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Symposium

A reference vessel for acoustic cavitation: initial characterisation of the spatial distribution of cavitation activity derived using an acoustic emission sensor

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Plan for presentation

- Background and up-date;
- Cavitation sensor;
- Reference vessel;
- Measurements of **acoustic pressure** distribution using a hydrophone;
- Preliminary characterisation of the **cavitation activity** distribution within the reference vessel;
- Future.

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Background

The requirement for characterisation methods for acoustic cavitation

- A uniform traceable base for measurement would be invaluable for checking equipment;
- It would lead to an acceleration in fundamental understanding of processes taking place - leading process optimisation;
- In medicine, it would result in improved surgical procedures and better planning of treatment regimes.

A measure of cavitation "quality" was required – cavitation "strength", cavitation energy, the number of events taking place per unit time and their violence;

The distribution of both types of quantity throughout the reaction vessel was required.

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Candidate monitoring techniques for inertial cavitation

- Sonochemistry: ESR and terephthalic acid
- ***Broadband acoustic emission***
- Sonoluminescence (chemiluminescence)
- Erosion – soil removal
- Erosion – aluminium foil
- Erosion – lead balls or stainless steel ball bearings (weight loss)
- Bio-effect (haemolysis)

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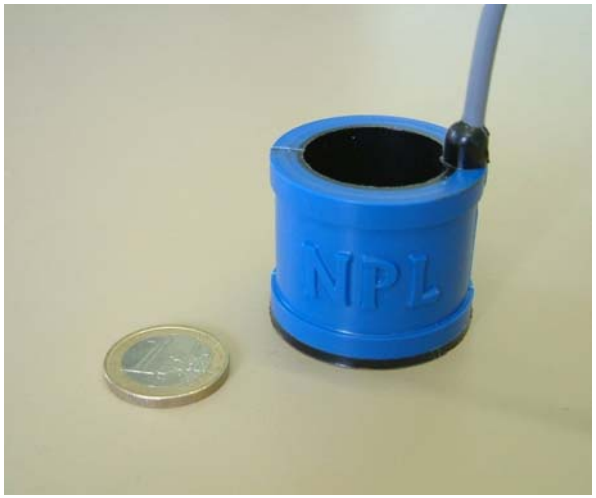
Cavitation sensor

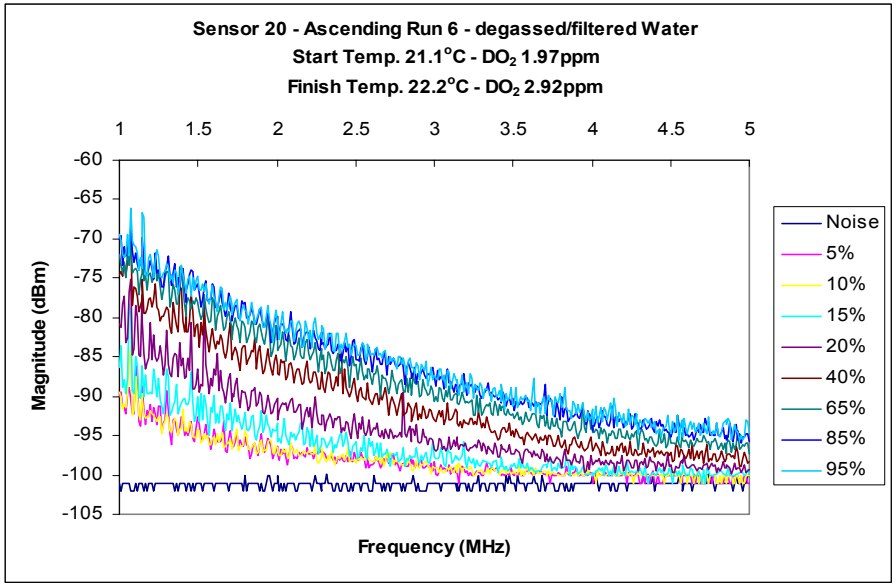
Concept for cavitation sensor developed at NPL under Strategic Research project



- acoustic emissions from bubbles detected using thin piezoelectric material (*pvdf*);

- 4 mm thick polyurethane absorber 'shell' eliminates MHz signals generated outside the cylinder;

- perturbation of 40 kHz component minimised by using absorber material whose acoustic impedance is matched to that of water,



For further information about the cavitation sensor:-

- **A novel sensor for monitoring acoustic cavitation. Part I: Concept, theory and prototype development.***

  Bajram Zeqiri, Pierre N Gélat, Mark Hodnett and Nigel D Lee, IEEE Transactions on Ultrasonics, Ferroelectrics and Frequency Control, Vol.50, No. 10, October 2003, 1342 – 1350.

- **A novel sensor for monitoring acoustic cavitation. Part II: Prototype performance evaluation.**

  Bajram Zeqiri, Pierre N Gélat, Mark Hodnett and Nigel D Lee, IEEE Transactions on Ultrasonics, Ferroelectrics and Frequency Control, Vol.50, No. 10, October 2003, 1342 – 1350.

* Awarded IEEE UFFC Outstanding paper award for 2003.

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Reference vessel

Rationale behind reference vessel

- To generate a cavitation field whose properties are **repeatable**, for use as a test bed to carefully compare cavitation detection techniques;

- Robert E Apfel, “three golden rules”:

  - “know thy liquid”
  - “know thy sound field”
  - “know when something happens”

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Requirements of a cavitation reference vessel

- Variable output power, above and below the **cavitation threshold**;
- Ideally generate a relatively **‘simple’** cavitation field, with some spatial variation;
- **Reproducible** and ideally **predictable** performance;
- Must include **environmental control** infrastructure;
- Number of device ports and linked devices;
- Useable with a range of cavitation monitoring techniques.

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Sonic Systems sonochemical cell specification

- Based on **P1800-25 Ultrasonic Processing cell** (Sonic Systems);
- Cylindrical volume, 330 mm high, I/D 312 mm (25 litres);
- 30 nominally identical 25 kHz transducers: three rows of 10;
- **Three generators** supplying 600 W electrical power per row.

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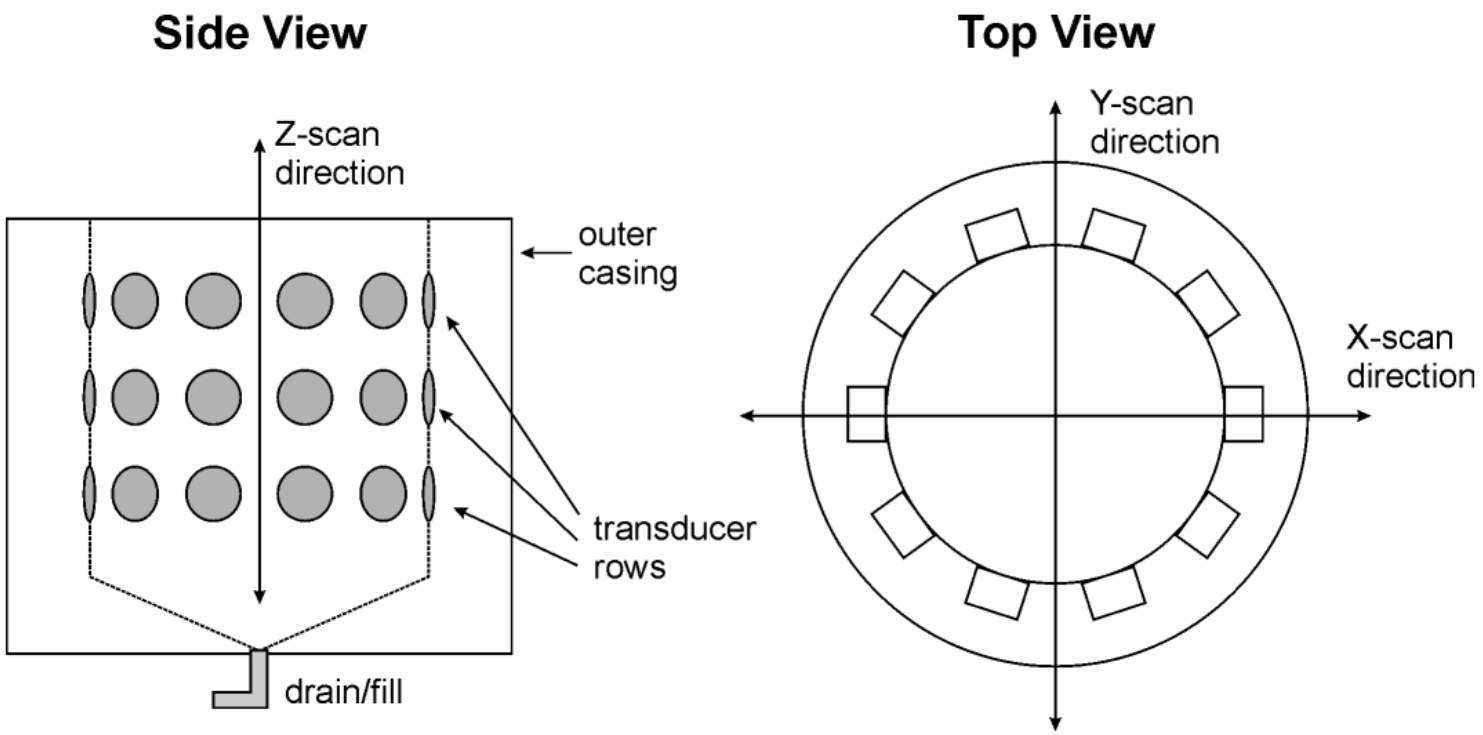
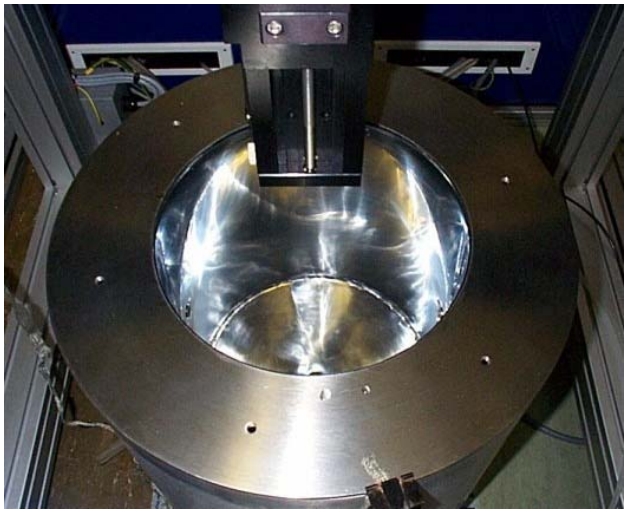
Schematic of 25 kHz reference vessel, describing X,Y and Z directions



Initial characterisation of the acoustic pressure field

- Carried out using Bruel and Kjaer 8103 hydrophone;
- **Filtered- deionised water used**;
- 50 ml of Olympus UCS II **surfactant** added;
- Typically, **pre-conditioning used**, 100 W for 30 minutes prior to measurements starting;
- Both spectral acquires, and $\mathbf{V}_{rms}$ undertaken.



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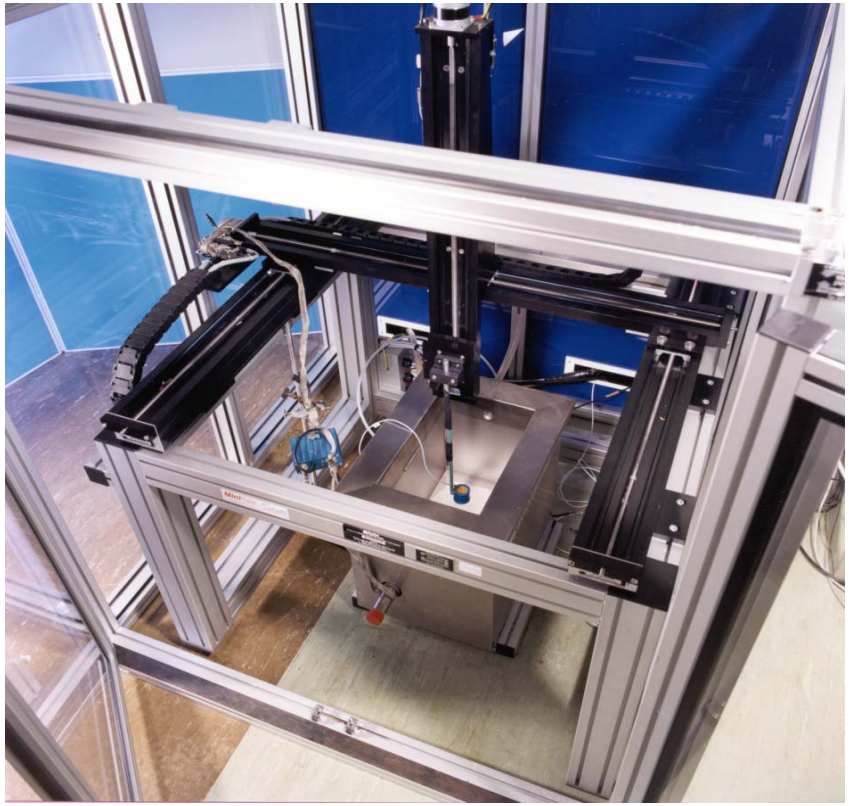
Integrated measurement facility

- Motor-driven three axis positioning system, resolution 5 μm;
- Environmental enclosure;
- Associated water management system;
- Responses of sensors measured using HP 3589A spectrum analyser or be-spoke prototype electronics.



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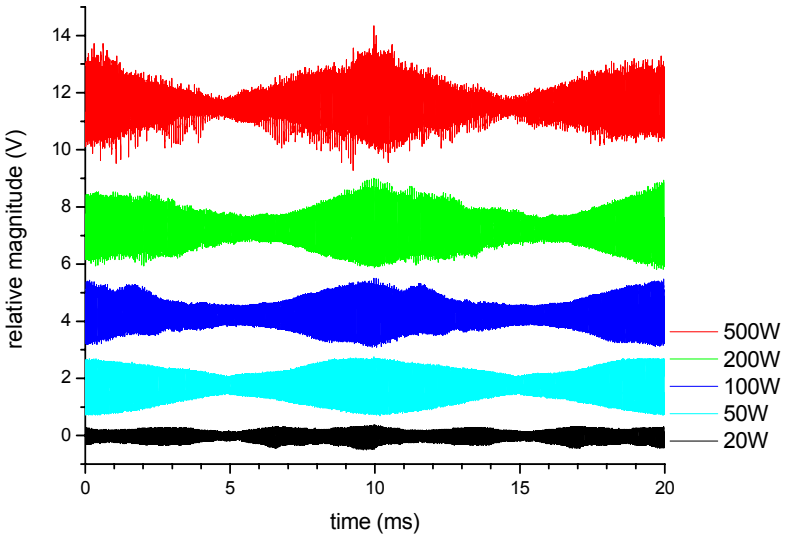
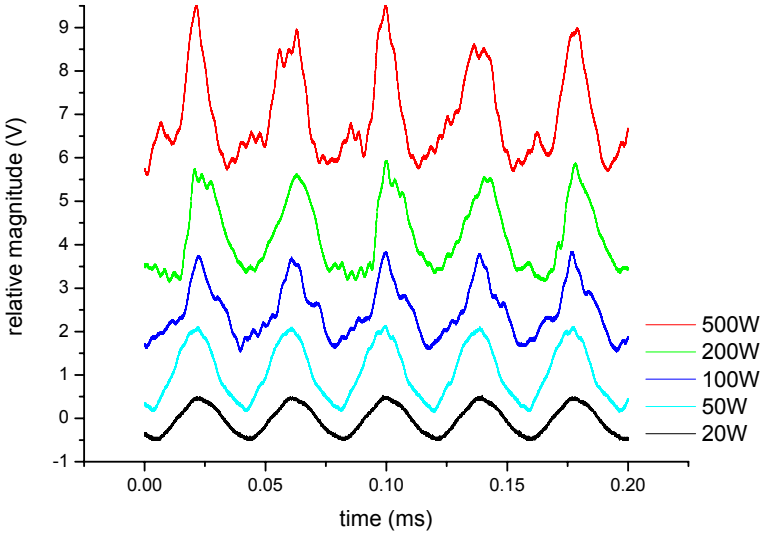
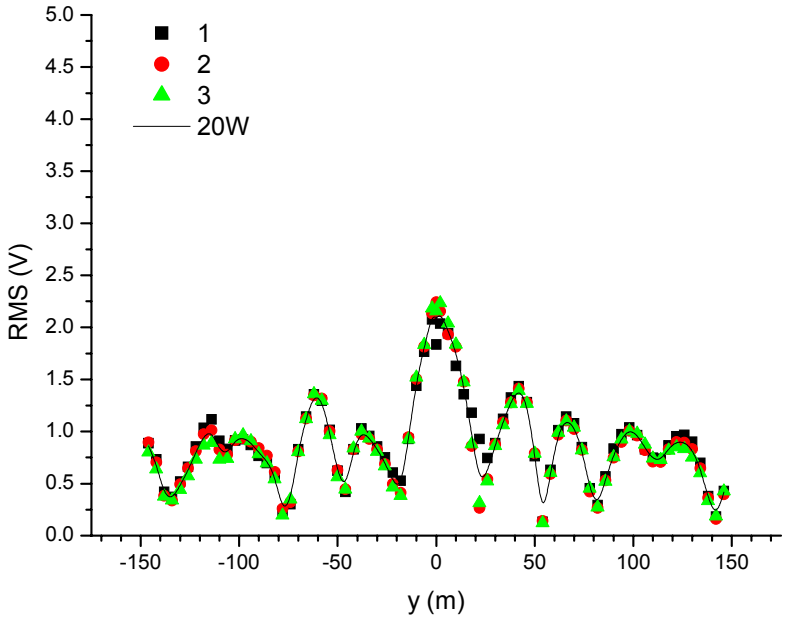
Acoustic pressure field: characterisation using a hydrophone

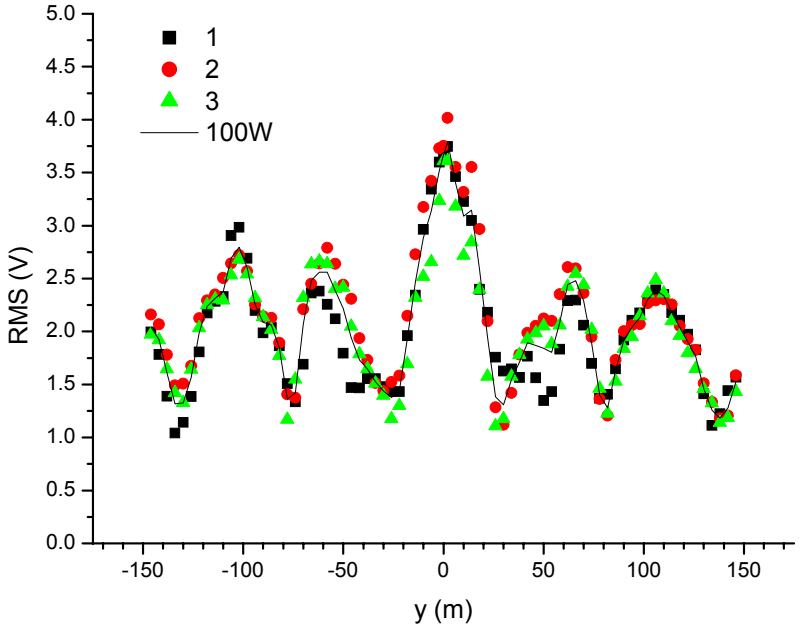
Typical waveforms 5 power settings and 5 cycles, determined using hydrophone





B&K 8103 hydrophone, at 20 W and 100 W; Y-axis, in-between transducers





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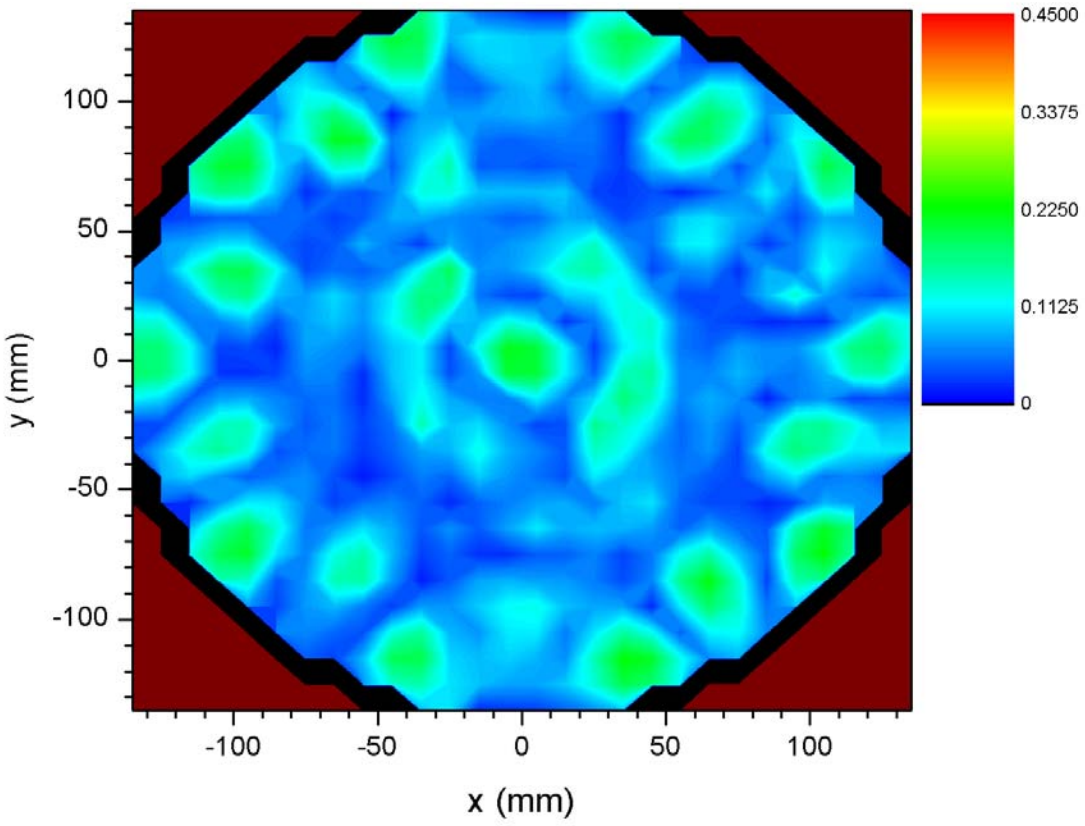
V_{rms}(x,y) at 20 W (dx = dy = 5 mm, 22.2 °C, color ranges:0 - 0.24).



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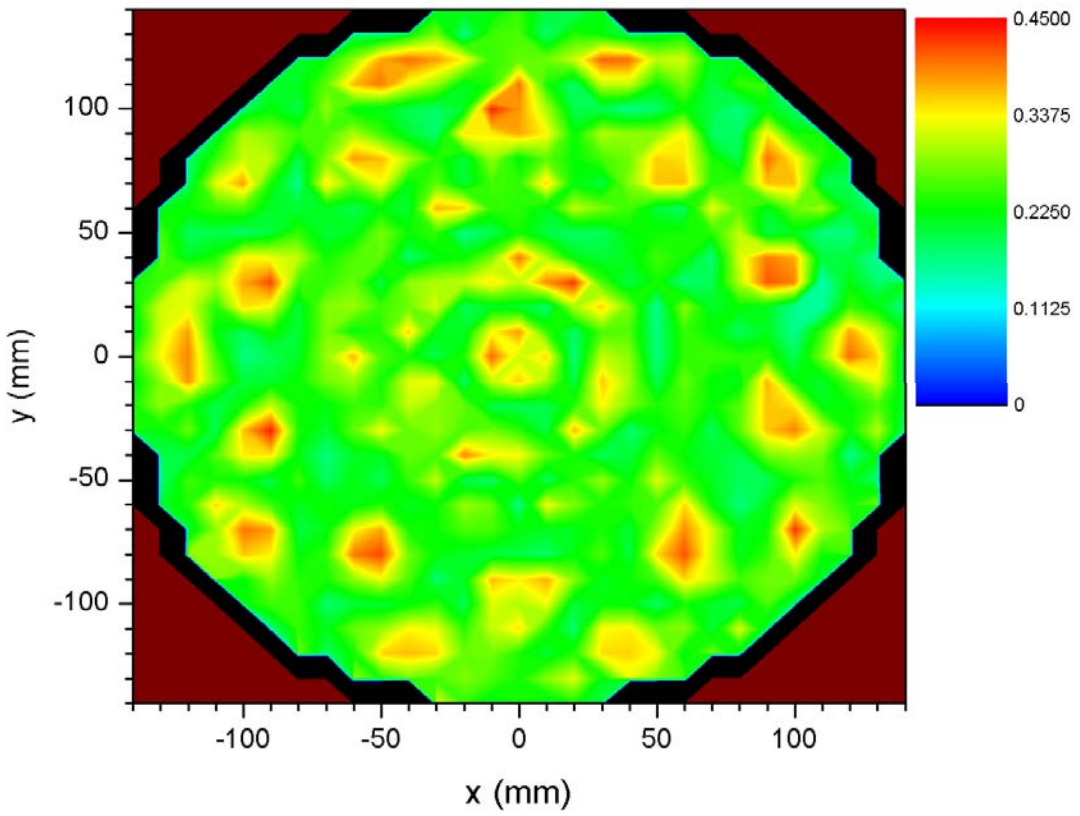
$V_{rms}(x,y)$ at 500W (dx = dy = 10mm, 25.6 - 33.9 °C, colour ranges: 0.1 - 0.45).



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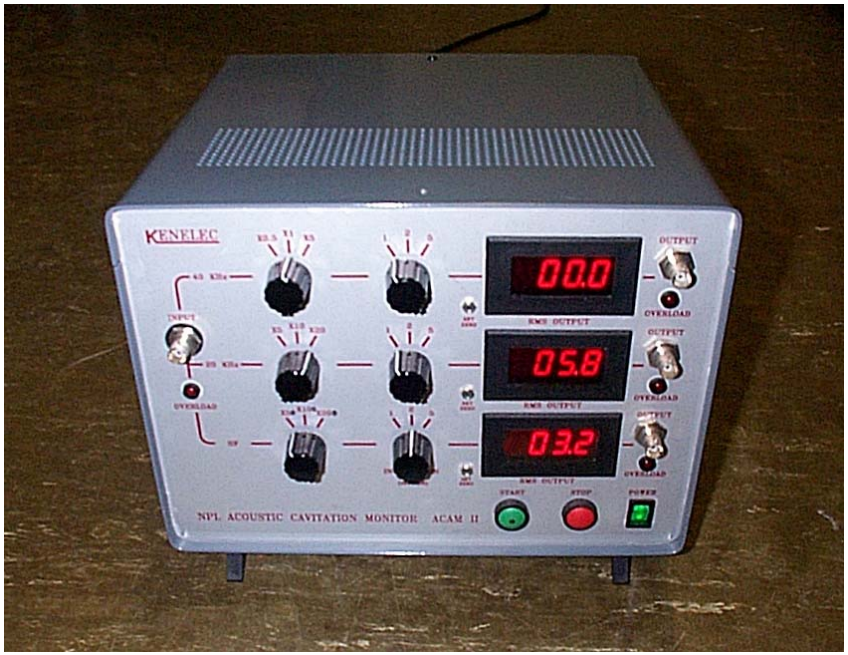
Preliminary characterisation of the cavitation activity distribution within the reference vessel

Custom-made electronics module used to analyse sensor signals

- Sensor signals fed to analogue electronics module (ACAM II);
- This gives the broadband *rms* signal level over the frequency range 1 to 7 MHz;
- This quantity is taken as a measure of the ‘degree’ of cavitation;
- Signal can be time-averaged over a period of 1, 2 or 5 seconds.



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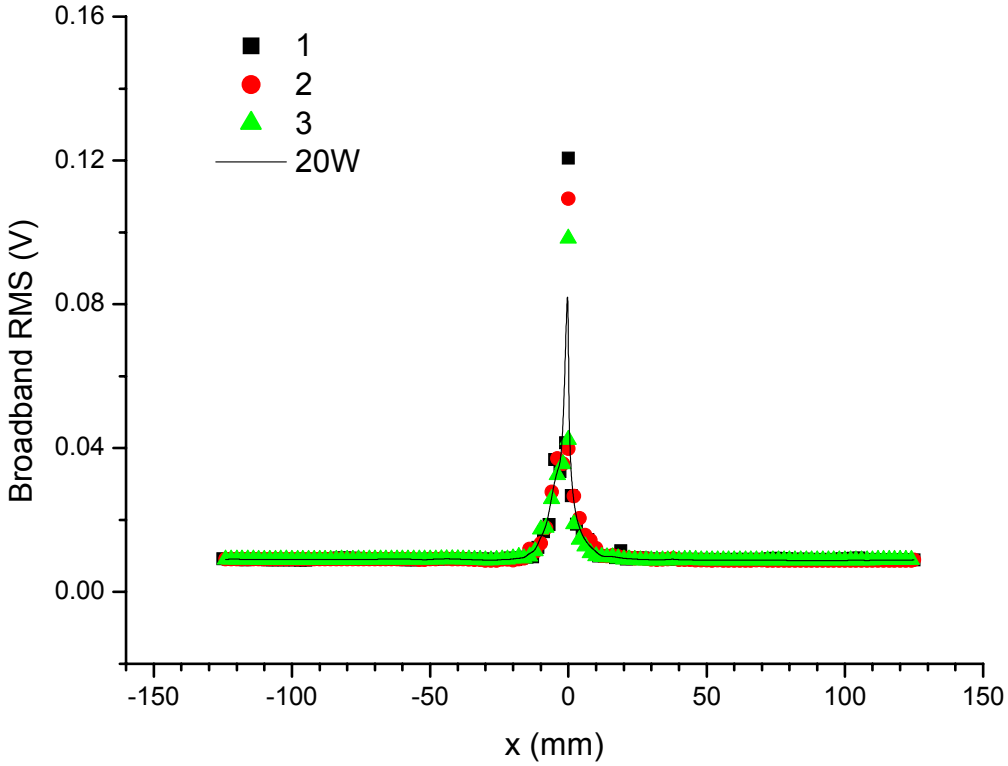
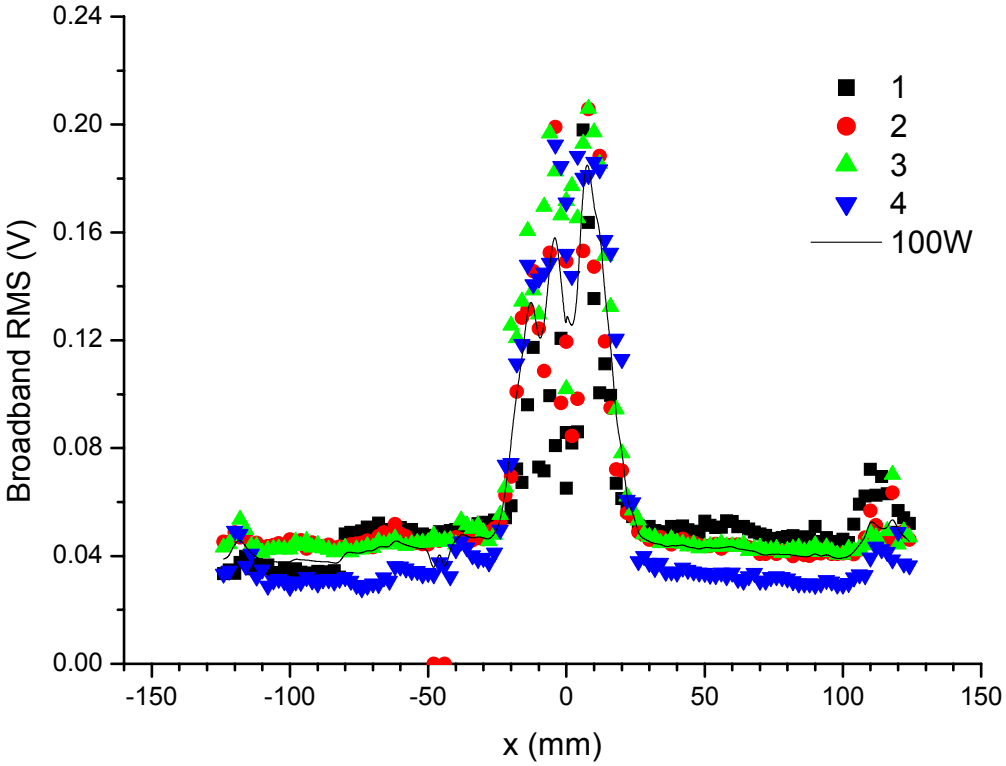
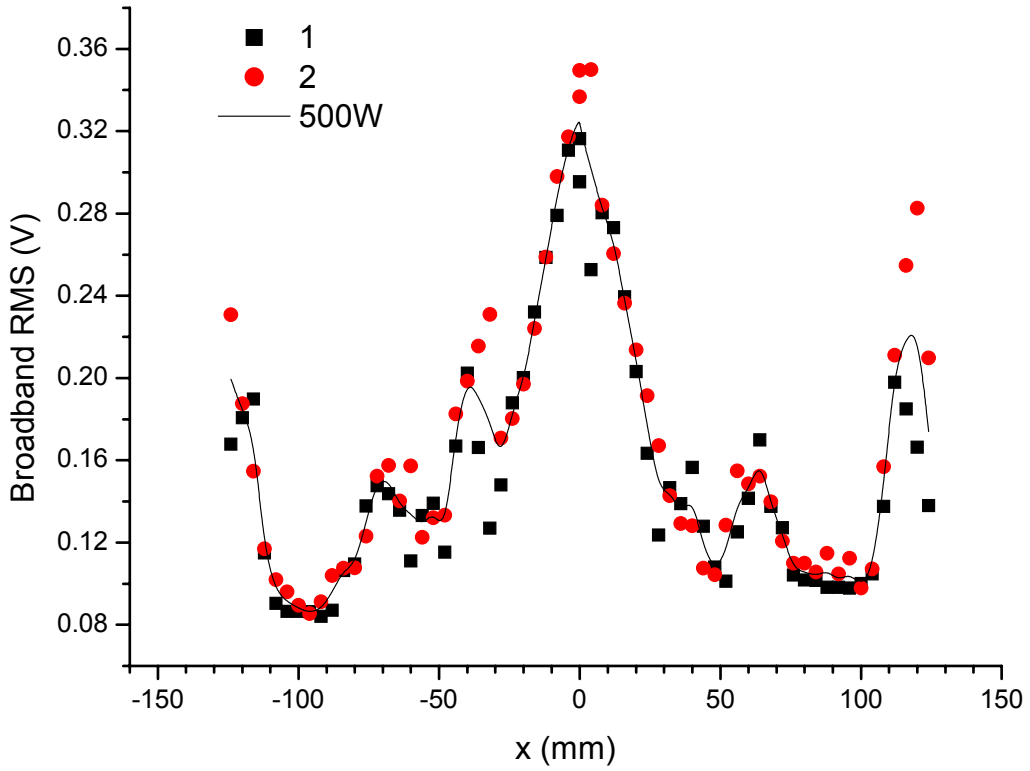
Nominal applied power: 20 W; Sensor: JIP_30_1; X-direction, 21.5 °C – 23 °C; 1 second averaging time.



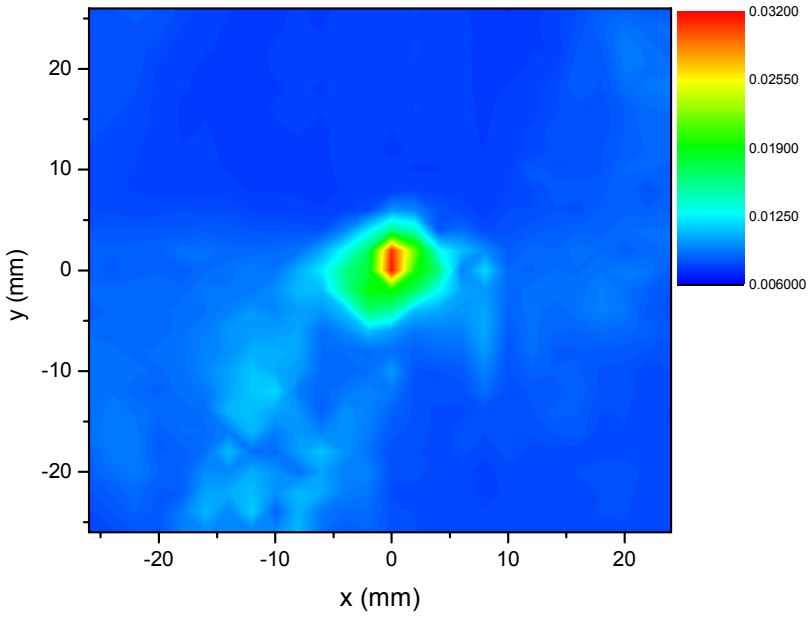
Nominal applied power: 100 W; Sensor: JIP_30_1; X-direction, 22.1 °C – 27.65°C;. 1 second averaging time.

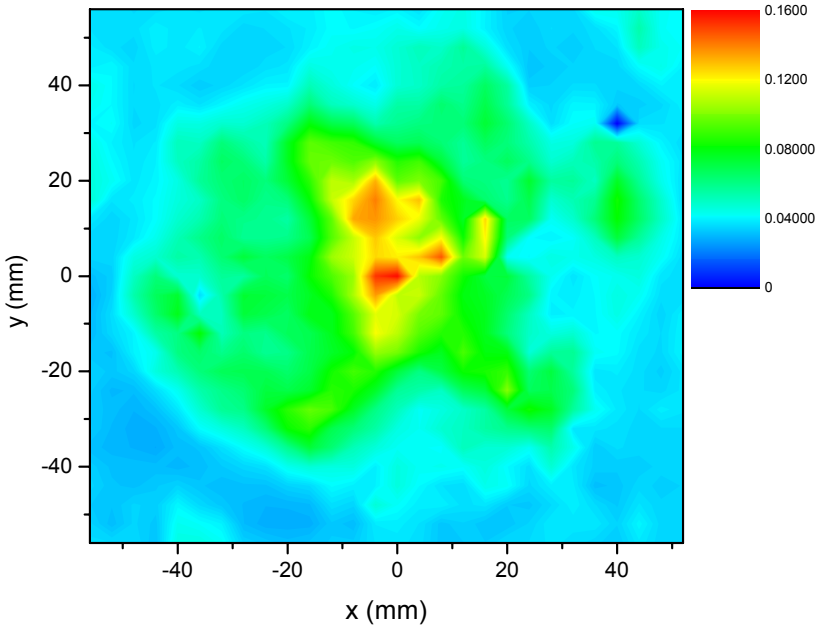


Nominal applied power: 500 W; Sensor: JIP_30_1; X-direction, 25.3 °C – 35.4 °C; 1 second averaging time.



2-D cavitation activity distribution, JIP_30_1. Left: 20 W; Right: 100 W.





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Future work

COMORAC: collaboration between NPL, ISVR, St. Thomas' Hospital, Bath University and Coventry University.

Bubble and Particle Dynamics in Acoustic Fields: Modern Trends and Applications, 2005:
ISBN: 81-7736-284-4 Editor: Alexander A. Doinikov

Characterisation Of Measures Of Reference Acoustic Cavitation (COMORAC): An experimental feasibility trial

T.G. Leighton[1], P. R. Birkin[2], M. Hodnett[3], B. Zeqiri[3], J. F. Power[1,2]
G. J. Price[4], T. Mason[5], M. Plattes[5], N. Dezhkunov[6] and A.J. Coleman[7]
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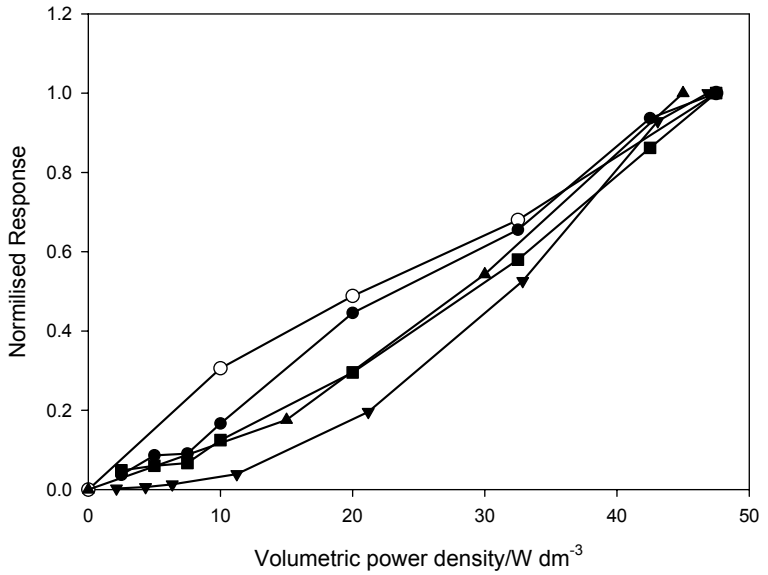
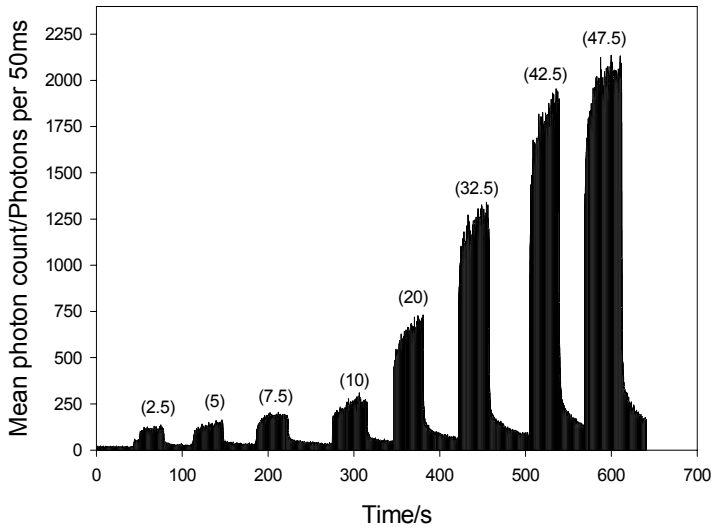
Abstract

There is a need to provide some standard measure for 'cavitation'. This has featured strongly within the requirements of the UK Department of Trade and Industry's National Measurement System Directorate,





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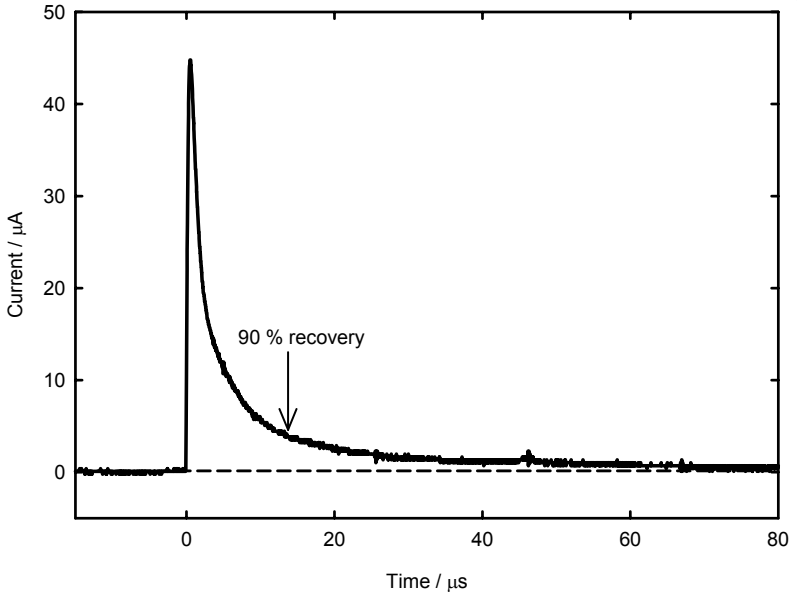
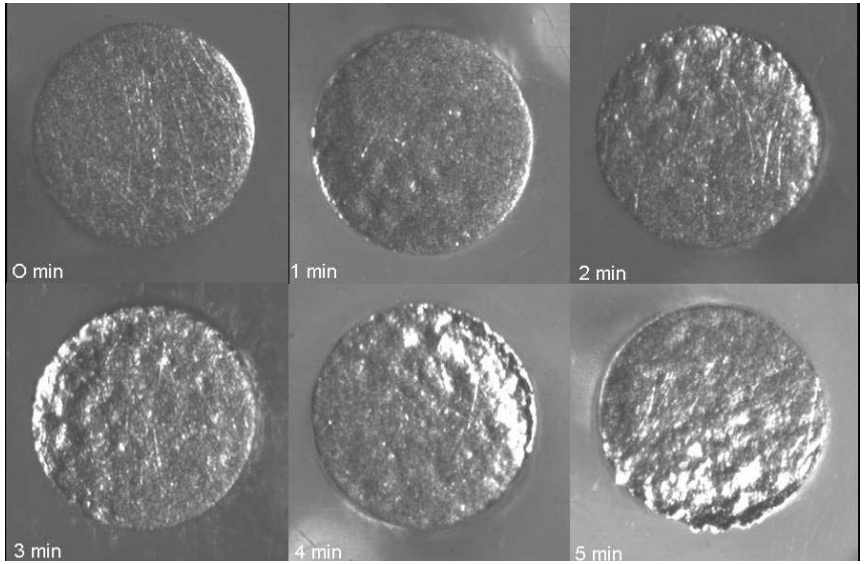
Surface erosion of an electro-chemical electrode

- Collaboration with Institute of Sound and Vibration Research, University of Southampton;
- novel electrochemical technique used to monitor surface erosion (Aluminium or Titanium);
- re-growth of passivating layer seen as rapid current spike;
- electrode is of high spatial resolution (250 microns).





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Summary

- Progress towards developing a **reference cavitation vessel** has been reported - the cylindrical sonochemical reactor vessel operates at 25 kHz and up to 1.8 kW;
- The spatial variation of **acoustic pressure** has been studied using an underwater acoustics hydrophone;
- The spatial distribution of **cavitation activity** has been evaluated using a novel cavitation sensor developed at NPL;
- Cavitation activity **correlates well** with the acoustic pressure distribution determined using the hydrophone.
- The performance of the **reference vessel** will be studied as the basis of a test-bed for cavitation monitoring methods.

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Support from the National Measurement System Directorate of the UK DTI is acknowledged

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