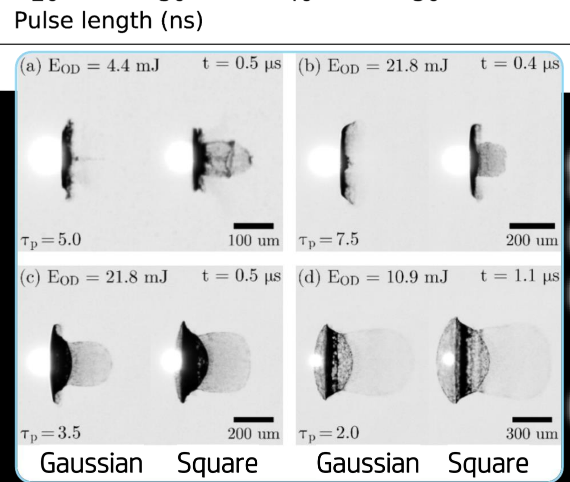
Emission spectra for various Nd:YAG laser intensities: 46 μm diameter tin droplet, 96 μm laser beam of 15 ns duration. The gray-shaded area shows a 2% bandwidth around 13.5 nm.

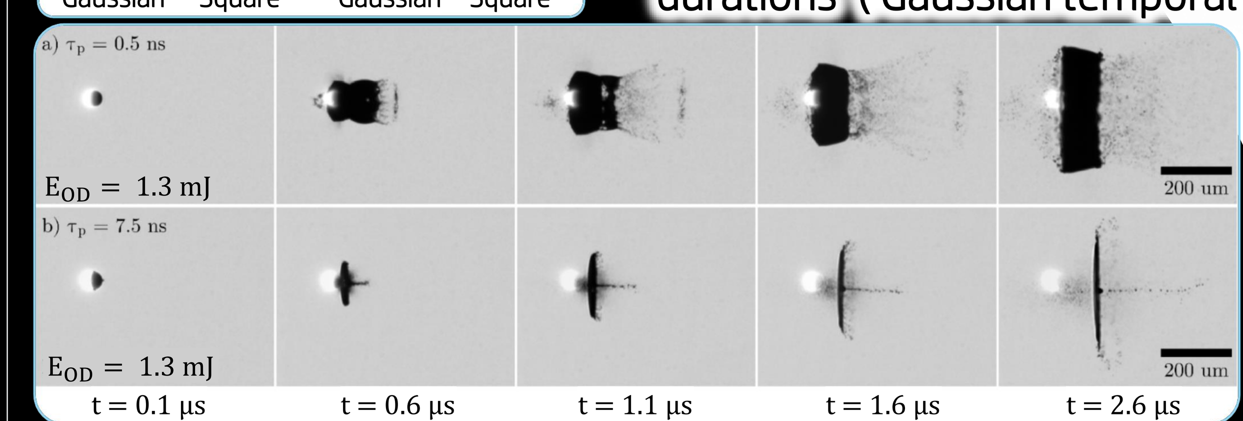


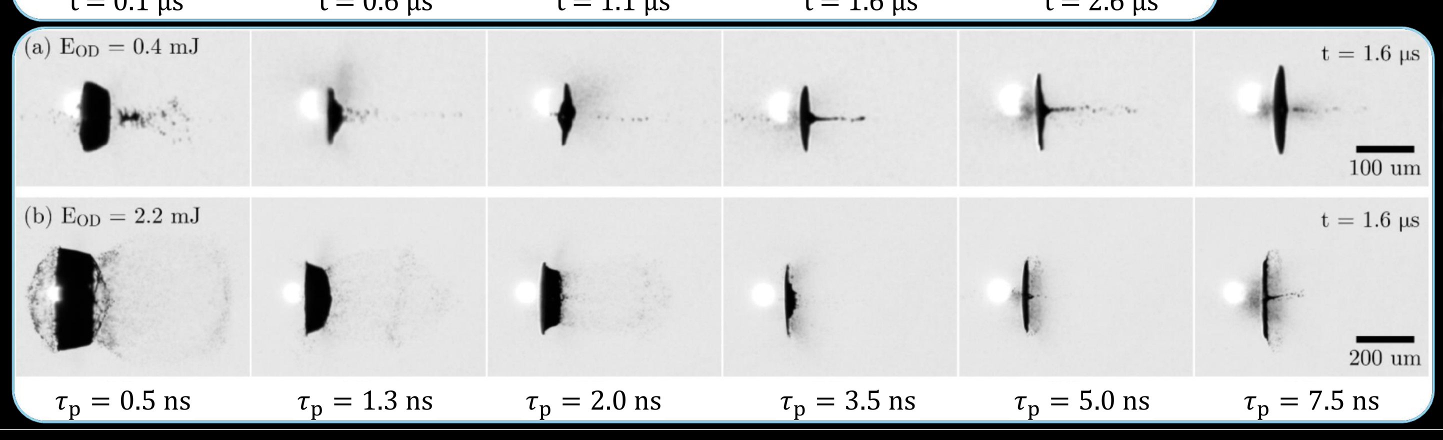
[2] Droplet deformation

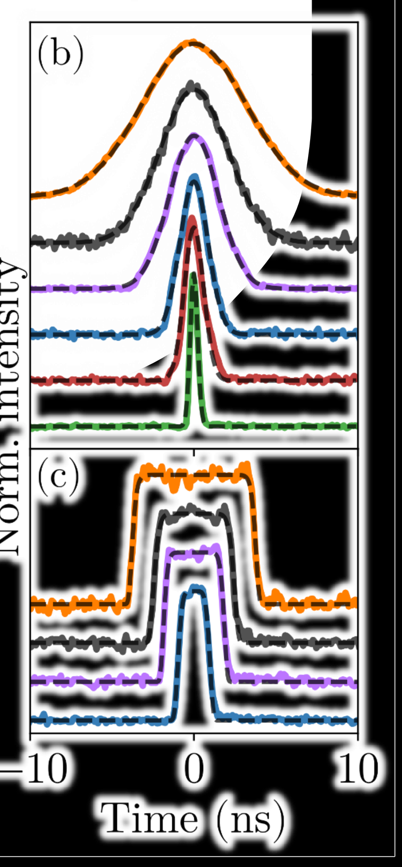
Shadowgrams from top to bottom:

- Comparing deformation using Gaussian and square pulses
- Deformation after laser impact of Gaussian shaped pulses for different delays.
- Target shapes 1.6 μs after laser impact for several pulse durations (Gaussian temporal profiles)









[1] "High-energy Nd:YAG laser system with arbitrary sub-nanosecond pulse shaping capability", R. A. Meijer, A. S. Stodolna, K. S. E. Eikema and S. Witte, Optics Letters **42**.14, 2758 (2017),
[2] "The transition from short to long timescale pre-pulses: laser-pulse impact on tin microdroplets", Randy A. Meijer, Dmitry Kurilovich, Oscar O. Versolato, and S. Witte (in preparation)
[3] "Efficient Generation of Extreme Ultraviolet Light From Nd:YAG-Driven Microdroplet-Tin Plasma", R Schupp et al, Phys. Rev. Applied **12**, 014010 (2019).
[4] "Radiation transport and scaling of optical depth in Nd:YAG laser-produced microdroplet-tin plasma", R. Shupp et al, Appl. Phys. Lett. **115**, 124101 (2019).

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