Development of Fiber-Optic Probe Hydrophone for Cryogenic Liquid

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A calibrated, high-speed and local density/pressure probe can extend our physical view of nonlinear phenomena of liquid helium such as a flow-turbulence and an acoustic-turbulence[1]. A fiber-optic probe hydrophone (FOPH)[2] system can be the one, if it is applied in liquid helium. Our aim is to optimize FOPH for a cryogenic use. Here, the measurement principle of FOPH is based on the law of the classical optics called Fresnel reflection loss, which describes the light reflection at the interface between the two medium by which refractive indices differ. If the optical fiber is immersed in liquid helium, the reflection takes place at the end-face of the optical fiber, whose reflectivity is described as $[(n_f - n)/(n_f + n)]^2$. Here, $n_f = 1.4583$ and n are the refraction index of the fiber-core and liquid helium, respectively. Since the refraction index is the function of the density, one can obtain the pressure by measuring the reflectivity. The advantage of using FOPH is that its sensitivity does not show any frequency dependencies, up to GHz range[2], so, it is possible to calibrate the absolute value of the time-varying density/pressure using the hydrostatic pressure. And, it acts as a local density/pressure probe because the spatial resolution of FOPH is identical to the mode field diameter of the optical fiber, which is 5.6 μm in our system. Up to now, we have succeeded in measuring the density of liquid helium at saturated vapor pressure from 1.4 K to 4.3K. We will report the technical details of FOPH and the results of the density measurement, and discuss the possibility of measuring the pressure fluctuation and other applications.

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2. J. Staudenraus and W. Eisenmenger, (1992). Ultrasonics, **31**, 267-273

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