亮点报道：基于四叉指石英音叉的高灵敏度激光光谱气体传感器

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石英增强光声光谱 (Quartz-enhanced photoacoustic spectroscopy, QEPAS) 和光致热弹光谱 (light-induced thermoelastic spectroscopy, LITES) 是两种互补的技术，各适用于不同的应用场景。如何进一步提高 QEPAS 和 LITES 传感系统的灵敏度是目前研究的重点，而对石英音叉这一核心探测元件进行优化设计将会有效提高传感器的探测性能。

哈尔滨工业大学马欲飞课题组设计出了一种新型四叉指石英音叉，通过增加叉指数目扩大了应力集中区域，从而有效提高了声波检测效率，并在相同的激励条件下产生更大的压电信号。同时，它还兼具低共振频率、大叉指间距和 T 形叉指等课题组前期所设计的新型音叉的优点。该研究在 QEPAS 和 LITES 传感系统中将四叉指音叉的性能与标准音叉的性能进行了对比验证。首先基于欧拉-伯努利理论和有限元方法，对四叉指音叉和标准音叉在 QEPAS 和 LITES 系统中的性能进行了理论对比。与标准音叉相比，四叉指音叉的应力和表面温度差分别提高了 11.1 倍和 11.4 倍。

该工作对气体传感系统中的核心探测元件——石英音叉进行优化设计，使系统的探测性能得到显著提升，为石英增强光谱气体传感技术的进一步发展提供了参考价值。

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Highlights: A highly sensitive laser gas sensor based on a four-prong quartz tuning fork

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Quartz-enhanced photoacoustic spectroscopy (QEPAS) and light-induced thermoelastic spectroscopy (LITES) are complementary techniques, each suited to different application scenarios. How to further improve the sensitivity of QEPAS and LITES sensing systems will be a key focus of subsequent research. Optimizing the design of the quartz tuning fork (QTF) will effectively enhance the detection performance of the sensor.

The research group of Prof. Yufei Ma from Harbin Institute of Technology reported a novel four-prong QTF to address those issues. The bifurcation of the two prongs into four increases the area of stress concentration, thereby effectively improving the efficiency of acoustic wave detection and producing a large piezoelectric signal under the same excitation conditions. Additionally, it retains the advantages of the novel QTFs previously designed by the group, such as low resonant frequency, large prong gap and T-head. The study compared the performance of the four-prong QTF with that of the standard QTF in both QEPAS and LITES sensing systems.

This work optimizes the QTF, the core detector of LITES and QEPAS sensors, resulting in a significant improvement in sensitivity. It offers valuable insights for the advancement of quartz-enhanced spectroscopy.

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