SPIE. PHOTOMASK TECHNOLOGY

Acoustic Characterization of Two Megasonic Devices for Photomask Cleaning

Claudio Zanelli[(1)†], Dushyanth Giridhar[(1)], Manish Keswani[(2)], Nagaya Okada[(3)], Jyhwei Hsu[(4)], Petrie Yam[(1)]

[(1)]Onda Corporation, [(2)]University of Arizona, [(3)]Honda Electronics, [(4)]Suss MicroTec

[†] Correspondence: et@ondacorp.com

INTRODUCTION

Wet photomask cleaning relies on megasonic agitation to enhance the process, but there are many challenges to reliably control performance in terms of particle removal efficiency (PRE) and damage. Typically all that is specified about the acoustic output is the driving frequency and the electric power delivered to a transducer. Although there are several studies on particle removal and pattern damage at 1 MHz, there is very little known about the cavitation performance at higher frequencies such as 2-4 MHz. Two transducer configurations are acoustically evaluated here to better understand how the acoustic waves interact with the substrate which is the basis to optimizing cleaning performance.

METHODS

Transducers

3 MHz Nozzle

(Honda: W-357-3MP)

3 MHz Cone

(Honda: W-357-3MQB-SKC)

Sensors

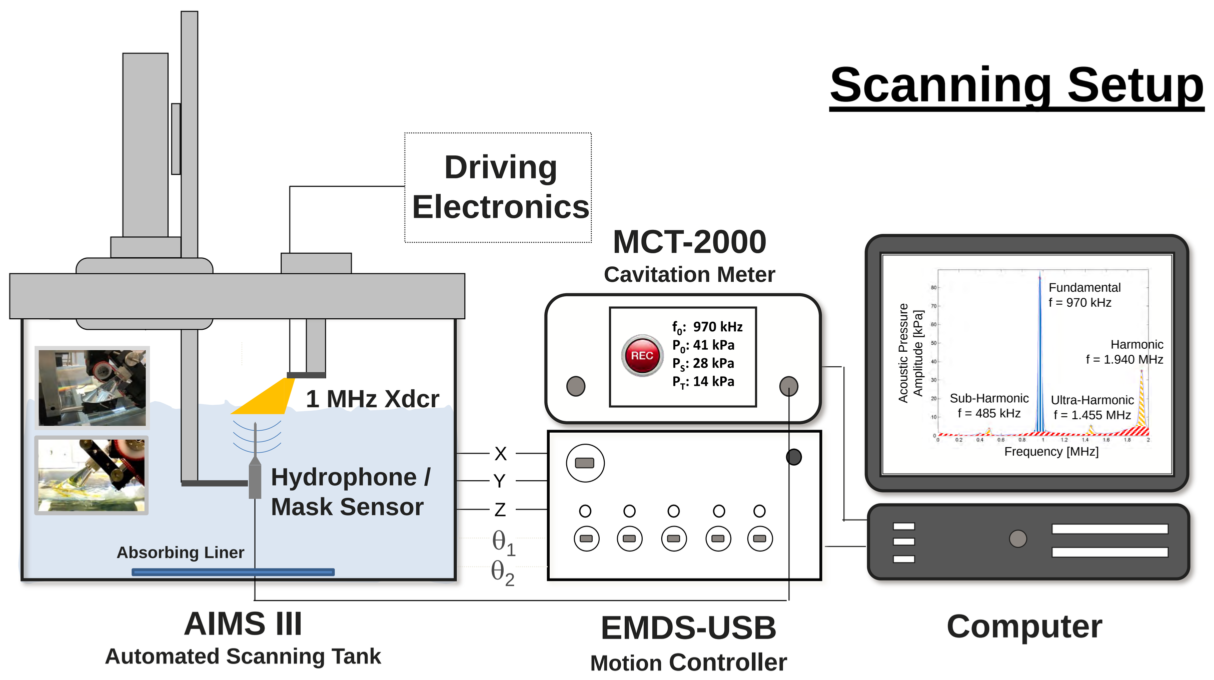
Needle Hydrophone

(Onda: HNA-0400)

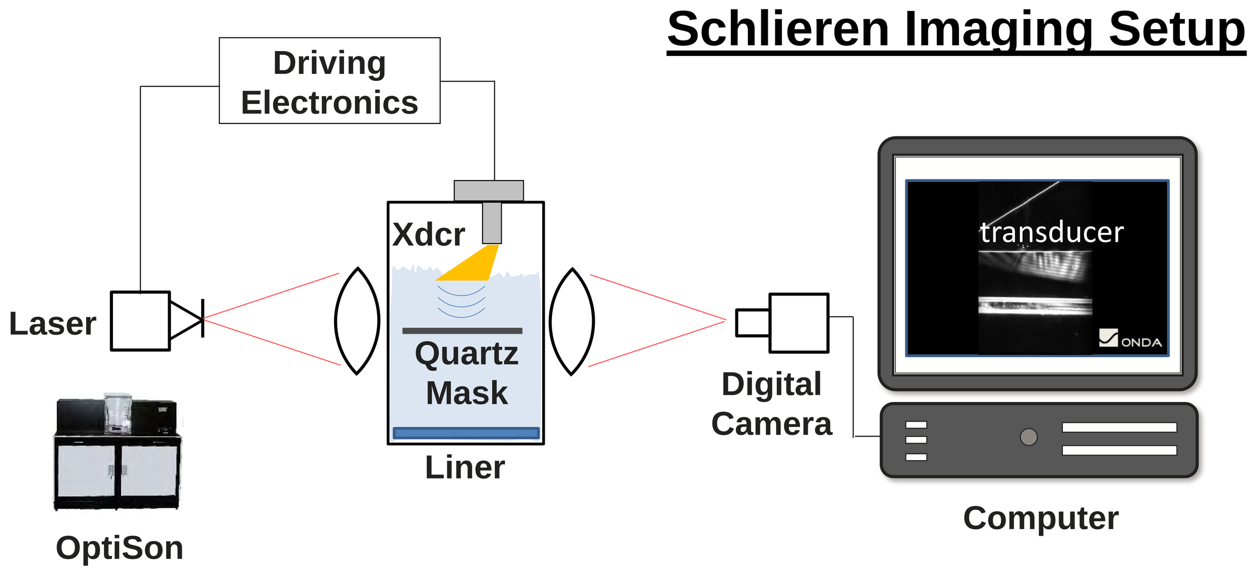
Mask Sensor Array

(Onda)

Scanning Setup

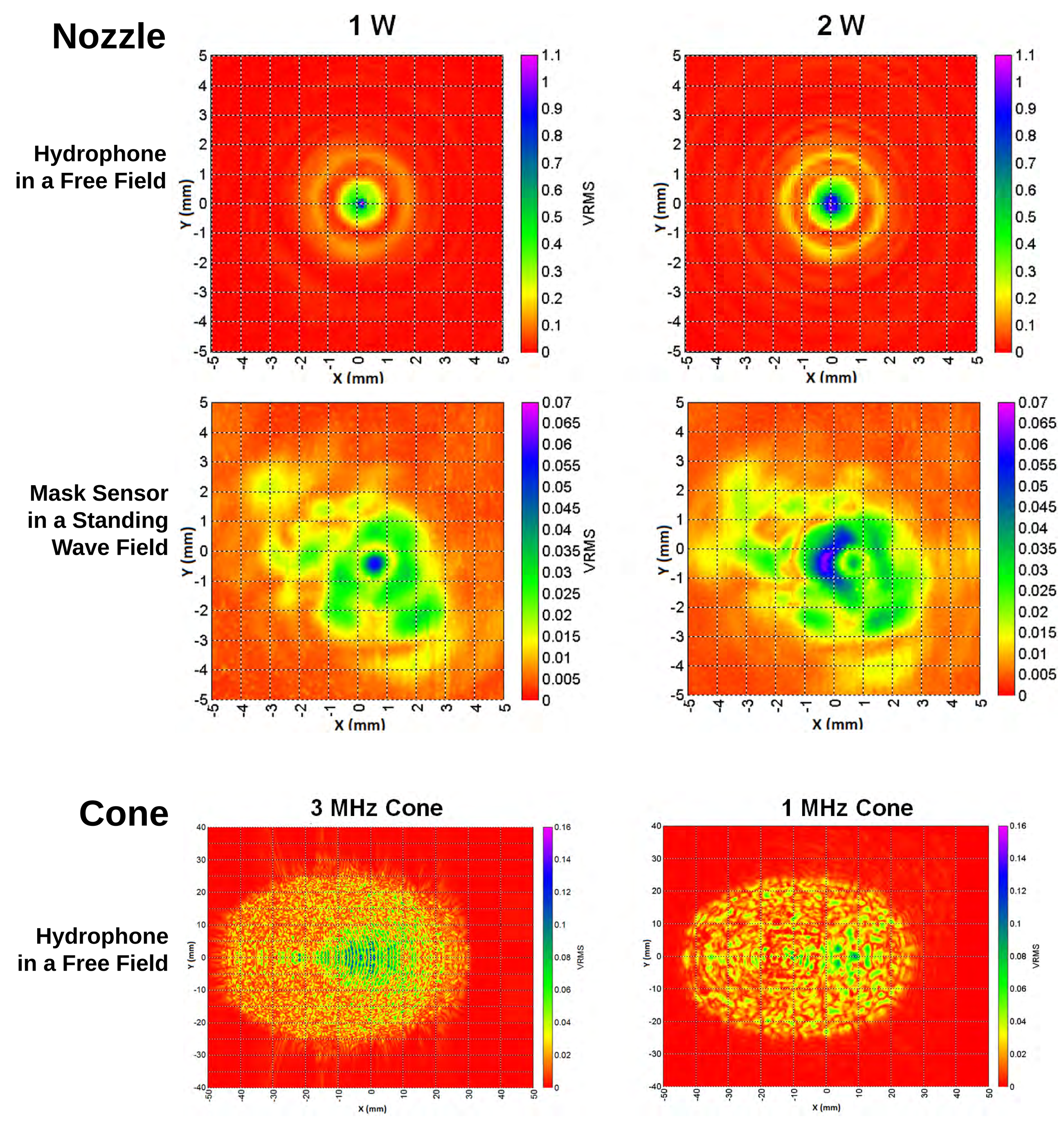


Schlieren Imaging Setup



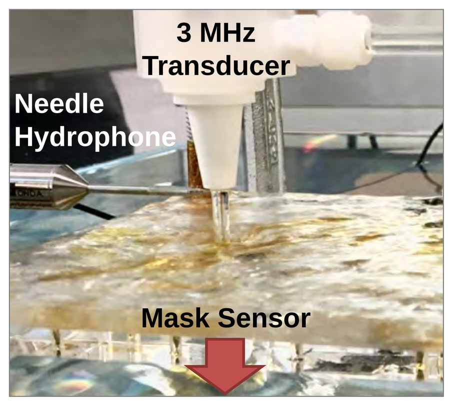
RESULTS & DISCUSSION

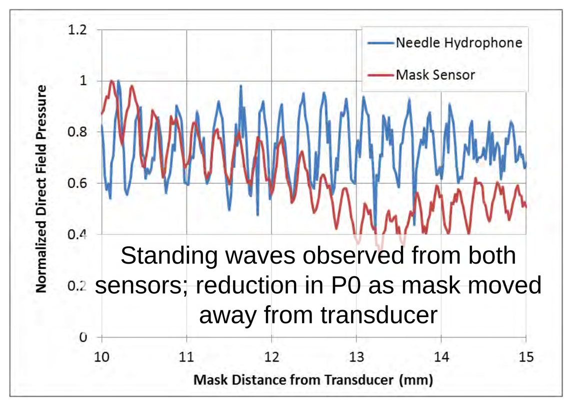
2D Sound Pressure Fields



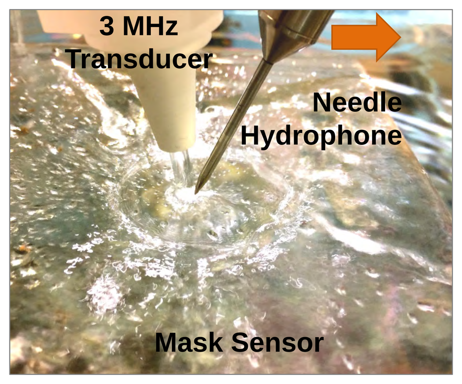
Nozzle: Pressure vs. Position from Transducer

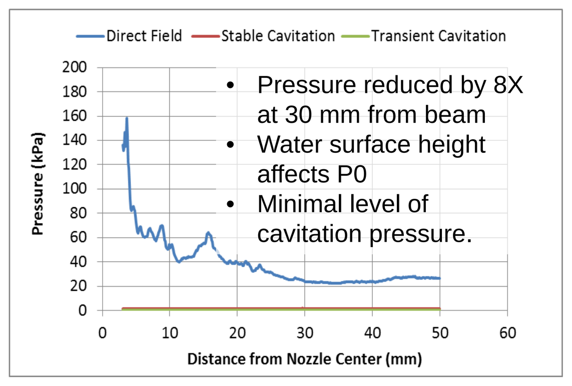
Mask Scanning Away from Transducer





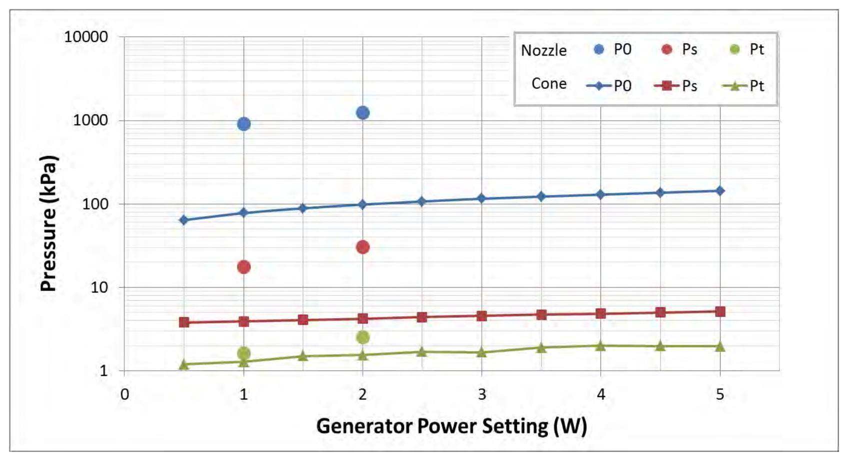
Hydrophone Scanning Along Mask Surface





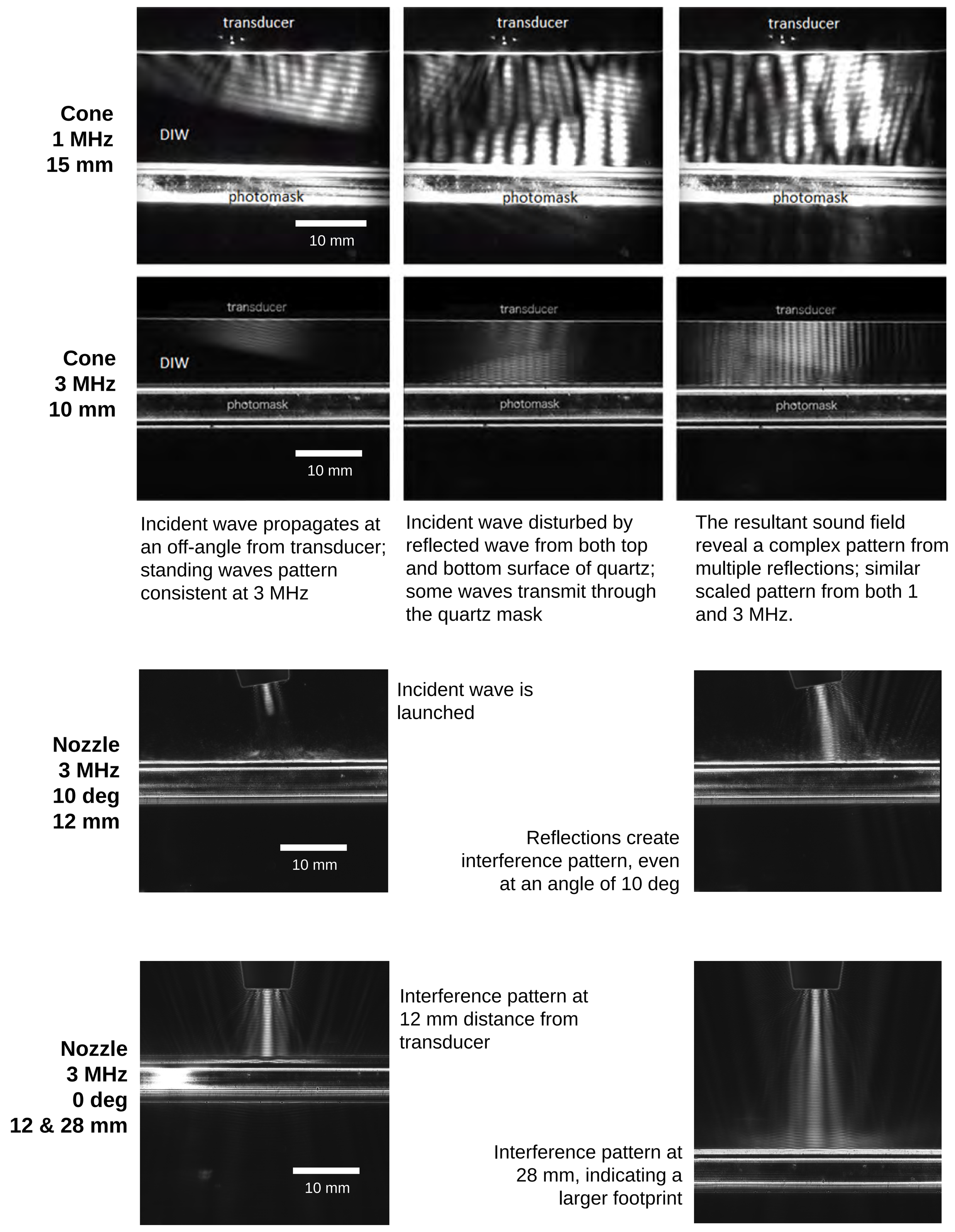
Nozzle & Cone: Varying Generator Power

Acoustic Pressure vs. Generator Power



- Direct field pressure is ≥ 10X higher than cavitation pressure for both nozzle and cone
- 3 MHz nozzle yields ~3X higher stable cavitation pressure than 3 MHz cone at generator powers of 1 and 2 W
- Low levels of transient cavitation pressure under all conditions

Schlieren Imaging (Videos: HERE)



CONCLUSIONS

Although the frequency and generator power settings are equivalent, the acoustic performance of the nozzle and cone transducers is significantly different. Clearly frequency and electrical power alone are not the only determinants of acoustic performance and the subsequent cleaning activity.

For the same input power, the direct field pressure output from the nozzle transducer is approximately 10 times greater than that from the cone transducer, certainly because of its smaller footprint. It is also observed that in both designs the pressure from cavitation is about two orders of magnitude lower than the direct pressures.

So, what physical mechanism from each megasonic transducer is cleaning? The results presented here indicate a significantly higher level of direct field pressure than stable and transient cavitation pressure. However, the test conditions may not fully represent actual cleaning processes leaving this still an open question.

Schlieren imaging highlights the complex behavior of the sound waves propagating between the mask, transducer, and water surface. For instance, it shows the nozzle transducer jet angle affects the interference pattern. Imaging the cone transducer indicates that the incident wave propagates at an offset angle from transducer. The resultant sound field reveals a complex pattern from multiple reflections, yielding a “scrubbing” mechanism at both 1 and 3 MHz.