Characterization of Acoustic Cavitation in Surfactant Containing Aqueous Solutions

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Introduction

- **Megasonic irradiation – Commonly used for particle removal in integrated circuit industry**
- **Use of surfactant assists in achieving higher cleaning efficiency**
- **Limited literature available on characterization of acoustic cavitation in solutions containing surfactant**
- **Proper understanding of the effect of surfactant on the bubble behavior will enable development of damage-free and efficient cleaning processes for the semiconductor industry**

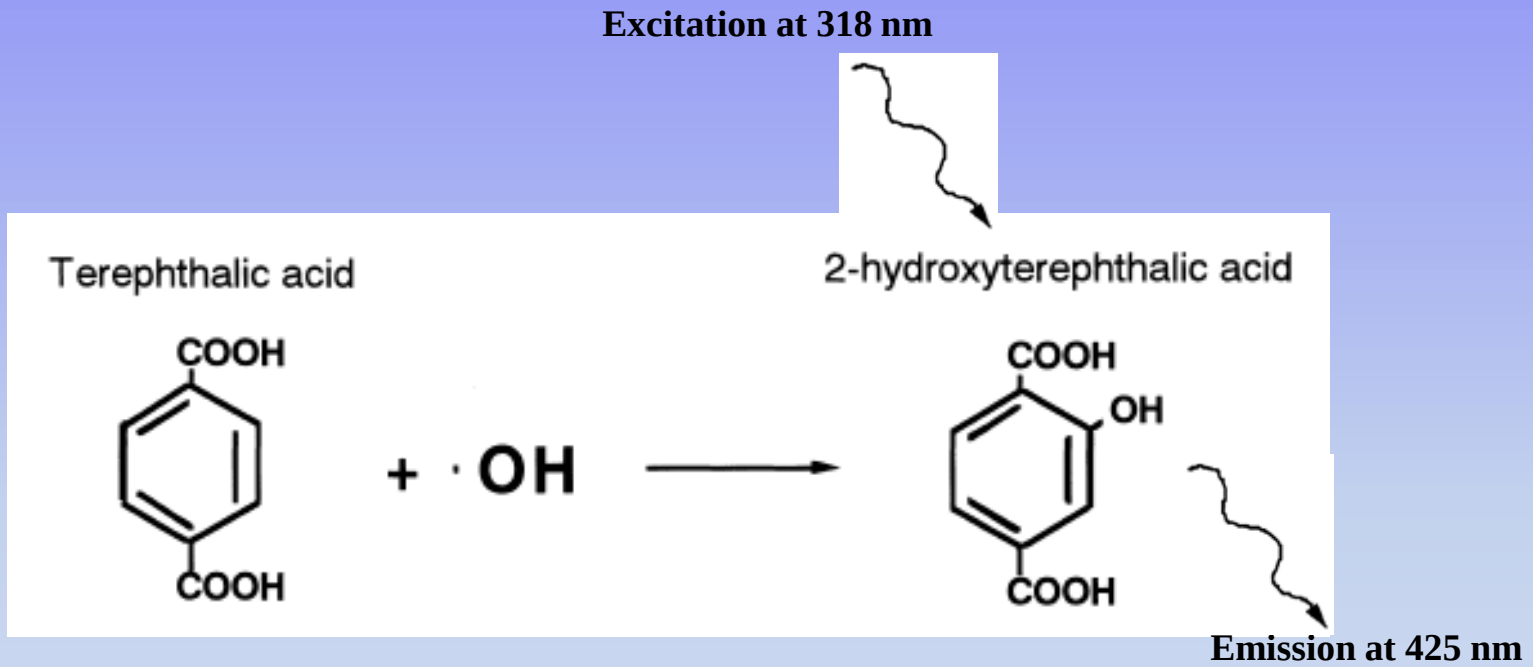
Key Objective and Approach

- **Key Objective :**
  - **Characterize cavitation/bubble behavior for solutions containing different concentrations of surfactants (Triton® X-100 and NCW® - 1002) at two different sound field frequencies (~ 0.7 and 1 MHz) and varying power densities**

- **Approach:**
  - **Fluorometric technique based on complexation of $OH^{\bullet}$ by terephthalic acid**
  - **Pressure measurements using a hydrophone**
  - **Microelectrode based chronoamperometric investigations**
  - **Sonoluminescence study using Cavitation Threshold Cell®**

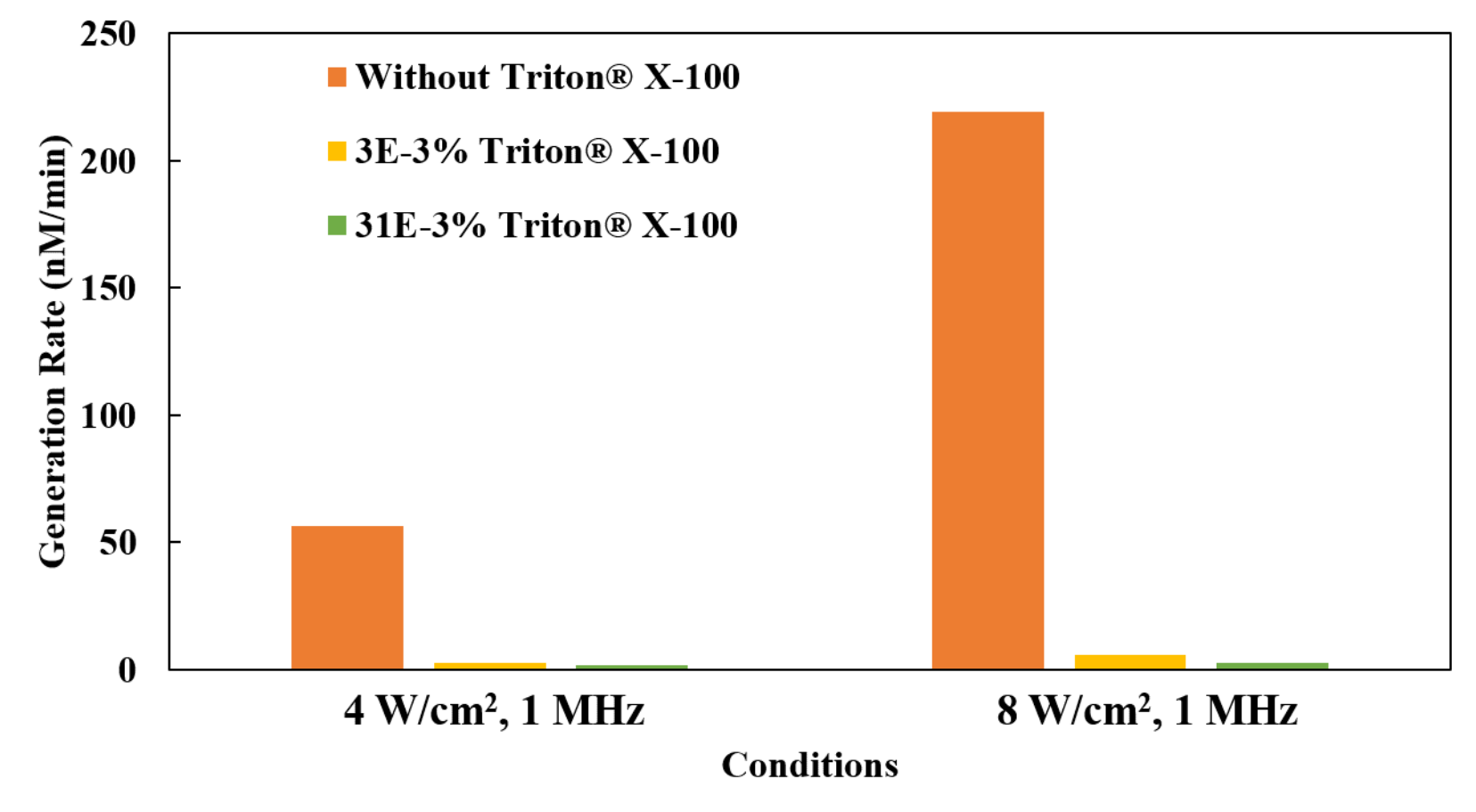
- **Surfactants:**
  - **Triton® X-100: polyoxyethylene alcohol based surfactant**
  - **NCW® - 1002: polyoxyalkylene alkyl ether**

Fluorescence Spectroscopy Using Terephthalic Acid



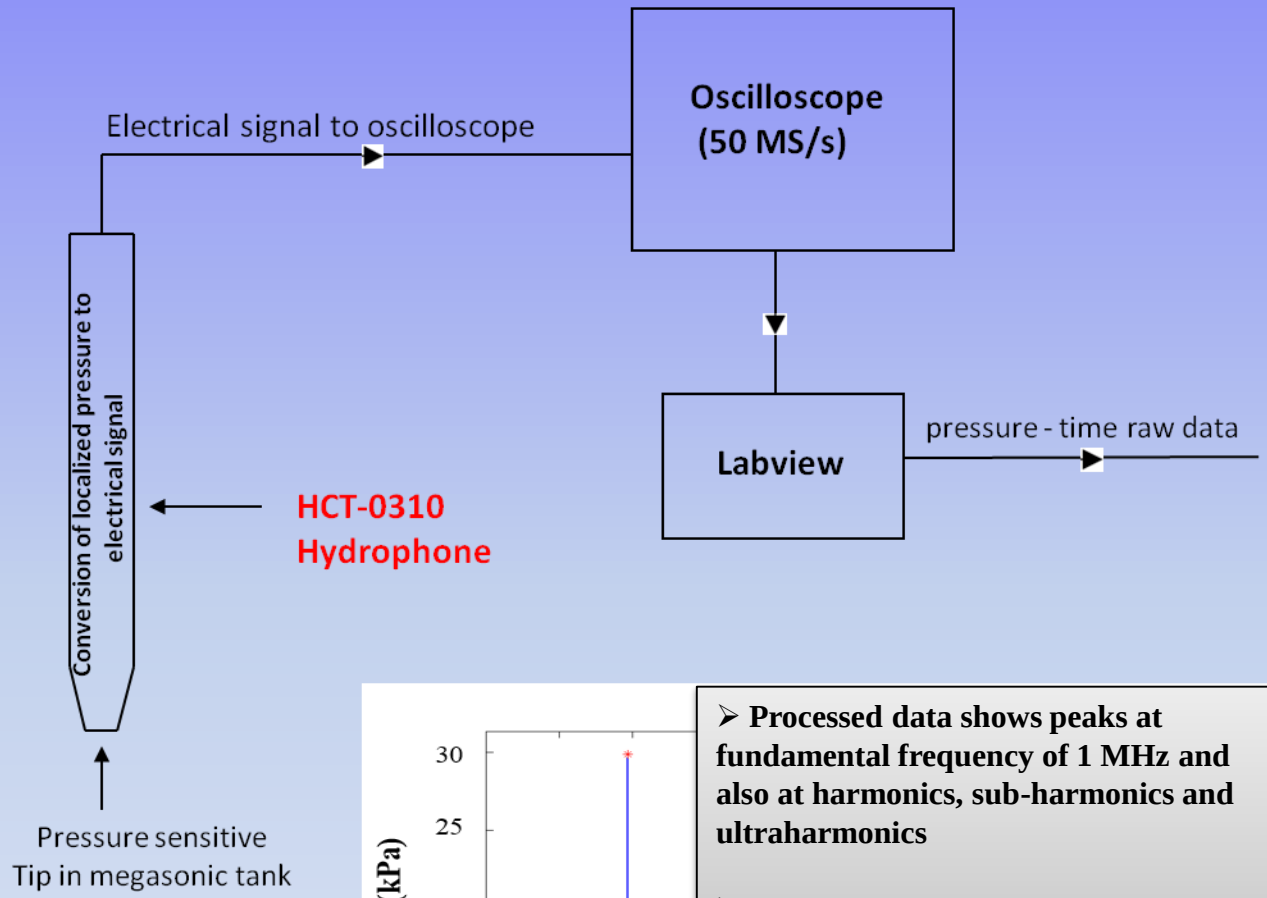
- **Hydroxyl radical trapped using terephthalic acid to form 2-hydroxyterephthalic acid, measured using fluorescence spectroscopy**
- **2-hydroxyterephthalic acid is stable up to 6 hours at room temperature**

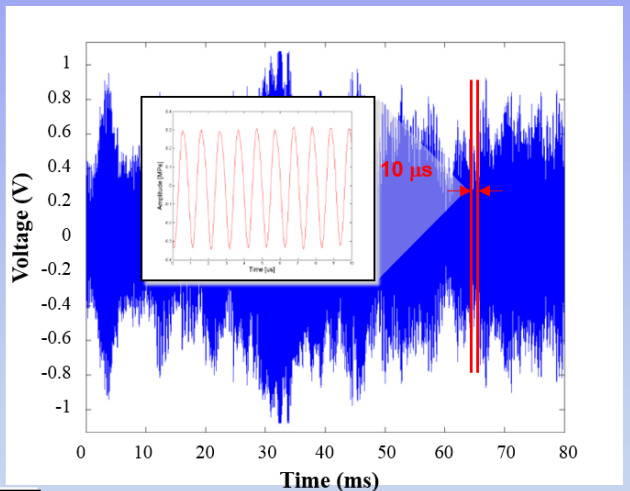
Effect of Addition of Triton® X-100 on Rate of Generation of OH•



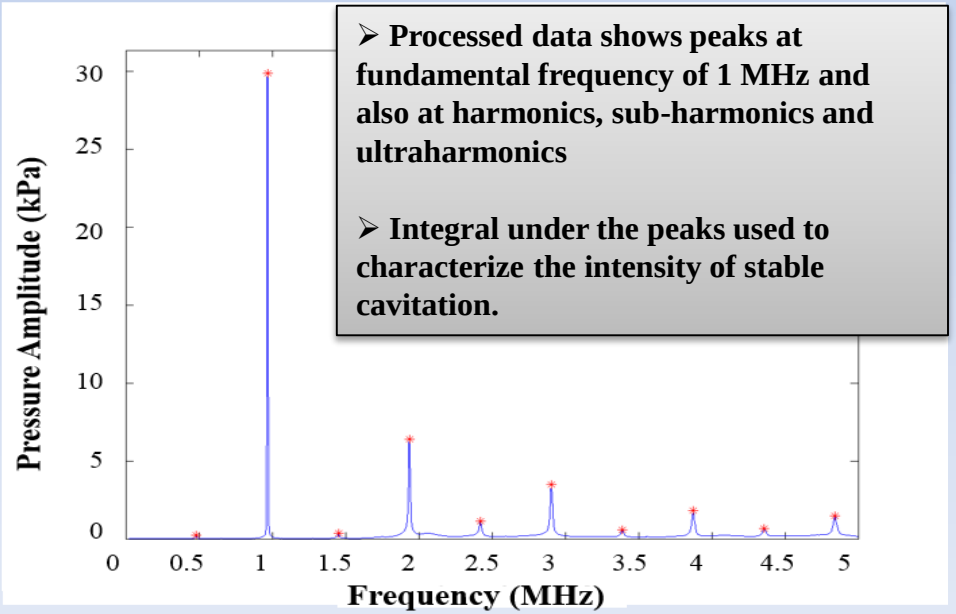
Decrease in generation rate of OH• with addition of Triton® X-100 at two different power densities

Hydrophone Set-up



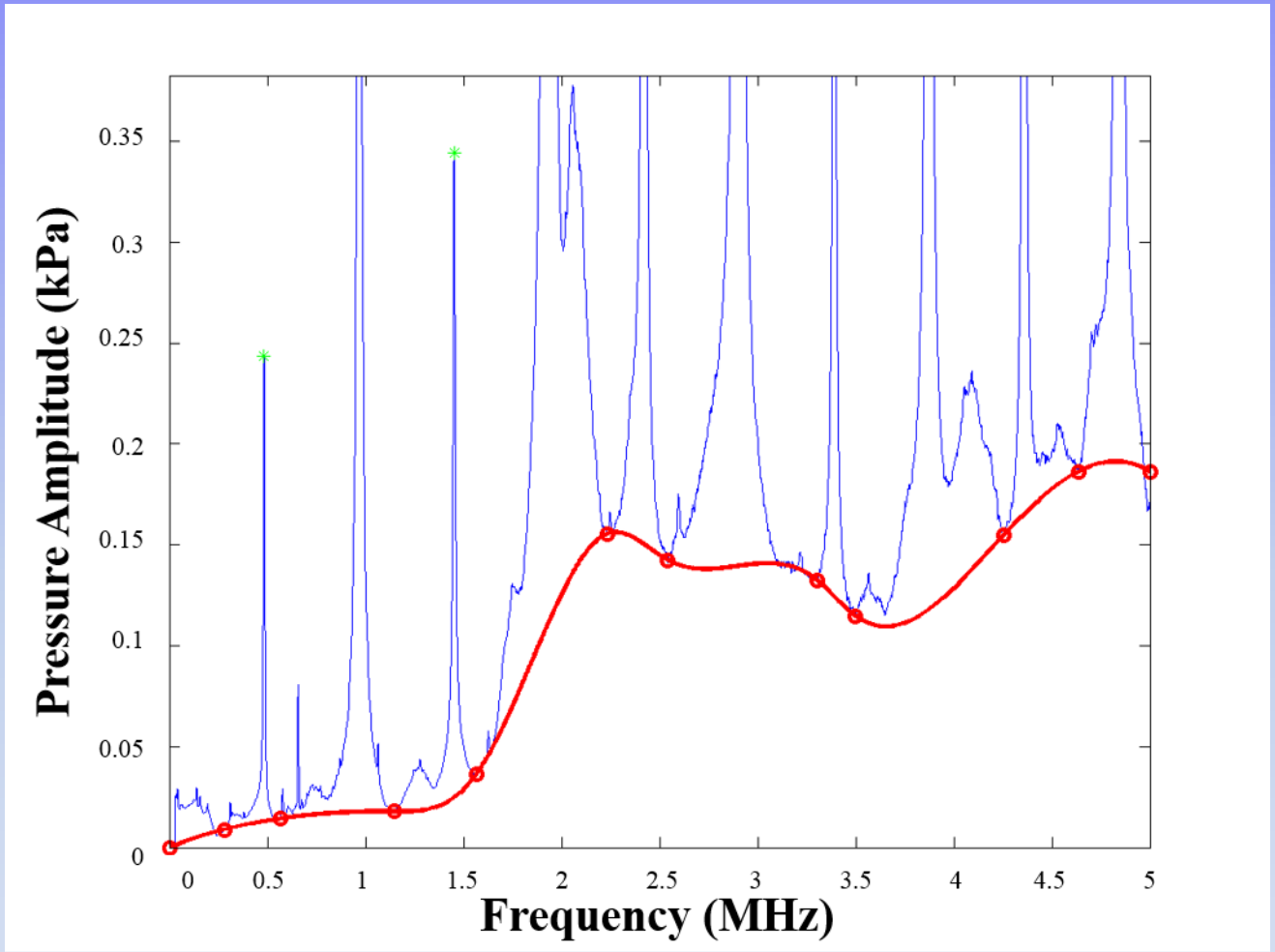


FFT



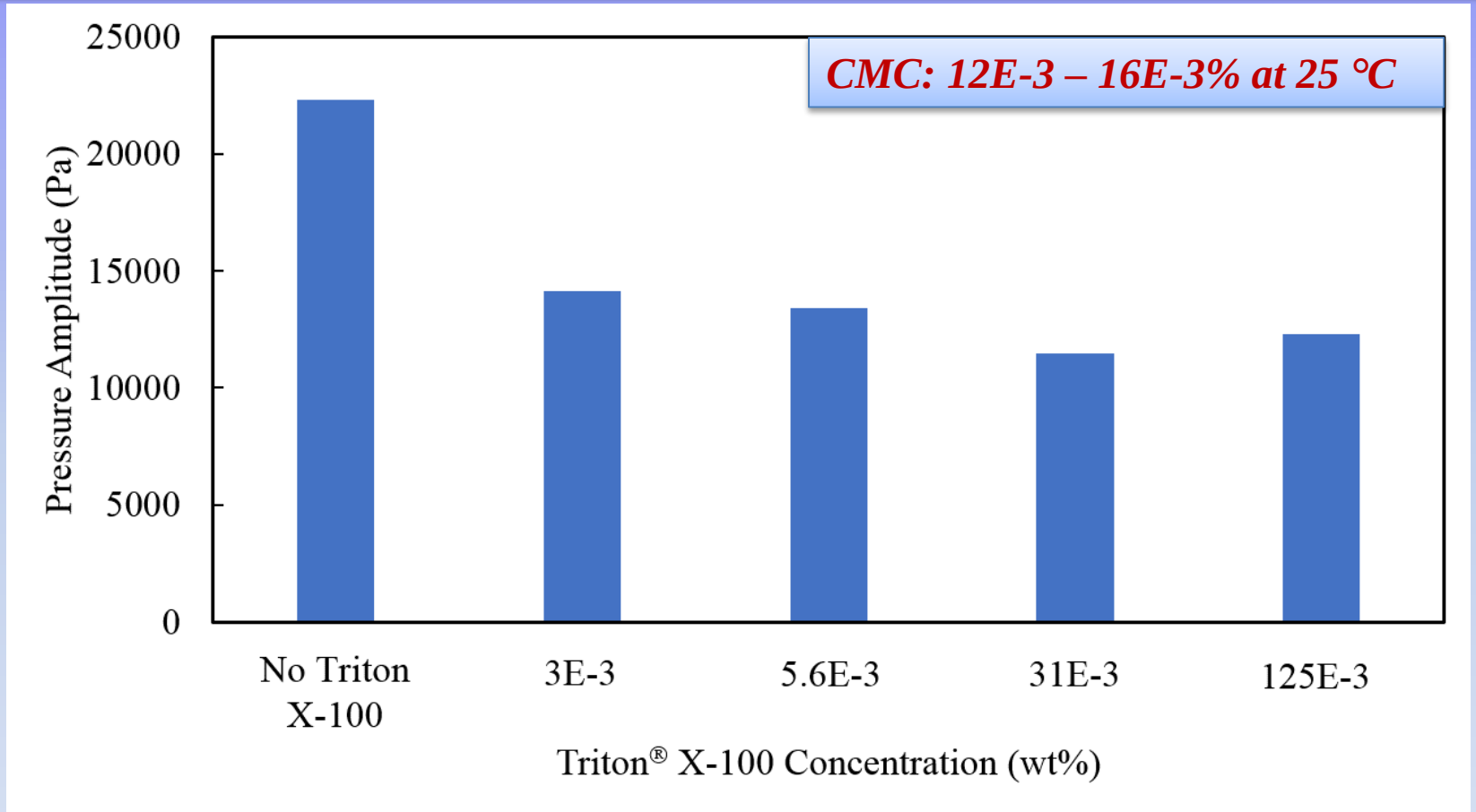
- **Processed data shows peaks at fundamental frequency of 1 MHz and also at harmonics, sub-harmonics and ultraharmonics**
- **Integral under the peaks used to characterize the intensity of stable cavitation.**

Quantification of Transient Cavitation



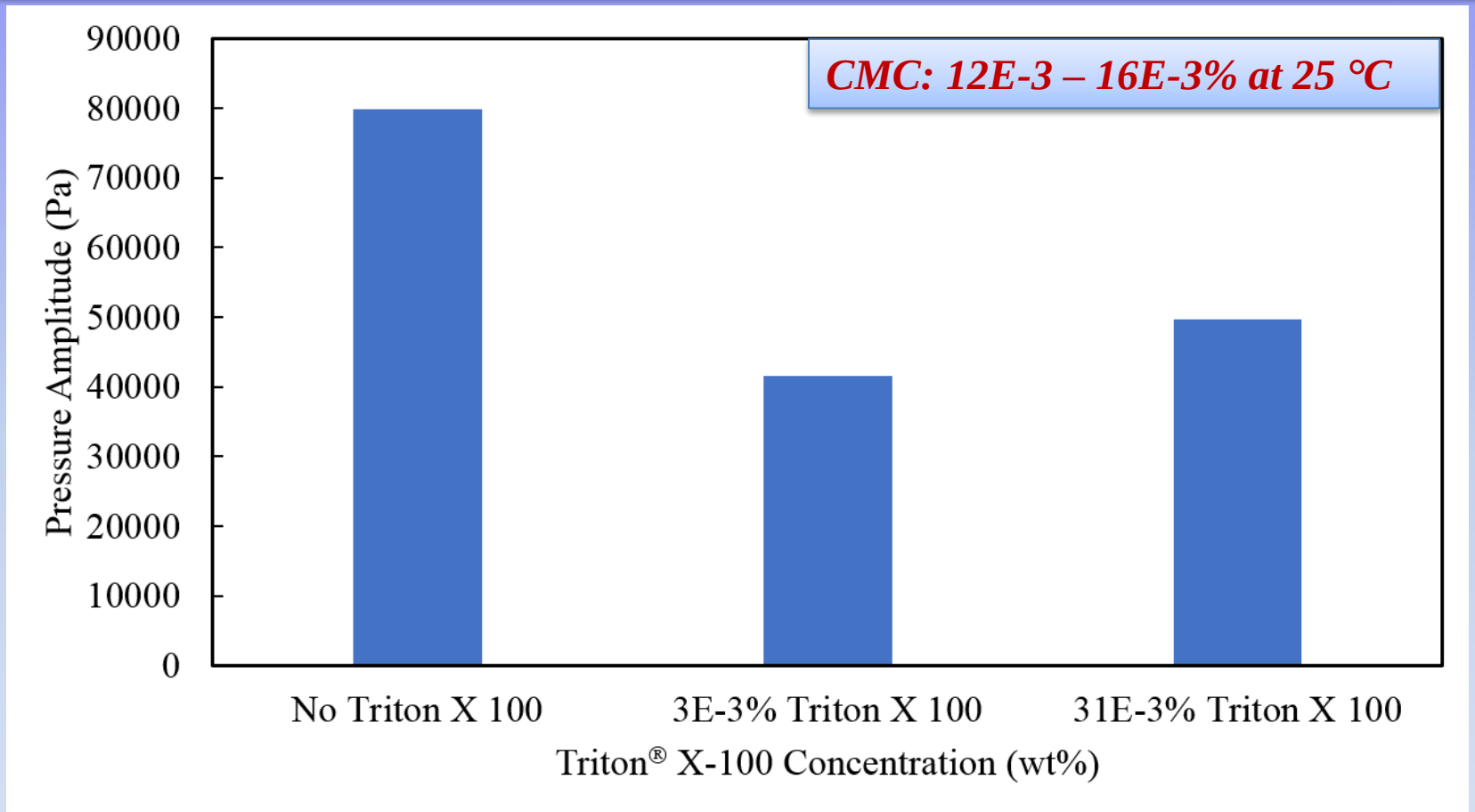
Integral under the broadband signal used for calculation of pressure due to transient cavitation

Effect of Triton® X-100 on Transient Cavitation Pressure in Solutions Subjected to 1 MHz (8 W/cm^2)



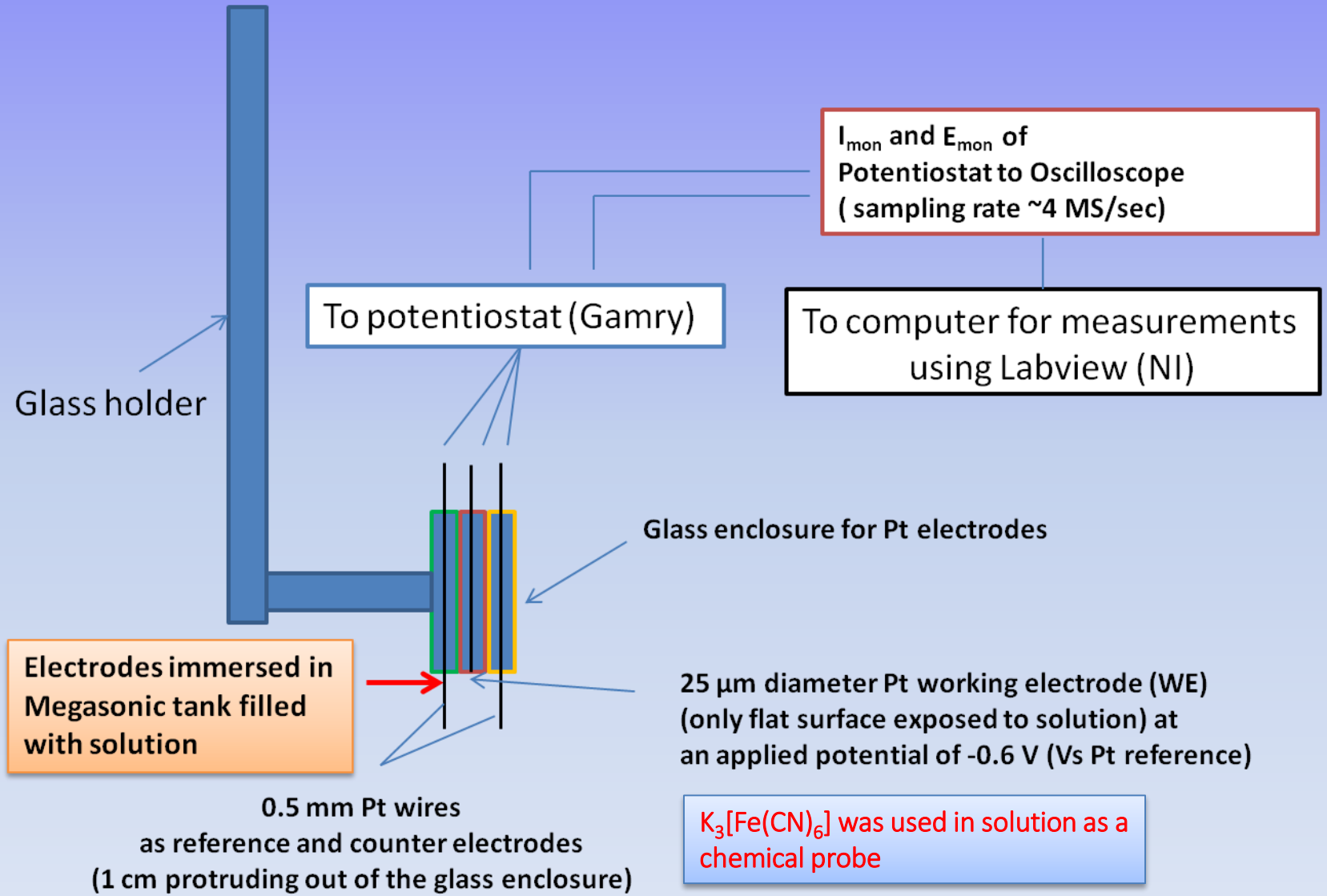
- Transient cavitation pressure suppressed in the presence of surfactant
- No effect of surfactant concentration on transient cavitation pressure

Effect of Triton® X-100 on Transient Cavitation Pressure in Solutions Subjected to 0.7 MHz (8 W/cm^2)



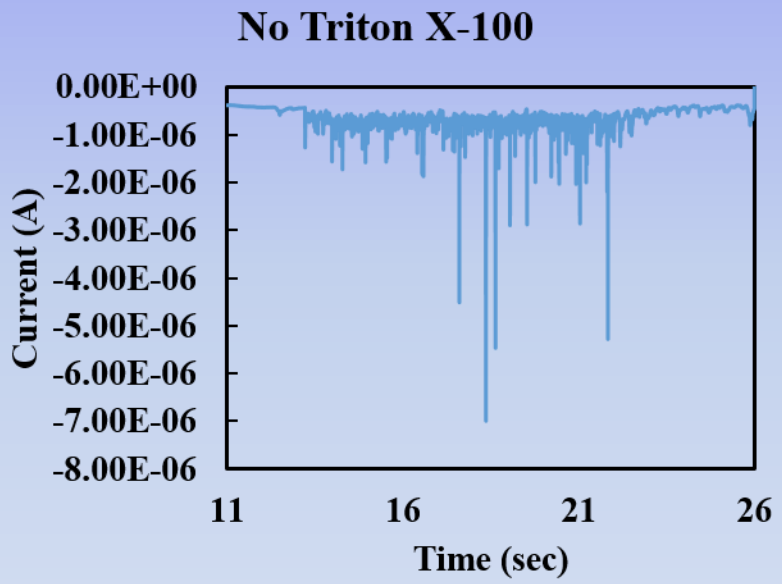
- Transient cavitation pressure significantly reduced after adding Triton® X-100
- No effect of surfactant concentration on transient cavitation pressure

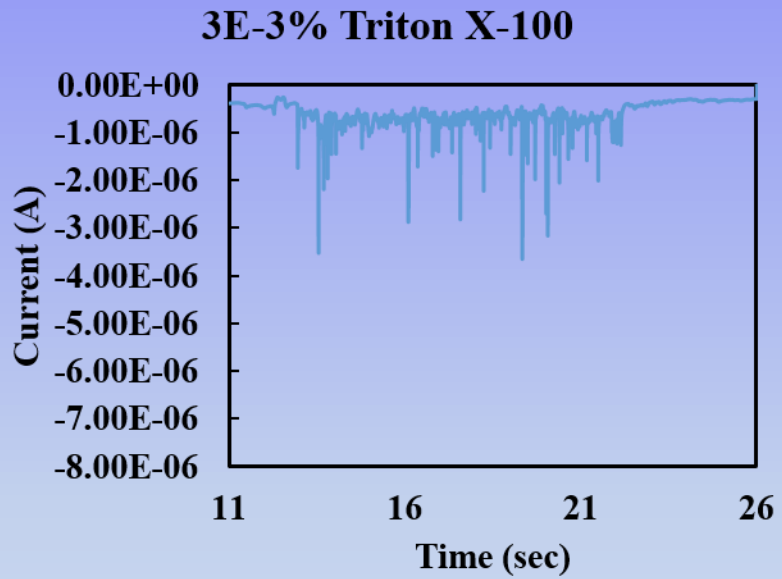
Electrochemical Sensor Set-up

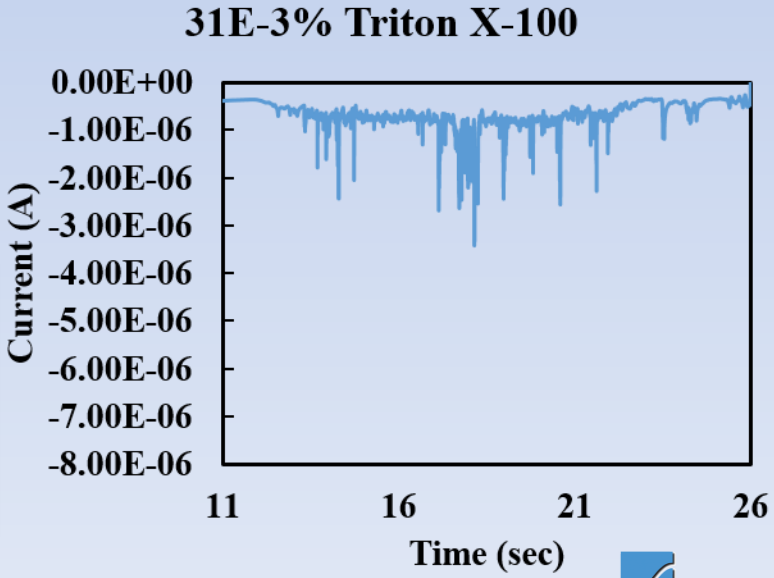


Investigations of Transient Cavitation in Solutions Containing Triton® X-100

1-2 s no meg, 12 s of meg (1 MHz), 1-2 s no meg



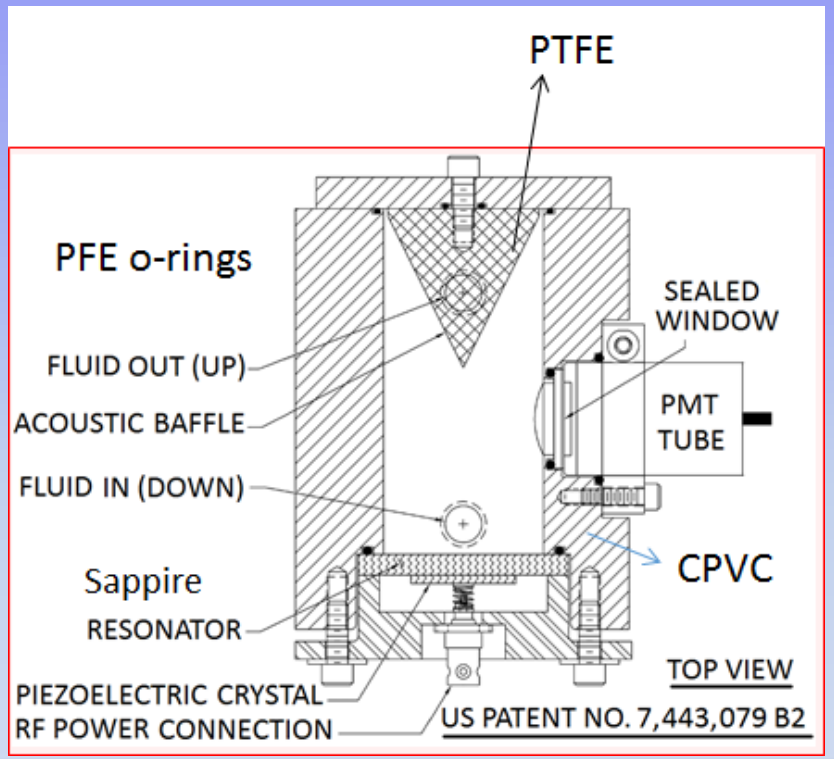




The magnitude of current peaks corresponding to transient cavitation intensity is lower in the presence of Triton® X-100

CT-cell Set-up

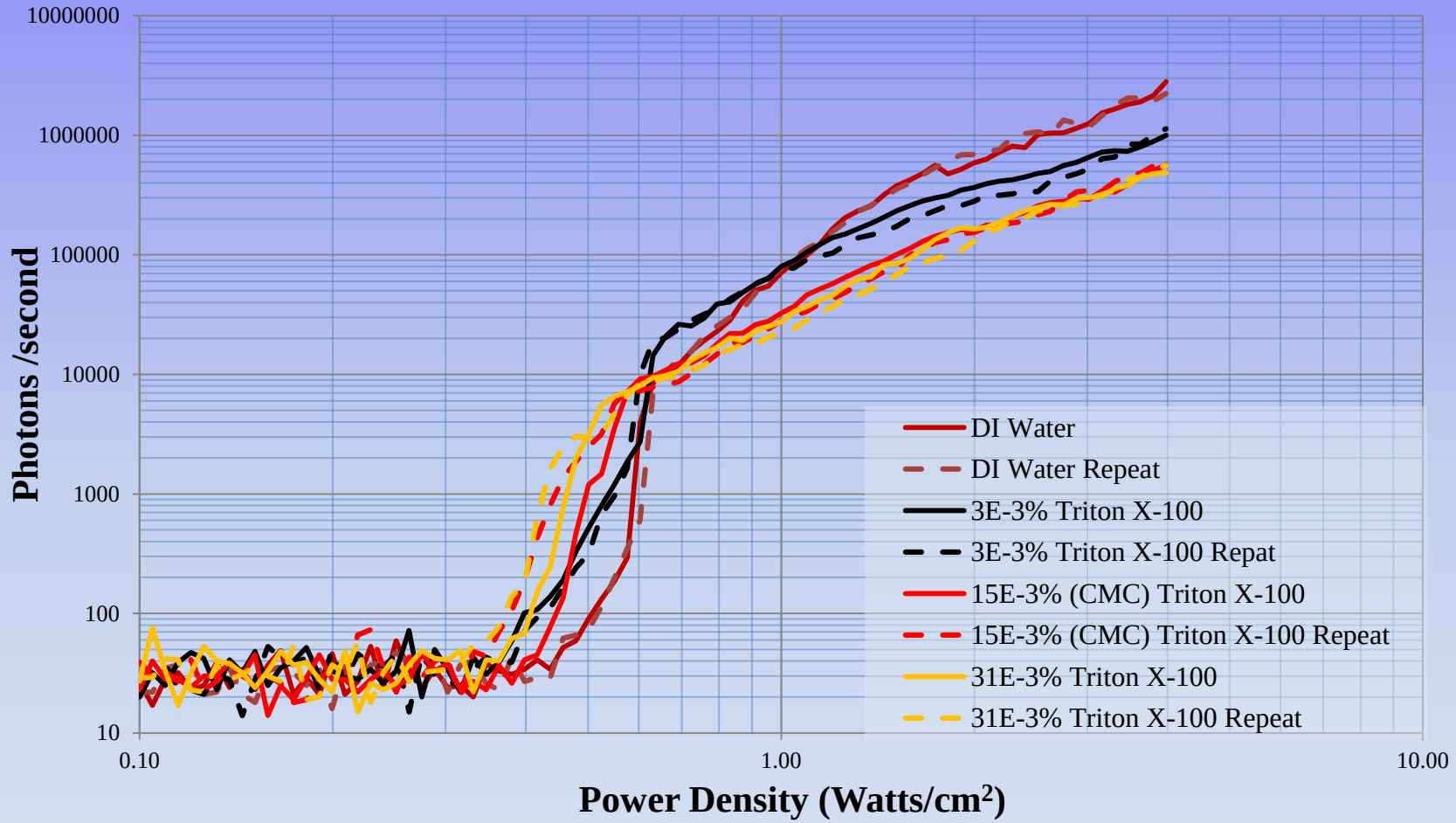
Cavitation Threshold (CT) Cell (*ProSys*®)



CT Cell Details

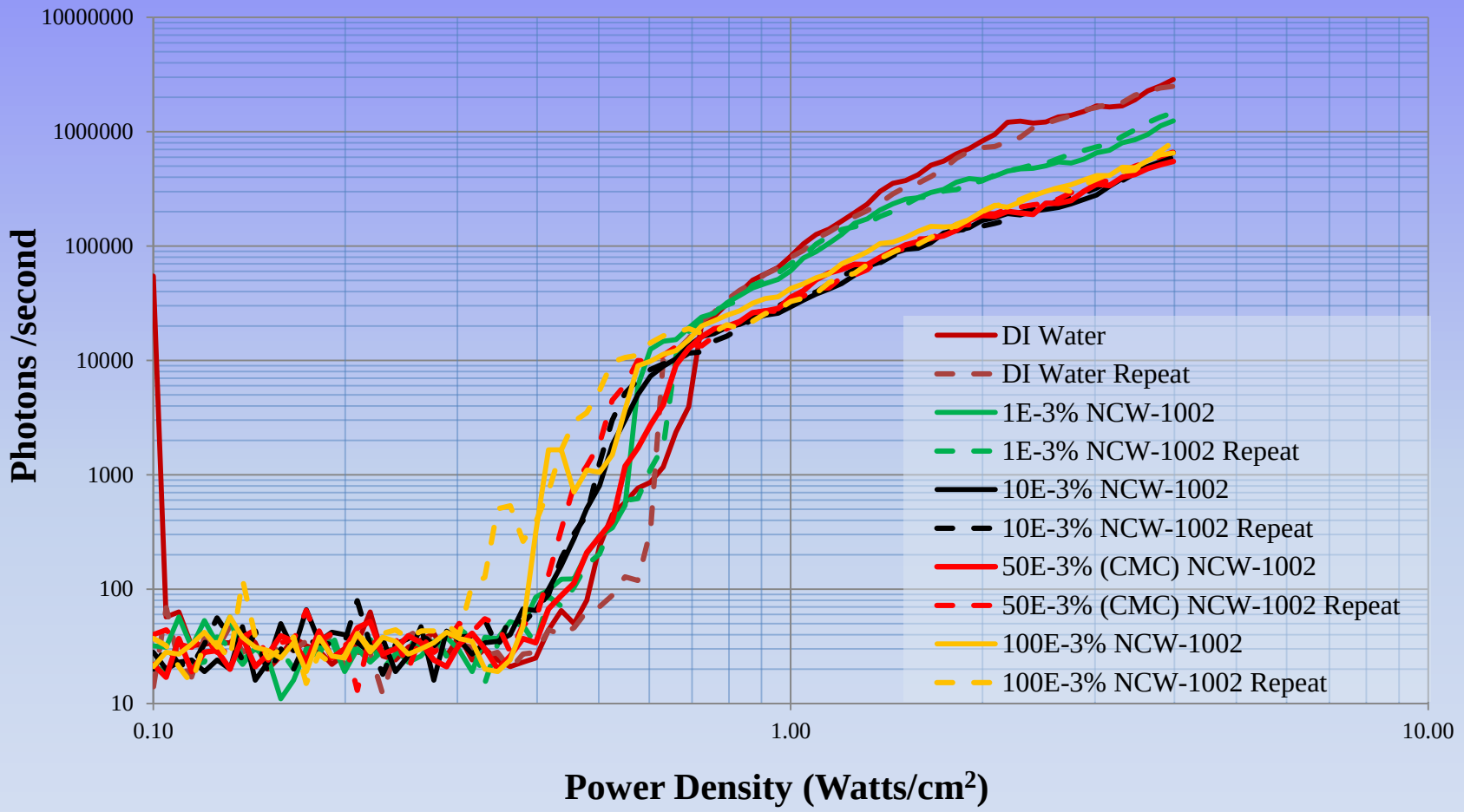
- *Volume = 163 cc, Length = 10.4 cm*
- *Internal Diameter = 4.8 cm*
- ***Sonic Frequency = 0.925 MHz***
- ***PMT Wavelength Range = 280 to 630 nm***
- ***Power Density Range = 0.1 to 4 W/cm²***

Sonoluminescence Studies on the Effect of Triton® X-100



- **Increase in Triton® X-100 concentration decreases transient cavitation when below CMC**
- **No further decrease in transient cavitation achieved above CMC**

Sonoluminescence Studies on the Effect of NCW® - 1002



Effect of NCW® - 1002 concentration similar to that of Triton ® X-100.

Summary

- **We have successfully characterized transient cavitation in aqueous solutions with and without surfactants using Hydrophone, Microelectrode and CT Cell based techniques.**
- **All studies indicated that transient cavitation decreased in the presence of surfactants (Triton® X-100 and NCW® - 1002).**
- **Hydrophone studies showed that Triton® X-100 concentration did not affect transient cavitation pressure.**
- **CT cell measurements revealed that Triton® X-100 and NCW® - 1002 concentration affected sonoluminescence intensity below CMC but did not have any effect above CMC.**

Acknowledgements

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