Extreme ultraviolet ablation of solid targets at 46.9 nm

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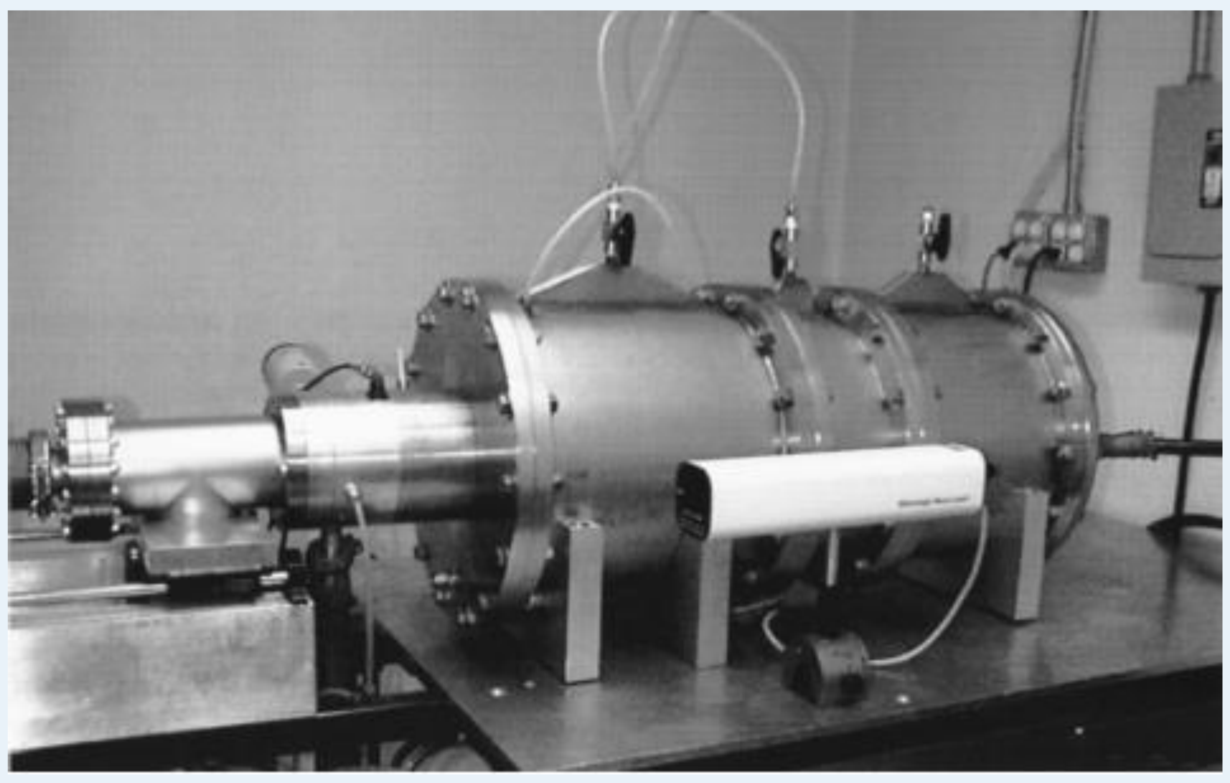
Summary

- A compact source of extreme ultraviolet (EUV) radiation at 46.9 nm [1] was used to produce single- and multi-shot ablation features on Al, Cu, Au and PMMA targets.
- The ablation profiles achieved are shown and, in the single-shot case, compared to two simple models – an ablation `velocity' model [2] and a modification of the Gamaly femtosecond pulse model [3].

Capillary Discharge Laser

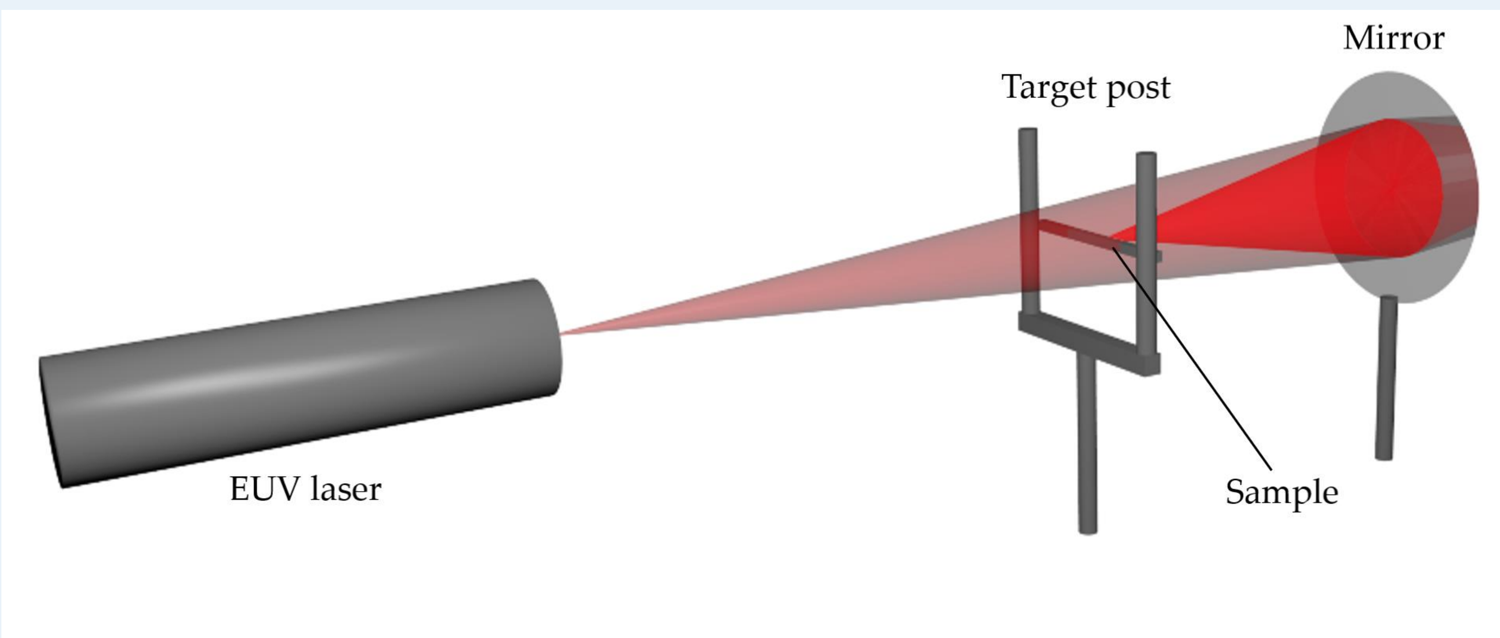
- The EUV light source in question lases at 46.9 nm between two excited levels of Ne-like Ar.
- Fast electrical discharge drives a z-pinch along the plasma column in the capillary, generating lasing conditions.
- Average pulse energies are ~50 µJ with a pulse width of ~1.2 ns.



Capillary laser with HeNe laser in foreground for scale [4]

Experiment

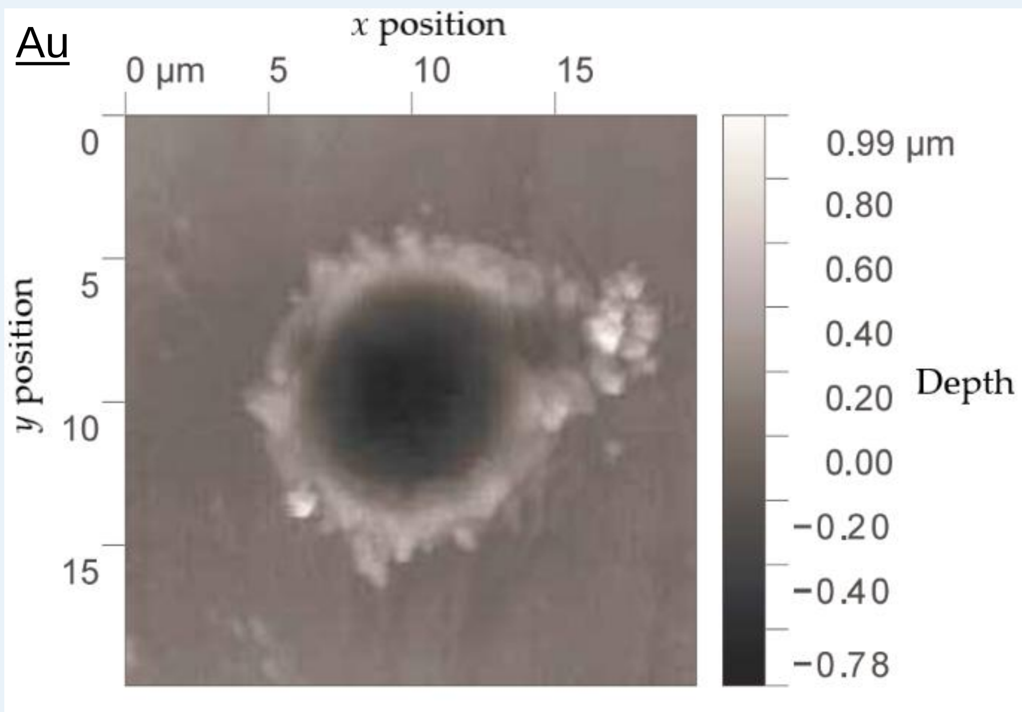
- Experiments were conducted in-line with the mirror behind the target – see figure below – to reduce spherical aberrations.

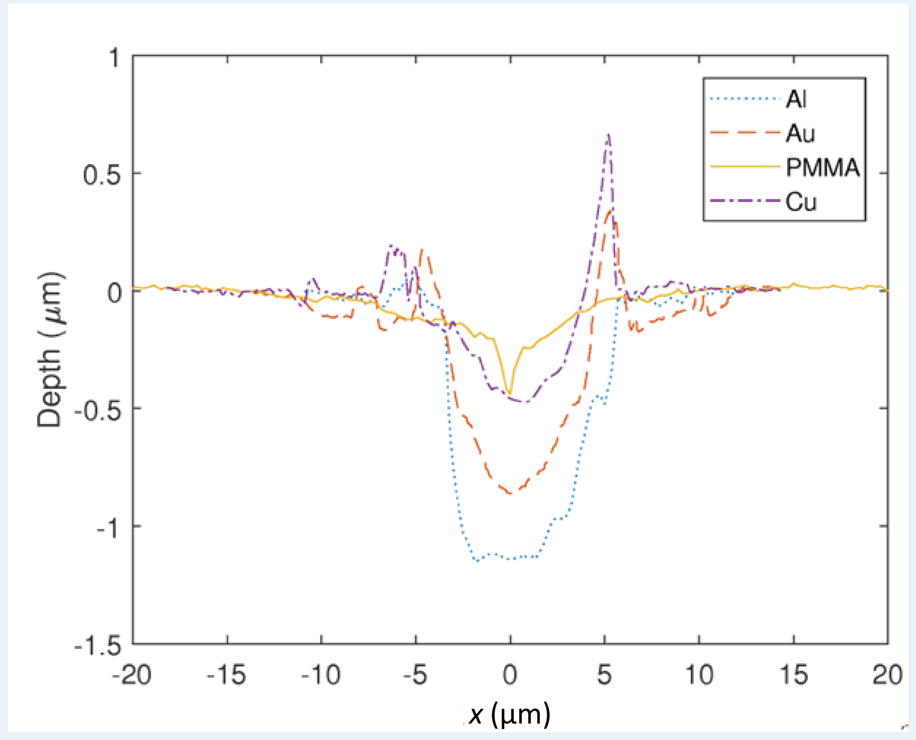


- Two different spherical mirrors (both f = 100 mm) focussed the beam, constructed from Sc/Si multilayers (R ≈ 45%) and unprotected Au (R ≈ 8%) respectively.
- Thin strips of each material were mounted on the target post to minimise obstruction of the beam to ≈ 10%.

Profile of ablated craters

- Irradiances of 2 x 10^{11} Wcm^{-2} and 5 x 10^{10} Wcm^{-2} were achieved for the Sc/Si and Au mirrors respectively.
- Single shot ablation features were generated on all four materials. Ablation profiles generated at focus with the Sc/Si mirror are shown below.





- Focal spot size is dominated by spherical aberrations.

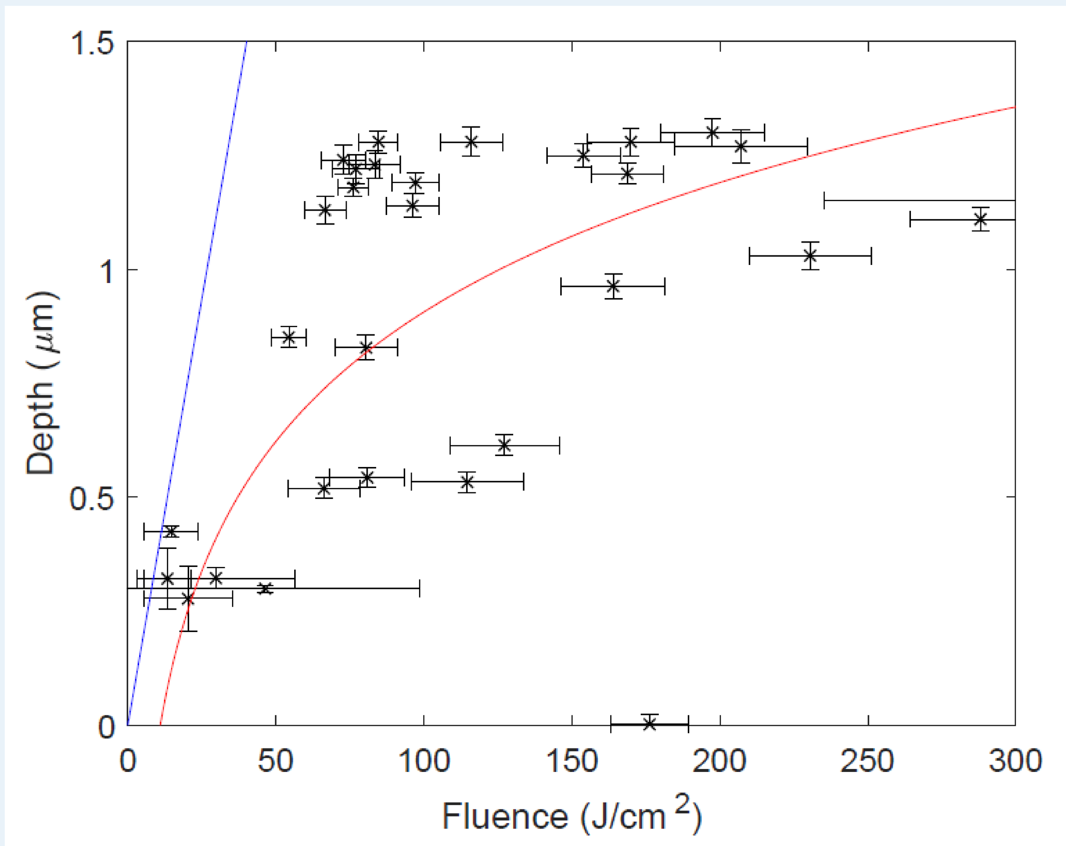
Simple modelling

- Two methods were used to model the depth of ablation features – a modified version of the Gamaly femtosecond pulse model [3] and an ablation velocity model [2].
- The Gamaly femtosecond pulse model assumes that the radiation penetrates to half the skin depth and deposits energy over this range – for long attenuation lengths l_a, as in Al, we predict that similarly:

$$d = l_a \ln\left(F/F_{th}\right) \quad (1)$$

for nanosecond EUV pulses.

- In the case of Al this has been fitted against experimental data.



Aluminium

- The ablation velocity model predicts that:

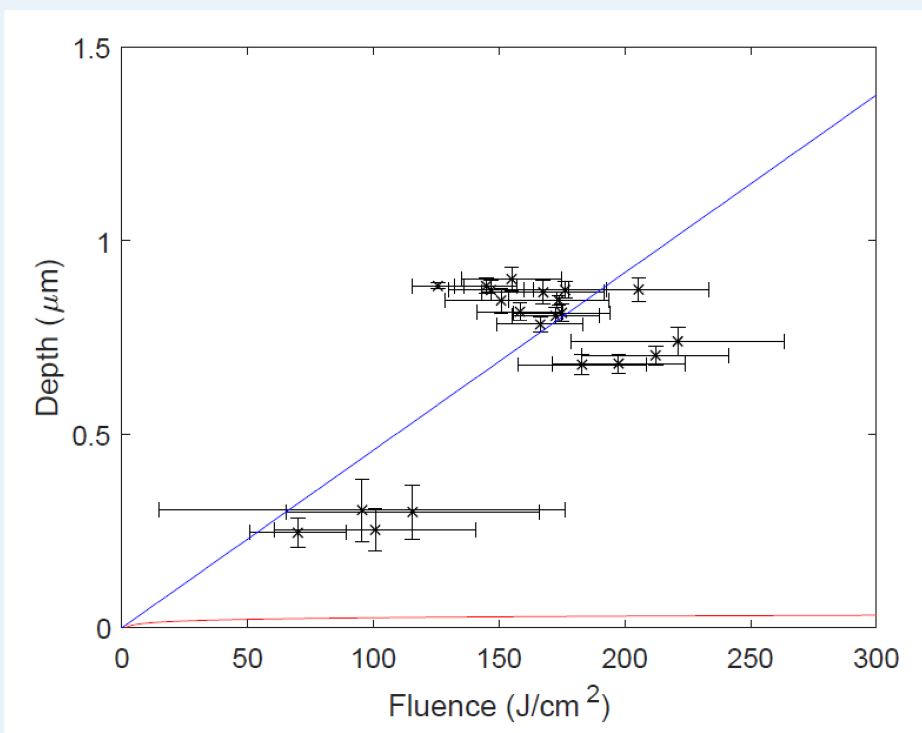
$$I\Delta t = H\Delta x \quad (2)$$

i.e. that a thin layer is bleached and this propagates with velocity

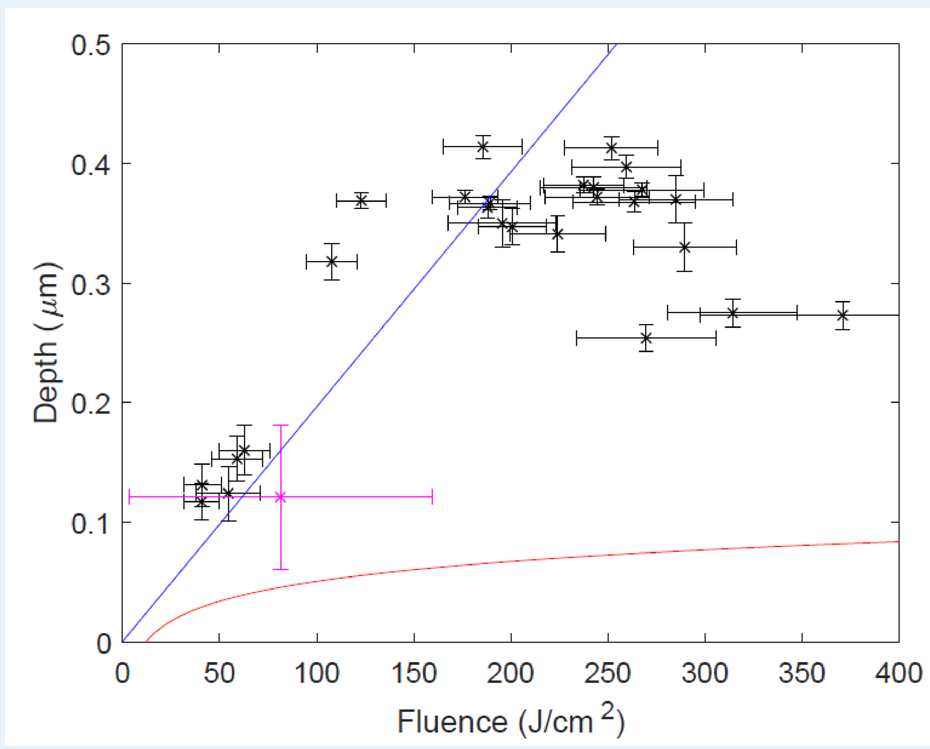
$$v = \Delta x/\Delta t = I/H \quad (3)$$

where H is the energy density required for bleaching.

- Integrating over time gives the depth to be $$d = F/H \quad (4)$$
- This model has been plotted against the shorter l_a materials, as shown below.



Gold



PMMA

- Improvements to the approximation of H are currently in progress.

References

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Acknowledgements

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