Fluid Dynamics in Resonant Acoustofluidic Atomizers

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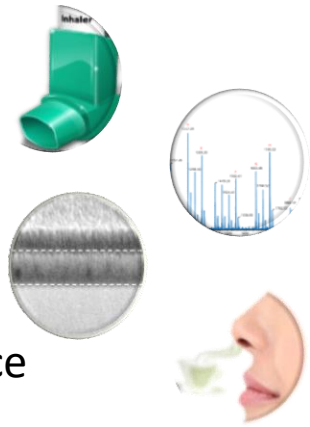
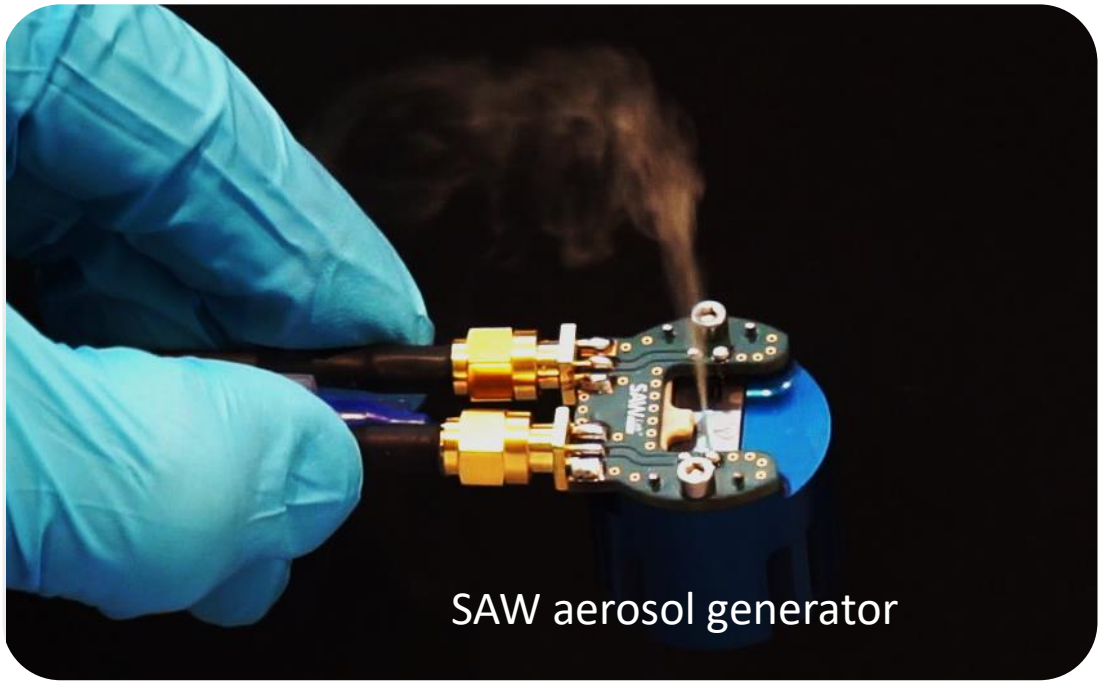
Introduction

- Adjustable droplet size range
- Broad liquid range
- Highly miniaturizable
- Low shear forces

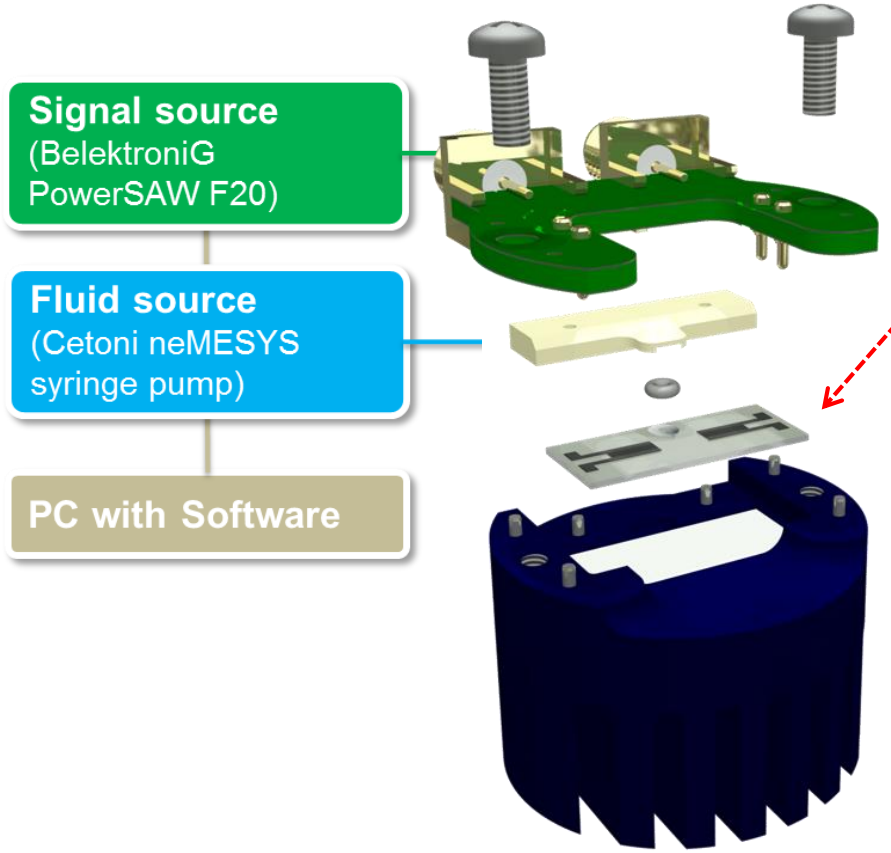
- Medical inhalators
- Mass spectrometry
- Thin film deposition
- Olfactory signal source



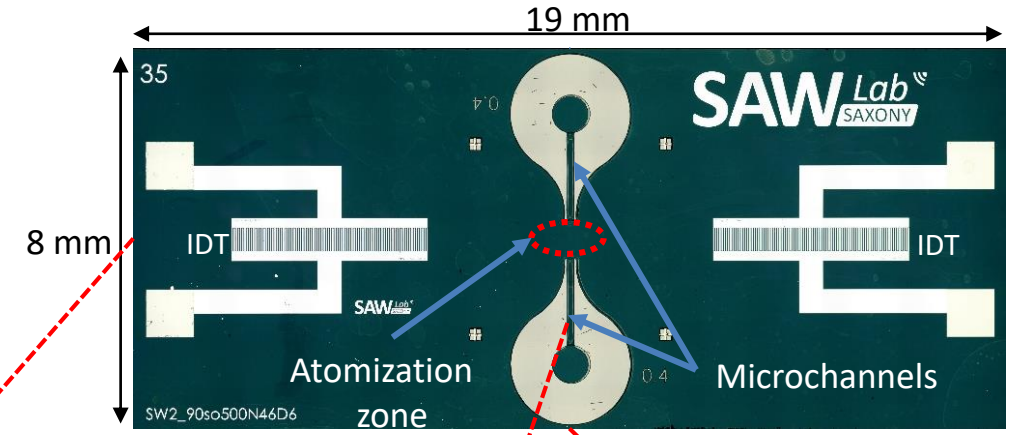


Introduction

sSAW aerosol generator

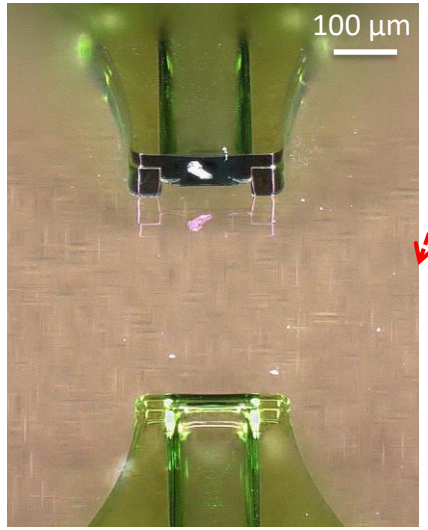


A schematic of sSAW atomizer

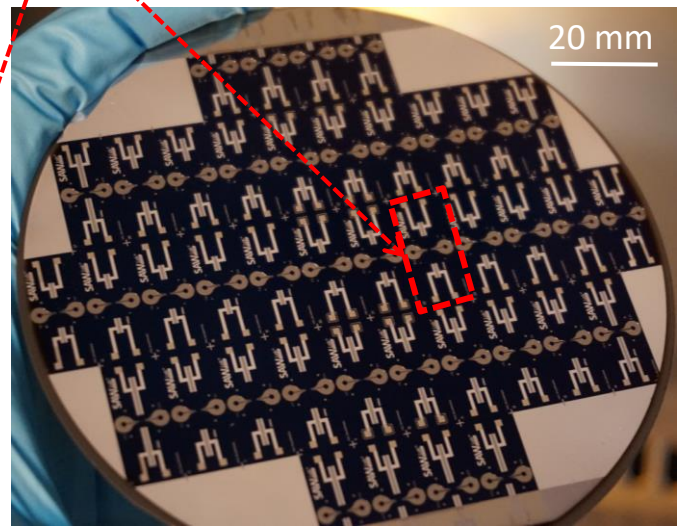


SAW atomization chip

f= 30-194 MHz



Microchannels

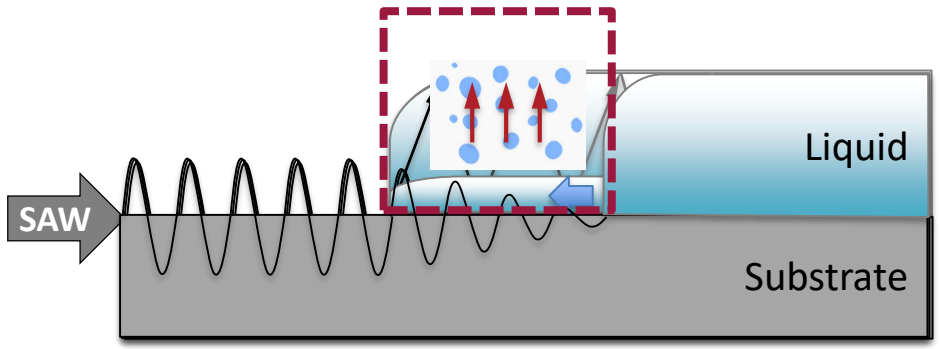


Chip Wafer

Fundamentals

Acoustowetting and SAW Atomization

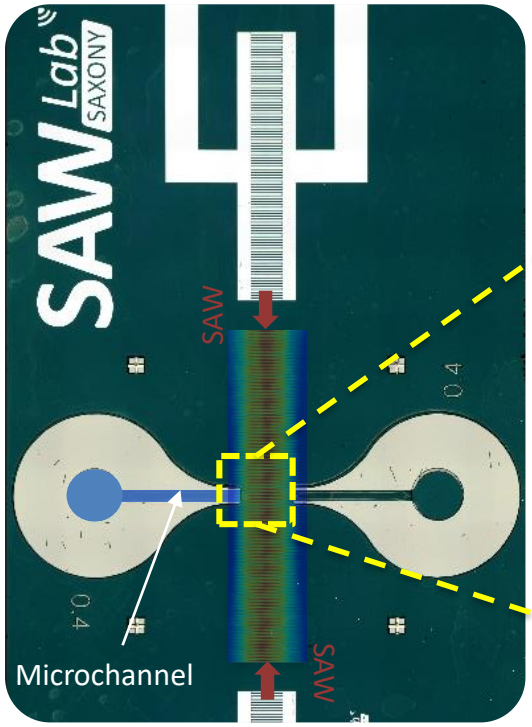
- SAW meets the leading edge of the liquid film
- SAW leaks energy in the liquid film under the Rayleigh-angle
- Excitation of longitudinal wave and reflection at the liquid/air interface
- Longitudinal wave resonance leads to acoustically stabilized liquid film which extends towards regions of higher SAW amplitude
- Aerosol droplets are generated off this film at sufficient SAW amplitude

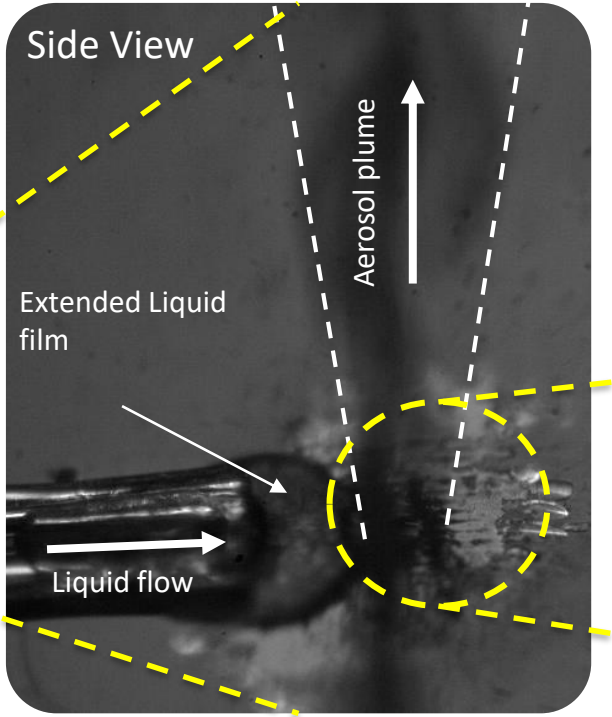


Results

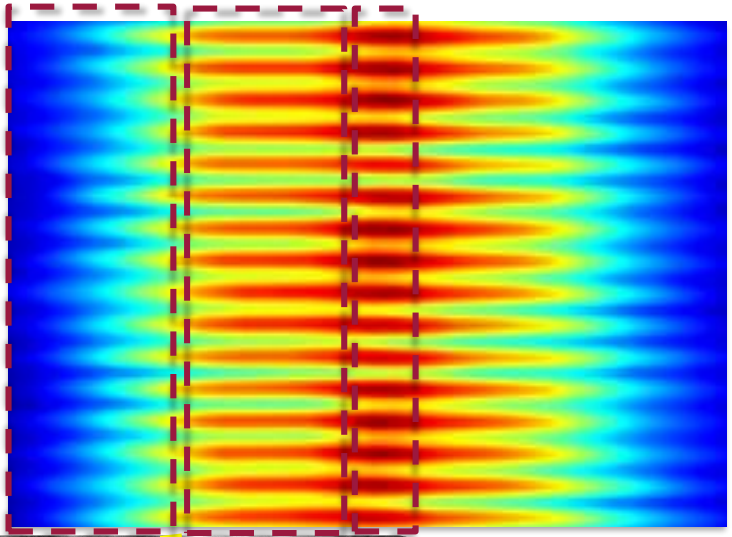
Atomization zone observation – Acoustofluidic effects

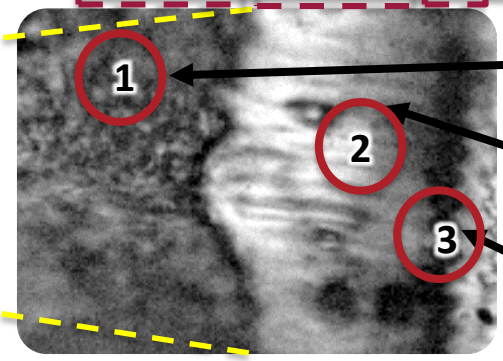
- **I:** Extended liquid film with chaotic surface fluctuation (streaming)
- **II:** Modulated thin film with oscillating droplet-shaped patterns
- **III:** Quasi stable liquid droplet-shaped patterns





SAW amplitude distribution in front of the microchannel outlet





Extended liquid film

Moving droplet-shaped patterns

Stable droplet-shaped patterns

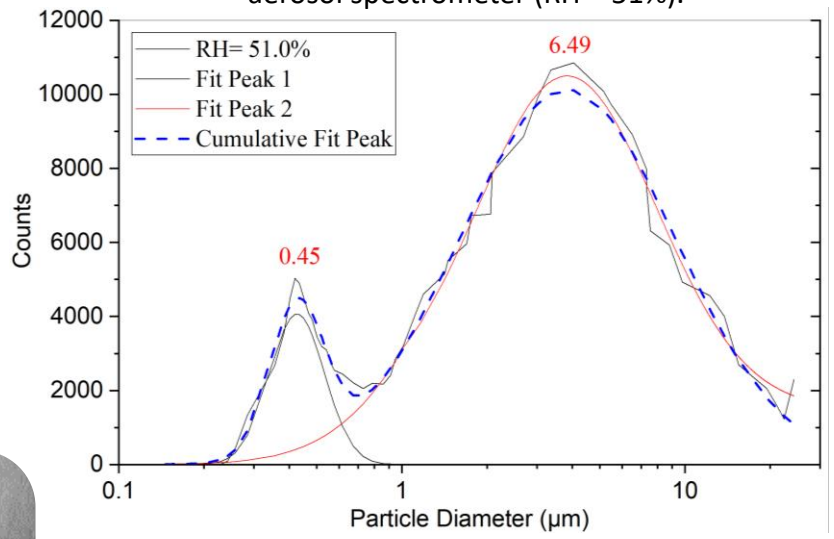
Roudini, M., Niedermeier, D., Stratmann, F. & Winkler, A. Droplet generation in standing-surface-acoustic-wave nebulization at controlled air humidity. *Phys. Rev. Appl.* **14**, 014071. https ://doi.org/10.1103/PhysR evApp lied.14.01407 1 (2020).

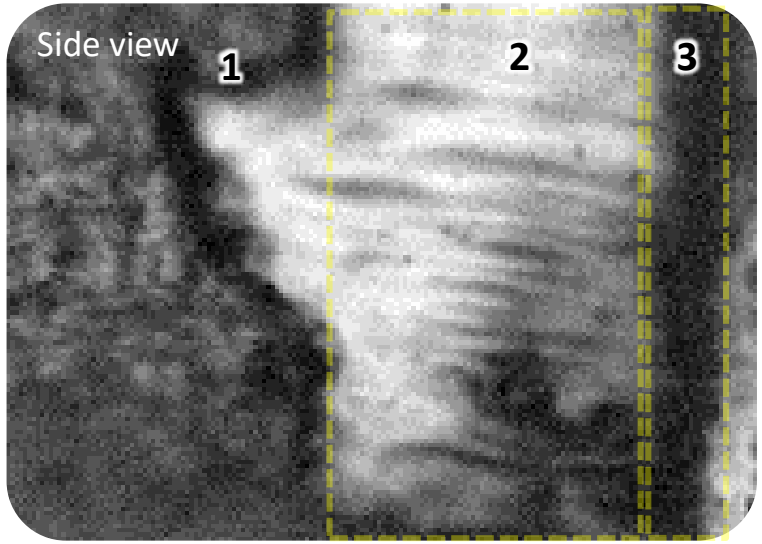
Results

Atomization zone observation – Droplet generation

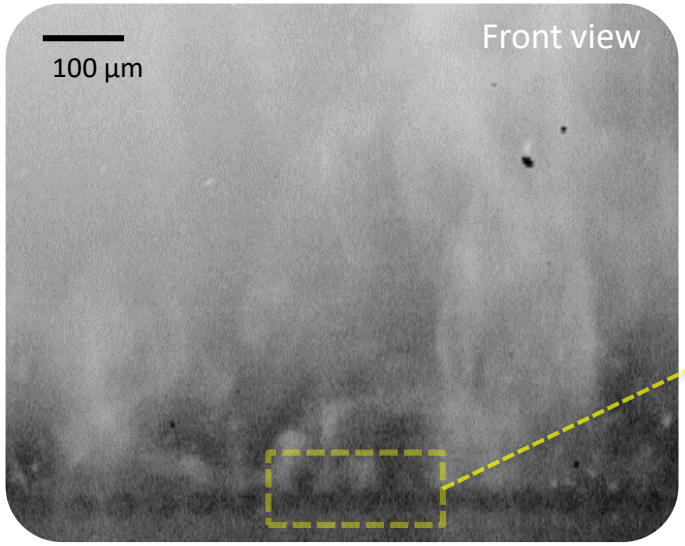
- The resultant droplets are originated entirely as aerosol sub plumes from observed individual droplet-shaped liquid patterns.
- The patterns are formed periodically at a distance of half of the SAW wavelength.

Droplet size distributions measured by aerosol spectrometer (RH = 51%).





Atomization zone – 10Kfps & exposure time 7 μs



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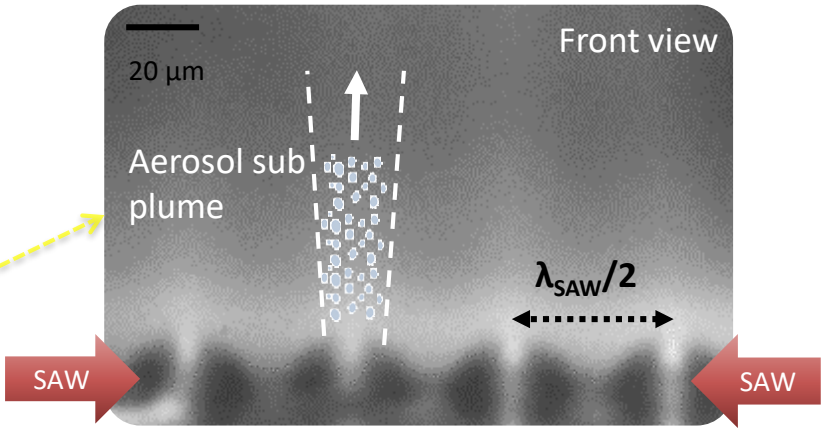
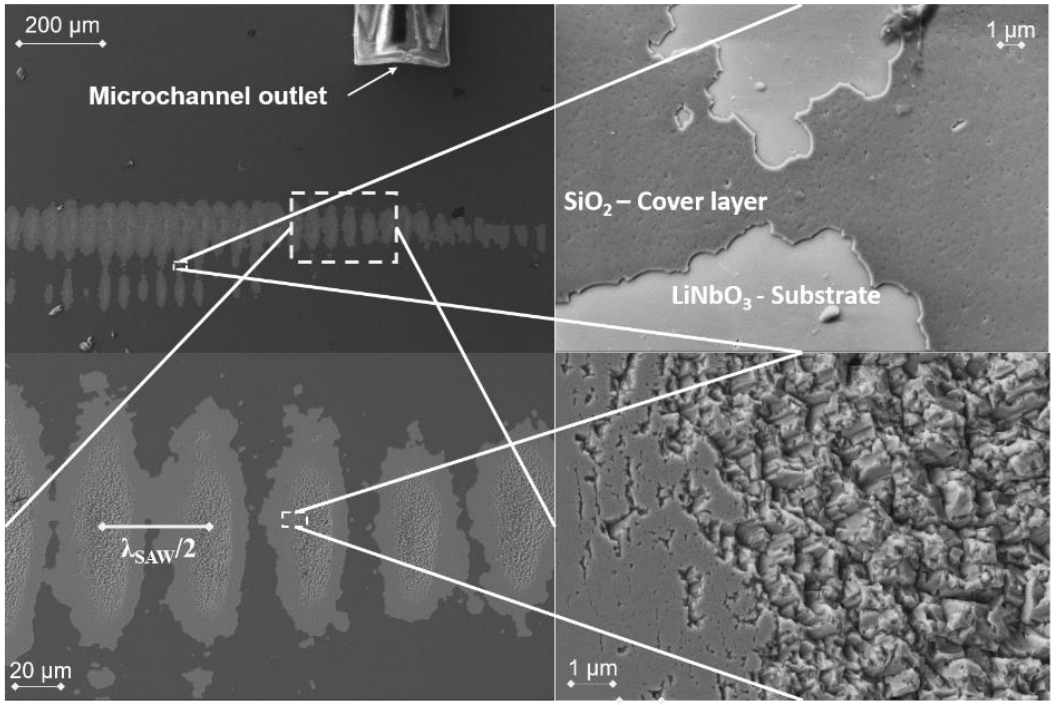


droplet-shaped liquid patters

Results

Atomization zone observation – Observed damage

- Observation of the substrate surface's yet unknown damage mechanism.
- The damages occur in the regions of high SAW amplitude with the overlying liquid film under droplet-shaped patterns.
- A possible explanation for the observed patterns of the damages provides the mechanism of cavitation erosion.



SEM image of typical damage pattern in the atomization zone after prolonged exposure to a standing SAW during the liquid atomization on the surface of a $LiNbO_3$ substrate.

Conclusions and Outlooks

- Different acoustofluidic effects in the atomization zone.
- Observation of the local origins of the resultant droplets in the atomization zone.
- Observation of yet unknown damage mechanism on the substrate surface with possible explanation providing the means of cavitation erosion.

➢ Understanding the complex acousto-hydrodynamics associated with interactions of sSAW with a liquid film and the droplet breakup mechanisms from developed liquid patterns.

➢ Proving the existence of acoustic cavitation as the possible source of observed damages.

THANK YOU

ANY QUESTIONS

Our research interests:

- Substrate surface modification and functional film design combined with unconventional lithography techniques for next-generation acoustic microsystems.
- Interaction of acoustic wave fields with fluids, particles, and microstructures.
- Cointegration of microfluidic, electric, and acoustic components in hybrid Lab-on-a-Chip devices.
- Emerging micro acoustic applications, including acoustically-driven microfluidics for new diagnostic and therapeutic approaches, aerosol generation, and (bio-)printing.

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