HIFU hydrophone

Introduction

The high-intensity focused ultrasound referred to as HIFU (also HITU, High Intensity Therapeutic Ultrasound) is used successfully increasingly in medical applications such as tumour therapy. All over the world, numerous research institutes are dealing with the application of extremely high-output ultrasound in order to treat cancer diseases. The ablation of tumours (thermal tissue destruction) of the prostate, the liver, the kidneys and the pancreatic carcinoma that is already a success demonstrate the tremendous development potential of this method. On the one hand, highly focused ultrasound fields generate temperature rises to up to 90 °C (hyperthermia) in the treatment area; on the other hand, locally occurring cavitations cause the destruction of the cancer cells.

The advantages of the HIFU method are, above all, the accuracy, the low invasivity and the lack of risks and side effects arising from the exposure to radiation.

In order to ensure an efficient and low-risk treatment using HIFU, a clear therapy regime is required. The prerequisite for this is detailed knowledge of the ultrasound fields to be used. To this end, it is necessary to measure the intensity distributions of the HIFU probes as precisely as possible as well as with high spatial resolution. Since it is mainly the extremely high sound pressure amplitudes of up to 100 MPa that have to be recorded, conventional membrane or pointed hydrophones are hardly considered for use as measuring equipment, as they are destroyed by means of the high intensities within a very short period of time.

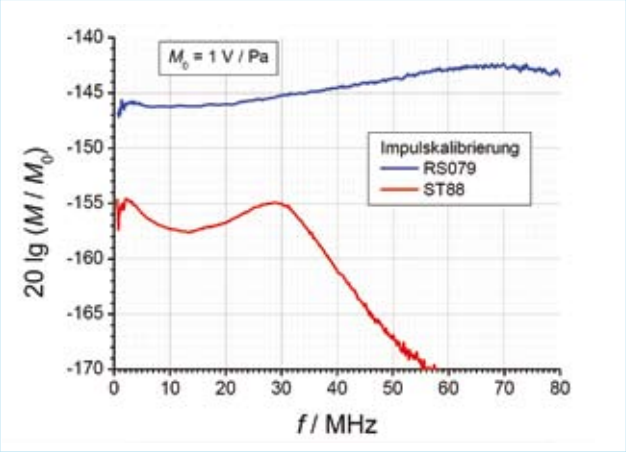
For these reasons, the company GAMPT has developed a special HIFU membrane hydrophone that meets these extreme requirements. The HIFU hydrophone is particularly characterised by an exceptionally robust design that withstands the sound power levels in the focus of a HIFU probe of up to 2,000 W/cm² and the cavitations occurring during this process. Here, the hydrophone has a flat transfer function whose bandwidth meets all requirements even if the much higher harmonious signal components for HIFU probes are taken into account. The spatial resolution of the HIFU hydrophone can be compared to that of high-sensitive broadband hydrophones.

Description

The main reasons for the problems associated with the measurement of HIFU sound fields are the extremely high sound radiation pressures, the thermal impact on the materials and the occurring cavitations. These effects result in the destruction of conventional ultrasound sensors. Thanks to the special design and various protective measures, it has been possible to develop a membrane hydrophone that can be used even if exposed to HIFU fields with maximum output that have a permanent impact. Above all, this was achieved by the application of protective films and damping elements. Due to the special materials used, the hydrophone is prevented from heating up in the HIFU sound field. The HIFU hydrophone is equipped with an integrated preamplifier that allows direct connection to an oscilloscope. In order to supply the hydrophone with power, a corresponding power supply unit is available.

Transfer function of the HIFU hydrophone

HIFU hydrophones must have a lower sensitivity than conventional hydrophones. As the HIFU sensors are, in most cases, operated in the lower MHz range (1 – 3 MHz), a bandwidth of 40 MHz at a signal change of 6 dB is also sufficient for recording the higher harmonious signal components resulting from non-linear effects. In the frequency range of interest, the HIFU hydrophones have a flat transfer function. In addition to this, the frequency-dependent variation of the transfer function can be compensated by means of a development algorithm if the hydrophone is calibrated appropriately.

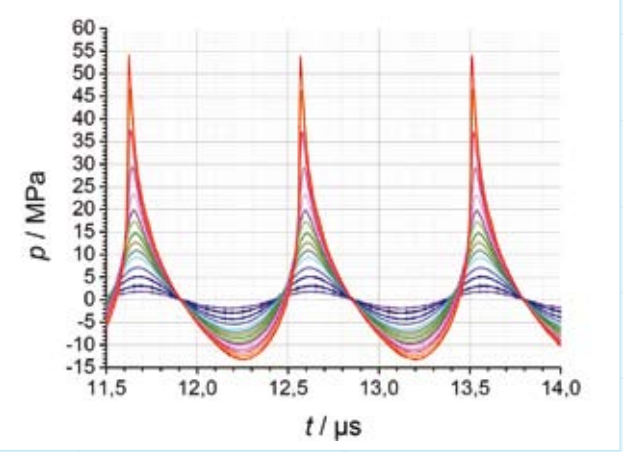


Calibration

Similarly to the membrane hydrophones of the MH-100 series, the HIFU hydrophones of the company GAMPT have a high spatial resolution of less than 300 µm. Thus, local intensity maxima can also be identified for high-intensity focused sound fields. When using HIFU fields in cancer therapy, this is, above all, of tremendous importance for a targeted therapy regime both with respect to the success of the treatment and patient safety.

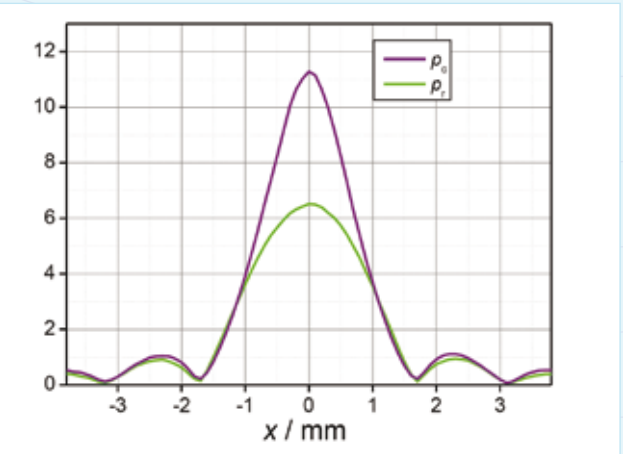
Measurements

The measurements in the focus of HIFU probes demonstrate the extremely non-linear curve of the positive and negative sound pressure amplitudes when stimulated heavily. The positive sound pressure peaks can reach values of up to 100 MPa. Due to the high sound radiation pressure, they represent an enormous load on the hydrophone membrane. In the water, the negative sound pressure amplitudes, however, cause cavitations with a high destructive potential during the implosion phases.



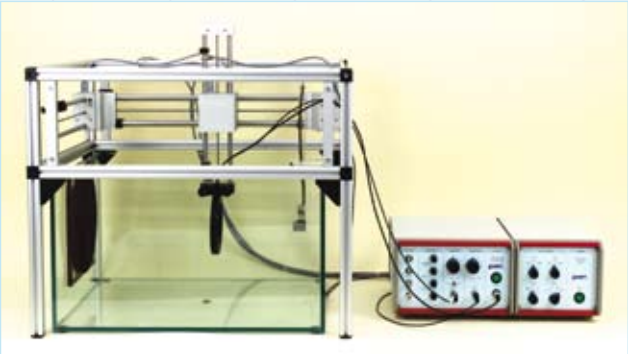
Application

The HIFU hydrophones of the company GAMPT are used for the characterisation and quality assurance when developing and producing HIFU probes. The detailed measurement of the local distribution of the sound intensities and the exact analysis of the sound pressure maxima are the prerequisite for a low-risk therapy regime and a successful ablation of tumours.
The currently ongoing international efforts to standardise and declare safety- and therapy-relevant parameters of HIFU probes (IEC 62649) primarily require suitable measuring systems that are able to meet the requirements of standardised measurements in the HIFU area. Moreover, regular constancy tests for the safe application of HIFU probes will be essential. In this respect, the HIFU hydrophones of the company GAMPT can make a vital contribution to ensure patient safety in the field of cancer therapy.



Accessories

A separate power supply unit is available for the operation of the HIFU hydrophone. In order to connect the hydrophone to an oscilloscope, a suitable broadband in-line network terminator (50 Ohm) can be supplied.
In addition to the HIFU hydrophones, the company GAMPT also offers other products that are intended for the characterisation of ultrasound probes and their sound fields. For the measurement of the local intensity distribution, the sound beam geometry and the focus dimensions, a high-resolution 3-axis scanning system with a corresponding measurement tank and an absorber mat for sound absorption is available. The scanner was developed to be used together with the HIFU hydrophone. In order to determine the time-averaged sound intensities, however, the thermo-acoustic sensor can also be used in the field of HIFU applications.



Technical data

Acoustic frequency range:	100 kHz to 40 MHz
Optional calibrated frequency range:	0.1 MHz to 40 MHz
Typical sensitivity:	~ 5 ∗10^{-8} V/Pa @ 5 MHz
Max. ultrasonic pressure:	100 MPa
Frequency response:	+/- 6 dB signal tolerance over 1-40 MHz
Effective diameter:	< 250 µm
Polarity:	noninverted
Output impedance	50 Ohm
Membrane:	4,5 µm PVDF film
Housing dimension:	130 mm diameter
Size	30 mm
Membran area:	40 mm diameter
Distance membrane to housing:	front side: 6 mm
Signal output:	RG174 cable (50 Ohm), BNC connector
Power input:	3 pole diode connector +8..15 V / Ground / -8..15 V
Input current:	+/- 20 mA

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The Company

GAMPT

Gesellschaft für Angewandte Medizinische Physik und Technik

(Company for Applied Medical Physics and Technique)

Founded in 1998 by employees of the Institut für Medizinische Physik und Biophysik of Martin Luther University Halle-Wittenberg, the name **GAMPT** now stands for comprehensive expertise in the field of ultrasonic measuring technology. We design our own projects and work together with partners from business and research to find solutions. A growing network of customers and partners in Germany, Europe, Asia and the USA is a reflection of many successful collaborations.

Top Products for Realistic Training

Based on many years of experience in supporting students in the widest variety of subject areas in physics practical work, we develop and produce equipment and experimental sets, with which clearly demonstrative training can be carried out in practical applications of ultrasonic technology in medicine, physics and materials science.

The Most Modern Ultrasonic Measuring Technology

Know-how gathered over many years in the field of ultrasonic measurement qualifies us to plan and realise even very complex and highly sensitive measuring methods and equipment – examples include the "BubbleCounter" in the field of medical technology and the membrane hydrophone for the measuring of sound fields.

Research on Behalf of the Customer

In addition to our own devices we also develop individual ultrasonic solutions upon request. From the circuit design to the construction of sensors, the development of suitable software solutions to the production of complete devices – the brains at GAMPT find the right concepts for highly specialised requirements.

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