

The prospects of photonic measurement for pressure, temperature and gas density

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Pressure, temperature and density are three variables to describe a gas sample in the thermodynamic equilibrium state, and they are constrained by the gas equation of state. Upon their triangular relationship, only two variables are independent, i.e., anyone variable could be interrogated from the measurements of the other two. From the metrology viewpoint, pressure and temperature are important SI units. The triangular relationship offers an approach to establish a pressure standard by measuring gas density at known temperature, which may surpass the classic mechanical pressure standards. This insight first came from Moldover [1] in 1998, who advocated the technique of capacitance measurement for measuring gas density. Comparing to the capacitance technique, the photonic measurement for gas density by tracking the laser frequency [2, 3] has higher resolution and is more suitable for low density, which is key for vacuum metrology [4]. The advantage of the optical technique opens the vision of the quantum pressure standard [5, 6]. Strictly speaking, a quantum pressure standard will be only based on the measurements of helium gas since only helium has full *ab initio* calculation data. The biggest obstacle for the optical technique based quantum pressure standard was the independent determination of pressure-distortion of the Fabry-Perot cavity. Determination of the pressure-distortion had relied on the mechanical pressure standard [7]. In 2025, the obstacle has been removed by a landmark work of the two-color measurement for helium [8]. An optical quantum pressure standard has been realized up to 5 bar with relative standard uncertainty of 5.7 ppm. This talk will review important progresses and achievements in optical pressure standards, and prospect the photonic measurements for high pressure and for low temperature.

References

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