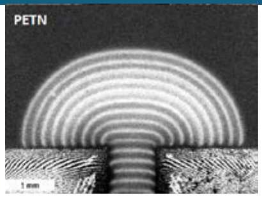
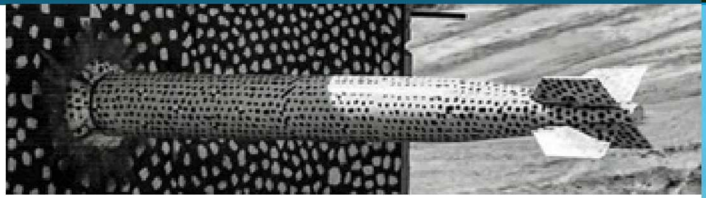
SAND2018-7696C

Detonation behavior in vapor-deposited 3,4-bis(4-nitro-1,2,5-oxadiazol-3-yl)-1,2,5-oxadiazole 2-oxide (BNFF)





Alexander S. Tappan, Michael P. Marquez, Jon Vasiliauskas, Stephen Rupper, Samuel D. Park and Robert Knepper

16th International Detonation Symposium, Cambridge, MD, July 15 – 20, 2018.

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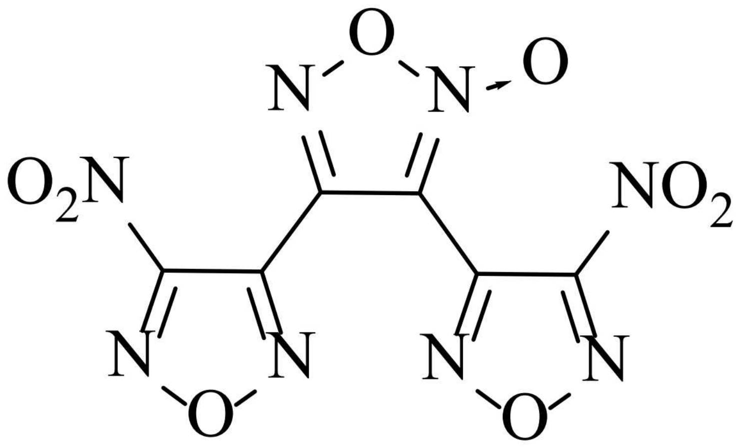
BNFF (aka DNTF)

BNFF has interesting properties

- High density and output: $\varrho = 1.937\ g/cm^3$, D = 9000 m/s
- Small failure diameter, $d_f = 0.15$ mm
- Hydrogen free, $C_6N_8O_8$
- High reaction zone temperature: ~4900 K, calc.
- Melt stable: m.p.: 106.5 °C, decomp.: 292°C

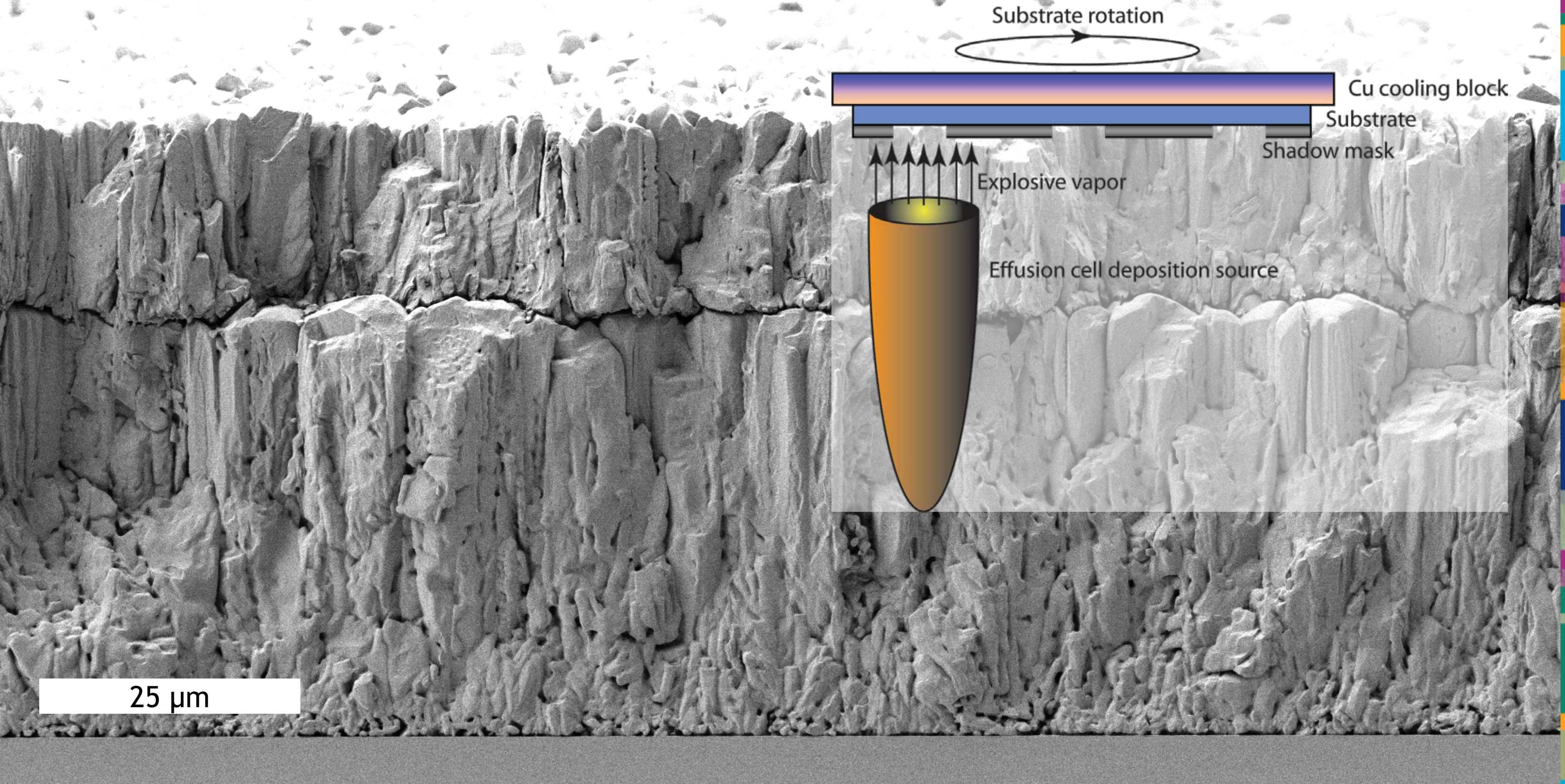
Motivation of this work is to study near-failure detonation behavior to provide data to parameterize reactive burn models



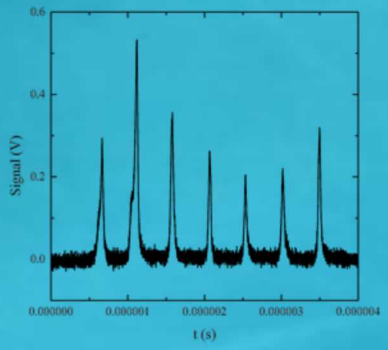
BNFF, 3,4-bis(4-nitro-1,2,5-oxadiazol-3-yl)-1,2,5-oxadiazole 2-oxide.

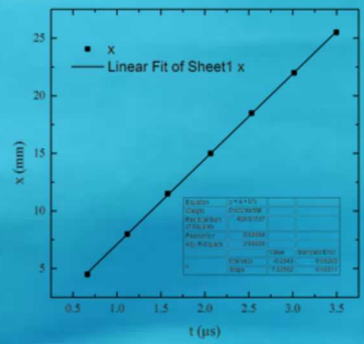
Kotomin, A., Kozlov, A., and Dushenok, S., "Detonatability of High-Energy-Density Heterocyclic Compounds," Russian Journal of Physical Chemistry B, Focus on Physics, Vol. 1, pp. 573-575, 2007.
Zhao, F.-q., Chen, P., Hu, R.-z., Luo, Y., Zhang, Z.-z., Zhou, Y.-s., Yang, X.-w., Gao, Y., Gao, S.-l., and Shi, Q.-z., "Thermochemical properties and non-isothermal decomposition reaction kinetics of 3,4-dinitrofurazanfuroxan (DNTF)," *Journal of Hazardous Materials,* Vol. 113, pp. 67-71, 2004.

Physical vapor deposition of BNFF

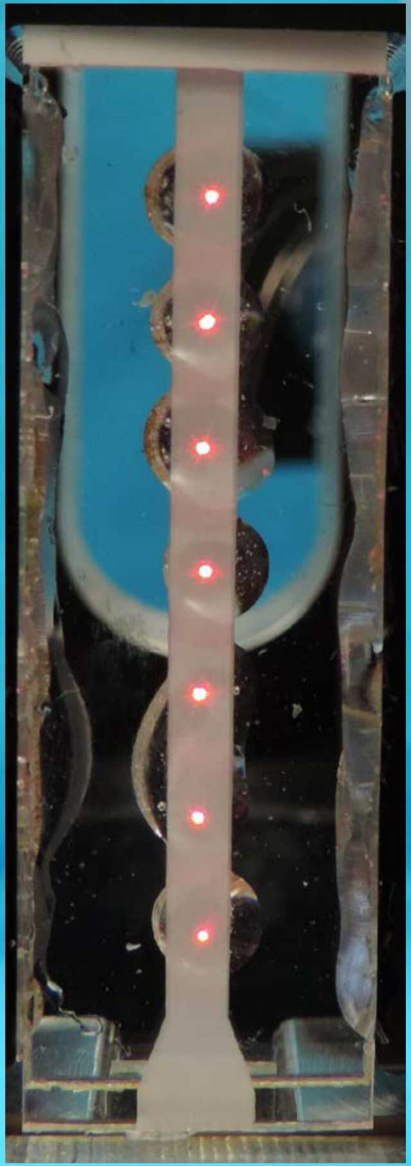


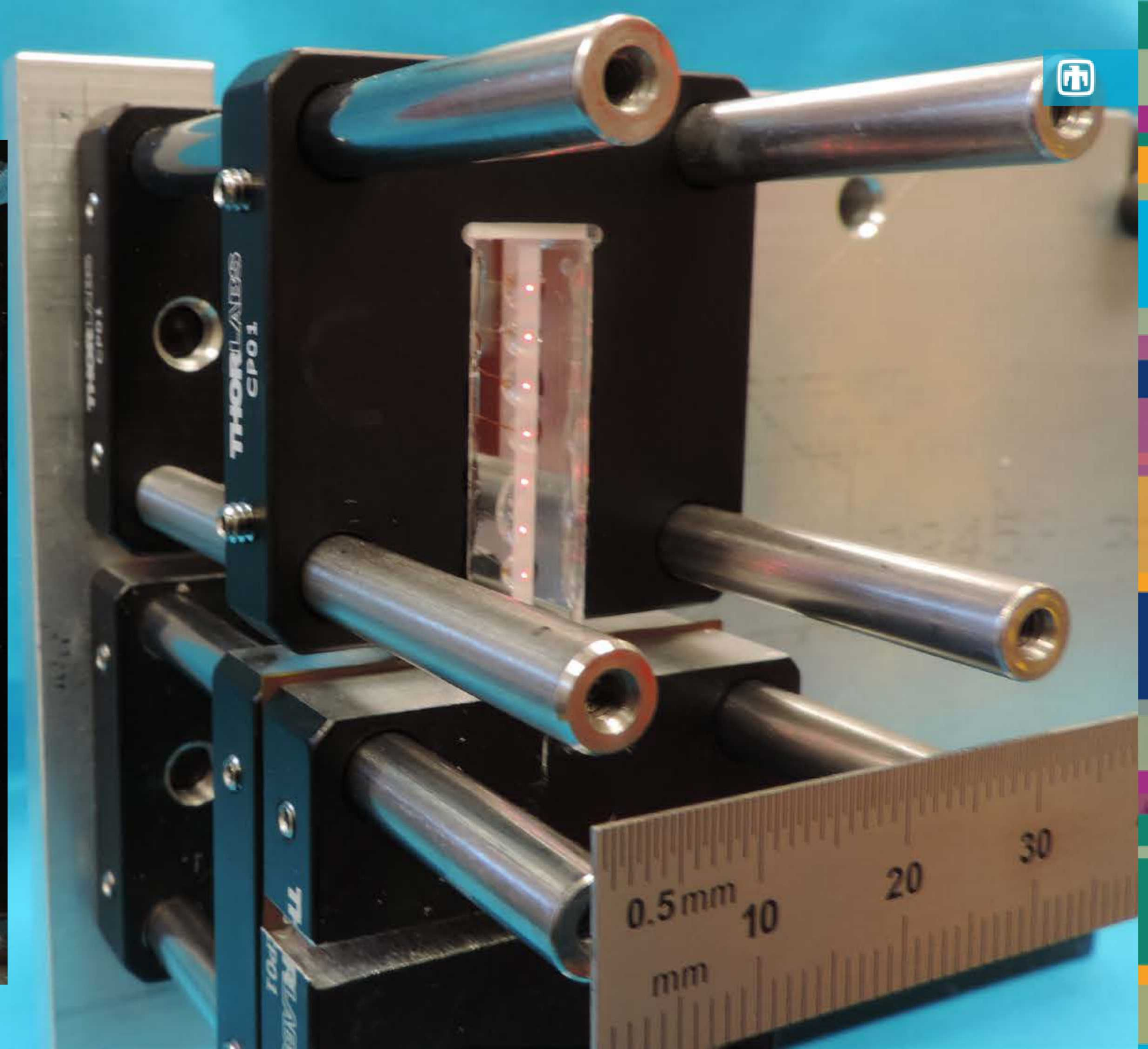
Critical detonation thickness experiment





Optical fiber data is used to produce a linear fit to position versus time.

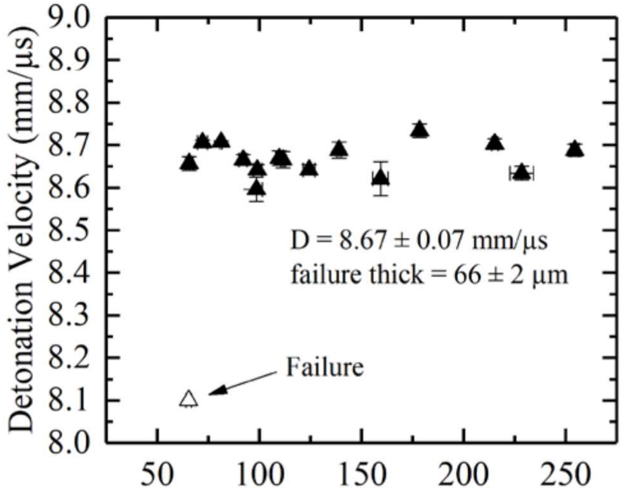




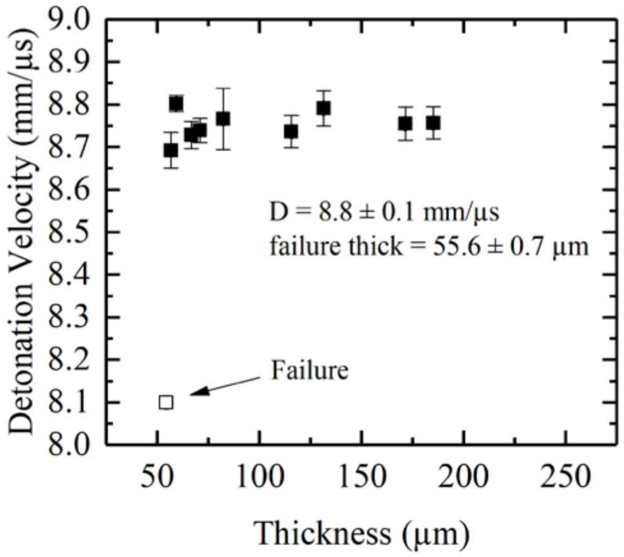
Critical detonation thickness experiment results

Detonation velocity is relatively consistent with decreasing thickness until reaching the detonation failure thickness

- 66 ± 2 μm for the Lot-1 BNFF material deposited on fused silica
- 55.6 ± 0.7 μm for the Lot-7 BNFF material deposited on polycarbonate
- Open point for the thickest film showing detonation failure is included for illustrative purposes.
- Near-failure detonation behavior consistent with a homogeneous explosive



Lot-1 on fused silica. Film width: 1 mm.



Lot-7 on polycarbonate. Film width: 1.6 mm.

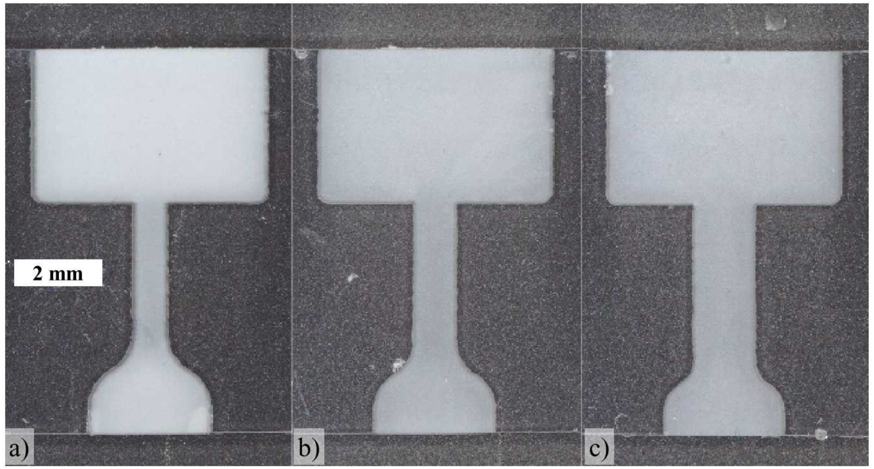
Micromushroom test to study corner turning

Polycarbonate substrates, 10 × 10 mm

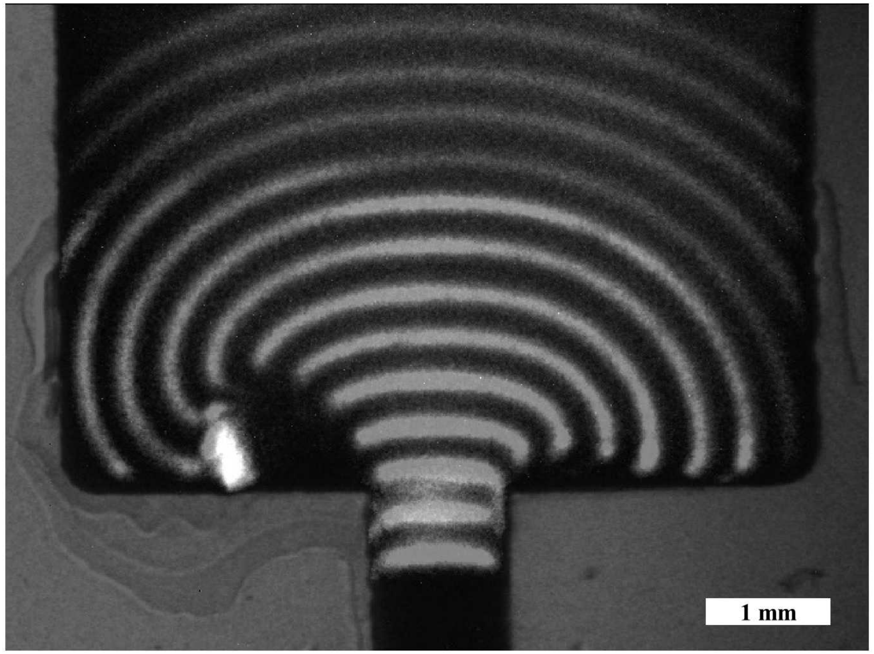
Stem width: 0.75, 1.00, or 1.50 mm

Cap width: 6 mm

Poly(dimethylsiloxane) (PDMS) to exclude air



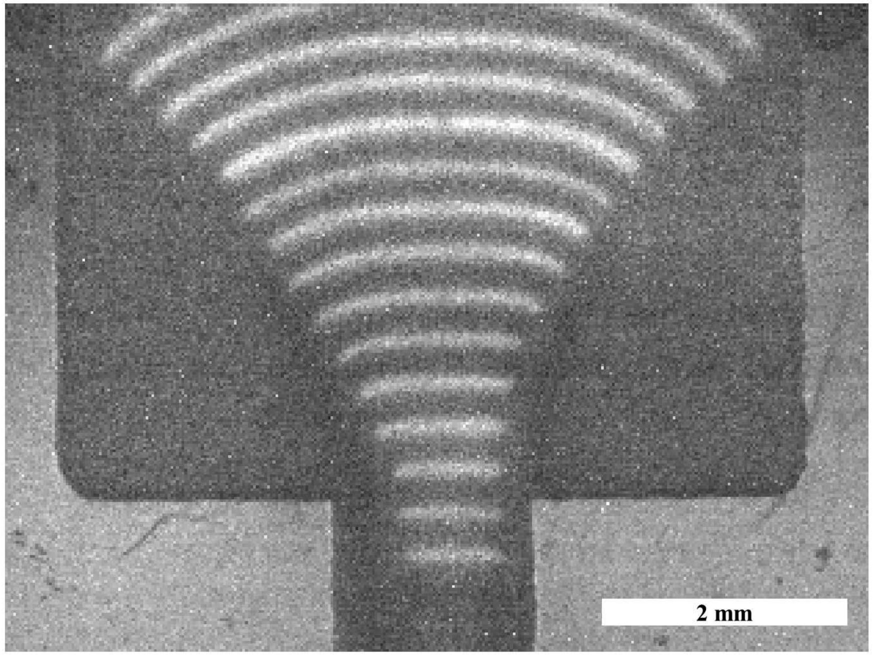
Photographs of vapor-deposited BNFF micromushroom samples with stem widths of 0.75, 1.00, and 1.50 mm



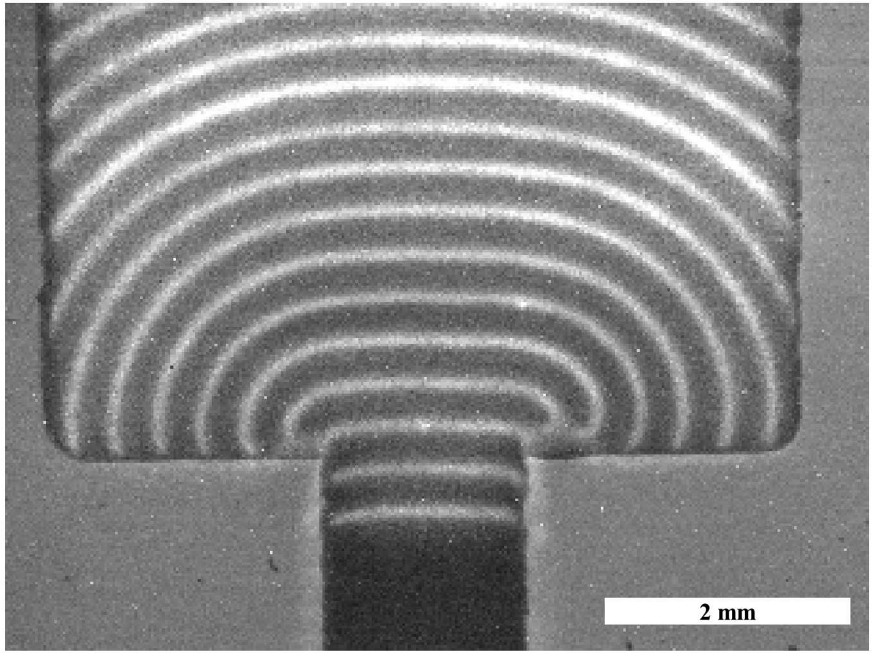
Composite framing camera image of detonation corner turning in BNFF micromushroom experiment. Original images were recorded at 25 MHz (1/40 ns) with an exposure time of 10 ns.

Micromushroom corner turning with different thicknesses

Dead zones are larger near failure thickness.



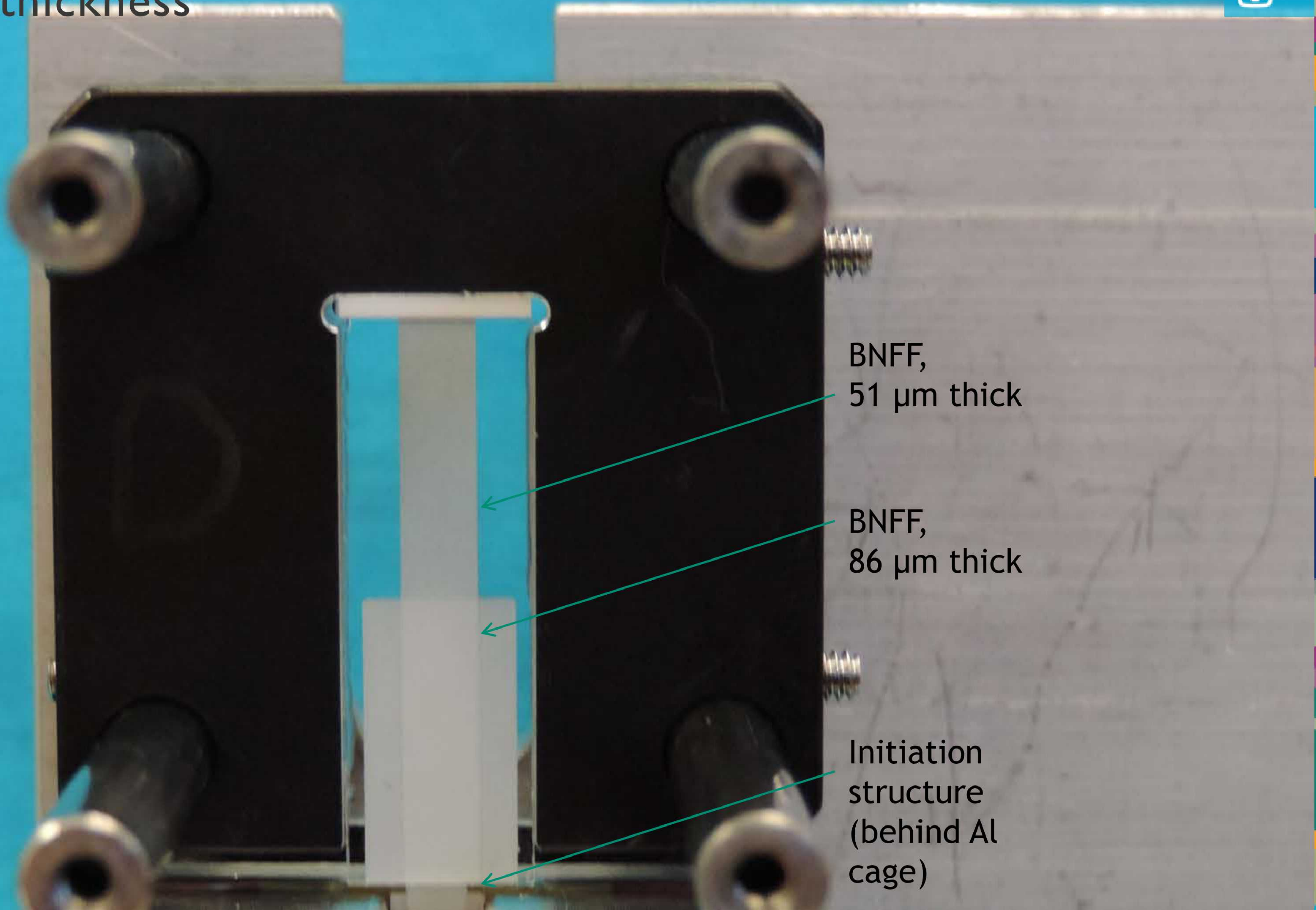
Near failure thickness.



Well above failure thickness.

Composite framing camera images of detonation corner turning in BNFF micromushroom experiment. Original images were recorded at 25 MHz (1/40 ns) with an exposure time of 10 ns.

BNFF arrested thickness

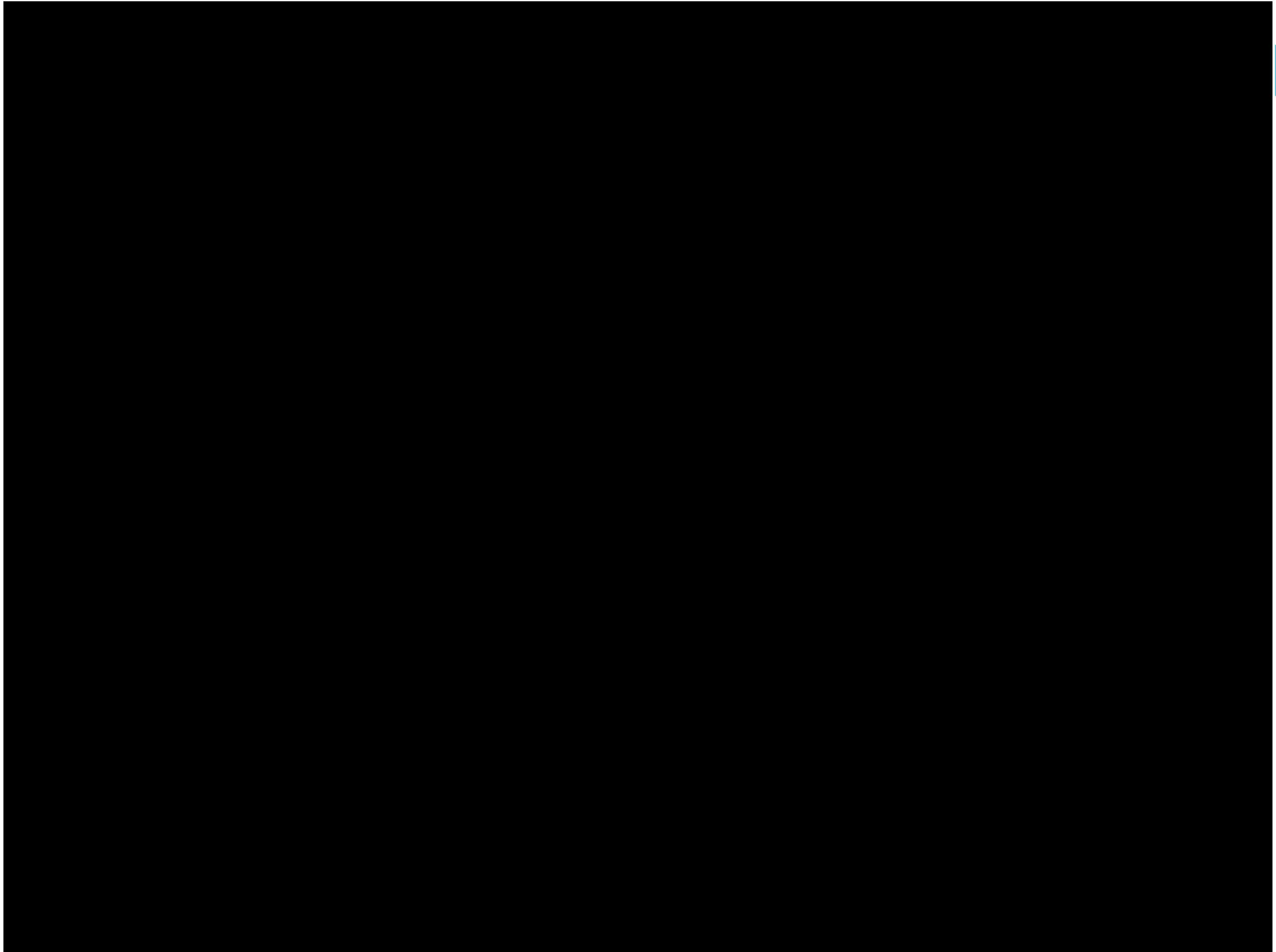


BNFF,
51 µm thick

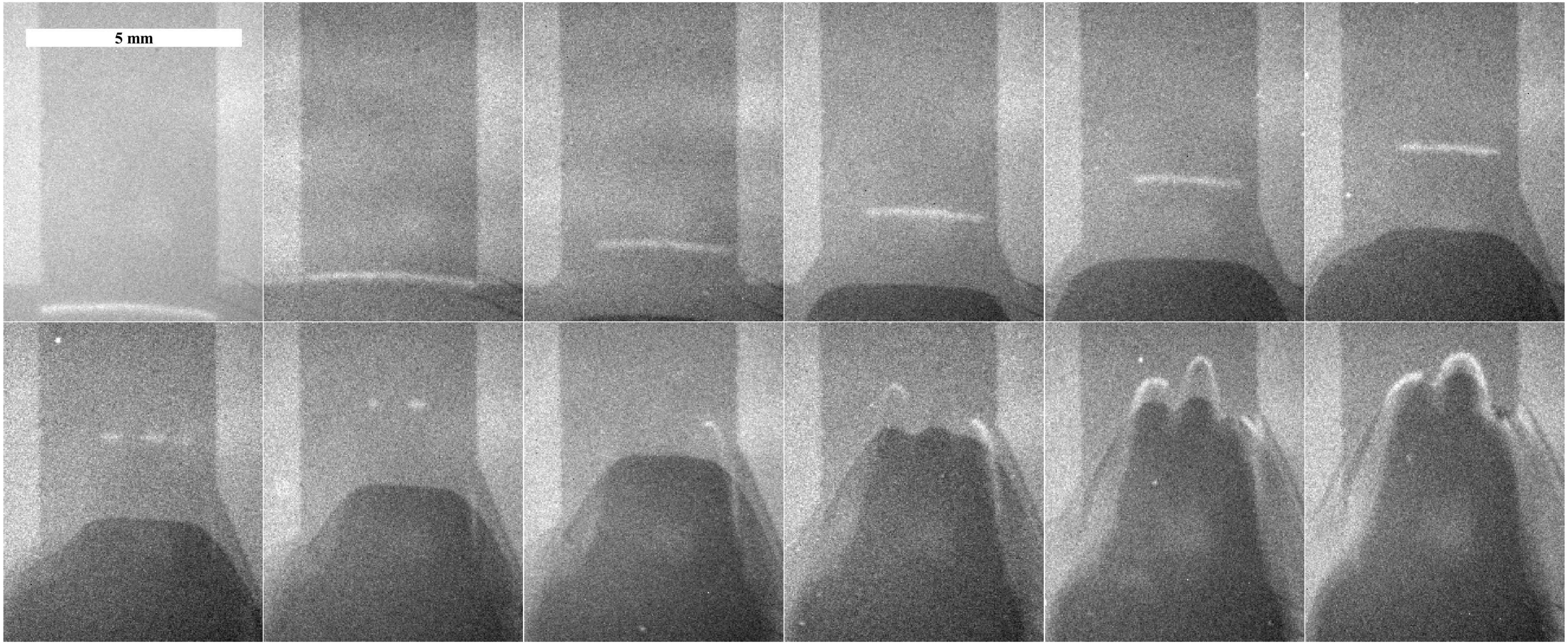
BNFF,
86 µm thick

Initiation structure (behind Al cage)

BNFF arrested thickness



BNFF arrested thickness



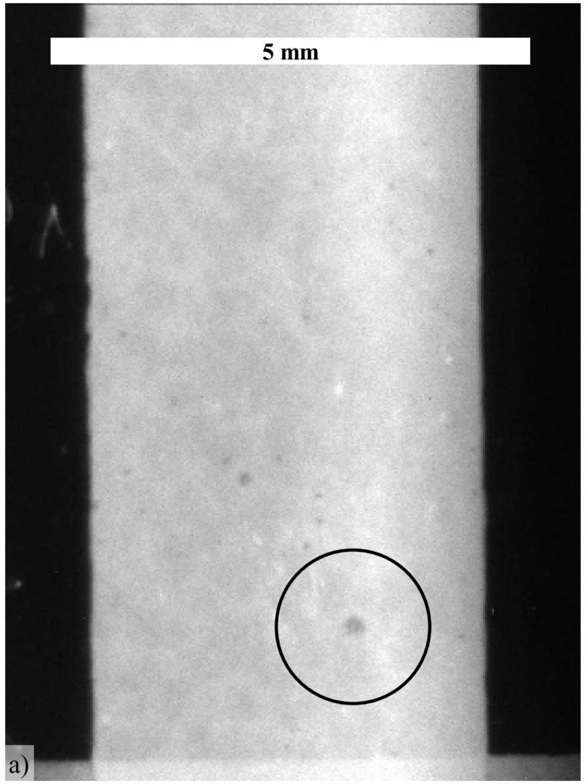
Framing camera images of detonation failure in vapor-deposited BNFF (51 μm thick) arrested thickness experiment. Images were recorded at 12 MHz (1/85 ns) with an exposure time of 10 ns.

BNFF arrested thickness

During failure, the detonation wave typically splits and forms a number of failure wedges

BNFF arrested thickness

Splitting of failing detonation wave appears to occur at a defect



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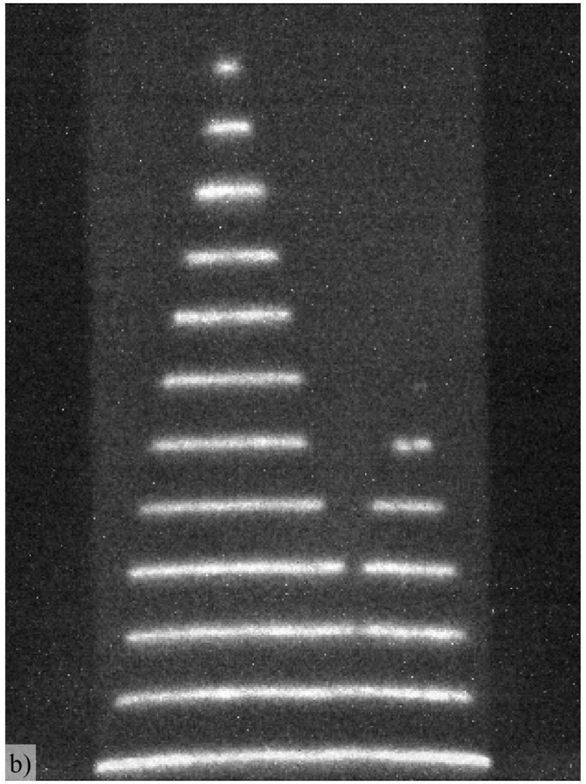


Composite dynamic image.

Composite framing camera images of failing detonation wave bifurcating in a 51 µm thick BNFF film. Original images were recorded at 13 MHz (1/75 ns) with an exposure time of 10 ns.

Radius-thickness scaling

Critical detonation thickness experiment

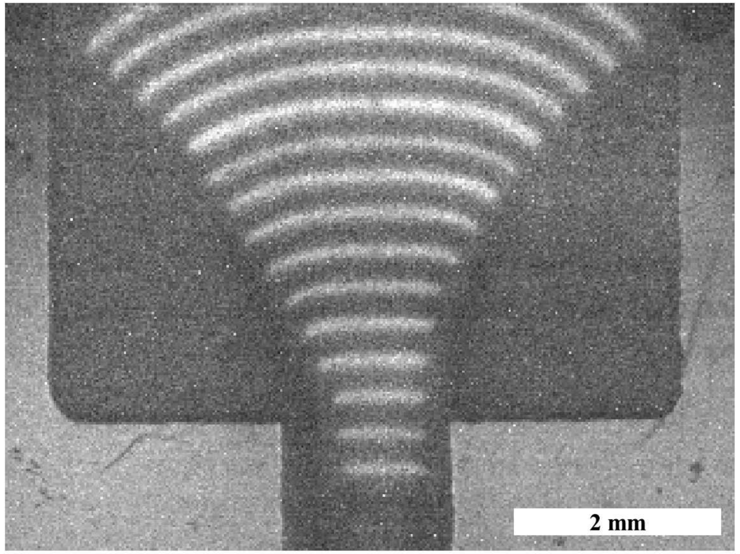
- 1 mm wide, fused silica, $t_{failure} = 66 \pm 2$ μm
- 1.6 mm wide, polycarbonate, $t_{failure} = 55.6 \pm 0.7$ μm

Arrested confinement experiment

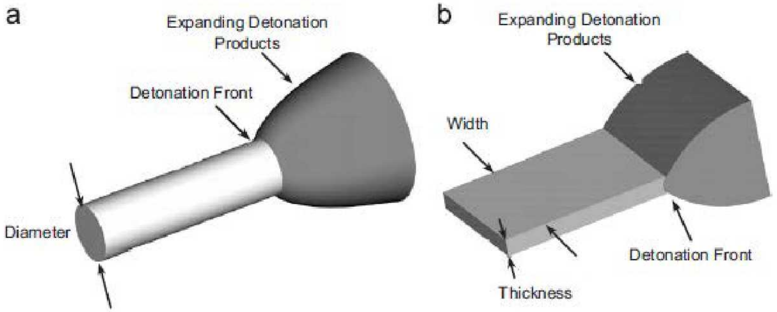
- 4 mm wide, polycarbonate, detonation at 53 μm

Radius-thickness scaling applied to thickness data suggests a failure diameter twice the failure thickness

- $d_{failure} \sim 111$ μm



Width effect seen in stem of micromushroom test.



Radius-thickness scaling in cylindrical and slab geometries. Petel (2007).

Jackson, S.I. and Short, M., "Scaling of detonation velocity in cylinder and slab geometries for ideal, insensitive and non-ideal explosives," Journal of Fluid Mechanics, Vol. 773, pp. 224 – 266, 2015.
Petel, O.E., Mack, D., Higgins, A.J., Turcotte, R., and Chan, S.K., "Minimum propagation diameter and thickness of high explosives," Journal of Loss Prevention in the Process Industries, Vol. 20, pp. 578 – 583, 2007.

Conclusions

Physical vapor deposition can be used to make thin samples for fundamental detonation research

- This allows large interfacial areas to be studied with optical diagnostics

Failure thickness of 1.6 mm-wide BNFF is 55.6 ± 0.7 μm

- Possible effect of explosive width on failure thickness observed
- Limited additional data suggest that it may be somewhat smaller at effectively infinite width conditions
- Estimated failure diameter is 111 μm

Corner turning behavior of BNFF shows that there is a strong dependence on film thickness

Splitting of failing detonation likely starts at defects

Acknowledgements

Philip F. Pagoria (Lawrence Livermore National Laboratory) and Bradley A. Sleadd (Naval Surface Warfare Center)

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Larry G. Hill (Los Alamos National Laboratory)

Leanna Minier, and Cody M. Washburn

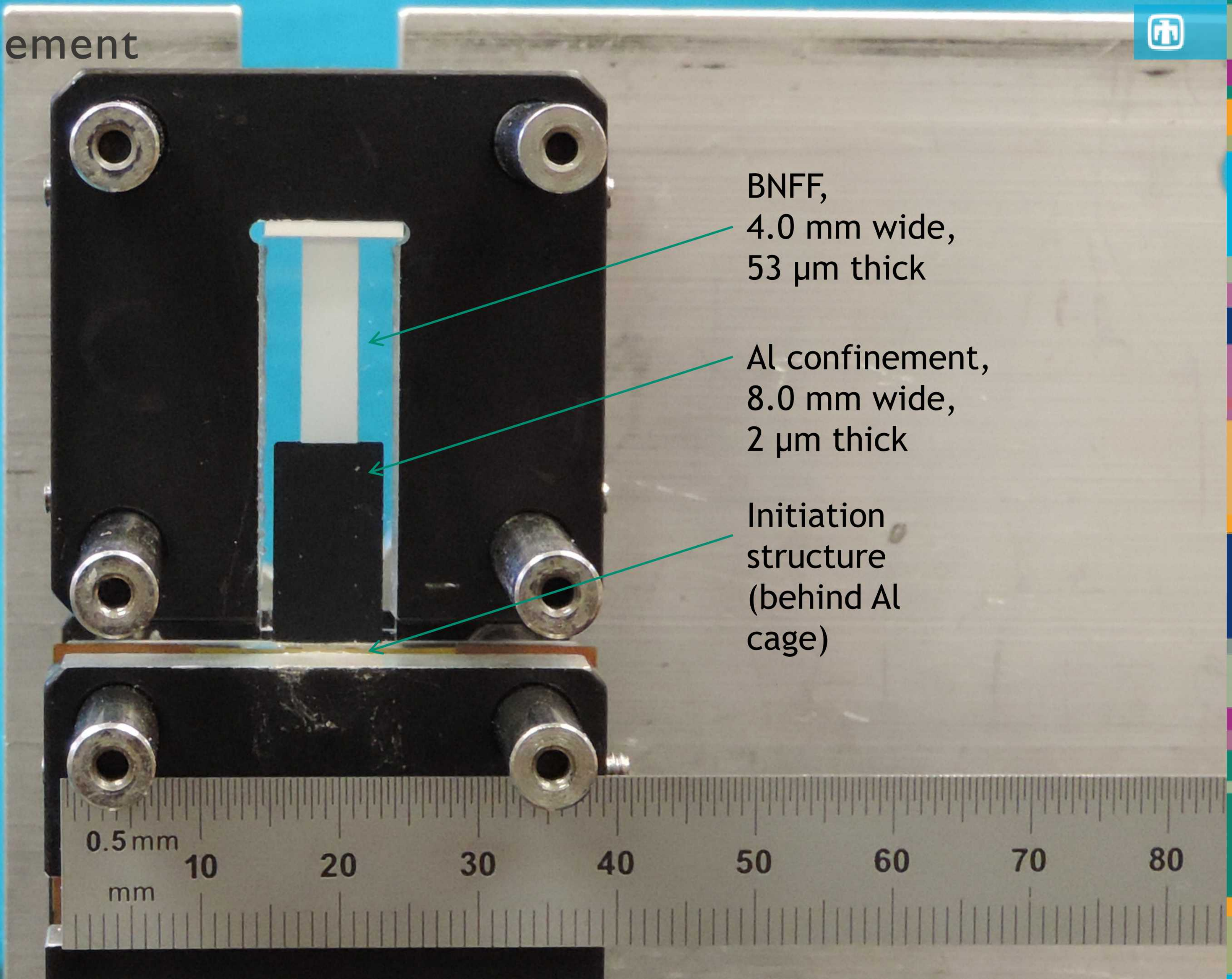
Joint Department of Defense/Department of Energy Munitions Technology Development Program

Laboratory Directed Research and Development

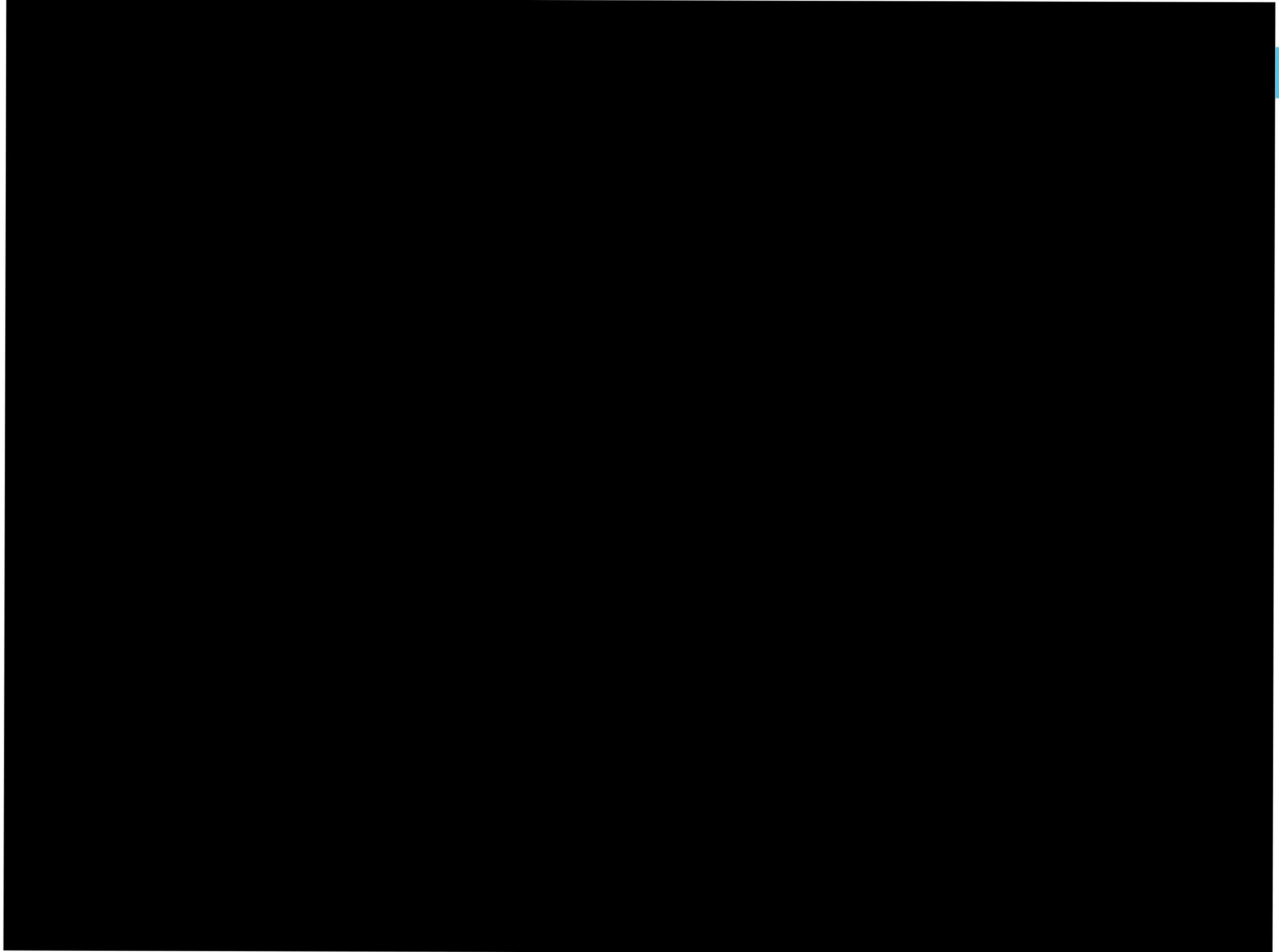
Questions?

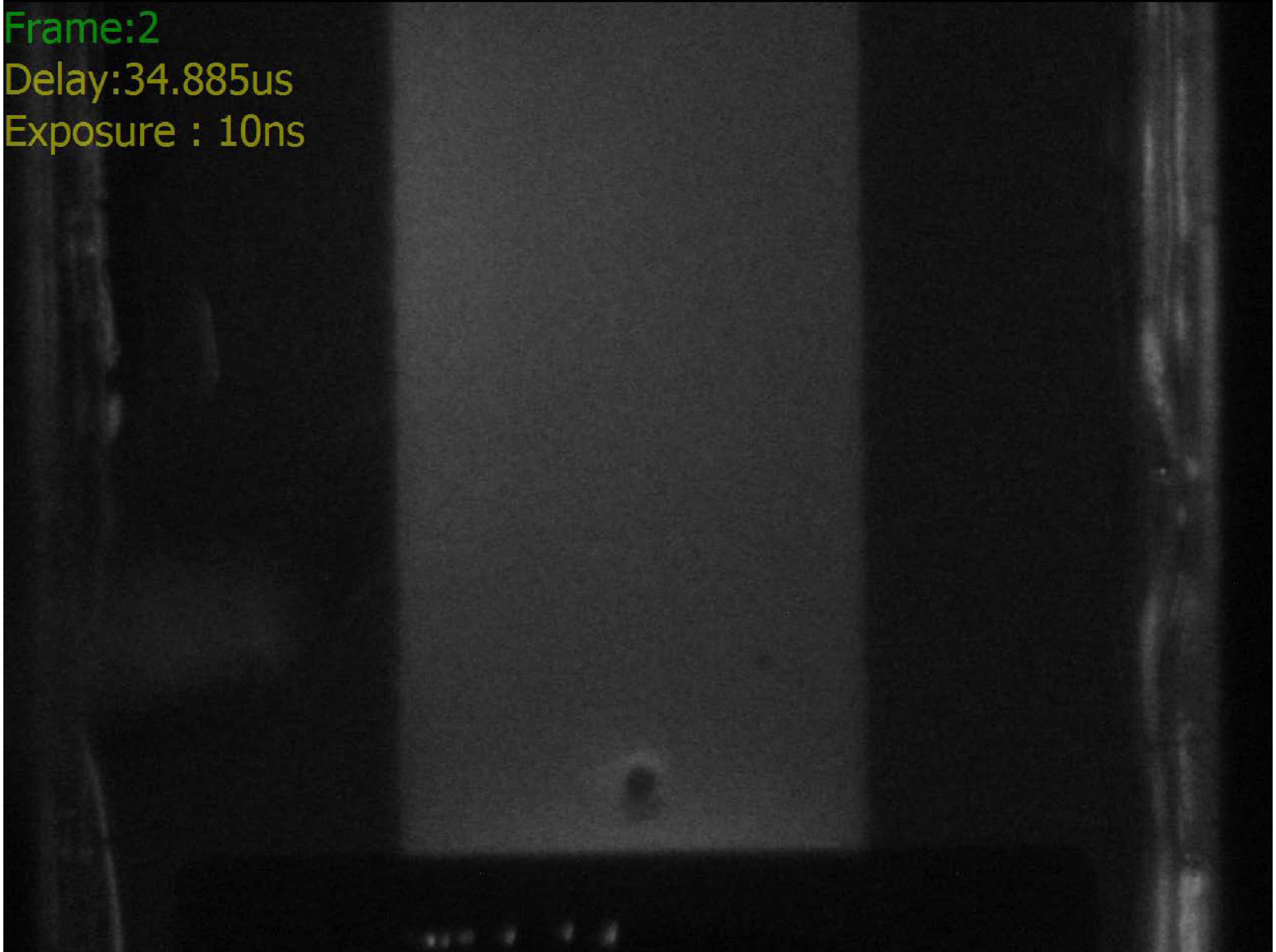
Backup

BNFF arrested confinement



BNFF arrested confinement (with a defect)

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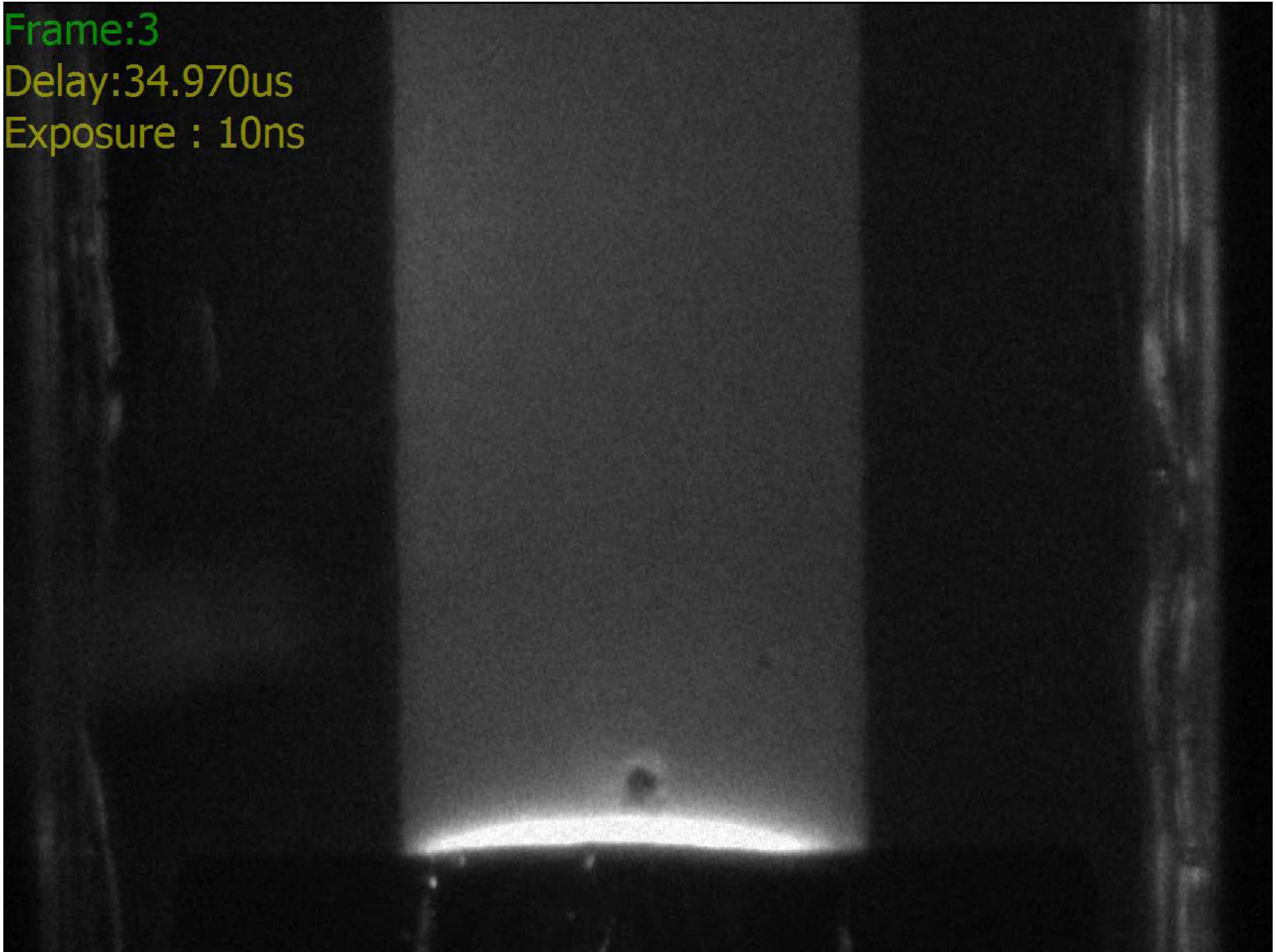
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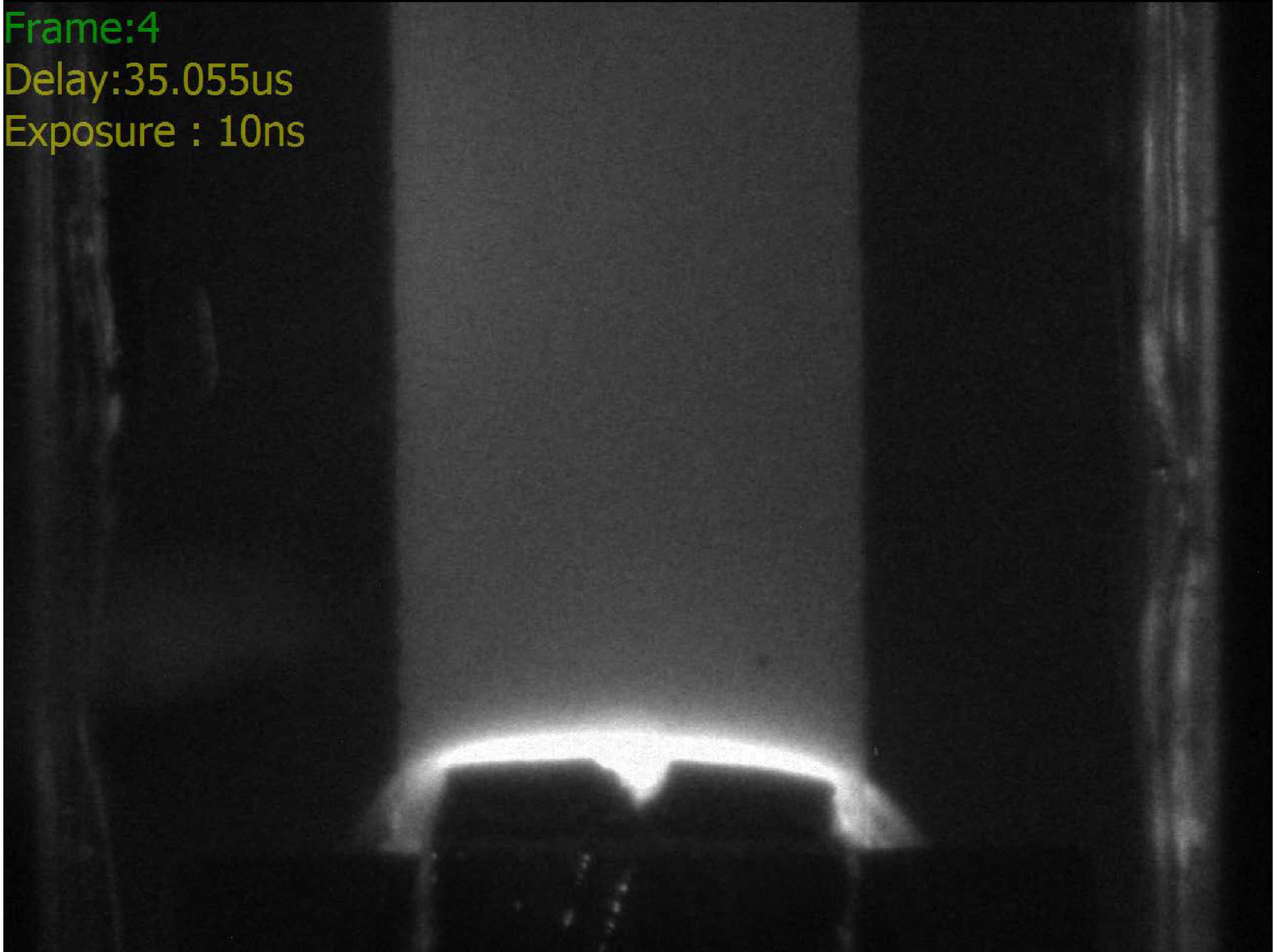
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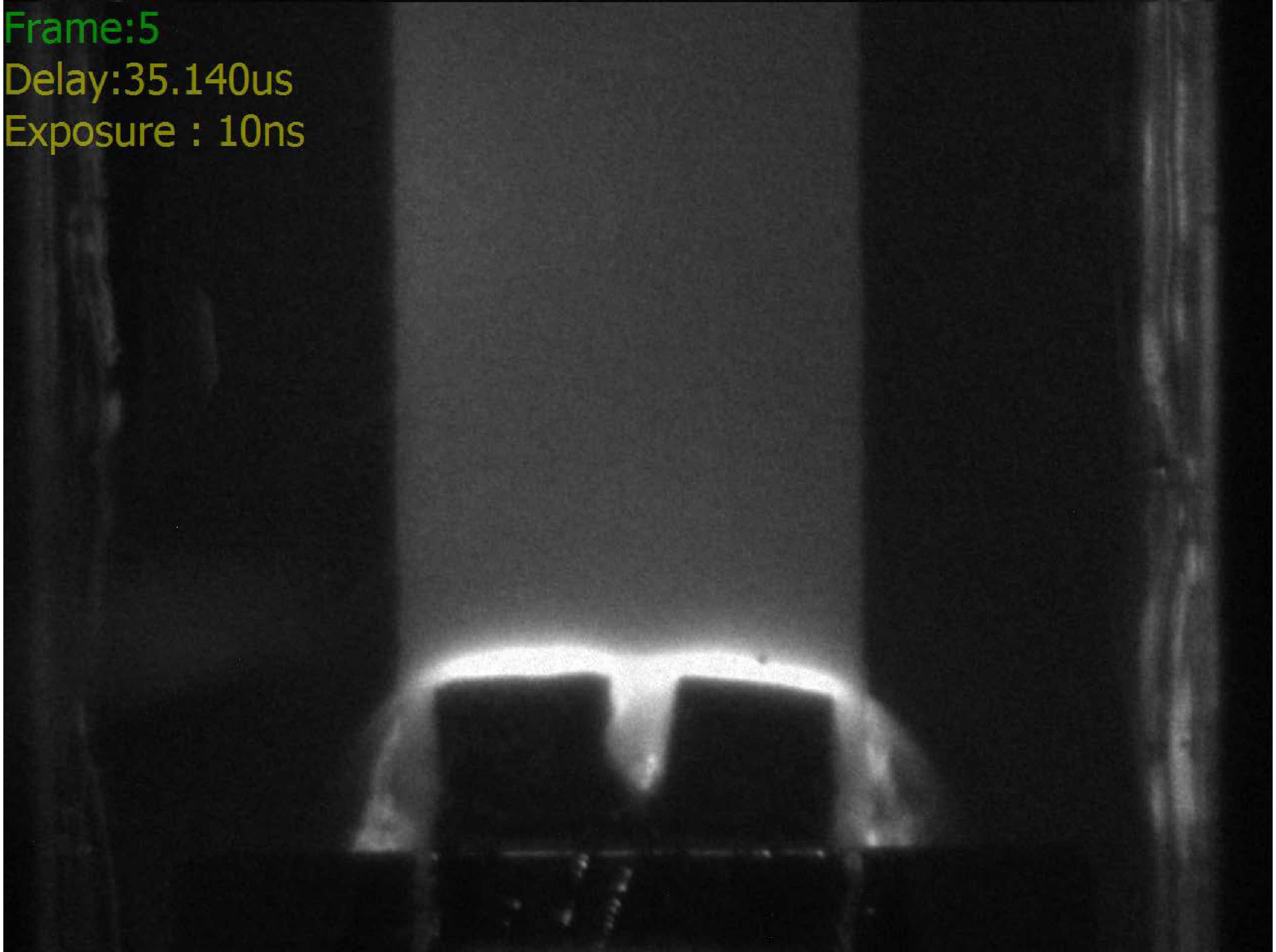
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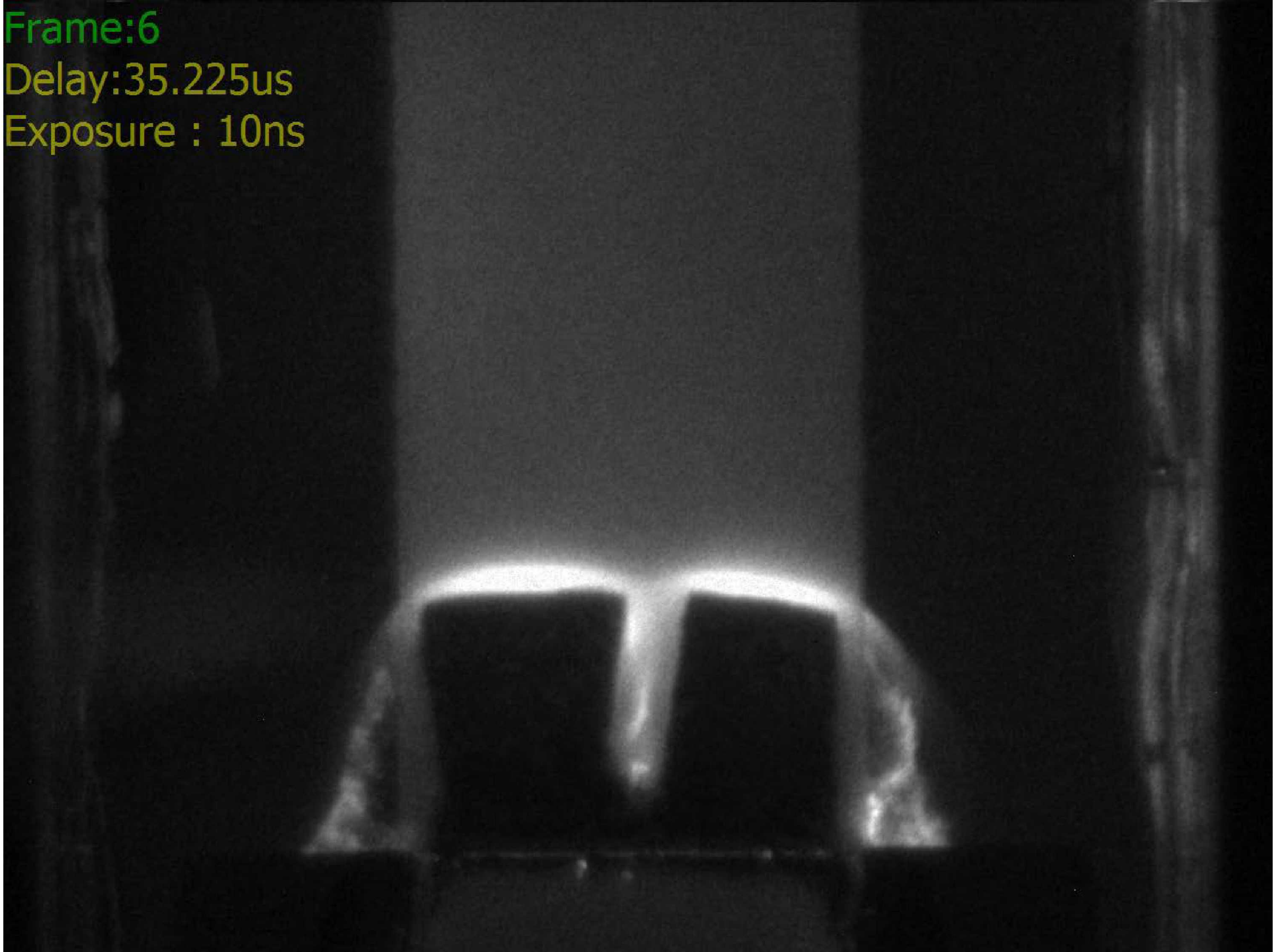
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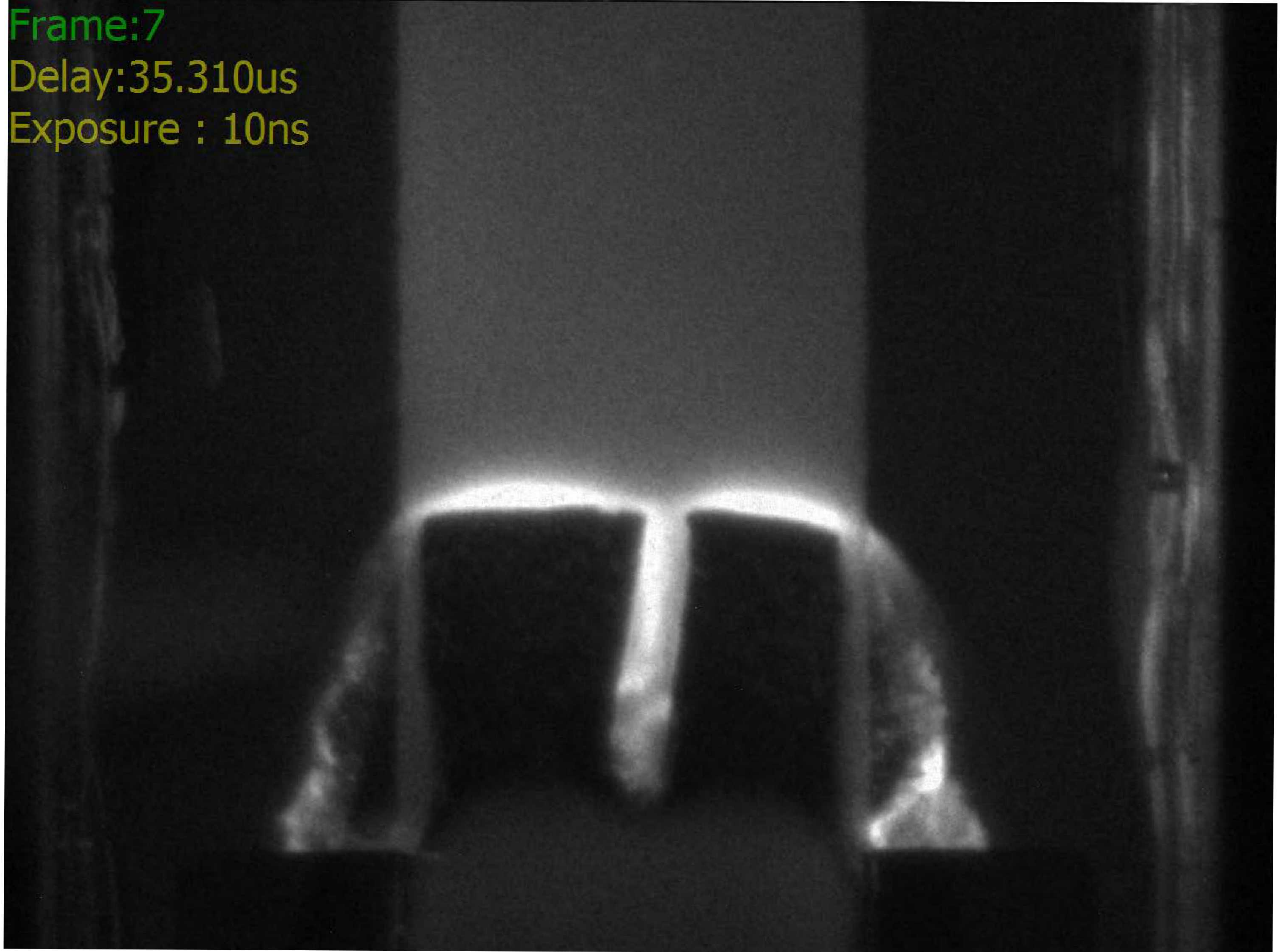
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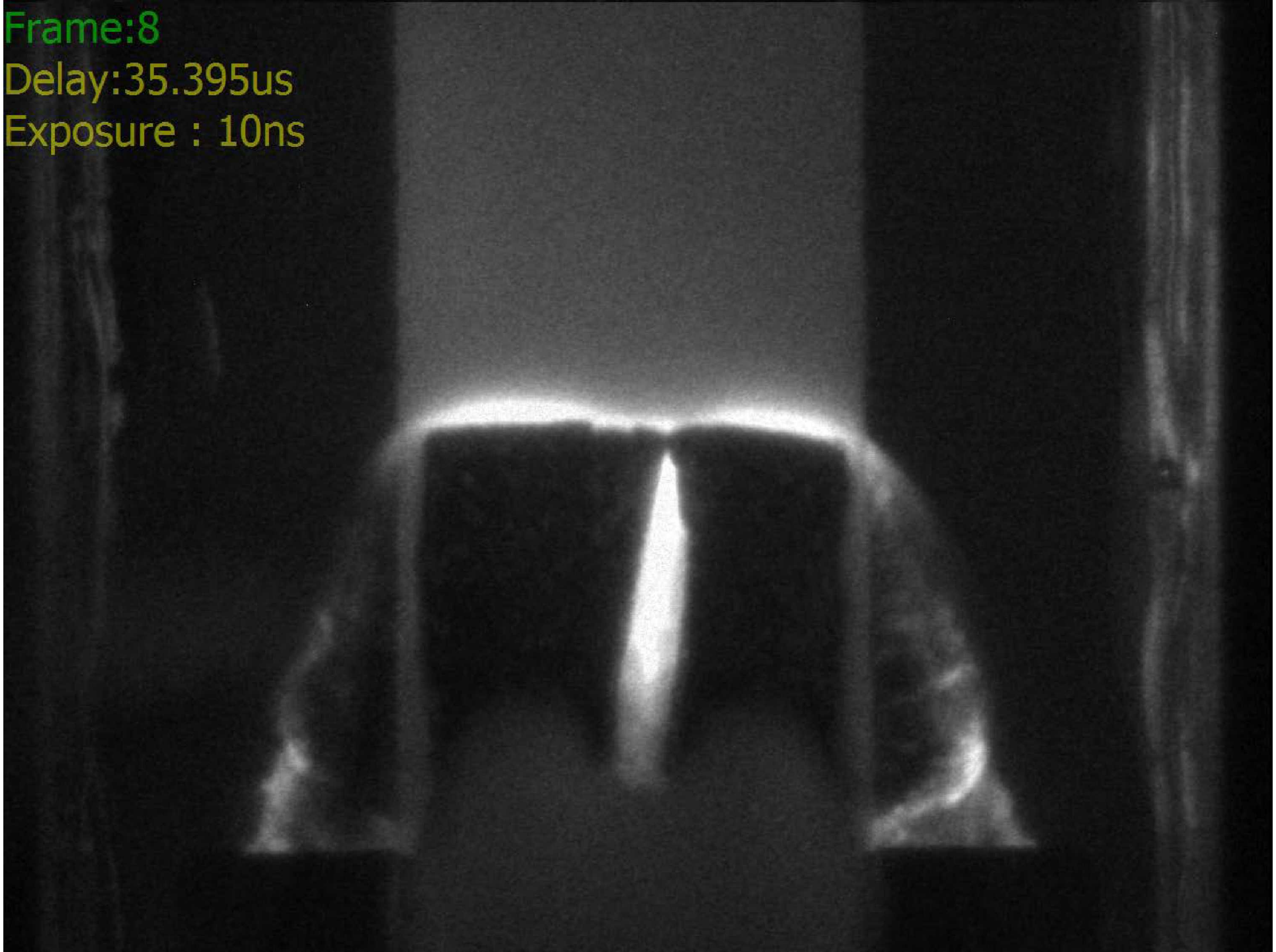
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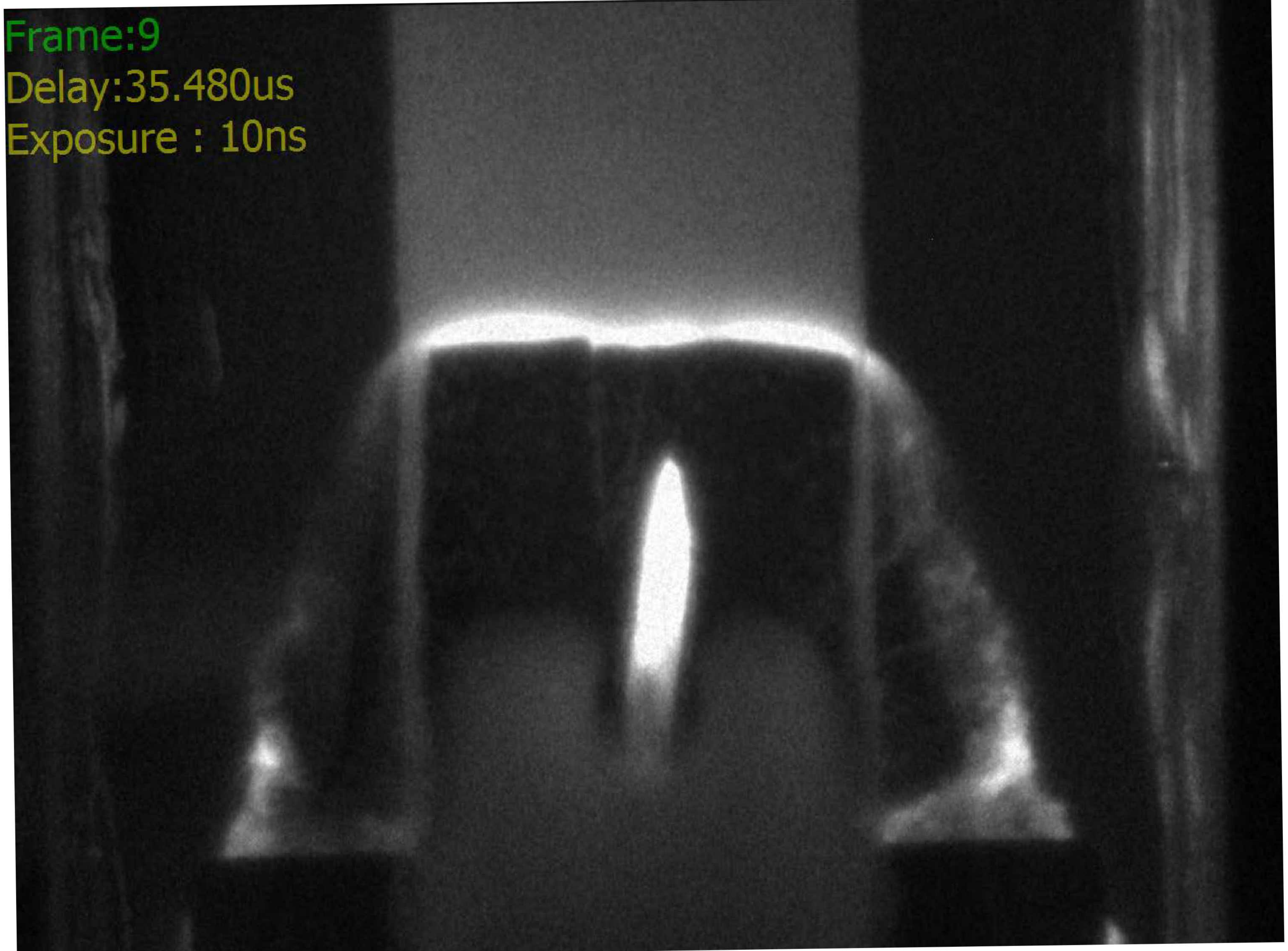
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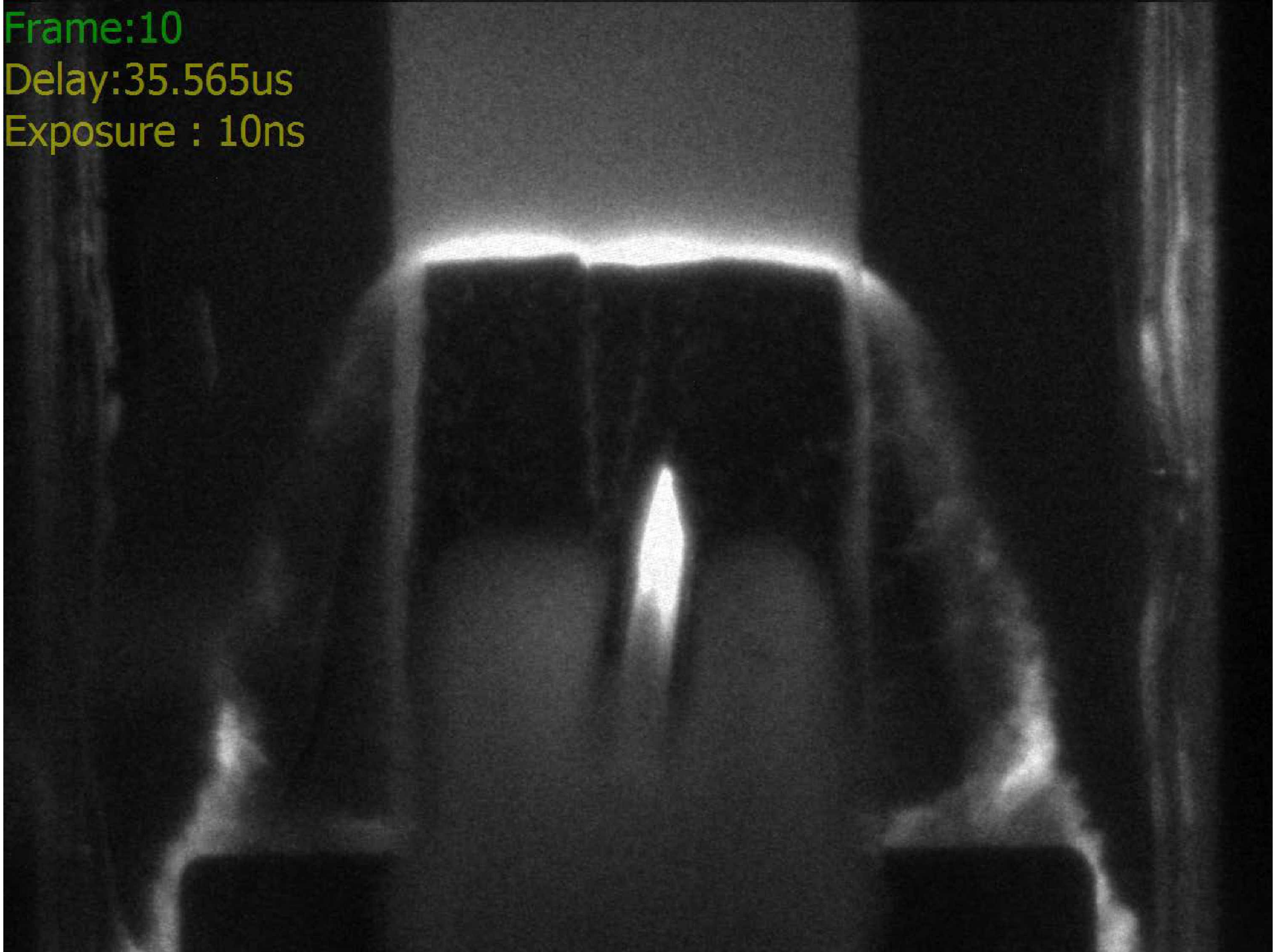
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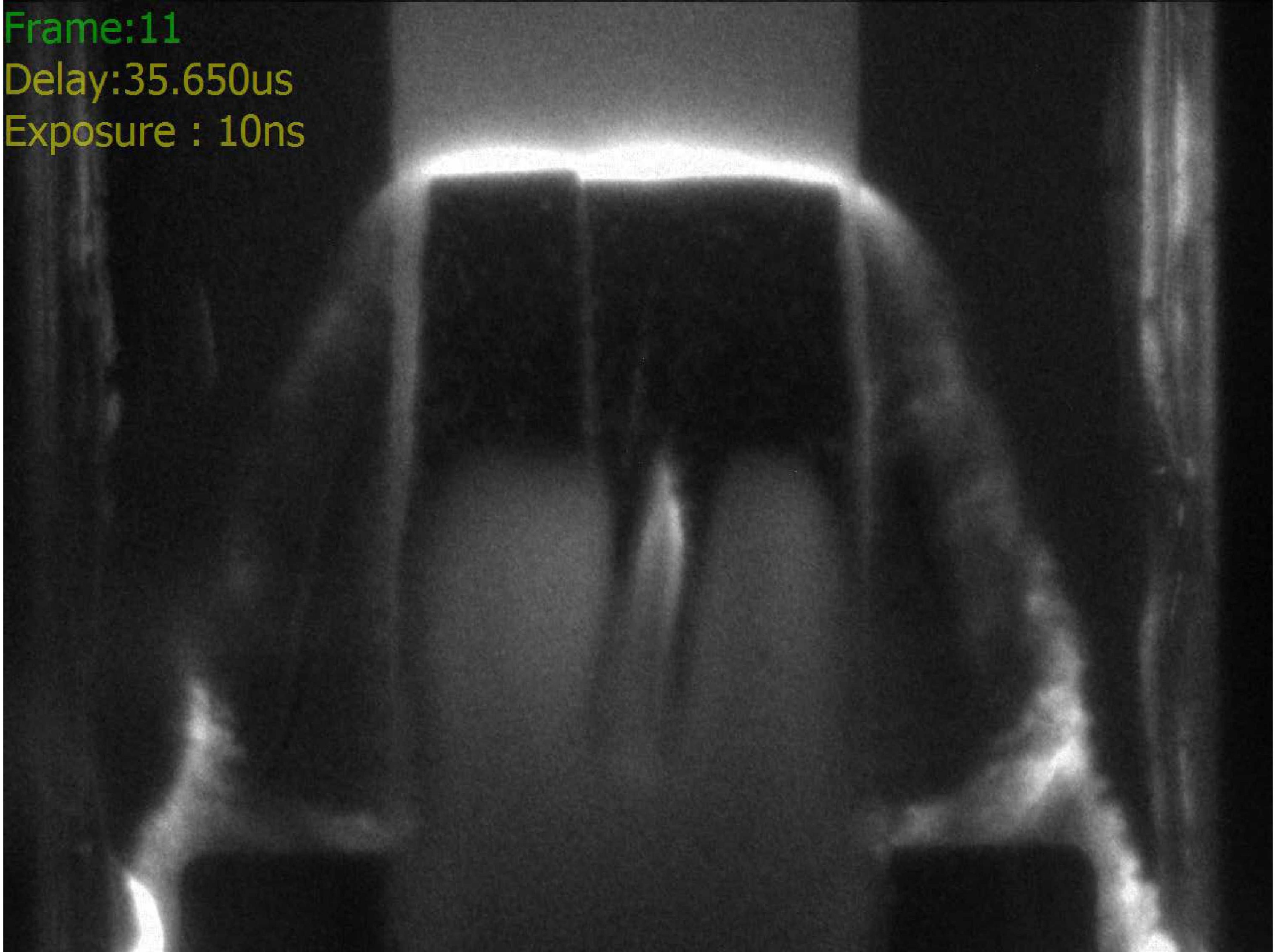
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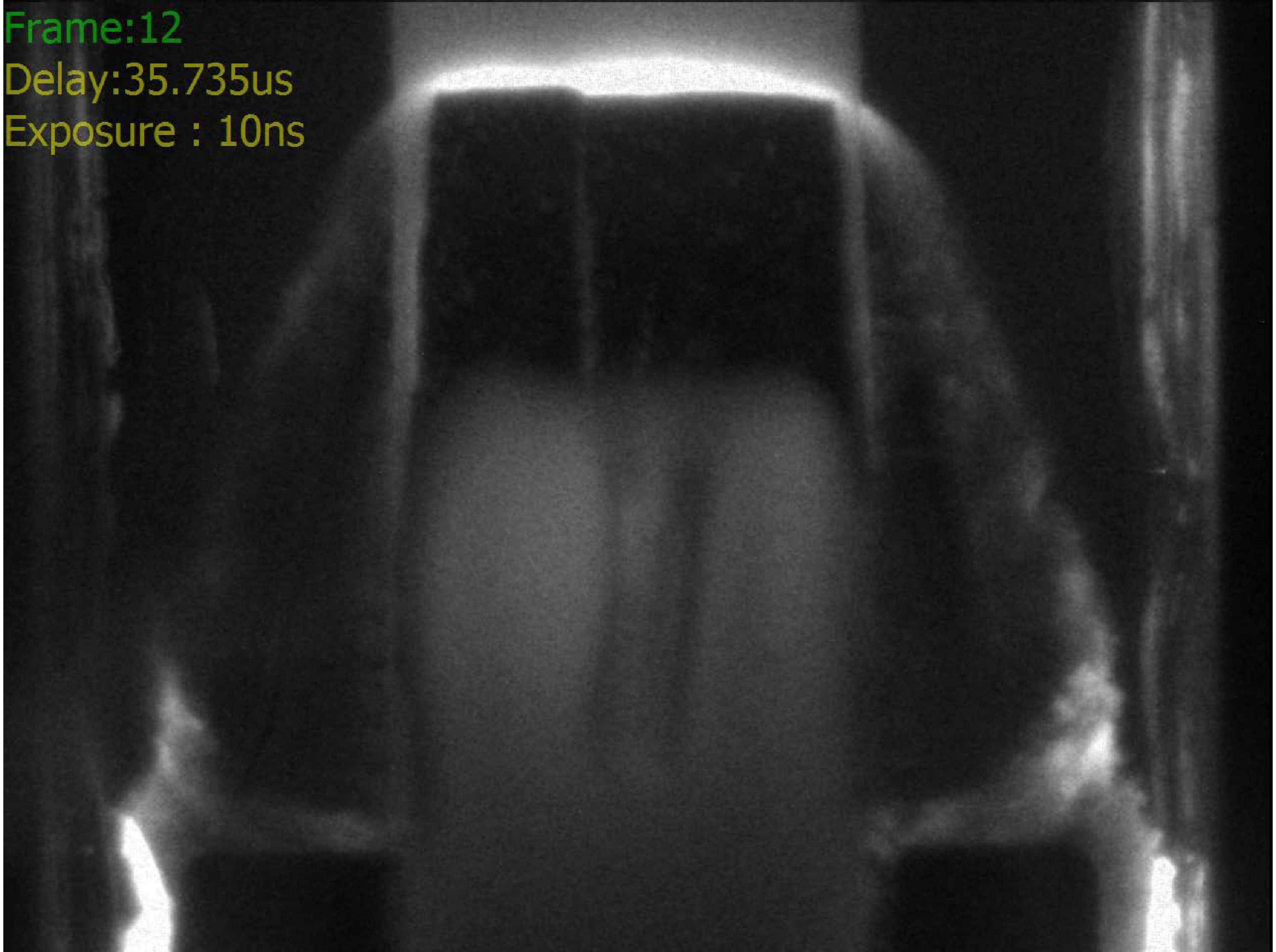
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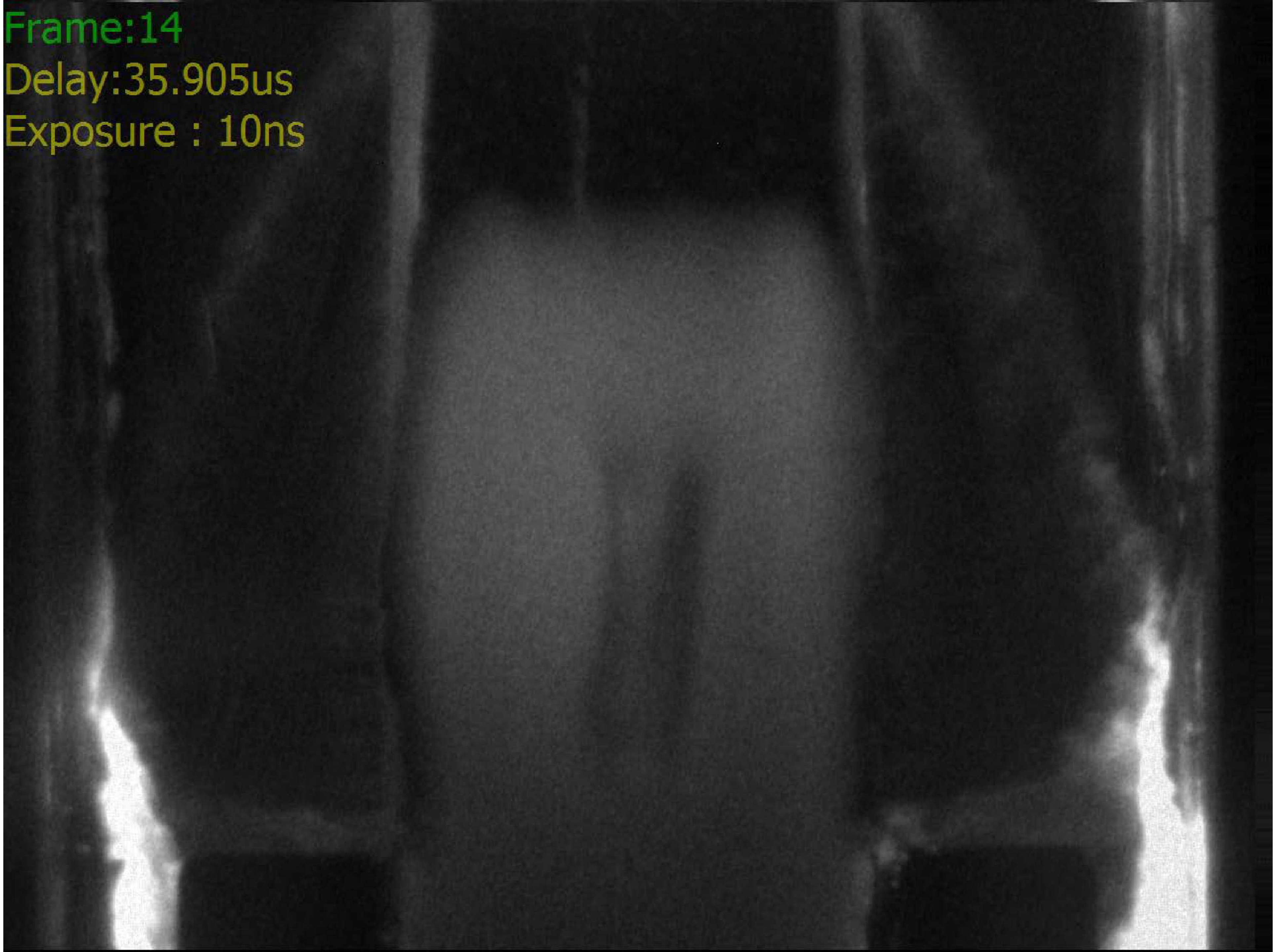
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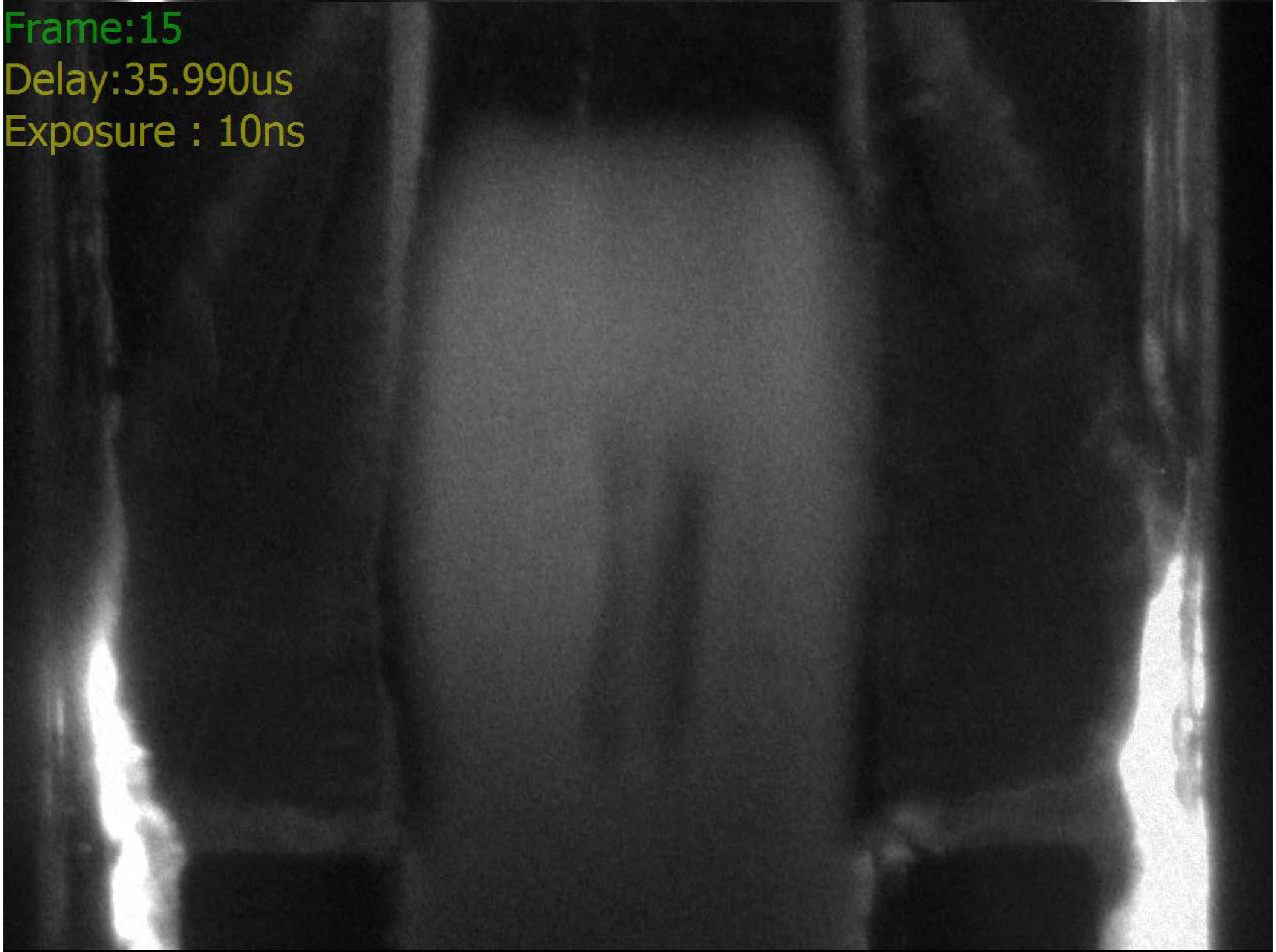
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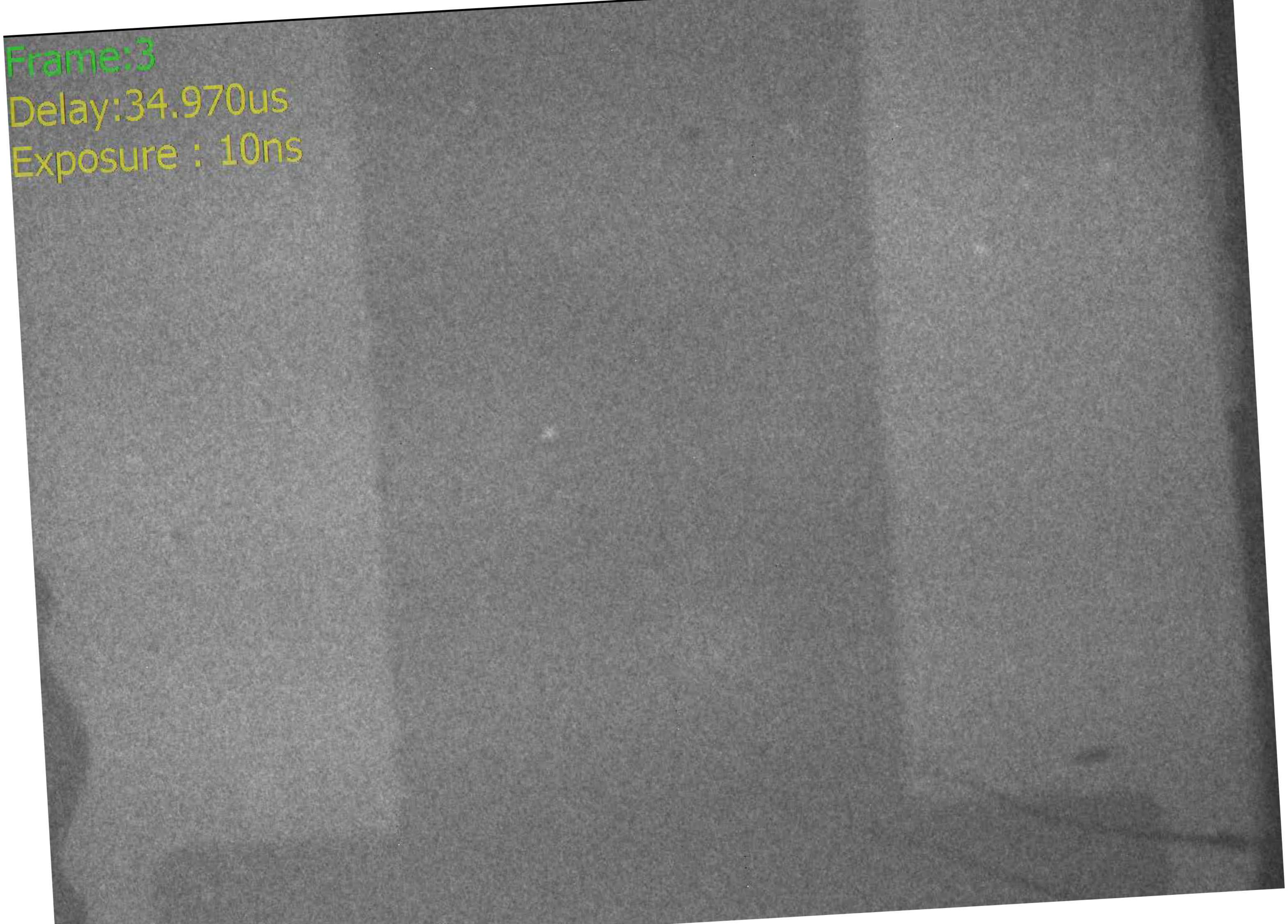
BNFF arrested thickness frames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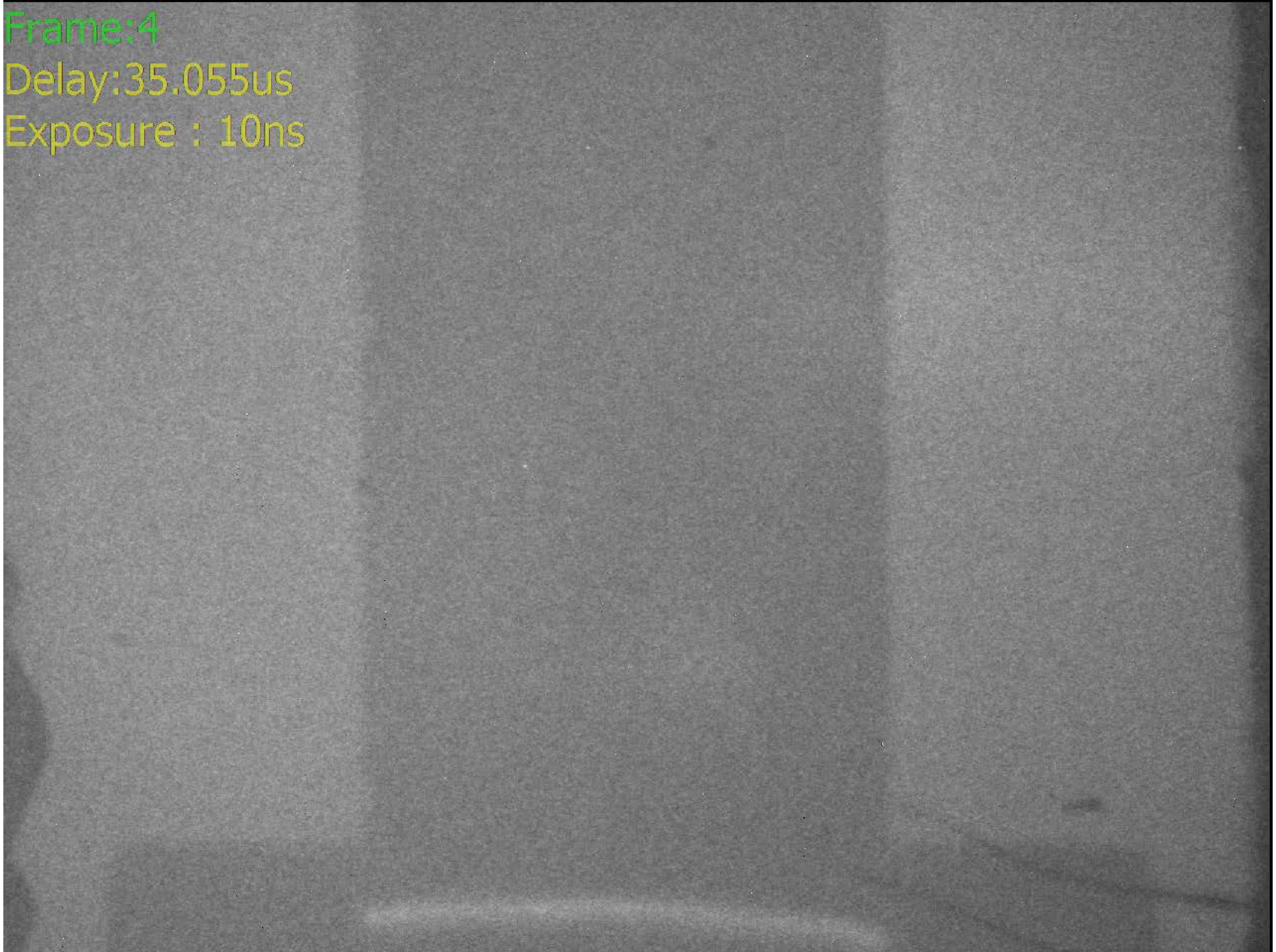
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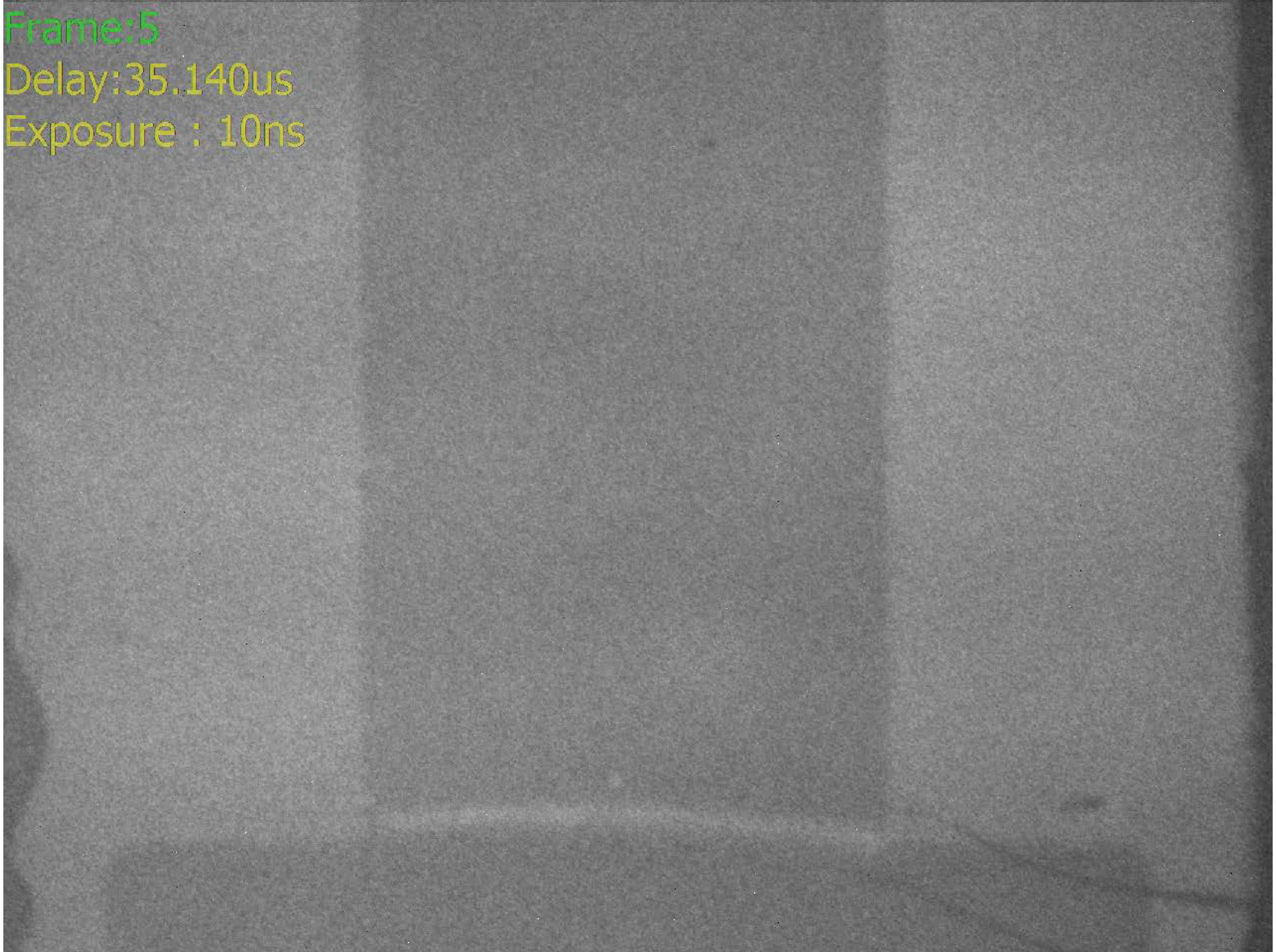
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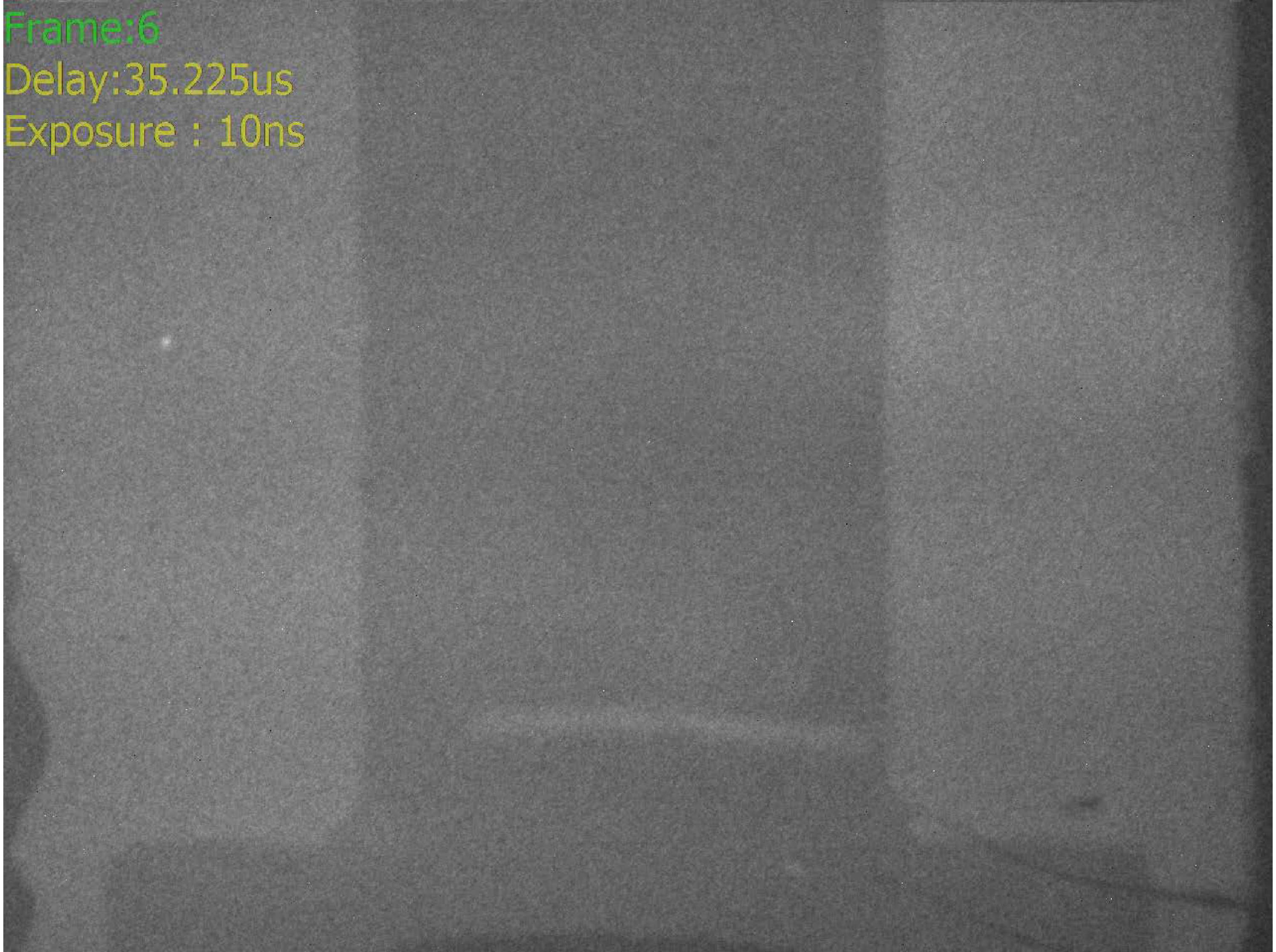
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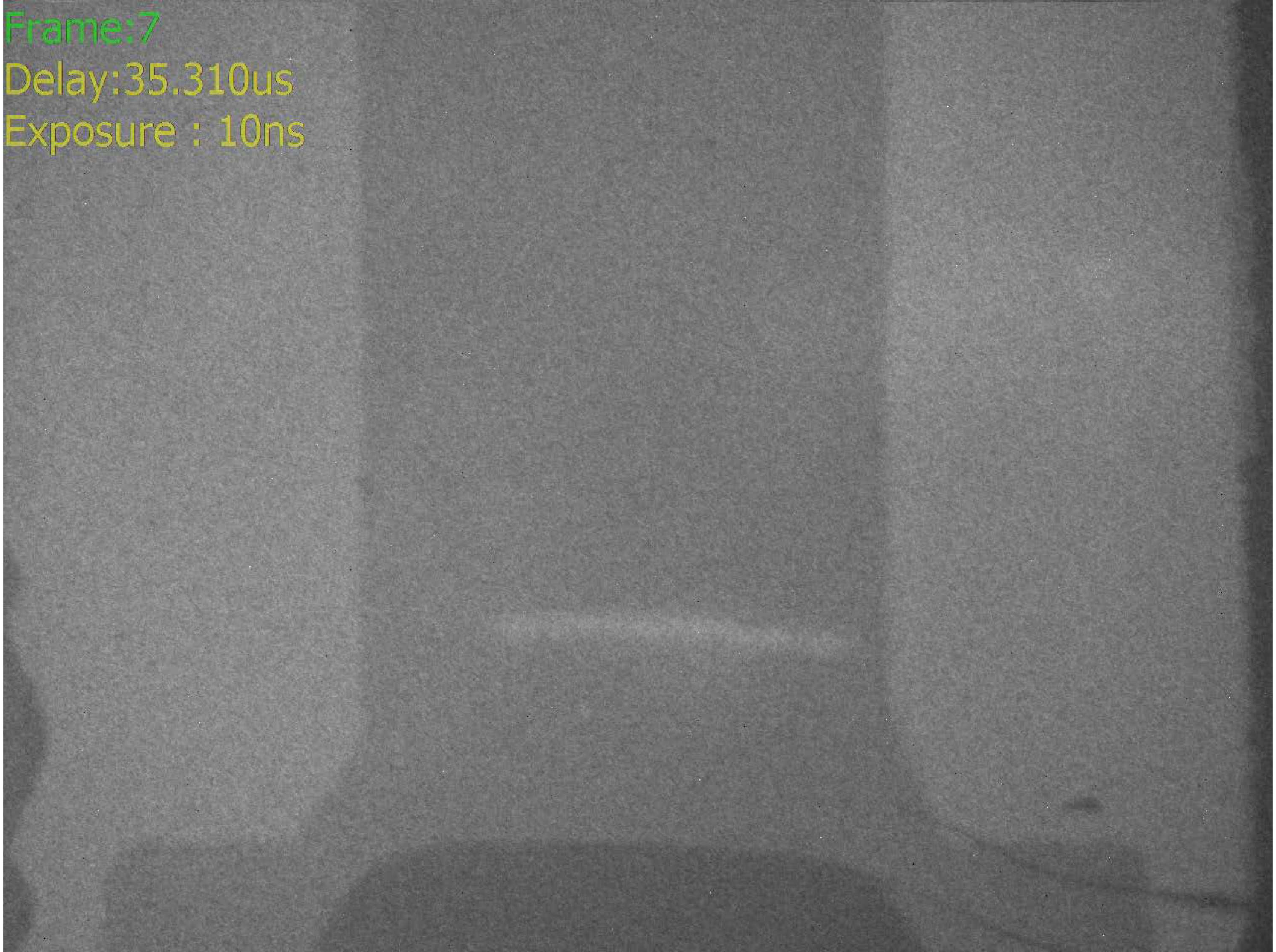
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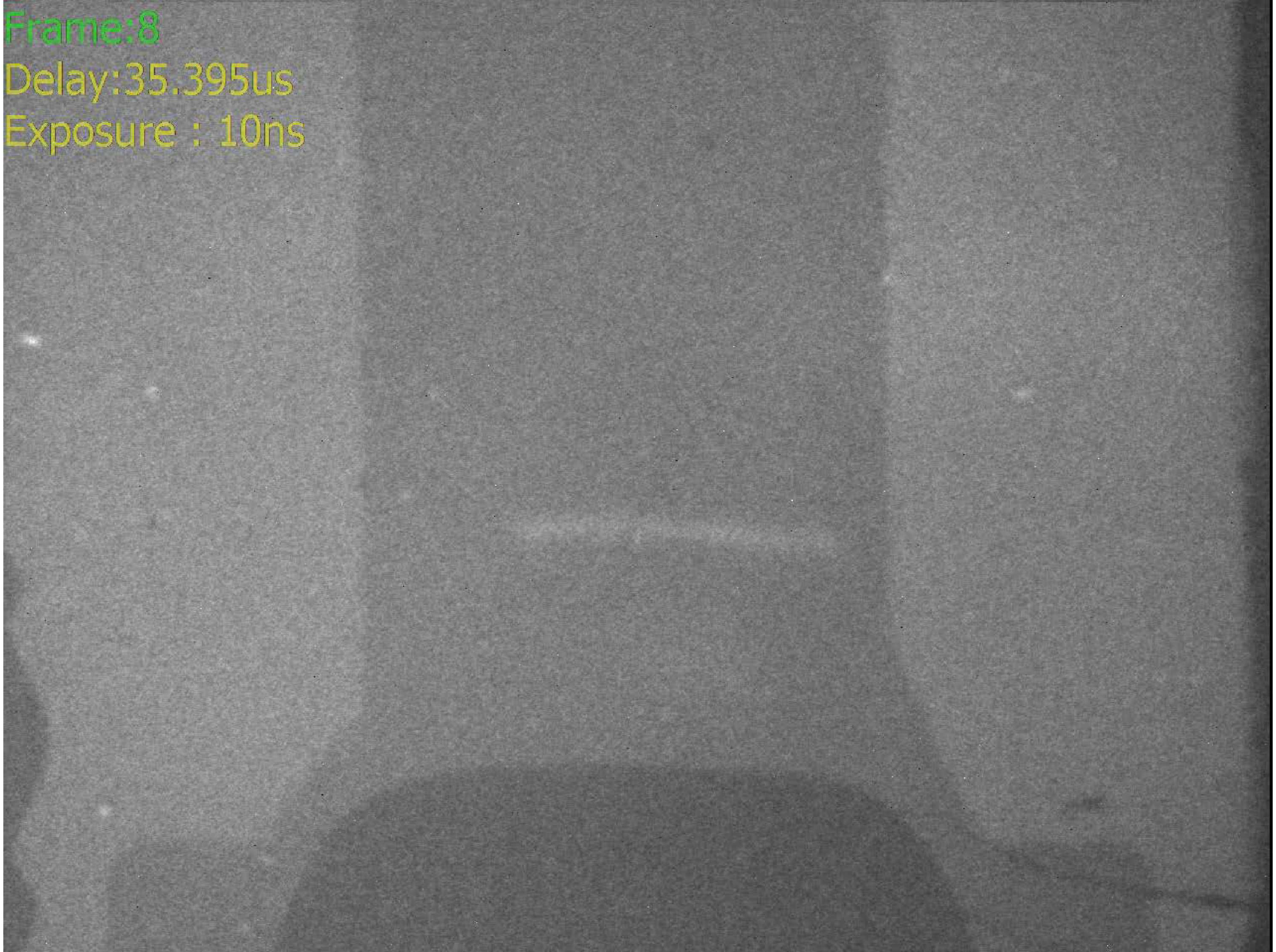
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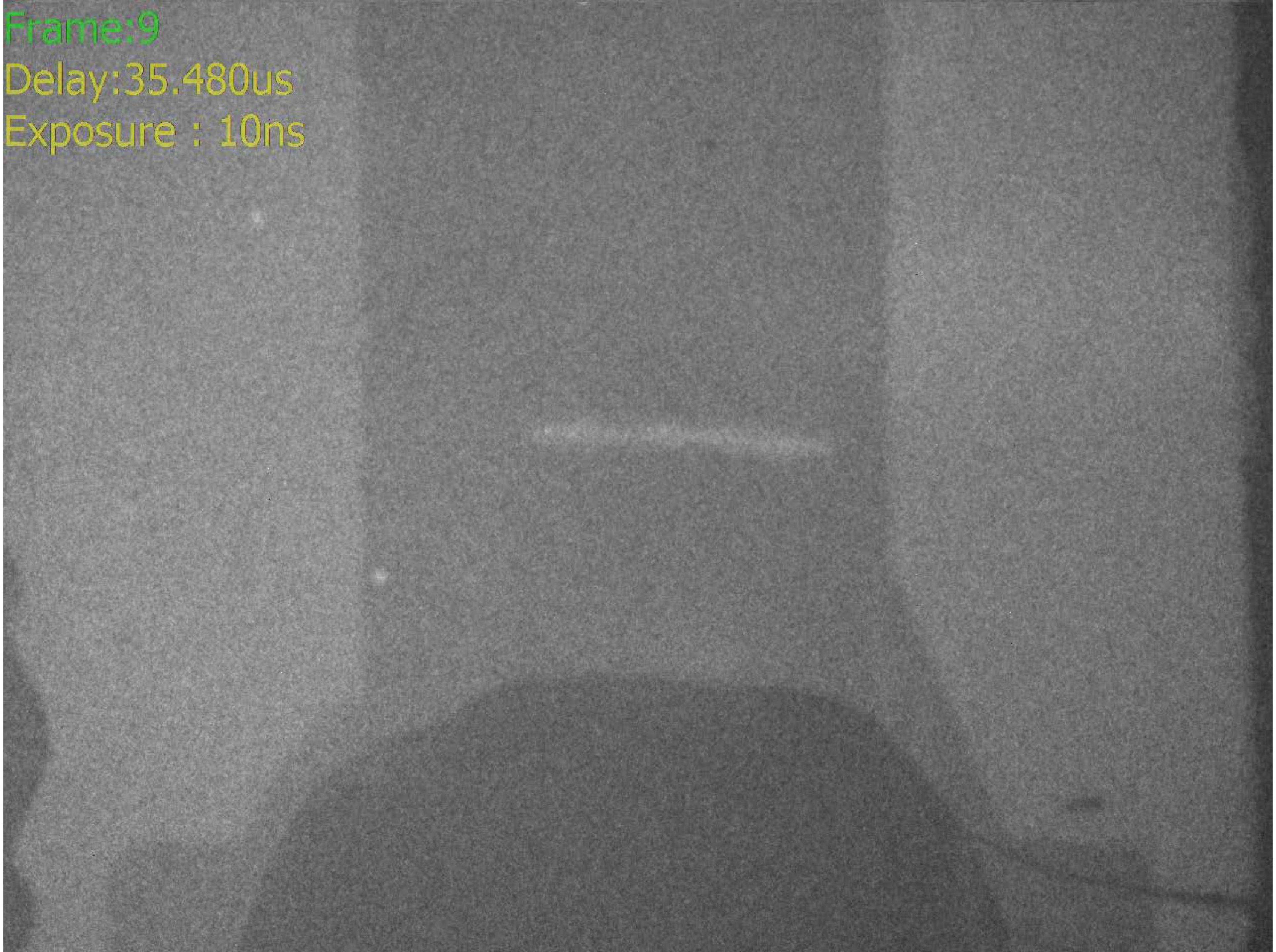
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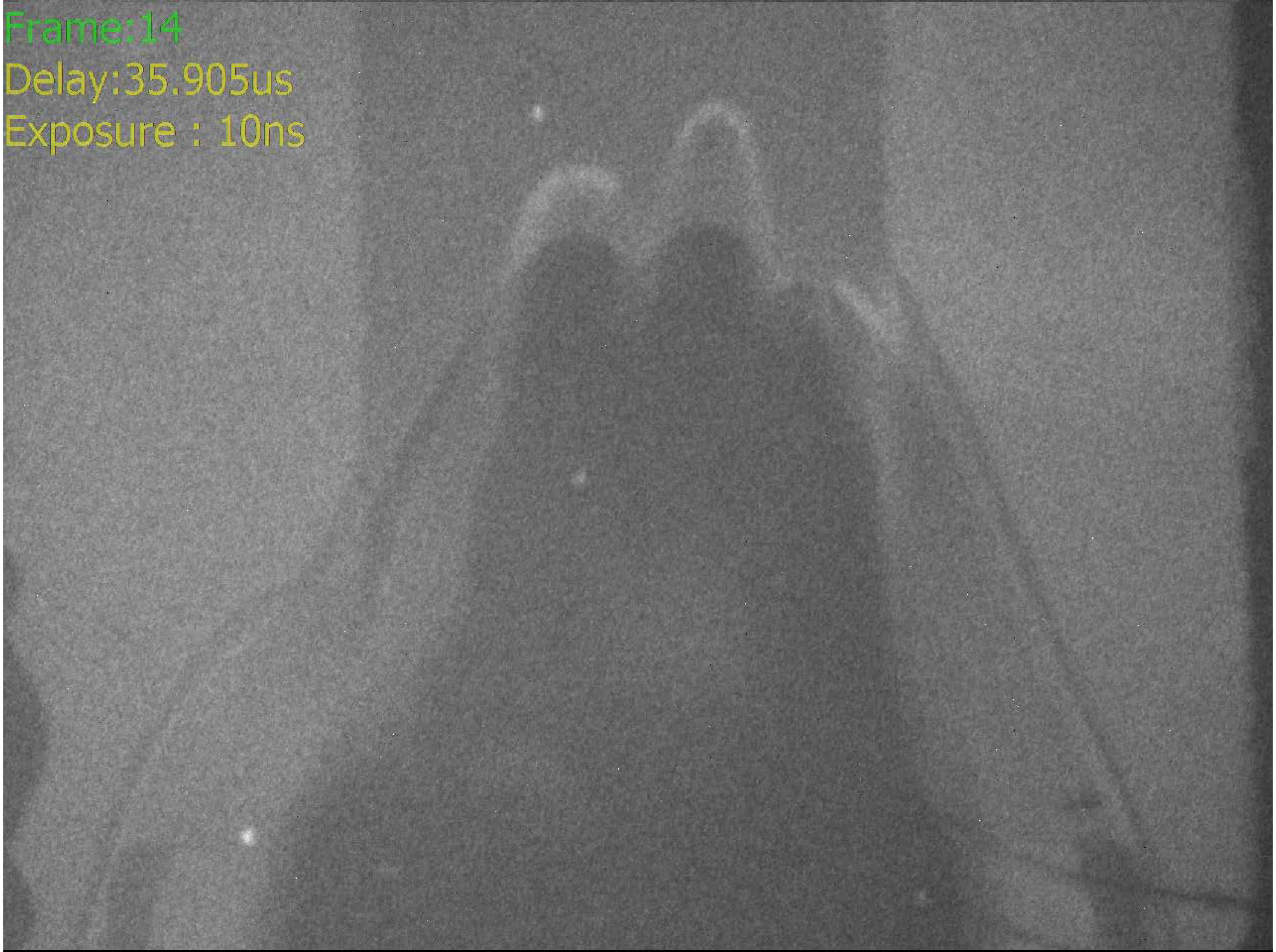
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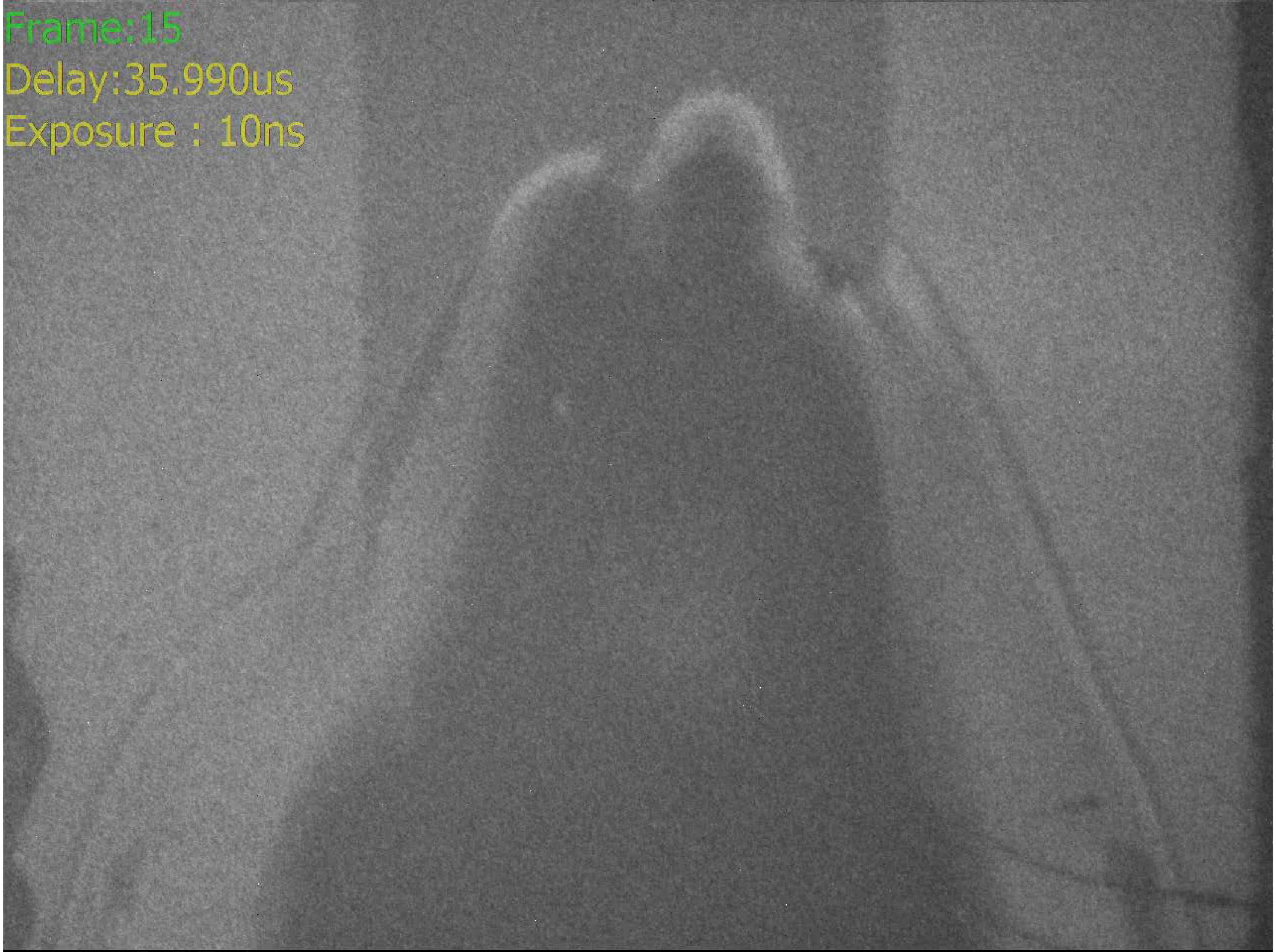
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