MODELING OF SPONTANEOUS PARAMETRIC DOWN-CONVERSION IN PLASMONIC AND DIELECTRIC STRUCTURES WITH REALISTIC BEAMS

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The main process to generate entangled photon pairs is spontaneous parametric down-conversion (SPDC) in a nonlinear crystal: pump photons split to two due to vacuum fluctuations. However, the process in usual nonlinear crystals is very weak, efficiency is only around 10^{-12}. The idea to considerably enhance the process by resonant surface waves was recently proposed by us [1]. The aim of this work is to fully model the enhancement process both in the plasmonic and in the dielectric structures supporting resonant modes.

To model the SPDC in resonant structures we use transfer-matrix method extended for second-order nonlinear processes [2]. The SPDC is considered as a quantum analog of difference-frequency generation where the second input beam is taken to be very weak to represent vacuum fluctuations. Another extension of transfer-matrix method was developed to replace infinite plane waves with realistic beams (e.g. Gaussian beam). All the code developed is available at GitHub (github.com/ardiloot/NonlinearTMM).

We studied the enhancement of SPDC in three types of resonant modes: ordinary surface plasmon polaritons (SPPs), long-range SPPs (LRSPPs) and guided dielectric waves (GDWs). In the case of SPPs, the enhancement factor of SPDC is around 10^4, however the process is strongly limited by the short coherent build-up length (ca 64 μm). LRSPPs and GDWs extend the coherent build-up distance considerably (up to several millimeters), however new limiting factor arise: as the resonances of LRSPPs and GDWs are very narrow, the enhancement factor is limited by the weak interaction with usual Gaussian beam.

References

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2. A. Loot and V. Hizhnyakov, "Extension of standard transfer-matrix method for three-wave mixing for plasmonic structures," Appl. Phys. A, vol. 123, no. 3, p. 152, 2017.

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