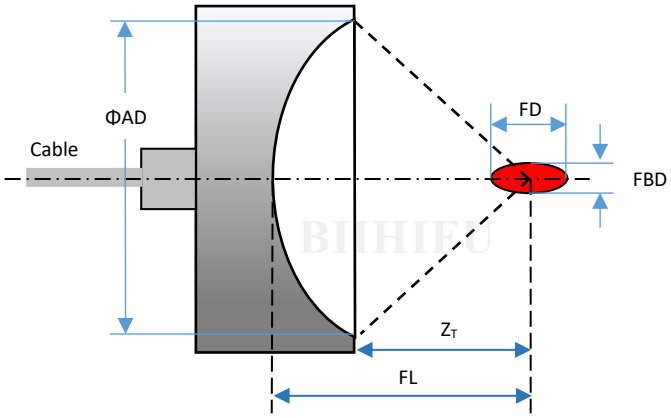
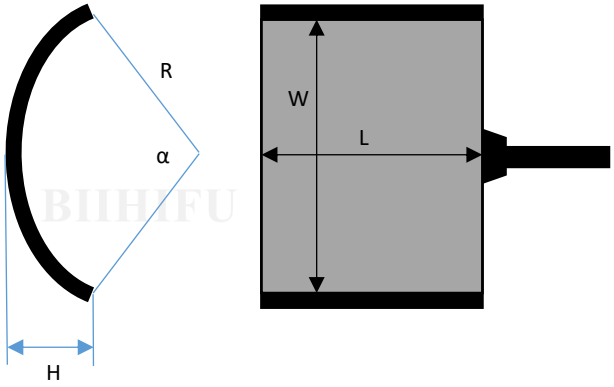
High Intensity Focused Ultrasound (HIFU) Transducer

BII's high intensity focused ultrasound transducers consist of apertures: bowl (concave, with or without a center hole), cylindrical sector, Linear (rectangular) and Annular Array. The energy at focal point or focal line is for physical, chemical, biological, thermal and high-stress uses in nonlinear underwater acoustics: cavitation, streaming, sonic processes and HIFU R&D. The focus of linear array and annular array can be manipulated with technology of array beamforming (beam steering and focusing). The bowl aperture transducers provide the best lateral and axial resolutions. For information on MRI compatibility or safety, please contact BII. To support HIFU R&D, BII provides customized designs on frequency, geometric focus, Fresnel number, focal diameter/length/intensity.

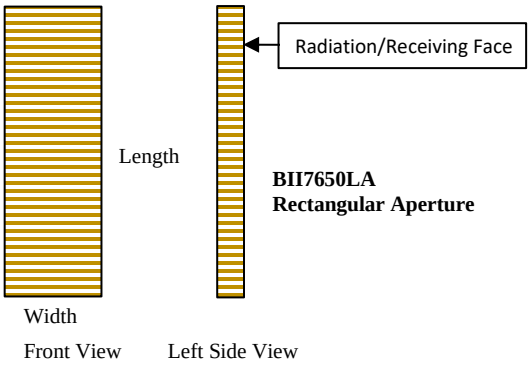
Concave Spherical Sector (Bowl) Aperture with or without Center Hole (Active)



Cylindrical Sector Aperture (Bespoke)



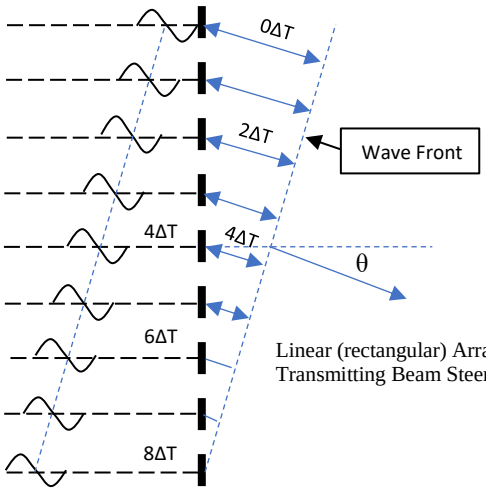
Line Array (Rectangular Aperture, Beam Steering and Focusing, Bespoke)



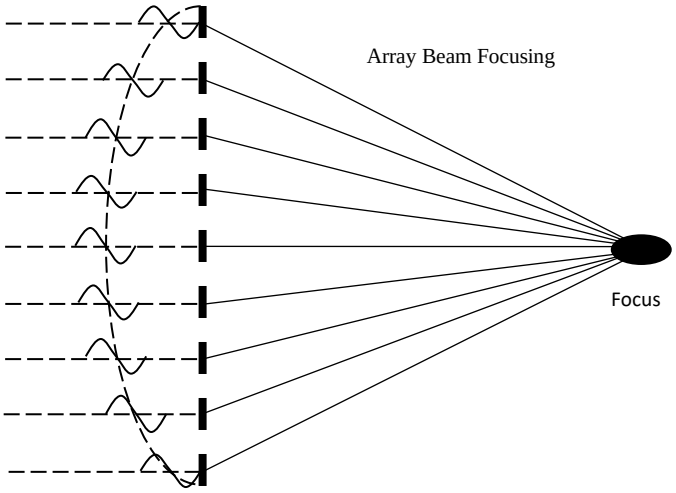
BII7650LA
Rectangular Aperture

Annular Array (Array Focusing, Bespoke)

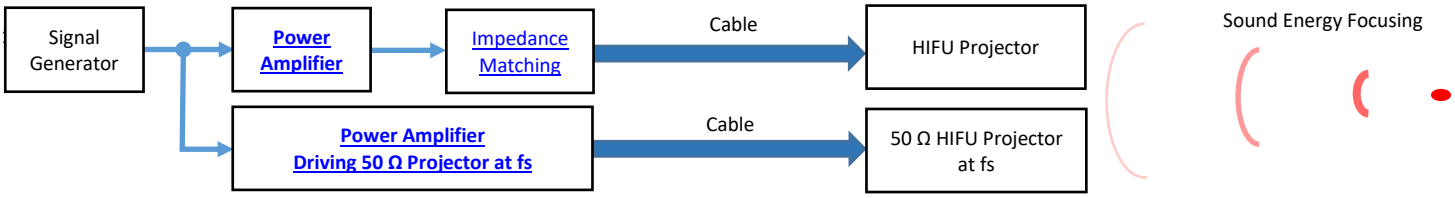
BII7650AA
Annular Array



Linear (rectangular) Array
Transmitting Beam Steering



SYSTEM CONFIGURATION: Transmitting Sounds.



RELATED PRODUCTS

Power Amplifier for SONAR, NDT, and HIFU	Impedance Matching between Transducers and Amplifiers

Typical Applications	
Cavitation/Streaming/Acoustic Wave Interaction	Thermal/Mechanical/Chemical/Biological Effects
High Frequency Ultrasound Energy Sources	Sonic Radiation in Sonochemistry/Material Processing/Sonoluminescence
Dispersion/Emulsification/Coagulation	Anti-algae & Anti-bacteria, Fluid Dynamics, Nonlinear Acoustics
Sonic Processing/Testing/Analysis	Focused Sound Sources for HIFU R&D
Features	
High Intensity: up to 5000 W/cm²	70 kHz to 2.0 MHz, and the Odd Harmonics

Specifications

High Intensity Focused Ultrasound (HIFU) Transducer	
Aperture:	**Concave or Bowl Aperture: Focal point.**
Focal Intensity:	(Input Electrical Pulse Power) * Transducer Efficiency * (Focal Intensity per Input Electrical Power)
ΦAD:	**Aperture Diameter:** the outside diameter of the piezoelectric concave spherical sector (bowl).
Z_T:	Perpendicular distance from acoustic focus to the imaginary plane of end face of the transducer housing.
FL:	**Focal Length:** Distance from acoustic focus to the center of concave face of the transducer.
FD:	**Focal Depth:** Focal Depth or distance between -3dB points of the focal zone along acoustic axis perpendicular to bowl. **FD** determines the best axial resolution.
FBD:	**Focal Beam Diameter:** the diameter of the beam at -3dB points. **FBD** determines the best lateral resolution.
Customization:	**1. Bespoke**: **HIFU with a center hole whose Diameters is Φ15 mm**. please append **-CH** to the part number. Note: BII7651 series and BII7651Q series are NOT recommended to have a center hole. **2. Minimum HIFU BII can manufacture:** Miniature HIFU Transducer, Aperture ΦD x Focal Length FL = Φ1.5 x 1.5 mm.
MIPP: Maximum Input Pulse Power. **MPW**: Maximum Pulse Width. **MCIP**: Maximum Continuous Input Power. **f_s:** Resonance Frequency. **D:** Duty Cycle.	
MPW: Maximum Pulse Width at MIPP; **η:** HIFU Transducer Efficiency; **FIPIEP**: Focal Intensity per Input Electrical Power, in W/(W*cm²). **Z**: Impedance.	
How to calculate the maximum acoustic focal intensity the HIFU which transducer can achieve theoretically: As an example, consider a power amplifier of 40 Watts RMS output power to drive BII7653/2000 at 2MHz, the peak intensity at center of the focus = Input Pulse Power * Efficiency * Focal Intensity per Input Electrical Power = 40W*0.7*175W/(W*cm²) = 4900 W/cm². Depending on the liquid or subject properties, cavitation might occur at much lower intensity and in regions between the transducer face and the focus.	

HIFU (Bowl)	fs (MHz)	Z (Ω)	FIPIEP W/(W*cm²)	η_{ea} at f_s	FBD (mm)	FD (mm)	FL (mm)	Z_T (mm)	MIPP at fs (W)	MPW at fs (s)	MCIP at fs (W)	Size:mm ΦDxH
BII7651-2100IM	2.1	50	52.0	0.5±20%	1.31	11.29	30.5	29.1	190	1.8	22	Φ33x26
BII7651Q-300IM	0.3	50	7.1	0.5±20%	3.55	11.85	17.5	10.5	600	10	35	Φ42x30
BII7651Q-500IM	0.5	50	14.0	0.5±20%	2.13	7.11	19.5	12.5	600	6	45	Φ42x30
BII7651Q-1000IM	1.0	50	78.6	0.5±20%	1.07	3.56	20.5	13.5	500	3	50	Φ42x30
BII7651Q-2000IM	2.0	50	314.4	0.5±20%	0.53	1.78	21	14.0	500	2	50	Φ42x30
BII7651H-300IM	0.3	50	4.8	0.5±20%	4.29	17.3	25.0	18.7	600	10	35	Φ48x30
BII7651H-500IM	0.5	50	13.5	0.5±20%	2.58	10.38	27.0	20.7	600	6	45	Φ48x30
BII7651H-1000IM	1.0	50	53.8	0.5±20%	1.29	5.19	29.5	23.2	500	3.5	50	Φ48x30
BII7651H-2000IM	2.0	50	215.4	0.5±20%	0.64	2.60	30.0	23.7	500	2	50	Φ48x30
BII7652-100IM	0.1	50	0.65	0.5±20%	10.8	53	36	26	1100	11	17	Φ60x35
BII7652-150IM	0.15	50	1.46	0.5±20%	7.2	35	36	26	980	7.5	20	Φ60x35
BII7652-200IM	0.2	50	3.0	0.5±20%	5.51	18.97	27.5	17.4	1300	16	70	Φ60x35
BII7652-300IM	0.3	50	6.6	0.5±20%	3.67	12.64	30.0	20.0	1300	10	80	Φ60x35
BII7652-500IM	0.5	50	18.4	0.5±20%	2.20	7.60	32.0	22.0	1200	7	100	Φ60x35
BII7652-1000IM	1.0	50	73.6	0.5±20%	1.10	3.80	32.5	22.4	1200	3	120	Φ60x35
BII7652-2000IM	2.0	50	294.6	0.5±20%	0.55	1.90	33.0	23.0	1200	1.5	130	Φ60x35
BII7653-70IM	0.07	50	0.3	0.5±20%	16.0	81.0	56.0	41.6	2900	16	32	Φ89x45
BII7653-100IM	0.1	50	0.6	0.5±20%	11.2	56.5	56.0	41.6	2400	11	37	Φ89x45
BII7653-150IM	0.15	50	1.3	0.5±20%	7.46	37.68	56.0	41.6	2100	7.5	43	Φ89x38
BII7653-200IM	0.2	50	2.7	0.5±20%	7.00	32.00	43.2	34.5	1500	8	80	Φ89x38
BII7653-300IM	0.3	50	4.0	0.5±20%	4.80	21.00	48.0	39.0	2500	10	190	Φ89x38
BII7653-500IM	0.5	50	11.0	0.5±20%	3.00	13.00	51.0	42.0	2500	7	230	Φ89x38
BII7653-1000IM	1.0	50	44.0	0.5±20%	1.50	6.00	52.5	43.5	800	4	200	Φ89x38
BII7653-2000IM	2.0	50	175.0	0.5±20%	1.00	3.00	53.0	44.0	2500	2	300	Φ89x38
BII7654-70IM	0.07	50	0.165	0.5±20%	21.5	144.85	100.0	86.6	5100	16	57	Φ114x45
BII7654-100IM	0.1	50	0.34	0.5±20%	15	101.4	100.0	86.6	4300	11	65	Φ114x45
BII7654-150IM	0.15	50	0.75	0.5±20%	10.0	67.60	100.0	86.6	3800	7.5	75	Φ114x38

BII7654-200IM	0.2	50	1.53	0.5±20%	7.70	36.60	88.0	74.6	5500	15	280	Φ114x38
BII7654-300IM	0.3	50	3.43	0.5±20%	5.10	24.40	92.5	79.1	4800	10	345	Φ114x38
BII7654-500IM	0.5	50	9.54	0.5±20%	3.06	14.64	95.5	82.1	4800	7	400	Φ114x38

Warning: the loading medium which the transducer is immersed in MUST be non-corrosive and non-flammable.

fs Tolerance:	±5% Typical
Third Harmonic:	2.9fs ~ 3.2fs; Transducers can operate at 3fs and an impedance matching network at 3fs should be ordered.
Impedance Matching:	Built-in Impedance Matching unit as a 50 Ω load.
Pulse Driving Signal:	Pulse and burst SINE/Square/Chirp excitation. To avoid overheating transducer, DO NOT use high power continuous signal to drive HIFU transducer.
	How to determine pulse width, duty cycle and off-time with input pulse power (peak power) at f_s: 1. Determine the input pulse power (IPP, peak power) with sound intensity required by the project. IPP MUST be less than MIPP. 2. Pulse Width ≤ (MIPP * MPW*(120°c-T)/103°c)/IPP. T: Water Temperature in °c. 3. Duty Cycle D ≤ MCIP*(120°c-T)/103°c)/IPP. 4. Off-time ≥ PW*(1-D)/D.
Quality Factor Q_m:	≥ 6. Note: -3dB bandwidth Δf = f_s/Q_m. Qm determines the transient response or the rise and fall rings of steady-state response.
Efficiency η_{ea} at f << f_s:	**1. Electroacoustic Efficiency η_{ea} is quite low at f << f_s and drops gradually at f > f_s, so it is NOT recommended for transducers to emit high power sounds at frequencies far from f_s. Otherwise, transducer may be damaged by overheating.** **2. Transducer can emit low power sounds at frequencies far from f_s. For example, input power P_i ≤ η_{ea}*MIPP at f ≤ 0.8*f_s and P_i ≤ 0.2*MIPP at f ≥ 1.3*f_s.**
Power Factor at f_s:	≥ 0.94
SPL at fs:	$Sound\ Pressure\ Level\ SPL = \sqrt{Focal\ Inensity * \rho C}$, ρC = Characteristic Impedance of loading medium.
	Greater than cavitation threshold at water surface. Cavitation at water surface is guaranteed.
Impedance at f_s:	Refer to Z-θ Graph. 1. Z = 50*$e^{j\theta}$, in Ω, and Phase Angle |θ| ≤ 20° at fs. 2. Customization: Specify bespoke Impedance at fs.
Driving Voltage V_i at f_s: (V_{imax}: Maximum V_i.)	**Pulsed Driving Signal and Duty Cycle D < 100%:** V_{imax} = √(MIPP * |Z|), in V_{rms}. Z is impedance at fs.
	Continuous Operation at 100% Duty Cycle: V_{imax} = √(MCIP * |Z|), in V_{rms}.
Input Power P_i:	$P_i = V_i^2$ / Z at f_s. Z is impedance at f_s.
Operating Depth:	Maximum 20 m.
	Limited by the cable length if the cable has wire leads or a non-waterproof connector.
Mounting Options:	1. Default: Free Hanging (**FH**) 2. Thru-hole Mounting with Single O-ring (**THM-M10, THM-7/16", or THM-5/8".)** 3. Thru-hole Mounting with Double O-ring (**THDO-7/16"**) 4. Bolt Fastening Mounting (Stainless Steel) (**BFM-7/16", or BFM-5/8".**) 6. Bolt-Fastening Mounting with Free Hanging (**BFM-FH-M6, BFM-FH-M8, BFM-FH-M10, or BFM-FH-3/8".)** 7. Free-hanging with Male Underwater Connector (**FHUWC-2P, or FHUWC-3P.)** 8. End-face Mounting (**EFMS or EFMM**) 9. Flange Mounting (**FGM-Φ220, FGM-Φ190, FGM-Φ165, FGM-Φ140, or FGM-Φ110.**) 10. Flush Mounting (**FSM-M35, FSM-M55, or FSM-M70**.)
	Please refer to online document **AcousticSystem.pdf** for a complete list of Mounting Options and more details.
Cable-Out:	By default, the cable goes out of the device from the end face. To save space and have the device shorter, the cable can go out of the device from the side wall. Specify when ordering.
Cable Options:	1. 50 Ω RG58 Coax (**RG58**). 2. 50 Ω RG174/U Coax (**RG174**). 3. 50 Ω RG178/U Coax (**RG178**). 4. Two Conductor Shielded Cable (**SC**), Rubber or PVC Jacket.
	Handling: Do not use the cable to support transducer weight in air and water if the transducer has a mounting part. Do not bend the cable.
Cable Length:	1. Default: 1 m with non-underwater connector. 0.6m with Underwater Mateable Connector (2 pins) (**UMC2P**). 2. Custom-fit.
Connector Options:	1. Default: Wire Leads (**WL**). 2. Male BNC (**BNC**) (Max. Diameter Φ14.3 mm). 3. MIL-5015 Style (3 pin) (**MIL3P**) (Max. Diameter Φ19 to Φ30 mm). 4. DIN Receptacle with 3 Male Pins (DIN3P), (Max. Diameter Φ17 mm), for SE or DF. 5. XLR Receptacle with 3 Male Pins (**XLR3P**), (Max. Diameter Φ20.2 mm). 6. Underwater Mateable Connector (2 pins) (**UMC2P**) (Max. Diameter Φ21.5 to Φ35 mm). Locking Sleeve: DLSA-M. Underwater Mateable Connector (3 pins) (**UMC3P**) (Max. Diameter Φ21.5 to Φ35 mm). Locking Sleeve: DLSA-M. Undewater Mateable Connectors are fixed with 0.6m unshielded cable. UMC is from global manufacturers of underwater connectors. Its part number is listed in quote in detail.
	Note: Underwater Mateable Connector is for uses underwater. Other connectors and wire leads are for dry uses and are not waterproofed.
Physical Size:	Refer to the table.
	Actual length depends on Mounting Parts and/or Add-on Parts such as-TS, etc.
Weight:	0.1 kg to 3 kg with 1 m cable.
	Actual weight depends on Mounting Parts, Cable Types and Length, and/or Add-on Parts such as -TS, etc.
Operation Temperature:	-10 °C to +60 °C or 14 °F to 140 °F.
Storage Temperature:	-20 °C to +60 °C or -4 °F to 140 °F.
Temperature Sensor:	1. Default: No built-in temperature sensor. 2. Built-in temperature sensor. Append **-TS** to part number (BIIxxxx-TS) for integrating a temperature sensor in the transducer.
Power Amplifier:	BII5000 Series Power Amplifier, Order Separately, or Third-party's power amplifiers such as 50Ω RF power amplifiers.

WARNING: DANGER — HIGH VOLTAGE on wires. Wires shall be insulated for safety. DO NOT TOUCH THE WIRES BEFORE THE DRIVING SIGNAL IS SHUT DOWN. Cable shield must be grounded firmly for safety.

for 50Ω BNC Male connector, it is buyer's sole responsibility to make sure that the (female) BNC shield of the signal source is firmly grounded for operating safety before hooking up transducer/hydrophone to the signal source. Coax with BNC is not intended for hand-held use at voltages above 30Vac/60Vdc.

Wiring Information

Transducer Wiring:	**Shielded Cable**	**Coax, BNC.**	**UMC3P, Locking Sleeve: DLSA-M.**	**MIL3P**	**XLR3P**
Signal:	White or Red	Center Contact	Contact 2	Contact C or G	Pin 2
Signal Common:	Black	Shield	Contact 1	Contact B	Pin 3
Shielding and Grounding	Shield	Shield	Contact 3	Contact A	Pin 1
Please contact us for bespoke wirings of differential transducers such as dipole, quadrupole, multimode rings, and flextensional sources.					
Wiring of Unshielded Cable:	**Wire Leads WL**	**UMC2P** (0.6m USC Cable originally coming from manufacturer of the connector, Fixed.). Locking Sleeve: DLSA-M.			
Signal	White	Contact 2			
Signal Common	Black	Contact 1			

Wiring Information of Temperature Signal.

Temperature Sensor Wiring:	**Shielded Cable**	**Coax, BNC**	**Underwater Connector UMC2P. Locking Sleeve: DLSA-M.**	**XLR3P**	**TRS Plug**
Signal:	White or Red	Center Contact	Contact 2	Pin 2	Tip
Signal Common:	Black	Shield	Contact 1	Pin 3	Ring
Shielding and Grounding	Shield	Shield	N/A	Pin 1	Sleeve

Maintenance and Operations of BII HIFU Transducers.

Cooling Transducer:	To avoid overheating the HIFU transducers during high power applications, pulse driving signal MUST be used to allow HIFU transducers to cool down in water or liquid. Effective cooling is necessary by liquid circulation and keep water/liquid in specified temperature range.
Remove Air Bubbles on Radiation Surface:	To increase power efficiency, the air bubbles on transducer radiation face developed during operation must be removed with soft cloth before driving the transducer. An flashlight is a useful aid to check the situation of the transducer surface underwater. It is a good routine to rub the transducer radiation surface lightly with soft cloth before operating the transducer each time. Do NOT touch the water/liquid and transducer when the system is powered.

Testing before shipment: BII carries out the cavitation test in water to HIFU transducers.

Disclaimer: The Focal Intensity, Focal Diameter and Focal Length in the specs are tested with low intensity sound level at BII or are calculated with electrical and physical parameters of the transducers. BII DOES NOT GUARANTEE THEIR ACCURACY. To get accurate data of these parameters, the buyer shall have the transducer tested at the buyer's cost by National Metrology Institutes or other organizations who provide calibration services.

General Operating Guide of BII HIFU Transducer

To produce the cavitation in liquids, please choose carefully the liquid (surface tension, viscosity, temperature), hydrostatic pressure, pulse length, operating frequency and driving voltage level or driving power. As a general guide, the cavitation threshold of the liquid increases as the operating frequency increases.

Driving HIFU Transducer	**Phenomenon on Water Surface at Room Temperature: Mist, Fog and Fountain.**
1 to 10 watt	Fountain occurs; Mist and Fog start to occur.
15 to 60 watt	Strong Fountain, Mist and Fog.
Cool down transducer	Refer to **How to determine pulse width, duty cycle and off-time with input pulse power (peak power)**.
Remove air bubbles	Air bubbles will develop on the radiation surface especially in fresh water or liquids. Rub the radiation surface lightly with soft cloth in water before driving HIFU transducer each time. Warning: Do NOT touch water and transducer when the system is powered.
Case Study:	
1MHz HIFU Transducer: (BII7653/1000)	**System Setup**: Pulse Signal Generator -> BII5121 -> BII6010 -> BII7653/1000 -> Water Tank. **Driving Signal**: SINE Pulse, 1MHz, Pulse Width=0.1mS, Duty Cycle=10%. **Electrical Power delivered to Transducer**: 5W **Phenomenon on Water Surface at Room Temperature**: Mist, Fog and Tiny Fountain with height of 8 to 10 mm.
2MHz HIFU Transducer: (BII7652/2000)	**System Setup**: Pulse Signal Generator -> BII5111 -> BII6010 -> BII7652/2000 -> Water Tank. **Driving Signal**: Pulsed/Burst Pulse Train, 2MHz, Pulse Width =10mS, Duty Cycle=10%. **Electrical Power delivered to Transducer**: 1.5 W. **Phenomenon on Water Surface at Room Temperature**: Mist, Fog and Tiny Fountain with height of 8 cm.

Frequency	**Aerated (tap) Water: Cavitation Threshold.**	**RMS Pressure MPa**	**Degassed Water: Cavitation Threshold.**	**RMS Pressure MPa**
70 kHz	0.8 W/cm²	0.035	8 W/cm²	0.110
100 kHz	1 W/cm²	0.039	9 W/cm²	0.116
150 kHz	1.6 W/cm²	0.049	11 W/cm²	0.128
200 kHz	2 W/cm²	0.055	13 W/cm²	0.140
300 kHz	7 W/cm²	0.102	25 W/cm²	0.194
400 kHz	8 W/cm²	0.110	40 W/cm²	0.245
500 kHz	10 W/cm²	0.122	60 W/cm²	0.300
1 MHz	600 W/cm²	0.949	600 W/cm²	0.949
2 MHz	1000 W/cm²	1.225	1000 W/cm²	1.225

3 MHz	5000 W/cm²	2.739	5000 W/cm²	2.739
4 MHz	10000 W/cm²	3.873	10000 W/cm²	3.873
5 MHz	80000 W/cm²	10.954	80000 W/cm²	10.954

Bespoke Array Transducers

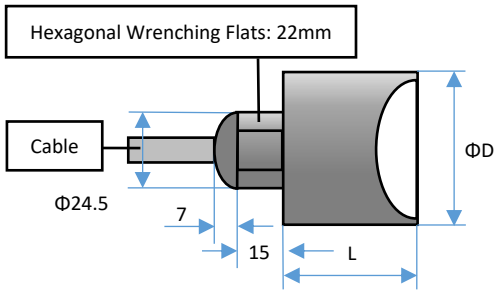
Line Array:	Rectangular Aperture, Beam Steering and Focusing.	Refer to BII7630 Series Phased Array Transducer.
Annular Array:	Array Focusing	Refer to BII7740 Series Transducer.

Package Types of HIFU Transducers

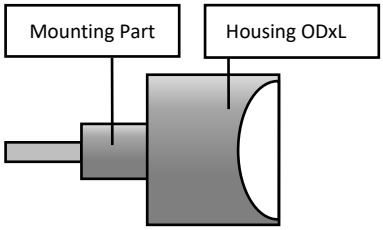
Physical Size of Bowl or Concave Spherical Sector without Center Hole (Dimensional Unit: mm): The overall length varies with the length of mounting parts. Please refer to online information of mounting options.

1. Cable goes out of the device from the end face.

a. Size information of Free Hanging.

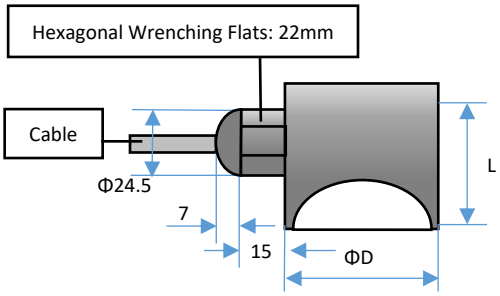


b. General Size information.

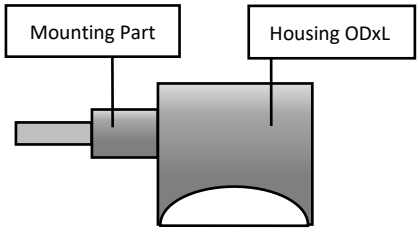


2. Cable goes out of the device from the side wall.

a. Size information of Free Hanging.



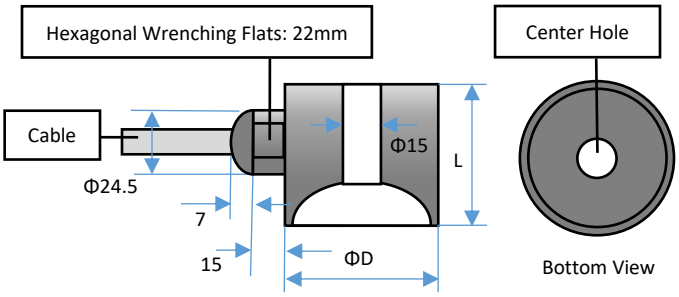
b. General Size information.



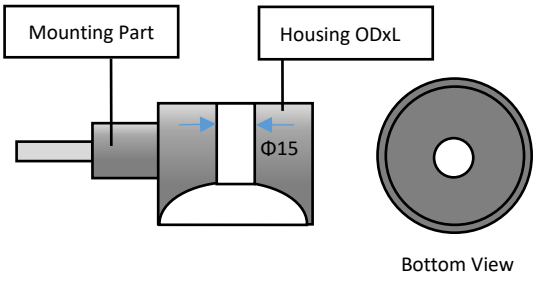
Physical Size of Bowl or Concave Spherical Sector with Center Hole (Dimensional Unit: mm):

The overall length varies with the length of mounting parts. Please refer to online information of mounting options. **Cable goes out of the device from the end face.**

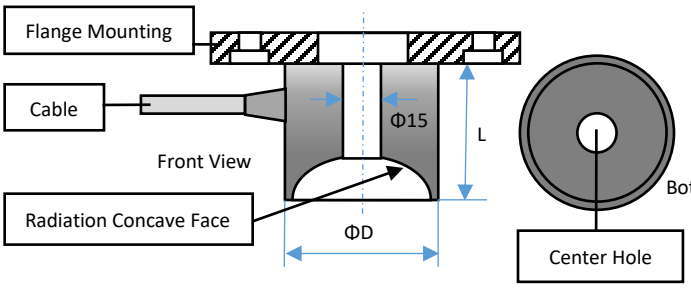
a. Size information of Free Hanging.



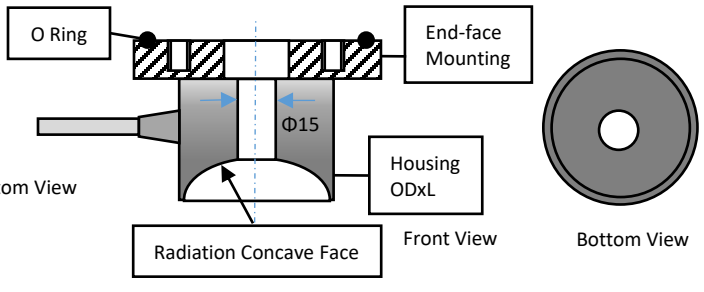
b. General Size information.



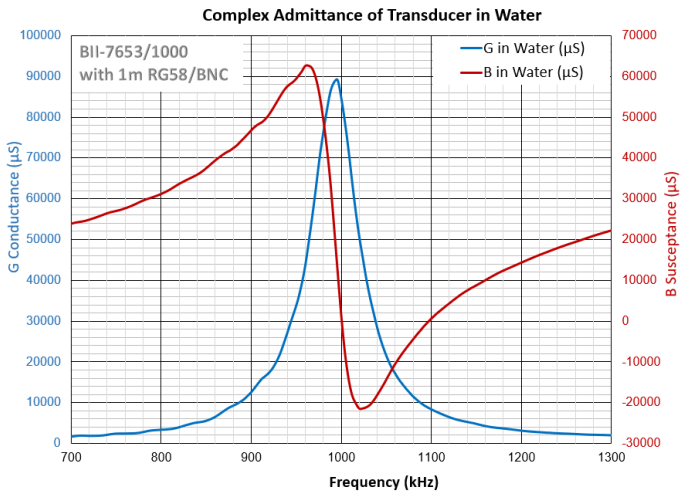
c. Size information of Flange Mounting.

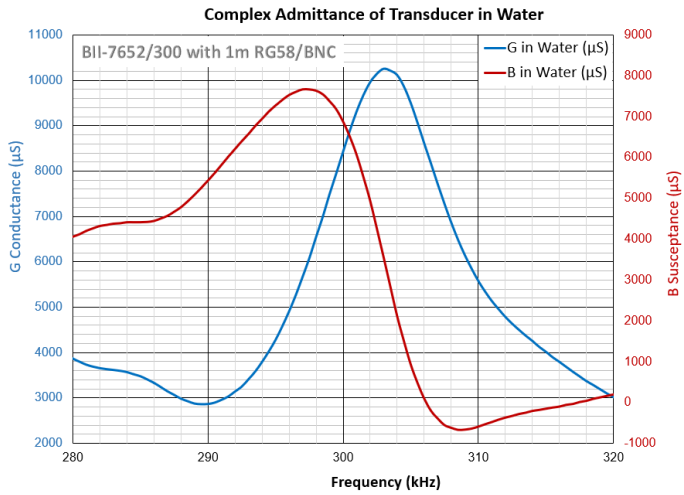


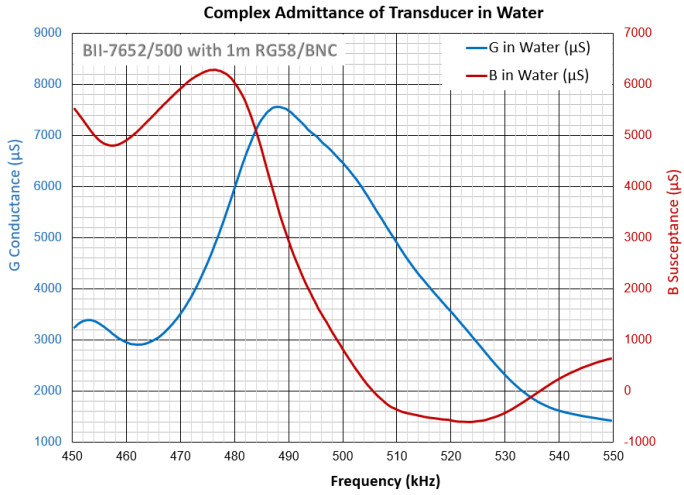
D. Size information of End-face Mounting.



Admittance in Water without BII6010 Impedance Matching







Impedance in Water with BII6010 Impedance Matching to BII Amplifier or 50Ω