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Characterisation of industrial high power ultrasound fields using the NPL Cavitation Sensor

Mark Hodnett
Senior Research Scientist
Quality of Life Division
National Physical Laboratory
Teddington
Middlesex, UK

Presentation roadmap

- Background
- Experimental set-up
- Systems studied
  - 40 kHz cleaning vessel
  - 20 kHz sonochemical horn
- Conclusions

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Background

- High power ultrasound and cavitation used across a wide range of applications
- No standardised measurement methods available
- Availability of such techniques would enable scale up of technology in an informed manner, and improve fundamental understanding of cavitation process
- NPL has been active in this technical area since 1995, surveying users, establishing reference facilities and developing sensors for characterising cavitation, and collaborating with industry and academia

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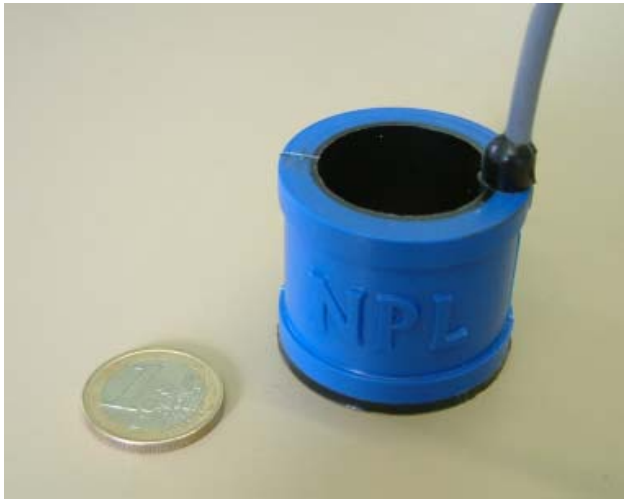
NPL cavitation sensor

- Hollow right-circular cylinder, 30 mm diameter, 28 mm high
- Acoustic emissions from bubbles detected using thin piezoelectric polymer material (~110 micron)
- 4 mm thick polyurethane absorbing ‘shield’ eliminates MHz signals generated from bubble events outside the cylinder
- Perturbation of drive signal kHz component minimised by using acoustically matched absorber material
- Cylindrical geometry provides central line focus



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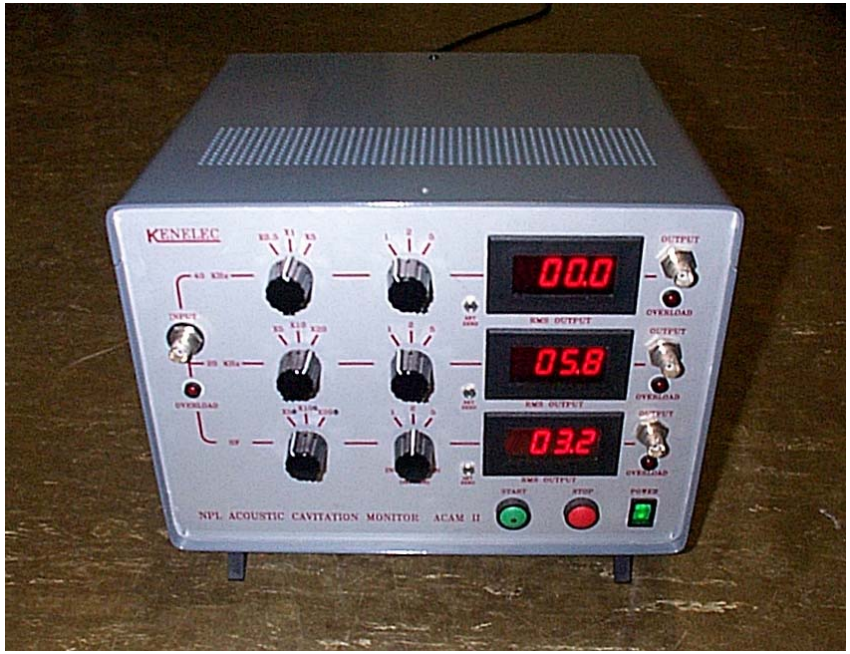
Custom-made electronics module used to analyse sensor signals

- 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 ‘amount’ of cavitation
- Signal can be time-averaged over a period of 1, 2 or 5 seconds
- BNC output for external monitoring of signals using ‘scopes or RMS meters under computer control



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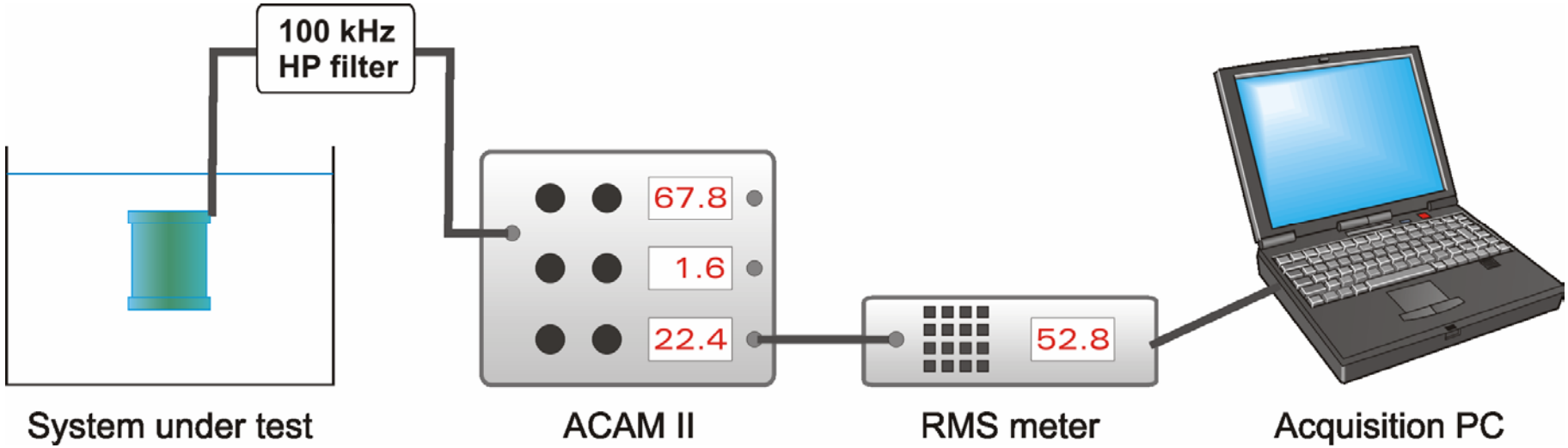
Experimental schematic



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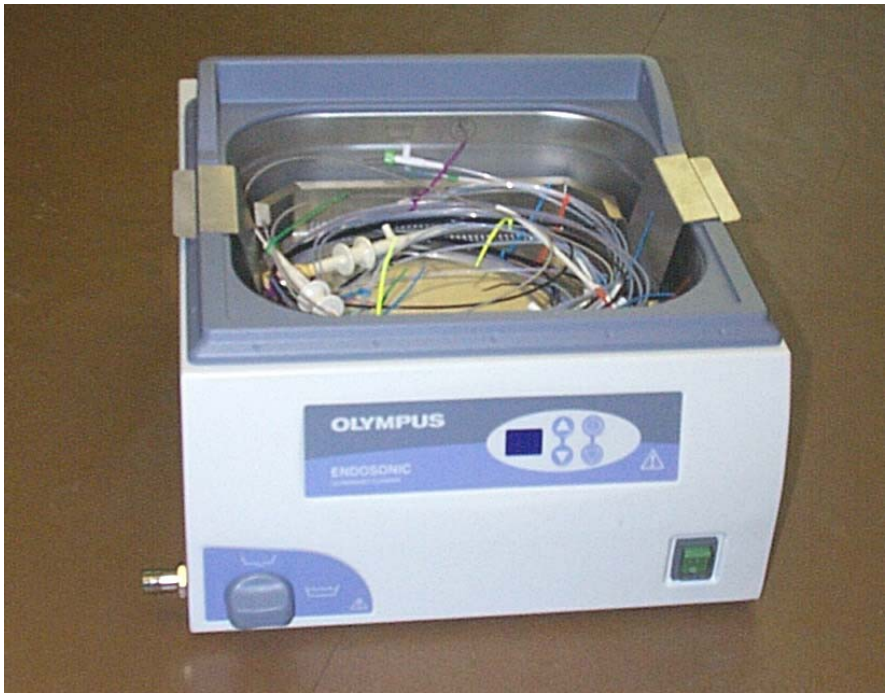
40 kHz Cleaning Vessel

Cleaning vessel specification

- Four transducer system, with a nominal operating power of 250 W
- 330 mm by 300 mm by 130 mm (depth)
- Nominal drive frequency of 40 kHz, swept over the range 38 to 43 kHz
- Vessel driven outside of specification, generating a power of 140 W



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Experimental investigations

- Vessel filled with 7 litres of deionised water, with Micro 90 surfactant added, to an average depth of 80 ± 2 mm

- ➢ Assessment of erosion of aluminium foil: samples deployed horizontally and vertically

- ➢ Assessment of cavitation distribution, using sensor, signal processing electronics and acquisition system

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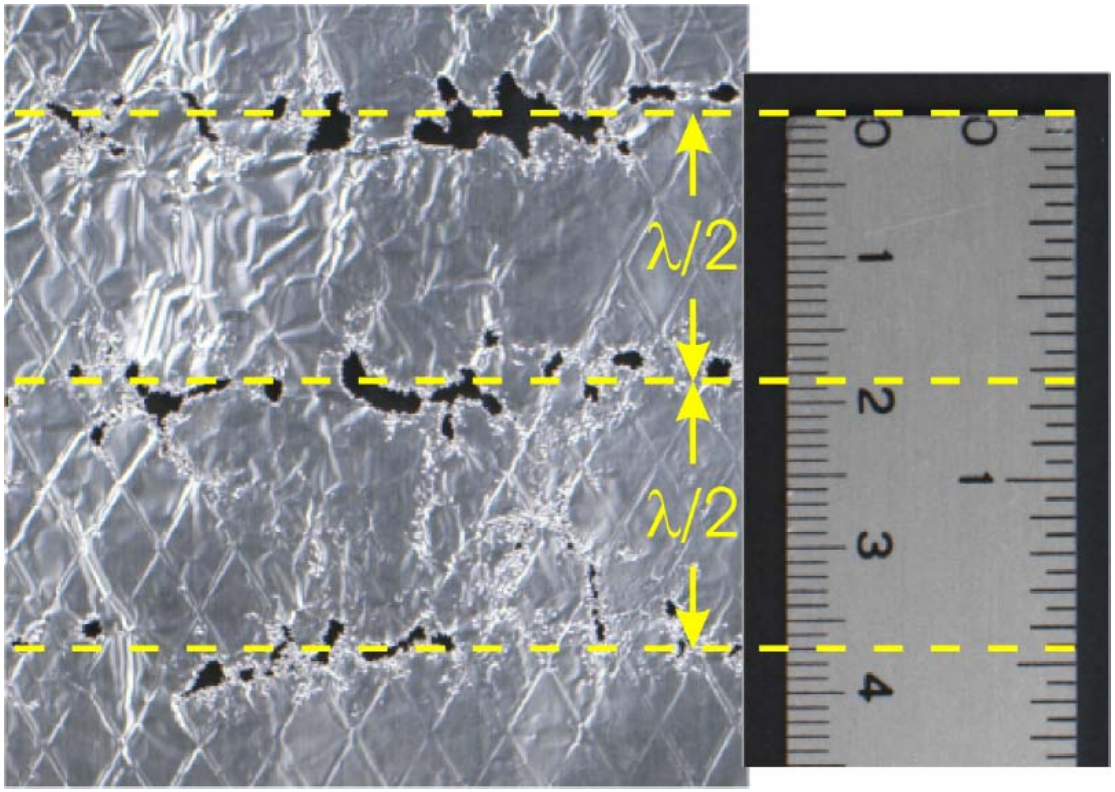
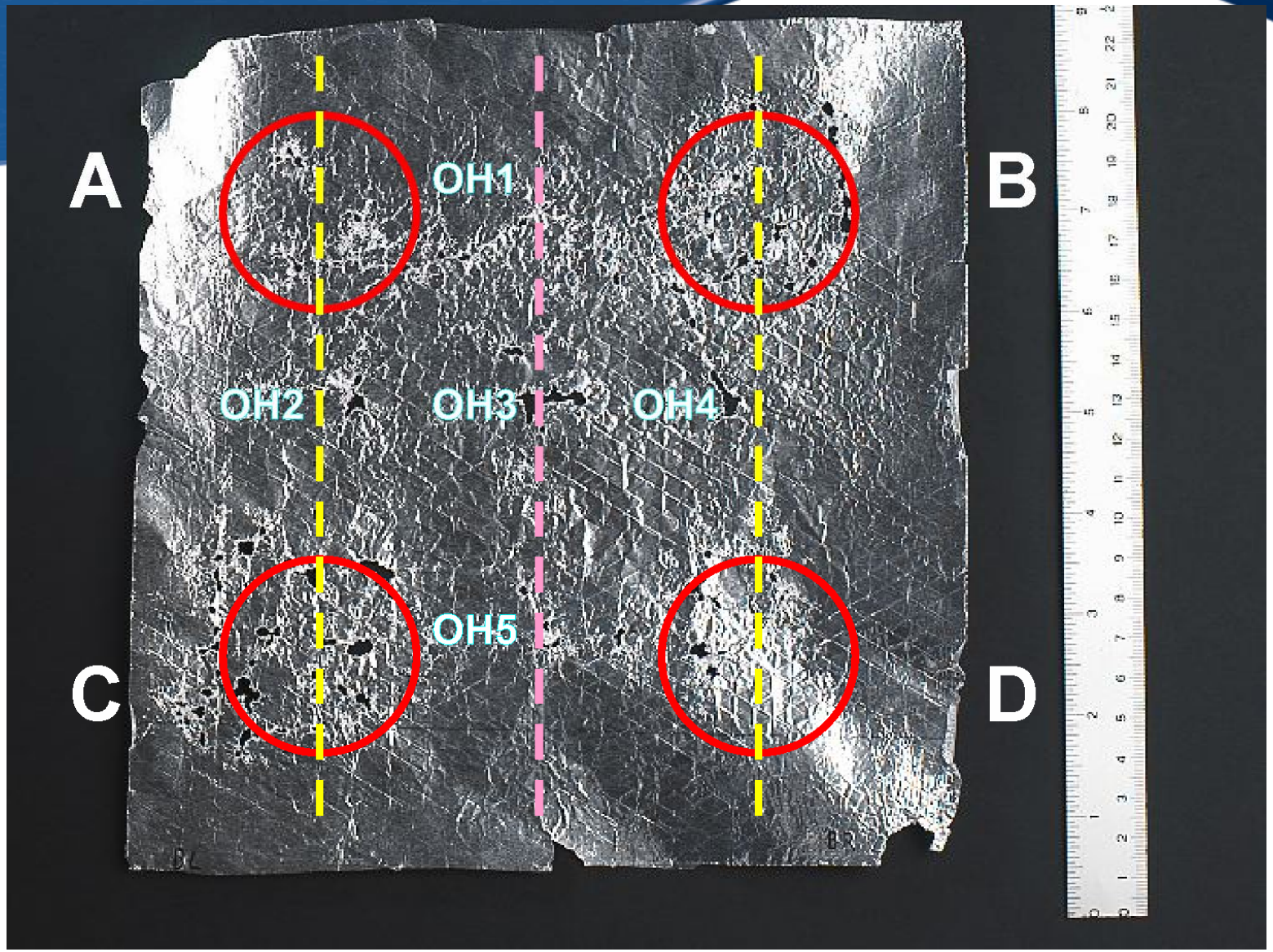
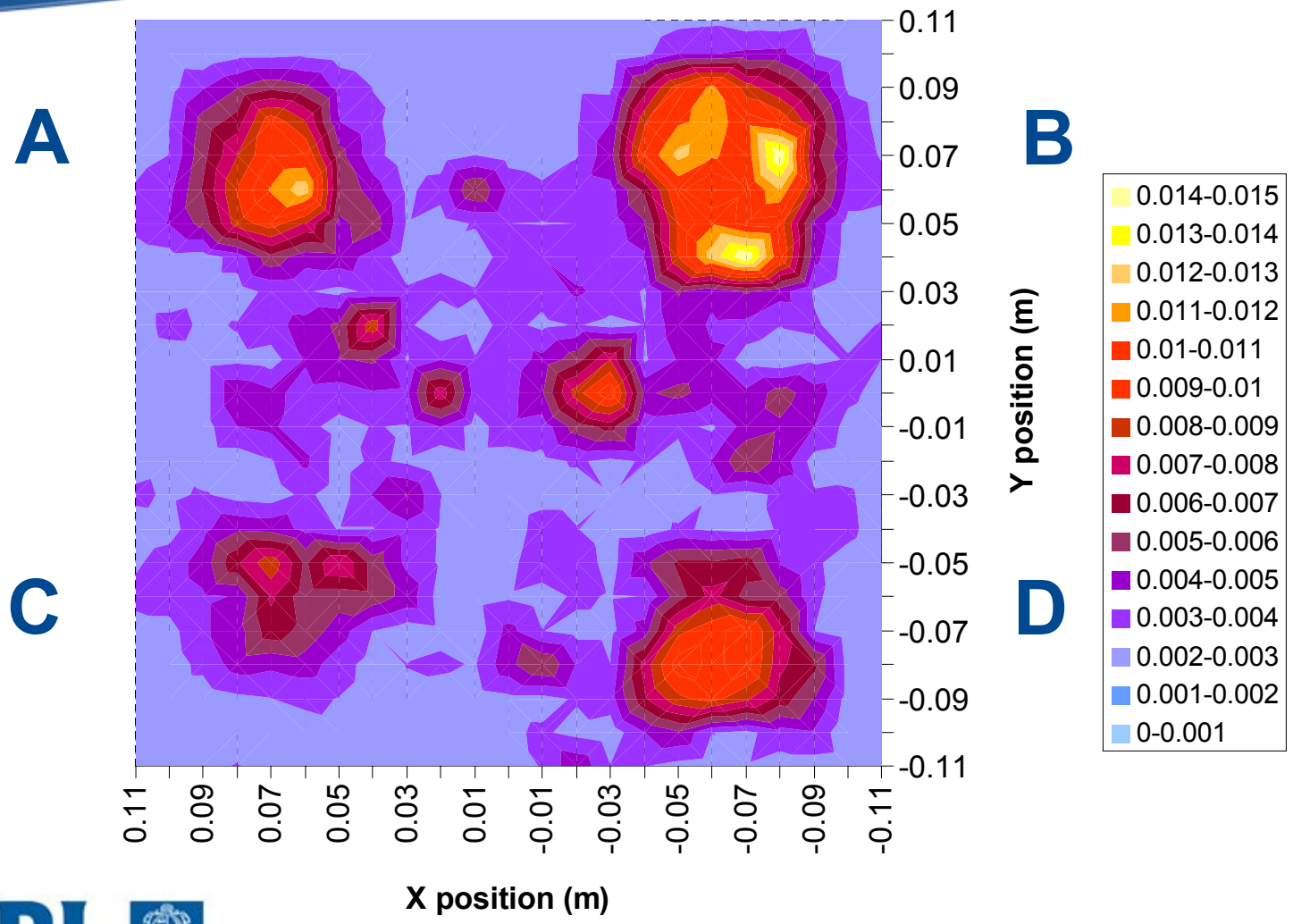
Erosion patterns – vertically deployed



Erosion results – horizontally deployed



Cavitation sensor measurements – 2D



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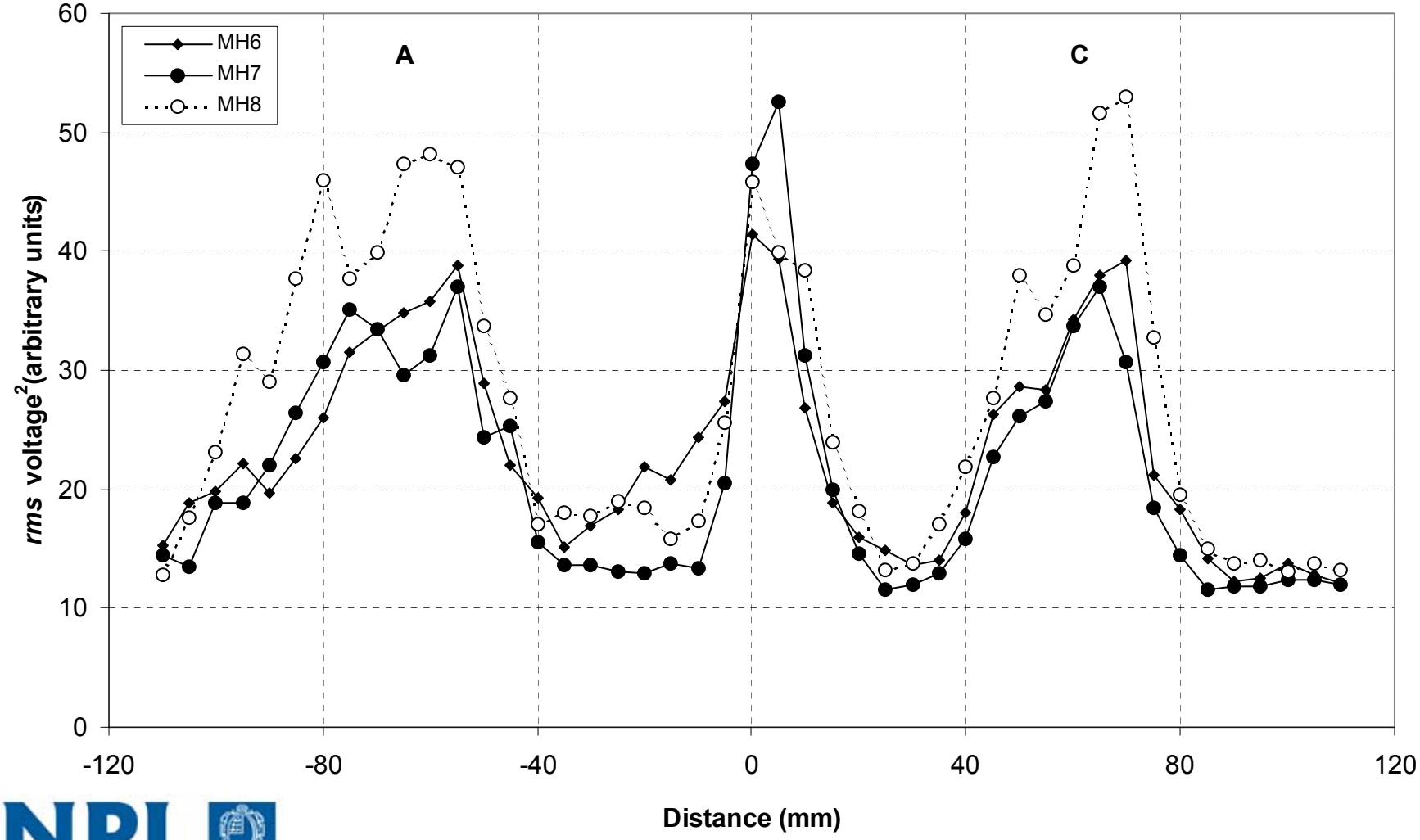
Cavitation sensor measurements – line through transducers A and C



Observations

- The sweep circuitry used does not prevent the formation of standing waves in the vertical plane
- Regions of strong foil erosion are noted directly over transducers and also between transducers (due to reflections and beam overlap)
- Cavitation sensor measurements of broadband emissions from bubble collapse are reproducible, and show a similar qualitative distribution, with clear local maxima over and between transducers

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20 kHz Sonochemical horn processor

Sonochemical horn specifications

- 20 kHz Sonics and Materials VC600 sonicator horn processor
- Calorimetric intensities in the range 0 - 120 W cm^{-2}
- Operated into a 350 cm^3 cylindrical vessel
- Measurements made of cavitation activity as a function of power setting
- Companion measurements of sonoluminescence and radical production carried out using the same experimental set-up

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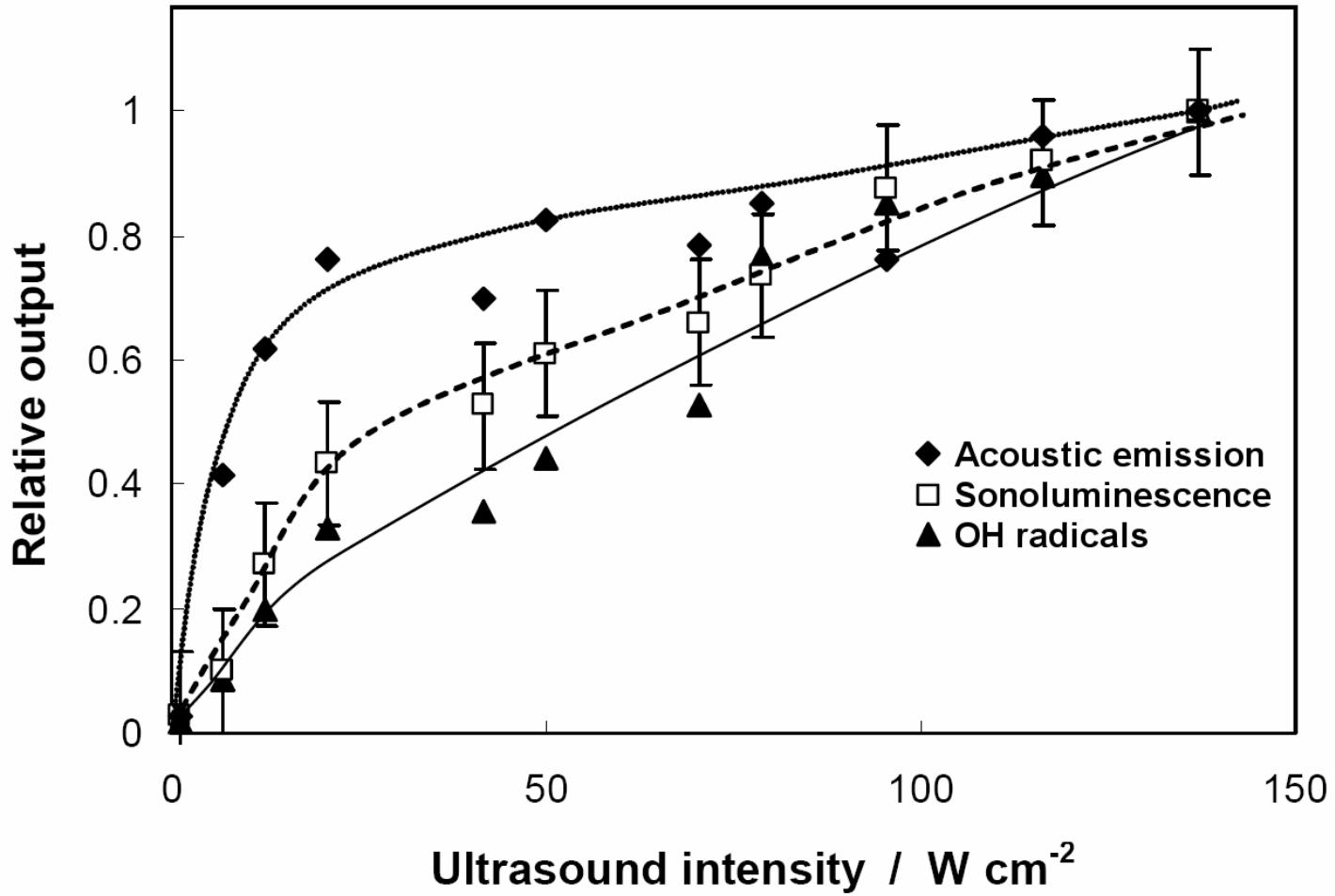
Results


Relative output
1
0.8
0.6
0.4
0.2
0
0
50
100
150
Ultrasound intensity / W cm-2
Acoustic emission
Sonoluminescence
OH radicals

Compare and contrast

- Relative levels from systems measured are difficult to compare directly due to a range of sensor designs being used, different frequencies and field geometries, and different containers
- Approximate broadband rms levels (using same sensor and electronics chain) are
  - 20 kHz sonochemical horn processor: **800 mV**
  - 25 kHz sonochemical processor: **300 mV**
  - 40 kHz cleaning vessel: **140 mV**

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Where are we now?

- Cavitation sensor data currently being compared with alternative cavitation monitoring techniques using reference vessel
  - Chemical, Optical, Erosive
- Specifications for sensor and signal processing electronics finalised
- Reproducible small batch manufacture of sensors now achievable

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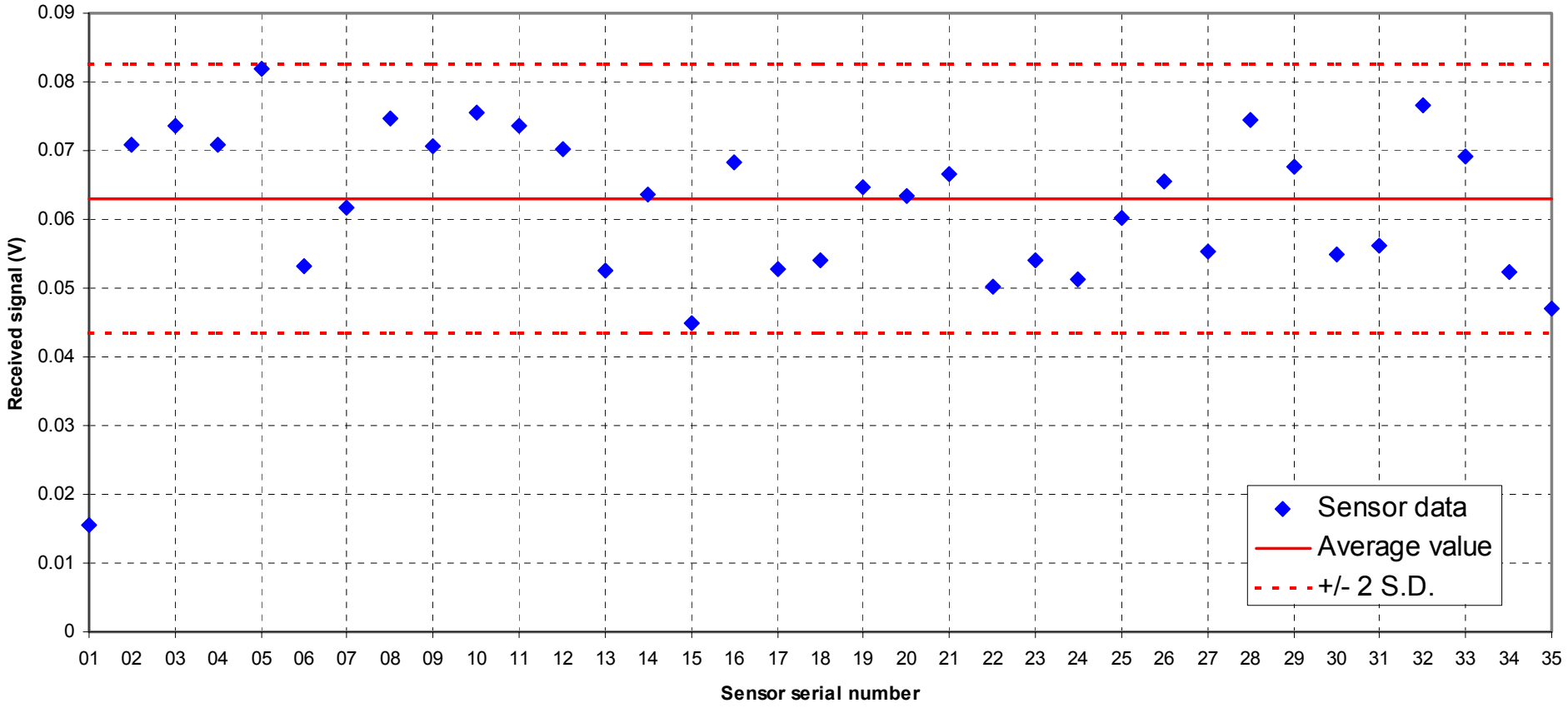
Reproducible manufacture



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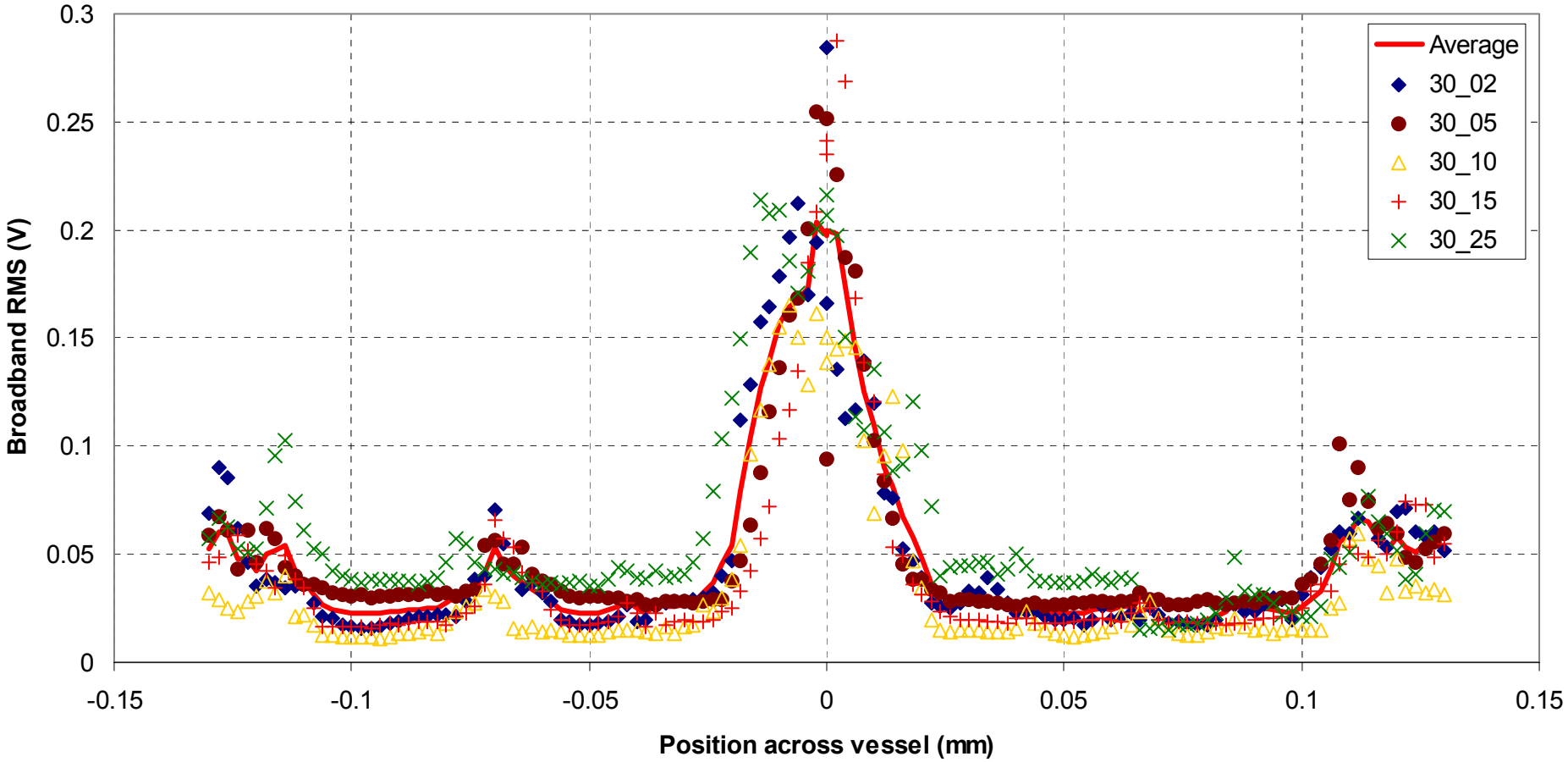
Consistent performance



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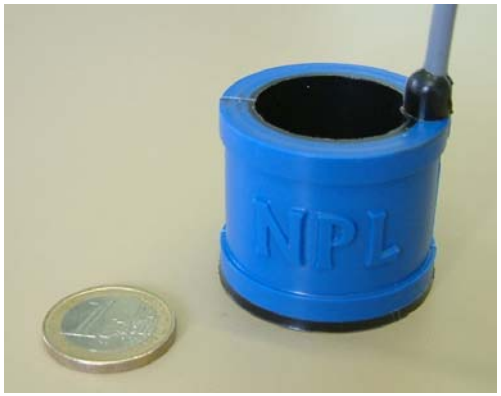
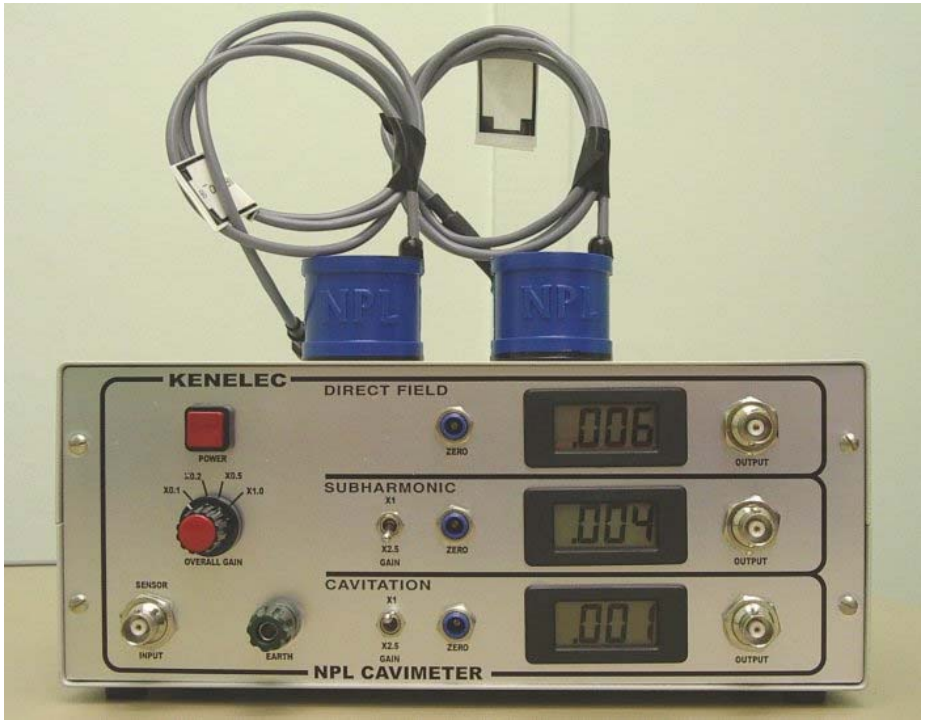
Next steps

- Four sets of cavitation sensors and processing electronics (‘Cavimeter’) will shortly be trialled by UK industry (KeyMed, MediSafe, Ultrawave and Sonic Systems) as part of UK Government Joint Industrial Project
- Sensor also being tested by UK water industry





Overall conclusions

- Sensor and signal processing electronics used to characterise cavitation produced by a range of commercial systems ranging from low intensity (cleaning vessel) to high intensity (sonochemical processor)
- Together, they represent versatile, valuable tools for characterising cavitation activity in real industrial systems
- Work is ongoing to investigate correlations with other cavitation monitoring techniques, and to trial the system on the ‘shop floor’
- Commercial availability of sensors and electronics – Q3 2006

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Acknowledgements

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