Wayne Kerr Electronics, Ltd., UK). The instantaneous power can be expressed as $P = (\sqrt{2}\tilde{V})^2 / R$, where R is the resistance value of the matched load and $\tilde{V}$ is the root-mean-square value of the voltage drop across the matched load. By connecting the matched load of 655 kΩ to the device and detecting the voltage drop across the matched load, 14.89 mV_{rms}, the instantaneous power is determined as 0.7 nW.

4. Discussions

The output power of the device is relatively low, given the structure design of the flow channel, the bluff body and the cantilever piezoelectric film. In order to obtain a higher output power of the piezoelectric energy harvester, the dimensions and structure of the device can be optimized, and a piezoelectric material with higher piezoelectric constants can be adopted. In this investigation, the device is not operated at its resonance frequency. Most energy harvesting device based on piezoelectric effects have focused on single-frequency ambient energy, i.e. resonance-based energy harvesting [16]. The resonance frequency of the energy harvesting device can be tailored to the shedding frequency of the Kármán vortex street in order to increase the output power of the device. For random and broadband ambient flow sources, such a device may not be robust. A structure with multiple resonant frequencies may also be considered for energy harvesting from random vibrations with multiple resonant peaks, for example a segmented composite beam with embedded piezoelectric layers [17].

In order to generate the pressure fluctuation of the Kármán vortex street in the channel, a flow source assisted by gravity is used to force tap water into the flow channel in the laboratory environment. Energy can be harvested from pipe flows, blood flow in arteries [18,19], or air flow in tire cavities. The proposed device can be deployed on slopes to provide electricity for wireless sensor networks for detection of landslides. Landslides are usually preceded by heavy rainfalls, and the device can harvest the energy of the water flow along slopes due to rainfall. E nergy harvesting from regular, periodic shedding can be integrated into tire pressure monitoring systems to harness the energy of air flow in tire cavities, or self-powering implantable and wireless devices in human bodies to convert the hydraulic energy of flow of body fluid.

References

[1] REN21, Renewables 2010 Global Status Report, 2010, pp. 15-16.

[2] D. Krähenbühl, C. Zwyssig, H. Weser, J.W. Kolar, Theoretical and experimental results of a mesoscale electric power generation system from pressurized gas flow, Journal of Micromechanics and Microengineering 19, 2009, 094009.

[3] A.S. Holmes, G. Hong, K.P. Pullen, Axial-flux permanent magnet machines for micropower generation, Journal of Microelectromechanical Systems 14, 2005, pp. 54-62.

[4] F. Herrault, C.-H. Ji, M. G. Allen, Ultraminiaturized high-speed permanent-magnet generators for milliwatt-level power generation, Journal of Microelectromechanical Systems 17, 2008, pp. 1376-1387.

[5] M. Sanchez-Sanz, B. Fernandez, A. Velazquez, Energy-harvesting microresonator based on the forces generated by the Kammon street around a rectangular prism, Journal of Microelectromechanical Systems 18, 2009, pp. 449-457.

[6] J.J. Allen, A.J. Smits, Energy harvesting eel, Journal of Fluid and Structures 15, 2001, pp. 629-640.

[7] G.W. Taylor, J.R. Burns, S.M. Kammann, W. B. Powers and T. R. Welsh, The energy harvesting eel: A small subsurface ocean/river power generator, IEEE Journal of Oceanic Engineering 26, 2001, pp. 539-547.

[8] L. Tang, M.P. Païdoussis, J. Jiang, Cantilevered flexible plates in axial flow: Energy transfer and the concept of flutter-mill, Journal of Sound and Vibration 326, 2009, pp. 263-276.

[9] R.D. Blevins, Flow-induced vibration, Van Nostrand Reinhold, ed. 2, 1990.

[10] R. Violette, E. de Langre, J. Szydlowski, Computation of vortex-induced vibrations of long structures using a wake oscillator model: Comparison with DNS and experiments, Computers and Structures 85, 2007, pp. 1134-1141.

[11] D.F. Young, B.R. Munson, T.H. Okiishi, A brief introduction to fluid mechanics, John Wiley & Sons, 2001.

[12] F.M. White, Fluid Mechanics, McGraw-Hill, 1986.

[13] Y.J. Chung, S.-H. Kang, Laminar vortex shedding from a trapezoidal cylinder with different height ratios, Physics of Fluids 12, 2000, pp. 1251-1254.

[14] C. Norberg, An experimental investigation of the flow around a circular cylinder: influence of aspect ratio, Journal of Fluid Mechanics 258, 1994, pp. 287-316.

[15] C.M. Ho, P. Huerre, Perturbed free shear layers, Annual Review of Fluid Mechanics 16, 1984, pp. 365-422.

[16] S. Adhikari, M.I. Friswell, D.J. Inman, Piezoelectric energy harvesting from broadband random vibrations, Smart Materials and Structures 18, 2009, 115005.

[17] S. Lee, B.D. Youn, B.C. Jung, Robust segment-type energy harvester and its application to a wireless sensor, Smart Materials and Structures 18, 2009, 095021.

[18] C. Mo, L.J. Radziemski, W.W. Clark, Experimental validation of energy harvesting performance for pressure-loaded piezoelectric circular diaphragms, Smart Materials and Structures 19, 2010, 075010.

[19] Z.L. Wang, J. Song, Piezoelectric nanogenerators based on zinc oxide nanowire arrays, Science 312, 2006, pp. 242-246.