High-Q Micro/Nanoresonators for Nonlinear/Quantum Photonics and Sensing

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ABSTRACT

In this talk, we will discuss our recent progress in developing high-quality micro/nanoresonators on material platforms such as silicon, silicon carbide, and lithium niobate, whose excellent material properties exhibit great potential for broad photonic applications. We will focus on our recent efforts in applying them for nonlinear and quantum photonics, and for sensing applications.

Keywords

High-Q micro/nanoresonators; silicon carbide; lithium niobate; nonlinear photonics; quantum photonics; sensing.

1. SUMMARY

High-Q optical micro-/nano-resonators, with an exceptional capability of dramatically enhancing optical fields inside a small volume, are critical foundations for many areas of optical science, such as integrated nonlinear optics [1, 2], cavity quantum electrodynamics [3, 4], cavity optomechanics [5], and biomedical sensing [6, 7]. In general, the underlying materials play a crucial role since most applications rely on the linear/nonlinear optical property [1, 2], the mechanical property [5], the quantum confinement effect [3, 4], defect characteristics [8], or thermal stability for proper operation [6, 7]. In recent years, significant interest has been focused on developing micro-/nano-resonators on various material platforms, including dielectrics, semiconductors, and polymers.

Silicon carbide (SiC) is a semiconductor [9, 10] with a wide band gap (2.3 – 3.4 eV), a large refractive index (~ 2.6), extremely large Young's modulus (~ 450 GPa), exceptionally low mechanical damping, a significant thermal conductivity (~ 490 W/(m · K)), very high hardness and chemical inertness, and unique point defect characteristics [11]. Moreover, SiC exhibit many crystal forms with various material isotropy and anisotropy. Therefore, SiC is outstanding material for broad quantum photonic and optomechanical

applications, particularly for sensing applications in harsh environment.

Lithium niobate (LiNbO₃), instead, exhibits exceptional nonlinear optical, electro-optical, piezoelectric, photoelastic, and ferroelectric properties [12, 13], with great potential as a universal material platform for making hybrid nanophotonic circuits for high-speed electro-optic and all optical signal processing, nonlinear wave generation, and photonic quantum state manipulation.

Their great potential for micro/nanophotonics has attracted significant interest in the past few years [14–24]. Unfortunately, the device development along these lines faces significant challenge due to the difficult in fabricating high-quality chip-scale photonic devices. We recently devoted considerable efforts in developing high-quality micro/nanophotonic devices in these material platforms. These devices allow us to observe intriguing nonlinear dynamics in thermal, optical, and mechanical degrees of freedom. Moreover, we have applied these devices for novel functionalities in nonlinear photonics, photonic signal processing, optomechanical sensing, and photonic quantum states generation. In this talk, we will discuss our recent progress along these lines.

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