PRECISION ACOUSTICS

Passive cavitation detector

The Passive cavitation detector is a type of hydrophone specifically designed to provide optimum signal-to-noise ratio in the measurements of cavitation induced acoustic signals. All PCDs are custom designed to suit the client's specific requirements. Typically PCDs are tuned to have a frequency response and focal region (if any) that is optimised for a given experimental configuration. Whilst most PCDs have circular or hemispherical active elements, alternative geometries such as annular (shown above), square or triangular are possible.

INTRODUCTION

Cavitation is often induced by an external acoustic field. Whilst these external fields typically have very high acoustic amplitudes, the acoustic emissions from cavitation events can be several orders of magnitude smaller. High sensitivity sensors are therefore needed for the measurement of these low-level signals arising from the cavitation. However this presents a problem since the high acoustic amplitude of the driving acoustic field is likely to overload the input of the data acquisition system connected to the cavitation detector. Even if the system is not overloaded, it will be very difficult to resolve the small signatures of cavitation in the presence of a large source signal.

For transient sources (e.g. from a medical lithotripter) it is possible to time gate the driving acoustic signal from the acoustic signatures of cavitation activity. However for continuous sources (e.g. from High Intensity Focused Ultrasound (HIFU) or High Intensity Therapeutic Ultrasound (HITU) devices) this temporal separation is not possible.

A solution to this problem arises from the typical acoustic spectrum arising from cavitation activity. The acoustic emissions from stable cavitation are characterized by well-defined spectral peaks at integer harmonics and sub-harmonics relative to the fundamental bubble resonant frequency. With the onset of inertial cavitation there will additional broadband high frequency contributions created by the collapsing bubble. For this reason it is common practice to use a PCD that has a centre frequency at least 3 times higher than the frequency of the drive signal and preferably 5 times higher. In this way you can use the natural frequency response of the PCD to filter out most of the drive signal yet remain very sensitive to the acoustic emissions of cavitation events.

The other advantage of higher frequencies is that the focal region of the PCD will be less than that of the HIFU source. If the focal region of the PCD is greater in axial extent than the HIFU source, there is a risk of being sensitive to cavitation induced emissions that have occurred in the pre-focal region. This is clearly undesirable. Clearly if the PCD is not being used con-axially, but simply in con-focal (ie transverse) arrangement, then focal region overlap is not an issue.

USE WITH OTHER MEDICAL IMAGING MODALITIES

Other imaging modalities such as MRI and CT are increasingly being used in conjunction with clinical HIFU systems to gain additional data. Often this other modality is being used to provide feedback with regards to the HIFU treatment. In these situations it may be advantageous to be able to correlate the imaging data with the acoustic emission data from a PCD.

Precision Acoustics Ltd is pleased to be able to provide both CT and MRI compatible PCDs. An example of a CT image of a PCD is shown in Figure 1.

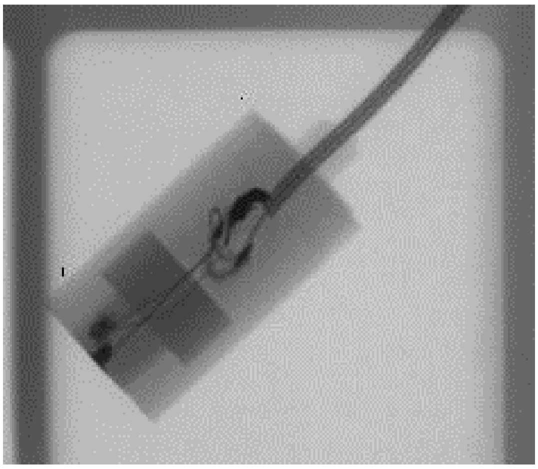


Figure 1 – X-ray image of a CT compatible PCD

MEASUREMENT CONFIGURATION

When using a PCD it is important to consider how it will be used, particularly if it will be recording the signals generated by a focussed ultrasound source like a HIFU transducer. As seen in Figure 2, con-focal and co-axial configurations are common.

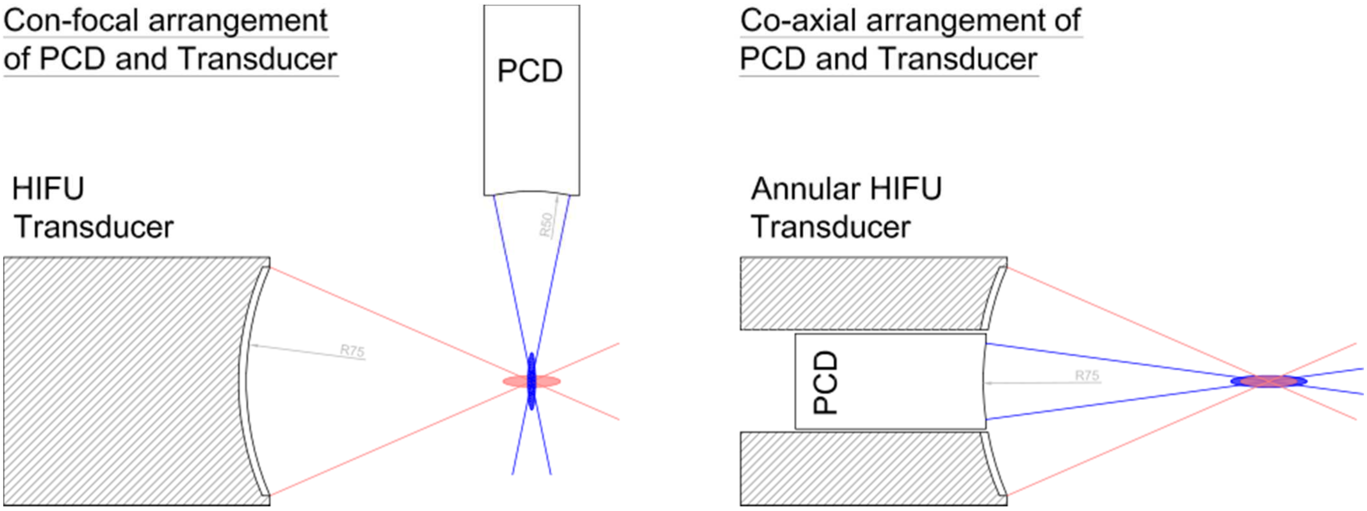


Figure 2 – Con-focal and co-axial configurations

The strongest cavitation activity will occur within the focal zone of the source (shown in pink regions within Figure 2) whereas the PCD will only be sensitive to the acoustic emissions from within its focal zone (shown in blue on the diagram). The con-focal arrangement has the advantage of having only a small region of overlap of the two focal zones. Therefore it is possible to map cavitation activity as a function of distance from the transducer by translating the PCD in the direction of the axis of the HIFU transducer.

However this arrangement incurs some measurement complexity as both PCD and transducer have to be aligned so that their focal zones overlap. This is typically done by temporarily placing a spherical reflector in the field of the PCD and using it as a pulse/echo transducer. The PCD is translated in three orthogonal directions until the back echo is maximised. The HIFU transducer is then also used as a pulse/echo device and the procedure repeated. The spherical reflector can then be removed once both PCD and transducer are aligned. Co-axial arrangements are most relevant for annular ultrasonic sources. The PCD can then be introduced via the central aperture and its position adjusted so that the focal regions of source transducer and PCD are aligned.

Whenever aligning a PCD with a focussed transducer it is important to compare the dimensions of the focal regions of the two devices. Sample PCD profiles (both axially and laterally) can be found later in this document. Note also that focal zones (PCDs and transducers) are typically elliptical with the axial width being 10-20 times greater than the lateral width.

TECHNICAL SPECIFICATION

PCDs can be constructed with a wide variety of different options. The table below provides examples of some of the construction parameters that can be altered, along with a typical range of values.

Combinations of parameters outside these ranges may also be possible. Please discuss your specific requirements with a member of our team.

Sensor material	Polyvinyl difluoride (PVdF)
Active element diameter	4 to 60 mm
Typical bandwidth	50 to 120% of centre frequency
Nominal centre frequency	3 to 15 MHz
Focus type	Spherical (point), Cylindrical (line) or unfocussed
Focal length	10 to 300 mm
Case material	316L Stainless steel or MRI/CT compatible polymer
Termination	1.5m RG58 50 Ω Co-axial Cable as standard but other options available on request

SAMPLE PASSIVE CAVITATION DETECTOR PERFORMANCE

Given the wide range of possible configurations of PCDs it is not possible to provide typical performance data. However this section provides some sample data for a PCD produced with the following design parameters:

Diameter 19mm, Focal length 50mm Centre frequency 11 MHz, Widest possible bandwidth.

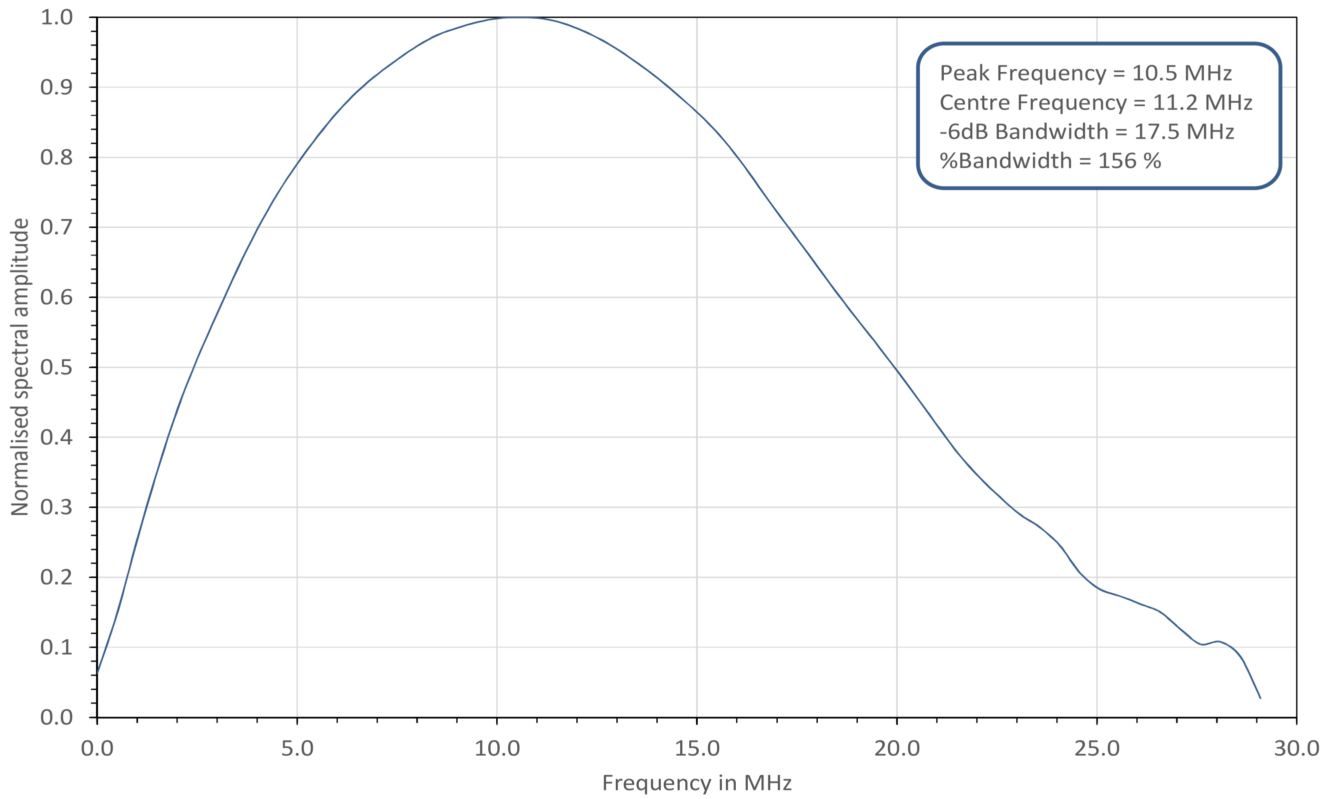
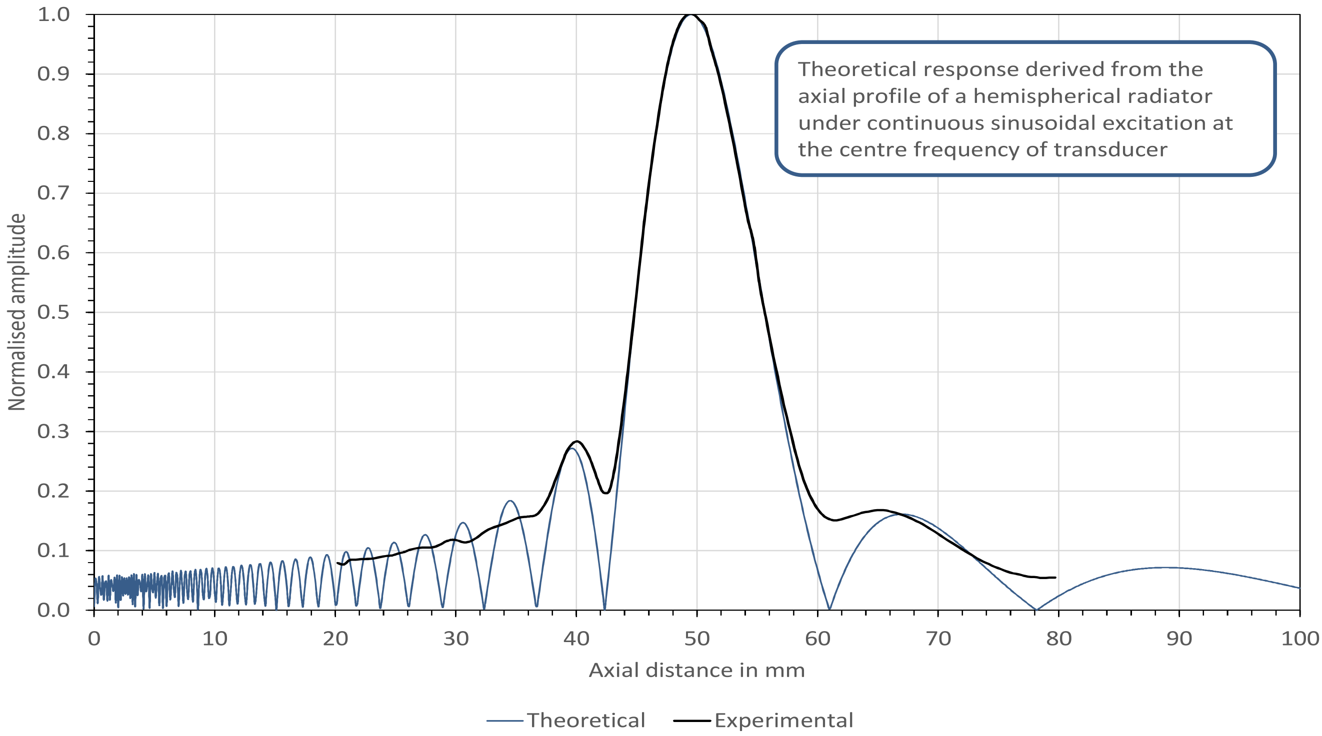
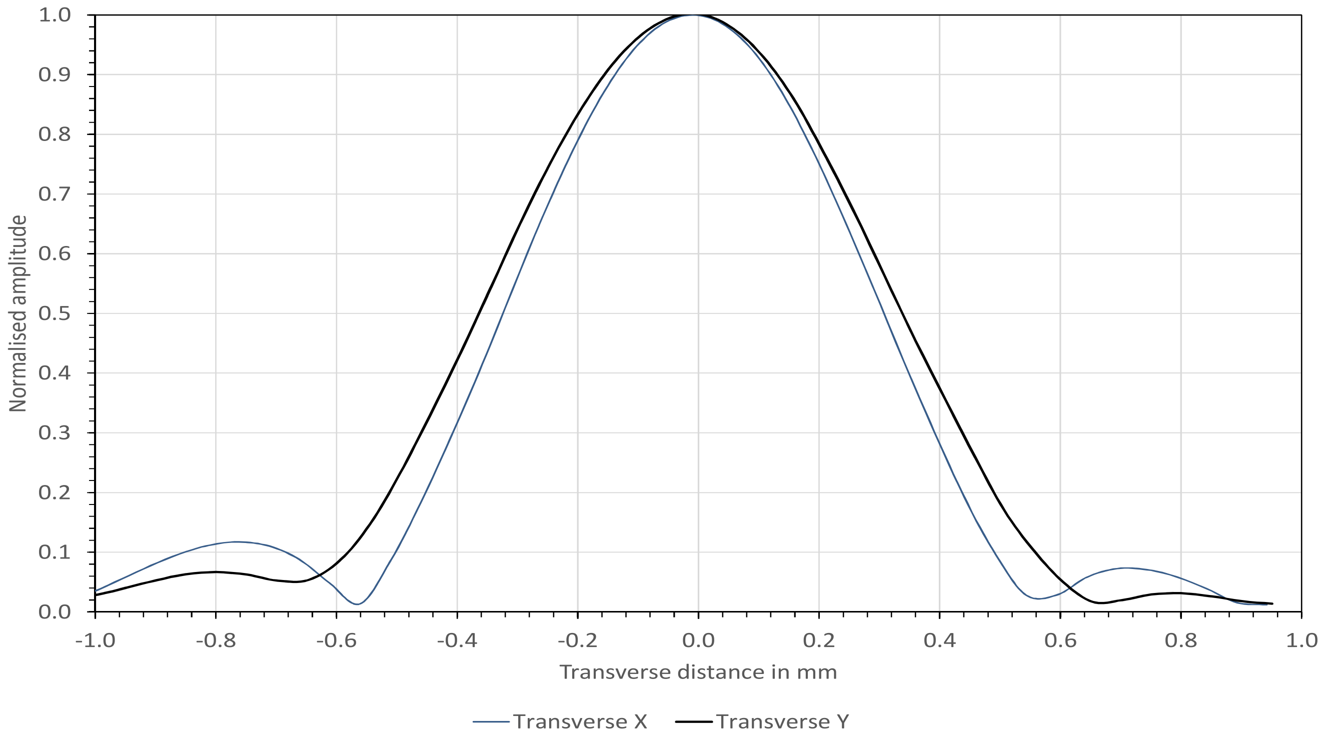


Figure 3 - Typical frequency response of a Passive cavitation detector

BEAM PROFILES

The axial and transverse pressure profile of this sample PCD is shown in comparison with the theoretical response for a hemispherical radiator of diameter 19mm, focal length 50mm and subject to continuous sinusoidal excitation at 11 MHz.





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