500 Word Abstract

Optical Sensing with Anderson-Localized Light

Optical sensing is of importance in a variety of applications: it can permit the detection of hazardous/desired contaminants, monitor chemical reactions and provide quantitative analysis of processes. To this end, a range of devices have been developed, based on the confinement of light via plasmonic resonances [1], which are relatively easy to fabricate with high yields, and photonic crystal cavities [2], which possess sharper resonances (thus providing higher sensitivity) but suffer from poor scalability due to their highly engineered design. In order to make use of the high sensitivity of photonic crystals and circumvent the problem of scalability, we realize optical sensors that use fabrication imperfections as a resource to confine light with high efficiency in disordered photonic crystal waveguides in the Anderson-localized regime [3].

We fabricate silicon nitride photonic crystal waveguides confining light in the visible and characterize them by means of confocal micro-photoluminescence spectroscopy. The emitted signal, due to the intrinsic silicon nitride luminescence that we use to probe the confined optical modes, presents sharp resonances, with linewidths as narrow as 0.085nm, signature of high-quality light localization [3]. By sweeping the laser along the waveguides, we observe tens of optical resonances due to disorder-induced light confinement.

In order to test the sensitivity of our devices to small refractive index changes, ~20pl of isopropyl alcohol (IPA) are deposited onto the surface of a device and the emission spectra are monitored in real time. The local refractive index change of 0.38 spectrally shifts the cavity resonances of as much as 15.2 nm, for a resonance with linewidth of 0.15 nm. Remarkably, the wavelength shift is more than 100 times the linewidth of the cavity, proving high sensitivity for relatively small refractive index changes. The shift is also fully reversible, with the resonance returning to its initial wavelength once the IPA evaporates [4].

By cooling the devices using a liquid helium flow cryostat, we also study the temperature dependence of the cavity resonances: the linewidth of a selected resonance decreases from 0.46nm at 300K to 0.22nm at 10K, with a blueshift of ~2nm. These results show temperature sensing, improved light confinement at cryogenic temperatures and the potential to temperature tune optical cavities in and out of resonance to solid-state emitters in cavity quantum electrodynamics experiments.

Our results prove that disorder-induced Anderson-localization of light can be used as a novel platform for high-quality optical sensing, benefitting from the sharp resonances proper to photonic crystal devices and the scalability provided by the use of fabrication imperfections as a resource to confine light. As opposed to standard photonic crystal sensors, given the multiple scattering process at the basis of the confinement of light by disorder, each device also provides tens of optical resonances that allow multiple readings from a single device.

[1] M. Li et al., Analyst **140**, 386 (2015)
[2] Y. Zhanga et al., *Sens. Actuators A* **233**, 374 (2015)
[3] T. Crane et al., *ACS Photonics* **4**, 2274 (2017)
[4] O. Trojak et al., *Appl. Phys. Lett.* **111**, 141103 (2017)

300 Word Summary

Optical Sensing with Anderson Localization

Optical sensing is of importance in a variety of applications [1]: it can permit the detection of hazardous/desired contaminants, monitor chemical reactions and provide quantitative analysis of processes [1] To this end, a range of devices have been developed, based on the confinement of light via plasmonic resonances and photonic crystal cavities. The former suffer from relatively broad resonances, the latter, while providing higher sensitivities thanks to the sharper resonances, are not scalable.
In order to circumvent the problem of scalability we realize photonic crystal sensors that use fabrication imperfections as a resource to provide highly efficient light confinement [2].

Photonic crystal waveguides confining light in the visible are characterized by means of confocal micro-photoluminescence spectroscopy. Isopropyl alcohol (IPA) is deposited onto the surface of a device: the local refractive index change (of 0.38) spectrally shifts the cavity resonances of as much as 15.2nm, for a resonance linewidth of 0.15nm. The shift is of more than 100 times the linewidth of the cavity and is fully reversible once the IPA evaporates [3].

By studying the temperature dependence of the optical resonances, we show temperature sensing, improved light confinement at cryogenic temperatures and the potential of temperature tuning the spectral resonances for quantum optics experiments.

Our results prove that Anderson localization of light can be used as a novel platform for high-quality optical sensing, benefitting from the sharp resonances proper to photonic crystal devices and the scalability provided by the use of fabrication imperfections as a resource to confine light. Each device also provides tens of optical resonances which could allow multiple sensor readings from a single device.

[1] J. Hodgkinson et al., *Meas. Sci.* Technol. **24**, 012004 (2013)
[2] T. Crane et al., *ACS Photonics* **4**, 2274 (2017)
[3] O. Trojak et al., *Appl. Phys. Lett.* **111**, 141103 (2017)