Nonlinear Processes in Lithium Niobate Metasurfaces

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Lithium niobate (LN), a birefringent crystal, is an attractive material for nonlinear photonics due to its wide transparency range and high second-order nonlinearity. Among other applications, it has been used for realisation of fast optical modulators and nonlinear frequency converters. However, almost all implementations to date were using bulk LN crystals or waveguides. Although isolated Mie-type nanoresonators in lithium niobate have been shown very recently [1], functional metasurfaces [2, 3] based on densely packed arrangements of such nanoresonators have not yet been demonstrated. The key feature of these metasurfaces, the resonant enhancement of local fields, may allow to boost nonlinear effects such as sum-frequency generation (SFG), e.g. second-harmonic generation (SHG), and spontaneous parametric down-conversion (SPDC, see fig. 1 *a*), thus offering interesting opportunities for the tailored generation of pairs of entangled photons.

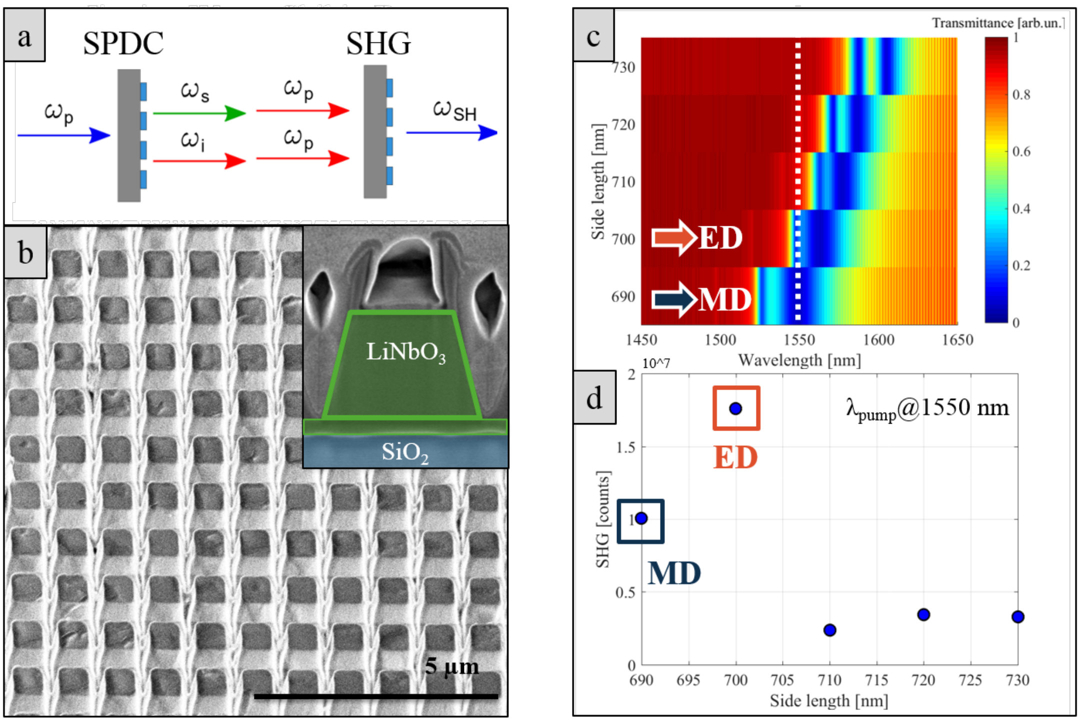

Figure 1: (*a*) Scheme of SPDC and SHG processes; (*b*) SEM image of a fabricated LN metasurface, the inset shows a cross section of a single nanopyramid; (*c*) Transmittance spectra and (*d*) SHG signal of five different metasurfaces, electric (ED) and magnetic (MD) dipolar Mie-resonances are indicated.

Sample and Methods

In this work, we have designed, fabricated and experimentally investigated nonlinear metasurfaces consisting of an array of LN nanopyramids featuring Mie-type resonances at the telecom wavelengths. We used electron-beam lithography to fabricate a sample with 49 large patches of 500x500 μm (see fig. 1 *b*).

Results

Prior to performing quantum experiments we characterized second-harmonic generation (SHG) from the metasurfaces. Firstly, in the optical transmittance spectra we observed electric dipole and magnetic dipole Mie-type resonances in the vicinity of a target wavelength 1550 nm (see fig. 1 *c*). Numerical simulations confirmed the nature of the resonances. Secondly, we carried out SHG measurements in transmission, which demonstrated strong SHG signal when exciting at 1550 nm with a pulsed laser. The stronger SHG signal was observed from metasurfaces exhibiting a resonance at the pump wavelength(see fig. 1 *d*). At the back-focal plane of the collecting objective the 0^{th} and 1^{st} diffraction orders can be seen corresponding to the period of the metasurface.

Conclusion

With these results we show that resonant metasurfaces based on lithium niobate are a suitable platform for second-harmonic generation. Due to the principle of quantum-classical correspondence, one can expect efficient spontaneous parametric down-conversion from these structures. To estimate the metasurfaces performance for non-degenerate photon-pair generation SFG is to be studied. With this, one can proceed towards examination of the quantum behavior of the fabricated metasurfaces.

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References

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