CLAIMS

What we claim is:

1. A piston-type underwater transducer operating at a central frequency range of 3 kHz to 300 kHz without a pre-stress mechanism, comprising a single crystal motor section, a first head mass, a second head mass, a housing and sound transparent window material,

wherein the motor section is constructed from multiple units of rectangular-shaped [011]-poled d_{32}- or d_{31}-transverse-mode piezoelectric single crystals in a form of a hollow polygonal pipe or spaced parallelly-oriented plates or bonded plates configuration and has an overall load bearing area of less than 40 mm^2,

wherein each of the first head mass and the second head mass have a diameter less than 0.4 times the wavelength of sound wave at the operating central frequency in a surrounding medium and wherein each of the first head mass and the second head mass weighs less than 4 grams,

wherein the housing and the sound transparent window material protect the motor section, the first head mass and the second head mass from surrounding medium, and

wherein at least one of the first head mass and the second head mass emits sound wave through the window material into the surrounding medium.

2. The piston-type underwater transducer of claim 1, wherein the piezoelectric single crystals are lead-based relaxor-PT solid solution single crystals comprised of lead zinc niobate-lead titanate ($Pb[Zn_{1/3}Nb_{2/3}]O_3$-$PbTiO_3$ or PZN-PT), lead magnesium niobate-lead titanate ($Pb[Mg_{1/3}Nb_{2/3}]O_3$-$PbTiO_3$ or PMN-PT), lead magnesium niobate-lead zirconate titanate ($Pb[Mg_{1/3}Nb_{2/3}]O_3$-$Pb[Zr_{1-x}Ti_x]O_3$ or PMN-PZT), lead indium niobate-lead magnesium niobate-lead titanate ($Pb[In_{1/2}Nb_{1/2}]O_3$-$Pb[Mg_{1/3}Nb_{2/3}]O_3$-$PbTiO_3$ or PIN-PMN-PT) or lead indium niobate-lead zinc niobate-lead titanate ($Pb[In_{1/2}Nb_{1/2}]O_3$-$Pb[Zn_{1/3}Nb_{2/3}]O_3$-$PbTiO_3$ or PIN-PZN-PT), including their doped and/or compositionally modified derivatives.

3. The piston-type underwater transducer of claim 1, wherein a ratio of head mass area to overall load bearing area of the piezoelectric single crystals is 3 – 10.

4. The piston-type underwater transducer of claim 1, wherein an overall crystal load bearing area is less than 25 mm^2, and

wherein the first head mass and the second head mass has a projecting area 4 – 8 times the overall load bearing area of the piezoelectric single crystals.

5. The piston-type underwater transducer of claim 1, wherein the first head mass and the second head mass are of equal or substantially equal dimensions and weight, or of different dimensions and weights and

wherein the first head mass and the second head mass emit sound waves into a surrounding medium in $\lambda/2$ mode.

6. The piston-type underwater transducer of claim 1, wherein the second head mass is heavier than the first head mass, and

wherein the first head mass emits sound waves into a surrounding medium in $\lambda/4$ mode.

7. The piston-type underwater transducer of any of claims 1 – 6, wherein the first head mass and the second head mass are comprised of one or more of aluminium and aluminium alloys, aluminium-beryllium alloys, aluminium-lithium alloys, magnesium and magnesium alloys, titanium and titanium alloys, including their monolithic alloys with micro-hollow-spheres.

8. The piston-type underwater transducer of any of claims 1 – 6, wherein the first head mass and the second head mass are comprised of one or more of high specific modulus metal matrix composites, ceramics or fiber-reinforced polymeric matrix composites.

9. The piston-type underwater transducer of any of claims 1 – 6, wherein the motor section has a two-layer or multi-layer multi-stake structure.

10. The piston-type underwater transducer of any of claims 1 – 6, wherein the first head mass and the second head mass are of different weights, and

wherein at least one of the first head mass and the second head mass emit sound waves into a surrounding medium.

11. The piston-type underwater transducer of any of claims 1 – 6, wherein the window material exerts a pull-down force onto at least one of the first head mass and the second head mass.

12. The piston-type underwater transducer of any of claims 1 – 6, wherein upon assembly the housing exerts a pull-down force via the window material onto at least one of the first head mass and the second head mass.

13. A two-dimensional omni-directional underwater transducer comprising multiple units of the piston-type underwater transducer of any of claims 1 – 6,

wherein the transducer is configured to provide two dimensional omni-directionality.

14. A three-dimensional omni-directional underwater transducer comprising multiple units of the piston-type underwater transducer of any of claims 1 – 6,

wherein the transducer is configured to provide three dimensional omni-directionality.

15. An acoustically-tunable $\lambda_w/2$-sized piston-type underwater transducer comprising multiple units of the piston-type $\lambda/4$-mode underwater transducer of claim 6.

16. A piston-type $\lambda/2$-mode underwater transducer of claim 5, further comprising a rigid plain baffle or a cavity baffle.

17. A planar, conforming, or shaped array comprising multiple units of the piston-type underwater transducer of any of claims 1 – 6 and 16.

18. A planar, conforming, or shaped array comprising at least two units of the piston-type underwater transducer of any of claims 1 – 6 and 17, per $\lambda_w/2$ x $\lambda_w/2$ array projecting area,

wherein λ_w is the wavelength of sound in water at the central frequency of the operating frequency range of the array.

19. A dual-frequency underwater transducer array comprising multiple units of the piston-type underwater transducer of any of claims 1 – 6 and 16.

20. A parametric array comprising multiple units of the piston-type underwater transducer of any of claims 1 – 6 and 16,

wherein the parametric array has a drop-down ratio of less than 10 and is of a single-frequency-band or a dual-frequency-band.

21. A dual-mode underwater transducer of the piston-type underwater transducer of any of claims 1 – 6 and 16,

wherein the transducer generates and receives sound waves in water.

22. A dual-mode underwater transducer array comprising multiple units of the piston-type underwater transducer of any of claims 1 – 6 and 16,

wherein the transducer array generates and receives sound waves in water.