School of Engineering &
Applied Science

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Effects of acoustic parameters on nanodroplet vaporization

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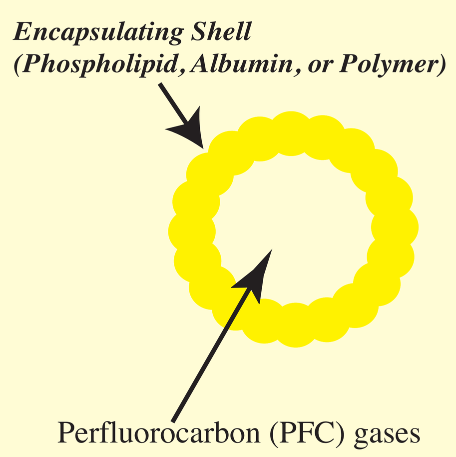
Background and Introduction

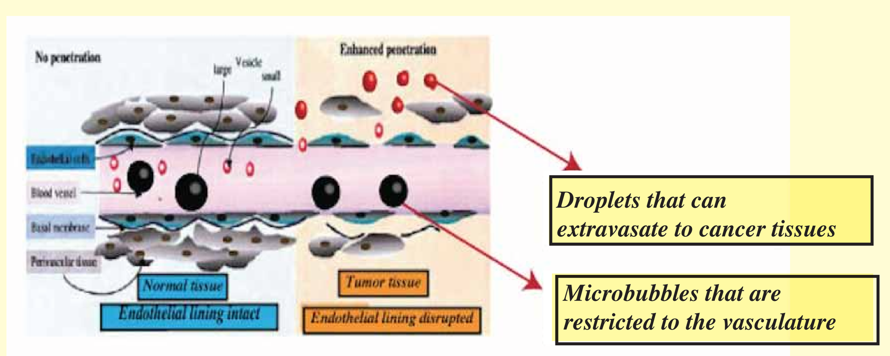
Despite a number of advantages ultrasound imaging offers, it suffers from low sensitivity.

To overcome this limitation, microbubbles (MB) have been introduced, which are gas-filled particles with a size range of 1-7 micrometers.



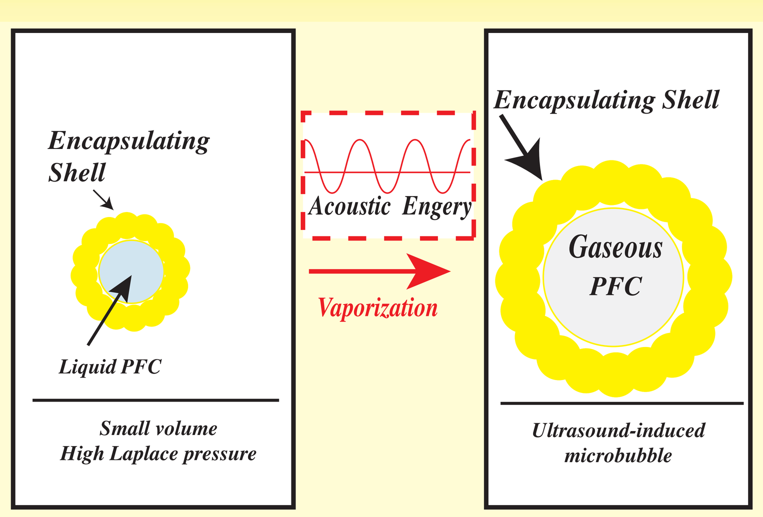
Because of their size distributions, MB can not be used for extravascular interogations.

Phase shift nanodroplets offer a number of advantages over ordinary microbubbles due to their enhanced stability and smaller size distribution.



These droplets undergo a phase transition to the highly echogenic gaseous state and are convertible to micron-sized bubbles upon the input of sufficient acoustic activation energy. This is called acoustic droplet vaporization (ADV).

Transition of a super heated liquid droplet into gas → ADV

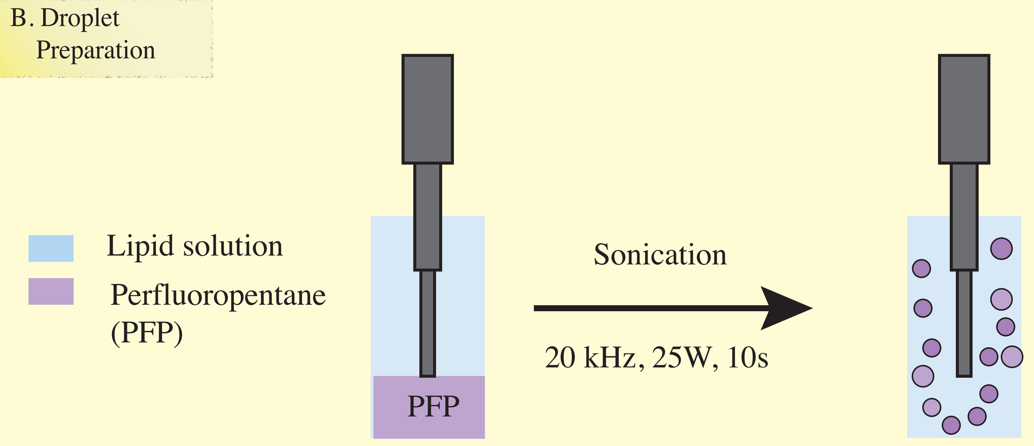


Once nanodroplets are exposed to ultrasound energy, vaporization of the droplet core occurs.

A. Microbubble Preparation

DPPC	7.5 mg
Propylene glycol	15 mg
TAP	30 mg
PBS	8 ml
Glycerol	0.5 ml
Propylene glycol	1.5 ml

B. Droplet Preparation

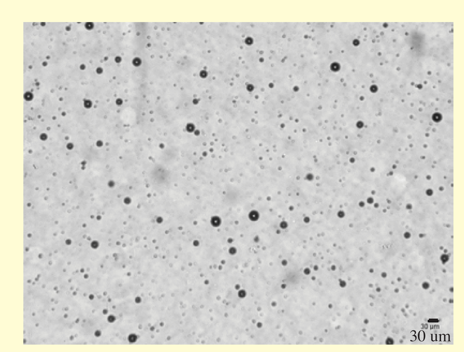


Objective

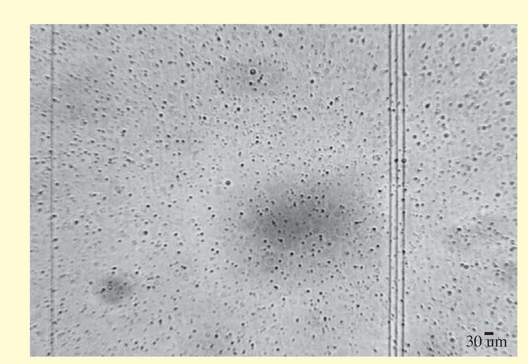
- The main focus of this study is to find droplet vaporization threshold of nanodroplets as a function of acoustic parameters including excitation pressure, frequency, pulse repetition period and number of cycles.
- Acoustic response of in-house made microbubbles with vaporized liquid nanodroplets at varying excitation pressures are compared.

Results

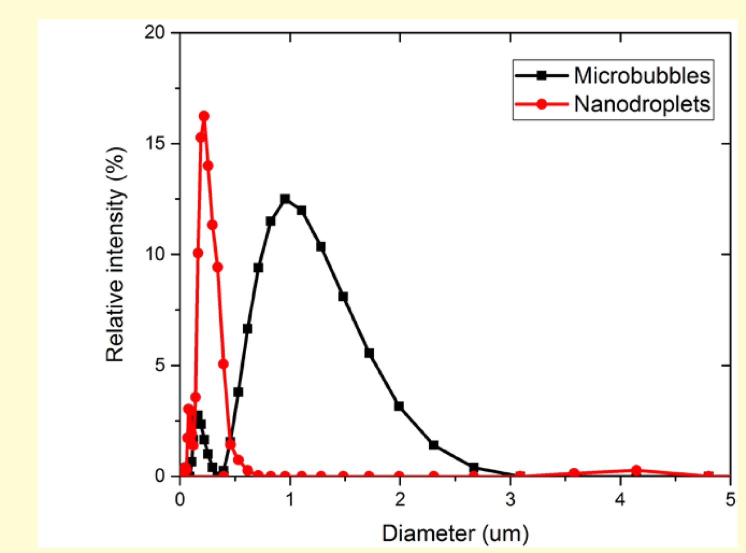
Light microscopy images and size distribution



Lipid-coated PFB filled MB

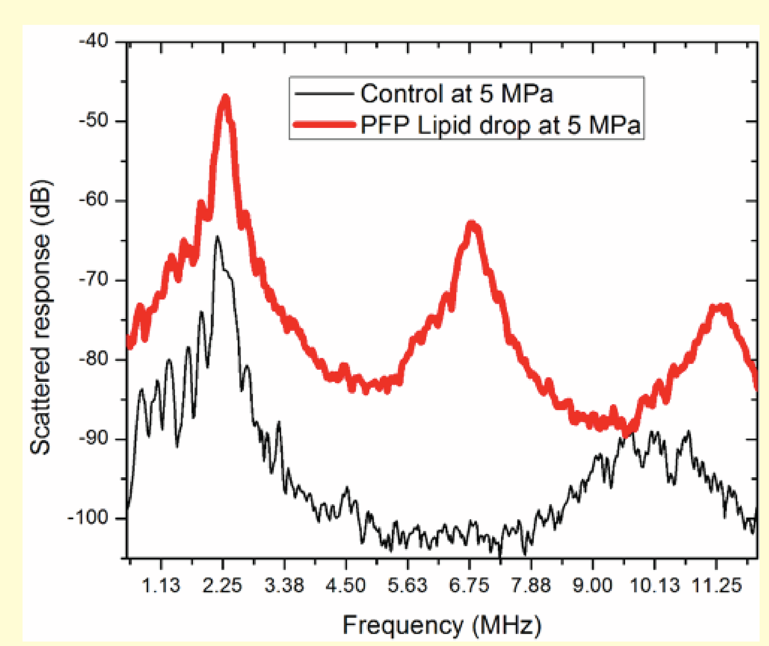


Lipid-coated PFP filled nanodroplets

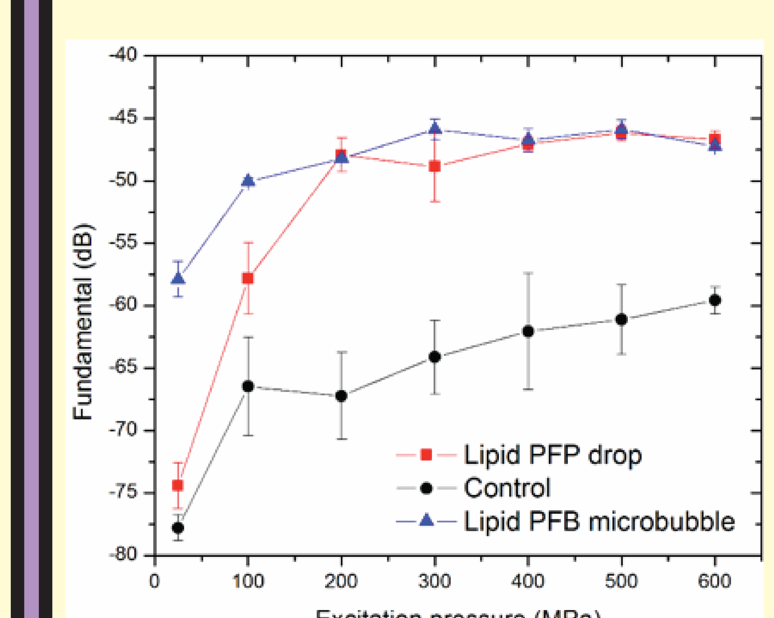


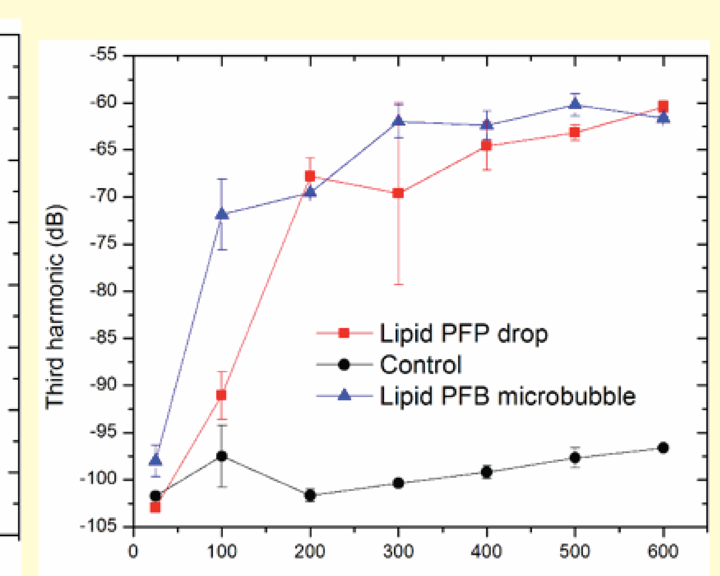
Dynamic light scattering results for size distribution

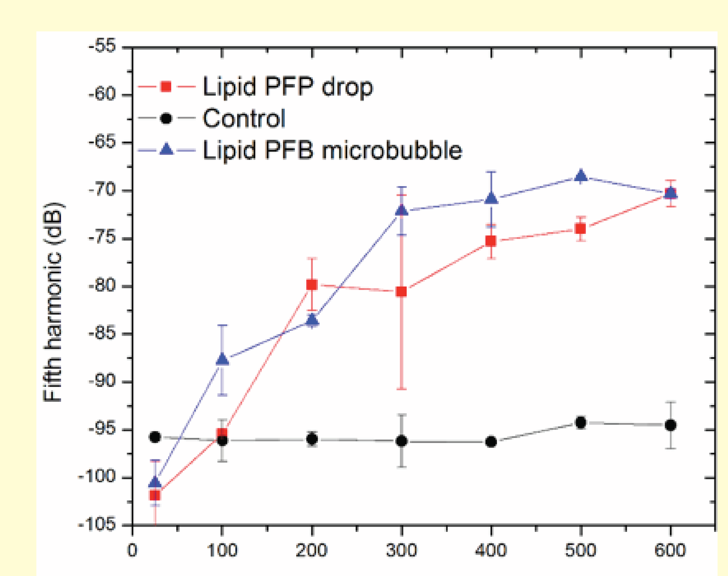
ADV Threshhold



At high excitation pressure, scattering signals from the vaporized nanodroplets were significant. This figure shows acoustic responses of vaporized droplets at 5 MPa with 2.25 MHz center frequency.



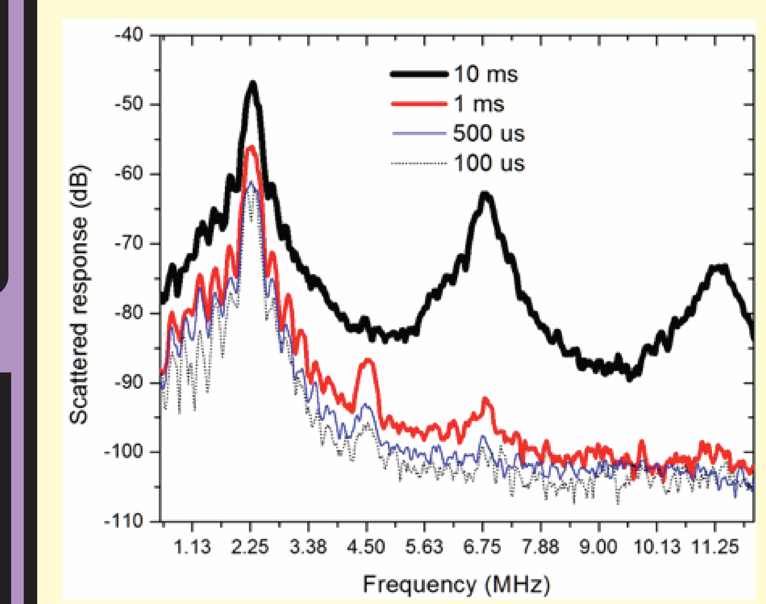




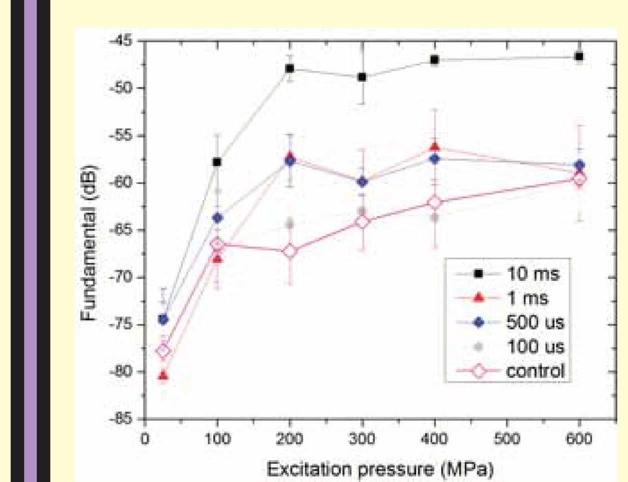
At ADV, odd harmonics were found to be significantly higher than the control (water).

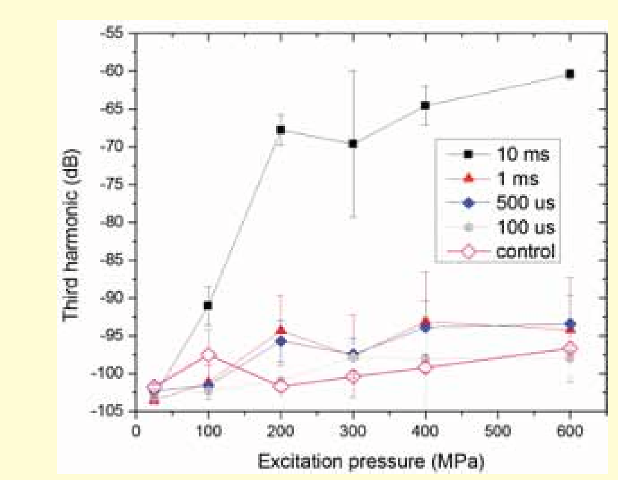
Above ADV threshold, both microbubbles and vaporized droplets showed similar responses.

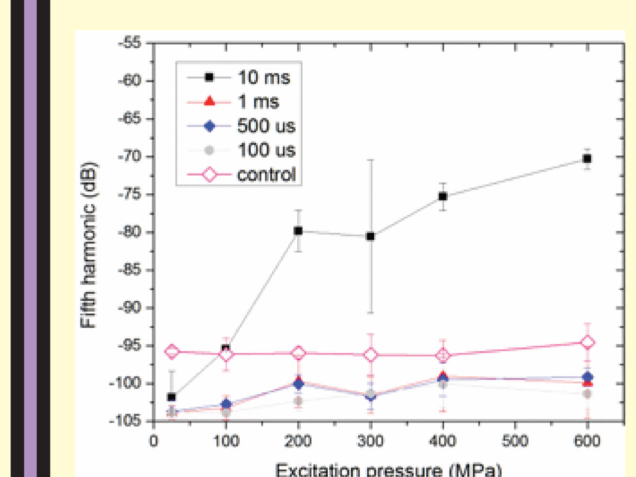
Burst period studies (PRP) on ADV

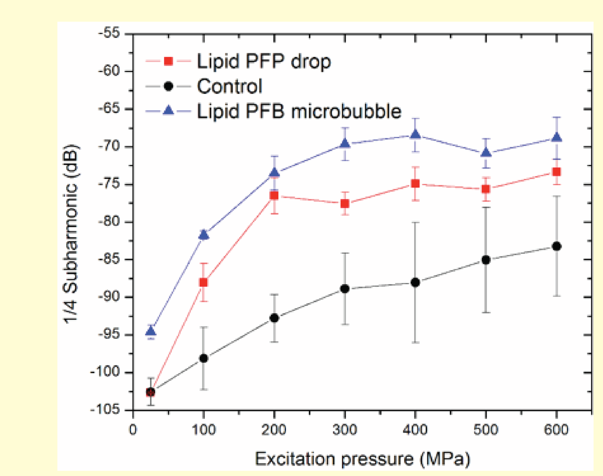


At PRP of 10 ms, all non-linear components are significantly higher than the shorter PRPs.









Conclusions

- Above ADV threshold, both microbubbles and vaporized droplets showed similar responses.
- At ADV, fundamental and odd harmonics were found to be significantly higher than the background noise.
- ADV threshold varies significantly with PRP; while at PRP of 10 ms, the ADV threshold was found to be 3.6 MPa (pk-pk), for PRP of 1ms, 100 µs and 500 µs, ADV was not observed even at 10 MPa.

Future Studies

- Further investigations are needed to characterize the stability of PFC droplets in vitro and in vivo.
- Since the ultimate goal of droplets is for in vivo applications where they will be exposed to different temperatures, pressures and blood viscosity, therefore it demands a thourough investigation of acoustic droplet vaporization threshold dependence on these ambient parameters.