Quantifying Acoustic Intermodulation Distortion from a Dual-Frequency (3+5 MHz) Megasonic Cleaning System

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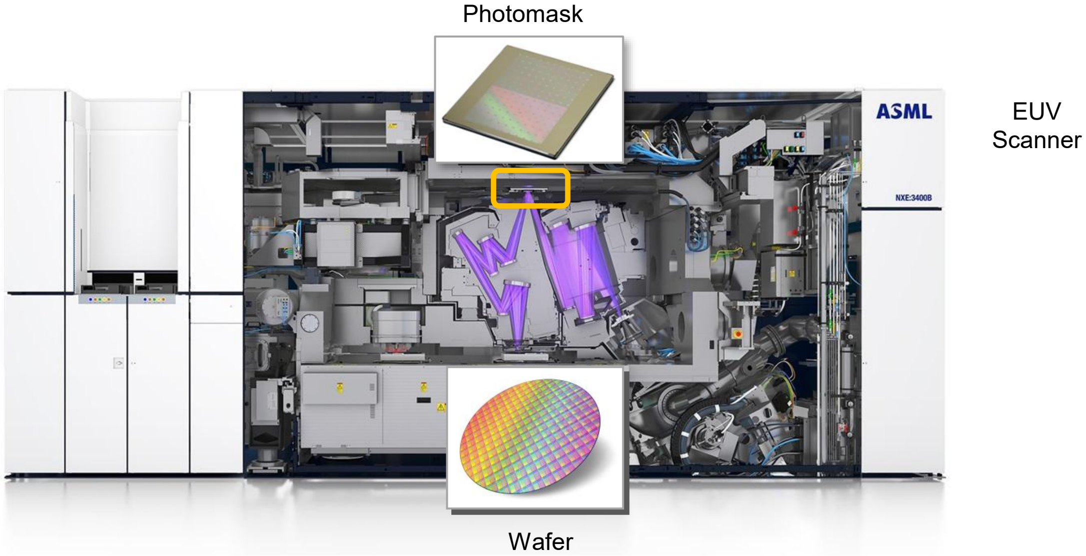
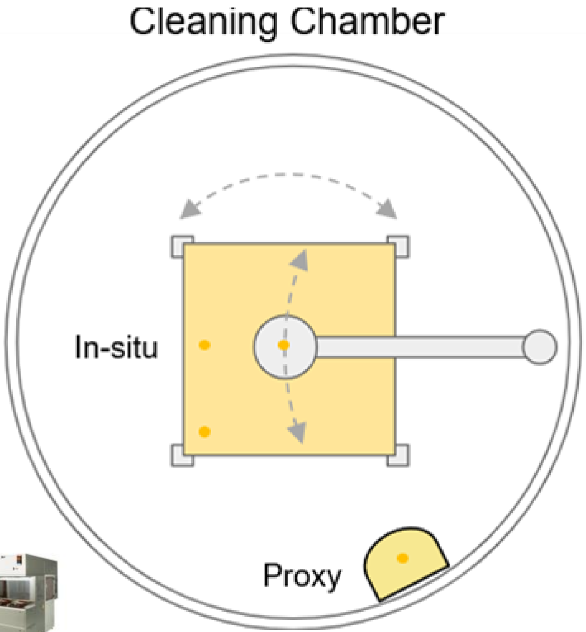
SPIE BACUS Monterey, CA

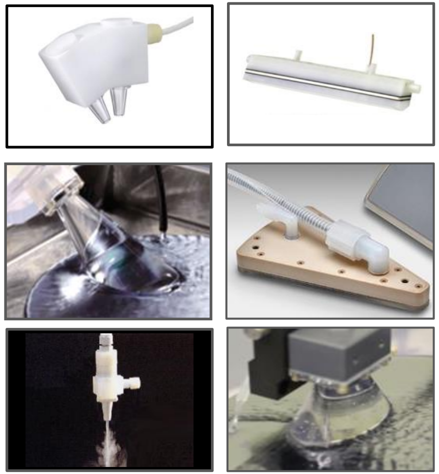
Advanced Photolithography



Advanced mask cleaning processes (193i and EUV) demand <u>zero-defects</u>

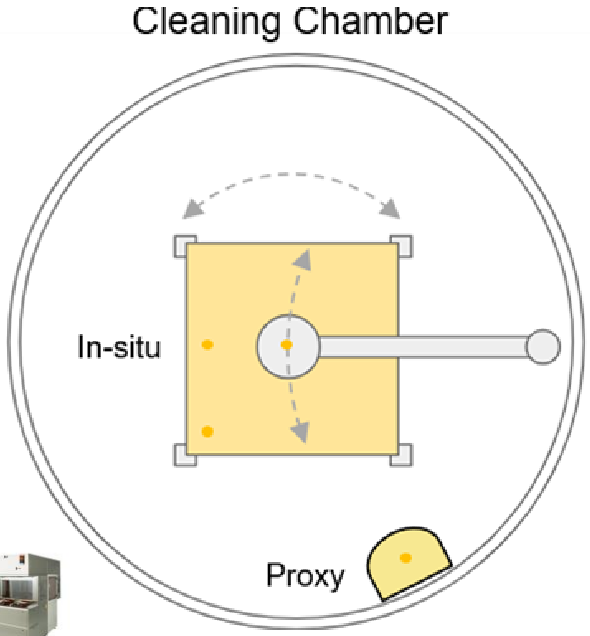
Photomask Cleaning Systems

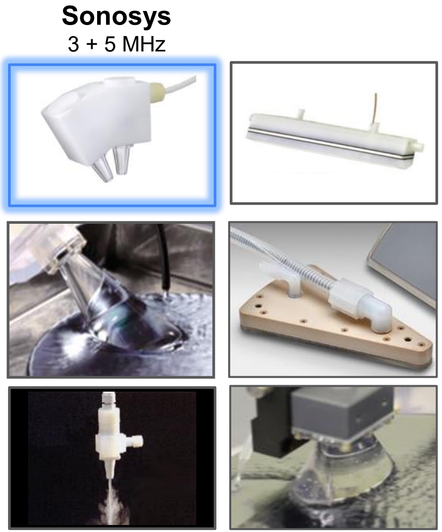




Transducers apply "Megasonic" pressure to mask surface to remove particles

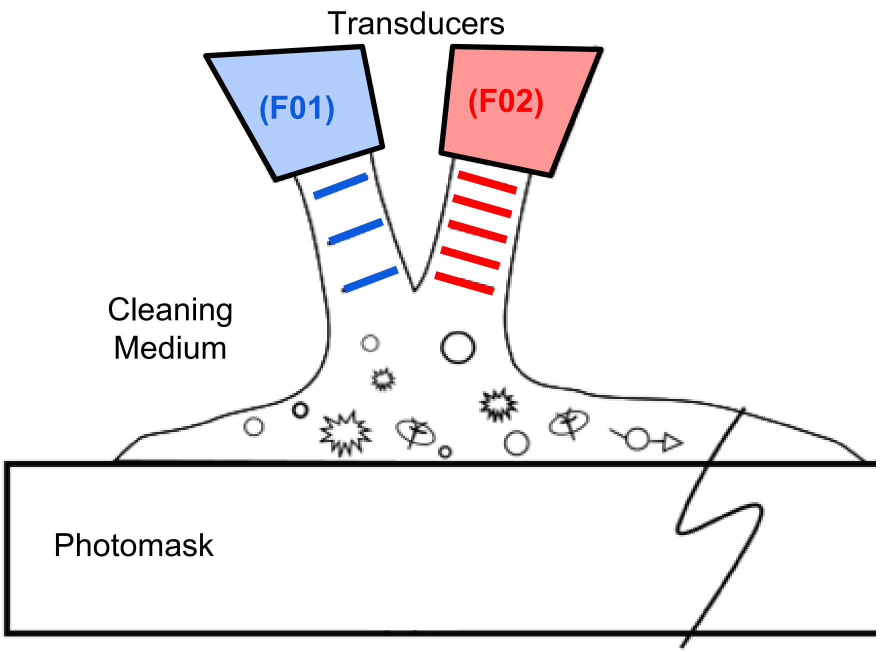
Photomask Cleaning Systems

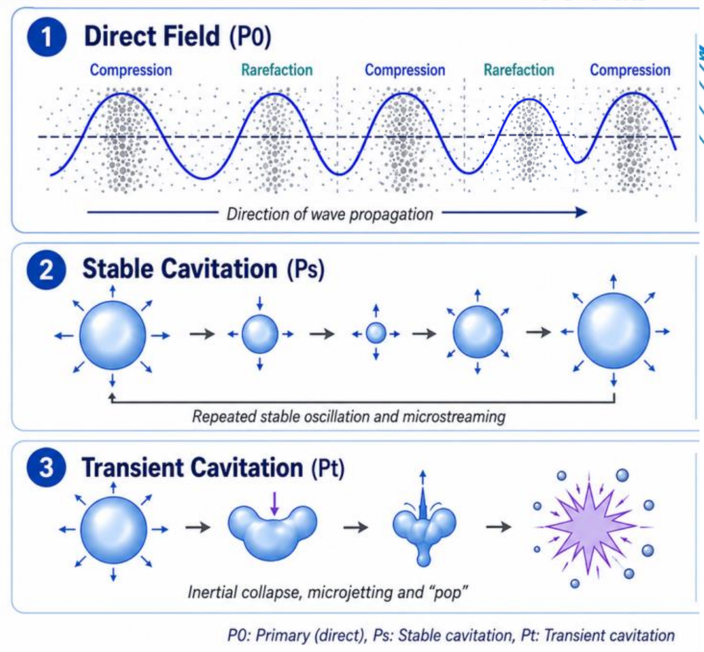




Transducers apply “Megasonic” pressure to mask surface to remove particles

“Mechanical Agitation” from Ultrasound





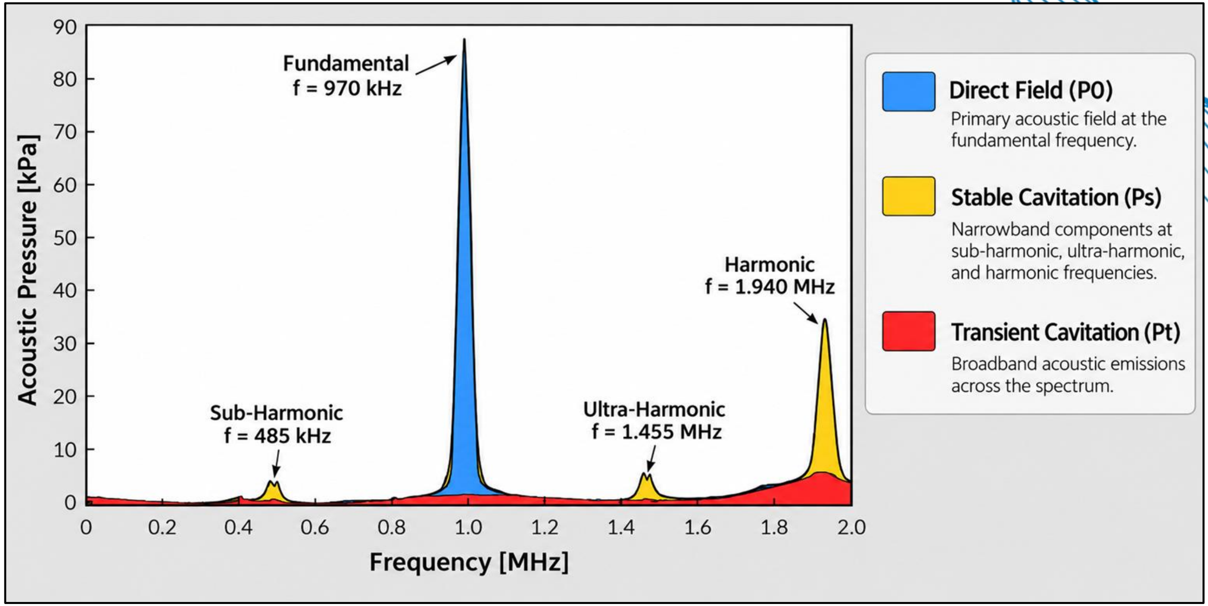
Anatomy of Acoustic Spectrum (Single Frequency)

ONDA MCT-20x0

Acoustic Cavitation Meter

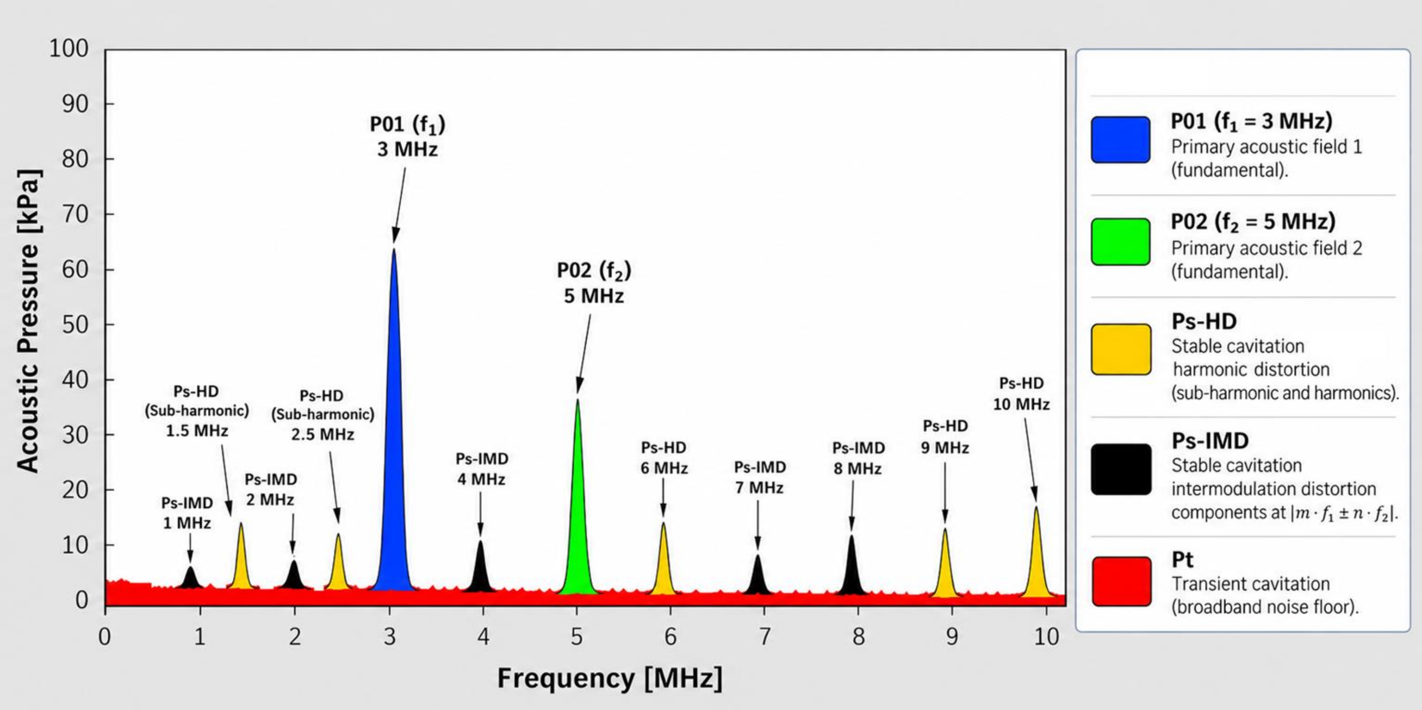
ONDA CMS-5000

Cavitation Monitoring Sensor



Different pressure components contribute to cleaning and damage

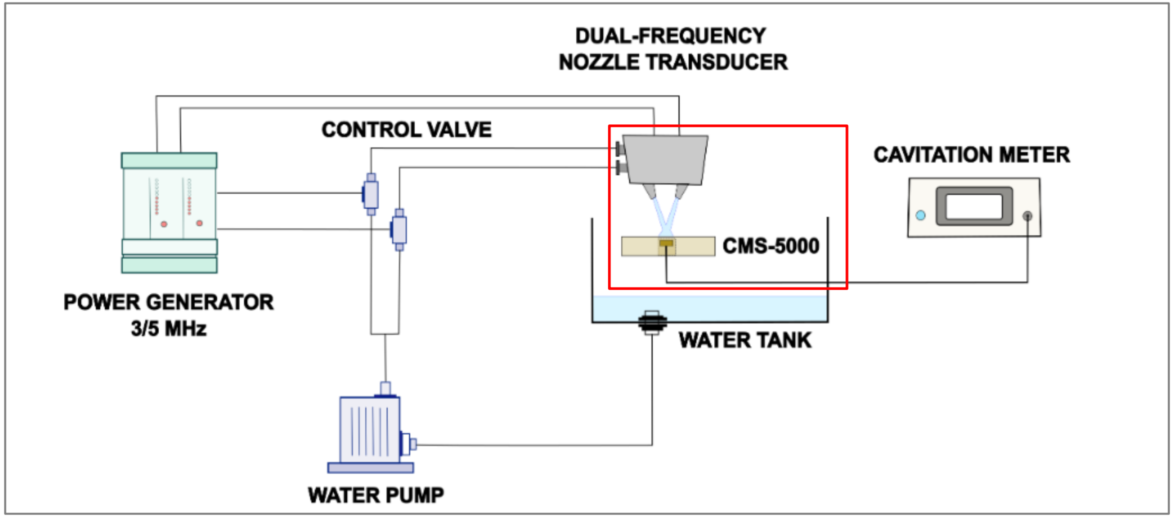
Anatomy of Acoustic Spectrum (Dual Frequency)



$$F\_IMD = |m \cdot F01 \pm n \cdot F02|$$

EX: F01=3 MHz & F02=5 MHz,
If n=1 & m=1, then F_IMD=8 MHz

Measurement Set Up



Power generator: 3 MHz, Max Power 18 W; 5 MHz, Max Power 18 W.
Distance transducer-sensor: 17 mm.
Flow Rate: 1 LPM per nozzle.

Two-Step Approach

1. Determine the “damage free” threshold by correlating Pt with defect analysis

2. Optimize particle removal by maximizing Ps while keeping Pt below damage threshold

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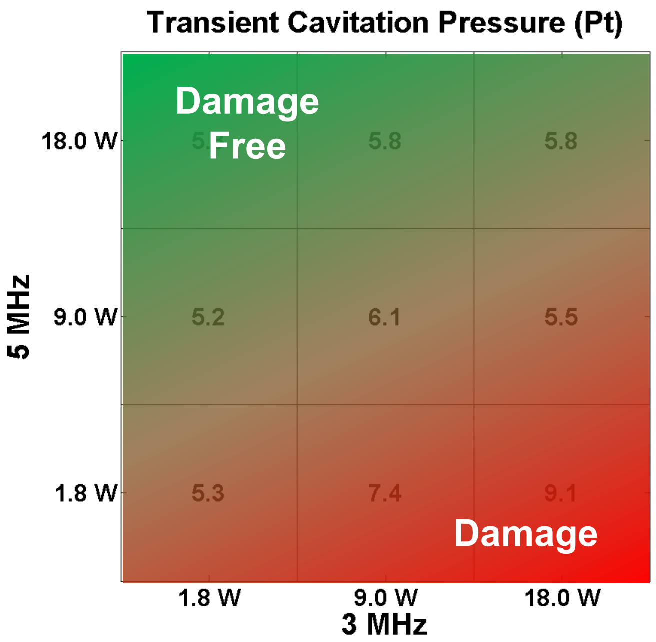
Determine Damage Threshold

Transient Cavitation Pressure (Pt)

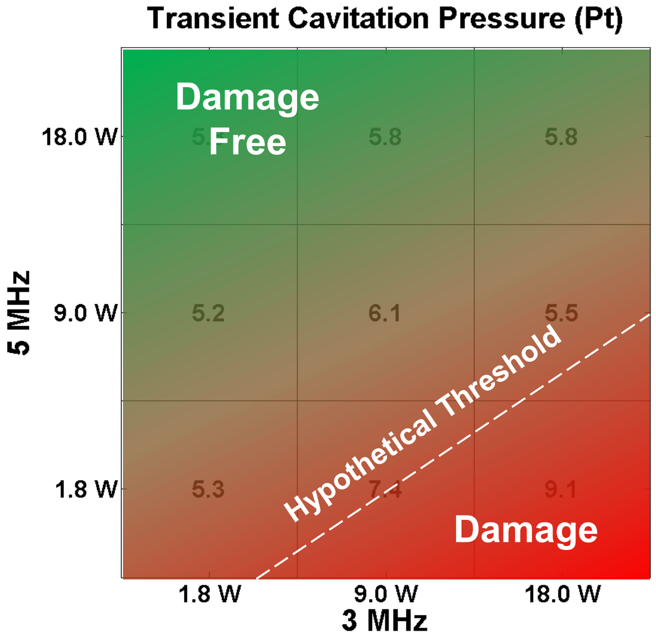
5 MHz \ 3 MHz	1.8 W	9.0 W	18.0 W
18.0 W	5.3	5.8	5.8
9.0 W	5.2	6.1	5.5
1.8 W	5.3	7.4	9.1

Determine Damage Threshold



Courtesy of Micron

Determine Damage Threshold



Courtesy of Micron

Two-Step Approach

1. Determine the “damage free” threshold by correlating Pt with defect analysis

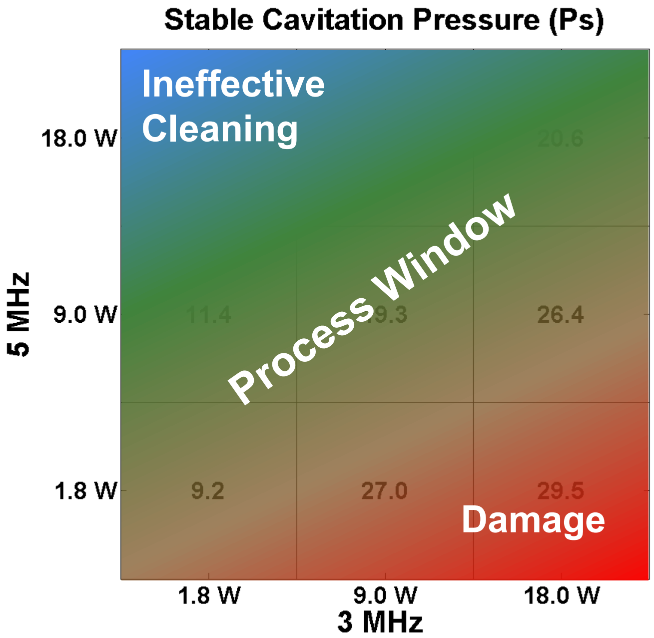
2. Optimize particle removal by maximizing Ps while keeping Pt below damage threshold

Determine Particle Removal Threshold

Stable Cavitation Pressure (Ps)

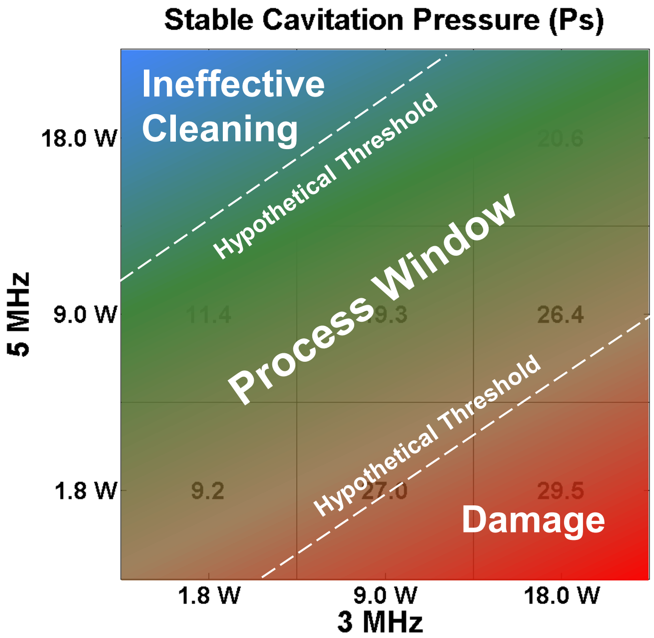
5 MHz \ 3 MHz	1.8 W	9.0 W	18.0 W
18.0 W	13.2	19.2	20.6
9.0 W	11.4	19.3	26.4
1.8 W	9.2	27.0	29.5

Determine Particle Removal Threshold



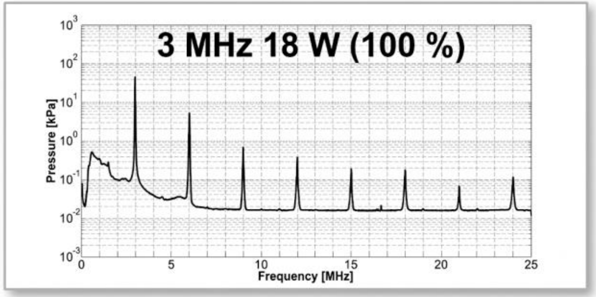
Courtesy of Micron

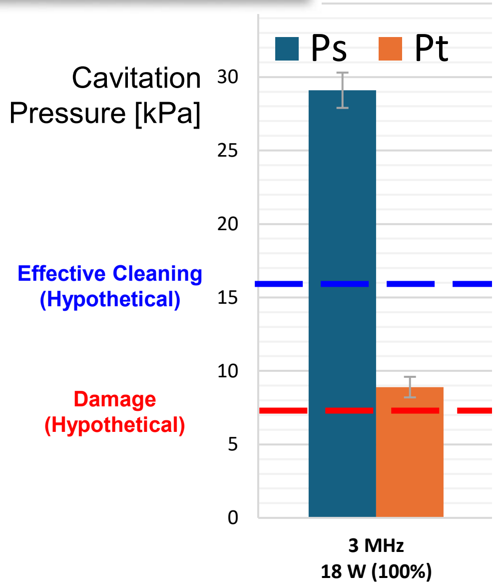
Determine Particle Removal Threshold



Courtesy of Micron

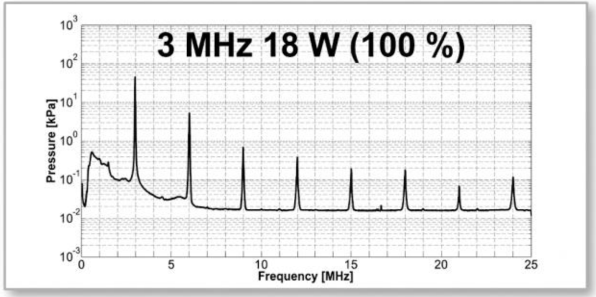
Cavitation Pressure at Different Frequencies

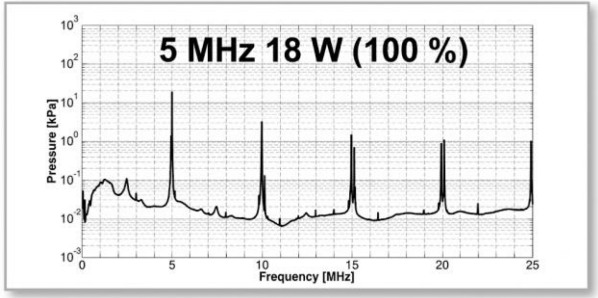


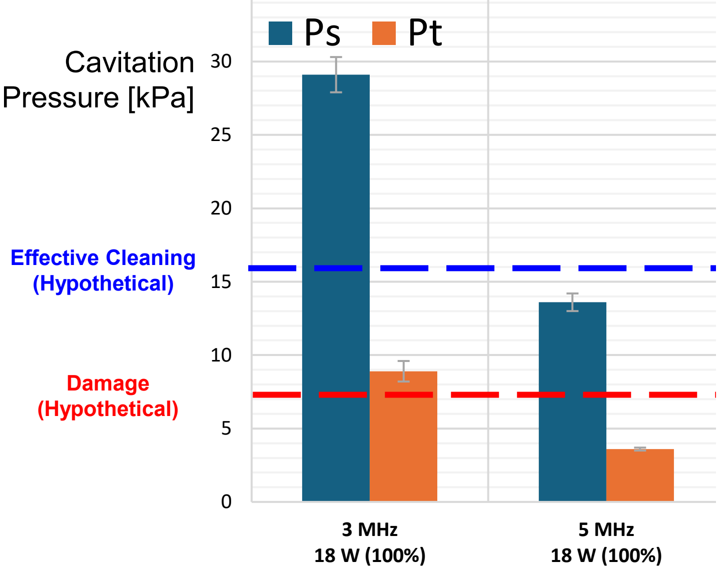


3 MHz cleans quickly but induces damage

Cavitation Pressure at Different Frequencies



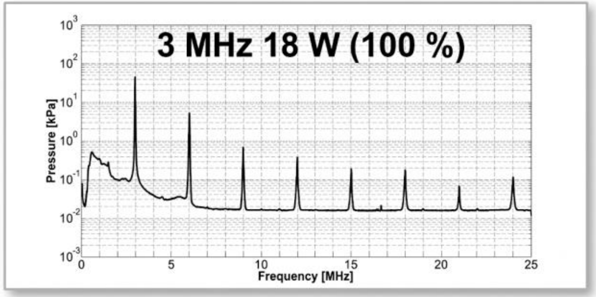


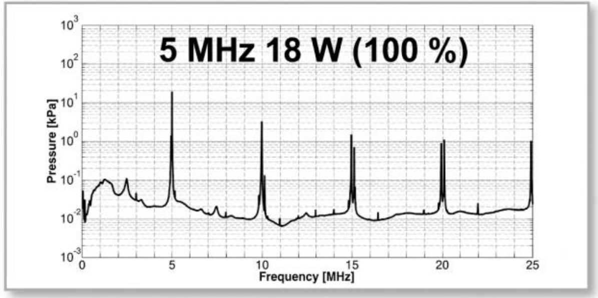


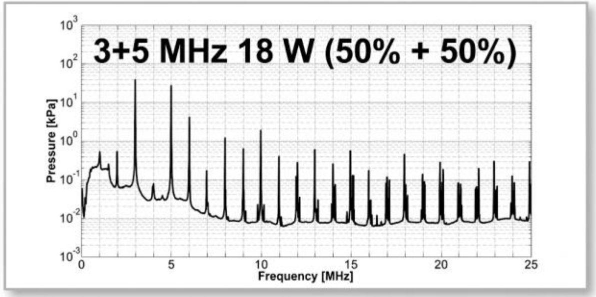
3 MHz cleans quickly but induces damage

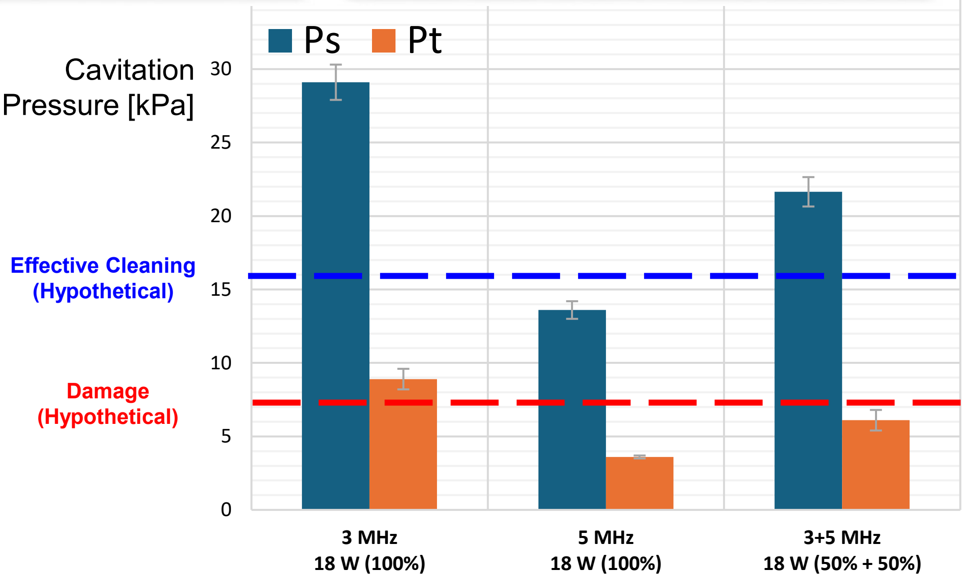
5 MHz avoids damage but is ineffective with cleaning

Cavitation Pressure at Different Frequencies







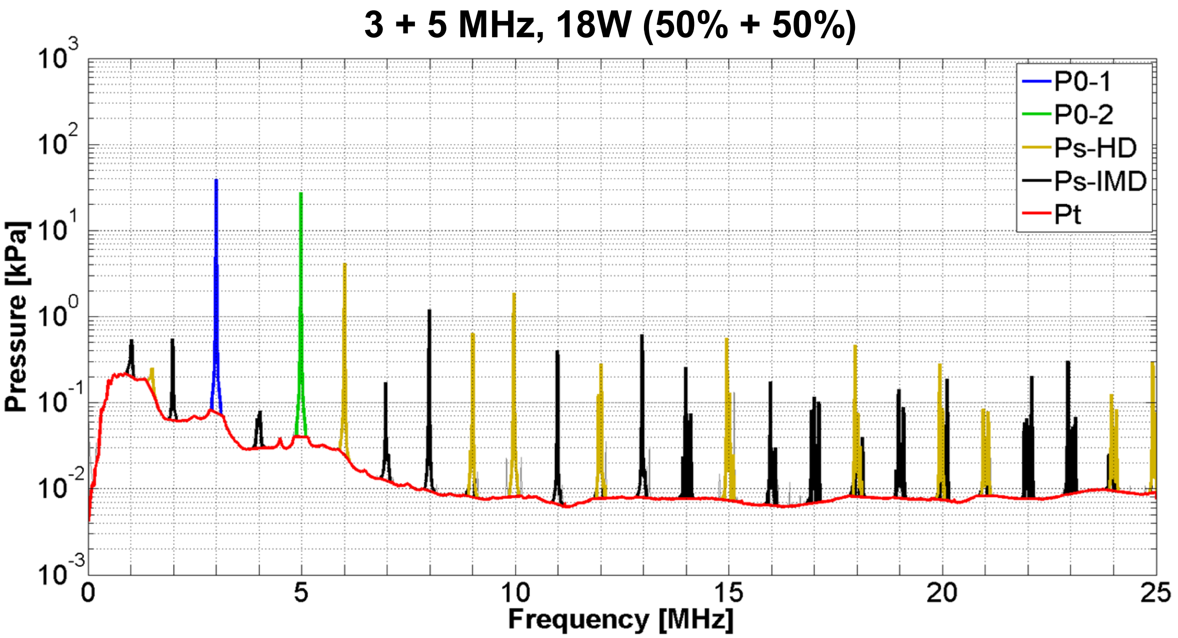


3 MHz cleans quickly but induces damage

5 MHz avoids damage but is ineffective with cleaning

Can 3+5 MHz Improve Cleaning while Avoiding Damage?

Non-linear Intermodulation Distortion from Mixing Frequencies



Ps-HD: Stable Cavitation due to Harmonic Distortion.

Ps-IMD: Stable Cavitation due to Non-Linear InterModulation Distortion.

Conclusion

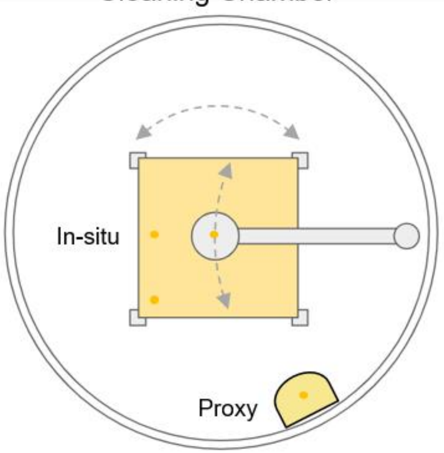
A novel quantitative measurement was presented to optimize the cleaning process window

Future areas to evaluate:

- Selection of frequency combinations (i.e., higher frequencies, triple frequencies)
- Optimization of power combinations for F01 and F02
- Characterizing how other process variables (e.g., gas, temp, chemistries, fluid dynamics) influence IMD
- Direct correlation with cleaning verification (e.g., damage and particle removal)

BACKUP

In-situ Mask Sensor Array & Proxy Sensor



MSA-5000
Wireless Mask Sensor Array (In-situ)

CMS-5000 & MCT-1x00
Cavitation Monitoring Sensor (Proxy)

MSA-5000 provides in-situ measurements to correlate with cleaning

CMS-5000 enables monitoring of the transducer output