Nanodiamonds from Laser-induced Shock Compression of Polystyrene Extraction Under Way

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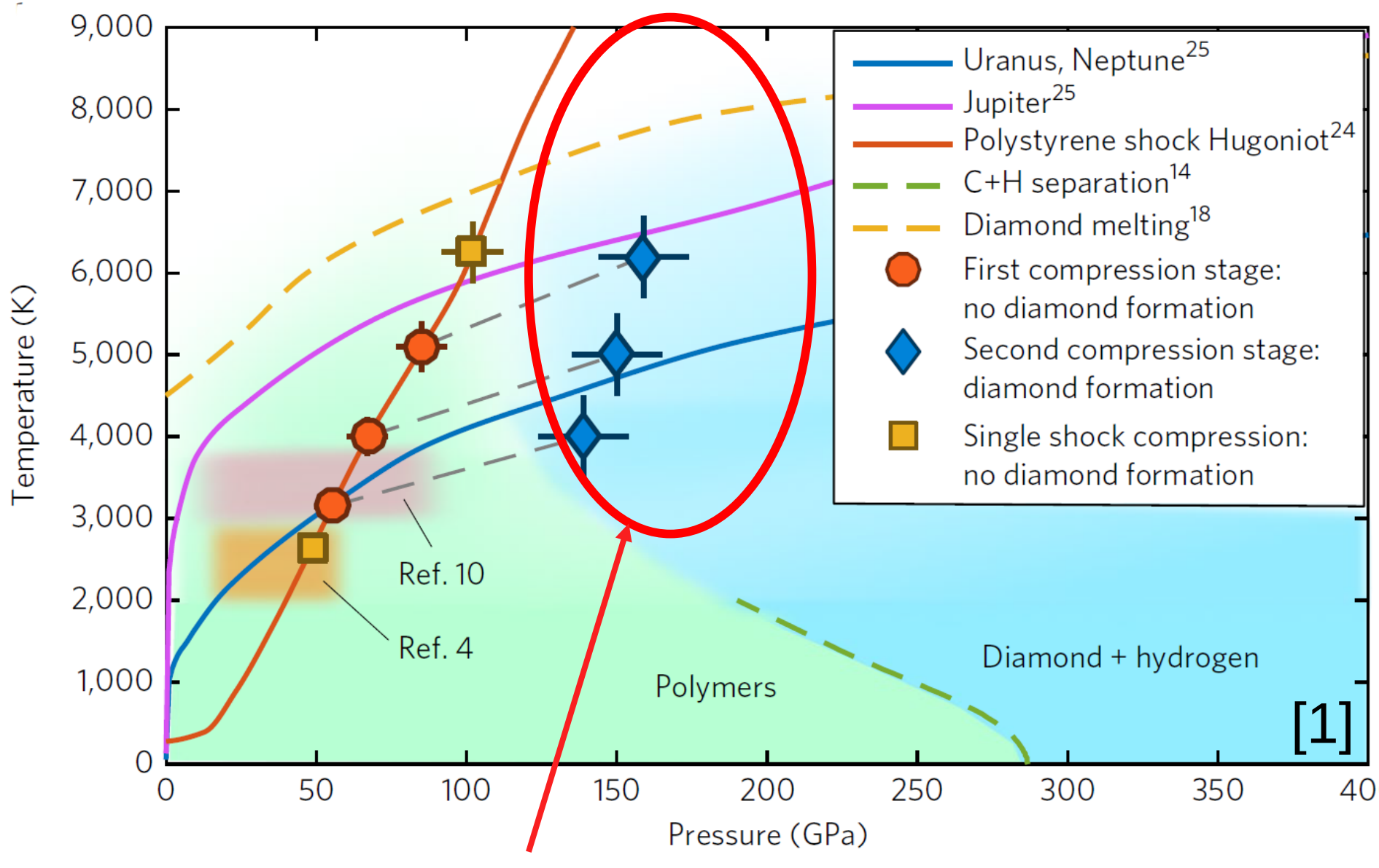
Nanodiamond production from polystyrene under planetary interior conditions in laboratory

Phase diagram of polystyrene

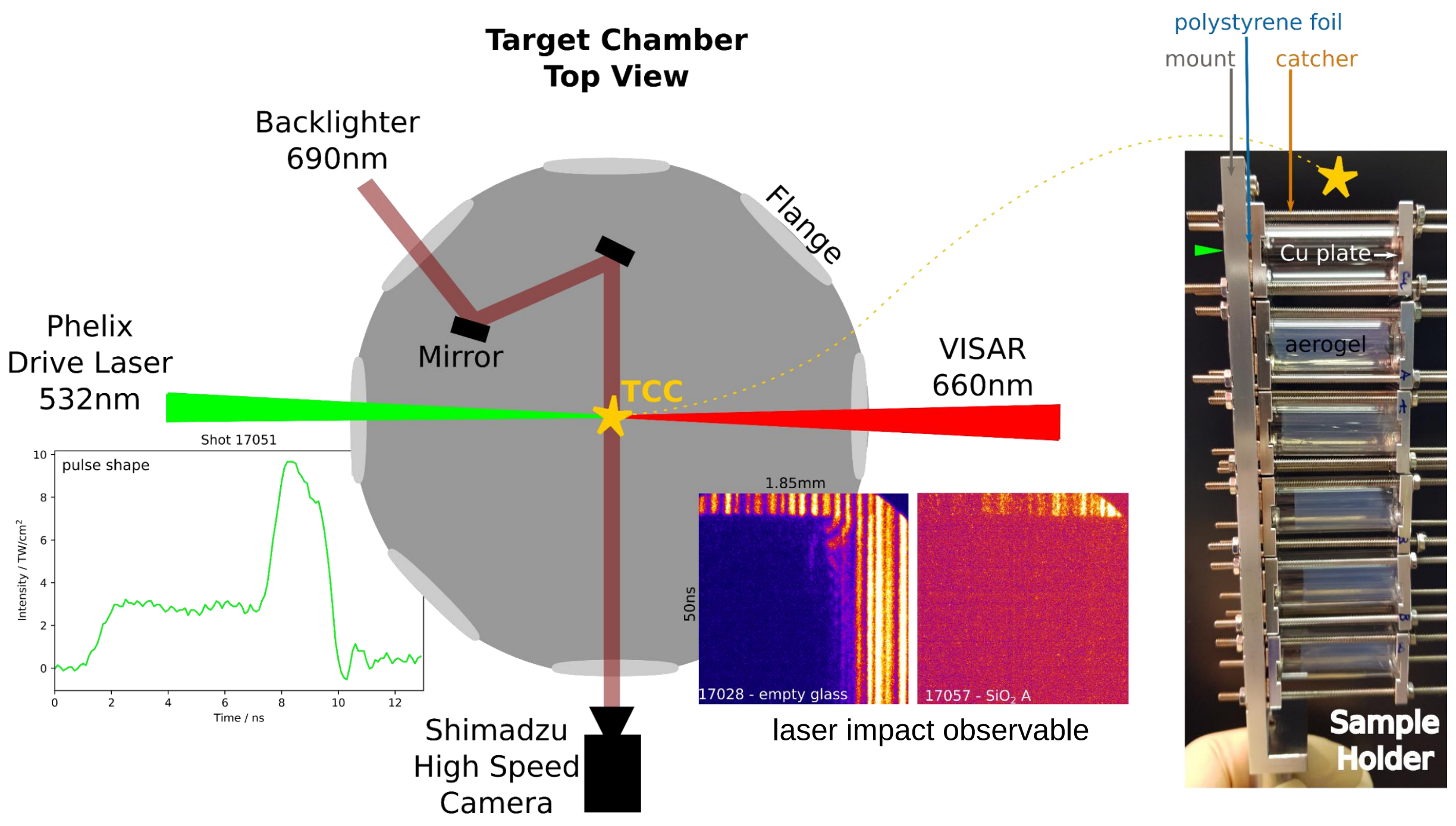


The region probed in the experiment is highlighted in red.

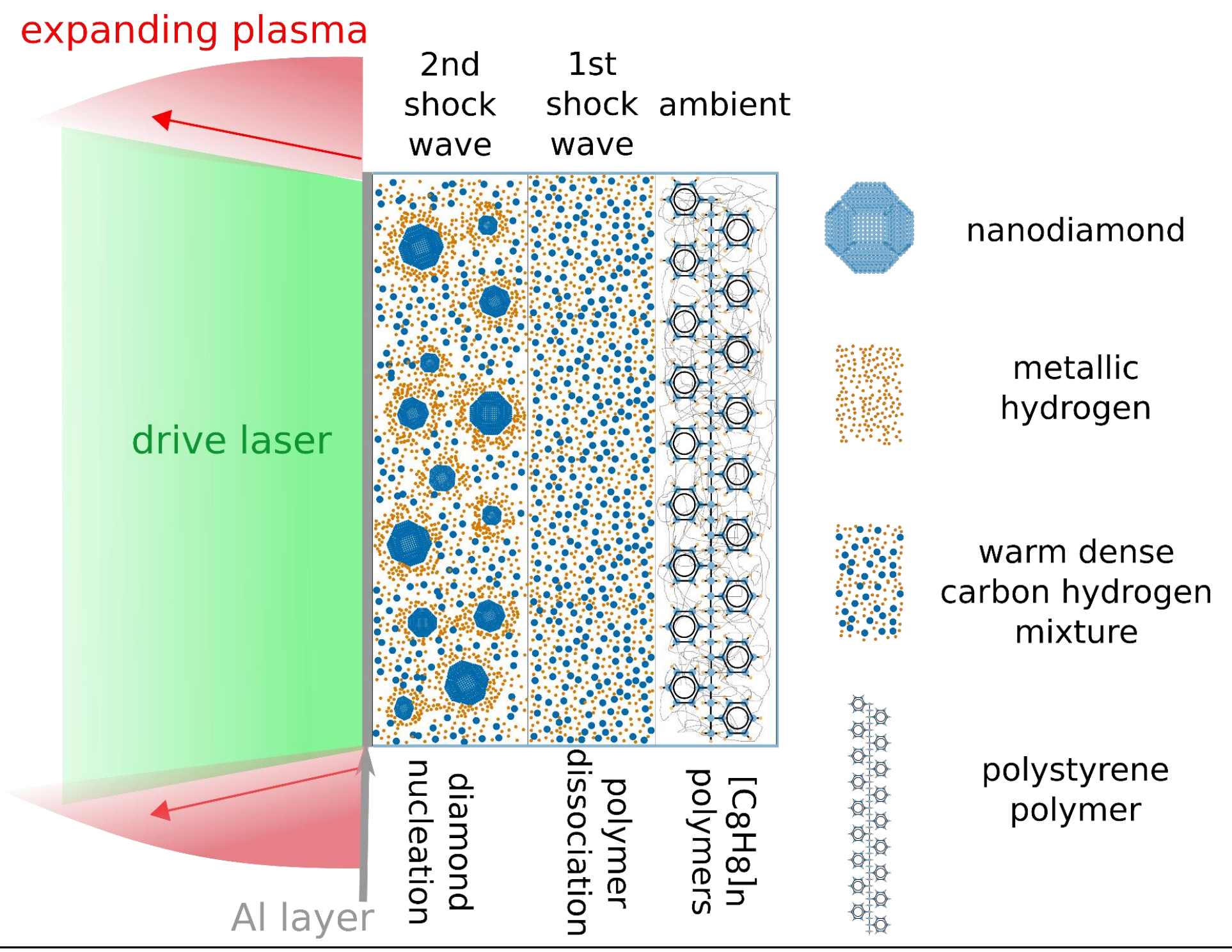
In Uranus and Neptune methane and other **hydrocarbons are highly** abundant. Their planetary interior conditions can be mimicked using high intensity lasers in the laboratory on a nanosecond timescale. **Nanodiamond formation** from shock-compressed polystyrene (~150GPa, ~5000K) was demonstrated via ***in situ* X-ray diffraction** with a XFEL [1, 2]. The lower size estimate is **4nm**. 60% of the carbon atoms in the plastic are transferred to a diamond lattice [3]. However, in total **a maximum of ~16µg** of nanodiamonds are expected from a 125nm CH foil and a 500µm focal spot. In order to understand the underlying hydrocarbon separation mechanism the **physical recovery of nanodiamonds** is pursued to learn from their shape, size, surface modifications and defects.

Nanodiamond Recovery Scheme

Experimental set-up P173 @ Z6 endstation @ GSI



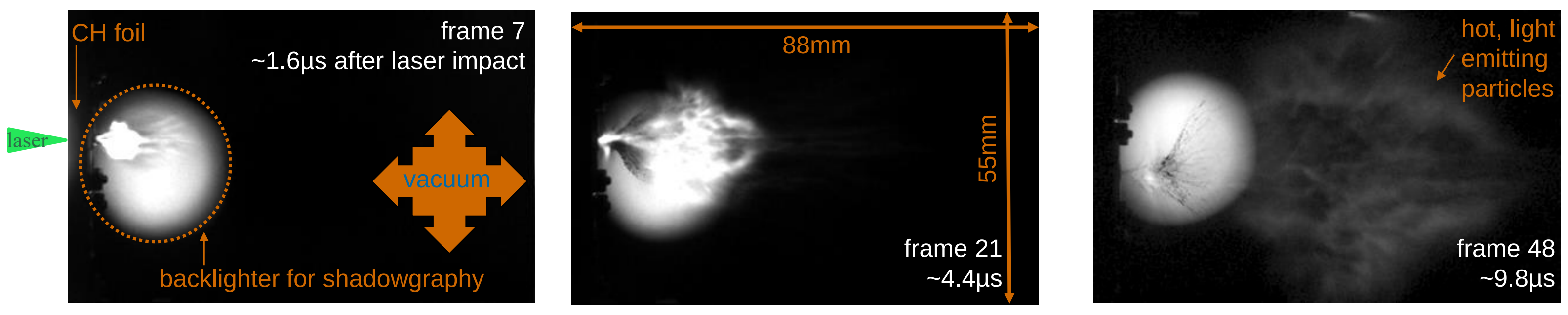
Model of double shocked CH sample



High speed recordings

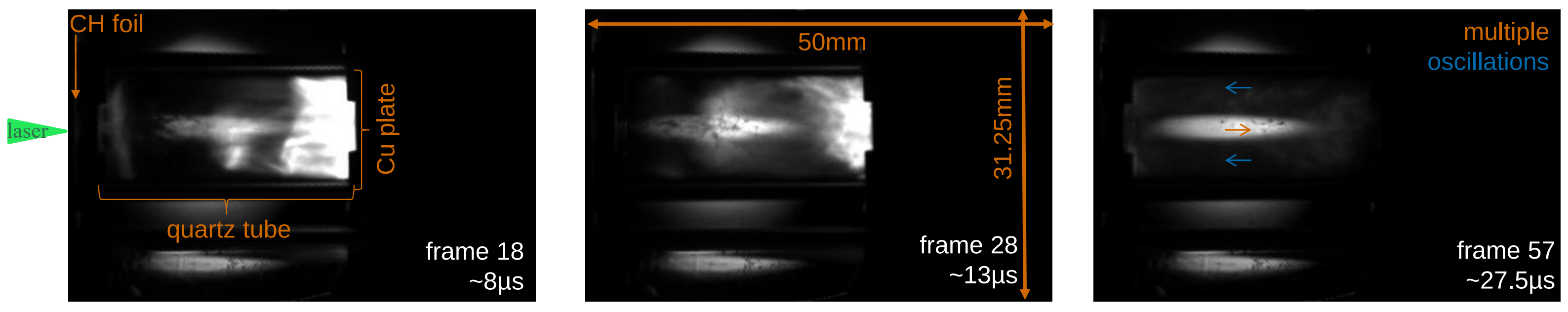
Unconstrained shock break-out in vacuum **particle velocities between 5-20km/s**

17025, PS125, 32.3J, VISAR, 5MHz, 200ns per frame, 1st objective, 0.22mm/pxl



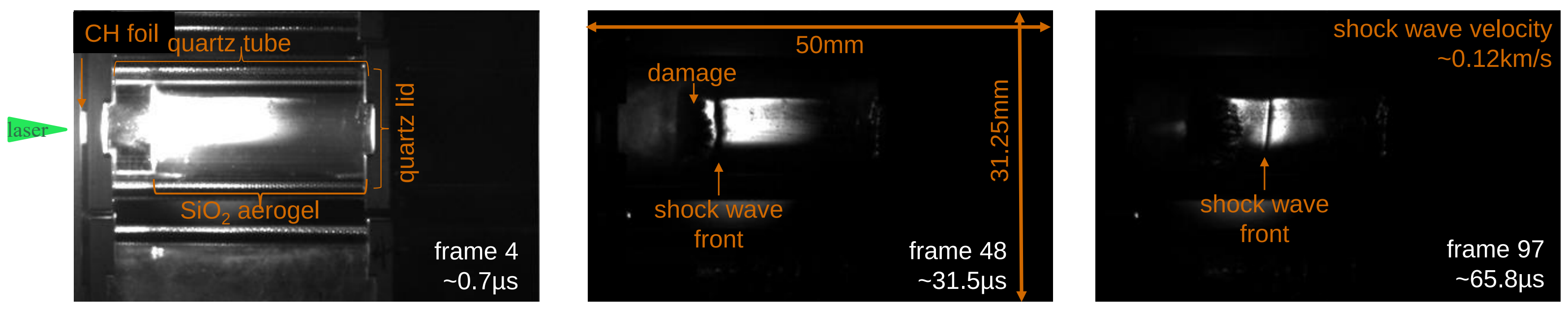
Constrained by closed quartz cylinder with Cu lid

17184, PS125, 60.4J, Cu plate, 2MHz, 500ns per frame, 2nd objective, 0.125mm/pxl



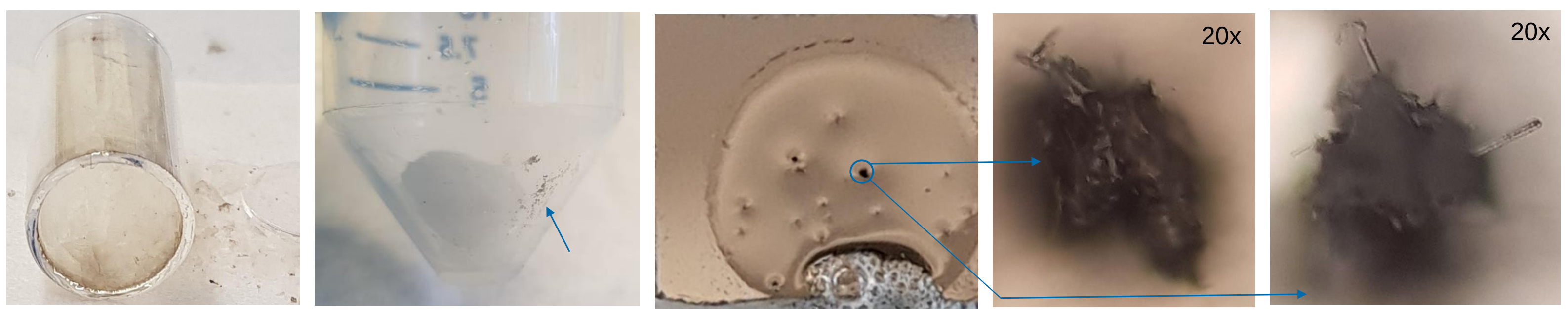
Constrained by closed quartz cylinder with SiO_2 aerogel

17104, PS125, 81.7J, SiO_2 B (ρ=90mg/cc), 1.428MHz, 700ns per frame, 2nd objective, 0.125mm/pxl

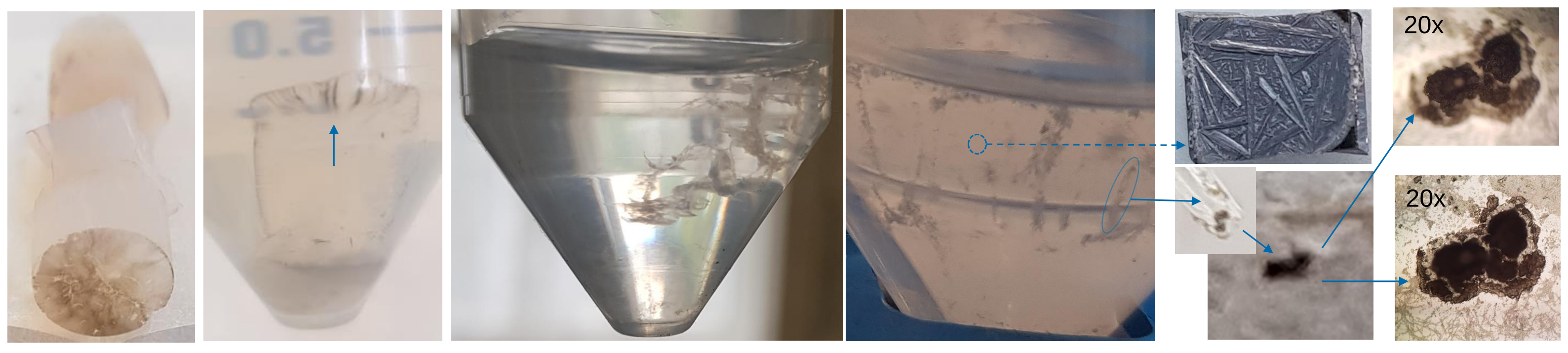


Dissolution of aerogel & aggregation of nanodiamonds to colloidal crystals

17186, PS125 (1), 55.8J, SiO_2 A (130mg/cc), treatment with **ethanol** and **KOH**

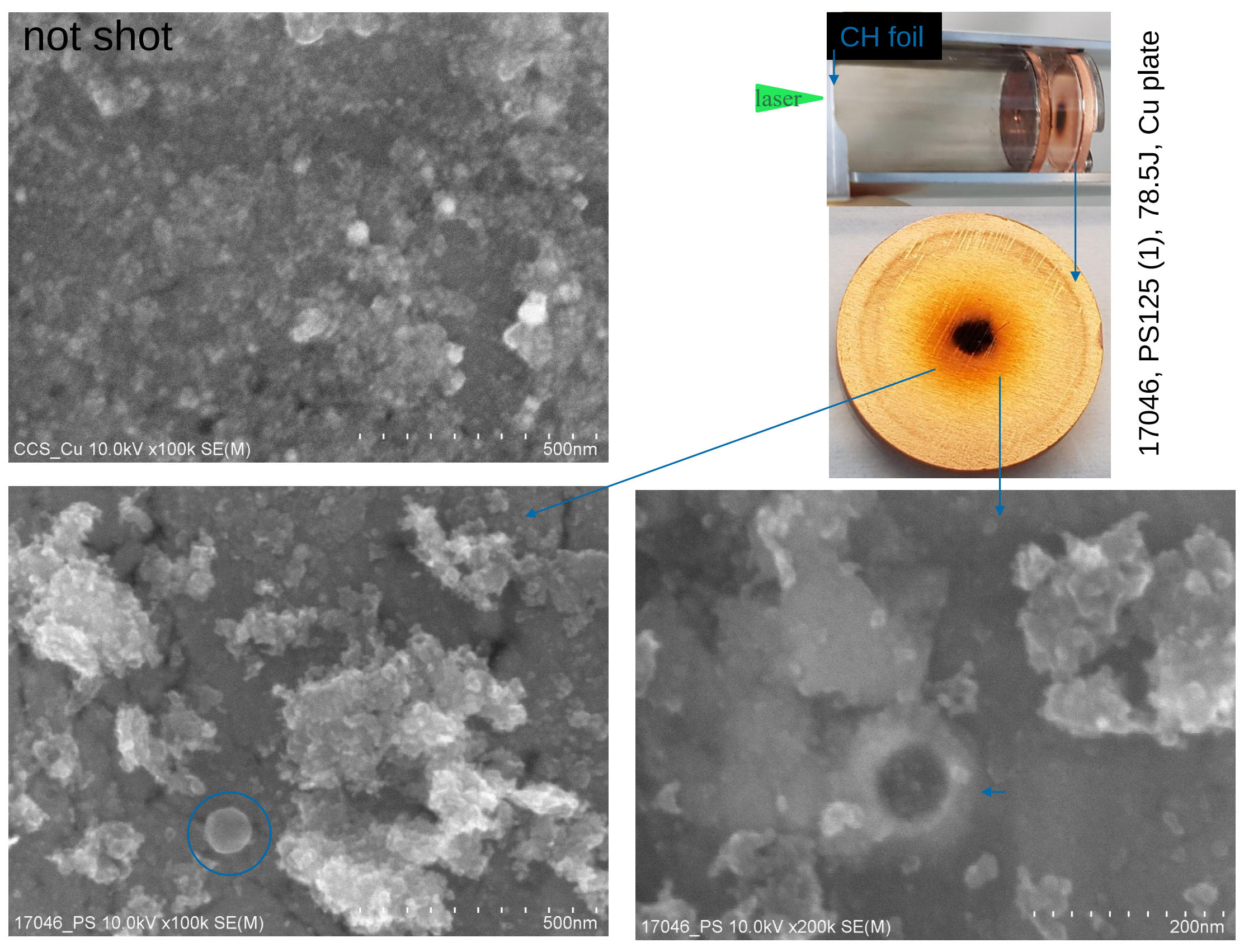


15675, PS125 (2), 54.9J, Al_2O_3 500, (80mg/cc), treatment with **isopropanol** and **NaOH**



Dissolution of aerogel was successful and aggregation of darker particles is observed. Upon drop-casting aliquots on silicon wafer and drying, the salt of the solution recrystallizes. **Raman** and **XRD** measurements were performed, but they **do not yet give conclusive results**.

Scanning Electron Microscopy of solid Cu plate catcher

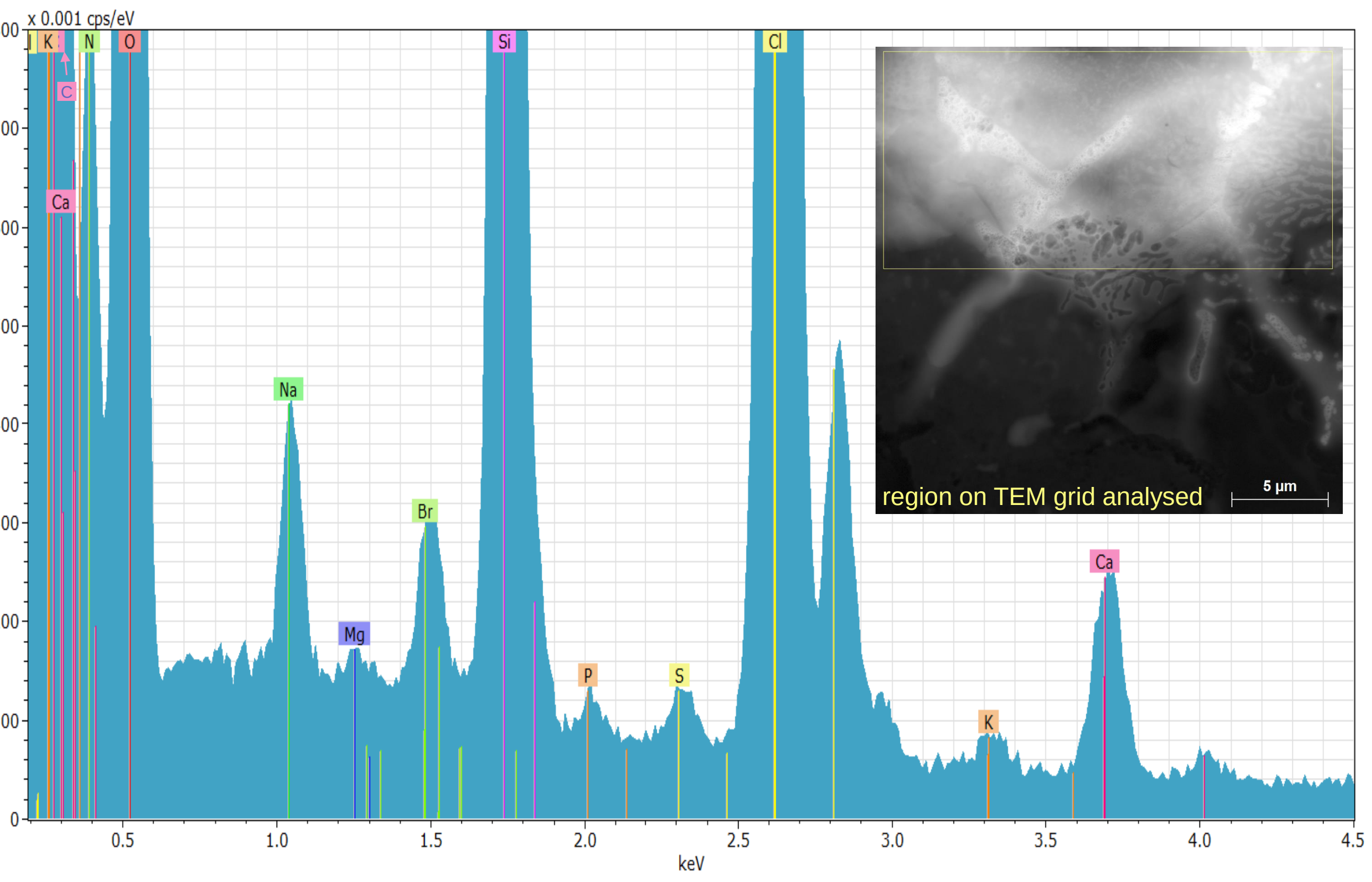


Solid catchers usually show craters after particle impact and a lot of fluffy material. Perfectly spherical particles are observed multiple times.

Conclusions

Energy dispersive X-ray spectroscopy (EDX)

HF, $HClO_4$,HCl, NH_4OH treatment of sample
Run 275, SiO_2 60mg/cc, PG [5], 27.84J



The most unambiguous identification of nanodiamond is its **elemental characterisation with EDX** (energy dispersive X-ray spectroscopy) and the verification of **lattice parameter via SAED** (selected area electron diffraction) after spotting a crystalline area with **HRTEM imaging** (high resolution transmission electron microscopy). The prepared samples unfortunately contained **too many contaminations** to allow identification despite the use of harsh chemicals and multiple washing cycles. The key parameter missing is proper purification which includes **strong acids under elevated pressures and temperatures** (e.g. microwave digestion).

References:

[1] Kraus, Dominik, et al. "Formation of diamonds in laser-compressed hydrocarbons at planetary interior conditions." Nature Astronomy 1.9 (2017): 606.
[2] Kraus, D., et al. "High-pressure chemistry of hydrocarbons relevant to planetary interiors and inertial confinement fusion." Physics of Plasmas 25.5 (2018): 056313.
[3] A. K. Schuster, N. J. Hartley, J. Vorberger, T. Döppner, T. van Driel, R. W. Falcone, L. B. Fletcher, S. Frydrych, E. Galtier, E. J. Gamboa et al., Measurement of Diamond Nucleation Rates from Hydrocarbon at Conditions Comparable to the Interiors of Icy Giant Planets, submitted.