500 Word Abstract

Anderson Localization of Visible Light for High-Quality on-chip Optical Cavities

Light confinement in optical cavities is of great importance in applications ranging from fundamental investigations of light-matter interaction to applications in sensing, imaging and quantum information technology. The development of efficient cavities that operate at visible wavelengths is needed for carrying out cavity quantum electrodynamic (QED) experiments with defect centres in diamond and in 2D materials, organic molecules and colloidal quantum dots, and to explore applications in energy harvesting and sensing [1].

Engineered 2D photonic crystal cavities in silicon nitride confining visible light have shown quality factors around 1000 [2,3], reaching 3400 in heterostructure cavities [4]. The low confinement efficiencies, compared to devices operating at longer wavelengths, is attributable to losses caused by fabrication imperfections that dominate at the smaller length-scales required in visible-wavelength on-chip devices.

We use a different approach that makes use of fabrication imperfections to trap light via multiple scatterings: disorder is intentionally introduced in the position of the air holes in a silicon nitride photonic crystal waveguide in order to achieve Anderson localization of light.

In a confocal micro-photoluminescence setup, a 473 nm continuous-wave laser and a 455 nm light emitting diode (LED) are used to excite the intrinsic photoluminescence of silicon nitride, that acts as an internal light source that can probe localized optical modes. Under LED illumination, applying a nanoscale-accurate photoluminescence imaging technique [5], we locate bright spots appearing along the photonic crystal waveguide, signature of light trapped within optical cavities [6].

We spectrally characterize the localized modes and, by moving the excitation spot along the waveguide, tens of resonances are visible, showing a distribution of quality factors and confinement wavelengths. In the samples where no intentional disorder is introduced, we observe optical resonances with the highest quality factors: this proves that unavoidable fabrication imperfections (like imprecision in the position and circularity of the air holes, roughness and imperfect verticality of the side walls) are sufficient to achieve light localization. We measure quality factors exceeding 5000, with a record of 9300±800: remarkably such values exceed 2D highly engineered photonic crystal cavities of up to an order of magnitude, proving that disorder can be a powerful resource for confining visible light on a chip.

We demonstrate, for the first time, Anderson localization of visible light on a nanophotonic chip and a nanoscale-accurate imaging of the localized modes [6]. Our results prove that disorder allows obtaining high-quality photonic crystal cavities, that can be used as a novel platform for cavity QED experiments with solid-state sources emitting in the visible range of wavelengths, such as defect centres in diamond and in 2D materials, colloidal quantum dots and organic molecules.

[1] O. Trojak et al., *Appl. Phys. Lett.* **111**, 141103 (2017)
[2] M. M. Murshidy et al., *J. Opt. Soc. Am. B* **27**, 215 (2010)
[3] M. Barth et al., *Opt. Express* **15**, 17231 (2007)
[4] M. Barth et al., *Appl. Phys. Lett.* **93**, 021112 (2008)
[5] L. Sapienza et al., *Nat. Commun.* **6**, 7833 (2015)
[6] T. Crane et al., *ACS Photonics* **4**, 2274 (2017)

300 Word Summary

Anderson Localization of Visible Light for High-Quality on-chip Optical Cavities

Light confinement in optical cavities is of great importance for a range of applications, from fundamental investigations of light-matter interaction to applications in sensing, imaging and quantum information technology [1]. The development of efficient cavities that operate at visible wavelengths is needed for carrying out cavity quantum electrodynamic (QED) experiments, as well as to explore potential applications in energy harvesting and sensing [2].

Engineered 2D photonic crystal cavities in silicon nitride confining visible light have shown quality factors around 1000 [3], reaching 3400 in photonic crystal heterostructures [4]. We use a different approach that makes use of fabrication imperfections to trap visible light via multiple scatterings: disorder is intentionally introduced in a silicon nitride photonic crystal waveguide by displacing the position of the air holes in order to achieve Anderson localization of light.

We spectrally characterize the localized modes, by means of micro-photoluminescence spectroscopy: by moving the laser excitation spot along the waveguide, tens of resonances are visible, showing a distribution of quality factors and confinement wavelengths. We measure quality factors exceeding 5000, with a record value of 9300±800 [5], up to one order of magnitude higher than engineered photonic crystal cavities.

We demonstrate, for the first time, Anderson localization of visible light on a nanophotonic chip and a nanoscale-accurate imaging of the localized modes and report quality factors of disorder-induced optical cavities exceeding highly engineered photonic crystal cavities.

[1] K. J. Vahala, *Nature* **424**, 839 (2003)
[2] O. Trojak et al., *Appl. Phys. Lett.* **111**, 141103 (2017)
[3] M. M. Murshidy et al., *J. Opt. Soc. Am. B* **27**, 17231 (2010)
[4] M. Barth et al., *Appl. Phys. Lett.* **93**, 021112 (2008)
[5] T. Crane et al., *ACS Photonics* **4**, 2274 (2017)